THE PALEOZOIC GEOLOGY OF THE CANAL FLATS AREA, BRITISH COLUMBIA

Abstract of a Thesis

Presented to

the Faculty of the Department of Geology

The University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Samuel Root

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THE PALEOZOIC GEOLOGY OF THE CANAL FLATS AREA, BRITISH COLUMBIA

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The Paleozoic rocks of the Canal Flats area, 30 miles north of Cranbrook, British Columbia are described. From the oldest to the youngest they are: the St. Piran formation (Lower Cambrian) with a basal unit of quartzites and pebble conglomerates, 750 to 950 feet thick, and an upper unit of shale, sandstone, and limestone 700 feet thick. The Jubilee dolomite 3,850 feet thick, conformably overlies the St. Piran formation. It is Middle Cambrian, Upper Cambrian or both. Next is the McKay group which conformably overlies the Jubilee dolomite. It is partly Upper Cambrian and partly Lower Ordovician in age. It consists of 2,850 feet of limestone and shale. The Glenogle shale overlies the McKay conformably and consists of 450 to 1,100 feet of black shale and limestone. It is of Lower and Middle Ordovician age. Overlying the Glenogle shale disconformably is the Wonah quartzite which is 50 to 300 feet thick. It is Middle Ordovician, Upper Ordovician or both. The Beaverfoot-Brisco formations, of Upper Ordovician and Middle Silurian age, overlies the Wonah quartzite in some places and in others the McKay group.

It consists of dolomite, limestone, shale, and quartzite. The Burnais formation which is Silurian, Devonian or both, is above the Beaverfoot-Brisco, and consists of gypsum. Contacts with the other formations were not observed. Mississippian rocks overlie the Burnais formation. These rocks are divided into an upper formation of cherty limestone, the Rundle, and a shaly lower formation, the Banff. Contacts with other formations were not observed.

The Canal Flats area contains three structural divisions. These are: the westerly division consisting of easterly dipping rocks; a central division consisting of upright folds; and an easterly division consisting of rocks overturned to the southwest. The Nine-Mile fault seperates the westerly and central structural divisions, and divides the area in two parts differing slightly in stratigraphic sequence. The Wonah and Glenogle are absent west of the Nine-Mile fault.

From this study it appears that: the St. Piran was deposited by a Lower Cambrian sea which transgressed from north to south. The Jubilee was deposited as a limestone and altered to a dolomite penecontemporaneously. The McKay was deposited in a shallow sea. The Beaverfoot was deposited as a limestone and dolomitized later.

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CHAPTER 1

INTRODUCTION

General Statement

During the field season of 1953 the writer was engaged as a Technical Officer with the Geological Survey of Canada in the Canal Flats Map-Area, B.C. Under the supervision of Dr. G. B. Leech of the Geological Survey, the writer mapped some of the Paleozoic rocks in the eastern part of the map-area, and wherever possible, measured sections of the various formations. The suites of specimens collected from the measured sections were studied at the University of Manitoba during the year 1953 and 1954.

The purpose of this work is to study the stratigraphy of the area with special emphasis on the petrology and petrography of the sediments. The writer feels that for an accurate regional stratigraphic interpretation, intensive sedimentary studies must be used as the basis of interpretation. In this thesis the writer hopes to show by virtue of the detailed examination of the formations that it is possible to establish some of the Paleozoic formations as control points for future stratigraphic study. The writer feels that such work is lacking in the westernmost Rocky Mountains.

Description and Location of Area of Study

The area of study is located within the eastern half of the Canal Flats Map-Area, British Columbia (see index map plate 1).

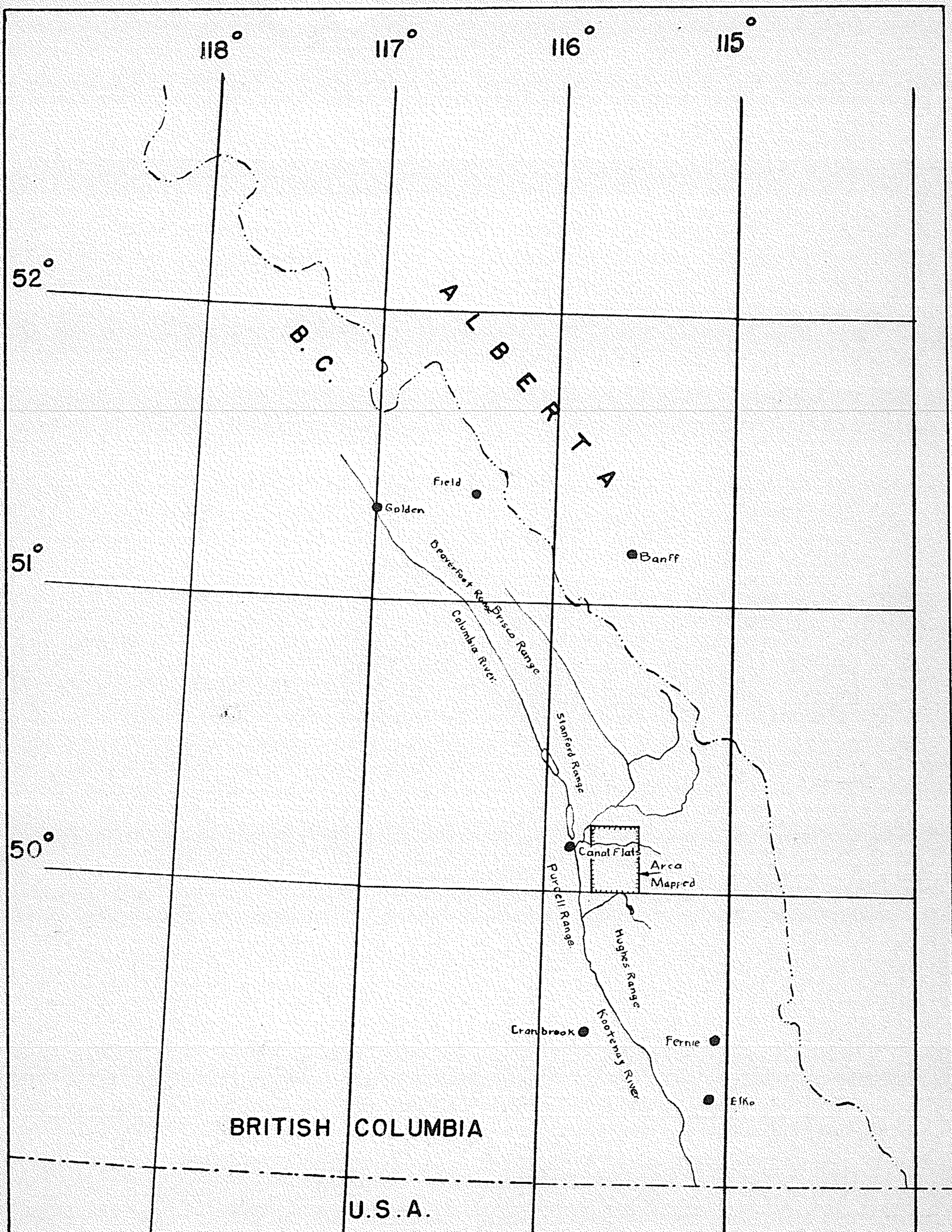

Plate 1. Index map showing location of area mapped.

The Canal Flats area includes the Purcell Mountains on the west, the Hughes Range (Rocky Mountains) on the east, and the Rocky Mountain Trench in the center. The coordinates of the area of study, which is approximately 120 square miles in area, are: north 50°15' latitude; south 50°00 latitude; east 115°30' longitude; and west 115°39' longitude.

The Paleozoic rocks occur in the eastern half of the Canal Flats Map-Area and in this thesis particular attention is given to a belt of rocks, seven miles wide, along the eastern boundary of the map-area. Most of the Paleozoic rocks are well exposed here, all the measured sections are located in this belt, and also the entire belt was mapped in detail. A map has been made of this specific area (see geologic map in pocket at back) adapted from the Geological Survey manuscript geological map. Mount Grainger which is not shown on the accompaning map is 4.5 miles southwest of Mount Glenn, located in the northeast part of the map. The term 'Canal Flats area' indicates the part of the Geological Survey Map-Area east of the Rocky Mountain Trench and the term 'map-area' includes only the area shown on the accompaning geologic map.

Previous Work

Little geological information is available about the Canal Flats area although considerable work has been done in adjacent areas. Dawson (1885) noted some Cambrian and other Paleozoic rocks in the general area of Canal Flats and Shepard (1926) briefly discussed the structures of the general area. Little knowledge, however, was contributed to the stratigraphy of the area.

Schofield (1922) examined Cambrian rocks one mile south of the map-area and the same rocks four miles east of the town of Canal Flats. Walcott (1924) examined the same Lower Cambrian rocks, at Mount Grainger, that Schofield had studied. At Sabine Mountain, above the town of Canal Flats, Walcott also examined a sequence of Lower Paleozoic strata. Walker (1926) traced a belt of Cambrian rocks from the Windermere area to Ram Creek, in the Canal Flats area.

A continuous strip 90 miles long has been mapped along the western flank of the Rocky Mountains from Canal Flats north to Golden, B.C. Henderson (1953) mapped the Stanford Range which adjoins the Canal Flats area on the north. Walker (1926) mapped the Windermere area which adjoins and in part overlaps Henderson's area on the west, and Evans (1932) mapped the Brisco-Dogtooth area which adjoins Walker's area on the north.

Methods of Study

Field Study

The Canal Flats area was mapped on a scale of two inches to one mile. Traverse lines were located by Brunton compass, and plotted on topographic maps and aerial photographs. Elevations were determined from topographic maps and by barometer readings.

Paleozoic sections were measured where exposures and accessibility were best. Specimens were collected at various intervals for detailed study and the section was fully described in the field. Wherever possible a six foot steel tape was employed for measuring true thickness. However, most of the sections were measured with a 100 foot cloth tape along a Brunton traverse, and the true thickness values were obtained by making simplified trigonometric corrections. These corrections gave an approximate true value and were checked against values obtained from a series of tables prepared by Mandelbaum and Sanford (1952). Where discrepancies between the two sets of values were great, the values of Mandelbaum and Sanford were used, but where only slight differences were apparent then the trigonometric values were used.

Laboratory Study

Several hundred field specimens were collected by the writer. The majority of these were cut by a diamond saw and the cut surface ground to a high polish. Where an intensive study was warranted a thin section was made from the specimen. The carbonate rocks were etched after the method of Lamar (1950) to bring out detail, and then either stained with Henbest's (1931) modification of Lemberg's solution or Rodger's (1940) copper stain to distinguish between calcite and dolomite. The X-ray diffraction patterns of carbonate rocks were compared with standardized dolomite-calcite patterns (Baillie 1950) to determine the composition of the rock. All specimens were crushed and then digested in hydrochloric acid, and the insoluble residue studied. Over 300 specimens, with polished surfaces and more than 50 thin sections were studied. Photographs and photomicrographs were taken to illustrate salient features of various rock types.

Acknowledgments

Thanks are due to Dr. G. Hanson, former chief geologist of the Geological Survey of Canada, for assigning the writer to the Canal Flats area.

To Dr. G. B. Leech, of the Geological Survey of Canada, thanks are rendered for much helpful criticism and advice both in the field and during the presentation of this report.

Thanks are due to the Geological Survey of Canada for faunal lists of identified collections, and the use of photographs and maps.

The writer wishes to thank Prof. E. I. Leith of The University of Manitoba for much helpful criticism in the manner of presentation of this report.

CHAPTER 11

STRATIGRAPHY

Introduction

The rocks in the Canal Flats area range in age from Precambrian to Paleozoic. The Precambrian rocks are not described in this report. The Paleozoic rocks range in age from Lower Cambrian to Mississippian (see plate 2).

Many of the formations described in this chapter have been measured and a detailed description, compiled from field notes, will be found in the appendix. The following are present in the appendix: Upper St. Piran unit; the Jubilee dolomite; the McKay group; the Glenogle shale; the Wonah quartzite; and a partial Beaverfoot section.

LOWER CAMBRIAN

THE ST. PIRAN FORMATION

Introduction

The St. Piran formation is Lower Cambrian in age and in the Canal Flats area overlies the Precambrian unconformably and is overlain conformably by the Jubilee dolomite. The formation is divisible in two distinct units, namely the Lower St. Piran which consists of quartzites and the overlying Upper St. Piran which consists of shales, sandstones and limestones. These rocks are correlative with the St. Piran formation of the Bow River Valley area as redefined by Rasetti (1951, pp. 53 and 54). Schofield (1922, pp. 13 and 14) mapped the Lower St. Piran

Plate 2. TABLE OF PALEOZOIC FORMATIONS IN THE CANAL FLATS AREA.

Period or epoch	Group or formation	Thickness in feet	Lithology
	Relationship unknown		
Mississippian	Rundle formation Banff formation (?)	≠ 1200 ?	Cherty limestone Black shale
	Relationship unknown		
Silurian and/ or Devonian	Burnais formation	?	Gypsum
	Relationship unknown		
Silurian	Brisco formation	?	Dolomite, limestone, quartzite, shale
Upper Ordovician	Beaverfoot formation	≠1100	Dolomite, limestone, quartzite
Middle and/or Upper Ordovician	Wonah quartzite	50-300	Quartzite, sandstone
	Disconformable contact		
Lower and Middle Ordovician	Glenogle shale	450-1100	Shale, limestone
Upper Cambrian and Middle Ordovician	McKay Group	2850	Limestone, shale
Middle and/or Upper Cambrian	Jubilee dolomite	3850	Dolomite
Lower Cambrian	St. Piran formation	1450-1650	Limestone, shale, sandstone, quartzite, pebble conglomerate

Disconformable contact

as the Cranbrook formation and the Upper St. Piran, in the Canal Flats area, as the Burton formation.

LOWER ST. PIRAN UNIT

Introduction

The Lower St. Piran unit consists of a series of well bedded, light colored, pure quartzites.

These are the beds identified by Schofield as the Cranbrook formation.

Lithology

The lower 5 feet is a basal congolmerate consisting of well rounded pebbles, .5 to 4 inches in diameter, of quartz, chert, red quartzite, pebble conglomerate and argillite with occasional lenticular pebbles. The matrix appears to be siliceous on the weathered surface but the rock crumbles on the fresh surface.

This conglomerate is overlain by 800 to 1000 feet of quartzites in beds from 1 inch to 3 feet thick. The quartzite is medium grained, equigranular, red, yellow, dark grey, and white on the weathered and fresh surfaces. Some beds contain pin-head size flecks of disseminated hematite but the major part of the formation is a pure, siliceous quartzite. Minor beds, 1 to 3 inches thick of intraformational (?) pebble conglomerate, are present and the quartzites may also be well laminated. A 15 foot thick, limy friable sandstone zone occurs 75 to 100 feet below the top of the unit at the south end of the map-area.

Thickness and Distribution

The Lower St. Piran was not measured in the Canal Flats area and the lithology listed above is an idealized section compiled from field notes. An idea of the thickness may be gained from calculations made from base map projections. On the west side of the Hughes Range, one half mile north of the south end of the map area the thickness was calculated as 950 feet and 2.5 miles north of this, but to the west on the bluffs facing Provincial highway no. 95, which is in the Rocky Mountain Trench, the thickness was calculated as 750 feet. Further north at Mount de Smet the unit is 260 feet thick and pinches out in the Stanford Range (Henderson 1953). A rapid thinning to the north is indicated with the source of sediments, as shown by cross bedding, from the south and southeast.

The formation is exposed in an area west of the Nine-Mile fault where it occurs as a cliff forming member on the western side of the Hughes Range, and as the bluffs which form the eastern wall of the Rocky Mountain Trench.

The Lower St. Piran rests on the Horsethief Creek series (Windermere system), in the center of the Canal Flats area and to the south rests on Toby conglomerate (Windermere system). Because the underlying formations are of different ages an angular unconformity is indicated. The Upper St. Piran overlies this formation conformably.

Faunas and Correlation

No fossils are present in the Lower St. Piran within the map area. However, a collection in this unit was made one mile south of the map-area and identified by R. V. Best of Princeton University.

Callavia and possibly *Nevadia* were collected a few hundred feet below the top of the Lower St. Piran quartzites from a rusty friable sandstone zone.

Callavia is found in other nearby areas where it is associated with Lower Cambrian fossils. Walcott (1924, p. 39) reported *Callavia* about 100 miles northwest of Canal Flats in strata he correlated with the Mount Whyte formation. In the Cranbrook area along the Cranbrook-Fort Steele wagon road he identified *Callavia* cf. *nevadensis* Walcott in a collection made by Schofield (1922, p. 12) from the Eager formation, and stated that the Eager fauna belongs to the upper part of the Lower Cambrian. Walcott (1928, p.362) collected *Callavia eucharis* Walcott and *C. perfecta* Walcott from the Lower Cambrian, Hota formation of the Robson Peak area. He stated:

> The Hota occupies the stratigraphic position of the Mount Whyte formation in the Bow River Valley . . . it is probable that the two formations were being deposited about the same time from different sources of sediments.

Evans (1932 A2, p.120) reported *Callavia* in a rusty sandstone in the uppermost twenty feet of the St. Piran formation. He correlated the overlying uppermost Lower

Cambrian Donald formation, with the Eager and the lower Mount Whyte. According to Grabau (1934, p.63), "*Callavia* is an older fauna than the Mount Whyte fauna and probably precedes the fauna with *Olenellus* in the St. Piran".

At present the exact stratigraphic range of *Callavia* is not known. It is therefore difficult to correlate these strata only on the basis of a single genus. The beds at Canal Flats are correlated on the basis of lithology, stratigraphic position, and *Callavia* with the beds that Evans (1932 A2, p.119) identified as St. Piran.

THE UPPER ST. PIRAN UNIT

Introduction

The Upper St. Piran unit consists of three lithic divisions. The basal division consists of variegated shales; the middle division of sandstones with interbedded quartzites, quartz pebble conglomerates and shales; the upper division of fossiliferous crystalline limestone.

The contact between the Upper and Lower St. Piran is easily seen in the field because the soft Upper St. Piran shales weather and leave a slackened quartzite dip slope of the underlying Lower St. Piran.

These are the beds identified as Burton by Schofield (1922, pp. 13 and 14) at Diorite Creek, 1.5 miles south of Ram Creek.

Lithology

Division 1 (Basal)

Division 1, 41 feet thick consists of shales, variegated in color and varying from a pure shale to an impure quartzose shale. The quartzose impurities occur as silty lenses and blebs along bedding planes. The shales are laminated in part and quite fissile. This lamination is due to the quartzose impurities which are concentrated along some bedding planes.

Division 11 (Middle)

Division 11, 620 feet thick, overlies division 1, and consists of sandstones (see Figure 1), quartzites, quartz pebble conglomerates and shales. This division is predominantly a well bedded pure quartzose sandstone which is fine grained, ranging in size from .1 to .5 millimeters in diameter and varying from subangular to subrounded. The grains generally show some frosting. The cement is mainly siliceous, or siliceous with minor amounts of lime, or it may also contain some argillaceous impurities. The beds of sandstone range in thickness from 2 inches to 3 feet.

Detrital muscovite and biotite are associated with the sandstones and occur as flakes or tiny books dispersed throughout the sandstone, or they may be minute shreds in the cementing medium.

At various horizons in the sandstone there are green detrital fragments, and the upper portion of this unit, from 633 to 661 feet above the base, contains as much as 15 percent of this green material. These fragments are green and waxy to slightly vitreous. They have a hardness of 1 to 2 (on Moh's scale) and are usually angular. The average grain size is .2 millimeters in diameter. These fragments are clear transparent to translucent and anisotropic. An X-ray diffraction pattern of these grains shows them to be a potassium aluminum hydrate with a probable composition of $(H,K) AlSiO_4$ which would indicate that they belong to the muscovite class. It appears that these grains are very fine fragments of a shale, high in muscovite content and slightly altered.

The clastic portion of the Upper St. Piran contains limonite which occurs in the porous part of the sandstone mostly as small spots or flecks (.1 to .5 millimeters)[1]. There may be patches of limonite as large as 25 millimeters in diameter which consist of a soft, earthy, limonite mass showing some porosity due to the leaching of the limonite. It may also form a coating on sand grains which gives some beds a ferruginous appearance. This is well shown in thin section. The limonite which occurs as flecks may comprise 15 percent of the rock, and may also occur finely disseminated throughout the cement. It is believed the limonite associated with porosity is introduced and the limonite which occurs as coatings on quartz grains is primary.

Some of the thinner bedded sandstones are laminated

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[1] Hereafter in the report when the figures in brackets are given they will indicate the diameter of the grain size of the mineral in question.

and cross-bedded. These features are shown by either a concentration of limonite along bedding planes or a change in grain size. Because the cross-bedding is varied in direction no source of sediments can be determined. Both interference and symmetrical ripple marked sandstones are associated with the thinly bedded sandstones and shales.

Friable sandstones occur at some places and these may grade laterally along strike to a more indurated sandstone that approximates an orthoquartzite. There are, however, few true orthoquartzite beds in the Upper St. Piran. The orthoquartzites are composed of quartz grains of .3 to .5 millimeters in diameter. The original grain outline is subrounded to rounded and the silica cement has grown in optical continuity about these grains. The quartz grains are equigranular with the original grain marked by a dark outline of limonite (?). Undulatory extinction is not shown in the grains. The sediment appears to be a first cycle pure orthoquartzite although some fine shreds of biotite are present in the cement.

In the middle of the section from 335 to 489 feet above the base there are some quartz pebble conglomerates. The sandstones in this interval contain some large pebbles of quartz and with an increase in the amount of pebbles they are gradational to the quartz pebble conglomerates which consist of 85 percent quartz sand matrix (.1 to .5 centimeters). The quartz sand matrix is white, but the pebbles are white, blue, rose and black. Both the sand grains and the pebbles are well rounded. The pebbles were derived mainly from a quartzite but some appear to be vein quartz. A slightly micaceous and argillaceous silica cement is the binding medium. Some beds of the conglomerate are limonitic with the limonite present as flecks in pores or as coatings on sand grains.

The shales are more abundant than the pebble conglomerates and quartzites in this central portion of the Upper St. Piran. There are some shale beds 3 feet to 7 feet thick, but the greater part of the shale occurs as 1 inch to 3 inch interbeds in the sandstones, or as shaly partings between very thinly bedded sandstones. These shales are green, brown and red, varying from fissile to laminated and may be waxy in appearance.

Division 111 (Upper)

The upper part of this unit, interval 661 feet to 709 feet is characterized by limestone. The basal 3 feet is composed of a brown fine grained (.05 millimeters) crystalline sacharoidal limestone which contains fine quartzose silt and green waxy muscovite shale. The limestone above this is fossiliferous and is also fine grained crystalline (.05 to .5 millimeters). It is pink to red with minor amounts of quartzose silt and argillaceous impurities. Detrital green muscovite is also present in some places. Some of this limestone forms a coquina of trilobite fragments. The interval 702.5 to 707 feet, above the base, consists of an oolitic limestone which is reddish white and coarse grained crystalline with fine earthy hematite oolites. This forms about 20 percent of the rock. The oolites, many of which are ellipsodial in shape, range in size from .5 to 1.5 millimeters in diameter. There is some limonitic alteration of these oolites. Some very fissile red shale interbeds are present in this part of the Upper St. Piran.

The uppermost 2 feet of the Upper St. Piran is poorly exposed but appears to consist of a white, fine grained quartzose sandstone and is overlain with apparent conformity by thick bedded dolostones of the Lower Jubilee.

Thickness and Distribution

The Upper St. Piran which was measured at the head of a cirque, one half mile south of the south end of the map-area, near Ram Creek is 709 feet thick.

The Upper St. P iran distribution is similar to the Lower St. Piran and overlies it conformably wherever exposed in the area. The contact between the Jubilee dolostone and Upper St. Piran was observed only at the Ram Creek section where it appears to be conformable.

Faunas and Correlation

The Upper St. Piran measured section at Ram Creek yielded two fossil collections from the uppermost 30 feet. As yet the fossils have not been identified but fossils from the same horizon have been identified by T. E. Bolton of the Geological Survey of Canada in collections made at Mount Grainger and two miles north, along strike, from the

Ram Creek section.

Wanneria walcottana (Wanner), *Paedeumias* cf. *clarki* Resser and *Olenellus* sp. were identified in a collection (G.S.C. Cat. No. 23907) made 3150 feet on a bearing 225° from the summit of Mount Grainger. The same species also occur in the Eager formation (G. B. Leech, personal communication). Also identified were *Bonnia fieldensis* (Walcott) (G.S.C. Loc. Cat. 23916) collected 11,200 feet on a bearing 92° from Muck (Mud) Creek at the main highway, and *B. fieldensis* and *Olenellus canadensis* (Walcott) (G.S.C. Loc. Cat. 23914) collected 8400 feet on a bearing 18° from latitude 50°00 longitude 115° 37' 30". When the identifications are completed the Ram Creek section should contain an identical fauna. The fauna of this limestone division also occurs in the Peyto limestone member of the St. Piran formation.

The Burton formation which Schofield (1922, p.15) identified at Diorite Creek is according to Burling (1914, p.33) Late Lower Cambrian (?) to early Middle Cambrian in age at its type locality near Elko, B.C. Further north, 4 miles east of Canal Flats, Schofield made a fossil collection from beds he identified as Burton, but Walcott who identified the fossils found no Middle Cambrian fauna and stated, "If the typical Burton is of Middle Cambrian age then this formation is not to be correlated with the Burton but with the Mount Whyte formation." Walcott (1924, p.29) collected *Olenellus* and *Wanneria* from equivalent beds at Mount Grainger, in the Canal Flats area and correlated the beds with the type Mount Whyte formation of the Lake Louise area. It is apparent that the name Burton formation cannot be applied to the uppermost Lower Cambrian rocks in the Canal Flats area as no Middle Cambrian faunas are present.

North of Canal Flats in the Brisco and Dogtooth Mountains, Evans, (1932 A2, pp.122 & 123) collected Bonnia and Olenellus from the Donald and correlated this formation with the lower Mount Whyte. The Donald occupies the same stratigraphic position in this area as the Upper St. Piran does in the Canal Flats area. Evans also correlated the Eager formation from which Schofield collected Wanneria and Olenellus with the Donald formation and the lower Mount Whyte. It can be concluded that the Upper St. Piran, of the Canal Flats area is correlative with the Donald formation, Eager formation and the lower Mount Whyte.

For a number of years there has been some question as to the age of the Mount Whyte formation. It has been placed as Lower Cambrian but the age determination has been questioned and it has been suggested that only the basal part is Lower Cambrian age. Walcott (1917) stated that in part of the Mt. Whyte:

> The fauna includes representatives of both Lower and Middle Cambrian genera. In fact at the present time, until more diastrophic evidence has been obtained, the exact boundary between the Lower and Middle Cambrian cannot be drawn with any degree of certainty.

Burling (1922, p.460) held similar ideas and stated, "I believe that the stratigraphic relations near the base of the formation justify the transfer of the major and upper portion to Middle Cambrian."

After an intensive study of the Middle Cambrian in the Banff and Yoho areas Rasetti (1951, pp.53 & 54) stated:

> The result of this study was the decision to transfer from the Mount Whyte to the St. Piran the basal limestone unit of the Mount Whyte formation as hitherto understood . . . The St. Piran-Mount Whyte boundary as here defined is at the same time the Lower-Middle Cambrian boundary according to the faunal definition . . . The writer does not believe that boundaries must necessarily coincide with unconformities and formational boundaries, but in the present instance, in the area investigated, this happens to be the case.

Rasetti transferred the 20 foot thick Peyto limestone member of the Mount Whyte to the St. Piran. The fauna of the Peyto limestone includes *Bonnia fieldensis* (Walcott), *Olenellus canadensis* (Walcott) and *Paedeumias* sp. and is named the *Bonnia fieldensis* faunule. This is the same fauna collected near Ram Creek, at the top of the strata, which Schofield correlated with the Burton, Therefore the writer has correlated the fossiliferous limestone containing the *Bonnia* faunule with the Peyto member at the top of the St. Piran as defined by Rasetti.

As *Bonnia fieldensis* (Walcott) is restricted to the top of the St. Piran and *Callavia* occurs stratigraphically below it, the quartzites in the Canal Flats area which carry *Callavia* must be St. Piran in age. The quartzites below the *Callavia* horizon contain no fossils and are included with the St. Piran. However, to the north in the Brisco-Dogtooth and the Bow River areas the shales of the Lake Louise formation underlie the St. Piran and below this are the quartzites of the Fort Mountain formation. No fossils occur in these formations.

The quartzite immediately below the Callavia zone may be equivalent in part or whole to time represented by the Lake Louise and Fort Mountain formations but it seems more probable that a great part of the St. Piran quartzite is missing in the Canal Flats area for Evans (1932) found 2360 feet of St. Piran Quartzites below the Callavia zone. This might indicate that there is a greater break between Cambrian and Beltian in the Canal Flats area than there is further north.

The writer suggests that because the two units of the St. Piran formation are excellent mappable units, the St. Piran formation be elevated to group rank and the two units to formational rank.

MIDDLE AND/OR UPPER CAMBRIAN

THE JUBILEE DOLOMITE

Introduction

The term Jubilee limestone was proposed by Evans (1932, p.124) for a series of Middle and/or Upper Cambrian limestones at Jubilee Mountain, and Henderson (1953, p.23) suggested the term dolomite be used instead of limestone. The Jubilee, in the Canal Flats area, is conformable with the underlying

St. Piran formation and the overlying McKay group. In the Canal Flats area, the Jubilee dolomite consists of a series of well bedded, well laminated light grey dolostones[1] and massive dark grey crystalline dolostone and is divisible into two mappable units which are the Upper Jubilee and the Lower Jubilee.

THE LOWER JUBILEE DOLOMITE

Introduction

The Lower Jubilee dolomite, the basal unit, consists of a series of light colored, interbedded laminated and massive dolostones. The laminated dolostones (see Figure 2) form the greater part of the unit, and occur in well defined beds, 3 inches to 3 feet thick.

Lithology

An examination of the measured section and other exposures in the map-area failed to show any limestone beds or calcitic dolostones in the Lower Jubilee. In this area, the Jubilee is a pure dolostone as hand specimens did not react to Lemberg's solution or copper stain, and the X-ray diffraction pattern showed the rocks to contain less than 10 percent of the mineral calcite.

The basal 1736 feet of the Lower Jubilee weathers blue grey and the upper 580 feet weathers light grey or greyish white.

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[1] The term "dolostones" as proposed by Shrock (1945, p.126) is used to indicate a rock consisting largely of the mineral dolomite.

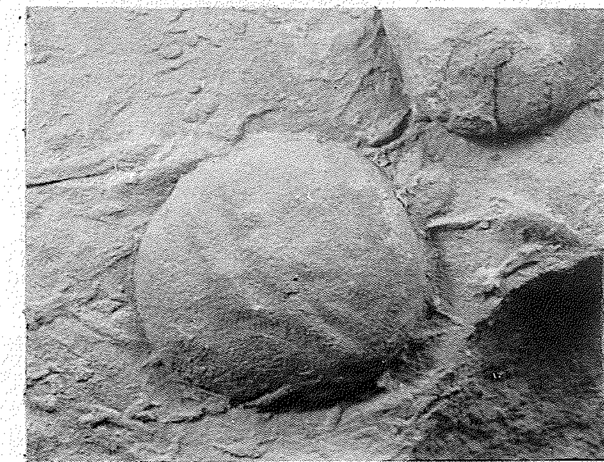

Figure 1. Organic like structure on sandstone bedding plane of Upper St. Piran unit. Specimen collected from measured section south of Ram Creek (magnification x 1)

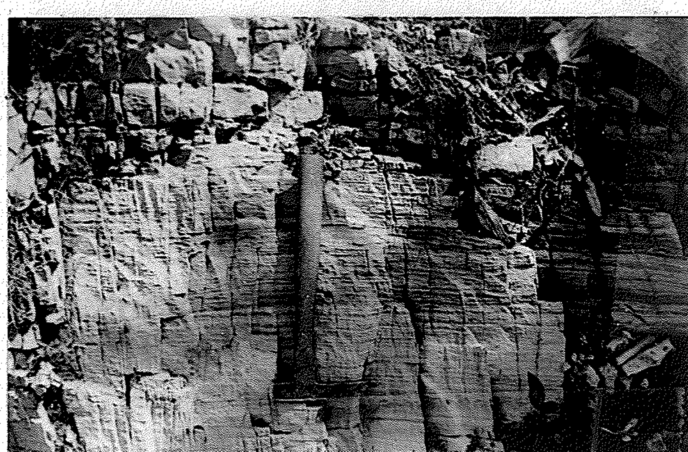

Figure 2. Well laminated dolostones of the Lower Jubilee, Marmalade Creek measured section. Length of geologic hammer is one foot.

The Lower Jubilee is characteristically a grey to white or blue well laminated dolostone. The following types of lamination occur in the dolostone,

1.) A concentration of dark brown clay along bedding planes. The clay laminae are .1 to .5 millimeters thick, crenulated and discontinuous, fading out within several centimeters.

2.) A poorly defined type of lamination (see Figure 3) in which there is an alternation of medium grained crystalline (.2 millimeters) dolomite laminae and pellitic dolomite which contains abundant silt size quartz grains. The pellitic dolomite is gradational into the crystalline dolomite and may contain patches of crystalline dolomite within the laminae.

3.) A well laminated dolostone (see Figure 4) which consists of alternating bands of medium grained crystalline dolomite (.1 millimeter) and pellitic dolomite. The coarse dolomite bands are from .2 to .5 millimeters thick and the pellitic bands may be as much as 1.5 centimeters thick. The boundary between the crystalline and pellitic dolomite is well defined. There are as many as 20 laminae per centimeter. This type of lamination shows sedimentary features such as slumping, crinkling and forset bedding. On the weathered surface these may form a series of small ridges and depressions. The crystalline dolomite weathers grey and forms ridges whereas the pellitic dolomite weathers white and forms depressions.

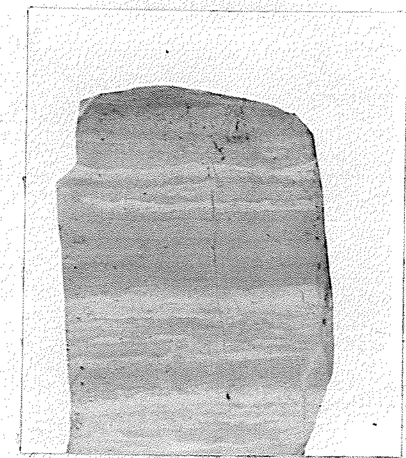

Figure 3. Coarse laminations in the Lower Jubilee, Marmalade Creek section (magnification x 1).

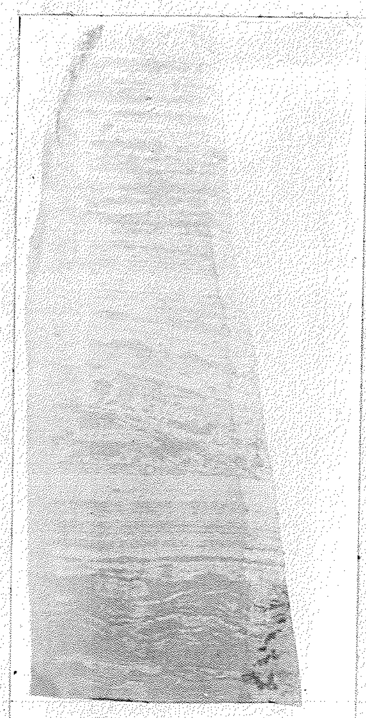

Figure 4. Fine laminations in the Lower Jubilee, Marmalade Creek section (magnification x 1).

4.) A) A spotty type of lamination consisting of small blebs and lenses of coarse grained crystalline white dolomite along bedding planes.

B) A laterally discontinuous laminated rock which is caused by discontinuous drusy crystalline dolomite stringers from .2 to .3 millimeters thick. The stringers may be associated with brown clay partings of hairline thickness.

5.) An intraformational breccia lamination consisting of elongated fragments, as long as three centimeters, composed of dark grey pellitic dolomite in a matrix of medium grained crystalline euhedral dolomite. The coarse matrix weathers less easily than the breccia fragments in a relief pattern. The fragments are in many cases not too disturbed from their original bedding planes and give a laminated effect. The intraformational breccia beds do not exceed 10 centimeters in thickness.

Some of the dolostone beds are brecciated. The fragments are dark grey pellitic dolomite and are cemented by a coarsely grained crystalline white dolomite. Reddish clay stylolites are present within the rock.

The interbedded massive dolostones are similar in lithology to the massive dolostones of the Upper Jubilee.

White, red and black chert associated with the Lower Jubilee beds may occur as lenses, blebs or lentils parallel to bedding. These are from six inches to 1 foot thick, discontinuous laterally, and in some instances destroy the dolostone laminae. Some associated chert veinlets, which are secondary, cut across bedding.

The insoluble residue contains:

1.) Clay - dark grey to black clay is the most abundant residue.

2.) Fine grained quartz - The quartz grains which are .02 millimeters in diameter vary from subangular to subrounded and some of the larger grains show strain effects.

3.) Muscovite - several shreds of muscovite are present.

There is a gradational zone of 20 to 30 feet between the Lower and Upper Jubilee. This zone is included in the Lower Jubilee.

THE UPPER JUBILEE DOLOMITE

Introduction

The Upper Jubilee consists of a series of dark grey, medium grained crystalline dolostone beds with a poorly defined bedding and almost complete lack of lamination. Where bedding is recognizable the beds range from 1 foot to 10 feet in thickness, and beds 3 feet to 6 feet thick are most common.

Lithology

Lithologic differences within the Upper Jubilee may be difficult to detect in the field. In the laboratory the best method for lithologic examination of this unit is by thin section and the acid etch surface. Stainings and X-ray patterns show the dolostones to be very pure.

The following occurrences of dolostones were observed and constitute the major lithic types in the Upper Jubilee:

1.) A massive light grey dolostone (see Figure 5) consisting of equigranular crystalline (.1 to .2 millimeters) dolomite.

2.) An Upper Jubilee dolomite breccia consisting of light grey crystalline (.3 to .5 millimeters) dolostone fragments sets in a more finely grained crystalline slightly calcitic dolostone. These fragments may be matched together with difficulty in most of the breccias. This rock type corresponds to the inhomogeneity breccia of Sanders (1951, p.2) who defines it as:

> Inhomogeneity breccia forms paradiagenetically by the rupture of relatively friable layers occuring within a more plastic pellite. In this way the broken pieces come to swim in the more plastic syngenetic matrix, forming sharp fragments with broken borders than can sometimes still be matched to each other.

3.) A very poorly laminated dolostone (see Figures 6 and 7) consisting of medium grey, fine grained crystalline dolomite alternating with white coarse grained crystalline dolomite parallel to bedding. This gives a laminated effect measured in centimeters.

Laminations on a macro scale occur near the base of the Upper Jubilee. Beds of creamy grey dolostone, 3 feet thick, are interbedded with beds of grey dolostone. These macro-laminations are continuous for distances of one-quarter mile.

Figure 5. Etched surface of fine grained massive dolomite of the Upper Jubilee, Marmalade Creek section (magnification x 1).

Figure 6. Etched surface showing coarse white dolomite crystals forming cuneiform pattern parallel to bedding in fine grained grey dolomite matrix. Upper Jubilee, Marmalade Creek section (magnification x 1).

White and black chert is present throughout the Upper Jubilee and is similar in occurrence to that in the Lower Jubilee. Near the top of this unit a boxwork pattern of chert veins, 2 to 3 millimeters thick occurs in fractures (?) in the dolostone.

Detrital minerals and insoluble materials are the same as in the Lower Jubilee, however, the amount of quartzose silt is less. Small pyrite nodules, altered to hematite and limonite along fractures, occur near the top of the unit. Rare comminuted trilobite fragments and some crinoid columnals occur near the very top of this unit and are the only evidence of fossils in the Jubilee formation.

Thickness and distribution of the Jubilee dolomite

The Jubilee dolomite section was measured along a number of ridges and slopes north of Ram Creek and west of Marmalade Creek. The Lower Jubilee is 2316 feet thick and the Upper Jubilee is 1536 feet thick. The contact between the Jubilee and the underlying Upper St. Piran is not exposed here, but, the contact between the Jubilee and overlying McKay group is exposed and the two appear conformable.

The Jubilee dolomite is exposed in an area west of the Nine-Mile fault and occurs as a continuous cliff and peak forming belt with extensive areal distribution.

Faunas and Correlation

Evans (1932 A2, p.124) proposed the name Jubilee limestone for a series of non-fossiliferous, magnesian limestones on Jubilee Mountain 32 miles southeast of Golden, B.C. The Jubilee is conformable on the Lower Cambrian Donald strata and conformably overlain by the McKay group. Henderson (1953, p.23) changed the name to Jubilee dolomite.

In the Canal Flats area the dolostones described above are conformable on the Upper St. Piran (which is correlative with the Donald) and overlain by the McKay group, and are correlative with the Jubilee.

In the Windermere area Walker (1926, p.21) correlated a series of magnesian limestones which were unconformable on the Horsethief formation with the Ottertail formation of Upper Cambrian age of Field map-area, 40 miles distant along strike of the strata, and he traced the Ottertail of the Windermere area for a distance of 25 miles south, to Ram Creek, where he found these rocks to be the Elko formation of Schofield. The rocks at Ram Creek which Schofield (1922, pp.13 & 14) named Elko overlie the Upper St. Piran and underlie the McKay group and are the same rocks that the writer mapped as Jubilee. It is apparent that the Jubilee is equivalent to Elko of Schofield at Ram Creek, and to the Ottertail of Walker in the Windermere area.

Evans assigned an age of Middle and/or Upper Cambrian to the Jubilee in the Brisco-Dogtooth area. At Ram Creek the Upper St. Piran underlies the Jubilee conformably and because the top of the St. Piran is uppermost Lower Cambrian (the Bennia fieldensis faunule), the base of the Jubilee dolomite must be the base of the Middle Cambrian. The St. Piran-Jubilee contact is therefore a time contact. At the head of Marmalade Creek, the Jubilee dolomite is overlain conformably by the McKay group. The basal McKay contains an abundant upper medial Upper Cambrian fauna and therefore, at Canal Flats, the Jubilee dolomite ranges in age from lowermost Middle Cambrian to Upper Cambrian.

In the Stanford Range, Henderson (1953, pp.23 & 24) found the Jubilee overlain conformably by the Sabine formation which contains a medial Upper Cambrian fauna. On Mount Grainger, which is in the Canal Flats area, the Burton formation of Schofield which Henderson believes to contain Middle Cambrian fauna underlies the Jubilee. However, Schofield (1922, p.14) and Walcott (1924, p.30) both examined the Burton on Mount Grainger and found very little to suggest a Middle Cambrian age. In the section on Upper St. Piran correlation it was shown that Schofield's Burton on Mount Grainger is correlative with the Upper St. Piran of the Canal Flats area. Therefore, no Middle Cambrian age as Henderson believes can be assigned to the formation underlying the Jubilee on Mount Grainger, and the base of the Jubilee here also marks the base of the Middle Cambrian.

UPPER CAMBRIAN AND LOWER ORDOVICIAN

THE McKAY GROUP

Introduction

The McKay group was named by Evans (1932 A, pp. 126 to 134) in the Brisco and Van Horne Ranges, and in the Canal Flats area consists of a thick series of interbedded shales and limestones which range in age from Upper Cambrian to Lower Ordovician. These rocks conformably overlie the Jubilee dolomite and are overlain with apparent conformity by either the Beaverfoot-Brisco formation or the Glenogle shale. It is divisible into four distinct units and consists of a thick series of well bedded shales, limestones, lenticular shaly limestones, intraformational conglomerates and breccias, and mud cracked limestones.

Unit 1, the lowest stratigraphically is poorly exposed and consists of shales and limestones. The slopes and peaks developed in this unit are subdues topographically, and a white to green scree is characteristic of the slopes. Unit 11, the overlying unit is primarily a cliff forming limestone. Unit 111, is somewhat similar to Unit 11, forming cliffs but the beds are thicker and darker. Unit 1V, the highest unit, is also a cliff former but contains more interbedded shales than Units 11 and 111. On the geologic map the McKay is not differentiated into the four lithic units.

A complete McKay section, with good development of

Figure 7. Etched surface showing coarse white dolomite crystals which form poorly defined laminae parallel to bedding in fine grained grey dolomite matrix. Upper Jubilee, Marmalade Creek section (magnification x 1).

Figure 8. Looking southeast across head of Marmalade Creek, McKay group forms main ridge. Unit 1 at base and wooded, Unit 11 first rock band, Unit 111 is light colored band, Unit 1V top of light colored band to skyline (Geol. Surv. Canada photo).

the four lithic units, was measured at Marmalade Creek approximately 2 miles north of the head of Ram Creek. A partial section of the McKay was measured at Moscow Creek, in the northwest corner of the map-area, but here only the uppermost lithic unit was developed.

The Sabine formation, which is present on the Sabine Mountain immediately north of the town of Canal Flats is believed by Henderson (1953, p.30) to represent the lower part of the McKay group but this formation was not examined or measured by the writer.

The McKay Group (Marmalade Creek)

Lithology

Four lithic units are developed in the McKay at Marmalade Creek (see Figure 8) and they consist of shales, shaly limestones, lenticular shaly limestones and intraformational conglomerates and breccias. They are described below starting with the lowermost unit.

Unit 1

Unit 1 of the McKay consists of shales at the base and the top, and a central part of intimately associated shales and limestones which form a lenticular limestone.

The basal shales (see Figure 9) are dark grey and limonitic, fissile and limy in places. Beds of dark brown, non-calcareous paper thin shales are present at the top of Unit 1.

The greater part of this unit is made up of intimately associated shales and limestones (see Figure 10) consisting

Figure 9. Conformable contact of dark colored McKay shales and light colored Jubilee dolostone at head of Marmalade Creek. Note man on contact (Geol. Surv. Canada photo).

Figure 10. Shaly nodular limestone of Unit 1, McKay group at Marmalade Creek section. Note pencil for scale (Geol. Surv. Canada photo).

of limestone lentils 1 to 2 inches thick and 3 to 5 inches in diameter which are surrounded by green shales or have thin green shale partings. The general effect is that of limestone lentils (see Figure 11) in a shale "matrix". There is a general parallelism of the lentils along the bedding planes. Some of the limestone lentils are joined together forming thin limestone beds which pinch and swell within short distances. These beds form only a small part of the shaly lenticular limestone. The shales are limy in places.

The limestone lentils are somewhat argillaceous, grey blue on the weathered surface and blue black on the fresh surface and consist of calcite grains (.01 millimeters). The boundaries with the enclosing brown or green shale are sharp. The lentils weather more easily than the shales and a characteristic pitted surface is formed on outcrop.

The shale, surrounding the lentils may contain scattered coarse grained crystals of calcite and finely disseminated small pyrite grains slightly altered to limonite. Fine shreds of muscovite and some fine silt size quartz grains are also present. The shales exhibit an irregular fissility about the limestone lentils and minor slickensides are present showing a little movement between the shales. Rare shale beds occur at certain horizons where the limestone lentils are poorly developed.

Numerous beds of intraformational limestone conglomerates and breccias (see Figure 12) occur throughout Unit 1. These beds average 4 to 12 inches in thickness and are interbedded with thicker beds of shaly lenticular limestone. The average size of the fine grained pebbles and breccia fragments are between .5 to 1 centimeter in thickness and 1 to 7 centimeters in length. Breccia fragments may occur in beds of conglomerate and pebbles may occur in the breccia beds. The pebbles, which occur in the blade shape class of Zingg[1], are well rounded. The breccia fragments are angular and irregular in shape. A zoning effect in the pebbles and fragments is often evident. They are red on the outer weathered surface but grade into light grey and blue grey on the fresh interior. Some pebbles have a green shaly coating.

The matrix is yellow or white, medium grained and contains comminuted fossil fragments of brachiopods, crinoid columnals and sponge spicules (?). "Veinlets" of argillaceous material occur throughout the matrix. Some veins of coarse grained crystalline calcite as much as 1 inch thick, cut through the matrix and pebbles displacing them slightly. Pin point size pyrite grains occur rarely in the matrix.

In addition to the intraformational conglomerates and breccias, which constitute 80 percent of the limestone interbeds in the unit, minor groups of limestone also occur.

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[1]Th. Zingg cited in "Sedimentary Rocks" by F. J. Pettijohn

Figure 11. Etched surface of irregular nodular limestone. The thin dark wavy bands consist of argillaceous material and the lighter colored rock is limestone. The McKay group, Marmalade Creek (magnification x 1).

Figure 12. Etched surface showing typical intraformational limestone breccia of the McKay group. Collected at the Marmalade Creek measured section (magnification x 1).

Six to 12 inch interbeds of fossiliferous limestones occur at the top of some intraformational conglomerates. These beds, which contain a few red limestone pebbles, contain approximately 50 percent crinoid columnals, brachiopod and trilobite fragments. The shell material is fine grained and the crinoid columnals are coarse grained crystalline. The matrix is fine grained, argillaceous, and contains quartz and minor plagioclase silt. Small flecks of limonite are associated with the argillaceous impurities of the matrix.

Angular silt size quartz and plagioclase grains are associated with the fossil fragments. The quartz silt is concentrated in brachiopod valves and the plagioclase is at the contact of the fossil fragments and the matrix. The coarser grained quartz replaces the matrix and fossil fragments, and has minute calcite inclusions as well as irregular sutured contacts. Quartz is secondary about some plagioclase nuclei. Small amounts of quartz silt which occur in the matrix are primary detritus. The plagioclase appears to be primary detritus. Traces of chert replacement of fossils are evident.

Some beds of well laminated limestone are also interbedded with shaly lenticular limestones and consist of alternations of shale laminae, .1 millimeter thick and laminae of limestone, .5 to 1 millimeter thick. They weather in small ridges which show such depositional features as scour and fill, and cross bedding, on a 1 centimeter scale.

Secondary limonite staining is present from the alteration of pyrite nodules 3 millimeters in diameter.

The limestone laminae are an intimate mixture of calcite, abundant angular quartz grains and argillaceous impurities. The average grain size of the constituents is .03 to .05 millimeters in diameter. The shale laminae which are slightly clacareous, are brown and carbonaceous in appearance. The contacts between laminae are slightly gradational, and the laminae which contain abundant quartz silt weather in ridges and show the primary sedimentary features.

Rare beds appear to be an incomplete phase of the shaly nodular limestone. Poorly developed limestone nodules contain hairline thin shaly bands which pass into the more shaly matrix which bends beneath and over the limestone lentils.

Another type of limestone is a thin bedded argillaceous one which consists of a network of argillaceous, slightly dolomitic and limonitic impurities hairline in thickness, in bands across the limestone. The limestone matrix is grey, crystalline, fossiliferous and fragmental with minute amounts of quartz silt. Some original (?) shell material is present in the fossils.

Unit 11

Unit 11 consists of a series of thinly bedded limestones, 1 inch to 6 inches thick. The limestones are light to dark grey on the weathered surface and dark grey to blue grey on the fresh surface.

Lenticular limestones in 1 inch to 2 inch irregular beds form the greatest thickness in this unit and consist of blue grey limestone lentils with a maximum size of three-quarters of an inch in thickness and 3 inches in length, separated by green or grey limy shale. Some of the lentils are laminated. The lentils may pinch in towards the center or have blunt rather than tapering ends. Often there is no definite line of demarcation between the shale coatings and the lime lentils. The limestone lentils are argillaceous and contain silt size detrital quartz grains which may show undulatory extinction. Shreds of either sericite or muscovite are also present. The limestone is crystalline (.05 millimeters) with some well developed calcite crystal faces. In contrast to the shaly lenticular limestone of Unit 1, the shale in this lithic type forms only minor coatings on the limestone lentils. This rock type does not weather easily and the shale coatings do not present directions of easy partings.

At the top of some intraformational conglomerates and overlying them with an irregular contact are limestone beds, 6 to 12 inches thick which are black on the fresh surface and blue grey on the weathered surface. The same type of limestone may occur as an interbed in the shale. The laminated beds consist of alternating bands 2 to 3 millimeters thick formed by medium grained calcite (.5 to 1 millimeter) laminae alternating with finer grained calcite (.1 millimeter) laminae. The medium grained calcite laminae are relatively free from argillaceous impurities and form minute ridges on the weathered surface. A gradation exists between the 2 types of laminae. The laminae of finer grained calcite consist of an intimate mixture of clay, subhedral calcite crystals and rare silt size quartz grains. The calcite grains in the clay appear to be recrystallized.

Intraformational conglomerates, 6 to 12 inches thick, similar to the types in Unit 1, are present but form minor interbeds. The pebbles are generally dark grey on weathered and fresh surfaces but some are red on the weathered surface as in Unit 1.

Desiccation cracks and symmetrical ripple marks (see Figure 13) are common at the top of this unit and associated with the thinly bedded lenticular limestones. The desiccation and ripple marks are confined to beds .5 to 1 inch thick. The beds are medium grey on the weathered and fresh surfaces, and contain green limy shale in depressions which outline the desiccation cracks. The cracks are pentameral in shape, and outline an area 1 inch in diameter. Abundant trilobite genal spines, as great as 2 inches in length, and other fossil fragments occur on the upper surface of the desiccation cracks. The limestone is crystalline and the calcite crystals (.05 millimeters) form a mosaic pattern. The few argillaceous or quartzose impurities present are concentrated in the original openings of the mud cracks.

A few interbedded impure clastic limestones with a matrix of an intimate mixture of calcite grains and brown clay pellets also occur throughout the unit. Fragments of fossils and coarse grained crystalline limestone are dispersed throughout the finer grained matrix. Silt size, angular, glassy detrital quartz grains and rare shale fragments may compose 5 percent of the rock.

Black and brown chert is present throughout Unit 11 and occurs as small blebs, several inches in length or as large lenses, 2 inches thick, and several feet in length. The chert may cut across bedding or show partial replacement of limestone.

Unit 111

Unit 111 is lithologically similar to Unit 11, but some of the beds range from 1 to 4 feet in thickness.

Shaly limestone similar to the shaly lenticular limestone of Unit 11 constitute about 80 percent of this unit. Interbedded blue limestones, from 1 to 2 inches thick, with distinctive brown markings are quite common in this unit. The markings consist of a concentration of argillaceous impurities and quartzose silt in the limestones, and weather in relief. Some thinly interbedded green limy shales occur with the thinly bedded limestone members. Intraformational conglomerates are also present in this unit and are lithologically similar to the intraformational conglomerates of Units l and ll.

Abundant mud cracks and ripple marks are associated with the thinly bedded limestones of this unit and give off a distinctive ringing sound when struck with a geologic hammer. Organic markings, similar to plant root systems and worm burrows are present on some of the shaly partings between limestone beds.

Unit IV

Unit lV which is the highest unit stratigraphically is essentially the same lithologically as the underlying units but contains more shales than underlying Units ll and lll.

Shaly lenticular limestone similar to the type in Unit ll is present at the base of the unit but the limestone lentils are smaller than those in the underlying units and their average size is one-eighth inch in thickness and l inch in length. The very thin shaly partings separating the lentils weather yellow-green. Beds of grey argillaceous, fragmental, and fossiliferous limestone, l to 2 inches thick and which are slightly laminated on the weathered surface are interbedded with the lenticular limestone.

Interbedded intraformational conglomerates and breccias occur at various horizons throughout the entire unit. Most of the clastic limestones are similar to those in the underlying units but a few beds consist of pebbles, composed of crystalline calcite (.5 millimeters) in a fine grained calcite (.1 millimeter) matrix. The matrix contains oolite like bodies of argillaceous impurities which are circular in cross section with a diameter of .2 to .5 millimeters, and have sharp contacts with the calcareous part of the matrix. Authigenic calcite growths are present on corners of the larger calcite grains.

In the middle of this unit there is a distinctive, 280 foot thick succession of thinly bedded blue limestones and green limy shales which contain minor, 6 inch thick interbeds of blue intraformational limestone conglomerates and breccias, laminated blue limestones and 1 inch thick limestone beds which show excellent desiccation cracks. The interbedded shales may be as much as 5 feet thick and are limy and almost an argillaceous limestone in composition. Some of these interbeds are composed of one-quarter inch thick irregular limestone beds which are argillaceous with shale coatings and so a limy shale appearance is imparted to the interbed. The interbedded limestones are as much as 2 feet in thickness, and are predominantly blue and grey intraformational conglomerates and breccias.

Towards the top of this succession the amount of interbedded shales decrease with a corresponding increase in the limestones. The shale interbeds decrease to a maximum thickness of 3 feet with average thickness 6 inches.

The more massive limestone beds may weather in a distinctive spherical exfoliation pattern.

From the top of the succession to the top of the McKay, the rock types are predominantly limestones and consist of blue limestone intraformational conglomerate (see Figure 14) and breccias, massive blue limestone with argillaceous laminae and 'dolomitic' markings, and nodular shaly limestones (see Figure 15) in beds from 2 inches to 3 feet thick with average thickness 2 inches to 6 inches. Occasional shale interbeds are also present. Organic markings, such as plant and root-like systems are present on thin bedded limestones. Comminuted fossil fragments are dispersed throughout most of the limestone beds. Brown and black chert beds, lentils and stringers as great as two inches in thickness and pyrite cubes as large as three-sixteenths of an inch in diameter occur at various horizons in the upper portion of Unit lV.

Detrital minerals present in the underlying McKay units are also present in Unit lV. Argillaceous materials are present as irregular patches or laminae and give rise to the brown or buff dolomitic mottlings. Some silt patches are stained by limonite derived from pyrite alteration. The plagioclase grains show calcite replacement (?) along twin planes, and the quartz may be authigenic or primary. Authigenic calcite growths occur on some calcite grains.

Two hundred feet below the top of the McKay the

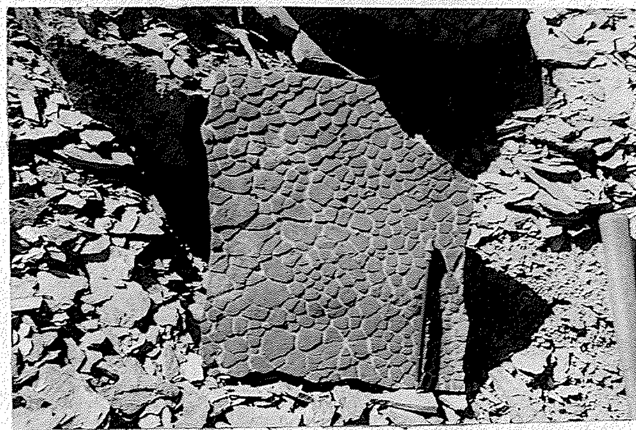

Figure 13. Mud cracks on thinly bedded limestone, Unit 111 McKay group, Marmalade Creek measured section. Note pencil for scale (Geol. Surv. Canada photo).

Figure 14. Thin section of clastic limestone. The dark fragments consist of fine grained calcite with clay, silt and fossil fragments. The lighter colored matrix consists of crystalline calcite. Unit IV, McKay group, Marmalade Creek measured section (magnification x 1).

mineral dolomite first appears and increases in quantity toward the top of the McKay. Dolomite first appears as white euhedral crystals, (.1 millimeters) dispersed through breccia fragments in intraformational limestone breccias or as fine to coarse disseminations throughout a fine grained limestone fragment. The dolomite may form an intimate mixture with the calcite or may comprise the entire breccia fragment. Discrete crystals of dolomite occur in the matrix.

Various beds are selectively dolomitized near the top of the McKay. These beds grade to normal limestones along strike. The dolomite is easily distinguished from the normal McKay limestone due to its buff weathered surface, coarse crystallinity, smooth weathered surface and minor porosity whereas the normal McKay weathers dark grey or blue, is fine grained, has irregular weathered surface and no porosity.

Thickness and Distribution

The McKay section was measured at the head of Marmalade Creek which flows south in Ram Creek. A complete section is exposed and total thickness of McKay is 2853 feet. The lithic units within the McKay have the following thicknesses: Unit 1-1183 feet, Unit 11-436 feet, Unit 111-148 feet and Unit 1V- 1086 feet.

The McKay occurs east and west of the Nine-Mile fault.

The McKay occurs east and west of the Nine-Mile fault. West of the Nine-Mile fault the base of the McKay is exposed and overlies the Jubilee dolomite conformably (see Figure 9). The McKay is overlain here, with apparent conformity by the Beaverfoot-Brisco formation. East of the Nine-Mile fault the base of the McKay is not exposed and is conformably overlain by Glenogle shale.

The McKay Group (Moscow Creek)

Introduction

At Moscow Creek, Unit lV of the McKay was measured on the east dipping limb of an overturned fold. Here the measured McKay can be divided into several prominent limestone sub-units most of which are comparable in lithology to Unit lV of the McKay at Marmalade Creek. The lithology is described from the base of the measured section upwards.

Lithology

From the base of the measured section upwards for 755 feet the interval consists of a succession of interbedded limestones which stand out as prominent ribs on the weathered surface, and 'shales' which weather in and form rubbly exposures. There are five dominant limestone "rib" formers; these are:

1.) An intraformational limestone conglomerate which is similar to the conglomerates described in the McKay at Marmalade Creek, however, a micro conglomerate consisting of well rounded pebbles (1 to 4 millimeters) is also abundant in this interval. These pebbles are of various rock types: a fossiliferous clastic limestone; a massive medium crystalline limestone; a laminated limestone; all of which are argillaceous; and grains (2 millimeters), of single calcite crystals which also form pebbles. Second cycle (?) conglomerate pebbles are present in minor amounts. The matrix is a fine to medium grained, slightly fossiliferous, intimate mixture of clay and calcite. Minor amounts of quartz grains (.01 millimeters), are present in the matrix. This rock has shaly partings which are stylolitic in appearance, minor calcite veinlets, and limonite which may stain either the pebbles or the matrix.

2.) A grey fine grained, massive argillaceous limestone with detrital quartz. Some shaly, limonitic stained partings and stylolites are also present.

3.) A clastic limestone consisting of patches to irregular fragments of blue grey limestone in a darker matrix. These clastic fragments are poorly defined and so similar to the matrix that it is difficult to consider this rock as breccia. Limonite altered from pyrite, has stained portions of the rock a bright yellow. Worm burrows are present on some of the surfaces of the limestone.

4.) A laminated limestone consisting of bands of crystalline calcite (1 millimeter), alternating with laminae consisting of argillaceous patches and 'oolites'

(.05 millimeters), intergranular clay-calcite mixtures and also detrital quartz. Hairline thick shale partings occur at intervals of .5 centimeters. Limonite flecks are disseminated throughout the rock.

5.) A mud cracked limestone in beds .5 centimeters thick consisting of limestone, blue grey, argillaceous and slightly laminated in part with detrital quartzose silt. The wedge shaped mud cracks are filled with very coarse grained greenish calcite. The fillings are 1 millimeter wide and a few of the cracks are filled with clay and pyrite slightly altered to limonite. The mud cracks have a maximum surface diameter of 2 centimeters. Light grey green, slightly limy shale coatings with organic forms occur on the mud cracked surfaces.

These limestone lithic types occur in varrying proportions and at various horizons throughout the entire interval.

The 'shale' interbeds vary in occurence throughout this interval but towards the base they decrease in amount. The 'shale' is actually a very nodular, intimate mixture of clay and calcite grains (less than .01 millimeters) in beds .5 to 1.5 centimeters thick. A few calcite grains (.05 millimeters) occur in the clay-calcite mixture. Abundant yellow green, slightly limy shale partings and patches occur as coatings and bands throughout the clay-calcite nodules and impart a fissility and shaly appearance to the bed.

This interval appears to be the base of Unit lV and although no section was measured below this interval, a limestone phase probably correlative with Unit lll of the McKay at Marmalade Creek begins a few hundred feet below this interval.

Forty feet of limestone breccia which is lithologically different from McKay limestone previously observed comprises the overlying interval. The breccia fragments which are blocky (1 to 3 centimeters), angular, dark grey, and a fine grained argillaceous limestone in composition, have been displaced 2 to 3 millimeters and can easily be matched together. The matrix is a buff, crystalline (.1 millimeter), limestone. White calcite coarse grained crystalline, (.5 to 1 millimeter) is present in replacement veinlets along minor fractures within the fragments and is slightly younger, genetically, than the matrix. It is not ascertainable whether the breccia is tectonic or sedimentary in origin.

This interval is overlain by 228 feet of shaly lenticular limestone, consisting of limestone lentils, 1 inch in length and 1.5 inches thick, which are grey, argillaceous and fossiliferous. The more argillaceous lentils grade into the shaly partings which are limy and limonitic. The limonite which imparts a yellow color to the shale is a hematite alteration product and no genetic determinations could be made on the hematite.

The shaly lenticular limestone is overlain by 94 feet of limestone similar to the uppermost limestone in the McKay and in general this interval is not as shaly nor are the shaly partings as well defined. Blebs of black chert occur in some beds.

Several beds in this interval are dolomitized but they grade laterally and vertically into limestone. The dolostone beds weather buff in contrast to the limestone beds which are dark grey. The dolomite is crystalline, (.5 to 1 millimeter). The argillaceous impurities are concentrated in irregular patches. Abundant silt size, clear, vitreous, detrital quartz occurs in the dolomite.

Clastic limestone which consists of grey, fine grained, (.02 millimeters) irregular limestone fragments in a yellow limonitic, argillaceous, very fine grained limestone matrix appears towards the base of this interval. The matrix grades into dark clay material or may be enclosed in the clay. The grey limestone fragments are slightly fossiliferous and in part may grade into the matrix. Both authigenic (?) and primary detrital quartz grains, (.02 millimeters) are present in the matrix and the fragments. The limonite flecks in the matrix are .05 millimeters in diameter.

This is overlain by 37 feet of light brown silicified limestone shich forms a distinctive rock type in the measured section and consists of approximately 80 percent quartz, by weight. All the limestone has been replaced by quartz grains which average .05 millimeters in diameter.

The detrital quartz grains of the original limestone are present as dark grey quartz "eyes". Argillaceous impurities are present, as in the original rock type, and contain very slight amounts of calcite. The original texture of the rock is destroyed. It is not known if this sub-unit extends laterally for any great distance.

This is succeeded by 16 feet of well laminated limestone consisting of alternating shale and limestone laminae. The shale laminae are .1 millimeter thick and the limestone laminae are one to 2 millimeters thick but the contacts are irregular and gradational. The limestone laminae consist of medium grained crystalline calcite with very slightly amounts of argillaceous impurities and detrital quartz. The shale laminae contain abundant angular silt size detrital quartz.

The uppermost part of the McKay, 280 feet, consists of a thinly bedded, argillaceous lenticular limestone. The limestone lentils are very irregular in shape, up to 6 centimeters in length and 1.5 centimeters thick, and consist predominantly of fine grained calcite (.01 millimeter), with individual crystals and patches of coarse grained calcite, (.1 millimeter), scattered throughout. The lentils are very argillaceous and contain up to 15 percent, by weight, of argillaceous impurities. The shale bands which coat the limestone lentils are brown to carbonaceous in appearance, contain abundant silt size detrital quartz and weathers in relief with irregular patches of the shale causing 'dolomitic markings' on the weathered surface.

An increase in the amount of shaly partings in the above rock type gives rise to a slightly different rock type with no lenticular pattern. This rock type consists of a heterogeneous mixture of crystalline calcite, (1.5 millimeter), which exhibits distorted twinning planes, coarse grained calcite, (.1 to .7 millimeters), argillaceous impurities, detrital quartz and limonitic stained shaly patches.

A minor rock type in this uppermost McKay interval is a poorly laminated limestone which consists of alternating limestone and shale laminae, which are hairline in thickness. The limestone contains abundant 'oolites' or 'pellets' of argillaceous material. Fine crystals of pyrite altered to hematite or limonite are abundant throughout this rock type. The thick shaly partings, are not limy.

The upper McKay grades abruptly into the Glenogle shales.

Thickness and Distribution

This section of the McKay group was measured along a ridge on the north side of Moscow Creek. The McKay-Glenogle contact here is 13,000 feet, on a bearing of 270°, from the northeast corner of the map-area. The McKay exposed here is on the east dipping, overturned limb of a westerly overturned fold. Fourteen hundred and fifty feet of exposed McKay was measured. It is impossible to estimate the total thickness of the McKay Group here as the McKay is poorly exposed for a considerable distance below the end of the measured portion of the section, and the base is not exposed. This section was measured with a 6 foot steel tape and therefore more inaccuracies are present than measurements made with a hundred foot tape and a Brunton compass.

The McKay Group of this structural division does not correlate well with the fourfold division of the McKay Group to the southwest at Marmalade Creek. The measured portion of the McKay probably is the equivalent of Unit lV McKay at Marmalade Creek. Unit lV at Moscow Creek is at least 400 feet thicker than at Marmalade Creek. No comparison can be made between the older, underlying units at Marmalade Creek and the older, overlying units at Moscow Creek.

Dolomitization of the McKay Group

West of the Nine-Mile fault, the uppermost 200 to 300 feet of the McKay are often dolomitized. East of the Nine-Mile fault, where the Glenogle and Wonah occur between the McKay and the Beaverfoot formations, the McKay is not dolomitized.

Dolomitization of the McKay is irregular as shown by the fact that some places where there is a sharp contact between McKay limestones and Beaverfoot dolostones, the McKay may grade laterally, in a short distance, to dolostones and there may be a band of dolostones 100 to 200 feet below the top of the McKay which is overlain by normal McKay limestones. Where 200 to 300 feet of the uppermost McKay are dolomitized the dolomitization is irregular and the most intense dolomitization does not necessarily occur in the beds nearest the Beaverfoot dolostones.

West of the Nine-Mile fault at the head of Nine-Mile Creek the McKay varies from its normal limestone habit. Here the uppermost blue limestone beds are crossed by dolomitized grey worm-burrow (?) tubes (see Figures 16 and 17), 4 centimeters long and 1 centimeter in diameter, which anastomose and are joined by smaller tubes. The tubes consist of a subhedral mosaic of dolomite, (.01 millimeter). The contact between the tubes and the calcite matrix is usually sharp but there may be a small gradation between the dolomite of the tubes and the calcite matrix.

This is underlain by a series of medium grained crystalline silicified dolostones with intercrystalline chert. The chert which is black on the fresh surface and red on the weathered surface has partly replaced the dolomite. Silicification appears to be related to dolomitization in the McKay.

This is underlain by blue limestones with abundant

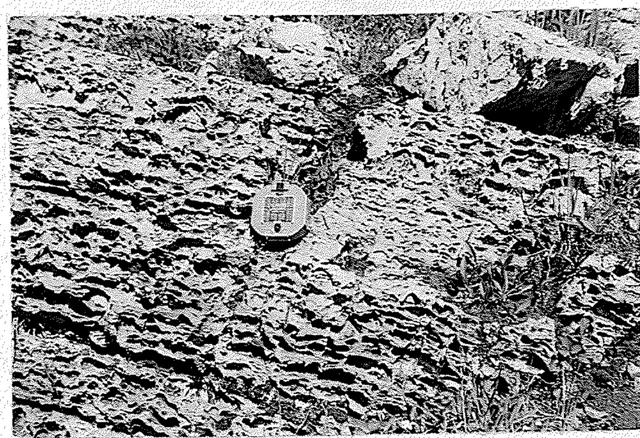

Figure 15. Lenticular limestone showing limestone lenses that weather as depressions in contrast to the argillaceous limestone matrix that stands in relief. Near top of Unit lV, McKay group, White Knight Mountain (Geol. Surv. Canada photo).

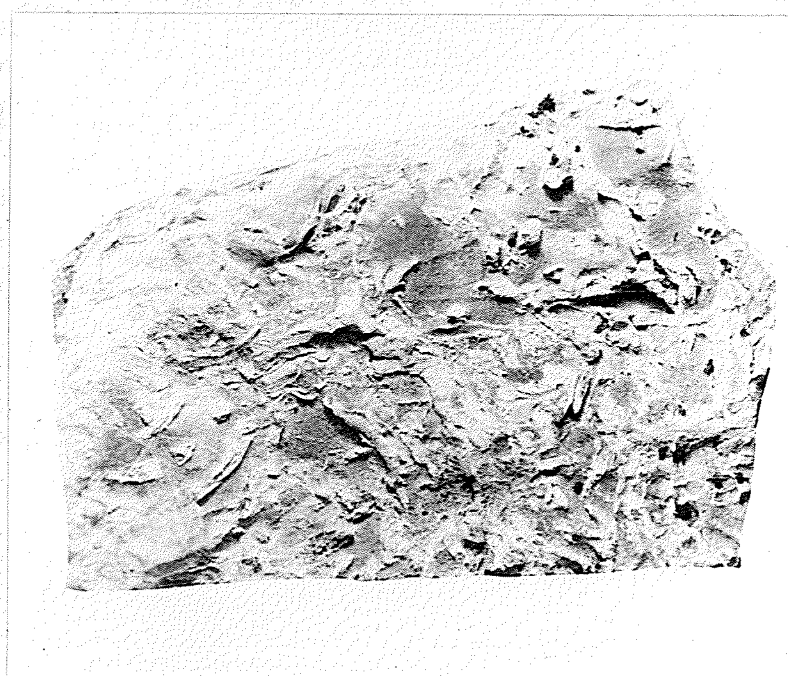

Figure 16. "Worm-like" structures on bedding plane of blue limestone. The tubes consist of grey dolomite and matrix is blue limestone. Near the top of the McKay group, north of Lamb Creek (magnification x 1).

well formed worm burrow tubes, 1 centimeter long and 2 millimeters in diameter, on bedding planes. The grey dolomite of the tubes is medium grained crystalline and dense. From these centers the rock grades from dolomite with intercrystalline calcite to calcite with discrete dolomite euhedra. Where dolomitization has been intense minute chert blebs are present in the tubes and adjacent areas. The total thickness represented by this section is 200 to 300 feet and these beds, within varying distances, grade laterally into normal limestones.

Some dolostones exhibit the original limestone structure. A specimen of white dolostone occurs with the nodular structure typical of many of the McKay limestones. The shaly partings and the individual carbonate nodules are readily distinguishable.

Faunas and Correlations

Evans (1932 A2, pp. 126 to 134) who measured and described the type McKay section recognized the following 8 fossil zones which range in age from Upper Cambrian to Chazy:

Chazy	Zone 8 - Ampyx Zone 7 - Megalaspis
Beekmantown	Zone 6 - Diplograptus Zone 5 - Xenostegium
Lower Ordovician	Zone 4 - Ozarkispira Zone 3 - Kainella Zone 2 - Symphysurina
Upper Cambrian	Zone 1 - Dikelocephalus (Briscoia)

In the Canal Flats area fossils were collected in the McKay from the measured sections at Marmalade and Moscow Creeks and 10 collections were made at various locations throughout the map-area and identified by T. E. Bolton. The fossils collected at Marmalade Creek are:

G.S.C. Loc. Cat.	Footage below top	Litho-logic Unit	Fossil Collection
#23887	50' - 60'	IV	Clarkella nona Walcott Eoorthis (?) sp. Hormotoma sp. Raphistoma (?) sp. Hystricurus (?) sp. Leiostegium formosa Hintze
23899	60' - 70'	1V	Lecanospira sp. Ophileta sp. indet. Raphistomina sp.
23902		1V	Ophileta leo (Walcott)
23889	580'-645'	1V	Eoorthis (?) sp. Kainella billingsi (Walcott)
23884	671'-664'	1V	Eoorthis (?) sp. Lingulella sp. Hystricurus sp. Kainella n. sp.
23891	693'-673'	1V	Eoorthis (?) sp. Hystricurus sp. Kainella billingsi (Walcott)
23894	1086'-1049'	111	Symphysurina spicata Ulrich Xenostegium sp.
23886	1363'-1357'	11	Eoorthis (?) sp. Blountia sp. of B. plana Resser Bynumia cf. venusta Resser
23890	1392'	11	Symphysurina spicata Ulrich
23888	1473'	11	Eoorthis (?) sp. Lingulella sp. Obolus sp. Blountia sp. Bynumia cf. venusta Resser Illaenurus cf. albertensis Resser

G.S.C. Loc. Cat.	Footage below top	Litho-logic Unit	Fossil Collection
23893	1836'	1	Briscoia sp. aff. B. coloradoensis (Walcott) B. cf. sinclairensis Walcott
23898	1893'	1	Briscoia sinclairensis Walcott
23897	2000'	1	Briscoia cf. sinclairensis Walcott
23892	2043'	1	Eoorthis (?) sp.
23885	2288'	1	Briscoia sinclairensis Walcott
23882	2333'	1	Briscoia cf. sinclairensis Walcott
23880	2473'	1	Lingulella sp. Briscoia sinclairensis Walcott
23883	2677'-2653' (loose)	1	Obolus concentricus Ulrich and Cooper
23881	2847'	1	Crinoid columnule Eoorthis (?) sp. Lingulella sp. Blountiella sp. cf. B. alberta Resser Pterocephalina (?) sp. Taenicephalus (?) sp.

Briscoia sinclairensis Walcott was first observed 400 feet above the base of the McKay and is found in abundance to 1039 feet above the base. This genus is reported by Howell et al. (1944, p.994) as being characteristic of the Briscoia zone of the Franconian stage, but as no other faunas are present with the Briscoia of this area no definite faunal zone can be established. Taenicephalus (?) which occurs 26 feet above the base is listed by Howell as indicative of the Conaspis zone of the Franconian stage and therefore the base of the McKay may be older than the Briscoia zone. While the definite zone cannot be established the basal McKay is of the Franconian stage. Zone 1 of Evans is well defined in Canal Flats by the fauna Briscoia. Walcott (1924, p. 45) reported Briscoia from the same zone as Evans found Dikelocephalus and it is on this evidence the basal zone is correlated with Zone 1 of Evans.

In the Canal Flats area the faunas above the Cambrian are only Canadian (Ordovician) in age. According to Evans Symphysurina marks the base of the Ordovician. A collection with Cambrian trilobite genera Blountia and Bynumia occurs over and below Symphysurina. Until the age range of Blountia and Bynumia are more fully known it is difficult to locate accurately the base of the Canadian, however the base of the Canadian is at least 1100 feet below the top of the McKay group.

Other collections, close to the Marmalade Creek section are listed below, so that the Ordovician part of the McKay in the Canal Flats area can better be correlated with Evans' faunal zones.

G.S.C. Loc. Cat.	Location	Lithologic Unit	Fossil Collection
#23878	2300 feet on brg. 240° from 7675 feet peak, three-fourths mile N.N.E. of Ram Creek-Roam Creek pass.	Base of Unit 11 (?)	Lingulepis cf. tenuilineata Poulson Symphysurina sp.

G.S.C. Loc. Cat.	Location	Lithologic Unit	Fossil Collection
#23875	2000 feet on brg. 240° from 7675 feet peak, 3/4 mile N.N.E. of Ram Creek-Roam Creek pass.	Top of Unit 11	Lingulella sp. Nanorthis cf. putilla (Walcott) Blountia sp. cf. B. plana Resser Pseudoagnostus cf. canadensis (Billings)
23872	1600 feet on brg. 240° from 7675 feet peak, three-fourths mile N.N.E. of Ram Creek-Roam Creek pass.	111	Xenostegium sp.
23876	3000 feet on brg. 0° from the Sharp Tooth.	111 (?)	Eoorthis (?) sp. Lingulepis sp. aff. L. tenuilneata Poulson Bellefontia nonius Walcott Symphysurina cf. spicata Walcott Trigonocerca sp. Xenostegium sp. Nereites or Trilobite track
23879	13,700 feet on brg. 156° from Mt. Glenn	11 (?)	Symphysurina spicata Ulrich
23870	N. shore Alces Lake approx. 175 feet from E. end.	About 125 feet below top of McKay	Crinoid stem
23869	N. shore Alces Lake approx. 250 feet from E. end.	Top 20 feet of McKay group	Michelinoceras sp. Calliops sp.
23811	2800 feet on brg. 34° from E. end of White Swan Lake		Eoorthis (?) sp. Ecculiomphalas sp. Trilobite fragments
23877	E. bank Lussier R. 7500 feet N. of Ram Creek		Eoorthis (?) sp. Symphysurina cf. spicata Walcott S. cf. walcotta Kindle Obolus sp.

G.S.C. Loc. Cat.	Location	Lithologic Unit	Fossil Collection
#23900	7500 feet on brg. 220° from Mt. Glenn		Ophite sp. indet. Rhaphistomina sp. indet. Trilobite cephalon and pygidium

A comparison of the faunas at Marmalade Creek, and in the adjacent areas, with the faunas as in Evans' area shows that in the map area discussed here no Chazy faunas are present and that there is little evidence for zones 5 and 6 of Evans. Xenostigium is characteristic of zone 5 of Evans, and in the Canal Flats area it is associated with Symphysurina or occurs without other genera. No fauna associated with the Xenostegium zone or the Ozarkospira zone below, were found in the McKay of the Canal Flats area, therefore it can be assumed that zones 4 and 5 are not present in the Canal Flats area, Evidence exists for the Kainella zone, as abundant Kainella and Hystricurus specimens, which are characteristic of zone 3, are present in the McKay.

At Moscow Creek in the northeast corner of the map-area, the following fossils were collected from Unit lV of the McKay:

G.S.C. Loc. Cat.	Footage below top	Fossil Collection
#23904	100'	Archeorthis cf. occidens Ulrich and Cooper Leiostegium manitouense Walcott
23901	265'	Syntrophina sp. Ophileta cf. leo (Walcott) Hystricurus (?) sp. Symphysurina spicata Ulrich
23905	492'	Nanorthis cf. putilla laeviuscula (Walcott)

G.S.C. Loc. Cat.	Footage below top	Fossil Collection
#23895	580'	Nanorthis sp. indet.
23903	610' - 620'	Archaeorthis cf. occidens Ulrich and Cooper Ophileta cf. leo (Walcott) Protopliomerops cf. superciliosa Ross
23896	960'	Ophileta sp. indet. Raphistomina sp. indet.

In this area, as at Marmalade Creek, the fossils indicate the <u>Kainella</u> zone for the upper part of the McKay in the Canal Flats area.

<u>Protopliomerops</u> cf. <u>superciliosia</u> is listed by Ross (1951, p.29) as occuring at the base of zone F of the Garden City formation which is equivalent to the Beekmantown. Other Beekmantown faunas are present in the McKay at Canal Flats but none of them are within the Beekmantown as defined by Evans.

From the above it is obvious that the age limits of the McKay group in the Canal Flats area are from medial Upper Cambrian to Canadian (Ordovician).

Walker (1926, p.23) mapped a series of Upper Cambrian and Lower Ordovician rocks as equivalent to the Goodsir formation. This correlation with the Goodsir was made over a gap of 40 miles along strike of the formation. Evans (1932 A2, p.131) was unable to prove definitely whether or not the McKay is to be correlated with the Goodsir to the north, but does correlate the Goodsir of the Windermere area with the McKay group of the Brisco Range. Walcott (1928, pp. 232 to 237) objects to this correlation from the Windermere area to the Goodsir on Mount Goodsir. His objections are partly based on faunal evidence, and Evans (1932 A2, p.131) states that these faunal objections are justified, but is however of the opinion that the Goodsir as a series is to be correlated with the McKay group, admitting that certain members (formations) present in one range may well be absent in the other. In view of this conflicting evidence the writer used the name McKay group rather than Goodsir formation for the Upper Cambrian-Lower Ordovician strata in the Canal Flats area.

Henderson (1953, p.33) correlates these rocks with the McKay group of Evans but the faunal evidence for such a correlation is poor. The Upper Cambrian, only, of the McKay is present at Sabine Mountain and this was found to contain a fauna equivalent in age to the Prosaukia sub-zone of the Franconian. The age of the basal McKay in the Stanford and Hughes Range (Canal Flats area) is similar. Faunal evidence is poor for determination of an upper age limit of the McKay in the Stanford Range.

In conclusion there is a belt of McKay that extends north from the Hughes Range in Canal Flats to the Brisco and Van Horne Ranges. The base of the McKay is medial Upper Cambrian in age. The upper age limit of the McKay is medial Lower Ordovician in the Canal Flats area, the Stanford Range, and Windermere area but in the Brisco and Van Horne Ranges the upper age limit is Chazyan.

LOWER AND MIDDLE ORDOVICIAN

THE GLENOGLE SHALE

Introduction

The Glenogle shales occupy a position between the McKay group and the Wonah quartzite. The shales are correlative with the Glenogle shales of Burling (1922, p.256). The Glenogle consists of a series of black, well bedded graptolitic shales of Upper Deepkill age.

Lithology

Two Glenogle sections were measured and the lithology is similar in both areas. The formation consists of a series of well bedded massive black shales; laminated black shales; shales with limestone concretions (see Figure 18); limy black shales; shales with minor limestone breccia interbeds; shales with marcasite concretions; and silty shales with quartzose siltstone interbeds. The laminations in the shales are due to white, silt size, quartz laminae one sixteenth of an inch thick and laminae consisting of white calcite. Laminae bend beneath and above the limestone concretions and pass through the concretions. The shales often are very limy and in places partly approach an argillaceous limestone in composition.

Figure 17. Etched surface showing "worm-like" structures. The light grey tubes consist of dolomite and the darker matrix consists of fine grained calcite. Near the top of the McKay group, north of Lamb Creek (magnification x 1).

Figure 18. Limestone lenses in limy shale. Glenogle measured section, White Knight Mountain (Geol. Surv. Canada photo).

They are more limy at Moscow Creek especially close to the McKay limestones and are silty towards the top with some siltstone beds occuring beneath the Wonah quartzite. This formation is fossiliferous throughout.

Fauna and Correlation

The Glenogle shale is the name proposed by Burling (1922, p.256) for a succession of graptolitic shales, Deepkill and Normanskill in age. This type section is near Golden, B. C. Walker (1926, p.24) correlated the graptolite shales of the Windermere area with the Glenogle shales of Burling. The Normanskill element was not present in the Windermere area. Evans (1932A, p.135) confirmed Walker's correlation. The northern portion of Evans' map-area contained Normanskill elements. Henderson (1953, p.42) was able to correlate the Glenogle of the southern Stanford Range with the Windermere area. Only three Deepkill zones are present in the Glenogle. Ruedemann (1947, pp. 100 to 106) gives a thorough discussion of the graptolites in the Rocky Mountains with special reference to the Glenogle shale.

Two sections of Glenogle were measured within the Canal Flats map-area. Extensive fossil collections were made in each section and identified by T. E. Bolton.

A section 454 feet thick was measured on the west face of White Knight Mountain. The following collections were obtained:

G.S.C. Loc. Cat.	Footage above base of the Glenogle shale	Fossil Collection
#23930	43' - 53'	Lingula sp.
23937	57'	Didymograptus cf. nitidus Hall Isograptus walcottorum Ruedemann Lingula sp. (in limestone)
23929	97'	Didymograptus nicholsoni planus Elles and Wood Phyllograptus (?) sp.
23935	105.5'	Isograptus walcottorum Ruedemann
23927	118'	Cardiograptus cf. folium Ruedemann Isograptus walcottorum Ruedemann cf. Leptograptus flaccidus (Hall) Phyllograptus sp. P. ilicifolius Hall
23925	153'	Cardiograptus angustifolius Ruedemann Isograptus walcottorum Ruedemann
23922 & 23936	191.5'-220'	Diplograptus sp. Glossograptus horridus Ruedemann Isograptus wallcottorum Ruedemann Phyllograptus cf. angustifolius Hall Trigonograptus insiformis Hall
23934	273'	Diplograptus sp. Glossograptus cf. ciliatus Emmons Leptograptus flaccidus (Hall) L. cf. logani pertenuis Ruedemann Phyllograptus sp. P. cf. angustifolius Hall
23926	359'	Climacograptus sp. Lasiograptus echinatus Ruedemann L. echinatus major Ruedemann Tetragraptus sp. T. pendens Elles
23924	447'	Climacograptus sp. indet. Didymograptus sp. D. cf. spinosus Ruedemann Glossograptus sp. Lasiograptus sp. L. inutilis (Hall) Loganograptus logani pertunuis Ruedemann Phyllograptus cf. ilicifolius Hall

Another section was measured along the north ridge of Moscow Creek. This section was 1103 feet thick and yielded the following collection:

G.S.C. Loc. Cat.	Footage above arbitrary contact in McKay-Glenogle transition beds	Fossil Collection
#23931	433'	Didymograptus cf. nicholsoni planus Elles and Wood Isograptus walcottorum Ruedemann Phyllograptus cf. angustifolius Hall
23928	484'	Didymograptus cf. euodos Lapworth Isograptus walcottorum Ruedemann
23932	576'	Cardiograptus folium Ruedemann Isograptus cf. caduceus (Salter) I. walcottorum Ruedemann
23933	860' - 861'	Climacograptus sp. Clonograptus sp. cf. C. flexilis Hall Glossograptus horridus Ruedemann
23919	899'	Climacograptus cf. antiquus Lapwor Didymograptus sp. D. cf. nicholsoni Lapworth Diplograptus sp. Glossograptus horridus Ruedemann Lassiograptus echinatus Ruedemann L. echinatus major Ruedemann Trigonograptus ensiformis (Hall)
23920	941'	Climacograptus sp. Isograptus caduceus armatus Ruedemann Lasiograptus cf. echinatus major Ruedemann
23918 A	1044'	Climacograptus sp. Didymograptus sp. Glossograptus horridus Ruedemann Lasiograptus cf. inutilis (Hall)

G.S.C. Loc. Cat.	Footage above arbitrary contact in McKay-Glenogle transition beds	Fossil Collection
#23918	1102' - 1103'	Climacograptus sp. Didymograptus sp. Diplograptus gladius Ruedemann Glossograptus horridus Ruedemann Climacograptus antiquus Lapworth Diplograptus sp. Lasiograptus echinatus major Ruedemann Thamnograptus sp.

In both sections the graptolites are of upper Deepkill age and correlated with the three Deepkill zones established in the Windermere area, and the Beaverfoot and Brisco Ranges. Normanskill elements are lacking also at Canal Flats. In the Moscow Creek section upper Deepkill graptolites are present immediately below the Wonah quartzite. At White Knight Mountain there is a gap of only 7 feet between the uppermost occurence of Deepkill graptolites and the Wonah quartzite. It is evident that the youngest age is uppermost Deepkill.

Thickness and Distribution

Two sections of the Glenogle were measured in the Canal Flats map-area. A section of shale, 456 feet thick, was measured on the west face of White Knight Mountain; 2000 feet distant on a bearing of 190° from White Knight peak. A section was measured along the north ridge of Moscow Creek. This section was 1100 feet thick. The Glenogle thickens to the northeast in the overthrust portion of the map-area.

The Glenogle shales are restricted to the area of sedimentation east of the Nine-Mile fault. These rocks overlie the McKay group with conformity and there is slight gradation in lithology between the McKay limestones and the Glenogle shale. The change in lithologic aspect is abrupt between the shales and overlying Wonah quartzite (see Figure 19).

MIDDLE AND/OR UPPER ORDOVICIAN

THE WONAH QUARTZITE

Introduction

The Wonah quartzite occupies a stratigraphic position between the Glenogle shales and the Beaverfoot-Brisco formation. The quartzites are correlative with Wonah quartzites which Walcott (1924, p.49) named at the north end of the Stanford Range. The formation consists of clean white quartzites and sandstones.

Lithology

Two sections were measured in the Canal Flats area, at White Knight Mountain close to the Beaverfoot measured section and at Moscow Creek.

On the west face of White Knight Mountain the Wonah varies in character. It is a quartzite in some places and grades to a friable sandstone in other places. The Wonah consists of rounded, equigranular quartz grains, (.5 millimeters) which have been recrystallized (see Figure 21) to form excellent quartz crystals, .1 to .5 millimeters in length along the C - axis. Both the sandstone and the quartzite have been recrystallized in situ. The sandstones are friable and porous with irregular patches of more consolidated quartzite. Some introduced limonite is present in the porous sandstone but as a rule the formation is pure. "Organic forms" (see Figure 20) are present on the weathered surface.

The uppermost Wonah consists of 9.5 feet of a very arenaceous dolomite which grades into normal Beaverfoot dolostones. This transition zone contained Richmond fossils such as branching bryozoans and Helopora.

Lithologically the formation at Moscow Creek is similar to the formation at White Knight Mountain. The transition zone between the Wonah and the Beaverfoot is not as well defined here and is marked by some shale interbeds as well as arenaceous dolostones.

Fossils are not present in this formation at Moscow Creek. The quartzite wherever present in the map-area, lacks fossils and the only occurence of fossils is within the transition zone and here they are also scarce.

Thickness and Distribution

The Wonah quartzite at White Knight Mountain consists of 39 feet of quartzite and sandstone and is overlain by

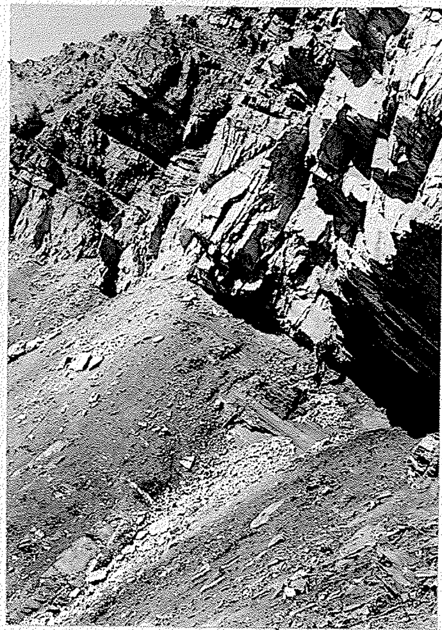

Figure 19. Glenogle-Wonah contact at White Knight Mountain. The Glenogle forms the darker colored, rubbly base and the Wonah forms the massive light colored cliffs above. The overhang is the base of the Wonah. Note man standing near contact (Geol. Surv. Canada photo).

Figure 20. Circular structures (organic?) in the Wonah quartzite at the White Knight Mountain measured section (Geol. Surv. Canada photo).

11 feet of Wonah-Beaverfoot transition arenaceous dolostone. The Wonah has a slightly variable thickness at White Knight Mountain.

A section of Wonah Quartzite was measured along the north ridge at Moscow Creek. The section is much thicker than at White Knight Mountain. It is 292 feet thick. The formation thickens to the northeast in the overthrust portion of the map-area.

In the Canal Flats area the Wonah quartzite is exposed east of the Nine-Mile fault where it is overlain conformably by the Beaverfoot-Brisco formation and underlain, with no discordance in attitudes, by the Glenogle shales (see Figure 19).

Faunas and Correlation

Walcott (1924, p.49) assigned the name Wonah quartzite to a white, unfossiliferous quartzite which overlies the Glenogle shales on Sinclair Mountain.

In the Canal Flats area the stratigraphic position of this formation can be determined, although faunal evidence is poor. The lower age of this formation must be Chazy because the underlying Glenogle contains uppermost Deepkill graptolites. The overlying formation, Beaverfoot formation, is of Richmond age. The age of the Wonah quartzite is somewhere in the range of Middle to Upper Ordovician. The presence of branching bryozoans and *Helopora* in the uppermost transition beds of the Wonah confirms an Upper Ordovician age.

This stratigraphic position is the same as determined to the north by Henderson (1953). In the Windermere area, Walker (1926, p.31) also concluded that the Wonah was at the same stratigraphic position but believed the beds to be younger than Chazy. Fossils were not present in the Wonah in these areas. Further north, Evans, determined sparse marine fossils (crinoid stems). Walker and Henderson both stated that although no discordance in attitudes between the Wonah and Glenogle is evident the Wonah rests on different parts of the Glenogle in different areas indicating a disconformity.

UPPER ORDOVICIAN AND MIDDLE SILURIAN

BEAVERFOOT-BRISCO FORMATIONS

Introduction

A complete section of the Beaverfoot-Brisco formations is not present in the Canal Flats area. The Beaverfoot consists of a series of cliff forming, massive, light to dark grey dolostones (see Figure 22) with minor limestone phases and interbedded quartzites. The Brisco consists of a series of interbedded quartzites, fossiliferous black shales and massive dolostones.

The formation is correlative with Beaverfoot formation of Burling (1922, p. 452) which is of Ordovician age.

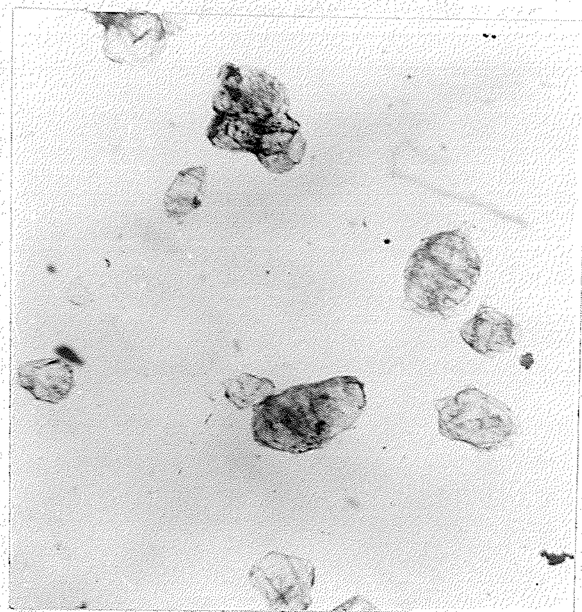

Figure 21. Wonah sand grains showing authigenic overlays. Black rims mark outline of original sand grains. From the White Knight Mountain measured section (magnification x 1).

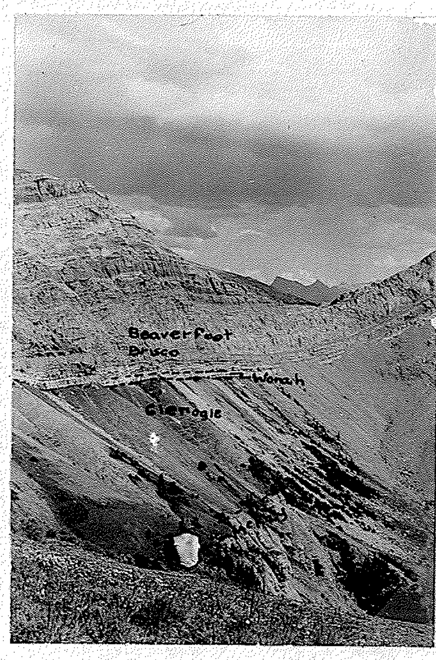

Figure 22. Measured sections at White Knight Mountain. The massive rocks capping the ridge are the Beaverfoot-Brisco and Wonah at the base. The less well exposed rocks are the Glenogle and the McKay. All contacts are apparently conformable (Geol. Surv. Canada photo).

However Walcott (1924, p.41) found the upper part of the formation to contain a Silurian fauna. He assigned the name Brisco formation to the Silurian element but because it is impossible to divide the two formations lithologically they have always been mapped as one, the Beaverfoot-Brisco formations. In the Canal Flats area and to the north the Beaverfoot-Brisco formations overlie the Wonah quartzite.

Lithology (Beaverfoot)

Two sections of the basal Beaverfoot-Brisco were measured east of the Nine-Mile fault on White Knight Mountain. Only a few hundred feet were measured because a complete section was not available. Sections were measured in the dolostone and limestone phases of the Beaverfoot for purposes of contrasting the lithologic differences.

A dolostone section was measured as a continuation of measured Glenogle and Wonah formations. The base of the Beaverfoot section is 1700 feet on a bearing of 192° from White Knight peak. Approximately 331 feet of section was measured.

The Beaverfoot is composed of a series of poorly bedded dolostones dark grey to buff on the weathered surface and light to dark grey on the fresh surface and in beds .5 to 3 feet thick.

The basal 28 feet of the Beaverfoot consists of massive fossiliferous coarsely grained crystalline dolomite (.1 to .5 millimeters) with some coarse grained dolomite euhedra as replacements in a finer matrix. This grades sharply into 8 feet of blue limestone which has an anostomosing series of shaly partings which gives the limestone a nodular structure. The limestone nodules are 1 inch long. The limestone grades laterally into dolostones of similar structure and vertically into 12 feet of dolostone similar in lithology to the basal dolostone. The fossils in the basal 28 feet are completely dolomitized (see Figure 23) and some cephalopods are very coarse grained crystalline toward the center, almost drusy in texture and structure.

The dolostone is overlain by 21 feet of quartzose siltstone (see Figure 24) which resembles dolostone on the weathered surface because of its orange buff color. The siltstone has excellent laminations due to cross-bedding, on a scale of several centimeters. The laminae consist of quartz grains (.05 to .1 millimeter) in diameter, well rounded, alternating with dolomite euhedra, (.1 millimeter), which contain abundant detrital quartz grains. This rock has been recrystallized so that the quartz grain laminae are now cemented by quartz and some grains exhibit authigenic overlays and undulatory extinction. The quartz laminae weather in relief.

The siltstone is overlain by 27 feet of fossiliferous,

Figure 23. Etched surface of partially dolomitized Beaverfoot limestone. The lighter colored crystalline dolomite has replaced the corals and portions of the matrix. The dark colored matrix xonsists of original finer grained calcite. From the section at White Knight Mountain (magnification x 1).

Figure 24. Etched surface showing Beaverfoot limestone with cross-bedded laminae of fine quartz sand. The sand, which is light colored and forms most of the mineral in this specimen, averages less than .1 mm. in diameter, and has authigenic overlays. The matrix which is darker colored consists of calcite. From the section at White Knight Mountain (magnification x 1).

grey, coarse grained dolostone. The fossils are replaced by very coarse grained crystalline dolomite. Intercrystalline calcite is present in small amounts. The rock has minor patches (1 to 2 millimeters), of white drusy dolomite which when combined with the grey dolomite of the matrix gives the rock a slightly patchy appearance. Detrital silt size quartz is present in small amounts.

This is overlain by 110 feet of blue to buff weathering dolostone (.1 millimeter) with patches of argillaceous impurities. The rock is fairly uniform in texture with minor patches of more crystalline dolomite throughout. Secondary veinlets of dolomite, .1 millimeter thick, occur through the rock and minor limonitic argillaceous partings are also present.

This is overlain in turn by 125 feet of light to dark grey dolostone poorly bedded with several 'intraformational conglomerates', and is lithologically similar to the underlying dolostones. This rock type is actually the remnant of a limestone intraformational conglomerate which has been dolomitized. The original texture has been obliterated and the outline of the conglomerate pebbles are preserved by limonitic rims. The texture of the rock is equigranular, medium grained crystalline with laminations .5 centimeters thick, composed of coarse grained crystalline, (.5 to 1 millimeter) white dolomite at 2 to 3 centimeters intervals. Where these laminae are thick they are drusy in structure and porous. Minute chert blebs are present in these laminae. This rock is slightly argillaceous with a few argillaceous partings.

No further section was measured above this horizon. From the end of the measured portion to the peack of White Knight Mountain, a thickness of 800 feet stratigraphically, the Beaverfoot-Brisco formation consists of massive to well bedded, grey dolostones similar in lithology to the rock types discussed above. Fossils were not observed above the measured portion of the Beaverfoot at White Knight Mountain. Cross-bedded quartzite interbeds, 30 feet thick and similar in lithology to the Wonah Quartzites were observed 6000 feet east-north-east from White Knight peak. The formation, however, is essentially a dolostone where observed in the Canal Flats area.

A section of basal Beaverfoot was measured 1200 feet north along strike from the previously described section. This section consists of a limestone lens, several hundred feet in length along strike and 245 feet thick stratigraphically, which graded laterally and vertically into dolostones. Fossils are present in much greater quantities in the limestone section than the dolostone section and the preservation is also better. This relationship is consistent throughout the Beaverfoot formation.

The limestone phase of the Beaverfoot formation consists of a series of well bedded nodular limestones. The basal 27 feet of the limestone consists of black limestone, fine to medium grained. Abundant comminuted brachiopods valves, corals and crinoid columnals which have been replaced by clear calcite are present in the rock. Silt size quartzose impurities and some small patches of white, medium grained crystalline, dolomite which grades into limestone matrix are also present. Some phases of this limestone approach a coquina in composition with bryozoans, up to 3 centimeters long, and abundant fossils, which have excellent preservation, comprising about 50 percent of the rock. Some fossils exhibit small dolomite replacement patches and discrete dolomite euhedra.

This is overlain by 12 feet of laminated quartzose siltstone. This rock consists of about 85 percent rounded quartz grains, (.05 to .1 millimeters) and is cross-bedded with the cross-bedded laminae 2 centimeters long. Most of the laminae consist of quartz grains but some laminae consist of calcite grains. The rock has been recrystallized and the quartz grains are cemented by silica with some quartz grains exhibiting authegenic quartz overlays. The final product of recrystallization has been to give the quartz laminae an even mosaic texture. This horizon was present in the dolostone section to the south and the proximity in elevation above the Wonah and Beaverfoot contact in both sections proves that the quartz horizon is continuous for at least several thousand feet.

This is overlain by 187 feet of black, thin bedded, nodular limestone. The nodular pattern of the rock is due to the reticulating pattern of shaly partings which divides the limestone into nodules 6 centimeters long. The shaly partings are irregular as is the nodular pattern of the limestone. The limestone is very fine grained and fossiliferous with quartzose and argillaceous impurities as well as minute pyrite cubes, .1 millimeter in diameter. Minute patches of medium crystalline dolomite are present throughout the limestone. Some dolomite occurs in a 'worm boring' pattern. This consists of anastomosing 'tubes' of dolomite, 6 centimeters long and .5 to 1 centimeter in circular cross section, which are interconnected by smaller 'tubes'. The dolomite and calcite contact in most instances is sharp, although there may be a slight gradation between the two. The dolomite 'tubes' are often bounded by calcite shell fragments with no replacement of the shells. Fossils rarely occur in the dolomite and when present may be partially replaced by dolomite which is fine grained, (.02 millimeters) and forms a subhedral equigranular mosaic within the 'tubes'. The calcite matrix is pellitic and has abundant dispersed dolomite metacrysts. At the top of this horizon dolomitization of fossils is common and small 'veinlets', 2 centimeters long, of white dolomite form trichinitic patterns on the weathered surface. Drusy dolomite occurs in some fossils and the limestone matrix contains abundant dispersed dolomite euhedra.

The succeeding interval, 21 feet thick, is a transition zone between the limestone and the dolostone which comprises the major portion of the Beaverfoot, and consists of a series of thinly bedded limestones and dolostones which grade laterally and vertically into each other within short distances. The lithology is complex and depends upon the degree to which the limestones have been dolomitized.

This transition zone becomes more dolomitic towards the top and at the very top is a dolostone. The stratigraphic thickness of the overlying dolostones is several hundred feet. The dolostones are thicker bedded, with a few silicified fossils at the base, and black chert nodules. The lithologic aspect is similar to the dolostones previously described.

Thickness and Distribution

The Beaverfoot part of the Beaverfoot-Brisco formations is present both east and west of the Nine-Mile fault.

To the west of the Nine-Mile fault, the Beaverfoot-Brisco overlies the McKay group with apparent conformity. East of the fault it also overlies the Wonah quartzite with apparent conformity (see Figure 22).

The Beaverfoot-Brisco is a well bedded cliff forming dolostone both east and west of the Nine-Mile fault. The basal portion of the Beaverfoot is not a dolostone in some places but is a limestone. Dolostone may grade along strike into limestone which is continuous for a thousand feet laterally and a few hundred feet vertically. All limestones appear as large lenses within the dolostone. Abundant Richmond faunas are present in the basal few hundred feet of the Beaverfoot but above this few fossils are present. No contact between the Beaverfoot (Richmond) and Brisco (Silurian) was observed in the field.

The top of the Beaverfoot-Brisco formations was nowhere observed in the Canal Flats area. An accurate estimate of the total thickness is therefore impossible, but on the west face of White Knight Mountain a thickness of 1100 feet of Beaverfoot was calculated from base map projections. An Ordovician-Silurian time line could conceivably be present in these beds but there is no faunal evidence to prove or disprove this. The total thickness of the formation is greater than 1100 feet.

Where the Beaverfoot overlies the McKay it is possible to differentiate the two formations because:

1) The Beaverfoot is usually a light grey massive dolostone in contrast to the darker shades of the McKay limestones.

2) Abundant typical Richmond faunas are present at the base of the Beaverfoot.

Difficulties may arise in placing the contact, however, if the uppermost McKay and basal Beaverfoot are dolostones or if they are both limestones. The error in placing the contact should not be more than 300 to 400 feet stratigraphically either way as only this much of the basal Beaverfoot may be a limestone or this thickness may be a dolostone in the McKay. It is still possible to differentiate between the McKay and Beaverfoot formations on a faunal basis as the base of the Beaverfoot is fossiliferous.

Difficulties, as discussed above, exist on the west shoulder of Mt. Glenn. Lithologically the contact is near the peak where there is a sharp change in lithology from limestone to dolostone. On a faunal basis the contact is 1500 feet west, where the McKay-like limestones contain typical Richmond fossils. It is difficult to place an accurate contact between the rocks with a Richmond fauna and true McKay limestones because of similarity of lithology.

Fortunately, relationships as above are rare and the McKay-Beaverfoot contact is usually well defined. Differentiation between the formations can often be made accurately from an examination of the topographic map. Pronounced Beaverfoot 'flat-irons' overlie a McKay homocline on the east side of the Hughes Range, and this relationship is manifest on the topographic map.

East of the Nine-Mile fault no difficulties exist in placing formation contacts as the Beaverfoot overlies the distinctive Wonah quartzite.

<u>Lithology and Distribution (Brisco)</u>

An isolated black shale Brisco outcrop occurs at the eastern edge of Alce's Lake.

The black shale outcrop (no. 7 on map) is the only observed Silurian exposure in the Canal Flats area. This outcrop consists of over 100 feet of west dipping, north-south trending beds. The sequence from east to west, is as follows:

Limestone (fossiliferous) more than 100 feet thick; black fossiliferous shale 100 feet thick; quartzite (resembles Wonah Quartzite, not fossiliferous) 30 feet thick; dolostone, 40 feet thick, not fossiliferous but resembles the Beaverfoot dolostones.

Faunas and Correlations

The Beaverfoot limestone was the name assigned by Burling (1922, p.453) for beds in the Beaverfoot Range that are Richmond in age. Walcott (1924, p.41) found that the upper portion of this formation contained Silurian faunas. No physical evidence of a systemic break at the upper limit of the Richmond is present. Walcott assigned the name Brisco to the Silurian portion of the Beaverfoot.

Wilson (1926) identified various collections from the Beaverfoot. These collections were made from Canal Flats north to Golden, B.C. with a single collection also present from the Kananaskis-Palliser, Alberta map-area. Wilson (1926, p.2) stated that the transition from Richmond to Silurian appears to have been gradual, indicating that deposition was continuous and undisturbed in the area under consideration. It has therefore been mapped as a single rock unit -- the Beaverfoot-Brisco formations.

Beaverfoot Correlations

Many new species were noted by Wilson which are indigeneous to the Beaverfoot formation. Of the Beaverfoot faunas, Wilson states (1926, p.3) :

> Any correlation of the Beaverfoot fauna has to be made mainly by means of corals and brachiopods. The Rocky Mountain collections do not include the ostracod and bryozoan fauna of Stony Mountain, Manitoba and Bighorn Mountains, Wyoming. Although the Beaverfoot is more closely allied to these two than to the Richmond of central and eastern America an examination of the internal structure of the brachiopods has shown in almost every case there is a very definite and specific difference ... although in a broad sense the fauna is allied to that of Manitoba and Wyoming, the differences are greater than they have been generally considered.

Wilson considers the Beaverfoot fauna to be Richmond in age.

Twenhofel et. al. (1954, p.263) cites Dunbar as assigning a Gamachian age to the Beaverfoot. This is done on the basis that the Stony Mountain formation of Manitoba, which is correlative to the Beaverfoot, is of Camachian age, however some writers believe that only the upper portion of the Stony Mountain is of Gamachian age. It has not been proven yet whether the Beaverfoot is correlative with the entire Stony Mountain formation. Beatricea which could be used for Gamachian age determination has been reported only by Burling and Evans in the Rocky Mountains. The paucity of this genus and lack of definite correlations leads the writer to believe, that until more data is available the Beaverfoot should still be considered only of Richmond age.

The faunas present in the Beaverfoot of the Canal Flats area are present also to the north, in the Rocky Mountains. Correlation is therefore relatively simple. The following fossils, identified by T. E. Bolton, were present in the Canal Flats area:

G.S.C. Loc. Cat.	Footage above base	Fossil Collection
	Section on west face of White Knight Mountain	
#23900	0 - 24'	Receptaculites sp. (R. occidentialis Salter type)
		Diplophyllum primum (Wilson)
		Favistella alveolata (Gold fuss)
		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.
		Pachydicta sp.
		Dinorthis rockymontana Wilson
		Rafinesquina sp.
		Rhynchotrema kananaskia Wilson
		R. pisina Wilson
		Sowerbyella sp.
		Fusispira sp.
		Liospira sp.
		Raphistoma sp.
		Endoceras sp.
23868	39'	Calapoecia n. sp.
23866	83-85.5'	Helopora sp. cf. H. harrisi James
		Pachydicta sp.
		Microtrypa (?) sp.
		Rhynchotrema increbescens occidens Wilson
		Skenidiodes sp.

G.S.C. Loc. Cat.	Footage above base	Fossil Collection
		Strophomena sp. Strophomena sp. cf. S. billingsi (W. and S.) Vogdesia sp. cf. V. vigilans (Meek and Worthen) Leperditia sp.
#23865	194-330'	Diplophyllum halsitoides (Wilson) D. primum (Wilson) Streptelasma sp. Halysites robustus Wilson
23843		White Swan Lake -- Basal beds 3700 feet on bearing 102° from west end of White Swan Lake. Receptaculites sp. Lichenaria sp. Halysites robustus Wilson Streptelasma prolongatum Wilson S. trilobatum Whiteaves Crinoid columnals Platystrophia sp. indet. Rafhinesquina sp. Opikina sp. Sowerbyella (?) sp. Hormotoma sp. and other Gastropoda indet. Armenoceras sp.
23845		Approximately 300 feet above base Favistella aleveolata stellaris (Wilson) Halysites delicatulus Wilson Streptelasma sp.
23862		East of Nine-Mile Creek - 10,000 feet on bearing 83° from Mt. Glenn. About 1000 feet above base of Beaverfoot. Lichenaria (?) sp. Cup corals indet. crinoid columnals Pachydictya sp. Helopora sp. Rafinesquina sp. Opikina sp. Rhynchotrema sp. Hormotoma sp. Cornulites sp. Bathyurus sp. Ceraurus sp. Encrinurus cf. cybeleformis Raymond

G.S.C.
Loc.
Cat.

Fossil Collection

#23859 Moscow Creek - 8100 foot peak at northwest headwaters of Moscow Creek. About 900 feet above base of Beaverfoot.

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

23860 Hughes Range - 2650 feet on bearing 238° from Mt. Glenn, basal beds.

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

23846 11,400 feet on bearing 146° from Mt. Glenn basal beds.

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

23863 4,000 feet on bearing 182° from Lussier River Hot Springs basal beds.

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

23852 4,000 feet on bearing 103° from the Shark Tooth, basal beds.

Favistella alveolata (Goldfuss)
Halysites delicatulus Wilson

G.S.C. Loc. Cat.	Fossil Collection
	Streptelasma distinctum Wilson S. trilobatum Whiteaves Dinorthis columbia Wilson D. rockymontana Wilson Rhynchotrema cf. kananaskia Wilson
#23848	about 150 feet above base. Halysites cf. pulchellus Wilson
23853	500 feet on bearing 225° from 7675 foot peak on north side of Ram Creek-Roam Creek pass, basal beds. Crinoid columnals Favistella alveolata stellaris (Wilson) Streptelasma prolongatum Wilson Rhynchotrema cf. increbescens occidens Wilson

Brisco Correlation

Walcott (1924, p. 12 and 47) described the Silurian portion of the Beaverfoot-Brisco formations. Ruedemann correlated the graptolites of the Brisco formation with the Clinton (lower Middle Silurian) formation.

The Brisco formation is represented in the Canal Flats area by a small outcrop at Alces Lake. The following fossils were collected from this exposure and identified by T. E. Bolton and R. Thorsteinsson:

G.S.C. Loc. Cat.	Fossil Collection
#23921	North shore of Alces Lake, 300 feet from east end. Monograptus cf. clintonensis (Hall) M. columbianus Ruedemann M. cf. vomerinus (Nicholson) M. walcottorum Ruedemann Stomatograptus grandis Suess Parmorthis (?) sp. Tryblidium (?) sp. Michelinoceras (?) sp.

The collection is lower Middle Silurian in age and correlates well in age and faunal content with the Brisco formation further north.

MIDDLE SILURIAN AND/OR MIDDLE DEVONIAN

BURNAIS FORMATION

Introduction

Middle Silurian and/or Devonian may be represented in the Canal Flats area by the Burnais gypsum which is correlated with Burnais formation of Henderson (1953, p.50).

Lithology

There appear to be three varieties of gypsum: An earthy gypsum; a crystalline gypsum; and a massive laminated gypsum. All the gypsum is white in color and the latter rock type predominated. It was waxy in appearance with abundant crystals of gypsum. The gypsum is brecciated in places but calcite is absent in the breccia zones.

Distribution and Thickness

Several exposures of gypsum occur along the Lussier River east of the Hughes Range. These outcrops form cliffs along the river bank and the maximum stratigraphic thickness observed by the writer is 40 feet. The gypsum may underlie considerable areas as abundant sink holes were present in areas of drift.

Faunas and Correlation

Henderson (1953, p.50) proposed the name Burnais formation for a gypsum, with interbedded limestone, sequence. No fossils were found in this formation but its stratigraphic sequence in the Stanford Range indicates that it was deposited somewhere between Niagaran (Middle Silurian) and Middle Devonian.

Several gypsum outcrops are present on the Lussier River north of Roam Creek and along Coyote Creek. These exposures occur as cliffs along river banks. The upper and lower limits of this formation are not exposed in the map area. Fossils are not present in this formation but from a lithologic study it appears to be the Burnais formation of Henderson.

MIDDLE DEVONIAN

HARROGATE FORMATION

Introduction

The Harrogate formation occurs in the Stanford Range, however to the south in the Canal Flats area no exposures are present.

Distribution and Correlation

The Harrogate formation was named by Shepard (1926) for a series of nodular, fossiliferous limestones of Middle Devonian age. Henderson reports 4 occurrences of this formation in the Stanford Range. In nearly all instances they are closely associated with the Burnais formation but exposures are poor.

Unless the Harrogate was either not deposited or eroded it should be present in the map area.

MISSISSIPPIAN

BANFF AND RUNDLE FORMATIONS

Introduction

The Banff shale and Rundle limestone, which occur at the southeast corner of the map-area, are the only known Mississippian rocks in this part of the Rocky Mountains. The Banff shale consists of black carbonaceous shales and the Rundle limestone consists of well bedded, dark cherty limestones.

Lithology

Shale, which may be equivalent to the Banff shale, did not outcrop but there was abundant scree, indicating a black, very fissile, carbonaceous shale. The shale was not fossiliferous.

The shale is overlain by 1200 feet of limestone, believed to be the equivalent of the Rundle limestone, which is divisible into 3 units. The description of the lithology as listed below begins at the base of the exposed limestone.

Unit 1 (400 feet thick) Base

100 feet limestone - weathered surface is light reddish grey (due to fire). Fresh surface is dark grey in

color. The rock is very fine grained, laminated, fetid odor, slightly argillaceous and silty. Thin bedded in one half to 3 inch beds with blebs of black chert also present; some 2 inch interbeds of very thinly bedded limestone. A 25 foot band of encrinal limestone is also present.

300 feet limestone - thicker bedded, 6 to 12 inches. Weathered surface is blue. Fresh surface is dark grey, fine grained with bands of black chert 1 inch thick and nodules of black chert up to 6 by 18 inches. In places the rock varies to a cherty limestone. It is crossbedded in places. There are 10 to 15 foot interbeds of laminated limestone and yellow siltstone with curved 'organic' markings on the bedded planes. The upper portion consists of interbedded cherty limestone and limy quartzose siltstone.

Unit 11 (300 feet thick) Middle

Silty limestone - thinly bedded in one half to 4 inch beds. The weathered surface is buff in color. Fresh surface is dark grey, The rock is laminated, very fine grained, contains a great deal of quartzose silt and in many places the rock is a limy siltstone.

Unit 111 (550 feet thick) Top

Cherty limestone - The basal 100 feet of this unit weathers white and has a slightly laminated appearance. The fresh surface is black, vitreous in part. The rock is very fine grained. There are some 2 to 4 inch interbeds of buff weathering limestones. The rock is in 4 to 12 inch beds. This is overlain by black cherty limestone and black limestone. These various types of limestone are repeated to form this unit. The major rock component of this is the black cherty limestone with buff interbeds and partings. This unit has a nodular appearance.

Distribution and Thickness

Approximately 1200 feet of black cherty limestones are exposed in the southeast corner of the map-area. These rocks form an island in a valley flat bounded by the Lussier River and Coyote Creek. The rock island is bounded by a fault on the west and probably by a fault on the east.

The top of the limestone is not present nor is the base exposed, although the limestones appear to be underlain by rubbly, black, carbonaceous shale which did not outcrop.

Faunas and Correlations

A fossil collection was made from these limestones, 8600 feet on a bearing of 147° from the junction of the Coyote Creek and the Lussier River. The collection (G.S.C. Cat. No. 23906), which was identified by Dr. P. Harker, yielded as follows:

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

The fossils of this collection are of Mississippian age. While the age of the formation is known, its exact stratigraphic relationship with other formations cannot be determined. Because the Mississippian is bounded by faults and the structure is not known, it may even be that the limestone is from a different sedimentary basin than the Canal Flats area of sedimentation. This is quite unlikely, and the Mississippian is probably part of a stratigraphic sequence normal to the map-area. No upper Devonian is present to the north of the map-area or in the map-area, therefore, the underlying formation must either be Burnais or Harrogate. Either formation would be bounded by an unconformity between it and the overlying Mississippian. There is the possibility that Devonian rocks conformably underlie the Mississippian but have been eroded in the north and until the base of the formation is exposed the writer hesitates to postulate an unconformity.

Henderson, Walker and Evans who mapped north of Canal Flats found no Mississippian rocks. Walcott who examined a large portion of the Rocky Mountains north and east of Canal Flats also found no Mississippian. Schofield (1915, p.55) reports Mississippian limestones (the Wardner formation) 12 miles due west of Elko in the Purcell Mountains. Few fossils have been collected from the Wardner formation and its exact age is not known.

The Mississippian of Canal Flats correlates better with the Mississippian of Alberta. Lithologically, the formation compares favorably with the Rundle as described by Kindle (1924) and Warren (1927, p.27) in the Banff, Alberta area. The black shale which formed very poor rubbly exposures beneath the limestone is lithologically similar to the Banff Shale (Mississippian) of the Banff area. Several fossils from the Canal Flats collection are identical with Rundle fossils as listed by Warren

(1927, p.29) and Beach (1943, p.30). Further work will probably yield better faunal evidence for correlation with the Rundle of Alberta.

CHAPTER 111

STRUCTURAL GEOLOGY

A major fault known as the Nine-Mile fault divides the map-area into two areas which differ slightly in stratigraphic sequence. Because the writer is concerned primarily with the stratigraphy of the area, the Nine-Mile fault will be used as the major structural division. West of the Nine-Mile fault the stratigraphic column ranges in age from late Precambrian to Ordovician-Silurian. East of the Nine-Mile fault the rocks range in age from Ordovician-Silurian to Mississippian. The major stratigraphic difference is that east of the Nine-Mile fault the Glenogle shale and Wonah quartzite formations occur between the McKay and Beaverfoot formations whereas west of the Nine-Mile fault the shale and quartzite is absent.

Nine-Mile Fault Western Division

The structure of this stratigraphic division is not as complicated as the eastern division. Essentially the structure is that of a large homocline, tending northwest and dipping northeast with the inclination between 25° and 35°. This homocline forms the Hughes Range.

The eastern flank of the Hughes Range, from the Lussier River pass southward, is marked by a north-south trending fault with the valley downdropped relative to the mountains. A similar structure occurs on the western flank of these mountains, however, lack of the exposures makes interpretation difficult. These major faults parallel the White River Break of Henderson (1953, p.98) which has a great deal of structural control over this portion of the Rocky Mountains.

Two minor, complimentary, east-west faults exist within this portion of the Hughes Range. An east-west dip-slip dip fault is present north of the Lussier River pass. The southern part of the Hughes Range is downdropped relative to the northern portion of the mountains. At Ram Creek a similar east-west fault is present with the mountains south of Ram Creek downdropped relative to the portion north of the fault. A similar structure could result from offset produced by a strike-slip dip fault. The east-west faults may be shear couples of the major north-south faults.

North of the Lussier River pass the structure is more complicated. The homocline trends more westerly and at Mount Glenn, where exposures are poor, it is difficult to solve the structure. Several faults are undoubtedly present but their exact position and effect on the structure has not been ascertained.

Nine-Mile Fault Eastern Division

The geology of this division is complicated by many faults and folds. A major anticlinal structure is present east of the Nine-Mile fault. The trend of the axis is northwest and the axial plane of the fold passes through the western edge of White Swan Lake. At White Swan Lake the fold pitches gently southeast. The fold has no pitch at White Knight Mountain but north of it the pitch is gently to the northwest.

East of White Knight Mountain the anticline passes into a complimentary syncline. The syncline exposes two Wonah and Glenogle inliers, in Beaverfoot cirques, east of White Knight Mountain.

The syncline is partly truncated by a large fault, 6500 feet east on a bearing of 70° from White Knight peak. The fault marks the sole of a southwest, almost recumbent overturned fold. The fault trends northwest but could not be traced beyond the south ridge of Moscow Creek. The fault must continue as the overturn continues across the northeast corner of the map-area. Henderson (1953) traced this overturn for 25 miles north of the map-area. Only the lower limb of the overturn is present and the beds dip 30 to 45 degrees northeast. Two minor north-south trending faults are present in the overturn. It is evident that all structural features in this division parallel the White River Break.

South of Alces and White Swan Lakes, and east from the eastern flank of the Hughes Range there are no exposures. Through this area, it is impossible to project with accuracy the faults which occur to the north. The country is drift-covered with numerous sinkholes throughout, indicating that perhaps the area may be underlain by gypsum.

At the very south-east corner of the map-area a series of almost flat lying Mississippian limestones are present. These beds represent a 'fault island' as they are bounded on the west by a fault on the Hughes Range and on the east by a fault that was observed east of the map limit. The Nine-Mile fault undoubtedly passes close to the fault island but it is impossible to ascertain whether it passes east or west of the island. It is difficult to fit the Mississippian into the stratigraphic sequence of Canal Flats as it may have been faulted in from another area of sedimentation, however, the presence of Burnais on the west banks of the Lussier River opposite the limestones may be of aid in correct interpretation of the structure.

The Nine-Mile Fault

Henderson (1953, p.60) devoted a great deal of his work to the structures north of the Canal Flats map-area, in the Brisco and Stanford Ranges. He found that two major north-south faults divided the area into 3 distinct structural divisions. These faults merged at the Kootenay River, a short distance north of the confluence of Nine-Mile

Creek and the Kootenay River. The merged faults were reported by Henderson to head up Nine-Mile Creek but he did no further work there.

The Nine-Mile fault in the Canal Flats area is prominent 2 miles north of the ridge at the head of Nine-Mile and Mutton Creeks. It is difficult to trace further north from that point but it probably swings down Nine-Mile Creek and is the southern extension of Hendersons' merged faults. The fault may be traced with some degree of certainty, south, to the west end of Alces Lake but it is lost in the drift south from that point.

The merging of the faults on the Kootenay River cuts out the central fault block of Henderson in the Stanford Range. However in the map area three structural divisions are apparent. These are:

Westerly division- west of the Nine-Mile fault the division consists of a normal succession of easterly dipping rocks.

Central division- between the Nine-Mile fault and the overthrust the division consists of anticlinal and synclinal folded sediments.

Easterly division- east of the overthrust the division is marked by a recumbent fold overturned to the southwest.

The relationship of the three structural divisions in the map area to Henderson's three structural divisions in the Stanford Range is not known.

CHAPTER IV

SEDIMENTATION AND THE STRATIGRAPHIC FRAMEWORK

Introduction

In this chapter an attempt will be made to place some of the rocks in the Canal Flats area in the general Paleozoic stratigraphic framework of the southwestern Rocky Mountains. The importance of sedimentology, in the interpretation of the stratigraphic framework is so great that sedimentation and stratigraphy will be considered together.

An attempt will be made to interpret the environment and conditions under which the sediments were deposited. These results, which reflect tectonism, will be utilized to reconstruct the general stratigraphic framework during Paleozoic time in the Canal Flats area.

Because the writer examined only an area of small extent, in relation to the Paleozoic area of sedimentation that constitutes the present southwestern Rocky Mountains, he acknowledges the fact that many of the ideas advanced are pertinent only to the Canal Flats area or to the more restricted map-area and have no relation to larger areas.

Lower Cambrian (The St. Piran Formation)

The Lower St. Piran unit, which overlies beds of the Windermere system, is the basal bed deposited by a transgressive Lower Cambrian sea in the Canal Flats area.

North of Canal Flats, in the Brisco-Dogtooth area, the St. Piran is underlain by the Lake Louise and Fort Mountain formations of Lower Cambrian age which are unconformable upon the Precambrian. This indicates that the sea transgressed from north to south.

The lithologic uniformity of the Lower St. Piran indicates that the sea advance was gradual. The cross-bedding features indicate shallow sea conditions and a southern source of sediments. The clean nature, and absence of breccias, in the well rounded quartz sands indicate that the sediments were derived from an area of low relief and probably underwent extensive reworking. North (1953, p.111) who studied the Cambrian of southern British Columbia also came to a similar conclusion and believed that the sands were deposited in quiet basins on the flanks of an emergent mass of low relief.

The depositional history of the Upper St. Piran unit is only slightly different from that of the Lower St. Piran. The interbedded shales, sandstones and fine pebble conglomerates suggest minor fluctuations rather than uniform conditions within the depositional basin. The shales and interbedded sandstones indicate shallow seas and stronger currents are indicated by the pebble conglomerates. The source of sediment was close to the depositional area and was still an area of low to moderate relief.

Henderson (1953, p.22) reported the absence of Lower Cambrian in part of the Stanford Range. Primary thinning, or pre Jubilee erosion or a combination of both may account for this absence. Because there is no unconformity at the top of the St. Piran in the Canal Flats and Brisco-Dogtooth areas and because the Ottertail rests on Windermere it appears that primary thinning on a Precambrian high may be responsible for the absence of the Lower Cambrian in that area.

Middle and Upper Cambrian (The Jubilee Dolomite)

The conditions of sedimentation under which the Jubilee dolomite was formed were radically different from those under which the St. Piran was formed.

The dolostones form a deposit of great areal extent. The large extent of the dolostones, lack of interbedded limestones, perfect preservation of minute depositional features, lack of destruction or partial destruction of structures by dolomitization, and absence of fossils during Jubilee time may all be explained by a sea that was high in magnesium content. In this sea a primary dolostone could have formed or conditions would have been favorable for immediate replacement of primary calcite without destruction of original texture or structure.

Sedimentologists believe that there is little evidence for deposition of primary dolomite. Secondary dolomitization late after lithification is a well known fact, but a process of this type usually obliterates original features. Therefore penecontemporaneous dolomitization is probably the agent that formed the Jubilee dolostones. Many authors have previously noted similar relationships. Van Tuyl (1914, p.284) cites Blackwelder as stating that the Bighorn dolomite is the result of progressive alteration of calcite to dolomite before actual lithification took place. Beales (1953, p.2287) stated:

> Dolomitization appears to have taken place early in diagenesis .... If, as is likely sea water was the source of the magnesian it would penetrate most rapidly at and shortly after deposition of the sediment.

If such is the case then a sea with a high magnesian content would greatly aid penecontemporaneous dolomitization and the high magnesium content might inhibit life.

Sanders (1951, p.143) in a discussion of the origin of lamination in dolostones cites Schmidt who stated that laminations are restricted to stagnant waters and Brinkman who stated that stratification is "anaerobic". These hydroclimatic features would preclude life and Sanders also believes that perhaps locally the water was more salty.

The laminations in the Lower Jubilee may be used as a further guide to the interpretation of the geologic history of the Canal Flats area. Concerning laminations of this type Sanders (1951, p.46) stated:

> The easily destroyed pellitic millimeter rythmites (laminations) must have been laid

> down below wave base (at present 100 to 200 meters in depth) in order to preserve their laminations.

The seas in the Canal Flats area, during Lower Jubilee deposition must have been deep, to preserve these delicate laminations.

The absence of laminations in the Upper Jubilee may be accounted for by rise of sea bottom. Diess (1941, p.1105) stated that there was a slight elevation in the west during Upper Cambrian times and this would be reflected in the east and lower sea level. North (1953, p.111) also noted this and stated:

> At the close of Middle Cambrian time, there was a renewal of earth-movement further west in the Purcell-Selkirk area .... this new uplifting extended far enough eastward to cause tilting of our present area slightly towards the east. Upper Cambrian seas were much less widespread in the Cardillera region than were those of the Middle Cambrian.

In the Canal Flats area, this western uplift at the end of Middle Cambrian time elevated the basin, so that the depositional surface was above the wave base interface and in such an environment laminations could not be preserved. This is reflected in the massive Upper Jubilee dolostones, and if North and Diess are correct in their dating of the western uplift it may be that the Upper Jubilee represents deposition only during Upper Cambrian time.

The thickness of the Jubilee dolomite, close to 4000 feet may be accounted for by deposition within a miogeosyncline (Kay, 1951, p.8). This miogeosyncline is part of the major geosynclinal belt that existed in the Cordillera during Paleozoic time. Sedimentary conditions at Canal Flats during Middle and Upper Cambrian time were different than sedimentary conditions further north at Field, B.C. At Field the Middle Cambrian alone, consists of 5000 feet (Allan, 1914, p.67 cites Walcott for this thickness) of fossiliferous, calcareous and dolomitic rocks. The difference in lithology, thickness of rocks and abundance of life at Field suggest that perhaps the sea in the Canal Flats area was partially isolated from and more salty than the sea at Field.

At the very close of Jubilee deposition the first evidence of life appears in the form of fossil fragments, and the Jubilee is overlain abruptly by the McKay shales. It appears, therefore, that at the close of Jubilee time sedimentary conditions in the sea changed to permit life and the basin became much shallower to permit deposition of the McKay shales.

Upper Cambrian and Lower Ordovician (The McKay Group)

The lithology of the McKay group indicates a radically different environment of sedimentation than that for the Jubilee dolomite. The abundance of life and type of sediment suggest a shallow sea of normal salinity.

In a study of the Cambrian shelf deposits of Montana, where the lithology is similar to the McKay lithology in the Canal Flats area, Lochman (1949, p.53) postulated the following origin for intraformational conglomerates and breccias:

> The probably mode of origin is through fragmentation by waves and currents of previously deposited silt limestones ... various types of ripple marks, mud cracks, worm tubes, tracks and trails and castings of mud eaters are common throughout the formation. The pebbles must have been deposited in a depth of water favorable for the development of such physiographic and faunal features. The similarity of the pebble and matrix indicates also that the original material of the pebble was deposited and fragmentation took place within the same facies area. Agitation of the bottom sediments by waves is known to extent to depths of 180 feet, though the usual depth is 100 feet ... Mud cracks necessarily imply exposures on todal flats.

This description and explanation can be applied to the McKay intraformational conglomerates and mud cracked limestones. Shallow water features are present within the entire thickness of the McKay group and the depth of water in which the sediments were deposited was therefore probably never greater than 180 feet, usually about 100, and often the sea bottom was exposed in tidal flats.

Lower and Middle Ordovician (The Glenogle Shale)

The Glenogle shale, is according to Evans and Henderson (1953, p.107), a black shale facies contemporaneous with the limestone and shale facies of the McKay group. In the Canal Flats area, it is probable that, the Glenogle was deposited in a more restricted eastern part of the basin than the normal McKay which occurs both east and west of the Nine-Mile fault.

In the Canal Flats area it is not possible to determine if the Glenogle was deposited contemporaneously with the upper part of the McKay, because the age of the Glenogle and the upper McKay are not delineated with sufficient exactness. The upper age limit of the McKay is Beekmantown (Lower Ordovician), and the upper age limit of the Glenogle is Deepkill. The Deepkill has recently been shown by Twenhofel (1954, plate facing p. 298) to range from Lower Ordovician to lower Middle Ordovician. Therefore it is possible that the Glenogle may represent only deposition during Middle Ordovician and is younger than the upper McKay.

If prior to Richmond time the sea partially withdrew from south to north, the graptolitic shales and limestones in the Canal Flats and Windermere areas would be eroded to approximately the Lower-Middle Ordovician level but in the Brisco-Dogtooth area where seas were present the Middle Ordovician element (Chazy and Normanskill) would not be removed. Walker, Henderson and Walcott believe that a disconformity is present between the Wonah quartzite and the Glenogle shale and Walcott (1924, p.27) states there is non-deposition and overlap of the Beaverfoot-Brisco on the underlying formation at Sabine Mountain. It appears that the Beaverfoot and Wonah rest disconformably on the underlying formations.

Although there is no direct evidence as yet concerning the movement along the Nine-Mile fault it is probable, in keeping with Henderson's structural concepts, that there has been juxtaposition of the Glenogle and the McKay with the Glenogle moved in a north-south trend so that it is now close to the McKay west of the Nine-Mile fault, which has no graptolitic facies. The Glenogle thickens rapidly to the east as shown by the contrast in thickness at Moscow Creek and White Knight Mountain and the graptolitic facies probably thinned out close to the Nine-Mile fault. Juxtaposition, therefore, may have been relatively little.

Walcott (1927, p.152) proposed the hypothesis of two separate north-south trending troughs of sedimentation passed through the Canal Flats area. These troughs, according to Walcott, varied in lithology and the more easterly trough was devoid of life. All evidence in the Canal Flats area is contrary to this idea. The similarity in lithology and abundant similar faunal content of the McKay group throughout the Canal Flats area refutes this concept. The occurrence throughout the Canal Flats area of the Beaverfoot-Brisco formation, with its uniform lithology and similar Richmond fauna is further proof that only one basin of sedimentation existed in this area.

Middle and/or Upper Ordovician (The Wonah quartzite and Beaverfoot formation)

The Wonah quartzite which overlies the Glenogle shale disconformably, is believed by Walcott (1924, p.32) to have been deposited by a transgressive Beaverfoot sea. Evans (1932 A2, p.139) however, believed that the Wonah represents a deposit formed along shore by persistent and fairly strong currents that would form bars and sandspits. This would also, according to Evans, account for the few marine fossils, the ripple marks and cross bedding, the occasional beds of well rounded, frosted wind blown quartz grains and the clean, even grained character of the sand. If the Wonah were a transgressive sea deposit it should also occur between the McKay and the Beaverfoot. However it may have been formed as a deposit along shore, in the same restricted area in which the black shales were formed and could not be deposited beyond the restriction.

The Beaverfoot formation is the extensive deposit of the Richmond sea. The rocks, of this formation, appear to have been laid down initially as a limestone. The occurrence of large limestone lenses at the base of the Beaverfoot and dolomitization of parts of the upper McKay indicate that dolomitization of the formation occurred after lithification. The destruction of original limestone textures is further proof the dolomitization was secondary. The paucity of fossils in the dolostones, in contrast with the abundance of fossils in the limestone, may also be accounted for by secondary dolomitization which has destroyed them.

If conditions in the Beaverfoot sea changed after the deposition of the basal few hundred feet of limestone, and the magnesian content became higher, it would account for the paucity of limestone lenses and fossils above the basal beds. This sea would be favorable for incomplete dolomitization of the overlying beds and could prohibit life.

The absence of secondary dolomitization in the limestones underlying the Beaverfoot, where the Wonah quartzite and Glenogle shale are present, is probably due to the fact that the Glenogle shales acted as a barrier to circulating waters rich in magnesia.

Silurian (The Brisco formation)

There is little information as to the environments of deposition of the Silurian formations, as exposures are poor in the Canal Flats area.

The Beaverfoot sea appears to be a normal part of the basin that existed in the Canal Flats area during Paleozoic time. Deposition of sediments, as indicated by relations to the north, may have been continuous through to Silurian time when the Brisco was deposited. There was some restriction of the seas in part of Silurian time to permit deposition of the graptolitic black shales.

Silurian and/or Devonian (The Burnais formation)

Gypsum, as represented by the Burnais formation, was deposited after Brisco time. The presence of gypsum in the Canal Flats area and the Stanford Range indicates, that here, seas were restricted. Little is known elsewhere about the rocks which were formed during Burnais deposition and therefore little is known about restriction in the Canal Flats area.

Devonian (The Harrogate formation)

To the north the Harrogate formation was deposited above the Burnais and it may or may not have been deposited in the Canal Flats area.

Mississippian (The Banff and Rundle formations)

The youngest Paleozoic rocks exposed in the Canal Flats area are the Banff and Rundle formations. These formations cannot be placed accurately in the stratigraphic framework of the Canal Flats area as no nearby occurrences of these formations have been reported. Because the Mississippian exposure occurs surrounded by faults it may be that these rocks are not part of the normal succession in the Canal Flats area. It may be that the Mississippian is part of the normal succession and that structurally it represents a down dropped fault block which has not been eroded as have other Mississippian rocks in this area. If the Mississippian is part of the normal succession here, it may or may not be conformable upon the underlying rocks and because these are the most westerly occurrence of Banff and Rundle the map-area may have been close to the western edge of the Mississippian sea.

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APPENDIX

DESCRIPTIONS OF THE STRATIGRAPHIC SECTIONS

Shale, green and red, fissile; exposure is poor and there may be a 5 foot thick bed of red quartzite interbedded with the shale	14.0
Sandstone, pink, green and brown and yellow weathering, fine-grained, in beds 3 inches thick	6.0
Quartzite, dark purple, fine-grained, siliceous, limonitic flecks are present; contains some large quartz grains 1/8 inch in diameter; in beds 2 inches to 2 feet thick; red shale partings and interbeds 1 inch thick are present	27.0
Interbedded sandstone and shale; sandstone is red and yellow; shale is green; poorly exposed	8.0
Sandstone, white, yellow weathering, fine-grained, siliceous; partly a pebble conglomerate in composition laminated in part and in 6 inch to 3 foot thick beds.	9.0
Shale, red; contain lenses of limonitic sandstone from 1 to 3 inches thick; rubbly exposure	3.0
Sandstone, white, purple and yellow, fine-grained; composition varies to a pebble conglomerate in part; in 6 inch to 3 foot thick beds; red shale partings and fragments are present	16.5
Sandstone pebble conglomerate, yellow, fine-grained, very siliceous, contains some green shale partings ..	8.0
Quartzite, purple, fine-grained, argillaceous; slightly laminated and symmetrically ripple marked with green shale partings on ripple marked surface; in 1 to 3 inch thick beds	25.0
Sandstone pebble conglomerate, white, purple weathering; matrix is equigranular fine-grained quartz sand; pebbles are quartz, 1/4 inch in diameter white and red	18.5
Shale, brown and red; poorly exposed	2.5
Sandstone, white, blue-grey weathering, friable, limonitic; contains minor amounts of pebble conglomerate; in beds 6 inches to 2 feet thick	6.0
Sandstone, white, medium-grained; contains quartz pebbles and is a pebble conglomerate in a few places; with better cementation varies to a quartzite in part; in beds 3 feet thick; contains some thin beds of green shale	154.5

Shale, green, very fissile	7.0
Sandstone, white to yellow, medium-grained; contains a few quartz pebbles;limonitic in part; in beds 6 inches to 3 feet thick; contains small fragments of green shale and green shale partings	20.0
Sandstone, yellow, brown weathering, fine-grained, very friable; in beds 2 inches thick; contains some green shale partings	3.0
Shale, green, green to brown weathering, fissile, well laminated in part	6.5
Sandstone, white, fine-grained, limy, friable, cross-bedded, limonitic, in beds 3 inches thick	6.0
Interbedded quartzite and shale; quartzite is fine-grained, siliceous, limonitic, in bed 1 inch thick; shale interbeds are 1/8 to 1 inch thick	5.5
Shale, green, mottled green to brown weathering, fissile contains some thin limonitic sand blebs parallel to bedding	3.0
Sandstone, brown, medium-grained, limy, limonitic, contains some quartz pebbles; in bed 1/2 inch thick ...	7.0
Sandstone, white and red, fine-grained, limonitic, calcareous; upper part is slightly laminated and hard; in beds 1 to 4 inches thick	22.5
Sandstone, white, white and pale red weathering, fine-grained; contains abundent hematite and limonite flecks in 2 to 4 inch beds; contains some thin green shale interbeds	12.0
Sandstone, red, fine to medium-grained; contains flecks of limonite; poorly laminated to massive; in 3 foot thick beds; contains some 3 inch thick veinlets of white quartz	12.0
Sandstone, green and brown, medium-grained, limonitic, limy in part; in 2 inch to 4 foot thick beds; thinner beds are friable and thicker beds are quartzitic in part and not limy	38.5
Sandstone, white; fine grained, argillaceous and limonitic to medium-grained and siliceous; in beds 2 to 6 inches thick; contains some interbeds of fine-grained, argillaceous green sandstone and waxy green and brown, sandy, fissile shale in beds 3 inches thick.	28.0

Sandstone, white, buff-grey weathering, fine-grained; in beds 1 foot thick; contains some 6 inch thick beds of siliceous quartzite and green and brown shale; specks of limonite and fragments of brown shale are present in some sandstone beds	34.0
Shale, green and brown; in beds 4 inches thick; contains 1 to 2 inch thick beds ripple marked sandstone	16.0
Sandstone, white, siliceous; contains limonite flecks; slightly argillaceous, friable and laminated in parts; in beds 6 to 12 inches thick; contains some 3 inch thick interbeds of green, fissile, banded shale	16.0
Sandstone, white and light green, fine-grained, argillaceous, limonitic; in interference ripple-marked beds 2 to 6 inches thick; contains 3 inch thick green shale interbeds	11.0
Sandstone, white, fine-grained, siliceous; in beds 6 to 9 inches thick and well laminated in part	5.5
Sandstone, white, fine-grained, limonitic, friable; in beds 2 inches thick	4.5
Sandstone, white, fine-grained, siliceous; contains flecks of limonite and hematite; partly a quartzite; contains some small quartz pebbles; thinly bedded	7.0
Quartzite, white, fine to medium-grained, slightly argillaceous in part; contains flecks of limonitic material and fragments of green shale; symmetrical and interference ripple marks; contains abundant interbeds of sandy, green shale	29.0
Shale, green; contains abundant quartz grains, sand to pebble size; in beds 6 inches to 2 feet thick ,,,,...	15.0
Shale, green grades to mottled red along strike	2.0
Shale, deep purple-red, fissile, laminated, in 1/4 to 1 inch thick beds	8.0
Shale, waxy green; red, yellow, brown and green weathering; contains flecks of muscovite; laminated with blebs and lenses of sand; in 1 to 2 inch thick beds	16.0
Total thickness (Upper St. Piran unit) ..	709.0

Underlying beds: Lower St. Piran unit.

The Jubilee Dolomite

The following section was measured along a number of ridges and slopes north of Ram Creek and west of Marmalade Creek. The line of section is approximately between numbered points 9 on the geologic map.

Overlying beds: McKay Group	Thickness Feet
Not Exposed	4.0
Dolomite, dark grey, blue-grey weathering; contains abundant 'dolomite markings'; massive; minor quartz veinlets are present	25.5
Dolomite, light grey, light buff weathering, medium crystalline, massive; contains abundant quartz veinlets	4.5
Dolomite, dark grey, blue-grey weathering, medium-crystalline, massive; contains 'dolomite markings' and patches of coarsely-crystalline dolomite and calcite; some quartz veinlets 1/4 inch thick are present	115.0
Dolomite, light buff, light grey weathering, fine to medium-crystalline; poorly bedded in 6 foot thick beds	80.0
Dolomite, light grey, light buff weathering, medium-crystalline; contains resistant 'buttons' of dolomite on weathered surface, abundant thin quartz veinlets are present	67.0
Dolomite, light grey, light buff weathering, finely-crystalline; weathered surface in part is mottled and hackly; massive; minor quartz veinlets are present	226.0
Dolomite, light blue-grey, mottled blue-buff weathering, medium-crystalline; some vugs, infilled with pink calcite and dolomite are present	192.0
Dolomite, white to light grey, light buff weathering; laminated in part; massive	237.0

Dolomite, light grey, light buff weathering, medium-crystalline; laminated in an irregular, discontinuous pattern; well bedded in 4 foot thick beds	43.0
Dolomite, dark grey, blue-grey weathering, medium-crystalline, massive	43.0
Dolomite, medium-crystalline; consists of interbedded grey and white dolomite beds 1 to 3 feet thick; in beds 6 inches to 2 feet thick	85.0
Dolomite, dark grey, dark blue-grey weathering, medium-crystalline; contains some 'dolomitic' markings on weathered surface	25.0
Dolomite, dark grey, sandy blue-grey weathering, medium-crystalline, poorly bedded	5.0
Dolomite, light grey and white, buff weathering, medium-crystalline, slightly laminated in part; poorly bedded in 3 foot thick beds	45.0
Dolomite, white, grey and purplish, buff weathering; fine to medium-crystalline with some blebs coarsely-crystalline; contains minor amounts of crystalline calcite; poorly bedded in 6 foot thick beds	74.0
Dolomite, purplish-grey, sandy buff weathering; medium crystalline with some patches coarsely crystalline	34.0
Dolomite, light grey; weathers buff with a brecciated pattern; finely-crystalline with minor amounts of pink calcite; poorly laminated in part ..	88.0
Dolomite, dark grey; knobbly, blue-grey weathered surface; medium-crystalline; poorly laminated in part and poorly bedded; contains patches of red dolomite and calcite	123.0
Total thickness (Upper Jubilee Dolomite)	1536.0
Dolomite, interbedded grey and white dolomite; in beds 1 foot thick; contains abundant lenses of chert 1 foot thick	9.0
Dolomite, thin bedded	9.0

Dolomite, dark grey, blue grey weathering, finely-crystalline; weathered surface is knobbly and has 'dolomitic markings'; in beds 2 feet thick	11.0
Dolomite, light blue; white weathering with some buff patches; finely-crystalline, slightly laminated in part; well bedded in 6 inch thick beds	127.5
Dolomite, light grey, white weathering; massive to poorly laminated; in beds 3 feet thick	12.5
Dolomite, dark grey, blue grey weathering, slightly banded	5.5
Dolomite, light grey, white to buff weathering, medium-crystalline; massive to laminated; poorly bedded in 1 to 2 foot thick beds	106.5
Dolomite, light grey, light buff weathering, medium-crystalline; massive to slightly laminated in part; vuggy in part; in beds 1 to 3 feet thick	27.5
Dolomite, blue grey, vuggy	4.5
Dolomite, light grey, white grey weathering; slightly laminated in part	21.5
Dolomite, light grey, light blue grey weathering, massive; vuggy with some crystalline dolomite infillings	39.0
Dolomite, light grey, white weathering, medium-crystalline; consists of interbedded massive and laminated beds; slightly vuggy at top; poorly bedded in 1 to 2 foot thick beds, Base unit 11	206.5
Dolomite, similar to previous; contains a few minor beds of intraformational breccia; this is the base of the white to light grey weathering dolomite	83.0
Dolomite, interbedded grey and white dolomite; interbeds 3 feet thick; mostly laminated but some beds are massive; some massive beds contain 'dolomitic markings'	116.0
Not exposed	50.0
Dolomite, light grey; contains 'dolomitic markings' on weathered surface; in beds 2 to 6 inches thick ..	28.5

Not exposed	27.5
Dolomite, light blue grey; 'dolomitic markings' on weathered surface; laminated in part at base; in beds 6 inches to 2 feet thick	68.0
Dolomite, grey, laminated; some laminations due to thin interbeds darker colored dolomite; vuggy in part; in beds 1 to 2 feet thick	31.0
Dolomite, white and grey; laminated on weathered surface; bedded	17.0
Dolomite, blue grey, medium-crystalline; 'dolomitic markings' on weathered surface; slightly vuggy at base; some beds slightly laminated; in beds 1 to 3 feet thick	179.0
Dolomite; consists of laminated blue and grey dolomite	15.5
Dolomite; coarsely laminated in white and grey; contains coarsely crystalline dolomite on bedding planes	33.0
Dolomite, dark grey, blue grey weathering, medium-crystalline; contains 'dolomitic markings' and some blebs of black chert; in beds 3 feet thick ..	110.0
Dolomite, dark grey, blue grey weathering, medium-crystalline, laminated in part; 'dolomitic markings' present throughout; thin bedded in lower half and thick bedded in upper half	69.0
Dolomite, blue grey, knobbly weathered surface; contains 'dolomitic markings'; in 6 inch to 1 foot thick beds	21.0
Dolomite, consists of interbedded white and grey laminated dolomite; in beds 1 to 2 feet thick	33.5
Dolomite, blue grey weathering, 'dolomitic markings' present; contains chert in a 'lace-work' pattern at top; in beds 6 inches to 1 foot thick .	46.0
Dolomite, light grey weathering, well laminated; some beds are an intraformational breccia, well bedded in 1 foot thick beds	12.0

Dolomite, light grey, blue grey weathering, massive; contains some buff dolomite veinlets and minor amounts of chert; poorly bedded	67.5
Dolomite, dark grey, blue grey weathering, finely-crystalline; contains abundant beds of red and black chert, 6 to 12 inches thick; poorly bedded	83.0
Dolomite, blue weathering; most beds massive but some are faintly laminated; minor amounts of chert are present; poorly bedded	78.0
Not exposed	73.0
Dolomite, white and grey, laminated, in beds 1 foot thick	31.0
Dolomite, dark grey, mottled blue grey weathered surface, medium-crystalline; poorly laminated in part but mostly massive; contains minor amounts of chert; fetid odour; in beds 6 inches to 2 feet thick.	78.0
Dolomite, interbedded grey and white laminated dolomite; mottled blue grey weathering	25.5
Dolomite, color laminated in blue and grey bands; grey bands form ridges on weathered surface; medium-crystalline; beds are 3 to 9 inches thick	36.5
Dolomite, blue weathering; knobbly and patchy weathered surface; thin bedded in 2 inch thick beds.	7.0
Dolomite, light and dark grey, grey weathering, medium-crystalline, well laminated, in 2 to 6 inch thick beds	38.0
Dolomite, dark grey; mottled blue grey weathering; medium-crystalline, thin bedded	25.0
Dolomite, white and blue grey, finely-crystalline, well laminated	7.0
Dolomite, dark grey, blue grey weathering; medium-crystalline; irregular mottled weathered surface ...	28.0
Dolomite, white, laminated in part	3.6
Dolomite, laminated in grey and white layers; in beds 1 to 2 feet thick	6.5

Dolomite, dark blue; mottled blue grey weathering; medium-crystalline, in 3 to 6 inch thick beds	2.0
Dolomite, light grey, grey weathering, laminated in part; contains minor quartz veinlets; in beds 1 to 2 feet thick	26.0
Not exposed	181.0
Total thickness (Lower Jubilee)	2316.5

Underlying beds: Upper St. Piran unit.

The McKay Group

This McKay section was measured along the eastern side of the head of Marmalade Creek which flows into Ram Creek. The line of section is between numbered points 8 on the geologic map.

Overlying beds: Beaverfoot formation	Thickness feet
Dolomite, limy, cream and grey; black weathering with a cherty appearance; massive, poorly exposed .	5.0
Limestone, blue; contains shaly partings and is in part nodular; 'dolomitic markings' are present; dolomitized in part; in beds 2 to 4 inches thick ..	16.0
Dolomite, dark grey, buff weathering, fine-grained; slightly limy; general muddy appearance	15.0
Limestone, blue, finely-crystalline, organic-like forms on weathered surface bedding planes; contains black chert blebs; in beds 1 to 3 feet thick	15.0
Limestone, dark grey brown, blue weathering, medium-crystalline; contains 'dolomitic markings' and abundant plant-like markings are present throughout on bedding planes; in beds 2 to 6 inches thick; black chert lenses and beds 2 inches thick are common	70.0

Not Exposed	6.0
Limestone, dark grey brown, blue weathering, medium-crystalline; contains abundant 'dolomitic markings'; in beds 2 to 6 inches thick	19.5
Limestone, dark grey, blue weathering, medium-crystalline, brecciated in part; in beds 2 to 6 inches thick; contains some 2 inch thick beds of black chert	13.0
Not exposed	8.0
Limestone, blue, buff weathering; contains limy argillaceous laminae which form ridges on the weathered surface; brecciated in part; in 6 inch to 2 foot thick beds	12.5
Not exposed	11.5
Limestone, light grey and blue, buff weathering, finely-crystalline; in beds 2 to 9 inches thick with some beds 3 feet thick; beds are argillaceous massive, intraformational breccia and laminated types; contains some shale interbeds 6 to 9 inches thick	105.0
Interbedded shale and limestone; consists predominantly of beds of limy shale, buff weathering, up to 5 feet thick; contains interbeds of limestone 1 inch to 2 feet thick with average beds 3 to 6 inches thick; intraformational breccia, mud-cracked, laminated and massive limestone are the lithic types; light grey and blue, buff weathering, fine to coarsely-crystalline	284.0
Limestone, blue, intraformational breccia	5.5
Shale, greenish brown; contains 1 inch thick interbeds of blue limestone	3.5
Limestone, blue; well laminated, massive and intraformational breccia lithic types, in beds 6 inches to 3 feet thick; contains some buff weathering limy shale interbeds	42.0
Limestone, blue, laminated and intraformational breccia type, in beds 2 inches thick	6.0
Limestone, blue, well laminated in part; contains buff limy shale veinlets and interbeds; shows features such as slumping	3.0

Limestone, interbedded intraformational breccia beds 6 inches thick and massive limestone beds 2 inches thick	4.0
Limestone, blue, intraformational breccia	0.5
Limestone, blue, intraformational conglomerate; contains well rounded fragments up to 2 inches ...	0.5
Limestone, blue, shaly, nodular; contains green shale partings and some 2 inch thick interbeds of blue limestone	14.0
Limestone, blue, medium-crystalline, laminated, fissile; in beds 3 inches thick; contains 2 inch thick interbeds of olive drab shale	4.0
Limestone, green grey, blue weathering, fine-grained; knobbly weathered surface; laminated, massive and intraformational breccia lithic types; in beds 2 to 6 inches thick	10.5
Limestone, black, purple weathering, medium to coarsely-crystalline, well laminated, in 1 to 3 inch thick beds	3.0
Limestone, blue; intraformational breccia type; contains some interbeds of massive fossiliferous blue limestone; poorly bedded in 6 inch thick beds	14.5
Limestone, contains buff veinlets which form ridges on weathered surface	4.0
Limestone, grey, intraformational breccia; contains red and black fragments up to 3 inches in diameter	1.0
Limestone, blue; shaly, lenticular; contains buff limy shale partings about the lentils	4.0
Limestone, dark grey, blue grey weathering, fine to medium-crystalline; intraformational breccia type; contains interbeds of laminated limestone; in beds 6 inches thick	19.5
Limestone, dark grey, blue weathering; knobbly weathered surface; finely-crystalline; well laminated, thin bedded	5.5
Limestone, dark grey, blue grey weathering, fine to medium-crystalline; intraformational breccia type, in beds 6 inches thick	8.5

Limestone, dark grey, blue grey weathering; some buff mottling on weathered surface; massive to laminated in part; in beds 3 inches thick; contains some buff shaly partings	94.0
Limestone, blue grey, laminated to massive; organic-like markings present on weathered surface; contains some buff shaly partings; in 2 to 6 inch thick beds	10.0
Limestone, blue and buff weathering; contains some buff shaly partings and three 5 foot thick interbeds of shaly limestone, poorly bedded	59.0
Shaly limestone, thinly bedded	2.5
Limestone, buff weathering; contains some shaly partings; in beds 6 inches thick	11.5
Limestone, buff weathering; knobbly weathered surface; buff partings; in ½ to 6 inch thick beds	66.5
Limestone, dark grey, seperated into 3 inch thick beds by buff partings and a buff network; consists of massive, laminated and intraformational lithic types, poorly bedded	6.5
Limestone, blue grey, finely-crystalline; contains white calcite partings	18.5
Shaly limestone, fine-grained; consists of limestone lentils in a green shale 'matrix'; in beds 2 to 3 inches thick; contains some beds of intraformational limestone conglomerate	57.5
Shaly limestone, <u>this is the base of Unit lV</u>	26.0
Shaly limestone, blue, green grey weathering; shaly lenticular limestone comprises 70 percent of this interval; contains 1 to 2 inch thick interbeds of blue grey, dark grey weathering, fine-grained limestone which has distinctive ringing sound when struck with geologic hammer ..	106.0
Shaly limestone, green; in beds 4 feet thick; contains 1 to 4 inch thick interbeds of nodular, mud-cracked, and intraformational conglomeratic limestone	28.5

Green shale and blue grey limestone, thinly interbedded, this is the base of Unit 111	13.5
Limestone, nodular, mud-cracked and symmetrically ripple-marked, in 1 to 3 inch thick beds, contains some dark grey conglomeratic beds	53.0
Nodular limestone, grey, dark grey weathering, medium-crystalline; in beds 3 to 6 inches thick; contains thin interbeds of intraformational conglomerates and laminated limestone	50.0
Nodular limestone, in beds 1 to 3 inches thick; contains some 6 inch thick beds of laminated limestone	50.0
Nodular limestone, in 2 to 6 inch thick beds, contains abundant brown and black chert lenses and beds	66.0
Limestone, interbedded shaly nodular limestone and laminated black, medium-crystalline limestone, thickly bedded; contains occassional beds of intraformational conglomerate and chert, in upper part	142.5
Limestone, interbedded dark grey nodular shaly limestone and black limestone intraformational conglomerate, thin bedded; some shaly partings present in the nodular limestone; this is the base of Unit 11	74.5
Shale, dark brown, paper-thin; contains thin interbeds of limestone conglomerate	78.0
Shale, green, limy; contains some thin interbeds of reddish limestone conglomerate, fossiliferous in part	45.5
Shale, green, limy; contains lenses of argillaceous limestone and beds of intraformational limestone conglomerate	13.5
Dolomite, rusty weathering, argillaceous; poorly exposed	40.0
Limestone, reddish brown, rusty weathering; very argillaceous; fine-grained, fossiliferous, shaly bedding	19.5

Shale, green, limy, poorly bedded; contains lenses of argillaceous limestone and beds of massive and intraformational limestone breccia; the limestone is grey and blue, and medium-crystalline; fragments are up to 4 inches in length; shale is in beds up to 3 feet thick and limestone is in beds up to 1.5 feet thick; shale forms greater part of interval ..	187.0
Shale, green, limy, in beds up to 10 feet thick; contains some beds of intraformational limestone breccia 1 foot thick	38.5
Shale, green, limy, fissile; contains interbeds of argillaceous and laminated limestone; some beds of intraformational limestone conglomerate are also present	56.0
Shale, green, limy; contains abundant lentils of blue green weathering, green limestone; this resembles a boudinage; many thin beds of argillaceous limestone lentils join; in beds up to 5 feet thick; contains abundant interbeds of red, intraformational limestone conglomerate and breccia and black, fossiliferous limestone; in beds 6 to 12 inches thick	641.5
Shale, dark grey and limonitic, buff weathering, fissile; contains thin interbeds of buff fossiliferous dolomite fossiliferous in part, and argillaceous and limy in part	63.5
Total thickness (McKay group)	2853.0

Underlying beds: Jubilee Dolomite

This McKay section was measured along the ridges which form the northern wall of Moscow Creek. This section is located approximately at numbered point 3 on the geologic map.

Overlying beds: Glenogle shale	Thickness Feet
Limestone, black, blue weathering, very fine-grained; buff weathering, shaly partings throughout form a nodular limestone, nodular thin bedding	280.00

Limestone, grey, brown weathering, fine-grained, finely laminated; in beds 1 to 3 inches thick	16.0
Siltstone, yellow-brown, white weathering, vuggy on weathered surface; massive and dense; in beds 3 to 6 inches thick	37.0
Limestone, black, blue weathering, very fine-grained; small shaly partings impart nodular structure to limestone; in part dolomitized to buff, medium-crystalline dolostone; contains some blebs of black chert; thin nodular bedding .	322.0
Limestone, black, blue weathering, very fine-grained; contains some irregular buff spots on weathered surface; nodular structure; in beds 6 inches thick	40.0
Limestone, blue and black; blue weathering, fine-grained; consists of laminated, massive, mud-cracked, and limestone intraformational breccias; in beds 1 inch to 2 feet thick; cherty in places; contains some 1 foot thick interbeds of green, limy shale	755.0
Total thickness exposed	1450.0

Underlying beds: covered

Glenogle Formation

The following section was measured along the western face of White Knight Mountain near numbered point 6 on the geologic map.

Overlying beds: Wonah Quartzite	Thickness Feet
Siltstone, very rusty, compsstion uncertain	1.5
Shale, black	3.0
Siltstone, laminated	2.5

Shale, black, laminated, brown "siltstone" appearance on weathered surface, contains some marcasite	5.0
Shale, limy, black, massive on fresh surface and shaly on weathered surface	73.0
Shale, limy, black, with interbeds of hard, dense limy shale with a conchoidal fracture, contains a thin bed of argillaceous fine-grained quartzite near top	80.5
Limestone, grey, conglomeratic, with argillaceous laminae	0.5
Shale, limy, black	9.0
Shale, limy, black, on fresh surface massive with appearance of limestone but on weathered surface it has shaly habit, laminated, fossiliferous	102.0
Shale, limy, black laminated in part, contains marcasite	54.0
Shale, limy, black, tan grey weathered, with some siliceous laminae and lenses, fissile, fossiliferous	42.0
Shale, black, brownish weathering, with approximately 10 percent limestone lenses, laminated, hard fossiliferous	25.0
Shale, black, brown weathering, with siliceous laminae, contains some lenses of blue limestone ..	20.0
Shale, very limy, black, laminated	16.0
Limestone, black, very argillaceous, fissile, laminated, dense, could be very limy shale	14.0
Not exposed	5.0
Limestone, black, with numerous light weathering laminae which do not show on weathered surface ...	3.0
Total thickness (Glenogle formation)	456.0

Underlying beds: McKay group

The following section of the Glenogle shale was measured along the ridges on the north side of Moscow Creek near numbered point 3 on the geologic map.

Overlying beds: Wonah quartzite	Thickness Feet
Siltstone, yellow with silt and dark argillaceous laminae hairline to 1/20 inch thick, platy	5.0
Siltstone, yellow grey weathering, dark grey fresh surface, slightly dolomitic	1.0
Shale, silty, laminated	7.5
Shale, yellow weathering, silty throughout, hairline laminations with abundant graptolites ..	22.5
Interbedded shale, silty shale and siltstone, brown	40.0
Shale, black, medium laminated, with minor black limestone interbeds which are laminated and weather yellow, cross bedded in part, in beds 3 inches to 1 foot thick	72.0
Limestone, grey, very argillaceous, thin platy bedding	14.5
Shale, black with some grey limestone interbeds, 4 to 10 inches thick; some sulphide	90.0
Shale, black, very limy	3.5
Shale, black, yellow grey weathering, limy in upper part	28.0
Argillite, black, limy, with some limestone beds ..	24.5
Shale, black, very limy, with some 6 inch thick limestone beds and lenses	63.0
Shale, black, with few limy lenses	42.0
Shale, black, limy, with some beds of very argillaceous limestone	90.0

Shale, black, limy, 70 percent, limestone, 30 percent	28.5
Limestone and shaly limestone 80 percent, shale, black, 20 percent	37.5
Shale, black, with a 1 foot limestone bed	42.0
Limestone, black, shaly	7.0
Shale, black, limy	32.0
Shale, black	64.0
Limestone, black, weathers yellow	1.0
Dolomite, dark, weathers yellow grey, cherty in upper part	10.0
Shale, silty, with abundant laminations hairline thickness, some concretions are present	10.0
Shale, black, limy	10.0
Shale, black, limy, with two limestone interbeds and one bed dolomite, interbeds ½ to 1 foot thick	82.0
Shale, black, with silty laminations, contains numerous thin interbeds of grey silty limestones, rock has banded appearance	40.0
Banded shale, with limestone as above but increasing in number of limestone interbeds	54.0
Thinly interbedded limestone and shale in equal amounts, lime is cream to dark; shale is black and fissile, with some fine white laminations, marked striped pattern to rock	107.5
Total thickness (Glenogle shale)	1101.5

Underlying beds: McKay group

Wonah Quartzite

The following section was measured along the western face of White Knight Mountain near numbered point 6 on the geologic map.

Overlying beds: Beaverfoot-Brisco formation	Thickness Feet
Dolomite, creamy grey weathered surface, grey fresh surface, crystalline, sandy throughout (transition zone)	11.0
Sandstone, creamy weathered surface, creamy grey fresh surface, pitted weathered surface, cross-bedded	18.0
Sandstone, creamy grey, hard, siliceous cement, numerous pits on weathered surface	7.0
Sandstone, creamy weathered surface, creamy grey fresh surface, large scale cross bedding with westerly source, brown laminae and lenses weather in, slightly limy cement	14.0
Total thickness (Wonah quartzite)	50.0

Underlying beds: Glenogle shale

The following section of Wonah quartzite was measured along the ridges on the north side of Moscow Creek near numbered point 3 on the geologic map.

Overlying beds: Beaverfoot-Brisco formation	Thickness Feet
Sandstone, yellow brown, slightly dolomitic, contains vitreous quartz grains, black chert grains and fragments of shale, has laminae which weather to form ridges, contains crinoid fragments at top	7.5
Sandstone, varies to quartzite in places, white to yellow, poorly laminated, with small shale fragments	16.0
Quartzite, white, siliceous, lower part in 1 to 2 foot beds but upper part is massive	71.5

Quartzite, light grey, siliceous, thin bedded	6.0
Quartzite, light to dark grey, fine grained, locally dolomitic, poorly bedded	191.0
Total thickness (Wonah quartzite)	292.0

Underlying beds: Glenogle shale

Beaverfoot-Brisco Formations

The following section was measured along the west face of White Knight Mountain, numbered point 5 on the geologic map, as a continuation of the Glenogle and Wonah sections. This section is typical of the dolomitic phase of the Beaverfoot-Brisco formations.

Overlying beds: Beaverfoot-Brisco formation	Thickness Feet
Dolomite, Dark brown grey, weathers mottled white-grey, medium-crystalline, fossiliferous, poorly bedded	38.0
Dolomite, weathers medium grey, massive, poorly bedded	26.5
Dolomite, dark grey, medium-crystalline, with small blebs black chert and some silicified corals, poorly bedded in 6 foot thick beds	36.0
Dolomite, medium grey, medium-crystalline, with lenses of limestone and argillaceous partings, in beds .5 to 1 foot thick	25.0
Dolomite, dark grey, medium-crystalline, variegated weathered surface, 'sandy' appearance, with fossils and blebs finely-crystalline dolomite along bedding planes, poorly bedded in .5 to 3 foot thick beds	110.0
Dolomite, dark grey, weathers grey, finely-crystalline, with some silicified fossils, poorly bedded	27.0

Siltstone, quartzitic, white, weathers orange or grey, well laminated in part, poorly bedded in 3 foot thick beds	21.0
Dolomite, blue to sandy buff, medium-crystalline	10.5
Dolomite, light grey, weathers light buff, nodular with shaly parting around nodules	2.0
Limestone, blue, very fine-grained, nodular with reticulating shaly partings	7.5
Dolomite, dark grey, weathers grey to buff, finely-crystalline, with a few crinoid columnals present and blebs of black chert; in beds 2 to 3 feet thick ..	28.0
Total thickness measured	331.5

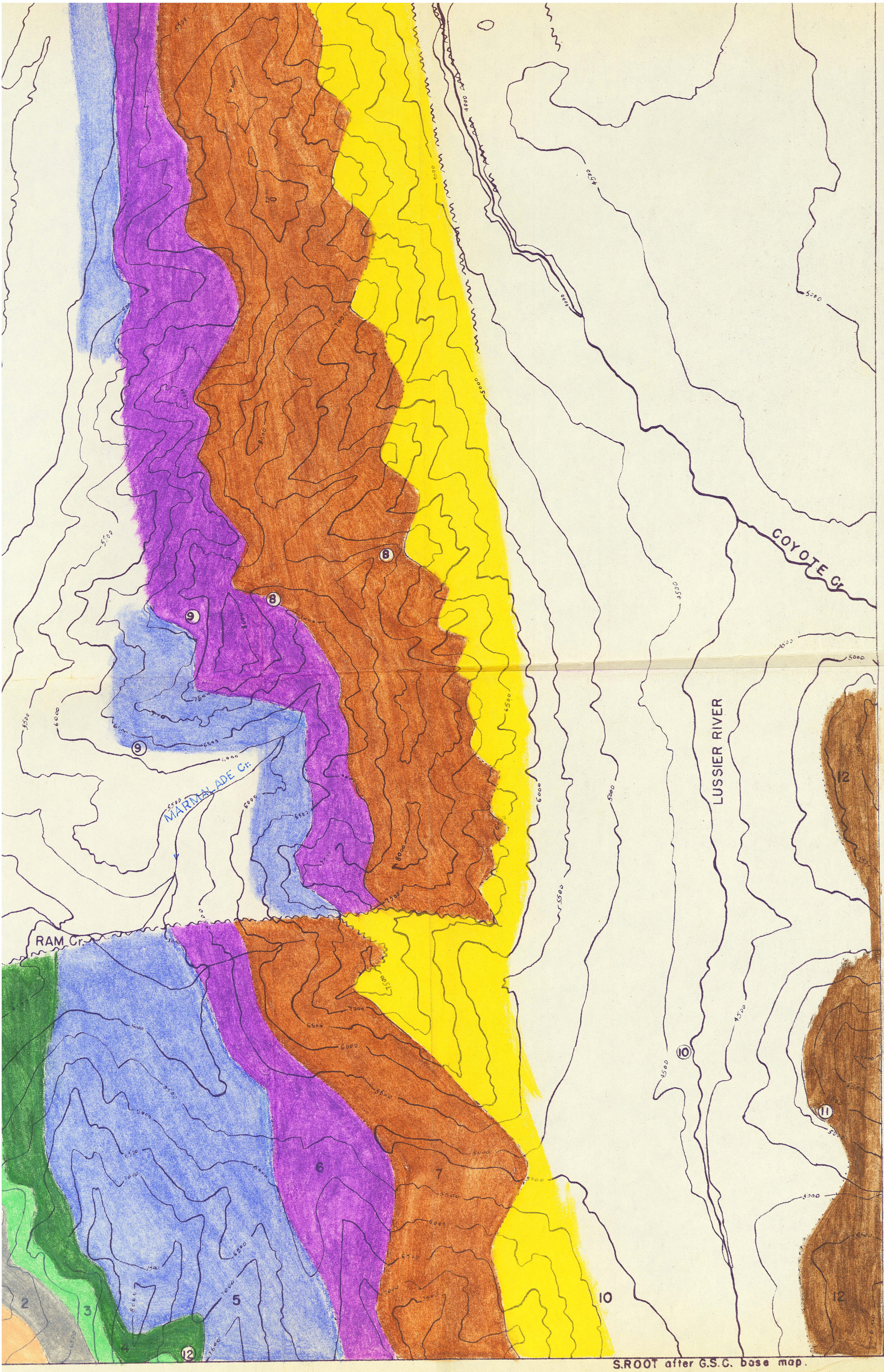
Underlying beds: Wonah quartzite

The following Beaverfoot-Brisco formations section was measured along the west face of White Knight Mountain, 1200 feet north of the Wonah-Glenogle section, and represents the limestone phase of the Beaverfoot-Brisco formations.

Overlying beds: Beaverfoot-Brisco formations	Thickness Feet
Dolomite, dark grey, medium-crystalline, with blebs black chert and silicified fossils, muddy-argillaceous laminae, grades into limestone laterally; in beds 2 to 4 feet thick	2.0
Limestone, blue, with interbedded dolomite weathering buff, grades to dolomite laterally, very irregular lithology; in 1 to 6 inch thick beds	19.0
Limestone, black, weathers blue, medium-crystalline, nodular with network of buff markings, weathers as nodular rubble; in beds 2 to 6 inches thick; contains abundant fossils in part and a few blebs black chert, in part this varies to shaly nodular limestone	187.0

Limestone, black, weathers dark grey, finely-crystalline, massive in lower part and nodular shaly in upper part, very fossiliferous throughout, with black chert lentils up to 10 inches long, laminated in part; massive limestone is thick bedded and nodular limestone is thinly bedded; upper 12 feet is very silty	39.0
Total thickness measured	247.0

Underlying beds: Wonah quartzite

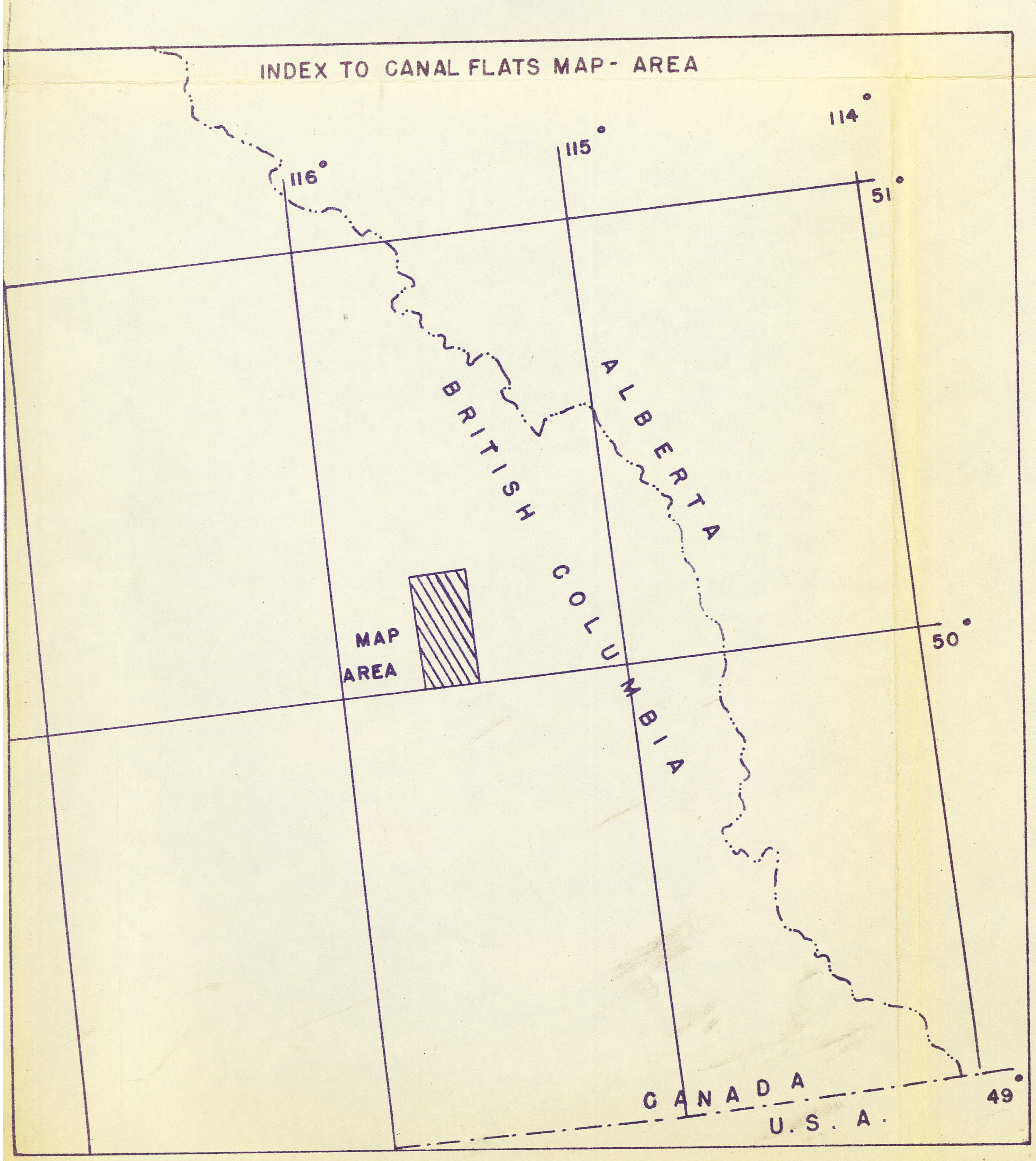


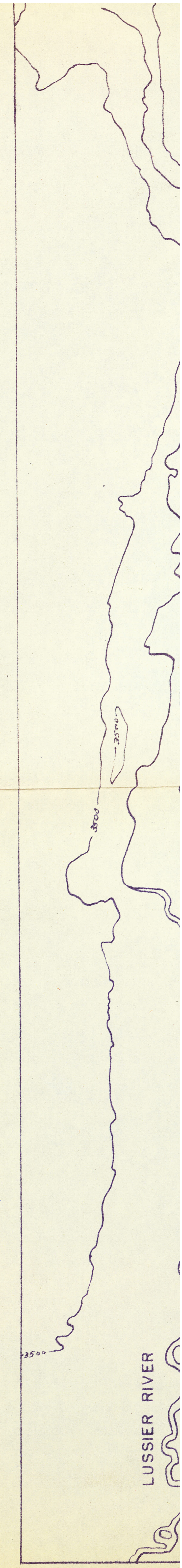
S.ROOT after G.S.C. base map.

NINE MILE FAULT
WHITE SWAN L.
ALCES L.
10
4
5
6
7
9
L.

SYMBOLS

Geologic boundary	defined	approximate	assumed
Fault	defined	approximate	assumed
Contours (interval 500 feet)	1000 500		
Streams			
Lakes	Lake		





PRELIMINARY GEOLOGIC MAP
CANAL FLATS AREA, B.C.

SCALE 2" = 1 MILE

GEOLOGY BY: S.ROOT & G.B.LEECH

LEGEND

RECENT
13 DRIFT

PALEOZOIC

MISSISSIPPIAN
- 12 BANFF & RUNDLE

DEVONIAN & SILURIAN
- 11 BURNAIS FM.

SILURIAN & ORDOVICIAN
- 10 BEAVERFOOT-BRISCO

ORDOVICIAN
- 9 WONAH QUARTZITE
- 8 GLENOGLE SHALE

ORDOVICIAN & CAMBRIAN
- 7 McKAY GROUP

CAMBRIAN
- 6 UPPER JUBILEE
- 5 LOWER JUBILEE
- 4 UPPER ST. PIRAN
- 3 LOWER ST. PIRAN

PRECAMBRIAN

WINDERMERE SERIES
- 2 TOBY CONGLOMERATE

UPPER PURCELL SERIES
- 1 PURCELL SERIES

NUMBERED POINTS

1. Mt. Glenn
2. Nine - Mile Creek
3. North ridge at Moscow Creek
4. Sole of overthrust
5. White Knight Mountain
6. Measured Glenogle, Wonah, Beaverfoot
7. Silurian outcrop
8. McKay measured section
9. Jubilee measured section
10. Burnais outcrop
11. Mississippian 'island'
12. Upper St. Piran cirque