GEOLOGICAL SURVEY OF CANADA

PARTMENT OF ENERGY,
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MEMOIR 366

GEOLOGY OF FLAT RIVER, GLACIER LAKE, AND WRIGLEY LAKE MAP-AREAS, DISTRICT OF MACKENZIE AND YUKON TERRITORY

PART I: General Geology, Structural Geology, and Economic Geology

H. Gabrielse, S. L. Blusson, and J. A. Roddick

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View westward in Ragged Range over Glacier Lake to Mount Harrison Smith.

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PREFACE

To provide information on the age, structure, sequence, relationships, thickness, and origin of bedrock formations, and on the size, grade, mode of occurrence, origin, and potential of the mineral deposits of this relatively unknown area, geological study and mapping was commenced in 1963.

The study provided a basis for an analysis of the tectonic history of the region throughout much of Proterozoic and early Paleozoic time, and has helped define regional tectonic elements of scientific and economic importance. Several stratigraphic units of regional extent were shown to be important relative to concentrations of copper, iron, and base-metals, and their distribution as shown on the maps that accompany this report will help focus exploration work in the region. The study has also shown the strong affinity of various types of mineral concentrations with certain ages of stratified rocks.

Y. O. FORTIER,
Director, Geological Survey of Canada

OTTAWA, June 26, 1970

MEMOIR 366 — Kartenblätter Flat River, Glacier Lake and Wrigley Lake (Mackenzie-Distrikt und Yukonterritorium)

Von H. Gabrielse, L. Blusson, und J. A. Roddick

Dieses Gebiet umfaßt drei durch ausgeprägte Fazies und Schichtmächtigkeit gekennzeichnete tektonische Elemente. Das Gesteinsalter reicht von spätkambrisch bis mississippian; im Südwesten des Gebietes tritt kreidiges (?) Quarzmonzonit-Intrusivgestein zutage. Weiter kommen Anhydrit, Gips, Eisen, unedle Metalle, Molybdän und Wolfram vor.

МЕМУАР 366 — Картографированные районы Флэт Ривер, Гласьер Лейк и Ригли Лейк, район Макензи и территория Юкон

Х. Габриелз, С. Л. Блассон и Дж. А. Роддик

Описываются три тектонических элемента, которые отличаются характерными фациями и толщей напластования. Горные породы охватывают время от позднедокембрийского до миссисипского и мелового (?) кварцевого монцонит обнажения пород в юго-западной части района. Известны нахождения и залежи ангидрита и/или гипса, железа, цветного металла, молибдена, а также вольфрама.

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GEOLOGY OF FLAT RIVER, GLACIER LAKE, AND WRIGLEY LAKE MAP-AREAS, DISTRICT OF MACKENZIE AND YUKON TERRITORY

Abstract

Flat River, Glacier Lake, and Wrigley Lake map-areas include an area of slightly more than 13,000 square miles in southeastern Mackenzie Mountains, Logan Mountains, Hyland Plateau, and Liard Plateau. The three map-areas include parts of three regional tectonic elements distinguished by contrasting facies and thicknesses of coeval strata.

More than 18,000 feet of probable Helikian clastic and carbonate strata underlie Redstone Arch and the eastern part of Selwyn Basin. This apparently conformable sequence is overlain unconformably by more than 10,000 feet of Hadrynian clastic and minor carbonate strata. The basal unit of the Hadrynian sequence includes iron-formation. Paleozoic strata, ranging in age from Early Cambrian to possible Mississippian, are less than 3,000 feet thick on Redstone Arch but more than 18,000 feet thick in eastern Selwyn Basin.

The area displays classic examples of facies changes. To the northeast, late Ordovician to Middle Devonian strata are mainly carbonates, whereas to the southwest, they are mainly fine-grained clastics. In most places the transition zone between facies is remarkably abrupt.

Northerly to northwesterly trending folds with moderately steep limbs are the most widespread structures in the three map-areas. These structures are locally broken by thrust faults that generally dip westerly, except in eastern Wrigley Lake and Glacier Lake map-areas where most dip easterly. The structural style suggests that the entire stratigraphic assemblage is allochthonous with reference to the basement. One well-exposed fault has effected an apparent transcurrent displacement of about 10 miles.

Cretaceous (?) quartz monzonite stocks and batholiths were emplaced subsequent to the latest deformation in the southwestern part of the region.

Excellent examples of rockfall- and rockslide-avalanche deposits are present in Mackenzie Mountains and rock glaciers are well developed locally in Logan Mountains.

A Cordilleran ice sheet moved easterly and northeasterly over the southern part of the area. Some glacial deposits in northeastern Wrigley Lake map-area are believed to be related to a westerly advance of Laurentide ice from the Canadian Shield.

Proterozoic strata contain concentrations of anhydrite and/or gypsum, copper, and iron. Base-metal deposits occur in Helikian, Lower Cambrian, and Siluro-Devonian rocks. Molybdenum and tungsten occur locally in or near granitic rocks.

Résumé

La région représentée sur les cartes des environs de la rivière Flat et des lacs Glacier et Wrigley occupe une superficie légèrement supérieure à 13,000 milles carrés dans les monts Mackenzie et Logan et sur les plateaux Hyland et Liard. Elle recouvre partiellement trois unités tectoniques régionales caractérisées par des faciès contrastants et des couches contemporaines de différentes épaisseurs.

L'arche de Redstone et le secteur est du bassin Selwyn reposent sur une couche de plus de 18,000 pieds d'épaisseur de dépôts clastiques et de roches carbonatées, probablement d'âge hélikien. Sur cette succession apparemment continue repose, en discontinuité, une couche de sédiments clastiques et de petites strates de roches carbonatées, le tout d'âge hadrynien et d'une épaisseur de plus de 10,000 pieds. L'unité de base de la succession hadrynienne comprend des couches ferrifères. Les couches paléozoïques, dont l'âge oscille entre le Cambrien inférieur et peut-être le Mississippien, n'ont pas plus de 3,000 pieds d'épaisseur sur l'arche de Redstone, mais atteignent plus de 18,000 pieds dans le secteur est du bassin Selwyn.

La région offre des exemples typiques de variation de faciès. Vers le nord-est, les couches de l'Ordovicien récent et du Dévonien moyen consistent principalement en roches carbonatées, alors que le sud-ouest présente surtout des dépôts clastiques à grain fin. La transition entre les faciès est généralement fort rapide.

Du point de vue structural, la région étudiée est caractérisée par des plis orientés vers le nord et le nord-ouest dont les flancs sont assez abrupts. Ces plis sont parfois interrompus par des failles de chevauchements dont le pendage est en direction ouest sauf dans le secteur est de la région des lacs Wrigley et Glacier, où les failles plongent vers l'est. La disposition de ces structures laisse penser que toute la série stratigraphique est allochtone par rapport à la roche de fond. L'une des failles, qui est fort bien exposée, accuse un décrochement apparent d'environ 10 milles.

Des culots et batholithes de quartz monzonitique du Crétacé (?) se sont formés à la suite de la dernière déformation dans le sud-ouest de la région.

Les monts Mackenzie offrent d'excellents exemples de dépôts résultant de chutes de pierres ou d'avalanches; les monts Logan offrent, en certains endroits, des glaciers de pierres.

Une calotte glaciaire de la Cordillère s'est déplacée vers l'est et le nord-est dans le secteur sud de la région étudiée. Il se peut que certains dépôts glaciaires du nord-est de la région du lac Wrigley soient le résultat de l'avance du glacier Laurentien vers l'ouest depuis le Bouclier canadien.

Les couches protérozoïques renferment des concentrations d'anhydrite ou de gypse, de cuivre et de fer. Il existe des venues de métaux communs dans les roches de l'Hélikien, du Cambrien inférieur et du Siluro-Dévonien. En certains lieux, le molybdène et le tungstène se présentent dans le granite ou non loin des roches granitiques.

Chapter I

INTRODUCTION

Flat River (95E, lat. 61 to 62°N, long. 126 to 128°W), Glacier Lake (95L, lat. 62 to 63°N, long. 126 to 128°W), and Wrigley Lake (95M, lat. 63 to 64°N, long. 126 to 128°W) map-areas were mapped mainly during the 1963 and 1965 field seasons in a project referred to as 'Operation Nahanni.' About $2\frac{1}{2}$ months were devoted to field work in 1963, mainly in Flat River and Glacier Lake map-areas; an additional month of geological mapping in 1965 completed Wrigley Lake map-area. About a week was spent in Glacier Lake map-area in 1965 and some observations were made in Glacier Lake and Flat River map-areas during 1966. The operation was supported by helicopter and fixed-wing aircraft. The data obtained from forty-nine measured sections form Part II of this memoir and are published separately.

Acknowledgments

Able assistance in the field was given by M. E. Atchison, T. M. Gordon, R. C. Handfield, P. J. Street, and Uldis Upitis in 1963, and by T. M. Gordon, R. C. Handfield, R. B. Helm, Rolf Ludvigsen, Uldis Upitis, and M. V. H. Wilson in 1965. B. S. Norford of the Geological Survey measured two sections in Glacier Lake map-area during the 1963 field season and one section in Wrigley Lake map-area during the 1965 field season.

Transportation in the field in 1963 was provided by a Hiller 12E helicopter supplied by Klondike Helicopters Ltd. of Whitehorse, Beaver aircraft supplied by Harrison's Flying Service and B.C.–Yukon Air Service Ltd. of Watson Lake, and by Cessna 180 and Piper Family Cruiser aircraft supplied by Watson Lake Flying Service of Watson Lake. Otter and Beaver aircraft supplied by Northwest Territorial Airways Ltd. of Yellowknife were used to cache aviation gasoline before the field season. In 1965 the operation was supported by a Bell 47G-3B helicopter provided by Associated Helicopters, Ltd. of Edmonton, and by Beaver and Cessna 180 aircraft supplied by Watson Lake Flying Service, Watson Lake. To these companies and their crews the writers extend their appreciation for excellent air support.

The writers also wish to acknowledge the co-operation and many kindnesses received from the management and personnel of Redstone Mines Limited and Canada Tungsten Mining Corporation Limited.

Access

Watson Lake on the Alaska Highway may be used as a base for supplies and communication. A road extending about 200 miles northerly from Watson Lake to the mining settlement of Canada Tungsten on Flat River provides access to the Logan Mountains region. A branch road leads to lakes, suitable for fixed-wing aircraft, in the divide near the head of Flat River.

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The following lakes are excellent for fixed-wing aircraft and each provides one or more good sites for base camps: Wrigley, Hayhook and Dal in Wrigley Lake map-area; Little Dal, Grizzly Bear, and Glacier in Glacier Lake map-area; and Rabbitkettle, Hole in the Wall,[1] Caesar, Seaplane, Skinboat, McMillan, and Clark, in Flat River map-area. In addition, fixed-wing aircraft may land locally on Keele and South Nahanni Rivers. Avalanche Lake in Glacier Lake map-area is suitable for aircraft but the valley is in constant danger from rockslides.

In general the terrain is admirably suited for the use of helicopters and, except for local areas in Ragged Range, landings may be made near any required point. Parts of Ragged Range and a few areas in Backbone Ranges are sufficiently rugged that special climbing techniques must be employed, but elsewhere the mountains afford relatively easy traversing and climbing conditions.

Climate

Good weather was experienced during both field seasons of the operation. Between June 15 and August 15 temperatures rarely fell below freezing at night and many days were pleasantly warm. As is typical of areas in this latitude, light snowfalls occurred at higher elevations on several occasions but the snow remained for only a day or so. Two periods of heavy rainfall, each of two days duration, curtailed helicopter operations in the early part of the 1963 field season. Five additional days were lost because of inclement weather in 1963, but none was lost in 1965.

Lakes at lower elevations such as Wrigley, Dal, Rabbitkettle, and Seaplane are generally free of ice early in June. In 1965 Grizzly Bear Lake remained frozen until late in June.

Precipitation is relatively heavy in Logan Mountains and light in Mackenzie Mountains. Snow cover may seriously hinder field work in Logan Mountains until the last part of June, whereas Mackenzie Mountains, particularly Canyon Ranges, are essentially free of snow before June 1st.

Field work in Ragged Range is difficult not only because of persistent periods of low cloud cover but also because of extreme, intermittent air turbulence. In the 1963 field season only about one day in three afforded suitable flying conditions.

Previous Geological Investigations

Very little published information has been available for the region encompassed by Operation Nahanni. In 1908 Joseph Keele (1910) travelled down Keele (then Gravel) River and described strata now referred mainly to the Rapitan Formation in and near Shezal Canyon. Keele used the names Sayunei and Tigonankweine for the two prominent ranges in northwestern Wrigley Lake map-area. These names were modified from names used on Petitot's map of 1875 (Sa-yunne-Kwe, meaning 'rocks of the bighorn,' and Ti-konan-Kwene, meaning 'backbone of the earth').

D. R. Kingston (1951) measured several sections along South Nahanni River below the mouth of Broken Skull River and proposed the name 'Sunblood Formation' for Ordovician strata on Sunblood Mountain north of Virginia Falls about 8 miles east of Flat River map-area.

D. W. Bolyard (unpubl. rept., 1953) described the geology in part of Ragged Range north of Rabbitkettle River and near Glacier Lake. He noted the chloritic volcanic rocks

[1]Also known as Hole-in-the-Wall.

south of Brintnell Creek and correctly inferred their Lower Cambrian age. He also made a number of useful observations on glacial features.

E. F. Roots of the Geological Survey examined the geology near Grizzly Bear Lake, Hole in the Wall Lake, and south from Lucky Lake west of Coal River. His unpublished notes contain an excellent description of granitic rocks near Hole in the Wall Lake.

In 1957 the three map-areas adjacent to the Operation Nahanni area on the east were investigated as part of the Geological Survey's Operation Mackenzie (Douglas and Norris, 1960, 1961, 1963). This work formed the basis for almost all the preliminary airphoto interpretation required for Operation Nahanni and established much of the stratigraphic nomenclature for post-Cambrian rocks used in this report.

Green and Roddick (1961) mapped most of Nahanni map-area and part of Frances Lake map-area west of Glacier Lake and Flat River map-areas respectively. This work was followed by a detailed investigation of the stratigraphic section in South Nahanni Anticline and detailed studies in the area near Canada Tungsten (Blusson, 1968). These projects laid the groundwork for mapping to the east in Logan Mountains.

Current Geological Investigations

A photogeologic map of Glacier Lake and Wrigley Lake map-areas, based largely upon the ground control available from Operation Mackenzie, was prepared prior to the 1963 field season. The main areas of granitic rocks in southwestern Glacier Lake map-area and in Flat River map-area were also outlined by photogeological methods. These interpretations were aided considerably by data obtained from fixed-wing reconnaissance flights made in 1962 by L. H. Green and S. L. Blusson. In general the terrain and geology of Mackenzie Mountains combine to make this region classic for photogeologic studies. As a result, much more time was devoted to detailed investigations of stratigraphy and structure than would normally have been possible.

Stratigraphic sections totalling about 200,000 feet were measured in varying degrees of detail. About a week was spent by one team of geologists on the well-exposed Proterozoic section southeast of Little Dal Lake. Two sections of the Rapitan Formation were examined in detail by Uldis Upitis for thesis purposes, and a number of Cambrian sections were also studied in detail by R. C. Handfield for the same reason. The three most carefully studied Ordovician sections were measured by B. S. Norford near the headwaters of Nainlin Brook, the north end of Thundercloud Range, and on the northern flank of Broken Skull Anticline. Particular emphasis was placed on stratigraphic sections near Grizzly Bear and Avalanche Lakes where important facies changes take place. Many well exposed Siluro-Devonian sections were studied in Mackenzie Mountains. Strata overlying the Middle Devonian Nahanni Formation are generally poorly fossiliferous and poorly exposed. As a result, these rocks were not studied in detail and only one section, that in Upper Devonian strata east of Tigonankweine Range, was measured.

In addition to mapping the boundaries of granitic bodies a few general reconnaissance traverses were made to establish the dominant lithologies of these rocks.

Chapter II

PHYSIOGRAPHY AND GLACIATION

The area investigated includes parts of Mackenzie Mountains, Logan Mountains, Hyland Plateau, and Liard Plateau (*see* index maps to Figs. 14–18 and Bostock, 1948). Canyon Ranges of Mackenzie Mountains in northeastern Wrigley Lake map-area consist of relatively subdued, bare, north-to-northwesterly trending ridges of resistant strata, attaining maximum elevations of just more than 5,000 feet, separated by broad, low-lying, forested areas underlain by relatively soft shales (*see* Pl. XXIV). Rouge and Redstone Ranges consist essentially of linear ridges, reflecting the relative resistance to erosion of various formations. In general, the ranges reveal faulted anticlinal structures that have a core of resistant lower Paleozoic dolomites and/or Proterozoic quartzites. The ranges are transected almost at right angles by streams including North Redstone and Redstone Rivers that lie in deep, flat-bottomed valleys. The streams have low gradients and as a result are braided. The western boundary of Backbone Ranges lies along the east side of Tigonankweine Range and the west side of Rouge Range.

Backbone Ranges of Mackenzie Mountains include moderately rugged mountain groups attaining a maximum elevation of 8,900 feet (*see* Pls. XVI, XXIX), separated by narrow to broad, flat-bottomed valleys, many of which display classic examples of braided streams. Many of the north-to-northwesterly trending valleys have been cut into synclines of easily eroded shales which are flanked by 'flatirons' of more resistant strata. Much of north-central Glacier Lake and western Wrigley Lake map-areas is a high, dissected plateau, herein referred to as Redstone Plateau, formed in gently dipping or flat-lying strata (*see* Pls. XIII, XIV, XVII). The eastern border of the plateau is defined by the upper reaches of Thundercloud Creek and by Plateau Fault which extends southeasterly and southerly from Keele River to west of Little Dal Lake. The western border is defined by Natla Fault and by the northeast side of a prominent quartzite ridge that includes the highest peaks in Backbone Ranges.

Ragged Range, part of Logan Mountains in southwestern Glacier Lake and northwestern Flat River map-areas, is a region of extremely rugged topography with maximum elevations of more than 9,000 feet and relief locally as much as 6,000 feet (*see* Pls. I, XL). The ruggedness and great relief are the result of extensive alpine glaciation of a resistant terrain that includes widespread granitic and metamorphic rocks. Several large snowfields and numerous small glaciers contribute to the spectacular scenery of the range.

Hyland and Liard Plateaux include isolated, bare-topped mountain groups and ridges separated by wide areas of low-lying forested valleys. In valleys, outcrops are restricted mainly to stream channels.

Most of the northern part of the area lies within the drainage system of Redstone River and most of the southern part is drained by South Nahanni River and its tributaries. Northwesternmost Wrigley Lake map-area is drained by Natla and Keele Rivers and eastern

Glacier Lake map-area contains the headwaters of Root and North Nahanni Rivers. Except for the silt-laden South Nahanni River and its tributaries, which drain glaciers in Ragged Range, the major streams are characteristically clear most of the summer.

Mass Wastage

Many examples of mass wastage are spectacularly developed in the report area. Most of these features were examined in only a cursory manner but it is apparent that much could be gained from detailed studies of selected examples.

Tigonankweine Talus Blanket

A thick blanket of relatively stable quartzite talus extends from the northeastern side of Tigonankweine Range for as much as 2 miles into the valley to the northeast. In places the talus blanket is more than 500 feet thick and locally may be as much as 750 feet thick. The average surface slope of the deposit is about 7 degrees into the valley. Were it not for the incised streams revealing the underlying Upper Devonian shales the talus could be mistaken for felsenmeer essentially in situ. From limited observations it appears that the talus initially formed a continuous blanket along the northeast side of Tigonankweine Range and was not the result of coalescing talus fans or aprons related to present-day stream valleys.

A suggestion is that uplift of Tigonankweine Range along Tigonankweine Fault produced a scarp that shed quartzite debris in a relatively continuous belt to the northeast. The deposit is probably no younger than early Pleistocene because well-developed, abandoned channels of glacial origin have been cut into the talus. Also the talus blanket seems to be unrelated to the details of the present drainage pattern. In Tsezotene Range, where similar geological and topographical conditions exist, no significant quartzite talus is present along the east side of the range. Presumably this means that if a talus blanket once existed it was completely removed by ice action or, more probably, large talus deposits never formed because sufficient local relief such as that provided by fault scarps never existed.

Rockslides

Numerous examples of rockfall- and rockslide-avalanche deposits (Mudge, 1965) occur in Mackenzie Mountains. In Redstone Plateau precipitous slopes related to steeply dipping joints, particularly in carbonate strata, provide an excellent environment for rockfall-avalanches. Deposits resulting from rockfall-avalanches are relatively small and comprise loosely packed, angular fragments, including enormous blocks. On the other hand, the three examples of rockslide-avalanches described below involve great volumes of rock material representing a significant modification of local topography.

The best example of a rockslide-avalanche deposit occurs in southwestern Wrigley Lake map-area north of the west end of Rockslide Pass (*see* Pl. II). There, the major part of a mountain mass has slid westerly on a bedding surface of Upper Cambrian dolomite that dips at slightly less than 10 degrees. Debris from the slide, containing many rectangular blocks of carbonate measuring tens of feet on the side, forms a hummocky terrain in the valley to the west, and a lobe about 4,000 feet wide and more than 6,500 feet long extends south–southwest into Rockslide Pass. The scar on the mountain from which the slide material was derived is roughly rectangular in plan, about 6,000 feet long and 3,200 feet wide, and in section is characterized by a vertical cliff on the east side more than 1,500 feet high. The bedding surface along which the slide moved is clearly defined at the north end of the mountain. A prominent ridge of debris forms the western margin of the scar. A rough estimate, based on the dimensions of the rockslide scar and plausible reconstructions of pre-rockslide topography, indicates that probably more than 500×10^6 cubic yards of material was involved in the avalanche.

Another example of rockslide-avalanche topography occurs in southwestern Wrigley Lake map-area and similarly involves westerly dipping Upper Cambrian dolomites. At the southern end of a ridge immediately west of Natla Fault, a prominent scar 8,000 feet long reveals that the western part of the ridge has slid into the valley. Bedding planes dip westerly at about 30 degrees. As in the example cited above, the rockslide scar is bounded to the west by a prominent ridge of debris. In the valley, slide material produces a hummocky terrain strongly modified by glacial action.

Avalanche Lake and nearby lakes in the valleys to the west, north, and south owe their existence to damming by rockslides (*see* Pls. III, IV). A remarkably planar bedding-plane scar occurring in dolomites of the Sombre Formation extends westerly from Avalanche Lake for almost 20,000 feet along the north side of the valley. The bedding surface dips southerly at 35 degrees and has a local relief of more than 3,000 feet. Avalanche debris comprising smashed finer grained material with huge blocks of dolomite forms mounds and ridges on the valley floor. A tongue of debris extends southerly in the valley south of Avalanche Lake and forms another lake by damming the drainage from several glaciers. Evidently slide material rushed up the slope southwest of Avalanche Lake to an elevation of about 1,500 feet above the valley floor where a well-defined upper limit of dolomite rubble is evident. Much material that had moved up the south wall of the valley slid back and formed a clearly marked upper limit of debris on the north side of the valley.

Steeply dipping, gaping fractures trending subparallel with the valley are abundant in carbonate strata forming the precipitous slopes on the south side of the valley, west of Avalanche Lake; undoubtedly further rockslides or rockfalls will occur.

Rock Glaciers

Rock glaciers are common in Backbone Ranges, particularly in areas underlain by gently dipping beds of the Rapitan Formation. In many places they coalesce to form aprons along the sides of major valleys. An excellent example of bedrock control on the development of rock glaciers occurs in western Flat River map-area near lat. 61°36′ and long. 127°47½′ (*see* Pls. V, VI). There, four rock glaciers, each about a mile long, are flowing easterly from cirques carved in silty limestones of Cambro-Ordovician age. Evidently the blocky and platy nature of the debris, in contrast to the finer grained talus derived from argillites and silty rocks in the same region, is favourable for producing rock glaciers. No significant rock glaciers are associated with the latter.

Glaciation

The entire region has been glaciated by alpine and valley glaciers and two or more ice sheets. The most prominent glacial features are shown in Figure 1, which combines information obtained in the field with that observed on air photographs.

A Cordilleran ice-sheet moved easterly and northeasterly over the southern part of Flat River map-area, as evidenced by the distribution of glacial erratics and the form of drumlinoid ridges. The upper limit reached by the ice is unknown, but the peak, elevation 6,415 feet, 5 miles southeast of Skinboat Lakes, appears to have been completely overridden. East of Irvine Creek and northeast of McMillan Lake granitic erratics are abundant above 5,000 feet and the highest erratics, clearly derived from the southwest, are at elevations greater than 5,500 feet. Aligned and parallel sequences of abandoned drainage channels indicate a southwesterly retreat of the ice.

A southeasterly movement of ice down the valleys of Flat and South Nahanni Rivers is shown by strong grooves and by the slopes of kame terraces. A northwesterly retreat is

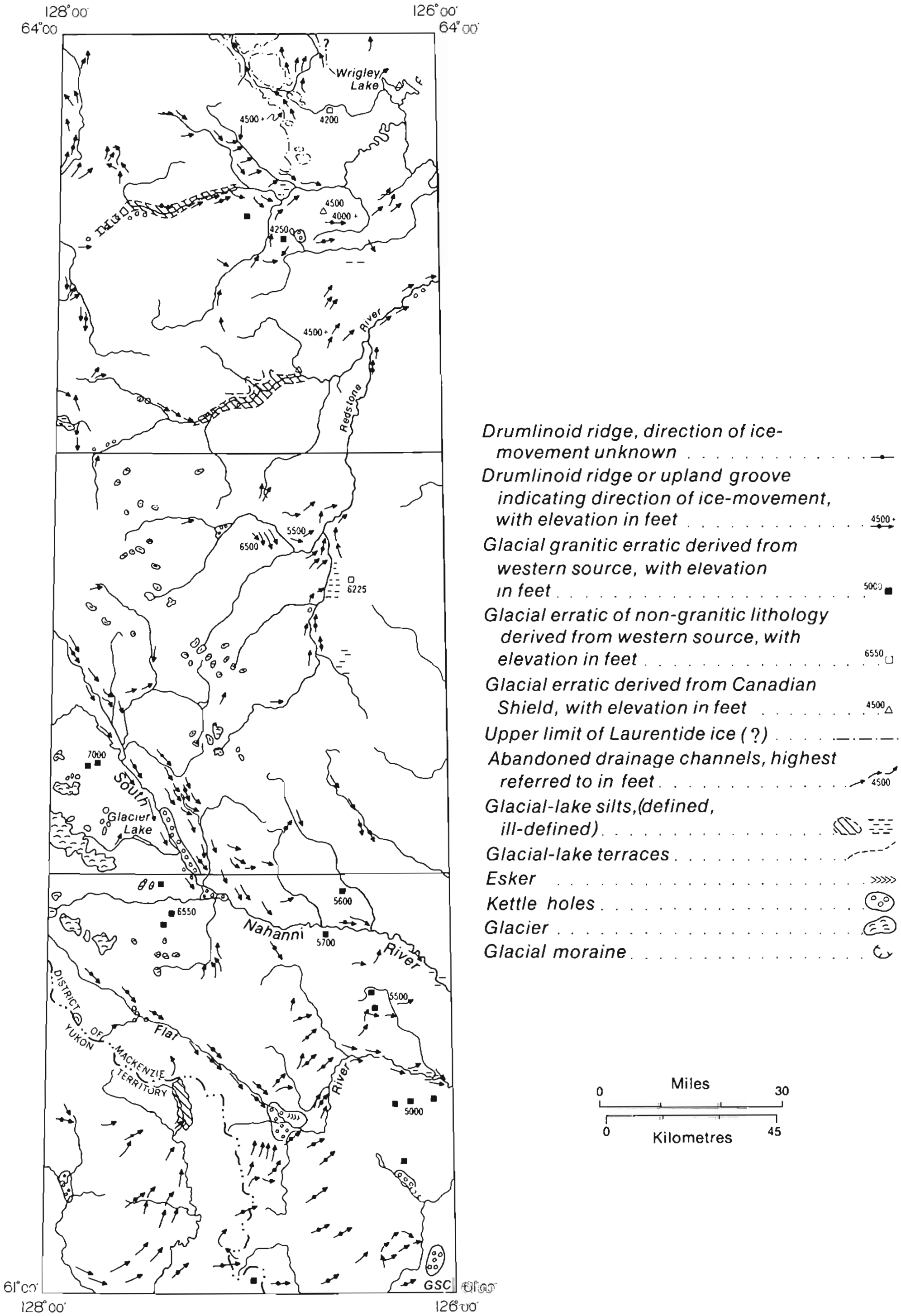

FIGURE 1. Glacial features of Flat River, Glacier Lake, and Wrigley Lake map-areas.

revealed by the slopes of many abandoned lateral drainage channels. Possibly this valley glaciation was a relatively late stage phenomenon because the upper limit of the ice seems to have been lower than that of the ice sheet that advanced from the southwest.

A general northerly and easterly movement of valley glaciers occurred in Backbone Ranges. Locally, south of Natla River and in the southwesternmost part of Wrigley Lake map-area, there is a suggestion that ice from the west pushed southerly in some of the valleys. The highest levels noted for features related to glaciation in Backbone Ranges are near Little Dal Lake. There, erratics derived from a westerly or southwesterly source occur at an elevation of 6,255 feet on the west side of Thundercloud Range. Also, strongly developed abandoned lateral channels are incised to elevations of 6,500 feet into the eastern slope of a mountain 8 miles northwest of the lake.

A large moraine, convex to the west on the east side of Wrigley Lake, is believed to be related to a front of Laurentide ice from the east. Debris near the moraine includes boulders of pink and orange weathering granitic rock characteristic of material derived from the Canadian Shield. Probably this morainal dam diverted North Redstone River to the southeast at almost right angles to its original course. Erratics also believed to have been derived from the east occur at an elevation of about 4,500 feet near the peak (elevation 5,410 feet) south of North Redstone River opposite the southeast end of Tigonankweine Range.

A minimum upper limit of an ice sheet is well defined by abandoned marginal channels on the northeast slope of Tigonankweine Range at elevations of about 4,500 feet. The slopes of channels indicate that the ice retreated southerly. Most likely these features are the result of Laurentide ice.

Late-stage ice movement from the west is indicated by the form of prominent grooves at an elevation of more than 4,000 feet in the valley south of the peak (elevation 5,410 feet) noted above. Possibly this late-stage valley glaciation obliterated or greatly subdued evidence of the westerly extent of Laurentide ice.

Numerous small glaciers occur on the northern or northeastern sides of the highest peaks in Backbone Ranges. Most appear to be almost stagnant and many cirques have probably become free of ice in recent times.

The largest and most active glaciers occur in Ragged Range. Many are distributary to the large ice field north of Rabbitkettle River and west of the headwaters of Brintnell Creek. The distribution of terminal moraines and areas of freshly scoured rock in front of many glaciers indicates that, in general, the glaciers are receding. Several glaciers west of Mount Ida have retreated more than 4,000 feet from the valley of Brintnell Creek. A comparison of air photographs taken in 1949 with photographs taken in 1963, however, reveals that the glacier at the head of Brintnell Creek has remained essentially stationary. The longitudinal profile of Brintnell Creek is typical of a stream valley modified by glacial action. A series of wide, flat, drift-filled outwash areas, in which the creek is braided, is connected by relatively steep sections where the creek is confined to one channel and forms rapids, cascades, and small waterfalls. The outwash formed behind terminal moraines at a time when the snouts of glaciers from the south reached the main valley.

Chapter III

GENERAL GEOLOGY

The three map-areas include parts of three regional tectonic elements, Selwyn Basin, Redstone Arch, and Root Basin, distinguished by contrasting facies and thicknesses of coeval strata (*see* index maps to Figs. 14–18 in Pt. II, and Gabrielse, 1967b).

Selwyn Basin to the southwest is characterized by thick sequences of generally fine grained clastic rocks ranging in age from Hadrynian to possibly Mississippian. Thick, Cambro-Ordovician carbonate strata occur within the basin and Middle Ordovician carbonates are conspicuous near the northeastern margin. A thin formation of extrusive basaltic rocks of Lower Cambrian age is the only volcanic unit within the entire sequence. Cretaceous granitic rocks form clearly defined intrusive plutons that underlie large areas of Selwyn Basin.

Northeast of Selwyn Basin, in Mackenzie Mountains, a great thickness of well-bedded carbonate and clastic rocks ranges in age from Helikian to late Devonian. Paleozoic strata are relatively thin on Redstone Arch but are thick along the northeast margin of Selwyn Basin and in Root Basin. Thin units of basic volcanics occur locally within Helikian and Middle Ordovician carbonates.

The area displays classic examples of facies changes, particularly near a narrow zone running from northeast of Clearwater Creek to Grizzly Bear Lake. To the northeast, late Ordovician to Middle Devonian strata are mainly carbonates, whereas to the southwest, they are mainly fine-grained clastics. The transition zone is marked locally by a reef in Upper Ordovician rocks and by extensive banks of crinoidal limestone in Middle Devonian rocks. Lower Cambrian to Middle Ordovician formations extend as carbonates and sandstones southwesterly into Ragged Range but they also exhibit significant facies changes.

Table of Formations

Era	Period or Epoch	Formation or Group	Lithology	Thickness (feet)
CENOZOIC	Pleistocene and Recent		Unconsolidated glacial and alluvial deposits	
MESOZOIC	Cretaceous(?)	Hole in the Wall Batholith Coal River Batholith	Quartz monzonite, megacrystic; granodiorite; syenite; minor granite	

Table of Formations—(Cont'd)

Era	Period or Epoch	Formation or Group	Lithology	Thickness (feet)
Intrusive Contact				
PALEOZOIC	Devonian and (?) Mississippian		Shale, black, pyritic; siltstone and sandstone, green, grey, maroon; minor limestone	1,700(+)
		Nahanni	Limestone, fine- to medium-grained, grey weathering	0–275
		Headless	Limestone, buff-brown platy, argillaceous shale, calcareous	425–990
		Landry	Limestone, crypto-grained to medium-grained, grey, commonly banded	100–1,610
		Manetoe	Dolomite, coarse-grained, cream and light grey; limestone, crypto-grained	0–200
		Natla	Limestone, thin-bedded, sooty; crinoidal limestone, light grey, resistant	0–1,450
		Funeral	Limestone, argillaceous, buff weathering; shale, brown and black	0–1,550
		Grizzly Bear	Limestone, grey, massive, cliff-forming; dolomite	0–700
	Middle Devonian	Arnica and Bear Rock	Dolomite, banded, medium and dark grey; dolomite breccia; limestone breccia	355–2,600
	Lower Devonian	Sombre	Dolomite, banded, light and medium grey; middle member of dark grey dolomite	390–2,350
	Devonian	Camsell	Limestone breccia, buff and orange; dolomite, buff and grey, well-bedded	540–2,000(+)

Table of Formations—(Cont'd)

Era	Period or Epoch	Formation or Group	Lithology	Thickness (feet)
PALEOZOIC	Silurian and Devonian	Delorme	Dolomite and limestone, buff, grey, cinnamon; limestone breccia	150–2,300
	Upper Ordovician, Silurian, and Lower Devonian	Road River	Shale, pyritic, black, calcareous, locally slaty and phyllitic; chert; siltstone; dolomite and limestone, thin-bedded and black	0–2,200
	Upper Ordovician and Silurian	Whittaker	Dolomite, dark grey, cherty; limestone, dark and light grey, cherty	990–2,300(+)
	Unconformity			
	Middle Ordovician	Sunblood	Dolomite, dark and light grey; limestone; sandstone; volcanic flows, vesicular	560–4,700
	Lower Ordovician and Upper Cambrian	Rabbitkettle	Limestone, argillaceous; shale, calcareous	300(+)
			Limestone, grey, silty, wavy-banded; siltstone; minor calcareous shale	4,000(+)
		Broken Skull	Dolomite and limestone, buff, orange, yellow and grey weathering, variably silty and sandy; sandstone, silver-grey, dolomitic	2,700–2,830
	Unconformity, locally angular			
	Middle Cambrian	Avalanche	Dolomite, buff, yellow and orange weathering; siltstone and mudstone, dolomitic	700–1,300
		Rockslide	Limestone, dark grey, sooty, platy; siltstone, dark grey; minor shale, sandstone	815–1,640(+)

Table of Formations—(Cont'd)

Era	Period or Epoch	Formation or Group	Lithology	Thickness (feet)
	Unconformity			
PALEOZOIC	Lower Cambrian		Argillite, slate, shale; minor argillaceous limestone	
PALEOZOIC		Sekwi	Limestone; siltstone; dolomite, sandy; sandstone, dolomitic, varicoloured, basic volcanics near Rabbitkettle River.	1,300(+)
			Brintnell Member: dolomite and limestone, brilliant orange weathering, silty	200(+)
PALEOZOIC		Backbone Ranges	Upper member: sandstone, pink, purple, grey, brown; siltstone; minor quartz-pebble conglomerate.	750–6,500
			Middle member: dolomite, brown, orange, yellow, cryptograined, sandy, silty.	190–1,000(+)
			Lower member: sandstone, white, brown, pink, purple, minor siltstone and sandy dolomite	893–1,650
PALEOZOIC – – – – – PROTEROZOIC	Hadrynian(?) and Lower Cambrian	'Phyllite Unit'	Phyllite and slate, greenish grey, rusty grey; quartzite, fine-grained; siltstone, dark weathering	2,000(+)
PROTEROZOIC	Hadrynian	'Grit Unit'	Shale and slate, dark weathering, red and green weathering; quartzite; calcarenite; quartz-pebble conglomerate; siltstone; minor limestone; phyllite	5,000(+)
PROTEROZOIC	Hadrynian	Sheepbed	Shale and siltstone, brown, dark grey, platy, thin-bedded	1,500–2,500(+)
PROTEROZOIC	Hadrynian	Keele	Sandstone and dolomite, orange and buff; mafic flow	1,500–2,000(+)

Table of Formations—(Conc.)

Era	Period or Epoch	Formation or Group	Lithology	Thickness (feet)
PROTEROZOIC	Hadrynian(?)	Local ? unconformity		
		Rapitan Group	Upper Rapitan: shale and sandstone, dark grey, greenish grey, platy	1,870–3,845
			Unconformity	
			Middle Rapitan: mudstone, conglomeratic	0–2,000(+)
			Angular unconformity	
			Lower Rapitan: mudstone, maroon; conglomerate; iron-formation	0–1,335
	Angular unconformity			
	Helikian	Coppercap	Limestone, in part silty, dark grey, buff, fetid; slate; limestone conglomerate	0–675
		Redstone River	Siltstone, pink, slaty; anhydrite, gypsum	0–1,500
		Little Dal	Upper member: dolomite, grey, buff, orange, sandy; minor siltstone, slate, conglomerate; mafic flows and/or sills	300(+)
			Lower member: limestone, grey, stromatolitic; dolomite	6,000(+)
		Tigonankweine	Quartzite, white, pink, purple; minor slate and dolomite	4,268–4,500
		Tsezotene	Shale, olive-green, dark grey, purple; dolomite, buff, orange; quartzite	3,600

Locally in northwestern Wrigley Lake map-area much of the interval between Middle Silurian and late Middle Devonian is represented by carbonate breccia (Bear Rock Formation), whereas farther south breccias are much less important (with the exception of those in the early Devonian Camsell Formation in eastern Wrigley Lake area and northeastern Glacier Lake area).

A pronounced angular unconformity separates the Hadrynian (?) Rapitan Formation from underlying Helikian rocks. Regional unconformities also occur beneath Middle Cambrian, Upper Cambrian (Franconian), and Upper Ordovician strata. In eastern Selwyn Basin the unconformity beneath Upper Cambrian rocks is markedly angular.

Helikian

A thick sequence of apparently conformable clastic and carbonate strata of Helikian age underlies parts of the eastern Backbone Ranges and western Canyon Ranges. For mapping purposes the rocks have been subdivided into five formations, in ascending order: Tsezotene, Tigonankweine, Little Dal, Redstone River, and Coppercap. These formations aggregate more than 18,000 feet thick but Helikian strata are probably not fully represented anywhere because of the profound unconformity beneath the overlying Hadrynian (?) Rapitan Formation.

Tsezotene Formation

The oldest completely exposed rocks in the map-area, herein named the Tsezotene Formation, occur in the hanging-walls of thrust faults on the northeast flanks of Tsezotene and Tigonankweine Ranges and on the east flank of the mountain about 6 miles southeast of Little Dal Lake (*see* Pls. VII, VIII). Much of the formation is recessive weathering and the only completely exposed section observed is the type section on the east flank of Tsezotene Range (*see* Section 1, Pt. II).

In the type section the Tsezotene Formation includes about 3,600 feet of dark grey, green and medium brown shale, purple, maroon, grey and green argillite, light grey and green, grey and brown siltstone, fine- to medium-grained quartzite, and interbeds of orange and buff weathering sandy dolomite to dolomite. The argillaceous rocks show gradations from fairly massive and competent, poorly bedded mudstones and argillites to strongly cleaved, thinly bedded and in places slightly phyllitic slates. Commonly the argillites and shales are finely laminated, platy, and flaggy. Laminations are also characteristic of the siltstones and dolomitic siltstones. Mudcracks are present locally. Dolomites, in platy beds from an inch to a foot thick are typically buff and orange weathered, bluish grey, crypto-grained to fine grained, and variably sandy. Locally the dolomites contain abundant stromatolitic structures as much as 6 inches in diameter. In a few places the rocks are laminated and platy. Grey weathering, light grey, green-grey, and white quartzite is generally very fine grained to fine grained and speckled with limonitic patches probably resulting from the weathering of pyrite. The quartzites form beds ranging from thin, platy, and flaggy to massive, and are as much as 10 feet thick. Crossbedding and ripple-marks are well developed in places. Quartzite is the dominant lithology in one prominent resistant member about 500 feet thick that forms the basal part of the upper half of the formation.

The upper part of the Tsezotene Formation comprises a distinctive varicoloured sequence of interbedded black, grey, green, maroon, and purple shales, slates and siltstones, and orange, light green, tan, brown and purplish weathering, fine-grained dolomite. Locally the green shales contain crystals of pyrite.

The Tsezotene Formation is gradational with the overlying Tigonankweine Formation. In the type section the base of the Tsezotene Formation is drawn at the top of a unit of well-bedded dolomite with chert nodules that appears to underlie Tsezotene strata conformably.

Therefore, for mapping purposes the dolomites are included with the overlying rocks. The dolomites are possibly more than 150 feet thick but seem to be truncated by Tsezotene Fault a short distance to the north and south of the measured section.

Tigonankweine Formation

A thick sequence of well-bedded, resistant quartzites and sandstones with subordinate shales, slates, and dolomites that outcrop in eastern Wrigley Lake and northeastern Glacier Lake map-areas is herein named the Tigonankweine Formation. The name is taken from the prominent range in north-central Wrigley Lake map-area underlain mainly by these rocks. The most accessible section, here designated as the type section, is exposed on the mountain about 6 miles southeast of Little Dal Lake (*see* Section 2, Pt. II, and Pl. VIII). In this locality, the base of the formation is clearly exposed. Complete sections are also exposed in Tsezotene Range (*see* Pl. VII) and in Tigonankweine Range, southwest of Tigonankweine Fault. In general, the rocks underlie the highest ranges in the northeastern and north-central parts of the region. They occur either in the cores of major anticlines or in the hanging-walls of major thrust faults.

The Tigonankweine Formation is about 4,268 feet thick in the type section southeast of Little Dal Lake and comprises mainly pink, white, and purple quartzite in beds a few inches to several feet thick. The base of the formation, gradational with the uppermost beds of the Tsezotene Formation consists of well-bedded, fine-grained quartzite sandstone with thinly laminated, purple weathering shale. Minor purple weathering slate and orange-buff and brown weathering dolomite occur in higher beds. Interbedded olive-grey and grey slate and ochre to orange weathering dolomite about 375 feet thick form a prominent marker member 900 feet below the top of the formation. The uppermost member of the formation is a conspicuous sequence of pink, cherry red to salmon red quartzites, and minor red slate 830 feet thick.

Near the south end of Tsezotene Range the Tigonankweine Formation is characterized by an upper unit of grey weathering quartzites and a lower unit of pink, orange-pink, and brownish weathering quartzites comprising possibly the lower two thirds of the formation. The total thickness of the quartzites is more than 4,500 feet. Similar units can be recognized in the broad anticline at the south end of Tigonankweine Range. The upper resistant quartzites and underlying recessive shales, slates, and dolomites on the southwest flank of Tigonankweine Range are probably correlative with two well-defined, similar members that also form the top of the Tigonankweine Formation in the type section. Neither member appears to be present northeast of Nainlin Brook in northernmost Wrigley Lake map-area, presumably because of sub-Upper Cambrian erosion.

According to D. G. Cook (pers. com., 1970) the upper two members of the Tigonankweine Formation are clearly defined throughout much of Carcajou Canyon map-area to the north of Wrigley Lake map-area. The uppermost quartzite member, however, thins markedly to the north and northeast.

The formation as a whole is well bedded. Beds range in thickness from a few inches to as much as 6 feet. Generally the finer grained rocks are thin bedded and platy.

Crossbedding, symmetrical and asymmetrical ripple-marks, scour and fill structures, and fucoidal markings are abundant in the coarser clastic rocks whereas the interbedded shales commonly display mudcracks.

Generally the sandstones are remarkably even grained and in this respect they contrast with those of the Lower Cambrian which include beds of pebble-conglomerates. In hand specimens pastel shades of pink and purple predominate and the fresh surface has a distinct sugary texture. In thin section the sandstones are remarkably uniform in grain size and are mainly well sorted. The average grain size in most samples is between 0.5 and 0.75 mm. Recrystallization has resulted in interlocking or quartzitic textures but in many places outlines of initially well rounded grains are apparent even though the grains have overgrowths of quartz in optical continuity with them. Fresh grains of microcline and less abundant andesine are present in all thin sequences but are not abundant, comprising at most, only a few per cent of the rocks. Chert grains are present in minor amounts and tourmaline is a common accessory mineral.

Compositions of selected specimens of sandstone are shown in Figure 2.

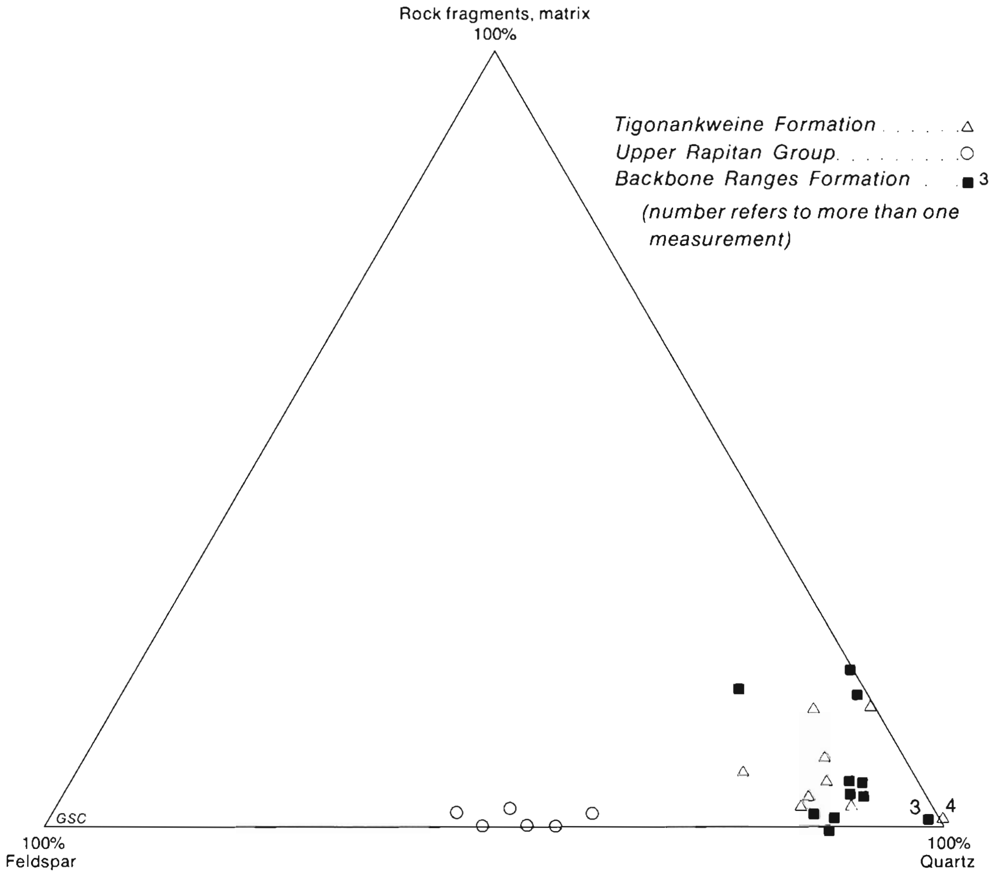

FIGURE 2. Modal analyses of arenites, Operation Nahanni.

Little Dal Formation

A thick sequence of resistant carbonates conformably overlying the Tigonankweine Formation is herein named the Little Dal Formation. The name is taken from the lake* 6 miles north–northwest of the type section (*see* Section 2, Pt. II, and Pl. VIII) in Glacier Lake map-area.

*Recently renamed Coates Lake.

In the type section the formation includes two well-defined members—a lower composed of stromatolitic grey limestones and dolomites, and an upper composed of buff-orange and reddish orange weathering dolomites and sandy dolomites. In Tsezotene Range, however, it can be seen that at least in places the two members are also in part lateral correlatives with sharply gradational boundaries. North of Redstone River and southwest of Plateau Fault the upper member is generally thin or absent because of erosion prior to deposition of the Rapitan Formation. The Little Dal Formation appears to be absent over much of northeastern and eastern Wrigley Lake map-area, probably due to the combined effects of several unconformities.

South–southeast of Little Dal Lake the lower member of the Little Dal Formation comprises 2,400 feet of stromatolitic and oölitic, grey weathering, grey and dark grey, cryptograined, fine-grained and medium-grained limestones and dolomites. The basal beds, about 100 feet thick, consist of bright yellow and buff weathering, thin-bedded, dolomitic siltstones. At the north end of Thundercloud Range the basal member is 84 feet thick and consists of greyish red, greyish green, and pale reddish brown, recessive mudstone, dark grey argillaceous dolomite, and quartz siltstones. There, the total thickness of the lower member is 1,468 feet, of which the lower half is mainly limestone and the upper half dolomite. The limestones are similar to those tentatively included in the Little Dal Formation on the southwest side of Tigonankweine Range.

Spectacular examples of abrupt lateral gradation between grey, stromatolitic limestone and buff weathering, light grey dolomite, can be seen on the west flank of Tsezotene Range. There, units as much as 150 feet thick, consisting of very fine grained carbonate, change from limestone to dolomite and maintain excellent preservation of stromatolites. Basal beds in this area include interbedded, dark maroon slates with salt casts and mudcracks, laminated green slate, fine-grained tan quartzite and purplish brown weathering sandy dolomite.

Strata tentatively assigned to the Little Dal Formation on the southwest side of Tigonankweine Range consist of 1,093 feet of platy brownish grey weathering, dark grey and black, cryptograined and fine-grained limestone, variably silty. In places the rocks are pisolitic and oölitic. Stromatolites, so common in presumably correlative strata elsewhere, were not noted. This sequence is apparently truncated to the southeast and northeast by an unconformity at the base of sub-Whittaker, buff-orange weathering dolomite.

The upper member of the Little Dal Formation varies in thickness from zero to several thousand feet. A measured thickness of 4,350 feet in the type area may be excessive because of repetition by faulting. The member is characterized by buff-orange and reddish orange weathering dolomites and sandy dolomites, but also includes thinly bedded and laminated siltstone, slate, and mudstone. Near the middle of the orange dolomite member south–southeast of Little Dal Lake is a sequence of sandy and cherty dolomite 200 feet thick with two interbeds of dolomite conglomerate less than 20 feet thick.

The upper part of the Little Dal Formation is well exposed on the southwest side of Thundercloud Range. There, a thick sequence of buff-orange weathering dolomite is overlain by four distinct units in ascending order: brownish weathering, blocky, slightly argillaceous fine-grained sandstone and minor purplish siltstone about 30 feet thick, with a basal grey-green weathering, vesicular basalt flow 20 feet thick; yellow and reddish weathering, cryptograined dolomites and siltstones more than 200 feet thick; orange-brown and reddish brown siltstone with interbeds of yellow weathering dolomitic siltstone, several hundred feet thick; and yellow-orange silty dolomite about 200 feet thick. The sequence is truncated to the northwest and southeast by the sub-Rapitan unconformity.

Rocks similar to those described above are exposed in the floor of a deep valley in Thundercloud Range. There, the assemblage includes buff-brown weathering, pink and rose, laminated dolomite and dolomitic sandstones. Beds of brick-red siltstones and slates are as much as 6 feet thick but appear to be markedly lenticular along strike. Mudcracks are well developed in some of the rocks.

Southeast of Little Dal Lake one or more dark green to black weathering, amygdaloidal, mafic flows with poorly developed columnar jointing occur in the Little Dal Formation. The volcanic sequence is about 100 feet thick. Amygdules of calcite occur in the upper, red weathering, highly vesicular part, and in places the rocks contain epidote. The volcanics overlie laminated buff and reddish weathering dolomites and are overlain unconformably by coarse conglomerate of the Rapitan Formation and elsewhere by grey, fine-grained dolomite of the Little Dal Formation. A plug of fine- to medium-grained hornblende diorite with abundant specular hematite along fractures outcrops in the same area.

A dark green to black weathering sill or flow as much as 100 feet thick occurs within the Little Dal Formation east of Keele River. On fresh surfaces the rocks display shades of purple or dark green. Vesicles, amygdules, pillows(?), and flow banding are conspicuous locally. Several samples contain abundant scattered specks of chalcopyrite and pyrite.

In thin section the volcanics comprise about 70 per cent andesine (about An_4) in laths between 1 and 2 mm long in an aphanitic or very fine grained groundmass masked by iron oxide. Amygdules are mainly calcite although some of the larger ones contain abundant quartz. Chlorite and very fine grained clinozoisite (?) are common alteration products. The texture is diabasic.

Redstone River Formation

The name Redstone River Formation is proposed for a distinctive succession of recessive, dominantly pink weathering siltstones with a type section on the east flank of Coppercap Mountain immediately east of Little Dal Lake. The formation is cut off at the base by a major thrust fault and is overlain conformably by strata of the Coppercap formation although locally, faults separate the two formations (*see* Pls. IX, X). Correlative rocks outcrop east of Keele River, near Little Dal Lake, and possibly along the southwest side of Thundercloud Range.

On Coppercap Mountain the Redstone River Formation is as much as 1,500 feet thick and comprises conspicuous, pink weathering, locally calcareous, thin-bedded and commonly laminated, argillaceous siltstone. In places the rocks display crossbedding, mudcracks, and raindrop impressions. On weathering, the rocks produce a fine, uniform, reddish pink talus that gives the mountain its spectacular appearance. From three to seven zones of greenish weathering, slightly dolomitic siltstone containing copper minerals occur near the top of the formation. A few small andesitic or basaltic dykes cut the siltstones.

About 1,100 feet of pink siltstone and shale outcrop north of the mouth of Thundercloud Creek. There, the rocks are intruded by black, medium-grained gabbro. As on Redstone Mountain, the siltstones contain copper minerals.

East of Keele River, in the northwest corner of Wrigley Lake map-area and north of Shezal Canyon, pink siltstones of the Redstone Formation are associated with beds of gypsum and with gypsiferous siltstones. North of Shezal Canyon several hundred feet of gypsum and gypsum-bearing siltstones overlie the pink siltstones. There, the underlying rocks are orange weathering dolomites of the Little Dal Formation and the overlying beds are silver and grey weathering carbonates tentatively included in the Coppercap Formation.

In the Keele River area the Redstone River Formation overlies orange weathering dolomites of the upper Little Dal Formation. In Thundercloud Range reddish and pink siltstones interbedded with dolomites have been included in the upper part of the Little Dal Formation but they may be in part correlative with the Redstone River Formation (*see* Fig. 3).

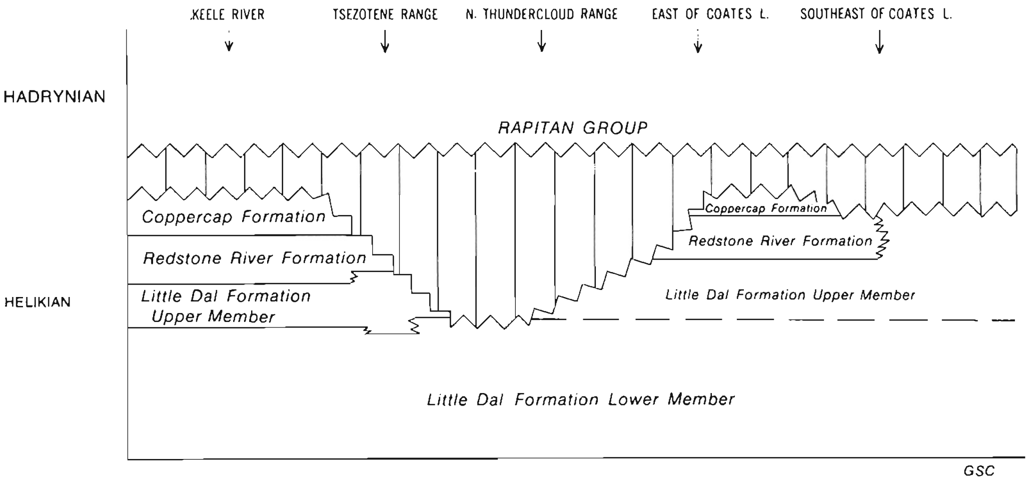

FIGURE 3. Relationships of Little Dal, Redstone River, and Coppercap Formations. Facies relations of Redstone River and Little Dal Formations are hypothetical. (Note: Coates Lake was formerly named Little Dal Lake).

Coppercap Formation

The type section of the Coppercap Formation, a succession of dominantly grey weathering carbonates, is on the east slope of Coppercap Mountain (*see* Section 8, Pt. II). The only other areas in which the rocks are exposed are north of the mouth of Thundercloud Creek and near Keele River in the northwestern part of Wrigley Lake map-area.

In the type section the formation is 675 feet thick. The basal contact with strata of the Redstone River Formation is locally marked by a fault. A lower member, 175 feet thick, comprises buff weathering, platy, silty limestone and calcareous siltstone and sandstone in beds half an inch to 3 inches thick. This member is overlain by 225 feet of dark grey to black, fine-grained, fetid limestone, and recessive black, buff, and grey calcareous slate. The upper 275 feet consist of resistant, fine-grained, dark grey to black, light grey weathering limestone. In places the upper member includes fairly coarse limestone-conglomerate in beds from 2 to 10 feet thick. The top of the formation consists of grey weathering, sandy limestones.

North of the mouth of Thundercloud Creek a lens-shaped remnant of the Coppercap Formation is preserved beneath the sub-Rapitan unconformity. There, a succession of limestone-conglomerate and black, fetid, cryptograined limestone ranges in thickness from zero to possibly 1,000 feet. A basal unit, not everywhere present, is from zero to several hundred feet thick and comprises orange weathering dolomite.

Strata of the Coppercap Formation were not examined in detail in northwestern Wrigley Lake map-area where they are represented by moderately resistant, grey and silver-grey weathering carbonates.

Age and Correlation of Helikian Rocks

No direct evidence is yet available to confirm the tentative assignment of the strata described above to the Helikian. On the basis of their stratigraphic position and general character, however, they can be best correlated with Helikian strata of the Purcell System in southeastern British Columbia and southwestern Alberta (*see* Price, 1964).

Bell (1968) described a thick sequence of Proterozoic mudstones, siltstones, quartzites, and dolomites in northern Rocky Mountains. The strata have not been correlated on a formational basis with those in Mackenzie Mountains but they are similar in many aspects. They are referred by Bell to the Helikian.

Proterozoic sedimentary strata of probable Helikian age form the core of northern Mackenzie Mountains. Thick sequences of slate, argillite, orange weathering dolomite, and quartzite are present in northwestern Mackenzie Mountains (Green and Roddick, 1962). Farther east quartzitic sandstones, probably correlative with the Tigonankweine Formation, are widespread.

Near Cap Mountain in Franklin Mountains three unnamed formations comprising green and dusky red shales, siltstones, sandstones, and dolomite are the oldest exposed stratified rocks (Douglas and Norris, 1963) and may be of Helikian age. They are overlain by the Proterozoic Lone Land Formation which is in turn overlain unconformably by Lower Cambrian rocks.

Helikian strata may also be included in the lower part of the Tindir Group near the Alaska–Yukon boundary (Cairnes, 1914; Mertie, 1937).

Hadrynian

A sequence of mainly clastic rocks with minor carbonates more than 10,000 feet thick, overlies older rocks with marked angular discordance on Redstone Plateau and in Thundercloud Range. The strata are subdivided into three well-defined units, from oldest to youngest: Rapitan Group, Keele Formation, and Sheepbed Formation. Correlation of these units with typical 'Windermere-like' Hadrynian rocks exposed southwest of Flat River, is uncertain. It is evident, however, that unless large unrecognized gaps are present in the late Proterozoic record in Mackenzie Mountains, the strata must change facies southwesterly into Logan Mountains as do the overlying Paleozoic rocks.

Rapitan Group[1]

A distinctive assemblage of dark weathering clastic rocks, locally including iron-formation in the lower part, is correlated with the Rapitan Group first described in the Snake River area of northwestern Mackenzie Mountains (Green and Godwin, 1963). These rocks underlie a large part of southern Redstone Plateau, extensive areas farther north along the northeastern and eastern margins of the plateau, and several smaller areas in southwestern Thundercloud Range (*see* Sections 9, 10; Pt. II; Pls. XI, XII, XIII).

Near Keele River the Rapitan Group comprises three well-defined units herein referred to as Lower Rapitan, Middle Rapitan, and Upper Rapitan. Farther southeast and particularly south of Redstone River a separation of the upper two units is difficult. South of South Redstone[2] River mapping was not carried out in sufficient detail to permit subdivision of the group.

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[1]Much of the material on the Rapitan Group used in this report is taken from a M.Sc. thesis prepared by Uldis Upitis (1966).

[2]Informal name—appears on some maps, but never proposed to Canadian Permanent Committee on Geographical Names.

The base of the Rapitan Group is a marked angular unconformity which, within the report-area, truncates as much as 4,000 feet of underlying Little Dal Formation. The unconformity is most evident along Redstone River. Another conspicuous angular unconformity, locally cutting out the entire Lower Rapitan unit, occurs at the base of the Middle Rapitan. A third unconformity marks the base of the Upper Rapitan.

In most places strata of the Keele Formation appear to overlie the Rapitan Group conformably but south of North Redstone River a distinct low-angle unconformity separates the two units.

Lower Rapitan. The Lower Rapitan is about 1,000 feet thick in Thundercloud Range, 230 feet thick north of Redstone River, and 1,335 feet thick south of North Redstone River. Locally it is missing completely. These variations in thickness are mainly attributable to truncation by an unconformity at the base of the Middle Rapitan. Dark reddish brown or maroon weathering mudstone ranging from clay mudstone to very slightly silty mudstone forms about 70 per cent of the formation. Platy beds, 1 inch to 3 inches thick, predominate but massive beds as much as several feet thick are present. Laminations occur on megascopic and microscopic scales. Slightly calcareous, finely crystalline, recessive, grey and grey-brown weathering mudstone occurs in places. Thin lenses of sand and fine conglomerate are common.

In thin sections the mudstones are seen to be hematitic and clayey or silty, being composed of angular, silt-sized quartz, feldspar, mica (?), and sericite in varying amounts in a finer matrix. The clay fraction is a mixture of clay minerals and red hematite pigment which give the rock its red or maroon colour. A green coloration, presumably due to reduction of hematite pigment, is present in a few beds.

Thin laminations and banding are caused by colour changes and by textural changes from almost pure clayey hematitic mud to fine silty mud. Small-scale scour and fill structures and graded bedding are exhibited by the silty layers.

Poorly sorted conglomerate in beds ranging from quarter of an inch to 5 feet thick makes up 25 to 30 per cent of the Lower Rapitan. Subangular to subrounded clasts comprise, in decreasing order of abundance, green mudstone, light grey dolostone, brown sandstone, maroon mudstone, grey chert, light grey limestone, some with stromatolites, and very minor gneiss (?). Nonlaminated, greenish, fine-grained volcanic clasts are conspicuous in some areas. Locally, solitary cobbles or boulders occur in fine- to medium-grained sandstones and laminated mudstones. The ratio of clasts to matrix ranges from 20:1 to 10:1 in thick-bedded conglomerates, and from 8:1 to 2:1 in thin-bedded conglomerates, the latter commonly showing poor vertical grading.

Under the microscope examples of red, almost opaque mudstone clasts with other clasts projecting into them are common, suggesting that the mudstone clasts were partly plastic when deposited. Samples collected from conglomerates in the Lower Rapitan west of Little Dal Lake contain as much as 10 per cent of highly chloritized and sericitized volcanic clasts consisting of altered plagioclase laths in an almost isotropic matrix. Lithic or slightly lithic sandstones contain from 26 to 61 per cent detrital grains, 9 to 47 per cent argillaceous matrix, and 5 to 30 per cent calcite cement, probably of secondary origin. Point counts of typical sandstones reveal the following amounts of constituents: quartz, in angular to subrounded grains averaging 0.16 mm—7 to 31 per cent; plagioclase, in grains generally less than 0.1 mm —less than 4 per cent; shale or mudstone, almost completely sericitized, ranging from 0.04 to 0.5 mm—5 to 25 per cent; reddish hematitic grains—5 to 13 per cent; and volcanic fragments—2 to 3 per cent (*see* Table I).

Jasper and hematite beds were noted near the top of the Lower Rapitan 8 miles northwest of Hayhook Lake and in several localities south of North Redstone River. A section of

TABLE I — *Sandstone compositions of Upper and Lower Rapitan Group (per cent)*

Lower

Thin Section	Quartz	Orthoclase	Plagioclase	Mudstone or shale fragments	Volcanic fragments	Red mudstone fragments	Calcite cement	Mudstone matrix	Chert
UB 1-1750	19.2	6.6	0.4	17.2	0.2	4.6	23.8	26.6	–
UB 1-770	7.2	9.6	–	4.6	–	3.4	39.0	35.0	–
UB 1-2625	15.0	6.8	.4	25.8	–	13.6	28.8	9.8	–
UB 3-300	31.2	13.0	1.4	8.6	.2	5.7	23.4	17.4	.2
Rd 63.145-900	21.4	9.2	.6	9.6	.6	3.8	5.4	47.2	2.2

Upper

Thin Section	Quartz	Orthoclase	Plagioclase	Microcline	Composite quartz	Igneous rock fragments	Muscovite	Chert	Matrix	Calcite cement	Siderite
UB 2-5950	40.4	44.6	1.4	–	0.6	–	–	–	8.6	–	4.4
UB 2-4525	35.6	39.6	.3	1.6	.6	3.0	–	–	11.0	–	11.0
UB 1-5945	31.1	30.3	.3	1.0	.3	1.0	1.0	–	18.3	12.6	3.6
UB 2-6300	48.3	25.0	2.2	.8	.8	.4	–	.4	18.2	4.8	–
UB 2-3850	52.0	36.8	.8	–	1.6	–	–	–	8.0	.4	.4
UB 2-4700	43.0	36.8	2.6	–	.4	–	.2	–	10.6	–	6.4

Recalculated Percentages (100 per cent)

	Quartz	Feldspar	Rock fragments and chert
2-5950	47.1	52.9	–
2-4525	46.3	53.0	.7
1-5945	48.4	48.4	3.2
2-6300	63.0	35.7	1.3
2-3850	58.7	41.3	–
2-4700	52.1	47.3	.6

typical, cherty iron-formation east of Little Dal Lake is about 100 feet thick and contains possibly 20 per cent hematite. The assemblage consists of interbedded, thinly bedded and laminated, red-orange weathering jasper, maroon weathering slate and steel grey weathering hematite. Purplish brown siderite is abundant in some samples. The jasper occurs as lenses or interbeds as much as 2 inches thick, or commonly as oval nodules in hematite. Characteristically, jasper is well jointed and breaks into angular, sharp fragments.

Polygonal structures, believed to be mudcracks, occur in mudstones associated with iron-formations south of North Redstone River. The polygons are separated by cracks an eighth to a quarter of an inch wide infilled with maroon mudstone.

Some surfaces on slaty siltstones contain shallow, curved, thread-like markings reflecting the presence of algal filaments (H. J. Hofmann, pers. com., 1966).

Ripple-marks were not observed in outcrops but occur in talus derived from thin-bedded, platy mudstone. The ripples with rounded crests and asymmetrical cross-section have amplitudes of an eighth to a quarter of an inch and wave lengths about a quarter to half an inch.

Laminations in mudstone are commonly bent beneath larger conglomerate clasts in thin beds of conglomerate. Scattered pebbles, cobbles, and boulders commonly have laminations bent beneath them as well as arching over them. Recumbent beds in laminated mudstones bounded by undisturbed laminations suggest penecontemporaneous lateral slumping or flowage.

Regular, alternating varve-like laminations about quarter of an inch wide occur between conglomerate beds in sequences as much as 1½ feet thick. Commonly these sequences contain widely dispersed isolated pebbles or cobbles.

Middle Rapitan. The Middle Rapitan consists almost entirely of recessive weathering, massive, blue-grey to grey, locally greenish grey, poorly sorted conglomeratic mudstone. The unit thickens from a thin wedge in Thundercloud Range to 1,215 feet north of Redstone River to 1,555 feet south of North Redstone River, and to more than 2,000 feet near Keele River. The formation weathers greenish grey and light and dark brown to dark reddish brown throughout much of the region, but near Keele River and to the northwest a distinct orange-brown weathering is typical. From a distance the assemblage appears vaguely bedded but in the outcrop bedding and structure are not readily apparent.

The ratio of clasts to matrix ranges from 5 to 30 per cent and perhaps averages between 15 and 20 per cent. The clasts range from one sixteenth of an inch to 2 feet in diameter but are generally between 1 inch and 1½ inches. They are mainly subrounded to rounded and some of the larger boulders are well rounded. Their compositions in decreasing order of abundance are: light and dark grey dolomite, greenstone, grey limestone, quartzite, grey and black chert, igneous and metamorphic rocks, and stromatolitic limestone (*see* Fig. 4). Striated pebbles and cobbles were noted in several localities and a few carbonate pebbles show flatiron shapes.

The matrix is very fine grained, dolomitic mudstone containing variable amounts of fine quartz sand. Small cubes of pyrite are ubiquitous.

Thin sections of the matrix reveal 5 to 15 per cent rock fragments, 15 to 30 per cent mineral grains, and the remainder fine-grained argillaceous material. Angular to rounded quartz grains from 0.04 to 3 mm are predominant among the minerals. The dominant feldspar, orthoclase, is about one third as abundant as quartz. Small amounts of perthite and microcline and very minor plagioclase are also present.

Upper Rapitan. The Upper Rapitan comprises a dark weathering, well-bedded sequence of interbedded shale and sandstone ranging in thickness from 3,845 feet north of Redstone

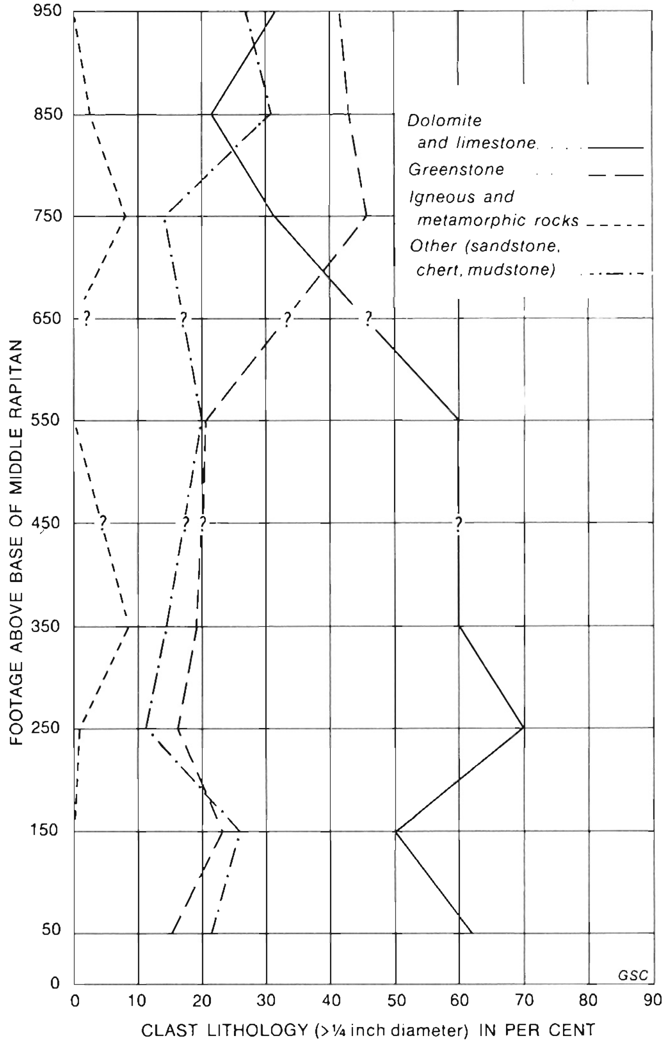

FIGURE 4. Variations in clast composition of Middle Rapitan Group, south of North Redstone River.

River to 1,870 feet south of North Redstone River and more than 2,000 feet near Keele River. These rocks probably underlie much of Redstone Plateau south of South Redstone River and west of Thundercloud Creek.

Blue-black, green-grey, or black, fissile to platy shales, in beds one eighth of an inch to 3 inches thick, form from 65 to 75 per cent of the Upper Rapitan. Lenses of fine calcareous siltstone one eighth of an inch to 1¾ inches thick, are common near the top of the formation. The rocks are recessive and weather dark grey to greenish grey.

From 20 to 30 per cent of the Upper Rapitan is very fine to fine-grained, light green-grey sandstone in beds half an inch to a foot thick. Lenses of sandstone are abundant, ranging from 1 foot to 15 feet long and as much as 2 feet thick.

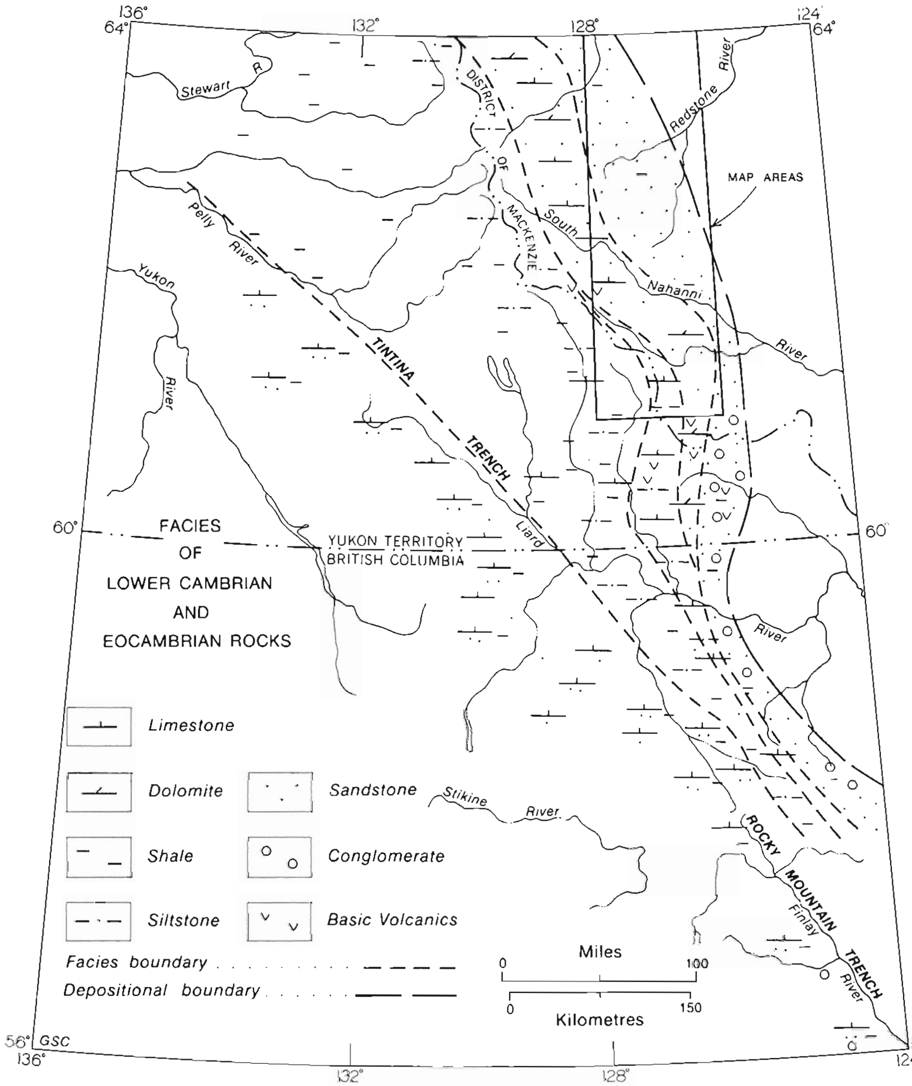

FIGURE 5. Lower Cambrian facies in part of the northern Cordillera.

Limestone and minor dolomite were observed only in the section north of South Redstone River. The rocks weather grey and orange-grey and are very finely crystalline. Algal structures are present in a few thin beds.

Under the microscope the sandstones are seen to consist of 31 to 52 per cent detrital quartz, 30 to 40 per cent orthoclase, and 8 to 18 per cent fine-grained, clayey matrix. The rocks may therefore be termed arkoses. The quartz grains, averaging about 0.20 mm, vary considerably in size and are generally subangular to angular. Many of the grains have authigenic quartz overgrowths or are replaced by secondary calcite near grain boundaries. Orthoclase, minor perthite and microcline, and very minor plagioclase occur as subangular to subrounded grains. The minerals, particularly orthoclase and perthite, are fresh, displaying only minor sericitization and kaolinization. Compositions of typical Upper Rapitan arkoses are shown in Table I and Figure 2. The rocks contain by far the highest proportion of orthoclase of any strata so far studied in the region.

Various ripple-marks are abundant throughout the Upper Rapitan. Many asymmetrical ripple-marks have amplitudes of half an inch to an inch and wavelengths ranging from 2 to 4 inches, but some, observed locally near the base of the Upper Rapitan, have amplitudes of 2 to 3 inches and wavelengths as much as 1½ feet. In some localities well-developed interference ripple-marks are present.

Crossbedding on a scale of inches occurs in the fine-grained sandstones. Most possess truncated topset and bottomset beds with straight, linear foreset beds that dip fairly consistently in one direction in a single outcrop. Convolute laminations are common in Upper Rapitan sandstones. The deformed zone generally includes the entire thickness of a sandstone bed 2 to 4 inches thick, and is probably attributable to slight differential forces acting on a weak hydroplastic deposit during accumulation. Overlying shales are not affected but underlying shales are slightly depressed. Slump structures, restricted to a few feet of shale bounded by undisturbed sections of shale, are not uncommon. The amount of translation generally appears to be small. Load casts in sandstone at sand–shale interfaces are abundant but generally show little or no alignment.

Current directions indicated by ripple-marks, crossbedding, and current lineations are shown in Figure 6. Although the paleocurrent measurements suggest a possible northeasterly source area the data are too sparse to be of real significance.

Origin of Rapitan Group. The angular unconformity at the base of the Rapitan Group indicates that Rapitan sedimentation followed a period of uplift, tilting, perhaps associated with block faulting, and erosion. The generally fine grain of Lower Rapitan strata, graded bedding of the coarser sediments, and a lack of evidence for significant current action suggest deposition in relatively deep water. From time to time conglomeratic material was introduced into this environment, possibly by mudflows and turbidity currents. The conglomerate clasts were largely derived from erosion of underlying strata but also partly from semiconsolidated sediments within the basin of deposition. Fault scarps may have provided a source for the coarse clastic material. Volcanic clasts, locally abundant in Lower Rapitan sediments may have been derived from erosion of older volcanic rocks or from explosive volcanism contemporaneous with Rapitan sedimentation. Orthoclase and perthite may have been derived from cratonal, crystalline rocks.

Where observed, the iron-formation occurs high in the lower Rapitan and therefore it is debatable whether absence of iron-formation is the result of nondeposition or of erosion preceding deposition of the Middle Rapitan. Nevertheless the entire Lower Rapitan succession is highly ferruginous and it is evident that enormous quantities of iron were introduced into the sedimentary basin during Lower Rapitan time. Gross (1965) suggested that alternating layers of iron and silica were chemically deposited in depressions on the sea floor after being carried in solution by fumarolic waters discharged along fault zones. Whether or not such a mechanism is adequate for the quantity of iron involved remains to be determined. Another hypothesis is that weathering and erosion of immense volumes of basalts on the craton contributed iron to the typical Precambrian iron-formations (Fahrig and Wanless, 1963). In the Redstone region the immaturity of the coarser basal Rapitan sediments is indicated by the relatively fresh volcanic clasts and orthoclase, and a deeply weathered source area for these products seems unlikely. It seems possible, however, that the coarser clastics may have been of relatively local derivation, whereas the finer-grained sediments and the iron were transported from a more distant source. During formation of banded

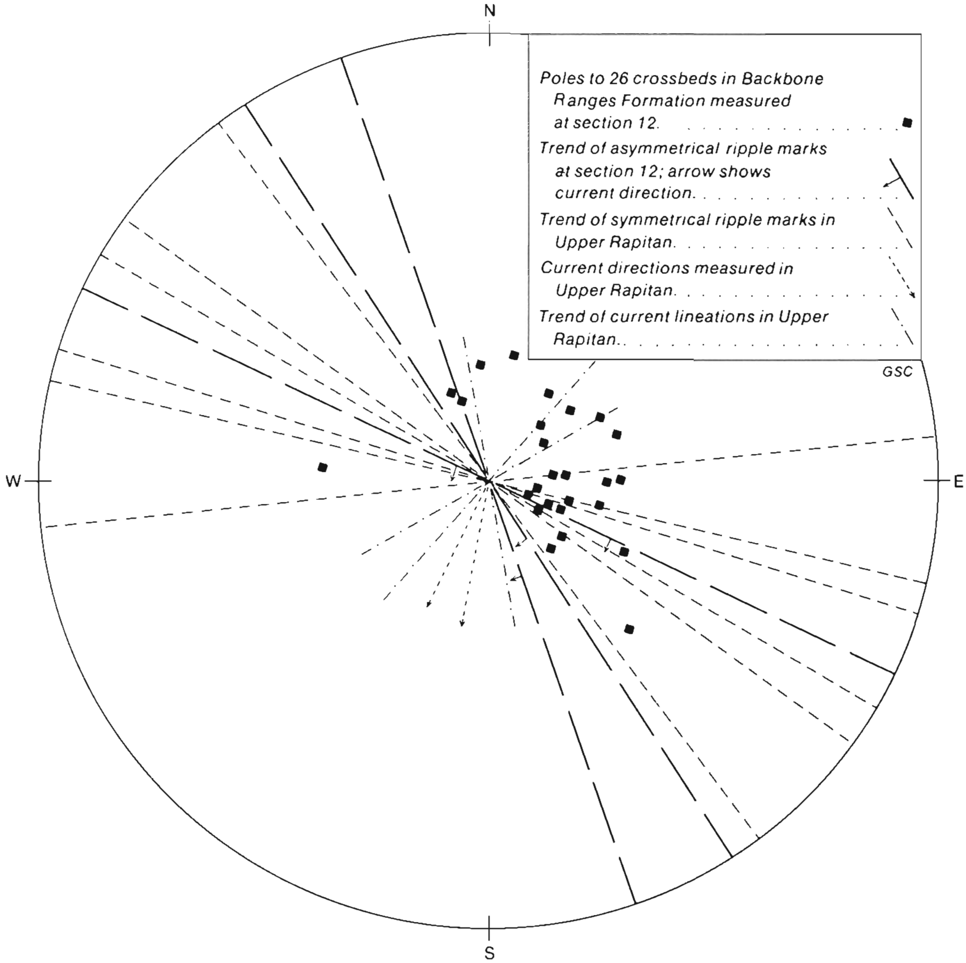

FIGURE 6. Sedimentary structures in Upper Rapitan Group and Backbone Ranges Formation, plotted on lower hemisphere projection.

hematite and jasper the influx of clastic material was relatively minor, probably because of rapid precipitation rather than remoteness from source areas of clastic sediments. Critical information regarding the lateral persistence and possible facies equivalents of the iron-formation is still lacking. The rocks could be deep-basin deposits homotaxial with mudstones and coarser clastics, or they could be entirely younger than most of the Lower Rapitan clastics.

The presence of ubiquitous, large, isolated pebbles and cobbles that evidently have dropped into semiconsolidated iron-formation is not explained by a turbidity current or mudflow mechanism. Such foreign clasts may have been ice rafted as suggested by Ziegler (1959).

Uplift and tilting, probably associated with block faulting, closed Lower Rapitan sedimentation. This was followed by the deposition of widespread, thick, poorly sorted and bedded, conglomeratic mudstones of the Middle Rapitan. These sediments are interpreted as having accumulated in a partly fault bounded, rapidly subsiding trough. Clasts could have been derived from uplifted regions bordering the trough, and subsequently rounded in streams or along beaches. Periodic mudflows or flash floods in the same areas may have provided debris that was in part faceted and striated. This material was eventually carried into the trough by subaqueous slumps developing into thixotropic turbid flows. Poorly bedded and sorted material may thus have resulted from the churning action of such flows. Repeated uplifts of source areas maintained a supply of coarse clastic material interrupted from time to time by periods of quiescence when interbeds of sandstone were deposited.

A possible role of glacial action in this postulated process cannot be ruled out. The enormous lateral extent of these sediments and the lack of striated pavements, however, cast some doubt on the idea of an exclusively glacial marine origin (Ziegler, 1959).

Upper Rapitan time witnessed a return to 'normal' sedimentation in the region. The only remarkable characteristic of the Upper Rapitan is the unusually high content of potash feldspar which may have been derived from the Canadian Shield.

Age and Correlation of Rapitan Group. A tentative late Proterozoic (Hadrynian) age has been suggested for the Rapitan Group (Gabrielse, 1967b) but the strata have not yet been observed in contact with typical 'Windermere' rocks of the 'Grit Unit' exposed to the southwest. Aside from the obvious unique characteristics of the Rapitan Group the two assemblages have several common features: both are thick, clastic units, in part poorly sorted; both contain relatively large amounts of potash feldspar; both units occupy similar stratigraphic positions relative to Lower Cambrian formations.

Strata of the Rapitan Group form a discontinuous belt of exposures extending essentially the full length of the great arc through Ogilvie, Selwyn, and Mackenzie Mountains (Green and Roddick, 1962; Norris *et al.*, 1963). Along the Alaska–Yukon boundary correlative strata are found in the upper part of the Tindir Group (Mertie, 1933; Brabb and Churkin, 1965). Near Cap Mountain, in McConnell Range east of Mackenzie River, Douglas and Norris (1963) have described several Proterozoic formations, all more or less ferruginous, that may be in part or entirely correlative with the Rapitan Group or older rocks. The southernmost exposures of Rapitan rocks are probably the oldest exposed strata on Liard Plateau (Douglas and Norris, 1959).

Keele Formation

A well-bedded, orange and buff weathering assemblage of sandstone, dolomitic sandstone, and dolomite that overlies the Rapitan Group is named the Keele Formation. Well-exposed sections occur southeast of Keele River and in general the assemblage forms prominent outcrops because of its resistance to erosion relative to the overlying recessive Sheepbed Formation and the underlying less resistant Rapitan Formation (*see* Pls. XI, XIII, XIV). In many places on Redstone Plateau erosion has produced a stripped surface on the uppermost member of the Keele Formation. In the report area thicknesses of the Keele Formation appear to range from about 1,500 feet to more than 2,000 feet.

Lower members of the Keele Formation were examined in the type section 20 miles southwest of Little Dal Lake, along a prominent northeast-trending fault in the southern part of Redstone Plateau, and near the eastern boundary of the plateau between Redstone and North Redstone Rivers (*see* Sections 9, 10, 11, Pt. II). Basal beds are light grey weathering, fine- to medium-grained sandstones, commonly showing well-developed crossbedding. In most places the clean and well-sorted sandstones contain numerous rusty weathering blebs of iron oxide and some samples contain a few coarse grains of quartz. Commonly the beds are between half a foot and 2 feet thick and aggregate thicknesses may range from 150 to more than 400 feet.

Strata overlying the sandy assemblage are dominantly orange-buff and yellow-buff weathering, light grey, cryptograined to medium-grained dolomites, variably sandy, and including minor members of cryptograined grey limestone, sandstone, and green-grey to buff and buff-red weathering siltstone. The dolomites are well bedded to massive and locally contain stromatolites. Six miles north of Redstone River thin-bedded, very fine grained, medium to dark grey limestones near the base of the carbonate sequence are about 150 feet thick.

A section of the upper part of the Keele Formation 20 miles west–southwest of Little Dal Lake consists essentially of dolomite with one member of coarse-grained sandstone 15 feet thick and one member of thinly bedded, crossbedded siltstone 20 feet thick. In this area the top of a rusty brown weathering, aphanitic, basaltic flow 75 feet thick, lies 35 feet below the top of the formation. The lower 10 feet of the flow contains numerous fragments of dolomite and limestone as much as 3 feet long. Many fractures produce a blocky talus in the lower part of the flow and a platy structure parallel with the upper surface near the top of the flow.

The uppermost member of the Keele Formation comprises a relatively continuous, distinctive unit of orange-buff weathering, platy to blocky, fine-grained, grey to buff dolomite. Where examined between Redstone and North Redstone Rivers, the strata are about 40 feet thick. The rocks form a resistant, light weathering rib below basal beds of the Sheepbed Formation.

In most places strata of the Keele Formation appear to be conformable with underlying strata of the Rapitan Group but near North Redstone River a distinct low-angle unconformity can be observed.

Sheepbed Formation

The name 'Sheepbed Formation' is assigned to a sequence of thick, recessive, fine-grained, clastic, dark weathering rocks that conformably overlies the Keele Formation. The strata are considered to be the youngest Proterozoic rocks exposed in Mackenzie Mountains within the report area. Characteristically the assemblage underlies relatively subdued terrain (*see* Pls. XI, XIII, XIV).

In the type area, 20 miles southwest of Little Dal Lake, the Sheepbed Formation appears to be more than 2,500 feet thick but precise measurement is difficult because of abundant talus (*see* Section 11, Pt. II). Near North Redstone River an essentially flat lying sequence is as much as 1,500 feet thick.

Most of the sequence comprises thin-bedded, locally platy, dark brown and black, noncalcareous shale and siltstone. Commonly the shales are very fissile and typically talus slopes glisten as the result of a phyllitic sheen on shale fragments. A few beds of fine-grained sandstone are present but are generally less than 6 inches thick and thus do not form conspicuous marker horizons. The upper part of the sequence is more resistant than the lower and in northwestern Glacier Lake map-area it forms a distinctive orange weathering unit between 500 and 1,000 feet thick. The more resistant beds include thin-bedded, argillaceous sandstone. Minor red and green weathering shales were observed in the uppermost 800 feet of the formation in the type area.

The Sheepbed Formation is conformable with the underlying Keele Formation. Absence of the Sheepbed Formation east of Plateau Fault probably reflects regional bevelling beneath Lower Cambrian strata.

'Grit Unit'

The oldest exposed strata in Logan Mountains outcrop in westernmost and southwestern Flat River map-area. Similar rocks underlie extensive areas elsewhere in central and southeastern Yukon and have been referred to informally as the 'Grit Unit' (*see* Roddick and Green, 1961; Green and Roddick, 1962).

The 'Grit Unit' comprises about equal amounts of argillaceous and quartzose rocks and includes from 5 to 10 per cent limestone and minor phyllite. The main rock types in decreasing order of abundance are: black and dark green shale and slate, quartzite (commonly gritty), calcarenite, feldspar–quartz-pebble conglomerate, sandstone, brightly coloured maroon, green, and buff shale and slate, and limestone. The maroon and green shales are the most conspicuous strata and appear to occur in the upper part of the sequence. Also distinctive are poorly sorted feldspar–quartz-pebble conglomerates and gritty quartzites which contain bluish opalescent quartz grains and cream weathering potash feldspar grains. In general maximum grain size in the coarsest clastic rocks is less than 1 cm. Quartz grains and pebbles range from subangular to well rounded whereas potash feldspar grains are commonly angular to subangular.

In thin section the clastic rocks are seen to contain quartz in amounts ranging from 40 per cent in poorly sorted varieties to more than 80 per cent in even-grained varieties. Quartz grains are typically fractured and in many places consist of a mosaic of areas with slightly different extinction. Many fractures are healed with fine-grained, crystalloblastic quartz. Lines of very small inclusions are abundant. In some specimens the larger grains are well rounded whereas the smaller grains are generally subangular to subrounded. Clasts 'floating' in a fine-grained matrix have retained their original outline but even-grained, quartz-rich specimens in which quartz grains are in contact show much recrystallization of quartz along grain boundaries.

Carbonate is abundant in the matrix of the gritty rocks and locally has replaced quartz along grain boundaries. Sericite is not common, and in several even-grained quartzites detrital muscovite is present along bedding planes. Angular grains of orthoclase occur in varying amounts and a few selected specimens may be termed arkoses. Highly feldspathic varieties are rare, however, even though the feldspar grains are conspicuous in many pebble-conglomerates and coarse grits. Plagioclase, including calcic oligoclase and sodic andesine, occurs as small grains and constitutes a maximum of a few per cent of the clastic rocks. The pebble-conglomerates form competent beds, generally from 50 to 100 feet thick, which break into large blocks. These rocks with interbedded shales occur relatively low in the map-unit. Blocky weathering limestone, in beds tens of feet thick, occurs at or near the top of the 'Grit Unit.' Minor dark grey, fine-grained limestone is present locally in the lower part of the sequence.

The 'Grit Unit' exposed in Flat River map-area appears to be several thousand feet thick but reliable estimates cannot be made because of complex structure and poor exposures. The rocks are overlain, apparently conformably, by fine-grained clastic strata of late Proterozoic and/or Lower Cambrian age, or unconformably by Middle and/or Upper Cambrian carbonates.

Age and correlation of 'Grit Unit'. The gross lithological characteristics of the 'Grit Unit' and its stratigraphic relationships with Lower Cambrian rocks suggest correlation with the Hadrynian Kaza, Miette, and Windermere strata farther south in the Canadian Cordillera. Strata of the 'Grit Unit' can be traced southerly through Watson Lake and Coal River map-areas in southeastern Yukon (Gabrielse, 1967a; Gabrielse and Blusson, 1969) into Rabbit River, Kechika, and Tuchodi Lakes map-areas in northern British Columbia (Gabrielse, 1962a, b; Bell, 1968). To the west and northwest the assemblage underlies extensive areas in Frances Lake map-area (Blusson, 1966), Nahanni map-area (Blusson, 1968a), and to the northwest and west as far as Tintina Trench at the Alaska–Yukon boundary (Roddick and Green, 1961a; Bostock, 1964; Green and Roddick, 1962). A suggested possible correlation of part of the 'Grit Unit' with rocks of the Rapitan Group in Mackenzie Mountains (*see* discussion above on correlation of Rapitan Group) must remain tenuous until more work is done in the region.

Hadrynian (?) and Lower Cambrian

'Phyllite Unit'

A sequence of dark weathering, fine-grained, clastic rocks outcrops in an anticline north of Brintnell Creek and underlies several areas in southwestern Flat River map-area. Several thousand feet of strata may be present but thicknesses are difficult to estimate because marker horizons are lacking and the effects of structural complications are essentially unknown.

Southeast of Caesar Lakes the rocks are recessive, rusty grey weathering, soft, greenish grey, noncalcareous, phyllitic slates. Faint bedding is revealed by alternating dark grey and greenish grey bands about half an inch wide. At least 1,000 feet of phyllitic slate is exposed in this area.

West of Skinboat Lakes near the Yukon–District of Mackenzie border the predominant rocks are rusty weathering, fine-grained, grey phyllites that include some units of light grey, fine-grained quartzite. Several limestone beds, between 10 and 15 feet thick were noted in this sequence but these beds may be, at least in part, repetitions of the same bed as local and major structures indicate the presence of overturned folds. The fine-grained quartzites and siltstones are blocky weathering, highly indurated rocks and they are mainly responsible for the resistant nature of the entire assemblage.

Strata outcropping in the anticline north of Rabbitkettle River are similar to those described above except that they appear to include a higher proportion of siltstone and sandstone. In this they resemble rocks west of Skinboat Lakes more than those near Caesar Lakes.

Near Caesar Lakes the 'Phyllite Unit' thins to disappearance northerly beneath the unconformity at the base of the Upper (?) Cambrian Rabbitkettle Formation. The unit appears to be conformable with strata of the underlying 'Grit Unit.'

Age and correlation of the 'Phyllite Unit.' No unequivocal age can be assigned to the 'Phyllite Unit.' Judging from the facies changes observed in Lower Cambrian strata in Mackenzie and Logan Mountains it seems reasonable to infer that at least some and perhaps most of the fine-grained rocks are of Lower Cambrian age. West of Skinboat Lakes a poorly preserved archaeocyathid was found in sandy carbonates presumably directly overlying the fine-grained clastic sequence. The clastic rocks there are probably, in part at least, Lower Cambrian. The stratigraphic relationship of these rocks to those east of Caesar Lakes, however, cannot be demonstrated.

Facies belts of Lower Cambrian strata in the region are shown in Figure 5. Strata discussed above are interpreted as forming a western, fine-grained clastic, probably relatively deep water facies.

Lower Cambrian

Three distinct facies of Lower Cambrian strata are in the report area—a predominantly sandstone unit (Backbone Ranges Formation) northeast of South Nahanni River; a vari-

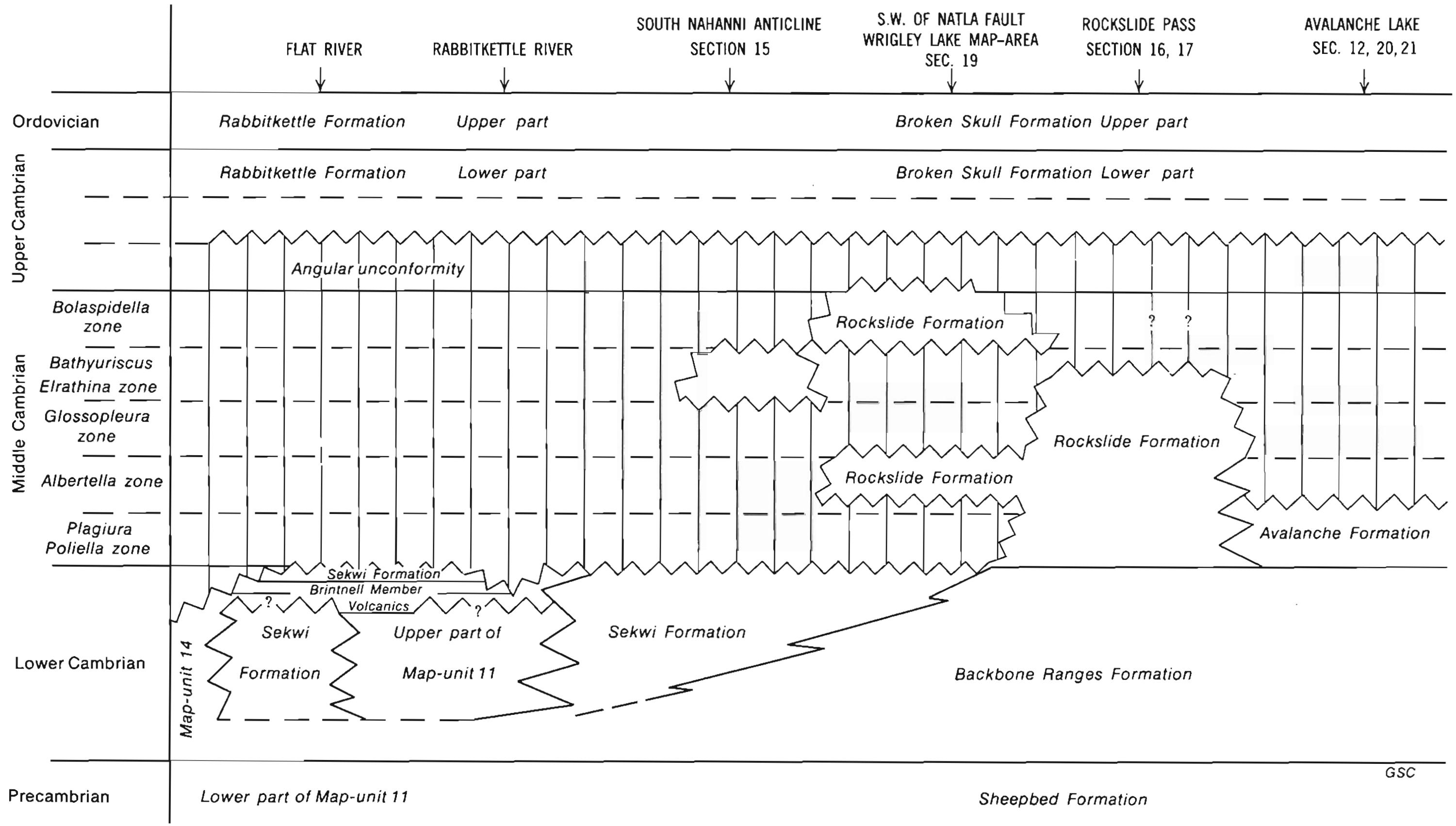

FIGURE 7. Correlation of Lower and Middle Cambrian formations. (Note: unit 11 is the phyllite unit of the text and unit 14 the unnamed argillaceous rocks.)

coloured sandy carbonate and siltstone unit (Sekwi Formation) exposed in South Nahanni Anticline near the west side of Glacier Lake map-area; and a predominantly fine-grained clastic unit, southwest of Flat River (*see* Fig. 7). Transitions between the last two facies are evident in the region near the headwaters of Rabbitkettle River.

Backbone Ranges Formation

Resistant, dominantly clastic strata of the Backbone Ranges Formation are well exposed on central Redstone Plateau north of Redstone River where they commonly form castellated peaks and ridges. Farther south the rocks underlie the highest mountains in Backbone Ranges and produce a conspicuous line of cliffs that defines the southwest side of Redstone Plateau (*see* Pls. XIII, XVI). The thickest sequence of rocks assigned to the Backbone Ranges Formation is exposed in Broken Skull Anticline. A thick, clastic sequence underlying the Sekwi Formation in the core of South Nahanni Anticline is considered correlative with part of the Backbone Ranges Formation.

The type area of the Backbone Ranges Formation is in northeastern Backbone Ranges about 7 miles north of Avalanche Lake (*see* Section 12, Pt. II). There, as elsewhere, can be recognized three well-defined members with an aggregate thickness of about 4,700 feet, consisting of two clastic units separated by a sequence of sandy dolomites. The lower member, 1,650 feet thick, comprises very well bedded, resistant, medium- to coarse-grained sandstones or quartzites with interbeds of thin-bedded siltstone and very minor silty and sandy dolomite. Sandstones, weathering white, brown, pink, and purple, range from thin bedded in finer grained varieties to thick bedded and massive in coarser types. Some beds display excellent crossbedding. Platy, fissile, thin-bedded siltstones commonly weather shades of brown and emphasize bedding in the dominantly arenaceous assemblage. Recessive silty and sandy dolomites are very fine grained to medium grained and thin to medium bedded. These rocks weather a conspicuous orange-brown or brown. The only significant dolomitic unit in the lowest member ranges from about 50 to 90 feet thick.

In the type area the middle member of the Backbone Ranges Formation comprises silty and sandy, thin-bedded, cryptograined to fine-grained dolomites about 500 feet thick. The assemblage forms a good marker because of its banded brown, orange, yellow, and ochre weathering. In hand specimens many of the dolomites are distinctly laminated, most reflecting differences in silt content. On fresh surfaces the rocks are mauve, pink, and buff. In general the upper part of the sequence weathers shades of pink and orange whereas the lower part weathers cream to buff.

The upper member is about 2,500 feet thick in the type area and consists of pink, purple, grey, and brown weathering sandstone with minor purple, brown, and maroon siltstone. Quartz-pebble conglomerate with pebbles of quartz as large as 1 cm forms thin interbeds in the lower part of the unit. Cream weathering, potash feldspar is present in minor amounts in most of the coarser grained rocks. Crossbedding is well developed locally.

Under the microscope sandstones of the Backbone Ranges Formation are commonly well sorted although some are distinctly bimodal with grains as large as 1 mm in a matrix of grains less than 0.1 mm. Quartz is by far the dominant constituent and occurs in well-rounded grains with a very minor sericitic matrix, or as interlocking grains displaying overgrowths on initially well rounded grains. Potash feldspar, in some places constituting as much as 15 per cent of the sandstones, appears to be mainly microcline. Commonly the grains are interlocking and form a quartzitic texture. Chert grains were noted in a few thin sections but are very minor. Tourmaline is present in some specimens and a few of the reddish weathering, ferruginous varieties have a hematitic matrix. Compositions of a few selected specimens of sandstone are shown in Figure 2.

In South Nahanni Anticline reddish weathering sandstones and quartzites, possibly as much as 4,000 feet thick, overlie about 500 feet of buff weathering dolomite. These units are probably correlative with parts of the upper two members of the Backbone Ranges Formation farther east.

In Broken Skull Anticline the upper member of the Backbone Ranges Formation appears to be more than 6,000 feet thick. The lowermost unit is a basal conglomerate a foot thick, consisting of angular fragments of the underlying dolomite in a matrix of quartz sandstone and pebble-conglomerate. The underlying carbonate unit is more than 1,000 feet thick.

In northwestern Glacier Lake map-area and southwestern Wrigley Lake map-area the uppermost part of the Backbone Ranges Formation consists of a distinctive, yellow-green, and maroon weathering assemblage of thin-bedded siltstones, variably calcareous, nodular, and concretionary, ranging from an aggregate thickness of 50 to more than 350 feet. These beds locally contain abundant worm trails (*see* Section 14, pt. II). The underlying sandstones are commonly hematitic. Thin interbeds of quartz-pebble conglomerate locally contain well-rounded pebbles of quartz as much as 2 cm in diameter.

An eastward thinning involving each member of the Backbone Ranges Formation is clearly shown in Glacier and Wrigley Lakes map-areas. North of the peak (elevation 7,799 feet) on eastern Redstone Plateau north of Redstone River, thicknesses of the lower, middle, and upper members are about 900, 170, and 760 feet respectively. Ten miles northwest of Dal Lake the Backbone Ranges Formation comprises only 180 feet of clastic rocks.

The Backbone Ranges Formation is structurally conformable with underlying and overlying rocks but the upper contact with Middle Cambrian strata appears to be a regional disconformity. East of Plateau Fault Hadrynian rocks appear to be bevelled easterly by an unconformity at the base of Lower Cambrian strata.

Sekwi Formation

Varicoloured carbonate and clastic rocks of the Sekwi Formation (Handfield, 1968) outcrop in South Nahanni Anticline and in a possible continuation of this structure offset along Broken Skull Fault immediately southeast of South Nahanni River. Although the formation overlies clastic rocks of the Backbone Ranges Formation, in this locality it seems probable that the Sekwi Formation is at least in part correlative with the upper part of the Backbone Ranges Formation as exposed farther east (*see* discussion under correlation below). Lower Cambrian rocks near the headwaters of Rabbitkettle River are included in the Sekwi Formation, although the assemblage there has some unusual features. A thin carbonate member overlying strata of the Backbone Ranges Formation in southwesternmost Wrigley Lake map-area is also assigned to the Sekwi Formation, as are Lower Cambrian carbonates in south-central Flat River map-area.

The Sekwi Formation probably includes the greatest variety of rock types of any map-unit in the report area and this is reflected in a spectacular range of weathering colours that are characteristic of the formation. About 1,300 feet of strata is present in South Nahanni Anticline (*see* Section 15, Pt. II). An angular unconformity at the base of Upper Cambrian (Franconian) strata truncates Lower Cambrian rocks to the southeast but does not appear to have removed a significant thickness of beds where the section was measured. Similar thicknesses of Sekwi Formation are preserved farther northwest where the unit is unaffected by the unconformity.

A basal member of the formation, more than 100 feet thick, comprises fine-grained, thin-bedded, buff and brown weathering, calcareous siltstone with pods of grey, fine-grained limestone. The limestone pods, ranging from about half an inch to 2 inches thick and 2 inches to 2 feet long, impart a mottled appearance to the rocks. Recessive weathering of the limestone produces a distinctive 'Swiss-cheese' structure. The relative amounts of limestone and siltstone vary considerably but generally the siltstone is more abundant.

Rocks overlying the basal 'Swiss-cheese' limestone member occur in units from about 14 feet to more than 200 feet thick. They include several members of thin-bedded, locally laminated, purple, yellow-green, and brown weathering greenish grey siltstones, variably sandy and dolomitic; fine-grained, medium grey weathering dolostones and sandy dolostones, weathering shades of orange and grey; one relatively thick member of fine-grained, brown to grey weathering limestone; and several thin units of medium-grained, purple weathering sandstone. The formation is well bedded throughout.

In southwesternmost Wrigley Lake map-area, 20 feet of grey and buff, mottled, grey, yellowish grey, and orange-grey weathering, very fine grained limestone is underlain by about 90 feet of reddish brown to brown weathering, slightly platy, light brownish grey, cryptograined dolostone. This carbonate assemblage overlies rocks of the Backbone Ranges Formation with apparent conformity. From fossil evidence (*see* discussion on age and correlation) a disconformity at the top of the carbonates is indicated.

Southwest of the headwaters of Rabbitkettle River a 'Swiss-cheese' limestone unit, about 200 feet thick and similar to that described above for the section in South Nahanni Anticline, is the basal member of the Sekwi Formation. This unit is overlain by a sequence of blue-grey, fine-grained limestone, and coarsely crystalline limestone, also about 200 feet thick. Overlying these rocks is a sequence of sandstone, buff weathering sandy and silty dolomite, dolomite, argillite, minor quartzite and impure limestone 2,000 feet thick. Basic volcanic flows and tuffaceous rocks are in the upper part of this unit.

Underlying the orange weathering Brintnell Formation north of Rabbitkettle River is a distinctive assemblage of green and maroon weathering rocks and chlorite schist, at least 200 feet thick, which in turn overlies fine-grained clastic rocks of the 'Phyllite Unit'. The uppermost part of the volcanic sequence consists of slightly schistose, green-grey weathering, aphanitic rocks with abundant veins of orange weathering carbonate as much as an inch wide. About 15 feet below the top is a layer of spectacular agglomerate consisting of angular to well-rounded fragments of green and maroon aphanitic and porphyritic volcanic rock and considerable limestone—in part silty, from an inch to 6 inches in diameter—in an aphanitic, maroon weathering matrix. One flow, between 5 and 6 feet thick, has a highly vesicular top and displays structures resembling pillows.

Pebbles and cobbles of fine-grained dolomite and limestone commonly have rims of fine-grained, reddish weathering rock from an eighth to a quarter of an inch wide. Many are enclosed in coarse-grained, white calcite.

Very tough, maroon weathering, laminated and well-banded waterlain tuff is fairly abundant. These rocks show graded bedding with beds as much as a foot thick containing fragments of pebble size at the base and thin bands, a quarter to half an inch thick, of dark maroon, very fine grained material toward the top.

Under the microscope the volcanics display a high degree of alteration resulting in an abundance of carbonate, sericite, and chlorite. Iron ore masks other minerals in many volcanic fragments but some display a faint diabasic texture. Blocky, green, fine-grained vesicular volcanic flows and breccias more than 400 feet thick underlie between 50 to 100 feet of orange-buff weathering sandy dolomite west of Caribou River in southernmost Flat River map-area. These rocks are possibly correlative with Lower Cambrian strata in the Ragged Range and are assigned to the Sekwi Formation.

Brintnell Member. A brilliant orange and yellow weathering assemblage of interbedded grey limestone and silty and sandy dolomite about 200 feet thick outcrops on the limbs of an anticlinal structure north of Rabbitkettle River. The unit is named the Brintnell Member with the type section south of Brintnell Creek 2 miles west of Mount Ida.

The silty dolomites, forming units from 5 to 7 feet thick, display well-developed laminations. Near the top of the unit limestone beds contain bands, lenses, and chips of orange-buff weathering silty dolomite. Except for the uppermost beds dolomite is more abundant than limestone.

The rocks described above are probably correlative with similar strata exposed southwest of Rabbitkettle River. There, a bright yellow and orange weathering silty and sandy dolomite unit, 150 feet thick, overlies strata of the Sekwi Formation. These rocks in turn are overlain by about 1,000 feet of buff weathering partly silty and sandy dolomite, and minor sandstone and shale also included in the Sekwi Formation. South of Brintnell Creek, however, the Brintnell Member appears to be directly overlain by strata of the Rabbitkettle Formation.

Neither the Brintnell Member nor the overlying sandy dolomites southwest of Rabbitkettle River have yielded fossils.

Cambrian Rocks Southwest of Flat River

Lower Cambrian strata undergo a marked facies change southwesterly across Flat River valley so that the conspicuous orange and buff weathering sandy dolomites are replaced by dark brown-grey to black, in part pyritic, calcareous argillite, slate, and shale. Locally, minor thin-bedded argillaceous limestone within the fine-grained sequence, contains archaeocyathids. These rocks are probably in part equivalent to rocks included elsewhere in the upper part of the 'Phyllite Unit.'

A succession of well-bedded, rusty, highly fractured argillite and siltstone in beds ranging from an inch to a foot is exposed in the canyon of Coal River. Minor blocky, black, medium-grained limestone is also present. These rocks are non-calcareous and contain abundant concretions, in places as much as 2 feet in diameter. Chert nodules were noted in one locality. Pyrite is abundant and melanterite stain is ubiquitous. This assemblage, although included with the Lower Cambrian argillite unit, has yielded no fossils and the strata could be as young as Devono-Mississippian.

Age and Correlation of Lower Cambrian Rocks

The following fossil collections were made from Lower Cambrian rocks in the report area and identified by W. H. Fritz of the Geological Survey.

Section 19. Southwestern Wrigley Lake map-area; 63°10′N, 127°53′W.

95–97 feet above top of Backbone Ranges Formation. GSC loc. 68983

Fremontia sp.
Onchocephalus sp.
Paedeumias sp.

W. H. Fritz commented that this fauna is assigned to the Upper *Olenellus* Zone and is typical of what is found near, but not at the top, of a normal Lower Cambrian sequence.

Section 15. West limb of South Nahanni Anticline; 62°19′N, 127°52′W.

220 feet above base of Sekwi Formation. GSC loc. 68948

Olenellus sp.
Paedeumias sp.
Olenellid with advanced genal spines

540 feet above base		GSC loc. 68947
	Wanneria? sp.	
685 feet above base		GSC loc. 68949
	Olenellus sp.	
0–100 feet above base		GSC loc. 68970
	Olenellus sp. archeocyathids	

W. H. Fritz commented that these faunas indicate a late Lower Cambrian age.

Section 14. Southwestern Wrigley Lake map-area; 63°11'N, 127°11'W.

110 feet below top of Backbone Ranges Formation		GSC loc. 68964
	Fremontella? sp. *Olenellus* sp.	
350 feet below top		GSC loc. 68967
	Olenellus? sp.	

According to W. H. Fritz these faunas indicate a late Lower Cambrian age.

A suggested correlation of Lower Cambrian strata in the report area is presented in Figure 7. Information on the rocks southwest of Rabbitkettle River is taken from S. L. Blusson's detailed studies in northeasternmost Frances Lake map-area. Because of a lack of faunal control the base of the Cambrian is arbitrarily taken as the base of the Backbone Ranges Formation. Strictly, however, basal beds of the Backbone Formation are probably diachronous although almost certainly not so much as the basal carbonates of the Sekwi Formation.

Figure 5 illustrates the distribution of Lower Cambrian facies in the report area and adjacent regions. In general, three main belts of facies can be recognized and their distribution indicates an easterly source for the clastic sediments—a situation that appears applicable to Lower Cambrian deposition the entire length of the Cordillera (Kay, 1951). Limited data on crossbedding and ripple-marks obtained from the type section north of Avalanche Lake are plotted on Figure 6 and the results agree with the concept of an easterly source area.

Middle Cambrian

Middle Cambrian strata form an important part of the lower Paleozoic assemblage in Mackenzie and Selwyn Mountains and on Hyland Plateau. Marked facies changes have resulted in two distinct formations which are named and described in this report.

Rockslide Formation

The Rockslide Formation, the most fossiliferous of the Middle Cambrian units, is well exposed in numerous places on Redstone Plateau in southwestern Wrigley Lake map-area and in Backbone Ranges in northwesternmost Glacier Lake map-area. The type section (*see* Section 16, Pt. II) is 1½ miles north of Rockslide Pass in west-central Wrigley Lake map-area (*see* Pl. XVII).

In the type area, highly fossiliferous strata of the Rockslide Formation comprise more than 1,640 feet of recessive, platy, nodular, black to orange-buff weathering, dark grey, fine-grained, argillaceous limestone and calcareous siltstone. Characteristically the more argillaceous parts of the sequence produce a fine, sooty talus.

The oldest exposed beds of the Rockslide Formation in the type area are commonly orange weathering, laminated, greenish grey, locally pyritic, cryptograined, dolomitic siltstones that in some places contain salt casts. Judging from the recessive nature of this unit it seems probable that more than 200 feet of silty or argillaceous strata occurs near the base of the formation. Overlying the siltstones is a distinctive sequence of somewhat more resistant, buff-orange or dark grey weathering calcareous siltstones containing recessive weathering pods of limestone as much as 1 inch thick and 3 inches long. The beds are typically thin bedded and nodular and in many respects are similar to those in parts of the Rabbitkettle Formation in Ragged Range.

The middle part of the Rockslide Formation includes as much as 500 feet of calcareous siltstone, argillaceous limestone, and shale. In general the interval is recessive and only the limestone beds form resistant ledges. The rocks weather buff or sooty black.

Perhaps the best lithologic marker horizon in the assemblage is a resistant member of light grey to brown weathering sandstone about 50 feet thick at the top of the middle recessive unit. These rocks are thick bedded, fine to medium grained and blocky weathering.

The upper part of the Rockslide Formation in the type area comprises thin-bedded, platy limestones variably argillaceous and silty, and minor sandstone or sandy limestone. Some of the calcareous shales and siltstones contain numerous limestone concretions as much as 4 inches in diameter. The uppermost beds, comprising possibly as much as 200 feet of relatively resistant, dark grey limestone were not examined.

In the easternmost outcrops in Wrigley Lake map-area east of Plateau Fault the Middle Cambrian rocks are significantly different from those in the type area of the Rockslide Formation. The strata are poorly fossiliferous and correlation with the type section is tenuous except for the lower members. Recessive weathering siltstones and nodular limestones near the base weather to shades of green, brown, and maroon. These beds, about 200 feet thick, are overlain by fine-grained, thin-bedded limestones, locally oölitic, that weather to shades of brown or grey, in places mottled with wine or pink. Fine-grained, in part oölitic, dolomite is fairly abundant in the upper part of the sequence. In several aspects the Middle Cambrian strata in this region are similar to those of the Avalanche Formation described below.

In southwesternmost Wrigley Lake map-area basal beds of the Rockslide Formation are dominantly black, slightly calcareous shales at least 60 feet thick that form a recessive interval above Lower Cambrian strata. The shales are overlain by more than 200 feet of uniformly thin bedded, platy, light grey to brownish grey cryptograined to fine-grained limestones that weather grey and yellow-brown. Chert nodules are present but very minor. The uppermost 120 feet of the Middle Cambrian sequence comprises light grey weathering, very fine to medium-grained dolomite in beds ranging from 2 to 10 inches thick.

The Rockslide Formation overlies Lower Cambrian strata disconformably and is overlain unconformably by Upper Cambrian (Franconian) strata. Erosion prior to deposition of the Upper Cambrian rocks has been partly responsible for marked changes in thickness of Middle Cambrian rocks from place to place. For example, in 3 miles south–southeast of the type section the formation is reduced from more than 1,640 to 680 feet in thickness. The apparent absence of faunal zones below the *Bolaspidella* Zone in the section in southwesternmost Wrigley Lake map-area suggests structural complications, unrecognized in the field, or a depositional break within the Middle Cambrian sequence. The latter seems almost a certainty because to the west at the type locality of the Sekwi Formation, strata assigned to the *Bolaspidella* Zone lie very close to the top of the Lower Cambrian succession (W.H. Fritz, pers. com., 1968).

Avalanche Formation

In most of Glacier Lake map-area a distinctive assemblage of buff, yellow, and orange weathering rocks, at least in part of Middle Cambrian age, is herein named the Avalanche Formation. The type section is on the northeast limb of Broken Skull Anticline, 5 miles southwest of Avalanche Lake and was measured by B. S. Norford (*see* Section 20, Pt. II). Because of its conspicuous weathering colours the formation forms an excellent marker in the lower Paleozoic sequence.

The type section of the Avalanche Formation is 1,300 feet thick and comprises in decreasing order of abundance, cryptograined to fine-grained dolomites, silty dolomites, dolomitic siltstones, siltstones, and dolomitic mudstones in beds ranging from an inch to several feet thick. The dolomites are mainly thin bedded and are commonly laminated. Pisolites are abundant in grey weathering dolomites in the lower part of the section and comprise 15 per cent of some beds. Mudcracks and salt casts are common and silty laminae showing grading and crossbedding can be seen in many places. The dolomites typically weather shades of buff, yellow, orange, and green but more spectacular members, ranging in thickness from a foot to several feet, weather shades of maroon, pink, purple, and brown.

Under the microscope, samples of cryptograined dolomites with banding on a scale of 1 mm to 2 cm reveal a distinct grading. The base of each band, in sharp contact with underlying cryptograined dolomite, consists of fine-grained dolomite with floating, well-rounded to subangular grains of quartz as much as 1 mm in diameter. A gradual decrease in grain size of quartz and dolomite takes place upward in each lamina.

Silty dolomites and siltstones weather out in relief over dolomites and produce ribbed or nodular structures. Limestone nodules in a matrix of siltstone were observed only in minor amounts of the lower part of the Avalanche Formation.

In the type section the base of the formation appears to be structurally conformable with sandstones of the underlying Backbone Formation. The top is drawn, somewhat arbitrarily, at the base of the first significant influx of sand into the dolomite sequence.

A section measured 6 miles north of Avalanche Lake and assigned to the Avalanche Formation is about 700 feet thick (*see* Section 21, Pt. II). Northwest from the locality of Section 21 to about latitude 62°48′N a basal unit of well-bedded, dark grey weathering crystalline dolomite is at least 250 feet thick. This unit, underlying the typical buff-cream and maroon weathering Middle Cambrian rocks, is strongly oölitic in the lower part and pisolitic in the upper part. Highly coloured rocks above the grey dolomites are spectacularly banded and contain maroon beds 1 inch to 2 feet thick.

Buff and orange weathering dolomites in Rouge Range may include Middle Cambrian rocks, but stratigraphic evidence favours a Late Cambrian age.

Age and Correlation of Middle Cambrian Rocks

Fossils collected from the type section of the Rockslide Formation in west-central Wrigley Lake map-area were identified by W.H. Fritz of the Geological Survey and are listed below:

Section 16. West-central Wrigley Lake map-area; 63°21′N, 127°32′W; east-facing ridge, 1½ miles north of Rockslide Pass. Measurements on far left indicate feet (stratigraphic) above base of Rockslide Formation.

Bathyuriscus–Elrathina Zone

1,685–1,725 GSC loc. 68925

Alokistocarella? sp.
Bathyuriscus cf. *B. rotundatus* (*Rominger*)
Elrathina cordillerae (Rominger)
Micromitra sp.
Prototreta sp.
Ptychagnostus cf. *P. burgessensis* (Rasetti)

1,380–1,405 GSC loc. 68924

Ehmaniella waptaensis Rasetti
Elrathina brevifrons Rasetti
Pagetia bootes Walcott
Peronopsis cf. *P. montis* (Matthew)
Protospongia sp.
Pytchagnostus sp.
Spencia? sp.

1,325–1,335 GSC loc. 68923

Corynexochides sp.
cf. *Chancia odarayensis* Rasetti
Olenoides? sp.
Olenoides cf. *O. serratus* (Rominger)
Pagetia sp.
Pagetia bootes Walcott
Peronopsis montis (Matthew)
Ptychagnostus? sp.
Zacanthoides sp.
Zacanthoides divergens? Rasetti

1,125–1,205 GSC loc. 68922

Chancia ordarayensis Rasetti
Ehmaniella sp.
Elrathina parallela Rasetti
Hyolithes sp.
Oryctocephalus sp.
Pagetia bootes? Walcott
Peronopsis columbiensis Rasetti
Tonkinella sp.

1,105 GSC loc. 68921

Bathyuriscus? sp.
Elrathina? sp.
cf. *Elrathina brevifrons* Rasetti
Hyolithes sp.
Kootenia? sp.
Oryctocephalus sp.
Pagetia sp.
Peronopsis sp.
Peronopsis montis (Matthew)

Bathyuriscus–Elrathina Zone

——— ? ——— ——— ? ——— ? ———

Glossopleura Zone

1,075 GSC loc. 68920

Kistocare? sp.
Pagetia fossula? Resser
Peronopsis sp.
Spencia sp.
Tonkinella? sp. (cranidium only)

930 GSC loc. 68919

Caborcella sp.
Pagetia fossula Resser
Pagetia aff. *P. resseri* Kobayashi
Spencia idahoensis Resser

915–916 GSC loc. 68918

Amecephalus sp.
Athabaskia sp.
Diraphora? sp.
Ehmania? sp.
Kootenia sp.
Polypleuraspis sp.

830–850 GSC loc. 68917

Amecephalus sp.
Glossopleura sp.
Spencia sp.

Glossopleura Zone

Albertella Zone

630–645 GSC loc. 68916

Albertella? sp. (cranidium only)
Lingulella sp.
Pagetia clytia? Walcott
Spencia sp.

545 GSC loc. 68914

Kootenia sp.
Pagetia clytia? Walcott
Peronopsis lautus? (Resser)
Spencia sp.

Albertella Zone

Plagiura–Poliella Zone

471–480 GSC loc. 68913

dolichometopid?
Spencia sp.
Syspacephalus laticeps Rasetti
Wenkchemnia sp. (cranidium only)

340 GSC loc. 68912

Ehmaniella? sp.
Fieldaspis aff. *F. furcata* Rasetti
Spencia sp.

330 GSC loc. 68911

Amecephalus sp.
Fieldaspis aff. *F. furcata* Rasetti

314 GSC loc. 68910

Fieldaspis aff. *F. furcata* Rasetti
Kochiella? sp.
Prototreta sp.
Spencia sp.

The following comments were made by W. H. Fritz:

The boundary between the *Bathyuriscus–Elrathina* and *Glossopleura* Zones is tentatively placed between localities 68921 and 68920. The upper locality, 68921, contains a faunule similar to that which Rasetti (1951) has placed in the *Bathyuriscus–Elrathina* Zone of the Canadian Southern Rockies. The lower locality, 68920, contains one form which may belong to the genus *Kistocare*. This genus is known only from the *Glossopleura* Zone. *Pagetia fossula*? in the latter collection resemble a species that is associated with a *Glossopleura* faunule in the Lakeville Limestone, Idaho.

The boundary between the *Glossopleura* and *Albertella* Zones is fairly well documented with *Glossopleura* in the locality above (68917) and a questionable *Albertella* cranidium and *Pagetia clytia*? below (68916).

The boundary between the *Albertella* and *Plagiura–Poliella* Zones is also fairly well established as the upper collection (68914) contains *Pagetia clytia*? and *Peronopis lautus*? known from an *Albertella* faunule from the Langstone Formation, Idaho. Below this boundary (68913) is a typical *Plagiura–Poliella* Zone faunule.

The uppermost beds of the Rockslide Formation in the type section were not examined and it is possible that at least part of the Middle Cambrian *Bolaspidella* Zone is present.

Section 17. West-central Wrigley Lake map-area; 63°21′N, 127°37′W; south-facing ridge on north side of Rockslide Pass. Measurements on far left indicate feet (stratigraphic) below top of Rockslide Formation.

90 GSC loc. 69828

Alokistocare sp.
Corynexochides? sp.
Ehmaniella sp.
Lingulella sp.
cf. *Pachyaspis* sp.
Peronopsis sp.
Ptychagnostus sp.

225 GSC loc. 68927

Bathyuriscus rotundatus (Rominger)
Kootenia sp.
Elrathina sp.
Peronopsis sp.
Ptychagnostus cf. *P. burgessensis*? (Rasetti)
Zacanthoides sp.

265 GSC loc. 68926

Elrathina sp.
Pagetia sp. (cranidium only)
Peronopsis sp.

W. H. Fritz commented that the three collections listed above probably belong to the *Bathyuriscus–Elrathina* Zone. He further stated that the presence of *Bathyuriscus rotundatus*, *Ptychagnostus* cf. *P. burgessensis*, and a species of *Elrathina* with a broad cranidium and short preglabellar field suggests a rather low position within this zone.

It should be noted that the uppermost beds exposed below the base of the Broken Skull Formation in Section 17 are probably several hundred feet stratigraphically below the uppermost beds of the Rockslide Formation exposed in Section 16 (*see* Pl. XVII).

Section 18. 63°11′N, 127°13′W; on ridge south of small lake 6 miles north of Redstone River. Measurements on far left indicate feet (stratigraphic) above base of Rockslide Formation.

230 GSC loc. 68966

Syspacephalus? sp.

140 GSC loc. 68965

Caborcella? sp.
Micromitra sp.
Syspacephalus? sp.

W. H. Fritz commented that the above faunas are probably of early Middle Cambrian age.

A section measured about 18 miles southwest of the type section of the Rockslide Formation yielded the following faunas identified by W. H. Fritz of the Geological Survey:

Section 19. 63°10′N, 127°53′W; east-trending ridge. Measurements on far left indicate feet (stratigraphic) above base of Rockslide Formation.

583–585 GSC loc. 68999

Helcionella sp.
Hemirhodon sp.
Homagnostus? sp.
Hypagnostus? sp.
Lingulella sp.
Modocia sp.

410 GSC loc. 69008

Bolaspidella ? sp. (free cheek only)
Lingulella? sp.
Modocia sp.

365 GSC loc. 69007

Baltagnostus sp.
Hemirhodon sp.
Hypagnostus sp.
Ptychagnostus sp.
Prototreta sp.
Modocia? sp.

285 GSC loc. 69006

Modocia? sp.

265 GSC loc. 69005

Eldoradia? sp.
Hypagnostus sp.
Modocia sp.
Ptychagnostus? sp.

235 GSC loc. 69004

Hypagnostus sp.
Elrathia? sp.
Lingulella sp.
Modocia sp.

2–5 GSC loc. 68992

Caborcella sp.
Chancia sp.
cf. *Kochiella* sp.
Ogygopsis spinulosa Rasetti
Hyolithes sp.
Olenoides sp.
Oryctocephalus sp.
Pachyaspis? sp.
Pagetia clytia Walcott
Pagetia resseri Kobayashi
Prototreta sp.
Syspacephalus? *tardus* Rasetti
Yohoaspis sp.
Zacanthoides sexdentalus Rasetti

W. H. Fritz reported on the fauna listed above as follows:

> Locality 68992 contains elements of what Rasetti (1951, p. 96) has described as the *Yohoaspis pachycephala* and *Chancia bigranulosa* faunules. These faunules were tentatively assigned by him to the *Albertella* Zone. Also in locality 68992 are two species of *Pagetia*, *P. clytia* and *P. resseri*, which are known from the '*Ptarmigania*' faunule of Northern Utah and Southern Idaho. This faunule belongs to the late *Albertella* Zone. In summary, this locality probably belongs to the late *Albertella* Zone, and its location of less than 50 feet above Lower Cambrian locality 68983, suggests the presence of either a fault or an unconformity between the two collections.

The remaining localities (69004–69009) contain approximately the same fauna which can be assigned to the late Middle Cambrian *Bolaspidella* Zone.

The fossils listed below were collected from the Rockslide Formation north of Redstone River.

63°15′N, 127°02′W GSC loc. 58859

inarticulate and articulate brachiopods
Fieldaspis sp.
Fieldaspis? *nahanniensis* Norford

Plagiura–Poliella fauna
(identified by B. S. Norford)

63°11′N, 127°13′W GSC loc. 58701

brachiopod
? *Parapoulsenia* sp.

probably *Plagiura–Poliella* fauna
(identified by B. S. Norford)

Section 20. Northeast limb of Broken Skull Anticline; 62°21′N, 127°20′W.
35–50 feet above base of Avalanche Formation. GSC loc. 58467

inarticulate and orthid brachiopods
Fieldaspis cf. *F. superba* Rasetti
Fieldaspis? *nahanniensis* Norford
Inglefieldia sp.
Kochiella mackenziensis Norford

Plagiura–Poliella fauna
(collected by and identified by B. S. Norford)

Section 21. Seven miles north–northwest of Avalanche Lake; 62°32′N, 127°10′W.

Basal beds of Avalanche Formation. GSC loc. 68946

cf. *Amecephalus* sp.
cf. *Albertella* sp. or *Fieldaspis* sp.
Micromitra sp.

Probably all the collections listed above represent part of the Early Middle Cambrian *Plagiura–Poliella* Zone, the lowest Middle Cambrian zone recognized in western North America by Lochman-Balk and Wilson (Norford, 1968).

From the data presented above it is evident that the basal units of the Rockslide and Avalanche Formations are essentially correlative. Correlation of the higher strata is tenuous, however, because faunal control is lacking in the upper Avalanche Formation. In the type area of the Rockslide Formation the Middle Cambrian rocks are apparently overlain unconformably by Upper Cambrian (Franconian) strata that are conspicuously sandy near the base. On this basis significantly sandy strata near Avalanche Lake are assigned to the Upper Cambrian and Lower Ordovician Broken Skull Formation and the underlying beds are assigned to the Avalanche Formation.

Disappearance of the Rockslide Formation to the south in northwestern Glacier Lake map-area may reflect a combination of facies changes and of pre-Franconian erosion, but the former is probably most important.

Middle Cambrian strata seem to be absent in Cassiar, Pelly, and parts of northern Rocky Mountains (north of Peace River), and in many parts of Mackenzie Mountains. Because of this the sub-Franconian unconformity is probably of major importance.

Upper Cambrian and Lower Ordovician

A thick sequence of dominantly carbonate strata of late Cambrian and early Ordovician age is exposed in western Mackenzie Mountains. Distinctive units within the assemblage can be mapped without difficulty in certain areas and eventually with detailed investigations they will probably attain formational status. Correlation problems resulting from facies changes and accompanying colour changes preclude a useful division of these strata at this time, however, and the individual units are treated as informal members of one formation named the Broken Skull Formation. In Ragged Range and to the south in Flat River map-area a poorly dated, very thick sequence of silty limestones named the Rabbitkettle Formation probably represents correlative rocks.

Broken Skull Formation

A thick sequence of well-bedded, dominantly carbonate strata that occupy the interval between the underlying Rockslide and Avalanche Formations and the overlying Sunblood Formation is named the Broken Skull Formation. The type section is 4 miles southwest of Avalanche Lake and was measured by B. S. Norford (*see* Section 20, Pt. II).

In the type area of the Broken Skull Formation the rocks are about 2,700 feet thick and include a lower member of buff, orange, yellow, brown and grey weathering dolomites and limestones, variably sandy, and an upper unit of dominantly grey and yellow-grey weathering dolomites and limestones. The lower unit, as much as 900 feet thick, weathers to colours similar to those of the underlying Avalanche Formation and separation of the formations is possible only on the outcrop.

Basal beds of the Broken Skull Formation are sandy dolomitic mudstones and dolomites commonly displaying mudcracks and crossbedding and locally containing fairly abundant pyrite crystals more than an inch long. Overlying strata range from thin bedded to thick bedded and are characterized by varying amounts of well-rounded silt, sand, and fine pebbles. The dolomites are well laminated in places and pisolitic beds occur here and there.

The upper unit, about 1,800 feet thick, includes laminated, crossbedded, and commonly flaggy or platy dolomites and limestones. Many of the carbonates have wispy, brownish and yellowish weathering silty partings. A thick grey weathering limestone member consists of fine-grained to cryptograined, grey limestone, variably argillaceous and dolomitic, in beds a quarter of a foot to 4 feet thick. Dolomites and limestones intergrade laterally and thicknesses of these units vary considerably from place to place. The youngest strata are strongly pisolitic, and in the uppermost 600 feet of the sequence dolomites may contain from 10 to 90 per cent of concentric pisolites ranging from a quarter of an inch to $1\frac{1}{2}$ inches in diameter.

The Broken Skull Formation 6 miles north of Avalanche Lake (*see* Sections 21 and 22, Pt. II) includes more dolomite than in the type area, but as noted the dolomite to limestone ratio varies considerably and direct correlation of carbonate units from one section to another is difficult. The total thickness of this sequence of more than 2,600 feet, however, is similar to that measured in Broken Skull Anticline. North of Avalanche Lake also, the uppermost unit, more than 500 feet thick, is abundantly pisolitic.

In the two areas described above, the basal sandy beds of the Broken Skull Formation can be separated from the underlying rocks of the Avalanche Formation only by close examination on the ground. In northwesternmost Glacier Lake and southwestern Wrigley Lake map-areas, however, a sharp contrast in colour and resistance between rocks of the Broken Skull Formation and the underlying Rockslide Formation can be readily observed on air photographs and from a distance in the field (*see* Pl. XVII). Throughout this region the lower part of the Broken Skull Formation comprises two distinct members—a lower, silvery grey weathering sequence of sandstone and sandy dolomites, more than 500 feet thick, and an upper, orange-buff weathering sequence of dolomites, several hundred feet thick. The boundary between the top of the upper member and the overlying carbonates is somewhat arbitrary and is drawn at the top of the distinctly orange weathering strata. The overlying strata, correlative with the upper part of the Broken Skull Formation in the type area, have not been separated from the younger Sunblood Formation, because in southwestern Wrigley Lake map-area the basal member of the Sunblood Formation, so distinctive elsewhere, has not been recognized.

West of Natla Fault, basal, silver-grey weathering beds of the Broken Skull Formation include from 150 feet to 300+ feet of blocky, vitreous, pure quartz sandstone and dolomitic sandstones in which quartz grains range from a half to a millimetre (*see* Section 19, Pt. II). These rocks grade upward into sandy dolomites that are also blocky and grey weathering. The aggregate thickness of the silver-grey weathering member in this region is about 500 feet.

About 2,500 feet of carbonate strata overlies the sandy lower member. A yellow to orange weathering unit, 50 feet thick, comprising fine-grained to cryptograined laminated dolomite, variably stylolitic occurs at the base of the upper member. This assemblage is overlain by approximately 600 feet of grey and buff, purplish red, and yellow-brown weathering, dark grey to black, cryptograined limestone in beds ranging from half an inch to 6 inches. These rocks are characterized by wavy parting planes which in places produce a platy talus. Stylolites and laminations are present locally.

Dolomites and limestones in the upper part of the assemblage are mainly grey weathering, fine- to medium-grained rocks. Chert nodules are present in some beds and wavy, silty or argillaceous laminae are common.

East and northeast of Natla Fault the lower member of the Broken Skull Formation is a distinct, silvery grey weathering unit more than 600 feet thick. The strata are medium- to thick-bedded and massive dolomites, with a high sand content in the lower part and variable sand content in higher beds.

Several hundred feet of orange weathering, medium- to thick-bedded dolomites overlying the sandy beds has been mapped in the area northeast of Natla Fault. This sequence grades upward into grey weathering, well-bedded dolomites and limestones that include strata of the Sunblood Formation in the upper part.

Thin sections from representative samples of basal sandy rocks of the Broken Skull Formation consistently show very well rounded quartz grains set in a homogeneous fine- to medium-grained matrix. These average perhaps 1 mm in diameter but range from 0.5 to 2 mm. One thin section of a sample collected southwest of Natla Fault includes very minor microcline. Some specimens from north of Avalanche Lake contain, in addition to floating grains of quartz, fragments of very fine grained silty dolomite presumably derived from the underlying Avalanche Formation.

Only the lower part of the Broken Skull Formation was examined in South Nahanni Anticline. There, the assemblage overlies Lower Cambrian rocks with marked, angular unconformity (*see* Pl. XVIII). A very conspicuous, maroon weathering basal unit about 85 feet thick consists of thin-bedded, sandy siltstone containing many worm trails. These rocks are overlain by medium- to thick-bedded, orange weathering dolomites that in turn grade upward into grey weathering dolomites.

Immediately northeast of South Nahanni River a completely exposed section of the Broken Skull Formation is 1,640 feet thick (*see* Section 24, Pt. II).

Generally, in northeastern and eastern Wrigley Lake map-area a succession of dominantly buff-orange weathering dolomites less than 1,000 feet thick overlies strata of the Tigonankweine Formation and underlies strata of the Whittaker Formation. No fossils were found in these rocks and hence their age assignment is provisional. According to R. Macqueen (pers. com., 1970) the rhythmically bedded and well-banded dolomites and limestones underlying the Whittaker Formation northeast of Wrigley Lake are correlative with similar rocks that contain a Late Cambrian fauna to the north near Keele River in Carcajou Canyon map-area. Unfortunately, this sequence is atypical of the sub-Whittaker rocks described below and either it changes facies to the west and southwest or, more probably, it is truncated by the sub-Whittaker unconformity.

Buff and buff-orange weathering dolomites, commonly fine to medium grained are 740 feet thick on the southwest side of Tigonankweine Range where they overlie strata possibly correlative with the lower member of the Little Dal Formation. Northeast of Tigonankweine Range and northwest of Wrigley Lake, however, buff weathering dolomites with minor red and green shale in two sections 500 and 620 feet thick, respectively, rest directly on rocks of the Tigonankweine Formation.

Orange and buff weathering beds overlying the Tigonankweine Formation east of Redstone River are crumbly, recessive, slaty, laminated, greenish grey shales and are overlain by a thicker unit of well-bedded, laminated, orange, brown, and buff weathering dolomites, grey limestones, and calcareous slaty siltstones.

In Rouge Range, strata more than 700 feet thick overlie quartzites of the Tigonankweine Formation and these are unconformably overlain by dolomites of the Whittaker Formation. The lower recessive beds, more than 200 feet thick, consist of orange and brown weathering shaly dolomites, variably sandy, interbedded with red and green dolomitic shales. Small cubes of pyrite are not uncommon in the dolomites. The upper 500 feet of strata is fine grained, orange and grey weathering, thin- to medium-bedded dolomites, variably sandy. Salt casts are present locally.

North of North Nahanni River in southern Thundercloud Range a sequence of buff and orange weathering dolomites and sandstones overlies the Rapitan Group and is unconformably overlain by the Whittaker Formation. The lowest member of this sequence, about 150 feet thick, comprises buff and orange weathering creamy crystalline dolomite with beds of reddish weathering, hematitic sandstone and dolomitic sandstone. The clastic rocks display crossbedding and locally contain salt casts. Beds range from 3 inches to 2 feet thick. A middle member comprises cryptograined dolomites, about 150 feet thick, that weather pale buff and grey and reveal pastel shades of wine and cream on fresh surfaces. The upper member consists of a basal unit, about 50 feet thick, of blocky, vitreous, clean, fine-grained sandstone in beds 1 foot to 4 feet thick, overlain by 40 feet of orange-buff weathering interbedded sandstones and dolomites.

Rabbitkettle Formation

A thick sequence of grey weathering, well-bedded to massive, silty limestones and calcareous siltstones overlies Lower and (?) Middle Cambrian rocks in southwesternmost Glacier Lake map-area and in Flat River map-area. The sequence is named the Rabbitkettle Formation with a type area near the headwaters of Rabbitkettle River. Because of its great thickness and monotonous uniformity no single section of the entire formation has been measured. Partial sections of lower and middle parts of the assemblage have been measured southwest of the headwaters of Rabbitkettle River and southwest of Flat River (*see* Blusson, 1968a).

The Rabbitkettle Formation, more than 4,000 feet thick in the type area, comprises a relatively uniform sequence of interbedded limestones, silty limestones, and siltstones. Limestones in beds a few inches to more than 10 feet thick are generally fine grained and variably silty or dolomitic. Silty limestones, yielding as much as 40 per cent argillaceous silt and coarse silt in acid residues, are characterized by a wavy banding of silty layers. In places a typical 'Swiss-cheese' texture results from the weathering of limestone pods in a more resistant anastomosing network of silty beds. Siltstones are variably dolomitic and argillaceous and commonly weather brownish grey. In some places they are finely laminated. In south-central Flat River map-area silty beds a few inches thick display excellent graded bedding (*see* Pl. XIX, XX).

An upper member included in the Rabbitkettle Formation is exposed locally southwest of the headwaters of Rabbitkettle River and along the river east of Hole in the Wall Batholith. In the former locality the unit consists of more than 1,000 feet of finely laminated, dark grey to black, argillaceous limestone and calcareous shale. East of Hole in the Wall Batholith grey, slaty, argillaceous limestone and buff, calcareous slate, as much as 300 feet thick, occupy a similar stratigraphic position.

The Rabbitkettle Formation is bounded by unconformities, the basal one being markedly angular. Thus in places southwest of Flat River the assemblage lies on rocks as old as those of the 'Grit Unit' and distinctly angular relations can be observed in several localities (*see* Pl. XXI). A strong unconformity is also present beneath overlying graptolitic shales near Flat River. This unconformity cuts out the upper argillaceous member southwest of Rabbitkettle River.

Age and correlation of Broken Skull and Rabbitkettle Formations.

Section 21. Seven miles north–northwest of Avalanche Lake; 62°31′N, 127°17′W.

295 feet above base of formation. GSC loc. 68945

Dunderbergia? sp.
Elburgia sp.
Irvingella sp.

These fossils were examined by W. H. Fritz of the Geological Survey who stated that they represent the Upper Cambrian *Elvinia* Zone. He commented further that, "Strata bearing this collection are equivalent to either the upper portion of the Lyell Formation or the lower Bison Creek Formation in S.E. British Columbia and S.W. Alberta. There the *Elvinia* Zone straddles the Lyell–Bison Creek contact."

Fossils collected from the type section of the Broken Skull Formation southwest of Avalanche Lake were examined by B. S. Norford of the Geological Survey who made the following determinations and comments:

Section 20. 62°21′N, 127°20′W.

608–612 feet above base of formation GSC loc. 65468

echinoderm columnals
orthid brachiopod
? *Briscoia* sp.
Ptychaspis sp.
? *Saukiella* sp.

Age: Late Cambrian, Late Franconian
Ptychaspis–Prosaukia fauna

Trilobite and brachiopod fragments collected higher in the section indicate a probable Early Ordovician age according to Norford.

1,485 feet above base of formation GSC loc. 69096

lingulid and orthid brachiopods
Kainella sp.
Leiostegium sp.

Age: Early Ordovician, Early Canadian, Zone D

Same footage as 69096 GSC loc. 69094

lingulid brachiopod
? *Nanorthis* sp.
Kainella sp.
Leiostegium sp.
? *Parapilekia* sp.
agnostid trilobite
undetermined trilobites

Same age as for 69096 above

1,499 feet above base of formation GSC loc. 69095

straight cephalopod
gastropod
orthid and lingulid brachiopods
undetermined trilobites
Leiostegium sp.
? *Protopliomerops* sp.

Age: Early Ordovician, Canadian, probably Zones D to G1

Section 19. Near peak, elevation 7,257 feet, in southwest Wrigley Lake map-area.

655 feet above base of formation GSC loc. 69039

Elkia? sp.
Idahoia? sp.
Macelloura? sp.
Prosaukia sp.

W. H. Fritz of the Geological Survey tentatively placed this fauna in the *Ptychaspis–Prosaukia* Zone of Late Cambrian (Late Franconian) age.

695 feet above base of formation GSC loc. 69000

Angulotreta sp.
aff. *Asaphopsis* sp.
Finkelburgia sp.
Homagnostus sp.
Hungaia? sp.
Lingulella sp.
Macelloura sp.
Richardsonella sp.
Tostonia sp.

990 feet above base of formation GSC locs. 69040, 69002

Finkelburgia sp.
Briscoia sp.
Pseudagnostus sp.
Idiomesus sp.
Lingulella sp.

W. H. Fritz commented that the collections listed above belong to the Upper Cambrian (Trempealeauan) *Saukia* zone.

The following Early Ordovician faunas from the same section were identified by B. S. Norford:

2,145 feet above base of formation GSC loc. 69027

?*Kayseraspis* or ? *Trigonocera* sp.

Age: Probably Late or Middle Canadian

2,750 feet above base of formation GSC loc. 69045

echinoderm fragments
Diparelasma sp.
Hesperonomia sp.

Age: Late Canadian

Section 17. North of Rockslide Pass, west-central Wrigley Lake map-area.

1,735 feet above base of formation GSC loc. 68929

Billingsella sp.
Eoorthis sp.
Dokimocephalus? sp.

W. H. Fritz stated that the fossils listed above are of Late Cambrian age and probably belong to the *Elvinia* Zone.

The following collection examined by W. H. Fritz was obtained from the lowest fossiliferous beds of the Broken Skull Formation so far recognized in the report area.

Section 15. South Nahanni Anticline, 62°19′N, 127°52′W. GSC loc. 68950

Conaspis sp.
Sinuella? sp.

Upper Cambrian, Franconian, *Conaspis* Zone

Fossils collected from beds high in the Broken Skull Formation near the base of the overlying Sunblood Formation were examined by B. S. Norford and are listed below:

61°51′N, 126°37½′W; approximately 8 miles northwest of mouth of Flood Creek. GSC loc. 58595

gastropod
? *Apheoorthis* sp.
indeterminable trilobite
? *Neoagnostus* sp.
Kainella sp.
Leiostegium sp.

Age: Early Ordovician, late Early Canadian,
Leiostegium–Kainella fauna (Zone D)

62°13′N, 126°38′W on ridge east of standard reference section of Sunblood Formation. GSC loc. 58740

gastropod
orthid brachiopod
? *Hesperonomiella* sp.
asaphid trilobites 2 spp.
? *Carolinites* sp.
Goniotelina sp.
Pseudocybele sp.

Age: Early Ordovician, Late Canadian (Zones H to I)

Thus, fossils collected from strata of the Broken Skull Formation range from Late Cambrian (Franconian) through Early Ordovician. From the meagre evidence available it appears that in most areas the Cambrian and Ordovician parts of the formation are each more than 1,000 feet thick.

Because no fossils were found in the Rabbitkettle Formation in the report area its correlation with the Broken Skull Formation is very tenuous. Trilobites collected in northeastern Frances Lake map-area, 6 miles west of the report area, were dated as Middle or Late Cambrian (Green and Roddick, 1961). Another collection of trilobites from a locality a mile southeast of Flat Lake in southeastern Nahanni map-area was made by E. F. Roots and F. Van Houten in 1953. These fossils were examined by B. F. Howell, Jr., of Princeton University who assigned them a definite Franconian age. S. L. Blusson concluded that the strata in which the fossils were found form part of the Rabbitkettle Formation.

The distinctive Rabbitkettle Formation can be traced northwesterly almost to Pelly River in Nahanni map-area (Green and Roddick, 1961) and southerly through Coal River map-area into northern Rocky Mountains (Gabrielse, 1962a; 1962b; Gabrielse and Blusson, 1969; Taylor, 1965). The rocks appear to be generally correlative with those of the Kechika Group in northern Rocky Mountains and Cassiar Mountains (Gabrielse, 1963; Taylor, 1965).

If correlation of the Rabbitkettle and Broken Skull Formations is correct, the unconformity at their base is one of the most important within the Paleozoic succession of the northern

Canadian Cordillera. Possibly the absence of Middle Cambrian strata in many parts of Mackenzie, northern Rocky, Pelly, and Cassiar Mountains is attributable to sub-Franconian erosion.

Middle Ordovician

Sunblood Formation

The type section of the Sunblood Formation as proposed by Kingston (1951) is on Sunblood Mountain north of Virginia Falls on South Nahanni River. In the type-section area basal beds are not exposed and some doubt exists as to the upper boundary (Douglas and Norris, 1960). Therefore, a very well exposed section north of Flood Creek (*see* Section 23, Pt. II) is proposed as a standard reference section for the Sunblood Formation (*see* Pl. XXII). As defined, this section includes all Middle Ordovician strata assigned to the Sunblood Formation by Kingston but includes, in addition, strata that form a well-defined base to the unit. The top of the standard reference section is drawn at the base of the overlying Road River Formation. The base of the Sunblood Formation seems conformable everywhere with underlying strata.

Near Flood Creek and on the flanks of Broken Skull Anticline the Sunblood Formation comprises a conspicuously banded sequence of dark grey, light grey, and cream weathering dolomites, pink and grey mottled limestone, and one prominent member of orange-brown sandstone and sandy dolomite. Twelve distinct members, with an aggregate thickness of about 4,700 feet, are present near Flood Creek.

The basal member of the Sunblood Formation, approximately 835 feet thick, comprises dark grey weathering, fetid dolomite in beds averaging perhaps 2 feet thick. Within the map-areas *Receptaculites* sp. has been found only in this unit. The contact with light grey weathering, slightly recessive limestones of the Broken Skull Formation is sharp (*see* Pl. XXIII). Overlying the dark grey dolomite is a member (informally referred to as the 'Zebra Member') comprising a strikingly banded assemblage of alternating light buff-grey and dark grey weathering dolomites as much as 418 feet thick, which together with the dark grey basal member can be recognized throughout much of the region. The dolomites range from very fine grained to medium grained and some beds in the basal member contain chert nodules. One bed, 5 feet thick, near the middle part of the 'Zebra Member' contains about 15 to 20 per cent pyrite in blebs as large as 4 by 6 inches, or as pyritohedrons ranging from one sixteenth of an inch to 2 inches across.

More than 1,900 feet of platy, light grey and buff weathering, pink-mottled, cryptograined to fine-grained limestones overlies the dolomites. This slightly recessive member is characterized by a conspicuous wine colour when viewed from a distance. Several thin, resistant, dolomite units are present within the assemblage. Near the top, thin-bedded, platy limestones commonly display wavy laminations and some beds are distinctly nodular. The 'wine beds' are characterized by the presence of abundant *Maclurites* sp.

A bright orange to dark brown weathering sequence of sandy dolomite, dolomite, sandstone, and limestone about 130 feet thick overlies the 'wine beds' and forms an excellent marker within the Sunblood Formation. Underlying this member is another distinctive unit—a five-foot-thick bed of light grey to cream weathering, cryptograined grey dolomite.

The upper part of the Sunblood Formation, about 1,450 feet thick, comprises a well-banded assemblage of light grey or buff-grey and dark grey weathering, interbedded dolomites and limestones, commonly cryptograined to fine grained, and variably cherty. The uppermost beds are blue-grey limestones and platy, shaly, bioclastic limestones containing many well-preserved fossils, including graptolites in a three-dimensional state of preservation.

The Sunblood strata described above can be traced, essentially member for member, throughout the region of Broken Skull Anticline and Flood Creek. A section measured by B. S. Norford southwest of Avalanche Lake (*see* Section 20, Pt. II) is about 3,100 feet thick. There, dolomites appear to be more abundant than in the Flood Creek section.

The Sunblood Formation thins rapidly northwesterly from the headwaters of Thundercloud Creek mainly as the result of erosion of the upper members prior to deposition of the overlying Upper Ordovician and Silurian Whittaker Formation. North of Avalanche Lake the Sunblood rocks are about 1,350 feet thick whereas west of Natla Fault they appear to be less than 600 feet thick.

East of Natla Fault in southwestern Wrigley Lake map-area, several thousand feet of well-bedded, dominantly light grey weathering, interbedded limestones and dolomites include the Sunblood Formation but probably belong mainly to the upper part of the Broken Skull Formation. These rocks are generally slightly recessive weathering relative to the overlying Whittaker Formation.

Northeast of Clearwater Creek the basal dark weathering dolomite and overlying silver-grey weathering rocks of the Sunblood Formation can be recognized, although the latter sequence is less well banded than correlative rocks to the southwest. Succeeding the silver-grey beds is an orange and buff weathering sandy member probably correlative with the 'wine beds' in the Flood Creek area. These rocks include a prominent andesite or basalt flow, or locally, two flows with an aggregate thickness of as much as 150 feet.

Thick sections of the Sunblood Formation are exposed in eastern Flat River map-area but the strata are commonly flat lying or gently dipping and a complete section is difficult to obtain. Platy, buff- and wine-mottled, highly fossiliferous, dark grey, cryptograined to fine-grained limestones are particularly abundant.

The uppermost carbonate unit in Ragged Range along Rabbitkettle River comprises banded, buff and grey weathering, blocky, dark grey, cryptograined limestone about 250 feet thick. Locally these rocks display buff, pink, and wine mottling.

On South Nahanni Anticline the Sunblood Formation has not been separated from the Broken Skull Formation. To the northeast, immediately northwest of South Nahanni River the formation is at least 3,000 feet thick (*see* Sections 24, 25, Pt. II).

Age and correlation of Sunblood Formation. Fossils collected from the standard reference section of the Sunblood Formation north of Flood Creek are listed below. Except where indicated all determinations and age assignments were made by B. S. Norford.

Section 23. On ridge north of Flood Creek.

Member 1—550 feet above base of formation — GSC loc. 58741

? *Lichenaria* sp.

—800 feet above base of formation — GSC loc. 58742

straight cephalopod
gastropods
orthid and rhynchonellid brachiopods
Receptaculites sp.

Member 10—3,755 feet above base of formation — GSC loc. 58743

? *Streptelasma* sp.

−3,855 feet above base	GSC loc. 58744

bryozoan
Hesperorthis sp.
Oepikina sp.

Member 11—4,120 feet above base of formation	GSC loc. 58745

trilobite hypostoma

Member 12—4,270 feet above base of formation	GSC loc. 58746

bryozoans
tabulate coral
? *Streptelasma*

Member 10—4 miles south of standard reference section	GSC loc. 58713

bryozoan
Dinorthis sp.
Hesperorthis sp.
Oepikina
Rostricellula sp.
Strophomena 2 spp.

Top of member 12—5 miles southeast of standard reference section	GSC loc. 58714

bryozoan
straight cephalopods
small gastropods
indeterminate brachiopods
trilobite
Cryptolithus sp.
? *Orthograptus* sp. } (both genera preserved as three-dimensional moulds,
? *Diplograptus* sp. } without periderm)

Member 12?—Four miles southeast of standard reference section.	GSC loc. 58628

straight cephalopod
gastropods, three or four spp. high spired and low spired
? clam
sowerbyellid and orthid brachiopods
? *Platystrophia* sp.

Section 20. Southwest of Avalanche Lake.

700 feet above base of formation	GSC loc. 58474

chaetetid coral

1,335–1,355 feet above base	GSC loc. 58475

gastropod
straight cephalopod
orthid brachiopod
? *Bathyurus* sp.

1,921–1,924 feet above base	GSC loc. 58477

? *Lichenaria* sp.

1,957–1,977 feet above base	GSC loc. 58478

echinoderm columnals
straight cephalopod
small gastropods
Maclurites sp.

2,072–2,080 feet above base GSC loc. 58479

echinoderm fragments
bryozoans
rhynchonellid brachiopod
? *Strophomena* sp.
Calliops sp.

2,390–2,400 feet above base GSC loc. 58480

echinoderm fragments
bryozoans
gastropod
clam
brachiopods 2 spp.
Hesperorthis sp.
stromatoporoid
Favistina spp.
Streptelasma sp.

2,937–2,950 feet above base GSC loc. 58481

clam
straight cephalopod
gastropod
bryozoan
trilobite fragments
indeterminate brachiopods
? *Rafinesquina* sp.
? *Rhynchotrema* sp.

3,171–3,174 feet above base GSC loc. 58482

echinoderm and brachiopod fragments
small gastropods and clams
bryozoan
trilobite
Cryptolithus sp.

Section 19. West of Natla Fault in southwest Wrigley Lake map-area.

420 feet above base of Sunblood Formation GSC loc. 69001

bryozoan
gastropods
ostracods
? *Bathyurus* sp.

Collections of fossils from the Sunblood Formation were made in numerous places apart from the measured sections. The most important of these are listed below:

Peak, elevation 5,948 feet, 6½ miles east of southeast end of Glacier Lake GSC loc. 58718

bryozoans
echinoderm fragments
orthid, lingulid, and rhynchonellid brachiopods
Hesperorthis sp.
? *Oepikina* sp.

Southwest limb of Broken Skull Anticline 2 miles southwest of peak, elevation 8,072 feet—possibly Member 10 of Flood Creek area GSC loc. 58751

echinoderm and trilobite fragments
bryozoans
gastropods
clam

? *Ctenodonta* sp.
rhynchonellid brachiopod
Hesperorthis sp.
? *Tetraphalerella* sp.
Streptelasma sp.

Five miles northeast of GSC loc. 58718 — GSC loc. 58550

echinoderm fragments, gastropods
bryozoans
undetermined orthid brachiopods
? *Strophomena* sp.
Hesperorthis sp.
Sowerbyella sp.
solitary coral
? *Bighornia* sp.
undetermined trilobite
isotelid trilobite
? *Triarthrus* sp.
? *Ectenonotus* sp.
? *Remopleurides* sp.
Ceraurinella sp.
Calliops sp.

On ridge 6 miles northeast of Rabbitkettle Hotsprings — GSC loc. 58706

bryozoan
gastropod
strophomenid brachiopod
Hesperorthis sp.
Rostricellula sp.

On ridge 9 miles north–northwest of Hell Roaring Creek, Flat River map-area — GSC loc. 58692

straight cephalopod
? *Eoleperditia* sp. (identified by M. J. Copeland)
gastropods
orthid brachiopods
asaphid trilobites
? *Pseudomera* sp.
? "*Barrandia*" sp. (*sensu* Hintze, 1952)
Maclurites sp.

On ridge 13 miles northeast of mouth of Flood Creek from strata near top of Sunblood Formation — GSC loc. 58635

asaphid trilobite
Cryptolithus sp.

Southeast end of ridge 4 miles northeast of mouth of Flood Creek from strata high in Sunblood Formation — GSC loc. 69053

echinoderm fragments
blastoid
chiton
trilobite fragments
gastropods
Lyrodesma sp. (identified by H. M. Steele)
Ctenodonta sp. (identified by H. M. Steele)
bryozoans
stromatoporoids
rhynchonellid brachiopod

Dolerorthis sp.
Hesperorthis sp.
Rostricellula sp.
tabulate corals (?)

Top of peak 2 miles southeast of peak, elevation 7,887 feet, north of North Nahanni River — GSC loc. 58676

straight cephalopod
gastropod
Maclurites sp.
Receptaculites sp.
Streptelasma sp.
Calapoecia sp.

Ridge crest 4 miles southwest of South Nahanni River in easternmost Flat River map-area — GSC loc. 58678

echinoderm fragments
bryozoan
orthid brachiopod
illaenid and asaphid trilobites
Calliops sp.
? *Paracybeloides* sp.

Low ridge 3 miles south of peak, elevation 5,687 feet and 8 miles east of Irvine Creek — GSC loc. 58685

echinoderm fragments
Porocrinus sp.
bryozoans
gastropod
? *Bucannia* sp.
clam
rhynchonellid brachiopod
Hesperorthis sp.
Oepikina sp.
Rostricellula sp.
illaenid trilobite

On Knob about 4 miles east–northeast of south end of Clark Lake — GSC loc. 58720

ostracods
bryozoan
asaphid trilobite
Bathyurus sp.
Illaenus sp.

Crest of ridge about 8 miles north–northeast of north end of McMillan Lake — GSC locs. 58721, 58724

(identified by M. J. Copeland)

Pteroleperditia sp. somewhat similar to *P. arbucklensis* (Harris) from the uppermost Arbuckle Limestone of Oklahoma of probable Champlainian (Black River) age.
? *Eoleperditia* sp. cf. *E. bivia* (White). This species was originally described from Upper Pogonip (Whiterock Stage) strata of Nevada.

In stream bottom 4 miles south-southeast of south end of Stonemarten Lakes — GSC loc. 58751

echinoderm and trilobite fragments
bryozoans
gastropods
clam

? *Ctenodonta* sp.
rhynchonellid brachiopod
Hesperorthis sp.
? *Tetraphalerella* sp.
Streptelasma sp.

In canyon, headwaters of Borden Creek 7 miles northwest of Skinboat Lakes GSC loc. 58638
gastropod
brachiopod and trilobite fragments
Ampyx sp.
? *Calliops* sp.
? *Porterfieldia* sp.
? tabulate coral

Numerous collections of fossils from the Sunblood Formation in southern Glacier Lake map-area and in eastern Flat River map-area not listed above include *Maclurites* sp. and ostracods. In the report area *Maclurites* sp. appears to be restricted to the 'wine beds', the middle, dominantly limestone assemblage of the Sunblood Formation.

Cryptolithid trilobites were found only in the uppermost beds of the Sunblood Formation.

Norford concludes that faunas from the Sunblood Formation indicate the rocks may be considered as entirely of Middle Ordovician age. Fossils from easternmost Glacier map-area, north of North Nahanni River (GSC loc. 58678) suggest the possibility that a thin remnant of Sunblood Formation is preserved locally beneath strata of the Whittaker Formation. If this is so it places a well-defined limit on the extent of pre-Whittaker erosion in this particular area.

The Sunblood Formation is most extensively developed in southern Glacier Lake, eastern Flat River, and westernmost Virginia Falls map-areas (Douglas and Norris, 1960). This region embraces southeastern Selwyn Basin and Root Basin (Gabrielse, 1967a). The western limit of deposition of Middle Ordovician carbonate rocks extends southerly from central Ragged Range near Rabbitkettle River to near the Yukon–District of Mackenzie border in southernmost Flat River map-area.

Sunblood strata are present northwest of the report area in Nahanni and Sekwi Mountain map-areas (Blusson, 1968a). To the south a thick section is exposed in eastern Coal River map-area (Gabrielse and Blusson, 1969) but in northernmost Rabbit River area and in northernmost Rocky Mountains the rocks are generally absent—at least in part the result of erosion prior to deposition of the Silurian Nonda Formation (Gabrielse, 1962b; Norford *et al.*, 1966).

The uppermost strata of the Kechika Group southwest of Deadwood Lake in eastern Cassiar Mountains (Gabrielse, 1963) are somewhat similar to the uppermost strata of the Sunblood Formation near Flood Creek. The faunas have much in common, even to the extent that both include diplograptid graptolites in a state of three-dimensional preservation.

Middle Ordovician carbonate strata are poorly developed elsewhere in the Canadian Cordillera and the Sunblood Formation in the South Nahanni–Flat River areas could possibly represent the thickest carbonate section of this age in western North America.

Upper Ordovician and Silurian

Northeast of a boundary of major facies change, Upper Ordovician and Silurian rocks are represented by a distinctive sequence of predominantly dark weathering carbonate strata that overlie older rocks with regional unconformity (*see* Fig. 8). With their contained faunas the strata form one of the most widespread, easily recognizable assemblages in Mackenzie Mountains (*see* Pl. XXIV).

Whittaker Formation

The name 'Whittaker' was given by Douglas and Norris (1961) to a sequence of carbonate strata about 4,000 feet thick in the type section on Whittaker Range in southeastern Mackenzie Mountains. In the report area the formation is considerably thinner and the three members described in the type area are not apparent.

The Whittaker Formation comprises well-bedded, commonly cherty, dark grey weathering dolomite and light grey to grey weathering dolomite and limestone. In many places alternating light grey and dark grey weathering units impart a conspicuous banding to outcrops. North of North Nahanni River in Thundercloud Range the formation includes a lower, light grey weathering limestone member and an upper, dark grey dolomite member. In Section 37 (*see* Pt. II), measured by B.S. Norford, the lower member is 102 feet thick and comprises cryptograined to fine-grained, resistant limestones, variably cherty. A well-defined erosion surface with a relief of as much as 6 inches defines the base of the sequence. Underlying strata belong to the lower part of the Helikian Little Dal Formation. The overlying dolomites, 1,267 feet thick, are resistant, well-bedded rocks, generally fine grained. Locally the dolomite is porous and contains vugs lined with dolomite crystals. The sequence appears to be overlain conformably by the Delorme Formation.

Near latitude 62°30′ in Thundercloud Range the Whittaker Formation is 1,100 feet thick and the lower, limestone member is 450 feet thick. There, an apparent angular discordance of about 15 degrees occurs between strata of the Whittaker Formation and underlying rocks of the Rapitan Formation (*see* Pl. XXV), the middle and lower members of which are bevelled progressively down section to the east.

In most parts of Wrigley Lake map-area a light and dark grey banding is characteristic (*see* Pl. XXIV). The rocks are mainly well bedded, medium-grained, fetid dolomites, locally vuggy. Locally, limestone is present in basal beds.

North of the headwaters of Redstone River and east of Natla Fault, the base of the Whittaker Formation is drawn at the bottom of a fairly massive to well-bedded resistant sequence, the basal part of which is a prominent limestone member about 30 feet thick. The limestone is light grey weathering, dark grey, cherty, and fine grained. The overlying rocks are mainly black, cherty, fossiliferous dolomites interbedded with units of light grey weathering non-fossiliferous dolomites.

West of Natla Fault in Wrigley Lake map-area (*see* Section 19, Pt. II) the Whittaker Formation comprises a lower unit of thin- to medium-bedded, grey weathering, dark grey, cryptograined limestone, 340 feet thick, and an upper unit of banded, light grey and dark grey dolomite, 800 feet thick. The contrasting dark grey weathering lower member and light and dark grey banded upper member can be traced south–southeasterly to north of Avalanche Lake.

Northeast of Avalanche Lake two distinctive members are present (*see* Section 44, Pt. II). The lower one, about 1,000 feet thick, consists of well-bedded, cherty black dolomite (*see* Pl. XXVI) and minor massive, porous dolomite. Near the base of the formation is a distinctive unit, about 80 feet thick, of platy, thin-bedded, very fine grained, black limestone (*see* Pl. XXVII). Beds range from a quarter to an inch thick and are in part finely laminated. Chert nodules and lenses form less than 5 per cent of the rocks. The upper member, locally as much as 900 feet thick, consists of light grey, massive, medium- to coarse-grained, vuggy and porous reefoid dolomite (*see* Pl. XXVIII). The latter assemblage thins rapidly to disappearance within several miles northwest and southwest of the measured section. A lens of similar lithology, 170 feet thick, occurs within the lower cherty dolomite unit but pinches out abruptly to the southeast. These massive, porous carbonates, characterized by discontinuous and lensoid form, probably represent reefs built along or near the facies boundary between shales to the southwest and carbonates to the northeast. Where they occur the thickness of the Whittaker Formation increases greatly.

In Grizzly Bear Anticline, strata assigned to the Whittaker Formation are slightly less than 1,000 feet thick (*see* Sections 42, 43, Pt. II). There, the rocks are similar to those of the lower, very cherty dark grey dolomite member north of Avalanche Lake.

Locally, on the flanks of Broken Skull Anticline and in the Flood Creek area, thin sequences of dark grey weathering dolomite containing *Catenipora* sp. overlie the Sunblood Formation and underlie graptolitic shales. These strata are possibly correlative with basal Whittaker rocks farther northeast but appear to be so minor that they are included with the Sunblood Formation for mapping purposes.

Thickness variations of the Whittaker Formation are shown in Figure 18, Part II. These variations reflect the presence of Selwyn Basin, Redstone Arch, and Root Basin.

Age and correlation of Whittaker Formation. The Whittaker Formation is abundantly fossiliferous and only the most important fossil collections are listed below. All identifications and age assignments were made by B. S. Norford.

Section 19. Southwest of Natla Fault in Wrigley Lake map-area GSC loc. 69009

65–69 feet above base of Whittaker Formation

echinoderm fragments
rugose coral
Bighornia sp.
Lobocorallium sp.
Paleophyllum sp.
Paleofavosites 2 spp.
Catenipora sp.
Plaesiomys sp.
Strophomena sp.
Thaerodonta sp.

Late Ordovician

Bighornia–Thaerodonta Fauna

165 feet above base of Whittaker Formation GSC loc. 69032

echinoderm debris
bryozoans
gastropod
orthid and rhynchonellid brachiopods
? *Glyptorthis* sp.
? *Resserella* sp.
Thaerodonta sp.
strophomenid brachiopod
undetermined trilobites, 4 spp.
? *Bumastus* sp.
Cybeloides sp.
Otarion sp.

Ordovician, probably Richmond

63°10½′N, 127°36½′W in southwest Wrigley Lake map-area; within 30 feet of base of Whittaker Formation GSC loc. 69041

echinoderm fragments
cephalopod fragment
trilobite fragments
zygospirid brachiopod
Diceromyonia sp.
Plaesiomys sp.
Hesperorthis sp.
Thaerodonta sp.
Bighornia sp.
Lobocorallium sp.
? *Streptelasma* sp.
? *Paleofavosites* sp.
genus aff. *Favistina* sp. (with dissepiments)

Late Ordovician

(*Bighornia–Thaerodonta* Fauna)

Section 20. Southwest of Tigonankweine Range 650 feet above base of Whittaker Formation GSC loc. 69021

straight cephalopod
stromatoporoids
phaceloid corals 2 spp. (one with dissepiments)
Favosites 2 spp.
Cystihalysites 2 spp.

Silurian

63°51′N, 126°44′W, 15 miles due west of Wrigley Lake in basal beds of Whittaker Formation GSC loc. 69064

echinoderm fragments
solitary coral
Catenipora sp.
Glyptorthis sp.
? *Hesperorthis* sp.
? *Rhynchotrema* sp.
Thaerodonta sp.

Late Ordovician

63°33′N, 126°10′W, in Rouge Range, 150–155 feet above base of Whittaker Formation GSC loc. 69030

echinoderm fragments
rhynchonellid and sowerbyellid brachiopods
? *Hesperorthis* sp.
Streptelasma
Catenipora
Plasmopora

probably Ordovician

probably Barneveld to Richmond

63°20½′N, 126°45½′W, 15 miles north-northwest of Dal Lake in basal beds of Whittaker Formation GSC loc. 58558

echinoderm fragments
bryozoan

Bighornia sp.
Grewingkia sp.
hesperorthid brachiopod
Plaesiomys sp.
? *Resserella* sp.
Rhynchotrema sp.
R. aff. *R. kananaskia* (Wilson)
? *Strophomena* sp.
worm borings (or other burrowers) in corals and brachiopods

Late Ordovician

Bighornia–Thaerodonta Fauna

Section 32. Southern Tsezotene Range, basal beds of Whittaker Formation GSC loc. 58702

echinoderm and trilobite fragments
clam (?)
bryozoan spp.
Rhynchotrema 2 spp.
? *Strophomena* sp.
? *Plaesiomys* sp.
favositid coral
Streptelasma sp.
? *Bighornia* sp.
Sarcinula sp.

Late Ordovician

Section 36. Painted Mountains, 610–670 feet above base of Whittaker Formation. GSC loc. 58618

Streptelasma sp.
Paleophyllum sp.
? *Catenipora* sp.
favositid coral

Late Ordovician

Section 37. Northern Thundercloud Range, measured by B. S. Norford.
0–12 feet above base of Whittaker Formation GSC loc. 58488

Leperditella? sp. (identified by M. J. Copeland)
echinoderm and bryozoan fragments
indeterminable trilobite
? *Austinella* sp.
Plaesiomys sp.
Resserella sp.
Rhynchotrema sp.
Thaerodonta sp.
brachiopods 4 spp.
Favistina 2 spp.
? *Grewingkia* sp.
? *Lobocorallium* sp.
Paleofavosites sp.
Paleophyllum sp.
? *Streptelasma* sp.

Late Ordovician

Bighornia–Thaerodonta Fauna

19–21 feet above base GSC loc. 58489

? *Dinorthis* sp.
Rhynchotrema sp.
Strophomena sp.
Catenipora cf. *C. rubra* Sinclair and Bolton
Favistina sp.
? *Streptelasma* sp.

Late Ordovician

95–99 feet above base GSC loc. 58490

Lobocorallium sp.
Paleophyllum sp.
Paleofavosites sp.
Catenipora sp.

Late Ordovician

227–252 feet above base GSC loc. 58492

echinoderm columnals
? *Lobocorallium* sp.
Paleophyllum, 3 spp.
Catenipora sp.

Late Ordovician

267–287 feet above base GSC loc. 58493

streptelasmid coral
Paleophyllum, 2 spp.
Paleofavosites sp.
Catenipora sp.
Manipora sp.

Late Ordovician

551 feet above base GSC loc. 58594

Cystihalysites sp.

Silurian

567 feet above base GSC loc. 58495

? *Pentamerus* sp.

Silurian

772–773 feet above base GSC loc. 58496

stromatoporoid
? *Tryplasma* sp.
solitary coral
Favosites sp.
Halysites or *Cystihalysites* sp.

Silurian

Section 22. Six miles northwest of Avalanche Lake in basal beds of Whittaker Formation. GSC loc. 69098

gastropods
bryozoans

trilobite fragments
? *Paleofavosites* sp.
Glyptorthis sp.
Lepidocyclus sp.
Onniella sp.
? *Rafinesquina* sp.
? *Rhynchotrema* sp.
Thaerodonta sp.

Late Ordovician

Section 43. Southwest limb of Grizzly Bear Anticline about 300 feet (?) below top of Whittaker Formation. GSC loc. 58710

auloporid
Coenites cf. *C. rectilineatus* (Simpson)
Planalveolites? sp.
Atrypa cf. *A. parva* Hume
Spinatrypa sp.
Cyrtina? sp.
echinoderm ossicles with single axial canals

Silurian

Four miles north of North Nahanni River in Thundercloud Range GSC loc. 58677

echinoderm fragments
bryozoan
indeterminate brachiopods 2 spp.
Glyptorthis sp.
Rhynchotrema sp.
Thaerodonta sp.
Bighornia sp.
Deiracorallium sp.
? *Grewingkia* sp.
Lobocorallium sp.
Catenipora sp.
Paleophyllum sp.
? *Paleofavosites* sp.

Late Ordovician

Bighornia–Thaerodonta Fauna

62°17½'N, 126°22'W, in saddle a mile northeast of head of North Nahanni River GSC loc. 58530

stromatoporoids
bryozoans
echinoderm fragments
solitary corals
brachiopods
? *Cystiphyllum* sp.
? *Fletcheria* sp.
Coenites sp.
Favosites spp.
? *Heliolites* sp.
Cystihalysites 2 spp.
Cystihalysites cf. *C. magnitibus* (Buchler)

Silurian, probably Late Llandoverian

61°59½'N, 126°21½'W, ridge 4 miles northeast of Flood Creek GSC loc. 58627

echinoderm fragments
possible clam and bryozoan
straight cephalopod
gastropods spp.
Deiracorallium sp.
Catenipora sp.
Calapoecia sp.
zygospirid brachiopod
Camerella sp.
? *Glyptorthis* sp.
? *Monomerella* sp.
Oepikina sp.
? *Rhynchotrema* sp.
Thaerodonta sp.

Late Ordovician

Bighornia–Thaerodonta Fauna

The following collections indicate that the uppermost beds included for mapping purposes with the Sunblood Formation on the southwest limb of Broken Skull Anticline and in South Nahanni Anticline probably belong to the Whittaker Formation.

62°17'N, 127°20'W, 4 miles southwest of peak, elevation 8,072 feet +, on southwest limb of Broken Skull Anticline GSC loc. 58750

bryozoans
Streptelasma sp.
orthid brachiopod
? *Plaesiomys* sp.
? *Rhynchotrema* sp.
? *Thaerodonta* sp.

probably Late Ordovician

Southwest limb of Broken Skull Anticline, 4 miles west of peak, elevation 7,895 feet GSC locs. 58614, 58554

Streptelasma sp.
Catenipora sp.
favositid coral

Late Ordovician

62°26'N, 127°53½'W, north of South Nahanni River, northeast limb of South Nahanni Anticline GSC loc. 58766

? *Rhynchotrema* sp.
Encrinurus sp.
Streptelasma sp.

probably Late Ordovician

The faunas listed above indicate the relative abundance of fossils in the Ordovician part of the Whittaker Formation and their paucity in the Silurian part. Throughout the report area basal beds of the formation can be assigned to the *Bighornia–Thaerodonta* Zone (Richmond) of the Upper Ordovician. This fauna is widespread in western Canada and is common in the lower part of the Beaverfoot Formation in southeast British Columbia (Norford, 1969). Norford states further that the Silurian fauna of GSC loc. 58530 has much in common with late Early Silurian faunas of northern British Columbia.

In northern British Columbia the Silurian Nonda Formation in northernmost Rocky Mountains (Norford, *et al.*, 1966) and Sandpile Formation in Cassiar Mountains (Norford, 1962) unconformably overlie older strata, and Upper Ordovician carbonates are present only locally, as for instance, in central McDame area in Cassiar Mountains (Gabrielse, 1963).

Strata similar to those of the Whittaker Formation in the report-area outcrop near Cranswick River in Canyon Ranges of northern Mackenzie Mountains (Norford, 1964). To the east in Franklin Mountains the carbonate Mount Kindle Formation contains Upper Ordovician and Silurian faunas (Norford, 1966).

Ordovician, Silurian, and Devonian

Near a line trending northwesterly from northeast of Clearwater Creek, to, and beyond, Grizzly Bear Lake, strata of the Whittaker and younger formations change facies rather abruptly from carbonates in the northeast to shaly rocks in the southwest (*see* Fig. 8). The argillaceous strata weather recessively and thus underlie large parts of major valleys such as those occupied by Broken Skull, Flat, and Caribou Rivers. Characteristically the lower part of the assemblage includes thin-bedded limestones or dolomites and is more resistant than the upper part. Only in Broken Skull Syncline can rocks of Ordovician, Silurian, and Early Devonian age be separated from strata possibly as young as Mississippian.

Road River Formation

Throughout northern Yukon and easternmost Alaska argillaceous graptolitic rocks ranging in age from Late Cambrian to Early Devonian are referred to as Road River Formation (Jackson and Lenz, 1962; Norford, 1964; Churkin and Brabb, 1965). Similar rocks are present in many parts of Selwyn Basin (Gabrielse, 1967b) and it is proposed that the name 'Road River' be applied there also.

In the report area the Road River Formation comprises fissile, thin-bedded, pyritic, black and grey shales, siltstones, cryptograined black limestones, and minor bedded chert. A section measured by Norford, 3 miles southwest of Avalanche Lake (*see* Section 20, Pt. II) includes a lower, recessive, graptolitic, calcareous shale and argillaceous limestone unit, 297 feet thick; a middle, thin-bedded, olive, grey, pale yellow, and dark weathering cherty and silty dolomite unit containing many beds, lenses, and nodules of grey and black chert, 476 feet thick; and an upper, recessive, dark grey calcareous, graptolitic shale unit, more than 1,396 feet thick.

On the northeast limb of Broken Skull Syncline the basal beds of the Road River Formation, about 350 feet thick, are thin-bedded, platy dolomite with abundant chert nodules interbedded with dark grey to black, fissile and platy, laminated calcareous siltstone and shale. The lower recessive unit at the base of the formation on the northeast limb of Broken Skull Anticline was not recognized on the southwest limb. The upper part of the Road River Formation on the southwest limb of the anticline comprises light buff-grey weathering, thin-bedded, platy and fissile, cryptograined black limestone and graphitic calcareous shale 1,865 feet thick (*see* Pl. XXIX). Most of the shaly rocks are cleaved and strongly jointed and in places erosion has produced a crude columnar structure.

A tongue of thin-bedded, dark grey to black graptolitic shale, variably dolomitic, between 50 and 80 feet thick, outcrops on the southwest and northeast sides of Grizzly Bear Anticline. These rocks are homotaxial with the upper part of the Whittaker Formation to

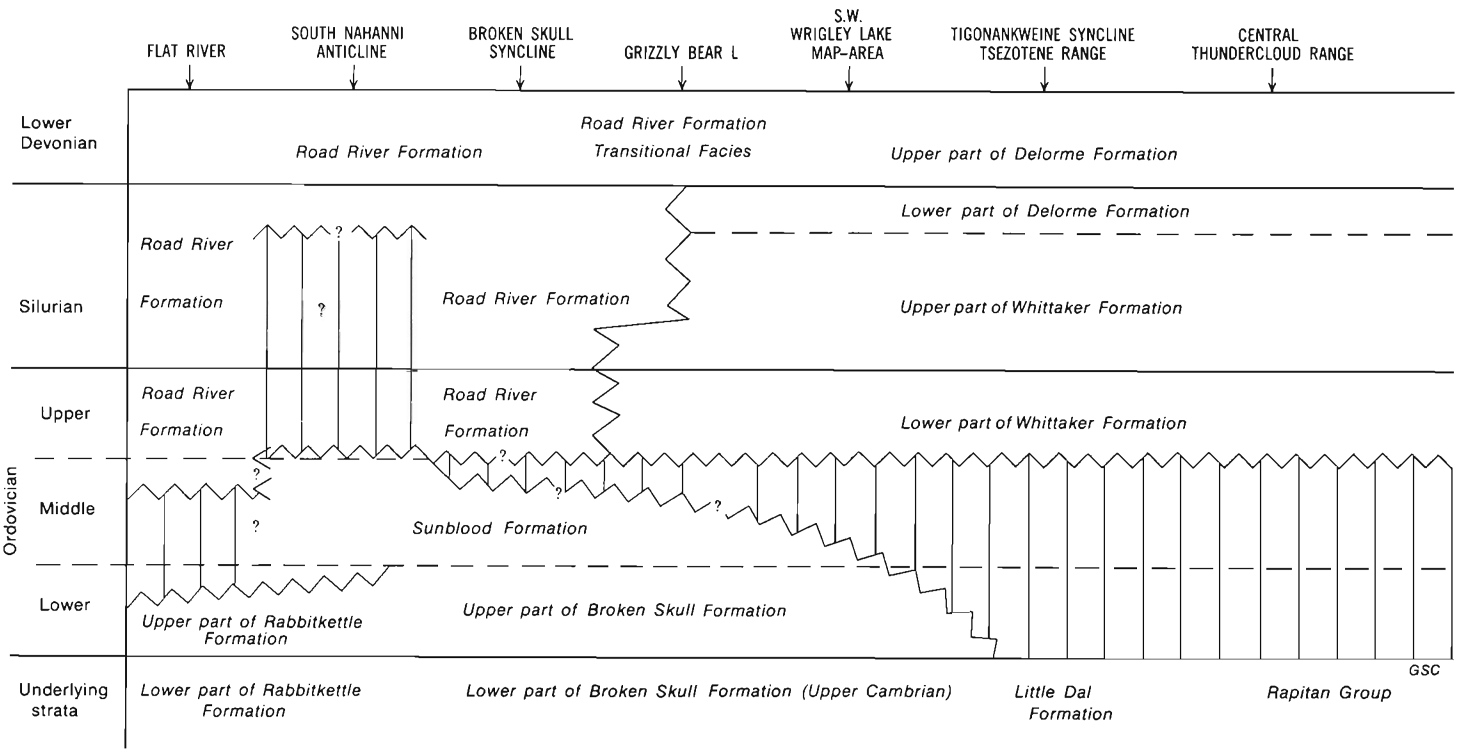

FIGURE 8. Correlation of Ordovician and Silurian formations.

the northeast. The black shales are overlain by 1,130 feet of thin-bedded, argillaceous, platy limestones, silty limestones and finely laminated calcareous siltstones. Calcareous black shale interbedded with medium- to coarse-grained coquinoid limestone forms a member about 120 feet thick in the middle part of the sequence.

In Ragged Range the Road River Formation consists of recessive, dark grey to black, thin-bedded and laminated strongly cleaved calcareous and non-calcareous slates, locally pyritic. Many of these rocks have a distinct phyllitic sheen. Basal beds southwest of Rabbitkettle Lake are black, carbonaceous, pyritic, slightly calcareous, graptolitic siltstones. Overlying rocks include some thinly bedded argillaceous, black, cryptograined limestones.

In northeasternmost Flat River map-area argillaceous strata overlying the Sunblood Formation contain more limestone than elsewhere and are a continuation of strata in Virginia Falls map-area (map-unit 5, Douglas and Norris, 1960). The light buff, tan, and pale olive-grey weathering there is unique.

Near Clearwater and Flood Creeks the lowest strata of the Road River Formation are recessive, platy, thin-bedded, argillaceous limestones, calcareous shales, and minor black chert that produce a characteristic silver-grey talus. Higher in the sequence the rocks are essentially noncalcareous and comprise phyllitic, black, locally banded slates with a strongly developed cleavage.

Outcrops in the canyons of Borden Creek and Flat River include considerable amounts of cryptograined black limestone in beds 4 to 6 inches thick interbedded with black, calcareous shale (*see* Pl. XXX). Much of the shale breaks into paper-thin fragments because of closely spaced cleavage planes. Beds of black chert about an inch thick are present in a few places.

Several hundred feet of well-banded, black, calcareous shales and slates, cryptograined limestones and minor chert outcrop in the canyon of Caribou River. The limestones locally constitute about 30 per cent of the assemblage and occur in beds ranging from 1 inch to 6 inches thick. In this region the youngest strata are essentially noncalcareous concretionary shales that are probably, in part, of Devono–Mississippian age.

In the canyon near the headwaters of Caribou River at longitude 126°45′W the Sunblood Formation is overlain by a sequence of limestone, black slate, and chert in beds ranging from 3 to 8 inches thick. Concretions as much as 2 feet in diameter and 8 inches thick are not uncommon. The Road River Formation in this vicinity appears to contain more chert than elsewhere.

Age and correlation of Road River Formation. Graptolites were collected from three measured sections and several spot localities. Corals and brachiopods from GSC loc. 69062, and fish from GSC loc. 69014 are from beds of a transitional facies between Road River Formation and Delorme, Camsell, and Sombre Formations.

Section 43. 62°32′N, 127°43′W, southwest limb of Grizzly Bear Anticline, in thin shale unit overlying Whittaker Formation. GSC loc. 69063

Monograptus cf. *M. vomerinus* (Nicholson)
Monograptus ex gr. *M. priodon* (Bronn)

Wenlockian Zones 26–30 (identified by D. E. Jackson)

Section 43. Southwest limb of Grizzly Bear Anticline, 630 feet above top of Whittaker Formation. GSC loc. 69062

echinoderm fragments
stromatoporoid
solitary corals

Coenites sp.
Favosites sp.
Atrypa sp.
? *Lissatrypa* sp.
Howellella sp.
orthid brachiopod
rhynchonellid brachiopods, 2 spp.

Silurian to Early Devonian, probably Silurian (identified by B. S. Norford)

Section 43. Southwest limb of Grizzly Bear Anticline, 850 feet above top of Whittaker Formation. GSC loc. 69014

Form	1	pteraspid (possibly a small protaspid)
"	2	cyathaspid, like *Poraspis*
"	3	cyathaspid, small, undetermined, and probably new
"	4	cyathaspid, large
"	5	a new flat form with endoskeleton of simple oval scales, each scale bearing a single tubercle ornament like *Traquairaspis*
"	6	acanthodian, small, with curved fin spines
"	7	acanthodian, larger, with straight fin spines

Early Devonian (Late Gedinnian or Siegenian)? (identified by D. L. Dineley)

Section 41. 8 miles north–northeast of mouth of Broken Skull River. Measurements on far left indicate thickness in feet above base of formation.

540 *Monograptus* cf. *M. spiralis* (Geinitz) GSC loc. 69075
Monograptus cf. *M. priodon* (Bronn)

Late Llandoverian, *M. spiralis* Zone

580 *Monograptus* cf. *M. priodon* (Bronn) GSC loc. 69076

Probably Early Wenlockian

731 *Monograptus* cf. *M. priodon* (Bronn) GSC loc. 69077

Probably Early Wenlockian

821 *Monograptus* cf. *M. dubius* (Suess) GSC loc. 69078

Wenlockian

828 *Monograptus* sp. undet. GSC loc. 69079

probably Ludlovian

912 *Monograptus roemeri* (Barrande) GSC loc. 69080

Ludlovian, probably *M. nilssoni* Zone

917 *Monograptus roemeri* (Barrande) GSC loc. 69081
Monograptus sp. (with biform thecae)

Ludlovian, probably *M. nilssoni* Zone

937 *Monograptus* cf. *M. uncinatus* var. *orbatus* Wood GSC loc. 69083

Ludlovian, probably *M. nilssoni* Zone

962 *Monograptus* sp. indet. GSC loc. 69084

? Ludlovian

1,626 tentaculitids GSC loc. 69085

probably Devonian

1,639 tentaculitids GSC loc. 69086

probably Devonian

1,644 tentaculitids GSC loc. 69087

probably Devonian

1,692 tentaculitids GSC loc. 69088

graptolite fragment (?)

probably Early Devonian

1,736 tentaculitids GSC loc. 69089
clam (?)
lingulid brachiopod
Monograptus sp.

probably Early Devonian

1,750 tentaculitids GSC loc. 69090
Monograptus sp. indet.

Ludlovian–Early Devonian

Collections 69075 to 69084, inclusive, and collection 69090 were identified by D. E. Jackson. The remaining faunas were examined by B. S. Norford.

The fossils listed below were collected and identified by Norford:

Section 20. Three miles southwest of Avalanche Lake, basal beds of Road River Formation. GSC locs. 58483, 58484

? *Glyptograptus* sp.
Climacograptus cf. *C. bicornis* (Hall)

Zone of *N. gracilis*, Caradocian

856 feet above base of formation GSC loc. 58485

Monograptus cf. *M. spiralis* (Geinitz)

Late Llandoverian, probably
Zone of *M. spiralis*

Spot collections from Road River strata examined by Norford are given below:

62°15′N, 127°16′W, a mile north of peak, elevation 6,572 feet, near base of upper member of Road River Formation? GSC loc. 58601

Monograptus spiralis (Geinitz)
Monograptus aff. *M. priodon* (Bronn)
Monograptus sp.

Late Llandoverian, probably
Monograptus spiralis Fauna

62°13′N, 127°30′W, southwest limb of Broken Skull Syncline GSC loc. 58600

Monograptus bohemicus (Barrande)
Monograptus aff. *M. uncinatus micropoma* (Jackel)
Monograptus sp.

Early Ludlovian
Monograptus nilssoni Fauna

Ridge 4.7 miles west of mouth of Broken Skull River, near carbonate-shale contact GSC loc. 58861

sponge spicules
Linograptus sp.
Monograptus 2 spp.
M. bohemicus (Barrande)
M. aff. *M. flemingii* (Salter)

Early Ludlovian
Monograptus nilssoni Zone

61°58′N, 127°24′W, ½ mile northwest of peak, elevation 6,141 feet GSC loc. 58529

diplograptids
? *Climacograptus*

Middle Ordovician to Early Silurian

Fossils collected by S. L. Blusson and identified by Norford are listed below.

61°48′, 127°52′W, northeast of Flat River, within 500 feet of base of Road River Formation GSC locs. 53670, 53675–81

? *Dicellograptus* sp.
? *Dicranograptus* sp.
? *Leptograptus* sp.
? *Glossograptus* sp.

Upper Ordovician (Caradocian)

West side of Caribou River, a mile upstream from Diamond Creek GSC loc. 58547

Climacograptus sp.
Monograptus spp.
Monograptus spiralis (Geinitz)
Monograptus cf. *M. turriculatus* (Barrande)
Monograptus aff. *M. priodon* (Bronn)
Monograptus aff. *M. sedgwicki* (Portlock)
Monograptus aff *M. barrandei* (Suess)

Late Llandoverian
(elements of several graptolite zones present)

61°09′N, 126°10′W, east side of Caribou River GSC loc. 58041

Monograptus sp.
Climacograptus sp.

probably Middle or early Late Llandoverian

Fossils from the Road River Formation thus indicate a range in age from Caradocian to probably early Devonian. In Ragged Range Blusson (1968a) reports an unconformity beneath the formation where it overlies the Rabbitkettle Formation. Southwest of the upper reaches of Rabbitkettle River the upper part of the Rabbitkettle Formation is truncated southwesterly to disappearance beneath the Road River Formation. Farther east, however, the base is structurally conformable with older rocks and no significant hiatus is indicated by the faunas.

Early Ludlovian graptolites of GSC loc. 58600 were collected a short distance stratigraphically above the Road River–Sunblood contact. Unless the contact is a fault, unrecognized in the field, a considerable stratigraphic hiatus is indicated.

The lack of late Ordovician graptolitic faunas on the limbs of the Broken Skull Syncline is surprising. Judging from the section measured by Norford southwest of Avalanche Lake, however, the graptolite-bearing part of the Upper Ordovician sequence is very thin and being recessive weathering it may have been overlooked elsewhere. An alternative is that on the limbs of Broken Skull Syncline and Broken Skull Anticline the uppermost carbonate beds included in the Sunblood Formation are correlative with the lower part of the Whittaker Formation. Faunas suggest this possibility but the evidence is inconclusive.

Graptolitic strata of the Road River Formation are widespread in northernmost Yukon and in Selwyn Basin. Strata of this lithology, northeast of Tintina Trench, reached their greatest areal extent during the Ludlovian (Norford, 1964; Gabrielse, 1967a).

Silurian and Devonian

Delorme Formation

The name 'Delorme' was applied by Douglas and Norris (1961) to "a sequence of buff and light brown weathering, thinly bedded limestones, dolomites, and shales that overlie the Whittaker Formation and underlie the Camsell Formation." The type locality is at the headwaters of Pastel Creek on Delorme Range in Root River map-area. These rocks are essentially continuous with those that outcrop in Thundercloud Range, in Painted Mountains, and throughout northeastern Wrigley Lake map-area. Similar strata also outcrop along and near the southwest side of Redstone Plateau.

In Wrigley Lake and Glacier Lake map-areas the Delorme Formation comprises generally recessive, buff, grey, cream, and cinnamon weathering, platy, mottled dolomites and limestones. The rocks are commonly cryptograined to fine grained, thin bedded, and in many places, delicately laminated. Alternating dark and light weathering members with somewhat diffuse boundaries owing to talus creep, impart a characteristic banded or striped appearance easily recognizable in outcrops and air photographs.

Dolomites in Thundercloud Range contain ubiquitous nodules of pink and orange-pink weathering dolomite. Mudcracks are common locally and salt casts occur in several localities. The upper part of the formation contains abundant dolomite breccia consisting of angular to subangular fragments of dolomite generally less than an inch long in a limestone matrix.

Thin sequences of Delorme Formation in Tigonankweine Syncline and west of Redstone River comprise relatively uniform, laminated, fine-grained, locally sandy, buff weathering dolomite in beds from half a foot to 1½ feet thick. Grey and brown, very fine grained sandstone and dolomitic sandstone form one unit about 40 feet thick near the middle of the formation. A sequence of buff weathering bluish grey and brown shales 4 feet thick contains pyrite and displays mudcracks. Farther east the thicker sequences include more shaly units and consequently are thinner bedded and produce a finer and commonly more platy talus.

Outcrops along the southwest side of Redstone Plateau are characteristically well bedded and yellow, buff, and orange weathering (*see* Pl. XXXI). Recessive, laminated, black, cryptograined limestone locally forms a minor part of the sequence.

Strata homotaxial with the Delorme Formation in Grizzly Bear Anticline represent a transitional facies between the Delorme Formation and Road River Formation and are included with the latter for mapping purposes. The sequence comprises buff weathering, thin-bedded, shaly, finely laminated, cryptograined, dark grey limestone in beds 2 to 6 inches thick interbedded with recessive, grey and black, slightly calcareous shale and siltstone.

The base of the Delorme Formation seems to be conformable everywhere with the underlying Whittaker Formation. The contact is determined by the change in weathering colours from the dark grey Whittaker Formation below to the light buff Delorme Formation above, and in many places is difficult to define precisely. To the southwest the weathering colours of the Delorme Formation become drabber, particularly in facies transitional with the Road River Formation.

Thickness variations of the Delorme Formation are shown in Figure 18, Part II; they range from a maximum of about 2,300 feet north of North Nahanni River (*see* Section 40, Pt. II) to a minimum of about 235 feet in Tigonankweine Syncline (*see* Section 28, Pt. II).

Age and correlation of Delorme Formation. For the most part the Delorme Formation contains few fossils. However in places some beds contain so many brachiopods that they form coquinas. Fish fragments have been found in several localities. The following fossil collections were examined by A. W. Norris:

62°17½'N, 126°09'W, 4 miles north of North Nahanni River, about 50 feet above orange weathering part of Delorme Formation — GSC loc. 58531

Aulopora sp.
"*Camarotoechia*" sp.
Schizophoria? sp.
Schuchertella? sp.
Spinulicosta? sp.
gastropod
cf. *Michelinoceras* sp.
ostracods

Lower ? Devonian

63°03'N, 125°59'W, on southwest side of Amber Fault in Dahadinni map-area, beds high in Delorme Formation — GSC loc. 68982

Schuchertella? sp.
"*Camaroteochia*" sp.
cf. *Murchisonia* sp.

Lower ? Devonian

63°29'N, 126°01'W, east flank of Rouge Range — GSC loc. 69065

Coenites sp. cf. *C. rectilineatus* (Simpson)
Schuchertella sp. cf. *S. adoceta* Crickmay

Silurian or Lower Devonian

Section 42. 62°42'N, 127°50'W, northeast limb of Grizzly Bear Anticline

620–625 feet above top of Whittaker Formation. — GSC loc. 58564

Coenites sp. cf. *C. rectilineatus* (Simpson)
solitary rugose coral
Lingula sp.
Gypidula sp.—coarsely costate
Carinatina? sp.
Meristella? sp.
rhynchonellid
echinoderm fragment

Silurian or Lower Devonian

Section 42. 965 feet above top of Whittaker Formation. GSC loc. 58565

Orbiculoidea sp.
Michelinoceras? sp.
Conularia spp.

Silurian or Lower Devonian

Section 42. About 675 feet (?) above top of Whittaker Formation. GSC loc. 58711

Alveolites? sp.
Coenites sp. cf. *C. rectilineatus* (Simpson)
Favosites sp.
Striatopora sp.
cup corals
Atrypella? sp.
Spinatrypa sp.
echinoderm ossicles—single, round, axial canals
echinoderm ossicles—single, star-shaped, axial canals

probably Upper Silurian

Section 42. 715 feet above base of Delorme Formation. GSC loc. 69059

Coenites sp.
Schizophoria sp.
Carinatina sp.
Spinatrypa—very finely costate

Lower Devonian

D. L. Dineley examined several collections of fossil fish; these are listed below:

Section 37. Northernmost Thundercloud Range, 180 feet above base of Delorme Formation. GSC loc. 58497

Vernonaspis sp.
Dikenaspis sp.
? *Homalaspidella* sp.
? *Traquairaspis* sp.
heterostraci indet. type B of Denison 1963

Late Silurian or Early Devonian

West of Natla River on border of Wrigley Lake and Sekwi Mountain map-areas 125 feet above base of Delorme Formation GSC loc. 69017

Heterostracan fragments including:
New form A. Very like *Cyathaspis* in part,
like *Tolypelepis* in part,
some resemblance to *Corvaspis*
New form B. Single small fragment most strongly *Ptomaspis* but without diagnostic features of the margin

Late Silurian ?

Section 19. Southwest of Natla fault, Wrigley Lake map-area.
262 feet above base of Delorme Formation GSC loc. 69010

A few small fragments and part of dorsal shield of a small cypathaspid, well preserved

300 feet above base of Delorme Formation GSC loc. 68033

Meristella sp.
fish fragments

Faunas obtained from the Delorme Formation indicate a probable range in age of strata from Late Silurian to Early Devonian. Thus the formation is correlative with part of the Road River Formation to the southwest (*see* Fig. 8).

Rocks of the Delorme Formation are widespread in southern Mackenzie Mountains (Douglas and Norris, 1960, 1961, 1963). In northern Rocky Mountains well-bedded grey and buff weathering, poorly fossiliferous dolomites overlying the Silurian Nonda Formation may include correlative rocks (Hughes, 1963; Taylor, 1965; Gabrielse, 1962a).

Devonian

Camsell Formation

Strata assigned to the Camsell Formation (Douglas and Norris, 1961) outcrop in the eastern parts of Wrigley Lake and Glacier Lake map-areas and in a belt southwest of Redstone Plateau. Elsewhere correlative strata are not so well defined and are included in the Delorme or Sombre Formations.

The most distinctive lithology of the Camsell Formation in southeastern Wrigley Lake map-area is grey, yellow, and orange weathering limestone breccia. These rocks are porous, vuggy, and poorly bedded. With the breccias are units of cryptograined grey limestone, and alternating beds of grey and buff weathering fine-grained, silty dolomites. In general, there appears to be an inverse relationship between the abundance of breccia and the amount of bedded dolomite. Salt casts are not uncommon.

Fragments in the breccias range from a fraction of an inch to several feet in diameter but most are less than an inch. In places the most conspicuous clasts are dark grey, cryptograined, laminated limestone. They are mostly angular to subangular and of intraformational origin. Some of the breccias are tightly cemented and form resistant cliffs of massive rocks. Elsewhere the rocks weather recessively and commonly form hoodoos. The lower part of the Camsell Formation near Redstone River is very recessive and in many places underlies valleys or subdued slopes. The uppermost beds in this area are relatively resistant and are characterized by pink-orange weathering.

Near North Nahanni River a sequence of well-bedded, alternating grey and buff weathering dolomites, 1,200 feet thick, is transitional between the Delorme and Sombre Formations. Most of the rocks are very fine grained dark grey dolomites, variably calcareous and silty. Beds range from half a foot to 10 feet thick and many show laminations.

In part of Thundercloud Range rocks mapped as Delorme Formation include breccias in the upper members that may be equivalent to the Camsell Formation.

In northwesternmost Glacier Lake map-area transitional beds between typical Delorme and Sombre strata are similar to those in Thundercloud Range described above. Characteristically they are very well bedded and resistant (*see* Pls. III, XXXI).

North of Dal Lake and in Tigonankweine Syncline silty, grey and buff weathering dolomites, generally cryptograined to fine grained, are mapped as Delorme Formation but are probably in part homotaxial with strata of the Camsell Formation farther east. Where typical Camsell strata are absent no depositional break was noted between rocks assigned to the Delorme and Sombre Formations.

Thicknesses of the Camsell Formation range from 540 feet, 6½ miles southeast of Dal Lake, to more than 2,000 feet, on the east flank of Rouge Range. In most places, however, the combined thickness of Delorme and Camsell Formations is more significant than the thickness assigned to each, because of the commonly arbitrary boundary between them.

Age and correlation of Camsell Formation. No fossils were obtained from the formation in the report area, nor have any been reported from adjacent areas. On the basis of its stratigraphic position, however, it seems most probable that the Camsell Formation is of Early Devonian age.

Breccias similar to those of the Camsell Formation outcrop in north-central and east-central Rabbit River map-area in northernmost British Columbia (Gabrielse, 1962b). To the southeast and east a possibly correlative formation consists of fairly pure sandstone (Taylor, 1965; Hughes, 1963).

In Cassiar and Pelly Mountains a widespread sequence of sandstones, dolomitic sandstones, and laminated dolomites that lie stratigraphically below Middle Devonian carbonates, may include strata correlative with the Camsell and/or Sombre Formations (Gabrielse, 1963; Green, *et al.*, 1960a, b).

Sombre Formation

The Sombre Formation (Douglas and Norris, 1961), well exposed in Glacier Lake and Wrigley Lake map-areas, comprises a cliff-forming succession of well-bedded, commonly laminated, alternating light grey and medium to dark grey weathering, cryptograined to medium-grained dolomites. In most places the formation can be divided into a medium to dark grey banded lower member, a conspicuous dark grey weathering middle member, and a silver-grey weathering slightly recessive upper member (*see* Pls. III, IV, XXXII). In Thundercloud Range, where the formation is typically developed, thicknesses of the lower, middle, and upper members are 415, 140, and 1,135 feet respectively. For mapping purposes, rocks correlative with the Sombre Formation found north of North Redstone River and in Rouge Range are included with those of the overlying Arnica Formation. Although very thin, the three members of the formation can be recognized in Tigonankweine Syncline. East of Tigonankweine Range and in the northern part of Rouge Range, however, the Sombre Formation is either absent because of pre-Arnica erosion (Douglas and Norris, 1963) or else it becomes indistinguishable from the Arnica Formation.

The lower member of the Sombre Formation consists typically of alternating beds between 4 inches and 2 feet thick of light grey and medium or dark grey, cryptograined to fine-grained dolomites. Many beds are finely laminated and may be in part silty.

The middle member of the formation is very well bedded and includes alternating light and medium to dark grey weathering fetid dolomite in beds from 1 foot to 6 feet thick with a higher proportion of dark weathering rocks than the members above and below. The dolomite is mainly fine grained and some beds are delicately laminated. Locally dark weathering varieties contain abundant, poorly preserved rod-shaped organic remains.

The uppermost member of the Sombre Formation produces a characteristic silver-grey weathering talus. Most of the member comprises cryptograined to fine-grained, light grey dolomite.

In the Sombre Formation intraformational breccia is present locally and vugs filled with calcite are common. In places the rocks are slightly calcareous. Except for the poorly preserved fossils noted in the middle dark grey member, organic remains are rare or absent.

In northwesternmost Glacier Lake and southwesternmost Wrigley Lake map-areas (*see* Section 45, Pt. II) the upper member of the Sombre Formation comprises light buff-grey to silvery grey weathering, in part laminated, light grey dolomite interbedded in the lower part with fine-grained, buff, light and dark grey weathering, dolomitic sandstone. In this unit beds range from 1 foot to 5 feet thick and comprise about 30 per cent dolomitic sandstone and 70 per cent sandy dolomite. Overlying strata, mainly light and dark grey weathering dolomites in units 2 to 10 feet thick impart a conspicuous banding to outcrops and talus.

Strata of the Sombre Formation undergo rapid facies and thickness changes in the region of Grizzly Bear Anticline and Avalanche Syncline. At Avalanche Lake (*see* Section 44, Pt. II) and along strike to the northwest the lower, middle, and upper members of the formation are typically developed and are 1,045, 100+, and 500 feet thick respectively. On the northeast limb of Grizzly Bear Anticline (*see* Section 42, Pt. II) probably correlative strata comprise thick-bedded to very massive, locally strongly bioclastic dolomites, about 1,150 feet thick. There, the three distinct members present in the Avalanche Lake area are not apparent. On the southwest limb of Grizzly Bear Anticline (*see* Section 43, Pt. II) only 575 feet of laminated, stylolitic dolomite typical of the Sombre Formation occur. This sequence is overlain by 325 feet of black shale of the Funeral (?) Formation. Farther northwest, on the southwest limb of the anticline, the entire assemblage representing the Sombre interval consists of argillaceous, dark grey weathering strata.

Age and correlation of Sombre Formation. No useful fossils were obtained from strata of the Sombre Formation. On the basis of stratigraphic position the rocks are assumed to be of Early Devonian age.

Well-bedded, laminated dolomites underlying Middle Devonian strata are widespread not only in southern Mackenzie Mountains where they attain their greatest thickness (Douglas and Norris, 1961) but also in northern Rocky Mountains (Hughes, 1963; Taylor, 1965; Gabrielse, 1962b) and in Cassiar and Pelly Mountains (Gabrielse, 1963; Green, *et al.*, 1960a,b). Precise correlations are impossible as the rocks contain few fossils.

Arnica Formation

In Glacier Lake and Wrigley Lake map-areas the Arnica Formation (Douglas and Norris, 1961) comprises a distinctive, thick assemblage of dark grey weathering, well-bedded, fine- to medium-grained dolomite (*see* Pls. III, IV, XXXII, XXXIII). Alternating medium grey and dark grey beds, generally from 6 inches to 4 feet thick, result in conspicuous banding, particularly well displayed in Thundercloud Range.

Where typically exposed on the west side of Thundercloud Range, the Arnica Formation is about 1,500 feet thick (*see* Section 39, Pt. II). In contrast to the underlying strata of the Sombre Formation the Arnica assemblage is generally thinner bedded, darker weathering, and shows a much more conspicuous striping or banding. Many of the dolomites are laminated, and 'spaghetti-stone' consisting of rod-like, white weathering remains of fossils in dark weathering matrix is common. The rocks are locally porous and contain vugs as much as 1½ inches long and three quarters of an inch across which are lined with white weathering dolomite crystals. Intraformational breccia is abundant locally. It consists of angular fragments of dark weathering dolomite, from less than 1 inch to 6 inches long, in a white weathering dolomite matrix. Characteristically the rocks are strongly fetid.

Southeast of Dal Lake and near the south end of Tsezotene Range the Arnica Formation includes abundant dolomite breccia. In places the cement is dolomite, but in thick sequences particularly, it is commonly calcite. The rocks are porous locally although many vugs are filled with calcite.

Farther north, in Wrigley Lake area, dolomites typical of the Arnica Formation are interbedded with thick units of breccia described below in the section on the Bear Rock Formation (*see* Pl. XXXIII). Throughout this area the Arnica Formation retains its dark weathering and well-bedded characteristics which contrast with the light grey weathering and massive nature of the Bear Rock.

Southwest of Redstone Plateau the lower and commonly thinner part of the Arnica Formation is typical of the assemblage farther east. The upper part of the sequence, however, as much as 1,500 feet thick, is markedly different from that in Thundercloud Range. Much of this assemblage in the area of Grizzly Bear, Avalanche, and Broken Skull synclines is described below in the sections on the Grizzly Bear and Funeral Formations. In southwesternmost Wrigley Lake and northwesternmost Glacier Lake map-areas another distinct facies is present and is named the Natla Formation (*see* below).

In most places the Arnica Formation is structurally conformable with the underlying Sombre Formation and if an unconformity exists it is of little importance. East–southeast of Avalanche Lake, however, the Sombre Formation is truncated sharply to disappearance beneath the Arnica Formation. In Rouge Range the Sombre Formation is thin near Redstone River but the three members are clearly recognizable (*see* Pl. XXIV) and sub-Arnica truncation is not evident. Farther north the Sombre Formation loses its identity because of either depositional thinning or bevelling by pre-Arnica erosion.

Bear Rock Formation

Massive, cavernous, light grey and locally orange-buff weathering limestone and dolomite breccias that occur possibly as tongues within dark grey weathering, well-bedded dolomites of the Arnica Formation or as lateral equivalents of the entire Arnica Formation, are assigned to the Bear Rock Formation (Hume and Link, 1945). These rocks outcrop in and near Tigonankweine Syncline and generally in the northeastern quadrant of Wrigley Lake map-area (*see* Sections 26, 28, Pt. II).

In places the Bear Rock Formation forms resistant ribs 20 to 200 feet thick of blue-grey weathering breccia. The unit is commonly devoid of bedding (*see* Pl. XXXIV). The resistant breccias, typically porous and cavernous, occur as markedly lenticular units that may pinch out completely along strike.

Where the breccias trend parallel with drainage they commonly outcrop poorly because of erosion. In these areas the rocks form isolated knobs and towers not unlike weathering remnants along fault zones.

In northwesternmost Wrigley Lake area most, if not all, of the interval between the Whittaker and Nahanni Formations is occupied by the Bear Rock Formation. The rocks are mainly buff-yellow weathering, massive dolomite and limestone breccias that locally contain clasts of medium grey, porous, fine-grained dolomite, as much as 6 inches long, in a light grey to creamy white, vuggy, fine-grained dolomite matrix.

Caves and sinkholes in the Bear Rock Formation contribute locally to an unusual phenomenon noted in Tigonankweine Syncline. There, a section measured along a stream course encountered a well-cemented, resistant, reddish brown conglomerate with rounded boulders of limestone and shale ranging from 4 inches to 2 feet in diameter in a matrix of limestone breccia. The conglomerate could not be traced laterally and evidently is of recent origin having been deposited in a sinkhole in the Bear Rock Formation.

Grizzly Bear Formation

In the area just southeast of Grizzly Bear Lake a prominent, light grey weathering, cliff-forming, massive limestone and, locally, a dolomite sequence ranging from zero to about 840 feet thick, is herein named the Grizzly Bear Formation (*see* Pl. XXXV). The type section is on the northeast limb of Grizzly Bear Anticline 1½ miles northwest of Grizzly Bear Lake (*see* Section 42, Pt. II). The formation, where present, forms an excellent stratigraphic marker beneath the overlying Funeral Formation (*see* Pl. XXXV).

In the type section which is by far the thickest, the basal member, 150 feet thick, comprises very coarsely crystalline limestone and cryptograined limestone. The coarse-grained material is porous, rusty, and bright orange weathering and may be partly related to faulting. This member is recessive weathering and is overlain by about 100 feet of massive, cryptograined, resistant limestones. Upward in the section is another massive, cryptograined limestone member about 100 feet thick, containing biostromal layers of colonial tetracorals. The remainder of the sequence, about 500 feet thick, includes very coarsely crystalline, light grey weathering, black and dark grey crinoidal limestone and coarse calcarenite in beds generally from 1 foot to 4 feet thick. This unit is similar to the resistant parts of the Natla Formation described below.

About 12 miles southeast of the section described above, the Grizzly Bear Formation near the peak (elevation 8,202 feet) consists of light grey to white weathering, porous, coarse-grained dolomite about 60 feet thick. Locally, the uppermost part of the sequence consists of dark grey, platy dolomite a few feet thick. The rocks in this succession are very similar to those of the Manetoe Formation in Thundercloud Range.

In Section 44 east–southeast of Avalanche Lake, about 130 feet of light grey weathering, massive, dark grey, very fine grained limestone, in part crinoidal, is assigned to the Grizzly Bear Formation. A similar sequence on the southwest limb of Grizzly Bear Anticline is 185 feet thick and is thin to medium bedded.

Characteristic of the Grizzly Bear Formation are the rapid changes in thickness and lithology. The formation is believed to be a facies equivalent to part of the Arnica Formation (*see* Fig. 9).

Funeral Formation

The name 'Funeral Formation' was given by Douglas and Norris (1963) to a buff weathering sequence of recessive limestones and shales representing lateral equivalents of the Arnica, Landry, and Manètoe Formations in Root River and Virginia Falls map-areas. Correlative strata of the same facies outcrop in the areas of Grizzly Bear and Avalanche Lakes and in Broken Skull Syncline.

At Grizzly Bear Lake the sequence is 1,105 feet thick. A basal member, 85 feet thick, comprises very fissile, recessive, brownish grey, pinkish grey, and black weathering shale. The overlying strata are interbedded yellow-buff and brownish grey weathering black shales and argillaceous limestones. Beds are from 1 inch to 2 inches thick and typically flaggy. In the uppermost part limestones are more abundant than shales.

On the southwest limb of Grizzly Bear Anticline the Funeral Formation is approximately 1,550 feet thick and consists of relatively uniform dark grey, calcareous, locally laminated highly cleaved shale. Bedding ranges from a quarter of an inch to 2 inches thick. Most of the sequence weathers buff to orange-brown.

Near Avalanche Lake platy, strongly cleaved, buff and grey weathering limestones and calcareous shales are more than 1,000 feet thick. To the southwest, in Broken Skull Syncline, strata included with the Funeral Formation for mapping purposes include more than 1,600 feet of very distinctive buff-tan weathering, platy, shaly and silty limestone and calcareous shale (*see* Pl. XXIX). This succession facilitates the separation of Road River strata from somewhat similar dark grey weathering shales that are Middle Devonian or younger.

Natla Formation

Northwestward from Grizzly Bear Lake the typical buff weathering shaly limestones and calcareous shales of the Funeral Formation change facies into an assemblage that contains a greater ratio of carbonate and weathers sooty grey and light grey. This assemblage, named the Natla Formation, is well exposed in southeastern Wrigley Lake map-area northeast of Natla Fault and in the southeasternmost northerly trending range in the Sekwi Mountain map-area. The type section is 3 miles west of the Wrigley Lake map-area and 9 miles south of Natla River (*see* Section 48, Pt. II).

Characteristically the Natla Formation comprises a recessive, thin-bedded, sooty grey weathering sequence containing resistant light grey weathering ribs of varying number and thickness. In the type section the basal member is a resistant, light grey weathering, medium-bedded to massive, fetid, coarse-grained crinoidal limestone, 375 feet thick. This sequence is overlain by a member 340 feet thick that comprises recessive, medium- and thin-bedded, medium to dark grey weathering, dark grey, very fine grained limestone with four resistant, light grey weathering ribs of coarse-grained crinoidal limestone ranging from 20 to 75 feet thick. Some of the thicker resistant units contain interbeds of thin-bedded, very fine grained limestone. The uppermost member, 710 feet thick, consists of recessive, dark grey or sooty weathering, thin-bedded, dark grey, very fine grained, shaly, platy limestone.

Following the strata described above along trend it is evident that the crinoidal limestone ribs, although locally tabular, are discontinuous. Another section measured in northeasternmost Nahanni map-area is 1,455 feet thick and consists entirely of the recessive, thin-bedded, shaly and platy, sooty limestones interbedded with slightly more resistant, medium-bedded, fine-grained, fetid limestone (*see* Section 47, Pt. II).

A sequence similar to that in the type section is well exposed northeast of Natla Fault. There the dark weathering limestone forms relatively smooth talus slopes and ridges whereas the limestone ribs, locally very numerous, form cliffs and hoodoos.

Manetoe Formation

In this report the name 'Manetoe' (Douglas and Norris, 1963) is restricted to rocks that outcrop in Thundercloud Range. They are particularly well developed in the west-dipping stratigraphic sequence east of Thundercloud Creek.

In Section 39, east of Thundercloud Creek, where a thickness of 200 feet was measured, the dominant rock type was found to be an extremely porous, light grey to creamy white, very coarse grained dolomite (*see* Pl. XXXVI). In the lower 40 feet of the section these rocks are interbedded with dark grey, fine-grained, fetid dolomites in beds 6 inches to 2 feet thick. The unit is characteristically thick bedded to massive and includes interbeds of medium grey, dark grey to black, cryptograined limestone as much as 4 feet thick. Coarse breccia occurs locally. The contact between the Manetoe and underlying Arnica Formations is distinct but gradational.

Landry Formation

Poorly fossiliferous, medium-bedded, cryptograined, light grey and medium grey weathering limestone of the Landry Formation (Douglas and Norris, 1963) overlies the Manetoe Formation in Thundercloud Range, the Arnica and Bear Rock Formations in eastern and northern Wrigley Lake map-areas, and the Natla Formation in southwestern Wrigley Lake map-area. The Landry Formation is absent in the region near Grizzly Bear Lake where homotaxial strata are probably included in the upper part of the Funeral Formation (*see* Fig. 9).

In the Thundercloud section (*see* Section 39, Pt. II), the Landry Formation comprises about 500 feet of well-bedded, blocky, light grey weathering, cryptograined, grey limestone in beds 1 foot to 5 feet thick. In places the grey limestone is mottled with an approximately

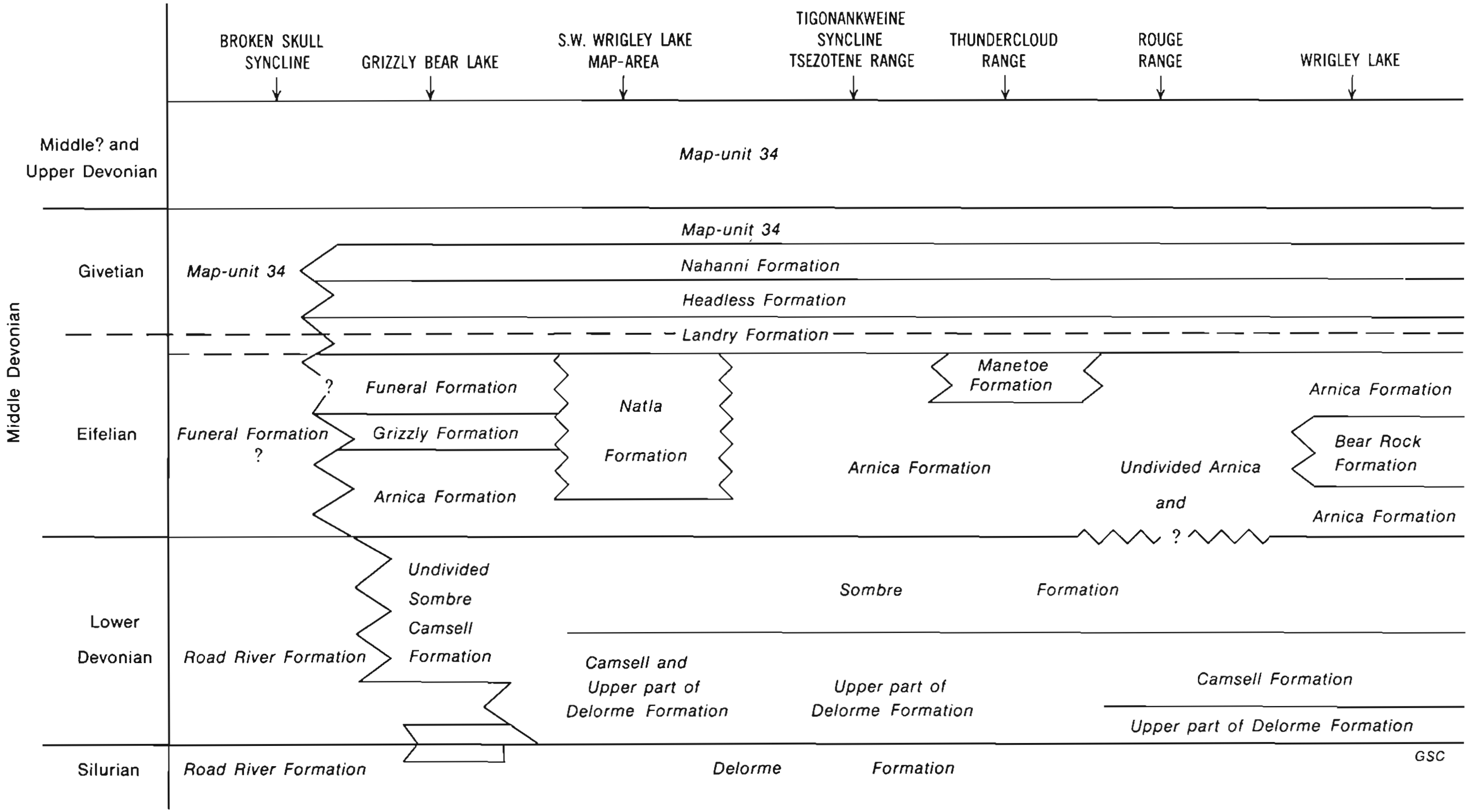

FIGURE 9. Correlation of Devonian formations. (Note: unit 34 is the slaty shale unit of the text.)

equal amount of medium to dark grey dolomite. In the upper half of the section some of the beds are platy and in places, laminated. Orange-brown weathering, black, fine-grained limestone, in beds a foot thick, is also present in the upper part of the assemblage.

In Wrigley Lake map-area alternations of light grey weathering and buff grey weathering beds impart a distinctive banded appearance to the rocks (*see* Pl. XXXVII). In Section 29, on the northeast flank of Rouge Range, the Landry Formation is 585 feet thick. The lower part of the sequence includes platy, light grey and brownish grey weathering, cryptograined, slightly dolomitic limestone in beds 2 inches to 1½ feet thick. Some beds are finely laminated. Bedding is accentuated by slight differences in resistance of light grey weathering limestones and more recessive, locally buff-brown weathering limestones.

The Landry Formation is only 75 feet thick in Tigonankweine Syncline and comprises an assemblage of dark grey, cryptograined to fine-grained limestones weathering light yellow-brown.

In southwestern Wrigley Lake map-area and adjacent parts of Sekwi Mountain and Nahanni map-areas strata assigned to the Landry Formation range from about 500 to 1,600 feet thick. The boundary between these rocks and the underlying Natla Formation is drawn at the top of the highest sooty, recessive, member of the latter. It is probable that correlative strata may be included in the Landry Formation in one place and in the Natla in another (*see* Fig. 9).

In southeastern Sekwi Mountain map-area about 1,600 feet of limestone is assigned to the Landry Formation. A lower member, about 1,300 feet thick, consists of resistant, light to dark grey weathering, medium-bedded, fine-grained limestone, in part crinoidal. These rocks are overlain by 285 feet of blocky, light grey and slightly brownish weathering, medium to dark grey, medium- to coarse-grained limestone.

In northeasternmost Nahanni map-area near the boundary with Glacier Lake map-area the basal member, 185 feet thick, comprises very resistant, light grey weathering, reefoid, fetid, well-bedded to massive, medium- to coarse-grained limestone, in part cherty and locally laminated. The overlying strata, about 1,100 feet thick, consist essentially of banded, thin- and thick-bedded, partly crinoidal, light grey weathering, fine-grained limestone. These rocks grade southeasterly into strata typical of the Funeral Formation and are included in that formation for mapping purposes.

Age and correlation of Arnica, Bear Rock, Landry, Manetoe, Grizzly Bear, Funeral, and Natla Formations. In general the formations, where exposed in the eastern and northern parts of the report area, are poorly fossiliferous and correlations are made mainly on observed facies changes or relative stratigraphic position (*see* Fig. 9). Southwest of Redstone Plateau, however, where limestone is the dominant lithology, fossils are more abundant.

The following fossil collections were assessed by A. W. Norris:

Two miles south of North Nahanni River in westernmost Root River map-area. Strata of Landry (?) Formation — GSC loc. 58542

Alveolites sp.
Coenites sp.
Atrypa sp.
Spinatrypa sp.
Plectospirifer? sp.
Gasterocoma? *bicaula* Johnson and Lane

Late Eifelian

62°27'N, 127°39'W, Glacier Lake map-area; 8 miles east and slightly north of sharp bend in South Nahanni River.

Funeral Formation (?) GSC loc. 58612

Styliolina sp.
Michelinoceras sp.
goniatites?

probably Middle Devonian

Section 42. Northwest of Grizzly Bear Lake; Grizzly Bear Formation 150–250 feet above base. GSC loc. 58567

Loyolophyllum cf. *L. creswelli* Chapman
**Hexagonaria* sp. F?
**Hexagonaria* sp. M
**Hexagonaria* sp. N
Hexagonaria sp.
Grypophyllum cf. *G. vermiculare* (Goldfuss)
Atrypa perfimibriata Crickmay
Gasterocoma? *bicaula* Johnson and Lane

Late Eifelian (?)

Section 42. Basal beds of Funeral Formation
Northwest of Grizzly Bear Lake. GSC locs. 58568, 58577, 58569

Coenites sp.—large form
Gasterocoma? *bicaula* Johnson and Lane?
Michelinoceras sp.
Styliolina sp.

Late Eifelian

Section 47. In northeasternmost Nahanni map-area; 62°57'N, 128°03'W.

550 feet above base of Natla Formation GSC loc. 69102

Favosites sp.
echinoderm ossicle with single axial canal
Gasterocoma? *bicaula* Johnson and Lane

Late Eifelian

75 feet below top of Natla Formation GSC loc. 69103

Schizophoria sp.
Atrypa sp. cf. *A. aperanta* Crickmay
"*Camarotoechia*" sp.
loosely coiled gastropod
Leptodesma sp.
fenestellid? bryozoan
Dechenella (*Dechenella*) sp.
echinoderm ossicle with single axial canal

Late Eifelian or Early Givetian

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*Species designated by letters of the alphabet are consistent with the classification employed in the Geological Survey index collection of Devonian fossils.

56 feet below top of Natla Formation GSC loc. 69109

ptenophyllid cup corals
Warrenella sp.
planispiral gastropod
trilobite fragments
echinoderm ossicle with single axial canal

Late Eifelian or Early Givetian

25 feet above base of Landry Formation GSC loc. 69107

Favosites spp.
Hexagonaria sp.
colonial corals
large cup coral
Atrypa sp.—m. costate, broad, thin form
Spinatrypa sp.
large annulated echinoderm ossicle with single axial canal

Late Eifelian or Early Givetian

150 feet above base of Landry Formation GSC loc. 69110

Favosites sp.
Cystiphylloides fragment

Late Eifelian or Early Givetian

Section 46. In northeasternmost Nahanni map-area, 62°55½′N, 128°05′W.

Base of Landry Formation GSC loc. 69047

Favosites sp.
cup coral
Schuchertella sp.
Atrypa sp. cf. *A. aperanta* Crickmay
Spinatrypa sp.
pelecypod
Bactrites? sp.
proetid pygidia

Late Eifelian or Early Givetian

350 feet above base of Landry Formation GSC loc. 69048

Atrypa sp. cf. *A. arctica* Warren
Atrypa sp. cf. *A. aperanta* Crickmay
Spinatyrpa sp.

Late Eifelian or Early Givetian

Section 48. In southeastern Sekwi Mountain map-area; 63°14′N, 128°06′W.

150 feet above base of Landry Formation GSC loc. 69042

Coenites sp.
Favosites sp.
Syringopora sp.
Utaratuia sp.

Late Eifelian or Early Givetian

1,140 feet above base of Landry Formation GSC loc. 69044

Alveolites sp.
Favosites sp.
Spinulicosta stainbrooki Crickmay
Schuchertella? sp.—finely costate
Spinatrypa sp.
bryozoan
fragment of very large cephalopod
trilobite pygidia
echinoderm ossicle with single axial canal

Late Eifelian or Early Givetian

Strata of the Arnica and lower parts of the Funeral and Natla Formations contain an echinoderm ossicle with double axial canals which was recently named *Gasterocoma*? *bicaula* Johnson and Lane. A. W. Norris stated that in northern Yukon this fossil occurs most commonly in the lower part of the Ogilvie Formation, in the middle part of the Prongs Creek Formation, and in the Cranswick Formation (*see* Norris, 1968). He further stated that "It occurs in beds older than the Hume Formation and younger than beds containing *Moelleritia canadensis* Copeland." He pointed out that although this form occurs most abundantly in beds of late to mid-Eifelian age (late Lower Middle Devonian) it ranges down sparingly into beds of late Emsian (late Lower Devonian) age. The collection from the Grizzly Bear Formation, GSC loc. 58567, is probably also of late Eifelian age. D. J. McLaren comments on this fauna: "The fauna . . . is remarkable and new. *Loyolophyllum* has previously only been recorded from the type locality—the Lower Devonian of Victoria, Australia. The species here is very close to and almost indistinguishable from the type species. *Grypophyllum* has hitherto been reported only from rocks of late Eifelian and Givetian age. The *Hexagonaria* sp. F? resembles a form collected by Wheeler from the Quiet Lake map-area, associated with *Stringocephalus* and therefore of Givetian age. It is, however, not identical and no conclusion can be drawn from it, as *Hexagonaria* is very common in all horizons in the Lower and Middle Devonian of northwestern Canada. The two other species, *H.* sp. M and N, are new."

The Landry Formation and upper part of the Natla Formation yield faunas of late Eifelian or early Givetian age. It is possible therefore that strata occupying the stratigraphic interval between the Sombre and Headless Formations in southern Mackenzie Mountains may range in age from late Eifelian to early Givetian.

Strata correlative with those described above outcrop in northern Rocky Mountains (Hughes, 1963; Taylor, 1965; Gabrielse, 1962b) but are much less varied in lithology than those in Mackenzie Mountains. Correlation with Middle Devonian strata in the Cassiar Mountains (Gabrielse, 1963) is uncertain. The fossiliferous Middle Devonian strata in the Cassiar Mountains and possibly in Pelly Mountains (Green, *et al.*, 1960a, b) unconformably overlie older strata and may be generally younger than most of the rocks described above. In McDame map-area in Cassiar Mountains (Gabrielse, 1963) dolomite breccias similar to those of the Bear Rock Formation locally underlie fossiliferous rocks probably of the same age as the Nahanni Formation.

Headless Formation

Buff-brown weathering, thin-bedded, fine-grained, argillaceous limestones of the Headless Formation (Douglas and Norris, 1961) outcrop throughout southern Mackenzie Mountains and generally form a recessive interval between the more resistant Landry Formation below and Nahanni Formation above. In Glacier Lake map-area southwest of Redstone Plateau the Headless strata are more thickly bedded and slightly more resistant than those of the underlying Funeral Formation.

The Headless Formation is by far the most fossiliferous formation in the report area and an extremely well preserved and varied fauna can be obtained almost anywhere the rocks are exposed. In contrast to the underlying Middle Devonian formations the Headless is of fairly uniform lithology throughout the region.

In Section 39, in Thundercloud Range, basal beds of the Headless Formation are buff-brown weathering, fine-grained, nodular, argillaceous limestones. Beds range from an inch to a foot thick. Relatively resistant units are silty and in some places lenses and pods of dark grey limestone are enclosed in silt. Higher in the section many beds are roughly platy and weather buff-brown, grey, and orange-buff. A resistant, well-bedded member of dark grey, crypto-grained to fine-grained limestone 190 feet thick is separated from the overlying Nahanni Formation by 195 feet of platy, recessive, argillaceous limestone. The Headless Formation in Thundercloud Range is 990 feet thick.

Elsewhere the Headless Formation is similar to that in Thundercloud Range although thicknesses are generally less and vary considerably. For instance, in Tigonankweine Syncline the rocks are only 265 feet thick in each of two measured sections.

Near Grizzly Bear Lake the Headless Formation includes a prominent resistant member in the upper part almost identical with that noted in the upper part of the section in Thundercloud Range. Farther south in Broken Skull Syncline homotaxial strata are either dark grey shales or are included in the upper part of an assemblage mapped as Funeral Formation (*see* Pl. XXXIX).

Age and correlation of Headless Formation. A. W. Norris identified the fossils listed below, except for corals which were examined by D. J. McLaren.

Section 39. Northwestern Thundercloud Range, 62°42 ½'N, 126°29'W.

190 feet above base of Headless Formation — GSC loc. 58663

Atrypa sp.
Actinopteria sp.
echinoderm ossicles with single axial canals

275 feet above base — GSC loc. 58665

Microcyclas kirbyi (Meek)
Schuchertella adoceta Crickmay
Spinulicosta stainbrooki Crickmay
Atrypa sp.—med. costate
Spinatrypa coriacea Crickmay

380 feet above base — GSC loc. 58666

Coenites sp.
Favosites sp.
'*Phillipsastrea*' sp.
Spinatrypa? sp.
Michelinoceras sp.
Actinopteria? sp.
echinoderm ossicles with single axial canals

550 feet above base — GSC. loc. 58664

Emanuella meristoides (Meek)
undetermined plecypod
trilobite tail fragment
echinoderm ossicles with single axial canals

585 feet above base — GSC loc. 58667

Coenties sp.
Favosites sp.
'*Phillipsastrea*' sp.
Syringopora? sp.
Atrypa cf. *A. arctica* Warren
Atrypa cf. *A. aperanta* Crickmay
Carinatina dysmorphostrota (Crickmay)
echinoderm ossicles with single axial canals

775 feet above base — GSC loc. 58672

Alveolites sp.
Coenites sp.
Favosites sp.
'*Phillipsastrea*' sp.
Atrypa aperanta Crickmay
Spinatrypa? n. sp.
Spinatrypa sp.
Plectospirifer sp.
echinoderm ossicles with single and star-shaped axial canals

Section 34. East of Redstone River, 63°02′N, 126°22′W.
382 feet above base of Headless Formation — GSC loc. 58731

Schuchertella adoceta Crickmay
Spinulicosta sp.
Actinopteria? sp.
proetid tail
echinoderm ossicles with single axial canals

564 feet above base — GSC loc. 58735

Alveolites sp.
auloporid
digonophyllid?
Favosites sp.
'*Phillipsastrea*' sp.

634–640 feet above base — GSC loc. 58738

Emanuella sp.
proetid? tail
echinoderm ossicles with single axial canals

677–685 feet above base — GSC loc. 58736

Favosites sp.
Spinulicosta stainbrooki Crickmay
Atrypa sp. cf. *A. arctica* Warren
proetid tail

770–775 feet above base — GSC loc. 58729

stromatoporoid
'*Pseudomicroplasma*' sp.
Favosites sp.
Hexagonaria atypica Crickmay?
Atrypa aperanta Crickmay
Spinulicosta sp. cf. *S. stainbrooki* Crickmay
Paracyclas? sp.
Charophyta

850 feet above base of Headless Formation — GSC loc. 58732

Aulophyllum? *richardsoni* Meek
Spinulicosta stainbrooki Crickmay
Atrypa sp. cf. *A. arctica* Warren
Carinatina? sp.
Spinatrypa coriacea Crickmay
Paelaeoneilo? sp.
Paracyclas? sp.

863 feet above base-top of Headless Formation — GSC loc. 58737

Favosites sp.
Spinulicosta stainbrooki Crickmay
Atrypa sp. cf. *A. arctica* Warren
trilobite tail
large echinoderm ossicles with single axial canals

Section 33. Five miles NE of Dal Lake, 63° 11 ½'N, 126°26W.

Basal beds of Headless Formation — GSC loc. 58762

Spinatrypa sp. cf. *S. andersonensis* (Warren)

4 feet above base — GSC loc. 58758

Spinatrypa coriacea Crickmay

381 feet above base — GSC loc. 58760

Atrypa aperanta Crickmay

409 feet above base — GSC loc. 58761

Microcyclas kirbyi (Meek)
echinoderm ossicles with single axial canals

414 feet above base — GSC loc. 58763

Schuchertella adoceta Crickmay

424 feet above base — GSC loc. 58765

Microcyclas kirbyi (Meek)
Schuchertella adoceta Crickmay
Nucleospira? sp.

Section 29. East flank of Rouge Range; 63°02'N, 128°12'W.

655–670 feet above base of Headless Formation — GSC loc. 69106

Digonophyllum rectum (Meek)
Favosites sp.
Schuchertella adoceta (Crickmay)
Spinulicosta stainbrooki Crickmay
Atrypa n. sp.
Spinatrypa sp. cf. *S. andersonensis* (Warren)
Emanuella meristoides (Meek)
bryozoa

Section 35. 62°58½'N, 126°42'W; west of South Redstone River.

110 feet above base of Headless Formation — GSC loc. 58622

Tentaculites sp.
Cornellites sp.
charophyta-*Trochiliscus* sp.

Section 48. Southeast Sekwi Mountain map-area; 63°13′N, 128°08′W.

Basal beds of Headless Formation — GSC loc. 69050

Spinulicosta stainbrooki Crickmay
Schuchertella sp.
Spinatrypa sp.
Spinatrypa lata (Warren)
Emanuella? sp.
Athyris? sp.
dechenellid tail

Section 47. Northeasternmost Nahanni map-area; 62°57′N, 128°03′W.

45 feet above base of Headless Formation — GSC loc. 69105

Favosites sp.
Spinatrypa sp. cf. *S. lata* (Warren)
dechenellid tail

170 feet above base — GSC loc. 69108

Coenites sp.
Digonophyllum rectum (Meek)
large planispiral gastropod
Atrypa n. sp.
Spinatrypa borealis (Warren)
Warrenella franklini (Meek)
stromatoporoid

Section 46. Northeasternmost Nahanni map-area. 62°55½′N, 128°04′W.

50 feet above base of Landry and/or Headless Formation — GSC loc. 69046

Trachypora sp.
cup coral
Spinulicosta stainbrooki Crickmay
Schuchertella sp.
Schizophoria sp.
echinoderm ossicle with single axial canal
Dechenella (*Dechenella*) sp.

235 feet above base of Landry and/or Headless Formation — GSC loc. 69049

Schuchertella adoceta Crickmay
Atrypa n. sp.
trilobite fragment

Section 42. One mile northwest of Grizzly Bear Lake.

105–107 feet above base of Headless Formation — GSC loc. 58570

Spinatrypa sp.
bryozoan
pelecypod
echinoderm ossicles with five-lobed; star-shaped axial canal

247–250 feet above base — GSC loc. 58571

Alveolites? sp.
Favosites sp.
undetermined coarsely costate brachiopod fragment

ostracods
Billingsastraea sp.
Mesophyllum (*Zonodigonophyllum*) sp.

300 feet above base GSC loc. 58572
Favosites sp.

449–454 feet above base GSC locs. 58573, 58574
Emanuella sp.
Dechenella sp.—tails
ostracods

740–742 feet above base GSC loc. 58575
Orbiculoidea sp.
Nervostrophia sp.
Atrypa perfimbriata Crickmay
Dechenella (*Dechenella*) sp.

Section 43. 62°31′N, 127°45′W
235 feet above base of Headless Formation GSC loc. 69061
Coenites sp.
Digonophyllum rectum (Meek)
Syringopora sp.
Atrypa sp. cf. *A. arctica* Warren

D. J. McLaren notes that the *Billingsastraea* sp. from GSC loc. 58571 suggests a Middle Devonian age and that the genus is common in the Hume (*see* Bassett, 1961) and Nahanni Formations of Mackenzie Mountains. He comments further that, "The species I am calling *Hexagonaria atypica* from GSC loc. 58729 is widespread in the Nahanni Formation of the Nahanni Range and may occur also in the Headless. It may belong to an entirely different group from true *Hexagonaria* possibly related to *Grypophyllum*."

A. W. Norris comments that the faunas in general are typical of the Hume Formation of the central Mackenzie region which is tentatively dated as early late Middle Devonian (early Givetian).

Nahanni Formation

The Nahanni Formation (Hage, 1945; Douglas and Norris, 1960, 1961) is the youngest prominent carbonate formation in the report area. It comprises resistant, grey weathering, well-bedded, fine- to medium-grained limestones that commonly form flatirons on the sides of synclinal valleys underlain by shales of the overlying black shale unit (*see* Pl. XXXVIII). In this report the name 'Nahanni' is restricted to the uppermost resistant weathering unit of Middle Devonian carbonates. These rocks grade into the underlying Headless Formation and the boundary is drawn at the top of the highest platy, slightly recessive, argillaceous, buff weathering limestones of the Headless.

The Nahanni Formation persists with remarkably consistent character and general thickness throughout the northern part of Glacier Lake and most of Wrigley Lake map-areas. West of Broken Skull River the strata thin southeasterly along the outcrops and appear to be replaced by argillaceous limestones and black shale.

In northwestern Thundercloud Range the Nahanni Formation is about 200 feet thick and comprises light grey weathering, blocky and cliff-forming, fine-grained, black limestone in beds ranging from 1 foot to 5 feet thick. Fossils are not so abundant as in the underlying Headless Formation and are much more difficult to obtain because of the massive character of the rock.

Northwest of Grizzly Bear Lake the Nahanni Formation includes minor recessive units of dark grey, shaly limestone. Also present are minor beds of brown, laminated, silty limestone. In general, however, the formation in this area forms a distinct resistant light grey weathering rib.

Age and correlation of Nahanni Formation. The following fossil collections were made by B. S. Norford and identified by A. W. Norris:

Five miles north of Hayhook Lake, 63°35′N, 126°47′W.

79–97 feet above base of Nahanni Formation — GSC loc. 69813

Alveolites sp.
Coenites sp.
Favosites sp.
Syringopora sp.
Billingsastraea? sp.

138–172 feet above base — GSC loc. 69815

Alveolites sp.
Coenites sp.
Favosites sp.
Billingastraea sp.
Spinatrypa sp.

172–174 feet above base — GSC loc. 69814

Devonoproductus sp.
Atrypa arctica Warren
Spinatrypa borealis (Warren)
Carinatina dysmorphostrota (Crickmay)
Emanuella meristoides (Meek)

The following collections were identified by A. W. Norris and D. J. McLaren (corals):

Section 34. East of Redstone River, 63°02′N, 126°22′W.

53–54 feet above base of Nahanni Formation — GSC loc. 58739

Atrypa sp. cf. *A. aperanta* Crickmay
Emanuella? sp.

165–175 feet above base — GSC loc. 58728

Favosites sp.
Spongophyllum sp. A
Gypidula sp.

Section 39. Six miles east–southeast of south end of Little Dal Lake; 62°42 ½′N, 126°29′W.

About 60 feet above base of Nahanni Formation — GSC loc. 58671

Longispina? sp.
Spinulicosta? sp.
Atrypa sp.
Spinatrypa sp.
Paracyclas? sp.
Leiorhynchus awokanak McLaren

Two miles west of Dal Lake; 63°05′ ½′N, 126°35′W.

27–29 feet above base of Nahanni Formation — GSC loc. 58551

Spongophyllum sp. A

D. J. McLaren commented that "*Spongophyllum* sp. A, a massive 'organ-pipe' compound coral with corallites 10–15 mm diameter, is very common in the upper part of the Hume and Nahanni Formations."

A. W. Norris stated that most of the brachiopods are present also in the upper part of the Hume Formation of the central Mackenzie region, which is tentatively dated as late Middle Devonian (Givetian). *Leiorhynchus awokanak* McLaren in GSC loc. 58671 is a form elsewhere commonly associated with *Stringocephalus* in beds younger than the Hume Formation, and definitely indicates a late Middle Devonian (Givetian) age.

It is apparent that a direct lithologic and faunal correlation can be made between the combined Headless and Nahanni Formations and the Hume Formation. The Nahanni correlates with the resistant, massive upper member of the Hume, and the Headless correlates with the less resistant lower part of the Hume (J. D. Aitken, pers. com., 1970).

Middle Devonian carbonate strata are found throughout southern Mackenzie and northern Rocky Mountains and at least partly correlative sequences occur in Cassiar and Pelly Mountains. Between these two regions data are meagre but the Middle Devonian is probably represented by shales in much of Selwyn Basin. An area extending northwesterly from central Watson Lake map-area (Gabrielse, 1967b) through southeastern-central and northwestern Frances Lake map-area (Blusson, 1966) and into northeastern Finlayson Lake and southern Finlayson Lake map-areas (Green, *et al.*, 1960b; Roddick and Green, 1961a,b), however, includes Middle Devonian carbonates.

Devonian and (?) Mississippian

Slaty Shale Unit

In southern Mackenzie Mountains the Nahanni Formation is in sharp but apparently conformable contact with overlying recessive, thin-bedded, pyritic, slaty shales and minor interbedded black, argillaceous limestone and black chert (*see* Pl XXXIX). Only where the Nahanni or Funeral Formation is present can these rocks be readily separated from those of the Road River Formation.

The lower part of the unit is very fine grained, black, phyllitic, fissile, or platy shale and calcareous shale, locally interbedded with finer-grained black limestone. The limestones occur only in the lowermost part of the assemblage. Overlying strata are commonly dark grey to greenish grey shales grading upward from calcareous to noncalcareous. In places black, noncalcareous shales display a phyllitic sheen and these beds are distinctly fissile. In Broken Skull Syncline the argillaceous rocks are well cleaved at angles to the bedding, which is revealed by alternating medium and dark grey weathering bands as much as quarter of an inch thick.

In southeastern Flat River map-area a thick section of noncalcareous slate and argillite overlies the graptolitic Road River Formation. The rocks are fairly well bedded but, at least locally, badly contorted—possibly because of a fault or faults trending along or near Caribou River.

About 3 miles south–southwest of the mouth of Diamond Creek near Caribou River black slate is interbedded, in places, with reddish weathering, grey, slaty siltstone that contains plant impressions and small tentaculitids. The slate is noncalcareous and graphitic with beds 2 to 10 inches thick.

Dark grey, fossiliferous mudstone in the footwall of a thrust fault on the west side of Thundercloud Creek shows well-developed cone-in-cone structure. This structure is best developed, however, in argillaceous strata northeast of Tigonankweine Fault.

The best-exposed rocks of this unit, more than 1,700 feet thick, outcrop between Tigonankweine and Nainlin Faults (*see* Section 49, Pt. II). The lower part of the assemblage, more than 500 feet thick, is more recessively weathering than the upper and comprises indistinctly bedded, steel-grey or blue-grey weathering fissile shales with a few more competent beds of siltstone. The dark grey weathering beds grade upward into grey and grey-brown weathering, very fissile, green-grey shales. Locally the shales contain concretions of calcareous mudstone as much as 10 inches in diameter and 4 inches thick that display cone-in-cone structure. Beds are from a quarter to half an inch thick. The upper part of the shale sequence is slightly more resistant and contains platy siltstone beds from quarter of an inch to 2 inches thick.

Very fine to fine-grained greenish grey siltstones that weather reddish brown and maroon overlie the shales. These rocks are relatively resistant and well-defined beds range from an inch to a foot thick. The upper part of the resistant sequence, which has an aggregate thickness of about 475 feet, comprises platy and flaggy, dull maroon and dull olive green weathering siltstone and fine-grained, slightly micaceous sandstone (*see* Pl. XL). Greenish grey silty shale is fairly abundant in the upper part of this sequence.

Overlying the siltstone unit is a distinctive, buff to yellow-brown bed of coquinoid limestone as much as 10 feet thick. This member, containing abundant brachiopod fragments, is locally an excellent marker horizon.

The uppermost part of the unit, between Tigonankweine and Nainlin faults, consists of as much as 600 feet of green-grey, silty shales with interbeds of maroon and green weathering, calcareous, locally laminated siltstones in beds from 4 inches to 2 feet thick. A few brown weathering limestone beds are present in the sequence and these are highly fossiliferous.

Age and correlation of slaty shale unit. The collections listed below were examined by A. W. Norris.

Section 49. East of Tigonankweine Fault; 63°47'N, 126°43'W.

905 feet above exposed base of map-unit 34 — GSC loc. 68976

small cup coral
Chonetes sp.
productellid
Grünewaldtia sp.
Cyrtospirifer sp.
Theodossia? sp.
Multiconus sp.
Nowakia? sp.
Tentaculites sp.

905 feet above base — GSC loc. 69031

Chonetes 2 spp.
large productellid
Grünewaldtia sp.
Cyrtospirifer sp.
Theodossia sp.
Sinotectirostrum? sp.
Tentaculites sp.

905 feet above base — GSC loc. 69054

Acanthatia sp.
Sinotectirostrum? sp.
leiorhynchid
Cyrtospirifer sp.

975 feet above base GSC loc. 69028

productellid
Cyrtospirifer sp.
Sinotectirostrum sp.

1,285 feet above base GSC loc. 69101

Sinotectirostrum. sp.
Cyrtospirifer sp.

1,265 feet above base—this part of composite section measured at 63°46′N, 126°47′W GSC loc. 69026

Leiopteria sp.
Cyrtospirifer sp. (probably Famennian form)

1,470 feet above base GSC loc. 69029

Sinotectirostrum? sp.
Cyrtospirifer sp.

Plant impressions were noted in talus near GSC loc. 69029.

The following spot collection was made from strata included in the Road River Formation and was examined by A. W. Norris:

61°10½′N, 126°11′W; elevation 2,800 feet on north-trending tributary of Caribou River GSC loc. 58553

Coleolus? sp.
Tentaculites sp.
plant stem impressions

Argillaceous strata of this unit in the footwall of a fault on the west side of Thundercloud Creek contain *Cyrtospirifer* sp. cf. *C. nahanniensis*. These fossils were collected by J. Coates and identified by D. J. McLaren.

A. W. Norris commented that some of the fossils in collection GSC locs. 68976, 69013, and 69054, including *Grünewaldtia* sp., *Cyrtospirifer* sp., and *Theodossia* sp., occur in the Jean Marie Member of the Redknife Formation of the Great Slave Lake area which is dated as early Upper Devonian (late Frasnian). He also noted that the criconarid *Multiconus* sp. has been recorded from beds of late middle Frasnian age in Russia. The remaining collections from Section 44 are probably of early Famennian age according to Norris.

Basal beds of the unit are apparently conformable with those of the underlying Nahanni Formation and thus could be in part of late Middle Devonian age. Without faunal evidence, however, it is impossible to assign with assurance the same age to all basal beds of the unit. To the north and northeast in the central Mackenzie River region a regional unconformity occurs at the base of Frasnian black shales of the Canol Formation and, in places beneath the unconformity, Givetian shales of the Hare Indian Formation have been removed (Bassett, 1961). A similar situation could exist in the northern part of the region covered by Operation Nahanni. On the other hand, the remarkable continuity of the Nahanni Formation indicates that no significant regional unconformity exists beneath the black shales in this part of Mackenzie Mountains. To the east in Dahadinni map-area, Douglas and Norris (1963) referred the basal shales to the Givetian Horn River Formation, although no fossils were obtained. If Mississippian strata are present they are probably restricted to the area near Caribou River.

The upper part of this map-unit, as described in Section 49, can be traced northerly into the widespread Imperial Formation (J. D. Aitken, pers. com., 1970).

Fine-grained argillaceous rocks of late Devonian and Mississippian age are widespread in southern Mackenzie and northern Rocky Mountains (Douglas and Norris, 1959, 1960, 1961, 1963; Gabrielse, 1962a; Taylor, 1963, 1965; Hughes, 1963). Farther west, thick sequences of argillaceous rocks, sandstones, and chert-pebble conglomerates in Pelly and Cassiar Mountains are probably, at least in part, of the same age (Green, *et al.*, 1960a, b; Roddick and Green, 1961a, b; Poole, *et al.*, 1960; Gabrielse, 1963).

Cretaceous (?)

Granitic Intrusives

Granitic intrusives underlie at least 25 per cent of Flat River map-area and a large part of the Ragged Range in southwestern Glacier Lake map-area (*see* Pl. XLI). Although a wide variety of rock-types ranging from diorite to granite occur, no attempt was made at systematic mapping or sampling and the character of the bodies is known only in a general way. Except in the Hole in the Wall area where considerable detail was obtained by E. F. Roots, and in the northwest corner of Flat River map-area, ground traversing over granitic terrain totalled less than 10 miles, the data being essentially spot observations at sampling localities. Contacts were readily mapped from the air. For reference purposes the large pluton northeast of Flat River has been named 'Hole in the Wall Batholith' and the large body southwest of Flat River the 'Coal River Batholith.'

The uniform character of the granitic plutons suggests that all have a similar origin and mode of emplacement and are part of the same intrusive episode, dated by potassium–argon methods as about Middle Cretaceous.

The dominant lithology is grey, medium-grained, massive, hypidiomorphic biotite–quartz monzonite, characterized in many areas by an abundance of potash feldspar megacrysts. Less common varieties include rocks richer in pink feldspar, leucocratic types, and locally, especially near margins of plutons, rocks richer in plagioclase and mafic minerals, principally hornblende, and low in quartz. Inclusions are rare but widely distributed. Especially striking in the Hole-in-the-Wall area are clots and lenses of quartz and black tourmaline, with or without cream feldspar. Roots reported that these clots are mostly uniformly spaced and tend to be oriented where the megacrysts are oriented or . . . "form streams or zones as if developed from inclusions or a contaminated zone." More commonly inclusions are dioritic and gabbroic in composition, or various mixtures of fine-grained plagioclase and hornblende. The largest inclusions noted were about 1½ feet across. Some inclusions have potash feldspar megacrysts as in the surrounding granitic rock. Dykes of aplite and alaskite were noted in a few places.

Figure 10 shows the distribution of individual intrusions and locations of specimens obtained primarily during spot observations. Modal data (*see* Table II) were obtained for all specimens by point counting on either stained sawn surfaces or thin sections. As shown in Figure 11 by far the most abundant lithology is quartz monzonite grading to granodiorite. Granite, quartz diorite, and quartz-poor lithologies are rare. Determination of plagioclase was made on three grains from each of thirty specimens by means of a three-axes universal stage. From these limited data no correlation of lithology and plagioclase composition was apparent, other than a tendency for plagioclase of granodiorite specimens to have a higher anorthite percentage than all other rock-types.

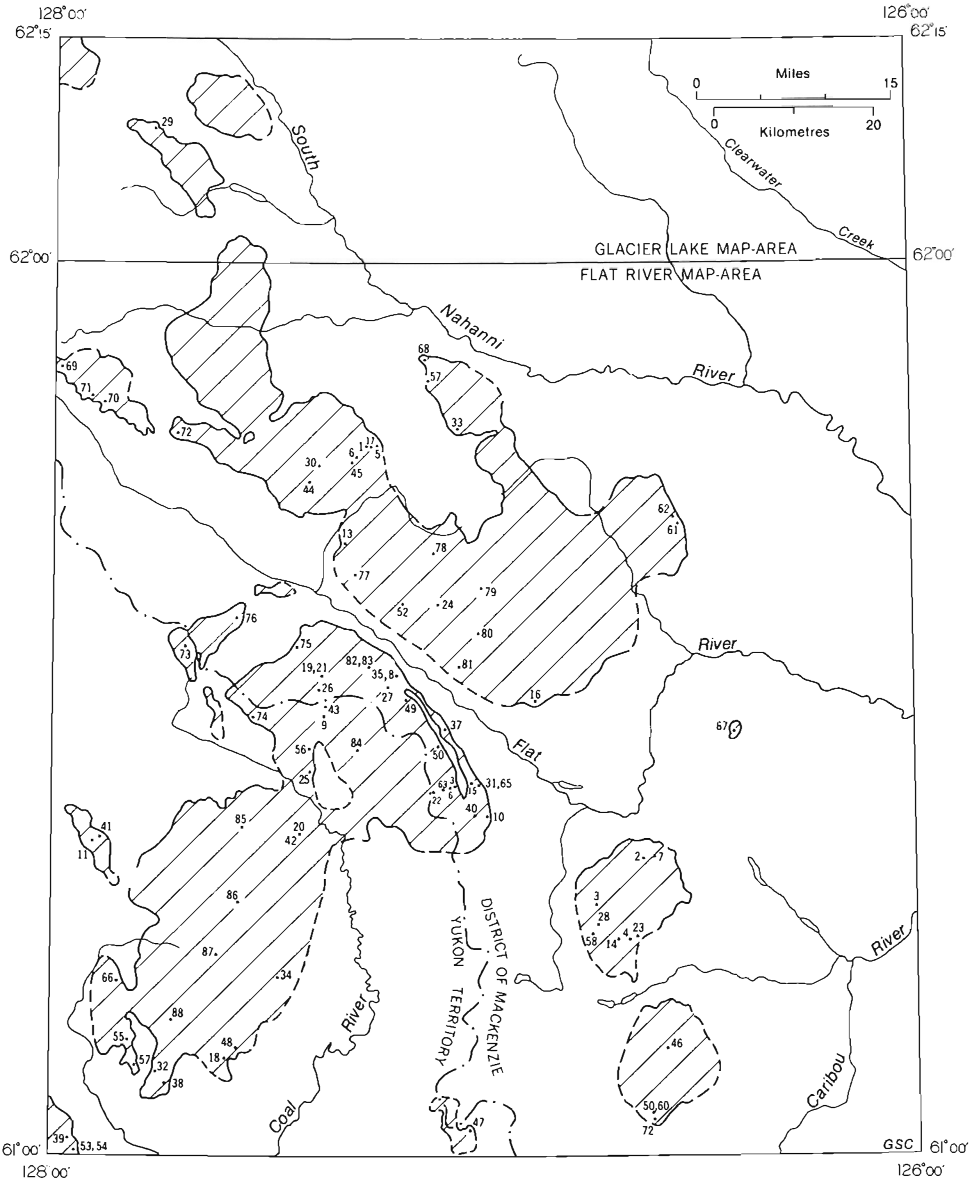

FIGURE 10. Map showing location of granitic bodies and samples used for modal analyses.

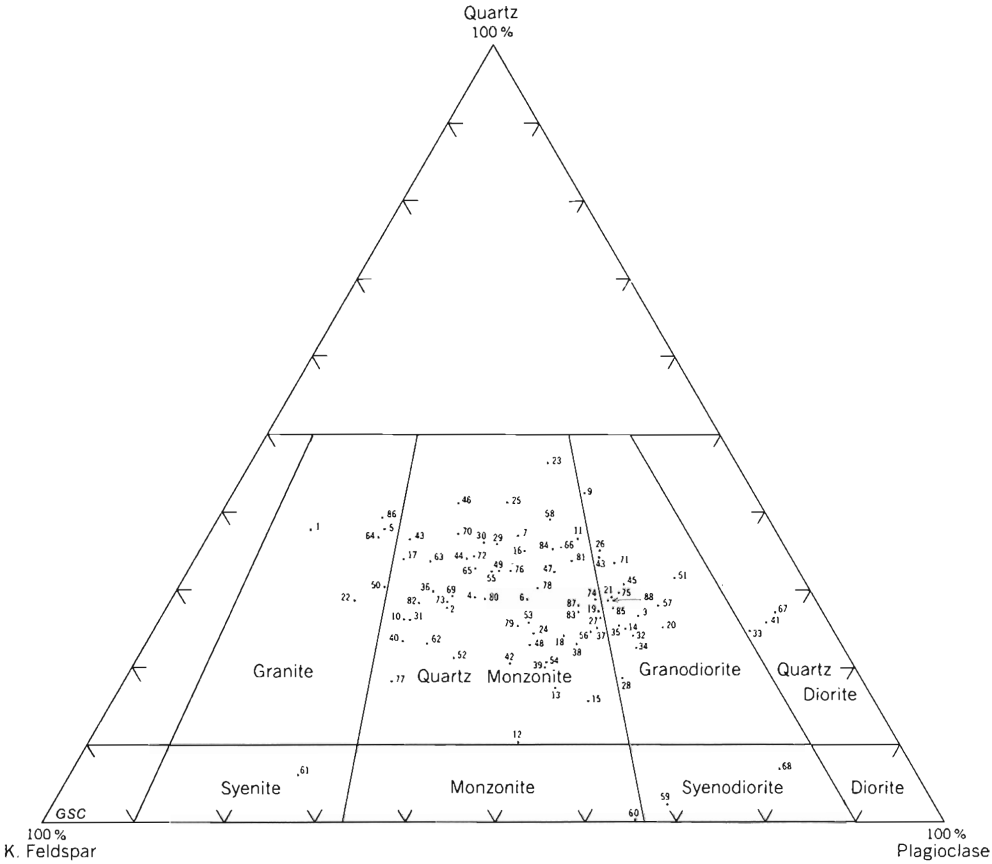

FIGURE 11. Modal analyses of granitic rocks, Operation Nahanni.

TABLE II — *Mineralogical compositions of granitic rocks from Flat River and Glacier Lake map-areas*

Specimen and specific gravity*		Plagio-clase	% An**	K-feldspar	Quartz	Biotite	Horn-blende	Accessories	
								Light	Dark
1	2.59	10.4	29	50.5	36.5	—	—	2.4	0.2
2	2.62	28.4	—	38.3	25.7	7.6	—	—	—
3	2.71	43.4	37	16.7	21.7	14.9	0.4	1.5	1.4
4	2.65	30.4	—	34.5	25.9	8.3	—	—	0.8
5	2.59	18.4	30	40.7	35.4	5.1	—	—	0.4
6	2.66	34.0	32	27.5	25.9	10.1	—	0.8	1.7
7		32.6	—	24.1	31.4	11.9	—	0.5	2.3
8	2.67	28.6	—	25.8	37.9	6.7	0.6	—	0.4
9	2.71	32.1	45–51	15.6	33.8	10.9	4.5	0.1	2.0
10	2.65	25.6	—	44.6	23.2	5.0	—	—	1.6

TABLE II —(*Cont'd*) *Mineralogical compositions of granitic rocks from Flat River and Glacier Lake map-areas*

Specimen	Specific gravity*	Plagioclase	% An**	K-feldspar	Quartz	Biotite	Hornblende	Accessories: Light	Accessories: Dark
11	2.74	36.5	—	20.6	31.1	4.1	6.4	—	1.3
12	2.65	40.1	—	35.8	8.4	9.1	5.0	—	1.5
13	2.65	44.0	—	30.3	16.2	7.9	—	0.3	1.4
14	2.59	47.7	—	20.9	22.2	5.7	—	—	3.5
15	2.66	48.0	—	28.6	14.2	6.9	—	—	2.2
16	2.65	31.0	—	24.7	30.1	12.1	—	0.5	1.7
17	2.59	21.1	—	38.8	30.7	8.6	—	0.4	0.4
18	2.69	37.1	—	23.5	18.2	4.7	12.2	0.1	4.2
19	2.66	43.1	—	21.6	24.1	1.0	4.8	—	5.0
20	2.30	47.7	49	15.5	21.3	7.7	3.6	0.1	4.1
21	2.67	43.2	48	19.6	25.7	8.5	0.8	1.0	1.1
22	2.63	19.2	16	48.4	27.2	4.7	—	—	0.5
23	2.64	29.3	27	18.2	41.7	7.7	0.6	1.2	1.3
24	2.67	38.5	—	30.3	22.7	4.3	3.2	0.1	0.9
25	2.59	29.7	—	26.7	39.5	3.5	—	0.3	0.2
26	2.66	35.9	48	16.6	28.4	—	—	3.1	15.9
27	2.69	44.6	—	22.5	24.4	6.1	1.3	0.3	0.8
28	2.65	45.3	30	21.8	15.6	13.4	1.2	0.2	2.5
29	2.62	31.5	—	29.9	34.7	2.8	—	0.2	0.9
30	2.62	28.6	—	30.5	33.5	4.5	0.4	0.4	2.1
31	2.66	24.1	—	38.8	30.4	6.5	—	—	0.4
32	2.72	44.5	58	18.5	20.0	4.1	10.5	—	1.9
33	2.70	58.5	31	8.6	20.5	9.3	0.9	0.1	1.1
34	2.69	47.2	56	19.9	19.5	4.0	7.1	—	2.3
35	2.66	45.8	40	20.6	23.0	8.8	—	0.3	1.6
36	2.62	27.3	—	40.4	29.4	1.2	—	0.1	1.6
37	2.67	44.5	—	23.4	23.8	6.7	0.4	—	1.2
38	2.67	40.7	—	25.6	19.0	5.5	5.8	—	3.2
39	2.66	38.3	—	32.1	23.7	2.9	—	0.2	2.8
40	2.61	27.3	38	40.7	28.1	3.1	—	—	0.8
41	2.72	53.1	41	5.6	22.1	13.5	3.8	—	1.8
42	2.63	37.6	—	34.3	18.4	6.9	0.1	0.5	2.2
43	2.59	21.9	—	40.3	35.9	1.9	—	0.1	—
44	2.54	29.5	—	36.0	33.8	—	—	0.7	—
45	2.66	44.5	32	19.1	26.8	7.9	—	0.1	1.6
46	2.63	23.1	16–18	30.1	37.7	7.1	—	1.3	0.7
47	2.66	38.2	—	24.4	26.9	7.7	—	0.2	2.5
48	2.68	39.6	—	32.3	21.6	3.9	2.6	—	0.4
49	2.63	33.0	—	32.0	31.9	3.1	—	—	0.2
50	2.60	21.1	34	45.8	29.4	1.7	—	—	0.5
51	2.70	44.7	37	11.9	26.1	15.1	1.4	0.6	0.3
52	2.56	33.4	—	42.3	20.4	2.7	—	0.8	0.4
53	2.69	37.5	—	30.9	23.7	1.6	3.0	0.2	3.1
54	2.65	37.8	—	28.3	15.1	0.4	15.2	0.7	1.0
55	2.64	32.1	—	32.6	30.9	3.7	—	—	0.4
56	2.70	39.5	—	22.3	20.2	12.4	3.4	0.3	1.7
57	2.69	46.0	41	14.8	23.6	8.8	5.6	—	0.5
58	2.65	33.6	—	22.5	36.1	6.3	0.3	0.2	1.1
59	2.75	50.7	38	21.9	1.9	9.2	14.0	1.0	1.3
60	2.73	53.0	27	27.5	—	—	17.8***	0.6	0.6

TABLE II —(*Conc.*) *Mineralogical compositions of granitic rocks from Flat River and Glacier Lake map-areas*

Specimen and specific gravity*		Plagio-clase	% An**	K-feldspar	Quartz	Biotite	Horn-blende	Accessories	
								Light	Dark
61	2.65	23.5	31	64.0	5.4	—	5.8	—	1.0
62	2.63	29.6	—	44.0	22.8	4.3	—	—	—
63	2.40	25.5	—	39.3	32.9	2.3	—	—	—
64	2.61	18.7	—	44.4	36.1	0.4	—	—	0.2
65	2.62	30.3	—	34.6	31.8	2.6	—	0.6	0.1
66	2.67	37.1	—	23.2	32.9	6.2	—	—	0.6
67	2.66	60.7	37	4.9	23.5	7.7	2.9	0.2	0.1
68	2.78	48.8	44	9.4	4.6	19.3	11.7	3.6	2.7
69	—	22.6	—	39.3	28.3	9.8	—	—	—
70	—	25.8	—	32.5	35.2	6.2	—	—	0.2
71	—	41.0	50	18.8	26.4	11.6	0.6	0.1	—
72	—	27.4	—	30.6	30.0	7.6	—	0.2	4.6
73	2.62	28.8	—	38.6	26.4	6.2	—	—	—
74	2.66	42.6	—	22.3	25.8	9.3	—	—	—
75	2.71	42.8	—	18.3	24.9	4.0	10.0	—	—
76	2.64	30.6	—	27.8	28.0	10.0	3.6	—	—
77	2.64	26.8	—	47.5	16.2	9.5	—	—	—
78	2.60	39.8	—	30.0	20.2	10.1	—	—	—
79	2.64	35.8	—	30.9	21.7	11.6	—	—	—
80	2.64	34.8	—	37.2	21.2	6.8	—	—	—
81	2.62	36.1	—	21.1	29.1	13.7	—	—	—
82	2.59	27.4	—	43.7	30.7	1.0	0.2	—	—
83	2.67	39.8	—	23.5	23.4	7.0	6.3	—	—
84	2.62	36.8	—	24.6	32.6	6.0	—	—	—
85	2.68	42.7	—	19.7	23.7	—	13.9	—	—
86	2.56	17.8	—	41.9	38.1	2.2	—	—	—
87	2.67	37.4	—	22.0	23.0	8.0	9.6	—	—
88	2.67	41.2	—	19.6	24.2	7.5	7.5	—	—

*It was found that a specific gravity of 2.67 could be fairly reliably taken as the boundary between quartz monzonite and granodiorite. Only 5 per cent of the specimens, all with a specific gravity near this value, gave conflicting results. All specimens containing megacrysts of potash feldspar have a specific gravity of 2.67 or less and all specimens of granite 2.60 or less.

**Average for three grains.

***Includes several per cent pyroxene.

Mineralogy. Potash feldspar, especially in coarser crystals, characteristically exhibits grid twinning in all rock-types. Less commonly the mineral forms untwinned interstitial poikilitic masses. Replacement of plagioclase by potash feldspar, shown by pseudomorphs of potash feldspar after plagioclase, and by replacement veinlets of myrmekite and albite cutting finely twinned and zoned plagioclase crystals, is common and widespread. The pseudomorphs usually contain optically aligned plagioclase relics forming a patch perthite—or where relics are rare, a string perthite is commonly developed due to exsolved albite. Poikilitic masses of potash feldspar contain randomly oriented inclusions of all other minerals, especially plagioclase. As inclusions in potash feldspar, quartz occurs in rounded, resorbed blebs as well as subhedral crystals. In some rocks, mainly those of granodiorite composition, anhedral crystals of potash feldspar form a fine-grained matrix. This feldspar is untwinned and seems to be a late interstitial filling enveloping subhedral plagioclase, quartz, and mafics. Rocks in which potash feldspar is most coarsely grained are usually quartz rich and mafic poor. The distinctive megacrysts are mostly microperthitic microcline. They range from about 1 inch to 3 inches long and locally make up as much as 50 per cent of the rock. Megacrysts are lacking in the coarsest grained rocks. Locally, euhedral megacrysts contain inclusions of all other minerals and rarely have overgrowths of untwinned potash feldspar.

Quartz, averaging about 2 mm in grain size, is mostly anhedral and commonly resorbed. In the more quartzose rocks it occurs occasionally as coarse crystals and as massive interstitial masses. It is commonly interstitial and finer grained in the more basic rocks. Undulose extinction is rare and seems most pronounced in the more acidic rocks.

Plagioclase forms subhedral to anhedral crystals, smaller on the average and with less size range than quartz and potash feldspar. Colour is white to pale grey-green and grain size averages less than 5 mm, ranging to as much as 1 cm in the interiors of some stocks. Albite and carlsbad twinning are common and zoning is mostly normal or rarely oscillatory. Composition ranges from albite to andesine, in general with increasing modal plagioclase. In some grains only two zones are present, calcic cores and albite rims, the more calcic parts commonly being highly sericitized. Plagioclase rarely encloses any other minerals.

Biotite is by far the most abundant mafic mineral and is much more uniformly distributed than hornblende. Modal biotite averages greater than 6 per cent for the sixty-eight specimens analyzed and ranges to as much as 19 per cent. It forms plates averaging 1–2 mm, or locally clusters of crystals. Pleochroism is X = pale grey-yellow, Z = greenish brown to dark brown.

Hornblende occurs in less than half the rocks examined, but in some it ranges to as much as 18 per cent, and is more abundant than biotite in about 16 per cent of the specimens. Crystals, like those of biotite, are of medium grain size. They are typically prismatic, or less commonly are anhedral, generally poikilitically enclosing plagioclase. Pleochroic colours are normally shades of dark green and light brown.

Clinopyroxene is present in several of the more hornblende-rich specimens as corroded relics forming the cores of hornblende. Optical properties are: pale green colour, high birefringence, extinction angle about 45 degrees, and 2V approximately 90 degrees, suggesting augite. In one specimen of syenodiorite clinopyroxene is present also as fairly coarse grains, corroded in part adjacent to quartz and feldspar. There appears to be no relationship between presence of clinopyroxene and the biotite–hornblende ratio.

Common accessory minerals are apatite, zircon, sphene, iron ores, allanite, and rarely, black tourmaline and pink garnet. Magnetite and ilmenite are present in all, and are especially abundant where colour index is high. Magnetite is commonly in part altered to hematite. Dark brown to yellow-brown sphene, typically well crystallized, is widely distributed as separate grains or occurs as irregular masses with ilmenite. Apatite is conspicuous in most sections as well-formed, normally stubby, prismatic crystals. Zircon occurs as fine, mostly anhedral grains in all rocks, but is more abundant in the more acidic varieties. Allanite, normally occurring in elongate grains with variable colour and pleochroism, is less abundant than the other accessories. Chlorite is present in most rocks, especially where the mafic content is high. In Hole in the Wall Batholith black, prismatic tourmaline is a very conspicuous accessory. It forms clots of radiating prismatic crystals as large as 10 cm with quartz and, locally, cream feldspar. Locally these clots are as numerous as potash feldspar megacrysts, constituting perhaps 20 per cent of the rock.

Contact relations. Contacts are sharp, steep, discordant, and locally have numerous associated apophyses, or dykes and sills. Marginal zones are commonly finer grained or porphyritic, with a groundmass richer in potash or silica, and rarely contain potash feldspar megacrysts.

Contamination of the intrusives by carbonate wallrock is notably restricted. At some dolomite contacts the granitic rock is desilicated in a zone as much as 3 feet wide with enrichment of $CaO + MgO$, whereas granitic rock adjacent to silty limestone commonly has an abundance of calcic plagioclase and accessory diopside in zones rarely more than a few inches wide.

Contact metamorphism. Rusty weathering contact aureoles are most strikingly developed in pelitic rocks, and are as much as 2,000 feet wide. Pelitic hornfelses consist of sericite, muscovite, quartz, biotite, rarely andalusite and cordierite, graphite, and minor opaque minerals. Andalusite forms poikilitic porphyroblasts, or subhedral crystals free of inclusions, or occurs with accumulations of sericite, and fine biotite in spots near the outer margins of aureoles. In the blacker slates, andalusite occurs principally with aggregates of organic matter and graphite. With increased metamorphism the spots grade to porphyroblasts of andalusite and cordierite.

Impure, silty limestones are little changed in appearance by metamorphism except that compositional differences are accentuated by growth of new minerals and subsequent differential weathering. This is strikingly shown in the wavy, banded limestone of the Rabbit-Kettle Formation where layers of fine-grained marble have weathered out between layers of more resistant calc–silicate hornfels, preserving the primary stratification of calcareous and silty bands and accentuating small-scale compositional features. Highest grade mineral assemblages consist of diopside, tremolite, idocrase, garnet, epidote, and rarely, potash feldspar, plagioclase, sphene, and biotite. With the exception of garnet and idocrase, which commonly form poikilitic porphyroblasts as large as 0.7 cm, all minerals are microcrystalline to very fine grained, seldom exceeding 0.1 mm. Though commonly homogeneous, the calc–silicate bands may be individually laminated, or more finely banded with contrasting mineral assemblages, variously coloured purplish brown, pale green, or white. This probably reflects local compositional variations and shows that even fine laminae are preserved during metamorphism.

Sandy and silty dolomite and dolomite-cemented sandstones of the Lower Cambrian units are altered to mixtures of tremolite, diopside, quartz, and carbonates, which reflect both primary layering and degree of metamorphism. Individual textures as well as stratification are sufficiently preserved in some places to permit detailed correlations of metamorphosed and unaltered stratigraphic sections.

Age. A potassium–argon age of 110 m. y. was determined by the Geological Survey of Canada on a specimen of biotite–quartz monzonite from the northwest corner of Flat River map-area (Leech, *et al*, 1963). This is consistent with other dates obtained on similar rocks to the northwest (Gabrielse, 1967b).

Chapter IV

STRUCTURAL GEOLOGY

Northerly to northwesterly trending folds with moderately steep limbs are the most widespread structures in the three map-areas. These structures are locally broken by thrust faults that generally dip westerly, except in eastern Wrigley Lake and eastern Glacier Lake map-areas where most dip easterly (*see* cross-sections). Structures in the anticlinal areas are generally clearly revealed or can be interpreted. On the other hand, synclines, because they commonly contain cores of incompetent, recessive shale, are poorly exposed and consequently the details of structures within them are not well known. In many places, however, they appear to be much more complicated than suggested by the simple geometry of the competent units comprising their limbs.

Canyon Ranges

Canyon Ranges include two main anticlinal belts coincident with Redstone and Rouge Ranges. Douglas and Norris (1963) have shown that the structure of Redstone Range in Dahadinni map-area is essentially an anticline broken near the crest by a major east-dipping thrust, the Redstone Fault. The continuation of this fault to the north–northwest is uncertain. It either ends in an anticline which exposes Whittaker Formation, or flattens and swings westerly to become a relatively low-angle fault where it is mapped in easternmost Wrigley Lake map-area.

If this is one continuous fault the flattening of the fault plane along the easternmost boundary of Wrigley Lake area is accompanied by the development of an anticline–syncline pair in the hanging-wall. A northerly trending fault clearly revealed east of Wrigley Lake appears to have a component of right-lateral displacement. This transcurrent fault may connect Redstone Fault with a west-dipping thrust fault northeast of Wrigley Lake.

The North Redstone Fault, an easterly dipping thrust fault, breaks the west flank of Rouge Anticline north of Redstone River. To the north the fault appears to swing diagonally across the axis of the anticline and then continues to and beyond North Redstone River into the range west of Wrigley Lake.

Rouge Fault, another westerly directed thrust fault in Dahadinni map-area (Douglas and Norris, 1963) crosses Redstone River about 2 miles west of North Redstone Fault, but its continuation from there is uncertain. It may swing northeasterly into North Redstone Fault. Directly to the northwest a fault on trend with Rouge Fault can be traced to near North Redstone River. The fault or fault zone is poorly understood because it lies in a valley underlain by recessive weathering rocks of the Camsell and Delorme Formations. For much of its length the structure is relatively downthrown to the east but at the north end relative movement appears to be reversed. Possibly two faults are involved, or alternatively, Rouge Fault has effected some transcurrent displacement.

Strata southwest of North Redstone Fault southeast of North Redstone River, occur in a well-defined syncline in part faulted and modified on its southwest limb by a tight anticline and syncline pair.

The low-lying terrain between Rouge and Redstone Ranges is underlain by recessive shales that occur in a continuation of Marten Syncline—a relatively broad, open structure, where defined in Dahadinni map-area (Douglas and Norris, 1963). Very little outcrop is available for examination of Marten Syncline in Wrigley Lake map-area, and details of the structure are not known.

The mountain range west of Wrigley Lake includes the broad, open Foran Anticline modified on its east limb by North Redstone Fault and related minor faults and folds.

Foran Anticline is flanked to the west by Foran Syncline which contains gently and uniformly dipping beds near the northern boundary of Wrigley Lake map-area. The structure is asymmetrical, with its axial plane dipping steeply to the east. Farther south the simple syncline is interrupted by a northerly plunging anticline with two flanking synclines. The west limb of Foran Syncline is essentially a gently dipping homocline underlain by the easterly dipping Nainlin (thrust) Fault. This fault can be mapped as far south as Redstone River where the apparent displacement is small. Nainlin and North Redstone Faults mark the southwestern limit of important southwesterly directed structures in Wrigley Lake map-area.

Between the westerly dipping Tigonankweine Fault and the easterly dipping Nainlin Fault, recessive, mainly Upper Devonian clastic rocks occupy a 'ramp graben.' Strata in this structure mostly dip gently except where tightly folded in the footwall of Tigonankweine Fault. In the southern part of the 'ramp graben' a northerly plunging anticline flanked on the east by a northerly plunging syncline in the footwall of Nainlin Fault is outlined by strata of the Nahanni Formation.

Backbone Ranges

Tigonankweine Range is bounded on the east by a major west-dipping thrust fault named Tigonankweine Fault. The stratigraphic displacement along the fault is locally more than 13,000 feet because strata as old as the Tsezotene Formation are thrust against rocks of Late Devonian age. Locally quartzites of the Tigonankweine Formation in the hanging-wall of Tigonankweine Fault are shattered and display slickensided surfaces in a zone at least 200 feet wide. In places weathering of the brecciated quartzites has produced a fine-grained sand. Minor manganese stain is present on some fractures. Banded, varicoloured strata of the Tsezotene Formation in the hanging-wall reveal two anticlines and an intervening syncline with axial planes dipping steeply southwest (*see* Pl. XLII). A fault or fault zone that appears to be a continuation of Tigonankweine Fault continues southeasterly to the southeast corner of Wrigley Lake map-area, where it becomes the Amber Fault of Dahadinni map-area (Douglas and Norris, 1963). The sense of vertical displacement is not consistent along the zone, however, and possibly, as suggested above in the discussion of Rouge Fault, several faults are involved or some transcurrent movement has taken place.

Tigonankweine Range is underlain mainly by gently dipping strata of the Tigonankweine Formation. These rocks occur in a simple anticline at the southeast end of the range but this structure dies out near or at a northeast-trending fault along which the southeast side has moved relatively downward.

A conspicuous north–northwesterly trending steeply dipping fault that crosses the northern boundary of Wrigley Lake map-area at longitude 127°30′ is downthrown to the west. The fault has a local stratigraphic displacement of at least 2,000 feet but seems to die out rapidly to the south.

Tigonankweine Range is bordered on the southwest by tightly folded and locally faulted rocks that lie in the footwall of Plateau Fault, a major westward-dipping thrust fault. One oJ the most continuous structures in this area is Tigonankweine Syncline, an asymmetrical structure with its axial plane dipping steeply southwest. A complicated anticlinal structure southwest of Tigonankweine Syncline is cut by several faults that trend north–northwesterly, similar to the fault described above in northwestern Tigonankweine Range. At least one of these faults swings into a more easterly trend to the southeast. This fault may change from a structure with dominantly dip-slip movement in the southeast to dominantly dextral strike-slip movement to the northwest.

In northwesternmost Wrigley Lake map-area the anticlinal area west of Tigonankweine Syncline plunges northerly and is bounded on the southwest by a horst of Proterozoic sediments. Where observed, the northeastern boundary of the block is a vertical fault flanked by younger rocks with asymmetrical and northeasterly overturned synclines. The southwestern boundary is covered by drift. Apparently the bounding faults converge southeasterly and the structure terminates as a wedge.

Plateau Fault, a thrust, is one of the most important structures in the region (*see* Pl. XI). This fault, locally with associated thrust faults, dips gently to the southwest and west and has a stratigraphic displacement in places of possibly more than 20,000 feet. The fault maintains a relatively constant stratigraphic position for many miles. Between Redstone and North Redstone Rivers the hanging-wall includes a thin sequence of resistant quartzitic sandstone near or at the base. Four miles south of North Redstone River the locus of Plateau Fault is marked by a gouge zone at the top of a recessive sequence of black slates about 125 feet thick. The apparent displacement on the fault decreases southerly and its continuation near South Redstone River, in Glacier Lake map-area, is uncertain. A northeasterly directed thrust fault on the west side of Little Dal Lake lies on trend with the Plateau Fault and is marked by a zone of buff weathering highly brecciated rocks several hundred feet wide, in a sequence of reddish weathering siltstones and slates. The continuation of this structure to the south is lost in the valley of Thundercloud Creek. For most of its length in the report area, Plateau Fault forms the boundary between gently dipping to flat-lying strata of Redstone Plateau and the region of folded and faulted strata to the northeast and east. Structures in the footwall between North Redstone and Keele Rivers are commonly masked because recessive shales comprise the bedrock. Near North Redstone River, however, resistant ribs of the Nahanni Formation clearly reveal tight folds that in places plunge northwesterly as much as 30 degrees.

Tsezotene Fault is a major, westerly dipping thrust fault that is well exposed in many places between Hayhook Lake and Redstone River. On the east flank of Tsezotene Range the apparent stratigraphic displacement is great as the oldest exposed rocks in the region have been brought into fault contact with some of the youngest. Northwest of Hayhook Lake Tsezotene Fault is revealed by a scarp of orange weathering, laminated dolomite of the Little Dal Formation which forms a breccia comprising angular blocks as large as 2 feet across but averaging between 1 inch and 6 inches across. In the creek 3½ miles south of Hayhook Lake, sheared and folded slates, shales, and sandstones of the Tsezotene Formation in the hanging-wall of the fault are in contact with folded and faulted Upper Devonian shales in the footwall (*see* Pl. XLIII). Essentially dip-slip displacement is indicated by horizontal fold axes. Farther south a well-defined overturned syncline containing strata of the Landry, Headless, Nahanni formations and the overlying black shale unit occurs in the footwall.

Northwest of Hayhook Lake Tsezotene Fault sharply truncates the east limb of a northerly plunging syncline in the hanging-wall. Continuation of the fault to the north is obscured by lack of outcrop. At its south end the fault truncates the east limb of Dal Anticline in the hanging-wall, but cannot be traced farther because of poor outcrop west of Dal Lake. Strata of the Nahanni Formation on the west side of Dal Lake, probably in the footwall of Tsezotene Fault, form tight folds overturned to the east. Another fault with an apparent component of right-lateral displacement swings south–southwesterly from Tsezotene Fault and connects with Hayhook Fault south of Redstone River.

Hayhook Fault is well exposed from central Wrigley Lake map-area to South Redstone River in Glacier Lake map-area. The structure is characterized by its crosscutting relationship to bounding strata (*see* Fig. 12(a)). Northwest of Hayhook Lake, strata in the footwall occur in a syncline overturned to the northeast with an axis plunging 30 degrees northwesterly. A tight, easterly, overturned syncline is also present in the footwall of Hayhook Fault in the southwestern part of Tsezotene Range. Near Redstone River the structure cuts across the east limb of a northwesterly trending syncline in the hanging-wall and continues southerly almost directly along the projection of the northerly plunging axis. Farther south the fault breaks the west limb of Dal Anticline and in northernmost Glacier Lake map-area where the anticline plunges to the north it cuts easterly across the anticlinal axis and then presumably southwesterly back across the axis into the valley of Redstone River.

About 8 miles north of Redstone River a fault that cuts sharply across structural trends connects Hayhook Fault with a northerly trending fault along which the eastern side is downthrown. The latter structure may truncate a northwesterly trending, westerly dipping thrust fault that locally effects a throw of more than 6,000 feet. An analysis of relative displacements along Hayhook Fault is presented below in the discussion of transcurrent faults.

The thrust fault that brings siltstones of the Redstone River Formation east of Little Dal Lake against an easterly overturned syncline, including strata as young as the black shale unit that overlies the Nahanni Formation, suggests a stratigraphic displacement of more than 20,000 feet. The suggested relationship of this fault to the southwesterly directed Thundercloud Fault on the southwest side of Thundercloud Range is shown in Figure 12(b).

Southeast of Redstone River and west of Amber Fault in Wrigley Lake map-area, two north–northwesterly trending anticlines are separated by a faulted syncline. The easternmost anticline can be traced almost continuously to the north–northwest into the anticline at the southeast end of Tigonankweine Range. Southeast of Redstone River the structure is, in places, slightly overturned to the southwest and is complicated by minor subsidiary folds. The eastern limb of the anticline swings southwesterly in Painted Mountains where the strata dip gently to the southeast. Details of the structure on the west limb are not known but in Glacier Lake map-area it is broken by a steep eastward-dipping thrust fault. Two easterly dipping thrust faults have been recognized in Painted Mountains, one of which is a northwesterly continuation of the Painted Mountain Fault in Root River map-area (Douglas and Norris, 1961).

Northwesterly plunging structures on the southwest side of Painted Mountains are truncated at an acute angle by a northwesterly trending fault. The *en échelon* folds could be the result of a component of right-lateral movement along the fault. Farther southeast the northeast side of Thundercloud Range is bounded by a complexly faulted zone. In general, the faults are thrusts directed to the northeast.

Thundercloud Range is underlain by gently dipping strata that for the most part form a simple, deeply dissected plateau. Thundercloud Fault, possibly a continuation of Clearwater Fault in Root River map-area, and related southwesterly directed thrust faults delimit

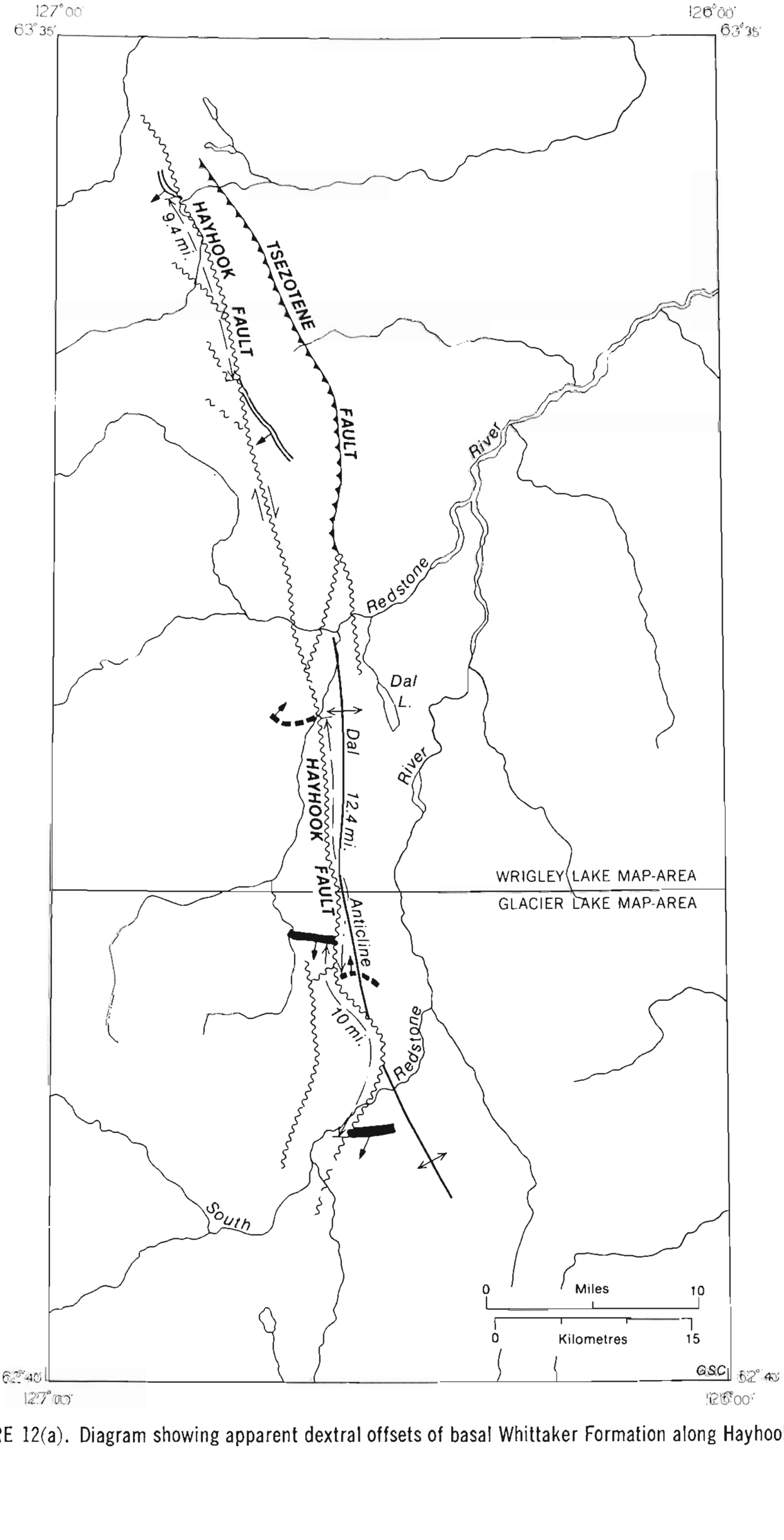

FIGURE 12(a). Diagram showing apparent dextral offsets of basal Whittaker Formation along Hayhook Fault.

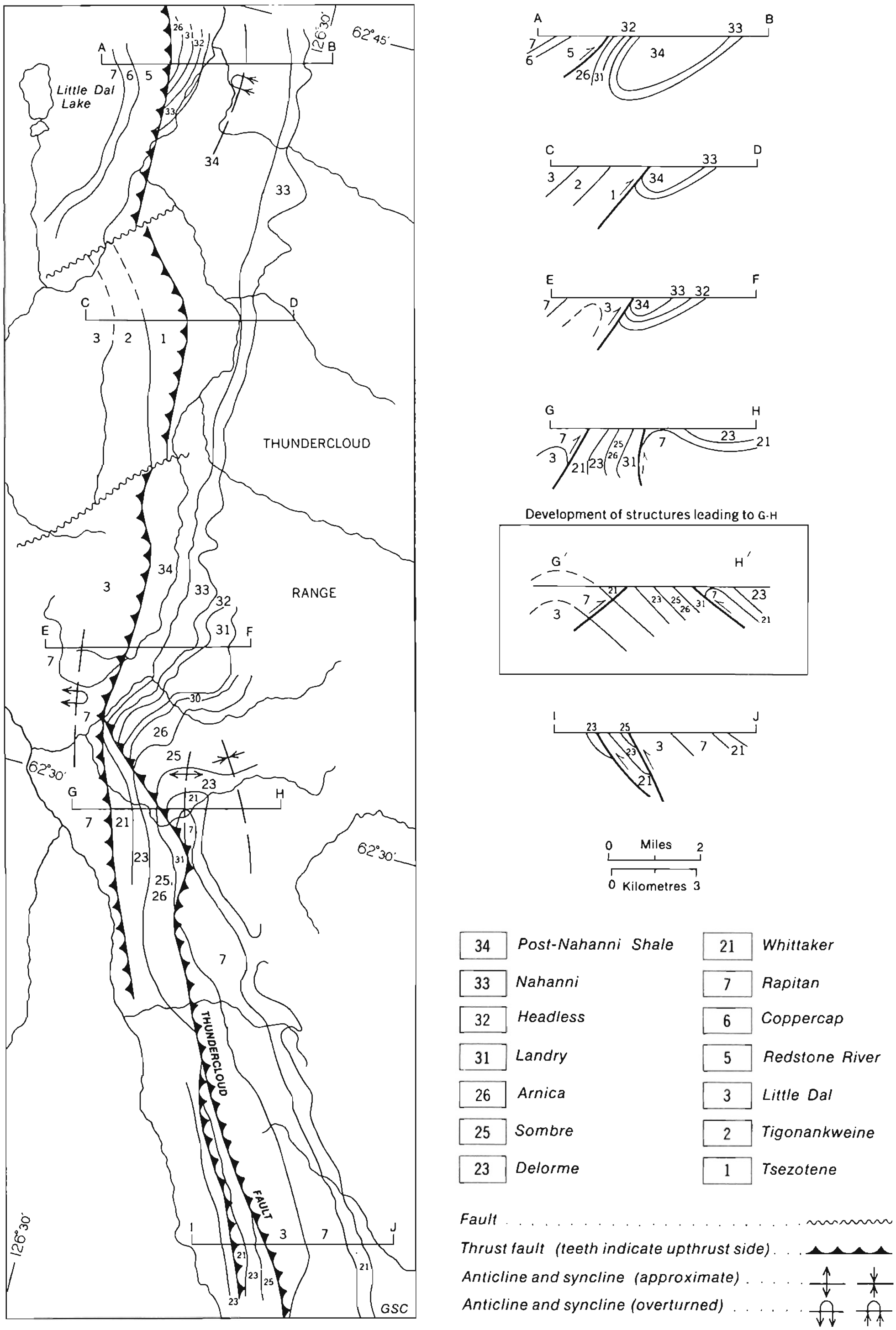

FIGURE 12(b). Suggested relationships between Thundercloud Fault and unnamed fault east of Little Dal (Coates) Lake.

the southwest side of the range. At its north end Thundercloud Fault truncates the westerly dipping strata of Thundercloud Range and cuts sharply across a northerly plunging anticline which has strata of the Rapitan Group in its core. Possibly the fault has been overridden by the southern continuation of the major fault east of Little Dal Lake (see Fig. 12(b)).

An extensive area of flat-lying to gently dipping strata, underlies Redstone Plateau west and southwest of Plateau Fault. Faulting appears to be of minor importance except in the southern part of the plateau where several steeply dipping, northeasterly trending faults have been recognized. Movements on these faults appear to be mainly vertical.

Redstone Plateau, in southwestern Wrigley Lake map-area and northwestern Glacier Lake map-area, is bounded on the west by Natla Fault, a steeply dipping, northeasterly directed thrust fault. Along the Wrigley Lake–Sekwi Mountain boundary an easterly overturned syncline is present in the footwall and a northeasterly overturned anticline occurs in the hanging-wall. Just north of the headwaters of Redstone River, the fault is marked by a remarkably straight scarp in the alluvium indicating that some recent movement has occurred.

Near the southern end of Natla Fault, highly brecciated, buff-orange weathering, Upper Cambrian dolomites of the Broken Skull Formation in the hanging-wall are faulted against contorted, black, argillaceous and silty, Middle Cambrian limestones of the Rockslide Formation in the footwall. This area is near the southernmost limit of the Middle Cambrian facies represented by the Rockslide Formation.

The structure of the complex synclinal area near Grizzly Bear Lake is little understood because of poor outcrops. The northeast limb of the structure is broken by several northeasterly directed thrust faults, the most important of which appears to be Grizzly Bear Fault. At its north end Grizzly Bear Fault has an apparent left-lateral horizontal displacement where it cuts sharply across the structural trend. An easterly overturned syncline is present in the Funeral Formation of the footwall near the south end.

Near Avalanche Lake is Avalanche Syncline—an asymmetrical structure with its axial plane dipping steeply southwest. The incompetent Funeral Formation in the core of the structure is cut by strongly developed nearly vertical cleavage, and many tight, locally isoclinal, small folds are present. The structural depression near the northwest end of Avalanche Syncline includes several tight folds locally overturned to the northeast. The folds are clearly outlined by the resistant Nahanni Formation which is thickened in the axial parts of folds (*see* Pl. XLIV). Grizzly Bear Fault may swing southeasterly and cut the southwest limb of Avalanche syncline.

Grizzly Bear and Broken Skull Anticlines are relatively simple, open structures linked *en échelon* through a structural depression between Black Wolf Creek and Broken Skull River. Broken Skull Anticline is linked in turn to an anticline west of Hell Roaring Creek.

Southwest of the open Clearwater Anticline northeast of Clearwater Creek a complex synclinal area comprising several obliquely trending, gently plunging synclines and anticlines, essentially represents a continuation of Avalanche Syncline. Tightly folded strata, in places nearly isoclinal, and locally overturned to the east, characterize the area defined by the Broken Skull anticlinal area on the west, and by the headwaters of Clearwater Creek and the lower reaches of Flood Creek on the east. In this area faulting appears to be subordinate to folding.

Southwestern Mackenzie Mountains, Hyland Plateau, and Liard Plateau, between Caribou River and South Nahanni River, are underlain by gently dipping strata displaying northerly trending open folds.

The southwestern boundary of Mackenzie Mountains in Glacier Lake map-area coincides with Broken Skull Fault—a major, steeply dipping, structural break. The fault is bordered to the northeast in part by an asymmetrical anticline with its axial plane dipping steeply southwest and in part by Broken Skull Syncline which flanks the anticline on the northeast. These structures and those southwest of Broken Skull Fault are truncated by the fault at acute angles.

Logan Mountains, Hyland Plateau, and Liard Plateau

South Nahanni Anticline in Glacier Lake map-area, is an open, symmetrical, southeasterly plunging anticline truncated by Broken Skull Fault. To the southwest, a faulted, northerly plunging anticline in rocks of undivided Broken Skull and Sunblood Formations is flanked by incompetent strata of the Road River Formation in which the structure is unknown.

Southeasterly plunging folds are well displayed southwest of Rabbitkettle Lake in northwest Flat River map-area, and tight folds are characteristic of the Ragged Range farther northwest. In general these structures are asymmetrical and are locally overturned to the northeast.

Elsewhere in Logan Mountains, the major structures are evident only from the general map pattern. In the south-central part of Flat River map-area strata trend northerly and commonly dip steeply, probably the result of tight folding about northerly trending axes. In places, structures are parallel with contacts of granitic bodies but elsewhere they are sharply truncated.

Much of eastern Flat River map-area is underlain by gently dipping strata of the Sunblood Formation. The rocks are more tightly folded and may be locally faulted in the more westerly exposures.

Incompetent strata of the Road River Formation in Hyland and Liard Plateaux are commonly tightly folded. To the south in Coal River map-area where the rocks are better exposed, Road River strata are highly contorted by a northeasterly trending fault that cuts the southeast limb of Caribou Anticline. The fault closely follows the contact between Road River and Sunblood strata and probably extends northerly into Flat River map-area.

General Considerations

Structural Style

Northeast and east of Redstone Plateau and northeast of Clearwater Creek the following characteristics apply:

1. A structural symmetry is revealed by the presence of both westerly and easterly directed thrust faults.

2. Most faults dip steeply at the present level of erosion.

3. Steeply dipping beds are almost invariably associated with faults.

4. Most fault planes are parallel with the bedding or cut the beds at a low angle. Exceptions are faults with suspected transcurrent movement.

The structural characteristics outlined above are consistent with the hypothesis that the thrust faults and related folds resulted from essentially horizontal compression perpendicular to the regional trend. Such a stress field would lead to shortening of crustal layers by means of conjugate low-angle planes or thrust faults at acute angles to the direction of maximum compression, if the direction of minimum compression were vertical. Such faulting would be facilitated by deformation above surfaces of *décollement* and thus the entire observed stratigraphic sequence may be allochthonous with reference to a crystalline basement. Steep dips on most faults presumably resulted from folding that accompanied thrusting.

Southwest of Redstone Plateau tight folds become progressively more important and thrust faults less so, perhaps because the strata in this region are less competent. Crustal shortening in the southwesternmost Mackenzie Mountains and adjacent Logan Mountains therefore appears to have been accomplished largely by folding, probably also above a surface of *décollement*.

Crustal Shortening

In tightly folded rocks between Clearwater and Hell Roaring Creeks and southwest of Rabbitkettle Lake, strata have been locally compressed as much as 30 per cent. For the region as a whole, however, an assessment of the amount of crustal shortening resulting from folding and thrusting combined is difficult without subsurface data. An indication of significant horizontal movement is provided, however, by a study of Plateau Fault. Along this fault between Keele and Redstone Rivers there is a remarkable contrast between stratigraphic sequences in the hanging-wall and in the footwall. The break is unaccompanied by any significant change in facies of the strata involved. Thus it may be assumed that the disappearance of the Sunblood Formation, the abrupt thinning of the Cambrian rocks, and, north of Redstone River, the disappearance of the entire Hadrynian and most of the Cambrian succession across the fault reflects, in part, considerable crustal shortening. All the units below the Whittaker Formation are bevelled easterly and northeasterly by several unconformities, but the post-Rapitan unconformities truncate underlying strata at low angles and cannot account for the abrupt thinning or removal of thick stratigraphic units. A similar situation is revealed by the abrupt disappearance of the Sunblood Formation across Thundercloud Fault.

If, as assumed in this report, deformation in this part of Mackenzie Mountains involved a relative easterly or northeasterly movement of strata on *décollement* surfaces, then it follows that horizontal movement along Plateau Fault and other faults bounding large areas of little-deformed strata must have been considerable. Between Natla and Plateau Faults the rocks are essentially undeformed. Therefore an amount of crustal shortening at least equivalent to that shown in the folded and faulted strata to the northeast must be largely limited to horizontal displacement on Plateau Fault. Presumably Plateau Fault flattens with depth and merges with a décollement surface beneath Redstone Plateau. On a cross-section such as C–D in Wrigley Lake map-area, where crustal shortening east of Plateau Fault is a minimum of 20 per cent (and may be considerably greater) and the width of essentially undeformed strata on Redstone Plateau is about 30 miles, a minimum horizontal displacement of about 6 miles is indicated. As the plateau wedges out to the south the apparent displacement on Plateau Fault decreases. Presumably equivalent shortening is achieved by displacements along faults farther east exposed near the boundary between Wrigley Lake and Glacier Lake map-areas, by displacement on Thundercloud Fault, which also bounds an extensive plateau-like area (Thundercloud Range), and by folding. Thundercloud Fault dips easterly and is considered to be one of the conjugate faults in the stress system that produced the west-dipping Plateau Fault.

Transcurrent Faults

Mention has been made of probable dextral movement on a transcurrent fault east of Wrigley Lake. It is postulated that this fault transects the anticlinal core of Redstone Range and connects a northeasterly directed thrust fault northeast of Wrigley Lake with a southwesterly directed thrust fault southeast of the lake (possibly a continuation of Redstone Fault).

Spectacular truncations of stratigraphic assemblages and fold structures can be observed along Hayhook Fault. An apparent dextral movement of about 9 miles is suggested by the relationship of westerly dipping Precambrian to Middle Devonian sequences southwest of Hayhook Lake and along the southwest flank of Tsezotene Range (*see* Fig. 12(b)). Restorations along the fault, assuming dextral displacements ranging from about 9 to 12 miles, bring into near juxtaposition two other structural elements—the northeasterly dipping sequence on the west side of the fault just south of Redstone River with the northerly dipping sequence exposed in Dal Anticline 12 miles to the south, and the southerly dipping strata west of Hayhook Fault, 8 miles north of South Redstone River, with southerly dipping strata at the northwest end of Thundercloud Range (*see* Fig. 12(b)). Such restorations, of course, disregard any vertical components of displacement and also any distribution of movement on other faults such as the one that connects Hayhook and Tsezotene Faults near Redstone River. Some details of the stratigraphy do not seem to be explained by this model of displacement but they might be attributed to one or both of the following possibilities:

1. The fault is the locus of an old fracture along which there were pre-Whittaker movements.

2. Facies and thickness changes in an east–west direction, e.g., the Manetoe Formation not recognized west of Hayhook Fault north of Redstone River may also not be present immediately east of Hayhook Fault south of South Redstone River (the formation was not recognized in the overturned limb of the syncline east of Little Dal Lake).

Several minor faults trending northwesterly from Hayhook Fault west of Tsezotene Range may be regarded as complementary shear fractures. Possibly the west–northwest-trending folds in the northern part of the wedge between Hayhook and Plateau Faults also resulted from a stress system that produced dextral transcurrent movement along Hayhook Fault.

If the analysis of Hayhook Fault outlined above is valid, the following sequence of structural events for this part of Mackenzie Mountains is indicated:

1. Folding, mainly along northerly or north–northwesterly trending axes.

2. Dextral transcurrent movement along Hayhook and possibly minor subsidiary faults accompanied by development of west–northwest trending folds.

3. Overriding of the earlier formed structures by Plateau Fault.

Offsets of strata along Broken Skull Fault in Nahanni map-area west of Glacier Lake map-area point to some sinistral transcurrent movement (Blusson, 1968a). The fault truncates northwesterly trending fold axes to the west and east at acute angles. A similar displacement is suggested by offset of South Nahanni Anticline by the fault in Glacier Lake map-area.

Apparent reversals of displacements along a number of faults in the report area have been noted above. Many of the anomalous relationships may be the result of transcurrent movements.

Structures and Granitic Intrusions

It is clear that the general structural style of strata in Ragged Range bears little relationship to the emplacement of granitic bodies. The style of deformation of strata along the valley of Flat River in Nahanni map-area to the west (Blusson, 1968a) appears similar to that in rocks cut by Hole in the Wall Batholith near Rabbitkettle River. Locally along the northern margin of Coal River Batholith and adjacent to stocks near Skinboat Lakes the intrusions appear to have had a slight doming effect on adjacent sedimentary rocks, but generally this phenomenon appears minor.

Age of Structures

Pre-Rapitan strata were tilted and probably block faulted during the Racklan Orogeny (Gabrielse, 1967b). This deformation resulted in the conspicuous unconformity beneath the Rapitan Group everywhere in southwestern Mackenzie Mountains. Unconformities within the Rapitan Group and, locally, at the base of the overlying Keele Formation indicate further mild deformation, possibly mainly gentle warping, in late Proterozoic time.

An important episode of deformation took place in Selwyn Mountains in pre-Franconian and probably post-Middle Cambrian (*Bathyuriscus–Elrathina*) time. The unconformity at the base of Franconian strata is a paraconformity in Mackenzie Mountains but becomes an angular unconformity to the west in South Nahanni Anticline. Farther south the unconformity beneath Upper Cambrian (?) strata of the Rabbitkettle Formation is still more pronounced. The underlying Upper Proterozoic and Lower Cambrian rocks were apparently folded and uplifted before deposition of the Rabbitkettle strata.

Further evidence for a significant regional deformation at this time comes from Watson Lake map-area southwest of Flat River map-area. There, Proterozoic and (?) Lower Cambrian rocks along Hyland River are strongly cleaved and tightly folded. The overlying strata (correlative with the Rabbitkettle Formation), although relatively incompetent, are much less deformed and form relatively open folds (Gabrielse, 1967a).

The regional unconformity at the base of the Whittaker Formation reflects widespread uplift and gentle warping or tilting. Possibly pre-Whittaker movements occurred along a fracture ancestral to Hayhook Fault, thus accounting for variations in Proterozoic stratigraphy across the fault.

The stratigraphy in the area at the south end of Redstone Plateau and south of the headwaters of Thundercloud Creek demonstrates the effects of repeated uplift. The stratigraphy is characterized by rapid thinning and disappearance of several formations in a southeasterly direction. East of Avalanche Lake the Sombre and Camsell Formations appear to be truncated by an unconformity at the base of Arnica Formation. Farther east the Backbone Ranges Formation thins rapidly to disappearance below the Avalanche Formation. Still farther east the Sunblood and Broken Skull Formations are bevelled eastward by an unconformity at the base of the Whittaker Formation. Whether these uplifts are associated with movements along Precambrian or early Paleozoic structures is not known.

Lack of strata younger than Devono-Mississippian precludes dating of most structures by normal stratigraphic methods. It is clear, however, that major folds in Ragged Range are cut by granitic plutons dated as about early Upper Cretaceous by the K–Ar method (Gabrielse, 1967a) .On this basis it is assumed that much of the structural development in southwestern Mackenzie Mountains occurred prior to Late Cretaceous time. Faults along which transcurrent movements have taken place sharply truncate folds, and either were the loci of lateral displacements late in the episode of major folding, or at an entirely later time. It is possible, however, that thrusting along Plateau Fault postdated transcurrent movements along Hayhook Fault.

Chapter V

ECONOMIC GEOLOGY

Oil and Gas

The widespread Mesozoic (probably mainly Cretaceous) granitic intrusions eliminate much of Flat River and southwesternmost Glacier Lake map-areas as potentially productive areas for oil and gas. Farther north in Glacier and Wrigley Lake map-areas restricted synclinal areas underlain by Upper Devonian shales and siltstones have some prospects for oil and gas, but most potential reservoir rocks are exposed in the adjacent mountains.

The two best reservoir rocks appear to be the porous, vuggy dolomites of the Manetoe Formation and the less porous but locally vuggy dolomites of the Whittaker Formation. Unfortunately the Manetoe Formation occurs in the subsurface in only a very small area on the west side of Thundercloud Range. The Whittaker Formation, however, is widespread; it and the somewhat less porous Arnica Formation are probably buried deeply enough in parts of Wrigley Lake map-area to constitute potential reservoirs.

Possibly the most favourable stratigraphy for potential reservoir rocks occurs in the belt of strata trending northwesterly from near Avalanche Lake to, and beyond, Grizzly Bear Lake. In this region the transition zone between carbonate strata to the northwest and fine-grained clastic strata to the southwest, is marked by reefoid porous dolomite in the upper part of the Whittaker Formation and by discontinuous crinoidal members in Middle Devonian rocks. These rocks can be expected in the subsurface only within Grizzly Bear Syncline and its continuation to near Natla River in southwestern Sekwi River map-area. This synclinal area, and many others in the region, appear to be structurally complex. The simple map pattern in some places is due to lack of structural data in the incompetent Upper Devonian shales. Thus anticlinal closures and structural traps may exist within the synclinoria.

The prospects of finding significant oil and gas concentrations in the region of Operation Nahanni are poor, except possibly for the northeastern part of Wrigley Lake map-area. The geology of northeastern Wrigley Lake map-area, however, provides information on stratigraphy and structural style that is applicable to the more favourable, less deformed region immediately to the northeast.

Metallic Minerals

Copper, Silver

Chalcopyrite, bornite, chalcocite, malachite, and azurite occur in bleached strata in the uppermost part of the Redstone River Formation and lowermost part of the Coppercap Formation east and north of Little Dal Lake. Redstone Mines Limited have carried out exploration work including trenching and drilling in the property east of Little Dal Lake. There, copper minerals occur in from three to seven zones of greenish weathering, slightly dolomitic siltstone and overlying sandy limestone. Mineralized strata have been traced along trend for almost 4 miles.

At one of the best-exposed showings at least six mineralized zones are evident. They range from 3 inches to 5 feet thick and occur within a stratigraphic interval of about 200 feet. Some of the mineralized rocks are sandy limestones belonging to the basal part of the Coppercap Formation. In this locality the copper-bearing strata are overlain by a resistant, blocky, quartzite bed about 15 feet thick.

Near the contact between Redstone River and Coppercap Formations the rocks are shattered and cut by faults parallel with and oblique to bedding. Sulphide veins, consisting mainly of bornite and chalcopyrite, occur parallel with bedding or in crosscutting fractures. Commonly the rock bordering veins contain disseminated grains of chalcopyrite bordered by a halo of malachite.

Copper minerals have been noted in strata of the Redstone River Formation about 5 miles north of the mouth of Thundercoud Creek. There also the mineralized rocks appear to be stratigraphically controlled. They have been traced for almost a mile just below the contact with the overlying Coppercap Formation.

The Redstone River Formation is present near Keele River, where it locally contains copper minerals. Elsewhere it has been removed by pre-Rapitan erosion.

Several showings of argentiferous tetrahedrite with some chalcopyrite, bornite, and chalcocite occur in dolomite breccias of the Little Dal and Whittaker Formations west and southwest of Dal Lake between Redstone and South Redstone Rivers. The breccias are cemented by crystalline calcite, ankerite, or dolomite and commonly the metallic minerals occur as blebs and masses in the calcite or as disseminations in the breccia. The mineralized carbonates are marked by rusty weathering zones.

Chalcopyrite is fairly abundant locally in the mafic sill or flow in the Little Dal Formation north of North Redstone River. The sulphide is associated with minor malachite stain.

Malachite occurs locally along the contact between the Rapitan Group and Whittaker Formation in Thundercloud Range in a southeasterly trending spur 5 miles northeast of the peak, elevation 8,230 feet.

A small copper showing consisting of bornite in fine-grained quartzites of the 'Phyllite Unit' occurs at lat. 61°16'N, long. 127°05'W in Flat River map-area (Skinner, 1961).

Lead, Zinc

Extensive gossans immediately south of North Nahanni River occur in thin-bedded grey limestones near the base of the Delorme Formation. The easternmost gossan contains coarse crystals of galena whereas a sulphide body farther west contains pyrite, galena, and sphalerite.

Considerable zinkenite float was noted on a ridge 4 miles west of the mouth of Broken Skull River. The mineral occurs in carbonate rocks of the undivided Sunblood and Broken Skull Formations.

Scattered deposits of sphalerite and galena occur in a skarn zone in Lower Cambrian strata about 5 miles northwest of Lucky Lake in Flat River map-area. The sedimentary and metasedimentary strata are cut by many feldspar-porphyry sills and dykes.

Tin

Tin-bearing minerals occur near lat. 61°24'N, 126°19'W in Flat River map-area. There, a trench in rusty argillite of the 'Phyllite Unit' exposes a narrow vein that includes pyrite, galena, sphalerite, stannite, franckeite, and possibly geocronite, in a matrix of calcite (Evans, 1957). The adjacent country rock has been pyritized.

Gold (placer)

Some placer gold has been obtained from Bennett Creek and workings were noted in McLeod and Grizzly Creeks. Little is known, however, about the nature and occurrence of the gold or of the quantity mined.

Tungsten

Minor amounts of scheelite occur along the contact between a granitic stock and the Rabbitkettle Formation northeast of Flat River in northwesternmost Flat River map-area. Lower Cambrian carbonate strata are host rocks for the scheelite deposit at the Canada Tungsten mine near Flat River in northeasternmost Frances Lake map-area (Blusson, 1968b).

Molybdenum

D. W. Bolyard (unpub. MS.) reports the presence of molybdenite along joint surfaces in porphyritic granitic rocks in the central part of the Mount Sidney Dobson massif north of Rabbitkettle River. Farther south in the Hole in the Wall Batholith southwest of Pass Creek a rusty weathering area of miarolitic granitic rocks is exposed. No molybdenite was noted in these rocks but they and other high-level granitic rocks in the region merit careful prospecting.

Springs

Description

Warm springs were examined 7 miles east-northeast of Seaplane Lake, 6 miles east-northeast of Seaplane Lake, 2 miles southwest of Seaplane Lake, immediately west of Hole in the Wall Lake, and at Rabbitkettle Hotsprings. With the exception of the springs near Hole in the Wall Lake all have deposited considerable amounts of cream, buff, and ochre calcareous tufa. Much of the descriptive material on springs in Flat River map-area was compiled by M. E. Atchison (1964).

The largest pools of warm water are associated with the springs 7 miles east–southeast of Seaplane Lake. There, three pools—an upper one about 250 feet long, 100 feet wide, and averaging 8 feet deep; a middle one about 575 feet long, ranging from 50 to 125 feet wide, and averaging 6 feet deep; and a lower pool about 110 feet long, 40 feet wide, with an average depth of 4 feet—are dammed by arcuate deposits of tufa convex downslope (in plan and in cross-section). Temperatures range from 64°F in the lowest pool to 79°F in the highest. Lush vegetation grows at the bottom of the pools.

The springs 2 miles southeast of Seaplane Lake have deposited calcareous tufa over an area from 400 to 500 feet long and 200 feet wide. The springs emerge from a hillside to the northeast. Locally, abundant ochre coats the tufa. The water temperature was estimated to be about 60°F, similar to that for the springs farther east on the north side of Flat River.

Rabbitkettle Hotsprings form a spectacular terraced, flat-topped deposit of tufa, roughly circular in plan, with a diameter of about 225 feet, which rises 90 feet above the level of Rabbitkettle River. Successive terraces of aragonite ranging from 6 inches to 12 feet high produce the appearance of a giant layer cake. Stalactitic flowstone structures are present on the sides of large terraces. The surface of the flowstone is creamy white and covered with closely spaced horizontal ridges, in some places protruding only an eighth of an inch and in others about three eighths of an inch, as a series of drooping lips. In longitudinal section the flowstone forms successive concentric layers about the long axis. Parallel horizontal banding caused by alternating layers of varying porosity connects the ridges. The main spring issues from a pool about 12 feet in diameter near the centre of the uppermost terrace.

Flat-lying tufa is associated with two warm springs a short distance southeast of the hot spring described above. The spring at the south end has the greatest volume of discharge of the Rabbitkettle springs. In all springs a temperature of 69°F was recorded.

Warm springs immediately west of Hole in the Wall Lake have deposited negligible material. Locally, granitic rocks are coated with a creamy white kaolin-like material.

The warmest hot spring, and the one with possibly the greatest flow noted in the region, occurs in Dahadinni map-area about three eighths of a mile south of Redstone River and about 1½ miles east of the eastern boundary of Wrigley Lake map-area. Tufa deposited by the spring covers an area about 200 yards long and 200 yards wide. The main terrace is about 150 feet high, 75 yards long, and 50 yards wide. A smaller deposit of tufa occurs quarter of a mile south–southwest of the main spring and is presumably also related to a warm spring. The springs are surrounded by a luxuriant growth of evergreen trees.

Discharge by the main spring was estimated at several hundred gallons per minute, at a temperature of more than 130°F. Where the water is warmest it flows in channels containing abundant, deep blue-green algal slime. In places where the water temperature is lower because of mixing with cold surface water, the algal slime is buff to cream and orange.

A spring about a mile south of Caesar Lakes in Flat River map-area has deposited tufa on a steep hillside over an area about 400 feet long and 240 feet wide. The deposit is terraced and cross-sections show well-defined layering parallel with the upper surfaces of terraces. The tufa weathers light and dark grey where dry but is brilliant orange where spring water flows over it.

Chemical analyses of spring waters and one analysis of Flat River water are given in Table IV.

TABLE III | *Insoluble residues of calcareous tufa deposits*

Locality	Material	Insoluble Residue	Weight (per cent)
7 miles east–northeast of Seaplane Lake	fresh, damp tufa from main deposit	fibrous orange–brown algae	6.30
	dry, weathered tufa from main deposit	fibrous green-brown algae	0.46
Caesar Lakes	riffle dams	dark brownish green algae	4.09
	pisolites	black algal mass, retains shape of pisolite	1.65
	pisolitic gravel	black algal mass	4.76
Rabbitkettle Hotsprings	tufa with leaf imprints	dark grey–brown algae	3.58
	tufa with leaf imprints	light green–brown algae	1.47
	coarsely crystalline aragonite	brown algae	1.12
	stalactitic flowstone	dark green algae	2.61
	fresh tufa from top of main deposit	light green algae	1.66

TABLE IV *Analyses by Industrial Waters Section, Department of Energy, Mines and Resources* (in p.p.m.)

Location	Date	Temp.	pH	SiO_2	Ca	Mg	Na	K	Fe	CO_3	HCO_3	SO_4	Cl	F	NO_3	Turbidity	Hardness ($CaCO_3$)
NE side of Flat River, 4½ miles NE of mouth of McLeod Creek	July 13, 1964	53°F	7.3	21	158	21	1.6	3.2	0.31	0	580	15.7	0.4	0.37	0.1	0	481
SE side of Flat River, 5½ miles NE of mouth of McLeod Creek a) 5 feet above river	July 14, 1964	51°F	7.3	22	151	33	2.0	3.5	0.31	0	563	54.3	0.2	0.48	0.0	0.2	512
b) 125 feet above river	July 14, 1964	63°F	7.3	21	96	34	1.9	5.2	0.05	0	391	60.4	0.3	0.38	0.1	0	379
c) 125 feet above river (70 feet downstream from (b))	July 15, 1964	63°F	7.4	22	152	33.6	2.0	3.2	2.0	0	558	61.3	0.1	0.43	0.2	1	518
7 miles ENE of Seaplane Lake	June 15, 1963	79°F	8.0	14	36.1	20.4	1.1	2.1	0.07	0	184	24.2	1.7	0.27	0.4	—	174
1 mile SW of Caesar Lakes	July 15, 1963	38°F	7.9	5.4	38.8	7.7	11.0	1.2	0.01	0	142	34.9	0.5	0.21	0.2	—	129
Rabbitkettle Hotsprings	July 26, 1963	69°F	7.9	15	44.8	41.2	3.9	4.9	0.11	0	317	32.2	4.1	0.25	0.2	—	281
Flat River, centre of river 5½ miles NE of mouth of McLeod Creek	July 15, 1964	56°F	7.6	5.4	31.5	5.2	1.0	0.7	0.69	0	94.1	21.8	0.1	0.13	0.0	0.4	99.9

Many of the tufa deposits display remarkable sedimentary features of carbonate deposition. The most conspicuous are the large-scale terraces best seen at Rabbitkettle Hotsprings. In places an anastomosing network of small riffles has developed on the surfaces of terraces (*see* Pl. XLV). The riffles average about a quarter to half an inch high and from an eighth to quarter of an inch wide. They form a series of dams, convex in the direction of stream flow, that impound pools as much as 2 to 3 inches wide and 12 inches long, elongate in a direction perpendicular to stream flow. The pools contain accumulations of aragonite crystals and in some places a spectacular development of pisolites. Pisolites range from an eighth to three quarters of an inch in diameter. They are concentrically banded, the larger ones being flattened ellipsoids and the smaller ones more nearly spherical.

Freshly precipitated aragonite at Rabbitkettle Hotsprings locally forms small cups, many containing a gas bubble. These bubble cups appear to form under about an inch of water.

Insoluble residues from some of the calcareous tufa deposits were obtained using dilute hydrochloric acid. In all instances most of the residue appears to be organic (*see* Table III).

Origin

Some generalizations may be made concerning the geological setting of springs in the region; these allow for speculation about the source of water and heat. A common characteristic of springs in the Operation Nahanni region and those to the south and southeast in Rabbit River and Toad River map-areas, is their occurrence far removed from areas of recent igneous activity. Most are related to bedrock formation that contains unusually high concentrations of iron sulphide, e.g., pyritic shales of Road River and Besa River Formations. This generalization might also apply to the springs at Cantung and Hole in the Wall Lake where sulphides are present nearby in contact metamorphic aureoles, and to the large spring south of Redstone River where pyrite nodules are locally abundant in the lower part of the Delorme Formation.

From the criteria noted above it seems probable that the spring waters are of meteoric origin. Furthermore, it is speculated that heat is derived from the oxidation of sulphide minerals, facilitated by the circulation of groundwaters. Presumably the cold springs have resulted from the depletion of sulphides in the immediate area.

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PLATES II TO XLV

PLATE II
View north over Rockslide Pass showing rockslide-avalanche scar in gently dipping Cambro-Ordovician strata of Broken Skull Formation. Debris from the slide extends down the valley to the southwest for more than a mile.

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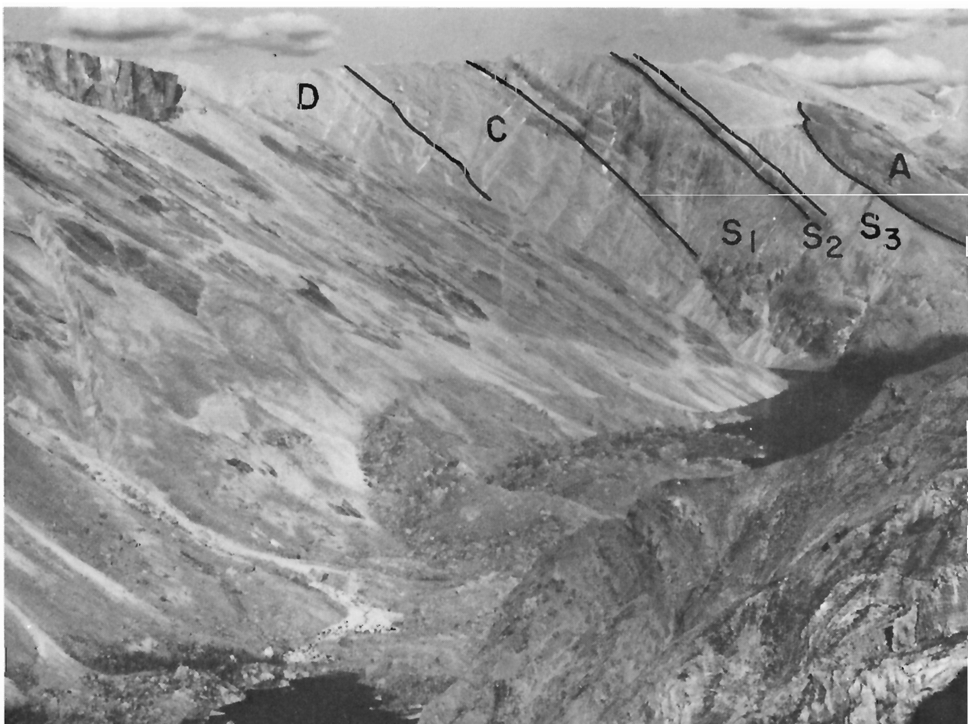

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PLATE III. View northeastward over Avalanche Lake formed as a result of damming by rockslide debris. Dip-slope in strata of Sombre Formation. A – Arnica Formation; S_1, S_2, S_3 – lower, middle, and upper members of Sombre Formation; C – Camsell Formation; D – Delorme Formation. Strata of Funeral Formation in foreground.

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PLATE IV. View just east of that shown in Plate III. Note rockslide debris in right middleground more than 1,000 feet above the valley floor.

PLATE VI
Rock glaciers derived from Rabbitkettle Formation on southwest side of the valley, about 11 miles north-northwest of Caesar Lakes.

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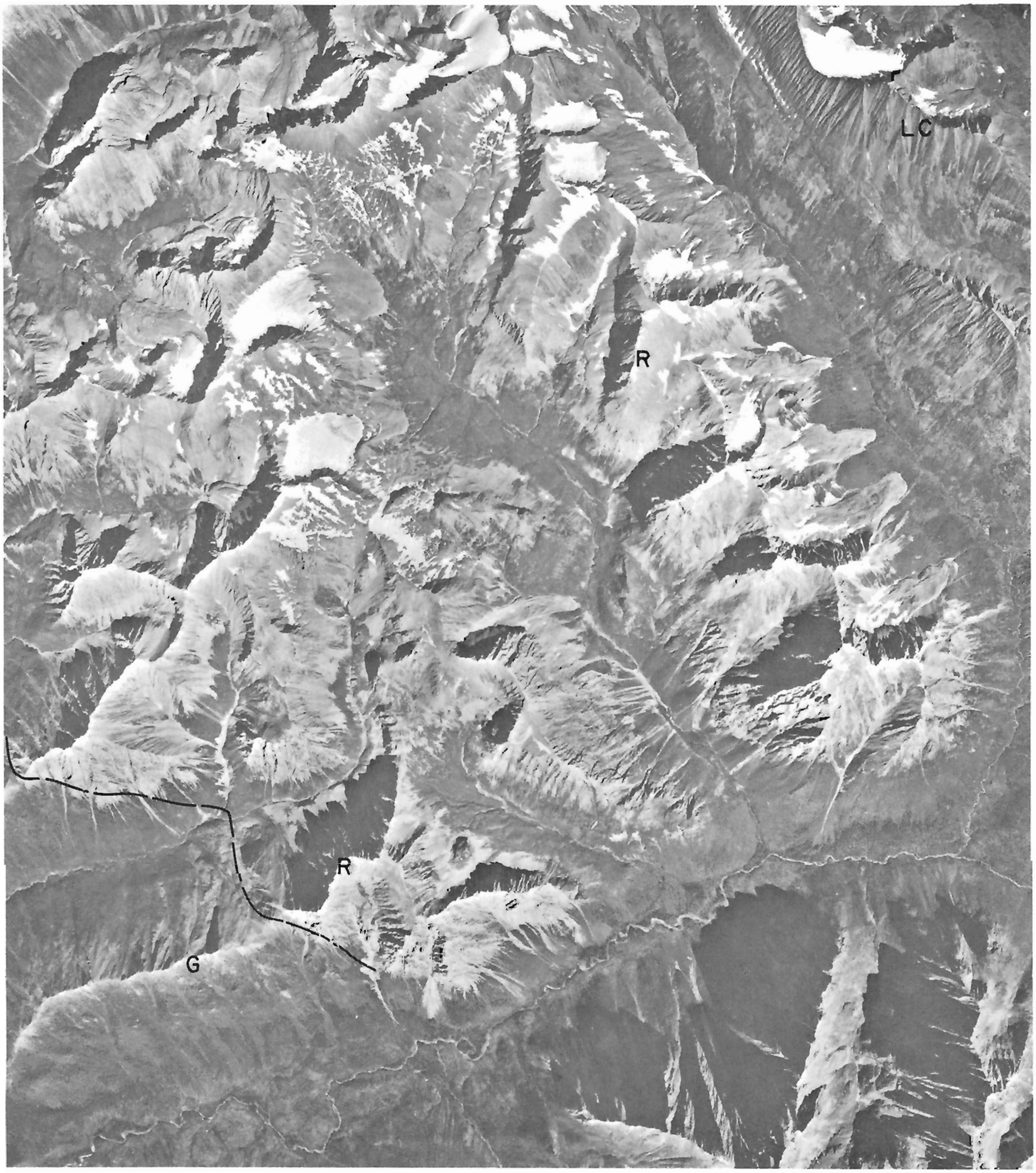

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PLATE V. Logan Mountains northeast of Caesar Lakes showing typical weathering characteristics of the "Grit Unit" – G, Lower Cambrian argillaceous rocks – LC, and Rabbitkettle Formation – R. Note mass wastage features such as rock glaciers and talus fans and aprons in areas underlain by Rabbitkettle Formation.

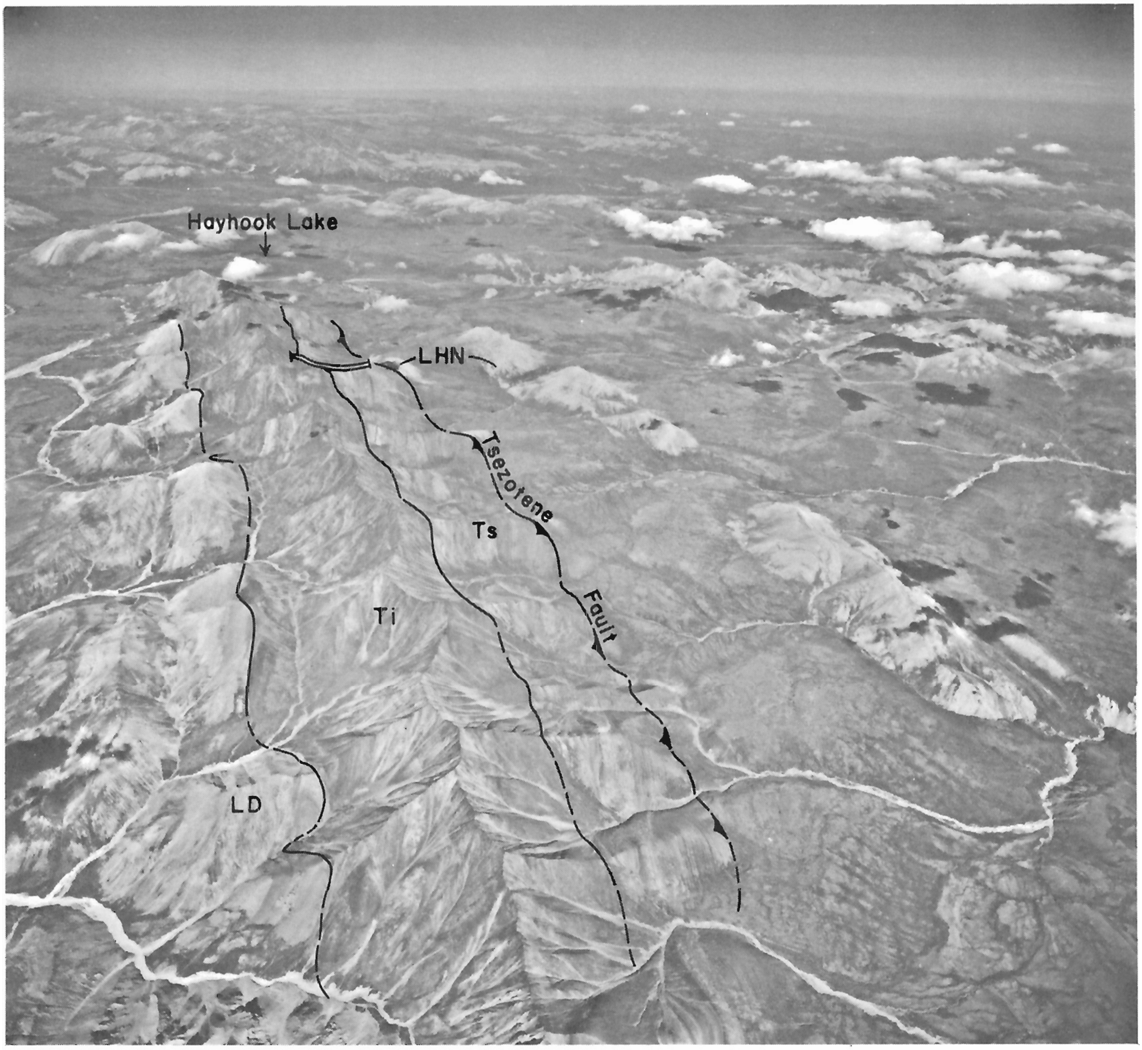

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PLATE VII. View northward over Tsezotene Range with North Redstone River and southeast end of Tigonankweine Range in background. Ts – Tsezotene Formation, location of type section indicated; Ti – Tigonankweine Formation; LD – Little Dal Formation; L H N – Landry, Headless, and Nahanni Formations. Recessive Upper Devonian shales underlie valley east of Tsezotene fault.

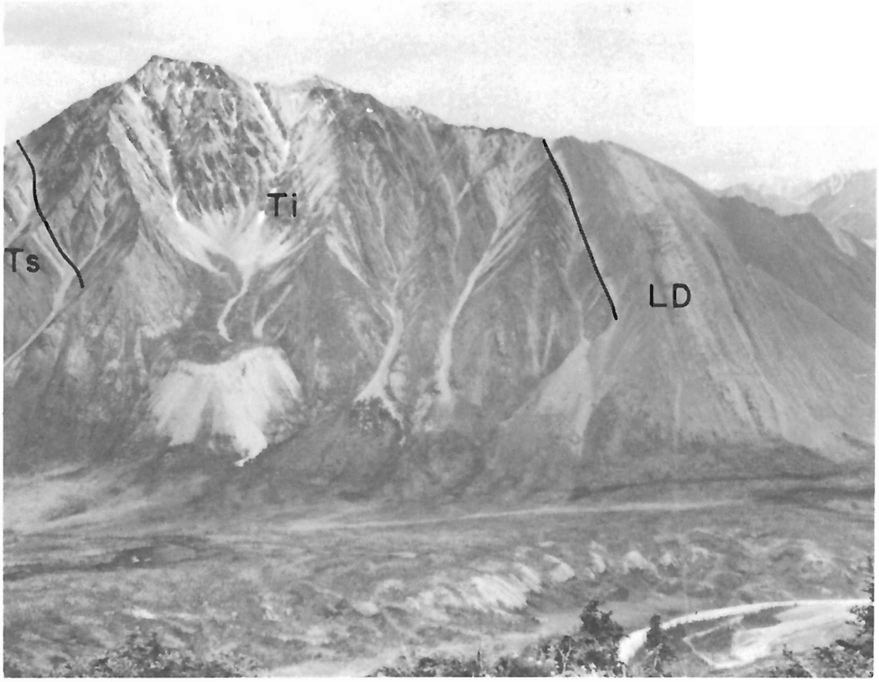

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PLATE VIII. View southeastward across Thundercloud Creek to mountain about 5 miles southwest of Little Dal Lake with Tsezotene Formation – Ts and type section of Tigonankweine – Ti and Little Dal – LD Formations.

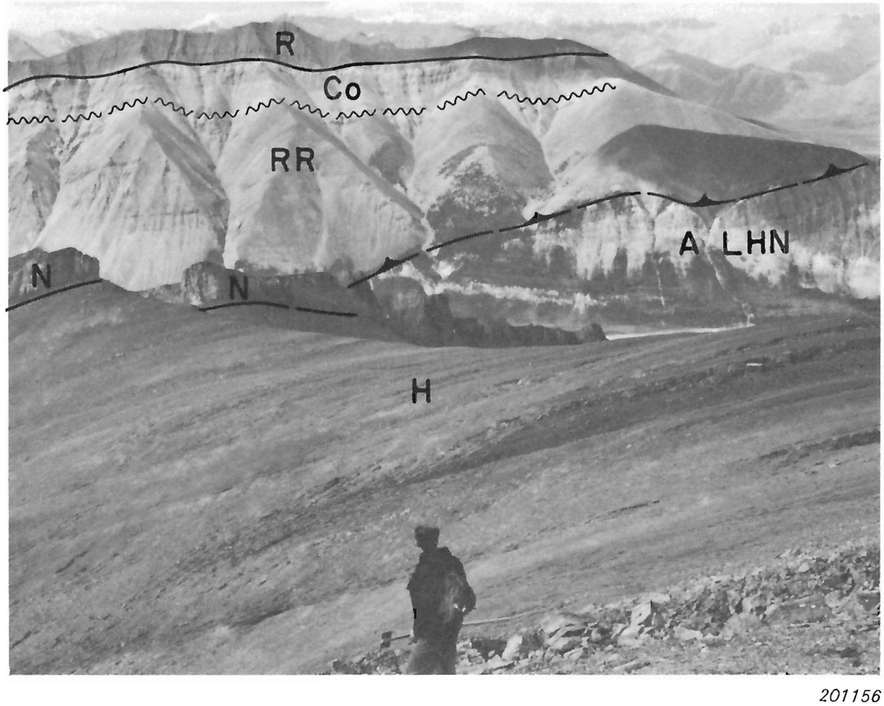

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PLATE IX. View westward from Thundercloud Range across valley of Thundercloud Creek. Strata in hanging-wall of thrust fault include Redstone River Formation – RR, Coppercap Formation – Co, and Rapitan Group, Lower Member – R. Easterly overturned and faulted limb of a syncline includes strata of Arnica, Landry, Headless and Nahanni Formations – A L H N. Strata in the foreground comprise the recessive Headless Formation – H and the overlying, resistant Nahanni Formation – N.

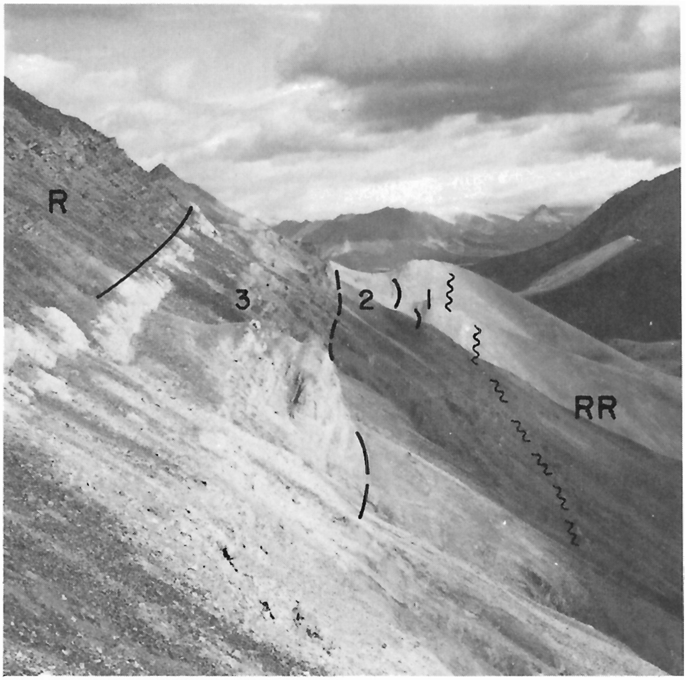

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PLATE X
View northward along east slope of mountain immediately east of Little Dal Lake showing type section of Coppercap Formation with its three members – 1, 2, 3. RR – Redstone River Formation, R – Rapitan Group, Lower Member.

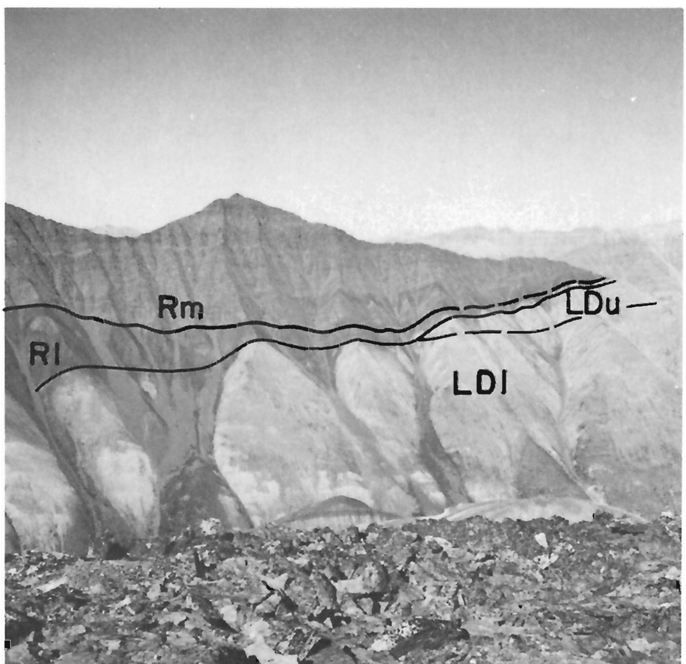

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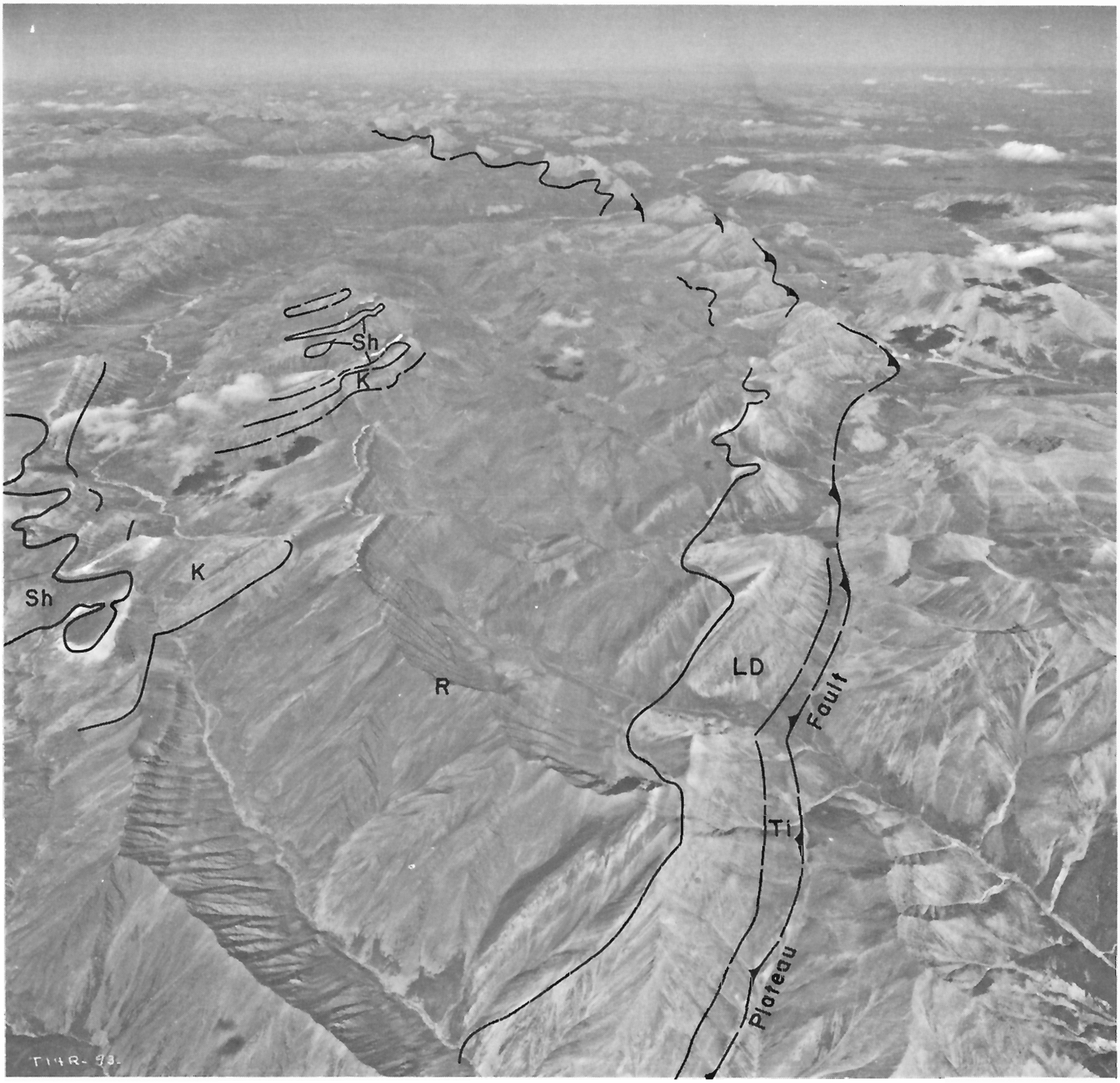
PLATE XII
View westward from mountain east of Plateau Fault and south of Redstone River in south-central Wrigley Lake map-area. Rapitan Group with the middle conglomeratic mudstone member – Rm unconformably overlying the Lower Rapitan – Rl which in turn unconformably overlies the upper and lower members of the Little Dal Formation – LDu, LDl.



EMR T14R-93

PLATE XI. View northward along Plateau Fault marking the east side of Redstone Plateau in central Wrigley Lake map-area. Strata east of Plateau Fault are mainly of Paleozoic age whereas those to the west are of Proterozoic age. Ti – Tigonankweine Formation (?), LD – Little Dal Formation, R – Rapitan Group, K – Keele Formation, Sh – Sheepbed Formation. Section 10 measured on ridge in left foreground.

EMR T8-162L

PLATE XIII. View northward over southwest part of Redstone Plateau. Strata of Backbone Ranges Formation – BR to the west underlie the highest peaks in this part of Mackenzie Mountains. Note typical weathering characteristics of Rapitan Group R, Keele – K, and Sheepbed Sh Formations. Type sections of Keele (1) and Sheepbed (2) Formations indicated.

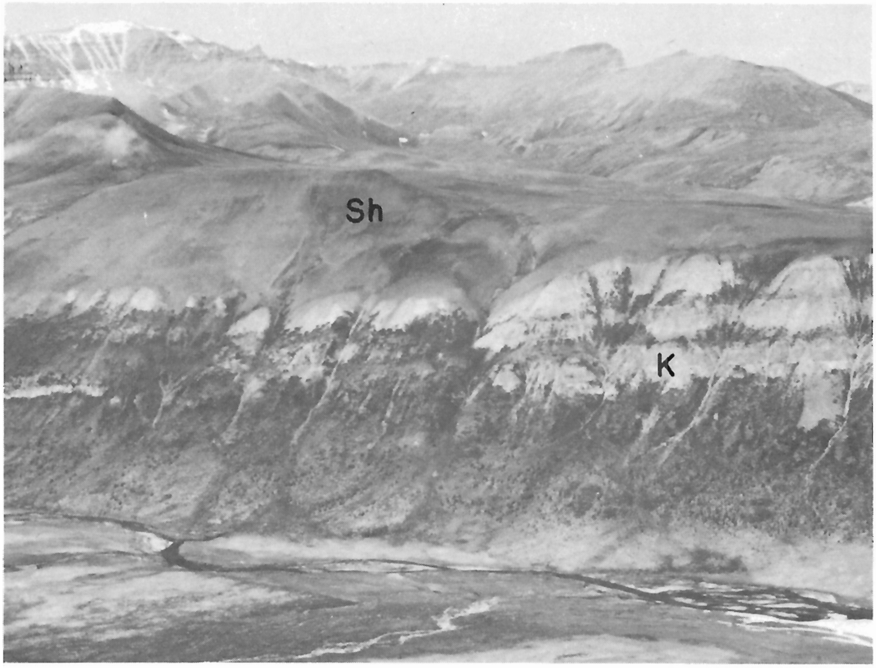


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PLATE XIV. View northwestward over valley in Redstone Plateau about 16 miles west – southwest of Hay-hook Lake showing typical weathering aspects of Keele – K and Sheepbed – Sh Formations.

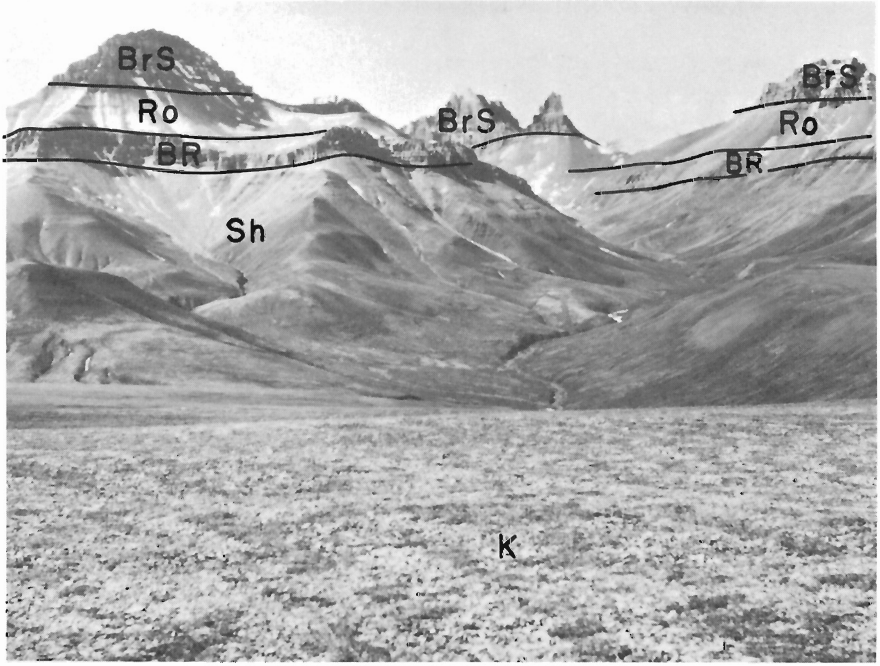

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PLATE XV. View southwestward from same locality as in Plate XIV. Peaks are underlain by resistant strata of Broken Skull Formation BrS overlying recessive rocks of the Rockslide Formation Ro. A relatively thin sequence of the Backbone Ranges Formation – BR forms cliffs above the subdued slopes underlain by the Sheepbed Formation - Sh. Surface in foreground is a stripped dip-slope on top of the Keele Formation – K.

201165

PLATE XVI. View northward over westerly dipping strata of Backbone Ranges Formation – BR and overlying Avalanche Formation – Av about 7 miles north of Avalanche Lake.

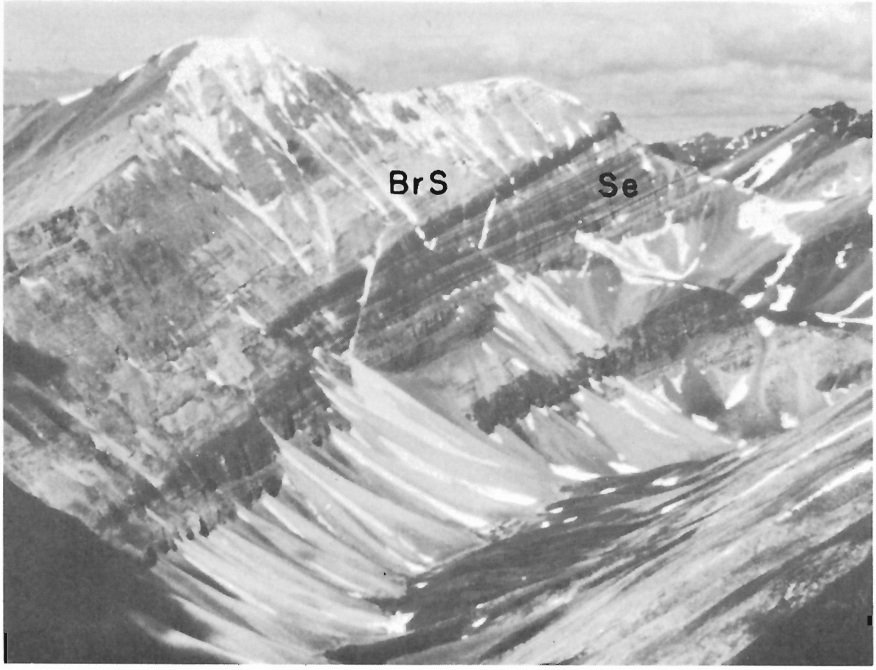

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PLATE XVIII. View northwestward over southwest limb of South Nahanni Anticline showing Broken Skull Formation – BrS resting unconformably on well-bedded strata of Sekwi Formation – Se.

EMR T8-151R

PLATE XVII. View northward over central Redstone Plateau in southwestern Wrigley Lake map-area showing type section 16 of recessive Rockslide Formation - Ro. Uppermost beds of the formation were not measured. Note well-defined 'silver beds' forming base of resistant Broken Skull Formation - BrS. Ridge in foreground shows apparent truncation of units in Rockslide Formation by unconformity at base of Broken Skull Formation. Section 17 measured in lower member of the Broken Skull Formation - BrS_l, comprising basal, sandy silver beds and an overlying unit of orange weathering dolomite, and upper member of Broken Skull Formation - BrS_u, comprising interbedded dolomites and limestones. Backbone Ranges Formation - BR.

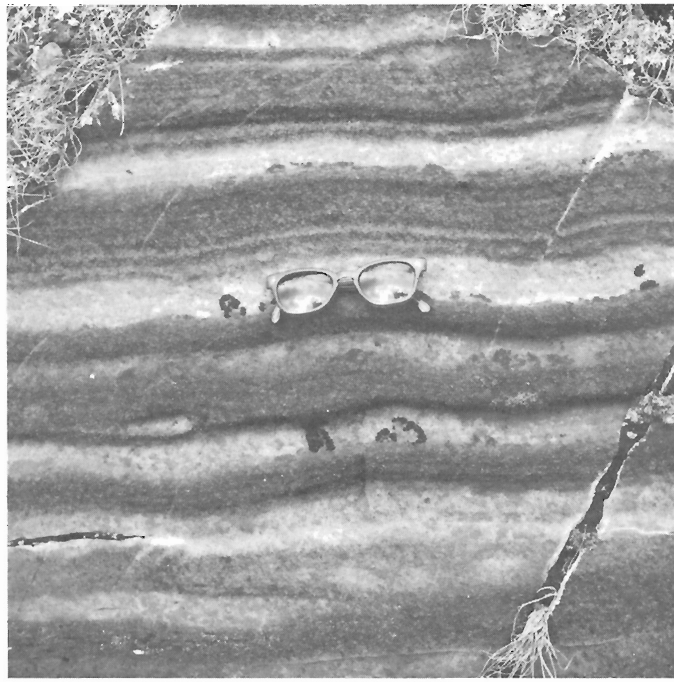

PLATE XIX
Graded silty layers in carbonate strata of lower Rabbitkettle Formation, southeastern Flat River map-area.

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PLATE XX
Well-banded strata of lower Rabbitkettle Formation in same locality as Plate XIX. Darker bands are silty and display graded bedding. Sun-glasses give scale.

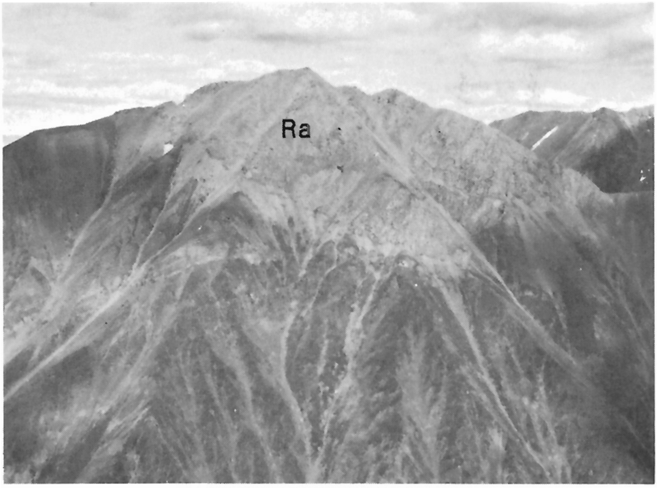

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PLATE XXI
View northward from point about 6 miles south-southeast of Caesar Lakes. Rabbitkettle Formation – Ra unconformably overlies strata of 'Phyllite Unit.'

A12277-137

PLATE XXII. Standard reference section of Sunblood Formation along crest of ridge north of Flood Creek in south-central Glacier Lake map-area. Numerals indicate members of Sunblood Formation. BrS – Broken Skull Formation. RRi – Road River Formation.

PLATE XXIII

Base of Sunblood Formation about 5 miles south of type section near Flood Creek. Note contrast between smooth weathering profile of the basal dark grey dolomite member of the Sunblood Formation and craggy weathering of the underlying upper part of the Broken Skull Formation.

123691

PLATE XXIV

View northward over Rouge Range and Redstone River near the boundary of Wrigley Lake and Dahadinni map-areas. Shows typical weathering aspects of Tigonankweine - Ti, Cambro - Ordovician ? -- 17d. Whittaker–Wh, Delorme–De, Camsell - C, Sombre three members: S_1, S_2, S_3, Arnica–A, and Landry – L Formations. H.S. – hot springs. *(EMR T8-123-R)*.

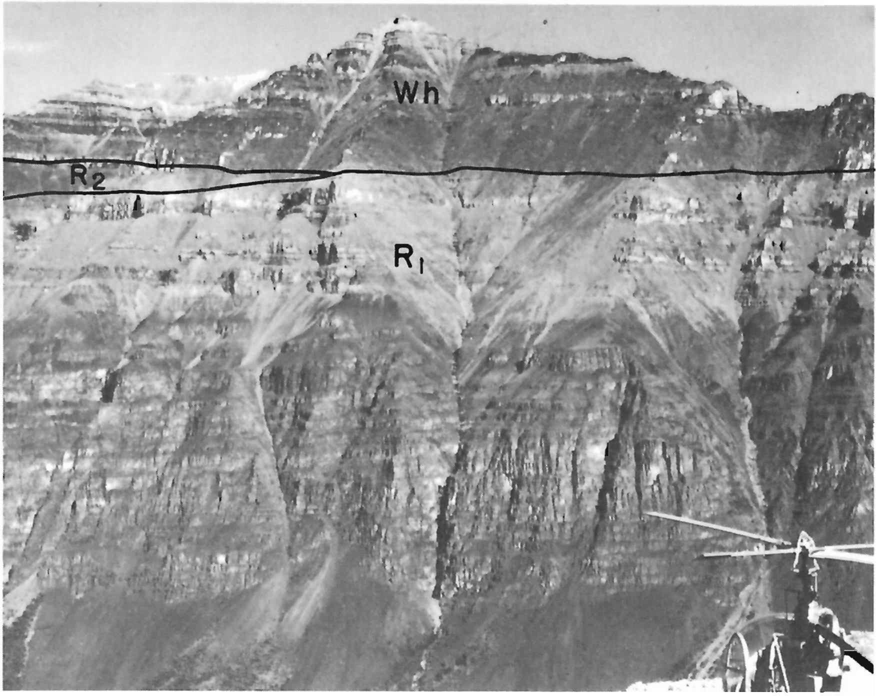

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PLATE XXV. View northward in central Thundercloud Range showing Whittaker Formation – Wh overlying lower two members of Rapitan Group -- R_1, R_2 unconformably.

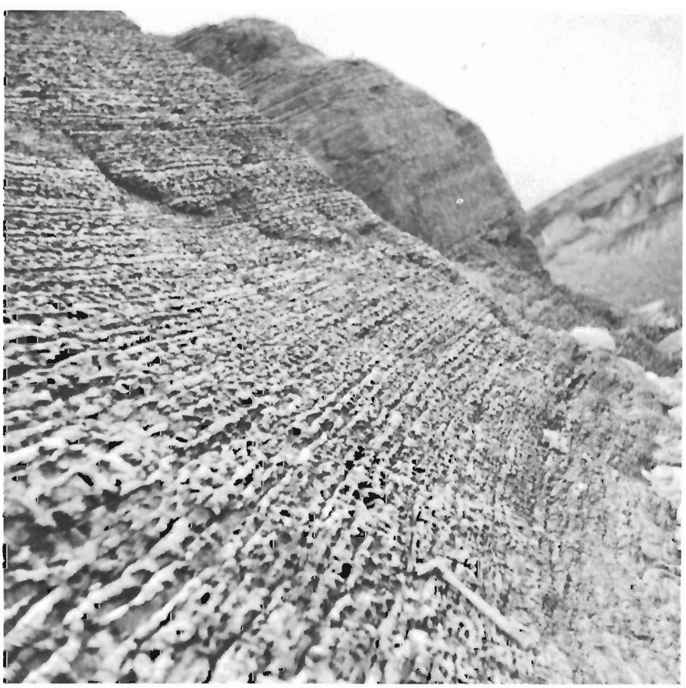

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PLATE XXVI
Lower, dark grey, cherty dolomite member of Whittaker Formation, 4 miles northeast of Avalanche Lake.

123649

PLATE XXVII
Platy, argillaceous limestone of Whittaker Formation about 4 miles northeast of Avalanche Lake.

PLATE XXVIII
Massive, reefoid limestone and dolomite of upper member of Whittaker Formation, about 3 miles northeast of Avalanche Lake. The reefoid strata are about 1,000 feet thick.

123852

EMR T11-118

PLATE XXIX. View northward over northwest end of Broken Skull anticline. On southwest limb light weathering strata of Funeral (?) Formation -- F separate Road River Formation -- RRi from Devono-Mississippian shales (MU 34). Backbone Ranges Formation - BR, Avalanche Formation - Av, Broken Skull Formation – BrS, Sunblood Formation -- Su. Location of section 41 indicated.

PLATE XXX
Typical weathering of argillaceous limestones of Road River Formation on northwest side of Flat River about 4 miles north of McLeod Creek.

GSC 1-5-64

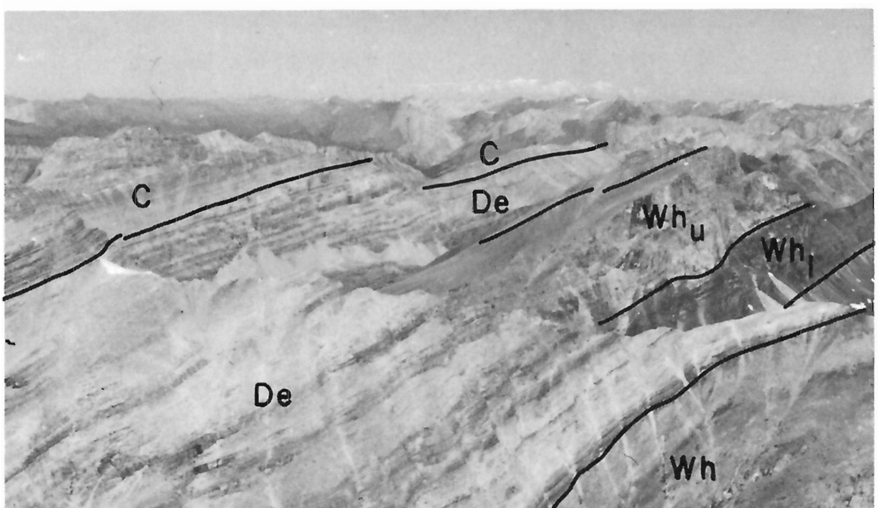

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PLATE XXXI. Westerly dipping strata of Whittaker (lower, cherty dark grey dolomite and upper reefoid carbonate members) – Wh$_l$, Wh$_u$; Delorme – De; and Camsell – C Formations northwest of Avalanche Lake.

EMR T22R-55

PLATE XXXII. View northward over headwaters of North Nahanni River and southwest side of Thundercloud Range where a thick sequence of Paleozoic carbonates overlie the Proterozoic Rapitan Group – R and Cambro-Ordovician (?) strata - 17d. Southwest of Thundercloud Fault the post-Whittaker rocks represent a transitional facies between carbonates to the northeast and shales to the southwest. Note black weathering mafic flow in Little Dal Formation in hanging-wall of Thundercloud Fault. Little Dal Formation – LD, Whittaker Formation – Wh, Delorme Formation – De, Camsell Formation - C, Sombre Formation - S, Arnica Formation - A.

123268

PLATE XXXIII
View northwestward over Middle Devonian strata about 8 miles east-southeast of Hayhook Lake. Dark weathering rocks of Arnica Formation – A with local brecciated limestone and dolomite of Bear Rock Formation – BR are overlain by Landry Formation – L. Southeast end of Tigonankweine Range in background.

PLATE XXXIV
Massive carbonate breccia of Bear Rock Formation in northwesternmost Wrigley Lake map-area.

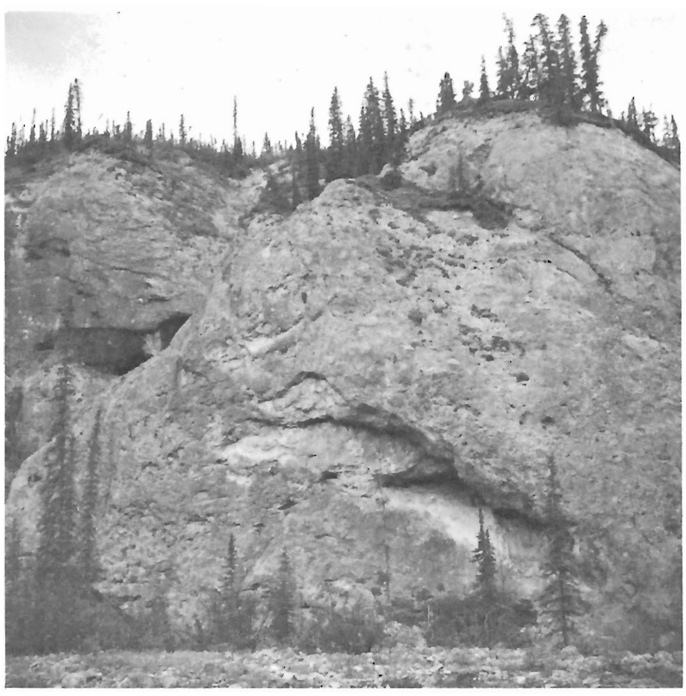

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PLATE XXXV
View eastward from fossil-fish locality about 12 miles south – southeast of Grizzly Bear Lake. Massive, light grey weathering Grizzly Bear Formation - GB underlies Funeral Formation – F and overlies well-bedded dolomites of undivided Camsell, Sombre, and possibly minor Arnica Formation.

123801

201155

PLATE XXXVI. Cavernous, extremely coarse grained white dolomites of Manetoe Formation in northwest Thundercloud Range.

PLATE XXXVII
Faulted box fold in Landry Formation forming all outcrop shown in this picture. View southeasterly from point about 10½ miles east-southeast of Hayhook Lake.

123631

PLATE XXXVIII. Flatirons of resistant Nahanni Formation overlying recessive Headless Formation on west side of Thundercloud Range.

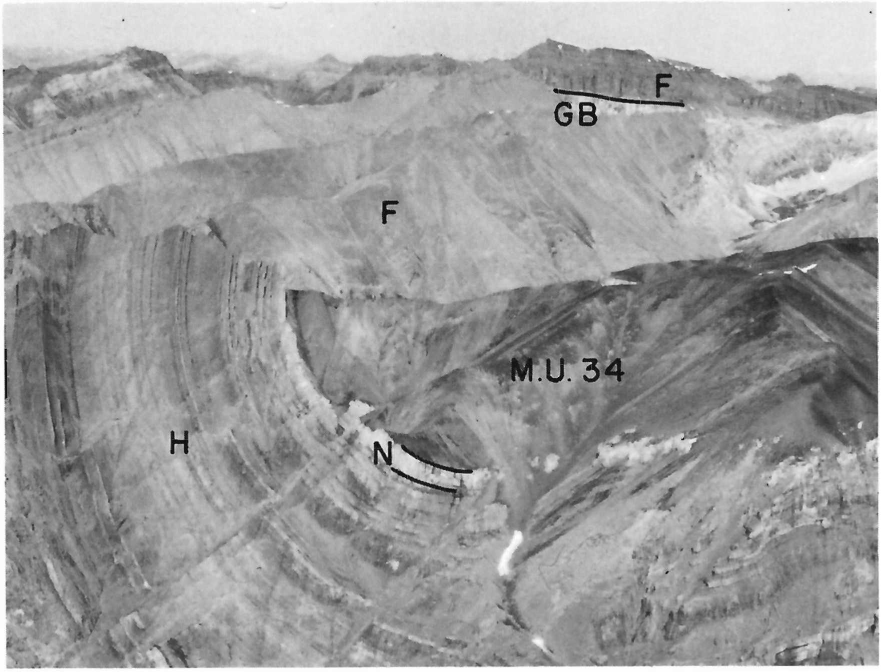

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PLATE XXXIX. Folded Headless – H and Nahanni – N Formations overlain by Middle (?) and Upper Devonian shales (MU 34) east of Black Wolf Creek, Glacier Lake map-area. Funeral Formation – F underlies ridges in middleground and background. Grizzly Bear Formation – GB.

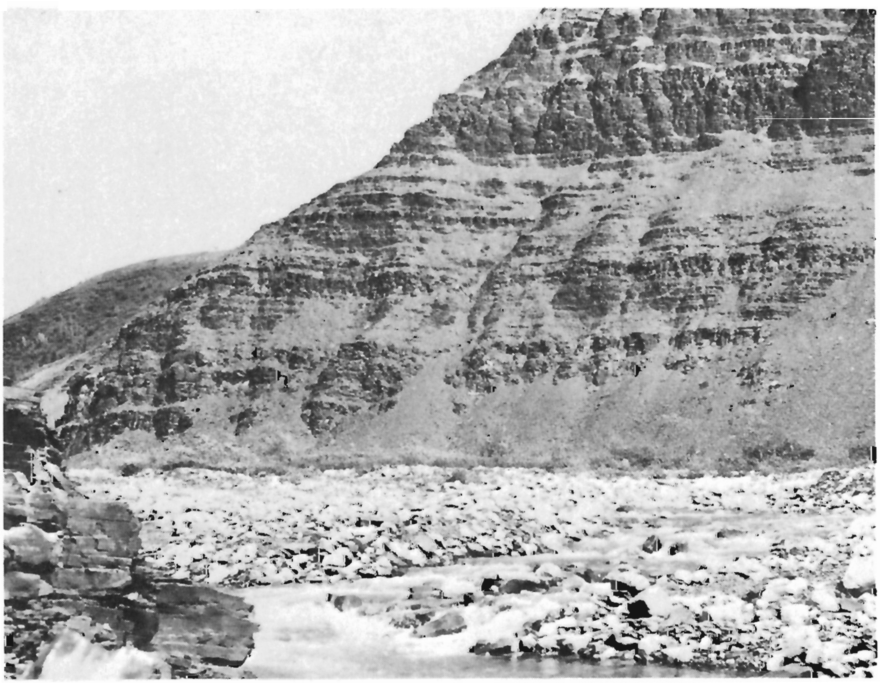

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PLATE XL. Typical weathering aspect of late Frasnian – early Famennian siltstones northeast of Tigonankweine Range.

PLATE XLI
View northward from Brintnell Creek to granitic peaks in Ragged Range. Granitic rocks are intrusive into dark weathering shales of Road River Formation which are underlain by well-bedded carbonates of Rabbitkettle Formation in left foreground.

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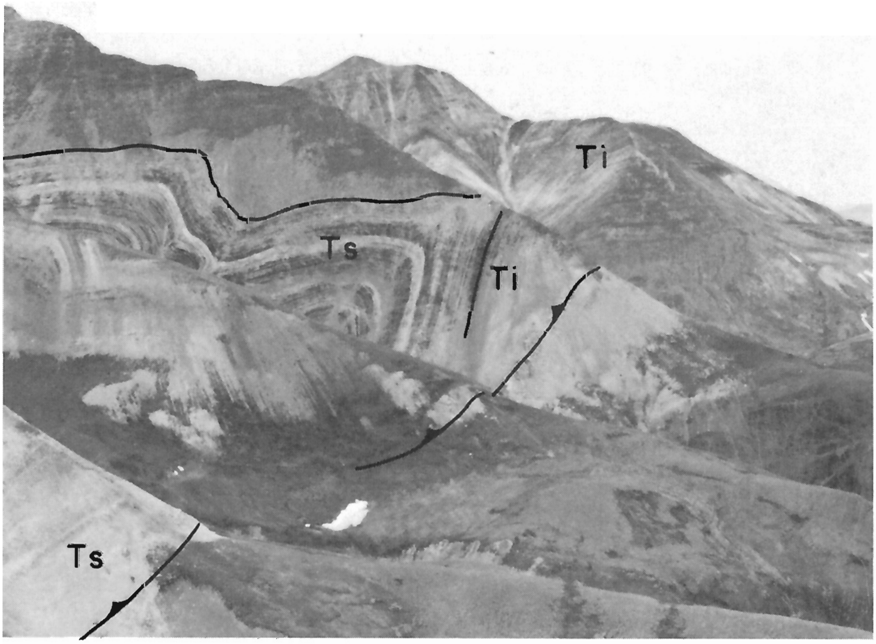

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PLATE XLII. Folded strata of Tsezotene - Ts and Tigonankweine - Ti Formations in hanging-wall of Tigonankweine Fault near latitude 63°45'N. Strata in the footwall are recessive Upper Devonian shales.

123635

PLATE XLIII
Folded and faulted strata of Tsezotene Formation in hanging-wall of Tsezotene Fault 2 miles south of Hayhook Lake. View northward.

201162

PLATE XLIV. View southeastward to tightly folded strata of Headless – H and Nahanni – N Formations overlain by Middle (?) and Upper Devonian shales southeast of Black Wolf Creek. Note thickening of beds in the axis of the syncline.

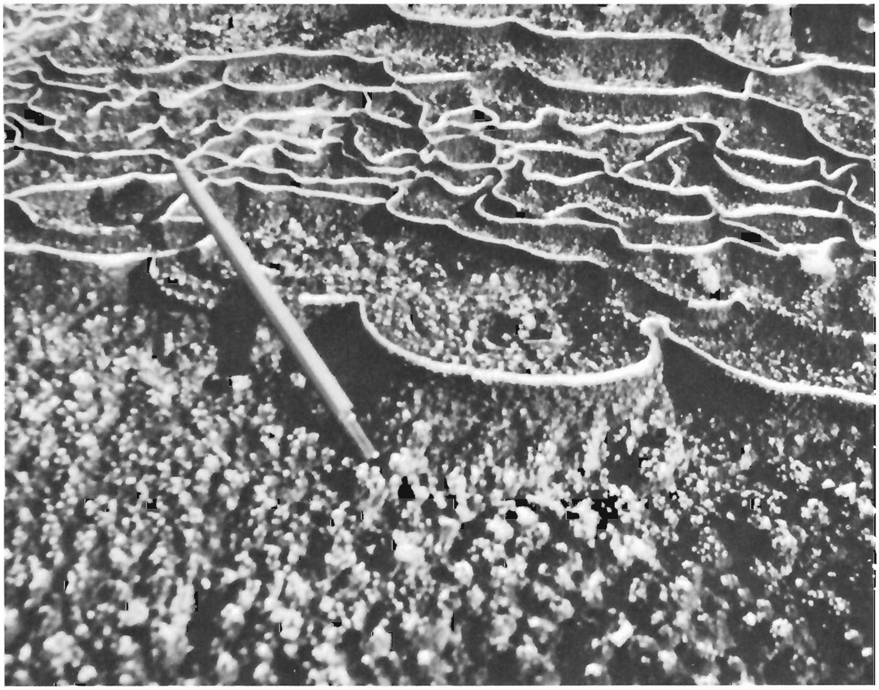

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PLATE XLV. Tufa dams or riffles on terrace of calcareous tufa, Rabbitkettle Hotspring.

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Comprehensive reports on the geology of specific areas, accompanied by one or more multicoloured geological maps. Some recent titles are listed below. (Information Canada Cat. No. in brackets):

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