GEOLOGICAL SURVEY OF CANADA

MEMOIR 319

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OF
CANADA

DEPARTMENT OF MINES
AND TECHNICAL SURVEYS

McDAME MAP-AREA, CASSIAR DISTRICT, BRITISH COLUMBIA

Hubert Gabrielse

Price, $2.00

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2,000—1962—2058

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PLATE I. *View southeasterly across the valley of Troutline Creek and the settlement of Cassiar.* (Photo by William Puritch)

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PREFACE

Since the discovery of placer gold on McDame Creek in 1874 intermittent prospecting has led to the finding of many mineral deposits in the McDame map-area. Some geological investigations were made, but it was not until 1949 that a systematic study of the entire area was commenced—a study that is the basis of this report.

A direct result of the field work in the first year was the recognition of the asbestos deposit now known as the Cassiar Asbestos Mine. Its description is an important part of the report, as are the problems of the stratigraphy and structure of the area that have been elucidated.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, May 23, 1960

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McDAME MAP-AREA, CASSIAR DISTRICT, BRITISH COLUMBIA

Abstract

The McDame map-area covers about 4,900 square miles in northernmost central British Columbia, bounded by latitudes 59° and 60° and longitudes 128° and 130°. The area embraces parts of the Cassiar Mountains and the Liard Plain. The southeastern part includes the western border of the Rocky Mountain Trench.

Bedrock formations include regionally metamorphosed and locally granitized sedimentary rocks of Cambrian and/or Precambrian age, unmetamorphosed, marine sedimentary strata of late Precambrian age, and marine sedimentary strata representing all periods from Cambrian to Mississippian. Upper Devonian and Lower Mississippian formations include volcanic rocks. Tertiary and (?) older terrestrial conglomerate and Tertiary or Pleistocene basalt underlie small areas. Much of the northeastern part of the region is covered with glacial and glacio-fluvial drift.

Significant disconformities occur below Middle Silurian and Middle Devonian strata, and a marked unconformity separates Lower and Middle Mississippian rocks.

Ultramafic rocks are believed to have been emplaced in early Mississippian time and granitic rocks of the Cassiar Intrusions in Mesozoic time.

The regional structural trend is northwesterly. Rocks east of the Cassiar Intrusions have been highly folded and faulted. Several major longitudinal faults, along which some movement has taken place in Tertiary time or later, have been recognized. In addition, the rocks are cut by numerous northerly and northeasterly trending faults.

The map-area includes a wide variety of mineral prospects. Placer gold has been mined since 1874 on McDame Creek and tributary streams. High-grade chrysotile asbestos is being mined near Cassiar.

Résumé

La région de McDame a une superficie d'environ 4,900 milles carrés et se trouve dans la portion la plus septentrionale du Centre de la Colombie-Britannique. Elle est bornée par les 59° et 60° parallèles ainsi que par les 128° et 130° méridiens, et comprend certaines parties des monts Cassiar et de la plaine Liard. La portion sud-est renferme la limite occidentale du sillon des Rocheuses.

La roche de fond comprend dans certaines régions des roches sédimentaires métamorphisées et granitisées par endroits, qui remontent au Cambrien et/ou au Précambrien, des strates sédimentaires marines non métamorphisées qui remontent au Précambrien supérieur, et des strates sédimentaires marines qui représentent toutes les périodes comprises entre le Cambrien et le Mississippien. Les formations du Dévonien supérieur et du Mississippien inférieur renferment des roches volcaniques. Le sous-sol de petites portions de la région contient du conglomérat subaérien d'âge tertiaire et (?) plus ancien, de même que du basalte du Tertiaire ou du Pléistocène. Une bonne partie de la portion nord-est de la région à l'étude est recouverte de drift glaciaire ou fluvio-glaciaire.

Il existe des discordances notables sous les strates du Silurien moyen et du Dévonien moyen tandis qu'une discordance marquée sépare les roches du Mississippien inférieur de celles du Mississippien moyen.

Les roches ultramafiques se seraient déposées au début du Mississippien tandis que les roches granitiques des intrusions Cassiar dateraient du Mésozoïque.

Dans la région à l'étude, les formations sont orientées en direction du nord-ouest. Les roches situées à l'est des intrusions Cassiar ont été fortement plissées et faillées. On a reconnu plusieurs failles longitudinales importantes le long desquelles certains mouvements se sont produits au Tertiaire ou à une époque subséquente. De plus, les roches sont coupées par un grand nombre de failles à direction nord et nord-est.

La région à l'étude comprend une grande variété de gîtes probables de minéraux. Le ruisseau McDame et ses tributaires fournissent de l'or placérien depuis 1874. On extrait présentement de l'amiante chrysotile de haute qualité à proximité de Cassiar.

Chapter I

INTRODUCTION

McDame map-area covers about 4,900 square miles in northernmost central British Columbia and is bounded by longitudes 128° and 130° and latitudes 59° and 60°. The northern latitude is the Yukon-British Columbia boundary. The area derives its name from the abandoned settlement of McDame on Dease River.

Most of the permanent residents live in, or near, the settlements of Cassiar and Lower Post.

Acknowledgments

The writer is indebted to the management of Cassiar Asbestos Corporation, Limited, for facilitating work on the Cassiar Asbestos property. J. Koski of Canadian Johns-Manville Company kindly provided much information on the Zus Mountain ultramafic body. The following provided invaluable general information on the area: G. Hope, G. Davis, S. Bridcut, J. C. Simpson, P. Hankin, P. Hamlin, W. Tisigar, B. Carlick, G. C. F. Dalziel, J. Cassidy, R. Wilms and W. Puritch.

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Professor V. J. Okulitch of the University of British Columbia examined many of the Cambrian fossil collections and F. W. Boswell of the Mines Branch, Department of Mines and Technical Surveys, made possible the use of an electron microscope for the study of serpentine minerals.

The writer wishes to express his gratitude for constructive advice and criticisms on laboratory work given by Professors Arie Poldervaart, C. H. Behre, Jr., W. H. Bucher, R. J. Holmes, and P. F. Kerr of Columbia University.

Accessibility

Most parts of the area are readily accessible. Watson Lake airport is 8 miles north of the map-area and 7 miles by road from the settlement of Watson Lake Wye at mile 635, Alaska Highway. In recent years the latter community has become the communications and outfitting centre for the region.

The Cassiar road runs from mile 648.5, Alaska Highway to Cassiar, a distance of about 87 miles. The Cassiar-Stewart road, under construction, leaves the Cassiar road a mile east of McDame Lake and runs southerly along Vines

Lake, Bass Creek, Cottonwood River, and Dease River, to Dease Lake. A tortuous road to McDame is passable for trucks and four-wheel-drive vehicles.

Dease River is navigable throughout its length although care must be taken in passing Two Mile and Four Mile Rapids near the mouth of the river.

Pack-train routes afford access to outlying parts of the map-area and fodder is commonly abundant.

Numerous lakes are suitable for small aircraft.

Previous Geological Investigations

Very little geological field work had been undertaken in McDame map-area prior to the present reconnaissance mapping by the Geological Survey of Canada. Four exploration parties under the direction of the Geological Survey of Canada and one under the direction of the British Columbia Department of Mines had previously entered the area. In 1887 G. M. Dawson (1889),[1] on his epic trip which covered a vast area in northern British Columbia and Yukon, travelled down Dease River and gave the name 'Cassiar' to the rugged mountains that trend northwesterly across the southwest part of the map-area. F. A. Kerr (1925) and W. A. Johnston (1925) examined the area near Dease Lake as far north as Cottonwood River. George Hanson and D. A. McNaughton (1936) reconnoitered the area south of Troutline and McDame Creeks and west of Four Mile River. M. S. Hedley and S. S. Holland (1941) examined the southeastern part of the area near Deadwood Lake. M. Y. Williams (1944) carried out geological investigations along the Alaska Highway near Lower Post and ascended Dease River as far as Two Mile Rapids. Annual reports of the British Columbia Department of Mines contain descriptions of mineral deposits in the region.

Current Geological Investigation

Geological mapping of the McDame map-area, begun by L. L. Price in the summer of 1949, was continued by the writer through the summers of 1950, 1951, 1952, 1953, and 1954. In 1951 two weeks were spent plane-table mapping the Cassiar Asbestos serpentinite body and surrounding rocks. Four days were spent on the property in 1953 after mining operations had begun.

Laboratory work was carried out during the winter of 1952-1953 at Columbia University and continued in the offices of the Geological Survey of Canada.

History

J. M. McLeod, in the employment of the Hudson's Bay Company, apparently was the first white man to enter the area (Dawson, 1889). In 1834 he explored Liard River upstream from Fort Halkett to the mouth of Dease River

[1] Dates, in parentheses, are those listed with authors' names in Bibliography.

and then followed Dease River to Dease Lake. He named the river and lake after Peter Warren Dease, the Arctic explorer. R. Campbell, also with the Hudson's Bay Company, followed the same route in 1838 with the purpose of establishing a trading post at Dease Lake. The post was abandoned in 1839 and no further interest was taken in the area until 1872.

R. Sylvester established the trading post of Sylvester's Landing (later McDame) at the mouth of McDame Creek in 1872. The post was taken over in 1875 by the Hudson's Bay Company and maintained until 1943.

Placer gold was discovered on McDame Creek in 1874 and on Walker Creek in 1877.

G. M. Dawson (1889), W. Pike (1896) and C. Camsell (1954) gave accounts of travel on and near Dease River before the turn of the century. The trail from Sandpile Creek, east of Deadwood Lake, to McDame and Lower Post was described by J. D. Moodie of the Royal North-west Mounted Police in a report on a trip from Edmonton to the Yukon (1899).

Equipment for the construction of Watson Lake airport in 1941 was brought by barge down Dease River from Dease Lake to Lower Post. About this time a paddle-wheel steamer was used on Dease River between Lower Post and McDame Post. After limited service the steamer was wrecked in Two Mile Rapids.

Construction of the Alaska Highway in 1942-1943 has contributed greatly to the development of the area. During the winter of 1946-47 Moccasin Mines Limited, with the assistance of the British Columbia government, constructed a road from the Alaska Highway to McDame Creek. This road provided the first all-land route to the area and thus stimulated prospecting and exploration.

The Cassiar Asbestos deposit was staked in 1950 and since that time the town of Cassiar has grown rapidly.

Climate

The Cassiar Mountains receive moderate precipitation but the bordering areas, Stikine Plateau to the west and Dease Plateau and Liard Plain to the east, are relatively dry. Average annual precipitation over a 12-year period at Watson Lake in the Liard Plain, as reported by the Meteorological Division of the Department of Transport in 1954, was 16.75 inches, of which 7.70 inches fell as snow (77 inches of snow). In the Cassiar Mountains the average annual precipitation is probably between 20 and 30 inches.

June, July, and August, are the warmest and wettest months during which unsettled weather is the rule and showers are frequent. In early August of 1953 temperatures of 85°F were recorded on four successive days. The average daily maximum temperature during the summer months, however, is generally between 60° and 70°F.

January and February are the coldest months and temperatures may fall below –60°F. Snowfall is light in Dease River valley west of the Horseranch Range and horses have wintered successfully without cut hay for many years near the north end of the range.

The months of June, July, August, and September are most suitable for prospecting although snow may hamper work in the mountains until the middle of June and after mid-September.

Flora and Fauna

Much of the area is below timber-line, about 4,500 feet above sea-level. White spruce and cottonwood are the largest trees and grow mainly in the moist but well-drained stream valleys. Gravel and sand terraces flanking the main streams support a growth of lodgepole pine, trembling aspen, and some birch. Black spruce and larch are abundant in poorly drained areas. Larch is particularly abundant in the valleys of Red, Deadwood, and lower Dease Rivers. Dwarf birch, willow, balsam fir, slide alder, and juniper, are locally abundant near timber-line. Willow grows along most of the stream courses. Willow, labrador tea, sedges, cotton grass, and peat moss are common in swamps and bogs.

Edible wild fruits include raspberry, strawberry, red and black currant, cranberry, several varieties of blueberry, gooseberry, and saskatoon (service berry).

Many of the high, open valleys provide excellent feed for grazing animals. Extensive grass-covered areas occur on the east flank of Horseranch Range and near Harvey and Horseranch Lakes.

Game is locally plentiful, particularly in areas remote from towns. Moose are found everywhere and appear to be increasing in number. Stone sheep live mainly in limestone ranges and were seen in flocks containing as many as seventeen. Mountain goat are frequently encountered in areas of rugged terrain. Mountain caribou, formerly numerous in some parts of the area, are apparently decreasing in number but mule deer are reportedly becoming more numerous. Black and brown bear inhabit the low country, especially near Horseranch Range. Grizzly bear were seen above timber-line in many places. Other mammals found in the district include timber wolf, coyote, lynx, wolverine, fox, otter, beaver, marten, fisher, mink, weasel, muskrat, porcupine, rabbit, squirrel, hoary marmot, ground squirrel, shrew, pika, lemming, and mouse.

Franklin's grouse (spruce hen), blue grouse and grey ruffed grouse (willow grouse) are plentiful in some areas below timber-line and ptarmigan are locally abundant above timber-line. The chief waterfowl are ducks, including mallard, Barrow's golden-eye, merganser, harlequin, teal, and scoter, geese, loon, grebe (Holboell's), and tern. Canada geese nest in the sloughs and ox-bow lakes along Dease River.

Grayling, lake trout, Dolly Varden, and whitefish are found in many of the lakes and rivers. Pike abound in ox-bow channels along Dease River.

Industries

Mining has been the principal industry in the area since gold was discovered on McDame Creek in 1874. The development of the Cassiar Asbestos deposit has, of course, been of major importance in terms of employment, revenue, and exploration of the area in recent years.

Lumber mills have operated on a small scale from time to time near Lower Post. In 1953 a sawmill was in operation at Blue River on the Cassiar road but the site was later abandoned. A small sawmill has been maintained on Troutline Creek near Quartzrock Creek for several years and a small unit was used to cut lumber for bridges over Cottonwood and Dease Rivers. Almost all the lumber has been cut from white spruce.

Trapping is carried on by a limited number of people but this industry is apparently becoming less and less important.

In recent years a demand for firewood by the town of Cassiar has given employment to many people. Most of the wood is cut from stands of dead timber near the Cassiar road.

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Chapter II

PHYSIOGRAPHY AND GLACIATION

Physiography

McDame map-area lies within the Interior System of the Western Cordillera of Canada (Bostock, 1948). Two main physiographic divisions are represented: Liard Plain, including the northernmost part of the Rocky Mountain Trench; and Cassiar Mountains, including Dease Plateau, Horseranch, Stikine and Kechika Ranges.

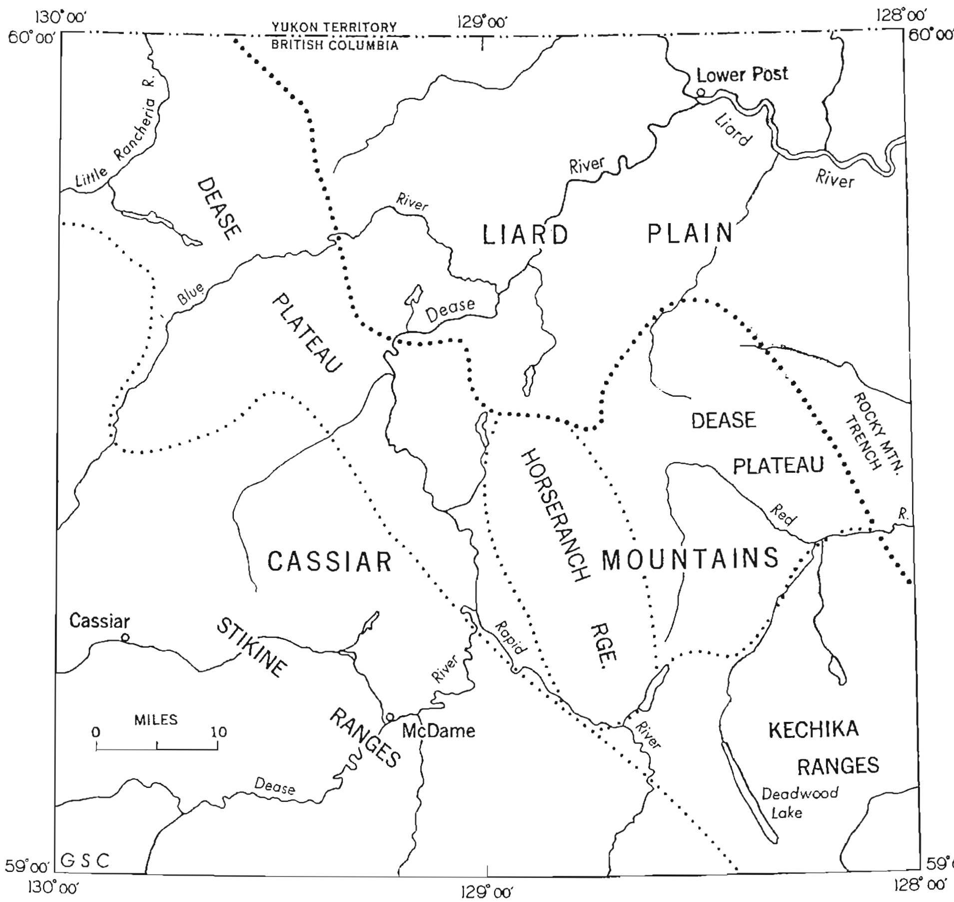

FIGURE 1. ***Physiographic divisions of McDame map-area*** **(revised from Bostock, 1948).**

Liard Plain is a relatively flat, low-lying, drift-covered region with a maximum relief of about 900 feet that occupies the northeast part of the area. Local topography in the plain is mainly the result of glacial, fluvioglacial, and post-glacial erosion and deposition. Parallel ridges and grooves of glacial origin are abundant. Locally, eskers and kettles form an extremely irregular, hummocky terrain. Terraces, cut into glacial material, are conspicuous along Liard, Dease, and Blue Rivers. The main streams are entrenched into the plain, generally into glacial drift but locally into underlying bedrock. Near Lower Post, Liard River has cut down as much as 160 feet into drift. Former courses of Blue River are represented by flat-bottomed abandoned channels up to 2 miles wide that are cut into glacial drift north of the lower reaches of the river.

The western border of the Rocky Mountain Trench forms a distinct straight escarpment where it enters the area from the southeast but merges with the Liard Plain north of Red River.

North of the Rocky Mountain Trench, Liard Plain is bordered on the west by Dease Plateau, an area characterized by northwesterly trending ridges of low to moderate relief.

The Horseranch Range is a striking physiographic unit; its crest line resembles a huge hogs back surrounded by the lower areas of Dease Plateau to the east and by the valleys of Dease and Rapid Rivers to the west. The highest point in the range is at 7,300 feet and is about 5,000 feet above Dease River, the maximum relief in the map-area. The western flank of the range is steep and streams are deeply incised. The eastern flank has a relatively gentle, remarkably uniform slope of about 8 degrees towards the valley of Red River. Streams occupy open valleys below an elevation of 5,000 feet.

The Cassiar Mountains occupy the southwest and southern parts of the map-area. This is a rugged region exhibiting many features typical of alpine glaciation and having a maximum relief of about 4,000 feet. The principal rivers flow through the mountains in deep, relatively broad, U-shaped valleys.

In a general way the topography of the map-area reflects the nature of the underlying bedrock; Liard Plain is underlain by soft, highly incompetent strata whereas Horseranch Range and Cassiar Mountains are underlain mainly by resistant rocks.

All streams belong to the Arctic drainage system and flow into Liard River or its tributaries.

Structural trends in underlying rocks appear to be a major control for valleys of the southeasterly flowing part of Red River, Wadin Creek, and streams east of Solitary Lake. Elsewhere stream directions and structural trends in underlying bedrock are apparently not related.

Most lakes have formed as a result of the interruption of pre-Pleistocene drainage by glaciers. Boya Lake, lakes at the north end of the Horseranch Range and many others in Liard Plain are dammed by eskers and kames or occur within esker complexes. Deadwood, Looncry, and Solitary Lakes lie in basins or trenches that have been partly filled by glacial and glacio-fluvial deposits.

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Glaciation

Well-defined glacial features are abundant (*see* Fig. 2, in pocket). The distribution of glacial erratics and the orientation of glacial striae and grooves indicate that, during Pleistocene time, ice moving northeasterly and easterly covered the entire area, with the possible exception of a few of the highest peaks.

Granitic boulders as much as 5 feet in diameter occur on Sheep Mountain at an elevation of 6,250 feet, and on the peak between Dease and Eagle Rivers at an elevation of 6,584 feet. Glacial grooves are conspicuous to an elevation of about 7,000 feet on Mount Dalton which lies 4 miles south of the map-area and 4 miles east of Eagle River. Striae, erratics, grooves, and drumlinoid lineations are abundant below elevations of 6,000 feet.

Locally, two advances of ice are suggested. In the valley of Dease River, west of Horseranch Range, well-bedded silt and clay, as much as 150 feet thick, overlie till and are in turn overlain by an esker complex. The silts contain ice-rafted boulders and were apparently deposited in a glacial lake.

In many places the nature of the ice-retreat is clearly evidenced by typical late-glacial erosional and depositional features. In general ice retreated southerly and southwesterly in the main valleys of the Cassiar Mountains but probably stagnated over much of the Dease Plateau and Liard Plain.

Features of Ice-Movement

Drumlinized till plain. Much of the northern and northeastern parts of the area are underlain by drumlinized till. Ice advancing over a heavily drift-covered area formed parallel ridges and intervening grooves as much as 2½ miles long. The most clearly defined ridges are long and narrow, have steep sides, and have a classical drumlin form. The stoss end has the greatest width, height, and steepest slope. Other ridges, roughly elliptical in plan have gently sloping sides. In air photographs the outlines of the ridges are commonly accentuated; the ridges are typically covered with trees whereas the intervening areas in many places are open and grassy or swampy.

Generally, the asymmetry of the ridges clearly indicates the direction of ice-movement although in some cases low hills with gentle slopes and intervening swales give little or no suggestion.

Armstrong (1949) suggested that the presence of a drumlinized till plain in Fort St. James area indicated at least two advances of an ice-sheet. The earlier advance deposited a thick mantle of till and the later advance of a lightly loaded ice-sheet moulded the till into drumlin-like ridges. Whether or not these features represent two advances of ice in McDame map-area could not be determined.

Rock drumlins, glacial grooves, striae, and erratics. Drumlins similar in form to the drumlin-like ridges of the drumlinized till plain, but composed, in part, of bedrock, are conspicuous in parts of the Dease Plateau and in almost all the main valleys. These drumlins generally have the classical form and are characterized by exposures of smoothed bedrock at the stoss end.

Glacial grooves and striae indicate that ice moved over most of the mountain ridges. Grooves are most prominent in areas underlain by granitic and volcanic rocks, particularly between Eagle and Four Mile Rivers. They are commonly associated with lee-and-stoss effects (plucking and rounding of outcrops), and therefore indicate the direction in which the ice moved. Striae are rare and were noted only in areas of volcanic rocks.

Glacial erratics are ubiquitous and are especially useful for determining the direction of ice-movement in McDame map-area because their source-area is rarely in doubt. Granitic and volcanic boulders predominate in the material transported northeasterly and deposited on the northeast flank of Cassiar Mountains. In the northern part of the area where ice moved in an easterly direction, large angular blocks of vesicular olivine basalt are numerous. These erratics were probably transported easterly from the western part of Jennings River area.

Deglaciation

Numerous abandoned drainage channels provide some evidence of conditions of deglaciation. Many channels were cut into bedrock on the flanks of ridges or valley walls by meltwater streams that flowed towards the ice-front along the margins of the ice. Frequently, as the thickness of ice decreased, channels were cut at successively lower levels on the hillsides. Parallel sequences of abandoned channels are particularly well developed on the east flank of Horseranch Range and near McDame Lake (*see* Fig. 3).

Well-defined, abandoned, aligned channels extend easterly from Horseranch Range and apparently represent courses of streams that drained proglacial lakes. Gradients of abandoned drainage channels on the east flank of Horseranch Range suggest that ice east of the north end of the range retreated northerly. Meanwhile, ice in the valley of Red River north of Looncry Lake and in the valley of Deadwood River retreated southerly. Evidently the overflow from proglacial lakes, contained to the north and south by ice, drained easterly and cut channels across the ridges south of the big bend in Red River and between Red River and Wadin Creek.

Eskers and kettles are abundant and esker complexes occupy large areas near Cassiar road north of Blue River and near Lower Post.

Crevasse-fillings have been preserved northwest of Captain Lake near Little Rancheria River and west of Cassiar road along the British Columbia-Yukon boundary. In the latter area they rest on a thick deposit of silt that had been only slightly grooved by ice advancing easterly over its surface (*see* Pl. II). The preservation of these features indicates that ice must have stagnated and ablated in these areas during deglaciation.

Bedded silts, presumably deposited in glacial lakes, are exposed in road-cuts along Cassiar road, along Dease River west of Horseranch Range, around Boya Lake, north of Looncry Lake, and north of Solitary Lake.

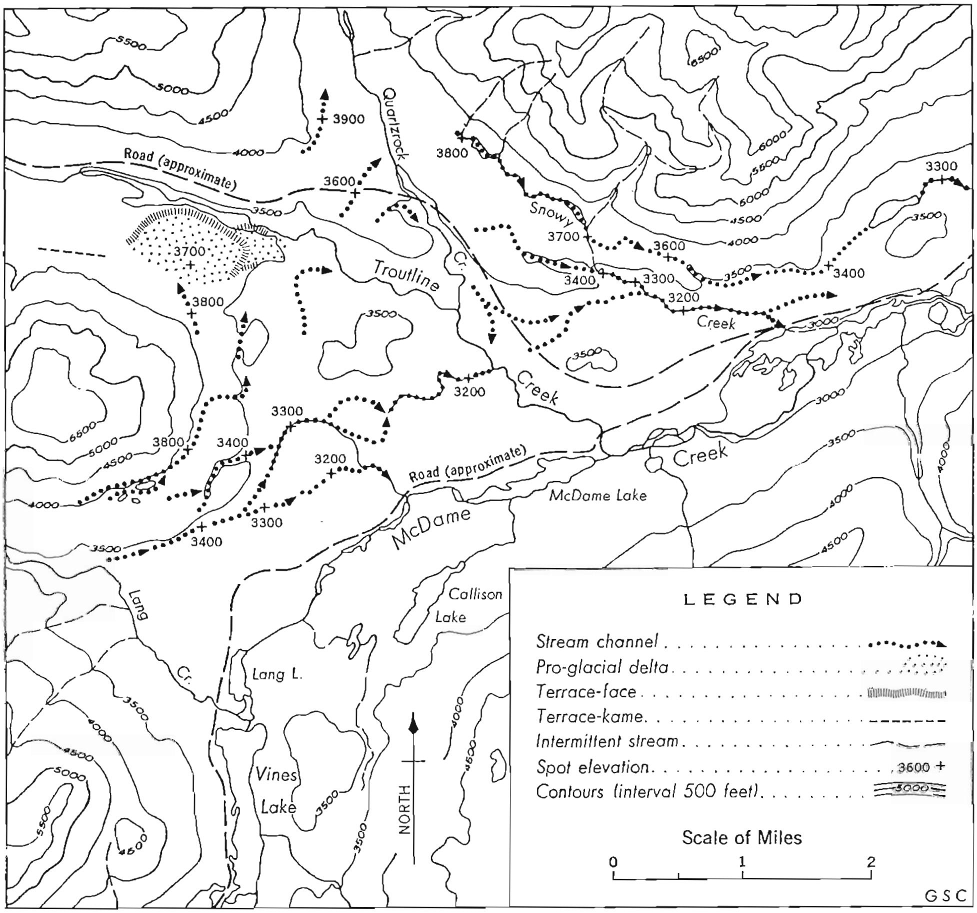

FIGURE 3. *Abandoned drainage channels near McDame Lake.*

Alpine Glaciation

Topographic features resulting from alpine glaciation are common in Cassiar Mountains and in Horseranch Range. Much of the alpine glaciation evidently took place before the last advance of ice over the area. Many of the cirques in Horseranch Range contain remarkably little debris, spurs are generally rounded, and one of the cirques above 6,000 feet elevation near the north end of the range has stream channels cut into its headwall. A similar situation prevails in Cassiar Mountains northwest of Blue River where, at one place, a direct overflow channel from melting ice has breached the headwall of a cirque at an elevation of 5,500 feet.

In the southernmost part of the area, limited alpine glaciation since the retreat of the last ice-sheet has locally produced sharp ridges, spurs, and horns. Apparently this glaciation never reached a widespread valley stage because terminal moraines and outwash deposits are notably lacking.

Chapter III

GENERAL GEOLOGY

Within the map-area, stratified, consolidated rocks of marine origin range in age from Proterozoic to Mississippian. The assemblage has been folded and faulted, and intruded by Mesozoic granitic rocks. Tertiary sediments and basalts occur locally.

The Horseranch Group, a regionally metamorphosed succession of Precambrian and/or Cambrian sedimentary rocks, underlies Horseranch Range. These rocks, exposed in a major doubly plunging anticline, are bounded by faults and drift so that their relations to other rocks are not known.

A thick, apparently conformable sequence of Precambrian and Cambrian limestone, dolomite, quartzite, and shale (Good Hope and Atan Groups) occupy a northwesterly trending, highly faulted anticlinorium on the east flank of Cassiar Mountains, and a narrow belt along the east margin of the Cassiar batholith.

The Kechika Group, comprising highly contorted, thin-bedded limestones and shales of Cambro-Ordovician age underlies many of the low-lying parts of the map-area. The group apparently lies conformably on the Atan Group.

In places east of the belt of Precambrian and Cambrian rocks, well-bedded carbonates and sandstones of Ordovician and Silurian age, the Sandpile Group, overlie the Kechika Group disconformably. Elsewhere, particularly on the limbs of the major synclinorium in the southwestern part of the area, strata possibly equivalent, in part, to the Sandpile Group rest directly on Lower Ordovician rocks.

The McDame Group of mid and possibly late Devonian age lies disconformably on rocks as old as Cambro-Ordovician. The group consists essentially of dolomite and limestone.

The Sylvester Group, a thick assemblage of volcanic and sedimentary rocks of late Devonian and early Mississippian age, lies conformably on the McDame Group on both flanks of the McDame synclinorium[1] in the southwest part of the map-area. Dykes and sills of greenstone, perhaps in part or entirely emplaced in Devono-Mississippian time are common in the Kechika and Sandpile Groups.

Ultramafic rocks of probable Mississippian age have intruded the eugeosynclinal assemblage.

The Nizi Formation, a well-bedded, predominantly carbonate succession of Mississippian age overlies unconformably the Sylvester Group in the south-central part of the area and the Kechika Group in the eastern part of the area.

[1] The major synclinorium in the southwest part of the map-area.

Table of Formations[1]

Era	*Period or epoch*	*Formation and thickness (feet)*	*Lithology*
Cenozoic	Pleistocene and Recent		Glacial and glacio-fluvial deposits, lacustrine deposits, stream deposits, felsenmeer, talus, soil
	Disconformable contact		
	Tertiary or Pleistocene		Vesicular basalt
	Relations unknown		
	Tertiary and (?) Earlier	Rapid Formation in part	Conglomerate, sandstone, shale; coal
Mesozoic	Rapid Formation in fault contact with, or overlying unconformably, Cambrian and Precambrian rocks		
	Jurassic or Cretaceous	Cassiar Intrusions	Quartz monzonite, granodiorite, granite, porphyritic granite; aplite, pegmatite
	Cassiar Intrusions not in contact with Nizi Formation are intrusive into Sylvester Group and older rocks		
Palaeozoic	Middle Mississippian	Nizi Formation 1,000±	Limestone, cherty limestone, greywacke, pebble-conglomerate; minor slate and quartzite
	Nizi Formation unconformably overlies Sylvester Group between Four Mile and Rapid Rivers and Kechika Group east of Solitary Lake; relations between Nizi Group and ultramafic rocks unknown		
	Mississippian (?)		Peridotite, dunite, pyroxenite, serpentinite
	Intrusive contact		
	Upper Devonian and Lower Mississippian	Sylvester Group 15,000+	Greenstone, chert-quartz arenite, chert, argillite, slate, quartzite; greywacke, limestone, conglomerate
	Conformable (?) contact		
	Middle and (?) Upper Devonian	McDame Group 375-560	Upper division: platy, grey limestone Lower division: grey and black, fetid dolomite
	Disconformable contact		
	Silurian and (?) Devonian	Sandpile Group (?) in part 1,160±	Upper division: laminated fine-grained dolomite Middle division: sandstone, quartzite, dolomitic sandstone, sandy dolomite, dolomite; dolomite breccia Lower division: laminated siltstone and dolomite

Table of Formations (Conc.)

Era	*Period or epoch*	*Formation and thickness (feet)*	*Lithology*
	Silurian and (?) Devonian strata overlie disconformably rocks of Kechika Group on limbs of the McDame synclinorium; may be in part or entirely, correlative to Sandpile Group		
	Upper Ordovician, Lower and Middle Silurian	Sandpile Group 1,500+	Dolomite, cherty dolomite, sandy dolomite, dolomitic sandstone, quartzite, chert
	Disconformable contact		
	Middle and (?) Upper Cambrian, Lower and Middle Ordovician	Kechika Group 1,000–2,500+	Upper division: black, laminated, pyritic and carbonaceous shale and slate, minor argillaceous limestone Lower division: limestone, argillaceous limestone, calcareous phyllite, phyllite, conglomerate
	Conformable contact		
	Lower Cambrian	Atan Group 3,000	Upper division: limestone, dolomite; minor shale Lower division: quartzite, argillite; slate, shale, siltstone, pebble-conglomerate
	Conformable contact		
	Late Precambrian	Good Hope Group 4,000±	Limestone, dolomite, quartzite, grit, siltstone, sandy limestone, argillite, slate, red and green slate, shale, limestone
	Precambrian and/or Cambrian	Horseranch Group 7,500+	Quartzite, feldspathic quartzite, quartz-mica schist, granitic gneiss; crystalline limestone, hornfels, skarn, peridotite, pegmatite

[1]Since compilation of this report the writer has collected fossils of late Triassic, possibly late Karnian, age from outcrops of platy, dark grey, fetid, crystalline limestone northwest of Blue River at latitude 59° 37′ 30″ and longitude 129° 58′ 05″. The fossils include *Halobia* sp. (identified by E. T. Tozer, Geological Survey of Canada) and vertebrae of the ichthyosaur, *Californosaurus* (identified by Wann Langston, Jr., National Museum of Canada). The limestone beds, less than 25 feet thick, are overlain, locally, in the core of a syncline by serpentinized peridotite forming three conspicuous small knobs. This locality was brought to the writer's attention by J. J. McDougall (personal communication, 1960). W. J. Wolfe (pers. comm., 1962) has collected Permian fusulinids from beds of sandy limestone outcropping on the southwest slope of a ridge 0.9 mile south of triangulation station, elevation 7,028 feet, northwest of Blue River. The limestone unit, about 500 feet thick, is overlain conformably by basalt and andesite flows. The lower contact is not exposed but appears to be marked by a major fault or unconformity. Although Triassic and Permian rocks may occur elsewhere in the McDame synclinorium they are believed to be restricted to the area northwest of Blue River.

Granitic rocks of the Cassiar and Four Mile batholiths and related stocks were probably emplaced in Jura-Cretaceous time.

The youngest consolidated rocks of sedimentary origin are coal-bearing terrestrial deposits of the Rapid Formation. Some of these rocks are of Tertiary age but others may be older.

Tertiary or possibly Pleistocene extrusive rocks of basaltic composition form a few small outcrops along Blue River.

A thick mantle of drift covers much of Liard Plain, parts of Dease Plateau, and the lower slopes and valley floors throughout the area.

Horseranch Group

The Horseranch Group is named after Horseranch Range to which it is entirely confined. In general, the rocks are exceptionally well exposed.

Lithology

The Horseranch Group is an assemblage of regionally metamorphosed and granitized, non-volcanic, sedimentary rocks including pure and impure quartzite, quartz-mica schist, granitic gneiss, augen gneiss, hornfels, skarn, and crystalline limestone. Minor amounts of pegmatite and one small body of ultrabasic rock are also present.

Quartzite and quartz-rich rocks. Well-bedded quartzites and quartz-rich rocks in beds from 6 to 9 inches thick are abundant in the Horseranch Group. The quartzose rocks vary in composition from almost pure quartzites to quartz-biotite-muscovite schists. In places the quartzites have undergone intense cataclasis resulting in a cherty texture. Elsewhere quartz grains are rarely, if ever, discernible in the hand specimen because of complete recrystallization.

In thin sections quartz grains are seen to be commonly lenticular and crystalloblastic and sometimes show a well-defined elongation parallel with the bedding. Thin sections of the cherty, sheared quartzite show a marked elongation of individual grains parallel with the direction of shearing and wavy and irregular extinction.

Crumpled, golden brown and silvery quartz-biotite-muscovite schists are interbedded with the quartzites but are much less abundant. The schists contain a great deal of accessory apatite, zircon and rarely, garnet.

Granitic gneiss. Foliated, leucocratic feldspathic rocks range in composition from feldspathic quartzites to biotite-muscovite-quartz-feldspar gneisses (*see* Table I and Fig. 5). These rocks are well exposed on the west flank of Horseranch Range east of Harvey Lake. Most of the gneisses are medium grained but some are fine grained.

The constituent minerals as seen under the microscope are extremely irregular. Sodic andesine is the predominant feldspar and occurs with orthoclase or microcline typically as relatively large crystals in a groundmass of fine-grained quartz, orthoclase or microcline, and andesine. The large andesine crystals, in many specimens, show both carlsbad and albite twins. Myrmekitic intergrowths of quartz and plagioclase feldspar are fairly common around borders of potash feldspar crystals. Muscovite is the predominant mica but occurs in relatively minor amounts. Tourmaline, zircon, and apatite are common accessories.

The foliation results from a concentration of micas in bands and is best developed in rocks rich in micas. The uniformity of the bands and their concordance with overlying rocks of different composition suggest that they reflect original bedding.

Augen gneiss. East of Harvey Lake a band of augen gneiss about 70 feet thick occurs in an assemblage of crystalline limestone, hornfels, and quartzite that overlies the foliated gneisses described above. In hand specimens the gneiss is a medium- to coarse-grained, foliated rock characterized by irregular, elongate augen of feldspar. In thin sections the rock is seen to consist of augen of well-twinned sodic andesine and orthoclase crystals up to 3 cm long in a matrix of fine-grained biotite, muscovite, quartz, orthoclase, and andesine. Wavy shreds of biotite and muscovite conform to the boundaries of the augen. Sphene and zircon are accessory minerals. The augen gneiss contains more plagioclase feldspar and less potash feldspar than the foliated gneisses (*see* Table I and Fig. 5).

Table I

Modal Analyses of Gneisses from North End of Horseranch Range

Specimen Number	A[a]	B[a]	C[a]	D[b]	E[b]	F[c]
Plagioclase (Andesine)	19	26	19	10	6	42
Orthoclase or microcline	34	33	41	40	46	21
Quartz	31	27	27	37	36	31
Biotite	7	9	12	5	5	3
Hornblende		2				
Muscovite	6			7	6	2
Total accessories	3	3	1	1	1	1
Apatite	XX	XX	X	X	X	XX
Zircon	XX	X	X	X	X	XX
Sphene	XX	XX	X			
Tourmaline				X	X	X

[a]Augen gneiss—medium to coarse grained.
[b]Granitic gneiss—fine to medium grained.
[c]From area underlain mainly by ultrabasic rocks.

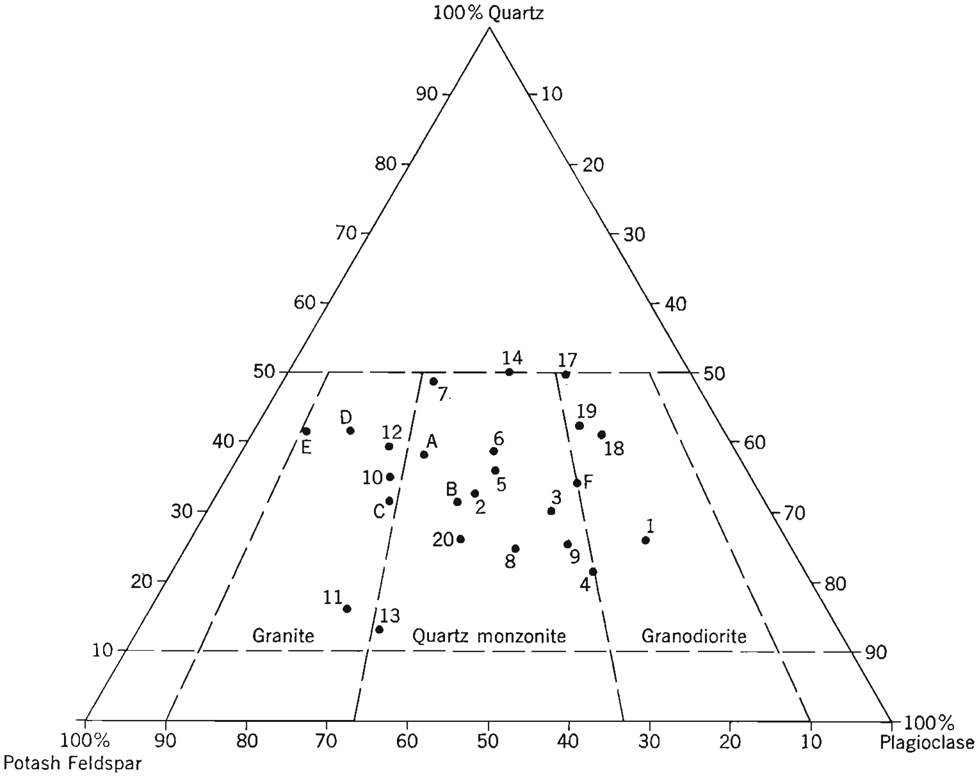

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FIGURE 5. *Modes of specimens from Cassiar batholith (numbered) and from Horseranch Range (lettered)*

Fractured augen, granulated borders and wavy extinction of the augen, and wavy extinction and markedly elongate and irregular character of quartz crystals in the matrix indicate that the augen gneiss has resulted from intense deformation of a granitic rock.

Crystalline limestone, impure calcareous rocks, and hornfels. The uppermost part of the Horseranch Group east of Harvey Lake consists of pure crystalline limestone, impure calcareous rocks, and hornfels.

The calcareous rocks are thinly banded and range from creamy crystalline limestones, through banded, crystalline, biotite-quartz-diopside limestones, to mauve and green calcareous hornfels. The average grain size as seen under the microscope is generally less than 0.1 mm. The compositional bands range in thickness from 0.5 to 2.0 mm.

Extremely fine grained and thinly banded hornfelsic rocks contain: abundant quartz, diopside, orthoclase, and reddish brown biotite; minor scapolite, sphene, tourmaline, and apatite. Alternating mauve and green bands reflect the presence of reddish brown biotite and green diopside, respectively.

Many bodies of skarn, comprising crystalline limestone, garnet, and diopside, occur in the Horseranch Group. These bodies are highly irregular and most appear to be discontinuous.

Pegmatite. Pegmatite sills and dykes are locally common and small patches of pegmatite are widespread. The sills and dykes, ranging in width from a few inches to a few tens of feet occur in quartzite, schist, and gneiss and are most abundant in those rocks that are structurally low in the Horseranch Group. Most of the tabular bodies are parallel with the foliation in the enclosing rocks.

Orthoclase or microcline, albite, quartz, and muscovite are the chief minerals in the pegmatites. In addition, black tourmaline and pale brown garnet are common subordinate minerals and minor beryl occurs in many of the bodies. The maximum size of the muscovite and tourmaline crystals is about an inch.

Pegmatite bodies examined by the writer were not distinctly zoned or banded. Holland (1955, p. 9) described the rocks about 3½ miles northwest of the highest peak in the range, elevation 7,300 feet, as follows: "Some of the narrower pegmatites are distinctly banded, some having coarse mica and tourmaline along their margins and largely quartz in the centre, and others having layers that are coarse-grained and composed dominantly of mica. One 12-inch dyke was seen to have a 2-inch marginal zone largely of muscovite, a 2-inch intermediate zone rich in tourmaline and garnet, and a 4-inch centre of coarsely crystalline feldspars and quartz containing a few small beryl crystals. In general, however, the pegmatites are not zoned . . . ".

In thin sections the minerals are seen to be extremely irregular and have a great range in grain size. In some specimens cataclastic textures indicate deformation after emplacement of the pegmatite bodies.

Ultrabasic rocks. Coarse-grained, dark green to rusty weathering ultrabasic rocks underlie an irregular area of about a square mile east of Harvey Lake. The rocks weather typically to rounded knobs and in places unconsolidated crystals and rock fragments form a veneer over the fresh rock. Gneissic, mafic-rich feldspathic rocks and leucocratic granitic rocks are associated with the ultrabasic rocks but their relations are not known.

Crystals of pyroxene and amphibole and patchy porphyroblasts of biotite up to 2 inches long occur. Under the microscope the constituent minerals are seen to be rhombic pyroxene, augite, tan-brown amphibole, locally clouded with finely disseminated magnetite, tan to orange-brown biotite, olivine, and minor plagioclase (calcic labradorite or sodic bytownite). Minor iron sulphide and magnetite are also present. These mafic-rich rocks are similar to a variety of peridotite known as cortlandtite; the feldspathic varieties are olivine gabbros.

Poikilitic or porphyroblastic crystals of biotite and hornblende enclose pyroxene and olivine. Rhombic pyroxene and calcic plagioclase include embayed crystals of augite and olivine.

In specimens containing about 50 per cent feldspathic material the mafic minerals are tan and brown, shred-like hornblende dusted with magnetite and reddish brown, patchy biotite. These rocks have a crystalloblastic texture. The plagioclase crystals are fractured and have irregular boundaries with the mafic minerals, which appear to have replaced them.

A specimen of gneissic leucocratic rock from within the area of ultramafic rocks has an aplitic texture and under the microscope is seen to consist dominantly of irregular sodic andesine crystals up to 1.5 mm long in a fine-grained matrix of orthoclase, biotite, quartz, and plagioclase feldspar. Apatite and zircon are abundant, the latter producing marked halos in biotite. In contrast to other gneisses in Horseranch Range this rock contains much more plagioclase than orthoclase (*see* Table I and Fig. 5).

Structural Relations

Internal

Rocks of the Horseranch Group are exposed in a broad, doubly plunging anticline, the axis of which is parallel to and east of the crest of the Horseranch Range. Near the central part of the range two minor anticlines with amplitudes of several hundreds of feet occur near the crest of the major anticline.

Tight folds with amplitudes of less than 10 feet are numerous in the quartzites and gneisses. Axial planes of these folds dip steeply to the west on the west side of the major anticlinal axis and steeply to the east on the east side of the axis.

The schists are everywhere crumpled and in many places have two sets of wrinkle-crenulations. The axes of the dominant crenulations are generally nearly horizontal whereas those of the minor crenulations, noted in several localities on the west flank of the range, pitch 30°W on surfaces dipping 40°SW. Locally, on the west flank of the range axial planes of crenulations in schists have shallow dips to the northeast, suggesting that during folding they formed in response to a relative upward movement of the lower of the two enclosing beds.

The irregular outlines of many of the crystalline limestone bodies and the discontinuity of structures within these bodies and the enclosing rocks indicate that they have been plastically deformed.

Joints are conspicuous in rocks of the Horseranch Group, particularly near the north end of Horseranch Range. There, three prominent sets dip steeply and have average strikes of N23°E, N37°E, and N55°E. Joints with a strike of N37°E are the most persistent. These structures appear to be a-c (cross joints) and related shear joints formed by compression at right angles to the axis of the major anticline. A steep plunge of the fold-axis in this area may account for the strong development of joints.

A generalized section near the north end of Horseranch Range and east of Harvey Lake is as follows:

	Approximate Thickness (feet)
Fault-contact with Silurian and (?) Devonian strata	
Limestone, crystalline, fine-grained, thinly banded; impure, crystalline limestone, containing biotite, diopside, and quartz; fine-grained, mauve and green hornfels	675
Gneiss, augen of sodic andesine and orthoclase in a granitic matrix	70
Gneiss, leucocratic, generally medium-grained, granitic; quartzite, commonly grey to purple, feldspathic	200
Gneiss, granitic; feldspathic quartzite; minor crystalline limestone	1,000
Quartzite, feldspathic; granitic gneiss	350
Gneiss, granitic; interbedded with minor feldspathic quartzite and biotite-muscovite-quartz gneiss	3,000
Base unexposed	
Total thickness (approx.)	5,295

The thinly banded calcareous rocks that form the top of the exposed section east of Harvey Lake may be equivalent to the less-metamorphosed calcareous schists and limestones in approximately the same stratigraphic position in the central and southern parts of the range. Crystalline limestone is most abundant east of Horseranch Lake where it overlies granitic gneiss on the nose of the northerly plunging anticline. These beds are probably faulted out, in large part or entirely, along the west side of the range.

About 7,500 feet of strata are exposed south of the highest peak in the range. The lower part of the section includes grey-purple feldspathic quartzites and rusty yellow crenulated schists containing abundant pegmatitic and aplitic material. These rocks grade upwards into quartzites, schists, and minor crystalline limestones containing little aplite and pegmatite. The top of the section comprises impure, argillaceous limestone and calcareous schist.

External

Contact relations between the Horseranch Group and adjacent rocks are obscured either by faults or overburden.

A major fault appears to follow the west side of Horseranch Range. Two miles southeast of Harvey Lake the fault is marked by a zone of brecciated and slickensided dolomite and quartzite more than 400 feet wide. In this area metamorphic rocks of the Horseranch Group have been brought against Silurian and (?) Devonian strata.

Limestone, argillaceous limestone, and phyllite east of Rapid River near the south end of Horseranch Range are highly contorted. The contact between these rocks and Tertiary rocks in the river valley is covered by overburden.

Four and one-half miles northeast of the mouth of Rapid River, rocks west of the fault are presumably of Cambro-Ordovician age.

Structural relations between rocks of the Horseranch Group and younger strata north of the north end of Horseranch Range are obscured by overburden. In this area, however, crystalline limestones at the top of the group may be conformable with overlying Cambro-Ordovician rocks.

The Horseranch Group appears to be faulted against Cambro-Ordovician and Silurian rocks west of Looncry Lake.

Metamorphism

Rocks of the Horseranch Group are evidently regionally metamorphosed and granitized quartzose, argillaceous, and calcareous sedimentary strata. In the central and southern parts of Horseranch Range it is clear that the grade of metamorphism increases progressively from the structurally highest to lowest beds. Near the north end of the range this phenomenon is not evident and it is in this area that granitized rocks are most widespread.

The highly quartzose rocks were particularly susceptible to feldspathization and granitization. This is best shown in rocks that have been only slightly granitized. Judging from examples in many parts of the area underlain by the Horseranch Group it would not be too difficult to reconstruct the original lithological composition of the rocks, even of some of the highly granitized varieties.

Calcareous rocks, representing the stratigraphically highest beds on the west flank of Horseranch Range east of Harvey Lake, are much more metamorphosed than calcareous rocks in a similar stratigraphic position in the southern part of the range. It is not known, however, whether these rocks are definitely equivalent. The rocks to the south are intensely contorted and may be separated from the nearby more highly metamorphosed rocks by a fault.

In the area east of Harvey Lake it is possible that, locally, some of the metamorphism may be related to the emplacement of the ultrabasic body. The peculiar lithology of the ultrabasic rocks, however, suggests that they were also metamorphosed.

Augen gneiss east of Harvey Lake probably represents a dynamically metamorphosed granitic sill.

Origin

The thickness and lithology of the Horseranch Group suggest that the rocks were deposited in a miogeosyncline. Rocks that have retained much of their original character are non-volcanic, well sorted, and even grained. The lack of coarse-grained clastic rocks indicates that the area near the depositional basin was relatively low lying. Subsidence of the basin and deposition were probably closely balanced as much of the assemblage reflects deposition in relatively shallow water.

The sedimentary strata were profoundly altered by regional metamorphism and granitization. Perhaps the peculiar lithology of the ultrabasic body east of Harvey Lake resulted from the metamorphism of a peridotite or serpentinite that had been emplaced at an earlier time.

Deformation following metamorphism and granitization produced the major anticlinal structure. The joint pattern at the north end of the range suggests that the major fold was produced mainly by compressional forces directed more or less horizontally.

Age and Correlation

Neither the age of the Horseranch Group nor the date of the regional metamorphism and granitization that affected the group is known. In gross lithology the assemblage resembles the Atan Group of Lower Cambrian age. In both groups the uppermost member is limestone. The limestones overlie argillaceous strata and these rocks in turn overlie dominantly quartzose strata. Quartzite of the Horseranch Group west of Looncry Lake is not unlike the Cambrian quartzite east of the lake. Furthermore, it is conceivable that the crystalline limestone at the north end of Horseranch Range is of Lower Cambrian age and conformable with overlying strata of Cambro-Ordovician age.

The thickness of quartzose and argillaceous strata in Horseranch Range is much greater than the member of similar lithology in the Atan Group to the west and southwest. To the southeast in Kechika map-area, however, Cambrian quartzose and argillaceous strata thicken markedly to the northeast between Dall Lake and the Rocky Mountain Trench. It is therefore possible that the part of the Horseranch Group beneath the limestone represents a thick facies of the lower part of the Atan Group.

The Horseranch Group has little in common with the Good Hope Group of Proterozoic age. If the rocks are of pre-Good Hope age they have been uplifted many thousands of feet as a block bounded on all sides by faults.

The writer favours the hypothesis that the Horseranch Group represents a regionally metamorphosed and granitized Lower Cambrian assemblage.

A definite dating of the metamorphism and granitization must await absolute age determination.

The Horseranch Group is similar in many respects to the Wolverine complex in the Fort St. James and Aiken Lake map-areas of British Columbia (Armstrong, 1949; Roots, 1954).

Good Hope Group

An assemblage of interbedded limestone, argillaceous limestone, sandy limestone, dolomite, slate, shale, siltstone, and quartzite, more than 4,000 feet thick, outcrops in a northwest-trending anticlinorium on the east flank of Cassiar Mountains, southwesterly from a few miles north of French River to Rapid River. The rocks also outcrop southeast of Looncry Lake and in a narrow belt along the east margin of the Cassiar batholith.

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The strata are especially well exposed in the mountains between French River and Dease River east of McDame. Excellent sections can be studied near the Cassiar road on both sides of the pass near Good Hope Lake and the assemblage therefore is here named the Good Hope Group.

Lithology

The Good Hope Group is characterized by conspicuous bedding resulting mainly from the differences in weathering and colour of the calcareous and argillaceous strata (Pl. III). The presence of rose, red, and green beds is also a distinctive feature.

Limestone and dolomite. Limestone and dolomite are the predominant rocks in the group. These strata occur in beds from 1 inch to 10 feet thick but most are between 1 foot and 2 feet thick.

The limestones vary from black to cream-buff and from fine grained to coarse grained. Commonly the thick beds are light coloured and medium to coarse grained and the thin beds are dark coloured and fine grained. Rusty and buff weathering euhedra and irregular particles of dolomite are numerous in the limestones. Many of the thin-bedded varieties are argillaceous or sandy.

Pisolitic and oolitic limestone, although not abundant, forms distinctive, relatively continuous beds. In any one bed the pisolites and oolites, emphasized by a dark grey outer shell less than 1 mm thick, are of roughly uniform size.

The limestone southeast of Looncry Lake contains sheared bodies of greenstone and in some places the beds have thin partings of schistose, chloritic and graphitic rock. The greenstones are probably intrusive.

Dolomite, typically coarse grained and blue grey or buff weathering, appears to be much less abundant than limestone in the Precambrian assemblage.

'Red beds'. Among the most distinctive rocks in the Good Hope Group are well-bedded red and green limestone, shale, slate, and siltstone. Although the proportions of red and green weathering rocks and of calcareous and argillaceous rocks vary the 'red-bed' assemblages can be readily recognized in isolated outcrops or from a distance.

Red and green, mottled limestone forms beds from less than an inch to several inches thick. Chip breccias are common in the calcareous strata and consist of angular fragments of rose and red limestone and slate, generally less than an inch long, in a matrix of light pink, green, or grey limestone.

Thinly laminated, cross bedded, red siltstone, and red and green fissile slate are interbedded with the limestones. Chlorite and muscovite are abundant on cleavage planes in the slate, and muscovite is common on bedding planes in the siltstone.

In a few localities the 'red beds' contain structures resembling mud-cracks. Locally, the beds are intricately contorted, apparently the result of intraformational flowage.

Slate, shale, siltstone. Thinly bedded, laminated, calcareous slate, shale, siltstone, and quartzite constitute about 15 per cent of the Good Hope Group. They are dark grey, light grey, or brown and generally occur in beds from 1 inch to 6 inches thick. At least one unit of slate and siltstone is over 100 feet thick.

Most of the argillaceous rocks contain much muscovite on bedding planes and locally the rocks are phyllitic. Highly contorted, calcareous, grey to buff weathering phyllitic rocks are exposed in the lower part of the group northwest and southeast of the northeast end of Good Hope Lake.

Structural Relations

Internal

The Good Hope Group is exposed, for the most part, in a major, complex anticlinorium in which one important structural element is an anticlinal axis that can be traced southeasterly from near Poorman Lake to east of Good Hope Lake (Pl. III B). The structure is asymmetrical; strata southwest of the axis dip more steeply than that northeast of the axis. Drag-folds with amplitudes in the order of tens of feet, and minor drag-folds and crumples are well exposed on the northeast limb of the anticline north of Good Hope Lake. In places the troughs of the drag-folds form the locus of small thrust faults that are parallel with the axial planes of the main fold and drag-folds. The minor folds have remarkably sharp crests and troughs and might be described as asymmetrical chevron folds.

One and one-half miles northwest of the northeast end of Good Hope Lake and $3\frac{1}{2}$ miles west-southwest of the mouth of Rapid River, folds with amplitudes of as much as 100 feet are slightly overturned to the northeast.

Many northerly and northeasterly trending faults cut the Good Hope assemblage. They are generally marked by brecciated and dolomitized rocks and commonly have offsets in the order of hundreds of feet. One inferred fault west-southwest of the mouth of Rapid River may have a considerable displacement.

A major longitudinal fault, downthrown to the northeast, trends southeasterly from north of Poorman Lake to the northeast end of Good Hope Lake and probably beyond. The geometry of folds near the fault zone suggest that the structure is a high-angle thrust fault.

Strata of the Good Hope Group have been thrust northeasterly against strata of the Atan Group west and south of Good Hope Lake.

Highly brecciated and dolomitized rocks occur in fault zones both west of, and southeast of, Good Hope Lake.

Southwest of Rapid River, strata of the Good Hope Group have been brought against rocks of the overlying Atan Group along a thrust fault. Thrusting in this area has also been directed to the northeast.

Generalized Section on Ridge 4½ Miles North of McDame

	Approximate Thickness (feet)
Overlain conformably by Atan Group	
Limestone, blue-grey, well-bedded; dolomite, blue-grey, well-bedded; rocks near top of unit pisolitic and oolitic	350
Limestone, slate, laminated siltstone, chip breccia, red, rose, and green; locally exhibits mud-cracks (?) and structures probably due to intraformational flowage; slate displays excellent slaty cleavage	200
Limestone, blue-grey, laminated; buff-brown, micaceous siltstone	140
Limestone, brownish grey, thin-bedded, slaty	130
Limestone, grey to dark grey, thick-bedded; contains many particles of rusty dolomite	250
Limestone, blue-grey; buff weathering dolomite; dark grey, thin-bedded, micaceous argillite and slate	320
Limestone, blue-grey, well-bedded	130
Slate, brown to grey, fissile; contains much muscovite on bedding planes	70
Limestone, dark grey, argillaceous	150
Slate, brown and grey, fissile	120
Limestone, dark grey to black, massive	310
Mainly overburden but scattered outcrops suggest that rocks are predominantly well-bedded, blue-grey limestone, buff weathering dolomite, and minor brown and grey slate	2,000
Base in fault contact with strata of Atan Group	
Total thickness (approx.)	4,170

Generalized Section on Ridge West and Northwest of Good Hope Lake

	Approximate Thickness (feet)
Overlain conformably by Atan Group	
Limestone and dolomite, blue-grey, thick-bedded; minor shale	700
Limestone, siltstone, and slate, red, rose, and green; chip breccias common; red and green slate displays excellent slaty cleavage	275
Limestone and dolomite, grey and blue-grey, interbedded with brown-grey slate	300
Limestone, and dolomite, grey, creamy grey; thin interbeds of highly cleaved, dark grey shale	1,100
Siltstone, limestone, slate, chip breccia, red, rose, pale green	50
Dolomite and limestone, buff-brown weathering, mainly thin-bedded but includes thick beds of blue-grey limestone	150
Limestone, blue-grey; minor dolomite; blue-grey, crystalline, thick-bedded near top	250
Limestone, blue-grey and dark grey, locally laminated, thin-bedded, fine-grained; limestone, buff and blue-grey weathering; limestone, arenaceous and argillaceous, laminated; argillite; quartzite	300
Fault contact with rocks of Good Hope Group	
Total thickness (approx.)	3,125

External

The base of the Good Hope Group is not exposed. The assemblage appears to be overlain conformably by the Atan Group of Lower Cambrian age.

Metamorphism

Rocks of the Good Hope Group have been metamorphosed to hornfels, crystalline limestone, and skarn northeast of the mouth of Bass Creek and north of Cassiar. In both areas the metamorphic rocks are distinctly banded, the bands representing, at least in part, original beds.

McDougall (1954) described the metamorphic assemblage north of Cassiar and his observations are incorporated in, and supplemented by, those of the writer's in the following discussion.

Along the east contact of the Cassiar batholith west of the Cassiar Asbestos Mine, metamorphic rocks include crystalline limestone and three varieties of hornfels. Grey-green to black, spotted, fine-grained hornfels, consisting of cordierite, orthoclase, quartz, and biotite with minor amounts of pyrite, tourmaline, epidote, white mica, sphene, and clinozoisite occur in bands from several inches to several feet thick and average about 5 inches thick. Under the microscope the constituent minerals show a crystalloblastic, interlocking texture typical of hornfels. The spotted appearance results from the presence of lens-like biotite-poor aggregates of cordierite crystals. The rocks are probably the metamorphic equivalents of aluminous, iron-magnesium shales.

A second variety of hornfels consists of alternating bands, as much as 2 inches thick but generally much thinner, of massive light brown garnet, diopside and calcite; orthoclase, cordierite, and biotite; and diopside and orthoclase. Minor amounts of magnetite, tourmaline, clinozoisite, white mica, sphene, and chlorite are also present. The rock is fine grained and has a greenish colour although in detail the bands are light blue-grey, light brown, black, and green. The dark bands are crossed by chert-like bands of green hornfels. These cross-cutting bands are the result of leaching of iron and the consequent lack of dark, iron-bearing minerals, mainly biotite, near fractures. The original rocks were apparently part of an assemblage of thinly interbedded, impure calcareous and argillaceous strata.

The third variety of hornfels contains much biotite and is dark grey to black. Cordierite, quartz, and orthoclase are also abundant and magnetite is minor but ubiquitous.

Marmorized limestone has a texture similar to that of commercial rock-salt and consists of twinned calcite crystals from 2 to 5 mm in diameter. One band of crystalline limestone is about 150 feet thick and being relatively resistant to weathering stands out as a distinct rib. In places the limestone is massive but a vague banding is generally present and in some places the rock is interbedded with thin bands of hornfels.

In general the contact metamorphic rocks are characterized by their rusty weathering colour due largely to the oxidation of pyrite and perhaps pyrrhotite.

Metamorphic rocks derived from the Good Hope Group and similar to those described above are well exposed in a thick section northeast of the mouth of Bass Creek and may be included in the metamorphic assemblage related to the Mount Haskin granitic body.

Mode of Origin

The general aspect of the Good Hope Group suggests that the sediments were deposited in relatively shallow water under stable conditions. The lithology and thickness of the strata indicate deposition in a miogeosyncline.

Age and Correlation

The Good Hope Group appears to underlie conformably Lower Cambrian strata and is believed to be of Proterozoic age.

Rocks correlative to the Good Hope Group have been traced by the writer southeasterly as far as Kechika River in Kechika map-area and it is probable that strata of similar age are included with those outcropping along and near the Rocky Mountain Trench between latitudes 55 and 58 degrees.

Coarse red conglomerate and grey sandstone that outcrops along the Alaska Highway near Muncho Lake may be equivalent either to part of the Good Hope Group or to the overlying Atan Group of Cambrian age.

The lower part of the Ingenika Group in Aiken Lake area (Roots, 1954) and the Kaza Group in Cariboo area (Sutherland Brown, 1957) are perhaps correlative to the Good Hope Group. In Aiken Lake area the exact position of the Cambrian fossils (Archaeocyatha) within the Ingenika Group is not known. In a general way, however, the lithology of the section containing the fossils suggests that they occur in the upper, dominantly calcareous part of the group. If this is so, the lower part may be equivalent to the Good Hope Group.

The Kaza Group and the lower part of the Ingenika Group are composed predominantly of siliceous, feldspathic, and argillaceous, impure clastic rocks that locally are relatively coarse grained and thus contrast to the Good Hope Group in which calcareous and fine-grained, non-feldspathic rocks predominate.

The Good Hope Group is similar, in many respects, to the Tindir Group, exposed along the 141st meridian between Porcupine and Yukon Rivers.

Atan Group

The Atan Group, more than 3,000 feet thick, comprises limestone, dolomite, quartzite, shale, slate, siltstone, and argillite. The group outcrops along the east margin of the Cassiar batholith, in a belt up to 10 miles wide extending southeasterly from the northwest corner of the map-area to the south boundary east of Rapid River. Rocks of probable Lower Cambrian age also outcrop in a narrow belt along the southwest side of the Solitary Lake-Burnt Rose Lake valley.

Excellent exposures occur in the mountains north and south of French River and near Atan Lake, after which the group is named.

As initially defined, the Atan Group included Lower and Middle Cambrian rocks, as well as a thick assemblage of sedimentary strata that conformably underlies the fossiliferous Cambrian strata (Gabrielse, 1954). For mapping purposes, however, it has been found practicable to include the thin-bedded and incompetent Middle Cambrian strata in a group of younger rocks (Cambro-Ordovician). Also, as no fossils have been found in rocks older than the quartzite sequence and as the base of the quartzite sequence forms a well-defined mappable horizon, the pre-quartzite beds are here assigned to the Precambrian.

Lithology

Two distinctive units constitute the Atan Group. The upper one comprises relatively pure, thick-bedded to massive, blue-grey, buff, and reddish buff, grey, and black limestone and dolomite and very minor slate. The lower one comprises well-bedded, tan, rose, and white quartzite, slaty quartzite, pebble-conglomerate, slate, siltstone, and argillite.

Beds of limestone and dolomite range in thickness from several inches to hundreds of feet but most beds are between a foot and 10 feet thick. Some of the limestone is coarse grained but fine- to medium-grained varieties predominate. Many of the fine-grained rocks have a porcellainous texture. A common and distinctive type of limestone is one in which the limestone has been irregularly replaced by dolomite, producing light grey vermicular areas that weather out in relief. Locally, the limestone is calcarenite and, in a few places, oolitic.

In the lower part of the carbonate member northwest of Atan Lake, grey weathering, dark grey to black limestone is relatively thin bedded and commonly platy. Platy, orange-buff weathering, dark grey, dolomitic limestone outcrops near the base of the carbonate sequence on the southwest flank of Mount Reed.

Dolomite is characteristically of coarser grain than the limestone and is either a buff-yellow or reddish brown iron-bearing variety, or a blue-grey to buff, bedded variety. Buff and brown dolomite is abundant in fault zones. Mottled carbonate rocks consisting of blue-grey to black limestone and buff and rose-tinted dolomite are common. In many places Archaeocyatha have been selectively replaced by dolomite.

One bed of red slate, possibly less than 25 feet thick, was noted in a dolomite sequence 3 miles northwest of Atan Lake and brownish weathering grey slate and siltstone containing well-preserved trilobites outcrops along Dease River 2 miles east of McDame.

The quartzite unit comprises rocks that range in purity from those consisting almost entirely of well-rounded and sorted quartz grains to those in which the argillaceous content predominates. Tan, rose, white, and green quartzite forms beds from several inches to 10 feet thick. Fine-grained, green, chloritic quartzite is characteristic of the lowermost part of the sequence. In thin sections this rock-type is seen to consist essentially of quartz with interstitial chlorite (probably penninite), and minor albite, microcline, sericite, zircon, and carbonate. Much of the tan, rose, and white quartzite is medium to coarse grained and includes minor quartz-pebble conglomerate. Bluish, opalescent quartz grains, irregular flecks and cubes of limonite, in part pseudomorphous after pyrite, and cream-coloured, interstitial argillaceous material are common. Under the microscope the rocks are seen to consist mainly of well-rounded to subangular quartz grains with interstitial hematite, limonite, carbonate, and sericite.

The uppermost 150 feet of the quartzite sequence are predominantly argillaceous and include slate, argillite, shale, and argillaceous siltstone. Brown, tan, and green slate, shale, and siltstone near, or at the top of the argillaceous assemblage are commonly fossiliferous.

Partings of micaceous slate and siltstone, ranging from a few inches to several feet in thickness, are common in the quartzite sequence.

Crossbedding is locally well developed and ripple-marks were noted in siltstone near the top of the quartzite unit near Atan Lake.

Structural Relations

Internal

The structure of the Cambrian strata northwest of Little Rancheria River is not known but Cambrian rocks in Wolf Lake map-area immediately to the northwest are exposed in what appear to be near-isoclinal, southwest-plunging folds (Poole, 1957). Similar structures are suggested by the outcrop pattern of the Lower Cambrian rocks between Gallic and Atan Lakes. It is possible, however, that longitudinal faults may also have contributed to the distribution of rocks in this zone.

The structure near Blue River is poorly known because of the lack of continuous outcrops. Between Captain Lake and One-Ace Mountain, however, fossiliferous limestone is repeated by either folding or faulting.

Northeast of the major axis of the anticlinorium north of French River prominent limestone ridges consist of strata that, for the most part, dip gently or moderately to the east and northeast. In each case an anticlinal axis trends along the west side of the ridge and the valleys have formed by erosion of the west limb of an anticline.

South of French River near Spring Creek the Lower Cambrian rocks are gently folded but are cut by at least one major fault.

In many places southeasterly from Mount Haskin the Atan Group has been offset by steeply dipping, northeasterly trending faults.

The Atan Group forms the core of a major, asymmetrical to southwesterly overturned fold southwest of Deadwood Lake. This structure plunges northwest so that only the upper part of the group is exposed on the ridge immediately southeast of Rapid River (Pl. IV B).

Generalized Section Northwest of Atan Lake

	Approximate Thickness (feet)
Top of section unexposed	
Limestone and dolomite, blue-grey, well-bedded to massive, fine-grained and porcellainous; yellow, buff, brown, and rose dolomite, commonly crystalline; fragmental and oolitic limestone, buff and orange, mottled limestone and dolomite; very minor slate	1,200
Limestone, dark grey, thin-bedded, platy; orange-buff, platy dolomitic limestone; overlain by blue-grey, well-bedded to massive limestone	300
Slate, green and brown, thin-bedded, locally laminated; brown and black shale, slate and siltstone; interbedded with quartzite near base	150
Quartzite, white, rose, and tan; well-bedded, beds average about 2 feet thick, commonly indistinctly crossbedded; pebble-conglomerate, pebbles as much as 1 cm long but generally less than ½ cm long; brown and grey, thin-bedded slate and siltstone forms interbeds in the quartzite sequence from a few inches to several feet thick; green, fine-grained, chloritic quartzite forms lowermost beds of quartzite unit	1,050
Overlies conformably Good Hope Group	
Total thickness (approx.)	2,700

On the west flank of Mount Haskin and along French River the Atan Group is probably more than 3,000 feet thick. A similar thickness is indicated for the Lower Cambrian strata along the southern boundary of the map-area southwest of Deadwood Lake.

Massive to thick-bedded, light grey weathering limestone, probably of Cambrian age, is about 500 feet thick southwest of Solitary and Burnt Rose Lakes.

External

The Atan Group is apparently conformable with the underlying Good Hope Group. The relations with the overlying Kechika Group, however, are difficult to determine because the Kechika Group is highly incompetent. In many places the contact is between uniformly dipping limestone of the Atan Group and highly folded and cleaved rocks of the Kechika Group. Locally, the two groups appear to be conformable.

Metamorphism

Near the Cassiar batholith, the Atan Group has been metamorphosed to crystalline limestone, skarn, and hornfels. In Marble Creek, south of Cassiar, irregular bodies of pyrrhotite and magnetite have formed through replacement of limestone. In places the limestone has been dolomitized; the dolomites commonly have distinctive buff, pink, and rose colours.

On Mount Haskin a westerly dipping assemblage of thinly banded, fine-grained, porcellainous, cherty, metamorphic rocks is probably the metamorphic equivalent of part of the Atan Group. The metamorphic rocks and underlying cherty limestone have a total thickness comparable to that of the Atan carbonate member elsewhere. In thin sections much fine-grained pyroxene and garnet are visible. Cherty metamorphic rocks also occur in the carbonate member of the Atan Group in the canyon of McDame Creek east of Centreville. On Mount Haskin the metamorphism is related to a sill of feldspar-quartz porphyry.

Mode of Origin

Sedimentary rocks of the Atan Group reflect a fairly uniform environment of deposition. The sediments apparently accumulated on a slowly subsiding surface and the entire sequence may be attributed to deposition in shallow water.

Uniformity of grain size, roundness of grains, and the purity of much of the quartzite suggest that the sediments were well sorted and mature. The source-area was probably highly weathered and of low relief.

Little evidence is available bearing on the direction of the source-area or areas. Okulitch (1955) believed that Archaeocyatha lived in relatively narrow belts parallel with the coast-lines of shallow Cambrian seas and that the Archaeocyatha localities in British Columbia outline the approximate western shoreline of the Lower Cambrian geosyncline. In McDame map-area Lower Cambrian carbonate rocks appear to thin northeasterly but whether this represents erosion prior to deposition of the Kechika Group or a facies change to a deeper water assemblage (argillaceous limestone and calcareous phyllite) is not known. As suggested by Okulitch (1949) and Kay (1951) the Lower Cambrian quartzite throughout the western Cordillera probably represents the basal beds deposited in an easterly transgressing sea.

Age and Correlation

Archaeocyatha were noted in the following localities:

- F_1. 4 miles northwest of the west end of Captain Lake.
- F_2. North flank of One-Ace Mountain, elevation 5,200 feet.
- F_3. 2 miles north of the east end of western Captain Lake.
- F_{11}. Southwest flank of Mount Reed, elevation 3,800 feet; trilobite fragments were also noted in this locality.
- F_{16}. 5.8 miles south of the confluence of Julian Creek and Rapid River; *Hyolithes* sp. were also noted in this locality in slate at the top of the Lower Cambrian quartzite member.

Well-preserved Archaeocyatha were collected from the following localities:

- F_4. GSC Loc. 17540. 2.2 miles east-southeast of the east end of western Captain Lake.
- F_5. and F_6. GSC Locs. 17541 and 17542. 5.6 miles west-northwest of the mouth of Spring Creek on French River.
- F_7. GSC Loc. 23350. 2.8 miles northwest of the confluence of Spring Creek and French River.
- F_9. GSC Loc. 17548. 4 miles south-southwest of the confluence of Spring Creek and French River.
- F_{10}. GSC Loc. 17226. 2.5 miles north of the north end of Gallic Lake.
- F_{13}. GSC Loc. 21666. 4 miles north-northeast of Sheep Mountain.
- F_{14}. GSC Loc. 21669. 3 miles northeast of locality F_{13}.
- F_{15}. GSC Loc. 22742. North side of Julian Creek 6 miles southwest of Rapid River and mouth of Julian Creek.

V. J. Okulitch, University of British Columbia, examined many of the fossil collections containing Archaeocyatha and supplied the following list (Okulitch, 1955):

Ajacicyathus nevadensis (Okulitch)
Ajacicyathus undulatus Okulitch
Ethmophyllum sp.
Thalamocyathus sp.
Coscinocyathus dentocanis Okulitch
Coscinocyathus sp.
Archaeocyathus atlanticus Billings
Archaeocyathus cf. *latus* (Vologdin)
Archaeocyathus loculiformis Okulitch
Archaeocyathus borealis Okulitch
Archaeopharetra sp.
Pycnoidocyathus amourensis (Okulitch)
Pycnoidocyathus columbianus (Okulitch)
Archaeofungia obliqua Okulitch
Archaeofungia sp.
Metacoscinus gabrielsensis Okulitch
Metacoscinus deasensis Okulitch
Archaeosycon sp.
Syringocyathus canadensis Okulitch

Fossils other than Archaeocyatha were collected from the following localities.

F_8. GSC Loc. 32425. Summit of 5,864-foot mountain 4 miles west of confluence of Spring Creek and French River.

Olenellus sp.
Wanneria (?) sp.
olenellid fragments
indet. brachiopods

F_{12}. GSC Locs. 20121, 20122, 25012. On north side of Dease River 2 miles downstream from McDame.

Wanneria n. sp.
Obolella sp.
Hyolithes sp.
Pagetia sp.
Ptychoparid tribolite cf. *Kochaspis*

According to Dr. Okulitch, the Archaeocyatha fauna resemble most the Lower Cambrian Donald fauna from the Purcell Mountains (Evans, 1933). The rocks in which they occur are considered to be uppermost Lower Cambrian.

A. W. Norris of the Geological Survey of Canada refers the fauna of locality F_8 to the younger of the two Lower Cambrian zones in the Canadian Rockies (*Olenellus-Bonnia* zone).

R. D. Hutchinson of the Geological Survey of Canada considers the fauna of locality F_{12} to be of uppermost Lower Cambrian age.

Many of the fossil localities represent horizons relatively high in the carbonate member of the Atan Group although fossils were noted in slates at the top of the quartzite unit southeast of Julian Creek. As all the fossils are of late Early Cambrian age the quartzite unit is probably Lower Cambrian.

In recent years, Lower Cambrian strata have been reported from many localities in the Canadian Cordillera west of the Rocky Mountains. Rocks correlative to the Atan Group trend northwesterly into Wolf Lake map-area in southern Yukon Territory (Poole, 1957) and have been traced by the writer to the southeast as far as Denetiah Lake in Kechika map-area. Farther to the northwest Archaeocyatha have been collected at the headwaters of Ketza River and White Creek in Pelly Mountains (Aho, personal communication to Okulitch, 1957).

The upper part of the Ingenika Group in Aiken Lake map-area of north-central British Columbia may be equivalent to the Atan Group (Roots, 1954). Lower Cambrian strata have also been recognized along the Hart highway where Archaeocyatha have been collected from the Misinchinka schists (Holland, personal communication to Sutherland Brown, 1957). Farther to the south Lower Cambrian rocks have been noted near Sinclair Mills on Fraser River in the Rocky Mountain Trench (Lay, 1941, p. 21) and in the Cariboo District (Lang, 1947; Sutherland Brown, 1957).

Kechika Group

A highly folded and cleaved assemblage of thin-bedded shale, slate, calcareous phyllite, phyllite, limestone, and limestone conglomerate has been named the Kechika Group because of its characteristic development in the Kechika Ranges. Much of the area east of Horseranch Range and Deadwood Lake is underlain by rocks of the group. The strata also outcrop in narrow belts on both sides of the major synclinorium in the southwest part of the map-area.

Rocks described as Kechika Group in this report include strata that were originally mapped as Wadin Group (Gabrielse, 1954). These rocks have since been subdivided into a Mississipian unit (Nizi Group) and an underlying unit that is thought to be largely correlative to the strata of the Kechika Group exposed farther west.

Lithology

In marked contrast to the overlying and underlying strata, rocks of the Kechika Group are characterized by thin bedding, well-developed cleavage, tight folding and crumpling, and a wide variety of colours. The rocks are predominantly argillaceous in the southwestern and southern parts of the map-area where they are more than 1,000 feet thick, and predominantly calcareous to the northeast and east, where, east of Deadwood Lake, they are more than 2,000 feet thick.

Rocks in the southwest and southern parts of the map-area. Near the Cassiar batholith the Kechika Group consists essentially of dark grey weathering argillaceous rocks. Laminated, dark grey and black argillite and cherty argillite are most abundant. Slates with well-developed cleavage are rare but ill-defined slaty cleavage is prevalent. In some places the argillites are calcareous and in others they are carbonaceous.

Strata on the northeast limb of the McDame synclinorium appear to include more limestone, calcareous argillite, and phyllite than those on the southwest limb. From Captain Lake to Long Lake the Kechika Group comprises glossy, buff, silver, and grey, calcareous phyllite, phyllitic limestone, and thin-bedded, blue-grey, platy limestone. In these rocks beds generally are less than an inch thick, and laminations in argillaceous beds are commonly a few millimetres thick.

Rocks similar to those described above outcrop on the west flank of Mount Haskin but dark grey and light grey chert and minor grey, fine-grained quartzite are also present. Lenticular limestone boudins, about an inch long, occur in black slate near Centreville. There, as on Mount Haskin, buff and silver, slaty limestone and calcareous phyllite are conspicuous.

Northeast of Sheep Mountain, the uppermost part of the Kechika Group consists of laminated, black, calcareous shale and siltstone with interbeds of calcareous quartzite between 1 inch and 3 inches thick. These rocks are underlain by buff and silver, glossy, calcareous phyllite and thin-bedded, blue-grey limestone.

Glossy, soft, grey, black, and pale green slate and argillite are well exposed southeast of Rapid River. Black slate occurs at the top of the section but is less abundant than the underlying grey and silver, glossy, phyllitic strata. Locally, thin interbeds of dark grey limestone weather out in relief. Several bodies of greenstone were observed in this area. These rocks are much altered and consist of carbonate, sericite, and chlorite.

Rocks northeast of the McDame synclinorium. Highly folded, grey, buff, and silver calcareous phyllite outcrops along Blue River west of the Cassiar road.

Black, pyritic, and graphitic slate containing calcareous concretions up to 1½ feet in diameter underlies Silurian and Devonian strata on the east side of Dease River near the mouth of French River.

Thin-bedded, blue-grey, highly cleaved limestone and buff-grey calcareous phyllite is exposed along Dease River near the mouth of Blue River. To the northeast, dark grey carbonaceous shales and slates containing graptolites outcrop along Dease River but their stratigraphic position in the Kechika Group is not known.

East of the north end of Boya Lake, on Dease River, a small outcrop of sheared, buff-brown weathering, phyllitic, grey limestone contains angular fragments of grey limestone as much as an inch long. Calcareous, phyllitic rocks on the west side of Horseranch Range, east-southeast of Boya Lake have also been mapped as Kechika Group. Saussuritized, pyroxene andesite is abundant in this area. These rocks are believed to be intrusive.

An extremely well-bedded assemblage consisting mainly of blue-grey and buff weathering limestone and glossy, buff and silver, calcareous phyllite underlies much of the Dease Plateau east of Horseranch Range. Black, carbonaceous shale outcrops locally and limestone-conglomerate and breccia were noted in many places.

Distinctive limestone-pebble conglomerate, in three beds, 6 feet, 2 feet, and 1½ feet thick, outcrops in a canyon of a creek that enters Red River from the east about 3 miles south of the mouth of Johnny Creek. The conglomerate consist of angular and rounded pebbles of thin-bedded, red and buff weathering limestone in either a carbonate or a siliceous matrix.

Strata east of Solitary and Burnt Rose Lakes and east of the southeasterly flowing reaches of Red River have been mapped as Kechika Group although they probably include minor infolded younger strata. These rocks, many of which have a reddish tinge, are similar to those that outcrop immediately to the west.

The best exposures of Kechika Group rocks in the map-area are those east of Deadwood Lake and southeast of Deadwood River. In this area the rocks consist of blue-grey limestone, buff and rose dolomitic limestone, glossy, paper-thin, buff, tan, silver and grey, calcareous phyllite, and limestone-conglomerate overlain by black, carbonaceous, pyritic, and graptolitic slate. Streams flowing over black slates southeast of Sandpile Lakes contain much iron sulphate and in places thick deposits of reddish ochre have formed along their banks.

In Hidden Valley Creek a limestone-conglomerate bed about 30 feet thick contains fragments a fraction of an inch to several feet long and 6 to 9 inches thick. Many of the fragments are platy and lie parallel with the bedding.

The upper part of the Kechika Group is well exposed in stream-cuts southwest of the south end of Deadwood Lake. There, buff and grey calcareous phyllite is overlain by laminated, black, calcareous, locally carbonaceous slate, and interbedded slate and limestone in beds about an inch thick. One bed of quartzite, more than 20 feet thick, was also noted in this assemblage. In places the slate contains lenticles of blue-grey limestone up to 4 inches long and half an inch wide.

The uppermost part of this assemblage is highly fossiliferous and comprises interbedded black slate and dark grey limestone. The limestone beds are from an inch to 8 inches thick, and partings of slate are from half an inch to 4 inches thick. In general, limestone becomes increasingly abundant, and, conversely, slate less abundant, upward in the sequence.

Green and buff weathering altered volcanic rocks are common in the Kechika Group. In most places these rocks are so altered that their origin is in doubt.

The buff rocks consist essentially of carbonate and sericite whereas the green rocks consist essentially of carbonate and chlorite. A few dykes have laths of carbonate that are presumably pseudomorphous after feldspar.

A large body of greenstone near the top of the ridge east of the north end of Looncry Lake has a porphyritic texture with dark green to black amphibole crystals in a light green matrix. In thin section the rock is seen to consist of aggregates of ragged actinolite crystals in a fine-grained matrix of epidote, chlorite, and albite. Accessory ilmenite and leucoxene are abundant.

Bodies of relatively fresh, fine- to medium-grained greenstones outcrop in stream-cuts southwest of the south end of Deadwood Lake and on the west side of Horseranch Range south of Harvey Lake. These rocks consist essentially of albite, pyroxene, and chlorite and commonly have a well-preserved sub-ophitic texture. Locally, pyrite is abundant.

Near the head of the stream flowing northerly into the south end of Solitary Lake and in the valley of Hidden Valley Creek, buff and green weathering, sheared greenstones occur in fault zones in black graptolitic slate.

In many places greenstone bodies and immediately surrounding strata are sparsely stained with malachite.

Structural Relations

Internal

Strata of the Kechika Group have been intensely drag-folded and crumpled in most parts of the map-area. The incompetent nature of the rocks and the lack of distinctive marker-beds makes a comprehensive picture of the structure impossible without extremely detailed studies.

East of Solitary Lake and the southeasterly flowing reaches of Red River small folds commonly have steeply plunging axes. Tight folds whose axial planes dip easterly from 20 to 45 degrees are abundantly visible in stream-gulleys east of Dease River and west of Mount Monckton. The thin-bedded rocks in this area have been sliced by minor thrust faults that have developed parallel with the axial planes of folds.

Isoclinal folds on a small scale are apparent east and southeast of Deadwood Lake, but it is difficult to estimate their influence on measured stratigraphic sections. Isoclinal folding on a large scale is thought to repeat a limestone member that crosses Walker Creek.

Phyllitic rocks in the Kechika Group generally exhibit well-developed crenulations on bedding and cleavage surfaces. These crenulations are parallel with the axes of drag-folds and in each small area commonly have consistent plunges.

East of Deadwood Lake the strata are cut by numerous northerly, northeasterly, and northwesterly trending faults. Many of these faults have minor offsets but some have lateral displacements of as much as half a mile. Some of the fault zones are marked by reddish weathering, brecciated rocks. A full discussion of these structures is given in the chapter on structural geology.

Cleavage is developed to a high degree in the argillaceous rocks of the Kechika Group. In general the attitude of cleavage planes is fairly consistent in a restricted area, although, in highly disturbed zones, these planes may also be crumpled and contorted. Shear folds, resulting from repeated small offsets along cleavage planes, are locally well developed.

Strong joints that greatly influence the local topography are typical of the Kechika Group rocks. The major joints appear to be a-c or cross-joints, roughly perpendicular to fold axes. These joints may be used to estimate the regional trend and plunge of strata in areas where bedding is not evident.

Generalized Sections in Valley of Stream Flowing Northeasterly from Divide at Head of Walker Creek

	Approximate Thickness (feet)
Overlain by Sandpile Group; contact not exposed	
Phyllite, calcareous, and limestone, blue-grey and buff, thin-bedded, lustrous, and highly cleaved; greenstone sills consisting essentially of chlorite and carbonate (much of carbonate is rusty and reddish weathering)	700
Limestone, buff and black weathering, well-bedded, fine-grained, porcellainous; beds from ½ inch to 6 inches thick	25
Phyllite and limestone, silver and buff, thin-bedded, highly cleaved	125
Limestone, blue-grey, massive	10
Limestone, buff weathering, well-bedded, beds from 1 inch to 6 inches thick	10
Phyllite, buff and silver, lustrous, calcareous	50
Limestone, black, well-bedded, platy, weathers black or buff; beds are between ¼ inch and 2 inches thick; overlies buff and blue-grey, well-bedded limestone interbedded with calcareous, lustrous, highly cleaved phyllite	300
Fault contact with Devonian strata (McDame Group)	
Total thickness (approx.)	1,220
Overlain unconformably by McDame Group	
Limestone, blue-grey, thin-bedded; calcareous phyllite	450
Limestone, blue-grey, well-bedded, highly cleaved; buff-brown, calcareous phyllite; beds ½ to 1 inch thick, uniform cleavage-bedding relationships suggesting beds are right side up	675
Limestone, blue-grey, well-bedded; buff to silver, calcareous, lustrous phyllite; beds as much as 9 inches thick	675
Limestone, blue-grey, buff, laminated; minor partings of calcareous phyllite	200
Conglomerate, limestone, laminated pebbles of limestone in a limestone matrix, noted in float but no outcrop seen; blue-grey, thin-bedded, laminated limestone, thin partings of calcareous phyllite	120
Limestone, blue-grey, buff weathering, massive	6
Phyllite, buff and grey, thin-bedded, calcareous	175
Base not exposed	
Total thickness (approx.)	2,301

Generalized Section Southwest of South End of Deadwood Lake

	Approximate Thickness (feet)
Disconformably (?) overlain by Sandpile Group	
Limestone and argillaceous limestone, blue-grey, extremely well bedded, beds from 1 inch to 8 inches thick, average about 3 inches thick; black and grey slate, laminated in part, beds as much as 4 inches thick but generally less than 2 inches thick; limestone relatively more abundant upward in section and in places contains chert nodules; abundant fauna, in large part dwarfed and replaced by pyrite (F_{22})	150
Slate, blue-black, buff weathering, in part calcareous, laminated, beds contorted in lower part of section, locally contains lenticles of laminated blue-grey limestone	100
Quartzite, purplish grey, fine-grained, massive, blocky; interbedded quartzite and calcareous slate	20
Slate, black and grey, grey and brown weathering, highly folded; contains lenticles of limestone up to 4 inches long and ½ inch thick; minor beds of blue-grey argillaceous limestone as much as 1 inch thick	100
Underlain by grey and buff, calcareous phyllite of Kechika Group containing irregular bodies of greenstone	
Total thickness (approx.)	370

Southeast of Sandpile Lakes the upper part of the Kechika Group, consisting mainly of black, graptolitic slate, is more than 150 feet thick.

On the southwest flank of Mount Haskin the total thickness of Kechika-Group strata (including little, if any, black slate) is about 1,000 feet.

External

In many places the mutual structural relations between rocks of the Kechika Group and strata above and below are obscured by the effects of intense deformation within the Kechika Group. A further difficulty is that contacts are rarely well exposed. In general, rocks of the Kechika Group are easily eroded, and for miles on the northeast limb of the synclinorium in the southwest part of the area, the contact with the underlying Atan Group lies in valleys. On the southwest flank of Mount Haskin and southeast of Rapid River, however, the Kechika Group is at least structurally conformable with the Atan Group. Furthermore, southeast of Rapid River, faunal evidence suggests that the two units are probably conformable.

In two areas, southwest of the south end of Deadwood Lake, and southeast of Sandpile Lakes, the uppermost strata of the Kechika Group are structurally conformable with overlying Ordovician and Silurian strata (Sandpile Group). Faunal evidence, although not conclusive, indicates that the contact is disconformable.

On the limbs of the McDame synclinorium in the southwest and southern parts of the area the Kechika Group is overlain disconformably by rocks of probable Middle Silurian age. A similar relationship exists in places northwest and east of the north end of Horseranch Range.

Metamorphism

Metamorphism of the Kechika Group has been mainly dynamic and has resulted in the development of slaty cleavage in all the argillaceous rocks and in most of the calcareous rocks.

North of Cassiar near the Cassiar batholith argillaceous rocks assigned to the Kechika Group have been locally metamorphosed to spotted slates.

Mode of Origin

The Kechika Group is believed to represent a relatively deep-water facies. This is suggested by the predominance of fine-grained calcareous and argillaceous material combined with the general paucity of fossils. In the western and southwestern parts of the area the source area may have been relatively distant and argillaceous sediments predominated. To the east and northeast, calcareous material, perhaps swept into the basin over an eastern shelf, mingled with the argillaceous sediments, thus giving rise to the interbedded argillaceous and calcareous strata.

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Limestone-conglomerate, restricted to the northeastern and eastern parts of the area, may be largely intraformational.

Black, graphitic, and pyritic slates containing graptolites apparently accumulated in one or more enclosed, stagnant basins. G. W. Sinclair (personal communication, 1955) pointed out that the dwarfed forms in the fauna collected southwest of the south end of Deadwood Lake are those of bottom-dwellers whereas normal-sized forms are those of swimming or free-floating organisms. The dwarfed bottom-dwelling organisms and the presence of ubiquitous pyrite indicate reducing, toxic conditions on the ocean-floor unfavourable for the normal growth of marine organisms.

Age and Correlation

The following fossil collections, identified by G. W. Sinclair, were made from rocks in the Kechika Group.

F_{17}. GSC Loc. 25002. 1 mile northeast of the mouth of Masidoor Creek on the north side of Dease River.
Glossograptus sp.

F_{18}. GSC Loc. 25013. 3.5 miles south of the mouth of Masidoor Creek and 0.5 mile east of Dease River.
Diplograptus sp.
Glossograptus sp.
Climacograptus sp.

From the same general area as the two fossil localities listed above G. M. Dawson (1889) collected graptolites that were determined by Lapworth as follows (Ruedemann, 1947):

Diplograptus euglyphus Lapworth
Climacograptus comp. *antiquus* (Lapworth)
Cryptograptus tricornis (Carruthers)
Glossograptus ciliatus (Emmons)
Didymograptus comp. *sagittarius* Hall (= *D. sagitticaulis* Gurley)
New form applied to *Coenograptus* (= *Nemograptus*)

F_{19}. GSC Loc. 25000. 4.5 miles southeast of the confluence of Deadwood and Red Rivers and 8.5 miles northeast of the north end of Solitary Lake.
Diplograptus sp.

F_{20}. GSC Loc. 32416. Approximately 2.5 miles northeast of Sheep Mountain.
Unidentifiable graptolites

F_{21}. GSC Loc. 32415. 6.3 miles north-northeast of the south end of Deadwood Lake.
Diplograptus (s.l.) sp. indet.
Climacograptus sp. indet.
Glossograptus sp. cf. *G. ciliatus* Emmons
Dichograptid stipes

F_{22}. GSC Locs. 25013, 24193, and 22749. 2 miles southwest of the south end of Deadwood Lake (in stream-cut).
Diplograptus n. sp.
Amplexograptus n. sp.
Climacograptus n. sp.
new genus of Diplograptids
Crinoid fragments
Ophiurian ossicles
Bryozoa spp.
cf. *Plectorthis* sp.

Lingula n. sp.
Ctenodonta n. sp.
Cyrtolites sp.
Holopea sp.
Tetranota sp.
Hormotoma sp.
Orthoceraconic cephalopod
Climacoconus n. sp., aff. *C. scotica* Lamont
Climacoconus n. sp.
Triarthrus n. sp.
Cryptolithoides n. sp.
new genus of cryptolithids
Lonchodomas n. sp.
Isotelus sp.
Ceratopsis n. sp., aff. *C. chambersi* (Miller)
Eopteria n. sp.

G. W. Sinclair (1958) also reports the presence of a fish plate with the fauna from locality F_{22}.

Poorly preserved graptolites were noted in black slate southeast of Sandpile Lakes and in the valley of Hidden Valley Creek. Graptolites, tentatively identified as *Dicellograptus* sp. by the writer were noted at an elevation of 5,000 feet on the crest of a ridge a mile north-northwest of the northeastern end of lower Sandpile Lakes.

G. W. Sinclair of the Geological Survey of Canada states that fossil collections F_{17}, F_{18}, and F_{19}, are of Middle or Upper Ordovician age.

Ruedemann (1947), commenting on the collection made by G. M. Dawson and determined by Lapworth, suggested that the fauna have distinct Normanskill elements although the Dease River beds may be a little older.

R. Thorsteinsson, Geological Survey of Canada, suggests that the rocks from which fossil collection F_{21} was obtained may be correlated with the Glenogle Shale (Lower and Middle Ordovician) of southeastern British Columbia. He points out that the dichograptid stipes are compared most readily with *Tetragraptus,* in which case the fauna is of Arenigian or Llandvirnian (Lower Ordovician) age.

G. W. Sinclair reports that the fauna of collection F_{22} are most probably of late Middle Ordovician (Trenton) age or early Upper Ordovician (Edenian) age.

Although graptolites collected from locality F_{20} were not identifiable, graptolites collected by the writer from rocks in a similar stratigraphic position on trend to the southeast, in Cry Lake map-area, were reported by R. Thorsteinsson to be of Canadian (Lower Ordovician or Arenigian) age.

The stratigraphic position of rocks containing the fossils listed above is not known in some cases but it seems probable that most of the collections represent horizons relatively high in the Kechika Group. One fossil collection was made from rocks in the lower part of the Kechika Group and is listed below.

F_{23}. GSC Loc. 22757. 7.3 miles west-southwest of the south end of Deadwood Lake.
Ptychoparid trilobite cf. *Chancia* Walcott

R. D. Hutchinson, Geological Survey of Canada, states that this specimen is of late Lower or Middle Cambrian age, probably of early Middle Cambrian.

Strata of the Kechika Group, therefore, range in age from possibly the earliest Middle Cambrian to the earliest Upper Ordovician. Upper Cambrian rocks have not been identified but may well be represented in the unfossiliferous lower part of the group east of Deadwood Lake, and, perhaps, in the thinner, possibly condensed section to the west.

Rocks similar to those of the Kechika Group outcrop in Wolf Lake map-area to the northwest, in southern Yukon Territory (Poole, 1957). Farther to the north and northwest graptolitic Ordovician strata outcrop in Quiet Lake map-area (Wheeler, personal communication 1956) and along the Canol Road (Keele, 1910).

Strata correlative to the Kechika Group have been traced southeasterly by the writer as far as Kechika River.

In many respects the Kechika Group is similar to the Goodsir Formation, the McKay Group, and the Glenogle Formation of southeastern British Columbia.

Sandpile Group

Resistant, ridge-forming dolomites and sandstones of the Sandpile Group are widespread in the map-area. Highly fossiliferous rocks of the group outcrop near the mouth of French River, south of Harvey Lake, east of Horseranch Range, and in the Deadwood Lake-Sandpile Lakes area. These rocks are well exposed near Sandpile Lakes and hence have been named Sandpile Group (Gabrielse, 1954).[1]

Rocks tentatively included in the Sandpile Group outcrop on both limbs of the McDame synclinorium.

Lithology

The lithology and thickness of the group vary considerably within the map-area. These variations are apparently the result of facies changes within the group and of erosion preceding deposition of the overlying McDame Group. East of the McDame synclinorium the group consists essentially of a lower, dolomitic unit—in part highly fossiliferous, and an upper, sandy unit. The total thickness of these units near Sandpile Lakes is about 1,600 feet. On the limbs of the McDame synclinorium, however, the highly fossiliferous carbonate unit is missing and in its place is a relatively thin, graptolitic siltstone member.

Sandpile Group near Deadwood and Sandpile Lakes. The Sandpile Group in this general area comprises blocky, cliff-forming, well-bedded dolomite, cherty dolomite, sandy dolomite, sandstone, quartzite, and dolomite breccia. The lower part of the group, best exposed on the north slope of the mountain a mile south-east of lower Sandpile Lake and on the northeast side of the ridge southwest

[1] A description of the fauna of the Sandpile Group near Sandpile Lakes is contained in the following publication:

Norford, B.S. (1962): The Silurian Fauna of the Sandpile Group of Northern British Columbia; Geol. Surv., Canada, Bull. 78

of Deadwood Lake, consists of grey to black weathering, dark grey to black, locally laminated, fine-grained dolomite in beds from 2 inches to 3 feet thick. Rugose corals, crinoid columnals, and brachiopod sections are present in these rocks but well-preserved fossils are not abundant. Upward in the section the dolomite beds contain increasing amounts of dark grey chert in the form of nodules, lenses, and, locally, entire beds. The cherty beds, commonly light buff to blue-grey weathering, are generally fossiliferous. In most beds, the fossils are highly silicified.

Near Sandpile Lakes the fossiliferous cherty dolomites are overlain by buff and orange weathering sandy dolomite and buff-orange, crossbedded, dolomitic sandstone and quartzite. Southwest of Deadwood Lake, however, the fossiliferous cherty dolomites are overlain by an unknown thickness of poorly bedded, grey and black dolomitic breccia.

Only a thin section of the Sandpile Group, perhaps less than 250 feet thick, underlies dolomite of the McDame Group along the easternmost belt of Sandpile Group east of Deadwood Lake. There, the rocks are mainly well-bedded dolomitic sandstones, quartzites, and cherty dolomites that locally display interference ripple-marks and well developed crossbedding.

Rusty weathering dykes of greenstone are not uncommon in rocks of the Sandpile Group east of Deadwood Lake. These rocks are characterized by a fragmental and vesicular texture. The fragments consist almost entirely of carbonate and in some places may be altered feldspar phenocrysts. Many, however, appear to be pieces of the wall-rock.

Sandpile Group in Looncry Lake and Red River areas. An unknown thickness of light grey weathering, cherty dolomite outcrops northwest of Looncry Lake. The rocks are highly fossiliferous and are similar to the fossiliferous strata near Sandpile Lakes.

South of Johnny Creek and west of Red River a section of black and grey, cherty, fossiliferous dolomite and dolomite breccia, and minor buff weathering dolomitic sandstone is more than 200 feet thick. The sandstone appears to underlie the dolomite in this locality.

A well-exposed section of the Sandpile Group outcrops on a ridge approximately 6 miles west-southwest of the confluence of Red and Deadwood Rivers. This section includes black, cherty dolomite and dolomite breccia, sandy, blue-grey dolomite and dolomitic sandstone, blue and grey weathering crinoidal and coralline dolomite, and buff-brown cherty dolomite.

Farther north near the big bend in Red River dolomitic sandstone and quartzite and minor dolomite are overlain by rocks of the McDame Group. Locally, the dolomite is brecciated and in a few places chert nodules are present. The Sandpile section in this area appears to be relatively thin.

Sandpile Group Northwest of Horseranch Range and near mouth of French River. Four miles south of Harvey Lake a highly contorted sequence of blue-grey, cherty dolomites contains Silurian fossils. To the north and northwest strata possibly equivalent to the Sandpile Group are included in an undivided assemblage of dolomite, dolomite breccia, dolomitic sandstone, and quartzite that is, in part, of Devonian age. No fossils of Ordovician or Siluran age have been found in this area.

More than 1,500 feet of Sandpile Group strata outcrop north and south of French River and west of Dease River. South of French River the strata comprise blue-grey and buff weathering cherty dolomite, dolomite breccia, and fairly massive white and pink quartzite. The breccias are probably intraformational and consist of angular to subangular and subrounded fragments of dolomite as much as 3 inches long in a matrix of dolomite. In this area the sequence of dolomites containing abundant chert appears to be relatively thick.

Similar rocks to those described above are exposed north of French River. There, however, chert nodules are not particularly abundant. About 7½ miles northwest of the mouth of French River and 3½ miles south-southwest of triangulation station elevation 5,011, a section of thin-bedded, rose-tinted, slaty siltstone and buff sandstone, as much as 200 feet thick, overlies dolomite breccia. These rocks are unlike those seen elsewhere in the area and could possibly be of younger age than the Sandpile Group.

Strata of the Sandpile Group may be included in the assemblage of highly folded rocks along Blue River west of the Cassiar road.

Sandpile Group (?) on limbs of McDame synclinorium. An assemblage tentatively correlated with the Sandpile Group overlies rocks of the Kechika Group along both limbs of the McDame synclinorium. The strata are particularly well exposed north of Sheep Mountain. There, black slates of the Kechika Group are overlain by laminated dolomites about 50 feet thick which are in turn overlain by flaggy, thin-bedded, grey, graptolitic siltstone as much as 100 feet thick. The upper part of the section consists of well-bedded quartzite, dolomitic sandstone, sandy dolomite, and dolomite about 550 feet thick.

The sandstone-dolomite unit is one of the most distinctive in the McDame map-area. Sandstone and quartzite beds range in thickness from a fraction of an inch to 12 feet, but beds from 2 to 4 feet thick are most common. In hand specimens the sandstones have a tapioca-like appearance, resulting from the distribution of rounded, translucent quartz grains, generally less than 1 mm in diameter, in a siliceous or dolomitic matrix. In thin sections the quartz grains show all gradations from those with a high degree of rounding to those that are irregularly replaced by carbonate.

Dolomite in the 'tapioca' sandstone sequence forms beds from less than an inch to 15 feet thick. These rocks are locally laminated and weather light grey to dark grey.

Sandy beds with a siliceous matrix weather out in relief. In beds with a carbonate matrix the percentage of quartz grains decreases upward in each bed, a feature that is especially evident in thin beds.

Crossbedding on a scale of less than an inch to several feet is characteristic of the sandy unit. Interference ripple-marks are conspicuous in some places.

At Centreville rocks similar to the graptolitic siltstones north of Sheep Mountain are directly overlain by the dolomitic sandstone unit. In the Hot Lake-Long Lake area, however, dark grey, brecciated dolomite underlies the dolomitic sandstones.

Although graptolitic siltstone has not been observed on the southwest side of the McDame synclinorium the section is otherwise similar to that on the northeast limb.

Structural Relations

Internal

Strata of the Sandpile Group are relatively competent and, as a result, dips are generally uniform and drag-folds are rare. East and southeast of Deadwood Lake the rocks are cut by numerous faults trending northwesterly, northerly, and northeasterly. North-northeasterly trending faults are prominent north of Sheep Mountain.

In general, with the exception of strata on the limbs of the McDame synclinorium, rocks of the Sandpile Group dip steeply only near major faults, as for example, south-southeast of Harvey Lake where the beds dip away from the major fault on the west side of Horseranch Range. Another example is the tight syncline southwest of Deadwood Lake which is bounded to the southwest by a fault.

East of Deadwood Lake several open folds were observed but mostly the rocks dip gently and uniformly in blocks bounded by faults.

The area northeast of Horseranch Range and near the mouth of French River is characterized by broad, open folds.

Section on North-facing Slope a Mile Southeast of lower Sandpile Lake

	Approximate Thickness (feet)
Top of section in fault contact with Cambro-Ordovician strata	
Dolomite, dark grey, laminated, platy, locally cherty; contains some poorly preserved fossils; this unit may be of Devonian age	100
Fault	
Sandstone, dolomitic, sandy, mottled, orange-buff dolomite; crossbedding conspicuous in places	450
Sandstone, dolomitic and sandy, mottled, orange-buff and grey dolomite; crossbedding on scale of several feet prominent, in sandy dolomites abundance of sand grains decreases upward in each layer	140
Dolomite, mottled, orange-buff; minor sandy dolomite; dolomite contains minor chert nodules; underlain by cherty, mottled, blue-grey and orange-buff, highly fossiliferous dolomite; silicified fauna, F_{33}	100
Dolomite, blue-grey, sandy; locally crossbedded	100
Dolomite, dark grey, thick-bedded to massive, fine-grained; chert nodules abundant locally; contains many crinoid columnals and poorly preserved sections of brachiopods	280

	Approximate Thickness (feet)
Quartzite, dark grey, fine-grained, even-grained	15
Dolomite, dark grey, nodular; characterized by wavy bedding; contains grey and buff weathering chert nodules	60
Dolomite, dark grey, fine-grained, well-bedded	40
Dolomite, light grey, coarsely crystalline	100
Dolomite, dark grey, fine-grained; laminated near top	50
Dolomite, dark grey to black, fine-grained, cherty; beds 2 inches to 3 feet thick; rugose corals and crinoid stems approximately 65 feet above base of section; minor dolomite breccia	145
Structurally conformable with underlying black slate of Kechika Group	
Total thickness (approx.)	1,580

Generalized Section 6.5 Miles West-southwest of Confluence of Deadwood and Red Rivers

	Approximate Thickness (feet)
Top of section unexposed	
Dolomite, black, massive, cherty, brecciated, coralline	500
Dolomite, dark grey, crinoidal, oolitic; oolites less than ½ mm in diameter	50
Dolomite, sandy and blue-grey fine-grained dolomite, well-bedded sandstone	200
Dolomite, blue-grey; crinoidal and coralline, F_{28}	20
Dolomite, buff-brown; abundant chert nodules, wavy bedding, beds generally less than an inch thick	200
Dolomite, grey, massive, crinoidal	30
Base unexposed	
Total thickness (approx.)	1,000

Generalized Section West of Cassiar Road 7 Miles South of Mouth of French River

	Approximate Thickness (feet)
Top of section unexposed	
Dolomite, blue-grey and buff, well-bedded, brecciated; contains abundant chert as nodules, lenses, and irregular beds, chert commonly weathers white or pink, subangular to subrounded fragments are common in the dolomite and possibly represent intraformational conglomerate and breccia	300
Dolomite, dull brown and grey weathering, cherty, intraformational breccia and conglomerate abundant, highly fossiliferous, fauna silicified, F_{25}	700
Dolomite, buff-brown, thick-bedded, brecciated; blue-grey, thin-bedded limestone and buff weathering, thin-bedded dolomite	200
Base of section unexposed	
Total thickness (approx.)	1,200

Section Approximately 2½ Miles Northeast of Sheep Mountain

	Approximate Thickness (feet)
Top of section conformable (?) with overlying Silurian and/or Devonian, laminated dolomite	
Sandstone, dolomitic, quartzite, sandy dolomite, dolomite; white, buff and grey, fine- to medium-grained tapioca sandstone and quartzite characteristically crossbedded and locally exhibits well-developed interference ripple-marks; dolomite is light grey and fine grained, porcellainous, locally laminated; near middle of section beds approximately 8 inches thick contain siliceous, concretion-like structures about the size of ping-pong balls	500
Dolomite and minor dolomitic limestone, grey, laminated; very minor light and dark grey tapioca quartzite	50
Siltstone, grey and buff-brown, platy, laminated; contains abundant graptolites, F_{41}	100
Dolomite, grey-black, laminated, medium-grained	50
Section underlain unconformably (?) by dark grey graptolitic shale of Kechika Group	
Total thickness (approx.)	700

External

Near Sandpile Lakes strata of the Sandpile Group are structurally conformable with underlying black slates of the Kechika Group and are overlain unconformably by Middle Devonian carbonates. The relatively thin section of dolomites, sandstones, and sandy dolomites east of the divide at the head of Walker Creek, however, appear to lie directly on blue and buff weathering phyllitic limestones and calcareous phyllites of the Kechika Group. The contact between the two groups was not observed and it is possible that they are separated by a fault.

Southwest of Deadwood Lake, the Sandpile Group is structurally conformable with underlying, interbedded black slate and blue-grey argillaceous limestone of earliest Upper Ordovician age. The top of the group is not exposed in this locality.

On the limbs of the McDame synclinorium the Sandpile Group (?) unconformably overlies black slates of probably early Ordovician age. The relations between the lowermost dolomite member, and the overlying siltstone member are not known. The thickness and character of the lowermost dolomite beds vary from place to place. The importance of these variations is not known; they may represent facies changes or erosion prior to deposition of the siltstone.

Sandstones and dolomites are underlain by contorted, black, pyritic slates, probably of Ordovician age, on the east side of Dease River several hundred yards below the mouth of French River. The contact was not observed.

The base of the sandstone and dolomite unit is not exposed between Dease River and the north end of Horseranch Range. The rocks are in fault contact with metamorphic rocks of the Horseranch Group southeast of Harvey Lake.

The base of the Sandpile Group was not observed in the Red River area where the strata overlie rocks of the Kechika Group.

In all places northeast and east of the McDame synclinorium where the top of the section is exposed, the Sandpile Group is overlain by fossiliferous dolomites of Middle Devonian age (McDame Group). On the limbs of the synclinorium the overlying rocks are laminated, unfossiliferous dolomites of Silurian and/or Devonian age.

North of French River the Sandpile Group is overlain by dolomite breccia of Silurian and/or Devonian age.

Mode of Origin

Evidently, the Sandpile Group was deposited mainly in shallow, well-aerated seas on a slowly subsiding shelf or platform. Judging from the widespread distribution of cherty, fossiliferous dolomites in northern British Columbia, Yukon Territory, and the Northwest Territories, similar conditions must have prevailed over an extensive area.

Graptolitic siltstones of approximately the same age as the carbonate strata may have accumulated in isolated basins within the subsiding platform.

During the deposition of the sandstones, sandy dolomites, and dolomites, conditions were apparently unfavourable for the growth of marine organisms.

Age

The following fossil collections were made from rocks of the Sandpile Group:

F_{24}. GSC Loc. 23337. 6.2 miles southwest of mouth of French River and 1 mile north of river at south end of small lake.

Cup coral indet.
Halysites catenularius (Linaeus)
Ptychophyllum stokesi Edwards and Haime
Favosites sp.

F_{25}. GSC Locs. 23994, 23345, and 23354. On west side of Cassiar road approximately 7 miles south-southwest of the mouth of French River.

Streptelasma spp. indet.
Cup corals indet.
Syringopora columbiana Wilson
Lichenaria sp.
Saffordophyllum franklini (Salter)
Diplophyllum sp.
Catenipora cf. *C. pulchellus* (Wilson)
Catenipora sp. cf. *C. rubra* Sinclair and Bolton
Cyathophyllid coral
Stromatoporoid
"Resserella" sp.

F_{26}. GSC Loc. 23341. On west side of Horseranch Range 3 miles south of Harvey Lake.

Cup corals—two types at least
Vermipora cf. *V. niagarensis* Rominger
Coenites sp.
Syringopora sp. (base)
Favosites sp.
Plectodonta sp.
Atrypa sp.
Howellella sp. cf. *H. crispa simplex* (Hall)
Parmorthis (?) sp.
Hormotoma (?) sp.

F_{27}. GSC Loc. 25009. 4.5 miles southwest of the confluence of Johnny Creek and Red River.
Catenipora sp. cf. *C. pulchellus* (Wilson)
Cup corals indet.
Crinoid columnals
Brachiopod sections—Pentamerids (?)

F_{28}. GSC Loc. 25008. 6.5 miles west-southwest of the confluence of Deadwood and Red Rivers.
Favosites sp. *F. hispidus* type
Halysites feildeni Etheridge
Catenipora microporus (Whitfield)
Lyellia sp.

F_{30}. GSC Loc. 23353. 6 miles southeast of the north end of Deadwood Lake.
Halysites sp.
Amplexus (?) sp.
Coenites sp. cf. *C. laminatus* (Hall)
Heliolites sp. cf. *H. megastomus* (McCoy)
Zaphrentis sp.
Pentamerus sp.

F_{31}. GSC Loc. 23355. 200 yards south on ridge from F_{30}, from rocks within a few tens of feet of underlying calcareous phyllite of Kechika Group.
Bryozoan indet.
Glyptorthis (?) sp. aff. *Plectorthis* (?) *sinuatus* Wilson
Cryptolithus sp.
"*Resserella*" cf. *R. rogata* (Sardeson)

F_{32}. GSC Locs. 23338 and 23344. 7 miles southeast of the north end of Deadwood Lake.
No. 23338
Halysites catenularius (Linaeus)
Coenites sp.
No. 23344 (about 600 yards northeast of 23338)
Catenipora sp. cf. *C. pulchellus* (Wilson)
Heliolites sp. cf. *H. megastomus* (McCoy)
Diplophyllum (?) sp.

F_{33}. GSC Loc. 22758. 5.3 miles northeast of the south end of Deadwood Lake.
Two forms of *Tetracoralla*
Halysites catenularius (Linaeus)
H. feildeni Etheridge
Favosites cf. *F. gothlandicus* (Fought)

F_{34}. GSC Loc. 22740. 1.9 miles northwest of north end of lower Sandpile Lake.
"*Halysites*" *labyrinthicus* (Goldfuss)

F_{35}. GSC Loc. 23995. 2.3 miles northwest of the north end of upper Sandpile Lake.
Diplophyllum sp.
Heliolites spp.
Halysites catenularius (Linaeus)
Coenites sp.

F_{36}. GSC Loc. 23359. 2.0 miles north of north end of upper Sandpile Lake, at elevation of about 6,300 feet.
Halysites catenularius (Linaeus)
Catenipora microporus (Whitfield)
Striatopora sp. cf. *S. huronensis* Rominger
Coenites sp.
Cystiphyllum sp. cf. *C. niagarense* (Hall)
Cystiphyllum (?) sp.
Atrypa spp.
Hesperorthis sp.
cf. *Dolerorthis* sp.
Plectodonta sp. cf. *P. transversalis* (Dalman)
Platyostoma sp.
Tiny gastropod—*Hormotoma* (?) sp.
Crinoid columnals

F_{37}. GSC Loc. 23358. 1.4 miles north-northwest of north end of upper Sandpile Lake, at elevation of 5,700 feet.

Cup corals indet.
Aulopora sp.
Heliolites sp. cf. *H. megastomus* (McCoy)
Striatopora sp. cf. *S. huronensis* Rominger
Syringopora sp.
Coenites sp.
C. cf. *laqueata* Rominger

F_{38}. GSC Loc. 23990. 0.6 mile southeast of south end of lower Sandpile Lake, at elevation of 4,950 feet.

Cup corals
cf. *Lichenaria* sp.
Diplophyllum sp.
Syringopora sp.
Plasmopora sp.
Catenipora microporus (Whitfield)
Halysites spp.
Coenites sp.

F_{39}. GSC Loc. 22748. 4 miles southeast of north end of lower Sandpile Lake and 0.9 mile northeast of peak, elevation 6,543 feet.

Halysites catenularius (Linaeus)
Halysites n. sp.—very large

F_{40}. GSC Loc. 25003. 3.3 miles west of south end of Deadwood Lake on crest of ridge.

Coenites sp.
Halysites sp.
Crinoid columnals
Brachiopod sections—Pentamerids (?)

F_{41}. GSC Loc. 32417. Approximately 2½ miles north-northwest of Sheep Mountain.

Monograptus dubius (Suess)
Monograptus sp. cf. *M. vomerinus* Nicholson
Monograptus sp. cf. *M. riccartonensis* Lapworth

T. E. Bolton, Geological Survey of Canada, reports that the fauna from localities F_{25} and F_{31} suggest an Upper Ordovician (Richmondian) age.

A. E. Wilson and T. E. Bolton, Geological Survey of Canada, refer the other collections, with the exception of F_{41}, to the Silurian (Niagaran) Period.

R. Thorsteinsson, Geological Survey of Canada, states that collection F_{41} represents a late Llandoverian (Lower Silurian) or Wenlockian (Middle Silurian) age, and that the fauna may possibly be correlative with the early Wenlockian graptolite zone of *Monograptus riccartonensis*.

In addition to the above collections *Halysites* (?) sp. were noted in rocks of the sandstone-dolomite unit southeast and north of Sandpile Lakes and poorly preserved monograptids (?) were noted in siltstone at Centreville.

Correlation

The Sandpile Group shows remarkable variations in thickness and character within the map-area. In particular, the absence of the highly fossiliferous, cherty dolomite unit on the limbs of the McDame synclinorium is noteworthy. There, the graptolitic siltstones and the underlying dolomite and dolomite breccia (not everywhere present) may be correlative with the fossiliferous dolomitic rocks to the east.

Another problem of correlation within the map-area involves the relation between the 'tapioca' sandstone-dolomite unit in the Sandpile Lakes area and that on the limbs of the synclinorium. Although fossils indicate that the sandy beds are of Silurian age near Sandpile Lakes, no such evidence was obtained on the limbs of the synclinorium and the correlation is based solely on lithology and stratigraphic position.

Graptolitic siltstone and shale, mapped by Poole (1957) in Wolf Lake map-area, forms part of an assemblage similar to that along the limbs of the McDame synclinorium. The southern limit of exposure of these rocks lies between Major Hart and Turnagain Rivers in Cry Lake map-area. There, older strata are exposed to the southeast in a northwesterly plunging synclinorium.

Fossiliferous, cherty, carbonate rocks, correlative with the Sandpile Group, have been traced by the writer southeasterly to the area between Dall Lake and Kechika River in Kechika map-area. The regional plunge in this area is also to the northwest so that rocks equivalent to the Sandpile Group probably do not extend to the southeast as far as Kechika River.

Rocks of Silurian age, at least in part correlative with the Sandpile Group, outcrop along the Alaska Highway east of McDame map-area (Williams, 1943; Laudon and Chronic, 1949) and in Quiet Lake map-area in southern Yukon Territory (J. O. Wheeler, personal communication, 1956). From these areas, however, Upper Ordovician rocks have not been reported.

Upper Ordovician strata have been recognized along Halfway River in the northern Rocky Mountains about 125 miles south of the section along the Alaska Highway mentioned above (Sutherland, 1958).

Silurian rocks (Ronning Formation, in part) outcrop in many places in Franklin, Mackenzie, and Selwyn Mountains. Upper Ordovician rocks appear to be widespread in Mackenzie Mountains.

In many respects the Sandpile Group is similar to the Beaverfoot-Brisco Formation in southeastern British Columbia.

Rocks of Silurian and/or Devonian Age

On both limbs of the McDame synclinorium a distinctive dolomite formation overlies the 'tapioca' sandstone of the Sandpile Group (?) and underlies black, fetid dolomite of the McDame Group. Dolomite breccia occurs in a similar stratigraphic position north of French River and also occurs in an isolated exposure north of Harvey Lake. These rocks are shown on the map as a sub-unit of the Sandpile Group but may prove to be a separate formation.

Lithology

On the northeast limb of the McDame synclinorium the unit consists of well-bedded, light to dark grey weathering, laminated, dense, fine-grained dolomites ranging in estimated thickness from 340 to more than 450 feet. Light grey and dark grey weathering beds from 1 foot to 10 feet thick emphasize the bedding as viewed from a distance. In hand specimens, however, most of the beds are in themselves distinctly laminated. The laminations are characteristically wavy on the scale of a few millimetres. No fossils were noted in this member. Similar rocks near Cassiar are about 75 feet thick.

The crest of the ridge between Little Blue River and French River that includes triangulation station elevation 5,011 feet, is underlain by dolomite breccia interbedded with grey-brown, laminated dolomite. Fragments in the breccia, as much as 12 inches long, are predominantly laminated, grey-brown dolomite but locally they consist of light and dark grey chert. Some of the fragments are subrounded but most are markedly angular.

Dolomite breccia north of Harvey Lake consists of dark grey and brownish grey dolomite fragments in a matrix lithologically similar.

Structural Relations

On the limbs of the McDame synclinorium the laminated dolomites appear to be conformable with the underlying sandy beds of the Sandpile Group (?). The distinction between the two units is determined solely on the presence or absence of sand. Since lateral variations in sand content are common in the Sandpile Group (?) it is probable that the boundary between the two units, chosen for mapping purposes, does not necessarily represent a time boundary.

The change in lithology from the laminated dolomites to the overlying black dolomites of the McDame Group is distinct but a disconformity has not been proved. However, where the McDame Group unconformably overlies Silurian and older rocks east of Deadwood Lake the laminated dolomite is missing.

Breccias north of French River underlie Middle Devonian rocks but the contact was not observed. The Sandpile Group south of French River includes dolomite breccia that underlies a thick succession of cherty dolomite. Possibly, the two breccias are correlative and the cherty dolomites north of French River were removed prior to deposition of the Middle Devonian strata.

Dolomite breccia north of Harvey Lake is not in observable contact with other rocks.

Mode of Origin

The general character of the breccias indicate that they are of intraformational origin. Insufficient evidence is available to permit a conclusive statement as to the origin of the laminated dolomites. Dolomites of similar character (fine-grained, laminated, unfossiliferous) are not uncommonly associated with evaporitic sequences. This environment, involving more or less isolated basins or lagoonal areas, apparently results in highly saline waters unsuitable for animal life. Possibly, such conditions existed in McDame map-area sometime between the Middle Silurian and Middle Devonian. The sandstone-laminated dolomite units of the Sandpile Group could conceivably reflect a similar environment with the additional factor that sand was introduced from time to time.

Age and Correlation

The available evidence suggests that the unfossiliferous laminated dolomites and dolomite breccias are more closely allied to the Silurian Sandpile Group (?) than to the Devonian McDame Group. Beyond this it can only be stated that the rocks could be of mid-Silurian, late Silurian, or early Devonian age.

McDame Group

Carbonate strata of the McDame Group, as much as 500 feet thick, are widely distributed in the map-area and are especially well exposed along the limbs of the McDame synclinorium.

The name Hidden Valley, first proposed by the writer (Gabrielse, 1954) for rocks including these Middle Devonian strata near Hidden Valley Creek, has been discarded. Further work in this area has shown that the Hidden Valley group as originally defined included strata of Cambro-Ordovician age.

Lithology

McDame Group on the limbs of the McDame synclinorium. The McDame Group on the limbs of the McDame synclinorium includes two distinctive members, a lower member consisting of black, fetid dolomite and an upper member consisting of grey, platy limestone.

The lower member comprises well-bedded, fossiliferous, fetid, dark grey and black dolomite and dolomite breccia. Because of its fossil content, distinctive lithology, and widespread occurrence, this unit is one of the most useful horizon markers in the map-area. The dark grey and black dolomite is generally crystalline and contains numerous veinlets and vugs filled with white, coarsely crystalline dolomite. Brecciated dolomite is not uncommon; the dark dolomite fragments are emphasized by a matrix of white dolomite. Near the top and bottom of the unit the beds are distinctly platy. Beds of 'spaghetti stone', consisting of dark grey and black dolomite containing numerous white weathering remains of rod-like organisms (*amphipora* sp. and *thamnopora* sp.) are particularly abundant in the upper part of the member.

Platy, well-bedded limestone forms the upper member of the McDame Group. The limestone beds are between half an inch and 4 feet thick; the thinner beds are distinctly platy. Some of the beds contain small nodules and irregular veinlets of chert. In contrast to the underlying dolomites, the limestones generally have a hackly and pitted surface, evidently the result of weathering by solution.

McDame Group in the Blue River Area. Tightly folded Devonian and older strata outcrop in the canyon of Blue River west of Cassiar road. The Devonian rocks include typical, black, fetid, 'spaghetti stone'. Black dolomite also forms isolated outcrops south and west of Blue River bridge. Black and grey dolomites outcrop along Blue River east of Cassiar road and underlie the prominent knob about 7½ miles north-northeast of the mouth of Blue River.

McDame Group near the confluence of Dease and French Rivers. Fossiliferous dolomites and limestones of Devonian age are included in an undivided assemblage in the area between the north end of Horseranch Range and Dease River. The thickness of the Devonian strata is not known.

A highly fossiliferous assemblage of Middle Devonian rocks underlies a ridge 7½ miles northwest of the mouth of French River. There, the strata are at least 125 feet thick and consist of well-bedded, dark grey to black limestone in beds ranging from 3 inches to a foot in thickness. Some of the beds in the lower part of the section have weathered to produce a hackly surface whereas others present a nodular appearance. Near the top of the exposed section chert nodules are common and the fauna is silicified.

Another highly fossiliferous section of Middle Devonian limestone and dolomitic limestone underlies an isolated knob about 2 miles southwest of the mouth of French River, and a small exposure of black fossiliferous dolomite occurs on the east side of Cassiar road 6.2 miles south of French River bridge.

McDame Group east of Horseranch Range and Deadwood Lake. Near the big bend in Red River, tightly folded rocks consist of typical, grey to black, fetid dolomite. Locally, 'spaghetti stone' is conspicuous.

Middle Devonian dolomites east of Deadwood Lake are similar to those of the lower member of the McDame Group on the limbs of the McDame synclinorium. Although the rocks are highly fossiliferous, most fossils are poorly preserved, perhaps in large part the result of dolomitization. In some places dolomite breccia contains shiny, black, bitumen.

The basal part of the dolomite member, at the peak of the mountain, elevation 6,266, east of lower Sandpile Lake, includes beds of grey, vitreous, well-bedded quartzite, grey and brownish shale, and chert-pebble and cobble-conglomerate. East of the north end of Deadwood Lake the basal part of the dolomite member includes thin interbeds of buff and brown calcareous shale.

Structural Relations

Internal

Generally, strata of the McDame Group dip uniformly on the limbs of the McDame synclinorium. The rocks are exposed in open, symmetrical folds northwest of Horseranch Range and east of Dease River, but to the north they form part of a tightly folded assemblage in the canyon of Blue River. East of Deadwood Lake dips are moderate and uniform although beds are locally contorted, as for example, near the divide at the head of Walker Creek.

The easternmost belt of strata assigned to the McDame Group east of Deadwood Lake is cut by numerous northerly trending, right-hand faults that have effected horizontal displacements of as much as a mile. Northerly and northeasterly trending faults also offset strata of the McDame Group north of Sheep Mountain. The faults are steeply dipping and are evidenced by zones of breccia and sharp offsets of beds.

Section Measured North-northeast of Sheep Mountain, 8.8 Miles West-southwest of Mouth of Julian Creek

	Approximate Thickness (feet)
Top of section conformably (?) overlain by slate of Sylvester Group	
Limestone, light grey, well-bedded, platy; one interbed of dark grey dolomite 10 feet thick near base; beds range from ½ inch to 4 feet in thickness; locally beds contain thin stringers and irregular patches of chert; solution channels common parallel with dip; locally contains brachiopod sections (*Stringocephalus* ? sp.)	175
Dolomite, grey and black, well-bedded, fetid, highly fossiliferous; beds average about 1 foot thick; locally dolomite breccia conspicuous; beds platy near top and bottom of the member; 'spaghetti stone' characteristic in upper part; white, crystalline dolomite prominent in vugs and as matrix of breccia	335
Disconformably (?) overlies Silurian and/or Devonian dolomite.	
Total thickness (approx.)	510

Section Measured about one quarter Mile northwest of Peak, Elevation 6,266 Feet, East of Lower Sandpile Lake

	Approximate Thickness (feet)
Top of section in fault contact with dolomite of the Sandpile Group	
Dolomite, grey and black, fine-grained, crystalline; weathers earthy black and brown-grey, contains thin white stringers of dolomite; poorly preserved fossils include *Amphipora*? sp. and *Syringopora*? sp.	50
Shale, grey and brownish	1
Quartzite, grey, vitreous, well-bedded	4
Conglomerate, chert pebbles and cobbles in a dolomite cement	2
Conglomerate, chert pebbles and cobbles in a siliceous cement	0.5
Overlies cherty dolomites of Sandpile Group with slight erosional unconformity	
Thickness	57.5

A section measured on the west limb of the McDame synclinorium east of Cassiar includes 275 feet of grey, platy, limestone overlying about 100 feet of dark grey and black, fetid dolomite.

Section Measured on Peak, Elevation 6,266, East of Lower Sandpile Lake

	Approximate Thickness (feet)
Fault contact with dolomite of Sandpile Group	
Dolomite, medium grey and black, crystalline, weathers dull black; rare beds of blue-grey, fine-grained, platy, dolomitic limestone; one bed 7 feet thick of blue-grey, fine-grained, cherty dolomite	150
Limestone, dolomitic, earthy, black and grey weathering, chocolate-brown tinge, bedding 3 to 18 inches; interbedded with grey to black shales between 75 and 90 feet above base; contains *Hexagonaria* sp., F_{64}	110
Quartzite, grey, vitreous, weathers light grey with brownish tinge, beds 2 feet to 4 feet thick	20
Unconformably (?) overlies thick-bedded dolomites of Sandpile Group	
Total thickness (approx.)	280

On the north slope of the mountain on which the above sections were measured the dolomite section below a thrust fault is about 560 feet thick. *Amphipora* sp. is abundant in the upper 240 feet of this section.

External

The McDame Group is structurally conformable with the underlying laminated dolomite unit of Silurian and/or Devonian age on the limbs of the McDame synclinorium. The contact may be disconformable. The rocks are also structurally conformable with strata of the overlying Sylvester Group although in places the contact is marked by faults. The persistence of the limestone on the limbs of the synclinorium indicates that, if an unconformity separates the two groups, it is insignificant in this area. South of Cassiar the limestone member of the McDame Group was not noted but whether this is the result of faulting or erosion is not known.

The contact between the McDame Group and underlying dolomite breccia north of French River was not observed.

The base of the McDame Group was not observed near the big bend of Red River and east of Dease River and northwest of Horseranch Range. In these areas the rocks are underlain by sandstones and dolomites of the Sandpile Group.

East of Deadwood Lake the McDame Group unconformably overlies rocks ranging from Cambro-Ordovician to Silurian age. The relations are well shown on the mountain, elevation 6,266, east of lower Sandpile Lake (Pl. IV A). There, rocks of the McDame Group that form the peak rest on different members of the Sandpile Group when traced northwesterly. Conglomerates appear at the base of the group only where the underlying rocks are cherty.

On the northeast slope of the mountain referred to above the McDame Group lies directly on Cambro-Ordovician, buff weathering phyllites and limestones of the Kechika Group. The upper contact is along a thrust fault that brings buff weathering phyllites and limestones of the Kechika Group into a position structurally above the McDame Group.

East of the north end of Deadwood Lake the McDame Group overlies calcareous phyllites of the Kechika Group. The contact is in a sense gradational in that the basal part of the McDame Group contains interbeds of phyllitic, calcareous shales identical with those of the underlying Kechika Group. These shales presumably represent re-worked Cambro-Ordovician strata deposited in Middle Devonian time.

Metamorphism

Along the east contact of the Cassiar batholith east of Eagle River 'spaghetti stone' of the McDame Group has been recrystallized but fossils have not been obliterated. Locally, the rocks have been metamorphosed to a calc-silicate skarn.

Mode of Origin

The McDame Group was apparently deposited on a slowly subsiding shelf or platform in relatively shallow, warm, well-aerated waters. The breccias are mainly intraformational. As was so with the Sandpile Group, uniform conditions must have existed over an extensive area in northwestern Canada because the black, fetid, fossiliferous dolomites of mid-Devonian age are widespread.

The upper member of the McDame Group on the limbs of the McDame synclinorium consists of poorly fossiliferous limestone and this unit may have been deposited in a deepening basin, perhaps heralding the rapid subsidence of the depositional basin that was to follow in late Devonian and early Mississippian time.

The lower member of the McDame Group is much thinner on the southwest limb of the McDame synclinorium than on the northeast limb. This may represent a primary depositional thinning as the contact with the overlying limestones appears to be conformable.

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Age

The following fossil collections were made from rocks of the McDame Group:

F_{42}. GSC Loc. 17547. 6 miles northwest of the north end of Gallic Lake.
Amphipora sp.
phaceloid corals, sp. cf. *Disphyllum*
shell fragments, cf. *Stringocephalus*

F_{43}. GSC Locs. 32418, 32421, 32420, and 32422 (in ascending order of section). South-facing ridge 1.2 miles southwest of peak, elevation 5,011 feet, and 7.6 miles west-northwest of the mouth of French River.

Elevation 4,300 feet (32418)
ptenophyllid coral genus A[1]
Schizophoria sp.
Devonoproductus sp.
Productella sp.
Camarotoechia cameroni Warren (?)
Nudirostra castanea (Meek)
Atrypa cf. *A. independensis* Webster
Warrenella sp. A
Tentaculites sp.
trilobite tails, genus A

Elevation 4,350-4,365 feet (32421)
Favosites sp.
ptenophyllid coral genus A
leptoinophyllid genus E
Schizophoria sp.
Atrypa sp.

Elevation 4,390-4,400 feet (32420)
Alveolites ex gr. *A. suborbicularis* Lamarck
Favosites sp. E
Acanthophyllum sp. B
Spongophyllum sp. E

Elevation 4,435 feet (32422)
Amphipora sp.
Coenites sp.
Dendrostella cf. *D. rhenana* (Frech)
Stringocephalus fragments

F_{44}. GSC Loc. 23991. On south side of Dease River 1.4 miles north of mouth of French River.
Favosites sp.
Syringopora sp.
Thamnopora sp.
cf. *Cystiphylloides* sp.

F_{45}. GSC Loc. 17546. Isolated knob 1.4 miles southwest of mouth of French River.
stromatoporoid
Alveolites sp.
Favosites sp. very large head
Syringopora sp.
cf. *Thamnopora* sp.
Cystiphylloides sp.
Disphyllum sp.

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[1] Some species and genera in the faunal lists are designated by letters of the alphabet. These letters are consistent with the classification employed in the Geological Survey index collection of Devonian fossils.

Hexagonaria sp.
Schizophoria sp.
Gypidula sp.
cf. *Leiorhynchus* sp.
Atrypa spp.
small spiriferoids
Emanuella sublineata (Meek)
stringocephaloid, genus unknown
gastropods indet.
cf. *Paracyclas* sp. and other pelecypods
nautiloid fragments
leperditioid ostracods
proetid trilobite remains

F_{46}. GSC Loc. 23340. 4.0 miles southeast of mouth of French River.
stromatoporoid
Amphipora sp.
fragments of thick-shelled brachiopod- (?) *Stringocephalus*

F_{47}. GSC Locs. 17544, 23996, and 32419. 30 feet east of Cassiar road 6.2 miles south-southwest of mouth of French River.
Amphipora sp.
Alveolites sp.
Aulopora sp.
Favosites sp.
Thamnopora sp.
Dendrostella sp.
productellid indet.
trilobite fragments, indet.

F_{48}. GSC Loc. 23343. 1.7 miles southwest of south end of Harvey Lake.
Alveolites sp.
Thamnopora sp.
brachiopod fragments

F_{49}. GSC Locs. 23342 and 23993. 0.2 and 0.5 mile north of big bend of Red River.
Coenites sp.
cf. *Syringopora*
Disphyllum sp. A
zaphrentid coral
rhynchonellid cf. *Pugnoides*
small martinioid brachiopod
crinoid stems

F_{50}. GSC Loc. 23357. On bare ridge 4.5 miles east-southeast of confluence of Johnny Creek and Red River.
Coenites sp.
Striatopora sp.
columnariid corals
rugose coral fragments
Atrypa sp.

F_{51}. GSC Loc. 22745. 5.1 miles east-southeast of north end of Deadwood Lake.
Amphipora sp.
Gypidula-like brachiopod

F_{52}. GSC Locs. 22754 and 23348. 6.2 miles east-southeast of north end of Deadwood Lake.
Amphipora sp.
Favosites sp.
cup coral—long Cyathophyllid type
Hexagonaria sp.

F_{53}. GSC Loc. 22750. 8.9 miles east-southeast of north end of Deadwood Lake.
Amphipora sp.
stromatoporoid
Favosites sp.—branching type
cup coral fragment
brachiopod fragments

F_{54}. GSC Locs. 23349 and 37264. On peak, elevation 6,226 feet, 1.7 miles east of lower Sandpile Lake.
Amphipora sp.
Alveolites sp. B
Aulopora sp.
Coenites sp
Favosites sp. H
Syringopora sp. D
Disphyllum sp. A cf. *D. goldfussi* (Geinitz)
Spongophyllum sp. E

F_{55}. GSC Locs. 20125 and 20127. On ridge 4.7 miles southeast of mouth of Fourmile River.
Amphipora sp.
Clathrodictyon sp.
Syringopora sp.
Favosites sp.
Thamnopora sp.
disphylloid corals
cf. *Eurekaphyllum* sp.
Hexagonaria sp.
Stringocephalus sp. cf. *S. burtini* Defrance
cf. *Murchisonia* sp.

F_{56}. GSC Loc. 22743. On ridge east of Eagle River 4.1 miles south of mouth of Eagle River.
Amphipora ? sp.

Fossil collections F_{51}, F_{52}, F_{53}, and F_{56} were identified by A. E. Wilson of the Geological Survey of Canada who reports that the lots represent rocks of Devonian, probably of Middle Devonian age.

The remaining fossil collections were examined by D. J. McLaren of the Geological Survey of Canada who states that most of the collections are definitely of Middle Devonian age and the remainder is probably of Middle Devonian age. He suggests that the fauna of collection F_{49} may possibly represent rocks of Upper Devonian age.

With the exception of part of fossil collection F_{55} the fossils were collected from typical, fetid dolomites and limestones of the McDame Group. *Stringocephalus* sp. of F_{55} was collected from basal beds of the upper limestone member. Fossils collected from the limestone member in the northeastern part of Cry Lake map-area, however, suggest a possible Upper Devonian age.

In summary, the McDame Group is of Middle, and possibly Upper Devonian age.

Correlation

D. J. McLaren suggests that the fossiliferous rocks of the McDame Group may be correlative with the Pine Point Formation of Great Slave Lake, the Winnipegosan Formation of Manitoba, and the Elk Point (subsurface) Formation of Alberta.

Fauna from fossil localities F_{43} and F_{45} suggest correlation of these rocks with the Nahanni Formation in the southern Mackenzie Mountains.

East of McDame map-area along the Alaska Highway, Middle Devonian rocks have been mapped by Williams (1944) and have been referred to the Ramparts Formation by Laudon and Chronic (1949).

Rocks correlative with at least part of the McDame Group are exposed in Wolf Lake map-area to the northwest of McDame map-area (Poole, 1957) and in Quiet Lake map-area farther north (J. O. Wheeler, personal communication, 1956).

In summary, rocks of Middle Devonian age are widespread in northern British Columbia, in southern Yukon, and in the southern part of Mackenzie Mountains.

Sylvester Group

The name Sylvester Group, is here proposed for a typical eugeosynclinal assemblage at least 15,000 feet thick exposed in a southeasterly plunging synclinorium, referred to in this report as the McDame synclinorium. The rocks are well exposed almost everywhere within the synclinorium, particularly along the northeast limb. An assemblage of chert, greenstone, and argillite underlying an area of less than 1 square mile about 3 miles south of Harvey Lake and a small outcrop of banded chert on the south bank of French River approximately half a mile west of Cassiar road have been mapped as Sylvester Group although their relations to other rocks are unknown.

Strata possibly correlative to the Sylvester Group outcrop along the Alaska Highway east of Hyland River and near Lower Post and along Dease and Liard Rivers near Lower Post.

Sylvester Peak south of McDame, for which the group is named, is one of the prominent mountains underlain by strata of the group.

Lithology

Dark weathering, and commonly structureless, rocks of the Sylvester Group contrast markedly to older strata in the area. The abundance of volcanic material, chert, and impure quartzitic rocks makes the assemblage distinctive in the field. The characteristic form of mountains on the limbs of the McDame synclinorium reflects the relative resistance to weathering of volcanic and sedimentary rocks. The smooth lower slopes are underlain by sedimentary strata and the craggy peaks are underlain mainly by volcanic rocks.

Sedimentary Rocks of the Sylvester Group

Sedimentary rocks of the Sylvester Group are comprised of chert, argillite, slate, quartz and chert arenite, argillaceous quartzite, greywacke, quartzite, conglomerate, and limestone. The composition of the rock types and their relative abundance vary from place to place as does the relative abundance of sedimentary and volcanic rocks. Relatively thick sections of sediments form the lower part of the Sylvester Group on the northeast limb of the McDame synclinorium.

Interbedded light and dark grey, green, and pink chert and grey argillite are common. Beds of chert ranging from half an inch to 5 inches thick, generally have partings of phyllitic, grey argillite less than an inch thick. Highly folded, grey and black chert, in beds averaging about an inch thick, overlies black, rusty weathering slate and argillite on the north side of the Alaska Highway at mile 603.

A section of chert on the ridge immediately south of Little Rancheria River displays intricately crumpled, alternating dark grey and white bands averaging an inch thick.

Beds of light to dark grey quartz and chert arenite are also common and consist essentially of angular to subangular fragments of quartz and chert in a fine-grained cherty matrix. These beds commonly have partings of phyllitic, grey argillite.

In some areas monotonous assemblages of dark grey, black, green, and brown slate and argillite predominate. The rocks are laminated locally on a scale of between 1 and 5 mm. Black argillite overlying the Cassiar Asbestos serpentinite body contains angular fragments of volcanic rock up to 2 inches long.

Micaceous quartzite forms part of a well-bedded assemblage 4 miles east of Four Mile River near the southern boundary of the map-area. The rocks consist of interlocking quartz grains and minor muscovite and chlorite. Locally, the quartzite is banded or laminated.

Black and grey calcareous quartzite and black, carbonaceous slate outcrop near Four Mile Rapids on Dease River.

Greywacke was noted in abundance only in the assemblage near the base of the Nizi formation south of Sheep Mountain. There, the rocks have a distinct fragmental appearance and weather to shades of green. Thin sections of the rocks show abundant albite or sodic oligoclase in addition to quartz, chert, and carbonate. In these rocks the grains are typically angular to subrounded and sorting is poor.

Chert-pebble conglomerate occurs several hundred feet stratigraphically above Middle Devonian rocks on the southwest flank of McDame Mountain but was not seen elsewhere in a similar stratigraphic position. The conglomerates consist of light and dark grey chert pebbles as much as 2 cm long in a dark grey cherty matrix.

Chert-pebble conglomerate in beds from 1 foot to 2 feet thick outcrops at Two Mile Rapids on Dease River. The conglomerate is interbedded with black, fissile slate that contains nodules of pyrite.

Discontinuous bodies of limestone constitute a small proportion of the Sylvester Group. South of Little Blue River buff weathering limestone in beds averaging about 2 feet thick is interbedded with slate, quartzite, and chert.

South of Juniper Mountain and north of Dease River beds of blue-grey limestone, ranging from a few inches to several feet thick, are interbedded with red and green weathering volcanic rocks in a highly folded assemblage several hundred feet thick.

East of Pooley Creek, discontinous bodies of limestone as much as 300 feet thick are interbedded with chert and greenstone. In this area limestone has been intruded by volcanic rocks and this may account, in part, for the discontinuity of the beds.

Highly contorted blue-grey and black limestone, black, graphitic limestone, and mottled, buff and rose-tinged limestone, form part of a fossiliferous sequence that includes white and pink quartzite, red, slaty siltstone, and black, graphitic, rusty weathering slate on the Alaska Highway north of Lower Post. Similar rocks outcrop in the canyon of Liard River north of Lower Post.

Greenstones of the Sylvester Group

Distribution.

Greenstones of the Sylvester Group are intimately associated with sedimentary and ultramafic rocks that underlie the area within the McDame synclinorium. On the scale of mapping no separation of sedimentary and volcanic members could be made. Sections consisting largely of volcanic rocks may be traced along strike into sections consisting largely of sedimentary rocks. Many outcrops yield little information as to whether sills, flows, or dykes, are represented. Massive, medium-grained greenstones are not uncommon and are particularly prominent in the vicinity of McDame Lake and near the mouth of Quartzrock Creek. Wedge-shaped sills are best revealed in cirque walls at Cassiar, and east of the northernmost exposures along Little Blue River.

Greenstones were studied in detail only in the area north of Cassiar road and the following descriptions deal mainly with rocks in this area.

Lithology. Fine-grained, green, structureless rocks dominate the volcanic sequence. Some of the rocks are porphyritic but this texture is more evident under the microscope than in hand specimens. Medium-grained, equigranular greenstones containing pyroxene and plagioclase are widespread. Vesicles, amygdules, and flow-banding were noted locally. Volcanic breccia, consisting of angular fragments of aphanitic greenstone in a greenstone matrix, and agglomerate, with angular volcanic fragments in a tuffaceous matrix, can sometimes be differentiated in the field. Homogeneous grey tuffs were observed but are generally difficult to recognize because of alteration.

Under the microscope the volcanic rocks may be subdivided into three types which grade into one another in the field.

Type 1, Sylvester greenstone. West of Quartzrock Creek and the upper reaches of Little Blue River, and especially along the western border of the eugeosynclinal assemblage, the greenstones are characterized by tremolite-actinolite, zoisite, clinozoisite, and albite. In addition, almost all thin sections contain calcite, chlorite, augite, leucoxene, sphene, and ilmenite. The average grain size ranges from 1½ to 2 mm. None of the minerals, with the exception of minor relict pyroxene, is euhedral. The typical texture is crystalloblastic and occasionally nematoblastic, the latter resulting from the orientation of amphibole crystals in zones of cataclasis.

Type 2, Sylvester greenstone. Volcanic rocks of type 1 grade easterly into rocks that are composed predominantly of sodic plagioclase, pyroxene, and alteration products of pyroxene. Chlorite and zoisite inclusions in plagioclase are ubiquitous and in some slides the feldspar appears turbid under low power. In most specimens the centres of crystals contain more inclusions than the borders but reversals of this phenomenon were noted. Andesine and labradorite were noted in a few slides in which most of the feldspar is oligoclase. One slide contains zoned plagioclase with turbid cores An_{55} and clear borders An_{20}. An x-ray powder diffraction pattern of feldspar from a typical type 2 greenstone indicates a composition An_{12} (Goodyear and Duffin, 1954). R. Traill (personal communication, 1954) stated that the plagioclase is a low-temperature type.

Optical properties of the augite are $Z \wedge C$, 39°-42°; $2V_z$, 48½°-53°; N_y, 1.686±0.004, indicating that it has an approximate composition $Ca_{41}Mg_{46}Fe_{13}$ (Hess, 1949, Pl. I). Alteration products of pyroxene consist of blue-green actinolite and chlorite.

Veinlets of prehnite and carbonate occur in rocks that have undergone deformation. Ilmenite, sphene, and leucoxene occur as accessory minerals.

The average grain size of type 2 greenstones ranges from ½ mm to 3 mm. Although crystal boundaries of plagioclase and pyroxene are sutured, a relict diabasic or sub-ophitic texture is well preserved in many specimens. Porphyritic texture is not uncommon.

In a sill exposed in Little Blue River canyon a specimen taken 6 feet from the lower contact consists predominantly of oligoclase and actinolite. A specimen taken 50 feet from the lower contact consists predominantly of oligoclase and augite that is only slightly altered. The feldspar in the actinolite-bearing greenstone is not as turbid as that in the pyroxene-bearing type because the inclusions are much more distinct.

Amphibole-feldspar gneiss adjacent to serpentinite northwest of Blue River contains equal amounts of amphibole and albite. Blue-green, pleochroic hornblende with a maximum grain size of 4 cms has a porphyroblastic texture. Euhedral, wedge-shaped sphene is conspicuous in these gneissic rocks.

Type 3, Sylvester greenstone. The third type of greenstone in the McDame ultramafic belt has the appearance of a medium-grained diorite. Pegmatitic segregations occur locally. An attempt has been made to show the distribution of these rocks on the map although they do not form definite mappable bodies. All gradations exist between the medium-grained types and fine-grained typical greenstones, and gradations occur over distances of several feet. No intrusive contacts were detected. South of the Zus Mountain ultramafic body, differences in mineral composition and texture have produced a banding that is roughly parallel with the bedding in the area.

In thin sections three major features characterize these rocks. They are: strong development of porphyroblastic amphibole; intense turbid alteration of albite; and presence, locally, of quartz. The amphibole encloses plagioclase, chlorite, pyroxene, and quartz. Sodic plagioclase, in crystals up to 3 mm long, has been altered to an opaque argillaceous material and includes chlorite and possibly zoisite. Several sections contain minor amounts of colourless mica. Extremely irregular crystals of quartz form as much as 20 per cent of some thin sections. Chlorite, probably penninite, has replaced pyroxene, and in some specimens pyroxene crystals are enclosed by chlorite, in turn surrounded by porphyroblastic amphibole. Ilmenite, sphene, and leucoxene are common accessory minerals.

Original lithology of Sylvester greenstones. The following criteria indicate that the Sylvester greenstones were originally pyroxene andesites or basalts:

1. Diabasic, ophitic, and sub-ophitic textures typical of doleritic rocks.
2. Presence of relict andesine and labradorite in specimens containing oligoclase or albite.
3. Presence of numerous inclusions of zoisite and chlorite in plagioclase.
4. Chemical composition of representative type 2 greenstone and partial analysis of a type 1 greenstone (*see* Table II).

The relatively low silica and alkali content, and high calcium and magnesium content shown by analyses 1 and 2, are in contrast to those of rocks that contain pyrogenetic albite or oligoclase. A comparison of the molecular norm (Niggli, 1936) calculated from analysis 1, with the mineral composition of the same specimen is given in Table III.

The feldspar indicated by the molecular norm is calcic andesine whereas plagioclase in the specimen is An_{14}. If 47 per cent by volume of the rock were plagioclase An_{14} the chemical composition should contain more than 4 per cent Na_2O. The discrepancy between this amount and the 2.64 per cent shown in the analysis indicates that zoisite and chlorite inclusions constitute a considerable part of the turpid plagioclase. Under the microscope rocks of this type could be mistaken for spilites.

The high olivine content of the molecular norm may be attributed, at least in part, to ubiquitous chlorite and serpentine in the specimen.

Table II

Analyses of Volcanic Rocks

	1	2	3	4
SiO_2	49.51	—	49.58	51.22
TiO_2	0.90	—	3.17	3.32
Al_2O_3	12.39	—	13.19	13.66
Fe_2O_3	1.72	—	2.40	2.84
FeO	6.83	9.27	9.49	9.20
MnO	0.15	—	0.12	0.25
MgO	10.42	6.83	8.30	4.55
CaO	11.45	8.08	10.69	6.89
Na_2O	2.64	3.07	2.25	4.93
K_2O	0.04	0.19	0.55	0.75
H_2O^+	3.23	—	—	1.88
H_2O^-	0.43	—	—	—
P_2O_5	0.07	—	0.26	0.29
Cr_2O_3	0.06	—	—	—
NiO	0.03	—	—	—
CO_2	0.06	—	—	0.94
Total	99.93	—	100.00	100.72
Sp. gr.	2.97			

1. Type 2 greenstone from sill in canyon of Little Blue River. Analyst John A. Maxwell, Geological Survey of Canada.
2. Partial analysis of type 1 greenstone from sill near Cassiar Asbestos mine. Analyst John A. Maxwell, Geological Survey of Canada.
3. Water-free average of eleven analyses of Hawaiian basalts (Daly, 1944, p. 1365).
4. Average spilite, nineteen analyses (N. Sundius, 1930, p. 9).

Table III

Molecular Norm and Mineral Composition of Analysis 1, Table II

Molecular norm (molecular per cent)		Mineral Composition (volume per cent)	
Or	0.5		
Ab	24.5		
An	22.5		
Total feldspar	47.5	Feldspar	47.0
Di	27.6	Pyroxene	37.5
Ol	21.5	Chlorite and serpentine	13.0
Mt	2.0	Ilmenite	2.5
Il	1.2		
Ap	0.3		
Total femic	52.6		53.0

Feldspar in the mineral composition actually represents original feldspar content as chlorite and zoisite included by the mineral are not represented. Molecular norm calculated water-free.

Structural Relations

Internal structural relations of the Sylvester Group are discussed in detail in the chapter on structural geology.

The Sylvester Group is structurally conformable with the underlying McDame Group. Furthermore, as mentioned previously, the Sylvester Group on the limbs of the McDame synclinorium in most places overlies the uppermost limestone member of the McDame Group. Therefore there is little probability that in this area the two groups are separated by a significant unconformity.

Metamorphism

Volcanic Rocks

The alteration of calcic plagioclase to albite and zoisite is widespread in eugeosynclinal areas. The formation of albite and zoisite is generally accompanied by uralitization of the pyroxene. Type 1 Sylvester greenstones are typical rocks of the albite-epidote-amphibolite facies (Turner, 1951, p. 460). Their mineralogical assemblage of tremolite-actinolite, zoisite, clinozoisite, chlorite, carbonate, and albite, could be derived from pyroxene andesites or basalts by addition of water and readjustment of elements originally present in the rocks. Locally, the presence of CO_2 would lead to development of carbonate minerals. This metamorphism can be referred to as saussuritization.

Most type 2 Sylvester greenstones are incipiently saussuritized, but local variations in mineral assemblage were noted. In fine-grained greenstones near borders of sills, in the groundmass of medium-grained greenstones, and in zones of rupture, amphibole and chlorite are generally well developed. It seems probable that in the initial stages of saussuritization shown by these rocks the fine-grained minerals are altered more readily than minerals of coarser grain. This phenomenon is not uncommon and may in part be due to the higher chemical potential of smaller grains (Verhoogen, 1948, pp. 210-217).

An attempt to explain differences in mineral assemblages of metamorphic origin in which water is an important constituent meets with many complications. As Yoder (1952, pp. 569-627, and 1954, p. 52) pointed out, the role of water in metamorphism is determined by four independent variables: rock pressure, temperature, water pressure, and amount of water present. The difficulties encountered in ascertaining the relative effects of each of these variables in different environments are obvious. Restriction of the type 1 greenstones to a zone near the Cassiar batholith suggests that the advanced saussuritization of these rocks was caused by contact metamorphism related to the emplacement of the granitic rocks. Type 2 greenstones may have attained their present mineral composition at that time but it is probable that the volcanic assemblage was saussuritized prior to emplacement of the Cassiar batholith. Type 2 greenstones are found throughout the ultramafic belt remote from granitic rocks.

The emplacement of volcanic sills into water-rich country rock could locally produce conditions favourable for metamorphism. The two degrees of saussuritization shown by type 1 and type 2 greenstones may be the result, in part, of a different length of time during which conditions favouring metamorphism existed in the particular environments. The type 2 greenstones may have been exposed to conditions promoting metamorphism for a short time due to the relatively quick cooling of the sills. On the other hand, conditions promoting metamorphism may have existed for a considerable length of time near the Cassiar batholith.

Field and microscopic evidence indicate that the type 3 greenstones are altered equivalents of the volcanic rocks. The evidence is as follows:

1. No intrusive contacts between type 3 greenstones and normal greenstones were noted. In all observed cases the two types grade diffusely into one another.
2. Compositional and textural banding indicate the original layering of these rocks. The bands are composed of all variations from typical greenstones to typical dioritic rocks. No suggestion of gravitational differentiation is revealed in the layering.
3. Porphyroblastic amphibole is clearly secondary. Relict pyroxene and plagioclase show that the grain size of these minerals was originally the same as that in normal greenstones. The coarse grain size is therefore a product of metamorphism and not of primary crystallization.
4. With the exception of quartz, the mineral composition of the dioritic rocks is similar to that of the greenstones. Quartz may be in part released from the replacement of augite and plagioclase by hornblende. There appears to be a direct correlation between the amount of quartz and the development of porphyroblastic hornblende.

Type 3 greenstones are restricted to the thickest piles of volcanic rocks. Water may not have been more abundant there than elsewhere but conditions favoured a development of coarse hydrous minerals during metamorphism. Once again evidence is not available to determine what these conditions were but the hypotheses outlined above for the metamorphism resulting in the type 2 greenstones may be applicable. If the emplacement of volcanic rocks raised the temperature of surrounding rocks sufficiently to promote metamorphism, then the thicker piles of volcanic rocks might show the more pronounced effects. Local variations in degree of metamorphism could reflect differences in any one or more of a host of variables such as original grain size, availability of water, relationship of water pressure to rock pressure and so on.

Another possibility, suggested by the distribution of these rocks, is that their metamorphism is related to the emplacement of the ultramafic bodies.

Gabbroic and dioritic rocks similar to those described are reported in areas containing ultramafic rocks throughout the western Cordillera of British Columbia. Leech (1953, pp. 18-19), in describing a greenstone-gabbro complex in the Shulaps Range, mentioned an erratic distribution of grain size in the complex. He suggested a possible replacement of the finer grained by the coarser grained type but pointed out that corroboration of this hypothesis is difficult. Stevenson (1948, p. 102) believed that augite diorite in the Cadwallader Creek-Gun region was formed by replacement of greenstone. Aitken (1953, p. 78) stated that completely altered, low-grade greenstones and spilites are restricted to areas of thick volcanic accumulations and related the complete alteration to volcanic activity.

In summary, the three types of greenstone in the McDame ultramafic belt seem to represent three degrees of metamorphism of original pyroxene andesites or basalts.

Sedimentary Rocks

Near the Cassiar batholith northwest of Blue River sedimentary rocks of the Sylvester Group have been metamorphosed to fine-grained rocks with hornfelsic texture. One mineral assemblage consists of quartz, orthoclase, muscovite, and biotite, whereas another consists of quartz, hornblende, biotite, and andesine.

Except for the pronounced metamorphic effects near the Cassiar batholith, most of the sedimentary rocks show low-grade metamorphism, characterized by the formation of chlorite and actinolite in the groundmass of impure arenites, and recrystallization of chert and quartzite.

Small garnets have developed in limestones that have been recrystallized by the emplacement of volcanic rocks east of Pooley Creek.

Mode of Origin

The thick accumulation of sedimentary and volcanic material of the Sylvester Group reflects a marked change in the behaviour of the area from that in earlier periods. The development of rocks that are typically miogeosynclinal in the earlier periods give way to the development of rocks that are typically eugeosynclinal. Thus after the Middle Devonian a volcanic belt was initiated in a region that had been previously relatively quiescent.

With the exception of relatively minor quartz-arenite, clastic sedimentary rocks of the Sylvester Group were evidently derived from the eugeosynclinal rocks themselves. The abundant cherts and argillaceous rocks were probably deposited in deep water whereas the limestones must have accumulated in shallow, well-aerated seas that were favourable to the growth of corals and crinoids. It is possible that the limestones were deposited near volcanic islands in the geosyncline. Local uplifts may have resulted in the erosion of cherts that contributed material to form chert-arenites and conglomerates.

Much of the structureless volcanic rock in the Sylvester Group is probably of intrusive origin. Extrusive activity also played a role, however, as evidenced by the presence of breccias and tuffs.

Volcanic activity probably did not reach as far northeast as the Lower Post area. The rocks there lack volcanic material and no volcanic rocks have been reported in Devono-Mississippian rocks to the east (Williams, 1944).

Age and Correlation

The Sylvester Group conformably overlies rocks of Middle Devonian age and is overlain unconformably by rocks of Middle Mississippian age. Fossils in limestones east of Pooley Creek are too poorly preserved to allow an age determination other than that the rocks are of Palæozoic age. The fossils include rugose corals and crinoid stems. The following were identified by Peter Harker of the Geological Survey of Canada:

F_{67}. GSC Loc. 25007. On ridge on east side of Alaska Highway at mile 625.
Spirifer sp. A
Spirifer sp. B
Camarotoechia sp.
Schellwienella sp.
Crinoid stems
Brachiopod fragments

Harker states that it is not possible to give an exact age for these fossils but it is believed that they are post-Devonian and possibly of early Mississippian age.

F_{68}. GSC Loc. 17543. In black shale on east side of stream, 2.2 miles southeast of east end of lower Captain Lakes.
Tentaculites sp.

This collection is not diagnostic as the genus is long ranging. Williams (1944, p. 7) reported the presence of abundant *Tentaculites spiculus* Hall (?) in rusty weathering shales at the contact with underlying carbonate rocks of Middle Devonian age along the Alaska Highway east of McDame map-area. He suggested that the rocks containing the fossils may be Upper Devonian.

Eugeosynclinal rocks of Devono-Mississippian age underlie extensive areas in the Cassiar and Pelly Mountains in southern Yukon Territory (Poole, 1957; J. O. Wheeler, personal communication, 1956).

The belt of rocks exposed in the McDame synclinorium trend southeasterly into Cry Lake map-area. There the major structure plunges northwesterly and the southern limit of exposure of rocks correlative to the Sylvester Group lies between Major Hart and Turnagain Rivers.

Volcanic rocks of unknown age, but perhaps correlative with the Sylvester Group, outcrop north of the mouth of Gataga River in the northern Rocky Mountains (Hedley and Holland, 1941). East of McDame area Devono-Mississippian rocks have been mapped along the Alaska Highway by Williams (1944) and Laudon and Chronic (1949). There the rocks contain no volcanic material.

Eugeosynclinal rocks of Mississippian age have been recognized in Aiken Lake map-area, British Columbia (Roots, 1954) and near Barkerville, British Columbia (Johnstone and Uglow, 1926).

Ultramafic Rocks

Ultramafic rocks and their serpentinized equivalents are restricted to the McDame synclinorium and, although sills and dykes of mafic rocks are found east of this region, no ultramafic bodies occur with them.

The ultramafic bodies are sills, dykes, and stocks that range in size from lenses a few tens of feet long to stocks several miles in diameter. In a general way the large stock-like masses occur near the axis of the synclinorium, whereas the small, lenticular, highly serpentinized bodies, are found on the limbs. The geological map shows that the large ultramafic bodies are restricted to horizons in the synclinorium that are stratigraphically low.

The most accessible area of ultramafic outcrops is in the vicinity of the headwaters of Little Blue River and Quartzrock Creek. A stock-like body is exposed between Little Blue River and Blue River, and another large body occurs west of Blue River. Small, highly serpentinized, ultramafic lenses, many too small to be shown on the map, are widespread. The most accessible of these include the Cassiar Asbestos serpentinite body 3 miles north of Cassiar and smaller bodies along strike to the south.

Lithology

The McDame ultramafic rocks comprise peridotite (harzburgite and lherzolite), dunite, pyroxenite, and serpentinite. Distinctive colours and lack of vegetation make outcrops of these rocks conspicuous.

Although small ultramafic bodies are completely serpentinized, their original mineral composition is indicated by relict textures. The abundance of antigorite pseudomorphs after orthopyroxene suggests that many of these bodies were originally rich in pyroxene. Apple-green serpentinite is the host rock to asbestos at Cassiar but elsewhere the rocks are generally dark green to black.

Dunite is characterized by a tan weathering product which is preserved even though the rock may have been partly serpentinized. The typical sugary texture of dunite is generally not apparent but can be detected in some specimens with a hand lens. Chromite is an ubiquitous accessory mineral and stands out in relief on weathered surfaces. Northwest of Blue River chromite occurs in tabular and irregular, discontinuous bodies up to 10 inches wide and 30 feet long. Although olivine is the most abundant mineral in the McDame ultramafic bodies, a much smaller area is underlain by dunite than by peridotite as many of the rocks contain from 10 to 20 per cent pyroxene.

In thin sections olivine is seen to be typically medium grained, inequigranular, and allotriomorphic. Grain size in a single specimen may range serially from 0.05 to 3 mm. Crystal boundaries are smooth, curving surfaces, and interpenetration of crystals is exceptional. In this respect the texture is much like that observed in quartzites. Wavy extinction and protoclastic structures are common. The composition of the olivine in the dunites and peridotites, suggested by indices of refraction (Winchell, 1951, p. 500) and x-ray diffraction patterns (Yoder, 1954, p. 120), ranges from 5 to 13 per cent fayalite. Colourless serpentine occurs either as incipient alteration along crystal boundaries and fractures, or as a pervasive replacement of olivine. Small flecks of magnetite are concentrated in the serpentine veinlets.

Peridotites, characterized by a tan to orange-brown colour, are the most widespread of the ultramafic rocks. Green crystals of pyroxene weather out in relief above olivine and impart a warty appearance to the rocks.

Thin sections of peridotites reveal the presence of orthopyroxene and clinopyroxene. Rhombic pyroxene occurs in anhedral crystals ranging from 6 to 12 per cent orthoferrosilite (Poldervaart, 1947, p. 167). Narrow, moderately high-birefringent plates in the rhombic pyroxene are probably exsolution lamellae of diopsidic pyroxene. This phenomenon is accentuated by serpentinization as the plates are more resistant to alteration than the host mineral. Optical properties indicate that the clinopyroxene is augite. Anhedral clinopyroxene is the only unserpentinized material in many specimens. Picotite, a chrome spinel, is not uncommon as an accessory mineral in the peridotites.

Colour, compositional and textural banding are prominent in the two large peridotite bodies near the headwaters of Quartzrock Creek and were noted to a lesser extent in the ultramafic body northwest of Blue River. The banding consists of alternating pyroxene-rich and olivine-rich layers, mostly less than 1½ inches wide (Pl. V, and Fig. 4). Borders of the bands are gradational. In some areas light coloured bands of fine-grained, extremely tough rock were noted. Individual layers generally do not persist for more than 10 or 15 feet along strike. Banding is preserved in highly serpentinized rocks because the clinopyroxene is resistant to alteration. In addition, an intense, turbid alteration, particularly of orthopyroxene, imparts a light colour to the pyroxene-rich layers. Garnet, chlorite, and clinopyroxene are present in the light coloured bands.

Pyroxenite, consisting entirely of clinopyroxene, forms tabular dyke-like bodies ranging from half an inch to 2 inches wide near the north end of the Zus Mountain ultramafic body. A similar rock underlies an extensive area about a mile long and half a mile wide east of the headwaters of Quartzrock Creek. Another body occurs near the south end of the Zus Mountain ultramafic body. A similar rock also underlies an area about a mile long and half a mile wide east of the south end of the Zus Mountain ultramafic body. In thin sections the pyroxene is characterized by schiller structure resulting from a concentration of oriented, black, opaque material, probably magnetite, along planes parallel with (100). Most of the crystals are anhedral and have interlocking boundaries. Maximum grain size of the clinopyroxene is about 8 mm. Optical properties are $2V_z$, 56°-59.5°, average of six determinations 57.5°; maximum extinction $Z \wedge C$, 44°-48°; N_y 1.700±0.004, suggesting a composition about $Ca_{50}Mg_{32}Fe_{18}$ (Hess, 1949, p. 640). Serpentinization of the clinopyroxene (salite) produces pale yellow serpentine and considerable magnetite.

Lithology of Contact Rocks

Contacts between ultramafic and country rock are generally characterized by evidence of deformation and lack of pronounced contact metamorphic effects. The contacts have been readily eroded and good exposures are limited.

Gneissic rocks were seen in two places. Northwest of Blue River albite-hornblende gneiss in contact with sheared serpentinite grades outward into normal, type 2 greenstone. East of Quartzrock Creek the sequence of rock types from greenstone to ultramafic rock is as follows:

1. Normal, type 2 greenstone.
2. Gneissic dioritic rocks characterized by poikilitic green-brown amphibole and highly altered plagioclase.
3. Well-banded rocks with alternating bands of clinopyroxene (salite) and highly altered feldspathic material which is a mixture of zoisite and albite. The layers average 2 to 3 inches wide but one band of salite 4 feet wide was observed. Contacts between the bands are gradational.
4. Highly slickensided serpentinite.

The gneissic rocks in this area form a zone at least 300 feet wide.

Massive, fine-grained, dark green serpentinite occurs along the upper contact of the ultramafic body at Cassiar. The serpentinite grades into a cream-coloured tremolite-zoisite hornfels zone which in turn grades into tremolitized greenstone. The transition from serpentinite to greenstone takes place over a distance of from 1 foot to 2 feet. Locally, the upper contact is sheared and in this zone chrome garnet, malachite, and green mica, are present.

Sedimentary rocks appear to have been little altered near contacts with ultramafic bodies. At Cassiar, where this relationship is well exposed, local tremolitization may reflect only the alteration of ultramafic rocks. Vesuvianite, colourless pyroxene (probably diopside), zoisite, and irregular patches of talc were detected in several thin sections. Narrow veinlets of anthophyllite are present in the tremolite-zoisite contact rock. Alteration of sedimentary rocks associated with the larger ultramafic bodies has been negligible. Utramafic rocks near these contacts are highly serpentinized.

In a zone 5 to 10 feet wide adjacent to the Cassiar batholith northwest of Blue River, ultramafic rocks are dark green to black. They are serpentinized and contain plates and rosettes of talc crystals. In thin sections talc and mesh-structure serpentine are seen to be the major constituents. Minor olivine (largely replaced by serpentine), tremolite, and clinochlore are present in all sections. Farther from the contact the peridotite contains considerable tremolite, in addition to olivine and serpentine. Tremolite has replaced both olivine and pyroxene. Granitic rocks along the contact show no alteration. The rock is unsheared, homogeneous quartz monzonite, medium to coarse in grain, and contains plagioclase (An_{20}-An_{26}), orthoclase, quartz, biotite, hornblende, and minor apatite, zircon, and rutile.

Structural Relations

Internal

Jointing is well developed in the Cassiar Asbestos serpentinite body and in the northern part of the Zus Mountain ultramafic body. The attitudes of these joints are similar to those in the country rocks. Conspicuous banding in peridotite and slickensided surfaces in serpentinite are other important internal structural features.

Most bands in the McDame ultramafic rocks dip steeply and strike roughly parallel with the regional structure. Shallow dips are present near the west contact of the Zus Mountain ultramafic body (*see* Figure 4). As a rule layers near the contacts of ultramafic rocks are parallel with the contact. Remote from the margins, however, the attitudes vary considerably, particularly in dip.

Nonetheless, in a particular locality the attitude of the banding is generally uniform. Minor folds in one locality have axes that are nearly vertical. A thin section of the orthopyroxene in one of these folds shows bent crystals, their attitudes indicating that they were deformed during the folding. Northwest of Blue River ill-defined banding in peridotite is parallel with bands of chromite and layers rich in chromite.

Highly sheared, slickensided serpentinite is abundant in the ultramafic belt. This phenomenon is characteristic of the completely serpentinized lenses, but is also well developed locally in serpentinized parts of the larger ultramafic bodies. The slickensides have no consistent orientation. The surfaces of shearing are generally curved and bound lenses of massive serpentinite. Planes of shear near borders of ultramafic bodies seem to be roughly parallel with the borders.

External

Gneissic structures in greenstone near ultramafic bodies are parallel with the contacts. Contacts between small, completely serpentinized bodies and country rock in most cases show evidence of shearing. At Cassiar the foot-wall of the serpentinite body exposed in the exploration drift typifies this phenomenon. The argillaceous rocks in this instance have been drag-folded and reduced to gouge adjacent to the serpentinite. Phyllonite is found along the foot-wall near the south end of the Cassiar Asbestos serpentinite body.

The elongation of the ultramafic bodies parallel with the regional trend is evident. Most of the bodies, in addition, have at least one side that is parallel with the structure of the enclosing rocks. The small bodies are markedly concordant and bending of strata around a lens of ultramafic rock is clearly revealed at Cassiar. Ubiquitous shearing of the contact rocks makes it difficult to determine whether the present contacts are the result of faulting or of original intrusion. The contact of the ultramafic body with the Cassiar batholith northwest of Blue River is remarkably straight and uniformly dipping for a horizontal distance of over a mile and a vertical distance of over 1,000 feet (Pl. VI A).

Mode of Origin

Hypotheses as to the origin and mode of emplacement of alpine-type ultramafic bodies have been much discussed. For papers on the distribution and origin of these rocks the reader is referred to Benson (1926), Hess (1937), Bowen and Tuttle (1949), and Sørensen (1953). A brief summary of the problems and arguments involved is given below.

Vogt (1921) proposed a magma derived from the remelting of olivine crystals that had settled from a crystallizing basaltic magma. The high temperature required for this process, however, is incongruous with the general lack of pronounced contact metamorphic effects associated with these bodies (Bowen, 1933). Hess (1938) proposed a highly aqueous peridotitic liquid which, because of its hydrous character and resultant lower temperature of consolidation, would not give rise to marked contact metamorphism. More recently, Little (1948) has suggested that in the Middle River Range district of British Columbia an ultramafic magma was intruded at about 1,200°C. Cooke (1937, pp. 64-66) and Armstrong (1949, pp. 85-86) maintained that field evidence in areas they studied supports the theory of a peridotitic magma. As evidence they cited examples of rough mineralogical gradations suggestive of gravity differentiation, narrow, dyke-like bodies of pyroxenite and peridotite that cut peridotite and dunite, and the great length of ultramafic sills compared with their thickness. All these suggested considerable mobility of the ultramafic material when emplaced. In Aiken Lake map-area, British Columbia (Roots, 1949, pp. 338-358), and on Blashke Island, Alaska (Walton, 1951), rocks adjacent to ultramafic bodies are highly metamorphosed. The authors concluded that the bodies were emplaced as magmas.

Emplacement of ultramafic bodies as a crystal mush. Bowen (1928) advanced a hypothesis involving the emplacement of ultramafic rocks as largely crystalline masses, perhaps lubricated by pore fluids. Protoclastic structure and evidence of strain so often observed in rocks of this type were cited as evidence. Bowen and Tuttle (1949, pp. 439-460), in a study of the MgO-SiO_2-H_2O system, showed that no mixture of this composition was observed as a liquid, even at temperatures up to 1,000°C and pressures up to 15,000 lbs/in.[2] Thus it appears that the theory of a peridotitic magma existing at a sufficiently low temperature to account for lack of contact metamorphism is incompatible with experimental evidence.

Metamorphic origin of ultramafic bodies. Several authors have advocated a metamorphic origin for certain ultramafic bodies. Sørensen (1953) suggested that the ultramafic rocks at Tovquassaq, West Greenland, formed by dynamic metamorphism of an amphibolite-gneiss sequence. Avias (1949, pp. 439-452) also interpreted field evidence in New Caledonia as supporting the hypothesis of a metamorphic origin for the ultramafic rocks. Cited as corroboration of this hypothesis are gradual transitions of country rock into serpentinite, preserved orientation of inclusions of country rock in serpentinite, country rock structures, and the heterogeneity of the peridotite masses.

Origin of McDame ultramafic rocks. In contrast to the occurrences described by Roots (1949) and Walton (1951), the McDame ultramafic rocks have produced, in general, little contact metamorphism of the country rocks. It seems impossible therefore to accept a hypothesis of magmatic origin for these rocks. The theory proposed by Little (1949) is not considered applicable. Large doleritic intrusions, considered by Poldervaart and Hess (1951, p. 478) to be intruded at temperatures about 1,150°C, are typically associated with clearly recognizable contact metamorphic phenomena.

The environment of the ultramafic rocks in West Greenland (Sørensen, 1953) is different from that in the McDame ultramafic belt. In West Greenland the metamorphic rocks associated with the ultramafic bodies are gneisses, garnet-sillimanite-mica schists, and diopside - calcic plagioclase - quartz hornblende amphibolites. These rocks represent a much higher degree of metamorphism than rocks of most alpine ultramafic areas. The generation of olivine and hypersthene from volcanic rocks is incompatible with the low grade of metamorphism observed throughout most of the McDame ultramafic belt. Locally in McDame area, olivine has been derived from serpentinite, but in an environment that has produced conspicuous metamorphism of the sedimentary rocks.

No evidence supports the hypothesis of Avias (1949) that serpentinite was derived from volcanic rocks and subsequently metamorphosed to peridotites. In McDame area serpentinization of volcanic rocks has been negligible. In addition, it was observed that chlorite, rather than serpentine, has formed as an alteration product in an environment in which aluminum is available in sufficient quantity.

A hypothesis involving the emplacement of the McDame ultramafic rocks in a largely crystalline condition at a relatively low temperature seems best to fit the facts. Locally, residual heat from the intrusive rocks and the dynamic effects of emplacement may have combined to produce metamorphism of contact rocks. Most of the alteration along contacts is believed to be a post-emplacement phenomenon as the extent of alteration bears no relationship to the size of ultramafic body.

The fabric of the serpentinite and unserpentinized bodies agrees with the above hypothesis. Protoclastic structures, wavy extinctions, zones of cataclasis, and highly slickensided and sheared serpentinite, reflect movement throughout these bodies. The slickensided serpentinite bodies may represent plastic, mobile masses that have been deformed more or less where they are now found, or masses that have been squeezed into their present position by later deformation. The pervasive wavy extinctions and protoclastic structures of minerals in the ultramafic rocks, however, do not suggest dynamic metamorphism after emplacement. Admittedly, a fabric of this type may have been developed locally along zones of movement, but the persistence of this phenomenon throughout large ultramafic bodies is more likely to have been brought about by the emplacement of these bodies in a largely crystalline condition. The 'quartzitic' texture of the dunites might be expected if a mush of olivine crystals were intruded and consolidated.

Origin of banding in the McDame ultramafic rocks. Any hypothesis as to the origin of the McDame ultramafic rocks must account for the banding in them.

Avias (1949), Roubault (1949), and Sørensen (1953), ascribe such banding to relict sedimentary and gneissic structures. Field evidence in the McDame ultramafic belt does not support this view.

Two other hypotheses might be considered in conjunction with a possible metamorphic origin for the banding. A regional axial plane cleavage, or shear planes parallel with contacts are structures that presumably could localize metamorphism and thus promote banding. Although axial plane cleavage is well developed in argillaceous sedimentary rocks the evidence of such cleavage is almost completely lacking in volcanic rocks in McDame map-area. It is consequently difficult to envisage a prominent axial plane cleavage in coarse granular rocks (represented by dunites and peridotites) in the same environment. Shear planes in serpentinite are roughly parallel with contacts but are curved and discontinuous. It is unlikely that structures originating through shearing of granular rocks could produce the remarkable uniform layering seen in the field (*see* Fig. 4, Pl. V). Moreover, metamorphism along planes of rupture would probably give rise to local thickening and thinning of bands.

Uniformity of banding and parallelism of bands to layers and lenses of chromite suggest a primary origin. The wide range of attitudes in the Zus Mountain ultramafic body, however, shows that gravitational settling in place is in itself incapable of producing such a result. Differentiation in place would also necessitate an ultramafic magma at this horizon for which there is no field evidence.

Banding similar to that in the McDame ultramafic rocks is seen in salt domes. Balk (1949) described instances of extremely well-developed banding in salt domes parallel with the borders of enclosing rocks. Attitudes of the layers are not as consistent in the interior of the bodies as they are near the margins. In this respect there is a close similarity between the two structures.

Cooke (1937, p. 62) attributed banding in ultramafic rocks to flowage in a partly differentiated magma just prior to consolidation. Like Cooke, the present writer believes that the banding is a type of flow banding but one that is analogous to that seen in salt domes in which the structure reflects solid flowage rather than flow of a magma. The pseudostratification may have formed prior to intrusion of the rocks into their present environment. Only a hypothesis of transported banding seems to reconcile the phenomena of remarkably uniform layering with lack of prominent contact metamorphic effects in the McDame bodies.

Age and Correlation

No evidence is available for precise dating of the McDame ultramafic rocks. The rocks intrude pre-Middle Mississippian rocks and are cut by granitic rocks of the Cassiar batholith, which were presumably emplaced in Mesozoic time. The close association of ultramafic rocks with volcanic rocks may indicate that the two rock types are related in time.

The McDame ultramafic rocks are, for the most part, restricted to the lower part of the Sylvester Group. This indicates either that the ultramafic rocks are older than the upper part of the group or that they were intruded to a lower stratigraphic level only.

In Quiet Lake map-area of southern Yukon Territory, Wheeler (personal communication, 1957) has found pebbles of serpentine in a conglomerate of probable Mississipian age. The ultramafic rocks in this area may be correlative with the McDame ultramafic rocks.

Metamorphism

Large areas of the McDame ultrabasic rocks have been altered to serpentine, and locally the rocks have been tremolitized, carbonatized, steatitized, and chloritized. Near the Cassiar batholith olivine appears to have been regenerated from serpentinite. Joints in the Zus Mountain ultramafic body have localized the formation of replacement clinopyroxene dikes.

Tremolitization

Tremolitization has been restricted to contacts, particularly those involving volcanic rocks. In a few instances an almost monomineralic tremolite hornfels has formed, but commonly zoisite, anthophyllite, and talc are present. Often it is difficult to determine whether the altered rock was originally of ultramafic or volcanic composition. Alteration along these contacts has evidently involved the transfer of calcium into the ultramafic rock and removal of iron from the contact area. Lack of correlation between size of ultramafic body and extent of alteration, and the absence of pronounced metamorphic effects in argillaceous sedimentary rocks, point to a post-emplacement origin for the tremolitic rocks. Near the Cassiar batholith tremolite has replaced olivine and pyroxene in the ultramafic rocks.

Carbonatization and Steatitization

Carbonatization and steatitization are not prevalent and are restricted to shear zones in the ultramafic rocks or to contacts. In the stock-like body just south of Blue River a highly sheared zone in serpentinite contains talc and nemalite (fibrous brucite). Steatitized ultramafic rocks are best developed in a narrow zone adjacent to the Cassiar batholith. The texture of these rocks suggests that the talc is, in part, pseudomorphous after enstatite.

Chloritization

Locally, at the Cassiar Asbestos property, chloritized rock forms an intermediate zone between serpentinite and greenstone. A chemical analysis of material containing fine-grained serpentinite and chlorite is included in Table V. The chlorite is evidently derived from the serpentinite by addition of aluminum and removal of magnesium. A comparison of the analyses suggests also that chromium and nickel have been leached to some extent. The introduction of titanium is similarly indicated.

Small patches of clinochlore are present in the steatitized rocks near the Cassiar batholith but may not represent an appreciable gain of aluminum by the ultramafic rocks. Rims of clinochlore around chromite crystals in serpentinized rocks in this locality indicate that aluminum has been provided by the chromite for the formation of chlorite.

Formation of Clinopyroxene Dykes

The development of narrow, tabular, clinopyroxene bodies in the Zus Mountain ultramafic body is controlled by joints. Although the dyke-like bodies are well defined, their borders are gradational with dunite or peridotite over widths up to half an inch. The clinopyroxene is characterized by a fresh appearance in hand specimens. Some dykes contain light green diopside whereas others contain salite. The latter has a metalloid lustre and is associated with considerable magnetite. The clinopyroxene, ranging in grain size from 2 to 5 mm, poikilitically encloses olivine. Chilled contacts were not observed. The bodies cut primary pyroxene-rich and olivine-rich bands.

The problem of dunite bodies apparently intrusive into pyroxenite or peridotite and vice versa has been discussed by many geologists. Cooke (1937, pp. 61-67) described pyroxenite dykes that cut banding in peridotite and attributed to them a magmatic origin. A theory proposed by Bowen and Tuttle (1949) appears to answer many of the difficulties. They suggest that silica-rich fluid streaming through cracks in dunite could produce pyroxenite dykes and similarly silica-poor fluids could produce dunite dykes in pyroxenite. Coarse-grained, narrow veinlets of pyroxenite without chilled contacts are more easily explained by this theory than by one involving an intrusive pyroxenic magma.

Relatively coarse grain size, lack of chilled contacts, gradational contacts with country rock, and local thickening and thinning of the bodies point to a metamorphic origin. If an introduction of calcium and silica is assumed the following equation might apply.

$$\underset{\text{olivine}}{3\,(Mg_9Fe)_2SiO_4} + 3Ca^{++} + 3SiO_2 \rightarrow \underset{\text{salite}}{(Ca_3Mg_2Fe)\,(Si_2O_6)_3} + 52Mg^{++} + 5Fe^{++}$$

Joints in many parts of the Zus Mountain ultramafic body have localized serpentinization. The formation of the clinopyroxene dykes may have been contemporaneous with serpentinization, the former restricted to areas of relatively high temperature. In this case alteration of clinopyroxene to serpentine could supply calcium for the reaction given above. The source of silica, in a silica-poor environment, presents a more difficult problem (Shand, 1945; Poldervaart, 1953). It seems probable that silica-rich fluids would locally precipitate quartz; but free quartz was not observed in the McDame ultramafic rocks. A possible explanation is that the amount of SiO_4 remained constant during the reaction (Poldervaart, 1953). The following equation is suggested:

$$\underset{\text{olivine}}{30\,(Mg_9Fe)_2SiO_4} + 15Ca^{++} + 30H_2O \rightarrow \underset{\text{salite}}{5\,(Ca_3Mg_2Fe)\,(Si_2O_6)_3} + 530Mg^{++} + 55Fe^{++} + 60\,OH^-$$

The dykes may have been formed concomitantly with the emplacement of the Cassiar batholith.

Serpentinization

The alteration of olivine, orthopyroxene, and clinopyroxene, to serpentine minerals has been widespread in the McDame ultramafic rocks. Almost all specimens show incipient alteration. Small, lenticular bodies, borders of stocks, areas near white rock bodies (*see* p. 83) and shear zones in ultramafic rocks are highly serpentinized.

Serpentinites in the area are characterized by a wide variety of colours and structures. In small bodies, black to dark green slickensided material predominates. Glossy slickensided surfaces ranging from inches to tens of feet in length bound lenses of blocky serpentinite. Light green, translucent serpentine is commonly restricted to slickensided surfaces in dark green serpentinite. Bent, glistening, bastite crystals are generally conspicuous in highly serpentinized rocks. At Cassiar, relatively blocky, greasy, light green serpentinite is host rock for chrysotile asbestos. The colours of partly altered ultramafic rocks reflect their original mineralogy.

In the initial stages of alteration serpentine veinlets have formed along crystal boundaries, cleavage planes, and fractures in olivine and pyroxene. The crystals in these veinlets are elongated parallel with the walls. An indistinct fibrous habit, with fibres oriented perpendicular to the walls, can sometimes be detected. In wider veinlets, or where narrow veinlets widen, a tripartite structure exists. The serpentine zones on the borders, with a positive elongation parallel with the vein are separated by a central band of serpentine that has a positive elongation perpendicular to the vein. The latter shows a distinct fibrous structure in wider veins. Finely disseminated magnetite occurs in the center of the veinlets.

Pervasive serpentinization of peridotites and dunites typically produces a mesh-structure serpentine with islands of homogeneous serpentine pseudomorphous after pyroxene in the former, and a simple mesh structure in the latter. The mesh structure arises from the encroachment of incipient alteration veinlets upon olivine relics. The cores of the former relics are generally represented by an almost isotropic serpentine (serpophite). Magnetite is widespread in the highly altered rocks and occurs either in veinlets, or is disseminated throughout the rock. It is particularly abundant where monoclinic pyroxene has been serpentinized.

The serpentine minerals were studied in detail with the aid of the petrographic microscope, chemical analysis, differential thermal analysis, x-ray diffraction, and electron microscope (Gabrielse, 1955). The results of this study are summarized in the following table.

Table IV

Mineralogy and Distribution of the Serpentine Minerals

Material	*Variety of Serpentine*	*Environment*
Mesh-structure serpentine, includes serpophite	Mainly chrysotile	Serpentinization of olivine
Bastite	Antigorite	Pseudomorphous after orthopyroxene; associated with mesh-structure serpentine
Feathery, reticulated serpentine	Antigorite	In contact metamorphic aureole of Cassiar batholith
Patchy serpentinite	Mainly antigorite (?)	Adjacent to asbestos veins
Greasy, fine-grained, banded, fibrous serpentine	Chrysotile	Adjacent to chrysotile asbestos veins (except at Cassiar occurs between asbestos veins and patchy serpentinite); minor veins at Cassiar
Asbestos	Chrysotile	Veins in serpentinite

Chemical analyses of five textural varieties of McDame serpentinites are given in Table V.

Table V

Chemical Analyses of Typical McDame Serpentinites

	1	2	3	4	5
SiO_2	39.72	39.73	40.78	42.24	39.41
TiO_2	0.01	0.00	0.01	0.00	0.39
Al_2O_3	1.49	1.35	1.20	0.48	4.68
Fe_2O_3	5.30	4.26	3.37	1.37	2.38
FeO	2.87	0.98	0.04	0.16	3.98
MnO	0.10	0.08	0.03	0.05	0.27
MgO	36.91	39.54	40.47	41.88	35.52
CaO	0.14	0.00	0.00	0.00	0.14
Na_2O	0.00	0.00	0.00	0.00	0.00
K_2O	0.00	0.00	0.00	0.00	0.00
H_2O^+	11.76	12.41	12.76	12.49	12.03
H_2O^-	0.74	0.95	1.18	0.90	1.07
P_2O_5	0.00	0.00	0.00	0.00	0.13
Cr_2O_3	0.29	0.36	0.16	0.16	0.01
NiO	0.26	0.27	0.13	0.17	0.07
CO_2	0.07	0.18	0.21	0.06	0.06
Total	99.66	100.11	100.34	99.96	100.14

Analyst, John A. Maxwell, *Geological Survey of Canada*.
1. Mesh-structure serpentinite with bastite crystals west of Gallic Lake.
2. Patchy serpentinite, Cassiar Asbestos property.
3. Greasy, fine-grained, banded chrysotile, Cassiar Asbestos property.
4. Chrysotile asbestos, Cassiar Asbestos property.
5. Fine-grained antigorite and chlorite, upper contact of Cassiar Asbestos serpentinite body.

Variations in iron content of analyses in Table V reflect, in part, variations in the amount of magnetite in the specimens. The aluminum content of analysis 3 is probably slightly higher than that of the banded chrysotile at Cassiar because the specimen contained inclusions of patchy serpentinite (analysis 2).

The Si:Mg ratio and the water content of the host rock (analysis 2) and chrysotile veins (analyses 3 and 4) at Cassiar are similar. Chrysotile asbestos (analysis 4) is characterized by relatively low amounts of aluminum and ferrous iron.

The chloritized serpentinite at Cassiar (analysis 5) contains considerable aluminum and ferrous iron which compensate for the relatively low amount of magnesium. A similar situation is revealed by the analysis of mesh-structure serpentine (including bastite). It appears that either ferrous iron or aluminum, or both, may replace magnesium in these serpentinites.

Origin of the serpentine minerals. Bates and Mink (1950) suggested that the tubular habit of chrysotile results from a difference in the dimensions of the brucite and silicon tetrahedra sheets that make up the structure. If trivalent ions such as aluminum and ferric iron are substituted for magnesium this discrepancy is reduced and may account for the tabular, lath-like habit of antigorite. A similar result may be obtained by increasing the Si:Mg ratio (Hess, Smith, and Dengo, 1952). Zussman (1954) suggested that antigorite may possess a corrugated structure in which there is no appreciable reduction in the curvature of the sheets. In this structure there may be a slight deficiency of magnesium and small replacements by aluminum as compared to the ideal formula.

Chemical analyses of the McDame serpentinites show that chrysotile contains less aluminum than the host rock. The hypothesis put forth by Bates and Mink (1950) could therefore be applicable. The analyses do not lend support to the hypothesis of Hess, Smith, and Dengo (1952). The Si:Mg ratio in the host rock at Cassiar which contains considerable antigorite is approximately the same as that in the chrysotile asbestos.

In the McDame area olivine alters to mesh-structure serpentine and orthopyroxene alters to antigorite (bastite) in the same environment. The general lack of aluminum in olivine and the presence, commonly, of about 1.5 per cent Al_2O_3 in magnesium orthopyroxene (Hess, Smith, and Dengo, 1952) fits well with the hypothesis that antigorite forms if aluminum is available to replace magnesium in the serpentine lattice.

Feathery, reticulated antigorite (Pl. VII B) appears to be a product of thermal metamorphism of serpentinite. Hess, Smith, and Dengo (1952) implied that shearing stress is necessary for the formation of this material. The fabric of the serpentinite and dunite near the Cassiar batholith, however, indicates that shearing stress must have been unimportant in the development of the feathery antigorite.

Origin of serpentinite in the McDame bodies. Marked peripheral serpentinization of the ultramafic stocks, complete serpentinization of smaller ultramafic bodies, and localization of serpentine along joints and shear zones, suggest that much of the water required for the process was derived from a source outside the bodies. Wet sediments invaded by the intrusive ultramafic bodies may have contributed water. Many of the structures clearly post-date emplacement of these bodies, and at least part of the alteration is a post-emplacement phenomenon. Perhaps the intrusion of the Cassiar batholith facilitated the movement of water at temperatures sufficient to promote serpentinization. In general, however, the degree of serpentinization of the ultramafic bodies bears little relation to their proximity to the Cassiar batholith. It is believed, therefore, that the bulk of the serpentinites formed prior to the emplacement of the Cassiar batholith.

The classic equation for the alteration of olivine to serpentine has been given as follows (Turner and Verhoogen, 1951):

$$\underset{\text{olivine}}{5Mg_2SiO_4} + 4H_2O \longrightarrow \underset{\text{serpentine}}{2H_4Mg_3Si_2O_9} + \underset{\substack{\text{removed in}\\ \text{solution}}}{4MgO + SiO_2}$$

Hess (1938) postulated a serpentine magma in which the olivine reacts with a hydrous, silicic acid solution that is the residual part of the magma:

$$3Mg_2SiO_4 + H_4SiO_4 + 2H_2O \longrightarrow 2H_4Mg_3Si_2O_9$$

Field evidence in McDame map-area does not support the hypothesis of a serpentine magma. Moreover, the products of serpentinization are not those that would be expected from such a reaction. Bowen and Tuttle (1949) have shown that below 600°C, in a closed system, enstatite in the presence of water will alter to talc and forsterite, and below 400°C, forsterite in the presence of water will alter to brucite and serpentine. Brucite and talc are absent throughout most of the McDame ultramafic belt. Abundant talc near the Cassiar batholith appears to be a product of contact metamorphism.

The reaction proposed by Turner and Verhoogen (1951) involves the release of silica during serpentinization. Quartz veins do not occur in or around most of the highly serpentinized bodies. It seems unlikely that silica could be removed completely in every case. Quartz veins are conspicuous near the Cassiar Asbestos serpentinite body but are equally abundant for several miles southeast along the ridge remote from ultramafic rocks.

In light of field evidence, the most probable reaction for serpentinization appears to be one involving a constant number of SiO_4 tetrahedra (Poldervaart, 1953). This might be expressed in the equation

$$\underset{\text{olivine}}{30\,(Mg_9Fe)_2SiO_4} + 36H_2O \longrightarrow \underset{\text{serpentine}}{15H_4Mg_3Si_2O_9} + \underset{\text{magnetite}}{2Fe_3O_4}$$

$$+\ 495Mg^{++} + 120H^{-} + O^{-2} + 54Fe^{++}$$

Bowen and Tuttle (1949) suggested that orthopyroxene may alter directly to serpentine below 350°C. Therefore, if serpentinization took place below this temperature, talc might not form. The absence of brucite, however, cannot be explained in this way. Another discrepancy between field evidence and experimental data is the lack of talc in the area underlain by regenerated olivine. In the experimental reaction, talc, forsterite, and water form from serpentine above 500°C. The lack of talc and brucite in the McDame ultramafic rocks may be the result of the reactions taking place in an open system. In the laboratory the reactions take place in a closed system.

Regeneration of olivine from serpentine. Near the Cassiar batholith northwest of Blue River a distinctive type of dunite underlies a considerable area, the boundaries of which were not established. The rocks consist of dark, equidimensional kernels of olivine up to 3 mm in diameter in a serpentine matrix (Pl. VI B). Borders of the kernels weather to the typical tan product of normal olivine but the centres are black. In thin section the olivine is seen to be characterized by a subhedral to euhedral habit, straight extinction, and numerous, small inclusions of magnetite concentrated in the centres of crystals. Serpentine in many cases is foliated parallel with the crystal boundaries of olivine. Fractures in the olivine have not been loci for serpentinization as they have in typical dunites. The composition of the olivine, suggested by indices of refraction and x-ray diffraction patterns, is very close to that of pure forsterite. Minor carbonate, probably magnesite, occurs locally along borders of olivine crystals.

The unique texture and composition of the olivine, the unusual texture of the serpentine, and the environment in which these rocks are found, point to a metamorphic origin for the olivine in this area. The following sequence of events is suggested:

1. Ultramafic rocks were emplaced and partly serpentinized to mesh-structure serpentine. This resulted in a distribution of serpentinized rocks like that now present in the Zus Mountain and other large ultramafic bodies.
2. Upon emplacement of the Cassiar batholith the rocks were metamorphosed, mesh-structure serpentine was replaced by antigorite, and olivine was regenerated from antigorite in areas where the temperature was sufficiently high. Unserpentinized ultramafic rocks near the batholith were locally tremolitized and ultramafic rocks in contact with the batholith were steatitized at this time.

The widespread presence of dust magnetite in the regenerated olivine indicates that ferrous iron, released upon serpentinization of the original rock and subsequently oxidized, was not reincorporated into regenerated olivine. The extremely low iron content of the metamorphic olivine supports this belief.

As mentioned above the lack of talc in the regenerated dunites may be the result of the reactions having taken place in an open system.

Leech (1953, pp. 33-34), Durrell (1940-41, pp. 82-88), and MacDonald (1941-42, pp. 236-245) described occurrences in which olivine is thought to be a metamorphic mineral. The environment in which these rocks occur and some of the unusual textures displayed by the olivine are similar to those of the McDame occurrence.

'White rock' Bodies in the McDame Ultramafic Rocks

Tabular, lenticular, and irregular bodies of highly altered gabbroic rock, ranging from a few feet to a few hundreds of feet in length and up to 50 feet in width, occur in the McDame ultramafic rocks. Figure 4 shows their distribution in the Zus Mountain ultramafic body.

Outcrops of the altered rocks are characterized by cream and buff colours which are in sharp contrast to the dark colours of the ultramafic rocks. Diabasic textures are common in the medium-grained varieties. Near contacts with serpentinite the rocks are fine grained. In thin section nearly all gradations are revealed between those of type 2 Sylvester greenstones and those in which garnet, probably a variety of grossularite, is the dominant mineral. In the latter, aggregates of equidimensional garnet crystals pseudomorphously replace plagioclase and preserve a diabasic texture. Augite in highly altered rocks is partly replaced by chlorite, garnet, and, in a few specimens, by vesuvianite. Other minerals present in significant amounts in almost all thin sections are albite, prehnite, zoisite, ilmenite, sphene, leucoxene, and unresolved clay minerals.

Thin sections of fine-grained borders of the white rocks reveal that the grain size is a chill phenomenon in some specimens and a reaction phenomenon in others. In the latter, relict, medium-grained plagioclase and pyroxene have been almost completely replaced by garnet, chlorite, and clay minerals.

In all cases the white rock bodies are enclosed by serpentinite. Near tabular or dyke-like bodies the serpentinite is generally massive, but near lenticular and irregular masses the serpentinite is highly sheared and slickensided. In some cases serpentinite has been strongly dragged along the contacts.

Origin. White rock bodies, or rodingites (Marshall, 1911, p. 32), frequently occur in serpentinites. The rocks show strikingly similar features wherever they are found. Grange (1927, p. 166), Turner (1933, pp. 280-284), and Bloxam (1954, p. 528) included references to much of the work published on this problem. The controversy concerns the mode of emplacement of the white rock bodies and their subsequent alteration.

The following evidence seems to favour a hypothesis involving the emplacement of the white rock bodies as dykes in the ultramafic rocks.

1. Tabular, dyke-like form in some cases.
2. Occurrence, locally, of chilled borders.
3. Uniform composition.
4. Association with highly serpentinized rocks suggesting their occurrence in zones of dislocation.

The irregular nature of the bodies may be explained by the following hypothesis. Tabular, dyke-like masses of diabase were emplaced along zones of weakness in the ultramafic bodies. Concomitant with, or later than serpentinization of these zones, the bodies were subjected to stress. The relatively competent diabase dykes were fractured and serpentinite moved into these fractures in a manner similar to the development of boudinage. In this connection tabular, dyke-like bodies of altered diabase generally are enclosed by massive homogeneous serpentinite whereas isolated masses are invariably enclosed by intensely sheared, slickensided serpentinite. The hypothesis also explains why some of the fine-grained selvedges are chilled borders and others are reaction borders.

Chemical analyses of typical rodingites (Grange, 1927, p. 165; Bloxam, 1954, p. 527) show that many of the rocks contain more than 25 per cent CaO. Generally, the silica and sodium contents are very low. The similarity between incipiently altered varieties of white rocks and type 2 Sylvester greenstones indicates that the former were initially pyroxene andesites or basalts. If this assumption is correct, then the alteration to white rock bodies involves marked introduction of calcium and a removal of sodium and possibly silica.

Alteration of the white rock bodies probably accompanied serpentinization of the peridotite country rock. If this was so serpentinization of monoclinic pyroxene could have provided calcium. Replacement of pyroxene by chlorite requires the addition of water which is also needed to form serpentine. In the advanced stages of alteration, in which plagioclase is completely replaced by grossularite, a removal of sodium is necessary. Albite is present in veinlets in McDame white rock bodies and may account, at least in part, for the released sodium.

Fine-grained borders are generally garnetized to a greater degree than the interiors of white rock masses. This may be the result of a concentration of hydrothermal solutions along margins of the bodies and of an originally fine-grained selvedge being more susceptible to reaction.

Nizi Formation

The name Nizi Formation is here proposed for a series of beds well exposed south of Sheep Mountain near the headwaters of a tributary of Nizi Creek and east of Solitary Lake. It consists essentially of well-bedded cherty limestone as much as 1,000 feet thick. The light grey weathering rocks contrast markedly in colour to the underlying rocks, both in the Nizi Creek area where they overlie dark weathering strata of the Sylvester Group, and east of Solitary Lake where they overlie buff weathering strata of the Kechika Group. East of Solitary Lake rocks of the Nizi Formation underlie the highest mountains in Kechika Ranges.

Lithology

Near Nizi Creek the lower part of the formation consists of well-bedded, green and buff weathering, fragmental, cherty limestone and dolomite and very minor chert-pebble conglomerate. The basal beds are relatively impure. In one locality they are composed of angular to subangular pebbles of carbonatized chert and angular grains of quartz and carbonatized plagioclase feldspar in a matrix of carbonate and chlorite. Elsewhere they are composed of carbonate and chert with minor plagioclase feldspar, quartz, and interstitial chlorite. Locally the beds contain crinoid stems as much as an inch in diameter.

The upper beds are mainly blue-grey, crystalline, cherty limestones and minor dolomites containing abundant silicified fossils. Some of the limestone beds are platy and have a granular appearance. They consist essentially of buff weathering fragments of chert; fine-grained, relatively unaltered, dominantly feldspathic volcanic rock; and fossils, generally less than 1.5 mm in diameter, in a matrix of blue-grey limestone. The rocks also contain scattered grains of quartz and plagioclase feldspar. Several specimens of pink weathering dolomite consist of an aggregate of interlocking dolomite crystals ranging in diameter from 0.1 to 2 mm and a few scattered grains of quartz.

Light, grey weathering quartzite was noted in one locality, and several beds of red slate and argillite, as much as 8 feet thick, occur near the top of a mountain bearing N 80°E from the mouth of Nizi Creek.

The basal beds of the formation east of Solitary Lake are interbedded grey and pink weathering quartzites, and buff-grey limestones and possibly dolomites. This assemblage, perhaps little more than 100 feet thick, is overlain by grey and black limestone containing abundant nodules of grey and black chert. The rocks are well bedded and beds range in thickness from 1 foot to 4 feet. Locally, the beds are coarse grained and weather buff to grey. These beds commonly contain abundant crinoid columnals.

Structural Relations

Northwesterly trending folds are prominent in rocks of the Nizi formation. East of Solitary Lake the folds are relatively open and have amplitudes of several hundreds of feet. In one locality, however, easterly facing beds have dips that are almost vertical.

In the Nizi Creek area folds are best seen on the mountains southwest of Sheep Mountain. There, the rocks are exposed in an open syncline complicated by tight folds on its southwestern flank, several of which are slightly overturned to the northeast.

East of Solitary Lake the Nizi formation is preserved as infolds in rocks of the Kechika Group. Much of the angular discordance between rocks of the two units may be attributed to the difference in their competencies. The beds of the Kechika Group are highly incompetent and are much more contorted than rocks of the overlying Nizi Formation. The absence of Silurian, Devonian, and Devono-Mississippian strata, however, is evidence of a marked unconformity between the Kechika Group and Nizi Formation.

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Near Nizi Creek an unconformity at the base of the Nizi Formation is indicated by the distribution of the formation. Southwest of Sheep Mountain, there appears to be an angular discordance between gently dipping beds of the Nizi Formation and steeply dipping beds of the underlying Sylvester Group.

Mode of Origin

Rocks of the Nizi Formation were probably deposited in fairly shallow, well-aerated, marine waters remote from high source-areas. During deposition of the rocks, volcanic activity within the map-area, so conspicuous during deposition of the underlying rocks of the Sylvester Group, appears to have been of little importance or possibly absent.

Volcanic fragments and plagioclase feldspar grains in calcarenites near the base of the formation near Nizi Creek may have been derived from rocks of the Sylvester Group or perhaps are tuffaceous particles related to contemporaneous volcanic activity. The presence of chert fragments in these rocks, however, suggests that these volcanic fragments and feldspar grains were mainly derived from rocks of the Sylvester Group.

Age and Correlation

The following fossil collections were made from rocks of the Nizi Formation:

F_{59}. GSC Loc. 23346. 4.2 miles northeast of north end of Solitary Lake, elevation 5,150 feet.

Solitary rugose corals of
Ekvasophyllum type

F_{60}. GSC Loc. 22751. 2.4 miles east-northeast of north end of Solitary Lake, elevation 3,500 feet.

Lithostrotion sp.
Pseudozaphrentoides? sp.
Rugose coral fragments

F_{61}. GSC Loc. 22752. 0.7 mile southeast of fossil locality F_{60}.

Lithostrotion sp.
Rugose coral fragments, probably including
Kakwiphyllum sp. (*see* F_{62})
Syringopora sp. of *S. pennsylvanica* Shimer.

F_{62}. GSC Loc. 21673. 5.4 miles south-southeast of confluence of Four Mile River and Sheep Creek, elevation 5,560 feet.

Kakwiphyllum sp.
Crinoid stems
Derbya? sp.

F_{63}. GSC Loc. 21672. 4.7 miles east-northeast of mouth of Nizi Creek, elevation 5,500 feet.

Smooth brachiopod fragments indet.
Large crinoid stems
Rugose corals, probably of lophophyllid type
Tabulipora sp.
Poorly preserved branching organisms; probably bryozoan
Fragments of large reticulate productid

F_{64}. GSC Loc. 21670. 6.2 miles east-northeast of mouth of Nizi Creek, elevation 5,680 feet.

Lithostrotion (*Diphyphyllum*) sp. aff. *Mutabile* Kelly
Lithostrotion sp. cf. *L. pauciradiale* McCoy
Zaphrentoides sp. cf. *Z. enniskelleni* Lewis
Zaphrentoides sp.
Dictyoclostus? sp.
Spirifer sp.
Composita sp.

Poorly preserved fossils including bryozoan, crinoid, and brachiopod fragments, and a fenestellid bryozoa were collected from a cherty limestone sequence on a ridge, at elevation 3,850 feet, about a mile north-northeast of the mouth of Deadwood River (GSC Loc. 23339). Brachiopod fragments were also seen in cherty limestone that forms a conspicuous ridge 7.3 miles northeast of the north end of Solitary Lake.

P. Harker, Geological Survey of Canada, suggests that collections F_{59}-F_{64} are of Mississippian age, perhaps entirely Middle Mississippian.

All these collections are from rocks in the lower part of the Nizi Formation although none represents basal beds, and precise limits cannot therefore be given for the age of the formation. The rocks may however be mainly of Middle Mississippian age.

Rocks of Mississippian age, including cherty carbonate strata, have been mapped in Wolf Lake map-area in southernmost Yukon Territory (Poole, 1957).

A Mississippian sequence, several hundred feet thick, consisting predominantly of limestone, has been studied along the Alaska Highway in the northern part of the Rocky Mountains (Williams, 1944; Laudon and Chronic, 1947, 1949). Williams suggested that fauna from the lower part of the section is of Osage age (early Middle Mississippian) and that fauna from stratigraphically higher beds may be correlative with the Rundle or younger limestone in more southern sections. Laudon and Chronic, on the other hand, considered the entire assemblage to be of Meremec age (late Middle Mississippian) and named the unit the 'Kindle' Formation.

Hage (1945) described a limestone and shale sequence of Mississippian age in Liard Range of the southern Mackenzie Mountains. These rocks are probably correlative, at least in part, with the Nizi Formation.

The Nizi Formation is probably correlative with part of the Prophet Formation in the Halfway River area and the Prophet-Muskwa Rivers in the Rocky Mountains of northeastern British Columbia (Sutherland, 1958).

Cassiar Intrusions

In this report the name 'Cassiar Intrusions' is given to granitic bodies that outcrop in the southwesternmost part of the map-area. The largest of these, the Cassiar batholith, forms the backbone of the Stikine Ranges, not only in the map-area, but for many miles to the northwest and southeast.

The mountains underlain by granitic rocks are characterized by their ruggedness, conspicuous jointing, and dark grey and light grey weathering, due largely to the presence or absence of dark grey lichen.

Cassiar Batholith

The northeast contact of the Cassiar batholith (Kerr, 1925) cuts across the southwest corner of McDame map-area.

In general the batholith consists of pinkish grey, medium- to coarse-grained, locally porphyritic, granitic rock containing essentially, plagioclase feldspar (mainly sodic andesine), alkali feldspar (almost entirely microperthite), quartz, and biotite. Hornblende is a relatively minor mafic mineral except in local areas of heterogeneous rock types, and is absent in many specimens from the main body of the batholith.

Porphyroblasts of pink microperthite as much as 2 inches long are prevalent in rocks containing dioritic inclusions, or, in some places, near contacts with sedimentary rocks. Coarse-grained rocks containing large crystals of microperthite were noted along the northeast contact of the batholith east of Eagle River and in the tongue of granitic rock south of Bass Creek.

Near inclusions and in some places near contacts of the batholith the granitic rocks have a splotchy appearance due to irregularly distributed concentrations of biotite and hornblende. In these rocks sphene is relatively abundant.

Aplite dykes, many of which have shallow dips, are abundant in metasedimentary rocks along the eastern contact of the batholith west of the Cassiar Mine. The dykes range in width from 6 inches to 3 feet and many are highly irregular. The aplites are leucocratic, fine- to medium-grained, equigranular rocks containing about equal amounts of albite, orthoclase, and quartz. Under the microscope the rocks display a characteristic allotriomorphic texture.

Pegmatite is not abundant. Granite and granite-pegmatite dykes, containing crystals of quartz, muscovite, potash feldspar, (probably microcline), biotite, and minor tourmaline and red garnet, cut metamorphosed rocks of the Sylvester Group north of the ultramafic body northwest of Blue River. Pegmatitic granitic rocks were also noted on the east slope of the mountain immediately west of the mouth of Bass Creek and on the mountain 3 miles west of the mouth of Cottonwood River.

Modal analyses of specimens representing typical granitic rocks of the Cassiar batholith (*see* Fig. 6) are shown in Table VI and Figure 5.

Inclusions

Dioritic inclusions, consisting essentially of andesine, hornblende, and biotite, are relatively abundant in the Cassiar batholith. The inclusions are of two distinct types. One type comprises roughly equidimensional, homogeneous bodies, commonly circular in section, and generally less than a foot in diameter.

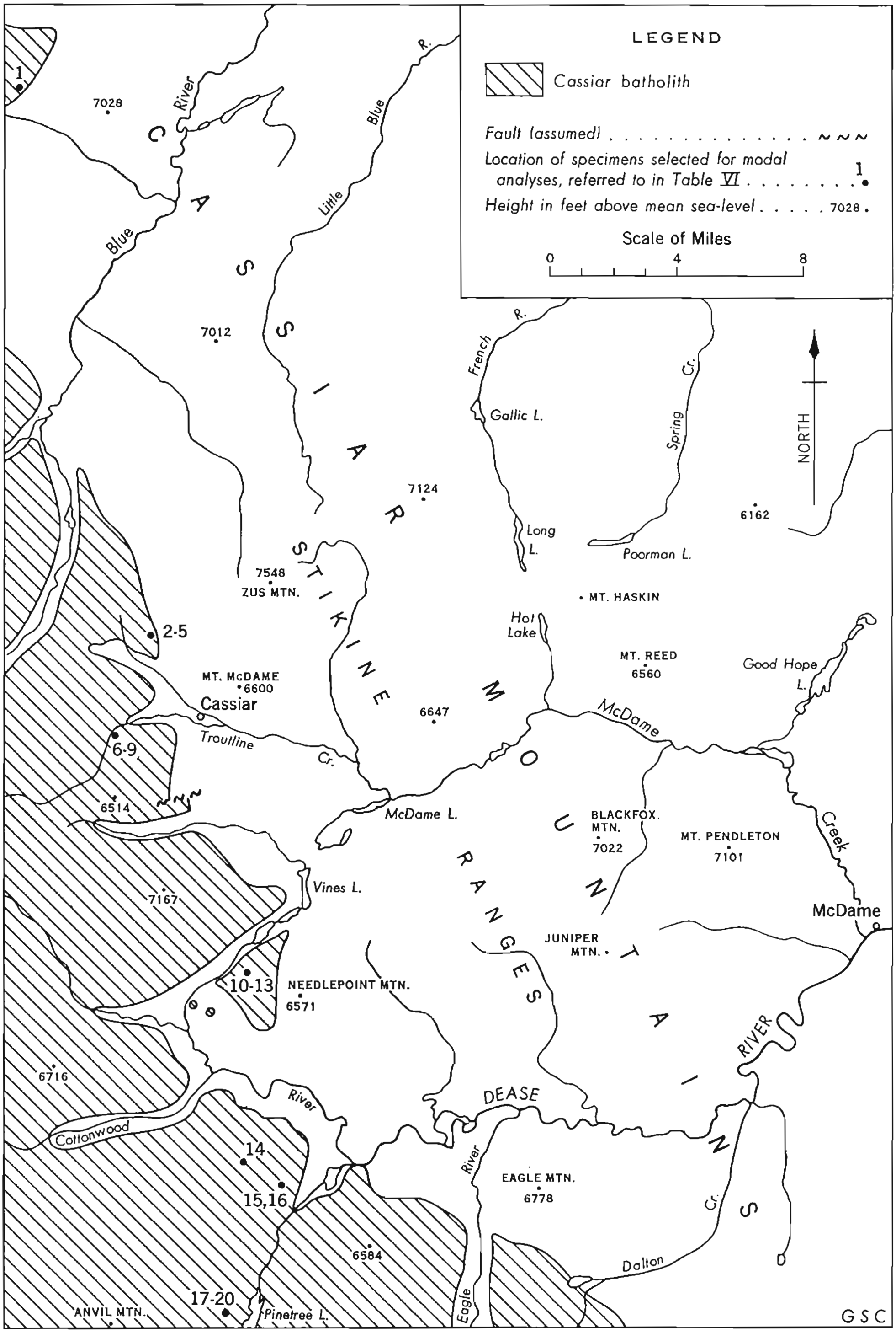

FIGURE 6. *Diagram of Cassiar batholith, showing location of specimens selected for modal analyses.*

The second, and more prevalent type, comprises elongate, platy bodies, ranging from a few inches to many hundreds of feet in length.

The small, equidimensional inclusions were noted only near the northeast contact of the batholith and are exceptionally well exposed near the small lake north of the ultramafic body northwest of Blue River.

The platy, elongate bodies have a metasedimentary aspect and generally have a conspicuous gneissic structure. Sharp folds are common in many of the small gneissic bodies. West and east of Cotton Lake gneissic inclusions are associated with northwesterly trending bodies of crystalline limestone.

Modal analyses of two specimens of dioritic inclusions are given in Table VI.

Structural Relations

The Cassiar batholith displays few conspicuous internal structural features. Large, elongate inclusions trend northwesterly more or less parallel with the contacts of the batholith. Generally rocks within a few feet of the northeastern contact are essentially homogeneous.

Contacts of the Cassiar batholith with bordering rocks are mainly discordant even though the trend of the batholith is roughly parallel with the trend of the regional structure. The eastern contact of the batholith cuts sharply across the trend of metamorphic strata east of Bass Creek and north of Cottonwood River. On a regional scale the eastern contact of the granitic rocks angles across the trend of the regional structure so that at Bass Creek the rocks are in contact with metamorphosed Precambrian strata and southeast of Eagle River they are in contact with Devono-Mississippian strata. Locally, for example near Cassiar, the eastern contact of the batholith is concordant with intruded bedded rocks and the contact dips easterly at a high angle.

Low-angle, westerly dipping thrust faults with offsets in the order of tens of feet have brought granitic rocks over metamorphic rocks along the eastern contact of the batholith west of the Cassiar Mine. On the easterly trending ridge south of Cassiar the contact swings sharply to the east. This swing may be due to a left-hand fault or, alternately, to a cross-cutting intrusive relationship.

Four Mile Batholith

An area of approximately 16 square miles west of Four Mile River is underlain by granitic rocks that form part of the Four Mile batholith. The rocks are well exposed on north-northwesterly trending ridges that have been sculptured by the movement of ice.

In the central part of the batholith, near the southern boundary of the map-area, the rocks appear to be essentially homogeneous, medium to coarse grained, and leucocratic, possibly ranging in composition from quartz monzonite to granite. Biotite is the most common mafic mineral in these rocks but is rarely abundant.

Table VI

Modal Analyses of Granitic Rocks of Cassiar Batholith

Specimen Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Plagioclase	50	30	38	44	33	29	18	38	36	19	21	17	29	26	49	43	28	33	32	29
Perthite and Microperthite	15	32	24	25	30	28	30	32	25	42	50	41	55	22			13	11	14	35
Quartz	23	30	27	24	35	35	45	22	29	32	13	36	12	48	4	7	40	33	34	22
Biotite	11	7	10	6		7	6	6	9	3	3	2	2	1	14	24	17	8	17	13
Hornblende										3	2	3	1		32	25				
Muscovite					1									2				8	1	
Total Accessories	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	2	1	1	1
Apatite	XX	X	X	X	X	X	X		X					X	XX	XX				X
Magnetite	X		X	X	X	X	X	XX	X	X	X	X	X							
Zircon	X	X	X	X	X	X	X			X				X	X	X	X	X		X
Sphene	XX					X	X		X	XX	XX	XX	XX		X	X				X
Rutile																			X	
Average Percentage An in Plagioclase	34	25	27	29	9	30	31	31	31	25	25	27	26	35	36	37	35	36	34	35

2 Contains minor myrmekite.
5 Aplite.
6, 7, 8, 9 Contains minor muscovite.
14 Pegmatite.
15, 16 Dioritic inclusions.
17, 18, 19 Contains red-brown shreddy biotite.
18 Contains 6% andalusite.
17, 18 Zircons small and anhedral.

The marginal phases of the Four Mile batholith show a greater range in texture, structure, and composition than those of the Cassiar batholith. Specimens taken near the margins of the batholith are mainly medium- to coarse-grained diorite and quartz-diorite. Angular, unoriented inclusions are abundant and include metasedimentary and meta-volcanic rocks.

The metasedimentary rocks are fine grained, except where veined by dioritic rock, and consist essentially of amphibole and andesine. The meta-volcanic rocks are also fine grained and contain much chlorite, in addition to amphibole and plagioclase feldspar. In some areas the inclusions constitute the bulk of the rock and are separated by thin, irregular veins of leucocratic dioritic rock.

The Four Mile batholith is most heterogeneous near its northern end. There the granitic rocks occur as well-defined sills in metamorphosed bordering strata and inclusions within the batholith are numerous.

The Four Mile batholith is intruded into sedimentary and volcanic rocks of the Sylvester Group and, at least locally, the contacts are discordant.

Stocks North of Cassiar

Two granitic stocks, each underlying an area of about 1½ square miles, outcrop near the eastern contact of the Cassiar batholith north of Cassiar and south of Blue River. No detailed examination was made of the northernmost of the two stocks. It has intruded Cambrian and Precambrian strata and is a medium- to coarse-grained biotite granite or quartz-monzonite.

The stock west and southwest of Cassiar Mine consists mainly of coarse-grained, porphyritic granite. The granite contains between 60 and 75 per cent microperthite in crystals as much as 4 cm long in a matrix of medium- to coarse-grained plagioclase feldspar, quartz, biotite, and hornblende. The microperthite crystals, some of which show pronounced oscillatory zoning, contain many small crystals of quartz and plagioclase feldspar. Many of the microperthite crystals have a white-weathering rim, mostly about 1 mm wide, of fine-grained oligoclase and quartz. Most of the plagioclase feldspar is distinctly zoned and ranges in composition from calcic andesine to calcic oligoclase. The texture of these rocks is allotriomorphic.

The border zone of the stock shows a remarkable gradation inwards from a rock composed mainly of randomly oriented, banded inclusions to a fairly homogeneous coarse-grained porphyritic granite. Two zones can be recognized in the marginal phase of the body on the west side of the stock approximately 4,000 feet from the north end, and are as follows:

1. A border zone between 10 and 15 feet wide adjacent to banded metasedimentary rocks; rocks contain between 60 and 80 per cent randomly oriented, angular inclusions of metasedimentary rocks, ranging from an inch to several feet in length, in which knotted hornfelsic tex-

ture is well preserved; inclusions contain a few white weathering porphyroblasts of microperthite; matrix is coarse-grained, microperthite granite.

2. An inner zone between 20 and 30 feet wide; rocks contain less than 50 per cent roughly equidimensional, relatively homogeneous, fine- to medium-grained dioritic inclusions, generally less than a foot in diameter; nature of the original rock is not readily discernible; inclusions contain porphyroblasts of pink weathering microperthite as much as 3 cm long as well as porphyroblasts of hornblende; matrix is coarse-grained porphyritic granite in which the microperthite content decreases near inclusions; grades inward into coarse-grained porphyritic granite that constitutes the bulk of the stock.

The metasedimentary inclusions in the first zone have retained textures like those in the wall rocks and are extremely fine grained and allotriomorphic. The rock is composed of cordierite, orthoclase, quartz, biotite, muscovite, and minor amounts of pyrite, tourmaline, epidote, sphene, and clinozoisite. The orthoclase and cordierite crystals contain abundant small inclusions. A knotted appearance is caused by spherical to lens-like, biotite-poor and biotite-rich segregations. Under the microscope contacts between the inclusions and the granitic rock are gradational over a zone about 1 mm wide. The limit of the zone is marked by the appearance of fine-grained andesine, the disappearance of cordierite in the hornfelsic rock and a relatively abrupt change in grain size.

The equidimensional, dioritic inclusions are fine to medium grained and allotriomorphic; they consist essentially of andesine, hornblende, biotite, and minor orthoclase.

Apatite, sphene, and magnetite are accessory minerals. Rod-like inclusions are abundant in the feldspar crystals. Locally, coarse-grained patches and veinlets of granitic rock occur in the dioritic inclusions.

The granitic stocks north of Cassiar have intruded rocks of Precambrian and Cambrian age. Contacts are, for the most part, discordant.

Age and Correlation

The Cassiar intrusions cannot be dated accurately by stratigraphic methods in McDame map-area. The youngest rocks intruded are of Devono-Mississippian age.

It is generally assumed that the Cassiar intrusions are correlative with the Omineca intrusions of north-central British Columbia. The Omineca intrusions were emplaced between late Triassic and late Cretaceous time and probably between late Jurassic and early Cretaceous time (Roots, 1954).

Minor Intrusions

Mount Haskin Porphyry

Light grey weathering granite porphyry underlies an area of less than half a square mile on the northwest flank of Mount Haskin. The porphyry consists of phenocrysts of quartz, microperthite, albite, and biotite as much as 1½ cm long in a matrix of fine-grained quartz, orthoclase, and albite. The phenocrysts of albite (An_{10}) are zoned and the crystals are irregularly embayed by the matrix. The rocks are relatively homogeneous although the border phases are finer grained than the central part.

Relations between the porphyry and the enclosing strata were not studied in detail but the body appears to be a sill about 100 feet thick. The porphyry has intruded strata of Cambrian age.

Dykes

Hornblende porphyry. Two easterly trending and steeply dipping dykes of hornblende porphyry, each about a foot wide, cut crystalline limestone on the Contact Mineral Claims west of Cassiar Mine. Several similar dykes, also restricted to marmorized limestone, occur 2 miles south of Cassiar.

The hornblende porphyries have a relatively simple mineral assemblage; labradorite (An_{80}) and hornblende with minor augite and biotite in an aphanitic matrix. The dykes show chilled edges against enclosing rocks.

Feldspar porphyry. Green weathering, feldspar porphyry dykes were noted in two places where exploration work has been carried out on base-metal mineral prospects.

On the Carlick Group 2 miles north of McDame, a dark weathering dyke, intrusive into Cambrian strata, contains feldspar crystals as much as 3 mm long in an aphanitic groundmass. The dyke contains ubiquitous cubes of pyrite that have locally weathered to iron oxide and have imparted a rusty colour to the dyke.

An irregular, lithologically similar dyke was seen on the south side of McDame Creek on the McDame Belle property. There the limestone country rock has been locally altered to calc-silicates.

In addition to the dykes described above, numerous dykes of greenstone have intruded Cambro-Ordovician and Silurian strata east of the McDame synclinorium. These rocks have been discussed previously.

Tertiary and (?) Older

Sedimentary Rocks

East of One-Ace Mountain. Well-indurated and sheared conglomerate outcrops on a northwesterly trending ridge about 4½ miles northeast of One-Ace Mountain. The rock is poorly sorted and consists of angular pebbles of chert, quartz, and black schist, as much as 1 cm long in an impure, coarse, sandy matrix. Muscovite is relatively abundant in the matrix.

The conglomerate was not seen in contact with other strata but the degree of induration and dynamic metamorphism suggest that the rocks may be older than Tertiary.

Rapid River. Terrestrial deposits comprising pebble, cobble, and boulder conglomerate, sandstone, shale, and coal, outcrop along Rapid River and its tributaries southwest of the southern end of Horseranch Range.

Most of the pebbles, cobbles and boulders in the conglomerates appear to be chert and limestone although many other rock types are present including gneissic quartzite and greenstone. In some places they are subrounded to rounded, whereas in others they are angular or subangular.

Sandstones interbedded with the conglomerates are generally calcareous and weather light grey. Locally, fine-grained sandstones contain carbonized plant remains.

Much of the shale weathers bluish grey and contains abundant carbonaceous material. Plant remains are particularly common in fine-grained, calcareous concretions in shale.

Coalified plant remains are abundant but only a few, small, discontinuous lenses of badly checked lignitic coal were noted. On the northeast side of Rapid River the northernmost outcrops of the terrestrial sediments contain several small seams. One seam, dipping easterly, is lenticular in a section at right-angles to the bedding and ranges in width from 6 inches to a foot. Distribution of coal float suggests that some seams are hidden by slumping.

The rocks are much contorted and cut by northwesterly trending faults, especially along the margins of the outcrop area. Dips as high as 40 degrees are prevalent.

A single collection of fossils was made from the rocks outcropping along Rapid River.

F_{65}. GSC Loc. 4235. 6.5 miles southeast of mouth of Rapid River. Fossils in calcareous concretions in shale on west side of river.

Coniferales
Taxodium dubium (Sternberg) Heer
Fragments of angiospermous leaves
Fragments of wood or bark

W. L. Fry of the Geological Survey of Canada states that the specimens that could be identified range in age from the Paleocene into the Pliocene.

Solitary Lake Valley. Red weathering conglomerate underlies a ridge flanking the valley west and southwest of Solitary Lake. The conglomerate consists of cobbles and boulders of chert, quartzite, and limestone in a matrix of coarse, calcareous and ferruginous, sandstone and grit.

Brick-red and grey, calcareous sandstone forms lenses and beds in the conglomerate sequence.

Cobbles and boulders as much as 2 feet in diameter are locally well rounded. Blue-grey limestone containing numerous crinoid stems is most abundant.

The conglomerate overlies unconformably blue-grey limestone of Cambrian or Ordovician age to the west, and is faulted against quartzite, probably of Cambrian age, to the east.

No fossils were noted in the conglomerate but it is not unlike the Sifton Formation of Tertiary age which outcrops in the Rocky Mountain Trench along Kechika, Fox, and Finlay Rivers (Hedley and Holland, 1941, p. 42; and Roots, 1954, pp. 190-191.)

Basalt

Olivine basalt occurs in small outcrops in the valley of Blue River west of Cassiar Road. Numerous boulders of basalt near the road and south of Cormier Creek have been transported easterly by ice. Most of these boulders, however, are believed to have been derived from the eastern part of Jennings River map-area.

The largest outcrop of olivine basalt noted in the map-area—about three quarters of a mile long and 600 feet wide—lies on Cambrian limestone on the southeast side of Blue River about 1½ miles northeast of the trail-crossing. There, a lava flow more than 30 feet thick exhibits well-defined, vertical columnar jointing. The rock is vesicular and is composed of phenocrysts of olivine and augite up to 1 mm in diameter in a matrix of lath-shaped labradorite crystals averaging ½ mm in length. The labradorite crystals show a trachytic texture. Magnetite is a relatively abundant accessory mineral. Similar rocks form small, isolated outcrops northeast of the locality described above.

The basalts are of Pleistocene or Tertiary age.

Chapter IV

STRUCTURAL GEOLOGY

Six more or less distinct structural units can be recognized in McDame map-area. From west to east these are as follows:

1. An anticlinal area occupied by the Cassiar batholith.
2. A southeasterly plunging synclinorium, herein referred to as the McDame synclinorium, occupied mainly by rocks of Devono-Mississippian age.
3. A mainly southeasterly plunging anticlinorium of Cambrian and Precambrian rocks.
4. A down-faulted block of Ordovician, Silurian, Devonian, and possibly Devono-Mississippian strata.
5. A doubly plunging anticline, bounded in part by faults, exposing Cambrian and/or Precambrian metamorphic rocks in the Horseranch Range.
6. A tightly folded and highly faulted synclinal area east of the Horseranch Range and Deadwood Lake underlain mainly by rocks of Cambro-Ordovician age but also containing infolded rocks of Silurian, Devonian, and Mississippian ages; probably merges with 4 north of the Horseranch Range.

Structural Units

1. *Anticlinal Area West of the McDame Synclinorium*

Structures within and on the borders of the Cassiar batholith have been described. Strata everywhere on the northeast flank of the batholith dip steeply to the east, which may reflect, in part, the forceful emplacement of the batholith into stratified rocks. On a regional scale, however, the east contact of the batholith trends more easterly than the trend of the bedrock formations. This suggests that the major folds formed early in the orogeny that culminated in the emplacement of the Cassiar batholith. Perhaps some folding pre-dated even this orogeny.

2. *McDame Synclinorium*

Detailed structural studies were made in the McDame synclinorium north of McDame and Troutline Creeks and most of the following description deals with that area.

Folds. Three miles northwest of the confluence of McDame Creek and Hot Creek a syncline in thin-bedded arenaceous rocks involves strata in excess of 100 feet thick. Tight, northeasterly overturned folds with amplitudes of as much as 50 feet involve a limestone and greywacke sequence east of Huntergroup Creek. Folds on this scale were not recognized elsewhere, but the presence of the folds described above indicates that bedding in the synclinorium does not necessarily conform to the simple pattern suggested by the beds that define the limbs.

As a rule, folded and contorted beds are conspicuous near the contact of the Sylvester Group and underlying rocks. They may reflect, in part, the relative movement between these rocks during folding of the synclinorium (*see* Fig. 7)

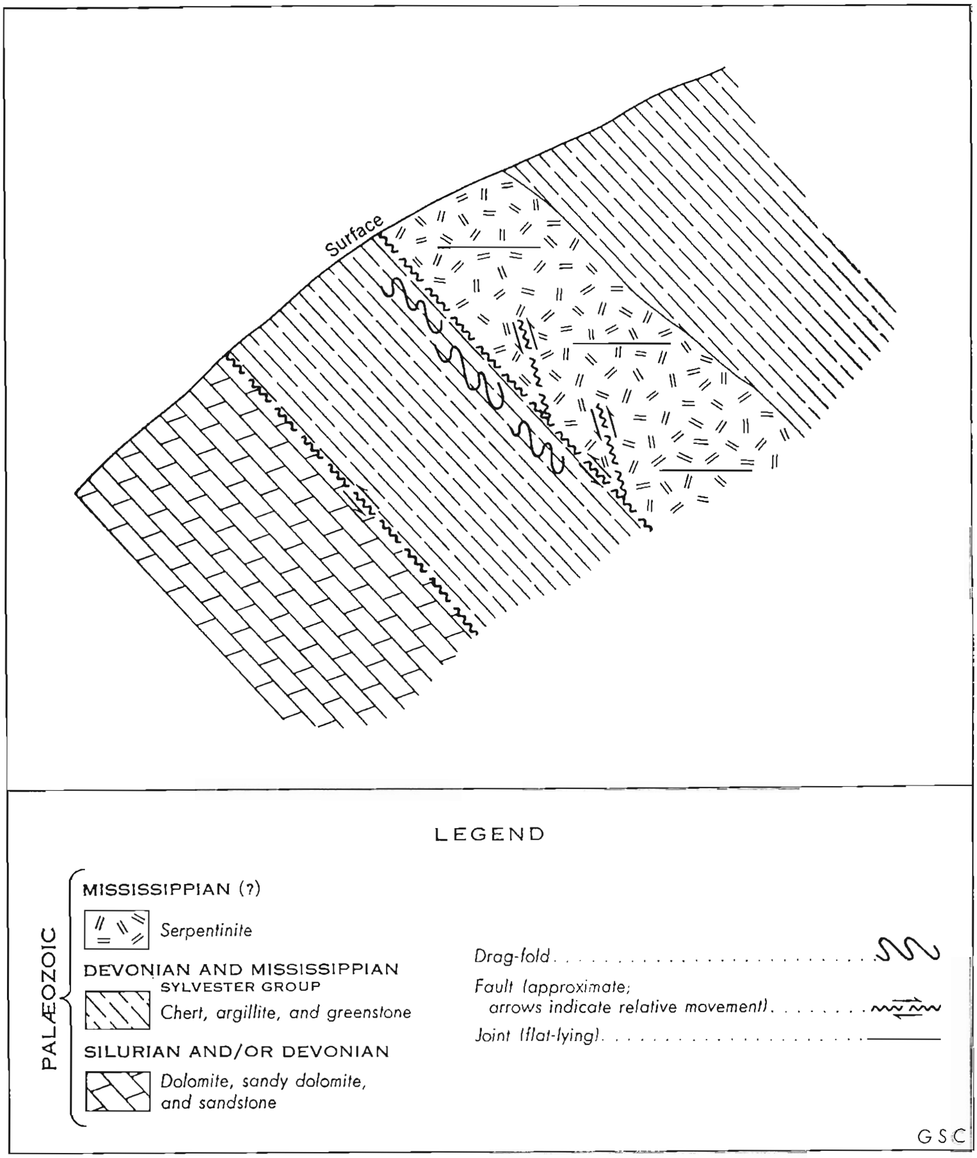

FIGURE 7. *Structures produced during folding on southwest limb of McDame synclinorium on Cassiar Asbestos property.*

Contorted strata mark many of the contacts between sedimentary and ultramafic rocks. Minor folds with amplitudes ranging from 6 inches to 3 feet occur in sedimentary rocks underlying the Cassiar serpentinite body. Axial planes generally dip northeasterly at steep angles and suggest that the structures are the result of differential movement between the serpentinite and the underlying rocks. Minute crumples also occur in a narrow zone of phyllonite adjacent to the lower contact of the Cassiar serpentinite body.

Faults. The absence of large-scale faults transverse to the major structural trend is indicated by the continuity along strike of the beds defining the limbs of the synclinorium. Minor transverse faults were noted however in the Zus Mountain ultramafic body. One of these, dipping steeply to the southeast, locally marks the contact of ultramafic with volcanic rocks. The other fault dips southeasterly at a moderate angle. Highly sheared and carbonatized rocks mark the structures where ultramafic and volcanic rocks are in contact. Sheared, serpentinized rocks occur where these faults cut ultramafic rocks.

Zones of brecciated and rust-stained material occur on the ridge above the Cassiar serpentinite body. These zones are in general parallel with joint directions and may represent a jostling or slight movement along joint planes.

The most conspicuous faulting occurs locally along the contact between Sylvester Group sediments and the underlying rocks. This type of fault may represent, in part, differential movement of the Sylvester and pre-Sylvester assemblages in response to compressive forces that caused folding of the synclinorium.

Joints. Joints are prominent in the McDame synclinorium. The arenaceous and cherty rocks are strongly jointed and the joint density is high. It is therefore possible to obtain sufficient joint readings for a statistical analysis in a restricted area. This facilitates a study of the effect of local variation in structure on the joint pattern.

Observations of joint densities in the various rock types leads to the conclusion that the density is controlled mainly by the thickness of the bedding in sedimentary rocks, and by width of sills or extrusive members in greenstone. Presumably the lithology also had an influence but this effect could not be checked as comparable thicknesses of different rock types were not observed close to each other. The meta-diorite bodies and large ultramafic bodies display poorly defined joints.

Joints were measured systematically in the ultramafic belt with special emphasis on the area near Cassiar. Localities represented by joint diagrams (*see* Fig. 8) are indicated on Figure 9 and Figure 14. Figure 11 shows the attitudes of major joint concentrations in the synclinorium. Figure 14 shows the attitudes of the major joint concentrations on the Cassiar Asbestos property.

Figure 11 illustrates the preponderance of steeply dipping joints that trend transverse to the major structure. This feature is evident in the field because it is reflected in the topography. The joint diagrams emphasize the dominance

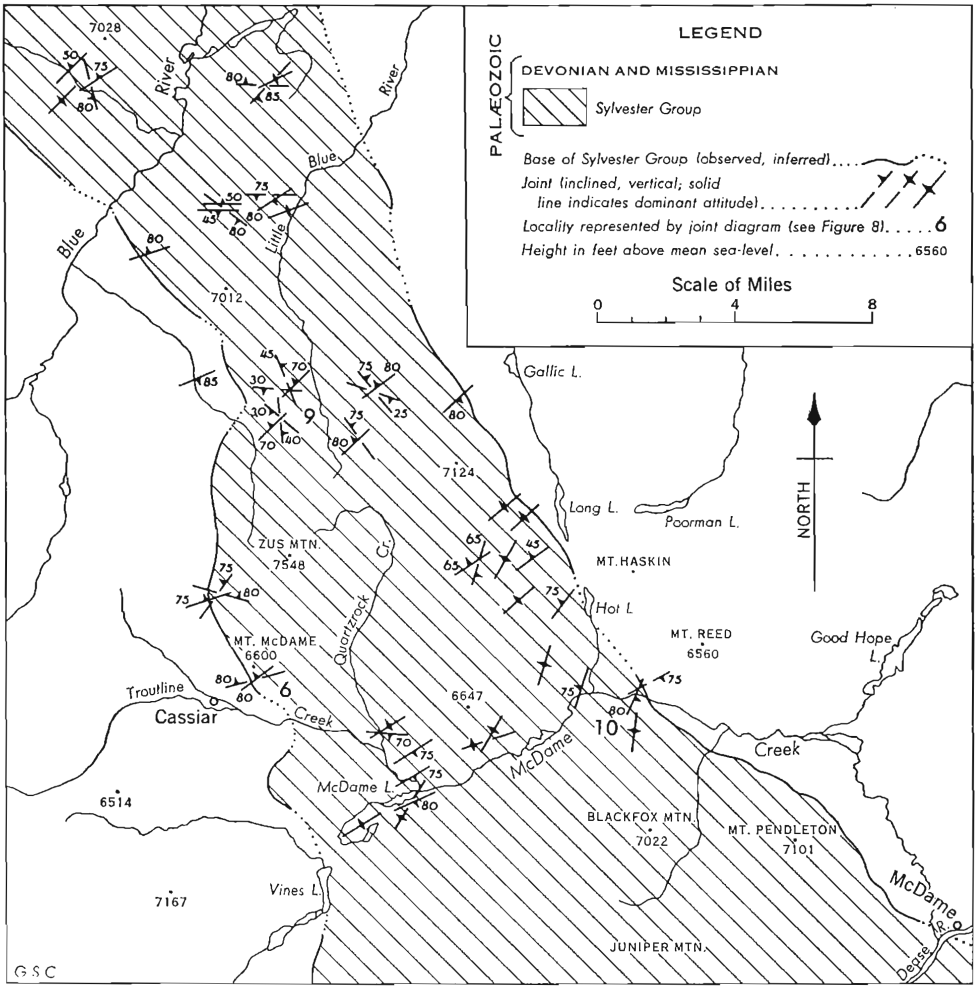

FIGURE 9. *Prominent joint attitudes in rocks of the McDame synclinorium.*

of these transverse joints. In addition, they show a marked relationship of major joint attitudes to the approximate axis of the synclinorium. At Cassiar, for instance, the jointing reflects the southeasterly plunge of the synclinorium. The dips of the major joints in other areas dip steeply northwest, steeply southeast, or vertically. This may indicate local variations in the plunge of the synclinorium. A projection of plunges noted at Cassiar would necessitate a much greater thickening of the stratigraphic section to the southeast than is evident in the field. Therefore the plunge of the synclinorium is not consistent along strike. Joint diagram 10 shows that the attitudes of joints reflect the easterly swing of the synclinorium axis in the area represented.

Joint diagrams at the Cassiar Asbestos property illustrate joint patterns in beds of different attitudes. A comparison of diagrams 2 and 3 with diagrams 4 and 5, shows that the joint attitudes are only slightly affected by changes in bedding attitudes. This is different from the condition noted in Horseranch Range. There, joints closely follow local variations in the attitudes of the beds in which they occur, remaining roughly perpendicular to the bedding.

Most of the joint diagrams show the striking development of one set of cross-joints with subordinate development of one or two other sets. The subordinate set, or sets, typically are intersected by the major sets at acute angles in a direction perpendicular to the axis of the synclinorium.

Joint diagrams 7 and 8, showing attitudes of joint concentrations at Cassiar, and diagram 9, representing part of the Zus Mountain ultramafic body, differ in several respects from the other diagrams.[1] Diagram 7 is in part similar to diagram 3 but shows in addition, a marked concentration of flat-lying joints. These joints are prominent also in diagram 8 but are associated with other joints that are not clearly related in attitude to joints in other diagrams. In the Zus Mountain ultramafic body the prominent cross-joints are well developed but the subordinate sets are more gently dipping than elsewhere.

Origin of Joints. The major concentration of joints across the synclinorium appear to represent typical 'a-c' or cross-joints produced by elongation in the direction of the axis. In some of the diagrams other joint sets are present and their attitudes suggest that they may represent shear directions. According to Hartmann's law, the angle between two shear planes if both are developed, should be acute in the direction of maximum compression. In the synclinorium the maximum compression presumably was in a northeast direction. Planes at a small angle to the major cross-joints could therefore be interpreted as shear planes. In several localities the theoretical arrangement of a tensional cross-joint bisecting the acute angle between two shear joints is evident. Far more common however, is the occurrence of a dominant cross-joint with one subordinate shear joint.

If the major joint direction in the Zus Mountain ultramafic body is assumed to represent a typical 'a-c' joint, then the other two attitudes might represent shear planes arising from a direction of least compression in a vertical direction, rather than in a horizontal direction as suggested for the other localities. A similar joint pattern is present in greenstones immediately north of the Zus Mountain ultramafic body. This area, near the axis of the synclinorium is stratigraphically high. It seems possible that the transition between maximum relief upward, and maximum relief in a horizontal direction, occurs between the stratigraphic levels represented by the Zus Mountain area, and the areas in which the other joint readings were taken. On the other hand, the stress distribution in a massive, homogeneous unit may be considerably different from that in enclosing sedimentary rocks.

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[1] Because of high, erratic concentrations of magnetite in many of the ultramafic bodies compass variations should be checked carefully before an attitude is taken.

Flat-lying joints in the Cassiar serpentinite body are conspicuous in that they contain long-fibre asbestos veinlets. The origin of these joints may be attributed to the relative movements during folding of strata enclosing the serpentinite. The joints in this hypothesis are regarded as tension joints.

In addition to the flat-lying joints, diagram 7 shows joint sets comparable to those in diagram 3. In diagram 8 joints that are flat lying have no apparent counterparts elsewhere. The reasons for this may be two-fold. First, the physical nature of the serpentinite may have caused it to react differently to stress than the enclosing rocks. The similarity of diagrams 3 and 7, however, suggests that this is not universally true. Second, the joint pattern as originally imposed on the serpentinite body may have been jostled by later movement, thus giving rise to joints that are related to the relative movement of individual blocks. The latter hypothesis is considered probable. The asbestos veins show abundant evidence that the host rock was deformed during asbestos formation. The jostling of blocks bounded by joint planes is considered to be important in the formation of cross-fibre asbestos veinlets at Cassiar.

Tremolitized contact rocks along the foot-wall of the serpentinite body at Cassiar contain anthophyllite and quartz-zoisite veins ranging from microscopic to megascopic dimensions. The attitudes of these veins conform to the major joint pattern.

The general joint pattern in the McDame ultramafic belt is fairly typical of folded rocks in which the folds are probably caused by compression (Gilkey, 1953; Irwin, 1951).

The orientation of the cross-joints is compatible with a hypothesis that jointing took place early in the folding episode (major variations in bedding strikes brought about by folding are generally reflected in joint attitudes). Attitudes of joints above and below the Cassiar serpentinite body, however, are consistent even though the beds vary considerably in strike. This would be expected if it were assumed that the difference in bedding attitudes is the result of the emplacement of the serpentinite body prior to the main folding.

In summary, most of the structural elements in the McDame synclinorium can be related to forces and movements associated with folding that resulted in the formation of the southeasterly plunging structure. Joint attitudes on the Cassiar Asbestos property suggest that the joints were initiated after the serpentinite body had been emplaced.

3. *Anticlinorium Northeast of the McDame Synclinorium.* The structure of this unit, as noted previously, is not fully understood. In general, folding is much more intense in the western part of the belt than it is in the east. Axial planes of the major anticlinal axes northwest of Good Hope Lake and southeast of Rapid River dip steeply to the northeast. Near the southern boundary of the map-area large, northwesterly plunging drag-folds, some slightly overturned to the southwest, occur on the northeast limb of a major anticline. The southwest limb of the anticline is vertical in some places.

The presence of overturned folds with axial planes dipping steeply to the southwest is suggested by the map pattern of Cambrian strata between McDame and Gallic Lake. These structures may be drag-folds on the steep southwest limb of the major anticlinorium but evidence for this is not conclusive. Indeed, it is possible that the map pattern results in part from longitudinal faulting.

Many of the longitudinal faults appear to be thrust faults. The stratigraphic throw on the thrust fault west and south of Good Hope Lake is more than 3,000 feet.

Numerous northerly and northeasterly trending faults in the Cambrian and Precambrian strata are presumably the result of movement along directions of shear and tension produced by the forces that formed the major anticlinorium. Similar faults cut Ordovician, Silurian, and Devonian rocks north and northwest of Sheep Mountain.

4. *Fault-block West of Horseranch Range.*

Within this block rocks overlying the incompetent Cambro-Ordovician sequence are rather uniformly folded. An exception to this generalization is presented by the tightly folded assemblage of Devonian and older strata exposed in the canyon of Blue River. In this area, however, many minor faults are present, and the tight folding may be related to a major fault zone.

5. *Horseranch Anticline.*

Horseranch Range is, in part, a raised fault-block in which the rocks have a doubly plunging anticlinal structure. Whether the range is completely bounded by faults is not known. The anticlinal structure appears to be more or less symmetrical although a complete section cannot be obtained because of insufficient outcrops on its eastern flank.

6. *Synclinal Area North and East of Horseranch Range and East of Deadwood Lake.*

This general area is characterized by intense folding in incompetent Cambro-Ordovician strata, gentle to moderate folding of overlying competent Ordovician to Devonian strata, and locally, by extreme faulting in both competent and incompetent strata. The fragmentation of the competent rock-units east of Deadwood Lake could be attributed to the adjustment of competent Ordovician to Devonian strata to an underlying incompetent unit that was highly deformed during folding.

The numerous northerly and northeasterly trending faults probably have the same origin as suggested for those in the strata north of Good Hope Lake (movements along directions of shear related to the forces that produced the northwesterly trending fold axes). Offsets on faults of this type range from several tens of feet to several thousands of feet.

The horizontal displacement on the longitudinal faults is not known but vertical displacements, as determined by the position of the boundary between Ordovician shales and overlying carbonate strata, must exceed 2,000 feet in some places.

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Devono-Mississippian strata near Lower Post and east of Hyland River have been tightly folded. Middle Mississippian carbonate rocks east of Solitary Lake occur in relatively uniform folds.

Major Faults

Northwesterly trending lineaments, reflecting the presence of major longitudinal faults or simply the presence of easily eroded strata, or a combination of both, are conspicuous in the map-area. The valleys on the eastern limb of the McDame synclinorium are, for the most part, underlain by soft, incompetent Cambro-Ordovician strata. Some of the contortion in the incompetent rocks may be due to faulting but evidence for this is meagre.

A major fault or fault zone marks the eastern boundary of the Cambrian and Precambrian outcrops west of Dease and Rapid Rivers and southwest of Deadwood Lake. Ordovician and Silurian rocks occur on the east side of the fault near French River and southwest of Deadwood Lake. Tertiary rocks are faulted against a Precambrian assemblage near the mouth of Julian Creek. In this area the rocks are highly deformed for several hundreds of feet along the creek. Another fault near French River has brought westerly dipping Devonian strata to the east against westerly dipping Ordovician and Silurian strata to the west. This fault or perhaps other parallel faults may mark the northeastern boundary of Ordovician-Silurian strata northwest of French River. The stratigraphic section bounded by the faults described above includes as much as 1,500 feet of Ordovician and Silurian carbonate strata whereas the sections east of Dease River include very little, if any, of this assemblage. This suggests the possibility that considerable translational movement may have taken place along one or more of the faults. The same situation prevails southwest of Deadwood Lake where the Ordovician and Silurian rocks are perhaps as much as 1,500 feet thick on the northeast side of the major longitudinal fault but do not appear 4 miles to the southwest across the Cambrian anticlinal axis. Perhaps rapid facies changes in the Ordovician and Silurian rocks combined with a pre-early Silurian erosion could have produced the relations described above, but the changes seem too abrupt for this alone to be sufficient.

Rocks of Silurian age have been brought against rocks of the Horseranch Group along a major fault east of Harvey Lake. The locus of this fault is marked by a breccia zone about 150 yards wide in the Silurian rocks. To the south Cambro-Ordovician strata outcrop on the west side of the fault. The vertical displacement on this structure is probably many thousands of feet.

Rocks near Looncry Lake appear to be down-dropped relative to rocks of Horseranch Range and rocks southeast of Looncry Lake.

A fault trending northwesterly from the north end of Deadwood Lake has brought Cambro-Ordovician strata to the east against Cambrian strata to the west. Highly brecciated and rust-stained rocks near the mouth of Walker Creek may represent a continuation of this fault.

On the west side of Solitary Lake valley a longitudinal fault has brought easterly dipping Tertiary (?) conglomerate against Cambrian quartzite. The vertical displacement on this fault may not be large, as the Tertiary strata unconformably overlie Cambrian limestone immediately to the west.

The southwest border of the Rocky Mountain Trench may represent a fault or fault-line scarp, but evidence is lacking. Steeply dipping and tightly folded rocks lying west of the Trench near Red River contain Ordovician graptolites. On Dease River Ordovician graptolites also occur in rocks west of the northwest projection of the Trench. Highly folded and faulted Devono-Mississippian strata occur in or near the projection of the Trench near Lower Post.

Chapter V

HISTORICAL GEOLOGY

An interpretation of the field data is given in the following discussion on the geological history of the McDame map-area.

Late Precambrian and Early Cambrian

During late Precambrian and early Cambrian times well-sorted, relatively fine grained, calcareous, arenaceous, and argillaceous, non-volcanic sediments were deposited in a geosyncline (miogeosyncline). Information on the distribution and variations in lithology and thickness of the sediments is meagre but the available data suggest that the geosyncline was probably continuous throughout the length of the Cordillera. In McDame area the source area or areas must have been stable, low lying, and deeply weathered.

The lower Cambrian quartzite unit is typical of the quartz arenites at the base of the Cambrian system in the Cordillera of Canada and the United States. As suggested by Okulitch (1949) and Kay (1951), the arenites were probably deposited as the basal beds in an easterly transgressing sea. The overlying limestones reflect deposition in shallow, well-aerated seas. Whether or not the Archaeocyatha-bearing limestones outline the approximate western shoreline of the Lower Cambrian geosyncline (Okulitch, 1955) is not known.

Mid-Cambrian to Mid-Ordovician

Sediments deposited from mid-Cambrian to mid-Ordovician times are believed to represent a relatively deep-water facies and, if so, indicate a deepening of the depositional basin. A facies change from predominantly argillaceous sediments in the southwest to predominantly calcareous sediments in the northeast may reflect an eastern source area. Local instability of the depositional basin is possibly indicated by intraformational conglomerates.

Black, pyritic, and graptolitic shales of early and middle Ordovician age were apparently deposited in stagnant, isolated basins or perhaps in a fairly continuous basin.

Late Ordovician to Mid-Silurian

Coralline, cherty dolomites of late Ordovician to Middle Silurian age were evidently deposited in warm, shallow, well-aerated seas on a slowly subsiding platform that must have extended over a tremendous area. Locally, graptolitic siltstones may have accumulated in stagnant, isolated basins within the platform.

A marked hiatus occurred in the southwestern part of the McDame area where late Lower or Middle Silurian siltstones locally overlie rocks of probably early Ordovician age.

During the Middle Silurian, sand was swept into the depositional area from time to time. The uniform fine grain-size and extreme purity of these sands suggests that they represent re-worked sandstones of an earlier period.

Mid-Silurian to Mid-Devonian

Possibly in late Silurian time laminated dolomites accumulated in the southwestern part of the map-area and possibly over the entire area. The environment was unsuitable for marine life and it seems possible that the rocks were deposited in enclosed basins or lagoonal areas in which the inflow of normal sea-water was restricted.

Widespread epeirogenic uplift, mild tilting, and erosion preceded the deposition of overlying Middle Devonian rocks.

Mid- and (?) Late Devonian

The highly fossiliferous dolomites of mid-Devonian age were apparently laid down under the same conditions as postulated for the coralline, cherty Silurian rocks. Again, these conditions must have prevailed over a vast area in northwestern Canada.

The platy, poorly fossiliferous limestones that overlie the dolomites may indicate a slightly deeper water facies. Perhaps they foreshadow the rapid subsidence of the depositional basin that was to follow in late Devonian time.

Late Devonian and Early Mississippian

During late Devonian time the depositional basin subsided rapidly, a volcanic belt was initiated, and by mid-Mississippian time a great thickness of sedimentary and volcanic rocks had accumulated. This assemblage contrasts markedly with those of previous periods and reflects the change from a miogeosynclinal or shoal-platform environment to a eugeosynclinal environment. Ultramafic rocks may have been emplaced during this time but evidence for this is not conclusive.

Middle Mississippian

A significant break in deposition accompanied by erosion preceded the deposition of fossiliferous, carbonate, Middle Mississippian strata. The carbonate rocks indicate a return to quiescent, platform-conditions of sedimentation.

Purely on speculation, it might be suggested that the marked unconformity between Lower and Middle Mississippian rocks may have coincided with the metamorphism and granitization of the Horseranch Group. At any rate this appears to be the main disturbance recorded in the Palæozoic stratigraphy of McDame map-area.

Mesozoic

No stratified rocks of definite Mesozoic age outcrop in the map-area.[1] Granitic rocks of the Cassiar intrusions were probably emplaced during the Jurassic and/or Cretaceous periods, and it is assumed that major deformation of the stratified rocks occurred at this time.

Tertiary and Quaternary

Tertiary time is represented by local valley accumulations of terrestrial strata. Movement along major longitudinal faults post-dated the deposition of these strata but probably started at a much earlier time.

Minor eruptions of olivine basalt took place during either pre-Pleistocene or Pleistocene time.

The region was extensively glaciated during the Pleistocene by one or more ice-sheets.

[1] See footnote on Triassic rocks in Table of Formations.

Chapter VI

ECONOMIC GEOLOGY

The McDame map-area includes a wide variety of mineral deposits. Until recently most of the mining activity was concerned with the recovery of placer gold, although exploration work had been carried out on a number of lode-gold deposits. Since 1949, however, the production of placer gold has been insignificant and the only important mineral production in the area has come from the Cassiar Asbestos mine. Exploration of base-metal deposits has been accelerated with increased transportation facilities but only minor shipments of ore, mainly for test purposes, have been made.

Classification of Mineral Deposits

With a few exceptions the mineral deposits appear to be controlled by the type of host rock and the proximity to granitic intrusive rocks. These relationships are emphasized in the following summary.

Mineral deposits in granitic rocks and pegmatites. Quartz veins in porphyritic granite north of Cassiar contain bismuthinite, molybdenite, and scheelite. Some of the pegmatites in the central and northern parts of Horseranch Range contain beryl.

Mineral deposits in contact metamorphic hornfels, skarn, and crystalline limestone near the Cassiar batholith. Pyrrhotite and magnetite are common near the Cassiar batholith. In particular, concentrations of these minerals were noted in crystalline limestone on the ridge south of Cassiar. Manganiferous magnetite is abundant in the silver-lead-zinc deposits near Cassiar. Scheelite and molybdenite have been found locally in contact metamorphic rocks near the Cassiar batholith. Beryllium minerals occur in skarn (tactite) northeast of the mouth of Bass Creek.

Mineral deposits in Precambrian and Lower Cambrian limestone. Most of the known zinc-lead-silver deposits in the area occur in Lower Cambrian limestone flanking the McDame synclinorium. Limestone of probable Precambrian age is the host rock of a deposit north of Cassiar. The mineral occurrences on the southwest side of the McDame synclinorium are within the contact metamorphic aureole of the Cassiar batholith. Those on the northeast flank of the synclinorium are spatially related to small sills and dykes of fine-grained, porphyritic granitic rocks. There, a highly mineralized zone extends southeasterly from Mount Haskin to Dease River near Atan Lake.

Mineral deposits in Cambro-Ordovician rocks. Sparse, disseminated chalcopyrite and oxidation products thereof were noted in five places in a narrow zone in calcareous phyllites extending for at least 12 miles northwest from Hidden Valley Creek. The mineralized rocks are generally near greenstone bodies that also commonly contain copper minerals (malachite mainly). Irregular bodies of massive pyrite occur in the creek bottom near the headwaters of Hidden Valley Creek and in Walker Creek 5 miles from its mouth. Showings of lead and zinc have been noted in calcareous phyllites along Rapid River south of Looncry Lake. Pyrite is conspicuous in black shales of Cambro-Ordovician age.

Mineral deposits near the top of the McDame Group. In numerous places copper minerals (chalcocite (?), malachite, azurite) occur, apparently in small amounts, in carbonate rocks at the top of the McDame Group.

Mineral deposits in Devono-Mississippian rocks. Gold-quartz veins are abundant along the southeast flank of the McDame synclinorium, particularly in a zone about 5 miles wide between Pooley and Quartzrock Creeks. Most of the veins are in greenstones but a few are in sedimentary rocks. Gold in the placer deposits has undoubtedly been derived from veins in the Sylvester Group. Argentiferous tetrahedrite (possibly tennantite) has been found on the northwest slope of Mount Pendleton and float of tetrahedrite and quartz was noted 4 miles north of Blue River on the trail to Captain Lake. Greenstone and limestone near the mouth of Nizi Creek have been mineralized with specular hematite, chalcopyrite, and galena.

Mineral deposits in ultramafic rocks. Ultramafic rocks in the area contain asbestos, chromite, and nickel. Many of the ultramafic bodies contain veinlets of asbestos but the only known body of commercial importance is that at Cassiar. Spectrographic analyses indicate that most of the ultramafic rocks contain an average of 0.2 per cent nickel. Regenerated dunite near the Cassiar batholith northwest of Blue River contains blebs of nickel-iron and these rocks contain between 0.2 and 0.6 per cent nickel. Minor lenses of chromite were noted in this area and chromite float has been collected near the serpentinite body on Sylvester Peak.

In addition to the occurrences noted above, coal occurs in terrestrial rocks of Tertiary age along Rapid River and placer gold is found in many unconsolidated stream deposits.

Descriptions of Properties and Prospects

Placer Deposits

Walker Creek (1)[1]

References: Ann. Rept. Minister of Mines, B.C., 1877.
Bull. No. 12, B.C. Dept. of Mines, 1941.

Placer gold was discovered on Walker Creek in 1877. Until 1887, the last year for which recorded gold was recovered, the creek yielded over 3,300 ounces of gold.

[1] Number in parentheses is that by which the property is located on the accompanying map.

Walker Creek is about 6 miles long and heads in an area underlain by cherty dolomite, dolomite, and sandstone of the Sandpile Group. For most of its course, however, it traverses incompetent, tightly folded phyllitic limestones, calcareous phyllites, black slates and argillites, limestones, and greenstones of the Kechika Group. The greenstones are highly altered rocks and may be intrusive.

The valley of Walker Creek is characterized by a lack of benches, steep walls, and interlocking spurs. The creek bottom contains many large boulders that are undoubtedly glacial erratics transported from an area to the southwest.

The lower 2 miles of the creek appear to have been the most productive as much of the work was concentrated in this area. Test pits in the broad, alluvial fan below the canyon have apparently yielded disappointing results.

A description of the gold as given in the reference cited above (1877) is as follows: "The gold is fine, of a granulated appearance, and heavy quality . . . the largest piece obtained weighing not more than fifty cents" (gold at this time sold for $19.00 an ounce).

The source of the gold is unknown. Gold has not been found in other creeks in the Deadwood Lake area although similar rocks are cut by many streams. Possibly the gold-bearing material was transported to the Walker Creek area by northeasterly moving ice. Volcanic rocks to the southwest contain gold-quartz veins and placer deposits in the Wheaton Creek area have yielded considerable gold.

McDame Creek (2)

References: Hanson, G. and McNaughton, D. A. Eagle-McDame Area, Cassiar District, British Columbia; Geol. Surv., Canada, Mem. 194, p. 13 (1936).
Mandy, J. T. Ann. Rept., Minister of Mines, B.C., pp. A54-A61 (1931).
Black, J. M. Ann. Rept., Minister of Mines, B.C., pp. A188-A190 (1947).
Bennett, J. H. Ann. Rept., Minister of Mines, B.C., pp. A173-A174 (1948).
Holland, S. S. Ann. Rept., Minister of Mines, B.C., pp. A236-A237 (1949).

Since discovery in 1874 McDame Creek has yielded gold valued at about $2,000,000, much of which was recovered by small-scale operations prior to 1900. In 1948 and 1949 Moccasin Mines Limited used a floating washing plant fed by a dragline shovel east of Centreville. Operations closed in the autumn of 1949, and since that time placer mining on McDame Creek has been negligible.

McDame Creek flows easterly from McDame Lake for about 6 miles in a broad, drift-filled valley underlain by rocks of the Sylvester Group. For the next 5 miles to Moccasin Mines the valley is narrow and the stream has cut gorges in rocks of mainly pre-Sylvester age. The remainder of the course to Dease River at McDame is in a wide drift-filled pass. During late Pleistocene time drainage was effected by streams that cut conspicuous high-level channels along the northern margin of a glacier north of McDame and Allan Lakes (*see* Fig. 3).

Most of the placer mining has been restricted to areas near the mouths of tributary streams, particularly on the north side of the valley. Mandy (1931) considered that the shallow bonanza gravels in the low sections of southerly flowing tributary streams (including Hot Creek and Snowy Creek) resulted from a concentration of gold that was in the benches of an old high-level channel. Bench gravels have been worked at Moccasin Mines, Centreville, and 3 miles northwest of Centreville. Present stream gravels have been worked on Snowy Creek and at Moccasin Mines. A buried channel on Quartzrock Creek near its confluence with Troutline Creek was mined by drifting and hydraulicking. At Moccasin Mines much of the gold is reported to have been in gravel immediately overlying lenses and layers of sand.

Apparently, much of the gold recovered from McDame Creek was relatively coarse and one nugget found in 1877 was worth \$1,300 (Howay and Scholefield *in* History of British Columbia). The placer gold has undoubtedly been derived from gold-quartz veins that are abundant in the Sylvester Group between Pooley and Quartzrock Creeks.

Other Placer-Gold Deposits

In the early days placer gold was recovered on Rosella Creek, Dennis Creek, and several other small creeks north and east of Poorman Lake. In 1949 Moccasin Mines Limited constructed a road along French River and Spring Creek to explore the possibility of placer mining in that area. The gold recovered from these streams was probably derived from rocks of the Sylvester Group and transported easterly by ice.

Minor amounts of gold have reportedly been recovered from bars along Dease River west of Horseranch Range.

Lode Deposits

Copper Deposits East of Deadwood Lake (3)

Reference: Bennett, J. H. Ann. Rept., B.C. Dept. of Mines, 1951, p. A73.

A small copper deposit is exposed along a tributary of Hidden Valley Creek about 12 miles east of the south end of Deadwood Lake. The showing was examined during the summer of 1951 by The Consolidated Mining and Smelting Company of Canada which later dropped its option.

The area is underlain by buff and black, slaty, well-bedded limestone and grey, glossy, calcareous phyllite of the Kechika Group. The rocks are highly contorted and phyllite is strongly drag-folded between beds of limestone. Cleavage strikes N45°W and dips from 65° to 70°SW.

Lenses and irregular bodies of rusty weathering sideritic or ankeritic carbonate and white, milky quartz lie in a zone between foot-wall (slaty limestone) and hanging-wall (calcareous phyllite). On the south side of the creek this zone dips about 65°SW but on the north side it dips about 25°SW. Chalcopyrite occurs as veinlets in quartz and as irregular masses in quartz and carbonate. The mineralized zone is about 40 feet wide where cut by the stream although in general it is extremely irregular.

Similar occurrences of chalcopyrite are exposed in roughly the same stratigraphic position in the Kechika Group in a zone extending for at least 12 miles northwest from Hidden Valley Creek. The mineralized rocks are characterized by the presence of rusty weathering oxidation products, white quartz, and splotches of malachite. One of these prospects, 8 miles northeast of the south end of Deadwood Lake, was staked by G. Hope of Quartzrock Creek. The showing contains minor amounts of massive chalcopyrite with pyrite in sideritic or ankeritic carbonate and occurs along the contact between white, massive quartz and grey, calcareous phyllite. Locally, the quartz vein is ribboned, the well-defined ribbons averaging about 6 inches wide. Well-developed quartz crystals are present in white quartz a few tens of feet northeast of the main showing.

Copper Prospect-Four Mile River (4)

A copper prospect, originally staked by Beal Carlick of Lower Post, is located about 1½ miles south of the mouth of Nizi Creek on the east side of the trail along Four Mile River.

Bedrock comprises greenstone, chert, limestone, and chert-pebble conglomerate of the Sylvester Group. Several test pits, one trench, and a stripped area reveal a steeply dipping, highly irregular, sheared, mineralized zone trending about N40°E. The southwest part of the mineralized area widens from 12 feet at the top of the exposure to 40 feet where it disappears under talus and drift.

The mineralized rocks contain specular hematite, pyrite, chalcopyrite, minor galena, azurite, and malachite. Sheared greenstone contains much cellular limonite. Galena appears to occur in or near limestone. A test pit 30 feet northeast of the stripped area contains a little fine-grained galena.

Carlick Group-Atan Lake (5)

Reference: Hemsworth, F. J. Ann. Rept., B.C. Dept. of Mines, 1949, pp. A71-A72.

The Carlick group, 2 miles north of McDame, was staked by Beal Carlick of Lower Post in the summer of 1949. The group was optioned by Moccasin Mines Limited in 1949 and additional claims were staked on strike with the initial discovery. After an exploration program which involved stripping and trenching by bulldozer, work was discontinued and many of the claims have lapsed.

The area is underlain by limestone, buff dolomite, black, cherty quartzite, and argillaceous limestone of the Atan Group. Locally, small bodies of feldspar porphyry have intruded the sediments.

Five trenches, four of which cut mineralized rock, delimit a mineralized zone about 600 feet long. The zone is roughly parallel with the trend of the bedrock formations. Most of the trenches had slumped when the property was visited by the writer.

Galena is the chief metallic mineral and is commonly coarse grained. Minor pyrite, sphalerite, azurite, and malachite, occur in the deposit. Coarse-grained barite is abundant and occurs with minor siderite.

Barite with sparsely disseminated galena was noted along the north bank of Dease River south of Atan Lake and Mr. Carlick reports that these minerals were also seen on trend with this occurrence south of Dease River.

Assays of samples taken by Hemsworth (1949) from the Carlick group are as follows:

Width	*Gold*	*Silver* (oz./ton)	*Lead* (%)
1. 2 sections, 9 feet and 5 feet wide separated by 10 feet of dyke rock and black limestone			
9-foot section	nil	0.7	6.8
5-foot section	nil	nil	10.6
2. 400 feet southeast of 1. 8 feet of barite and limestone	nil	0.2	1.2
3. 200 feet southeast of 2. across width of 10 feet	nil	0.6	10.0

McDame Belle (6)

The McDame Belle property is on McDame Creek about a mile east of Centreville. J. Bartle of Good Hope Lake has worked on the showing since 1950.

Country rocks comprise massive and well-bedded, grey limestone and minor fine-grained quartzite of the Atan Group striking N55°W and dipping 55°SW. Near the mineral deposit limestone has been replaced by buff-weathering crystalline dolomite.

Three irregularly mineralized shear zones are exposed in a steep wall of the gorge on the southeast side of the creek. The zones dip steeply and strike N80°W. A short adit intersects one of the zones. Rocks exposed on the northwest side of the creek have been dolomitized and Mr. Bartle reports that these rocks have been sparsely mineralized.

Ore minerals in order of abundance are galena, sphalerite, chalcopyrite, scheelite, and hydrozincite. Gangue minerals include calcite, garnet, diopside, and tremolite.

Seven hundred and fifty pounds of picked material is reported by Mr. Bartle to have returned $177 per ton plus smelter charges. The shipment contained 80 ounces per ton of silver.

Reed Claims (7)

Claims staked by J. Reed of McDame Creek are at an elevation of between 4,500 and 5,000 feet on the south slope of Reed Mountain (*see* Fig. 10).

The area is underlain by purple and grey, calcareous, micaceous quartzite, thin-bedded, blue and grey limestone, and blocky, buff weathering dolomite of the Atan Group. The formations strike S55°E and dip 50°SW. Near the mineralized area quartzite of the hanging-wall strikes N10°W and dips 75°W. Thin-bedded limestone of the foot-wall is much faulted and contorted.

Mineralized rock is localized in a shear zone from 10 to 20 feet wide along the contact of quartzite and limestone. The mineralized zone shown by exposures in the creek, a short adit, and small trenches is over 250 feet long. Drift obscures the southern extension of the zone and a cut 15 feet deep did not reach bedrock. Although the fault persists beyond the northern extremity of the workings it is only sparsely mineralized.

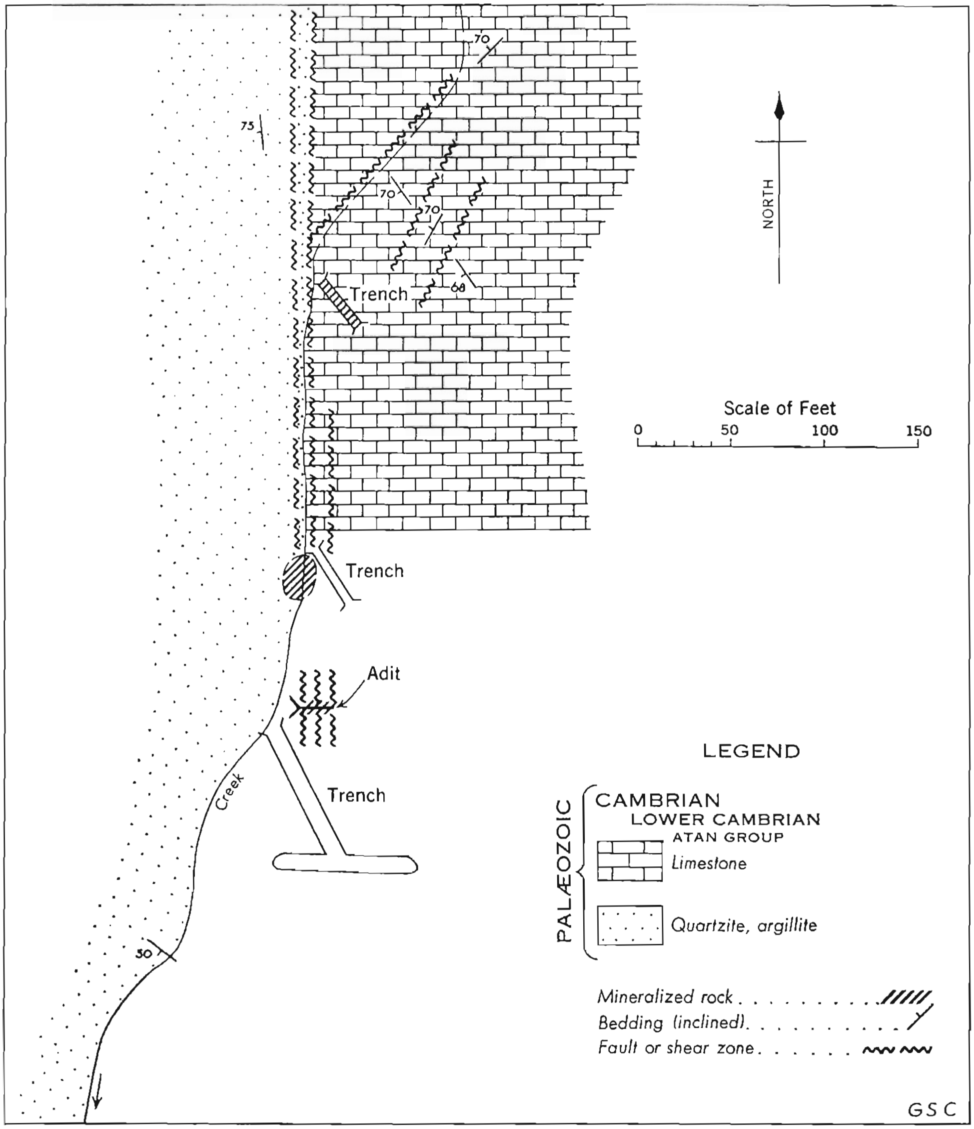

FIGURE 10. *Geological sketch-map of main showings on Reed claims.*

Medium- to coarse-grained sphalerite is the chief ore mineral. Fine-grained galena is dominant in several exposures and pyrite is widespread.

Mr. Reed reports that three grab samples assayed as follows:

	Gold (oz./ton)	Silver (oz./ton)	Lead %	Zinc %	Copper %
1.	0.02	9.5	5.86	11.94	0.07
2.	0.02	19.9	12.58	15.9	
3.	0.02	17.18	8.76	11.17	

Mount Haskin (8)

Reference: Derry, D. R.: Ann. Rept., Yukon Ranges Prospecting Syndicate, 1948.

Mount Haskin is about 4 miles north-northeast of the confluence of Hot Creek and McDame Creek (*see* Fig. 11). The area was staked in part by Yukon Ranges Prospecting Syndicate in the spring of 1948. The property had been staked originally about 40 years before this and was the centre of a promotion that collapsed with the death of the promoter, Haskins. Since 1948 two claims and a fraction have lapsed and were re-staked in 1954 by G. Hope of Quartzrock Creek and J. Thompson of Watson Lake. Three claims owned by Mr. Turner of Telegraph Creek and two claims owned by G. C. F. Dalziel of Watson Lake have been Crown-granted.

The mineralized rocks on Mount Haskin belong to the Atan Group. Light grey weathering granite porphyry, possibly a sill about 100 feet thick, underlies part of the northwest flank of the mountain. Argillaceous rocks near the porphyry have been metamorphosed to hornfels, and limestones have been metamorphosed to light grey skarn, chert, and cherty limestone. A pronounced fault striking northwest and dipping steeply trends through the top of the mountain and near the fault the rocks are contorted.

Mineralized rocks are restricted largely to the main fault and to the contact between quartzite and overlying grey limestone. A mineralized zone exposed in a steep gully on the northwest side of the mountain can be traced southeasterly for more than 1,000 feet to the crest of the mountain. The zone has a maximum width of about 25 feet at the head of the gulley.

Pyrrhotite and sphalerite are the most abundant sulphides, which also include galena, pyrite, and chalcopyrite. Oxidized material is widespread.

Hurricane Group (Vollaug Group) (9)

References: Mandy, J. T. Ann. Rept., B.C. Dept. of Mines, 1937, Part B; pp. B24-B34.
Bennett, J. H. Ann. Rept., B.C. Dept. of Mines, 1948, p. A61.

The Hurricane group on the crest of a mountain 2 miles south of McDame Lake, was originally staked as part of the Vollaug group in 1935 by John Vollaug and Hans Ericksen of McDame Creek. In 1936 the group was optioned by the Cassiar Syndicate which, in the same year, transferred its option to the Consolidated Mining and Smelting Company of Canada, Limited. The latter company dropped its option after carrying out extensive exploration in 1937. The claims were

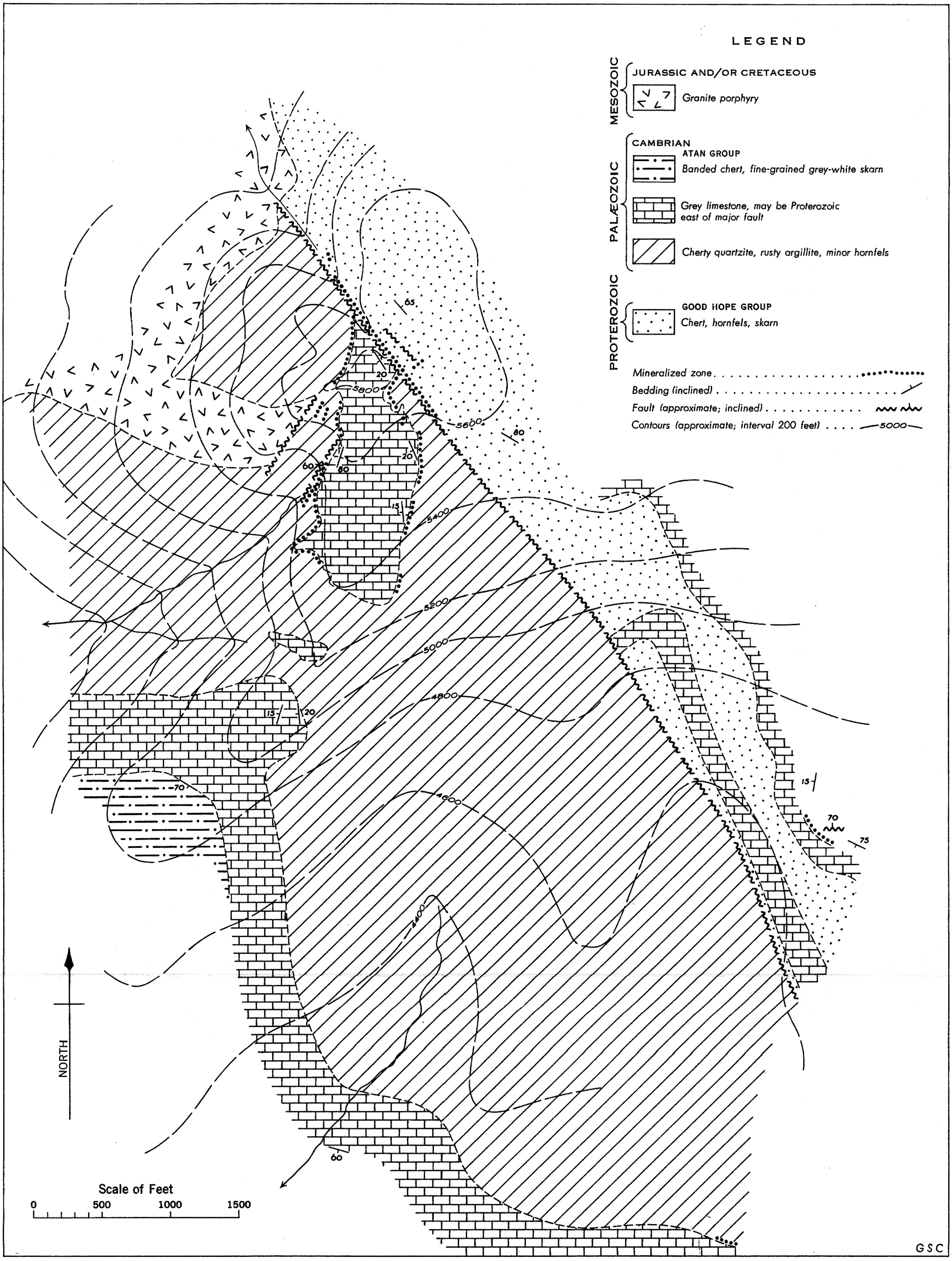

FIGURE 11. Geological sketch-map of part of Mount Haskin (after Derry, 1948)

re-staked as the Hurricane Group and in 1953 Silver Standard Mines Limited Crown-granted four of the claims. During the summer of 1954 a road was constructed from McDame Lake to the top of the mountain.

The area is underlain by greenstone, argillite, slate, tuff, greywacke, and quartzite of the Sylvester Group. The lower west, north, and east slopes of the mountain are underlain mainly by massive greenstone. Tuff, greywacke, and greenstone are exposed on the foot-wall or south side of the gold-quartz vein which has an average strike of N70°W and dips from 20° to 60°N. Slate, argillite, and impure limestone are exposed north of the vein. The vein is roughly concordant with overlying beds. Impure quartzite south of the vein, however, dips 20°S in one locality. Rocks near the deposit have been carbonatized.

Test pits, trenches, and stripped areas reveal the main quartz vein over a length of more than 3,000 feet. The width ranges from half a foot to 9½ feet and averages about 5 feet. The deposit is terminated to the west by a fault and disappears to the east under a heavy cover of drift. At least four north-northeasterly trending faults have dislocated the vein so that the west side has moved relatively north.

Unlike most of the quartz veins in the McDame Lake area, the Vollaug vein is distinctly ribboned parallel with its walls. The ribbons consist of black, graphitic argillite. In some places inclusions of sedimentary and volcanic rocks occur.

The quartz vein contains free gold, pyrite, chalcopyrite, tetrahedrite, galena, and azurite.

Gold-quartz Veins in Pooley Creek, McDame Lake, Troutline Creek and Quartzrock Creek Areas (10, 11, 12, 13, 14, 15)

References: Mandy, J. T. Ann. Rept., B.C. Dept. of Mines, 1935, pp. B12-B22.
ibid., 1937, pp. B34-B37.
Black, J. M. Ann. Rept., B.C. Dept. of Mines, 1947, pp. A70-A73.

Gold-quartz veins are abundant in greenstones in a zone roughly 5 miles wide extending from Pooley Creek to Quartzrock Creek. Although many separate properties have been explored they are treated collectively here because their mode of occurrence is similar. The groups and claims examined in this area are listed below and numbered from south to north.

10. Turmoil and Turmoil Extension Mineral Claims—staked by P. Hamlin of Lower Post between 1942 and 1946.

11. Gold Hill and Lakeshore claims—initially held by F. Crawford and associates of McDame Creek and optioned to the Consolidated Mining and Smelting Company of Canada, Limited in 1937. The claims were later held by P. Hankin of McDame Lake and are now held by S. Bridcut of Lower Post.

12. Nora claims—a group of four claims held by G. Davis of McDame Lake and W. Harper of Dawson Creek. A 5-ton mill was operated by Mr. Davis during the summer of 1951.

13. Cornucopia group—a group of seven claims staked by J. C. Simpson of Teslin in 1935 and sold in 1946 to Benroy Gold Mines, Limited. Trenching and diamond-drilling were carried out in 1946 but since then little work has been done on the property.

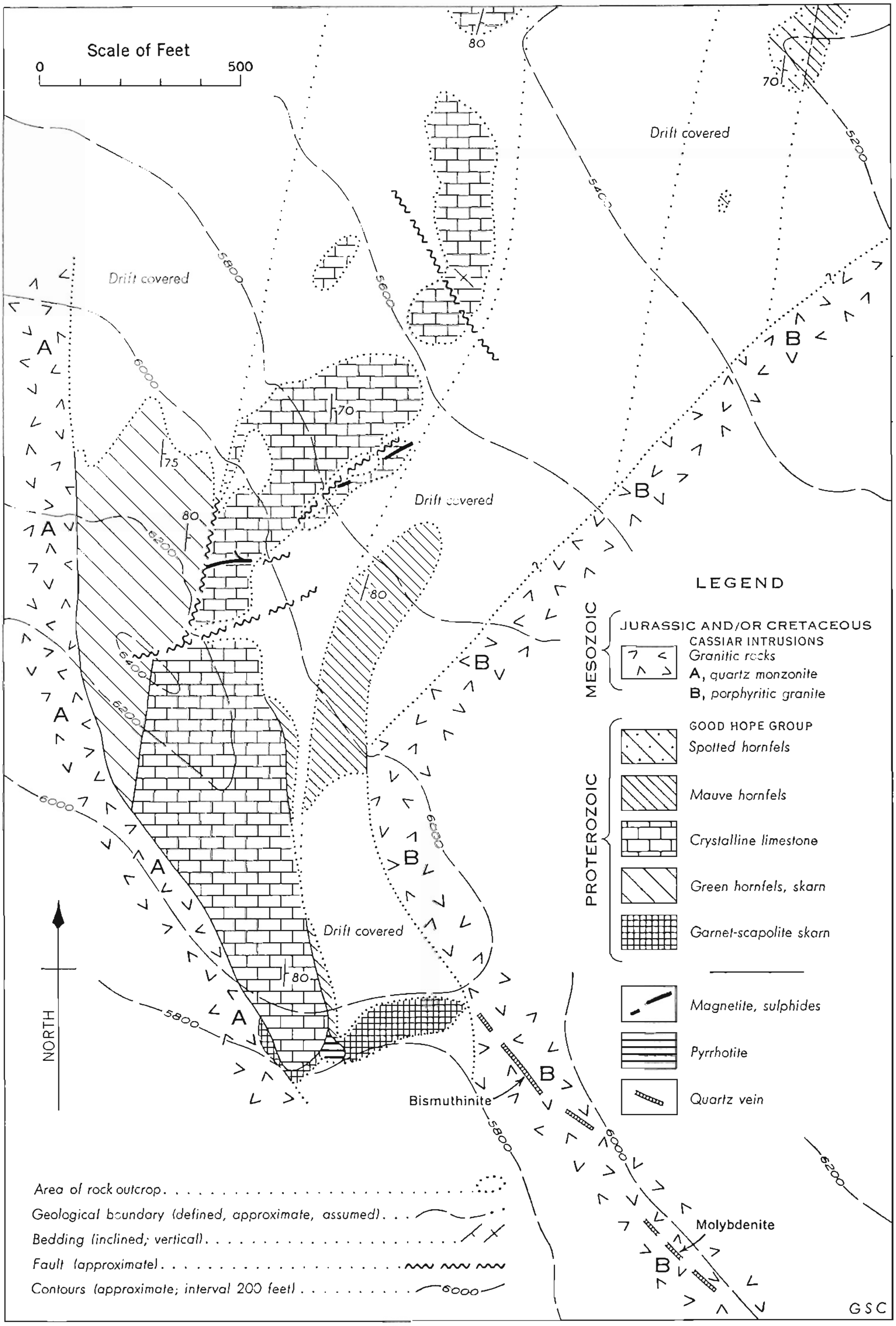

FIGURE 12. *Geological sketch-map of the Contact Group (after McDougall, 1954).*

14. Homestake, Lodestone, Bonanza No. 1, and Midge No. 3 claims—held by Cassiar Yukon Gold Mines, Limited.

15. Mac, High Grade, and Hopeful groups—held by J. G. Hope of Quartzrock Creek.

Gold-quartz veins on the properties listed above are controlled, for the most part, by joints in greenstone. Most of the veins strike northeasterly and dip steeply in accordance with the dominant joint trend. Veins on the Nora and Mac groups are restricted to places where movement along curved joint planes has produced openings.

Near the gold-bearing quartz veins the greenstones have been pyritized and carbonatized. On the other hand, barren, white, milky quartz veins show little, if any, contact effects. Gossan resulting from decomposition of pyrite, and buff weathering carbonate of the altered wall-rocks is therefore a good prospecting guide.

The greatest exposed concentration of quartz veins is in the canyon of Quartzrock Creek. Quartz veins in this area locally form from 30 to 60 per cent of the outcrop.

Free gold generally occurs in vugs near the margins of the quartz veins. Pyrite, tetrahedrite, chalcopyrite, sphalerite, azurite, and malachite are minor in amount but widespread. On the Nora claims free gold is largely restricted to the walls of the veins. One extremely vuggy quartz vein on the Cornucopia group has yielded some spectacular specimens of free gold.

Diamond drilling and other sampling methods have shown an erratic distribution of gold in these quartz veins. Without bulk sampling, therefore, it would be difficult to obtain an average value for most of the veins.

Contact Group (16)

Reference: McDougall, J. J. The Telescoped Silver-Lead-Zinc Deposits of the Contact Group Mineral Claims, McDame Map-Area, British Columbia; Masters thesis, Univ. British Columbia, 1954.

The Contact group, 2 miles north-northwest of Cassiar, was staked in the summer of 1951 by G. Davis of McDame Lake and W. Puritch of Grand Forks, British Columbia (*see* Fig. 12). In 1953 Harvest Queen Mill and Elevator Company, Plainview, Texas, obtained an option on the property, and in 1954 the company conducted a restricted diamond drill exploration program. No work was being done on the claims in the summer of 1954.

Most of the ore minerals on the Contact group are restricted to a screen of hornfels, skarn, and marmorized limestone between the Cassiar batholith to the west and a porphyritic granite stock to the east. Aplite, pegmatite, and basalt dykes are present in the contact zone.

The metamorphic rocks are a remnant of the easterly dipping limb of a syncline. In this area the beds strike northerly and dip steeply to the east. North of the property rocks are thrust easterly on fault planes that dip at low angles to the west. On the property a bedding-plane fault occurs at the base of the marmorized limestone member. Locally, the limestone is highly contorted.

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Three types of mineral deposits are present. In one type of deposit pyrite, bismuthinite, molybdenite, scheelite and cosalite occur in quartz veins that are restricted to the porphyritic granite. The veins strike northwesterly and dip easterly at low angles. One vein near the contact with metamorphic rocks contains crystals of pyrite, bismuthinite, and cosalite in drusy cavities in quartz. Bismite coats granite talus near the vein. Quartz veins along strike to the south contain molybdenite. Molybdite is present on weathered surfaces.

A second type of deposit occurs along the southern exposure of the marmorized limestone. There, an irregular body of pyrrhotite is associated with andradite-scapolite skarn. The pyrrhotite, largely altered to marcasite, contains minor chalcopyrite.

The third type consists of a complex association of metallic minerals in two veins in marmorized limestone that strike roughly east and dip 75° to 80°S. To the west, the upper vein stops abruptly at the bedding fault between marble and hornfels. About 100 feet to the east and 100 feet lower the vein passes under talus. Over this distance the vein averages between 3 and 4 feet in width. The lower vein strikes northeasterly and dips 70°S. In one exposure the vein is about a foot wide but its dimensions are generally obscured by talus.

The main vein is banded parallel with the walls and contains manganiferous magnetite, galena, sphalerite, and pyrite as chief constituents. Metallic minerals present in minor amounts are molybdenite, pyrrhotite, arsenopyrite, alabandite, chalcopyrite, tetrahedrite, dyscrasite, native antimony, bismuthinite, native silver, pyrargyrite, marcasite, and wad. The chief gangue minerals are calcite, quartz, and rhodonite. Dolomitization is the predominant wall-rock alteration.

Because of the inaccessibility of the upper and lower veins little exploratory work has been done. Diamond drill holes in sulphide-bearing talus 500 feet below the lower vein gave no information on the vein's continuity. It seems possible that the veins are largely restricted to the marmorized limestone member.

Marble Creek Claims (17)

Silver-lead-zinc deposits have been explored in the basin of Marble Creek about 2 miles south of Cassiar (*see* Fig. 13). The main showings are owned by R. Gamble of Toronto and were optioned to Cassiar Yukon Gold Mines, Limited, for development work in 1953. In that year a road was built to the property. In 1954 a bulldozer was used for stripping and 22½ tons of ore were shipped for tests.

The mineral deposits occur in marmorized limestone of the Atan Group. Bedding in this area strikes northerly and dips from 40° to 60°E, the dips being steepest near the Cassiar batholith.

Two mineralized areas have been delimited by stripping. One is an oxidized zone on the west side of Marble Creek basin which is about 375 feet long and ranges from 7 to 40 feet wide. The zone contains abundant manganiferous magnetite and minor irregularly distributed pods and seams of galena. Galena appears to occur with a yellow-brown oxide. Psilomelane pellets were noted in one exposure

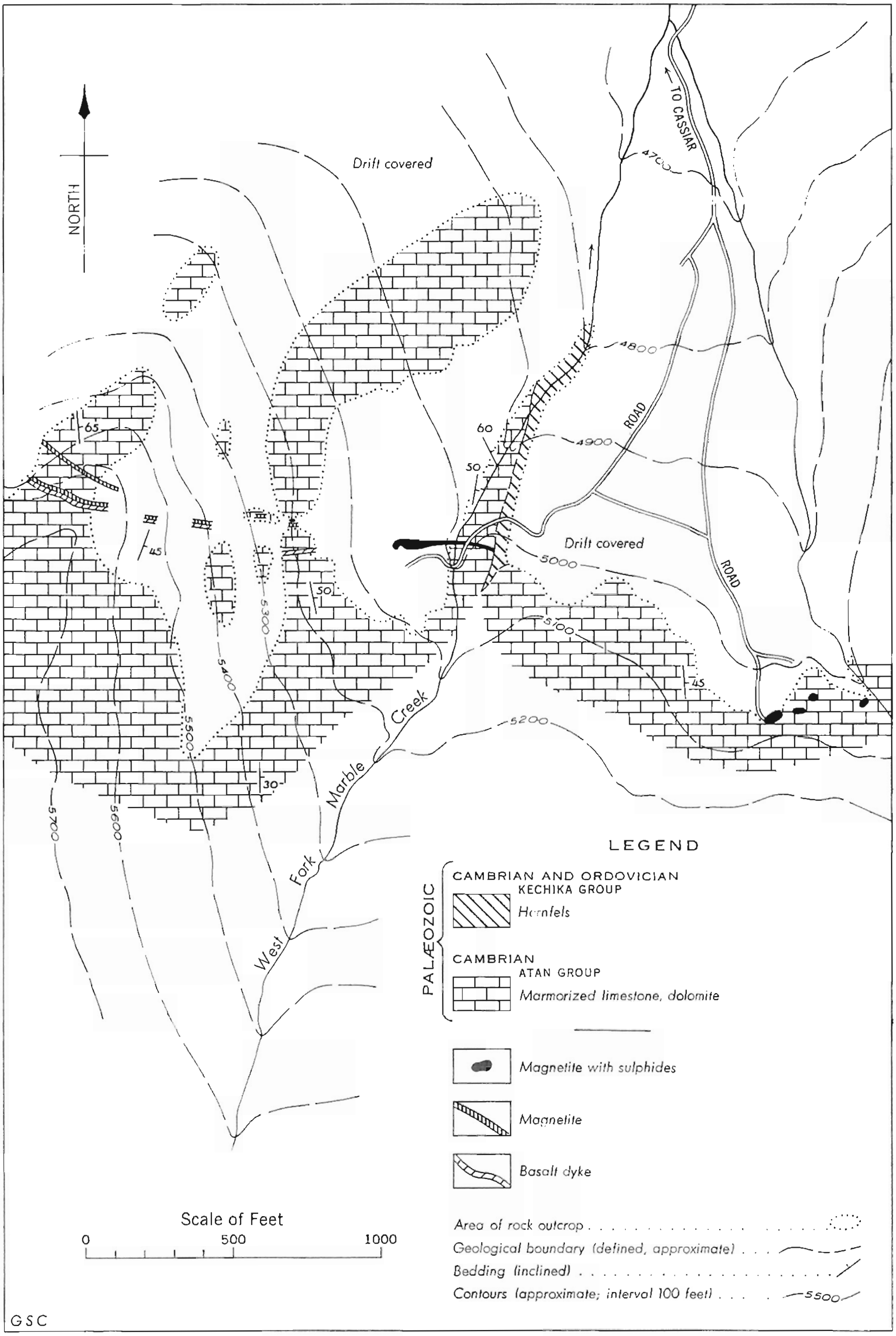

FIGURE 13. *Geological sketch-map of Marble Creek area.*

of unconsolidated material. At the western end of this mineralized area magnetite with minor amounts of galena is in contact with coarse-grained, translucent, crystalline limestone. To the east, the zone ends against hornfels. Oxide can be traced to the crest of the ridge west of the main showing but very little sulphide was noted in this area.

The east showing consists of at least four individual, irregular, oxidized areas containing magnetite, galena, sphalerite, pyrite, and chalcopyrite. Siderite and dolomite are common gangue minerals. Tremolitic carbonate rocks are host-rocks in this area.

The ridge at the head of the west fork of Marble Creek is underlain by dolomitized carbonate rocks in which magnetite is abundant. One oxide zone trends easterly along the ridge.

According to R. Wilms the shipment of 22½ tons of picked material assayed as follows:

Au (oz./ton)	Ag (oz./ton)	Pb (%)	Cu (%)	Zn (%)	Sb (%)	Mn (%)	Fe (%)
0.065	53.6	69.1	0.1	1.5	0.22	0.1	6.0

Low Grade Claims (18)

The Low Grade claims, located in 1954 by J. J. McDougall of St. Eugene Mining Corporation, Limited, are at an elevation of about 5,000 feet, 2 miles northeast of the confluence of Bass Creek and Cottonwood River.

The area is underlain by hornfels, crystalline limestone, skarn (tactite), and quartzite, which are metamorphosed equivalents of the Atan and Good Hope Groups, and by granitic rocks of the Cassiar batholith. Bedding in the metamorphic rocks strikes northwesterly and dips from 40° to 60°NE.

Helvite- and danalite-bearing tactite is localized along or near the contact of the granitic rocks with the metasedimentary rocks (mainly crystalline limestone in the immediate area). The tactite, composed of magnetite, dark green chlorite, dark reddish brown garnet, and minor fluorite and quartz, outcrops for about 300 feet along the contact and has a maximum width of about 40 feet near the west end of the deposit. The greatest concentration of beryllium minerals appears to occur in the central part of the widest exposure of this zone.

Mr. McDougall reports that a series of channel samples gave assays of less than 1 per cent BeO.

The significant feature of this deposit is that the beryllium minerals would almost certainly never have been recognized if an assay had not been made.

Non-Metallic Deposits

Coal (19)

Small, in part discontinuous, lenses and seams of coal occur in terrestrial deposits of Tertiary age along Rapid River. The reader is referred to the description of these deposits in the chapter on regional geology.

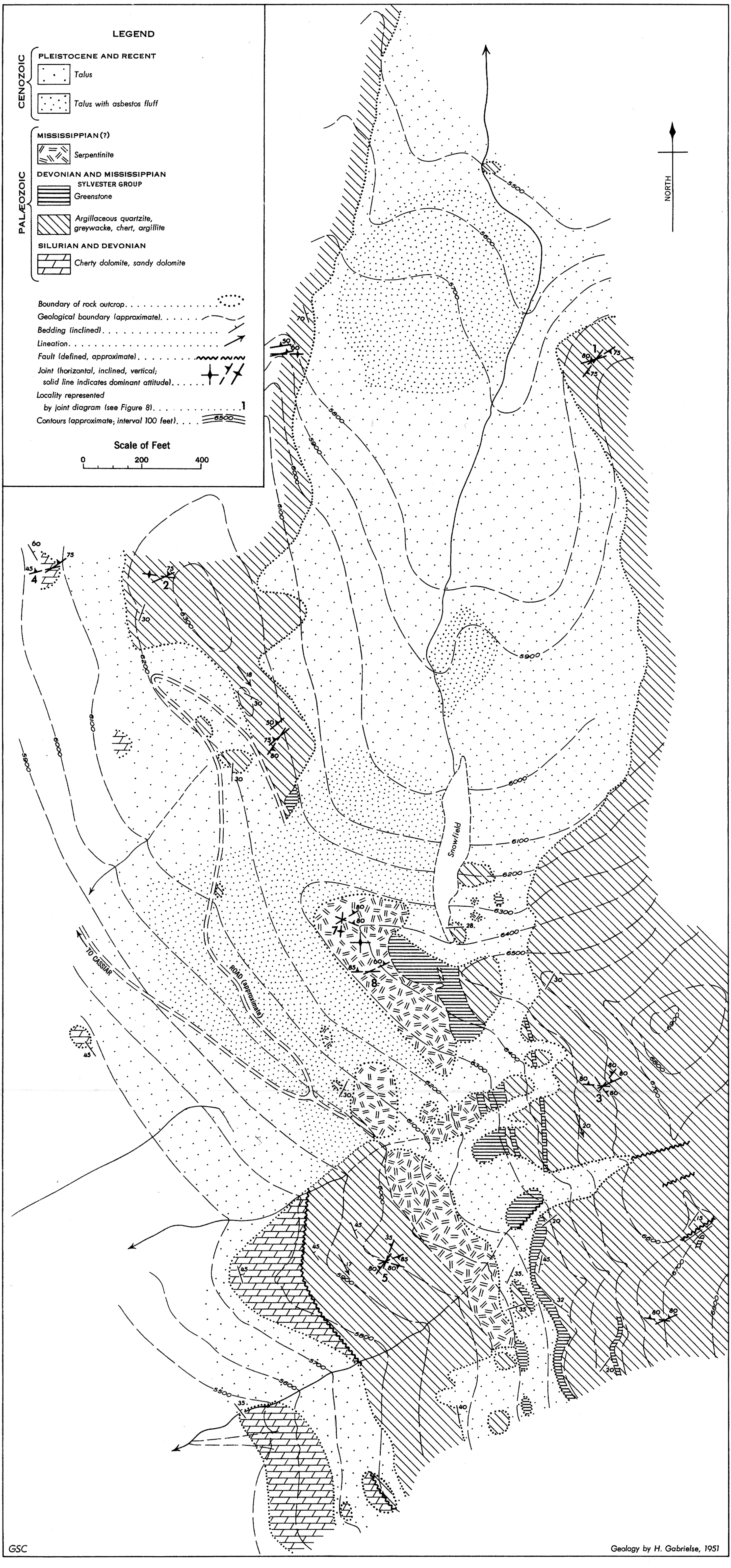

FIGURE 14. Geological sketch-map of Cassiar Asbestos property

Asbestos-Cassiar Asbestos Mine (20)

Reference: McCammon, J. W. Ann. Rept., B.C. Dept. of Mines, 1951, pp. A211-A214.

The Cassiar Asbestos property, on the northwest flank of Mount McDame about 3 miles north of Cassiar, was staked by Messrs. V. A. Sittler, R. L. Kirk, and H. H. Nelson of Fort Nelson, B.C. and R. W. Kirk of Lower Post, B.C. in July, 1950. The claims were optioned to Conwest Exploration Company in October, 1950 (*see* Fig. 14).

Near the mine the rocks comprise chert, argillite, argillaceous quartzite, greenstone, and greywacke of the Sylvester Group. These rocks lie just within the contact metamorphic aureole of granitic rocks exposed about 3,000 feet to the west. This is indicated by the texture and mineralogy of the greenstones (type 1 Sylvester greenstone) and by the texture of the serpentinite (includes metamorphic, feathery reticulated serpentinite).

Chrysotile asbestos veins at Cassiar occur in a mainly concordant, steeply dipping, lenticular serpentinite body that is intrusive into argillite, chert, quartzite, and greenstone. The ultramafic body has a maximum width of about 500 feet and a minimum length of 1,700 feet.

The host rock consists mainly of blocky, locally slickensided, light to dark green serpentinite containing scattered, glistening crystals of serpentine pseudomorphous after rhombic pyroxene. Magnetite is fairly abundant and occurs in microscopic veinlets or in veins as much as a quarter of an inch wide. The original rock was presumably a harzburgite.

Contacts between the ultramafic body and enclosing rocks are locally well exposed. Argillaceous rocks of the foot-wall are highly sheared, folded, and brecciated. Greenstones along the hanging-wall have been altered to light coloured, zoisite-quartz-tremolite hornfels. Adjacent to the tremolite hornfels, and gradational into it over an unknown width, is a zone of serpentinite that has been partly altered to fine-grained, dark green, chlorite-antigorite rock. This alteration zone forms an envelope around much of the central ore-bearing part of the body and contains little asbestos fibre. In places along the highly sheared foot-wall, however, high-grade fibre occurs adjacent to the country rocks.

Mineralogy of the Cassiar serpentinite body. Serpentines in the ore-bearing part of the Cassiar serpentinite body are mainly textural varieties of chrysotile and antigorite and are classified as follows:

1. Patchy antigorite; appears to be the most abundant serpentine in the host rock; invariably it is serpentine that borders asbestos veins; many include minor chrysotile (Pl. VII A).
2. Antigorite pseudomorphous after rhombic pyroxene; bastite.
3. Antigorite, feathery reticulated; a metamorphic serpentine; replaces mesh-structure serpentine and bastite; relatively minor (Pl. VII B).
4. Chrysotile; occurs as asbestos and perhaps as part of mesh-structure serpentine derived from olivine.

5. Chrysotile, fine-grained, banded; very minor at Cassiar; occurs in veins as much as half an inch wide; homogeneous and waxy in hand specimen.

Chemical analyses of specimens from the Cassiar serpentinite body are included in Table V.

Asbestos veins. In a general way the chrysotile-asbestos veins at Cassiar are similar to those in many of the asbestos deposits in the Eastern Townships of Quebec (Cooke, 1937; Riordon, 1955). The Cassiar serpentinite body has been highly fractured, much more so than any other ultramafic body examined in the area, and most, if not all, fractures in the ore-zone contain asbestos.

For the most part the veins, locally, have a systematic arrangement (Pl. VIII A; Figs. 8, 14). Some of the veins are parallel to joints in enclosing strata and elsewhere in the synclinorium (*see* Figs. 8, 9). These appear to be 'a-c' or cross-joints and related shear joints resulting from a northeast-southwest compression and attendant elongation parallel with the axis of the synclinorium. Flat-lying and gently dipping joints, many of which contain long-fibre asbestos, are apparently tensional joints related to relative movements during folding of strata enclosing the serpentinite body (*see* Fig. 7). The same stresses may have given rise to joints that are roughly parallel with the foot-wall of the body. In addition to the major joints, many joints appear to have resulted from relative movements of blocks bounded by joints. The result of the deformation was a complex set of fractures that formed loci for the deposition of chrysotile asbestos.

Most of the asbestos occurs in cross-fibre veins in which the chrysotile crystals are oriented at large angles to the walls. One or more partings are generally present in the veins and are emphasized by magnetite grains or stringers and serpentinite chips. The partings are mostly irregular, and more irregular in wider veins. On the other hand, the vein-walls are, in many cases, remarkably planar regardless of the width of vein. This characteristic implies that the partings probably do not represent initial fractures that formed the loci of replacement veins. Matching irregularities of vein-walls are sufficiently abundant to indicate that fracture-filling played a dominant role in ore deposition.

Individual veins may persist for as much as 10 or 15 feet but generally they are much shorter, particularly where the fractures are densely spaced. They split, branch, and terminate either by merging with veins running in other directions or by pinching out. Short veins without apparent connection to other veins are commonly lenticular.

The fibre is exceptional both for length and quality. Fibres ranging from half an inch to an inch in length are common. The milled product has a relatively low iron content although magnetite is fairly abundant in partings and along vein-walls. As is pointed out below, the low iron content of the asbestos may be due to the early accumulation of magnetite in fractures. Where cross-cutting relationships are present asbestos veins invariably cut magnetite veinlets.

Some veins show remarkable effects of post-vein shearing. Such deformation is most apparent near the foot-wall of the deposit. Off-setting of one vein by another, although not particularly common, points to deformation accompanying asbestos-formation.

In country rocks near the asbestos deposit, many steeply dipping veins and veinlets containing quartz, tremolite, zoisite, and carbonate have a cross-fibre structure identical with that of the asbestos veins (Pl. VIII B). Many veins display a banding parallel with the walls, similar to the wavy banding observed in fine-grained, banded chrysotile that borders asbestos veins in the partly altered dunites and peridotites elsewhere in the area. In both types, fine-grained banded material forms the margins of veins and coarse-grained material forms the central part.

Genesis of the chrysotile asbestos. Before the emplacement of the Cassiar batholith the Cassiar serpentinite body apparently consisted essentially of mesh-structure chrysotile, serpophite, and minor bastite. This mineral assemblage is typical of all small ultramafic bodies in the area remote from the batholith.

Restriction of asbestos veins to the serpentinite and the general similarity in composition of the veins and the host rock suggests that the vein material was derived from the host serpentinite and that the material had limited mobility. The following succession of events is postulated:

1. Folding and metamorphism of the serpentinite and enclosing rocks accompanied the emplacement of the Cassiar batholith. As a result the serpentinite body was complexly fractured and brought into a metamorphic environment perhaps equivalent to the upper part of the greenschist facies.

2. Recrystallization of the serpentinite and the diffusion of asbestos-forming material into areas of low rock pressure promoted the growth of chrysotile asbestos. The slightly increased concentration of aluminum in the host serpentinite (*see* Table V) possibly was an important factor in the formation of patchy antigorite (Bates and Mink, 1950). Recrystallization of serpophite probably resulted in a slight volume decrease, thus effectively increasing the volume of the low-pressure zones.

3. The growth of fibre in the single-fibre veins kept pace with the rate at which the walls moved apart. In the two-fibre veins the walls moved apart more rapidly than material could diffuse into the openings. Hence fibre grew from both walls in the direction of least pressure and finally met to form a central parting, the irregularity of which reflects the different rates of addition of material from place to place along the veins. Some of the pre-asbestos magnetite and serpentine chips from the walls of the fracture were pushed outward on top of the growing fibre and thus accumulated along the partings. In many places the remainder of the magnetite formed the base on which the fibre grew. This hypothesis would explain why the magnetite is loosely bound to the asbestos.

4. Simultaneous with asbestos-formation and under similar conditions the quartz-tremolite-zoisite-carbonate veins were formed in the country rock. The composition of fibrous materials in these veins simply reflects the composition of the rocks in which they occur.

5. Metamorphism along the margins of the asbestos deposit produced the chlorite-antigorite envelope. In places along the foot-wall later shearing brought high-grade fibre into juxtaposition with country rock.

No conclusive evidence was obtained to explain the origin of the delicately banded, fine-grained chrysotile that forms a few veins at Cassiar and almost invariably borders asbestos veins in partly serpentinized dunites and peridotites elsewhere in the area. The fine grain of the chrysotile may reflect a rapid nucleation of material that first diffused into the veins. If this was so at Cassiar, the fine-grained material was generally recrystallized at a later time. Perhaps the fine-grained chrysotile formed when the temperature was relatively low, probably during the waning stages of asbestos growth. This might explain why the material is most abundant in the ultramafic rocks occurring in the lowest grade metamorphic rocks. Except at Cassiar the delicately banded serpentine also occurs as microscopic veinlets in completely serpentinized rocks. It is noteworthy that in these rocks, also, the banded structure is commonly present along the entire length of fibres in macroscopic asbestos veins.

Summary

It is suggested that the following combination of conditions led to the localization of high-grade chrysotile asbestos at Cassiar:

1. Pervasive serpentinization of an ultramafic body resulting in mesh-structure serpentine, serpophite, and bastite.
2. Development of abundant fractures in the serpentinite body.
3. Recrystallization of the serpentinite during low-grade metamorphism, perhaps equivalent to the upper part of the greenschist facies.

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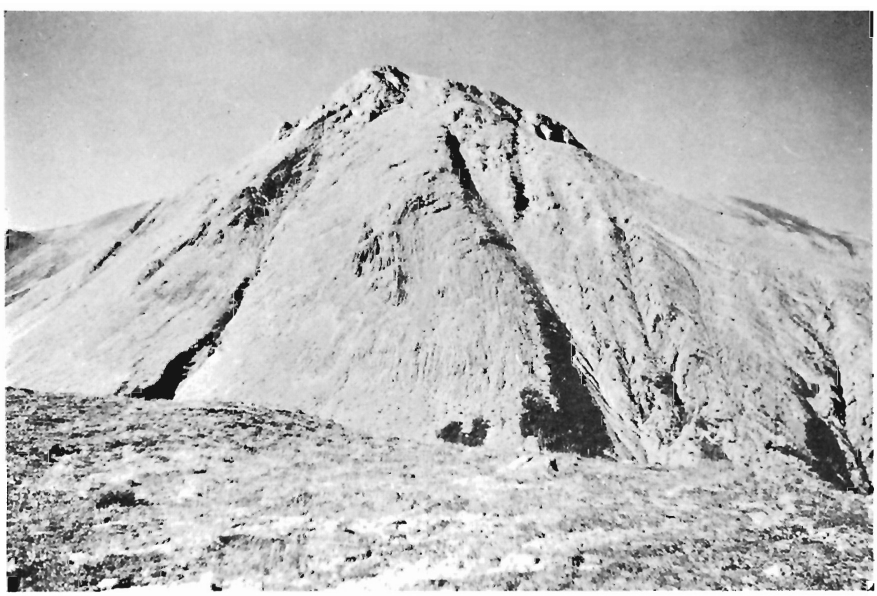
PLATES II TO VIII

PLATE II. *Ridges formed by crevasse-fillings on slightly grooved silt. On British Columbia-Yukon boundary about 6 miles west of Cassiar road.* (RCAF photo A10524-139)

110457

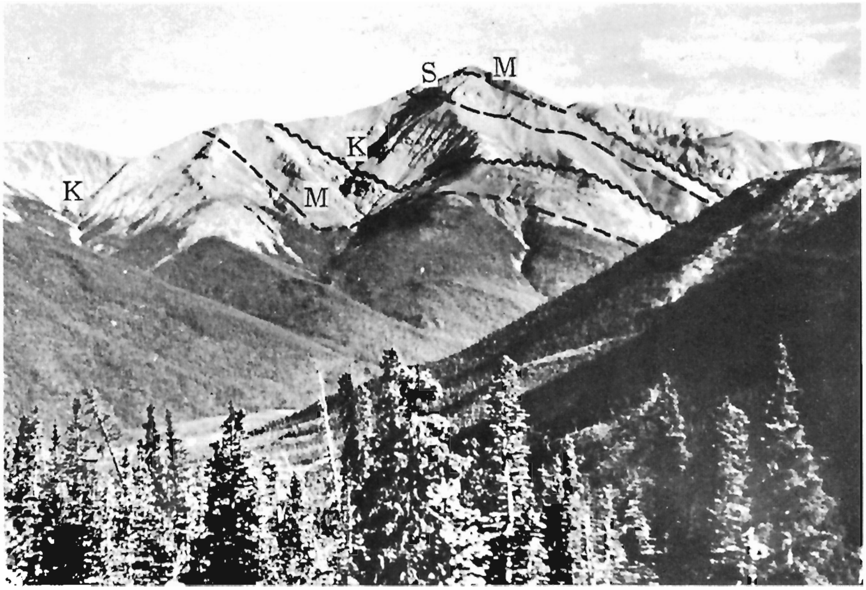
A. *View south-southeast over southwest end of Good Hope Lake to mountains underlain by Good Hope and Atan Groups. Note relatively heavy vegetation on quartzite member (A) of Atan Group.*

PLATE III



110458

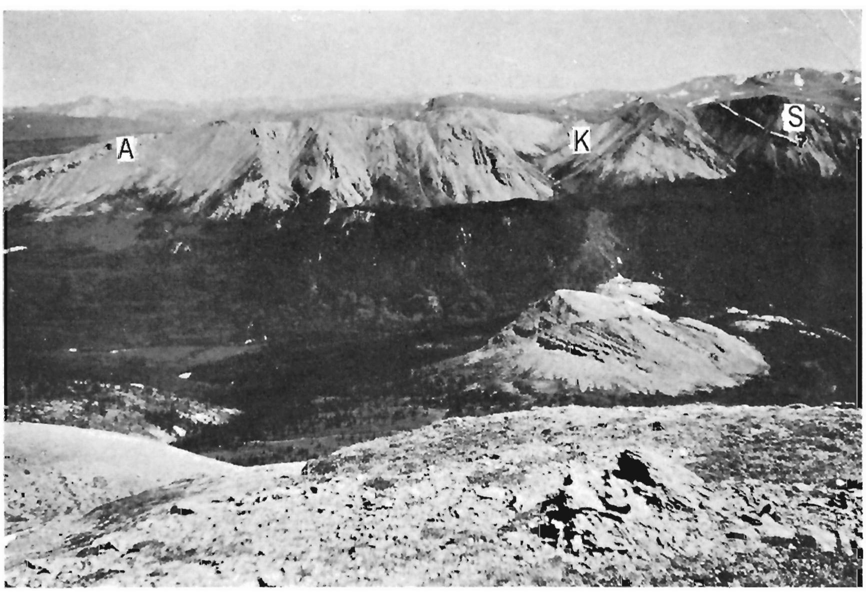
B. *Asymmetrical anticline in limestone, dolomite, and minor shale of Good Hope Group. Note asymmetrical chevron drag-folds on gently dipping limb. Looking northwest from ridge on northwest side of Good Hope Lake.*



110454

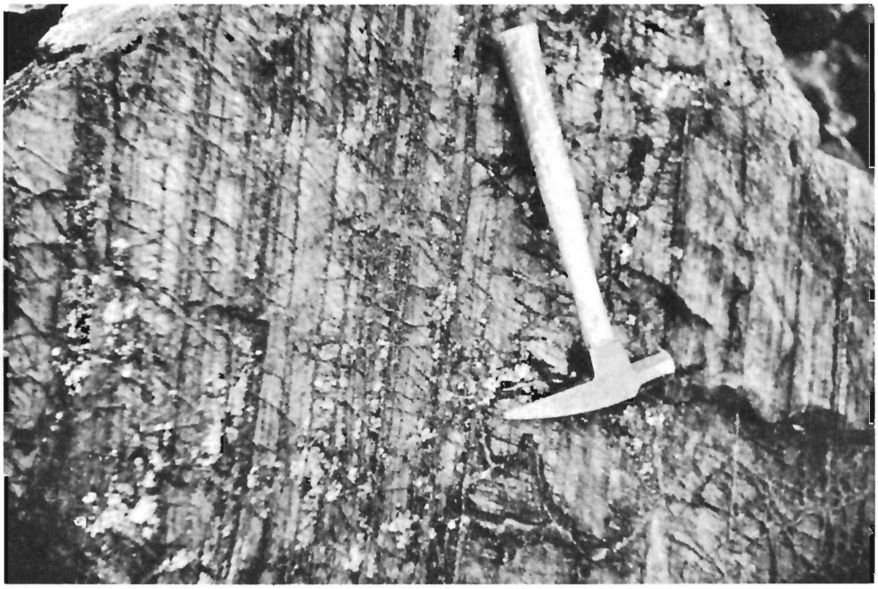
A. View south-southeast over Sandpile Creek. Dolomites of McDame Group (M) overlie unconformably Kechika Group (K) in sequence below southwesterly dipping thrust fault. In sequence above thrust fault dolomites of McDame Group (M) unconformably overlie strata of the Sandpile Group (S) that in turn overlie disconformably (?) Kechika Group (K).

PLATE IV



110455

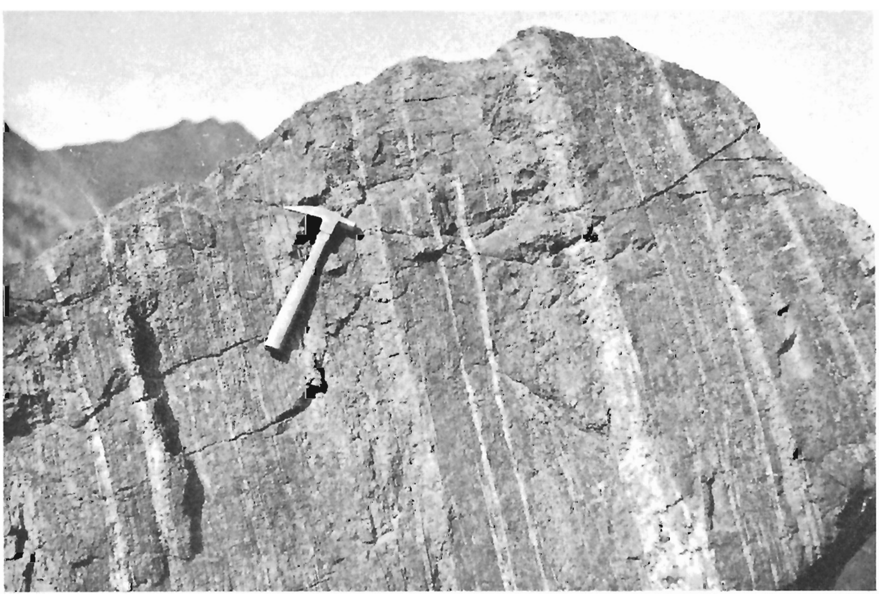
B. View southeast over Rapid River showing anticline in limestone member of Atan Group (A). Drag-folded rocks of Kechika Group (K) overlie Atan Group to the southwest and are in turn overlain by strata probably correlative to part of the Sandpile Group (S).



107072

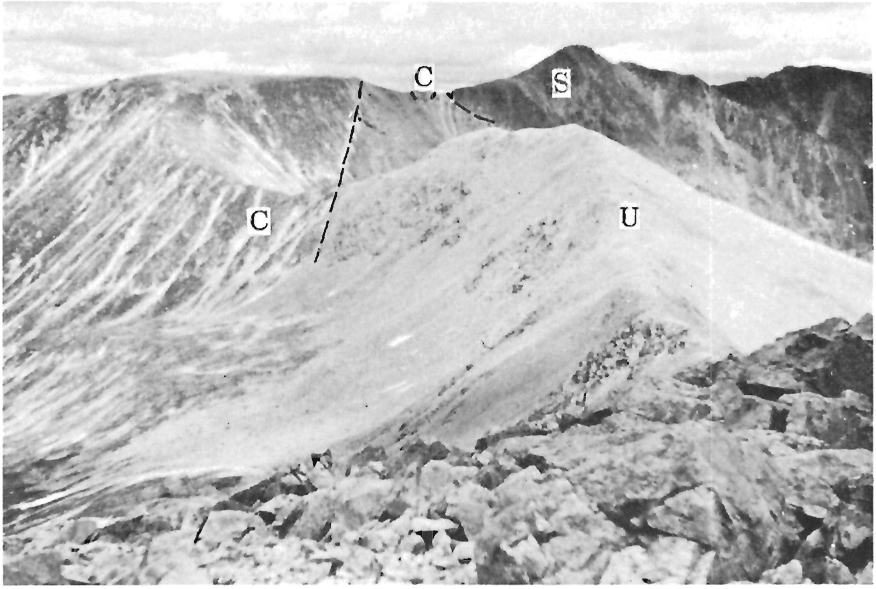
A. *Banding in peridotite east of Quartzrock Creek. The wider bands are composed mainly of olivine and the thinner, dark coloured bands are composed mainly of pyroxene.*

PLATE V



H.G. 4-6-1954

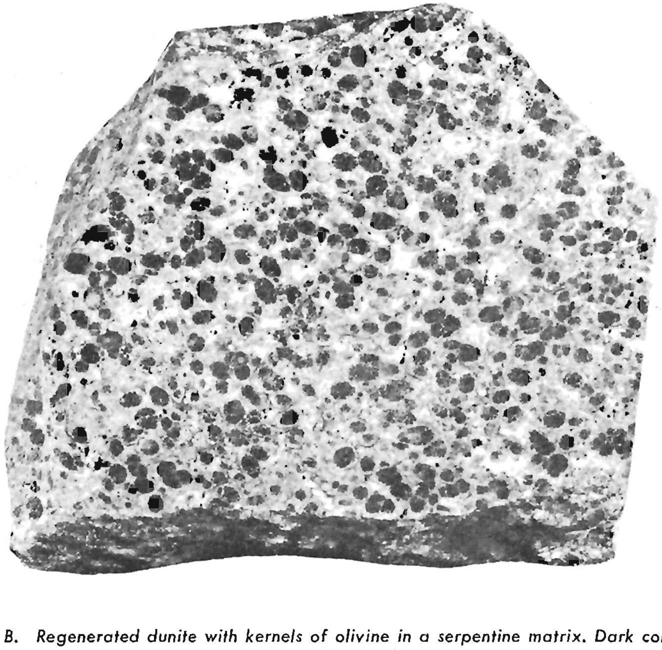
B. *Banding in ultramafic rock east of Quartzrock Creek. Dark coloured rock is peridotite and light coloured bands may represent altered feldspathic material.*



107073

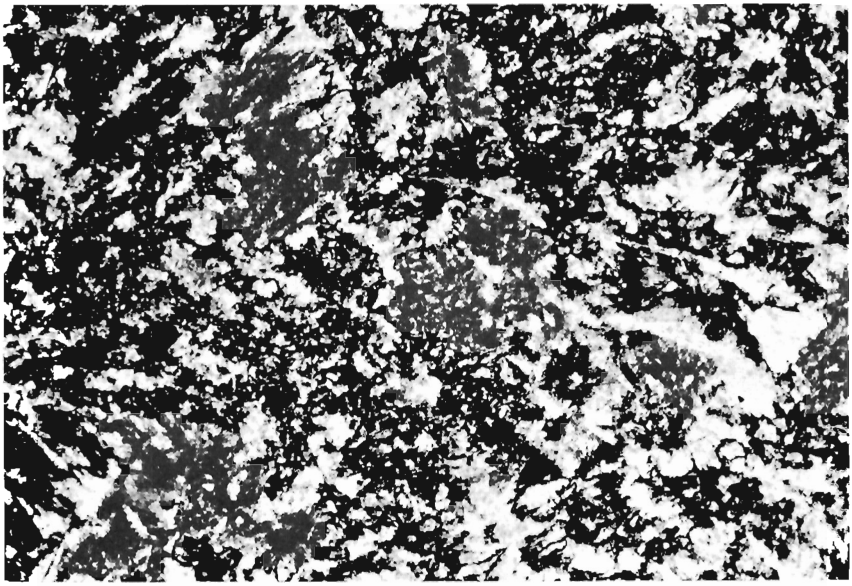
A. Contact between granitic rocks of Cassiar intrusions (C) and ultramafic rocks (U) northwest of Blue River. Peak in the background is underlain by metamorphosed Sylvester Group rocks (S).

PLATE VI



107269

B. Regenerated dunite with kernels of olivine in a serpentine matrix. Dark colour of olivine crystals is due to a high content of finely disseminated magnetite.



H.G. 6

A. Patchy serpentinite (mainly antigorite (?)) from Cassiar Asbestos serpentinite body. X78.

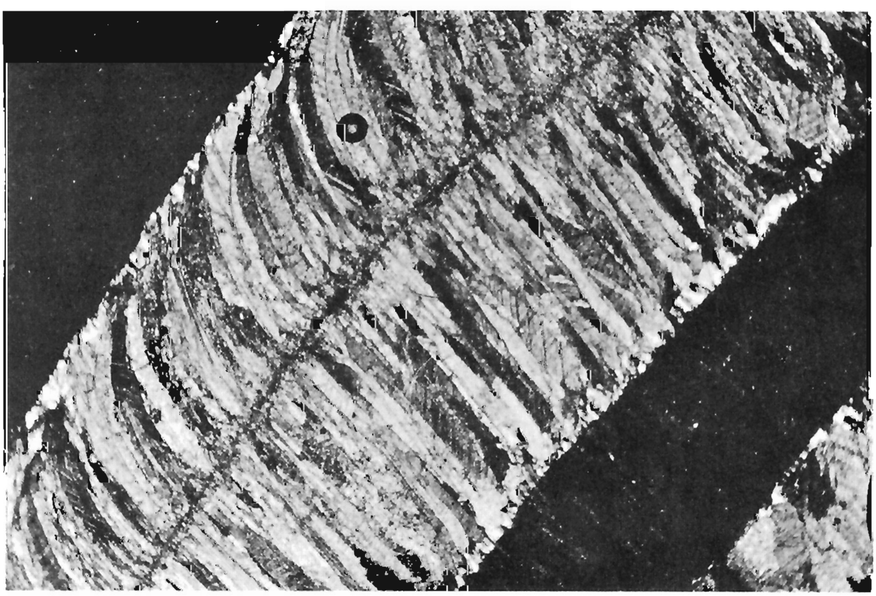
PLATE VII

H.G. 7

B. Feathery, reticulated serpentine (antigorite), Cassiar Asbestos property. X150.

A. Fracture pattern emphasized by asbestos veins on Cassiar Asbestos property.

PLATE VIII



H.G. 5

B. Asbestiform calcite forming vein in black, calcareous argillite. Note central parting. X20.

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