CANADA
DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
MEMOIR 279

OLDMAN RIVER MAP-AREA, SASKATCHEWAN

BY
Donald A. W. Blake

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1955

Price, 75 cents

No. 2520

View looking north over Kisiwak Lakes from the top of a cliff of amphibolite. Nevins Lake may be seen in the background. (Page 4.)

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PREFACE

Oldman River map-area is on the eastern margin of the Goldfields uranium district. It contains several structures and rock formations that extend northeastward from the better known uranium district to the west and is considered to be favourable for the occurrence of uranium minerals.

The metamorphic rocks are classified and described. Those along certain zones along major faults are similar in many details to the wall-rocks of producing uranium deposits to the west and the nature and origin of these are discussed in some detail. When the field work was done some occurrences of uranium-bearing minerals were already known and these are described.

The report is illustrated by figures, plates, and a coloured geological map on a scale of 1 inch to 1 mile.

GEORGE HANSON,
Director, Geological Survey of Canada

OTTAWA, November 4, 1954

Oldman River Map-Area, Saskatchewan

CHAPTER I

INTRODUCTION

GENERAL STATEMENT AND ACKNOWLEDGMENTS

The north shore of Lake Athabasca has been the scene of intensive prospecting since the restrictions pertaining to the search for uranium by private interests were repealed in 1948. The Geological Survey of Canada, in response to the demand for geological maps of the region, initiated a program of mapping on a scale of 1 inch equals 1 mile. This memoir summarizes the results of that part of this mapping program done by the writer in 1950 (10)[1] and 1951 (11). The geological problems of the map-area were the subject of a doctorate dissertation submitted by the writer to McGill University in 1952. W. E. Hale in 1953 assisted the writer in the preparation of this memoir from the manuscript of the dissertation.

Special thanks are due E. H. Kranck of McGill University for his friendly guidance and constructive criticism during the preparation of the doctorate dissertation. In the field work G. L. Colborne, R. A. Cormier, T. G. Wong, K. N. Beckie, and R. C. McKenzie rendered efficient service as geological assistants and P. Dallaire, J. Digby, and P. MacIntosh carried out their duties as canoemen in a satisfactory manner. The courteous and prompt service given by Saskatchewan Government Airways and McMurray Air Service is acknowledged with appreciation, also the many acts of kindness of A. MacIver, general merchant at Goldfields. A. M. Christie, formerly of the Geological Survey, gave many useful suggestions during the course of the work.

LOCATION AND ACCESSIBILITY

Oldman River map-area comprises about 390 square miles between longitudes 107°45′ and 108°15′, and latitude 59°45′ and the north shore of Lake Athabasca just north of latitude 60°30′. The area is about 12 miles east of Uranium City and about 20 miles west of the settlement of Fond du Lac.

Most points in the area are easily reached by air from Uranium City using the numerous lakes as landing fields for small aircraft on floats in summer and skis in winter. The southern part of the map-area may be reached by boats on Lake Athabasca, but travel on this lake is hazardous unless large freighter canoes or skiffs are used. Uranium City is connected by scheduled flights from Prince Albert, Saskatchewan (440 miles), Edmonton, Alberta (450 miles), and Fort McMurray, Alberta (215 miles). There are also regular flights from Uranium City to Fort Smith (125 miles) and Yellowknife (285 miles).

[1] Numbers in parentheses refer to Bibliography at the end of this chapter.

Within the map-area travel by canoe is best along chains of lakes, and well-marked portages have been cut where necessary. Oldman and Beaver Rivers, although obstructed in part by rapids and waterfalls, offer passage during the period of high water in the spring. Travel on foot across the parallel ridges is difficult but along and between these ridges walking is generally much easier.

HISTORY, EXPLORATION, AND TECHNICAL SURVEYS

Samuel Hearne, an employee of the Hudson's Bay Company, was the first explorer to travel extensively in northwestern Canada. He passed within 70 miles of the north shore of Lake Athabasca on his return journey from the mouth of Coppermine River to Fort Churchill in 1771. Peter Pond, a famous Montreal trader, was the first white man to reach the lake. He established a fort at the mouth of Athabasca River in 1778 and from it made several exploratory excursions. Alexander MacKenzie replaced Peter Pond in 1787 and became the first representative of the newly formed Northwest Company. MacKenzie's brother Roderick established Fort Chipewyan in 1788 while Alexander prepared for a journey down the river that now bears his name. The latter reached the Arctic Ocean in 1789. The Hudson's Bay Company began trading in the region in 1815 and 6 years later the two rival companies were united. At present there are four Hudson's Bay Company trading posts on Lake Athabasca.

Survey work was begun in 1790 when Philip Turner mapped the north shore of the lake. His work was continued to the east the following year by David Thompson. A century later, in 1892-93, J. B. Tyrrell and his assistant (51) surveyed both the north and south shores of Lake Athabasca. A transit and stadia survey of the lake shore was made by Haultain and MacKay in 1914-15. By 1935 the Topographical Survey had issued a series of sheets, compiled from oblique air photographs, on a scale of 1 inch to 4 miles, that cover the part of Saskatchewan between Lake Athabasca and the Northwest Territories. The region was vertically photographed in 1948 and accurate topographic maps of a large part of this region are published on a scale of 1 inch to 1 mile.

A. S. Cochrane did the first geological work in the region when he made his canoe trip from Saskatchewan River to Lake Athabasca. The records of his scientific observations, however, were lost.

R. G. McConnell (40) surveyed the west half of the south shore of Lake Athabasca in 1888 and named the clastic formation he found there the Athabasca sandstone. J. B. Tyrrell and D. B. Dowling in 1892-93 made long reconnaissance traverses along the shores of Lake Athabasca and along rivers east and southeast of that lake. In 1914 Charles Camsell (14) traversed the hitherto unknown region between Black Bay on Lake Athabasca and Great Slave Lake. F. J. Alcock, in 1914 and 1916, geologically explored the north shore of Lake Athabasca (1), and in 1922 J. A. Allan and A. E. Cameron (4) investigated an iron deposit east of Lodge Bay near Goldfields.

The discovery of gold near Lodge Bay in 1934 resulted in a staking rush and the establishment of the now-abandoned town of Goldfields. In response to the ensuing demand for geological information F. J. Alcock (2) of the Geological Survey mapped the area near the gold occurrences on a scale of 1 inch equals 1 mile. Concurrently Alcock supervised mapping on a scale of 1 inch equals 4 miles along a large part of the north shore of Lake Athabasca from the Alberta boundary to Stony Rapids, and from Lake Athabasca to the northern boundary of the province. Exploration during the interval 1934-36 resulted in the Box mine of The Consolidated Mining and Smelting Company Limited of Canada and the Athona mine of Athona Mines Limited, both near Lodge Bay. These mines ceased production in 1942.

The great demand for uranium near the end of World War II (1939-45) prompted a joint examination of the Nicholson property, about 2 miles east of Goldfields, by officers of the Crown company Eldorado Mining and Refining (1944) Limited and the Geological Survey of Canada. Radioactive material had been reported from this property in 1935 (2). The Crown company expanded and intensified its search for uranium deposits and by 1948 was developing, north of Beaverlodge Lake, what now appears to be major deposits of uranium ore. Government restrictions on prospecting for uranium were relaxed in 1948 and a second staking rush began; as a result, Goldfields again became a boom town and was for several years the organization point for prospecting parties. In 1951, however, a new town site near the important deposits was established at Uranium City.

During this second boom, part of the region of known uranium occurrences was mapped on a scale of 1 inch to 1 mile or greater detail by officers of the Geological Survey. A. W. Jolliffe and A. M. Christie (15, 16) mapped the geology of Goldfields map-area in 1945-46 and in 1947-48 Christie (16) continued this mapping to include Martin Lake map-area. Christie's work was continued eastward by the writer in 1950 (10) to include Forget Lake map-area and in 1951 (11) to include Nevins Lake map-area, both of which have been included to form the subject of the present report and accompanying map (Oldman River map-area). W. E. Hale mapped Black Bay map-area to the west of Christie's work in 1951-52 (30) and Gulo Lake map-area in 1953 (31). A. J. Fraser mapped Crackingstone Point map-area in 1953 (25). To the end of 1953, an area roughly 54 miles wide and extending inland from the north shore of Lake Athabasca to latitude 59°45′ has been mapped geologically on a scale of 1 inch equals 1 mile.

TOPOGRAPHY

The present landscape of the region north of Lake Athabasca closely resembles that of pre-Glacial times. Except for rounding the hilltops and leaving local concentrations of glacial deposits, the advances and retreats of the Pleistocene ice-sheets have had little effect on the general appearance of the hills and valleys and only a slightly greater effect on the drainage pattern. This region is one of closely spaced ridges and valleys between which broad upland surfaces and low-lying tracts are rare. The summit levels are approximately concordant, but their elevations decrease southward from a divide that extends across the map-area just south of its northern boundary. The local relief is in the order of 100 or 200 feet in the divide area and near the shore of Lake Athabasca. However, 8 or 10 miles inland from the lakeshore where the local relief is greatest, hills, many bounded on one side by prominent cliffs, rise several hundred feet above the valley floors. At Kisiwak Lakes the tops of some hills (*See* Plate I) are about 700 feet above the level of Lake Athabasca, which is 699 feet above sea-level.

The ridges and valleys of the map-area parallel the structural trends of the highly folded, metamorphic rocks, and those depressions that cross the structural trends mark the sites of faults and fracture zones. Bands of highly fractured quartzite have been eroded and are thus covered by drift along the bottoms of valleys or exposed along the walls of valleys. Amphibolite, on the other hand, has been particularly resistant to erosion and, consequently, forms many of the most prominent ridges. Where it overlies quartzite an abrupt cliff invariably marks the contact. Granite, paragneiss, and migmatite presented a variable resistance to erosion. The ease with which lamprophyre dykes are eroded has resulted in miniature canyon-like depressions, which in many cases may be traced on air photographs for thousands of feet. The region has entered a stage in the regional erosion cycle having a maximum diversity of relief and only scattered remnants of the original plateau surface.

Stream patterns have been little changed by glaciation but stream profiles have been greatly disturbed. Lakes and stretches of streams meandering on flat surfaces of glacial outwash are separated by boulder rapids and waterfalls. In pre-glacial times, most if not all of the streams were youthful as there is no evidence of continuous valley flats.

GLACIAL FEATURES

The erosive action of the Pleistocene glaciers that spread southwestward over the region smoothed the topography, but apparently nowhere removed great quantities of rock. Hills have been rounded and depressions deepened (later to form rock-margined lakes) and fresh unweathered rock has been exposed. The occurrence, however, of gossans of pre-Glacial age suggests shallow glacial erosion along some valleys. The retreat of the final ice-sheet left ablation deposits that are now represented by scattered boulders resting on glaciated surfaces along the tops of hills and as thicker deposits of boulders and sand in many of the depressions and valley bottoms. Partly eroded glacial deposits form sand plains in some low-lying tracts of land. Because the sand of such plains is well stratified and crossbedded it probably was deposited as a delta. Eskers occur in a few of the valley bottoms. An esker west of Forget Lake is typical of those in the area. It is a narrow sinuous ridge composed of coarsely bedded sand and gravel that follows first one side and then the other of the flat bottom of a major valley. Short tributary eskers that trend nearly parallel with the main esker join it at intervals and the whole passes southward into a sand plain.

The water of Lake Athabasca stood at a considerably higher level after the withdrawal of the last ice-sheet than at present. Strand lines at several localities along the north shore, and others suggested by a study of air photographs of the country far inland from the south shore, indicate post-Glacial beaches. Christie gives 100 feet as a minimum figure for the former high level of Lake Athabasca. The north coast of the present Lake Athabasca exhibits characteristics typical of a drowned shoreline, suggesting that the lake was smaller in size before the last ice-sheet advanced than at present.

Since the glacial period the rivers of the area have made little progress in reaching grade. Lakes remain dammed by glacial deposits, and boulders are abundant in some rapids.

Slabs of buff weathering, finely bedded, quartzitic sandstone occur among the glacially transported boulders in many parts of the southeast corner of the map-area. The sandstone of these slabs resembles closely Athabasca sandstone that outcrops in Martin Lake map-area to the west and also that observed by the writer at Poplar Point on the south shore of Lake Athabasca. These sandstone slabs perhaps originated from an unknown area northeast of Nevins Lake underlain by sandstone resembling the Athabasca sandstone of other areas. The angularity of most of the slabs and their limited distribution in one part of the map-area suggest a nearby source. It is possible, however, that the slabs came from sandstone exposed over a large area in Keewatin District and some 200 miles northeast of Nevins Lake.

CLIMATE

The Lake Athabasca region has a typical continental subarctic climate.

The ice of Lake Athabasca generally breaks up early in June, but cool weather with temperatures only slightly above the freezing point persist until the middle of the month. The latter part of June, all of July, and the first part of August are characterized by spells of hot, humid weather when temperatures often exceed 80°F. at midday. As the nights lengthen in August, however, they become cooler with frost several nights during the last half of August 1950. The rainfall is light, consisting mainly of local thunder showers during hot days. Commonly there are only 2 or 3 days of heavy rain each summer. The small lakes freeze in October and the main lakes in December. The winters are long and cold, and during December and January the daily daylight period is only a few hours long.

FLORA AND FAUNA

The warm weather and long days of summer favour the growth of heavy stands of spruce in sheltered valleys. Elsewhere the forest is sparse and consists mainly of black and white spruce, poplar, birch, and Banksian pine. The pine grows to a considerable size on sand plains to form park-like areas. The rocky ridges and upland surfaces, although nearly bare of trees, support a profusion of flowers, mosses, and lichens. Many low areas, some of the lake shores, and parts of valleys are occupied by treeless muskeg. Bedrock is exposed in over 50 per cent of the southern half of the area, but in some parts of the northern half drift is widespread and rock outcrops form about 10 per cent of the surface.

Game is not plentiful. However, moose, black bear, and wolves are encountered here and there and during the spring and autumn migrating caribou pass in huge herds. Fur-bearing animals include fox, beaver, marten, wolverine, muskrat, and skunk. Lake trout, white fish, pike, Arctic grayling, and other fish thrive in great numbers in both Lake Athabasca and inland lakes, and form an important part of the diet of the several hundred native inhabitants and their sleigh dogs. Black flies and mosquitoes are numerous during the first half of the summer.

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CHAPTER II

GENERAL GEOLOGY

GENERAL STATEMENT

The oldest rocks in the area, the Tazin group (14, 16), consist of quartzite, migmatite, paragneiss, amphibolite, and related rock. They are regionally metamorphosed equivalents of geosynclinal sedimentary rocks and gabbroic sills. Mountain building accompanied metamorphism, and during the final stage the metamorphosed rocks were invaded by conformable sheets and masses of granite. Dykes of quartz monzonite and minnette-vogesite lamprophyre followed the intrusion of the granite, to which they are probably genetically related. This period of orogeny ended with thrust faulting from the southeast and the rocks locally were mylonitized. In late Precambrian time clastic sediments, the Athabasca series, were deposited in tectonic basins and are expressed west of the map-area. A second period of orogeny post-Athabasca series in age was, in Oldman River map-area, represented by normal faulting and the intrusion of diabase dykes.

TABLE OF FORMATIONS

Age	Formation	Description
Proterozoic		Diabase dykes
Archæan or Proterozoic	Intrusive contact	
		Lamprophyre dykes
	Intrusive contact	
		Reddish, porphyritic, gneissic quartz monzonite dykes Pink, grey, or white, generally medium-grained and gneissic granite, granite-gneiss, and pegmatite
	Intrusive contact	
	Tazin group	Amphibolite, pyroxene-bearing amphibolite, and other mafic rocks[1] Norite Hornblende gabbro Homogeneous, coarse-grained, gneissic, grey to pink paragneiss Layered, gneissic, generally reddish, medium- to coarse-grained migmatite and related rocks White, grey, reddish, fine- to coarse-grained quartzite, impure quartzite, garnetiferous quartzite, and iron-formation

[1] Age relations of some bodies with members of the Tazin group uncertain and mode of origin of others unknown.

TAZIN GROUP

Introductory Statement

The term 'Tazin Series' was first applied by Camsell (14) to metamorphic rocks examined by him along the canoe route from Camsell Portage on the north shore of Lake Athabasca, down Tazin and Taltson Rivers to Great Slave Lake. Alcock (2) used 'group' rather than 'series' because he considered possibly more than one series was included. The Tazin group rocks along the north shore of Lake Athabasca are described by Alcock (2) and in general terms are referred to by him as dominantly sedimentary strata with a few flows of ellipsoidal lava. Carbonate rocks, quartzite, argillite, and conglomerate are the common members of the group and garnetiferous mica schists and gneisses are apparently metamorphosed equivalents of them. Christie (16) included in the Tazin group the Beaverlodge series originally defined by Alcock (2) as overlying the Tazin group. In addition to the rocks referred to by Alcock, Christie added 'mafic rocks', including several types having different compositions and probable origins. The writer has placed the mafic rocks as amphibolites and norite in units at the right side of the map-legend indicating some uncertainty locally regarding their origin and relation to members of the Tazin group.

In Oldman River map-area the writer has attempted to separate metamorphosed sedimentary rocks of approximately granitic composition from rocks of granitic composition that appear to have been formed as a result of the intrusion of igneous material. Thus the main difference in the writer's conclusions regarding the Tazin group, as compared with the results of earlier work, is that a large part of the rocks hitherto referred to as granite-gneiss or similarly designated are considered altered members of the Tazin group.

Quartzite, Impure Quartzite, and Garnetiferous Quartzite

The writer has, as a rule, mapped as quartzite only those beds that contain more than 70 per cent quartz. Quartzitic and related Tazin rocks with less than this amount of quartz have been mapped chiefly as paragneiss and migmatite.

The proportion of quartzite to other rocks of the Tazin group increases toward the west. More quartzite has been outlined in the west half than in the east half of Oldman River map-area, and Christie (16) has mapped a still larger amount in Goldfields and Martin Lake map-areas adjoining to the west.

The quartzite, in general, varies from pure white to grey, pink, red, and purple and from fine to coarse grained. A pronounced greasy lustre on both fresh and weathered surfaces is typical. Banding that represents bedding is commonly vague or absent, but where biotite is an important impurity it is generally oriented parallel with the bedding planes and thus makes them more obvious. The quartz has been completely recrystallized to form an intergrowth fabric and the individual strained grains are both dimensionally and optically oriented. In addition to biotite, the most abundant and widespread impurity, chlorite, garnet, feldspar (usually oligoclase), pyroxene, magnetite, graphite, sericite, and sillimanite occur in various amounts.

There are local differences in the quartzite of the map-area. On the basis of general similarity, however, these rocks are referred to three broad zones, as follows: (1) the southwest quarter of the map-area; (2) the area that includes MacRae, Forget, and Dyke Lakes; and (3) the narrow zone extending southeast from Alces Lake to Nevins Lake and thence to the southeast corner of the map-area.

In the southwest quarter of the map-area the quartzite is white to grey, medium grained to coarse grained, and locally stained by hematite along fractures. The purer varieties of quartzite commonly grade upward and downward into impurer varieties of metamorphosed sedimentary rocks. Banding varies from poor to well defined and in one place, near Mackintosh Bay, the bedding is so well preserved that ripple-marks can be identified. Garnet generally is present in these quartzites and locally constitutes as much as 50 per cent of the bulk of the rock. The garnets vary greatly in size and at Hayter Bay they average over 1 inch across.

Pure varieties of quartzite are composed almost entirely of interlocking, slightly elongated grains of quartz that commonly show marked undulatory extinction. The original sedimentary grains have been obliterated by recrystallization. Inclusions within the quartz grains are poorly arranged in trains. Biotite, chlorite, and carbonate make up as much as 5 per cent of the rock and are commonly confined to individual layers.

Impure varieties of quartzite contain, in addition to quartz, plagioclase, microcline, biotite, garnet, chlorite, sericite, and graphite. The amount of feldspar (An_{15} and microcline) and biotite together equal the amount of quartz in one specimen of impure quartzite from Mackintosh Bay. Graphite is present in some impure quartzitic rocks near Hayter Bay.

The bands of quartzite that outcrop in the southwest quarter of the map-area appear to have been part of a continuous body of sediments, remnants of which have been partly preserved from erosion in southerly plunging folds.

The quartzitic rocks in the area that includes MacRae, Forget, and Dyke Lakes are similar to those described above but nearly pure varieties are rare; pyroxene is more abundant and drag-folds more characteristic.

Sillimanite occurs as small augen and rod-shaped grains that are parallel with each other and evenly distributed throughout one specimen of quartzite from MacRae Lake. A specimen of pyroxene-bearing quartzite, also from MacRae Lake, is composed of 90 per cent quartz, 8 per cent pyroxene, and 2 per cent feldspar. In it quartz grains are orientated so that each has one of three extinction positions the same. Sutured boundaries, undulatory extinction, and planes of inclusions are characteristically well marked. Stubby prisms of diopside are scattered at random through the rock and are nearly completely altered to chlorite and carbonate. Iron oxide (probably magnetite) occurs in the pyroxene as poorly defined schiller inclusions. A few rounded grains of altered feldspar, of which at least some are microcline, are present.

Small diopside crystals are common in the quartzites near MacRae Lake but were found in abundance only at one locality on the south shore. There a band 4 feet thick is composed mainly of large diopside crystals set in a medium-grained matrix of calcite and diopside to the complete exclusion of quartz.

The quartzite that extends from Alces Lake southeastward to Adair and Narrow Bays on Lake Athabasca is characterized by less variation in lithology than the quartzites about MacRae, Forget, and Dyke Lakes. In many places, however, bands and lenticular bodies of pyroxene-bearing amphibolite and small bodies composed almost entirely of diopside occur within the Alces Lake zone.

The rock of the largest band of quartzite east of Nevins Lake probably is typical of that of most of the quartzite in the east half of the map-area. A specimen is composed of 92 per cent quartz, 5 per cent plagioclase (An_{22}), 2 per cent biotite, and 1 per cent garnet. The quartz grains are slightly elongated, severely strained, have intergrowth boundaries, and a common optical orientation. The plagioclase is extremely altered. The light brown biotite is evenly distributed, partly altered to chlorite, and exhibits parallel orientation. Quartzite exposed along the east shore of Sapsford Lake in the southeast quarter of the map-area is composed of 90 per cent quartz, 5 per cent diopside, 2 per cent plagioclase, 2 per cent brown biotite, and minor magnetite. The microscopic characteristics of the quartz are similar to those described above. The diopside occurs as stubby grains and along with brown biotite is distributed in definite zones. Irregular grains of magnetite, however, have an uneven distribution. Quartzite from 1 mile northeast of Nevins Lake is composed of 85 per cent quartz that is completely recrystallized to form a mosaic and 15 per cent of coarse grains of diopside partly altered to chlorite and carbonate.

The structural features of the quartzites throughout Oldman River map-area are generally similar. Hematite-stained fractures are common and drag-folds are numerous, particularly in the impure quartzites near Forget Lake. The quartzites at the north end of Forget Lake and between Fennell Lake and Reed Bay contain zones of mylonite.

The quartzitic rocks of Oldman River map-area almost invariably contain concordant lenticular bodies and bands of amphibolite and pyroxene-bearing amphibolite. The latter is more characteristic of the eastern than the western part of the map-area. A band of marble, composed of 20 per cent diopside and 80 per cent calcite with some garnet, is interbanded with quartzite near the northeast end of Mackintosh Bay. Small bodies of rock composed almost entirely of diopside are intimately associated with quartzite near Nevins Lake.

Locally, discontinuous bands of pegmatite and granitic material are intermixed with quartzite in such a way as to result in a migmatitic phase of the latter. These granitic layers in one exposure at Hayter Bay cut crystals of garnet.

The boundaries between quartzitic rocks and other metamorphosed sedimentary rocks in Oldman River map-area are generally gradational, hence difficult to define precisely. Commonly the quartzites grade through impure quartzites to migmatite and paragneiss.

The quartzites of the map-area have been severely metamorphosed, as indicated by their recrystallization, coarseness of grain, the widespread occurrence and local abundance of garnet and diopside, the presence of sillimanite, and the occurrence of magnetite. The mineral constituents present, however, do not indicate the grade of metamorphism attained. The banded character, the local preservation of original structures, the composition, and the relation to other rocks of the map-area leave little doubt regarding the sedimentary origin of these rocks. The quartzites are correlative with those described by Christie (16), Hale (30, 31), and Fraser (25) in areas to the west.

Iron-formation

Iron-formation outcrops on the north shore of MacRae Lake and also on Oldman River nearly 2 miles south of MacRae Lake. In the first location it is 10 feet thick and lies between two amphibolite bands. In the second it is over 20 feet thick and is within quartzite. The iron-formation in the northern exposure is well banded, fine grained, and highly magnetic. In a thin section it is composed approximately of 30 per cent magnetite, 50 per cent quartz, and 20 per cent diopside. Intergrown quartz and magnetite form regular layers of various grain sizes. Some layers also contain diopside with magnetite along cleavage planes. The narrow red bands on weathered surfaces are largely composed of this iron-enriched pyroxene. The southern exposure of iron-formation shows a similar alternation of quartz-rich and magnetite-rich bands. Some of the magnetite-rich layers are several inches thick and appear to be composed almost entirely of magnetite with minor quantities of quartz and red-stained pyroxene.

Another narrow iron-formation extends along the southeast boundary of the quartzite area south of Alces Lake. This consists of fine-grained beds composed of various amounts of magnetite, quartz, and pyroxene. The rock closely resembles that of the iron-formation found farther south and may represent an extension of the same sedimentary belt.

Migmatite

Migmatite in the present report refers to bodies of rock that consist of megascopically distinct layers of granitic material in alternation with layers of gneiss. Such rocks are widespread in some granitized terrains. In Oldman River map-area those areas of layered rocks of two main components are mapped as a separate unit distinct from paragneiss and quartzite with which they are associated. Such layered rocks are more abundant in the east half than in the west half of Oldman River map-area. They occur around Hill Lake and near Felix Lake, along Felix Bay, Hayter Bay, and near Hayter Lake, along Reed Bay and Reed Lake. A band of migmatite extends from Ramstaad Island north along Oldman River. North of Fennell Lake, a fairly continuous band of migmatite follows Oldman River to MacRae Lake, and thence south of this lake and along Forget Lake to Dyke and Alces Lakes. From Alces Lake, a broad belt of migmatite extends southeastward along the west side of McInnis Lake, along the north side of Roberts Lake, and southeast from there along Narrow Bay to Lake Athabasca. This belt of migmatite is joined around Neiman Lake by another that occurs on the south side of Oldman River, east of Morris Lake, and is exposed south from there along parts of Sutherland, Schmitt, and Louder Lakes. Migmatite is also widespread east and southeast of Nevins Lake.

The general nature of the migmatite is uniform throughout the area. It is characterized by layers of granitic material, mostly $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches wide, alternating with layers of grey to nearly black garnetiferous biotite gneiss of somewhat greater average thickness. In detail, however, the

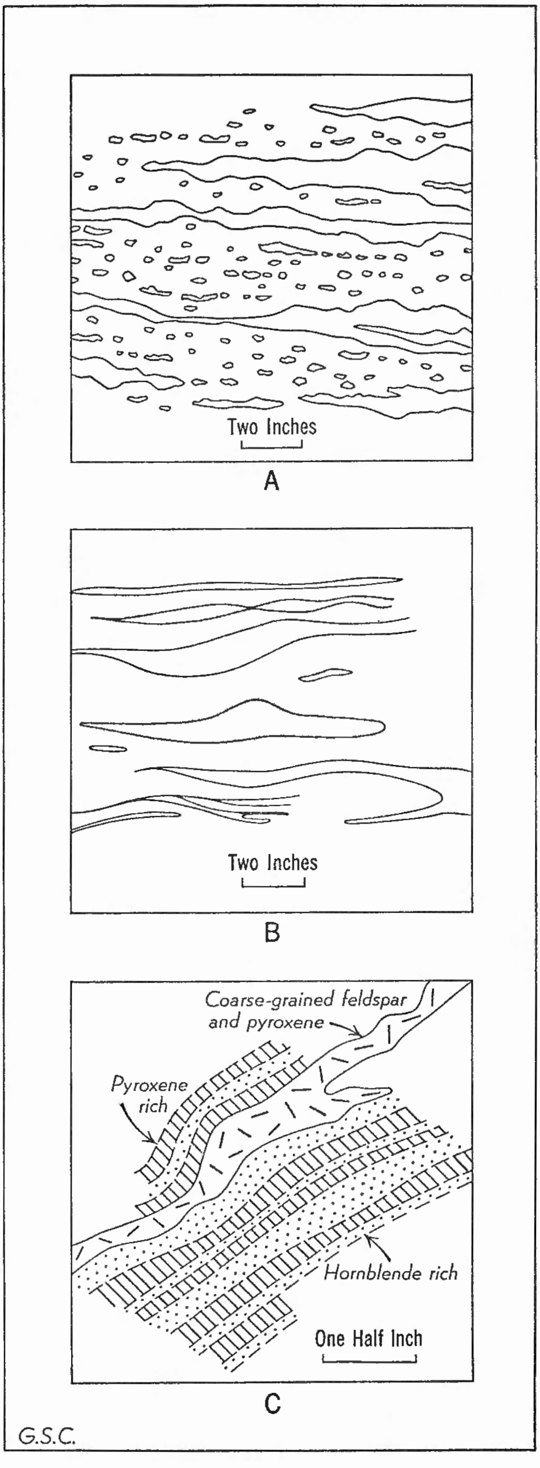


Figure 1. A. Sketch of typical migmatite west of Adair Bay.
B. Sketch of mylonitized migmatite near Prince Lake.
C. Sketch of banded pyroxene amphibolite east of Adair Bay.

layers are strikingly variable in form, composition, and texture, and these features probably are related either to the differences in composition of the original rock or to the degree and nature of the metamorphism it has undergone.

The local composition of the granitic layers of the migmatite varies from nearly pure quartz to nearly pure feldspar although an intermediate composition is most widespread. Coarse-grained (pegmatitic) phases are common. The gneissic component varies in grain size from fine to coarse and concentrations of biotite and garnet along definite layers generally cause a rude banding. Porphyroblasts of feldspar and more rarely quartz are extensively developed locally and all gradations exist along and across the strike between parts of layers containing alined porphyroblasts and the normal granitic type. The granitic layers may be continuous over a considerable distance, but most are discontinuous and in the form of elongated lenses (*See* Figure 1A). Some layers branch at a sharply acute angle, but they have not been observed to transect the structure. Many layers are of constant width, others are strongly bulged (boudinage structure) (*See* Plate II A). The strike and dip of beds over considerable distances are regular or complexly contorted. Intermediate stages of contortion are the most common.

In hand specimen the relation of the two migmatite components can be seen. In some specimens the only apparent difference in layers is the relative proportion of biotite present. In most specimens, however, the granitic layers are coarse in grain, more quartzose, and completely lacking in mafic minerals except for rare, thin folia of biotite. Although the boundaries are sharp, the minerals of the two types are intimately intergrown along the contacts.

Migmatite of the area is mainly composed of quartz, plagioclase, potash feldspar, and biotite. Garnet, however, is generally present in small amounts and hornblende and pyroxene are rare. Quartz occurs in widely varying amounts, but on the average forms between 30 and 40 per cent of the rock, distributed as an aggregate of interlocking grains, as stringers, and as disseminated grains of various sizes. Undulatory extinction is pronounced in all but one thin section but planes of inclusions are only moderately well developed. Mortarization has affected the quartz in many cases. Plagioclase forms 35 to 40 per cent of the rock. Its composition is widely variable, ranging from An_{15} to An_{32} (average, An_{26}). There is some indication that the plagioclase of migmatite from the western side of the map-area is more sodic than that from the eastern side. The extent of alteration in the feldspar of the migmatite varies from slight to moderate and mermykitic structure is not uncommon. Potash feldspar (microcline) forms up to 40 per cent of the rock and averages about 15 per cent. Grid twinning is commonly well developed but may be entirely absent or present only in patches. Minute, roughly rectangular inclusions of what is probably plagioclase form a type of perthitic structure in microcline. Brown biotite quite consistently constitutes about 10 per cent of the rock and is in perfect orientation and chiefly confined to individual layers. The secondary green variety is present in some places, and in one instance pseudomorphous chlorite occurs to the complete exclusion of biotite. In

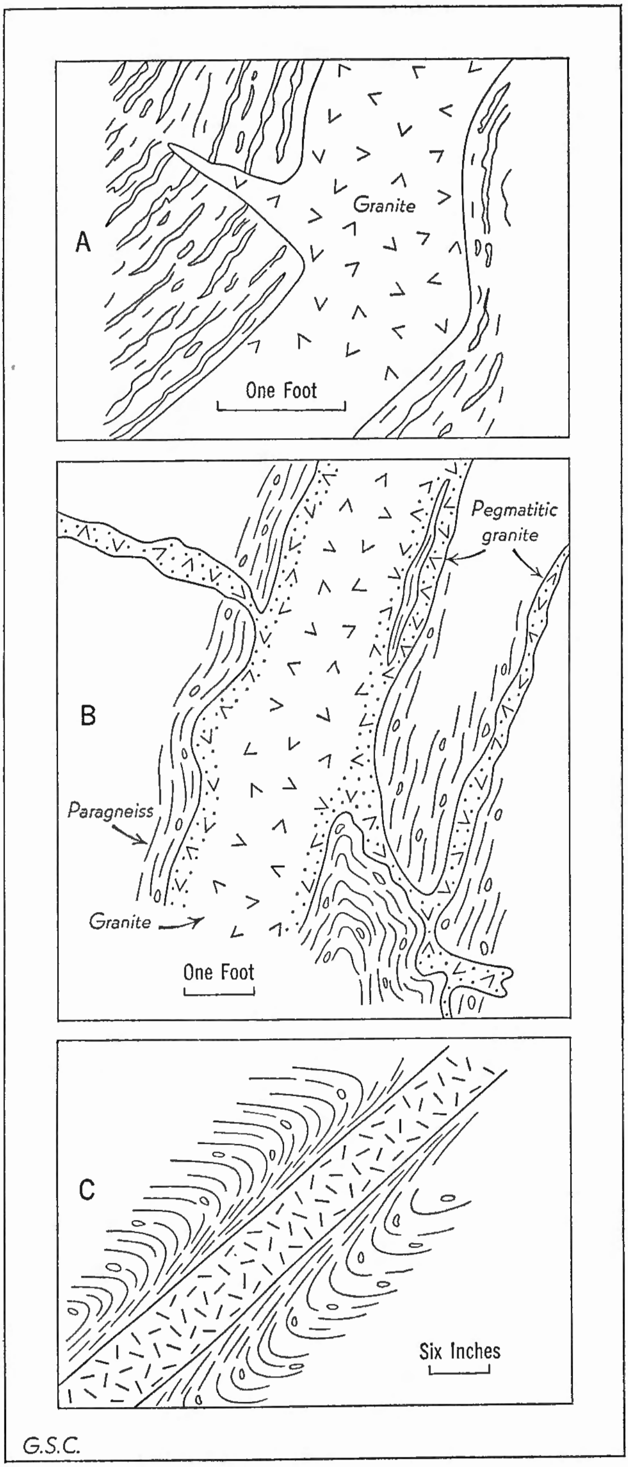


Figure 2. A. Sketch of granite intruding migmatite, 1 mile southwest of Dinty Lake.
B. Sketch of intrusive granite with pegmatitic borders in paragneiss, Lake Athabasca, 5 miles west of Narrow Bay.
C. Sketch of pegmatite dyke intruded along fault in drag-folded paragneiss, Lake Athabasca, 5 miles west of Narrow Bay.

one section acicular inclusions of rutile in biotite are arranged along lines intersecting at about 60 degrees. Magnetite, sphene, pyrite, apatite, and zircon occur in accessory amounts.

The rock has a crystalloblastic texture in which the essential minerals are xenoblastic. The gneissosity is marked by folia of biotite and slightly elongated, partly segregated grains of quartz and feldspar. Both quartz and feldspar tend toward a porphyroblastic habit (*See* Plate IV A). Tongues and embayments of one mineral in another indicate replacement of plagioclase and microcline by quartz and all three of these by biotite. The two feldspars have apparently developed simultaneously although some mermykite embays, and is, therefore, later than, the potash feldspar.

The strike and dip of axial planes of small folds in the migmatite vary considerably even within a distance of a few feet. They do, however, broadly conform in strike to that of the major fold axes of the region. The chief variation is commonly the steeper plunge of the axial planes. Small cross faults are abundant and their walls commonly exhibit drag-structures containing granitic and pegmatitic dykes. Near the St. Louis fault and in other localities, migmatite is mylonitized and this is discussed on pages 35-38.

Broad zones in which migmatite forms the dominant rock type occur as continuous bands that mark the general pattern of the folded Tazin group. The migmatite banding is parallel with original sedimentary stratification, as indicated by its parallelism with narrow conformable bands of quartzite, and some gneissic parts show relict varve structures. The nature of the original sedimentary rocks probably was the main control in localizing the development of migmatite, and all areas of migmatite are not concentrically distributed around a granitic mass.

Migmatite grades both into paragneiss and into quartzite. In the former case, as paragneiss is approached, the boundaries of the granitic components of the migmatite become progressively more vague and the sedimentary component more coarsely gneissic. As quartzite is approached, the proportion of granitic material decreases and the rocks become more quartzitic. In many cases, however, the boundaries are rather abrupt. In addition to quartzite the belts mapped as migmatite contain narrow zones of paragneiss and of rock intermediate between paragneiss and migmatite. Amphibolite, pyroxene-bearing amphibolite, and related mafic rocks, containing minor amounts of introduced granitic material also occur as bands and lens-shaped bodies within migmatite. Some of these show definite intrusive relationships, others are of doubtful origin but probably intrusive, although some narrow bands composed almost entirely of diopside and calcite are of sedimentary origin. The migmatitic assemblage is intruded by dykes, sills, and sheets of granite that range from a few inches to thousands of feet in width. The narrow dykes are well defined and sharply intrusive (*See* Figure 2A), but the large bodies, which are always conformable, mostly contain zones of migmatite, paragneiss, and contaminated phases. Pegmatite is common in migmatite as well as in other metamorphic rocks of the Tazin group and occurs both as intrusive dykes and as probable replacement masses.

PARAGNEISS

The term paragneiss is applied to distinctly gneissic rocks believed to be mainly of sedimentary origin and represented by a broadly homogeneous gneiss of granodioritic composition and closely resembling granite-gneiss in general appearance. Most of the larger bodies of paragneiss probably have been mapped separately from the gneisses believed to be of igneous origin, although considerable amounts of paragneiss have been included with the granite and granite-gneiss north and northwest of the St. Louis fault. Possibly most of the rock mapped as granite-gneiss in the Dinty Lake-Hurry Lake part of the area is of sedimentary origin.

Paragneiss is exposed near Gibbs, Gale, Stephens, Hutton, MacRae, and Dodds Lakes, and also along the shore of Lake Athabasca between Narrow Bay and Ramstaad Island and intermittently inland from there almost to Alces Lake. In the northeast corner of the map-area paragneiss was observed at Sutherland, Schmitt, and Louder Lakes and also along the east boundary, east of Nevins Lake.

The general nature of the paragneiss is remarkably constant throughout the area. It is, typically, a coarse-grained, grey to pink weathering, garnetiferous, biotite gneiss. Except for vaguely defined compositional banding it is homogeneous over large areas. Feldspar porphyroblasts are locally prominent and in a few outcrops crystals of pyroxene are recognizable. The abundance and size of red garnet crystals vary from area to area, and in many individual outcrops garnets are concentrated in definite layers. Most of the rock is strongly folded to give locally sweeping curves in areas only a few yards across. The complex folding, however, so typical of migmatite, is lacking. Small cross faults are common as in migmatite and almost invariably the adjacent rock shows the effect of drag. The rock has been mylonitized along most of these faults, and the faults themselves are followed by dykes of granite and pegmatite.

Sharply defined elongated lenses of mafic rock, mostly less than a foot or two in length and an inch or two in width, occur in various amounts in the paragneiss; at some localities the bodies of mafic rock are closely spaced and present in uniform concentrations and in others they are rare and widely separated. Such bodies probably are concentrations of mafic material segregated during the period of metamorphism (*See* page 23).

The paragneiss exposed along Lake Athabasca is the coarsest in grain and richest in garnet of any in the map-area. The rocks of the areas centred around Forget Lake and west of Nevins Lake are, except in these respects, similar to that on the shore of Lake Athabasca. The areas at Dinty, Louder, and Sutherland Lakes and that east of Nevins Lake resemble one another but differ from the more westerly and southern areas in being medium grained instead of coarse grained and more gneissic. The proportion of granite in these latter areas, although variable, is generally greater and occurs commonly as concordant sills spaced at intervals of 1 foot or 2 feet.

The paragneisses are composed of quartz, plagioclase, potash feldspar, and various mafic minerals, chiefly biotite. The relative proportions of these minerals are remarkably uniform throughout the area. Table I gives the average mineral composition of eleven thin sections from the paragneiss body along the shore of Lake Athabasca and of thirteen thin sections from other areas of paragneiss.

TABLE I

Average Mineral Composition of Paragneiss

Minerals	Lake Athabasca shore area (11 thin sections)	Other areas (13 thin sections)
	Per cent	Per cent
Quartz	35	30
Plagioclase	36 (An_{31})	34 (An_{34})
Potash feldspar	12	20
Mafic minerals	16	15

The mineral composition of the paragneiss is similar to that of the migmatite except that the latter is somewhat richer in quartz and plagioclase and poorer in potash feldspar and mafic minerals. Also the composition of the plagioclase in paragneiss is more calcic and grid twinning is completely lacking in the potash feldspar.

Quartz occurs as irregular grains of various sizes and with an unequal distribution. Much of the quartz is confined as interlocking grains to augen and discontinuous bands. In some thin sections evidence of the effects of deformation is lacking, but in most undulatory extinction and planes of inclusions in quartz are distinct. Locally also some of the quartz is crushed and this now occurs around and between feldspar grains. Most plagioclase is well twinned and only slightly altered. Much of it contains irregular intergrowths of potash feldspar (antiperthite) and vermicular quartz (mermykite). Potash feldspar, probably orthoclase, is generally free of alteration products and commonly untwinned. Minute inclusions of what is probably plagioclase occur as a type of perthitic intergrowth in much of the potash feldspar. The chief mafic mineral is brown biotite that invariably has a common orientation and is confined to definite zones. It is generally partly altered to chlorite and leucoxene and more rarely to epidote and the green variety of biotite. In a few slides grains of irregular, embayed green hornblende occur with biotite and are partly altered to biotite, chlorite, and magnetite. Diopsidic pyroxene is present in four of twenty-four slides and hypersthene in one slide. Both minerals are partly altered to biotite and chlorite. Irregular grains of garnet are commonly present in amounts ranging up to 15 per cent. They may be large, with many over an inch in diameter. In thin section the large grains of garnet contain inclusions of the other minerals of the rock, and these may or may not be arranged in trains. Only the smallest garnet grains show crystal outlines. Invariably garnet is altered around its edges and along cracks to biotite and chlorite. At Sutherland Lake the mafic minerals are chiefly chlorite and muscovite, which together are distributed through the rock as layers and irregular masses. Magnetite is the most persistent accessory mineral and apatite and sphene occur with the mafic minerals. Hematite and carbonate are commonly present in minor amounts.

Like migmatite, paragneiss has a crystalloblastic texture in which the xenoblastic grains vary greatly in size. The segregation of mafic minerals from quartz and feldspar marks the gneissosity and excessive growth of quartz and feldspar or garnet produces the widespread porphyroblastic texture. The quartz apparently has developed later than the feldspars and the garnet, biotite, pyroxene, and hornblende later than the quartz. Minerals, as chlorite, resulting from retrogressive metamorphism are the youngest.

Summary of General Features and Origin of the Paragneiss and Migmatite

The gneissosity of paragneiss and the bedding and boundaries of contained and nearby narrow bands of quartzite and zones of migmatite are parallel. The quartzite bodies in paragneiss, however, are smaller and more scattered than those in migmatite. Amphibolite and other mafic rocks also occur in bands or lenticular bodies of variable size in both paragneiss and migmatite. Some bodies of the mafic rocks cross the gneissosity of the paragneiss and the layers of the migmatite. Granite also intrudes the paragneiss as dykes, sills, and large conformable sheets and pegmatite is plentiful in both paragneiss and migmatite. Paragneiss at some localities grades along the strike into migmatite.

The paragneiss and migmatite in addition to abundant quartz are characterized by garnet occurring with potash feldspar, oligoclase, or andesine. Hornblende and pyroxene rarely occur together and in those rocks from the western half of the map-area hornblende is present whereas pyroxene is confined to the paragneiss of the east half. In the large body of paragneiss north of the shore of Lake Athabasca, east of Oldman River, there is some evidence that the lime content of the plagioclase increases from west to east. Greenish plagioclase occurs at a few places east of Oldman River. These features suggest a change from west to east from the amphibolite to the granulite facies of metamorphism. Perthitic intergrowths of plagioclase in potash feldspar are present in all feldspar and quartz phases and in many cases the quartz has migrated from its original position to form minute lens-shaped particles and bands. This also is considered by some as typical of the granulite facies. All these features together with field relations indicate a metamorphic rather than an igneous origin of the migmatite and paragneiss of Oldman River map-area.

A comparison of the average mineral content of the paragneiss and migmatite with that of sedimentary rocks of orogenic belts (42) suggests a close similarity of the Oldman River gneisses and greywacke or subgreywacke. Both the paragneiss and migmatite contain too much quartz to have been derived from shale unless a large amount of quartz was added, and no evidence of this was noted. Although the average greywacke contains less than 20 per cent of feldspars and the paragneiss and migmatite contain 50 per cent, this excess is probably the result of metamorphism of argillaceous material (49). The migmatite furthermore has a higher average quartz content and less garnet and biotite than the paragneiss, hence probably represents greywacke more quartzitic and less argillaceous than the original sediment of the paragneiss. The areal distribution of quartzite, paragneiss, and migmatite in long, parallel adjoining belts may indicate differences in character of the original strata. Those beds rich in quartz become quartzite, those carrying some clay with quartz migmatite and those with quartz and abundant clay become paragneiss. In each relicts of bedding, although deformed, remain and the presence of the three rock types in well-defined belts is interpreted as representing different stratigraphic units in the sedimentary succession.

AMPHIBOLITE, NORITE, AND HORNBLENDE GABBRO

Amphibolite and Pyroxene-bearing Amphibolite

Holmes (33) defines amphibolite as a granulose glomeroblastic metamorphic rock composed of hornblende, plagioclase, and small amounts of one or more of quartz, epidote, or garnet. Amphibolite as so defined is widespread north of Lake Athabasca. Some amphibolite in the east half of Oldman River map-area contains considerable pyroxene. The larger amphibolite bodies are shown on the map but it is emphasized that a large proportion of the amphibolite occurs as small bodies not indicated on the map. The largest exposures occur: (1) in a zone extending from Gibbs Lake through Prince Lake to Alces Lake; (2) northeast from the shore of Lake Athabasca in a band that includes part of Oldman Island, most of the west shore of Reed Bay to near Reed and Fennell Lakes and north of the latter; and (3) west of Adair Bay northwest to Kisiwak Lakes. Pyroxene is rare in the amphibolite bodies west of Oldman River and north of the St. Louis fault, whereas this mineral forms a major part of the amphibolite in the part of the area east of Oldman River south of the St. Louis fault.

Pyroxene-free amphibolite is a rusty brown weathering, dark grey to dark green rock and remarkably uniform in nearby exposures, but in different parts of the body shows variations in the relative proportions of black hornblende and white feldspar, in grain size, and in the degree of alinement of hornblende crystals. Generally, the rock is medium grained, but some of the largest masses contain fine-grained zones. Coarse-grained phases are rare but occur to some extent near granite. Amphibolite masses never seem to exhibit fine-grained border zones but sheared rock, largely composed of biotite, is widespread at contacts.

Pyroxene-bearing amphibolite resembles the pyroxene-free variety in all respects except for a characteristic, rather prominent banded structure (*See* Figure 1C) and, of course, its pyroxene content. Pyroxene, which is mostly reddish brown or, rarely, green, may form as much as 30 per cent of the rock in apparently unalined grains of a size comparable to that of hornblende and feldspar. The three minerals have a random distribution, with hornblende and pyroxene segregated from one another in most thin sections. In some places poorly defined lenticular patches rich in pyroxene occur in nearly pure amphibolite, and vice versa. Layers a fraction of an inch across and rich in pyroxene alternate with layers rich in hornblende. This banding is accentuated at intervals of 1 foot or 2 feet, by narrow, coarse-grained, discontinuous bands composed solely of feldspar and pyroxene (*See* Figure 1C). The coarse-grained fractions are, with few exceptions, concordant although a few small offshoots are discordant.

Red garnet is rare but occurs in both types of amphibolite. Locally, both kinds of amphibolite are heavily stained along fractures by iron. Foliation, marked by orientated hornblende grains, by the banded structure mentioned in the above paragraph, or by layers of granitic material, is conformable to the over-all regional structure although here and there small folds and contortions are developed.

TABLE II

Average Mineral Composition of Amphibolite and Pyroxene-bearing Amphibolite

Minerals	Amphibolite	Pyroxene-bearing amphibolite
	Per cent	Per cent
Hornblende (and biotite)	62	37
Pyroxene	—	22
Plagioclase	34 (An_{37})	38 (An_{41})
Quartz	2	—
Black opaque minerals (other than schiller inclusions)	2	1

The average per cent of hornblende in amphibolite is approximately that of the combined hornblende and pyroxene in pyroxene-bearing amphibolite (*See* Table II). Quartz is absent in pyroxene-bearing amphibolite and the plagioclase is slightly higher in lime. The hornblende is in slightly ragged, dimensionally alined grains. In amphibolite it is pleochroic in shades of green, olive-green, and yellow, and in one specimen blue. In the pyroxene-bearing amphibolite hornblende is pleochroic in shades of brown and yellow. In both types the extinction angle in the vertical zone varies between 20 and 25 degrees and alteration to either biotite or chlorite is slight or absent. Irregular-shaped grains of magnetite, probably chiefly an alteration product, occur in and around grains of hornblende. Sieve-structure is common.

Pyroxene with optical properties near that of the polyaugite diopside occurs, like hornblende, as ragged poorly defined grains. In one case the pyroxene surrounds and penetrates hornblende, suggesting that this pyroxene has been derived from hornblende. In all but one specimen pyroxene contains numerous schiller inclusions of hematite, with minor leucoxene, thus accounting for the reddish brown colour of the rock. Most amphibolite and pyroxene amphibolite contain felsic material in some places as quartz and feldspar porphyroblasts. In the large mass east of Reed Bay narrow, discontinuous stringers, networks of stringers, and irregular patches of felsic material give a spattered appearance to outcrops (*See* Plate II B). Dykes of granite and pegmatite, some over 300 feet wide, form concordant or nearly concordant bodies, and in the pyroxene-bearing amphibolite extending inland from Adair Bay these are larger than the average elsewhere. Amphibolite north of the St. Louis fault locally is crossed in all directions by dykes of granite and pegmatite. In other areas, as north of Hamilton Lake, the granite follows the foliation to give a migmatitic appearance. Layers and lenses of quartz from a few inches to a few feet thick are present in some amphibolite, especially the body extending inland from Adair Bay. Some of these perhaps represent inclusions of quartzite.

Areas of a fine-grained, dark green, porphyroblastic rock about Alces and Prince Lakes were mapped as amphibolite. The subsequent study of thin sections of some of this rock, however, indicates that the bodies are only in part composed of amphibolite and that these zones are chiefly of mylonite formed from a quartz-feldspar rock.

The rock of the lenses of amphibolite contained in paragneiss is dark green or nearly black on both fresh and weathered surfaces. It is massive and much finer grained than the host rock. A thin section from a lens in the paragneiss exposed on the shore of Lake Athabasca (*See* Figure 3A) is composed of 30 per cent diopsidic pyroxene, 45 per cent plagioclase (An_{45}), 20 per cent clear nearly unstrained quartz, 3 per cent deep brown biotite, and 2 per cent pyrite. A section from a lens at Dinty Lake consists of 25 per cent biotite, 50 per cent plagioclase (An_{42}), and 25 per cent clear, slightly strained quartz. Apatite is a prominent accessory in both slides. Both rocks are composed of fresh, equigranular though xenoblastic grains with random orientation. The absence of potash feldspar and the high lime plagioclase are noteworthy features.

Norite

Norite has a limited distribution, being chiefly confined to the part of the area about Dinty Lake. A large body occurs at McInnis Lake and a small one at Sutherland Lake. Norite is unknown in the map-area west of McInnis Lake. Only a few bodies are over 250 feet across, but smaller ones are numerous. Some of the norite at Dinty Lake is nickeliferous. Except in mineral composition, the norite bodies closely resemble those of amphibolite; they both occur as concordant lenticular masses; both show sharp but occasionally interfingering contacts; and both are intruded by granite and pegmatite. Even the grain size and appearance of the weathered surface are comparable.

Table III

Mineral Composition of Norite

Minerals	McInnis Lake	South of Dinty Lake	North of Dinty Lake	Sutherland Lake
	Per cent	Per cent	Per cent	Per cent
Pyroxene (and uralite)	19	55	65	35
Biotite	4	10	1	4
Plagioclase	77 (An_{60})	33 (An_{53})	30 (An_{56})	55 (An_{56})
Quartz	—	2	1	3
Black opaque	x	x	2	3
Apatite	x	x	1	x

The rock presents a wide range in composition and the texture is hypantomorphic granular. The proportion of the chief constituent, plagioclase, varies from 30 to nearly 90 per cent (anorthosite) (*See* Table III) and the colour of the rock accordingly varies from dark to light. The plagioclase (labradorite) occurs as well-developed and well-twinned crystals, and most are unaltered. Pyroxene, which is colourless and nearly non-pleochroic, is an anomalous type with a chemical composition near hypersthene (3/5 MgO. 2/5 SiO_2) (24). Unlike hypersthene, however, it is monoclinic with a maximum extinction angle ($z \wedge c$) of 38 degrees. It is optically negative (unlike clinohypersthene) with positive elongation and an optical angle of about 62 degrees. Schiller structure is poorly developed, and alteration, mainly to uralite and chlorite, is slight to moderate. Biotite (brown) is moderately well alined and evenly distributed. Quartz when

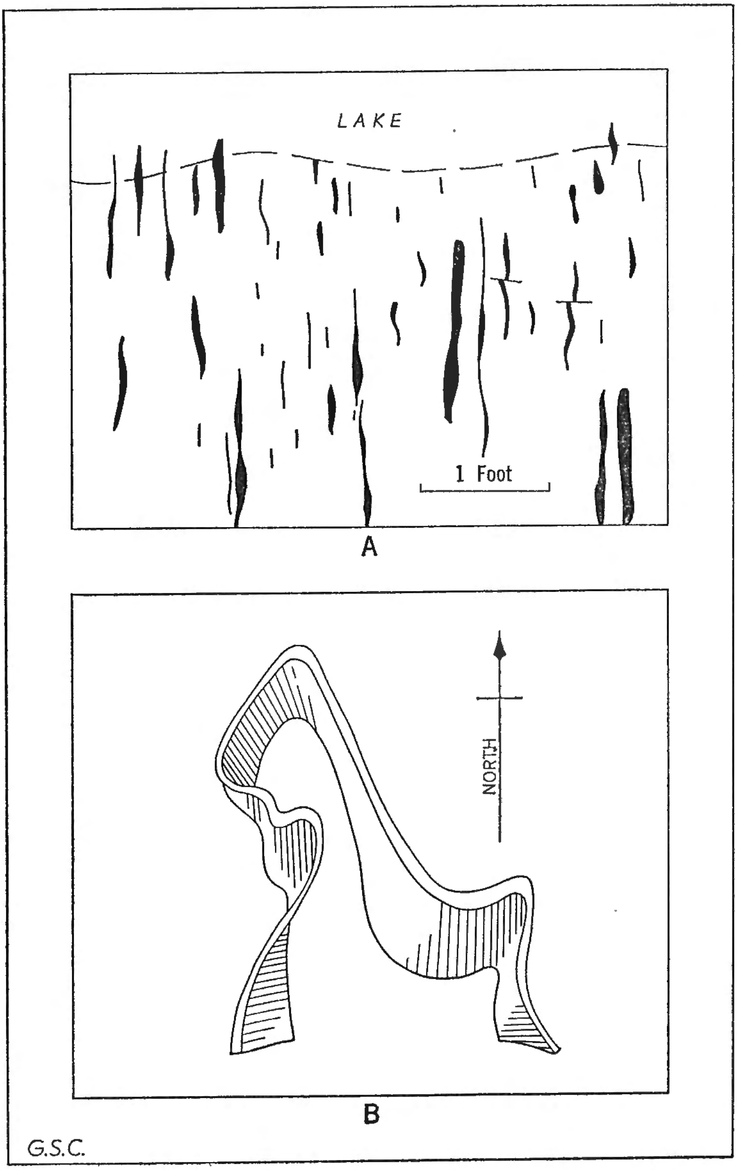


Figure 3. A. Sketch to show distribution of amphibolite lenses (solid black) in paragneiss, shore of Lake Athabasca, 4 miles west of Narrow Bay.
B. Diagrammatic three dimensional sketch to show interpreted shape of major syncline of map-area.

present occurs as stained, irregular, evenly distributed grains. Apatite and black opaque minerals (magnetite, pyrite, and nickel sulphides) are important accessories, and garnet, some of it altered to chlorite and biotite, is recognizable in hand specimens.

Hornblende Gabbro

Two dykes of hornblende gabbro about 1 mile apart, one 8 feet and the other 50 feet wide, cut paragneiss on the shore of Lake Athabasca east of Oldman River. The rock of the two dykes is identical in appearance, weathers deep red, and is massive. The fresh surface is nearly black and shows hornblende, green or reddish brown pyroxene, and white feldspar in grains of medium size. The contacts with paragneiss are sharp, irregular in trend, and crosscutting. The dyke rock at the margin of one body is altered to a mylonite. Pegmatite cuts the rock of both dykes.

A thin section of the rock of one dyke shows a crystalloblastic aggregate of 30 per cent brown hornblende, 20 per cent diopsidic pyroxene, 50 per cent plagioclase (An_{46}), and accessory amounts of quartz, brown biotite, magnetite, and pyrite. The silicate minerals are fresh and without preferred orientation. The rock is a hornblende gabbro, probably closely related to the amphibolite in age.

Mode of Occurrence and Origin

Almost all amphibolitic rocks occur as concordant lenticular bodies and bands. Some bands are 5 miles long and two masses, inland from the shore of Lake Athabasca, occupy an area of over 3 square miles. All bodies have well-defined boundaries. In quartzite or migmatite the contact is straight or gently curved, but in paragneiss and granite-gneiss contacts are irregular and interfingering. In granite as in the area about Dargavel, Dusyk, and Powley Lakes, only angular inclusions of amphibolite are present. No amphibolite is known in the Cameron Island granite mass. Only a little amphibolite occurs within the granite forming sheets. Amphibolite thus is confined in distribution chiefly to formations older than granite.

Small and closely spaced lenses of amphibolite are abundant in some paragneiss, especially that extending north from the shore of Lake Athabasca. Such lenses have not the appearance of having been formed by the pulling apart of continuous bands or layers and the minerals in thin section are not deformed. Their discontinuity along the strike is not characteristic of intrusions and a suggested interpretation is that the lenses represent pockets wherein constituents of the minerals of the amphibolite segregated during the growth of the paragneiss.

The distribution of pyroxene and hornblende in alternating layers less than an inch thick characterizes pyroxene amphibolite. In such layers the feldspar content is constant. Some pyroxene is interpreted as forming from hornblende by increase in the degree of metamorphism and under plastic deformation possibly pyroxene would grow rather than hornblende in locations of little or no strain, resulting in metamorphic differentiation. Such conditions, however, would not be expected to recur at regular spacing to produce the small-scale banding as developed. Amphibolite free of pyroxene is not banded and this would be expected if the structure reflected an original layering of igneous rocks. The alternating hornblende and pyroxene layers could result from the recrystallization of beds of slightly different materials, as a series of calcareous and argillaceous beds.

Replacement has occurred locally in the amphibolite to give splashes of quartz-feldspar material distributed at random throughout the rocks and without disturbing the structure (*See* Plate II B). Quartz is not present in the original rock and the content of feldspar nearby is not decreased, hence the quartz and feldspar of the splashes probably were added from without. In the large masses of amphibolite east of Oldman River, this added material must have migrated some distance.

The minerals present in the amphibolite from point to point give an indication of the metamorphic facies of the area. From west to east hornblende-andesine amphibolite gives place to pyroxene-bearing amphibolite. There is little indication that, originally, the two types represented markedly different rocks and each presents the same field associations. In coincidence with the appearance of pyroxene, green hornblende is converted to brown hornblende and the plagioclase becomes slightly more calcic andesine. These mineralogical variations in the amphibolite strongly suggest a change in metamorphism from the amphibolite facies to the granulite facies of Eskola (23).

The norite bodies do not exhibit chilled margins and other intrusive relations characteristic of dykes, sills, or bosses. The variable mineral content within individual bodies and from body to body also would not be expected within intrusive masses of limited extent. The norite possibly represents pyroxene-bearing amphibolite where all hornblende is converted to pyroxene and andesine to labradorite. The local high content of labradorite, however, suggests that the source material of norite was different from that of pyroxene-bearing amphibolite, in which case norite and pyroxene-amphibolite represent the end products of the same degree of metamorphism of different materials.

GRANITE, GRANITE-GNEISS, AND PEGMATITE

In Oldman River map-area at some points it is difficult to distinguish between granitic rocks of intrusive origin and paragneiss similar in composition and appearance. Dykes and sills of small size are easily recognized, but most large conformable sheets have contaminated borders and contain zones and shred-like remains of older rock to such an extent that in many cases it is impossible to outline accurately individual bodies. Criteria used to distinguish granite in the field were: the common absence of garnet, the paucity of ferromagnesian minerals, the finer grain size, the more massive nature, and, where present, intrusive relationships. Petrographic studies have verified the field separations. In certain parts of the area, however, some paragneiss has been included with granite because in some cases time did not permit detailed mapping, and in others paragneiss occurs only in minor proportions. Northwest of the St. Louis fault the rocks between Zenith, Dusyk, and Powley Lakes are mapped as almost entirely of intrusive origin, whereas those in adjacent areas include various amounts of unmapped paragneiss. North of Hill Lake a large part of the area mapped as granite probably is paragneiss, and in the vicinity of Dinty Lake it is possible that all is paragneiss. Pegmatite and pegmatitic granite occur in minor quantities except north of the St. Louis fault, where they form a major part of the intrusive body.

The granite of sills, dykes, and conformable sheets is pink, grey, or white, generally medium grained and gneissic although massive and pegmatitic phases occur. The small dykes and sills are massive with gneissic borders, although in a few cases the borders are pegmatitic (*See* Figure 2 A and B). The granite between Zenith, Dusyk, and Powley Lakes megascopically resembles in all respects the granite of the smaller bodies. It is homogeneous over large areas with little change in grain size, composition, or even in colour. Between Dargavel and Zenith Lakes, however, large areas contain pink, massive, well-defined dykes of pure quartz-orthoclase pegmatite forming a giant stock-work, in which large blocks of granite are isolated from one another. In places as much as 50 per cent of the rock is pegmatite. In some areas also, notably north of Alces Lake, patches of finer grained, massive, grey biotite granite occur with, and are intruded by, the typical white and pink granite. The Cameron Island granite is a uniform red, coarse-grained, markedly gneissic rock cut by a few pegmatite dykes.

The granite-gneiss outlined in the vicinity of Dinty and Hurry Lakes is white to pink, coarse grained, gneissic, and remarkably homogeneous over large areas. It differs from other rocks in containing small circular patches and lenses composed of garnet, biotite, chlorite, and epidote. The last three minerals apparently are alteration products of garnet and they weather to give the rock a characteristic pocked appearance. Elongated, lenticular, or rarely angular, bodies of norite are locally common. The remarkably homogeneous nature, the composition similar to that of the other granites in the area, and the presence of angular inclusions, suggest that the granite-gneiss is intrusive. On the other hand, the presence of considerable garnet, the coarse grain size, and the occurrence of lenticular bodies of norite, suggest a derivation from paragneiss.

Two main types of pegmatite occur, the one intrusive (*See* Figure 2C), and the other probably of replacement origin (*See* Plate III A). The first crosses all earlier formed rocks as well-defined dykes and masses. Their boundaries, commonly straight, are either sharply defined or gradational over a distance of 1 inch or 2 inches into the wall-rock. Some intrusive pegmatite bodies show irregular outlines. These pegmatites are composed of various amounts of quartz and feldspar, the latter generally dominating and occurring in crystals ranging up to 1 foot in length. In most cases biotite is also present. In some bodies muscovite occurs with, or to the exclusion of, biotite. Tourmaline, magnetite, pyroxene, and garnet are rare, but locally may form an important part of the body. Most contain two feldspars, the one pink and the other pearly grey, probably representing orthoclase and microcline. Some pegmatite bodies are zoned, but this feature has not been studied in detail. In the northwest corner of the map-area and at other localities white, fine-grained pegmatite forms dykes composed solely of white feldspar and quartz. Such dykes probably represent the albite pegmatite of Christie (16).

Some bodies of pegmatite are exceptionally irregular in shape and grade outward into the wall-rock through a zone of scattered feldspar porphyroblasts. They are principally composed of light-coloured pearly microcline with minor amounts of quartz and biotite. Although they cross the structure as irregular patches and even appear to deform the wall-rock in places, they tend to follow the direction of foliation and contain undisturbed remnants of the host rock. In a few cases the containing rock near the pegmatite has apparently been partly leached of feldspar. These features suggest a replacement origin, but the proportion of their material that has been derived from the enclosing rock and the proportion from an outside source is difficult to evaluate. Such pegmatites are chiefly confined to migmatite and paragneiss, whereas intrusive pegmatite in addition cuts granite, amphibolite, and the probable replacement pegmatite.

The approximate mineral composition of granites from Oldman River map-area has been estimated from petrographic studies of twenty-three thin sections (*See* Table IV).

TABLE IV

Estimated Mineral Composition of Granite of Dykes, Sills, and Sheets, Southeast to Northeast and South of the St. Louis Fault and the Northern Mass (Nos. 17 and 18)

No.	Qtz. %	Plag. %	Micro. %	Bio. %	Gar. %	Pyx. %	Plag. An cont.	Plag. %	Micro. %
1	20	10	70	x	x	....	26		
2	25	2	71	2	....	....	28	7	68
3	20	9	68	3	....	....	27		
4	25	8	63	1	3	....	?		
5	30	5	60	2	1	2	27		
6	16	3	71	10	....	....	?	8·5	59
7	42	16	40	x	....	2	26		
8	25	10	65	x	....	....	26		
9	27	26	40	5	2	....	26		
10	35	50	10	5	....	....	21	16	52
11	25	13	62	x	....	....	?	excluding No. 10	
12	30	10	55	5	....	....	21?		
13	30	25	45	5	....	....	28		
14	25	20	55	x	....	....	29	24	47
15	25	20	50	5	....	....	22		
16	30	32	38	x	....	....	24		
17	25	55	10	10	....	....	33	40	25
18	30	25	40	5	....	....	......		

All the slides with one exception (No. 6) are rich in quartz. Biotite, on the other hand, forms a consistently small percentage of the rock. It is noted, moreover, that the proportion of plagioclase increases to the northwest whereas microcline decreases. The composition of the plagioclase in the dykes and sills varies between An_{21} and An_{29}, with most determinations near An_{26}, whereas that of the northern mass is slightly over An_{30}. There seems to be no progressive change in the composition of the plagioclase to coincide with the change in its relative abundance. In all cases except one the content of quartz is high and in most cases that of mafic minerals low. Most of the dykes and sills of the large sheets vary in mineral content with a composition varying from a potash granite in the southeast to a quartz monzonite in the northwest. The two slides from the northern mass, which can by no means be considered to represent the entire body, are quartz monzonite and granodiorite.

The Cameron Islands and Dinty Lake granites are different in nature from the granites of the dykes and sheets. The estimated mineral content of the Cameron Island granite (Nos. 19 and 20, Table V) indicates a slightly more sodic plagioclase than that of the other known granites of the area. The granite-gneiss at Dinty Lake (Nos. 21-23 inclusive) also has an indicated average mineral content of granite.

TABLE V

Estimated Mineral Composition of Cameron Island (Nos. 19 and 20) and Dinty Lake Granites (Nos. 21 to 23 inclusive)

No.	Mineral composition					
	Qtz.	Plag.	Micro.	Bio.	Accessory	Plag. An con.
	%	%	%	%	%	
19	25	20	40	15	Chlorite	25
20	25	5	60	10	epid. horn.	24
21	30	30	35	x	5	27
22	30	13	40	17	x	?
23	25	10	55	x	10	?

Most of the quartz is uniformly distributed in grains of various sizes, although it commonly forms irregular layers or irregular augen. Undulatory extinction and planes of inclusions are always distinct and in a few slides sutured contacts and mortar structure are pronounced. An almost universally present feature of the microcline is the presence of minute, often approximately rectangular and sometimes greatly elongated inclusions, of what is probably sodic plagioclase. These form a type of perthitic structure. Some appear to be without alinement, but mostly they follow one or both twinning directions. Perthitic structure of the usual type, i.e., irregular patches of sodic plagioclase in potash feldspar, was also noted in a few slides. Plagioclase is well twinned although most of it is moderately altered. Nearly all sections contain mermykite in which vermicular quartz is intergrown with plagioclase. Biotite is brown to green, generally the former, invariably contains leucoxene, and in part is altered to chlorite. Hornblende occurs in the Cameron Island granite but is nearly completely altered to biotite, chlorite, and epidote, and in most cases only its outline remains. Monoclinic pyroxene was noted in two slides from sills. Rounded grains of garnet also appear in a few slides and as a major constituent in the gneisses from Dinty Lake although there it is nearly completely altered to chlorite, epidote, and biotite. Magnetite, sphene, and apatite are rare accessory minerals. Dusty hematite clouds the plagioclase in a few slides and in the Cameron Island granite is associated with aggregates of ferromagnesian minerals. Typically the rock has an unequiangular granitic texture. Rarely an alinement of minerals, especially biotite, gives a gneissic texture. Crushing has partly mortarized the quartz in some cases.

In summary, granite and granite-gneiss occur in bodies of many different sizes. The small bodies occur as well-defined dykes and sills and the large bodies and those of mappable size occur chiefly as conformable sheets that follow the trend of the older rocks. Most of the latter have vague boundaries and contaminated hybrid borders and show little evidence of intrusion. There are two exceptions to this. The granite underlying Cameron Islands and adjacent islands is exceptionally uniform and free from contamination products, and apparently has thrust aside the surrounding rocks during its emplacement. It is stock-like rather than sheet-like and presents definite intrusive relationships along the contact exposed on the northeast island of the group. Evidence of contamination and of sheet method of intrusion was not noted, suggesting the country rock at the time was rigid and, if so, that the Cameron Island granite formed later than some of the other granites. Lamprophyre dykes are interpreted as being related in origin to the Cameron Island granite which suggests that this granite is younger than other granites of the area. The second exception is the large mass of granite near Zenith, Dusyk, and Powley Lakes that exhibits sharp contacts and abundant pegmatite. The older rocks around this granite body appear to have been domed. Inclusions are rare and many of those present are of amphibolite in angular fragments.

QUARTZ MONZONITE

A dyke of quartz monzonite varying between 100 and 200 feet in width extends at least 4 miles northeastward from the shore of Lake Athabasca. This dyke was crossed in four places, but the outcrops are not perfectly alined, suggesting two or more separate bodies. Several other quartz monzonite dykes with approximately the same strike occur on an island in Lake Athabasca south of Oliphant Lake. There, the largest dyke is 30 feet across although most are only a few inches wide. No other dykes of this type were found in the map-area in spite of the excellent, nearly continuous rock exposure along lake shores.

On the reddish brown weathered surface large iron-stained feldspar phenocrysts stand out in rough alinement in a dark groundmass. On the fresh surface considerable biotite is recognizable in the groundmass. In the large dyke some phenocrysts are over half an inch long in the strongly porphyritic phases, but in the small dykes they are rarely more than one-eighth inch long. The degree of gneissosity varies but locally is marked.

Three thin sections of quartz monzonite were studied; two are from the large dyke and the third is from a dyke 30 feet wide that is exposed 4 miles east of the large dyke. Quartz varies from 25 to 30 per cent, microcline from 20 to 35 per cent, biotite from 5 to 15 per cent, and 35 per cent of the volume of each of the three slides is composed of plagioclase that varies from An_{30} to An_{33}. The rock is then a quartz monzonite, between granodiorite and quartz diorite (13).

The three sections examined have similar characteristics. Subhedral phenocrysts of potash feldspar with well-developed microcline twinning stand out in a granitic groundmass composed of biotite, plagioclase, quartz, and brown biotite. The minerals are moderately well alined and may be partly confined to individual layers in which quartz-rich bands are segregated from biotite-rich bands. The trend of foliation is moulded around the potash feldspar phenocrysts, thus giving the rock a fluidal appearance. Plagioclase, although usually highly altered, is sodic andesine. In one slide, however, a few grains of albite are present that contain antiperthitic intergrowths of potash feldspar. Microcline is nearly unaltered whereas brown biotite is partly altered to green biotite and chlorite. Vermicular quartz in plagioclase (mermykite) is common. Apatite, sphene, and shapeless grains of magnetite are accessory minerals and hematite occurs as clouds and disseminations along fractures and cleavages, chiefly confined to plagioclase and to the rims of microcline. Quartz grains are highly strained in all the slides and more pronounced deformation is evident in the eastern dyke where mortar structure is developed.

The quartz monzonite dykes transect the structure of the paragneisses, but their contacts, over short distances, are gradational into them with little change in grain size. Quartz monzonite intrudes the lamprophyre dykes, but some pegmatite dykes are younger and a few older than quartz monzonite. Granite dykes are cut by quartz monzonite. Narrow dykes of quartz monzonite are offset and slightly dragged by small faults and the dyke 30 feet wide mentioned above apparently was deformed plastically. The boundaries although gradational definitely transect the structures. All these features suggest that the quartz monzonite represents a differentiate from magma of the same age as that forming the Cameron Island granite.

LAMPROPHYRE DYKES

Hundreds of lamprophyre dykes, of which nearly two hundred have been plotted on the map, occur in the southeastern two-thirds of the area. The dykes have a surprisingly consistent northeasterly strike and apparently everywhere a nearly vertical dip. Many are only a few inches wide and a few exceed 50 feet in width, the average being perhaps 6 feet. Even the narrowest dykes have relatively great longitudinal extent and the widest can be traced on air photographs for over a mile on their strike. All the dykes, except about ten that cross the others roughly at right angles, strike consistently northeast with a slight tendency of radial arrangement about a point southwest of the area. The number of dykes increases progressively from northwest to southeast across the map-area, to near the eastern boundary, where their frequency decreased. Christie (15, p. 46) found eight lamprophyre dykes in the southeast corner of the area adjoining to the west that are part of the same swarm, but none has been reported from more westerly districts. To the east the dykes may not occur in such abundance as in the map-area but many were observed by the writer along the lake shore between the map-area and Fond du Lac. Alcock (2) mentions a lamprophyre exposed 9 miles east of Fond du Lac but none has been reported east of that. Lamprophyre dykes thus are known for a distance of about 50 miles along the north shore of Lake Athabasca and inland for at least 20 miles.

Shining flakes of biotite are visible on the chocolate-brown weathered surface of the lamprophyre. On the fresh surface the texture is strongly porphyritic. Phenocrysts of biotite up to one-third inch across and a few of pyroxene and amphibole stand out in a massive, fine-grained, dark reddish green groundmass in which pink feldspar can be identified in some specimens. The grain size of both phenocrysts and groundmass varies with the width of the dyke and the position with respect to contacts. At contacts biotite is alined and enclosed in a nearly aphanitic groundmass. The following table gives the approximate mineral composition of lamprophyre from nine widely separated dykes as determined in thin section.

TABLE VI

Estimated Mineral Composition of Lamprophyre

Minerals	1	2	3	4	5	6	7	8	9
	%	%	%	%	%	%	%	%	%
Biotite	20	10 (chl.)	18	30	20	20	30	25	17
Amphibole	2	3	19	......	......	......	5	5	18
Pyroxene	......	......	......	......	20	......	20	......	......
Orthoclase	60?	60	55	40	55	25	35	50	48
Plagioclase	5	10	......	5	......	......	......	......	5
Quartz	5?	15	4	2?	3	15	4	10	10
Carbonate	5	2	......	20	3	35	4	8	......
Apatite	1	1	2	3	x	x	x	2	1
Magnetite	1	1	x	x	x	3	x	x	x

Brown biotite forms from 10 to 20 per cent of the rock and occurs in two grain-size ranges probably representing two generations of crystallization. Biotite of the first generation averages about 4 mm. in length and that of the second less than 1 mm. Bleaching has left dark brown iron-rich rims and alteration, mainly to chlorite, varies from slight to complete. In some grains hair-like crystals of rutile occur in webs.

Hornblende commonly accompanies biotite as euhedral phenocrysts in amounts ranging up to 20 per cent of the rock. Its light green colour, positive optical character, and dispersion $R > V$ correspond to those of paragasite, the iron- and magnesium-rich and aluminium-poor variety of hornblende. Chlorite and rarely biotite are slightly developed around the rims as alteration products.

A third ferromagnesian mineral, a diopsidic pyroxene, accompanies biotite in two of the nine slides as euhedral, unaltered phenocrysts.

Orthoclase forms most of the groundmass in slightly altered, subhedral to euhedral grains. Twinning, although not prominent, follows the Carlsbad law.

Plagioclase was identified in four of the nine slides in which it occurs as subhedral, highly altered grains that form up to 10 per cent of the rock. The alteration is so intense that twinning has been obliterated in all but one case, determined to have the composition of medium oligoclase.

Quartz occurs in all slides as small irregular grains, the last to crystallize, in amounts ranging up to 15 per cent of the rock. Undulatory extinction was noted in nearly all grains.

Of the accessory minerals apatite and magnetite are the most characteristic. The former occurs in larger amount as euhedral crystals up to 1 mm. in length. The latter occurs both as well-formed crystals and as irregular grains scattered throughout the groundmass.

Chlorite occurs in various amounts, depending on the degree of alteration of the ferromagnesian minerals. It commonly shows the anomalous, ultra-blue interference colours typical of penninite. Carbonate is invariably present in small quantities as irregular masses and shreds and as a replacement of plagioclase. In one slide carbonate is abundant and this probably resulted from extensive metasomatic addition of CO_2.

The lamprophyre dykes are rich in biotite and orthoclase, and poor or lacking in plagioclase, quartz, and ferromagnesian minerals other than biotite. The rocks of the dykes are classed as minnette tending toward vogesite.

The lamprophyre dykes in general cut sharply across all the rocks of the map-area with the exception of diabase and their direction is uncontrolled by structural trends. In detail, however, many contacts are highly irregular along the strike with offshoots extending along blocky fractures into the country rock. Commonly they are arranged in an *en échelon* pattern with fairly consistent right-hand offsets. Inclusions of country rock are either rounded or angular in shape. Although the dykes nearly everywhere appear to be little deformed, one at Sutherland Lake contains three zones, each about 6 inches wide, in which the rock has been mylonitized. A lamprophyre that extends along the west shore of Forget Lake near the St. Louis fault has been deformed dynamically along one contact.

DIABASE DYKES

Seven diabase dykes were found in the map-area, and of these six are in the west half. Although rare in the area being considered they are abundant in the northern half of the Goldfields-Martin Lake map-area adjoining it on the west. Farther west, in Black Bay and Gulo Lake map-areas, diabase dykes several hundred feet wide and traceable for great distances occur (Hale, 30, 31). Diabase dykes have not been reported from districts east of Oldman River map-area. Christie (16, p. 60) concludes that they are related, both in composition and in age, to the spilitic basalts and andesites that form part of the Athabasca series in the vicinity of Martin Lake.

The dykes in the area being studied are not over 3 feet wide except for a dyke 25 feet wide north of MacRae Lake. The grain size of the brown weathering, dark green diabase varies with the width of the dyke. In the smaller dykes, small feldspar laths stand out in an aphanitic groundmass, but in the rock of the larger dyke other minerals are recognizable. Cubes of pyrite are commonly present.

A sample of fine-grained diabase from a mylonitized zone near Viking Lake was seen in thin section to be undeformed although extensively altered. The diabase is composed of a network of poorly twinned plagioclase laths of undetermined composition, set in a fine-grained, dense mass of chlorite that is apparently pseudomorphous after pyroxene, plagioclase, and minor amounts of carbonate, potash feldspar, and quartz.

The diabase dykes of Oldman River map-area are younger than all other rocks in the area, but, as one dyke south of MacRae Lake terminates along its strike at a fault, they are probably older than some of the faults.

CHAPTER III

SUMMARY OF METAMORPHIC FEATURES AND STRUCTURAL GEOLOGY

GENERAL STATEMENT

The effects of metamorphic agencies are widespread in the bedrock of Oldman River map-area. Strata of the Tazin group are adjusted to pressure and temperature conditions characteristic of the amphibolite and granulite facies of metamorphism. Some material appears to have been added locally, chiefly quartz and feldspar, to form pegmatite, migmatite, and granite-gneiss. The evaluation of the relative importance of this and recrystallization is difficult.

Eskola's (22) classification of metamorphic facies modified by Turner (49) and Ramberg (44) is useful in analysing the conditions under which the metamorphic rocks of a particular area formed. In Oldman River map-area the amphibolite facies and the granulite facies of this classification are represented, these corresponding to conditions of high temperature and pressure.

The foliation in the quartzite, migmatite, and paragneiss of the Tazin group everywhere is conformable to the original stratification. This relationship helps in determining structure on a regional scale from trends on aerial photographs and indicates that the beds have been buckled into large, relatively simple, open folds. In detail, however, the limbs of these major folds contain complex minor folds in many places. These and the many poorly defined boundaries of some formations render the determination of detailed structure difficult. Major faults follow prominent valleys containing thick drift deposits.

All rocks except diabase are deformed by mylonitization along certain zones to cherty appearing, dense to banded types. In these hornblende and plagioclase are in large part altered to chlorite, sericite, and other products. Quartz is in small uniform-sized grains. Faults follow some bands of mylonite as does the eastward extension of the St. Louis fault from Goldfields area follow the large belt of mylonite that passes through Prince and Alces Lakes. Northeast of Beaverlodge Lake in Goldfields-Martin Lake map-area important deposits of pitchblende are present in the altered rocks adjoining the St. Louis fault (16), consequently, mylonite is regarded as an important guide in directing prospecting.

AMPHIBOLITE TO GRANULITE FACIES

In the general description of the amphibolites (pp. 20-22) the change from normal amphibolite to pyroxene amphibolite (granulite) from west to east across Oldman River map-area is described in detail. With the change from normal amphibolite to a pyroxene-bearing type the content of the anorthite molecule of the plagioclase increases, this by some being interpreted to indicate an increase in the intensity of metamorphism in this case from west to east. The amphibolite also assumes a banded structure as pyroxene appears and some bodies are strikingly layered with hornblende and pyroxene segregated into alternating bands. This structure possibly represents the results of metamorphic differentiation and is considered to indicate high temperature and pressure conditions of origin. The amphibolites and granulites give the best idea of the grade of metamorphism the rocks of the area have undergone, and although quartzite, migmatite, and paragneiss occurring with the amphibolite cannot be assigned to a specific facies, they nevertheless support the conclusion that the amphibolite and granulite formed by metamorphism under conditions of high temperature and pressure.

GRANITIZATION

Granitization or the progressive metasomatic transformation of rocks into granite undoubtedly affected certain formations of Oldman River map-area. Amphibolite is generally regarded as particularly resistant to granitization; nevertheless, the rocks of some bodies carry quartz and abundant feldspar. These minerals were probably introduced and some granitic layers in migmatite and paragneiss, without definite outline, were formed as replacements by introduced material under conditions of high temperature and pressure. Widespread quartz and feldspar porphyroblasts and bodies of pegmatite with irregular outline also are interpreted as replacements by introduced materials. Some postulate that material to form granitic bodies passes upward through an advancing migmatitic phase and if so the considerable quantity of material thus involved will undergo some transformation in passing through the rocks. The average mineral assemblage of paragneiss is further removed from typical granite than that of migmatite, and this suggests that possibly paragneiss is a less granitized type than migmatite. The variation in composition of the granitic rocks from a potash-rich variety in the southeast corner of the map-area to calcium-sodium types and as quartz monzonite towards the northwest also supports the hypothesis of transformation of rocks as a phase of regional metamorphism. The intensity of metamorphism decreased northwest, and a possible interpretation of the relations is that the granitic rocks in the northwest part of the map-area formed farther from the source of metamorphism than did those in the southeast part and that the material of the monzonite has moved farther than that of the potash granite. This also suggests that potassium in the process left the granitic liquid to enter the country rock.

Layers of some migmatite, some replacement pegmatite, quartz and feldspar porphyroblasts, and concentration of quartz in minute bands possibly formed by the segregation of material from near by. The banding of pyroxene and hornblende in separate layers in pyroxene amphibole and the many scattered, lens-shaped, small bodies of mafic rocks in paragneiss also suggest concentration of local materials. In these cases the source of end product perhaps is best explained by "sweating out" of certain elements from the surrounding rock and representing a type of metamorphic differentiation. More quantitative data and detailed field investigation than that undertaken are required to evaluate the relative importance of granitization and metamorphic differentiation in the formation of the granitic appearing banded rocks of the map-area.

ROCK FLOWAGE

The parallelism of bedding and foliation where determinable in Oldman River map-area is a feature common to many parts of the Canadian Shield. In some areas this relation is explained by the coincidence of axial plane cleavage and bedding in isoclinal folds, as in many parts of northern Ontario and Quebec and in the Appalachian region. However, in Oldman River map-area, where there is little or no isoclinal folding, the foliation is apparently due to flowage (22) along bedding planes. Boudinage structure in migmatite and other rocks (*See* Plate II A) indicates that flowage has occurred along the strike of the formations. In thin sections evidence of molecular flow and granulation is seen in the segregation of easily mobilized quartz into individual layers. Conybeare (18) gives other evidences of flowage along the direction of bedding in Martin Lake map-area and points out that the quartz fabric shows a pronounced orientation. Flowage in rock is induced by high temperature and pressure and by the permeation of solutions. As these same conditions are also responsible for regional metamorphism, bedding-foliation probably was developed during metamorphism, and metamorphism and folding are contemporaneous.

LINEATION

Measurements of the attitudes of lineation were made only on the axes of minor contortions or drag-folds. Hornblende, arranged in planes, accounts for the foliation in amphibolite but is poorly alined in any specific direction. Other elongate minerals are rare. Rodding and mullion structure are absent in Oldman River map-area. Most drag-folds, except those in the southeast corner of the area, plunge south-southwest, as do the major folds, and both drag-folds and major folds vary considerably in their angle of plunge. Despite these variations, however, the attitudes of the drag-folds roughly coincide with the attitudes of the major folds and have no doubt been formed as a result of flowage between competent layers. Drag-folds with exceptionally steep plunges, incongruous drag-folds of Hill (32), may have resulted from an abnormal direction of movement between beds, due to a change of stress during orogeny, perhaps accompanying the intrusion of granite at an advanced stage. At some points on a syncline inner layers appear to have had a minor component of movement of beds in a direction perpendicular to the fold axes. In the southeast corner of the map-area drag-folds with one exception plunge directly down the dip of the formations that form the southwest side of a major anticline, indicating considerable horizontal movement between beds forming the limbs of the fold.

MYLONITIZATION

Mylonite is interpreted as forming by deformation under conditions that favour the retention of coherence (52). Most mylonite is probably formed along thrust zones of high dip and under great pressure. The rock is dense to finely banded, dark greenish or reddish, and "cherty looking", in most of which rounded and augen-shaped remnants remain in a streaked groundmass. Some mylonite because of its cherty appearance is readily mistaken for chert, cherty quartzite, or certain rhyolites. North of Lake Athabasca and west of Oldman River map-area mylonite is confined chiefly to the vicinity of Black Bay and St. Louis faults and to an area between Ace and Melville Lakes (16).

Mylonite in Oldman River map-area is local in distribution and occurs chiefly in zones that extend from Prince Lake northeastward to and beyond Hamilton Lake. Because of the over-all great width of some of the zones of mylonitized rocks, they are best considered as representing a broad belt of continuous slippage and plastic flow rather than an individual fault or faults. The name "St. Louis fault" then should apply only to the sharply defined normal fault that follows the mylonite zone. At Prince Lake zones of mylonitized rocks have an aggregate width of at least 3 miles. This width decreases northeastward so that at the eastern boundary of the map-area the breadth of the zone is only a fraction of a mile. Banding is prominent in most of the mylonite (*See* Plate III B) and is marked by an alinement of porphyroclasts, mostly feldspar, pyroxene, or hornblende; by fluidal structure (*See* Plate IV A); by discontinuous streaks of crushed material; or by ribbon quartz developed by the segregation of quartz into minute discontinuous and interwoven layers (*See* Figure 1B). Zones of mylonitized rocks are indicated on the map by stipple, but their outlines are approximate because they lack sharp boundaries and describe an interwoven pattern.

All rocks in these zones are altered to dense, "cherty looking" products containing porphyroclasts, streaks, and bands. Although the end product is the same in general appearance regardless of the rock affected, it is possible in many cases to identify its original nature. Granitic rocks poor in mafic minerals have taken on a pink or red colour and gneisses rich in mafic minerals are dark in colour; thus much migmatite displays an alternation of pink layers and dark-coloured layers. Remnants of alined feldspar and hornblende are abundant in mylonitized amphibolite and quartzite assumes a dense texture and lacks the characteristic rind on weathered surfaces.

The wide belt of mylonite along the St. Louis fault appears to represent a zone of slippage along which the rocks were upthrust from the southeast and against a stable area. The banding in the mylonite dips moderately or steeply south and approximately parallels the plane of the St. Louis fault. This mylonite is folded complexly.

Mylonitized rocks, however, are not confined to the zones along the St. Louis fault. Many of the small faults that break the arch of drag-folds in quartzite are marked by mylonite across widths of a fraction of an inch. In the extreme northwest corner of the map-area the bands of mylonitized amphibolite probably reflect the extension of the zone of mylonite followed by the Black Bay fault. At Sutherland Lake a lamprophyre dyke is transected by three zones of mylonite, each 6 inches wide. In these, although most minerals are crushed and alined, the specific gravity is the same as that of the adjoining lamprophyre.

Various stages of mylonitization are represented in the thin sections examined. In some sections only a little of the quartz has been crushed and segregated in layers between grains of other minerals. In other sections all minerals of the rock have been crushed, except for perhaps 5 per cent that form augen-shaped porphyroclasts from which extend streaks of crushed material. Most sections exhibit a marked banding, which may be regular as in Plate IV B or fluidal as in Plate IV A. In all thin sections quartz grains are approximately 0·03 mm. in diameter and form an equigranular aggregate. The uniformity of the minimum grain size in specimens from many parts of the area indicates that subsequent recrystallization was not important, although elongate grains of quartz in a mosaic of fine-grained quartz suggest some recrystallization.

All quartz grains in a mylonitized rock are similarly orientated optically, and appear to show strain shadows, although because of their small size it is difficult to be certain of this. Minute flakes of chlorite and sericite with common orientation occur in the quartz mosaic. Grains of feldspar, pyroxene, and hornblende are invariably fractured, highly strained, and rounded, and have extending from them tails of their crushed products. Many of the fractures in these minerals have been penetrated by quartz. In some slides the fine-grained products contain feldspar, although usually it is difficult to recognize. In one slide a tail of crushed apatite has been drawn out from the parent grain. Plate IV A and B and Figure 1B illustrate various phases of mylonitized rocks.

Extensive alteration of the mafic minerals and feldspars to chlorite, sericite, epidote, carbonate, etc., is a feature that is characteristic of all mylonitized rocks in the map-area. In many cases feldspar porphyroclasts have been entirely converted to sericite and minor amounts of other alteration minerals. Small veinlets of quartz, chlorite, and carbonate indicate that these have at least in part been introduced. Hematite also occurs as veinlets, probably mostly introduced, and also as a dusty component of much of the feldspar, resulting in the characteristic pink or red colour of mylonite derived from felsic rocks.

Minerals elsewhere characteristic of the granulite and amphibolite facies have in mylonitized zones been altered, in many places completely, to chlorite and other products characteristic of the low-grade facies of metamorphism. Quartz, iron oxide, carbonate, chlorite, and, according to Christie and Conybeare (16, 18), albite in Martin Lake map-area, have been added. High shearing stress and the presence of solutions apparently favoured retrogressive metamorphism along zones of slippage.

The time of mylonitization in relation to other processes that have affected the Tazin rocks may be defined within narrow limits. Because migmatite is among those rocks that have been crushed the period of mylonitization must have followed migmatization. Also because high-grade metamorphic minerals occur as porphyroclasts and in many places these have been altered to lower grade minerals, mylonitization followed regional metamorphism. Mylonite at a few localities is cut by undeformed pegmatite, and in several localities by undeformed lamprophyre. Thus mylonitization was active after the main period of metamorphism and before the final stages of intrusion. Mountain building must have been in progress subsequently, because some mylonite is strongly folded. During the period of metamorphism and mountain building, conditions probably were such that the rocks reacted to differential forces by flowing to form complex minor folds, boudinage structure, and bedding-foliation relationship. As the rocks became more brittle in the final stages of orogeny they failed along definite zones to form the mylonite. A few mylonite zones north of Lake Athabasca are followed at some points by normal faults whose fissures probably served as channels for the migration of uranium-bearing solutions.

All parts of mylonite carrying minerals indicative of low facies metamorphism also perhaps reflect channels along which uranium-bearing solutions could migrate, and these and normal fault zones in mylonite deserve special attention in prospecting.

FOLDS

The large synclines south of Alces Lake, Forget Lake, and MacRae Lake; at Nevins Lake and Hill Lake; those that extend along the two major amphibolite masses; and the large dome structure west of Alces Lake are prominent structural features. These synclines, as well as other smaller folds, plunge toward the south. A few plunge over 40 degrees, a few are horizontal, but most have an intermediate angle of plunge. The axial plane of many of the folds is warped along the strike, as indicated by trend variations in lines drawn through the "noses" of formations seen on air photographs. Although no individual bed has been traced very far, it seems probable from an examination of structural trends that the rocks exposed in the southeast corner of the map-area, in the vicinity of Beaver River, extend northward to Nevins and Neiman Lakes and thence northwestward to Alces Lake where they form the nose of a major syncline and, in a general way, follow southward the course of Oldman River to Lake Athabasca. Probably the large paragneiss mass exposed on the lake shore and that south of Alces Lake occupy the central region of a major syncline, and if so the metamorphic rocks immediately east and west represent stratigraphically lower horizons.

An attempt has been made to draw a simplified, highly diagrammatic structure-section across the formations as exposed on the lake shore (*See* Map 1047A). Its accuracy leaves much to be desired due to the nature of the metamorphosed rocks and the complexity of minor folds, but it does portray the simplicity of the major folds. The paragneiss is shown occupying the central region of a large syncline, although the interpretation at the western contact is in doubt. West and east of the paragneiss the formations are repeated and possibly some of this repetition is due to faulting. The major folds at some points were deformed locally by faulting.

Although the major folds have simple cross-sections, difficulties are encountered in following them along their strike. The angle of plunge in some cases varies, folds inclined to the west become inclined to the east and vice versa, or upright folds become overturned. These variations are illustrated in the folds between Adair Bay and Kisiwak Lakes. At Forget Lake quartzite and migmatite extend in an eastward direction, separating two large synclinal areas of paragneiss. The western limb of the major syncline that embraces most of the area probably has been buckled inward over the axial region (*See* Figure 3B). If so, the paragneiss exposed south of Forget Lake is overturned and occupies the same stratigraphic position as that exposed north of Neiman Lake.

As mentioned previously, the limbs of the major folds also are folded. These subsidiary folds vary in size from those in the paragneiss exposed on the lake shore about Hayter Bay, to minor folds only a few inches to a few feet across. Minor folds, or drag-folds, are particularly well developed in the migmatite and related rocks. In a few cases the contortion is complex, to give 'ptygmatic' folding.

FAULTS

Several faults were mapped, and many others too small to map are known. They are marked by definite planes along which gouge, slickensides, and epithermal veins occur. Some are strike-slip and normal oblique-slip faults that belong to a much later and shallower period of deformation than that which was responsible for the folding and mylonitization.

Prominent valleys mark the sites of the larger faults although lakes and drift along them mask the fault surfaces. Displacement of structures and formations is the criterion by which they may be recognized. All topographic lineaments in the area do not follow faults, for many are due to differential erosion of layered rocks and others have been formed by glacial erosion. Lineaments, however, that are neither parallel with the strike of the rocks nor with the direction of glaciation are more likely to represent faults than those that are parallel with the direction of structure and ice movement.

Five faults have been mapped near Kisiwak Lakes; three strike approximately east and two slightly west of north. All displace the rock formations. Those striking east end at a large mass of amphibolite that, being less brittle than the surrounding rocks, was deformed by folding. There has been, evidently, a rotational movement on the most easterly of these, as the displaced formations on either side dip in opposite directions. The northwesterly fault between Mathews and Kisiwak Lakes is followed by a stock-work of quartz veins. Slickensides indicate vertical movement and the horizontal separation of rock units suggests that the west block moved downward relative to the east block.

The major fault that extends through Gibbs and Stephens Lakes on the west side of the area is marked by a particularly pronounced valley and the structure in the adjacent rock is offset. A profusion of quartz veins follow the fault zone in a few places near the western boundary of the map-area, and south of MacRae Lake slickensides that plunge in both directions are exposed. The curved surface trace of the fault suggests that the main component of movement was in a vertical direction. Horizontal separation of rock units along this fault indicates that the northwest side moved down relative to the southeast side. A major fault that follows Dead Man Channel and Wallace Bay also contains quartz veins in many localities and a right-hand horizontal separation.

The St. Louis fault follows a slightly irregular course from Beaverlodge Lake in Goldfields-Martin Lake map-area through Prince and Alces Lakes to beyond the eastern boundary of Oldman River map-area, a distance of over 30 miles. Local irregularities in trend may indicate branch faults or even sets of faults. This fault follows in general the zone of mylonitized rocks but is not everywhere confined to them. At Ace Lake, in Martin Lake map-area, diamond drilling intersections show that the fault plane dips at 50 degrees toward the south and is marked by several feet of gouge and fault breccia (16), and uranium-bearing veins are present in altered wall-rocks. Displaced structures, as determined by Christie, indicate a horizontal component of relative movement of the south wall amounting to 1,100 feet toward the west. The preservation of strata of the Athabasca series on the south side in Goldfields-Martin Lake map-area indicates that in addition to horizontal movement some dip-slip movement also has occurred.

In Oldman River map-area quartz stock-works, many containing comb quartz, and veins of chlorite, hematite, epidote, and carbonate are common, and, at one locality at McKay Falls, veinlets of pitchblende are known. Many of the parallel fractures in the adjacent rock show small displacements and invariably dip at a steep angle toward the south. A small area of quartzite that outcrops between Forget Lake and Prince Lake is brecciated. Slickensides of different attitudes were observed in a few localities adjacent to the fault.

Gossan zones that conform to the attitude of the formations probably mark the sites of faults but are shown on the map by a separate symbol. One such zone contains fault gouge. Commonly pyrite, graphite, and specularite are visible in the weathered rock and the presence of radioactive minerals have in a few localities been proved by tests with a Geiger counter.

Along most faults, separations are right hand and horizontal, with the south blocks moving downward and westward relative to the north blocks. The dip of the fault planes is rarely known. The St. Louis fault represents a normal fault and the presence of normal faults suggests that tensional stresses were dominant during faulting. In Oldman River map-area, however, an additional stress that caused the apparent movement of the southern part of the area westward relative to the northern part was also important. Lamprophyre dykes that were intruded at the end of the period of orogeny describe right-hand *en échelon* patterns, interpreted to reflect an effect of this stress. Even the small pre-lamprophyre faults that ruptured drag-folds commonly have right-hand strike separations.

Possibly the amount of upthrusting during mylonitization was greater than the later normal movement on the St. Louis fault. If so, rocks south of the fault represent a deeper level in the crust than those north of the fault and, consequently, a higher grade of metamorphism. Field evidence substantiates this possibility as the boundary between the granulite and amphibolite facies follows the eastern part of the St. Louis fault.

It is not known whether the late faults represent one or more than one period of dislocation. In the adjacent map-area to the west, faulting was well advanced before deposition of the Athabasca series (16), to form tectonic basins in which deposition occurred. Faulting must, however, have continued during deposition to allow great thicknesses of shallow water sediments to accumulate in the tectonic basins. Evidence from outside Oldman River map-area (16, 30, 31) indicates that faulting was active after both the folding of the Athabasca series and the intrusion of diabase dykes.

CHAPTER IV

ECONOMIC GEOLOGY

URANIUM DEPOSITS

General Statement

At present the main interest in Oldman River map-area is its nearness to the Goldfields region[1] where important uranium deposits are developed. Although prospecting within Oldman River map-area to date has revealed only a few uranium occurrences, the area warrants further exploration. The formations adjacent to the several major faults, including the St. Louis fault, deserve close attention. It is significant, also, that the limited amount of testing with a Geiger counter in conjunction with the writer's geological field work revealed several anomalies. In addition to uranium deposits, prospectors should search for sulphide deposits, particularly those of nickel and copper, which, in the neighbourhood of Dinty Lake, occur in lens-shaped bodies of norite. Many gossan zones, some of which indicate faults or shears, follow the structure in the southern part of the map-area and deserve investigation.

Because the area under study contains only a few known mineral occurrences, problems relating to them are not discussed in detail, but a brief summary is given of the conclusions and observations of Christie, Lang, Robinson, and Dawson regarding the major uranium deposits known west of Oldman River map-area. The uranium prospects examined in the map-area are similar in all respects to those occurrences described by these authors.

In the Goldfields region uranium oxide is found as uraninite in pegmatite and pegmatitic granite and as pitchblende in hydrothermal veins. Pegmatite deposits are numerous, but are characteristically spotty in their uraninite content, and on the average are of low grade. Pitchblende occurs in veins along faults, shears, and fractures or fracture zones adjacent to the St. Louis, Black Bay, and other faults. Structural conditions seem important in determining the exact location of an orebody. Amphibolite, basalt, dolomite, graphitic bands in quartzite, chlorite-epidote rocks, and carbonate-bearing zones are most favourable host rocks whereas quartzite and other siliceous rocks are definitely unfavourable. Hematite, specular hematite, carbonate, quartz, chlorite, and albite are the common gangue minerals. Pyrite, chalcopyrite, galena, bornite, copper selenides, niccolite, cobalt-nickel arsenides, arsenopyrite, pyrrhotite, native copper, silver, and gold occur locally in addition to pitchblende. Pitchblende, which is usually botryoidal or colloform, is commonly weathered or altered hydrothermally to a greenish or brownish black colour. The wall-rock is commonly stained red by introduced hematite, this coloration serving as an important indicator of the presence of radioactive minerals.

[1] Goldfields region refers to an area on the north shore of Lake Athabasca, within about a 25-mile radius of Goldfields. Oldman River map-area is partly included in this region but part of it lies to the east.

Most pitchblende deposits of the Canadian Shield occur in deformed Proterozoic rocks and in adjacent older rocks, and in the Goldfields region the deposits appear to be related spatially to the folded Athabasca series probably of Proterozoic age. Determinations of the age of samples of pitchblende from the Goldfields region vary and include many anomalous results. They range from 18 x 10^8 years to 6 x 10^8 years (16). Many of the samples tested were, however, somewhat altered. The age determinations, nevertheless, suggest that uranium was deposited in more than one period. Little is known concerning the origin of the uranium-bearing solutions except that they were apparently most active after the deposition of the Athabasca series and the deposits are not related spatially to diabase dykes.

Descriptions of Uranium Deposits

AL Group

The AL group of three claims was staked by J. Lawson and G. Berg in the autumn of 1949 while prospecting for Noracon Exploration Company. The group is along the west shore of Felix Bay on the north shore of Lake Athabasca, in an area underlain by steeply dipping, highly metamorphosed, dark weathering paragneiss cut by sills of granite, and dykes and masses of pegmatite. A shear zone 5 feet wide that parallels the steeply dipping gneiss contains a fault marked by a seam of gouge $\frac{1}{2}$ inch thick and horizontal slickensides. In two closely spaced pits straddling the fault several veins of pitchblende filling nearly vertical cross fractures are exposed. These veins do not exceed $\frac{5}{8}$ inch in thickness and none seems to have a length of more than 4 feet. Pyrite occurs in the shear zone as veins or scattered grains and has weathered to produce a limonite capping. Purple hematite stain and disseminated graphite are associated with the pitchblende. Two grab samples taken from the pits by the writer assayed[1] 4·92 per cent and 0·36 per cent U_3O_8 equivalent respectively. Five grab samples taken by the prospectors assayed from 1 to 10 per cent U_3O_8 equivalent. A preliminary Geiger counter survey of the immediate area failed to locate other radioactive occurrences.

L and B Group

The L and B group of three claims lies at the northeast end of Mackintosh Bay near the western boundary of the map-area. On the shore of the extreme northeastern corner of the bay several closely spaced pits have been dug in well-bedded, buff weathering quartzite and impure quartzite cut by irregular masses and dykes of pegmatite. A small, lens-shaped, twisted mass of amphibolite exposed in the pits has been sheared, whereas the surrounding, steeply dipping quartzite has been only mildly fractured. Both the shear zone in the amphibolite and some of the fractures in the quartzite contain pitchblende-bearing veins, which nowhere appear to exceed 6 feet in length or $\frac{1}{8}$ inch in width. With the pitchblende are yellow and green oxidation products, purple hematite stain, and pyrite, the latter being particularly prominent in the amphibolite body. Geiger counter readings average twice the background count within an area of about a 30-foot radius of the pits, and beyond this the readings decrease rapidly within a few feet.

[1] Assays, unless specified otherwise, refer to a radiometric assay by the Radioactive Resources Division of the Geological Survey of Canada on samples collected by the writer.

Dello Group

The Dello group of nine claims, situated northeast of Reed Bay, is held by the Neiman Lake Uranium Prospecting Syndicate. Five closely spaced pits, situated $\frac{3}{4}$ mile north-northeast of Reed Bay, and in a large amphibolite mass, have been dug along a northwest-striking fracture zone 5 feet wide. The amphibolite is intersected by small irregular dykes and masses of granite and pegmatite. Veins of calcite containing pitchblende are visible in three of the pits. One vein has been traced for 8 feet and attains a thickness of $\frac{1}{2}$ inch. The amphibolite has been silicified near a few of the pitchblende-bearing veins. Much of the rock bordering and within the fracture zone contains abundant pyrite. The pitchblende-calcite veins carry specular hematite and red hematite stain in addition to the usual uranium oxidation products. A grab sample taken by the writer assayed 0·17 per cent U_3O_8 equivalent.

MM Concession

The MM concession of Goldfields Uranium Mines Limited is $2\frac{1}{2}$ miles wide and 12 miles long, and extends along the St. Louis fault northeastward from the west end of Prince Lake to the middle of Alces Lake. The concession was traversed at 200-foot intervals during the summer of 1950 by prospectors under the direction of Technical Mines Consultants, and about thirty radioactive anomalies were found. Further work was planned by the owners on five of these anomalies. Thirteen grab samples collected by the operators assayed from nil to 2·58 per cent U_3O_8 equivalent. The writer examined two of the more important radioactive occurrences, the one north and the other south of Alces Lake. The northern anomaly extends easterly for 400 feet. Pegmatite, pegmatitic granite, and granite are intrusive into amphibolite, altered quartzite, and gneiss of unknown origin. Most of the radioactivity is due to disseminated radioactive minerals near weak fractures in the amphibolite.

The anomaly south of Alces Lake occurs along a narrow shear zone that cuts white pegmatite and pegmatitic granite. Most of the radioactive minerals are disseminated in lenses of chlorite and biotite schist that flank the shear zone.

DDD Concession

Claims located along the east side of Mathews Lake, in the expired DDD concession, were staked in 1949 (?) by S. Yaniak and B. Berry. A series of trenches extend 200 feet along a sheared zone at the contact between quartzite and pyroxene-bearing amphibolite. At the contact, the amphibolite is highly chloritized, and in one place horizontally slickensided. A little disseminated graphite, hematite, and pyrite occur in the wall-rock, and pitchblende and its yellow alteration product are found in minor amounts at intervals along the main shear zone. Mr. Yaniak states that the contact zone is mildly radioactive for its investigated length of 200 feet. A sample taken by the writer across the shear zone, where it is 8 inches wide, assayed 0·19 per cent U_3O_8 equivalent.

Neiman Lake Occurrence

The Neiman Lake occurrence was not seen by the writer, but Lang (41) describes it as follows: "The Neiman Lake Uranium Prospecting Syndicate reported a discovery from the vicinity of Neiman Lake about 25 miles northeast of Goldfields. The occurrence was described as being along the contact of a basic dyke with granite, and a selected sample sent to the Geological Survey showed 0·67 per cent U_3O_8 equivalent".

Other Occurrences

Several minor radioactive anomalies were discovered during the course of the geological work. Many of these are along or in fractures adjacent to gossan zones in the Narrow Bay-Adair Bay area. In the small area prospected at McKay Falls several anomalies occur along and adjacent to the St. Louis fault. One stringer of pitchblende follows a subsidiary fracture.

GOLD, NICKEL-COPPER, AND IRON DEPOSITS

General Statement

During the period 1934 to 1942 many gold deposits were discovered, a few were explored underground, and two were brought into production at Goldfields. No promising deposits of gold are known to have been discovered in Oldman River map-area. At Dinty Lake nickel and copper sulphides were discovered in bodies of norite. The low-grade iron-formation near Oldman River and at MacRae Lake has been described on page 12.

Dinty Lake Nickel-Copper Deposits

In 1936, J. W. Warren, Manager of The Consolidated Mining and Smelting Company's Borealis Syndicate, staked an interesting deposit of nickel and copper just north of Dinty Lake. During the autumn of 1936 and the following winter the deposit was explored by several trenches and twelve drill-holes. Exploration and staking were apparently continued until 1942. Claim maps, assay plans, drill plans, drill model, and logs and core of diamond drill-holes were examined by the writer. In April 1951, W. W. Archer, acting as engineer for Goldfields Uranium Mines Limited, restaked twenty-two claims, the Achok group, and sampled the trenches of the main deposit.

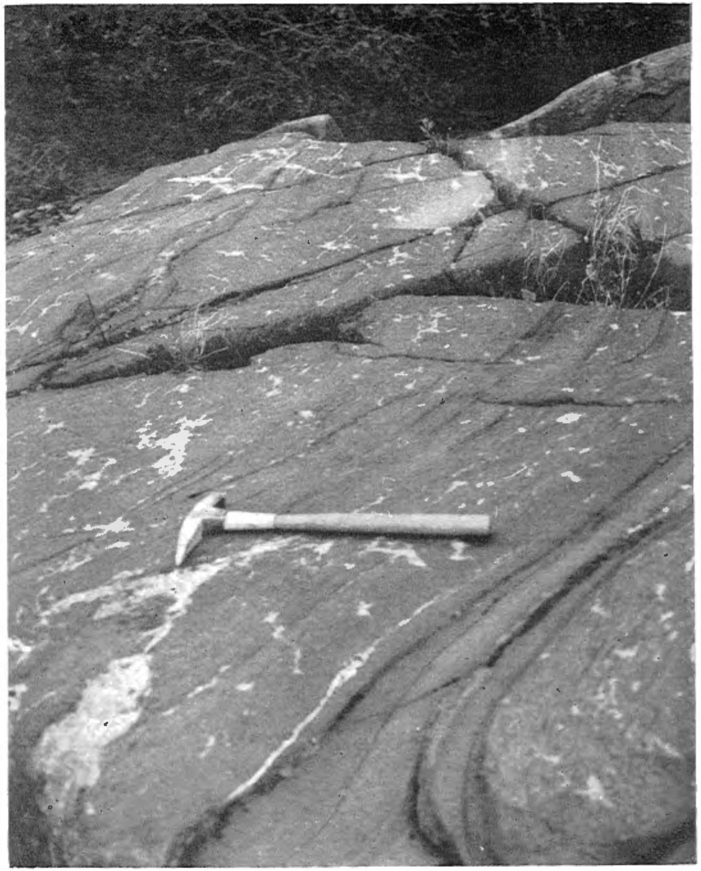
In his preliminary report on the Goldfields area, Cooke has given a thorough description of the main Dinty Lake deposit, and most of the following information is derived from his report and an unpublished company report by W. W. Archer.

An elongated body of norite, exposed by eight trenches and small, scattered outcrops, extends along a low northerly trending ridge for at least 900 feet. The norite body is in contact with granite-gneiss on both sides. At the surface the body is up to 200 feet wide. The dip is westward at an angle that decreases with depth, and at a depth of 200 feet the body narrows and apparently ends.

The norite is a grey, fine- to medium-grained, equigranular rock, which, according to Cooke, is composed of andesine and a monoclinic pyroxene closely related to hypersthene, with minor amounts of uralite, biotite, magnetite, and red garnet. "Two polished sections of the sulphide ore show it to consist almost entirely of pyrrhotite. A small amount of chalcopyrite is also present in small veinlets and areas, and a little sphalerite, a little of the mineral probably the iron-copper sulphide cubanite, and a very small amount of an unidentified mineral. No pyrite appeared in these samples but in the field considerable amounts of it were noted". The norite has in part been brecciated to give zones containing numerous slips with slickensided walls. The sulphides occur as cementing material in the breccia, as fracture filling, and as disseminated replacement.

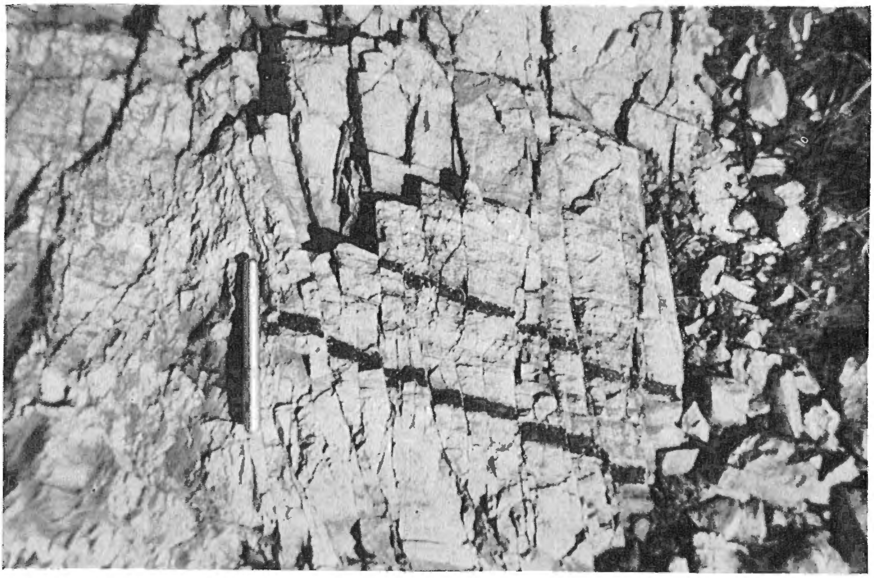
Goldfields Uranium Mines Limited reports about 1,500,000 tons of indicated ore containing up to 0·6 per cent nickel. Samples selected by Cooke assayed 0·94 per cent nickel, 0·04 per cent copper, 0·01 ounce of gold a ton, and 0·10 ounce of silver a ton. The writer tested with a Geiger counter all the trenches of the main showing and found no evidence of radioactive minerals in the deposit.

A. Boudinage structure, garnets (black spots), and banding resulting from alternating layers of quartz and feldspar and layers containing some ferromagnesian minerals are characteristic of migmatite. (Pages 14, 35.)



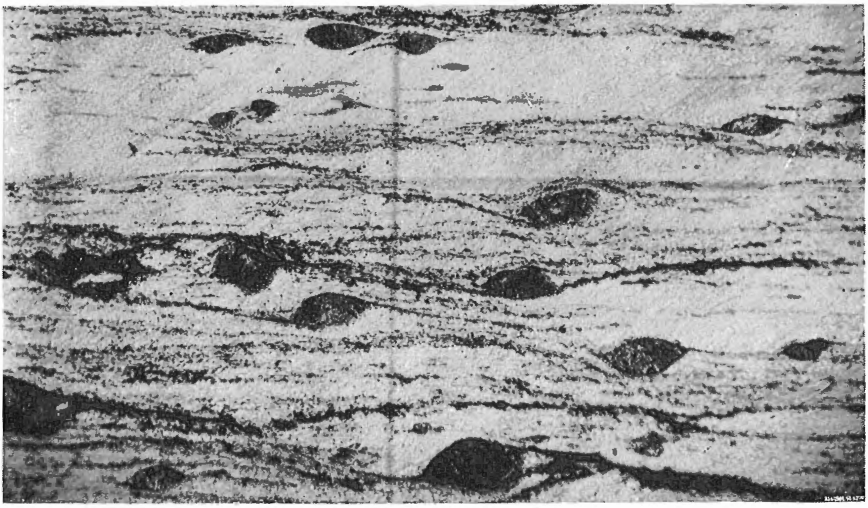
B. White splashes of quartz and feldspar occur in amphibolite west of Felix Bay. (Pages 21, 25.)

A. Pegmatite (light grey) apparently replaced paragneiss west of Narrow Bay. (Page 26.)



B. Fracture cleavage in banded mylonite is parallel with the nearby St. Louis fault between Zenith and Forget Lakes. (Two layers of the mylonite have been painted on the outcrop.) (Page 36.)

A. Feldspar porphyroclasts in a mylonitized rock that shows typical fluidal structure. The white streaks are mainly fine-grained quartz and feldspar and the dark areas are mixtures that include chlorite, sericite, and iron oxides. (Plane polarized light, x80.) (Pages 16, 36, 37)



B. Altered feldspar porphyroclasts in mylonitized quartzite have tails of crushed products. (Plane polarized light, x28.) (Page 37.)

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