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MEMOIR 367

GEOLOGY OF THE BEAVERLODGE MINING AREA, SASKATCHEWAN

L. P. Tremblay

Ottawa
Canada
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By
L. P. Tremblay

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PREFACE

Complex Precambrian gneisses yield some of their secrets only after long, tedious, patient study. The complexities of their structure must, however, be understood if the discovery and development of their contained ore deposits are to be efficiently conducted.

The Beaverlodge mining area is in just such a complex, and as it contains some of Canada's principal uranium producers, it was the subject of careful study. From 1952 to 1957 the author mapped the area in great detail, in places following the gneisses almost layer by layer through complex structures. Gradually an integrated picture emerged, into which the course of mineralization and the causes for its localization can be fitted and on which further exploration and development can be based. The methods and results of this study will also be useful in areas of comparable complexity far removed from Uranium City.

To expedite the release of the data obtained by the author, an advance edition of this report was published in 1968, but since this lacked many of the illustrations necessary to an understanding of the problems discussed and since there is a continuing interest in the area, the report is being republished in final form.

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

OTTAWA, October 1, 1970

MEMOIR 367 — Geologie des Bergbaugebiets Beaverlodge (Saskatchewan)

Von L. P. Tremblay

Die Uran-Mineralisierung und die allgemeine Geologie des Gebietes werden beschrieben. In der Nähe grösserer Verwerfungen in metamorphisiertem präkambrischem Gestein kommt Pechblende vor.

МЕМУАР 367 — Геология горного района Биверлодж, Саскачеван.

Л. П. Тремблей

Описывается минерализация и общая геология урана. Урановая слюдка встречается вблизи главных сбросов в метаморфических горных породах докембрия.

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GEOLOGY OF THE BEAVERLODGE MINING AREA, SASKATCHEWAN

Abstract

The Beaverlodge area is rugged; relief reaches 550 feet locally but commonly is less than 300 feet. Outcrops are common in areas of Tazin rocks, less so in areas of Martin rocks. The direction of ice movement, indicated by glacial striae, is S42°W. In the valleys gravel and sand deposits occur as alluvial fans, deltas, river bars, and lake shore deposits. Drainage is to the south, toward Lake Athabasca.

Rocks of the Beaverlodge area are all of Precambrian age. They have been mapped as belonging to the Tazin Group, to the Martin Formation, and as late gabbro dykes. The Tazin rocks are the oldest, probably Archean. They were once a thick succession of interbedded greywackes, shales, sandstones, and basic tuffs but have been regionally metamorphosed into rocks of the amphibolite facies. They are now quartzites, amphibolites, garnet-bearing rocks, and red granite and quartzo-feldspathic gneisses over large areas. The gneiss and red granite are both granitized products of this regional metamorphism. The process seems to have taken place without the addition of material from outside. The texture and appearance of the quartzo-feldspathic gneisses vary greatly according to the degree of granitization and the nature, texture, and structure of the original rocks. Their composition is mainly quartzo-monzonitic and granodioritic. Two mappable types were recognized: the Foot Bay gneiss and the Donaldson Lake gneiss. The Foot Bay gneiss is well layered, red, and high in dark minerals; the Donaldson Lake gneiss is rather massive, more granitoid, grey to white, and low in mafic minerals. To distinguish the large area of ungranitized metamorphosed sedimentary and tuffaceous rocks about Murmac Bay, which is part of the Tazin Group, from other areas in the Shield, it has been named the Murmac Bay Formation. This formation is made up mainly of coarsely interbedded, glassy, white, well-jointed quartzite, amphibolites in thick layers, some quartz–biotite–garnet schists, and a little limestone or dolomite.

The Martin Formation overlies unconformably the Tazin Group rocks and probably belongs to the (Aphebian) Lower Proterozoic. It is made up of basal conglomerate, great thicknesses of arkose and siltstone, a few conglomerate interbeds, and some basaltic flows and gabbroic sills. It is unmetamorphosed. The angularity of the fragments in the basal conglomerate and of the grains in the arkose and siltstone, as well as the poor sorting of the fragments and grains as to composition and size in all rock types, suggest short transportation, rapid deposition, and mainly mechanical weathering. The nature of the fragments and grains,

the composition of the various rock types, and the crossbeds in arkose indicate that the area of Tazin rocks to the northeast and north is the source area.

Gabbro dykes trend mainly west-northwesterly and become abundant north of the Black Bay fault. They are missing south of the St. Louis fault. They cut all rock types except those above the Martin volcanic flows. One whole rock K-Ar age on the large dyke in Fredette Lake is 1,490 m.y.

All the rocks of this area are coloured red with hematite. Many of them are chloritized, carbonatized, and slightly silicified, particularly near the major faults. Most rocks, mainly the amphibolite, are also slightly epidotized. Some of the rocks have been slightly altered locally by soda metasomatism.

Folding has affected rocks of both the Tazin Group and the Martin Formation. The folds in the Tazin rocks trend northeasterly to northerly, are tight to open, and in general are complex. The fact that some of the fold axes are bent and that some minor ones cross the main ones may indicate two periods of folding. The folds in the Martin rocks are gentle and open, and although they, too, trend northeasterly, they probably belong to a different period of folding from the main one of the Tazin rocks.

Large areas of Tazin rocks are brecciated and mylonitized. These early features probably represent major thrust faults probably closely related in time to the main folds of this group. A large number of clean-cut fractures were mapped in all rock types throughout the area. These are late faults, many perhaps block faults. They probably began to form early, possibly shortly before the deposition of the Martin rocks; but since in certain places they have displaced the late gabbro dykes, it may be deduced they were active for a long period of time. This deformation has been sufficiently intense to have produced zones of multiple fracturing. All joint fractures of the area were probably part of this deformation. The main faults, such as the St. Louis, the Black Bay, and the ABC are late.

Uranium is the only metal found in economic quantity in the area, although gold was once mined from a deposit a short distance south of the area, near Goldfields. Uranium occurs mainly in the form of pitchblende; it is found in close association with the major faults, in areas of heavily granitized mixed rocks, in zones of mylonitic and brecciated rocks, and in places where the rocks are hematitized, chloritized, and carbonatized or silicified to various degrees. The Fay–Ace–Verna mine of the Eldorado Mining and Refining Company Limited is the main uranium producer of the area.

Résumé

La région minière de Beaverlodge est fortement découpée; le relief en général est inférieur à 300 pieds, mais il peut atteindre 550 pieds en certains endroits. Les affleurements sont nombreux dans les régions recouvertes par les roches du groupe de Tazin; ils sont moins nombreux dans les régions de la formation de Martin. Le mouvement des glaces, indiqué par les stries glaciaires, est de direction S42°W. Il y a dans les vallées des gîtes de sable et de gravier, sous forme de cônes d'alluvions, de deltas, de barres de rivières et de plages lacustres. Le drainage se fait vers le sud, vers le lac Athabasca.

Les roches de la région de Beaverlodge appartiennent toutes au Précambrien. Elles ont été cartographiées comme appartenant au groupe de Tazin, à la formation de Martin et à des dykes de gabbro plus récents. Les roches du groupe de Tazin sont les plus anciennes, elles sont probablement de l'Archéen. Elles formaient autrefois une épaisse succession de couches interstratifiées, de grauwacke, de schistes argileux, de grès et de tufs basiques, mais elles ont été métamorphisées à l'échelle régionale en des roches du faciès amphibolite. Elles sont actuellement des quartzites, des amphibolites, des roches grenatifères et, sur de grandes superficies, du granite rouge et des gneiss quartzofeldspathiques, ces deux derniers étant le produit gra-

nitisé de ce métamorphisme régional. Cette transformation semble s'être produite sans l'apport de matières étrangères. La texture et l'aspect des gneiss quartzofeldspathiques varient considérablement en fonction du degré de granitisation et aussi en fonction de la nature, de la texture et de la structure des roches originales. Leur composition est essentiellement quartzomonzonitique et granodioritique. On en a distingué deux types lors de la cartographie: le gneiss de Foot Bay et le gneiss de Donaldson Lake. Le gneiss de Foot Bay est bien stratifié, de couleur rouge et possède une forte teneur en minéraux foncés tandis que le gneiss de Donaldson Lake est plutôt massif, plus granitoïde, de couleur variant du gris au blanc et à faible teneur en minéraux mafiques. La vaste région de roches sédimentaires et tufacées métamorphisées mais non granitisées du groupe de Tazin, qui borde la baie Murmac, a été nommée la formation de Murmac Bay pour la distinguer des autres régions du Bouclier. Cette formation est surtout constituée de quartzite blanc, vitreux, bien diaclasé et à stratification grossière, d'épaisses couches d'amphibolites, d'une certaine quantité de schistes à quartz, à biotite et à grenat et d'un peu de calcaire ou de dolomie.

La formation de Martin repose en discordance sur le groupe de Tazin et est probablement de l'Aphébien (Protérozoïque inférieur). Elle consiste en du conglomérat de base, en de grandes épaisseurs d'arkose et de siltstone, en quelques intercalations de conglomérat et en quelques coulées de basalte et de filons-couches de gabbro. La formation n'est pas métamorphisée. Le caractère angulaire des fragments du conglomérat de base et des grains de l'arkose et du siltstone, et le pauvre classement des grains et des fragments de toutes ces roches du point de vue de la composition et de la dimension, permettent de déduire que le transport fut court, que la déposition a été rapide et que l'action des intempéries a été surtout mécanique. La nature des grains et des fragments, la composition des divers types de roches et la stratification entrecroisée de l'arkose, semblent indiquer que la région source est celle des roches du groupe de Tazin situé au nord et au nord-est de la région cartographiée.

Les dykes de gabbro ont une orientation généralement ouest–nord–ouest et deviennent abondants au nord de la faille Black Bay, alors qu'ils sont absents au sud de la faille St-Louis. Ils traversent toutes les roches à l'exception de celles qui sont au-dessus des coulées volcaniques de la formation de Martin. Un échantillon du gros dyke de gabbro affleurant dans le lac Fredette a donné par la méthode de la roche entière au K-Ar un âge de 1,490 m.a.

Toutes les roches de la région sont teintées de rouge par de l'hématite. Nombre de ces roches sont chloritisées, carbonatées ou légèrement silicifiées, en particulier près des principales failles. La plupart, mais surtout l'amphibolite, sont légèrement épidotisées. Quelques roches ont été légèrement altérées par endroits par une métasomatose sodique.

Les roches du groupe de Tazin et celles de la formation de Martin sont plissées Les plis des roches de Tazin sont orientés vers le nord-est à vers le nord, sont serrés à ouverts et en général ils sont complexes. On peut déceler deux périodes de plissement vu que les axes des plis sont parfois courbés et qu'il y a des plis secondaires qui traversent les plis principaux. Les plis de la formation de Martin sont plus simples et ouverts et, bien qu'ils soient orientés aussi vers le nord-est, ils n'ont probablement pas été formés au même temps que les plis principaux du Tazin.

De grandes étendues des roches du groupe de Tazin sont broyées et mylonitisées. Ces caractéristiques représentent probablement d'importantes failles de chevauchement. Ces failles sont les plus anciennes et elles sont vraisemblablement plus ou moins contemporaines des principaux plissements des roches du groupe de Tazin. De nombreuses fractures bien définies ont été reconnues dans tous les types de roches à travers toute la région. Ces fractures sont des failles récentes, il est possible que plusieurs de ces failles soient des failles à bascules. Leur formation remonte à une époque reculée, peut-être légèrement antérieure à la mise en place des roches de la formation de Martin, mais leur mouvement a été de longue durée puisque dans certains cas elles ont déplacé les dykes de gabbro plus récents. Cette déformation fut en certains endroits si intense qu'elle a donné lieu à la formation de zones où les fractures sont très abondantes et très peu espacées. Toutes les diaclases de la région sont probablement le résultat de cette déformation. Les failles principales telles les failles St-Louis, Black Bay et ABC sont récentes.

L'uranium est le seul métal qui a été trouvé en quantités économiques dans la région de Beaverlodge; toutefois un gîte d'or a été exploité il y a quelques années aux environs de Goldfields au sud de la région étudiée. L'uranium se présente surtout sous la forme de pechblende; il est en relation étroite avec les grandes failles, avec les régions de roches mixtes fortement granitisées, avec les zones de mylonite et de brèches et avec les régions où la roche est hématitisée, chloritisée, carbonatée ou silicifiée à divers degrés. Le principal producteur d'uranium dans la région est la mine Fay-Ace-Verna de la société *Eldorado Mining and Refining Company Ltd.*

Chapter I

INTRODUCTION

Location and Size

The Beaverlodge area is within the Canadian Shield, about 100 miles east of its western boundary. The southern boundary of the area is about 4 miles north of the north shore of Lake Athabasca, except at its west end where it touches Lake Athabasca at Black Bay. The area under discussion covers about 110 square miles. A 95-square-mile part of the area, about 8 miles north–south by 12 miles east–west, lies between latitudes 59°30′ and 59°37′ and longitudes 108°25′ and 108°45′. The remaining 15 square miles adjoins the above area to the east and is 5 miles north–south by 3 miles east–west between latitudes 59°32.5′ and 59°37′ and longitudes 108°20′ and 108°25′.

Accessibility

The area can be reached either by plane or by boat. Two airways keep a regular daily service with Uranium City; one from Edmonton, Alberta, with a stop at McMurray, the other from Prince Albert, Saskatchewan, with a stop at Lac La Ronge. These airways have the facilities of a 5,000-foot all-weather runway (elevation 1,042 feet) at Beaverlodge. A DC3 plane is generally used for this service. In both routes, the distance is about 450 air-miles. The area can also be reached by rail from Edmonton to McMurray and from there by boat or barge from Waterways to Bushell, where a dock and hangars for storage space have been installed at the north end of Black Bay on Lake Athabasca in the southwest corner of the map-area. The train part of the trip is 305 miles and the boat part 260 miles. There are also winter roads from McMurray and Lac La Ronge. Most of the heavy freight, such as food, equipment for the various mines, and building material, is carried by barge during the summer when Athabasca River is navigable, or by tractor trains on the winter roads in cold weather.

The area is serviced by about 60 miles of fairly good, all-weather, gravel roads. Most of these roads are narrow, but the 15-mile road that joins Uranium City with the dock at Bushell at one end and the Eldorado mines at Eldorado on Beaverlodge Lake at the other end is about 30 feet wide and is the best in the area. The other 45 miles of road are branches extending like the legs of a spider from this main section to the various mines, prospects, and camps.

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These roads do not reach all parts of the area, but they allow access to most of the large lakes. The only parts not easily accessible are those in the extreme northwest and along the east boundaries of the map-area; these have to be reached on foot or by aircraft.

Travel in certain parts was also facilitated by cut lines. These were found over large areas north of the Black Bay fault and on the Eldorado property. Averaging 400 feet apart, they had been cut by mining companies for mapping and prospecting by geiger counter.

Scope of Work

When this project was initiated, uranium was in great demand and the area appeared to be one of the main uranium-bearing areas in Canada. It was thought that detailed mapping would not only help the mining companies but also assess the uranium possibilities of the area as a whole. Field work commenced in the summer of 1952 and continued to the end of the summer of 1957. In the field, most of the geology was plotted directly on aerial photographs enlarged to the scale of about 500 feet to the inch. No definite system of traversing was followed, but most of the areas of outcrop were visited and studied, the degree of examination varying with the complexity of the geology. In areas of complex geology, traverses were spaced as if for mapping on a scale of 100 feet to 1 inch, but preliminary publication was at a scale of 800 feet to the inch. Final compilation was at the scale of 1,200 feet to 1 inch for publication at the same scale.

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Rock Outcrops and Forest Cover

Areas of rock outcrops are generally abundant. They account for about 60 per cent of the land surface in the area underlain by rocks of the Tazin Group and by granites, but in the area underlain by rocks of the Martin Formation, 80 per cent of the bedrock may be covered. Rock exposures may be fairly clean north of Black Bay, where recent fires have freed the outcrops of lichens and moss, but as a rule the rock surface is largely obscured by black and green lichens, and locally outcrops may be covered with thick moss and a thin layer of till.

The area is timbered to varying degrees. Trees are generally small in areas underlain by the Tazin rocks and granites and are sparse to absent on outcrops of these rocks. They may however be fairly thick in the valleys or in the areas covered with till. In areas underlain by the Martin Formation the trees grow more luxuriantly; they are bigger and more closely spaced. In the Martin Lake basin, some spruce trees are 2 feet in diameter at the butt and about 50 feet high. The most common trees in the area are black spruce and jack pine. In the Martin Lake basin and around Murmac Bay of Lake Beaverlodge there is a fair amount of birch and poplar. The largest birch or poplar trees are about 10 inches in diameter at the base.

Climate

Data on the climate were gathered during five of the six summers that the writer worked in the area. The temperature was recorded at 6:00 P.M. every day, the amount of sunshine during the day was arbitrarily estimated, and the approximate amount of precipitation was recorded.

The climate of the Beaverlodge area is continental with extremes of temperature and very little precipitation. On certain days during the summer the temperature may reach 100°F; in the winter it may go down to 50° or 60°F below zero. The annual precipitation is about 13 inches. Break-up of ice on the lakes usually comes late in May or very early June and the freeze-up early in October. Snow clouds were encountered as late as June 11 and as early as September 8. The climate during the summer is generally very pleasant and good for field work. In an average field season of about 100 days, approximately 65 days may be expected to be sunny and bright, and suitable for outside work. The remaining days may be cloudy with or without some precipitation, but a few of these are as suitable as sunny days for work outdoors. Days with precipitation are scattered throughout the season but are most common in the last ten days of July and in August and September. In a normal field season about 10 days with rain or mist are to be expected. The temperature varies from year to year, from month to month, and at times from day to day. Generally June has an average temperature of about 65°F, and August is much the same or somewhat warmer. The first three weeks of July appear to be the warmest part of the summer.

The Beaverlodge area is near the southern limit of the permafrost zone. Leggett (1955) reported that permafrost in this area is not everywhere present; it has been found to a depth of 30 feet. In 1952 it was noted in the Martin Lake basin.

Settlement and Population

As a result of increased mining activity in the area and the prospect of its continuance as a likely source of income, Uranium City was established in 1952. It soon became the main settlement in the area and filled the need for a central point for supplies. In 1957 the population had reached its peak, about 1,500. These were mostly white, they included a few Indian families living on the outskirts of town. Uranium City was not previously an Indian settlement, but the Indians went there for work, from either Fond du Lac or Camsell Portage. In the late 1957 the town had its own electrical plant and permanent watér and sewer mains and could offer advantageous community services such as a 40-bedroom hotel, a 25-bed hospital, churches, good schools, a large theatre, and several dependable stores. The other settlements in the area, all mining townsites, were somewhat smaller. Most of them provided housing for only a small number of their staff. In 1957 there were seven operating mines in the area, and exploration was still fairly active. In 1960 however, when it became apparent that the demand for uranium would not increase for at least a decade, many of the mines shut down either because their ore was exhausted or because their marketing contracts had ended. Because of lack of work, the people gradually started to move out, and in 1961 only. about 800 people remained in the immediate area of Uranium City.

Physical Features

Elevation and Relief

Physiographically, the area is part of the Canadian Shield. As in most parts of the Shield, the tops of the highest hills suggest that the area was formerly a peneplain. Now, heavily dissected, it slopes gently to the south. In detail, it is very rugged, probably more so than most parts of the Shield.

In the southwest, the land rises gradually to the north and east from an elevation of 700 feet at Black Bay on Lake Athabasca to 1,500 feet at some hills near Bellegarde Lake a rise of 800 feet in 8 miles. From Beaverlodge Lake, the land also rises gradually in almost all directions. To the north within about 5 miles it goes from 800 feet on Beaverlodge Lake to about 1,450 feet near Virgin Lake. Eastward toward Yahyah Lake from the north end of Beaverlodge Lake, the land rises 550 feet within about 3.5 miles. Similarly, east of Donaldson Lake the land is about 850 feet above the level of Beaverlodge Lake, some 7 miles distant.

The area is now dissected into wide and long ridges, oriented parallel with the regional trend of the formations or the foliation in the rocks. These ridges are separated by deep valleys and crisscrossed by transverse, somewhat shorter and narrower gullies. Most of the ridges trend northeasterly, and in general their tops slope gently southwesterly. A few ridges south of Murmac Bay and in the Martin Lake basin trend northwesterly. A few others east of Murmac Bay and about Yahyah Lake trend easterly. Valleys separating the main ridges are generally very pronounced lineaments. Several are the loci of major faults such as the St. Louis and the Black Bay; others, however, are due to differential erosion only. On aerial photographs the gullies transverse to the ridges show, generally, as well-defined lineaments.

In the field they were noted to be narrow, not so deep as the main valleys, and in general to contain minor cross-faults. An apparent offset along these faults was not always observed, probably because of a lack of good horizon-markers.

The relief varies commonly between 200 and 500 feet and reaches 500 feet or more east of Bushell, northwest of Melville Lake, and north of Padget Bay on Beaverlodge Lake. Around Yahyah and Flack Lakes, on the outside periphery of Martin Lake, east and west of Fredette, Jean, and Donaldson Lakes, and in the vicinity of Murmac Bay, relief varies between 300 and 500 feet. Elsewhere in the area, as around Ace, Eagle, and Mickey Lakes and near Bellegarde Lake, it is about 200 feet. Where the relief is pronounced, as on the shores of several lakes, the land in most places rises fairly abruptly from the lake shore for a couple of hundred feet in elevation; then the slope is somewhat more gentle, the land rising gradually away from the lake. This was noted particularly around Murmac Bay and Donaldson, Yahyah and Flack Lakes, and on the west side of both Fredette and Jean Lakes. This is also in part true of the periphery of Martin Lake.

The conglomerates, volcanic rocks, and gabbroic sills of the Martin Formation, the amphibolite or hornblende schist, the chlorite-rich argillite, and rarely the granitic gneisses of the Tazin Group are all responsible for the highest hills in the area. The areas of granite and gneisses and also those of siltstone and arkose are generally more subdued and of lower relief. There are indications that the relief is mainly due to differential erosion, that is, certain rock types weathering faster than others. The orientation of the ridges parallel with the trend of formations is also an indication that differential erosion was the main factor responsible for the trend and relief of the ridges and in general for the main physiographic features of the area. Not much is believed to be due to glaciation. The main effects of the Pleistocene glaciers have been the removal of most of the overburden from the area, the removal of some of the sharp edges along valley walls, the deepening of some of the valley bottoms, and the polishing of the bedrock surfaces. In other words, most of the physical features observed in the area probably predate the Pleistocene ice invasion.

Drainage

Drainage is to the south, and eventually all water reaches Lake Athabasca. Much of it is through Beaverlodge and Martin Lakes. The drainage system is poorly developed and in some sections is highly disorganized. Water generally flows from lake to lake through small narrow, fast-flowing creeks or rivers and locally through ill-defined creeks and swamps. Much of the water is retained in the various lakes, which act as reservoirs either along the drainage system or in isolated spots.

Most of the lakes in the map-area lie along the apparent drainage system, and many seemingly occupy deepened parts of valleys or basins. Presumably Pleistocene glaciers widened and deepened old river valleys or scoured them into basin-like depressions, subsequently to be filled with water. Martin, Jean, and Fredette Lakes represent widened and deepened valleys, and Beaverlodge, Ace, and Donaldson Lakes are examples of basin-like depressions. The lakes in isolated spots within rocky areas are generally small. They stand also at somewhat higher elevations than the lakes along the drainage system, and most seem to occupy true rock basins scoured by the Pleistocene glaciers.

The rivers are all small, really creeks only a few feet wide and very shallow. Since they are interrupted by numerous rapids they are not navigable by canoe. During the summer they are almost dry. Fredette River, which is the largest, may be navigable between Lake Athabasca and Cinch Lake, but it is definitely not an efficient travel route.

Glaciation

The area was entirely glaciated. This is indicated by erosional features such as glacial striae or grooves, polished surfaces, and *roches moutonnées*; by deposits such as erratics and ground moraines; and by other deposits of glaciofluvial and glaciolacustrine origin. Figure 1 shows the main glacial features of the area. Striae were seen on outcrops of all rock types but were rare on the relatively fresh siltstone and arkose of the Martin Formation. They were best formed on amphibolite in the area south of Yahyah Lake, where grooves up to 6 inches deep were seen. The main trend of the striae east of Black Bay fault is S40°W and west of it is S45°W. Polished surfaces are well displayed on some of the fine-grained gneisses of the Tazin Group, particularly on the mylonitic rocks northwest of Black Bay fault. They were observed on most outcrops in the area underlain by rocks of the Tazin Group but are rare on outcrops of the Martin Formation. Many of the outcrops and most of the ridges composed of rocks of the Tazin Group are now in varying degrees *roches moutonnées*.

The surficial deposits present are characteristic of glaciation. Most widespread are erratics and ground moraine, deposits formed directly by the Pleistocene ice sheets. Erratics occur everywhere. In general they are not large, but a few are 10 feet in diameter. In composition they resemble the local bedrock.

Ground moraine covering most of the area occurs in the form of a sheet or layer. It varies in thickness from place to place but is probably nowhere very thick. On areas of plentiful outcrops it is only a few inches thick but is probably much thicker in hollows and depressions. The other deposits are much smaller but are generally thicker. They are of more theoretical interest because their distribution and shape suggest a possible mode of origin. Figure 1 shows the approximate location and extent of these deposits, as obtained from aerial photographs and field traverses. Sections of most of them were examined as they have been exploited as gravel pits. All show good stratification, crossbedding, and various degrees of sorting. In plan these deposits, which consist of gravel, sand, silt, and clay, resemble deltas, alluvial fans, and bars, and therefore may be glaciofluvial and glaciolacustrine. The gravel may be either coarse and unsorted or fairly fine and well sorted. Although the sand generally varies in size, in some deposits it is well sorted in grain size and nature. From the shape, the nature, and the distribution of these deposits, it may be concluded that they were left by water (probably the meltwater derived from the ice sheets during deglaciation) flowing in a southerly direction along fairly definite channels. Four main discharge channels were inferred, namely, from west to east: the Powerline Creek, the Foot–Jean Lakes, the Fredette River, and the Flack–Ace Lakes. Several branch channels were also inferred. The material transported by the water along these discharge courses was entirely derived from material previously deposited by the ice sheets and was deposited as deltas in lakes, as river bars along the course of the streams, as lake shore deposits, and, finally, as possible alluvial fans. Table I summarizes the information obtained in the various gravel pits, except for deposits at Uranium City, which were examined in trenches dug for water and sewer pipes.

Only two eskers were recognized in the area, one north and one south of Nero Lake. They are prominent features where present but could not be traced far. They indicate the same southwesterly direction of ice movement as the *roches moutonnées*.

Raised beaches were noted about 1,500 feet due east of Crackingstone Inlet on Lake Athabasca, in the southwest corner of the map-area. They suggest that Lake Athabasca was a much larger lake during the deglaciation period. In fact such beaches were "noted by F. J. Alcock at a few points along the north shore of the Lake (Athabasca) up to elevations as high as 200 feet above the present level of the Lake" (Camsell, 1916).

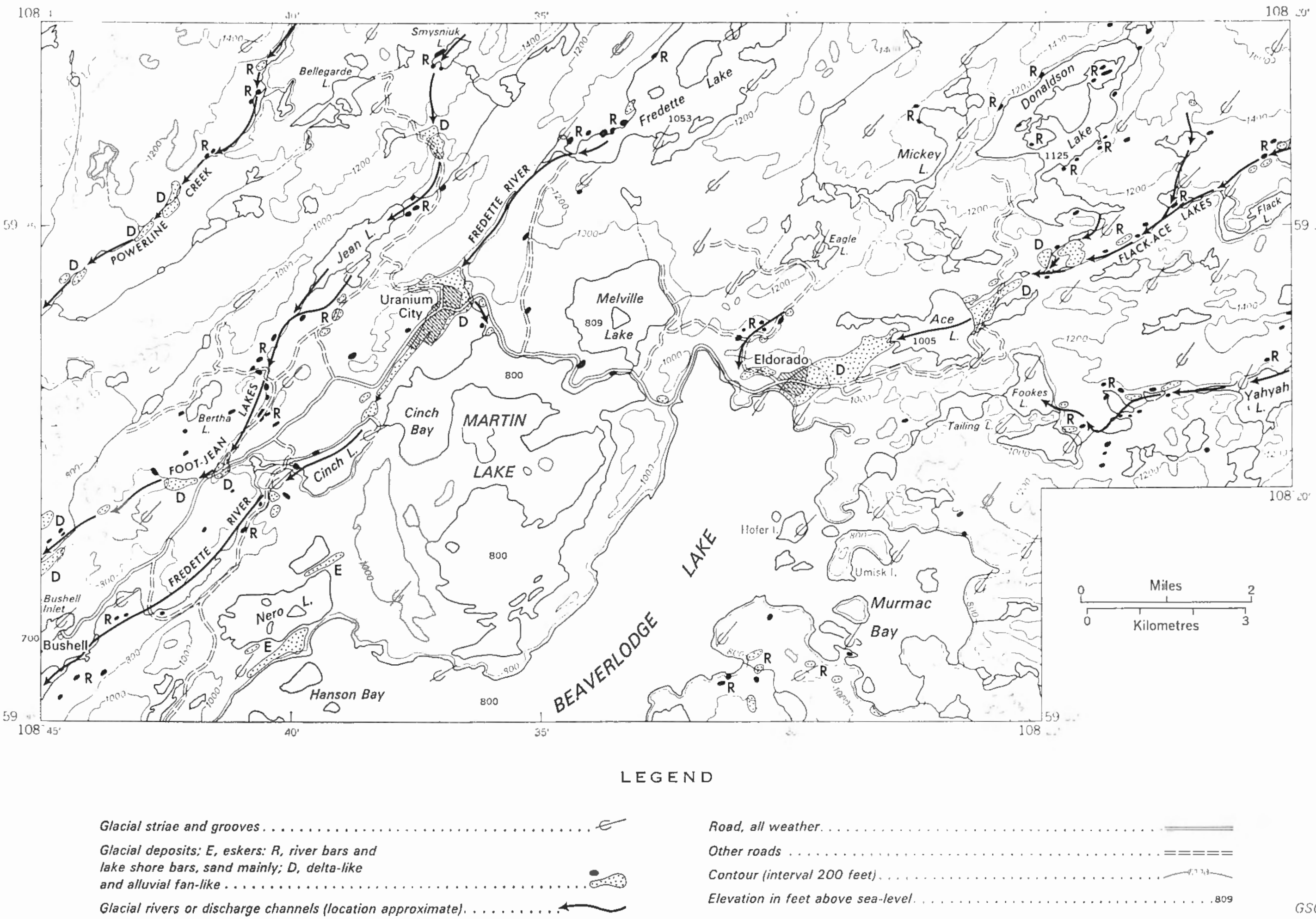

FIGURE 1. Main glacial features, Beaverlodge area.

TABLE I

Description of glacial deposits seen in gravel pits

Area	Powerline Creek	Foot–Jean Lakes				Fredette River				Flack–Ace Lakes			
Location of section	None	North		South		North		South		North		South	
Location of gravel pits	None	1,000 feet east of Foot Lake		6,000 feet west of Cinch Lake		None		Uranium City		1,000 feet south of Strike Lake		1,500 feet west of Fay shaft	
		Thickness	Lithology	Thickness	Lithology	Thickness	Lithology	Thickness	Lithology	Thickness	Lithology	Thickness	Lithology
Description of sections	No sections seen	A few inches	Sand with a few fragments		Missing		This section probably missing	At least 20 feet thick	Section not measured. It is similar to the section south of Foot-Jean Lakes	1 foot	Reddish brown sand rich in clay with occasional fragments		Missing
										4 inches	Yellowish clay		
		10 feet +	Gravel, well sorted, sandy grey, southerly dipping cross-bed, inter-bedded with thinly stratified fine sand	A few inches to 6 feet	Gravel, coarse, layer thicken-ing toward north and east					12 feet +	Gravel, grey sandy, cross-bedded, very little clay; a few inter-calated beds of fine sand and clay	A few inches to a few feet	Gravel, poorly sorted
				At least 20 feet	Sand, coarse and fine, thinly bedded, southerly dipping crossbed; some clay beds					3 feet +	Sand, fine, thinly bedded	12 feet +	Sand, fine, well sorted, thinly bedded, crossbedded; with abundant intercalated clay beds near top, only a few near bottom

There is probably a layer of gravel underneath the sections above. The lower limit of these deposits was not seen.

Previous Geological Work

In 1888, R. G. McConnell (1893) examined the south shore of Lake Athabasca from Athabasca River to William Point and noted a granular siliceous sandstone, which he named 'Athabasca sandstone.' In 1892 and 1893 J. B. Tyrrell (1895) mapped the north shore of Lake Athabasca. He reported that the rocks were mainly granite and gneisses and here and there small areas of Athabasca sandstone. In 1914, C. Camsell (1916) carried out exploratory work along Tazin and Taltson Rivers between Lake Athabasca and Great Slave Lake, west of the Beaverlodge area. Near the Northwest Territories boundary he encountered some sedimentary and volcanic rocks, which he regarded as remnants in a large granite mass and named them the Tazin Series. Because of the granite pebbles in a conglomerate he postulated an older granite. The rocks of the Tazin Series and the granites were overlain by younger rocks, the Athabasca Series.

In 1914, F. J. Alcock (1914) studied the geology of a narrow strip of land along the north shore of Lake Athabasca. In 1916 (Alcock, 1916) he continued this study and spent most of the summer in the Beaverlodge Lake and Lodge Bay areas. In 1935 (Alcock, 1936a) he undertook, with the assistance of thirty-two men, the reconnaissance mapping of all the area north of Lake Athabasca in Saskatchewan and also mapped on the scale of 1 mile to 1 inch the Goldfields region, which includes the Beaverlodge area. The results of this work were presented in a memoir (GSC Mem. 196) in which he described three different series of stratified, sedimentary and volcanic rocks, separated from one another by an unconformity and a period of igneous activity. He called his oldest series the Tazin Group, his intermediate one the Beaverlodge Series, and the youngest the Athabasca Series.

In 1946, 1947, and 1948, A. M. Christie (1947 and 1953) remapped on the scale of 1 mile to 1 inch the Goldfields – Martin Lake area of about 500 square miles, which includes the Beaverlodge area. This mapping included work done at 400 feet to 1 inch or in greater detail by H. C. Cooke (1937a) in 1937, by A. W. Jolliffe (1946) in 1945, by A. M. Christie in 1946, and by many company geologists named in Christie's memoir (GSC Mem. 269) on the area. The results of this work were presented in a doctorate thesis for McGill University entitled "The Geology of the Goldfields Area, Saskatchewan," which later was incorporated in GSC Memoir 269. Christie placed in the Tazin Group all the oldest sedimentary and volcanic rocks of the area. He did not recognize the Beaverlodge Series of Alcock. The granite and granite-gneisses were assumed to be separated from the Tazin Group by an intrusive contact. Overlying all these was the Athabasca Series. He described all the rock types in some detail, defining and, in part, explaining their structure, and included a chapter on their alteration with emphasis on dynamic metamorphism and granitization.

From 1949 to 1953, S. C. Robinson (1950, 1955a) studied the mineralogy of the uranium deposits in the Goldfields area, Saskatchewan. His study resulted in a bulletin in which he included a brief note on the uranium deposits of the area that he examined and a detailed description of the ore minerals and of most of the associated minerals. The spatial distribution and the abundance of these minerals were indicated. A chapter on age determination and classification of the uranium deposits of the area completes the bulletin.

During the summers of 1949, 1950, and 1951, K. R. Dawson (1951, 1956) made a study of the wall-rock alteration of a group of uranium-bearing deposits in the Goldfields region, most of which are in the Beaverlodge area. He described the minerals that formed as a result of this alteration and briefly indicated their abundance and spatial distribution. His study included information on the red alteration and the red coloration associated with the uranium deposits of the area. Somewhat similar studies were reported by C.E.B. Conybeare and C. D. Campbell (1951). The scope of their work, however, was more limited. They showed that the rocks forming the deep red zones, which are commonly more radioactive than the other rocks of the area, are mylonites.

In 1948, A. H. Lang began an inventory of the uranium occurrences in Canada. In 1952 an interim account of his work was published (1952a), which included not only general considerations on the uranium deposits of the Beaverlodge area but short descriptive notes on each deposit. Included also was a brief outline of the geology of the area. Notes on the Beaverlodge area appeared also in several papers on the broad aspects of the geology of uranium in Canada by the same author (*see* Bibliography). Similarly, many papers (by many writers) dealing with lead–uranium ages have short notes on the geology of the Beaverlodge area or mention very briefly a few geological features of interest in connection with the ages of the pitchblende of the area (*see* Bibliography).

R. W. Edie wrote three papers on various phases of the geology of the Beaverlodge area. They incorporate most of the results presented in an unpublished Ph.D. thesis at M.I.T. (1951). Much of Edie's information was obtained from mapping on the Eldorado property only, but some of his results could probably be extended to much of the Beaverlodge area. In one paper (1952) he described the main types of rock he mapped on the Eldorado property, and for each of them he presented one or more quantitative spectrographic chemical analyses. These are included at various places in this report. In another paper (1953a), with the aid of quantitative spectrographic chemical analyses he tried to show the changes that took place in the various rock types during their alteration. In a third paper (1953b) he showed that the diabases of the Beaverlodge area are not substantially different from diabases all over the world and that they are much lower in radioactivity than the acidic rocks of the area.

Chamberlain (1959), in a paper on the structural history of the Beaverlodge area, suggested a way to work out the possible amount of movement along the St. Louis fault and postulated a net-slip of 3.9 miles plunging 43 degrees south-southwest.

Seven preliminary maps, on the scale of 800 feet to 1 inch, with marginal notes (Tremblay, 1954, 1955, 1956, 1957a, 1958a), and two papers (Tremblay, 1957b, 1958b) have been published by the writer. In these the general geology of the area is described briefly and its main structural features are explained.

In 1952, D. A. W. Blake (1956) made a reconnaissance study of the Athabasca sandstone south of Lake Athabasca and of rocks then considered to be similar in the small areas north of the lake. As had been done previously, he correlated the steeply dipping and deformed Athabasca rocks of the Martin Lake basin with the flat-lying ones south of Lake Athabasca. W. C. Gussow (1957, 1959) reviewed critically the genetic history of the Athabasca rocks and established a distinction between the typical Athabasca Formation outcropping south of Lake Athabasca and the exposures of folded strata north of the lake. He named these folded strata the Martin Lake Series and assumed them to be Precambrian, though he suggested that the typical Athabasca Formation south of the lake might be younger.

In 1957 and 1958, W. F. Fahrig (1961) re-studied the Athabasca problem. He proposed (1961) the use of the name Martin Formation for the steeply dipping Athabasca rocks north of Lake Athabasca and restricted the name Athabasca Formation, as Gussow had done, to the almost flat-lying sandstone north and south of the lake.

Still other papers on the uranium deposits of the Beaverlodge area have been published, most of which carry short notes on the general geology of the area. Many of them are briefly reviewed below. In 1950, R. B. Allen (1950) published a short paper in which he briefly described the then known mineralized fracture systems and suggested the most favourable direction for intense prospecting. In 1953, R. B. Allen, B. C. Macdonald, and E. E. N. Smith (1954) presented a paper that included interesting geological information, but no maps, on the main uranium deposits along the St. Louis fault on the Eldorado property. B.

C. Macdonald (1954) and B. C. Macdonald and J. S. Kermeen (1956) published their findings on the ore deposits of the St. Louis fault and described the characteristic features of the deposits in relation to the main structural features of the area. F. R. Joubin (1955) suggested that most of the pitchblende occurrences of the Beaverlodge area were "surface phenomena," having formed near the "old unconformable Tazin–Athabasca contact," the overlying Athabasca rocks acting as a blanket for the uranium. D. D. Campbell (1957) had interesting suggestions on the succession of geological events in the Beaverlodge area and described the apparent interrelationships of ore, rock, and structure at the Verna mine. In the same year, B. S. W. Buffam, D. D. Campbell, and E. E. N. Smith (1957) published an interesting paper on the various Beaverlodge mines of Eldorado Mining and Refining Limited. The information is given in a concise manner and deals with the geology and structure of these deposits. A booklet on the Beaverlodge Uranium District for the members of the Sixth Commonwealth Mining and Metallurgical Congress, 1957 (Beaverlodge, 1957) contains useful information on the geology of the mines then operating in the area. Another paper on the Beaverlodge operation of the Eldorado Mining and Refining Limited (Eldorado, 1960) includes a chapter on the geology of the area and on the work of the operating mines owned by Eldorado.

Several students at various universities have submitted theses on phases of the geology of the Beaverlodge area, all of which contain valuable information. Most of them have not been published. For the most part, the problems studied for these theses dealt with the geology of the Eldorado property. In 1949 E. E. N. Smith submitted a M.Sc. thesis on the geology of the area around Eagle shaft. The main rock types were described, and attempts were made to determine their genesis, their degree of metamorphism, and their structural relationship. Later, Smith (1952) submitted a Ph.D. thesis at Harvard in which he made a special study of the Martin Lake syncline or basin. He described the rock types of the basin, determined their conditions of deposition, and suggested how this basin had been formed. He described also the type of uranium deposits associated with the Martin rocks and explained briefly their wall-rock alteration. J. S. Ross (1949) submitted a M.Sc. thesis at the University of Toronto on the stratigraphy of the Goldfields area. His succession of the various rock types is similar to Christie's (1953). The thesis also presents detailed descriptions of the three known areas of Tazin conglomerate. D. A. W. Blake (1949) submitted a M.Sc. thesis at McGill University on the Athabasca Series at Beaverlodge Lake. It dealt mainly with descriptions of the rock types and included notes on the conditions related to the deposition and formation of the Martin Lake basin. S. J. T. Kirkland (1953) submitted a manuscript to Queen's University on the Tazin Athabasca unconformity, Middle Lake area, Saskatchewan. From the weathered material found at the unconformity he tried to determine the type of climate present when the Athabasca Formation was deposited or was at least in the early stages of deposition, extending his conclusions to include the Martin Lake area. A. Bodnarchuk (1956) gave useful descriptions of the argillite and its altered phases from the area of the Verna mine. E. Frank Evoy (1952) studied very briefly the amphibolites and granitic rocks in the vicinity of the Leonard Adit on the property of Rix Athabasca. John S. Dudar (1957, 1960) described in some detail the argillites and their mechanical and hydrothermal alterations in conjunction with the uranium mineralization in the Verna mine. C. R. Saunders (1957) presented a description of the geology of the Ace mine, which is very similar to that presented by Buffam, Campbell, and Smith (1957). J. A. Chamberlain (1958), in a Ph.D. thesis submitted to Harvard University, described the geology and structure of the Beaverlodge area and included a somewhat different and controversial succession of tectonic events for the area and also statistical data on fracture patterns in the Verna mine.

The areas adjoining the Beaverlodge area to the east, to the west, and to the south have been mapped recently on the scale of 1 mile to 1 inch, and the results have been published mainly in the form of preliminary maps with marginal notes. More extensive studies on these areas were reported in the form of unpublished Ph.D. theses. Two areas to the east were mapped in 1950 and 1951 by D. A. W. Blake. These two map-areas were the subject of a Ph.D. thesis at McGill University (Blake, 1952b), which was incorporated in GSC Memoir 279 (Blake, 1955). In 1951, 1952, 1953, and 1954, W. E. Hale (1954a, b, 1955) mapped the Black Bay, Gulo Lake, and Forcie Lake map-areas, which are directly west of the Beaverlodge area. The Black Bay area was the subject of a Ph.D. thesis (Hale, 1953) submitted to Queen's University. The genesis of the uranium deposits of the Beaverlodge area constitutes a major part of this work. In 1953, J. A. Fraser mapped the Crackingstone Peninsula, that is, the area adjoining the Beaverlodge area to the southwest. From 1954 to 1958 inclusive, C. K. Bell mapped almost the entire Crackingstone Peninsula on the scale of 500 feet to 1 inch (Bell, 1959, 1961, 1962a, b).

Chapter II

GENERAL GEOLOGY

The rocks of the Beaverlodge area are Precambrian. They have been mapped as parts of the Tazin Group, as the Martin Formation, and as late gabbro dykes (Fig. 2, *in pocket*). The rocks of the Tazin Group are the oldest in the area and may be Archean. They cover about 70 per cent of the map-area in two large areas of about equal size: the eastern, which is in the eastern part of the area; and the western, which is along its western boundary. These two areas are separated by a central one, which covers about a third of the map-area; this is underlain entirely by the Martin Formation. For clarity and descriptive purposes in this report, each of the areas of Tazin rocks has been subdivided into two parts, separated in the eastern area by the St. Louis – ABC fault and in the western area by the Boom Lake fault.

The geological succession in the eastern area is better known than that in the western. The former therefore is described first, and map-unit numbers started arbitrarily with its units. The two successions are placed side by side on the legends for Figure 2 and Map 1247A to suggest that they are in general equivalent. After both of the above successions have been dealt with, the metasomatic granite is described, because it was the last to form and is essentially common to both areas. The Tazin Group is made up of metamorphosed sedimentary, tuffaceous, and volcanic rocks (about 15 per cent of the area mapped), of quartzo-feldspathic gneisses in all stages or degrees of granitization (about 40 per cent of the area mapped), and of metasomatic granites (about 15 per cent of the area mapped). The Tazin Group in this area has been estimated to reach a thickness of possibly more than 30,000 feet. Its rocks are cut by granite and pegmatite dykes and sills, which represent the molten and mobile parts of the metasomatic granites. They are intensely folded, faulted, and fractured. Large areas of them are also intensely brecciated and mylonitized, and some are hydrothermally altered.

The Martin Formation is probably Aphebian to Helikian (Lower to Middle Proterozoic) and overlies unconformably the rocks of the Tazin Group. Its outcrop area is a large triangular mass that represents about 30 per cent of the area mapped. This extends right across the central part of the map-area from south to north. The Martin Formation is made up of basal conglomerate, arkose, basaltic and gabbroic rock, a few conglomerate interbeds, and siltstone, altogether forming a succession about 15,000 feet thick. These rocks are gently folded but intensely faulted and fractured. They are relatively unmetamorphosed and unaltered.

The gabbro and basalt dykes are probably also of Proterozoic age. They cut the rocks of both the Tazin Group and the Martin Formation below the volcanic rocks. They are not yet known to cut the volcanic rocks and the rocks above them. The gabbro dykes represent about one per cent of the rocks of the map-area and trend mainly west-northwesterly.

Table of Formations

EON	ERA	EPOCH	DESCRIPTION
	Cenozoic	Recent Pleistocene	Morainic material, gravel, sand, silt, and clay
PRECAMBRIAN	Proterozoic		MAP-UNIT 27: GABBRO and BASALT DYKES and SILLS; in part porphyritic and amygdaloidal
	Intrusive contact		
	Proterozoic and Archean (?)		MAP-UNITS 20 to 26: *MARTIN FORMATION* SILTSTONE, arkose, conglomerate UPPER ARKOSE, siltstone, conglomerate CONGLOMERATE INTERBEDS, arkose BASALT FLOWS, GABBRO SILLS, amygdaloidal and porphyritic LOWER ARKOSE, siltstone, conglomerate BASAL CONGLOMERATE and BRECCIA, siltstone and arkose
	Unconformity		
	Proterozoic and Archean (?)		GRANITE and PEGMATITE DYKES and SILLS
	Intrusive contact		
	Archean and/or Proterozoic		*TAZIN GROUP* MAP-UNIT 19: METASOMATIC granite, quartz monzonite, monzonite, granodiorite, quartz diorite *EASTERN AREA* MAP-UNITS 6 to 9: Murmac Bay Formation; quartzite, amphibolite, garnetiferous quartz-feldspar-biotite gneiss, crystalline dolomite and limestone *WESTERN AREA* MAP-UNIT 18: Uranium City amphibolite, some quartzite

Table of Formations—(conc.)

EON	ERA	EPOCH	DESCRIPTION	
			MAP-UNIT 5: Buff quartzite, impure quartzite, chlorite-sericite schist, argillite	MAP-UNIT 17: Cayzor Unit; quartzite, impure quartzite, chlorite schist, quartzo-feldspathic gneiss
			MAP-UNIT 4: Argillite, slate, and quartzite; hornblende schist, amphibolite, chlorite-epidote rock	
			MAP-UNIT 3: Quartzite, chlorite-sericite schist	MAP-UNIT 16: Jean Lake amphibolite
PRECAMBRIAN	Archean and/or Proterozoic (?)		MAP-UNIT 2: Donaldson Lake gneiss, quartzo-feldspathic gneiss, quartzite, amphibolite	MAP-UNIT 15: Rix Unit; quartzo-feldspathic gneiss, quartzite, mafic schist and gneiss
				MAP-UNIT 14: Chance Lake Unit; amphibolite, quartzite, schist and gneiss
			MAP-UNIT 1: Foot Bay gneiss, quartzo-feldspathic gneiss, amphibolite	
				MAP-UNIT 13: Quartzo-feldspathic gneiss; some amphibolite, quartzite
				MAP-UNITS 11 and 12: Powerline Creek Belt; garnetiferous feldspathic quartzite, amphibolite
				MAP-UNIT 10: Quartzo-feldspathic gneiss, amphibolite, quartzite

Tazin Group

In 1914, Camsell (1916) made a reconnaissance trip from Lake Athabasca north along Tazin River to Thekulthili Lake. Near the Northwest Territories boundary he encountered "remnants of an older series of stratified rocks, dominantly sedimentary," which he named the Tazin Series. The remnants were interpreted as being engulfed in a great composite batholith, probably made up of two distinct types of granite, one gneissoid and the other massive. Furthermore, as he placed the sedimentary rocks outcropping on the north shore of Thekulthili Lake within the Tazin Series and as the conglomerate in these sedimentary rocks contained pebbles of granite, he had to assume a granite older than his Tazin Series. In the field he was unable to recognize this older granite. The rocks of the Tazin Series and the granites were overlain by the younger Athabasca Series. In 1935, Alcock (1936a) mapped the area north of Lake Athabasca as far as the Northwest Territories boundary. He recognized three different series of stratified, sedimentary, and volcanic rocks, separated from one another by an unconformity and a period of igneous activity. Assuming that these rocks could have formed in more than one geological period, he kept the term 'Tazin' for the oldest series but referred to it as the Tazin Group. He believed that above the Tazin Group he had recognized a younger series, which he called the Beaverlodge Series. Both these series were overlain unconformably by the still younger Athabasca Series. In 1946–48, Christie (1953) mapped the Goldfields – Martin Lake area on the scale of 1 mile to 1 inch and retained the term 'Tazin.' He used it to include all the sedimentary and volcanic rocks underlying the Athabasca Series. The Beaverlodge Series of Alcock was not recognized by Christie nor by the present writer during this project. The Beaverlodge Series is part of the Tazin Group. As was done by Alcock previously, Christie omitted from the Tazin Group all the quartzo-feldspathic gneisses and granite of the area. The term 'Tazin Group' is used in this report to cover all the rocks included by Christie in the Tazin Group, but its meaning has been extended to include also all their metamorphic equivalents and even their granitized counterparts. Thus, in the Tazin Group are included all the rocks underlying the Martin Formation (previously known as the Athabasca Series) except the granite and pegmatite dykes; the gneisses and the metasomatic granite are included as they are believed to be derived by metamorphism and granitization from the sedimentary and volcanic rocks that are part of the Tazin Group.

Area North of St. Louis – ABC Fault

(*Map-Units 1 to 5*)

This part of the area mapped covers approximately 18 square miles in the northeast corner. It extends from the St. Louis – ABC fault north to the northern boundary of the map-area and from the Tazin–Martin unconformity, east of Fredette Lake, east to the eastern boundary of the map-area north of Raggs Lake.

About 80 per cent of this area is underlain by granite and granitic gneisses, most of the gneisses being well layered. The remaining 20 per cent is underlain by quartzite, argillite, and hornblende schist, which are remnants of the original rock succession, largely preserved from alteration and granitization. All these rocks, including the granite and gneisses, were once sedimentary or pyroclastic. Subsequent to their formation, many were intensely folded, metamorphosed, and granitized, and large areas were subjected to intense cataclastic deformation. The ungranitized remnants were apparently not disturbed by the alteration or granitization of nearby parts and are still in their original position. The Ace Lake – Donaldson Lake anticline is believed to be the main structure in this area, and on this assumption the thickness of the stratigraphic succession has been calculated to be about 5,000 feet, from the oldest rock in the core of the anticline east of Donaldson Lake to the youngest near the Tazin–Martin unconformity, east of Fredette Lake.

The main rock units recognized and mapped in this area and their estimated thicknesses are listed below, the oldest at the bottom. The granite is derived by granitization from all the other rock units, but mainly from the buff quartzite and the quartzite–chlorite schist. The argillite–hornblende schist (unit 4) and the quartzite–chlorite schist (unit 3) are the best horizon-markers in the succession.

Rock units	Thickness (feet)
Map-unit 5: Buff quartzite	800
Map-unit 4: Argillite–hornblende schist	400
Map-unit 3: Quartzite–chlorite schist	800
Map-unit 2: Donaldson Lake gneiss	1,200
Map-unit 1: Foot Bay gneiss	2,000

Map-Unit 1: Foot Bay Gneiss

The name Foot Bay gneiss is used to describe the quartzo-feldspathic gneisses that cover most of the area east of Donaldson Lake. This area is wedge-shaped and at least 18,000 feet long; it tapers southwesterly from a width of about 8,000 feet at the northeast corner of the map-area to less than 1,000 feet on the lake shore at Foot Bay. These gneisses are considered to be the oldest rocks in the eastern area, as they have been interpreted as being along the core of what is regarded to be the main anticline (Ace Lake – Donaldson Lake) east of the Black Bay fault.

Other areas of lithologically similar gneisses have been mapped north of the St. Louis fault west and south of Donaldson Lake, but all of them are much smaller; they probably occur at somewhat higher stratigraphic horizons. Since in general they do not constitute a distinct stratigraphic unit like the Foot Bay gneiss, they were not mapped separately. Most of these masses are at the contact between granite and less metamorphosed rock.

The Foot Bay gneiss is in sharp or gradational contact with the associated rocks. On the west, from Foot Bay to the northern boundary of the map-area, the contacts of these gneisses with the quartzitic rocks above were sharp where seen, except at one spot where quartzitic rocks and the Foot Bay gneisses are intimately interbanded, giving rise to a contact gradational over a few feet. On the south, from the east end of Foot Bay, by Schmoo Lake to slightly north of Raggs Lake, the contacts with the granites are gradational within a few hundred feet. Most of the contacts with smaller areas of granite are gradational over a few feet. The distinctive features of the Foot Bay gneiss, used to locate its boundaries, were a definite and marked layering, a granitic appearance, and an increased mafic content.

The Foot Bay gneiss is a red to dark red and reddish black or reddish green rock. On the outcrop it has a massive appearance even when well jointed, and generally it displays a pronounced foliation or layering, that is, layers of different mineral composition and of different colour alternate. These layers vary greatly in shape and thickness. They may be of uniform width for great distances and may alternate with each other as regularly as in stratification. Generally, however, the layers vary considerably in thickness. Ordinarily they are less than 3 inches wide and may be as narrow as a pencil line. Most, however, vary in thickness along strike and may even be wavy and flame-like or wedge-shaped, and may pinch out over short distances, giving short, narrow lenticular bodies. In detail also they have very irregular margins. In all places, the layers are elongated in the direction of the foliation. They are light to dark green, black or light to dark red, and pink to almost white. In places, they are brown and buff. The light coloured bands are generally coarse grained and granitic looking and are composed mainly of glassy grey to white quartz, microcline (locally showing perthitic intergrowth), and oligoclase. They carry little or no mafic minerals. The lenticular and augen-like masses of light coloured rocks that also occur in the dark coloured layers emphasize the layering, so typical of these gneisses. Locally the granitic layers are up to a few feet wide and resemble sills and dykes, as in a few places they cut the foliation at an angle. Not many dykes were recognized, possibly because of obscuring overburden.

The dark coloured layers do not show the granitic texture of the light coloured ones and vary much more in grain size. They are generally fine or medium grained with local coarse patches. Their texture is granoblastic or hornfels-like, and porphyroblastic. In composition they are made up mainly of chlorite and /or hornblende and epidote and also carry oligoclase and microcline. The plagioclase occurs mainly in small round grains, either mixed with the mafic minerals or surrounded by them. Microcline is widespread, interstitial to the plagioclase, and occurs in tiny grains of irregular shape or in wormy masses, cutting the rock in all directions as if of later formation. In the light coloured layers or in the augen-like and lenticular masses scattered within the dark coloured layers, microcline occurs mainly in large grains.

The mineral composition of the Foot Bay gneisses, believed to represent an overall average mineral composition, not only of the dark coloured bands but also of the light coloured ones, was measured by counting[1] grains in fourteen thin sections and on stained polished surfaces of five hand specimens (Tables II and III). Although it was not possible to assess accurately the content of all the minerals in the rock, it was possible in all instances to get an accurate measure of the two or three principal minerals.

TABLE II — *Estimated mineral composition of Foot Bay gneiss (map-unit 1), in percentages*

	Thin sections														Hand specimens				
	Quartz monzonite								Granodiorite			Granite							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Albite–oligoclase	34	34	29	31	37	28	?	?	44	43	45	14	?	?	29	?	29	25	?
Microcline	31	25	40	26	30	25	21	31	18	10	21	40	?	?	31	?	?	36	?
Quartz	26	19	19	22	23	31	19	?	18	20	17	21	19	16	19	20	26	18	13
Chlorite	9	19	10	21			?	15	16	21		20	11	17					
Biotite											16								
Hornblende					8	14													
Opaque		2	2		1	2	3	1	4	4	1	2		1					
Epidote		1			1		10			1									
Garnet												2							
Apatite										1		1							
Mafic minerals															21	?	?	21	?

The figure for quartz is probably the most reliable. On the stained polished surface of a hand specimen it showed as clear tiny lenticular or irregular masses, all with a common orientation. As determined in both thin sections and hand specimens, its amount varies but

[1]All grain counts in this report were made on traverses at least 40 mm long and most commonly on traverses between 60 and 100 mm long, using an enlargement of 80.

averages around 20 per cent. The content of the mafic minerals was readily assessed in thin sections but not always so on hand specimens. Their amounts vary but average about 18 per cent of the rock as a whole. The total feldspar content is generally greater than 54 per cent and less than 69, but the proportion of oligoclase to microcline varies greatly. In general the plagioclase content averages about 33 per cent; the microcline content around 27 per cent. Yellowish green epidote and dark red hematite are widely distributed as seams and thin films along joint planes. Locally, particularly in areas of uranium mineralization, fluorite and white to buff calcite are associated minerals. By composition this rock is mainly a quartz monzonite; part of it, however, is a granodiorite and in rare instances it appears to be a granite (Table III).

TABLE III | *Average modes of the Foot Bay gneiss (map-unit 1)*

	Average of all (14) thin sections and all (5) hand specimens	Average of eight thin sections	Average of three thin sections	Average of three thin sections
	Range %	Range %	Range %	Range %
Albite-oligoclase	33(14–45)	32(28–38)	44(44–46)	16(14–?)
Microcline	27(10–40)	29(21–40)	17(10–22)	48(40–?)
Quartz	20(13–31)	23(19–29)	18(17–20)	18(16–21)
Mafic minerals	18(9–32)	16(9–21)	21(16–25)	18(11–25)
Rock composition	quartz monzonite		granodiorite	granite

In thin sections the plagioclase (albite–oligoclase) is seen to be slightly altered to sericite and is, in part, stained faintly red. Microcline is fresh, and some of it is perthitic. It is interstitial to the plagioclase or occurs as rims around it. It was seen also in elongated masses and in large grains enclosing a few remnants of plagioclase. Quartz mixed with the feldspars generally occurs in agglomeration of tiny individuals forming long narrow lenses and elongated irregular patches, all aligned. The dark minerals are in layers and rods or flakes, oriented parallel with the quartz lenses and dark bands. This defines the layered structure seen in thin sections. Apatite, zircon, and sphene are accessory minerals. Pyrite is present locally. Chlorite is the most common mafic mineral, and most of it is probably an alteration product after biotite. Locally the dark mineral is green biotite; elsewhere it is hornblende. Epidote was probably introduced, and some may be an alteration product.

A group of hand specimens were collected from the area underlain by the Foot Bay gneiss. The specimens were combined, and the sample obtained was chemically analyzed. The results are presented in Table XXIV. For comparison, the average chemical analysis of forty-one hornblende-biotite adamellites (quartz monzonites) is given. The striking similarity is readily apparent. The only marked difference is in the lime content, and this is probably due to the general lack of hornblende in the Foot Bay gneiss.

Throughout the area of the Foot Bay gneiss there are zones, tens of feet wide, of thinly bedded quartzite. A few of these zones were traced for more than 2,000 feet along strike. Attempts to trace them farther along the strike with the hope of using them as horizon markers were unsuccessful, as they became lost under overburden and appeared to change facies or to be altered into the typical Foot Bay gneiss. This quartzite is granoblastic and is made up of sand-size grains of clear quartz, and possibly feldspar, with small amounts of biotite and chlorite in tiny flakes. Bedding is well marked, and the quartzose nature of the rock is very characteristic.

In other places in this gneiss are diffuse patches somewhat richer than the gneiss itself in dark minerals, particularly hornblende and chlorite. Such patches pass gradually into the gneiss and generally are finely gneissic rather than coarsely layered. The high mafic content of these patches suggests that they may once have been amphibolitic masses, now partly granitized and almost altered to the Foot Bay gneiss. Furthermore, locally they grade into amphibolite masses and occur commonly on strike with them. However, owing to poor exposures and the relatively high mafic content of the Foot Bay gneiss as a whole, it was not always possible to outline these masses, and many were probably missed in the field and are not shown on the map. Nevertheless they are so common that the original source material must also once have been common.

Near or at the margins of some of the amphibolite masses and at irregular spots within the Foot Bay gneisses, zones of a coarse-grained white weathering rock occur, usually rich in quartz and white feldspar and carrying biotite. These were mapped as quartzitic gneiss and are believed to be similar in composition to the Donaldson Lake gneiss, described fully later in this chapter. Originally these areas were probably somewhat more quartzose.

Finally, in the Foot Bay gneisses, there are, in addition to dykes and sills of granite, masses of coarse-grained, massive, locally gneissic, red granite. Some of these masses were extensive, and distinctive enough to be mapped separately, but many because of poor exposures and apparent lack of continuity or because of their extremely irregular shape, could not be outlined in the field. However, in the area east of the east end of Foot Bay, granite is particularly abundant, and many large masses were recognized there and mapped.

Map-Unit 2: Donaldson Lake Gneiss

The Donaldson Lake gneiss is well exposed between Donaldson Lake and Mickey Lake. Its outcrop area extends west from the Foot Bay gneiss area east of Donaldson Lake as far as the western shore of the northern end of Mickey Lake and south almost as far as Verna Lake. This area is about 2 miles wide at the northern boundary of the map-area and less than a mile wide southwest of Foot Bay. East of the bay it seems to end very abruptly and to be replaced by red granitic rocks. The Donaldson Lake gneiss forms part of the west flank of the Ace Lake – Donaldson Lake anticline. Near the nose of this anticline the gneiss is in both open and tight folds, but on its western flank it is in open rolling folds. On the eastern flank, it has disappeared. Apparently it has changed into granitic rock as a result of granitization and possible facies changes. Its eastern extension north of the St. Louis fault was not recognized.

The Donaldson Lake gneiss is not in direct contact with the Foot Bay gneiss on the east but is separated from it by a narrow zone of dense quartzitic rock, locally thinly bedded. This zone of quartzitic rock was observed all along the east shore of Donaldson Lake, and it is in sharp contact with the Foot Bay gneiss. On the west, the Donaldson Lake gneiss is in sharp contact with map-unit 3. On the southwest and south, the gneiss appears to change facies or to be more or less metamorphosed or granitized both along and across the strike so that the contact is very irregular and hard to determine. As shown on the map, the gneisses appear to finger in and out in an irregular fashion along and across the strike.

The Donaldson Lake gneiss is a white to light brown weathering rock with a generally crude coarse granitic texture and a rough layering. Locally, as in the area south of Foot Bay, the weathered surface may have a light greenish cast. The rock as a whole is massive in appearance and hard. Although it may be locally homogeneous, in general it seems to be made up of two main rock types, intermixed in such a fashion as to produce the rough layering mentioned above. This layering may be well defined, as may be seen on the slopes of the west shore of Donaldson Lake where it is believed to represent bedding. There, it is due not only to beds originally of different composition but also to beds that have been variously granitized. It is emphasized by interbedded lenses of hornblende schist and glassy quartzite. In general, however, the layering is rough, irregular, and discontinuous or incipient. It may even be almost completely lacking, as on the east shore of Mickey Lake where the rock is so uniform and so homogeneous that it resembles a coarse-grained white granite. The apparent homogeneity in this particular instance is believed to be the result of a low westerly dip and of the topography, so that the entire area may be underlain by a single thick bed. Finally, the layering is in part so irregular that it is nebulitic. Fresh exposures of the Donaldson Lake gneiss are light greenish grey and granular, and generally they show a rough foliation and some variations of mineral content.

As mentioned previously, the Donaldson Lake gneiss seems to be made up of two rock types, a white granite–gneiss and a rusty quartz–feldspar–biotite gneiss.

1. The granite–gneiss is a white weathering, coarse-grained granite or granitoid gneiss that occurs in layers, lenses, and even in large masses. The large masses, which also weather light brown in spots, are characterized by patches with a glassy, smooth, weathered surface. Locally these patches, which show bedding, are distributed in such a way as to suggest stratification. They generally have a high quartz content and show all gradation from a rare feldspar free rock to a rock with patches made up entirely of feldspar. In those glassy patches that contain feldspar, it may be found along the margins only, along planes and zones or in isolated spots within them, or as round grains, sparsely and uniformly distributed or concentrated in irregular masses. Rocks with abundant and evenly distributed feldspar are coarse grained and granitic, a common rock type in large areas of the Donaldson Lake gneiss. This feldspathization suggests a progressive granitization of possibly a quartzite. Locally there are also large patches made up mainly of white albite. Here the albite is generally coarsely crystalline and occurs with nodular concentrations of black biotite. These may represent the final step in the feldspathization of the hypothetical quartzite.

2. The quartz–feldspar–biotite gneiss is a rusty brown weathering granoblastic rock that also occurs in layers and lenses. It is definitely not so granitic looking as the granite–gneiss described above. Its weathered surface is also rougher as it weathers deeper and as the round grains of white feldspar stand out in relief. This rock is also more finely gneissic than the granite–gneiss and locally is even schistose. The higher content of biotite or chlorite accounts for the rusty brown weathered surface, the deeper irregular weathering, and the more finely gneissic structure. Large areas of this rock have been noted along the east shore of Mickey Lake, but generally it occurs in lenses, a few feet long by a few inches wide and in irregular layers or patches within large areas of the granite–gneiss or interlayered with it as if it were stratified.

Of the two rock types described above and believed to constitute the bulk of this gneiss, the layers that weather mainly white and that are coarse grained and granitoid are the more abundant. Several specimens of this rock were stained to determine the approximate content of the feldspars and quartz; also several thin sections were studied (Tables IV and V). From the study of two specimens of the rusty bands it was concluded that they were similar in all aspects to the white weathering, coarse-grained granitoid rock, except for a much higher mafic content with a greater variation from place to place. The averages of the data of Table IV, given in Table V, suggest a quartz-monzonitic composition.

TABLE IV *Estimated mineral composition of the Donaldson Lake gneiss (map-unit 2), in percentages*

	Thin sections															Hand specimens							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1	2	3	4	5	6	7	8
Feldspars				46		60								48									
Albite	28	19			35		43.5	28.5	23.5		37	33	48		36								
Microcline	39	31	28		21		25	44	37	29	29	30	25		5								
Quartz	31	42		45	36	25	21	20	30		31	26	20	41	28	40	38	38	44.5	31	54	28	34
Biotite						5					2			11									
Chlorite	2	6	9	7.5	7	8	6	5.5	7	8	1	9	3		17								
Muscovite						1	4		1			2			6								
Opaque		2	2	1.5	1	1	0.5	2	1	0.5			1		6								
Epidote													3		1								
Carbonate															1								
Plagioclase																21	21	20	27.5	30.5	21	20	2
K-feldspar																36	34	40	21	34.5	18	43	42
Mafic minerals																3	7	2	7	4	7	9	4

TABLE V | *Average mode of Donaldson Lake gneiss (map-unit 2) and granite derived from it*

	Donaldson Lake gneiss	Granite derived from Donaldson Lake gneiss
	Range %	Range %
Albite–oligoclase	27(19–48)	33(28–37)
Microcline	32(18–44)	32(22–40)
Quartz	34(20–54)	28(21–40)
Mafic minerals	7(2–11)	7(1–14)
Rock composition	quartz monzonite	

The description below, which is mainly based on the study of thin sections of the white granitoid gneiss, applies equally to the rusty granoblastic gneiss. In thin sections, the white granitoid gneiss is seen to be hypidiomorphic granular. It is made up of anhedral to euhedral grains of plagioclase, scattered in a mass of irregular grains of microcline and interstitial quartz. The plagioclase, which is generally heavily altered, occurs in two grain sizes. The larger grains, around 1.5 by 1.3 mm, are generally anhedral and equant to round. Their uniform distribution throughout the rock and their shape suggest that they formed earlier than the microcline and quartz. The smaller grains, about 0.15 mm, are euhedral and are concentrated at the boundaries of the other minerals or within them. They probably formed later as they seem to replace the microcline forming myrmekitic intergrowth around the larger grains. The plagioclase of both grain sizes is an albite of about An_5 composition. Locally, however, as in the area north of the National Exploration shaft and also in a specimen from within the mine, it is oligoclase to acid andesine. Microcline is generally fresh and occurs in large to small irregular grains. The larger grains are up to 6.0 by 3.2 mm and are uniformly scattered throughout the rock, but much of the microcline is in grains similar in size to the larger grains of plagioclase. It is usually embayed by quartz, and in some places seems to replace albite, although its relationship to plagioclase is not always clear. Quartz is in patches interstitial to the other minerals. These patches are made up of several grains of various sizes displaying an imbricate structure; that is, each grain has a wavy irregular outline against its neighbour. All quartz grains have an undulatory extinction. The other minerals, in order of decreasing abundance, are: biotite, chlorite, muscovite, opaque substances (pyrite and magnetite), carbonate, and sphene. In some sections chlorite is the main mafic mineral, and biotite may be completely lacking. In others, chlorite is almost absent. Muscovite, carbonate, and pyrite may or may not be present, but when present they are always in small amounts.

A chemical analysis of this gneiss is presented in Table XXIV. It was made from hand specimens collected at fairly regular intervals throughout the wide area underlain by this gneiss west of Donaldson Lake. The chemical analysis is almost identical to that of an average biotite granite presented in the same table. The main differences are in its slightly lower potash content and in its slightly higher magnesia content. These differences may be explained by the local abundance of chlorite, probably at the expense of biotite.

Throughout this gneiss there are layers, lenses, and irregular masses of hornblende schist and gneiss, amphibolite, and chlorite schist. These all have sharp contacts with the Donaldson Lake gneiss. Some of these bodies are massive and coarse grained; others are fine to medium grained and are well foliated to strongly gneissic. The regularity of the foliation and the fineness of the gneissic structure suggest relict bedding. Dark green to bluish green hornblende is the main mafic mineral of most of these bodies, particularly the larger ones. Other masses, generally the smaller, have only chlorite or biotite. Locally chlorite or biotite may form a narrow zone at the margins of some of the larger masses, as if it had formed as an alteration product of hornblende. The mode of a specimen studied in thin section is given in Table VI. This specimen was collected from an amphibolite mass located about 1,000 feet west of the National Exploration shaft.

TABLE VI | *Mode of amphibolite in Donaldson Lake gneiss, in percentages*

Green blocky hornblende	47
Brown biotite in blades and laths	19
Andesine (about An_{45})	22
Quartz	7
Opaque	3
Muscovite and sericite	1
Apatite	1

Brown biotite is mixed with green hornblende and in a few places has formed at the expense of hornblende. Plagioclase (andesine) is in all places interstitial to the mafic minerals in grains almost as large as those of hornblende and is slightly altered to sericite and muscovite. Quartz is always in tiny grains associated with feldspar. Apatite is uniformly distributed. The opaque substance is in irregular masses and shows a marked association with the mafic minerals.

On the large island in Donaldson Lake several masses and lenses of hornblende schist and gneiss were mapped. A few are large, strongly foliated, and gneissic. All are composed mainly of acicular bluish green hornblende and feldspar. Most of them seem to rest on the gneisses, but the most western masses are probably interlayered with them.

Several other amphibolite masses were noted in the vicinity of the National Exploration shaft and along the northwestern shore of Donaldson Lake. Several of these are lenses of various sizes. Many are aligned along the same horizon, as if they were parts of a continuous bed now broken into boudins of various sizes. Other lenses occur by themselves. Although most of these lenses or masses are oriented parallel with the regional foliation of the area, a few are not. Randomly oriented lenses were noted, particularly in the area south of the National Exploration camp on Foot Bay. There they are probably in an area of more intense deformation and represent parts of beds that have been moved from their original position. A few are cut by veinlets of red granite.

Within the Donaldson Lake gneiss there are also many small irregular masses of red granite. Many of these are several hundred feet long by a few hundred feet wide, the largest being near the northern boundary of the map-area and in the area south of the National Exploration shaft. Most of these granite masses are elongated parallel with the main trend of the foliation. The largest are shown on the map. This granite is coarse grained and homogeneous or roughly layered, and in general it resembles the Donaldson Lake gneiss. From the field work one would infer that it has indeed formed directly from the Donaldson Lake gneiss as it grades into the gneiss within a few feet. The red colour characteristic of this rock suggests the addition of ferric iron or transformation of the existing iron into ferric iron. The granites are more common where fracturing is intense, as if the solutions that account for the transformation of the Donaldson Lake gneiss into the red granite have circulated more readily along these fractured areas than through massive rock.

Of the two main types of rock that make up the Donaldson Lake gneiss, the layers and lenses that weather white and are granitoid seem to change more readily into this red granite than those with a rusty surface and a high mafic mineral content. Locally the granite includes a few patches or lenses of chlorite schist, but in general it is a uniform looking rock, and in many instances the red colour is the only difference apparent in the field from the Donaldson Lake gneiss. Its composition, however, is different, as can be seen by comparing the results of thin sections (Tables IV, V, and VII) and of chemical analyses (Table XXIV) from both rocks. Actually the granite is composed of the same minerals as the Donaldson Lake gneiss though in somewhat different proportions. As in the gneiss, chlorite may be abundant or almost absent, and quartz may be plentiful or scarce, suggesting that the amount of some of the minerals in the granite depends upon and varies with the original composition of the Donaldson Lake gneiss from which it was derived. The diffuse contacts between both rock types also indicate that one formed from the other.

TABLE VII — *Estimated mineral composition of red granite in Donaldson Lake gneiss, in percentages*

	Thin sections						Hand specimens				
	1	2	3	4	5	6	1	2	3	4	5
Feldspars	50		74	69		91.5			71		
Albite	?	28	?	?	33	?					
Microcline	?	26	?	?	38	?					
Quartz	36.5	40	24.5	24	24	0.5	33	21	28	24	35
Chlorite	12	5.5	1	6.5	4	7					
Muscovite	1.0										
Opaque	0.5	0.5	0.5	0.5	1	1					
Plagioclase							33	32	?	34	37
K-feldspar							33	40	?	28	22
Mafic minerals							1	7	1	14	6

As seen in the hand specimen, this granite is made up of red to pink feldspar, grey quartz, and some mafic minerals. In thin sections it shows the same structural features as the Donaldson Lake gneiss. The relationship of the two feldspars to each other and of quartz to the feldspars is the same as in the Donaldson Lake gneiss. The plagioclase is albite, and the microcline usually perthitic. Chlorite is the most common mafic mineral, but in a few places hornblende is also present. Thus, a hornblende granite was noted a short distance southeast of the National Exploration shaft. Biotite also occurs locally with chlorite, but only rarely. Chlorite is generally in shredded grains interstitial to the other minerals but was noted also in large flakes, including tiny muscovite flakes and many tiny specks of leucoxene.

Chlorite also occurs along fractures or in cracks cutting all other minerals. Other dark minerals present, but in minor quantities only, are epidote, pyrite, leucoxene, probably magnetite, zircon, muscovite, apatite, and carbonate. Hematite dust is often present.

The mineral composition of this granite was estimated from six thin sections and five stained hand specimens (Table VII), and its average mode corresponds to that of a quartz monzonite (Table IV).

A group of hand specimens from the various parts of this granite were chemically analyzed, and the results are presented in Table XXIV. Comparison of these results with those of the Donaldson Lake gneiss, from which this granite is believed to have been derived, indicates that there is a decrease in silica content as well as a marked change in the proportion of the various alkalis, although the total alkali content remains about the same in both rocks. The decrease in silica is marked by a decrease in quartz, the decrease in potash probably by the absence of biotite, and the increase in soda by an increase in plagioclase. This may suggest soda metasomatism. The higher content of ferric iron explains its red colour. If this analysis is compared with that of an average granite, the differences are small, except for the low potash and high soda. The relatively high magnesia is probably due to its high chlorite content.

Map-Unit 3: Quartzite–Chlorite Schist

An interbedded mixture of dirty grey quartzite and chlorite–sericite schist was mapped as map-unit 3. It occurs as a belt overlying the Donaldson Lake gneiss. The features that distinguish this unit are its stratigraphic position above the Donaldson Lake gneiss, its thinly bedded nature, and the close interlayering of the two main constituent rock types: quartzite and chlorite–sericite schist.

The belt follows closely the upper contact of the large area of Donaldson Lake gneiss in a big arc from the north boundary of the map-area, about 1,500 feet east of Hab Lake, to as far south as St. Louis fault near Ace and Verna Lakes and east as far as Flack Lake south of St. Louis fault. Locally the position of this belt is difficult to establish accurately, because in places it is much deformed and granitized and because it is not everywhere present immediately above the Donaldson Lake gneiss. Thus, in the area south of Mickey Lake, the rocks of this map-unit are separated from the Donaldson Lake gneiss by a wide lens of hornblende schist (map-unit 4), with which they are in sharp contact. In general the contacts of map-unit 3 are sharp, as for example north and west of the northwest arm of Mickey Lake where these rocks are in sharp contact with the top of the Donaldson Lake gneiss. There also, it is in equally sharp contact with overlying map-unit 5. However, between the north and south arms of Mickey Lake and north and east of Ace and Verna Lakes, the contacts are irregular and gradational. There, the interfingering of the map-unit 3 rocks with the Donaldson Lake gneiss suggests lateral variation and facies changes along strike, and the position of the contacts seems to be partly controlled by the degree of metamorphism and deformation.

At the surface this belt is about 500 feet wide west and north of the northwest arm of Mickey Lake. In the area south of the northwest arm of Mickey Lake and in the area about 1,500 feet east of the Nesbitt Labine shaft, the belt varies from more than 2,000 feet to not more than a couple of hundred feet, possibly because of changes in the dip and facies and in the degree of deformation and granitization. East and southeast of the main argillite–granite contact east of Eagle Lake, and as far south as the St. Louis fault, most of the area mapped as map-unit 3 is now granite and brecciated granite with only small remnants of ungranitized or partly granitized quartzite. It is mapped thus, as it is believed that these rocks before granitization were quartzite with only small amounts of schist, which probably belong in map-unit 3.

The quartzite–chlorite schist belt occupies a position on the Ace Lake – Donaldson Lake anticline comparable to that of the Donaldson Lake gneiss, that is, along its western limb. As the anticline plunges southwest, the belt wraps around the nose in that direction, and there are indications that some increases in the thickness of the succession took place in the axial region of the fold. The extent of the eastern limb east of Verna Lake is uncertain as the rocks in that area are much granitized and have been truncated by the St. Louis fault. It is, however, on scanty information, that it is believed to extend almost to Flack Lake north and south of the fault. On the north side of and near the St. Louis fault, this belt is represented by the thinly bedded quartzite and schist in the area of the Ace shaft and west of it, by the thick masses of quartzitic rocks northwest of Verna Lake, and by a granitized schist west of Flack Lake. South of the fault, it is believed to be represented by the wide belts of quartzitic rocks interbanded with the hornblende schist and the argillite east of Verna Lake and, as suggested by small quartzite remnants, may extend as far as Flack Lake.

In the axial zone or the apex of the anticline, where most of the rocks of this belt are now granite or greatly granitized, some of the quartzite resembles the Donaldson Lake gneiss. However, some of it is still dense and siliceous and recognizable as quartzite, but even these rocks are now red and in many places look granitic. These mixed rocks were observed over a very large area, and it must be assumed that the entire area was once mainly quartzite, now changed almost entirely to granite.

Small masses of quartzite almost entirely without schist outcrop within the large areas of argillite and hornblende schist (map-unit 4) southwest of Eagle Lake. Although these lie stratigraphically below or within map-unit 4 they were mapped on structural evidence with map-unit 3. Dawson (1956, p. 15) and R. W. Edie (1952, p. 681) are believed to have reported the analyses of the rock from some of these masses. Dawson called it a chert whereas Edie referred to it as quartzite. These analyses are presented in Table VIII, together with the analysis of an average orthoquartzite by Pettijohn (1949) for comparison. The quartzite of these small masses is rarely schistose or bedded. It locally contains specularite flakes or hematite dust. Its outcrops are traversed by seams, patches, and stringers of red feldspar. In thin section this rock is seen to be a mass of fine-grained recrystallized quartz, exhibiting an imbricate structure, that is, the quartz occurs as tiny (less than 0.02 mm), round or irregular grains, closely packed with sutured boundaries, or as slightly larger, aligned elongate oriented patches, also with sutured boundaries.

In general the quartzite of map-unit 3 is massive and dense and is thinly bedded or foliated. It is generally grey to light brown but may also be creamy white and dirty greenish white. Fresh surfaces are dark grey and green and have a glassy appearance. The schist interbedded with the quartzite is dirty grey to dirty light yellowish green and brown. It is also a dense to fine-grained massive rock with, locally, a pronounced schistose or foliated structure. Both rock types occur in thin beds or layers, generally half an inch thick, and are traceable for long distances along strike. Each bed has sharp boundaries, and both rock types are thinly interbedded. North and west of the northwestern arm of Mickey Lake they are both present in about the same amount. South of Mickey Lake and in general in the area north of the St. Louis fault, quartzite seems to be the predominant rock type, locally being almost the only rock present. In some areas where the schist is abundant, seams of possibly later milky white quartz were noted along the schistosity planes. Locally the quartzite is more schistose, and the quartzite and schist may be indistinguishable. If they are granitized particularly near granite masses, they carry abundant red feldspar augen.

Under the microscope most of the rocks of this belt are fine grained and strongly foliated. The grains rarely exceed 0.3 mm. A thin section generally shows a few large grains averaging about 0.2 mm in width resting in a matrix of grains that average about 0.02 mm. Locally the

TABLE VIII — *Chemical analyses of quartzites from southwest of Eagle Lake, north of St. Louis fault, in percentages*

	1	2	3	4
SiO_2	95.55	95.51	89.1	92.5
Al_2O_3	2.26	1.86	6.7	1.4
Fe_2O_3	0.48	0.26	2.1	0.2
FeO	.74	.44	1.4	.3
CaO	.73	1.12	0.7	3.0
MgO	.08	0.11	2.0	0.1
Na_2O	.48	.49	0.5	.1
K_2O	.17	.23	.2	.1
H_2O^+	.12	.21		
H_2O^-	.18	.15		
TiO_2	.03	.07		
P_2O_5	.03	.05		
MnO	nil	nil	0.1	
CO_2	nil	nil		2.3
C				
S	nil	nil		
Total	100.85	100.50		

Niggli Numbers

	1	2	3	4
si	2568	2306	859	
al	30	32	38	
fm	30	19	48	
c	20	29	8	
alk	20	20	6	
si^1	180	180	124	
qz	2388	2126	735	

1. Mildly reddened chert, taken 3 feet from a radioactive vein, Tam Lake area, northeast of Padget Bay on Beaverlodge Lake, Beaverlodge area, Sask.
   Analyst: R. J. C. Fabry, K. R. Dawson, 1956, p. 15.
2. Reddened chert from the immediate vicinity of same radioactive vein, same locality as above.
   Analyst: R. J. C. Fabry, K. R. Dawson, 1956, p. 15.
3. Quartzite, Eagle mine, Beaverlodge area, Sask.
   Quantitative spectrographic analyses by R. W. Edie, 1952, p. 681.
4. Average orthoquartzite, F. J. Pettijohn, 1949, p. 241.

matrix may constitute most of the slide, but elsewhere it forms only a narrow filling between the large fragments. In such cases the rock exhibits an augen-structure, since the large fragments are generally lenticular, with a common orientation, and rest in a matrix with pronounced flow structure. Locally, throughout the matrix some of the quartz has recrystallized in larger patches, and lenses, patches, and vein-like masses in the slide may contain grains up to 2 mm and minerals distributed as in granite. There the rock is much coarseı grained and resembles a granite. These represent a step toward the granitization of the rock. In such places, some brecciation was usually noted.

In thin section the foliation is indicated by zones of different mineral composition, such as zones rich in muscovite or void of mafic minerals; by the alignment of the larger grains and the flakes of mica and chlorite; by zones of different grain sizes; and by the parallel orientation of streaks and lenses of recrystallized material, usually quartz. Locally the rock is much deformed; this is shown under the microscope by crenulation, drag-folding, and faulting of the foliation plane.

Most of the grains, particularly the larger ones, look like fragments. Their shape, distribution, and appearance suggest that they are clastic, more or less deformed, and recrystallized. The large fragments are made up mainly of albite or quartz and rest in a matrix of the same minerals, along with some chlorite in rod-like and irregular masses. Muscovite is a common associate of chlorite and, like chlorite, is found mainly in rod-like masses oriented parallel with the foliation. Zircon, tourmaline, garnet, opaque minerals, and some carbonates have also been recognized in small or trace amounts. Tourmaline was noted in one slide. Much of the garnet is altered to chlorite. The fine-grained nature of the rock in general and the streaks and lenses of recrystallized quartz are responsible for the dense and cherty appearance of some of the rocks.

In addition to quartzite and chlorite–sericite schist, the presence among the rocks of this belt of a few (map-unit 3e) masses, generally too small to map separately, which are rich in diopside, micaceous material, and carbonate, suggests a derivation from impure carbonate rock such as marl or dolomite. In other words, the three main types of rock (sandstone, shale, carbonate) ordinarily found in a sedimentary sequence, all appear to have been present in this belt and now are metamorphosed to quartzite, chlorite schists, and diopside-carbonate rocks, respectively.

There are also within the belt small areas of red granite, some large enough to be shown on the map. This granite resembles the red granite derived from the Donaldson Lake gneiss described before, or, in general, the normal granite of the Beaverlodge area.

Map-Unit 4: Argillite–Hornblende Schist

Map-unit 4 comprises two relatively distinct groups of rocks. One group includes such rocks as argillite, slate, siliceous argillite, chlorite–epidote rock, and occasionally chlorite–biotite schist. The other group includes hornblende schist, coarse-grained amphibolite, and incipient hornblende schist. Both groups are probably related in some ways since they are both coarsely interlayered and thinly interbedded. The interlayering can readily be seen in a stripped area on a small peninsula about midway along the south shore of Eagle Lake, and also in the underground workings of Eagle–Ace mine. All areas of argillite show, in varying degrees, some interbedding with hornblende schist. Both groups of rocks are also in most places at about the same stratigraphic horizon, generally closely associated with map-unit 3. Occupying about the same position in relation to the axial plane of the Ace Lake – Donaldson Lake anticline as map-unit 3, they have been found above, below, or within it. However, most of the rocks of map-unit 4 are stratigraphically above those of map-unit 3.

Rocks similar to those of map-unit 4 have been mapped at other horizons in the area north of the St. Louis – ABC fault. Indeed, hornblende schist and amphibolite have been recognized at almost every level in the stratigraphic succession of this area but are nowhere so abundant nor so widespread as at this horizon. There they are abundant enough to constitute a distinguishable mappable unit, even if the rocks occur mainly in lenticular masses and even if they are spread within a vertical stratigraphic range extending from within map-unit 3 below to within map-unit 5 above. Where these rocks were recognized at other levels in the older or younger map-units, they were considered as components of those map-units. Nevertheless, they all are similar lithologically, and they were probably formed from a rock of about the same original composition as those of map-unit 4.

All the rocks of map-unit 4 are crisscrossed by an irregular network of tiny interlocking seams of pink feldspar, silica, carbonate, and/or quartz and feldspar. In addition to these minerals, chlorite and epidote, filling closely spaced, narrow, tight (less than one-quarter inch wide), irregular fractures and forming irregular patches a few inches across, occur abundantly in the hornblende schist and amphibolite, particularly in those masses south of Mickey Lake. Hematite is also found with either the chlorite or the epidote.

Argillite, slate, chlorite–epidote rock, and minor chlorite–biotite schists were recognized at many places north of the St. Louis fault and were mapped separately from the more mafic group in the area that extends southwest of Mickey and Mic Lakes to as far south as the St. Louis – ABC fault. Elsewhere the two groups were not mapped separately because the different kinds of rock are mostly too closely interbedded and interlayered, too fine grained, and too similar in the hand specimen to allow a safe distinction. The rocks of the argillite group are in some aspects very similar to some of the rocks of map-unit 3, and in some areas, particularly south of Mickey and Mic Lakes, they seem to grade into one another in outcrops. Consequently, the two may be related in composition, and, as mentioned previously, the rocks of the two map-units are in part intermixed and must therefore be of about the same age. This is why map-units 3 and 4 were in the same legend block in the map. For the same reasons map-unit 5 was in the same legend block also.

The argillite (map-unit 4a) is dense to fine grained, and massive to well bedded. The grain cannot usually be distinguished with the naked eye. Beds are generally narrow and sharply defined, and although no attempts were made to estimate accurately their average thickness most of them are less than a couple of inches thick. Where exposures are fairly good, relatively thick black beds and interbedded narrower white to buff beds can usually be seen. These white beds usually occur in groups of two or three, and each bed is less than half an inch thick. Considered as a whole, the rock is grey to black and brownish black on weathered surfaces, and black to grey where fresh. Much, however, is dirty white with black patches. Fresh cuts of the thickest beds usually show conchoidal fractures. Locally the argillite is fissile or becomes a slate. It is also contorted and brecciated. Intricate folding was noted on the north shore of Eagle Lake, and brecciation was observed on the islands and at various places on the shore of the same lake. This brecciation seems to be a local intraformational feature only. The thickest beds are locally slaty and also in part schistose.

Locally this rock's weathered surface becomes reddish white to light orange-red, and although still dense and fine grained, if traced farther it passes gradually into a coarse-grained red granite with white milky quartz and remnants of dark green argillite, rich in chlorite.

Under the microscope the argillite is seen to be very fine grained, the grains generally being less than 0.01 mm across and in spots too small to be distinguished. The rock also exhibits a pronounced foliation, which is due to the alignment of mica and chlorite flakes, to different concentrations of dust particles in adjoining layers, and to variations in the proportions of the minerals present. Each layer or bed is slightly different in composition from the adjoining layers, but the rock as a whole seems to have the following approximate mineral composition: chlorite and sericite or in part muscovite, about 30 per cent each; quartz and albite–oligoclase, about 15 per cent each. There are also minor amounts of iron ore, pyrite, zircon, carbonate, leucoxene, and epidote. The late fractures are filled with chlorite, epidote, quartz and feldspar, and carbonate.The figures mentioned above are broad averages only, and any two slides may have a quite different mineral content. In siliceous looking argillite, the amount of felsic minerals and mica may indeed be higher than that in chlorite. It is possible that the feldspar composition varies toward the north, but the grain was so fine that no attempts were made to determine its composition. Smith (1949) described a typical black slate from the area near Eagle Lake as being composed of very fine grains of chlorite, sericite, and quartz in thin lamina with numerous small porphyroblasts of quartz. J. S. Dudar (1960), who studied some rocks from the large mass of hornblende schist east of Verna Lake and south of the St. Louis fault, referred to them as chlorite rock and epidote rock. He assumed that they were once argillite. He describes his chlorite rock as being made up of "chlorite (30–45%), sericite (5–30%), feldspar (20–30%), quartz (10–14%), calcite (2–5%), and accessory specular hematite, pyrite, apatite, and zircon." His chlorite "rock may be chlorite rich or have equal proportions of chlorite and sericite" (p. 38). He considered the epidote rock as a "variety of the chlorite rock veined with an apple-green mineral," and as being made up of "clinozoisite (10–15%), epidote (5%), calcite (3–5%), chlorite (45%), feldspar (15–20%), quartz (10–15%), and accessory hematite and pyrite" (p. 41). These rocks are interpreted in this report as being either altered phases of the hornblende schist south of Verna Lake or zones of interbedded argillite within the hornblende schist, the argillite being of the type described previously and similar to the one for which the chemical analysis is presented in Table IX, No. 6.

Hornblende schist and amphibolite (map-unit 4b) are the most common rocks of map-unit 4. They occur most abundantly in the area that extends from Mickey Lake south to the St. Louis – ABC fault. In this area they occur on both limbs, and near the apex, of the Ace Lake – Donaldson Lake anticline. These rocks appear as small isolated masses and lenses passing by Hab Lake on the western limb of the anticline, and on the eastern limb as lenses and masses outcropping along the St. Louis fault near Ace and Verna Lakes. These masses are truncated by the St. Louis fault, and their extension farther to the east, south of the fault, is represented by the masses southwest of Collier Lake. The hornblende schist occurrences north of the Fish Lake fault, east of Fish Lake, and north of Billo Lake are regarded as part of this map-unit, although the relationship is uncertain. North of St. Louis fault the map-unit has been traced as far as Raggs Lake on very scanty information, and this relationship is also uncertain. Although the outcrop areas of most hornblende schist and amphibolite bodies are roughly lenticular, not all are so. Thus, south of Mickey Lake their outline is very irregular, probably the result of a low-dipping sheet cut by rugged topography.

The large masses of hornblende schist and amphibolite south and around Eagle Lake lie directly above the main known layer of argillite and slate (map-unit 4a); they are considered to be erosion remnants of a once continuous layer. In most places observed, the remnants were conformable with the argillite (map-unit 4a) below, but locally, as at a point about 1,500 feet west of Eagle–Ace shaft, the argillite beds are truncated by the overlying hornblende schist and fragments of the argillite are even enclosed in the hornblende schist just above the contact; this suggests that the contact is unconformable. At another point about 1,000 feet north of Padget Bay on Beaverlodge Lake, the angle of unconformity was measured to be 15 degrees. The contacts between the argillite and the hornblende schist are generally sharp, and locally there may be a faint suggestion of some baking of the argillite right at the contact. In a few places, the contacts are gradational within a few feet, and the two are interbedded. The erosion remnants of the once continuous layer vary in thickness from place to place with the amount of deformation and with their structural position. The thickest parts are generally in synclinal troughs, as was inferred from the attitudes of the underlying argillite and from information on drilling and underground work at Eagle–Ace mine.

The rocks of these remnants appear to be generally massive and structureless, possibly because they are almost flat lying. A pronounced layering, possibly bedding, is present near the western contact with the overlying massive glassy quartzite, and the mafic rocks there probably dip steeply west. The mass of hornblende schist outcropping along the south and north shores of the southeast end of Mickey Lake is characterized by a pronounced foliation (*see* Pl. 1), which varies greatly in its attitude. North of the lake, readings on the foliation indicate a thinly bedded rock that has been involved in complex close folding, as the foliation varies

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PLATE 1

Hornblende schist and gneiss, Mickey Lake, north of St. Louis fault. The fine, regular layering believed to be relict bedding.

from horizontal to inclined toward both east and west. South of the lake, the attitudes on the foliation are so irregular that only by very detailed mapping could the structure possibly be deciphered. It is however believed to represent the complex folding common at the apex of folds. In composition, this mass is made up mainly of hornblende schist, but there are also small amounts of interbedded argillite and biotite schist.

The lenses south and west of Ace Lake are massive to thinly bedded and are composed of an intimate mixture of argillite and hornblende schist. The general dip of the foliation is steeply south, and the strike is uniformly northeasterly to easterly. The small masses in the area between the northwest arm of Mickey Lake and its southwest arm are also said to be small erosion remnants in synclinal troughs, locally almost flat lying. The western masses of this group are probably interbedded with overlying quartzite beds, since both rocks dip west. The masses at the extreme northern end of this stratigraphic unit, or south of Hab Lake, are probably also partly flat lying and partly interlayered with the quartzite below and above. The irregularities and variations in the strikes and dips of the foliation in most of these lenses and masses of hornblende schist and their continuity along strike and down dip indicate that the layering or foliation is relict bedding rather than a product of metamorphism.

Most of these mafic masses are in sharp contact with the rocks below and above. Near granitic rocks, the contacts are still sufficiently sharp to locate within a few feet, but some blurring as a result of local granitization is evident. This granitization is represented by a feldspathization, that is, the development of large white to pink feldspars in the hornblende schists and amphibolite. It is also represented in some of these masses, particularly in the one directly south of Mickey Lake, by several small bodies, sills, and dykes of granite, many of which have been mapped separately; the largest are shown on the map.

The hornblende schist, the amphibolite, and the incipient hornblende schist are massive to well bedded and foliated. They are mainly dark green on fresh and weathered surfaces, and in general their grain is fine to medium. The hornblende schist is the most common rock of this group. It generally exhibits a gneissic structure and a pronounced layering. Each layer or bed is usually less than an inch thick and differs from the adjoining layers in colour, grain size, and composition. The amphibolite, on the other hand, is generally coarser grained, more massive looking, and, where foliated, more coarsely foliated than the hornblende schist. It occurs usually in small masses or irregular patches in the hornblende schist and may represent facies in the original rock of slightly different composition. Amphibolite is a very common rock in the masses and lenses interbedded with the older and younger stratigraphic units. Such masses are generally small and coarse grained. The incipient hornblende schist is a dense massive rock that may be faintly schistose. It is dark green and was recognized northwest of Mickey Lake.

Under the microscope the foliation or bedding of the hornblende schist is readily seen. It is characterized by the alignment of the hornblende grains, by streaks of opaque minerals and sphene, by grain size variations from bed to bed, and by the concentration of certain minerals into distinct layers. The grain size of the schist averages 0.1 mm and may be as low as 0.04 mm in the matrix of the incipient hornblende schist. The hornblende schist is composed of about 78 per cent dark bluish green hornblende in short prisms and rod-like grains, 17 per cent feldspar and quartz, 3 per cent opaque minerals, and 2 per cent carbonate, chlorite, epidote, or quartz and feldspar, in veinlets filling fractures that cut all the other minerals in the rock. The opaque minerals and sphene are commonly associated with hornblende, but the felsic minerals are interstitial to the hornblende grains and about similar in size. The feldspar of the masses northeast of Verna Lake, around Mickey Lake, and south of Hab Lake is generally fresh and untwinned and has been identified as andesine. In the area about Ace and Eagle Lakes and farther southwest, the feldspar is usually altered and is albite–oligoclase. Some quartz is apparently always mixed with the feldspar present, but it was impossible to estimate the amount of each mineral.

Froese (1955) studied specimens of the amphibolite outcropping south of the St. Louis fault east of Verna Lake. His typical amphibolite contains 70 per cent hornblende, 20 per cent oligoclase, 7 per cent epidote (clinozoisite), and 3 per cent chlorite (pennine); it was cut by quartz–feldspar and chlorite–quartz veinlets, which in turn were cut by epidote and epidote–carbonate veinlets.

Three separate groups of fifteen hand specimens of map-units 4a and 4b were collected for chemical analysis. One of the groups is from the large body of hornblende schist (map-unit 4b) south of Eagle Lake; another is from the mass of hornblende schist (map-unit 4b) west of the Ace shaft; and the third is from the argillite (map-unit 4a) mass southwest of Eagle Lake. The resulting chemical analyses are presented in Table IX. For comparison, the chemical analyses of an average basalt and an average greywacke are included. The mass of hornblende schist south of Eagle Lake is very uniform, and its chemical analysis (Table IX, 2) is considered representative of the rock. When it is compared with the average analysis of

137 basalts (Table IX, 3), the striking similarities indicate that both groups are of the same rock type. The mass of hornblende schist west of the Ace shaft includes some interbedded argillite, and as the mass is finely recrystallized, somewhat altered, and mainly green in colour, it is quite possible that the sample used for the chemical analysis included some argillaceous material. This would explain why the results of this analysis (Table IX, 1) differ slightly from the results of the other (Table IX, 2).

The chemical analysis of the argillite (Table IX, 6) shows definitely that it has some affinity with that of the hornblende schist (Table IX, 1). Probably the parent material for the argillite was not unlike that for the hornblende schist. If the chemical analysis of the argillite is compared with that of an average greywacke (Table IX, 8), there are also some similarities. It is therefore possible that some of the material used for this chemical analysis was in part hornblende schist, since both rocks are locally thinly interbedded and fine grained. The chemical analysis of a glacial varved silt (Table IX, 12) is added to show that possibly no more chemical weathering accompanied the formation of this argillite than in the formation of normal glacial deposits. Analysis No. 7 is that of an Archean greywacke near Manitou Lake, Ontario, and is similar to the analysis of argillite (Table IX, 6). Four other chemical analyses of argillaceous rocks from about the same area suggest that the composition of this argillite may vary from bed to bed. Three quantitative spectrographic analyses by R. W. Edie are also added. Two are from the hornblende schist or amphibolite near Eagle Lake; the third is from a rock described as a bedded slate and is probably related to the argillite.

All these rocks are believed to have been once sediments of tuffaceous or terrigenous origin. There is no doubt about the origin of the argillite and slate. Their grey to black colour, grain size, thinly bedded structure, chemical and mineral compositions, and their interbedding with quartzite, all point to their having once been mainly shales. It is possible, however, that parts of them were pyroclastic and that locally they were both terrigenous and tuffaceous. The origin of the hornblende schist and amphibolite is somewhat less certain. A few features, however, indicate that they also were formed by particles settling, probably in water. The thinly bedded appearance of many of the mafic masses, the uniformity in thickness and the continuity of the beds or layers along strike and down dip, the interbedding of these rocks with definite argillite and slate, and the interlayering with much thicker lenses of thinly bedded quartzite, all suggest that the hornblende schist and the amphibolite were formed by the same process that formed the undoubted sedimentary rocks. Some masses south of Eagle Lake are structureless and massive, and on the outcrops closely resemble the greenstones mapped elsewhere in the Shield. However, in thin sections they are much fresher than the greenstones, and no structures of volcanic origin were recognized or suspected in them anywhere in the field. Nevertheless, their mineral composition and their chemical analyses (for example, see the titanium content, which is indicative) suggest that they are related to the greenstones and that they were probably formed from tuffaceous and pyroclastic material. It is possible, however, that a few of these masses, or at least some parts of them, were originally limy shale and marl. The frequency of the rapid changes in the dip, from horizontal to inclined, in either direction and within very short distances, is an indication that they are deformed beds rather than layers due to metamorphism. The massive appearance of much of the rocks in the many masses south of Eagle Lake is probably because the layers are generally almost flat lying.

Several radioactive fractures were noted in all the rocks of map-unit 4. They traversed these rocks mainly in a northwesterly direction. All these fractures are characterized by a reddening of the hornblende schist or argillite along the border of the fractures; generally they carry small amounts of carbonate (white to buff), hematite, pitchblende, clausthalite, and chlorite.

TABLE IX

Chemical analyses of hornblende schist, amphibolite, argillite, and slate from north of St. Louis – ABC fault, in percentages

	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	52.50	50.33	50.83	44.6	44.4	59.14	60.51	64.0	65.76	68.39	61.84	59.20	67.7
Al_2O°	13.28	13.34	14.07	16.2	16.2	13.97	15.36	14.0	12.84	13.20	17.42	16.14	13.1
Fe_2O_3	3.55	3.78	2.88	1.7	1.9	1.84	0.76	1.3	1.10	1.86	0.07	4.36	0.7
FeO	7.84?	9.58?	9.06	10.8	10.6	7.55?	7.63	4.1	3.09	4.26	6.12	3.24	4.3
CaO	6.90	8.53	10.42	5.9	5.2	4.49	2.14	3.4	3.20	0.93	1.82	2.52	1.0
MgO	6.32	6.28	6.34	7.0	6.0	4.15	3.39	2.9	2.62	2.17	3.35	3.14	2.6
Na_2O	3.88	3.18	2.23	3.6	3.0	2.86	2.50	3.5	3.70	2.08	5.32	3.82	3.1
K_2O	0.73	0.58	0.82	1.6	2.0	1.45	1.69	2.1	0.54	2.10	0.90	1.97	2.1
H_2O^+	2.39	2.13	.91			2.53	3.38	2.0	1.67	3.03	2.41	1.16	
H_2O^-	0.17	0.15				0.14	0.15	0.1	0.11	0.08	0.30	1.15	
TiO_2	1.41	1.58	2.03			1.12	.87	.5	.31	.53	.52	1.20	
P_2O_5	0.13	0.15	0.23			0.13	.27	.1	.05	.12	nil	0.17	
MnO	.18	.29	.18	0.3	0.3	.21	.16	.1	.04	.04	0.03	.09	0.1
CO_2	.66	.00				.05	1.01	1.5	4.12	nil	nil		
C	.08	.02				.09	0.05		0.08	0.23	0.24	1.94	
S							.42		.40	.12	.04		
Total	100.02	99.92				99.72	100.24		99.63	99.14	100.28		

Niggli Numbers

	1	2	3	4	5	6	7	8	9	10	11	12	13
si	137	124		110	117	192		258	296	336	220		322
al	20.4	19.1		23	25	26.7		33	34	38	37		37
fm	49.3	50.2		50	49	45.7		33	34	43	36		37
c	19.3	22.4		16	15	15.6		15	14	3	7		5
alk	11.0	8.4		11	11	11.9		19	18	16	20		21
si^1						148		176	172	164	180		184
qz						44		82	124	172	40		138

1. Hornblende schist and gneiss, Ace shaft west of Ace Lake, Beaverlodge area, Sask. Composite sample. Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
2. Hornblende schist and gneiss, southwest of Nesbitt Labine shaft, Beaverlodge area, Sask. Composite sample. Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
3. Normal tholeiitic basalt and dolerite, average of 137 analyses, S. R. Nockolds, 1954, p. 1201.

4,5. Plagioclase amphibolite, Eagle mine area, Beaverlodge area, Sask. Quantitative spectrographic analyses by R. W. Edie, 1952, p. 684.

6. Argillite and slate, southwest of Nesbitt Labine shaft, Beaverlodge area, Sask. Composite sample. Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
7. Archean greywacke, Manitou Lake, Ontario. Analyst: B. Brun; Pettijohn, 1949, p. 250.
8. Average greywacke, Pettijohn, 1949, p. 250.
9. Altered argillite obtained from the immediate vicinity of radioactive vein, Tam Lake area, northeast of Pudget Bay on Beaverlodge area, Sask. Analyst: R. J. C. Fabry; K. R. Dawson, 1956, p. 19.
10. Unaltered argillite 6 feet from the nearest radioactive vein, same locality as 9. Analyst: R. J. C. Fabry; K. R. Dawson, 1956, p. 19.
11. Unaltered argillite, 10 feet from the nearest radioactive vein, same locality as 9. Analyst: R. J. C. Fabry; K. R. Dawson, 1951, p. 46.
12. Summer fraction (silt) of late glacial varved sediment, Leppakoski, Finland. Analyst: L. Lokka; F. J. Pettijohn, 1949, p. 272.
13. Bedded slate, area southwest of Eagle Lake, Beaverlodge area, Sask. Quantitative spectrographic analysis. R. W. Edie, 1952, p. 683.

Map-Unit 5: Buff Quartzite

Map-unit 5 is a buff to creamy white and light brown quartzite. Stratigraphically, it is situated mainly above map-unit 4 but found locally also directly above map-unit 3, mainly as a result of the lenticular nature of some of map-unit 4. The main occurrence of this quartzite is as small to large irregular masses distributed in an irregular fashion in the granite areas southeast of the Tazin–Martin unconformity east of Fredette Lake. The greatest concentration, which contains the largest of these masses, is near the eastern margin of these granite areas. Nearer the Tazin–Martin unconformity or in the western part of the granite areas, the quartzite exposures are generally less common and smaller. They are almost completely missing right at the unconformity. The largest continuous exposure of this quartzite forms a belt about 2,500 feet southeast of Eagle shaft which directly overlies map-unit 4 and extends continuously northeast from the ABC fault to as far as Mic and Mickey Lakes, where it is interlayered with rocks of map-unit 4. The entire area southeast of the Tazin–Martin unconformity east of Fredette Lake, now characterized by granite, was probably once underlain by rocks of map-unit 5, as suggested by the large number of masses of map-unit 5 in the granite and by their restricted distribution. Most of the quartzite is now changed to granite, and the quartzite masses are clearly remnants of what is left of the quartzite by incomplete granitization. The largest remnant is about 2,500 feet across, but remnants no larger than the size of a hand have been noted. Much quartzite in all stages of granitization is included in the granite areas, and similarly much granitized quartzite and granite are included in the quartzite areas. However, the remnants within the granite are generally widely spaced and are locally very sparse.

This quartzite (5) is massive, dense, and locally thinly bedded. It is also brecciated over large areas (5a). The granite derived from it is also widely brecciated. Most of the massive quartzite is brown and buff but may also be light grey, green, and white. Some is glassy white; this is usually massive and well jointed. The brecciated quartzite, which locally may enclose large areas of massive quartzite, has a rough weathered surface; it is made up of white to light brown fragments in a light to dark brown or dark green dense chlorite matrix. It grades within a few feet into the massive quartzite. Where it is red, it may still resemble a quartzite, but where it displays an incipient granitic texture, it somewhat resembles the granites described later (*see* under Metasomatic Granite (map-unit 19)).

South of Mic Lake the quartzite is interfingered and interbedded with rocks of map-unit 4, enclosing small lenses of them. It is buff, yellowish orange, and orange–red on weathered surfaces. A fresh cut is black with tiny scattered orange–red spots. Much of the rock is dense and massive with a baked appearance, but locally it is faintly foliated, resembling mylonite. Locally on weathered surfaces the presence of a few milky white and glassy quartz eyes, streaks, and blebs in a dense, red, possibly feldspathic mass suggests incipient granitization. The area south of Mic Lake therefore is one of highly siliceous rock, probably of map-unit 5, slightly granitized and possibly at least partly intensely crushed.

The large continuous zone of quartzitic rocks about 2,500 feet east of Eagle shaft, in addition to the buff quartzite described above, includes other varieties of quartzites, three of which are described briefly below. One variety occurs as lenses of various sizes in the buff quartzite and resembles an impure quartzite since it contains a somewhat larger amount of mafic minerals. This variety shows faint and irregular bedding. Its weathered surface is dirty brown to greenish grey, and the rock is somewhat more schistose than the other quartzites in map-unit 5. It carries some garnet. Locally it is slightly granitized and may be cut by a few granite dykes. Specimens presumably from this impure quartzite were studied by E. E. N. Smith (1949), who reported that one specimen consisted of coarsely banded segregations of cordierite, garnet, chlorite, and quartz. Another specimen had large augen-like masses of andalusite, almost completely altered to sericite and strung out in a fine-grained quartz–chlorite matrix, together with some garnet porphyroblasts. The garnet in both specimens is partly altered to chlorite. Cordierite was found with quartz and is also faintly altered to chlorite. Chlorite carries rutile and leucoxene. Tourmaline was noted with andalusite. As cordierite and andalusite were not recognized by the writer in the thin sections of correlated rocks farther north, it is believed that these minerals are local features only. Another variety is found at the contact of this zone with map-unit 4 below. It is well bedded and glassy and carries much hematite. A third variety, also found near the contact with the underlying rocks, is a creamy white, well-bedded quartzite, interbedded with dark green chloritic layers that may be related to the rocks of map-unit 4.

The remnants of massive and brecciated quartzites in the wide zone of red granite southeast of the Tazin–Martin unconformity east of Fredette Lake have gradational contacts with the granite, passing from quartzite into granite within a few feet, and locally even within a few inches. In the transition zone the buff quartzite is traversed, invaded, and impregnated with dots, seams, and irregular patches of red granite, all having gradational contact with the quartzite. These patches, seams, and dots of granite also occur in the quartzite at some distance from the contact, but in much smaller amounts than in the transition zone. Where the quartzite is white and glassy, granitization seems to start from sparse grains and seams of red feldspar and milky quartz. Where the quartzite is impure and has more mafic minerals, the granitization is as described for the buff quartzite but is more diffuse.

Almost all the rocks of this unit lie west of the Ace Lake – Donaldson Lake anticline and possibly along the trough of the major syncline west of Eagle Lake. This unit is not believed to be represented east of the Ace Lake – Donaldson Lake anticline; or if it is, it is south of the St. Louis fault and south of the main zone of map-unit 4 south of Verna Lake.

In thin sections the buff quartzite is seen to be composed of quartz, albite, and perthite in about the same proportion as in granite, and the rock possibly should be referred to as arkose. Its grains average 0.3 mm in diameter. The rock shows much brecciation and locally also some recrystallization of the quartz into elongate lenticular masses. There are minor amounts of chlorite, sericite, and opaque minerals. The rock is crossed in many directions by seams and veinlets of late quartz, chlorite, albite, and carbonate.

Area South of St. Louis Fault

(*Map-Units 6 to 9: Murmac Bay Formation*)

The area south of St. Louis fault is all underlain by the Murmac Bay Formation or by granite, except the part north of the Fish Lake fault as far west as Ace Lake. In this part are small areas of non-granitic rocks that were mapped as part of the stratigraphic succession north of the St. Louis fault, although only a few are definitely known to be related to that succession, the relationship of the rest being less certain; indeed, much of the amphibolite masses of this part of the area (north of Billo Lake) resemble rocks of the Murmac Bay Formation and are described with them, but were included in the succession north of the St. Louis fault. The granites and gneisses south of the St. Louis fault are included in map-unit 19.

The Murmac Bay Formation is believed to overlie conformably the succession north of the St. Louis – ABC fault. Its northern limit is the St. Louis fault from Beaverlodge Lake to Ace Lake, an arbitrary line from Ace Lake southeasterly to the north end of Fookes Lake, and the Fish Lake fault from Fookes Lake almost to the east boundary of the map-area. To the south, the formation probably extends beyond the southern boundary of the map-area, possibly as far as Lake Athabasca. The Murmac Bay Formation is here defined to include all the ungranitized layered rocks south of the northern limit as defined above, at least as far as the southern boundary of the map-area.

Stratigraphically this formation constitutes a normal sedimentary succession overlying conformably the rock succession north of the St. Louis – ABC fault. As its main trend is easterly and its dip southerly, the stratigraphic succession can be deduced by examining a section from a point slightly east of Verna shaft south to the southern boundary of the map-area. This section shows that close to 12,000 feet of sediments was deposited in this area alone. As at least another 5-mile stretch of the succession south of the area is suggested by Christie's map (GSC Map 1015A, 1953), map (GSC Map 1015A, 1953), it is obvious that this formation is of great thickness and consequently as it is part of the Tazin group, how thick is this group? Christie indeed has estimated that 30,000 feet of Tazin Group rocks is exposed in the Goldfields area (Christie, 1953, pp. 20–21). The Murmac Bay Formation comprises many different kinds of rocks, the most striking being a glassy white, well-jointed massive quartzite. Other common rock types are hornblende-bearing rocks, limestone, and massive garnetiferous quartz–biotite schist. So far this formation name may be useful mainly for description and reference, but it can apply to rocks over a large area north of Lake Athabasca and may eventually be useful for comparison and correlation with successions elsewhere in the Shield.

Map-Unit 6: Quartzite

Quartzite is the most widespread rock seen in the area south of St. Louis fault and may actually be the most abundant one in the succession there. It is easily distinguished from the other rocks, at least where it is not too heavily altered and granitized. Generally it is white or creamy white, fresh looking, and typically massive. It is closely jointed where it outcrops in high ridges with steep slopes, and the outcrop areas of such slopes are generally covered with a multitude of small angular fragments, mostly derived from the quartzite outcrops themselves and making these slopes difficult to climb. Weathered surfaces may be glassy and polished but are generally dull white. The rock is rarely bedded, and even where it is, the bedding appears only as faint lines on the outcrop. The quartzite occurs mainly as thick homogeneous beds or layers and lenses interbedded with the other rock types of the succession. At least seven thick layers and several narrow ones, not all mapped separately, were recognized in the area extending from Ace Creek to the southern boundary of the map-area. Quartzite is most abundant and widespread on the west near the Martin Formation. Near the southern boundary of the map-area it becomes less abundant as one approaches the eastern edge of the map-area. It seems there to be replaced by an impure quartzite or greywacke, for, to the east, a massive, brown to rusty weathering, quartz–biotite schist is more abundant and more widespread and the quartzite less so. This is believed to represent a change of facies, as, near the southern boundary of the map-area, in the area west of Kram Lake, the quartzite can be seen to grade into greywacke. In the vicinity of Fulton and Fookes Lakes, however, the quartzite is still abundant; it is only farther east that it is replaced by granitized rocks and granite.

Many varieties of quartzites were recognized:

1. In places, particularly south of Murmac Bay, the quartzite is red and patchy red, and is in various shades of reddish white due to dissemination of fine hematite flakes in various amounts. This hematite is probably introduced material, since much of it occurs also as seams along joint planes.

2. The quartzite may be black, as in the area northwest of Kram Lake, for no reason apparent in the hand specimen. Locally this black quartzite is traversed irregularly by seams, veins, and small masses of white quartz, or it may be altered along joint and fracture planes to a buff coloured material.

3. The band of quartzite along the south shore of Murmac Bay and in part the bands east of this bay are in places faintly green to patchy green on weathered surface due to large

and small grains of light green diopside in patches, nests, lenses, bands, and isolated grains throughout the quartzite. The diopside-bearing quartzite is seen in several localities closely associated with limestone, where it grades into carbonate rock and appears to be locally rich in carbonate.

4. Where the quartzite is schistose, crenulated and contorted, it may be greenish yellow to dirty white and seems to be higher in sericite, and locally also in chlorite, which probably accounts for the greenish cast. Large areas of this schistose quartzite were mapped west and southwest of Greer Lake near the Martin Formation.

5. In an area southwest of Sells Lake the quartzite is rusty in spots on the weathered surface, apparently due to clusters of tiny biotite flakes, and is thinly bedded and interbedded with a rusty weathering quartz–biotite schist.

6. Some quartzite is locally ferruginous, and areas were mapped separately where possible. This quartzite is a dense, very fine grained, siltstone-like rock that weathers dark red. It probably grades into type 1.

7. Other quartzites are fragmental; the fragments (generally less than an inch in diameter) are contained in a fine-grained, red, hematitic and siliceous matrix. This fragmental texture is believed to represent a primary clastic feature. However, Ross (1949) called this fragmental quartzite a conglomerate, and Christie (1953, p. 10), implying cataclastic effects, described it as follows: "In irregular areas, the quartzite is brecciated, and consists of angular to subangular fragments of white quartz usually less than 1½ inches in diameter, cemented by quartz." Elsewhere, as south of Collier Lake, the fragments have chlorite as their host, and these structures are believed to be cataclastic. In so far as it was possible to recognize such structures, these cataclastic areas are shown on the map as brecciated zones. In one instance, however, on the south shore of Murmac Bay, the fragmental structure represents a quartz-pebble conglomerate interbedded with quartzite and narrow bands of chlorite schist. Christie described these bands as narrow and discontinuous pebble-bands, made up only of quartz pebbles, interbedded with quartzite.

The quartzite is thinly to thickly interbedded with amphibolite, hornblende schist, quartz–biotite schist, chlorite schist, argillite, and limestone. Its contacts with these rocks are generally sharp and well defined, at least in most places where seen. Schistose contacts are rare. At two or three places north of Kram Lake the quartzite–amphibolite contact is wavy and in part schistose, since graphite schist exhibiting crenulations and drag-folds has developed in the amphibolite. Pockets of chlorite and graphite schists occur locally in the quartzite. Quartzite contacts with the limestone and with granitized rocks and granite are more commonly gradational than sharp. They are also irregular.

In the main areas of granitic rocks south of St. Louis fault are several remnants of quartzite still fresh looking and unaltered. These are of irregular shape and innumerable sizes. They are the ungranitized part of the quartzite and are probably in their original position. The quartzite of these remnants is somewhat different from the white massive quartzite described above, as it is granular and coarse grained, coarsely and irregularly layered, and slightly schistose. The colour is generally white but may be reddish and creamy. Dykes and sills of coarse-grained red granite and pegmatite invade many of the remnants, and a few of these may grade into granitized rock or granite. One mass was studied in some detail in the field, and there it was possible to see how the granitization proceeds. This quartzite is glassy white and faintly thinly bedded, and the remnant is sufficiently large for this study. Its contacts with the granitized rocks are generally sharp where they are parallel with the strike of the beds, but in a few places along these same contacts they are gradational over a few inches, and very little effect of granitization can be seen in the quartzite a short distance from the contact. This quartzite is traversed also by narrow (about 2 inches) dykes of granite cutting across the bedding. In such places the granitization is more intense near the dyke than elsewhere in the quartzite and seems to be more effective along the bedding planes than across it. Indeed, granitization has extended at least 14 inches from the dyke along a few beds. Near contacts parallel with the bedding and within the granitized rock, there are locally a few relict beds or remnants of ungranitized quartzite. Such beds or remnants are generally only a few inches away from the contact and represent rocks that have escaped granitization. In summary, it appears that this granitization is characterized by 1, a red coloration of the rock; 2, what may be termed a red feldspathization; and 3, a few dykes and sills of red granite. The red feldspar is concentrated in lines and bands along the foliation or beds and in lines, patches, or masses in the quartzite near contacts and dykes.

Specimens were collected from the large layer of quartzite forming the north shore of Murmac Bay, and these were analyzed chemically. The results are given in Table X. This rock contains a fair amount of potash, although very little feldspar was noted under the microscope. No lime was present in the analysis, although much of the quartzite that carried diopside must have been limy at one time. The results compare well with the quartzites north of St. Louis fault mapped with map-unit 3.

Most thin sections of quartzite are made up mainly of recrystallized quartz in grains with sutured outlines. The granitized quartzites have a granitic texture, and the amount of feldspars in them may be as high as in granite. Bedding or a thin lamination was recognized in two slides. A clastic texture was suggested in four slides by the distribution of the dark minerals, and in one case the clastic structure was indicated by the quartz grains themselves.

TABLE X — *Chemical analysis of quartzite south of St. Louis fault, in percentages*

SiO_2	94.43	K_2O	1.12
Al_2O_3	2.75	H_2O^+	0.33
Fe_2O_3	0.26	H_2O^-	.03
FeO	.54	TiO_2	.08
CaO	.00	P_2O_5	.02
MgO	.26	MnO	.003
Na_2O	.10	CO_2	.01
		Total	99.933

Niggli Numbers

si	2710	alk	24.2
al	46.5	qz	2513
fm	29.3	si^1	197
c	0.0		

Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.

A few specimens were definitely gneissic, the quartz grains having recrystallized and formed lenses or irregular patches, all oriented parallel with each other or with the mafic grains, and resting in a fine- to medium-grained aggregate of round grains of quartz and feldspars. The fresh looking quartzite has between 85 and 95 per cent quartz, the other minerals being mainly sericite, feldspar, and opaque substances, probably mainly hematite. Sericite is in tiny grains interstitial to quartz but may also occur in streaks, lenses, and narrow layers. Feldspar is at this stage interstitial or in blebs and lenses in quartz. Hematite occurs either in small granules or as dust scattered over all minerals. Chlorite has been recognized in the schistose quartzite. The black weathering quartzite does not appear to differ in composition from the ordinary white quartzite but in general appears to be finer grained. It is, however, an entirely recrystallized rock, but the white quartzite is in part composed of residual grains. Where the quartzite is ferruginous, hematite in round clastic granules is abundant. Thin sections of the ferruginous variety contained 25 per cent hematite and about the same amount of sericite. In those areas where diopside was recognized, the thin sections, in addition to pyroxene which occurs in either large or small grains, reveal the presence of much cummingtonite as a possible alteration product after pyroxene, some carbonate, and various amounts of quartz. Apatite was noted in most thin sections of quartzite.

In the area where the quartzite passes gradually into granite, the grain size becomes progressively coarser and more uniform. The feldspar content also becomes gradually higher and the rock more granitic. The feldspars are microcline and albite–oligoclase, microcline apparently the later of the two. Plagioclase may be faintly altered and coloured, but both feldspars are generally fresh. Chlorite is the dark mineral.

Some of the quartzite is traversed by seams and veinlets of carbonate, feldspar, and/or quartz.

Map-Unit 7: Amphibolite and Hornblende Schist

Amphibolite, hornblende schist and gneiss, hornblende–biotite schist, and chlorite schists or their altered equivalents occur widely and abundantly in the area south of St. Louis fault. They occur either as wide and narrow layers and lenses interbedded with the other layered rocks, or as masses and boudins of various sizes in granitic rocks. At least seven major layers, several minor lenses, and many wide zones carrying irregular masses or boudins were traced. The layers and lenses dip with the other layered rocks. None seems to lie flatly on top of the other rock types, as was so with many of the irregular masses of hornblende schist north of St. Louis fault.

The rocks of this group weather dark green, brownish green, black, grey, and various shades of brown. They may be fine to coarse grained, massive, gneissic to bedded and layered, schistose, and irregularly foliated. Locally they look dioritic. The massive, coarse-grained, and in part dioritic-looking rocks were called amphibolite; the gneissic and layered rocks, hornblende schist or gneiss.

The wide amphibolite layers north and east of Kram Lake and south and west of Sells Lake are made up mainly of amphibolite, as defined above. Locally, however, these layers, and a few others also, display much variation of grain size, texture, and composition. Thus, the layer north of Kram Lake is in part porphyritic, having white feldspar phenocrysts up to half an inch wide, or carries locally rosettes of a fibrous amphibole. Similarly the amphibolite layer north of Greer Lake is locally fine grained, weathers in part light brown with dark brown patches and lines, and is in places more siliceous where it seems to carry mica and chlorite.

The large amphibolite layers north and south of Fish Lake fault east of Fish Lake are different from the normal amphibolite layers as defined above, as they are interbedded with many other rock types, the whole being mapped as a single unit. Both layers are described here, although the layer north of the fault is mapped as part of (map-unit 4) the area north of St. Louis fault.

The amphibolite of these two layers is in narrow layers and is interbedded with beds or layers of quartzite, chlorite schist, biotite schist, chlorite–biotite schist, hornblende–biotite–chlorite gneiss, and gneissic granite. These rock types vary in amount from place to place in both layers as mapped and grade into each other along the strike, changing with the intensity of granitization. However, the amphibolite and the chlorite or biotite schist were sufficiently abundant and distinctive for both layers to be mapped separately as parts of the amphibolite map-units (4a, b, c, d, e and 7e).

The amphibolite masses in granitic rocks are large to small, with sharp well-defined contacts and mostly with fairly angular outlines. They are altered and granitized to various degrees, the smallest being more commonly completely altered to chlorite schist than the largest, although even these are generally partly altered. Furthermore, granitization in the smallest masses is generally slightly more uniform than in the largest, in which it is usually uneven and irregular. Indeed, parts of the largest masses may be so granitized that they resemble an impure granite whereas the remaining parts are unaffected. Granitization is marked by the development of feldspar in the amphibolite and by the presence of dykes, sills, and irregular masses of granite or pegmatite throughout the amphibolite mass. The parts altered to chlorite schist are generally also crossed by seams of epidote and veins of milky quartz and specularite, all oriented with the foliation of the schist or at right angles to it. In rare instances, and generally over very small areas only, these large amphibolite masses pass locally through narrow transition zones into impure carbonate rocks.

Many of the amphibolite masses in granitic rocks seem to be distributed according to a definite pattern, and where the distribution is complex, attempts were made in some cases to explain this distribution. Thus, the masses in the area south of Ace Lake form a wide zone that can be traced from Ace Lake to about 6,000 feet past Fookes Lake. These masses are of various sizes and shapes and are unevenly spaced and irregularly distributed. Each mass is also entirely enclosed in granitic material. It is likely that many of these masses were once parts of a single layer, but because of their complex distribution it is very difficult now to determine which should be correlated with which. However, a detailed study of their distribution in relation to trends in the enclosing rocks has suggested that they are the broken parts of several narrow layers, and that these layers were folded and faulted, as shown on the accompanying structural map (*see* trace of bed south of Ace Lake south of St. Louis fault, Fig. 11), and stretched and broken into the masses or boudins as mapped. It was found also that the largest and the most complexly shaped masses are from the nose of tight folds whereas those that are straight are from the limbs of folds. Many of the latter were, however, too narrow to map.

There are many other somewhat similar zones in the area of granitic rocks south of St. Louis fault. Most of these, however, are not so complex as the one described above. They contain far fewer masses; most of these can be correlated with one another or with the main mass. All, even the isolated ones suggest intense deformation.

The many masses in granitic rocks northeast of Murmac Bay can be correlated with the large amphibolite body between the granite and quartzite mapped there. The masses around Yahyah Lake are layers broken into boudins and masses from the nose of tight folds or the thickest mappable parts of some layers.

Under the microscope these rocks are seen to be composed of large, lenticular to elongate, irregular patches of coarse-grained hornblende and chlorite in a matrix of fine-grained feldspar, quartz, and opaque minerals. A few scattered tiny grains of chlorite and biotite are also present in the matrix interstitial to the feldspar and quartz. The large mafic patches, the elongated minerals forming them, and all the mafic minerals of the matrix except biotite are in parallel orientation. Even the felsic minerals of the base are locally in aligned lenses. Hornblende is commonly in large, ragged dark green to colourless grains and is the main mineral of the large mafic patches. It occurs also as small short, greenish blue prisms, in a very fresh-looking matrix suggesting a completely recrystallized rock. The ragged grains are generally altered to chlorite and locally in part to brown biotite. Locally the amphibole is fibrous. One slide had no amphibole, but comprised garnet porphyroblasts in a base of serpentine, talc, chlorite, and opaque minerals. The garnet crystals were concentrated along a few foliation planes and were heavily fractured and chloritized. In five thin sections, hornblende (Table XI) averaged about 60 per cent of the rock but varied from 40 to 73 per cent. The matrix in which the mafic minerals lie is made up mainly of quartz and feldspar in fine, equigranular, clastic-looking grains. Feldspar is probably the main felsic mineral but mostly could not be distinguished from quartz. It is mainly a calcic oligoclase, although locally it may be albite. The feldspar content varies between 25 and 40 per cent. Quartz is present in amounts less than 5 per cent, and its main occurrence is in small clastic-looking grains, in clusters of tiny recrystallized grains clustered in lenses elongated parallel with the foliation, and in a few large and irregular grains. The opaque minerals, probably mainly magnetite, occur in small grains, distributed uniformly all through the rock, or in clusters, patches, and irregularly oriented streaks. There is also some apatite, tourmaline, epidote, and sericite. In some instances a layering is apparent in thin sections, each layer being different in composition from its neighbours. Some have only mafic minerals; others are composed only of feldspar and quartz.

These amphibolites are traversed by veinlets and seams of quartz, quartz and carbonate, sericite, chlorite, and epidote. Where age relation could be obtained, the quartz veins are earlier than the quartz–carbonate veins, and the chlorite veins are earlier than the epidote veins. The chlorite and epidote veins were noted mainly in the Yahyah Lake area.

Two decrepitation tests (Smith, F. G., 1953) were made on schistose amphibolite from the north shore of Lake Athabasca. These tests indicate that the primary crystallization took place at a temperature of 595° ± 20°C. Although the specimens are not from amphibolite masses of this area, they are believed to be related to them.

TABLE XI | *Modes of amphibolites (map-unit 7) south of St. Louis fault, in percentages*

	1	2	3	4	5	6	7	8	9
Hornblende	66	60	73	40		61			
Chlorite				2	40		31	88	52
Opaque	5	3	2	3	7	4	2	2	2
Feldspar	26	34	25	47	38	27	36		42
								} 10	
Quartz	3			4	15	6	31		4
Biotite		3		2					
Sericite–muscovite				2					
Carbonate						2			

1. Amphibolite, about 3,000 feet west of Kram Lake, near the south boundary of the map-area.
2. Amphibolite, about 1,200 feet north of Kram Lake, south of Murmac Bay.
3. Amphibolite, about 1,600 feet south of the west end of Glauser Lake, east of Murmac Bay.
4. Amphibolite, about 400 feet north of the north shore of Murmac Bay and 1,300 feet south of the west end of Sells Lake (*see* chemical analysis, Table XII, No. 1).
5. Amphibolite, about 200 feet west of Ace Creek, near the spot where it reaches Beaverlodge Lake. Interbedded with argillite.
6. Amphibolite, about 1,600 feet due north of the northeast end of Greer Lake.
7. Amphibolite, about 1,000 feet east of portage between Fookes and Fulton Lakes.
8. Amphibolite, about 3,200 feet west of the northwest end of Kram Lake and 1,000 feet south of the south shore of Beaverlodge Lake. Interbedded with quartzite.
9. Amphibolite, from a small mass about 1,200 feet west of the southwest end of Flack Lake.

Hand specimens were collected for chemical analysis from an amphibolite mass south of St. Louis fault. The results of this analysis are presented in Table XII. If this analysis is compared with the analysis of the average normal tholeiitic basalt of Nockolds (1954) (Table IX) and with that of the average amphibolite of Poldervaart (1955) (Table XII), the Murmac Bay amphibolite, even if it is low in lime and somewhat high in potash, would appear to be related to these rocks. The fact that this amphibolite carries more biotite and sericite than a normal amphibolite may explain its relatively high potash content. The low lime content indicates relatively less hornblende than a normal amphibolite and possibly a plagioclase somewhat less calcic. A spectrographic analysis by R. W. Edie of another amphibolite south of St. Louis fault, but about 3 miles south of the southern boundary of the map-area, is added.

TABLE XII — *Chemical analyses of amphibolites south of St. Louis fault, in percentages*

	1	2	3
SiO_2	50.36	51.6	50.3
Al_2O_3	16.13	11.2	15.7
Fe_2O_3	1.67	3.2	3.6
FeO	9.33	9.2	7.8
CaO	5.38	6.6	9.5
MgO	6.82	4.8	7.0
Na_2O	2.48	3.0	2.9
K_2O	1.92	1.2	1.1
H_2O^+	3.01		
H_2O^-	0.19		
TiO_2	1.74		1.6
P_2O_5	0.16		
MnO	.19	0.2	
CO_2	.87		
Cr_2O_3	.03		
Total	100.28		

Niggli Numbers

	1	2
al	24.7	20
fm	50.9	48
c	15.0	21
alk	9.4	11
si	131	153

1. Amphibolite, north shore of Murmac Bay, Beaverlodge Lake. About due north of the east end of Umisk Island (*see* Modes, Table XI, No. 4).
Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
2. Plagioclase amphibolite, south shore of Beaverlodge Lake, Goldfields region, Saskatchewan. Spectrographic analysis by R. W. Edie.
3. Average of 200 amphibolites by A. Poldervaart (1955, p. 136).

Map-Unit 8: Quartz–Biotite Schist

Quartz–biotite schist and related rocks, such as impure quartzite, argillite, and possibly greywacke, occur interbedded with the other main rock types of the Murmac Bay Formation in the area south of St. Louis fault. About Umisk Island the quartz–biotite schist and related rocks are rare, but toward the east boundary of the map-area or east of Murmac Bay they are very extensive and locally may constitute about 50 per cent of the succession. They seemingly have replaced the white massive quartzite that was so abundant in the Umisk Island area, perhaps by a change of facies from a relatively pure quartzite to a rock close to greywacke in composition. Their contact with the other rock types appears to be conformable except at one place a short distance east of the east shore of Murmac Bay where it appears to be unconformable. Most of the rocks mapped with the quartz–biotite schist in the southeast corner of the map-area are massive and resemble impure quartzite or siliceous greywacke. Some of the quartz–biotite schist near the granite northeast of Murmac Bay is schistose, and its mica content is relatively higher. Locally this schist is bedded or layered, and in such areas the weathered surface is rough and strikingly layered owing to differential weathering of the various beds. A few beds or layers at one place north of the north shore of Murmac Bay are pitted or nodular, and such beds may carry andalusite or cordierite in addition to the principal components quartz and biotite. Most of the rocks mapped as unit 8 weather light to rusty brown, but some weather grey-black. Garnet was widely noted in the massive siliceous varieties. Hornblende and rarely chlorite were seen in the schistose, mica-rich variety.

Seen under the microscope, the quartz–biotite schist is a fine- to medium-grained rock, composed mainly of quartz, biotite, feldspar, opaque minerals, and garnet metacrysts. Mineral counts in two thin sections gave the composition shown in Table XIII. A mode for a similar rock in the Goldfields area was presented by Christie (1953, p. 17) and is shown in column 3 of the same table. In the two thin sections studied by the writer it was not possible to distinguish feldspar from quartz, but the albite–oligoclase content is believed to be about one third of the quartz content. Brown to greenish brown biotite occurs either in rods and short prisms or in large irregular masses and lenses, all similarly oriented. Some of the biotite grains may be derived from hornblende; others are partly altered to chlorite. Tiny individual grains of interstitial quartz and feldspar form the host for the mafic minerals. Opaque substances are mainly pyrite and hematite and occur in small grains mixed with quartz and biotite, concentrated in lines or streaks. Tourmaline shows zoning. Garnet is red and is well fractured and scattered throughout the rock. Other minerals recognized are apatite, zircon, and possibly magnetite.

TABLE XIII | *Modes of quartz–biotite schist south of St. Louis fault, in percentages*

	1	2	3
Quartz	31	35	35
Biotite	64	60	46
Opaque	5	4	
Tourmaline		1	
Garnet			5
Oligoclase			8
Chlorite			5

1. On the point, west shore of Fretwell Lake, east of Murmac Bay, Beaverlodge Lake, Sask.
2. About 400 feet south of the west end of Glauser Lake, east of Murmac Bay, Beaverlodge Lake, Sask.
3. From Christie, 1953, p. 17.

Argillite was mapped locally with the quartz–biotite schist. It is black to grey, fine grained, and massive to thinly bedded and occurs in narrow layers interbedded with the other rock types. It was recognized and mapped a short distance south of Kram Lake; right below the unconformity north of the small fault cutting the arkose southwest of Murmac Bay; south of Ace Creek, due south of Fay shaft; and at a few places east of Murmac Bay. It is in general very similar to the argillite (map-unit 4a) of the area north of St. Louis fault.

Map-Unit 9: Limestone

Limestone and carbonate-bearing rocks occur in small amounts south of St. Louis fault, and the individual areas underlain by these rocks are so small that most of them cannot be shown at the scale of the map. The largest bodies are parts of thick beds or masses and boudins that have developed by flowage at the noses of folds. All these occur interbedded with amphibolite and quartzite in the areas east of the south end of Murmac Bay and south of this bay a few feet south of the southern boundary of the map-area. A few masses, rich in carbonate, diopside, and locally quartz, occur in the massive, well-jointed white quartzite. Most of these are widely spaced and irregularly distributed within the various quartzite layers east of Mur-

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PLATE 2

Limestone, Murmac Bay Formation. Close network of seams standing in relief are siliceous material, found throughout this limestone.

mac Bay. Also several very small masses of carbonate-rich rock were recognized in amphibolite and hornblende schist. All these masses were too small to be mapped separately, but they all show the typical carbonate rock-weathered surfaces. They are rich in mafic minerals, and all pass gradually into amphibolite within a few feet. The amphibolites that carry them are locally rich in hematite and are reddish. Finally, rare masses of carbonate rocks were noted completely surrounded by granitic rocks. These probably are remnants within a once dominantly quartzite succession, now largely granitized. An example is the mass that was located a short distance east of Fish Lake.

The limestone and the carbonate-bearing rocks have a grey-black to black weathered surface, are white on fresh fractures, and are dense or finely to coarsely crystalline. They may be almost pure; but generally they carry large amounts of impurities in the form of silicate minerals and dense cherty silica, showing as ridges and patches on weathered surfaces which make them rough and uneven. Throughout the body of the rock the impurities form an irregular network (*see* Pl. 2). The silicate minerals recognized are feldspar, tremolite, talc, micaceous material, amphibole, diopside, and chlorite. Quartz and cherty silica are also present.

Christie (1953, p. 12) described the composition of the carbonate rocks from the area south of this one as follows: "Analyses of five iron-rich carbonate rocks from Fish Hook Bay show an average content of 25 per cent lime (CaO) and 18 per cent magnesia (MgO), or about in the same proportion as they occur in pure dolomite (30.4 and 21.7 per cent CaO and MgO respectively). These analyses and the invariable alteration of these rocks to the magnesia-rich silicate minerals, diopside, tremolite, and actinolite, leave little doubt that the carbonate of the sedimentary series is mainly dolomite." This may apply in part to the masses described here. However, their grey instead of brown weathered surface and the fact that they do effervesce violently with dilute HCl at ordinary temperatures indicate they are mainly limestone.

Area North of Boom Lake Fault

(*Map-Units 10 to 13*)

The area north of the Boom Lake fault covers approximately 15 square miles in the northwest corner of the map-area. It is bordered on the southeast by the Boom Lake fault and on the west and north by the limits of the map-area.

The area is underlain almost entirely by well-layered gneisses, but there are small amounts of amphibolite and granite. These occur locally in masses that can generally be readily distinguished from the layered gneisses and are large enough to be mapped separately. Although all the rocks of this area closely resemble rocks mapped elsewhere in the Beaverlodge area they possess some distinctive characteristics. Some of the amphibolites, for instance, are associated with ultrabasic and limy rocks; the layered gneisses are thinly rather than coarsely layered and are not generally so granitized nor so extensively mylonitized as those of the area between the Boom Lake and Black Bay faults, to which they are spatially related.

The layered gneisses are made up of several rock types; the main ones are quartz–feldspar granoblastic gneiss with various amounts of biotite or chlorite and hornblende; coarse-grained red granite; and mafic-rich rocks and gneisses, such as amphibolite, biotite–feldspar gneiss, and schist; and chlorite schist. All these rocks occur in thin layers; they are also interlayered. Few layers are wide enough to be mapped separately, but layers of a particular rock type may recur at a certain horizon, and the assemblage makes a mappable unit that generally can be traced and recognized fairly readily. The gneisses were subdivided on the basis of such mappable units which roughly correspond to those used elsewhere in the Beaverlodge area, specifically with the granitic-layered gneiss of the Foot Bay gneiss type and the quartzitic-layered gneiss of the Donaldson Lake gneiss type.

All the rocks of this area are believed originally to have constituted a normal succession of thinly bedded sediments, which were later folded, metamorphosed, and granitized. Grading to granite locally, they are cut by numerous dykes and sills of partly pegmatitic red granite. The rock succession, as suggested by structural features, grades from the oldest in the west to the youngest near the Boom Lake fault. The structure is monoclinal and is believed to be part of the major structure at Fold Lake to the north of the map-area (Christie, 1953, Map 1015A). The monocline dips steeply southeast and is locally much folded, and therefore gives rise to structures like those that characterize the area between Boom Lake and Black Bay faults. The thickness of this succession is believed to be about 9,000 feet. On the aeromagnetic map (GSC Map 433G), this area shows as a zone of higher magnetic intensity than the area south of Boom Lake fault. The lower magnetic intensity south of the fault may be related to the retrograde effect present there.

For descriptive purposes, the area north of Boom Lake fault has been subdivided into three map-units, all trending northeasterly and all having different thicknesses. These map-units are, from west to east: a lower belt of granitic layered gneiss resembling the Foot Bay gneisses with rare amphibolite lenses; the Powerline Creek belt of amphibolite masses interfingered into and interlayered with garnetiferous feldspathic quartzites; and an upper belt of granitic layered gneiss, also resembling the Foot Bay gneisses but including much quartzitic layered gneiss, like those of the Donaldson Lake gneiss, and some amphibolite masses. The granite masses also present are described with the granite of map-unit 19.

Map-Unit 10: Lower Belt of Granitic Layered Gneiss

This unit covers all the rocks in the area northwest of and below the Powerline Creek belt (11 and 12). It probably includes the oldest of the Tazin Group rocks in the area. As far as known, it is here at least 3,500 feet thick, but older rocks probably occur farther west. This map-unit is made up almost entirely of granitic layered gneisses of the Foot Bay gneiss type. Other rocks included in it are small amounts of granite, amphibolite, and layered gneisses of a composition slightly different from the bulk of the granitic layered gneiss.

This granitic layered gneiss is of various shades of red. Its weathered surfaces exhibit a pronounced and ubiquitous layered structure, and the rock has a general granitic appearance due to the presence throughout of many layers of coarse-grained red granite. The grain is generally medium and coarse, but locally it is fine. The grain size generally varies from layer to layer, the greater the degree of granitization the coarser the grain. The layered structure on a large scale is composed of relatively thick layers of coarse-grained red granite, widely spaced and separated by layers fairly rich in mafic minerals. These mafic-rich layers are themselves layered and may be thicker or narrower, and more or less abundant than the granite layers. In general, however, the granite layers constitute more than 50 per cent of the rock. The layers in the dark bands are thin, generally less than one quarter of an inch, irregular, and their contacts are gradational. Each layer dies out a short distance along the strike and in many instances is no more than a seam, a streak, or a lens. This layering may be made up of red granite layers in a foliated mass rich in mafic minerals (Fig. 3, details of this layering), or it may be a concentration of dark minerals in lines and streaks in a coarse-grained, impure red granite. The contact of the large granite layers with the mafic-rich ones is usually sharp, as the difference in composition is marked, but it may be in part gradational if their compositions are similar or if they are granitized to almost the same degree; the contacts of the layers within the wide, mafic-rich layers are, however, generally gradational. The mafic

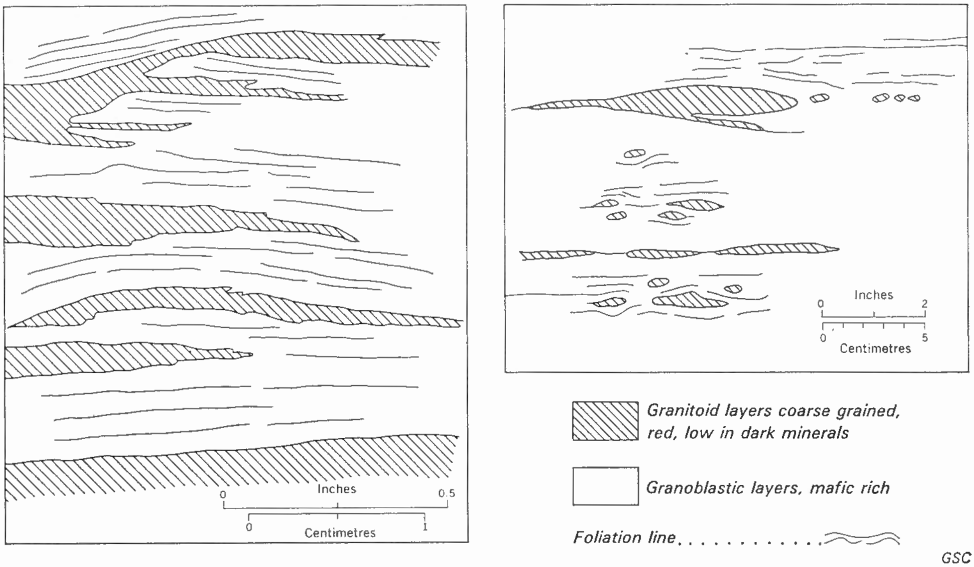

FIGURE 3. Sketches of granitic layered gneiss and augen gneiss, map-unit 10, north of Boom Lake fault, showing relationship of granitoid layers to granoblastic gneiss. Augens made up of quartz and feldspar.

layers weather brown, dark brown, and black, and their rocks are fine- to medium-grained granoblastic gneisses, composed mainly of quartz, feldspars, and biotite or chlorite. Much of the coarse-grained red granite of this layered gneiss occurs in dykes, sills, and irregular patches with crosscutting relationship. As such masses are never very large, most of them cannot be mapped separately. Where the grain is very coarse, they are pegmatite, and masses of pegmatite may be locally fairly large. Some of them carry black tourmaline. Where the red granite masses are abundant, migmatitic rocks may develop; for example, in the area adjoining Fault Lake to the west. Locally narrow layers and short lenses of amphibolite occur interlayered with the other rock types. Some of these are large enough to be mapped separately as map-unit 10a. They are not, however, different from the larger amphibolite masses included in map-unit 12.

The granitic layered gneiss of map-unit 10 is a fairly uniform rock in composition and appearance but has some striking local variations. The following are particularly noticeable:

1. In some areas the layered structure is characterized by seams and thin streaks of dark minerals, very closely spaced and irregular in length along strike. There, the rocks resemble a medium-grained gneissic granite, but this feature was of small extent and the rock was seen to grade within short distances into the well-layered rock.

2. The layered gneisses also grade locally into rock in which the layered structure has become sufficiently obscure for the rock to have a more granitoid and massive appearance. These rocks somewhat resemble the coarse-grained red granite, but as they have retained very faintly some of the layered structure, they are believed to be layered gneiss not completely changed to metasomatic granite. Similar granitoid rocks are locally high in mafic minerals and may represent granitic layered gneiss originally fairly high in mafic minerals. Several areas of these rocks were recognized west of Fault Lake. Adjoining these areas, much of the layered gneiss is migmatitic in character.

3. There are also large areas almost completely devoid of layers or patches of coarse-grained red granite. In such areas the rocks are granular, fine to medium grained, and resemble the granoblastic gneiss typical of the mafic-rich layers. Being less metamorphosed than most of the rocks of this map-unit, they are probably parts that have escaped granitization. Areas of such rock were seen west of Fault Lake and also in a wide zone, rich in pyrite and rusty on weathered surface, east of Folk Lake. This rusty zone, which trends parallel with the main trend of the rock of the area, was traced for almost 2 miles.

4. Locally the granitic layered gneiss weathers white and has more quartz. These rocks grade into the ordinary granitic layered gneiss with very indefinite contacts. They are regarded as lenses or bands of particularly quartzitic phases of the granitic layered gneiss. Where possible, their occurrence is noted on the map, and they are probably related to the Donaldson Lake type of layered gneiss.

On some outcrops it is obvious that this granitic layered gneiss was once a normal sedimentary succession, the original sedimentary nature of some of the layers being clearly recognizable. Some layers are almost quartzite, others are almost chlorite or biotite schist, and still others are quartz–feldspar gneiss with various amounts of mafic minerals. All these are garnetiferous and occur in layers that suggest relict bedding.

Under the microscope the granitic layered gneiss is seen to be allotriomorphic granular and fairly fresh and is characterized by a well-developed layered structure. The minerals are generally of irregular outlines and have partly interlocking boundaries. Their distribution is fairly uniform within each layer but varies from layer to layer and may be responsible for the layered structure. In general the layered structure is due to segregation of large quartz grains in lenses up to 10 mm long and 0.5 mm wide, oriented parallel with one another, and to the concentration, elongation, and alignment of biotite, chlorite, and feldspars, or mixture of these, in layers and lenses. The grain size varies from 0.1 to 1.0 mm and averages 0.5 mm.

In summary, a thin section reveals large lenticular masses of quartz in parallel orientation in a mass of quartz, feldspar, and biotite, in grains usually less than a millimetre in size and roughly parallel with each other.

Five thin sections have shown that this granitic layered gneiss is made up of plagioclase, quartz, and microcline with some chlorite, locally biotite, and small amounts of epidote, opaque substance, apatite, and zircon. These specimens were not from the red granite layer

TABLE XIV | *Average mode of granitic layered gneiss (map-unit 10)*

Number of thin sections studied	2	3
	Range %	Range %
Albite–oligoclase	28(23–33)	47(43–53)
Microcline	41(37–45)	14(8–21)
Quartz	26(19–34)	19(13–25)
Chlorite (biotite)	4(2–6)	15(13–17)
Opaque	1(0–1)	3(1–6)
Others		2(0–2)
Rock composition	quartz monzonite gneiss	granodiorite gneiss

but from layers that are granoblastic, have a fairly high mafic content, and are relatively thinly foliated. The plagioclase is a slightly altered albite or sodic oligoclase. Microcline is fresh, occurring in many instances as rims around plagioclase. It may be a product of granitization. Chlorite is probably an alteration product after biotite. Biotite is yellowish green and was recognized abundantly only in one slide. Epidote is probably also an alteration product, and much of it is probably later, since a dense green substance believed to be epidote was noted abundantly as seams throughout the rocks of this area. Apatite and zircon are common accessories. Grain counts in thin sections have suggested two main classes: a quartz monzonite gneiss and a granodiorite gneiss. The granodiorite gneiss is believed to be the characteristic gneiss of this zone. These are presented in Table XIV.

Map-Units 11 and 12: Powerline Creek Belt

The Powerline Creek belt represents an interbedded mixture of garnetiferous feldspathic quartzites and amphibolite in the proportion of about 65 per cent quartzite to 35 per cent amphibolite. The belt was traced for about 5 miles along strike across the northwest corner of the map-area. It extends for great distances to the north outside the map-area, as shown on Christie's map (1953, No. 1015A) where it is part of the main folded structure at Fold Lake. To the southwest it pinches out within a short distance. In the part of the area north of the Boom Lake fault it serves to separate two wide belts of the Foot Bay type of granitic layered gneiss. Quartzitic rocks were recognized at the base and at the top of this belt and in both places were seen to grade into the granitic layered gneisses above and below. In cross-section the belt appears to be about 1,000 feet thick. It is much cross-faulted. Its dip is uniformly steep to the southeast. At its southwest end it is made up almost entirely of mafic-rich rocks. At one point slightly east of Folk Lake it is less than 800 feet wide, but near Fault Lake the surface expression is at least 2,200 feet wide.

Map-Unit 11: Quartzites

Garnetiferous feldspathic quartzites (11) occur as wide zones interlayered with amphibolite (12) and as narrow lenticular beds or masses in amphibolite. The zones are up to 600 feet thick and at least six of them, of various widths, separated by amphibolite layers, were mapped across the width of the Powerline Creek belt in the area south of the Fault Lake fault. Elsewhere there are at least three zones, whose contacts with the granitic layered gneisses below and above are gradational. Each zone is believed to represent a thick succession of thinly bedded quartzites. The masses in amphibolite are in general less than 5 feet thick, and few of them were mapped separately.

In general these quartzites are light weathering, well-bedded, and coarse-grained rocks in which garnet is readily noted and white feldspar is abundant. In detail, however, they show much variation in texture and composition from bed to bed; this suggests that these rocks are related to the Donaldson Lake gneiss. Four main varieties of quartzites were recognized in these beds.

1. Variety 1 is a glassy white to clear grey coarse-grained quartzite, almost devoid of mafic minerals. Although this is generally massive, it may be locally thinly bedded. It is composed almost entirely of quartz, except that white feldspar is usually present in small amounts as scattered grains in quartz. As the feldspar content increases, the rock grades into variety 2.

2. This variety of quartzite, which resembles a white granite, is believed to be related to the white granitoid gneiss variety of the Donaldson Lake gneiss. It is massive, coarse grained and white weathering and is made up mainly of quartz and white feldspar, distributed as in a

granite. Locally the white feldspar constitutes more than 80 per cent of the rock. The weathered surfaces exhibit widely scattered rusty patches where the rock is rich in biotite flakes. Here garnet may be present as occasional grains. Where these rusty patches increase in number and size or become true layers, the rock grades into variety 3.

3. This variety is a foliated to layered rock, made up of two components, thinly and intimately interlayered. One component is a coarse-grained, white weathering granitoid rock, similar to variety 2 occurring in layers less than a fraction of an inch thick that pinch out over a short distance along strike. The second component constitutes the major part of this variety and occurs in wider layers. It weathers rusty brown to cream coloured, and where fresh it is dark grey and is strikingly foliated or layered. It is rich in biotite with generally some garnet. It is a fine- to medium-grained, granular, quartz–feldspar–biotite gneiss with a biotite content generally less than 20 per cent. It corresponds to the rusty granoblastic gneiss of the Donaldson Lake gneiss. This gneiss locally may be faintly schistose, particularly where biotite is slightly more abundant.

4. This variety is more coarsely layered than variety 3 but has the same components. The light brown weathering component generally has less biotite and is slightly coarser grained. Thus, variety 3 grades into variety 4 as the layering becomes wider, the grain coarser, and the mafic content lower.

Under the microscope, the mafic-bearing quartzites are fresh looking, allotriomorphic granular, and porphyroblastic. Garnet is generally responsible for the porphyroblastic texture. It occurs in grains that average 4 mm in diameter and that locally attain 12 mm. The matrix, on the other hand, averages 0.01 mm and exhibits occasional grains about 0.5 mm in size. The porphyroblasts of garnet are widely scattered. They represent less than 3 per cent of the rock and vary substantially in size. The matrix may be roughly layered as a result of segregation and recrystallization of some of the minerals and may also present some mineral alignment, particularly of biotite and quartz. Where the rock is coarser grained, the feldspar and quartz may occur in grains as large as the garnet grains, but the rock is still allotriomorphic granular. In general the rock is composed mainly of quartz, microcline, albite–oligoclase, red-black biotite, and garnet. There are minor amounts of epidote, muscovite or sericite, opaque material, chlorite, zircon, and possibly pyroxene. Grain counts on four specimens of quartzite gave two main composition trends. These quartzites were all rich in white feldspar and had varying amounts of biotite and garnet. They were massive to foliated and are believed to represent variety 3, described above. Two specimens have the composition of a granite, the other two of a quartz monzonite (Table XV).

TABLE XV | *Average mode of quartzites (map-unit 11)*

Number of thin sections studied	2	2
	Range %	Range %
Albite–oligoclase	8(7–9)	27(24–30)
Microcline	53(48–58)	29(21–38)
Quartz	29(27–31)	30(25–35)
Biotite	10(2–18)	4
Garnet		2
Others		8
Rock composition	granite	quartz monzonite

The garnet grains may be much embayed along their contacts with quartz and feldspar. They are generally much altered to chloritic and sericitic material and enclose numerous foreign inclusions, particularly round quartz blebs. Quartz is interstitial to feldspar and garnet, has a wavy extinction, and may be in grains up to 2 mm in size, although 0.06 mm is more usual. The glassy quartzites consist almost entirely of quartz, but most beds have both quartz and feldspar associated as in granite. Locally quartz has recrystallized and concentrated in narrow layers, accentuating the layered structure. Microcline is generally the most abundant feldspar. It is fresh and may be in grains up to 4 mm. Plagioclase is closely associated with microcline and occurs in irregular altered grains.

Biotite flakes and rods, less than 0.2 mm long, occur concentrated in parallel zones and are most abundant where there is feldspar. They are generally reddish brown and may be oriented parallel with each other. Biotite is nowhere very abundant. It varies in amount from layer to layer and may be an alteration after garnet. Some of it is chloritized. Chlorite, sericite, and epidote are alteration products after garnet and biotite. The opaque substance is in part leucoxene, and some of it is associated with biotite. Generally it occurs in irregular patches.

A few grains of a clear mineral occurring as remnants with a ragged outline in sericitic material and with a high relief were noted, particularly where garnet is plentiful. This mineral was assumed to be an orthopyroxene.

Map-Unit 12: Amphibolite

The amphibolite is in sharp contact with the quartzites of map-unit 11. It occurs as long, narrow layers interbedded with the quartzites, as small lenses within the quartzites, or as larger lenticular masses enclosing quartzite lenses. In most places, small amounts of quartzitic rocks were mapped with the amphibolite. The larger amphibolite masses die out by separating into layers of amphibolite interfingered with the quartzites. Individual layers are generally less than 400 feet wide, but lenses too small to be mapped separately are present locally. A few irregular masses of amphibolite up to 1,200 feet wide make up most of map-unit 12 at its southwest end. Many layers of amphibolite were mapped in the part of map-unit 12 north of Doreen Lake and as far as the north boundary of the map-area, where they are represented by at least five main layers across the width of the map-unit. All these mafic-rich rocks were probably derived from coarsely and finely bedded basic sediments, such as pyroclastic rocks and limy shales, but locally they may be partly metamorphosed gabbroic sills.

The amphibolite is generally dark green and black. It is brown locally on weathered surfaces. It is a medium- to coarse-grained rock and may be massive to gneissic or strongly layered. The larger bodies are generally massive and gneissic; the smaller ones are commonly foliated and layered. On weathered surfaces, the amphibolite appears to be composed mainly of hornblende and feldspar. If the feldspar is reddish, the amphibolite is in part chlorite-bearing and carries some biotite. Locally the amphibolite masses show variations of compositions and are then mixed or interlayered with rocks that may be ultrabasic. Thus the large mass of mafic-rich rock at the southwest end of this map-unit, near the western boundary of the map-area, is now largely a serpentine mass, coarsely interlayered with coarse-grained, relatively unaltered, massive amphibolite. Near the margins with granitized rocks, this serpentine mass carries pockets and irregular masses or patches, rich in biotite and possibly other micas. This same mass also exhibits large scattered pyroxene crystals, irregular nodules of pyroxene or olivine, completely altered to serpentine, micas, and an opaque substance. This opaque substance in the nodules, as seen in thin section, definitely follows either the cleavages of pyroxene or the fractures of olivine. The nodules even carry locally tiny grain of pyroxene, which may be remnants of pyroxene or an exsolution product of its alteration.

In addition, the mass of serpentine encloses patches rich in talc and a few small (about 50 feet across) irregular areas composed of approximately 80 per cent calcite and 20 per cent serpentine. There the serpentine is in round grains pseudomorphic after olivine or an orthopyroxene and is contained in the calcite.

In the remaining part of map-unit 12, toward its northeast end, the amphibolite is more uniform in composition, although even there it shows some variations, as follows:

1. It grades locally into a rock with a fairly high white feldspar content that resembles a dioritic rock, but this phase is generally of small extent and was not mapped.

2. Other small areas within the amphibolite are darker and have abundant pyroxene, which may be slightly altered to serpentine. This rock may be in part pyroxenite and as such is probably related to the large serpentine mass described above, but nowhere is it abundant.

3. Finally, some of the amphibolite layers are porphyritic and exhibit large hornblende crystals in a coarse-grained hornblende–feldspar matrix. Near granite dykes and sills, they may carry occasional large feldspar metacrysts. Garnet was also recognized near granite. Epidote alteration in seams and veinlets, and grains of pyrite, uniformly distributed, were also observed.

These amphibolite masses are all traversed by dykes and sills of granite and pegmatite. A few of the pegmatite have black tourmaline, large (up to 6 inches) books of white mica, and a pink mineral, probably feldspar, in addition to the normal quartz and feldspar of pegmatite.

In thin section, the amphibolite is seen to be made up mainly of hornblende and plagioclase, usually uniformly distributed and intermixed. The texture is allotriomorphic granular. The hornblende grains are about 2 by 1 mm, and their outline is irregular. The feldspar grains are round with many embayments into the amphibole. The rock may be fresh or altered. In a fresh rock, the hornblende is only slightly altered to chlorite and the feldspar to sericite. Where the rock is much altered, the hornblende is discoloured, changed to a fibrous amphibole, and heavily chloritized; the feldspars are intensely sericitized, and large flakes of muscovite have developed. The feldspar is generally well twinned and is probably locally a calcic andesine or labradorite. It appears to be, in part, an oligoclase. There are also minor amounts of an opaque substance. In the fresh rock the opaque substance is outside the hornblende and in small amount only; in the altered rock, much of it is in or at the margins of the altered amphibole and constitutes about 10 per cent of the rock. Epidote, garnet, apatite, and zircon are all present. Grain counts suggest the following mineral composition for this rock: 60 per cent hornblende, 37 per cent plagioclase, 2 per cent opaque substance, and 1 per cent chlorite. The other minerals are accessory.

Map-Unit 13: Upper Belt of Granitic Layered Gneiss

This map-unit underlies all the area between the Boom Lake fault and the southeast margin of the Powerline Creek belt. It forms a belt about 1½ miles wide south of Bellegarde Lake and was traced for a distance of 7 miles along the strike in a northeasterly direction. This belt occurs widely outside the map-area. Overlying conformably the Powerline Creek belt, it is believed to represent a thick succession of highly granitized sedimentary rocks. These occur on the eastern limb of a major fold and at a place on the limb where the map-unit as a whole is almost flat or dips very gently southeasterly. In detail, however, the beds of this unit are closely folded, as they dip steeply both east and west. The close folding explains the apparent great thickness of the unit on the surface and indicates some repetition. The thickness as measured on the structure sections, based on the available information, is of the order of 4,500 feet.

Unit 13 is made up mainly of granitic layered gneiss like the Foot Bay gneiss, of quartzitic layered gneiss like the Donaldson Lake gneiss, and of minor amounts of metasomatic granite, pegmatite, and amphibolite. All these rocks, except the amphibolite, are related to each other, differences being the result of either original compositional differences or variations in the degrees of granitization. The various rock types are described below, except the granite, which is described with the granites in map-unit 19.

Map-Unit 13a: Granitic Layered Gneiss of the Foot Bay Type

The granitic layered gneiss is the most abundant rock type in this map-unit and underlies most of the area covered by it. Like all the other granitic layered gneisses of the Foot Bay gneiss type in the Beaverlodge area, it is red, it looks like granite, and it is well layered. However, it resembles particularly the granitic layered gneiss of map-unit 10. It is characteristically fine to medium grained, thinly layered, in part finely gneissic, but locally more siliceous than the normal granitic layered gneiss.

Weathered surfaces are smooth or streaky rough, and red, orange-red, and whitish to reddish brown. Fresh surfaces are red and light brown.

The rock is made up of two components: a fine- to medium-grained, granoblastic mixture of quartz, feldspars, and biotite or chlorite, and a coarse-grained, granitoid mixture of quartz and feldspars with few to practically no mafic minerals. The occurrence of these two components in regular alternating layers or in streaks and patches within each other produces the layered structure. It is like the layered structure observed elsewhere in the Beaverlodge area, but the layering here is typically much narrower or thinner, generally less than half an inch, than in the other units, except possibly in the granitic layered gneiss of map-unit 10. It is believed that the granitoid rock represents highly granitized parts of the original rock and that its abundance explains the granitic appearance of this layered gneiss. The layers of granoblastic gneiss vary slightly in mafic content and, consequently, in colour from layer to layer. Some layers are dark brown to black; others are almost white.

Thicker layers were recognized locally. They probably occur everywhere in this belt, but in general it is believed that their boundaries are obscured by the more pronounced thinner layering or gneissic structure that now characterizes most of the rock. However, it was noted that some thick layers of granoblastic gneiss low in mafic minerals are locally so granitized that they resemble a layer of coarse-grained granitoid rock. The mafic minerals of such layers are distributed in fine lines parallel with the main layering, a structure that produces the gneissic appearance and accentuates the layered structure but masks the margins of the main layers.

The granitoid rock generally forms the thickest layers, but some of this rock is also enclosed in the mafic-rich layers in the form of narrow, short lenticular masses, uniformly distributed and oriented parallel with the layered structure. Some of the granitoid layers may be transgressive and form true dykes. Locally these dykes are so abundant that they give rise to migmatite, as for example, north of Betty Lake and in the general area near the south edge of the Powerline Creek belt.

The layered gneiss described above shows much variation:

1. It passes locally into areas exhibiting a typical gneissic but not layered structure; that is, areas where the dark layers are lenses or irregular streaks that pinch out along the strike or are discontinuous lines of pencil width. Such gneissic rock and all gradations to a well-layered rock were abundant in the areas near the Powerline Creek belt, near Ornie Lake, and west of Don Lake, where it grades into gneissic granite.

2. In general, this layered gneiss seems to have fewer mafic-rich layers than similar gneiss in the Beaverlodge area, but the abundance of these layers seems to vary appreciably from place to place. Moreover, their mafic content decreases as the structure becomes gneissic (not layered) and as the rock becomes more granitized. Locally, however, as in the area northwest of Jean Lake and near Bush Lake, the dark layers are more abundant, thicker, and richer in mafic minerals than they are in the general area southwest of Bellegarde Lake.

3. Where the mafic content is low, some of the rock appears to be siliceous and grades into rocks resembling quartzite or rocks rich in quartz; indeed, locally a few quartzite beds are present. Siliceous rocks were noted in many parts of this belt, but their appearance is not distinctive enough to permit mapping separately. However, they all grade into the granitic layered gneiss and appear on the map at the places where they were recognized, particularly northeast of Bush Lake and southwest of Pig Lake. In many instances they are closely associated with zones of quartzitic layered gneiss of the Donaldson Lake gneiss type, which are described later and are outlined separately on the map (13b). Many of them grade into these masses, particularly those areas north and west of Chance Lake and north of Bush Lake.

4. Where granitization was intense, much of the granitic layered gneiss was changed into a coarse-grained granitized rock or granite. If the mafic content was fairly high in the original layered rock, a gneissic granite was the end result; where the original rock was almost devoid of mafic constituents, a coarse-grained red granite developed.

In thin section, this layered gneiss is seen to be fresh, allotriomorphic granular, fine grained, and crudely foliated. It is also locally porphyroblastic. Most of the minerals are closely intermixed. Quartz has sutured boundaries and is in concentrations (less than 5 by 1 mm) elongated and oriented parallel with the foliation. These quartz concentrations accentuate the foliation but are not so well developed in this rock as the lenses and patches of map-unit 10. In size, most of the grains are below 0.6 mm and average around 0.2 mm. Some of the feldspar and quartz grains reach 4 mm in diameter and these, particularly the feldspar grains, produce the porphyroblastic texture mentioned above. Accessory minerals include apatite, zircon, and sphene; alteration products are carbonate and epidote.

Grain counts on fourteen thin sections indicate two main composition groups: a granodiorite and a quartz monzonite (Table XVI). The granodiorite is believed to be the most common and the most typical component, the quartz monzonite probably being a phase in the process of granitization.

TABLE XVI | *Average mode of granitic layered gneiss (map-unit 13a)*

Number of thin sections studied	10	4
	Range %	Range %
Albite–oligoclase	50(40–70)	30(26–35)
Microcline	10(1–24)	33(24–38)
Quartz	27(11–45)	24(18–32)
Biotite or chlorite	12(5–29)	12(4–19)
Others	1(0–3)	1(0–4)
Rock composition	granodiorite	quartz monzonite

The albite–oligoclase is generally heavily altered to sericite, but the microcline is fresh. Both are twinned. Much of the microcline is interstitial to the plagioclase but locally is in much larger grains than the plagioclase. Although these grains (up to 10 by 6 mm) formed later than the primary constituents of the rock, they are regarded as the earliest mineral to form in the granitization of the rock. Quartz shows a wavy extinction and occurs in grains interstitial to the feldspars or in large agglomeration of recrystallized grains.

The mafic minerals are green biotite or chlorite. They occur in laths and irregular flakes or patches, oriented parallel with the quartz agglomerations and interstitial to the feldspars. Chlorite is an alteration product after biotite. The opaque substance is closely associated with chlorite and biotite.

Crushing occurs at the meeting points of a few grains of quartz with feldspars or in narrow zones at the boundaries between the two. No true mortar structure was observed. It is believed that the rock is nowhere so extensively crushed as the rocks between the Boom Lake and Black Bay faults, but some mylonitic rocks are present. In the field, mylonite was suspected along the northwest side of the depression occupied by the Boom Lake fault and also along the depression extending southwesterly from Doreen Lake. These two zones are parallel with the main mylonite zones associated with the Black Bay and the Boom Lake faults. They seem, however, to be narrower. The presence of mylonite in these zones was verified with the microscope. The mylonite of these zones appears on the outcrops as a dense rock with a fine foliation due to quartz occurring in tiny hair-like lines in parallel orientation. These mylonite zones were nowhere associated with wide zones of granulation as with the mylonite near the Black Bay fault. A wide zone of brecciated rock (unit 13e), entirely separated from mylonite, was mapped in the area extending from Betty Lake to the south end of Boom Lake, passing by Jeff Lake. Weathered surfaces of these brecciated rocks are dark red with a striking brecciated appearance.

Map-Unit 13b: Quartzitic Layered Gneiss of the Donaldson Lake Type

Quartzitic layered gneiss is a fairly abundant rock type in this belt. It grades along and across the strike into the granitic layered gneiss. The gradation across the strike is generally by interlayering of the two with a decrease in one direction in the amount of the quartzitic gneiss. The gradation along the strike is either a change in facies or an interfingering with the granitic gneiss and may be, in part, the result of granitization. This quartzitic layered gneiss occurs mainly as short and narrow lenses, discontinuous layers, and irregular masses with irregular ends along the strike. It occurs abundantly as irregular masses north of Bellegarde Lake where it underlies about 30 per cent of the area. Two layers were traced almost continuously from the west boundary of the map-area to Bush Lake, where they seem to pass into irregular and much larger masses. One of these layers outcrops a short distance north of the Boom Lake fault and is parallel with it. The other layer outcrops about 500 feet south of the depression, extending southwesterly from Doreen Lake. Other irregular areas occur near the western boundary of the map-area and a short distance south of the Powerline Creek belt. Much of this quartzitic gneiss is also found closely associated with the large amphibolite masses near Doreen and Leibel Lakes. Everywhere it is traversed by a few dykes or sills of red granite. Included in the area mapped as granitic layered gneiss are many beds, small areas, and lenses of quartzitic layered gneiss.

In outcrops the rock of the layers and lenses is fairly distinctive and generally can be readily separated from the granitic layered gneiss of the Foot Bay type, with which it is closely associated and in which it is commonly found. On the other hand, the rock of the large irregular masses is not so distinctive, and in most instances it is difficult to distinguish it from the granitic layered gneiss. Locally the two rocks are so closely related in composition that on weathered surfaces they look almost alike. This probably explains the irregular outlines of the large masses on the map.

Weathered surfaces are characteristically white or rusty white, generally with black or grey layers. Locally, as in zones transitional to the granitic layered gneiss or in those areas where the gneiss is partly altered to red granite, they are pink or patchy red on white. A fresh surface is white or peppery and/or striated black or grey on white. Weathered surfaces are massive to generally gneissic or layered; they are rough and granular and in general have a granoblastic or granitoid appearance, depending on the grain size and the composition of the rock. The grain averages 0.6 mm. Scattered feldspar or quartz grains occasionally reach 3 mm in width.

The layers and lenses of this quartzitic gneiss (13b) are seen to be composed of two main rock types:

1. One is white weathering granitoid rock, made up mainly of grey quartz, white to buff feldspar, and biotite, generally in small amounts. This rock forms layers and lenses interlayered with the second rock type but also large masses that locally enclose lenses and patches of the second rock type. These large masses, where the second rock type is absent, constitute the massive parts of the granitoid gneiss that resemble a coarse-grained white granite.

2. The second rock type weathers white or grey and black, depending on the amount of dark minerals in it. It is mainly fine to medium grained and is generally granoblastic and gneissic to locally porphyroblastic. It is a garnetiferous quartz–feldspar–biotite gneiss or schist and occurs as layers, lenses, and patches, interlayered with or enclosed in the granitoid gneiss. Generally the mafic content is less than 40 per cent, and garnet was noted almost everywhere. Garnet grains 3 inches across were noted in the vicinity of Doreen Lake.

On the other hand, the large irregular masses of the quartzitic gneiss (13b) are more thinly layered than the layers and lenses just described and are more varied in composition. They appear to have more quartz, and their mafic content can be as high as in biotite schist. Some outcrops have much coarse garnet, and others exhibit porphyroblasts of white feldspar. In general they are granoblastic and fine grained, but an irregular mass of garnetiferous biotite schist, black weathering and coarse grained, was mapped west of Bellegarde Lake.

Minor amounts of other rock types, such as beds of true glassy quartzite, fine-grained amphibolite, and biotite or chlorite schist, occur locally but are in general very narrow, widely spaced, and discontinuous or exhibit a boudin structure. True, glassy, thinly bedded quartzites, in part hematitic and in part garnet-bearing, were noted in the depression extending southwest or northeast from Doreen Lake and in close proximity to the large amphibolite masses there (unit 13c). Tiny lenticular bodies of amphibolite occurring abundantly with the layers and lenses of the Donaldson Lake type of quartzitic layered gneiss suggests a close association in the field.

Under the microscope the quartzitic layered gneiss is fresh, allotriomorphic granular, and in part layered and gneissic; the mafic minerals occur in various amounts in different layers and in alignment. Brecciation occurs locally around a few quartz or feldspar grains. It is composed of quartz, albite–oligoclase, microcline, biotite, and garnet, in amounts that vary appreciably from place to place. The true quartzite, which is a rare rock, has no feldspar. The gneiss of the layers and lenses is believed to have the composition of a quartz monzonite, the gneiss from the irregular masses that of a granodiorite, similar to the granitic layered gneiss of the Foot Bay type. These two compositions are shown in Table XVII.

TABLE XVII | *Average mode of quartzitic layered gneiss (map-unit 13b)*

Number of thin sections studied	4[1]	2[2]
	Range %	Range %
Albite–oligoclase	47(33–56)	29(22–36)
Microcline	10(2–17)	39(31–47)
Quartz	28(20–36)	27(22–31)
Biotite	14(2–22)	4(0–8)
Garnet and others	1(0–2)	1(0–2)
Rock composition	granodiorite	quartz monzonite

[1]Biotite-rich granoblastic gneiss (probably similar to type 2 of the layers).
[2]Granitoid gneiss (type 1 of the layers).

The grain size is generally less than 0.6 mm; about 1 mm in rocks free of mafic minerals. Occasionally grains of feldspar and quartz reach 3 to 4 mm. Garnet is in grains larger than 1 mm, and in highly granitized rocks most of it is altered to chlorite. It is much embayed with quartz and feldspar.

Albite–oligoclase is altered to sericite, whereas the microcline is fresh. Microcline and quartz are interstitial to the plagioclase, and in some instances microcline forms a rim around albite. Quartz is in large crystals or in tiny individuals displaying the imbricate pattern characteristic of granulated and recrystallized quartz. Brown biotite is in oriented ragged laths or rods and is locally an alteration product after garnet. It is altered to chlorite where the rock is altered to red granite.

Apatite, zircon, and opaque substance are accessory minerals. Apatite is locally concentrated in zones at right angles to the gneissic structure of the rock or the elongation of the quartz. Epidote, probably a late alteration product, occurs as seams, mainly in those areas heavily changed to granite.

Map-Unit 13c: Amphibolite

Amphibolite was recognized at many places in this belt. It occurs as large lenticular masses along a zone passing by Doreen and Leibel Lakes and extending from the western boundary of the map-area to the south end of Bellegarde Lake, where it seems to be cut off by the Bellegarde Lake fault or to die out. This zone is locally 1,200 feet wide on the surface and appears to be an agglomeration of lenticular bodies of various sizes, distributed irregularly along its length, more abundantly in the vicinity of Doreen and Leibel Lakes. The amphibolite also occurs as small lenticular or irregular masses throughout all the rocks of map-unit 13. Few of these masses are more than 500 feet long, and most are less than 100 feet wide; only rare ones are slightly larger. In general they occur in clusters distributed over a fairly wide area as in the area east of Betty Lake, or they may be distributed as boudins along a certain horizon for several miles. Such features can be observed south of Kaput Lake and for great distances northeast, and southwesterly from Smysniuk Lake and near the Boom Lake fault at the western boundary of the map-area. Several amphibolite masses were mapped against the Boom Lake fault between Boom Lake and Chance Lake, and, as in the other instances, they seem to be parts of a single layer.

The rock of all these amphibolite masses is in general similar to the rocks of the amphibolite masses elsewhere in the Beaverlodge area, except that much of it exhibits a porphyroblastic texture, which is rare or practically nonexistent elsewhere. Most of the small masses of amphibolite mapped between the Boom Lake fault and the large belt of amphibolite at Doreen and Leibel Lakes are porphyroblastic, whereas the large belt is not.

The amphibolite in general is dark green or brown, medium to coarse grained, and massive to well foliated and gneissic. The large belt passing by Doreen and Leibel Lakes is a massive to well-layered rock, locally much fractured, and generally fairly high in white to red feldspar. It is serpentinized along some zones and invaded along fractures and joints by granitic or dense cherty siliceous material. The porphyroblastic amphibolite shows porphyroblasts of white feldspar in a coarse-grained dark green matrix of hornblende and some white feldspar. Most porphyroblasts are about one inch in width, but a few reach 6 by 4 inches. In shape, a few are euhedral and typical of feldspar, but most of them are round, lenticular, square, rectangular, and even irregular. Most are now greenish yellow and seemingly intensely altered. This is in sharp contrast to the dykes and masses of red granite in the amphibolite, which are all fresh looking. Also much biotite seems to have developed in the amphibolite near these metacrysts. In thin section the porphyroblasts seem to be oligoclase, altered to sericite and locally associated with quartz. They may therefore represent remnants of gneiss (unit 13a) in the amphibolite or phenocrysts resorbed and altered by granitization.

Several small irregular amphibolite masses were outlined near the Boom Lake fault between Boom Lake and Chance Lake. These are closely associated with quartzitic Donaldson Lake type layered gneiss, and many of them include irregular masses of carbonate. The amphibolite itself does not differ from the ordinary amphibolite except that, being locally serpentinized, it resembles the serpentine mass of the Powerline Creek belt, which was thought to be partly ultrabasic. The amphibolite masses of map-unit 14, south of the Boom Lake fault, are possibly the extension of these amphibolite masses.

Under the microscope the amphibolite belt passing by Doreen and Leibel Lakes is made up mainly of yellowish green hornblende and altered plagioclase. It has minor amounts of epidote, chlorite, sphene, or opaque substance, pyrite, and quartz. Locally the hornblende is entirely altered to chlorite; in other places, chlorite forms only a ragged rim around the hornblende. Epidote is in clusters, as if replacing hornblende. The feldspar is heavily altered to sericite and is probably a calcic oligoclase or an andesine. The opaque substance is at the margins of hornblende and seems to be more abundant where there is more chlorite. Most of the quartz is as tiny round grains mixed with chlorite, generally interstitial to plagioclase.

Area Between Boom Lake and Black Bay Faults

(*Map-Units 14 to 18*)

This area covers approximately 15 square miles and extends from Bushell in the southwest to Pluton Lake in the northeast. It is roughly wedge-shaped, being about a mile wide near Pluton Lake and 2 miles wide at Bushell. Rock exposures are in part fairly clean and in general amount to more than 60 per cent of the area. From the outcrops it is apparent that the geology of this area is very complex and that the rocks were subjected to close and intense folding, to widespread granitization, and to repeated and extensive cataclastic deformations. As a result of granitization, the original diverse rocks have lost much of their identity and have become locally a fairly homogeneous red granite. The cataclastic effects have also destroyed much of the rock's entity, reducing all types to a crushed and mylonitic rock. These alterations make it difficult to reconstruct the stratigraphy of this area with any degree of certainty, although certain evidence suggests that the rocks were once a sedimentary succession, that this succession was subsequently folded, metamorphosed, granitized, and deformed, and that the end product is a complex mixture of gneisses, schists, and granitized and cataclastic rocks. No top determinations could be made, and most of the dips measured, either on probable beds or on foliation, were steep. However, field work suggests that the lower part of the succession is near the Boom Lake fault and the higher near the Black Bay fault. Between these two extremes there is some repetition and thickening of parts of the formation by folding, but the maximum thickness of the succession is believed to be about 5,000 feet.

The general structure is believed to be monoclinal with a steep dip to the east. Here and there the regional dip of the formation may become almost horizontal, but in detail such areas are intricately and isoclinally folded, giving dips in both directions. It is at these places that parts of the formation are repeated and thickened. They represent areas of drag-folding.

The assumed stratigraphic succession for this area is summarized in Table XVIII. It is possible that this succession represents more than one formation; in any case it is believed to be a composite section. Most units comprise several rock types, and several units may consist of similar rock types. These units are separated from each other by definite markers, such as the Jean Lake amphibolite, which serves to separate the Rix unit from the Cayzor unit. The granites are considered to be part of the succession, for they are metasomatic; they were mapped separately. However, they are not described here.

TABLE XVIII | *Assumed stratigraphic succession in the area between the Boom Lake and Black Bay faults*

Units and rock types	Estimated thickness in feet
Map-unit 18: Uranium City amphibolite; feldspar–hornblende schist and gneiss; dykes and sills	400
Map-unit 17: Cayzor unit; impure feldspathic quartzite, augen gneiss and chlorite schist; granitic and quartzitic layered gneiss; granite, mylonite, glassy quartzite	1,800
Map-unit 16: Jean Lake amphibolite; hornblende–feldspar schist and gneiss; granite dykes and sills	400
Map-unit 15: Rix unit; quartzitic layered gneiss, granitic layered gneiss, amphibolite; granite masses, dykes and sills	2,000
Map-unit 14: Chance Lake unit; augen gneiss, impure quartzite, chlorite schist, granitized gneiss and quartzite, amphibolite and granite; about the same rock types as those of the Cayzor unit	400

Map-Unit 14: Chance Lake Unit

The Chance Lake unit (14) is the lowest known unit in this part of the area. It is bordered and truncated on the northwest by the Boom Lake fault, but its extension north of the fault may be represented by the amphibolite (13c) and associated quartzite (13b), mapped against the Boom Lake fault. It occupies a small wedge-shaped area, which was traced from the Crackingstone River fault for 2 miles almost to Pig Lake. It comprises rocks very similar to those of the Cayzor unit (17): augen gneiss, impure quartzite, some amphibolite, and a few granitoid derivatives of the first two. The augen gneiss and quartzite, which are interbedded locally, grade into one another; the gneiss is distinguished from the quartzite by its more pronounced schistose appearance, its higher chlorite content, its less quartzose appearance, and finally by its widespread and generally well-developed augen structure. Near the Crackingstone River fault, the quartzite seems to be more abundant, and about halfway toward Chance Lake the augen gneiss is more common. It seems that one grades into the other along and across the strike, the gneiss possibly representing in part the schistose part of the quartzite. Slightly past this point, about halfway to Chance Lake, there is again less gneiss and more quartzite, but amphibolite in small irregular bodies becomes fairly abundant there. Northeast of Chance Lake the belt is very narrow and includes all rock types.

The augen gneiss is really a chlorite schist with augen of red feldspar and quartz, and it is believed to be the granitized phase of a chlorite schist. It is a dirty whitish green to yellowish green rock with a streaky coloured layering and a schistose appearance, whereas the quartzite is a massive, fine-grained, locally thinly bedded rock that is very hard and sounds like glass when struck. In thin section the gneiss is seen to be fine grained and to be made up of about 20 per cent quartz, 55 per cent sericitized feldspar (probably albite–oligoclase), 20 per cent biotite and chlorite, 4 per cent opaque material, and 1 per cent accessory minerals, such as epidote, sphene, leucoxene, and pyrite.

The contact of this unit with the Rix unit (15) to the south is gradational, the rocks of both units being in narrow alternating beds over a few feet. The schistose nature of the augen gneiss helps to locate the contact where exposed. It is possible that the southern part of this contact is the location of a fault zone, as the Chance Lake rocks seem to strike into the rocks of the Rix unit.

All these rocks are intensely crushed along the Boom Lake fault. In outcrops along the depression marking the fault, the rock is coarsely brecciated or is a dense, cherty, black to dark grey mass resembling argillite. It was probably an augen gneiss and is now an ultramylonite. Seen under the microscope it is fine grained, and porphyroclasts, if present, are rare. About 800 feet away from the fault, the gneiss and the quartzite are still brecciated, but at that distance the original nature of the rock can be recognized. There they are a crushed gneiss or quartzite, that is, a protomylonite.

Map-Unit 15: Rix Unit

This unit covers all the area between the Jean Lake amphibolite (16) and the Chance Lake unit (14). It occupies a belt that extends from Bushell northeasterly to northwest of Jean Lake where it is cut off by the Boom Lake fault. It is about a mile wide in the south.

The Rix unit (15) comprises several rock types, most of which have already been mentioned in the description of the Chance Lake unit, but the augen gneiss, characteristic of the Chance Lake unit, is almost absent here, being found only as rare thin layers or beds and in the south as one small mass large enough to show on the map. The most common rock types in this unit, although not necessarily all large enough to map, are quartzites and their granitized phases, biotite–chlorite and amphibole-bearing gneisses, red granitic gneiss, amphibolite, massive and gneissic red granite, and pegmatite. The red granite and the amphibolite are the only rocks that occur locally in individual masses large enough to be mapped separately. However, a rock type such as quartzite or granite may so dominate the assemblage in some parts of the area that the whole becomes a mappable unit. A few such units were traced almost the whole length of the Rix unit. These mappable assemblages in their approximate order of abundance are as follows: quartzitic layered gneiss of the Donaldson Lake gneiss type, granitic layered gneiss of the Foot Bay gneiss type, amphibolites, and granites, the first two, together, underlying most of the area covered by this unit. The granites and amphibolites form small bodies within the quartzitic and granitic gneisses.

Map-Unit 15a: Quartzitic Layered Gneiss of the Donaldson Lake Gneiss Type

The quartzitic layered gneiss is an assemblage of several rock types, all interlayered and in places visibly high in quartz. It has a general white to rusty white weathered surface. It includes also dykes and sills or layers of red granite and pegmatite.

This assemblage forms wide lenticular zones and narrow elongate belts, oriented parallel with the main trend of the Rix unit and intermixed with the granitic layered gneiss of the Foot Bay gneiss type (15b). It also grades into the latter, and locally it is difficult to tell which of the two assemblages is present. Along the strike the transition is gradual, but across it the contact may be sharp or may be represented by a zone where rocks of both assemblages are intermixed. There, the position of the contact can be located within a few feet.

In unit 15a the beds and layers are generally less than 2 feet thick but locally are more than 15 feet. In some places, as in the area slightly north of Bushell, most are less than an inch thick. The contact between two individual beds or layers is usually knife sharp, but in areas where the rocks of adjoining beds are related or of similar composition, as quartzite beds with varying amounts of biotite, or are highly granitized quartzites, as the nebulites in the area south of the Crackingstone River fault, the contacts are indefinite and obscure. The layering may be as regular as in bedded sediments or very irregular where the rocks are deformed, drag-folded, and contorted (*see* Pl. 3). This is particularly true for the highly granitized areas south of the Crackingstone River fault. The layering is also accentuated by a pronounced striped effect and by a gneissic structure within individual beds or layers, particularly the thicker ones. These coloured stripes are probably a secondary feature superimposed by metamorphism and are believed to be due to segregation of a certain mineral or minerals into layers or to an orientation of some minerals into planes parallel with the beds

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PLATE 3. Quartzitic layered gneiss, Rix unit. Layers are highly contorted and in places nebulitic. White granodiorite and quartz monzonite interlayered with grey layers of similar composition but biotite bearing.

or layers. Some may represent relict bedding. The coarser layering is probably in most cases a relict bedded structure, possibly accentuated locally by metamorphism and granitization.

The grain size may be fine and medium or coarse. Where the texture is granoblastic, the grain is fine to medium and the rock has a sandy appearance, resembling a recrystallized sediment. Where it is porphyroblastic, it has large feldspar crystals or aggregates of coarse quartz and feldspar in a granoblastic fine- to medium-grained matrix. This is probably one of the first steps in the granitization. Where the texture is granitic and granitoid, the rock is now a white granite and probably represents the last stage of the granitization.

The rock types forming this quartzitic layered gneiss (15a) are varied. Many varieties of quartzites, biotite- and/or hornblende-rich gneiss forming dark layers, granites, amphibolites, and chlorite schists were recognized. Most of these rocks grade into one another, both across and along the strike, either by one passing imperceptibly into another or, in mixed rocks, by one dominant type giving place to another. The layers may be classified into three principal types—quartzitic, mafic, and granite—and are so described below.

Quartzitic layers. Quartzites and their granitized counterparts are by far the most abundant rocks in unit 15a, and for this reason the unit is identified as quartzitic layered gneiss. Many types of quartzites are present, but true quartzites, that is rocks made up almost entirely of quartz, are rare. Most are indeed really impure feldspathic quartzites, as in them white feldspar is abundant and some biotite is also present.

These feldspathic quartzites are white to light brown on weathered surfaces, and white on fresh fractures. Their grain size is fine to medium or coarse. In some layers they are granoblastic and sandy looking, in others coarse grained and granitoid, resembling a granite. Most beds of this rock also exhibit an internal layered or gneissic structure, oriented parallel with the trend of the main beds or layers. All are composed of quartz and feldspars with varying amounts of biotite, hornblende, and chlorite. Three main varieties were recognized in the field:

1. Rock in some layers is white weathering with little or no biotite and is generally coarse grained and granitoid. It is made up mainly of quartz and oligoclase and resembles a white granite and the typical white granitoid layers of the Donaldson Lake gneiss. Where the amount of quartz is high, the rock grades into type 3 below.

2. Some layers are light brown weathering, generally fine to medium grained, and have a sandy appearance. They are granoblastic quartz–feldspar–biotite gneisses. These layers are themselves layered and gneissic. This layering and gneissosity are due not only to variations in biotite content from layer to layer within the main layer but also to variations in grain size and colour, and in the quartz and feldspar content of the various layers within the main layer. Where biotite is absent, the layers resemble the white weathering granitoid layers of type 1. Where it is abundant, the rock is like the mafic layers described later. The feldspar grains are usually round, white, and abundant.

3. Type 3 layers are grey to bluish white glassy quartzite and may be thinly bedded or massive. They are not very common. Generally they are devoid of white feldspar. They are typical members of the quartzite clan, as white feldspar is rarely present and no feldspar is as common as in the other quartzite layers. Some biotite may be present, and it is usually aligned and concentrated in streaks parallel with the foliation, accentuating the layered and gneissic structure of the rock.

Under the microscope the quartzite layers show wide variations in composition and textures. Although they are made up of only a few minerals, these vary so much in abundance from layer to layer or even within a single layer that the average composition of the quartzite is difficult to determine. All contain quartz, oligoclase or albite, and some mafic minerals, and microcline is also present in those that are granitized. Variations in the abundance of these minerals and in their distribution determine the textures of the quartzites The plagioclase is mainly oligoclase, rarely albite, and is usually heavily altered to sericite and carbonate. Much of it is twinned. It occurs generally in equidimensional grains with irregular outlines. These grains are the largest in the rock, and since they are either evenly distributed or distributed in layers, they impart a crude foliation. In size they average 1 mm and reach 2 mm. In all cases the oligoclase seems to have been the earliest mineral to form, but this may be in part a secondary effect, owing to cataclastic deformation and later recrystallization of the crushed material. Microcline, in part perthitic, occurs in small round grains or in somewhat larger grains with irregular outlines. It may be extremely rare or form up to almost 40 per cent of the rock. Where rare, it occurs in small round grains in quartz. Some of the microcline is concentrated in zones parallel with the foliation; some grains have myrmekitic intergrowths along their edges. Quartz is interstitial to oligoclase and in quartz-rich rock forms the matrix. It has a wavy extinction and generally occurs in tiny (less than 0.05 mm) round grains with an imbricate appearance. Locally, quartz is in zones parallel with the foliation, and in such zones some of it is in grains larger than the grains of the imbricate quartz.

The mafic minerals are biotite, chlorite, and rarely hornblende. In some beds or layers, mafic minerals are very scarce; in others, they may be as much as 25 per cent. In all places the mafic minerals are interstitial to oligoclase. In some cases they merely surround the oligoclase grains, but generally they are oriented parallel with the foliation of the rock. Chlorite is an alteration product after biotite and, locally, hornblende. The biotite is green, and some of it may be an alteration product after hornblende. Accessory minerals are apatite, sphene, opaque substance and zircon. Some epidote, possibly an alteration product, was also noted.

Table XIX gives the mineral composition of five specimens from these quartzitic layers, as estimated from grain counts.

TABLE XIX | *Estimated mineral composition of the quartzitic layers in map-unit 15a in percentage*

Specimen	A	B	C	D	E
Quartz	26	63	19	26	25
Oligoclase	52	28	47	31	27
Microcline		6	20	37	38
Biotite			4	6	10
Chlorite	19	2			
Hornblende			9		
Opaque	3				
Epidote		1	1		
Rock composition	quartz diorite (?)		granodiorite	quartz monzonite	

A. White weathering, medium- to coarse-grained, granitoid feldspathic quartzite (variety 2),
B. White to grey weathering, medium-grained, glassy quartzite with white feldspar specks surrounded by quartz (variety 1),
C. Similar to (A) but granitized, and
D and E. Highly granitized quartzite (variety 2).

All thin sections show some cataclastic effects, the most common being a mortar structure and the imbricate structure of quartz. In all cases narrow margins of the feldspars are crushed, and locally the whole grain is fractured.

Mafic layers. The dark brown and the light to dark green layers also constitute an important part of the quartzitic layered gneiss. Most are very thin, less than an inch wide. They account generally for less than 15 per cent of the unit as mapped and are interlayered with the quartzitic layers described above. Locally they may be more plentiful, but such sections are rarely more than a few feet thick.

The rocks of the mafic layers are massive or layered and gneissic, and in all cases carry more mafic material than the quartzite layers. Hornblende, biotite, and chlorite are the most common dark minerals and account generally for more than 25 per cent of the rock. In some layers, hornblende is the only mafic mineral present; in others small amounts of biotite may also be present. Other layers have only biotite or chlorite. Finally, in some others, all three minerals occur in various amounts, but in these the chlorite is usually an alteration product. The rock of these layers is really amphibolite, hornblende–plagioclase gneiss, quartz–biotite–hornblende–oligoclase gneiss, quartz–biotite–oligoclase gneiss, and quartz–chlorite–albite to oligoclase gneiss. In some of them the biotite content is so high that the rock resembles a rusty brown quartz–biotite schist. All are fine to medium grained and granoblastic, and in all, except the amphibolite and the biotite schist, the evenly distributed oligoclase constitutes more than 60 per cent of the rock. It is heavily altered and faintly or poorly twinned. It occurs in round to irregular grains, generally less than 1 mm in diameter. The mafic minerals are in smaller grains and interstitial to the feldspar. Locally they may be oriented parallel with the foliation. The dark green hornblende is in ragged grains, and some parts may be altered to green biotite, others to chlorite. Where biotite is the main mafic mineral, it is green and in lath or irregular flakes, and may be locally heavily altered to chlorite. Quartz also is interstitial to feldspar and has a wavy extinction. It occurs in some rocks in small pods of tiny round individuals, scattered irregularly throughout the rock. Where the rock shows cataclastic effects, such as fractured grains and crushing at the grain boundaries, quartz occurs in lenses and layers oriented parallel with the main foliation. In such areas the quartz presents the imbricate texture mentioned previously or is in large patches of recrystallized quartz. These patches are usually elongated parallel with the foliation. Individual quartz grains are in general less than 0.04 mm wide. Apatite, sphene, zircon, opaque substance, and possibly some epidote are accessory minerals.

Granite layers. Red granite also occurs in this assemblage and, like the other rock types, is generally in layers or sills of various widths. It occurs also as dykes cutting across the main trend of the layered structure. Most such dykes are connected with some of the sills, paralleling the layered structure and resembling apophyses of the dykes. This red granite is generally medium to coarse grained and locally is pegmatitic. It is described more fully later.

Map-Unit 15b: Granitic Layered Gneiss, Foot Bay Gneiss Type

The granitic layered gneiss is an assemblage of rocks very similar in general appearance to the quartzitic layéred gneiss described above. The two assemblages grade into each other, and both bear similar rock types but in slightly different proportions. The descriptions presented above for the rock types in unit 15a apply equally to the rock types forming this unit (15b). The main characteristics of the granitic layered gneiss are the red colour on weathered and fresh surfaces, the greater proportion of mafic-rich layers or an overall mafic content of 15 to 50 per cent, and the more advanced stage of granitization of the rock as a whole (*see* Pls. 4 and 5). Most of the light weathering layers in this unit do not look like quartzite but are either a coarse-grained red granite or a highly granitized feldspathic quartzite. These layers, like the quartzitic layers of unit 15a, carry very little mafic material. The sill-like layers of red granite are more common in this gneiss (15b) than in unit 15a, the quartzitic-layered gneiss. The layering is also finer and more accentuated because of the sharper boundary between layers and the greater differences in composition between adjoining layers. The layers themselves show the internal layered and gneissic structure mentioned previously. The mafic

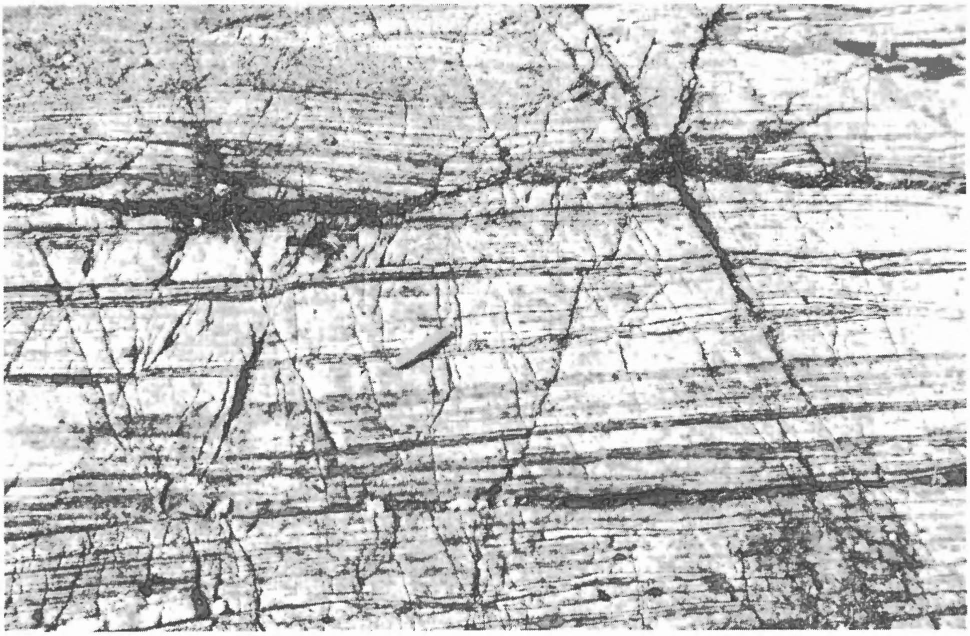

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PLATE 4. Granitic layered gneiss, Rix unit. The regularity and the continuity of the layers is well displayed; a tight drag-fold can be seen in the upper right corner.

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PLATE 5. Granitic layered gneiss, Rix unit. White granodiorite and quartz–monzonite interlayered with dark granoblastic gneiss. Tight drag-folds and gentle bends can be seen.

bands are similar in composition to those of the quartzitic layered gneiss (15a) but are more abundant here. Under the microscope these rocks seem to carry more microcline perthite, and the red colour is due to hematite dust on the feldspars and the quartz.

Map-Unit 15c: Amphibolite

Some amphibolite masses within the Rix unit were large enough to be mapped separately (15c). Others in the granitic and the quartzitic layered gneisses are in beds and layers too narrow to be mapped separately. These represent some of the interbedded mafic-rich layers and are in sharp contact with the quartzitic and granitic layers. They are generally less than an inch thick, and few can be traced for more than a few tens of feet along strike. Some thicker and shorter lenticular bodies were also noted but were too small to be mapped separately. Their occurrence suggests that they are boudins, as they are parts of the same layer broken up into blocks of various widths and lengths, possibly by stretching and flowage (*see* Pl. 6). The masses that were mapped separately average 20 feet thick, and some of them could be traced for as much as a mile, although they all pinch out eventually. Since many of them have been cut and offset several times by transverse fractures it may be difficult to trace them along strike. The rock of both larger and smaller masses and layers is very similar to the rock of the much larger amphibolite bodies in the other units of the area between the Boom Lake and Black Bay faults, described later as the Jean Lake and the Uranium City amphibolites and therefore need not be described separately here. It is interesting to note, however, that most of the amphibole of these small masses and layers is altered to chlorite. Locally the alteration has been so intense that it changed an amphibolite almost completely to a chlorite

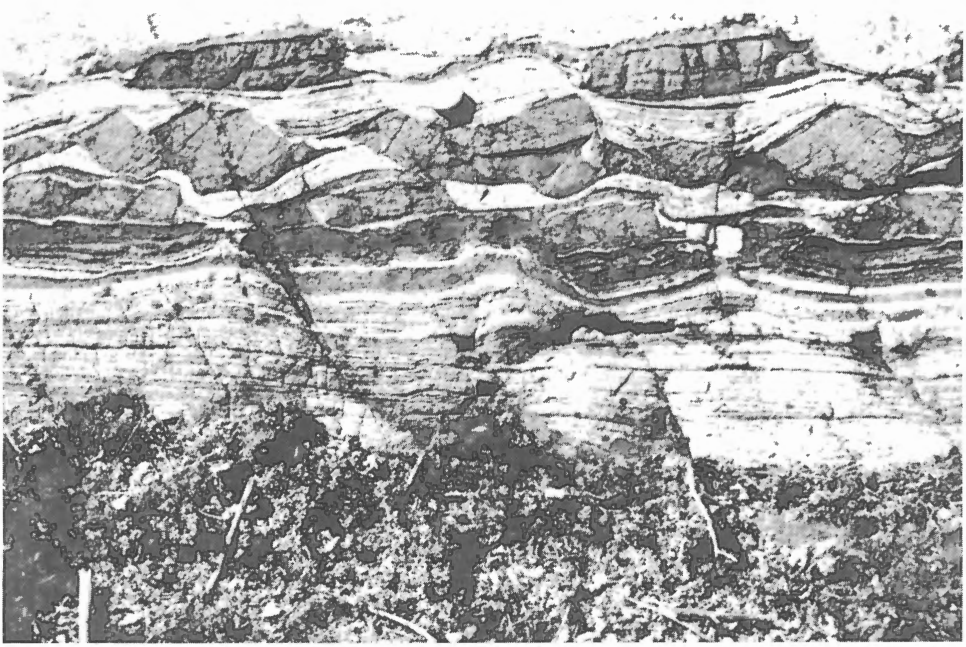

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PLATE 6. Rix unit. The dark layers, about six inches thick, are hornblende schist or gneiss in granitic layered gneiss, and display boudinage structure, seemingly due to stretching. Transverse joints displace some boudins.

schist. The rock is then made up mainly of penninite, bleached amphibole, and heavily carbonatized and sericitized feldspar. A few grains of quartz were noted, and an opaque mineral, also present, was uniformly distributed.

Map-Unit 16: Jean Lake Amphibolite

The Jean Lake amphibolite (16) is so named to distinguish it from the other amphibolite masses of the Beaverlodge area. It is a good horizon marker in the area north of the Black Bay fault where it follows the trend of the rocks for almost 9 miles. The north end is truncated by the Boom Lake fault, but on the south it extends as far as Lake Athabasca, outside the map-area. So far, there are no known ways to correlate it with any of the other amphibolite masses in the Beaverlodge area.

The Jean Lake amphibolite unit is made up of several bodies. Between the Crackingstone River fault and Jean Lake it is represented by a large lenticular body that pinches out at both ends. Slightly northeast of Jean Lake and again about a mile south of the Crackingstone River fault it is replaced by two or three belts of smaller lenses of similar rock. These smaller lenses are, in both cases, interbedded with rocks of the Cayzor unit (17). Both the main mass and the small lenses are narrow, but all vary greatly in width, probably due to the lenticular nature of the bodies and also to variable vertical movement of the many transverse faults. The wide arc (note shape) of the main mass is believed to be due to a later period of folding, caused by forces acting in the same direction as those of the main deformation, although some of the curvature of the arc is possibly the result of displacements on the transverse faults.

The amphibolite is a massive to finely gneissic and rarely layered rock. Where layering was noted, it is irregular or contorted and drag-folded, probably indicating plastic deformation. The grain is generally fine to medium. The weathered surface is normally dark to bluish green or black, but near granite masses it is in various shades of brown. A fresh fracture is dark green to black. It consists mainly of hornblende, white to red feldspar, and occasional grains of quartz. Biotite was recognized near granite bodies where it is locally fairly abundant, particularly where pink feldspar is plentiful. This is probably a phase in the granitization of the amphibolite.

Under the microscope the amphibolite is a uniform-grained rock, composed mainly of fresh hornblende and slightly altered plagioclase. Quartz and an opaque mineral occur in tiny, uniformly distributed grains and constitute less than 10 per cent of the rock. Quartz and feldspar are interstitial to hornblende whereas the opaque mineral is usually contained in the hornblende. The hornblende is strongly pleochroic. It constitutes about 70 per cent of the rock and occurs in equidimensional grains with irregular outlines averaging 0.4 mm in diameter. The plagioclase is an andesine, and it and the hornblende are uniformly distributed. It occurs in small irregular grains and constitutes about 25 per cent of the rock. The following mineral count was obtained from a specimen near the Rix Leonard adit: hornblende, 68 per cent; andesine, 23 per cent; quartz, 5 per cent; and opaque mineral, 4 per cent. A few grains of pyrite and sphene were noted. Chlorite was also observed in tiny particles. Epidote occurs in thin, discontinuous short seams. Dawson (1956, p. 11), who made a thin section study of a specimen of this amphibolite 24 inches from a radioactive vein near the Rix Leonard adit, suggested the following mode for this rock: 9.6 per cent chlorite, 8.6 per cent biotite, 47.2 per cent hornblende, 6 per cent epidote, 20.8 per cent plagioclase, 1.2 per cent calcite, 6 per cent quartz, 0.6 per cent apatite, and traces of sphene and chalcedony.

Hand specimens were collected from the main amphibolite body between Rix Leonard adit and the Crackingstone River fault and were chemically analyzed (Table XX, No. 1). The results suggest a rock related to a gabbro or basalt if compared with the normal tholeiitic basalt of Nockolds (Table XX, No. 2).

The Jean Lake amphibolite is traversed by several dykes, sills, and irregular masses of granitic material (*see* Pl. 7). These are described with map-unit 19. Abundant seams of light green epidote traverse this amphibolite north of Jean Lake but not south of it, where seams of pink felsic material are more common.

TABLE XX *Chemical analysis of Jean Lake amphibolite (map-unit 16), in percentages*

	1	2		1	2
SiO_2	48.65	50.83	H_2O^+	1.84	.91
Al_2O_3	13.88	14.07	H_2O^-	0.08	
Fe_2O_3	2.97	2.88	TiO_2	1.77	2.03
FeO	11.38	9.06	P_2O_5	0.15	0.23
CaO	9.18	10.42	MnO	.24	.18
MgO	6.38	6.34	CO_2	.27	
Na_2O	2.48	2.23	Cr_2O_3	.02	
K_2O	0.95	0.82	Total	100.24	

Niggli Numbers	
al	19.2
fm	50.7
c	23.1
alk	7.1
si	114

1. Composite sample collected in the area between the Leonard adit and the west boundary of the map-area. Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
2. Normal tholeiitic basalt and dolerite, average of 137 analyses, S. R. Nockolds, 1954, p. 1201.

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PLATE 7. Massive to roughly gneissic amphibolite, Jean Lake amphibolite. Granitic material is in irregular masses veining the rocks. It is locally in seams parallel with the foliation.

Map-Unit 17: Cayzor Unit

The Cayzor unit (17) covers most of the area east of the Jean Lake amphibolite and west of the Black Bay fault. North of Cinch Lake its east boundary is the Black Bay fault, but south of the lake, west and south of Nero Lake, rocks belonging to this unit may outcrop east of the fault. If the quartzites near Nero Lake can be correlated with those north of the Black Bay fault, it is with those near the Black Bay fault, on the west shore of Fredette Lake, rather than those near the Jean Lake amphibolite (16). This is based on lithology only and not on rock succession because no horizon markers that could be correlated with rocks west of the Black Bay fault were recognized near Nero Lake.

At surface the Cayzor unit is about 3,000 feet wide southwest of Cinch Lake, more than 4,000 feet wide about Uranium City, and about the same west of Fredette Lake. This suggests that part of it has been cut off in the south by the Black Bay fault, or that there has been some thickening because of folding and faulting about Uranium City and that this thickening may also be true for the area west of Fredette Lake. The truncated part may be represented by the area already mentioned east of Black Bay fault around Nero Lake.

The Cayzor unit is made up of the same rock types as the Chance Lake unit (14), but the two are not believed to be parts of the same formation on opposite limbs of a large fold. As a complete description of these rock types was not given under the Chance Lake unit, it is presented here. The Cayzor unit is a thicker succession than the Chance Lake unit and covers a larger area, and exposures are better and more numerous. The relationship of the various rock types to each other is, however, the same here as it is in the Chance Lake unit, although in this area a facies change or a gradation is suggested. The chlorite content is higher near the Jean Lake amphibolite than near the Black Bay fault; that is, the rocks pass from a chlorite schist in the west to a quartzite void of mafic minerals in the east. In addition, the Cayzor rocks are more heavily granitized and more extensively cataclastically deformed than those of the Chance Lake unit. Indeed, most of the rocks of the Cayzor unit are now mylonite and ultramylonite. However, mylonites were also recognized on a minor scale in the Chance Lake unit, against the Boom Lake fault. As a late cataclastic effect, the mylonites of this area were brecciated and fractured near the Black Bay fault, and coarse breccia and heavily fractured rocks were formed. Locally it seems that they shattered, like glass.

The main rock types of the Cayzor unit, but not necessarily the mappable ones, are impure feldspathic quartzite, quartz–feldspar–chlorite schist and gneiss, augen gneiss, red massive granite, red foliated and gneissic granite, granitized quartzites and chlorite schist, granitic gneiss, amphibolite, diopside–carbonate rocks, several types of mafic-rich quartz–feldspar gneisses, and finally rocks that show various degrees of cataclastic effects.

Because of the scale of mapping, most of these rock types were not mapped separately, but a few assemblages were, generally with some indication of the predominant or most characteristic rock type. Most of these rocks were once sediments and occur mainly as beds, layers, and lenses, generally too narrow and too closely interbedded with each other to be mapped separately. Furthermore, most of the rocks grade into each other along and across the strike. They may be interfingered along their contacts or be so like each other in composition that even if they were large enough bodies to map separately, it would be very difficult, if not impossible, to do so, particularly in an area like this one where most of the rocks are heavily granitized and intensely deformed.

The rocks of the Cayzor unit were grouped for mapping into rock assemblages and types similar to those of the other units in the area between Boom Lake and Black Bay faults. The same classification was found suitable and in part applicable to the rocks of the Cayzor unit. The names used previously are retained but are qualified where it appears necessary to describe the rocks more fully. These mappable assemblages, in approximate order of abundance, are as follows: massive to foliated red granite; impure feldspathic quartzite and chlorite schist; thinly layered granitic gneiss; thinly layered dense and granitoid quartzite and schist; amphibolite; and diopside–carbonate rocks. All but the granites are described below.

Map-Unit 17a: Feldspathic Quartzite and Chlorite Schist

The feldspathic quartzite and the chlorite schist (17a) are described together here, because in the field it was not found practical to map them separately. Both rocks are too similar in composition and are too intimately interbedded and have reacted too similarly to the effects of granitization, to permit one to be distinguished from the other with certainty. It was also noted that they grade into each other, making their distinction almost impossible on this scale of mapping. Both rocks are interbedded with small amounts of glassy white quartzite and dark green amphibolite, and coarse-grained red granite is also present in large amounts.

The two rock types underlie most of the area east of the Jean Lake amphibolite unit, and together they constitute most of the known section above it. It is believed, however, that the distribution of the two rock types is not the same everywhere. Chlorite schist is common and widespread near the Jean Lake amphibolite, but farther up in the succession, that is, farther to the southeast toward the Black Bay fault, chlorite schist becomes less abundant and quartzite more so. Furthermore, much of the impure feldspathic quartzite appears to give place to a white weathering quartzite almost devoid of mafic minerals.

Many of these rocks are heavily granitized and intensely mylonitized, and more than half the area underlain by this unit is now granitic and mylonitic rocks. Near the Black Bay fault these rocks are brecciated and fractured as a late, superimposed effect. However, even in the area of granitic and mylonitic rocks, there still are remnants with the obvious characteristics of the feldspathic quartzite and chlorite schist. Locally such remnants form large lenticular masses or wide belts; a few were mapped with some success in the immediate vicinity of the Black Bay fault, particularly in the area extending from Uranium City northeasterly to the north boundary of the map-area. Such a wide belt was mapped a short distance west of the south end of Fredette Lake, and in it a pronounced layering was observed almost everywhere. The rock of this belt is composed of a succession of layers of about the same composition, exhibiting only slight variations in the mafic content of adjoining beds. In some places the layers may be of fairly pure quartzite but of various colours; in others the layers may be of different composition, such as chlorite schists and quartzite, in regular repetition just as in bedded rocks. In general, the chlorite schist in this belt is not so abundant as it is on the west, in the main zone of impure quartzite and chlorite schist against the Jean Lake amphibolite. It is also finer grained, and the augen structure, so typical of the main zone, is rare. It is, in part, also black to grey and resembles argillite. The quartzite layers appear to have a lower mafic content than the impure quartzite, so common in the main chlorite schist zone near the Jean Lake amphibolite and are more abundant here. Farther south toward Uranium City, lenses of chlorite schist were mapped on the possible extension of this wide belt. In these lenses. schist is the main rock type, and quartzite layers are few. The schist however is not so well layered as in the belt described above, and although it has large red feldspar crystals, the augen structure is not so obvious nor so typical as it is in the main zone near the Jean Lake amphibolite.

Other lenses of chlorite schist, mostly fairly heavily granitized or feldspathized, were traced and mapped in the area southwest of Uranium City, but many small ones not shown on the map are also present. A fairly large lens was recognized near Cinch Lake and is a good horizon marker, at least on the surface in the immediate area of Cinch Lake shaft.

The feldspathic quartzite is interbedded with, and grades into, the chlorite schist and has indeed a relatively high chlorite content. It is fine to medium grained, granular, massive, and dirty looking. Its weathered surface is light brown with patches of various shades of green and white. Fresh surfaces are glassy and dark brown or grey to black. On a weathered surface it was seen to be composed of grey quartz, white feldspar, and biotite or chlorite, or both, in rusty to green lenses and patches. The rock is faintly schistose locally, where it has more chlorite and biotite than usual and resembles the chlorite schist. This variety would indeed be mapped as chlorite schist if the typical chlorite schist predominated in the assemblage. This schistose quartzite appears to be transitional between the true feldspathic quartzite and the chlorite schist. A few quartzite beds are grey and fine grained, and are rich in biotite; they are really fine-grained quartz–feldspar–biotite gneisses.

Where the weathered surface of the rock is reddish brown, most of it is like the impure massive quartzite described above, but it has abundant streaks and lenses of chlorite, and patches, seams, and lenses of a massive coarse-grained red granite. Augens of red feldspar and white quartz are also present. This is regarded as a phase in the granitization of the quartzite. Where the impure quartzite is intensely granitized it becomes a coarse-grained red granite.

The chlorite schist is related to the impure quartzite as it grades into it; the two look much alike in outcrops. However, for descriptive purposes the two are described separately, even though the one may be but schistose parts or a chlorite-rich phase of the other. Indeed, the original rocks from which the two types were derived may have had slightly different compositions.

The term 'chlorite schist' is sometimes used here for a few small masses of typical chlorite schist present near large amphibolite masses but mainly for a rock that in general looks heterogeneous, is crudely foliated, and is partly schistose, chlorite rich, and dark green. On outcrops, the wide variation in colour and texture of this rock is probably due to its grading into quartzite and its intense granitization. Its colour on weathered surfaces is generally a dirty light green or yellowish green, and locally it may be of various shades of brown and grey with a greenish cast, or a light brown with numerous dirty green streaks and lines. A fresh fracture is green, greenish brown, and black. Where the rock is granitized or is rich in chlorite, the areas are brown on weathered surfaces. Locally, such areas are biotite schist zones. The parts that weather grey are those close to the feldspathic quartzite in composition, which carry somewhat more quartz and less chlorite than the rock normally mapped as chlorite schist.

The schistose, chlorite-rich part of this heterogeneous rock occurs in lenses, patches, and streaks. These are the typical chlorite schist, being dark green, and schistose, and are made up mainly of chlorite. These lenses, patches, and streaks are enclosed in a fine- to medium-grained, faintly schistose, light greenish brown host rock. This host rock, which constitutes the bulk of the rock, is made up of quartz, feldspar, and some chlorite. Indeed, it is the many chlorite schist lenses and streaks present and the amount of chlorite in the host rock that differentiate the chlorite schist from the feldspathic quartzite. The chlorite schist lenses are all aligned and in part are responsible for the foliation. The low chlorite content of this rock as a whole and the coarseness and abundance of quartz and feldspar in the host rock explain the crudeness of the schistosity in the outcrop.

The chlorite schist, like the impure quartzite, carries much granitic material as augens of feldspar and quartz, and as lenses, patches, and pods of coarse-grained red granite. The augens are generally less than half an inch in size (*see* Pl. 8). The lenses, patches, and pods may be in masses large enough to be mapped separately, and most are oriented parallel with the schistosity or foliation. The augens are locally fairly abundant and in general are most plentiful where the schist lies between lenses, patches, and pods of red granite. In all places they impart to the rock an augen structure. The amount of granitic material seems gradually to increase nearer the granite areas. This can readily be seen northeast of Jean Lake and also west of Fredette Lake.

Under the microscope, the feldspathic quartzite is a fresh looking rock, composed almost exclusively of quartz, oligoclase, and biotite or hornblende. Microcline, which may be present in small amounts, is believed to represent the first stage in the granitization of the quartzite. Chlorite may also be present but generally appears to be an alteration product after biotite or hornblende. Muscovite, interlayered with biotite and chlorite, occurs in small amounts. Accessory minerals are apatite, zircon, sphene, and opaque substances. Carbonate and epidote were also recognized locally and are probably introduced material or alteration products. Oligoclase constitutes between 29 and 44 per cent of the rock, averaging around 37 per cent. It is in irregular to roughly lensoid grains, generally less than 1.0 mm in size, averaging 0.5 by 0.3 mm. These grains are fairly evenly distributed and locally may be

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PLATE 8

Augen chlorite–quartz–feldspar gneiss, Cayzor unit. The augen structure is regarded as a step in granitization, in this instance of chlorite schist and impure feldspathic quartzite.

crudely aligned. They are also slightly altered to sericite. Interstitial to the oligoclase is quartz, which is the most abundant mineral, amounting to between 30 and 53 per cent of the rock and averaging 43 per cent. The quartz grains have a wavy extinction and are small, round, and less than 0.05 mm wide with a granoblastic texture, or as large as the oligoclase grains with sutured boundaries and an irregular shape. Biotite is generally reddish brown and interstitial to the feldspar grains surrounding them or oriented with the feldspar ovoids. This orientation explains the rough schistosity of the quartzite. The biotite content varies between 12 and 29 per cent, averaging about 19 per cent; where the mafic mineral is hornblende, its amount is about the same. Opaque substances account for 1 per cent of the rock.

In thin section, the chlorite schist is distinguished from the feldspathic quartzite by a pronounced fluidal or flow structure and generally by a higher mafic content. The flow structure is apparent in narrow and irregular layers of varying composition and on a still smaller scale by a much narrower layering in the mafic layers. The narrower mafic layers are wavy, in part lenticular and irregular, and are the ones responsible for the fluidal appearance of the rock. The mafic content is generally around 30 per cent but may be less locally, as this rock grades into the feldspathic quartzite. The other minerals are the same as those in the quartzite but generally occur in slightly different amounts. In some places the quartz content may be much lower; in others it may be the plagioclase that is much lower. Most of the chlorite schist studied had some potassic feldspar; therefore it may be that the rock is more easily granitized, at least in the early stages, than the quartzite. The mafic minerals are ordinarily chlorite and green biotite, with locally some hornblende and epidote. Some muscovite is present. The grain size in general is less than 0.5 mm, averaging 0.03 mm or of about the same as in the quartzite. Grains are larger only in the more granitized phases.

Map-Unit 17b: Amphibolite and Chlorite–Feldspar Gneiss

Masses and beds of amphibolite and of quartz–chlorite–feldspar gneiss occur at all levels in the succession of feldspathic quartzite and chlorite schist and are closely interbedded with them. Some occurrences are in short thick masses; others are in long narrow beds. A few have irregular ends. Most are of small extent, but some beds were traced along the strike more than 7,000 feet. The short thick bodies are mostly true amphibolite, whereas the beds are in part chlorite–feldspar gneiss, which may be a coarse-grained phase of the chlorite schist described above or an amphibolite granitized to a chlorite–feldspar gneiss. All the rocks of this unit weather green to black, are gneissic and foliated, and have a high mafic content. Most of the amphibolites have more than 70 per cent hornblende and close to 30 per cent oligoclase or a sodic andesine. Minor amounts of biotite, chlorite, and epidote (as an alteration product or as introduced material) are present. There are also some carbonate, opaque substances, zircon, apatite, and sphene. Epidote and sphene are found locally associated with chlorite. Hornblende is yellowish green and is uniformly distributed; it occurs in prismatic grains (less than 1 mm wide) with ragged edges. Its grains exhibit cataclastic effects. The feldspar is slightly altered and interstitial to hornblende. It occurs in very small grains as if intensely granulated. Some of the epidote, biotite, and chlorite are alteration products after hornblende, because they occur at its margins or are pseudomorphic after it.

The chlorite–feldspar gneiss has generally some quartz and, locally, green biotite. The specimens studied have a high feldspar content and show a mortar structure. In all cases, chlorite, biotite, and sphene are interstitial to feldspar and occur in the granulated material. Seams of chlorite and opaque substances were noted in these rocks. These seams are in turn cut by seams of either carbonate or quartz–albite.

Map-Unit 17c: Amphibole–Diopside–Carbonate Rock

This rock was recognized at three different places in the area between the Boom Lake and Black Bay faults, and all three occurrences are within the Cayzor unit. The main occurrence is a lens about 1,500 feet long by 100 feet wide, located approximately 1,200 feet southeast of Bushell. The second occurrence, lying about 1,500 feet east of St. Michael shaft, consists of two small lenses, less than 500 feet long and 100 feet wide. The third occurrence, located about 1,500 feet northeast of the northeast end of Jean Lake, is of three small lenticular bodies less than 500 by 100 feet in size.

In all three occurrences the lenses are within quartzites, locally slightly granitized, and in close association with small amphibolite masses. Locally, as in the occurrences east of St. Michael shaft, one of the lenses even grades into amphibolite. The occurrence east of Jean Lake not only lies within quartzite but in part grades into quartzitic rocks.

This diopside–carbonate rock is massive and coarse grained, light green on weathered surfaces, and yellowish to dark green on fresh fractures. The lens southeast of Bushell shows variations of composition. It is biotite rich at the west end, grades into amphibolitic rock in the east, and occurs in sharp contact with thinly bedded, locally hematite-rich quartzite. It is crossed by narrow seams of pink, fine-grained felsic and granitic material. The rock itself appears to be much granulated, and in thin section is seen to be composed of amphibole, mica, and feldspar. The hornblende is in large to small grains. The large grains are ragged in outline, up to several millimetres in size, and are much granulated. The feldspar is interstitial, granulated, and in grains generally less than 0.2 mm across. The rock in the slide is traversed by narrow zones of fine-grained, dense felsic material, believed to be material crushed to powder.

The lenses east of St. Michael shaft are made up mainly of a fibrous dark green amphibole in a matrix of somewhat lighter green, probably of diopside, feldspar, and carbonate. These lenses are in sharp contact with an amphibolite mass and are much granulated. They are also locally traversed by a white weathering material in the form of irregular lenses, veins, and masses, made up mainly of white to purplish pink feldspar and quartz. Only one mass was mapped east of Jean Lake, although the rock was recognized in at least three places. The mass is light green, very coarse grained, and massive. It is made up of large (up to 2 inches) diopside grains, closely packed in carbonate and feldspar and cut by a dense pink felsic material.

Map-Unit 17d: Granitic Layered Gneiss, Foot Bay Gneiss Type

Although this granitic layered gneiss (17d) occurs mainly west and southwest of Uranium City, small amounts were also mapped west of Fredette Lake. West and southwest of Uranium City it occurs in belts that were traced fairly continuously from near Jean Lake to Bushell or the southern boundary of the map-area. In the area between Jean Lake and Cinch Lake and north of the Crackingstone River fault, it is interlayered with, and occurs in, granite. South of this fault it is interlayered with quartzitic layered gneiss of the Donaldson Lake gneiss type (17e). The belts locally coalesce to form wide bands and subdivide once more farther along strike. West of Fredette Lake the gneiss is present in much smaller amounts and is in lenses or irregular masses in granite.

This rock is in general similar to the granitic layered gneisses in the other map-units of this area. Its contacts are all gradational, except those with amphibolite and glassy quartzite, which are sharp. As a rule this gneiss is a red weathering, fine- to medium-grained rock with a granitic appearance and a strikingly well-developed layered structure. This layered structure is the feature most apparent on outcrops and is characterized by layers of various colours and composition alternating with each other but without any regularity of succession. Close study has shown that, although most of the layering is strikingly fine, some broad layering is also present. The broad layering is not readily seen, but it probably represents original bedding; it is described later. The fine layers are generally less than an inch wide. They serve to accentuate the broad-layered structure with which they are parallel, but on many outcrops they are the only observable layered structure. This is particularly true for the layered structure of the granitic layered gneiss in the area between the Crackingstone River fault and the Lorado Road. In this area the layers are so thin and so closely spaced that they impart a crude schistosity to the rock. They are pencil-like markings less than half an inch apart. The general appearance of the rock suggests that it may have been a chlorite schist, now highly granitized and crushed. Two thin sections from rock of this zone have indicated that most of it is now either a protomylonite with a pronounced foliation or a mylonite. It is definitely a granitized rock or a rock related to the granite, since it carries much microcline. The quartz content, however, is generally low. Two modes gave the following average: quartz, 13; albite–oligoclase, 37; microcline perthite, 37; chlorite, 8; opaque material, 4; and epidote, muscovite, apatite, and zircon, 1.

The broad-layered structure mentioned above is not always easily seen as the rock types forming adjacent layers may be very similar in composition. Some of the features recognized on the outcrop are, however, given below; they may be clues to the original nature of the rocks and may help to define this broad layering. Four different types of layers were noted:

1. Some with a smoothly polished bright red weathered surface are composed mainly of quartz and feldspar. In these, mafic minerals are scarce or absent. A fine-layered structure defined by layers of white quartz alternating with feldspar layers of various shades of red, all in an irregular succession, characterizes these felsic layers. They are now actually granitic gneiss but were probably quartzitic rocks originally.

2. Some layers that resemble a granitized sedimentary rock are fine-grained, granular, quartz–feldspar–chlorite gneiss. They have a rough, brownish red, weathered surface, and a high chlorite content, and they display a rough layering; that is, the boundary between layers is not sharp.

3. Some layers have light brown, rough weathered surfaces. In these the mafic content is low, and the mafic minerals are distributed irregularly and in pods and broken lines. Their fine-layered structure is also poorly developed, it being really, as in No. 2 above, a gneissosity or a crude schistosity.

4. Finally some of the layers are narrow and discontinuous, are rich in biotite and/or hornblende, and are actually mafic layers.

Map-Unit 17e: Quartzitic Layered Gneiss of the Donaldson Lake Gneiss Type

Quartzitic layered gneiss (17e) is another rock type found abundantly in the Cayzor unit. It occurs in long lenticular masses and wide belts in, and interbedded with, chlorite schist, feldspathic quartzite, and granitic layered gneiss. It is a main constituent of the granitic layered gneiss (17d) constituting most of the felsic layers that were described with the broad layered structure of 17d. It occurs also in the red granite as small and large irregular masses and forms an almost continuous belt along the southern part of the Black Bay fault and adjoining it to the northwest. The quartzitic gneiss constitutes about 50 per cent of the Cayzor unit south of the Crackingstone River fault. It is rare around and west of Uranium City but is fairly common south and east of Pluton Lake.

It resembles the quartzitic layered gneiss of the Rix (15a) and other units of this area and probably has a similar origin. It is made up of the same minerals, but it generally appears to be more granitized. Structurally, it is not so well bedded but is generally more finely layered. As much of this gneiss has been intensely granulated, the grain size, too, varies more. Nevertheless it seemed necessary to use the same rock name, even if this map-unit occurs at different stratigraphic levels.

The rock is generally white weathering and is locally buff, pink, and reddish white. It is highly siliceous and carries very little or no chlorite and biotite. Much of it is dense and cherty, but some is coarse grained and granitoid.

The dense siliceous type is a rock crushed to a powder and forms wide zones against, along, and near the Black Bay fault; much of it is interlayered with the granitic layered gneiss south of the Crackingstone River fault. Its other occurrences are small. This dense rock is, in general, fairly homogeneous but in detail is strikingly heterogeneous. It is composed of patches and zones displaying a coarse-grained granitoid texture in a dense matrix, which accounts for more than 60 per cent of the rock. The granitoid parts of the rocks are those that have not been granulated and crushed to a powder.

The coarse-grained granitoid component of this layered gneiss (17e) (not of the dense rock) resembles the white weathering, massive, granitoid part of the Donaldson Lake gneiss (2). Many of the more westerly belts, particularly the irregular patches south and east of Pluton Lake, are of this type and resemble white granite. This granitoid rock is homogeneous over large areas, but much of it is in wide layers interbedded with much narrower beds of glassy white quartzite and with layers of mafic-rich gneiss and schist. Similarly, the dense siliceous rock has zones somewhat more quartzose or feldspathic and others (fairly narrow) high in chlorite. Thus, in general the quartzitic layered gneiss (17e) is also finely layered. In it, the layers, generally less than a quarter of an inch wide, are made up of white quartz or of pink, red, reddish white, and orange feldspar, or quartz and feldspar. Locally, chlorite may be present as tiny specks oriented parallel with the layers. Rocks forming this quartzitic gneiss, which are feldspathized to various degrees, locally grade into red granite. All are believed to be derived from a granitized feldspathic quartzite. Thin sections of the dense rock are of mylonite, ultramylonite, and augen mylonite; most of them exhibit a strong foliation. Those from the granitoid rock are fresh looking and are only slightly granulated; they are also allotriomorphic granular but are really protomylonite. Grain counts made on eight specimens of the granitoid rock and on two of the dense rock gave the average modes presented in Table XXI.

Feldspars are in grains up to 3 mm wide. The microcline is generally fresh and in grains interstitial to oligoclase. Where it is in contact with oligoclase, it presents a wavy outline;

TABLE XXI *Average modes of quartzitic layered gneiss (map-unit 17e)*

Number of thin sections studied	6	2	2 (dense)
	Range %	Range %	%
Albite–oligoclase	30(24–37)	6(5–7)	21
Microcline	29(18–40)	60(53–66)	52
Quartz	35(25–42)	32(28–37)	20
Chlorite	6(3–10)	2(0–3)	6
Opaque			1
Rock composition	quartz monzonite	granite	granite

sometimes it is separated by a narrow zone of myrmekitic intergrowth. The oligoclase is altered, and its grains are small and equant or large and irregular. The small grains occur in microcline. They may be relicts or indicate a second generation. Quartz is interstitial and in small grains exhibits imbricate structure. Part of it is in large recrystallized patches. Chlorite is mainly secondary, most after biotite but some after garnet. Biotite is present locally. Small amounts of muscovite, sphene, zircon, and opaque substances were noted.

Map-Unit 17f: Cataclastic Rocks

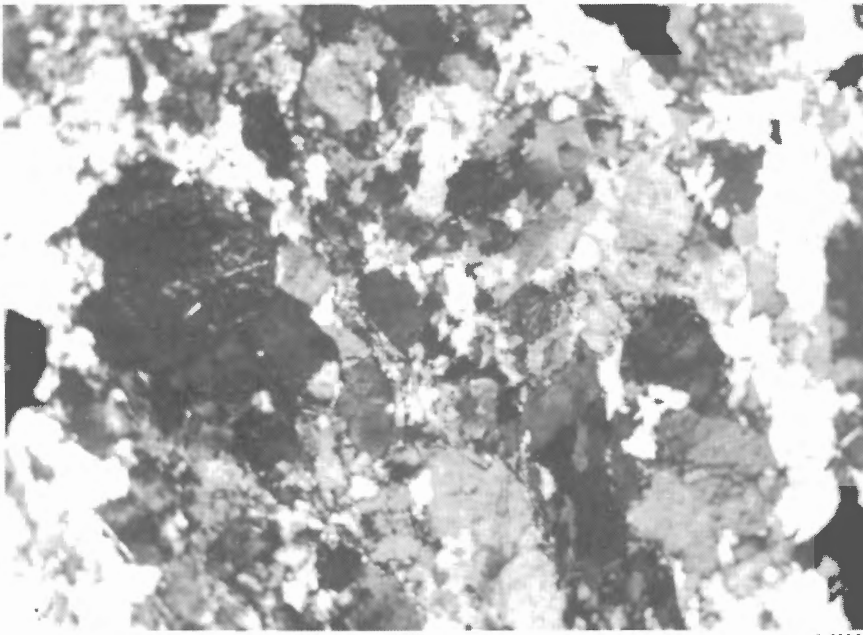
Most of the rocks of the Cayzor unit (17) have been intensely crushed. The intensity of crushing is at its greatest in a wide zone about parallel with the Black Bay fault and decreases gradually to the northwest; indeed, the rocks near the Jean Lake amphibolite are in places not crushed at all. Thus, the Cayzor unit can also be classified according to the intensity of crushing and granulation exhibited by the rocks. For this purpose, certain units were selected and arbitrary limits were assigned. It was necessary to make these limits as broad as possible because in the field more attention was paid to the nature of the rock than to the intensity of crushing. The intensity of crushing was, however, recorded so far as it could be noted in the field from outcrops or hand specimens, and later from a few thin sections. The limits chosen allowed separation of the rocks into three main divisions: 1. uncrushed rock, 2. protomylonite or partly crushed rock, and 3. mylonite, augen mylonite, and ultramylonite or rocks crushed almost to a powder. These rock types reflect a progressive increase in crushing or granulation from uncrushed rock to a rock that was almost powdered. These three divisions were distinguished at many places in the field but unfortunately not everywhere; only two divisions could profitably be shown on the map. One division comprises uncrushed and partly crushed rocks only, and these are the rocks typical of the succession in this area. The other includes the mylonite, augen mylonite, and ultramylonite, or all the heavily brecciated and mylonitized rocks. On the outcrop it was not always possible to evaluate the intensity of granulation and consequently to distinguish uncrushed rocks from protomylonite. As their mutual boundary could rarely be recognized, the two were perforce mapped together. Thin sections might have helped to locate this boundary but would not have solved all difficulties, as the problem is further complicated by the heterogeneous nature of the Cayzor unit. This unit is composed of many different rock types, all interbedded. Since not all rock types react similarly to stress, the end products of adjoining rock types may be very different. It is possible that much finer distinctions could have been made, but it is questionable if the resulting pattern would have been meaningful.

In thin sections of the uncrushed rock, granulation is lacking or is incipient at only a few spots and is not a distintictive feature of these rocks as it is in the protomylonite and mylonite (*see* Pl. 9).

A protomylonite is a rock transitional between the uncrushed rock and the mylonite, that is, a partly crushed rock. Locally, it is interlayered with mylonite or uncrushed rock, and there, particularly on outcrops, it is impossible to outline the extent of the protomylonite zone. If thin sections are available, however, it can generally be distinguished from the uncrushed rock because the amount of granulation and the intensity of crushing can readily be determined. Where a protomylonite is nearly a mylonite, however, the two can readily be distinguished on the outcrop, because in the protomylonite some of the original nature of the rock is still recognizable. In thin section the partly crushed rock shows mortar structure; that is, it still retains in general its original appearance, but granulation is a characteristic feature. The entity of the rock is thus not completely destroyed, even if the rock is clearly a breccia made up of angular fragments of the original rock, hardly disturbed and fairly closely spaced, but separated from each other by a narrow zone of crushed or granulated material.

PLATES 9 to 15

Cataclastic granitized rocks from area extending from Black Bay fault northwest to the Jean Lake amphibolite. All stages from uncrushed rock to mylonite, ultramylonite, rebrecciated mylonite are displayed. Crossed nicols. Enlarged about 30 times.



112122C

PLATE 9. Incipient crushing or granulation.

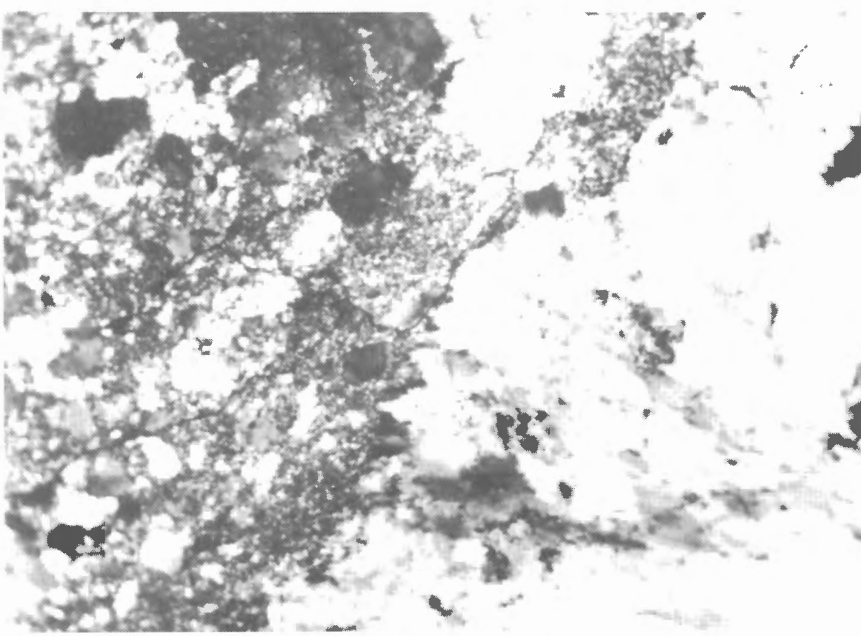


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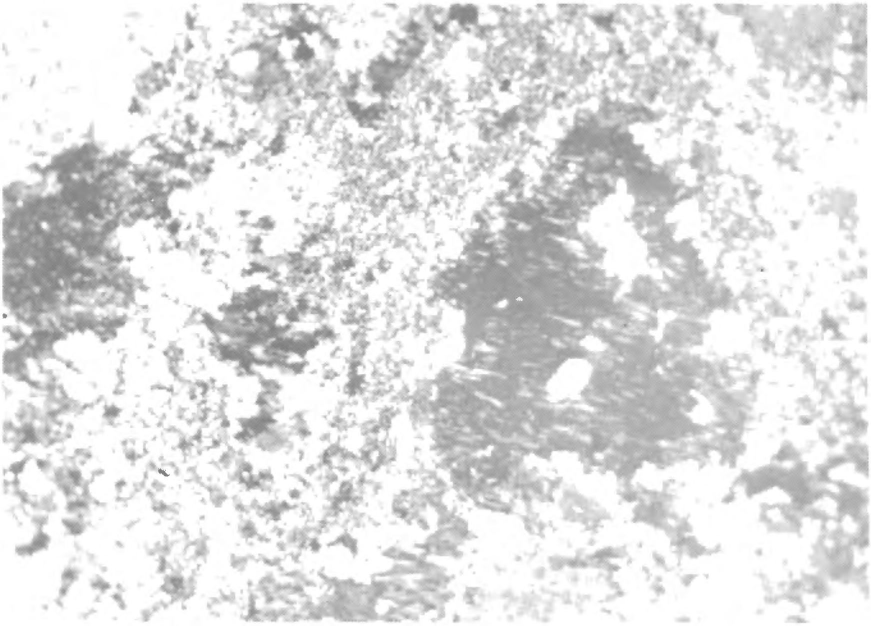
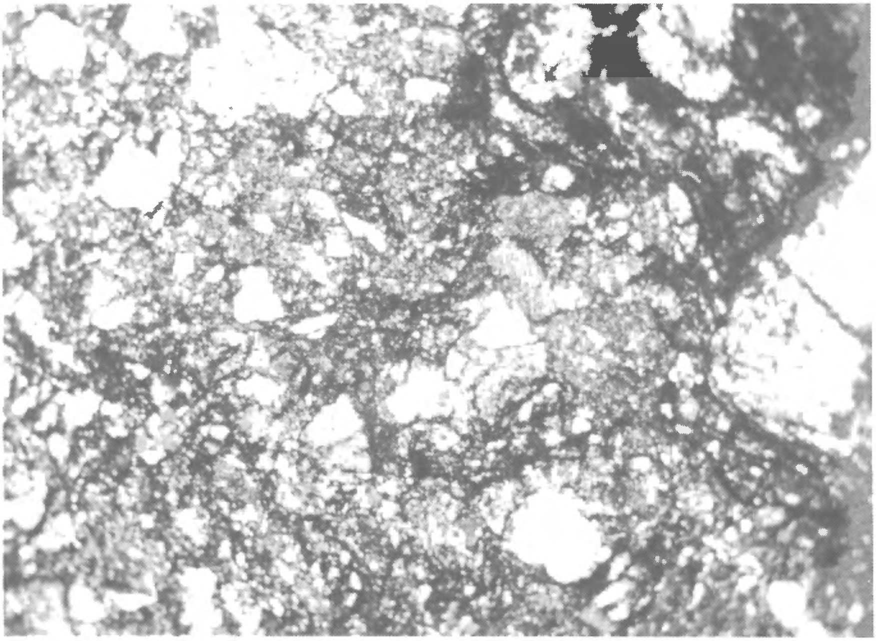
PLATE 10. Largel oca area of uncrushed rock entirely enclosed in crushed material.



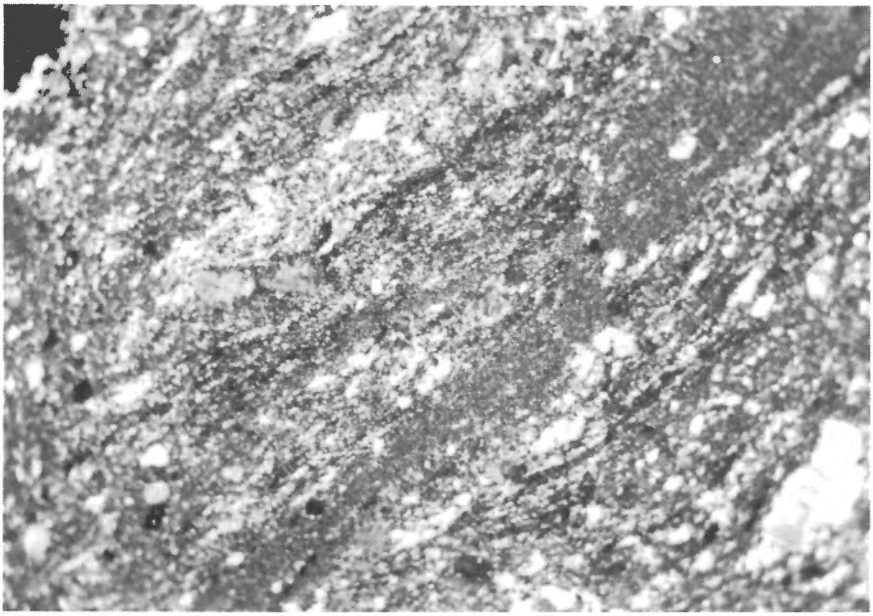
112122I

PLATE 11. Mortar structure. A large microcline cataclast visible along the right edge of photograph.



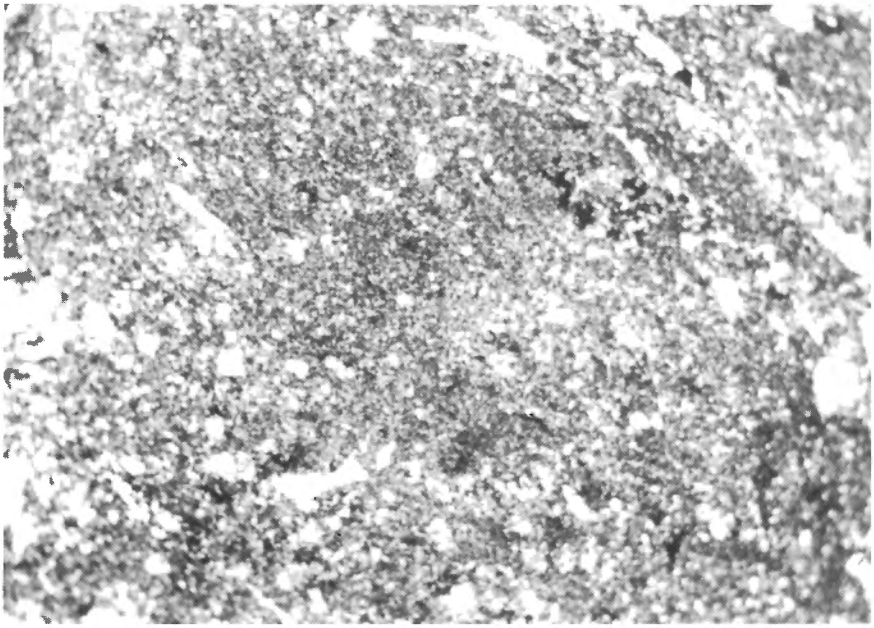
112122B

PLATE 12. Mylonite; rock entirely crushed. No flow structure, only fragments of slightly different size.



112122E

PLATE 13. Mylonite. Flow structure well displayed.



112122G

PLATE 14. Ultramylonite. Recrystallization of quartz and development of some flow structure locally.

PLATE 15

Hand specimen of mylonite from near and northwest of Black Bay fault. Rock is dense, reddish, and layered. Tiny white specks scattered all over surface of specimen are feldspar (mainly microcline) cataclasts. Natural size.

112121D

A mylonite may be suspected in the field, but in general it is only in thin section that it can definitely be recognized. However, its presence in this area has already been reported by Christie (1953), Dawson (1956), and Conybeare (1951). A mylonite is a rock crushed almost completely to a powder. It generally exhibits a flow structure and carries a few large fragments of the original rock (*see* Pls. 10, 11). The flow structure is, however, not always present (*see* Pl. 12), at least not on the scale of a thin section. In this area, the flow structure is expressed by lenses and streaks of recrystallized quartz, by concentrations of the small amount of dark minerals into streaks and lines, by alignment of fragments, and by streaks of crushed material of assorted sizes (*see* Pl. 13). The fragments are generally angular. They average 1 mm in width and rest in finely crushed material, averaging less than 0.05 mm in size. The greater number is mainly or entirely feldspar, most commonly microcline, but some are of quartz.

If the fragments are lensoid or ovoid in shape and tend to be aligned, the rock is slightly different in appearance and could be called an augen mylonite. If, on the other hand, the entire rock has been reduced to a powder and if the flow structure is strikingly well developed, partly as a result of solution and recrystallization, the rock is called an ultramylonite (*see* Pl. 14). On the outcrop, these varieties of mylonite cannot be distinguished from each other, because they all look alike except in very rare cases. However, the augen mylonite generally seems to carry more mafic minerals than the ordinary mylonite, but the ultramylonite looks more like quartzite. It is better layered or foliated and resembles a thinly bedded quartzite.

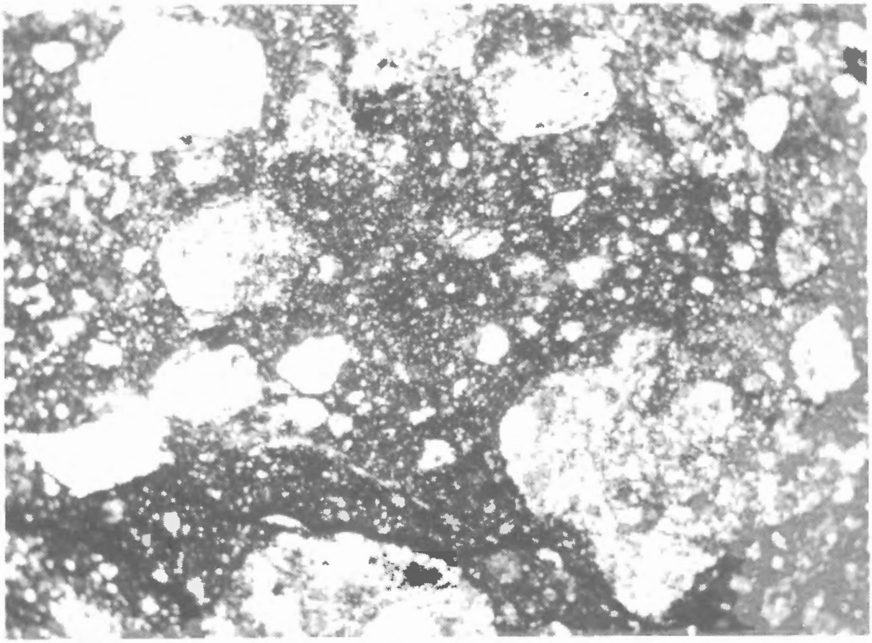
On the outcrop the mylonite of this area is hard, well jointed, and fresh looking. Locally it has a baked appearance. It is remarkably well and thinly foliated, this foliation being really a pronounced and fine-layered structure. The colour is satin-red, but locally it is orange, pink, light red, and various shades of light brown. The rock itself is dense, cherty, and quartzitic in appearance; in fact, the grain is so fine that it is generally not discernible with the naked eye. Numerous tiny white specks can, however, readily be seen on weathered surfaces (*see* Pl. 15). These specks are widely scattered through the dense mass and are less than one-sixteenth inch in size. As seen in thin sections, these specks are feldspar fragments and represent the cataclasts of the mylonite.

The layered structure of foliation mentioned above is a fairly uniform feature, generally readily noted. It is characterized by layers of various colours, which are usually less than a quarter of an inch wide. These colours are due to concentrations or segregation of various minerals, generally quartz and/or feldspar but locally chlorite and sericite. In places, as on the northwest shore of Cinch Lake, the rock shows very little variation in colour, and its foliation is so fine that it can be recognized only after close inspection. It is there represented by hair-like lines of quartz in parallel orientation. Locally this fine foliation is associated with a slightly coarser foliation, that is, where a structure resembling that of a thinly bedded sediment is also present. These rocks are grey and when first seen were thought to be thinly bedded grey quartzite. However, from an examination of a few thin sections it was found that they are really ultramylonite or partly fused mylonite.

The dense rock constitutes the major part of the mylonite zone. In it, however, there are locally small areas of rock carrying slightly more quartz than the rocks of the zone proper. These areas have gradational contacts. In the field the rocks were thought to be remnants of quartzite beds not entirely changed by granitization and mylonitization. However two thin sections have shown that the quartz in them has been recrystallized more extensively, giving rise to larger patches of quartz. They may of course be metamorphic segregations, but their occurrence, distribution, frequency, and association indicate that they were originally more siliceous zones, perhaps beds or lenses.

Within this dense rock, and grading into it, are also various-sized patches of a crude granitoid rock. These patches are made up mainly of grey and white quartz and red feldspar, and, although they are fairly common and can be readily noted, they do not ordinarily constitute more than 20 per cent of the mylonite zone. As seen under the microscope, these patches are made up of relatively uncrushed material. They are considered to be uncrushed remnants of the original rock, not patches of late formed rock, that is the product of a late granitization subsequent to the mylonite formation. Indeed the main period of granitization is definitely earlier than the mylonite, and nowhere else in the area is late granitization even suggested.

A white milky quartz, intergrown with some of red feldspar, is common in these granitoid patches. This milky quartz is also locally connected with larger bodies such as blebs, dots, seams, veins, and fracture fillings of white quartz in the dense rock. This quartz is of late formation. It may be that it was mobile enough to move and that it was deposited where it occurs. It may represent reactivated or remobilized quartz, produced by solution and recrystallization in the mylonite zone and closely associated with the late deformations along the Black Bay fault, which produced intense brecciation and fracturing (*see* Pl. 16).



112122A

PLATE 16. Crushed mylonite; fragments are mylonite. Specimen from close to Black Bay fault.

Locally the faintly layered dense rock of the mylonite zone is dark grey and black and much resembles an argillite. Such argillite-like rocks were recognized at irregular intervals forming narrow layers or zones about parallel with the Black Bay fault or the main mylonite zone. None could be traced very far along the strike. They are of various widths and are somewhat lenticular. When first seen they were considered to be ordinary beds, but a few thin sections indicate that they are really flinty, crushed rock. They probably represent zones of maximum crushing. These layers or zones were not mapped separately. They trend parallel with the Black Bay fault or the main mylonite zone, and their presence at irregular intervals suggests the type of deformation (*see* section on structure) responsible for the abundance and extent of mylonitic rocks in this area. They may possibly also indicate a late cataclastic deformation subsequent to the formation of the main mylonite zone, but this is unlikely as movement later than the formation of mylonite mainly resulted in brecciation.

The results of grain counts on two specimens of this dense rock, from localities where the rock appears to have been originally a highly granitized quartzite or a red granite, are shown in Table XXI.

The main zone of mylonite along the Black Bay fault is believed to have formed at the expense of a sedimentary succession, predominantly quartzitic and already in places highly granitized or altered to red granite. This is indicated by—

1. The broad succession of the various rock types in wide lenticular zones, elongated and oriented parallel with each other, and also their interlayering and their interfingering on a broad scale. The various rock types also suggest a progressive change in the nature of the rocks from west to east, from a schist to a quartzite, suggesting a lateral and vertical gradation in the nature of the rock.

2. The layering of the same rock types on a much smaller scale, their close interlayering and interfingering, and the gradual change from one rock type to another.

3. The presence here and there of an occasional quartzite bed or of layers of chlorite schist and quartz–biotite schist, rarely garnetiferous. These rocks are interbedded just as in a sedimentary succession.

4. The quartzose and siliceous nature of the rocks locally, their well-jointed light coloured weathered surface, and their cherty appearance, which call to mind the white quartzite of the Beaverlodge area as a whole.

5. The fragments in the mylonite. These are microcline, microcline perthite, plagioclase, and locally quartz. They suggest that the original rocks were granite, granitized quartzite, and feldspathic quartzite or schist.

6. The folds, outlined by measuring the strike and dip of the foliation, which suggest that it is probably relict bedding. These folds are too uniform all through this mylonite zone not to represent an original folded sedimentary succession.

Map-Unit 18: Uranium City Amphibolite

The Uranium City amphibolite (18) is composed of several amphibolite masses all at approximately the same stratigraphic level within the Cayzor unit (17) and near the Black Bay fault. Its limits are determined by the boundaries of the various masses, which are of different sizes and shapes but are mainly lenticular. These masses form a zone or a belt that extends from the northern boundary of the map-area to a point slightly south of Uranium City where they are cut off by the Black Bay fault. The extension of this belt south of the Black Bay fault has not been picked up in this map-area. Although these masses are very similar to others in the Beaverlodge area, no correlation is possible because all are at different stratigraphic levels. Even if they were related and even if their present positions were due to repetitions by folding and faulting, it cannot be proved, because no individual masses of distinctive appearance could be recognized.

The largest masses of Uranium City amphibolite are those northeast of the city. These are up to 500 feet wide and were traced for at least 2 miles from the city to Fredette Lake. North and south of these masses, the amphibolite bodies are much smaller and more irregular, but as they appear to be on the extension of the larger masses they are assumed to be parts of the same belt.

The rocks of this unit (18) are massive and foliated to gneissic. Locally, particularly near the Black Bay fault, they are not only granulated but also coarsely fractured and brecciated as a late superimposed feature. The grain is medium to coarse, rarely fine. In colour the rocks are dark green to shades of brown on weathered surfaces and dark green to black on fresh fractures. The brown colour is in patches. The rocks are mainly amphibolite, hornblende–feldspar gneiss, and hornblende–feldspar–chlorite–epidote gneiss. As seen in outcrops, they are composed mainly of dark green hornblende, white to buff feldspar, and much epidote and chlorite in the brown weathering patches.

Under the microscope, the amphibolite is fresh looking and fine grained. The hornblende is in small blocky grains averaging 0.7 by 0.3 mm but locally up to 1.0 by 0.5 mm. Hornblende is the most abundant mineral, forming over 60 per cent of the rock and locally as much as 90 per cent. It is dark green, fresh, and aligned. In altered areas, the hornblende is either completely discoloured and much altered to chlorite, or much of it is fibrous. Some of it is locally granulated. Where it is fractured, it is traversed by numerous seams of chlorite, epidote, carbonate, and quartz–albite. Feldspar is next to hornblende in abundance and is interstitial to it. It is an albite–oligoclase, most of it slightly altered to sericite. There are also small amounts of apatite, sphene, zircon, epidote, chlorite, carbonate, and of an opaque mineral. The opaque substance is closely associated with the hornblende and is usually iron oxide, rarely pyrite. Apatite and zircon are accessory minerals. Chlorite is an alteration product after hornblende. Some of it is in the form of veinlets and seams along fractures in the heavily fractured rock or as irregular grains and flakes in the granulated areas. Sphene is a close associate of chlorite. Epidote is present in large agglomerations and as veinlets and seams. Clear albite, usually associated with some quartz, was noted as veinlets, seams, and locally as small round patches. The chlorite and the epidote veinlets are in part earlier and in part later than the other veinlets.

Mineral counts on three specimens of this amphibolite gave the average mineral composition shown in Table XXII.

Like the other amphibolites of the area, all the amphibolite masses of this belt are cut by numerous coarse-grained red granite dykes and sills. This granite is not described here as it is not different from the red granite of the Rix unit. It is locally pegmatitic.

TABLE XXII | *Average mineral composition of Uranium City amphibolite* (*map-unit 18*), *in percentages*

Hornblende	62
Plagioclase	30
Opaque	2
Chlorite	1
Epidote	3
Carbonate	1
Apatite	tr
Sphene	1
Zircon	tr
Pyrite	tr

Metasomatic Granite (Map-Unit 19)

Metasomatic granite (19) is widespread in the Beaverlodge area; indeed, the areas of granite shown on the map constitute about 15 per cent of the whole area. Granite is abundant in all rock types of the Tazin Group but was not seen in the Martin Formation or cutting the gabbro dykes and sills (27). In the area north of the St. Louis fault, four large granite areas are shown on the map: the first south of Virgin Lake; the second about Eagle shaft; the third between Ace, Eagle, and Beaverlodge Lakes; and finally the area between Verna, Donaldson and Raggs Lakes. South of St. Louis fault, only one large area, the one east of Fookes and Fulton Lakes, is shown. Between the Black Bay and Boom Lake faults a wide belt of granite, extending almost the whole length of the Cayzor unit, is shown, together with several small masses in the Jean Lake amphibolite and the Rix unit. The granite areas mapped northwest of Boom Lake fault are all small. The above large granite areas are each described separately, but all the small bodies within a single map-unit are described together, even though some of them are shown on the map. They are small and are considered to be related to the large bodies that occur nearby. As these are described fully, no separate descriptions of the small areas are regarded as necessary.

Much granite also occurs as layers or sills, dykes, and patches in the granitized rocks of the map-area, particularly in the granitic layered gneisses. This granite is an integral part of the granitized rocks and was described with them. In any case, this granite is very similar to the granites of the large areas.

Several types of granite were distinguished, namely: the normal type, the gneissic and foliated, the impure hybrid, the brecciated, and the carbonatized. These main types were distinguished in the field, and where they occupied sufficiently large areas and where the rock was sufficiently characteristic, their areas were outlined and they were mapped separately. The normal granite is by far the most common type in all granite areas. The gneissic and foliated granite is particularly abundant northwest of Black Bay fault, and large areas of carbonatized granite are known in the area north of St. Louis fault. The hybrid granite is widespread mainly in the area both north and south of St. Louis fault. The brecciated granite was recognized abundantly almost everywhere but particularly in the area between the Boom Lake and Black Bay faults and north of St. Louis fault.

All these granites are believed to be derived by granitization from pre-existing rocks. The nature of the pre-existing rocks and the intensity of granitization determine the type of granite present. The hybrid granite and the gneissic and foliated granite represent intermediate stages in the process of granitization, the ultimate stage being normal granite. All these granites grade into each other and into most of the other granitized rock types. However, with rock types such as amphibolite and quartzite, their contacts may be sharp. In general the nature of the pre-existing rocks can be determined. Thus, the granite in the areas south of Virgin Lake and about Eagle shaft was developed at the expense of the buff quartzite (5), the granite at the apex of the Ace – Donaldson Lakes anticline at the expense of the quartzite–chlorite schist unit (3), and the granite in the large area northwest of and near the Black Bay fault from the Cayzor unit (17). However, in some places for example, the granite mass along and north of St. Louis fault, it is not possible to determine with certainty the nature of the original rock. In general it appears as if granite bodies are more numerous and larger in areas of quartzite than in areas of other rock types such as amphibolite and chlorite schist.

The normal granite is a red, medium- to coarse-grained massive rock, made up mainly of milky white quartz, red feldspars, and less than 5 per cent chlorite. Rarely, the mafic mineral is hornblende. The white quartz occurs as large irregular grains, crude segregations, seams, and lenses, and in many instances it has a wormy appearance. Feldspar is plentiful locally. In general this granite resembles an igneous rock and is definitely granitoid but grades into the other granite types.

Although the gneissic granite resembles the normal granite it is characterized by a faint, fine gneissic structure. Compared with the normal granite, its grain is somewhat finer, its mafic mineral content is somewhat higher, and its dark minerals definitely are better aligned and locally faintly segregated or concentrated in thin lines.

The impure hybrid granite is characterized by a higher mafic mineral content than the gneissic granite, by a more pronounced gneissic structure, by a larger number of schlieren in all phases of transformation and alteration, by ghost effects and relicts of structure such as bedding, and locally by the presence of white feldspar porphyroblasts. The weathered surface of this granite is generally rough because quartz and feldspar grains stand out in relief and form spots, streaks, and fine ridges that are in sharp contrast to the smooth surface of the normal granite and the finely gneissic effect of the gneissic granite.

The foliated or layered granite is related to the gneissic and the impure hybrid granites. It grades over short distances into them or passes into normal granite through a narrow zone of the gneissic and hybrid granites. Compared with these granites, the layered type has a slightly higher content of dark minerals, a more pronounced and better developed gneissic and layered structure, and a somewhat finer grain. In the layered granite the dark minerals are concentrated, possibly segregated, in lenses, lines, streaks, and layers, which are repeated several times at irregular intervals. These alternate with red to reddish white layers composed either of quartz or feldspar, or both. On account of this pronounced layering, the granite closely resembles the granitic layered gneiss (Foot Bay type), recognized and mapped abundantly in the map-area. In many instances it is not possible to distinguish between the two, and depending on the association, extent, and location in the stratigraphic succession of the occurrence, it was mapped either as granite or as layered gneiss.

The carbonatized granite is a rock related to the normal, hybrid, and brecciated granites, as it was found with them. It is coarse grained, massive, and lighter red than the normal granite. It is made up mainly of red feldspar and carbonate, generally calcite, with minor chlorite and quartz. Its weathered surfaces are pitty and spongy due to the weathering out of the carbonate. Its quartz content appears to be lower than that of the normal granite, seemingly as a result of its replacement by calcite. Its chlorite content, on the other hand, appears to be somewhat higher. This granite occurs in large irregular areas, lenses, elongated masses or belts, and small irregular patches, all grading into the rocks in which they are found. The carbonate content varies from place to place, and a granite with a high carbonate content may grade into one almost completely devoid of carbonate over distances that vary appreciably from place to place. Transitions generally take place within a few feet, and it appears that the carbonate content of the transition zone decreases very rapidly at first, then slowly until it passes to a granite that has no visible carbonate in the hand specimen. The location and intensity of carbonatization seems to be controlled by a system of parallel, unevenly spaced fractures, and possibly by local variations in the rock being carbonatized and by its intensity of brecciation.

The brecciated granite is a rock derived from all the other granite types except the carbonatized variety. It is generally a somewhat deeper red than the others. Its chlorite content varies, and its weathered surface is rough, displaying fragments of granites of various sizes in a matrix of finely crushed granitic material. The fragments generally stand out in relief. They may be sparse or abundant and are lighter red than the matrix, which is reddish brown and black. Where the fragments are abundant, they may be so closely packed that they have only a thin film of brecciated material separating them, and the brecciated nature of the rock may be obscure. On the other hand, where the fragments are sparse, the rock becomes an accumulation of crushed material or a mylonite. As seen in thin sections, the first indications of brecciation in a massive granite are fractures across and offsetting twin lamellae in albite, undulatory extinction in quartz and albite, and incipient brecciation of protuberances at the meeting points of several minerals. At a stage of brecciation a little more advanced, the rock is traversed by definite zones of brecciated material, and in the more massive part of the rock a narrow zone of brecciated material may occur at the boundary of the mineral grains. This narrow zone may vary in width and may be present or not, according to the degree of brecciation. At a still more advanced stage, the whole rock is a mass of brecciated material. Large and small closely packed fragments of all kinds rest in a matrix of finely crushed powdery material. The final stage of brecciation is a rock where the finely crushed material forming the matrix in the less severe stages of brecciation is the main, and locally almost the sole, constituent of the rock, with only scattered small fragments of microcline and quartz here and there. This is regarded as a mylonite without the typical flow structure. In many instances quartz has recrystallized and assumed the imbricate structure described previously; that is, the quartz has been entirely crushed and has recrystallized into lenses or clusters of fine-grained round particles.

Granite in the Area North of St. Louis – ABC Fault

Granite South of Virgin Lake

The limits of this granite area are the northern boundary of the map-area at Virgin Lake, the Tazin–Martin unconformity east of Fredette Lake on the west, the assumed Mic Lake fault or quartzite and hornblende schist on the south, and buff quartzite (5) on the east. In the eastern half and southern part of this granite area, remnants of ungranitized buff quartzite are common, and toward the south the granite is interfingered and interlayered with buff quartzite (5).

The granite of this area is mainly the normal type. Brecciated granite is fairly abundant west and southwest of Virgin Lake where it occurs in masses large enough to be mapped separately. The Baska adit on Virgin Lake is in such a mass. In general, however, the brecciated granite occurs within the normal granite in irregular patches, too small to be mapped.

Locally some of the granite is hybrid, and in other places it is finely gneissic to coarsely layered and resembles the Foot Bay gneiss (1).

Most of the normal granite of this area has probably formed at the expense of the buff quartzite (5); many remnants of the buff quartzite, of all sizes and still seemingly in their original position, are present in it, and many are indeed mapped separately. Their contacts with the granite are always gradational and diffuse within a few feet. Much of the rock in both the granite and quartzite remnants is dense, glassy, and red, with only an incipient granite texture, and the quartzite remnants contain numerous irregular, large to small patches of the red granite. Both rocks are also similarly brecciated, and foliation in both is of the same nature and has the same attitude, as if one was a relict structure of the other. All these features suggest that the granite was derived from the buff quartzite by direct recrystallization, possibly with the addition and removal of some material. The end product is the normal granite.

The other granitic rocks in this area, such as the hybrid granite and the gneissic and layered granites, were probably derived from rocks originally somewhat different in composition, probably a rock that did not granitize so readily as the buff quartzite.

The thin sections of these granites were studied. All seem to be made up of the same minerals in about the same proportions, but because of brecciation it was not always possible to estimate accurately the amount of the various minerals. The main constituent minerals are quartz, albite, and microcline, and all three show the effects of brecciation, although the intensity of brecciation varies greatly. These constituent minerals form 95 per cent of the rock; quartz forms between 20 and 30 per cent, microcline around 30 per cent, and albite about 40 per cent.

Microcline is in grains up to 5 by 2 mm. It is generally fresh, perthitic, and earlier than albite and quartz. Quartz occurs in long narrow parallel streaks, lenses, and patches of recrystallized quartz up to 5 by 1 mm in size. These and the pattern of brecciation impart to the rock a foliation that is locally very pronounced. Albite is generally in tiny (less than 0.2 mm) euhedral grains. They are generally well twinned and clear. The small and even grain size of albite, its wide distribution and clear appearance, its good twinning, and its late relationship to the large microcline grains, all suggest a late time of formation and imply a late soda metasomatism in the rocks of this area. Chlorite is nowhere abundant. It is generally interstitial, although it is also along late fractures. Other minerals noted in very small quantity and only in a few sections are carbonate, apatite, opaque substances, and zircon. Hematite colours some of the minerals, particularly feldspar.

Granite in the Eagle Shaft Area

This area is bounded on the southwest by the ABC fault, on the north by the Martin Formation, on the east by the assumed Mic Lake fault, and on the southeast by unit 5 of the Tazin Group.

The granites in this area are very like the granites in the area south of Virgin Lake but are brecciated more intensely and over a much larger area. They are mainly of the normal and brecciated types. The normal granite occurs everywhere but is most common in the northwestern half of the area, that is, near the Tazin–Martin unconformity. The wormy appearance of the milky white quartz, characteristic of the normal granite, is particularly well exhibited north of Shaft Lake and near the Eagle shaft. The normal granite of this area is leucocratic and has very little chlorite.

Some of the granites in this area are gneissic; others are dense, cherty, somewhat more glassy, and a lighter red than the normal granite. The latter passes gradually into rocks that were mapped as remnants of buff quartzite, and this gradation and their apparent high quartz content suggest they were derived from the buff quartzite by incomplete granitization, just as the granite in the area south of Virgin Lake. This is also suggested by the many remnants of buff quartzite that were mapped separately in some parts of this area and that show all grades of granitization up to granite. It is only rarely that the granites of this area are layered in such a way that they resemble the Foot Bay gneiss.

The granites of this area, particularly the normal type, are brecciated over large areas, and the intensity of brecciation varies over short distances. The brecciated granite generally forms areas of irregular shape and size throughout the normal unbrecciated granite. It occurs also as wide irregular zones or belts trending northeasterly. Where its occurrence is patchy and where the patches are closely spaced, it was all mapped as brecciated granite. Much of the granite so mapped northwest of Beth Lake is of this type. The brecciated granite near Eagle shaft, which is shaded to brown, is made up of light to dark brown fragments in a black to brown base. In general the fragments of the brecciated granite are of uniform size or vary from blocks over 50 feet across to fragments smaller than an inch wide. The matrix is finely crushed to powdery granitic material. In most instances, the fragments are of the typical normal granite, but where there are remnants of buff quartzite the fragments may be all quartzite. Some of the fragments are so large that they are really areas of normal granite or quartzite in brecciated rocks.

In a few places, brecciation resulted in mylonite. Mylonite zones were recognized, locally outlined and traced for several hundred feet, but in general, due to poor exposures and rather heavy bush, it was impracticable to outline them fully. The mylonite is massive, dense, and glassy. Its brown weathered surfaces appear to be sandy and show tiny fragments of quartz, feldspar, quartzite, and granite, all standing out in relief in a dark brown to black matrix. Locally they are cut by seams of felsic material, which may be related to the veinlets described later. Their fresh surfaces are dense, cherty, and dark green to black, and show tiny white to green fragments of quartz and feldspar in a black base. Their contacts with the normal granite are sharp to gradational, both along and across strike. The fragments may be abundant or rare, and they may be scattered all through the rock or be distributed in layers. This mylonite, which resembles the mylonite described earlier in this report (*see* end of section on map-unit 17f, Cataclastic Rocks), a flinty crushed rock or pseudotachylyte, is not fracture filling, and no glass was recognized in it.

Ten thin sections of the normal and brecciated granites were studied. The normal granite is allotriomorphic granular, and its grains are interlocked as they are in an igneous rock. Locally it is porphyritic: larger grains of microcline, quartz, and rarely albite in an even-grained matrix of albite, quartz, and possibly microcline. The grains of the coarse granite and the phenocrysts are up to 5 mm wide, whereas those of the fine-grained granite and of the matrix are about 0.5 mm. All rocks, even those mapped as normal granite, show some cataclastic effects under the microscope. Brecciation is highly variable in intensity and occurs as described in the definition of the brecciated granite.

The normal granite is made up essentially of quartz, albite, and microcline, in the proportions shown in Table XXIII.

TABLE XXIII | *Average mode of the granite in the Eagle shaft area*

	Average of ten thin sections	Two stained specimens after E. E. N. Smith (1949)	
		Specimen A	Specimen B
	Range %	%	%
Albite	40(22–60)	25	22
Microcline	*ca.* 30	48	36
Quartz	26(23–42)	26	42
Chlorite	4	?	?

Quartz in grains of various sizes is interstitial or occurs in clusters of small particles with sutured outlines that form lenses and patches of various sizes. Smith (1949) reported that quartz may reach 50 per cent locally. Albite is generally in euhedral to subhedral grains less than 1 mm in size. Its grains are well twinned, equant in shape, and clear. These features and the small grain size suggest a late formation for the albite. In thin sections it is seen to replace microcline but to be earlier than quartz. Albite is locally the only feldspar present, and the rock is an albite granite. The microcline, generally dusty and perthitic, is in large anhedral grains. In a few places it is also found in small grains mixed with albite and quartz and seems to be later than albite. Chlorite amounts to less than 5 per cent, although 11 per cent was found in one instance. Chlorite is both interstitial and along late fractures; in the latter it has a deep blue to purple interference colour and may be penninite. Other minerals present, all in very small amount, are pyrite, ilmenite, carbonate, zircon, apatite, and muscovite or sericite. The brecciated granite is composed of the same minerals. The largest fragments are commonly microcline or quartz but locally are quartz and feldspar. All these rocks are traversed by numerous narrow intersecting veinlets of quartz, albite, quartz–albite, and carbonate–albite–quartz–hematite. As these veinlets cut the brecciated rocks and are not brecciated or sheared, they probably represent a late fracture filling.

A spectrographic chemical analysis of a granite specimen near Eagle shaft was made by R. W. Edie (1952, p. 685); it is given in Table XXIV, No. 7.

Granite in the Area Between Ace, Eagle, and Beaverlodge Lakes

This granite area extends from Eldorado townsite on the north side of St. Louis fault almost as far north as Eagle and Mickey Lakes and from Ace Lake west to Padget Bay on Beaverlodge Lake. The area is within the quartzite–chlorite schist unit (3), and to the east and west it underlies locally the argillite–hornblende schist unit (4). On the west, in the workings at Eagle–Ace mine, granite was intersected at a depth of 643 feet. On the east, in the general vicinity of Fay and Ace shafts, it was intersected at a depth of about 1,400 feet.

The granites in this area are generally in sharp contact with amphibolite, altered amphibolite, hornblende schist, chlorite schist, argillite, and glassy white massive quartzite. Most of the contacts in the western part are with rocks of these types. Some contacts are fault planes or zones of faulting and are sharp; for example, the contact separating Martin arkose from granite east of Padget Bay on Beaverlodge Lake is a fault. Another example is the contact between granite and hornblende schist along the powerline to Eldorado, about 300 feet west of the main road to Eagle–Ace shaft, east of Tam Lake. This contact is sharp and dips about 65°SW, and the granite appears to overlie the argillite–hornblende schist unit, the latter apparently having moved southward, down and underneath the granite. Slickensides, the offset of contacts, the brecciation of the rocks on both sides of the contact, and the parallel strike of foliation on both sides all suggest a fault along this contact.

Gradational contacts are found mainly east of the area and within the area itself where remnants of the original rocks are abundant. A gradational contact with argillites was noted in the area between Eagle and Mickey Lakes near the northern boundary of this area. In general, gradation is within a few feet, and on the whole much of the rock that has been mapped as granite is actually mixed rock.

Variations in colour, texture, and composition are common in the granites in this area, and it is believed that these variations are mainly due to the varied nature of the original rocks and to their incomplete or partial granitization. Most of the rocks here are red, orange-red, and reddish white, and many are massive, coarse grained, and granitoid. These rocks were mapped as the normal granite type.

The normal granite of this area passes within short distances into a red to reddish white, dense, cherty rock (19f) with areas of incipient granitization, generally small, very irregular in shape, and widely distributed. The areas are characterized by an irregular development of small to large grains of milky quartz in a dense cherty looking mass, probably mainly of red feldspar and quartz. Such areas of dense rock with incipient granitization locally grade into what looks like a definite, buff to white, massive, dense quartzite or a rock where bedded structure is well preserved and where beds appear to be in their normal position. This is very apparent south of Mickey Lake near the northern boundary of this granite area and within its central part.

Much of the rock of this granite area shows a colour layering, which is locally so well developed that areas of granitic layered gneiss (19g) are shown on the map. This rock type was observed over large areas north of Hoey Lake, a short distance east of the western boundary of this area, and also near its northern limit. These occurrences seem to bear a relationship to the Ace Lake – Donaldson Lake anticline and indirectly suggest the nature of the original rock on account of their position on the anticline. This layered rock is very similar in appearance to the Foot Bay gneiss. The layers are of various shades of red, cream, white, and also of various shades of green to almost black and brown. In width, they are generally less than three inches, the widest being the red, white, buff, and brown ones. The green and black layers are generally less than an inch thick. Most layers are long. The layering is due to an alternation of layers rich in white quartz, with layers rich in red to buff feldspars and others rich in green chlorite. In places white quartz-rich layers alternate with red albite-rich layers, the dark layers being absent or rare and widely spaced; in other places white quartz-rich layers alternate with red albite – pink microcline – grey quartz-rich layers and buff albite – red microcline-rich layers; chlorite-rich layers alternate regularly with the other layers.

Near the Eldorado townsite and north of the main road east of Padget Bay on Beaverlodge Lake, the rock, instead of being coarsely layered, is thinly layered and faintly gneissic. Much of this layering or gneissic structure is due to recrystallized quartz in tiny elongate lenses in parallel orientation and is separated by intensely crushed powdery feldspathic material and a few aligned grains of mafic minerals. Most of this rock, in addition to being thinly layered and gneissic, is dense, cherty, and pink to deep brick red. It probably represents a mylonite, whereas the wide layering of the granitic layered gneiss, described above, is probably relict bedding.

Locally a gneissic structure is present, due to the parallel orientation and concentration of chlorite, in pencil-like lines, streaks, and tiny lenses. This kind of rock, although observed at several places in this granite area, was not mapped separately but was included with the granitic layered gneiss.

Much of the granite in this area is brecciated and mylonitized (19b). Brecciated rock occurs mainly near the St. Louis – ABC fault and resembles that of the Eagle shaft area. It is a pink to brick red, dense, massive rock that exhibits fragments of granite of various sizes in a dense cherty hematitic matrix. Near the arkose area along the fault east of Padget Bay, the granite is so intensely brecciated that it is in places a deep red dense cherty rock, rich in hematite and peppered with a few small red fragments. Locally near the fault it is sheared, and there the amount of chlorite is somewhat higher, and slickensides and silicification are present.

This granite area includes many remnants of country rocks, many of which were identified as quartzite, amphibolite, chlorite schist, and hornblende schist. But it includes also, as already mentioned, many hybrid rocks that vary in composition from normal granite to quartzite and from layered gneisses with layers of normal granite alternating with layers of chlorite schist and quartzitic rocks, to thinly bedded mixtures of schist and dense quartzite. Because of the gradations in composition, the mixtures, and the incipient granitization, particularly in rocks such as quartzite, it is believed that most of this granite area was once a normal sedimentary succession that has been differentially and selectively granitized. The areas where the rocks are now mainly normal granite are believed to have been once mainly massive and well-bedded quartzite, whereas those areas where the rocks are layered and in-

TABLE XXIV *Chemical analyses of the Foot Bay gneiss, the Donaldson Lake gneiss, and the granites in the area north of St. Louis – ABC fault, in percentages with some calculated norms and measured modes*

	1	2	3	4	5	6	7	8	9	0 0 0
SiO_2	65.91	65.88	73.86	73.28	71.80	73.5	76.5	72.8	71.59	0
Al_2O_3	15.86	15.07	13.12	13.33	13.90	14.5	13.7	12.8	14.69	0
Fe_2O_3	0.35	1.74	0.09	0.87	0.46	0.9	0.8	0.3	0.56	0
FeO	3.77	2.73	2.00	1.38	1.74	.6	.7	.8	1.56	0
CaO	2.63	3.36	1.10	1.17	1.15	.5	.6	.4	1.28	0
MgO	1.49	1.38	1.05	0.50	1.03	.9	.9	.6	0.54	0
Na_2O	3.07	3.53	2.75	2.96	4.78	5.4	5.8	2.2	2.97	0
K_2O	4.43	4.64	4.48	5.52	2.97	1.0	0.3	7.5	5.48	0
H_2O^+	1.12	0.52	0.86	0.50	0.90				0.69	0
H_2O^-	0.15		.14		.12					0
P_2O_5	.20	.26	.11	.14	.11				.26	0
TiO_2	.53	.81	.26	.30	.29				.31	0
MnO	.07	.08	.03	.05	.03		0.1		.07	0
CO_2	.16		.06		.45					0
					Calculated Norms					
qz		18.8		31.2					29.5	0
or		27.2		32.8					32.8	0
ab		29.9		25.2					25.2	0
an		11.7		5.0					4.5	0
c		–		0.5					2.1	0
Others		11.9		4.7					5.4	0
					Measured Modes					
Quartz	20		34		28	30.4	30.3	23.2		0
Microcline	27		32		32	–	–	73.7		0
Albite–										0
oligoclase	33		27		33	57.6	66.9	–		0
Others	20		7		7	11.9	2.8	3.3		0
					Niggli Numbers					
si	278		416		369	425	452	440		0
al	39		44		42	50	48	46		0
fm	24		18		18	13	14	10		0
c	12		7		6	3	4	2		0
alk	25		31		34	34	34	42		0
si[1]	199		223		236	236	236	268		0
gz	79		193		133	189	216	172		0
(al+fm)–										0
(c+alk)	26		25		20	26	24	12		0

1. Foot Bay gneiss, Beaverlodge area, Sask.
   Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
2. Hornblende-biotite adamellite, average of 41 analyses, S. R. Nockolds, 1954, p. 1014.
3. Donaldson Lake gneiss, Beaverlodge area, Sask.
   Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
4. Biotite granite, average of 37 analyses, S. R. Nockolds, 1954, p. 1012.
5. Red granite, held to be derived from the Donaldson Lake gneiss, Beaverlodge area, Sask.
   Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
6. Albite alaskite, Ace mine area, Beaverlodge area, Sask.
   Analyst: R. W. Edie, quantitative spectrographic analysis, 1952, p. 685.
7. Albite alaskite, Eagle mine area, Beaverlodge area, Sask.
   Analyst: R. W. Edie, quantitative spectrographic analysis, 1952, p. 685.
8. Microcline alaskite, Ace Creek, Beaverlodge area, Sask.
   Analyst: R. W. Edie, quantitative spectrographic analysis, 1952, p. 685.
9. Muscovite–biotite granite, average of 21 analyses, S. R. Nockolds, 1954, p. 1012.

clude many chlorite-rich layers were once a thinly bedded mixture of quartzite and chlorite or hornblende schists. The quartzite was granitized, but the mafic layers were transformed into chlorite or hornblende schist and amphibolite. In other words, rocks in this area are almost the end product of the granitization of a sedimentary succession, the degree of granitization reached having varied with the nature of the original rock and probably also, to a certain extent, with the intensity of metasomatism and ease of circulation through the rock; the quartzite may have been more porous than the chlorite or hornblende schists. Although the composition of some of the quartzite may have differed very much from the composition of the normal granite, it seems on the whole to have changed readily to granite; indeed, the appearance and nature of many outcrop areas suggest that these quartzites needed the addition of little material to bring them to the composition of the normal granite.

In thin sections the granites of this area are similar to those of the two granite areas described below. They are made up of the same minerals in about the same proportions, and many of them have been intensely brecciated. In fact, some of them are microbreccia and resemble mylonite without flow structure. Wide zones of brecciated rocks were outlined not only near and along St. Louis fault but also north of Ace Lake and east of Eagle Lake.

Two spectrographic analyses, one of granite in the Ace mine vicinity, the other of granite in the area near Fay shaft, south of St. Louis fault, were presented by R. W. Edie (1952, p. 685) and are given in Table XXIV. For comparison the average analysis (No. 9) of twenty-one analyses of muscovite–biotite granite is added.

Granite in the Area Between Verna, Donaldson, and Raggs Lakes

This granite area extends from Raggs Lake in the east to Verna Lake in the west and from the St. Louis fault in the south to Foot Bay on Donaldson Lake and Schmoo Lake in the north. Its northwestern and northeastern contacts are irregular, wavy, and gradational. Rocks in this area show great variation in composition. Although all the main types of granite described previously are present, two types are widespread and characteristic of this area. They are hybrid granite (19c) and carbonatized granite (19d). Nevertheless the normal granite, the gneissic to foliated granites, and the brecciated granite are also present. The normal granite occurs mainly as small irregular patches throughout the hybrid granite and carbonatized granite. A few areas of this granite were large enough to be shown on the map. These areas may be faintly gneissic, as in the area of normal granite about 2,000 feet northeast of Verna Lake.

The hybrid granite is most common south of Foot Bay and south of Schmoo Lake. It displays a rough granular weathered surface, which is particularly evident about 2,000 feet southeast of Schmoo Lake. The mafic mineral is generally chlorite but locally is hornblende or biotite. Its aligned occurrence, clustered in streaks, lenses, and elongate patches, generally all oriented parallel and locally in large ghost-like agglomerations suggests that these may be remnants, almost granitized, of older rocks. Remnants of older rocks are indeed common south of Foot Bay and Schmoo Lake, but they are there mainly amphibolite and mafic-rich schist or gneisses. Because of their nature they are readily recognized; this is not always so if dark minerals are few. In a few places, the remnants are so abundant that they constitute most of the rock, which was then mapped as amphibolite, schist, and/or gneiss, with granitic material. One such area, made up of amphibolite remnants surrounded by granite, is described later in this report. The granitic part of the hybrid granite is composed of red and white to buff feldspars, grey to white quartz, and chlorite. The red feldspar may also occur as augens, lines, streaks, and elongate patches throughout the rock and may account for the porphyroblastic texture and the foliation.

Rocks in parts of this granite area are layered, and they resemble the Foot Bay gneiss. Locally this layering strikingly resembles bedding and may indeed be relict bedding; thus, some layers high in grey to white quartz with very small amounts of white feldspar and chlorite were regarded as quartzite beds. Others have a high chlorite or hornblende content, and these were locally deformed into lenses of various sizes. Where such lenses were abundant and were closely spaced, even when mixed with some granite, they were mapped as amphibolite or as a zone of some other mafic rocks with granitic material, as in the area about half a mile southeast of Schmoo Lake. There the lenses and masses of amphibolite form a belt, and although they seem to have moved slightly from their original positions and to have rotated in part, they are probably parts of one bed. Their apparent rotation suggests that some mobility was present in this area. This is the only part of the Beaverlodge area where some indications of movement in granite were observed.

In parts of this granite area carbonate is abundant, and where it was sufficiently plentiful and where the carbonatized rock was clearly recognizable and uniform over a wide enough area, it was shown on the map. Carbonatization seems to have affected mainly the hybrid and brecciated granites. Thus, in the area about 2,000 feet west of the northwest end of Flack Lake, the carbonatized rock was found to occur in lenses, masses, and bodies of otherwise hybrid and brecciated granite. These lenses and masses were all elongated parallel with the trend of the formations or with the foliation of the rock, and the dimensions seem to have been controlled by cross-fractures both along and across strike.

The main occurrence of carbonatized granite in this area is a northeasterly trending belt south of the southeastern end of Foot Bay, which extends for at least 4,000 feet from Emar Lake east to a point south of Schmoo Lake. In this belt, the intensity of carbonatization continues over fairly large areas, but in general, as mentioned previously, it is patchy or in lenses, belts, and elongated bodies in a mass of granite, which is, as a whole, only faintly carbonatized, although it is pyritized and heavily brecciated. The brecciation has preceded the carbonatization. Pyrite was probably formed at the same time as the original rock, but some of it may have been added during carbonatization. The other areas of carbonatized rock are all small, and most of them were not mapped separately. Carbonatized rocks, whether mapped or not, occur most commonly on the probable extension of the belt described above, or in close proximity to the St. Louis fault and in areas of brecciated granite.

Much of the rock in this area is brecciated. In a few places, brecciation affects large areas, but generally it occurs in irregular small patches and lenses and in narrow elongate masses along fractures or zones of fracture. The extent of these bodies and of their distribution varies throughout the area. Where brecciation is mainly in patches and where these are closely spaced, the area is mapped as a brecciated zone. Most zones have a northeasterly trend and vary in width. The rocks composing them vary in appearance and composition. The zone south of the east end of Foot Bay, extending northeasterly from Emar Lake, is made up mainly of rocks that weather red to orange red and that are composed of orange-red, mainly small fragments in a dark reddish brown matrix. Locally, however, and particularly in the western part of the belt, much of the rock is heavily carbonatized. Pyrite in small quantities was noted almost everywhere in this zone, but locally it is abundant enough to impart a rusty weathered surface. To the northeast the zone still carries tiny cubes of light yellow pyrite, but as a whole the rock becomes denser, finer grained, and finely gneissic. It then resembles a mylonite or ultramylonite. The brecciated appearance so well displayed in the western part of the zone, south of Foot Bay, is not so obvious there. Along and against the St. Louis fault, another zone of brecciated rock was traced almost continuously from Verna Lake to Raggs Lake. This zone is of irregular width. It is probably narrow or missing near Raggs Lake, but in the Verna Lake area it is up to 1,000 feet wide; there the rocks are also slightly carbonatized. In addition to these two zones, other wide areas of brecciated rock are known east and northeast of Foot Bay and at other places in this granite area, but these in general are very irregular with no definite trend. All brecciated rocks of this area are criss-crossed by many tiny fractures filled with chlorite, epidote, and hematite.

Granite in the Area South of St. Louis Fault

Most of the area from Ace Lake to Flack Lake and east of Fookes and Fulton Lakes, south of St. Louis fault, is covered with granite and related gneisses. In addition to this main granite area, a few smaller ones, mainly in the vicinity of Murmac Bay, were mapped separately. Many dykes and sills of granite and pegmatite were also noted in the area northeast of Murmac Bay, but most of them were not mapped because they were too small to be shown.

The main granite area mentioned above is largely made up of granites and granitic gneisses. The granites may be of the normal, hybrid, gneissic, or brecciated and carbonatized types. The gneisses are layered and granitic and are generally traversed by irregular masses, dykes, and sills of the normal granite. They were mapped with the granites.

The normal granite is possibly the most common type in the granite area south of St. Louis fault; other types are abundant locally but are nowhere so widespread. The normal granite occurs as large masses north and west of Yahyah Lake, east of Collier Lake, and south of Flack Lake. It is also found as smaller irregular bodies scattered in an haphazard manner in the gneissic granite, the hybrid granite, and the layered gneiss. It cuts these rocks sharply or grades into them within a few feet. The large areas of normal granite are not entirely homogeneous. They vary noticeably in composition and texture, but in general the unusual varieties are of small extent. Only in rare instances were they mapped. Most of the normal granite in this area is very similar in appearance to the normal granite elsewhere in the Beaverlodge area. It varies in colour from red to almost white. The quartz, however, may be grey locally, and where it is white, it is not so wormy as in the area of the Eagle shaft. The mafic content of the rock, although it is definitely less than 10 per cent, may be somewhat higher than that of the normal granite north of St. Louis fault. It is distinguished from the other types of granite by the features described in the beginning of this section on granites. In the area between Flack, Collier, and Yahyah Lakes it is locally carbonatized.

Gneissic granite is abundant north and south of Yahyah Lake and also in places north of Fish Lake. It is red to white, locally brownish red, orange, buff, and cream. It is not so coarse grained as the normal granite. Its gneissic structure is due to the mafic minerals, but quartz is also in narrow oriented lenticular seams and streaks. This rock is commonly homogeneous, but north of Yahyah Lake it is either cut by normal granite in dykes, sills, and masses, or grades into it. It also carries partly granitized chlorite-rich zones, small areas of quartzitic material, and a few amphibolitic remnants. Their continuity along strike and dip suggests that they rest in their original position. The gneissic granite also passes locally along the strike into a thinly layered gneiss. These features, as well as the gneissic structure, are believed to be relict and to indicate that these rocks were once sedimentary rocks, though now more or less granitized.

East of Collier Lake the granite is hybrid. It is red, white to dirty reddish white, and grey. It is made up of red feldspar in a dirty white base of quartz and mafic minerals with tiny round grains of yellowish white feldspar. This feldspar gives it a spotty appearance. It also carries many schlieren, and part of it is carbonatized and layered.

Elsewhere the granite resembles the Foot Bay gneiss north of St. Louis fault. Areas of these rocks are outlined on the map (19g). They may represent a less advanced stage of granitization than the normal granite and may possibly be rocks originally of slightly different composition than the rocks from which the normal granite was derived. Like the Foot Bay gneiss, they are typically layered and gneissic. They are also dense and siliceous, or spotty white due to the white feldspar grains they contain. The weathered surfaces of these rocks are rough, granular, and light brown to reddish brown. They are crossed by pegmatite dykes and sills and also by seams, small patches, lenses, and irregular masses of granite, all composed of the same minerals in about the same proportions. North of Flack Lake these rocks are thinly layered and dense. North of Yahyah Lake they are not granitized like the rocks near the St. Louis fault but were mapped with these rocks (19g) because of their high mafic content and because of their being mixed with many granite dykes and masses.

Pegmatite dykes and sills were observed mainly east of the north end of Murmac Bay and around Yahyah Lake. They may be almost 400 feet wide. Some small granite masses shown on the map east of the north end of Murmac Bay are also pegmatite; a few of these were traced for almost a mile. Most trend parallel with the foliation or gneissic structure and dip with the formations. Their weathered surfaces are red to white. They are slightly coarser grained than the normal granite and are composed of milky white quartz, red feldspar, muscovite, and locally black tourmaline.

All these types of granite have been brecciated to a greater or lesser degree, but in general the intensity of granulation is nowhere so pronounced nor so widespread as it is near the Eagle shaft north of St. Louis fault or along the Black Bay fault. Wide mylonite zones were not observed, but the rocks show all gradations from massive to brecciated rocks, composed mainly of angular to subrounded fragments (averaging about 1 inch in size), resting in a dark red matrix of chlorite and crushed quartz and feldspar. Except for the fairly extensive zone of brecciated rocks south of Verna Lake, which extends from the St. Louis fault easterly for almost 2 miles, all the areas of brecciated rock seem to form only small isolated patches with no apparent structural relations, or at least do not seem to be related to faults, although they may be in the axial region or the apex of folds, particularly drag-folds, and as such they would be fold breccia.

Thin sections of the brecciated rocks definitely show two periods of deformation. The earlier period is represented by the intense granulation of the rock, the second by fracturing. These fractures are now partly filled with chlorite. The fact that hematite, which is a common mineral in brecciated rocks, may also have been deposited before the fracturing but later than the granulation suggests a time relationship for the hematite deposition in these rocks and possibly in the rocks of the Beaverlodge area as a whole. Thin sections of these brecciated rocks are made up of large to small, rounded to subangular, irregular fragments of feldspar, mainly potassic, resting in a mass of fine-grained crushed material. Small elongate lenses of recrystallized quartz are also contained in the matrix. This crushed rock passes gradually into normal granite or into the other types of granite and gneiss in this granite area.

The normal granite is made up of albite–oligoclase, microcline, quartz, and some interstitial chlorite and muscovite; average grain size is 1 mm. Plagioclase is altered, but microcline is fresh. Microcline occurs as rims with ragged outlines against and around plagioclase, as tongues and re-entrants into plagioclase, or as large crystals enclosing several island-like patches of plagioclase, all disappearing simultaneously. Quartz is later than microcline and occurs as individual grains or as large areas (2.5 by 2 mm) of recrystallized quartz in small to large grains with intricate boundaries. Chlorite is light green. Other minerals noted particularly in the brecciated granite are epidote, hematite, pyrite, apatite, and possibly biotite. Thin sections of the layered gneisses show a few (up to 1.0 mm) areas of recrystallized quartz or a few (up to 1.0 by 0.5 mm) feldspar grains in a matrix (averaging 0.3 mm) made up of the same minerals as the normal granite. Where the granite is carbonatized, it is made up of equant to occasionally large plagioclase grains and of interstitial carbonate, chlorite, and apatite. Some of these granites have a much finer grain and may represent brecciated or mylonite zones.

Froese (1955), who has studied some of the granite in the area about half a mile northeast of Moran Lake, called it oligoclase gneiss with the following mineral content: 35 per cent oligoclase, 10 per cent microcline, 30 per cent quartz, 8 per cent biotite, 6 per cent sericite, 6 per cent chlorite (pennine), 5 per cent calcite, and some zircon, apatite, sphene, and pyrite.

Grain counts were made on a few thin sections of the granitic rocks of this area, and the results are given in Table XXV.

TABLE XXV — *Estimated mineral composition of granitic rocks south of St. Louis fault, in percentages*

	Granites				Layered gneisses	
	1	2	3	4	5	6
Albite–oligoclase	41	31	31	45	49 {38?	56
Microcline	31	15	15	12	11?	16
Quartz	27	45	32	30	28	15
Chlorite	1	9		12	17	13
Muscovite	trace		22	0.5		
Opaque				0.5		trace
Apatite					0.5	
Epidote					5.5	

1. Gneissic granite, about 2,400 feet due north of Yahyah Lake and 2,800 feet southeast of the east end of Fish Lake.
2. Hybrid granite, about 500 feet south of the southwest end of Flack Lake.
3. Normal granite in an area of granitic rock, about 400 feet south of the south end of Yahyah Lake.
4. Normal granite, from small mass west of Kram Lake and near east shore of Beaverlodge Lake.
5. Granitic layered gneiss, in large area of granitic rocks south of Fulton Lake, about 3,200 feet due south of Fulton Lake near east boundary of map-area.
6. Granitic layered gneiss, in large area of granitic rocks due east of Murmac Bay and near east boundary of map-area

Granite in the Area Between the Boom Lake and Black Bay Faults

Granite in Map-Unit 17 (Cayzor Unit)

The granites in this map-unit, which occur as a wide belt and as small isolated masses among the rocks of the unit, were probably derived from them, mainly from the quartzite and schist. The belt extends along the strike of the Cayzor rocks for almost the length of the area. It is about 2,000 feet wide west of Fredette Lake, and near Uranium City, possibly due to repetition by faulting, it is more than 5,000 feet wide. Northwest of Cinch Lake it is interfingered with thinly layered granitic gneiss, and altogether it is less than 2,000 feet wide. Southwest of Cinch Lake and almost as far as Bushell, the belt is irregular, discontinuous, and in general difficult to trace. It does not seem to extend as far as Bushell, and part of it, which may have been cut off by the Black Bay fault, now lies east of the fault that is west of Nero Lake, suggesting a possible offset on the fault.

The contacts of these granites are fairly definite west of Fredette Lake, for, although gradational, they can be located within a few feet. On the northwest, near Pluton Lake, the granites grade into chlorite schist and quartzite, and their boundary was placed at a small amphibolite layer, east of which the rocks resemble granite, whereas west of it they resemble schist. On the southeast near Fredette Lake, the granites are in contact with thinly interbedded quartzite and schist. This contact is locally very sharp, even where it cuts across the formations. Northwest of Uranium City and southwest of it as far as the belt could be traced, the contacts of the granite were gradational, irregular, and difficult to locate because the rocks with which these granites are in contact are granitic layered gneiss, granitized chlorite schist, quartzite, coarse-grained granitized quartzite, and rocks that are locally altered almost to granite. In all places the gradation is across as well as along the strike.

This granite belt and, to a lesser degree, the smaller masses, are made up of normal and gneissic granites. The granites enclose remnants of quartzite and chlorite schist. In general the remnants, which have almost faded into the granites, can be recognized only by slight local variations of texture and composition. This heterogeneity is characteristic and indicates that the areas were originally quartzite and schist, granitized to such a degree that most of the original rock has changed to granite, only here and there leaving spots of the original rock not as yet completely altered to granite.

The granite is red to white and brown. Much of it is gneissic and foliated, and this foliation was measurable almost everywhere, though locally it is very faint. Generally the intensity of the gneissic structure varies so much that a massive, completely unfoliated area may pass within only a few feet or inches into an area with a pronounced foliation. This foliation or gneissic structure is believed to be a relict structure derived from the schist and quartzite. The gneissosity, which is locally almost a schistosity, is represented on the outcrop by chlorite seams, lines, and streaks, all in parallel orientations; in places where it is very fine, it seems to be a relict of thinly bedded and interbedded quartzite and schist. The foliation on the other hand consists of thin layers that may or may not be continuous and that may be chloritic, quartzose, or feldspathic. It suggests that the original rock was a granitic layered gneiss and establishes a possible relationship between granitic layered gneiss and interbedded quartzite and schist.

Under the microscope the rocks of these granitic areas show medium to coarse grain, but locally, as a result of cataclastic effects, they are fine to dense. Where subsequent recrystallization took place, some of the grains are much coarser. The normal granite is allotriomorphic granular with no apparent preferred orientation of the minerals. The gneissic and foliated granites exhibit a preferred orientation of most minerals, a pronounced elongation of a few, and a segregation of some into layers and lenses. Much of the gneissic granite shows also a rough augen structure not apparent on the outcrop. The augen structure is due to large microcline perthite grains, roughly lenticular but of ragged and irregular outline, resting in a medium- to fine-grained matrix of quartz, plagioclase, and chlorite. These augens are generally oriented parallel with the foliation.

Most thin sections show cataclastic effects. The normal granite is generally not granulated but shows strain shadows in quartz, fractured feldspar laths, or some granulation at the meeting point of two grains or at the periphery of some grains. Most of the gneissic and foliated granites are intensely granulated. They exhibit a typical mortar structure represented by large fragments of feldspar and locally of quartz, closely packed and separated from each other by a narrow zone of fine quartz and feldspar. Much of the quartz has recrystallized into tiny round individuals or slightly larger elongated irregular patches. This rock has still the appearance of a granite on the outcrop, and in thin sections it is apparent that it has been derived from granite. This type of crushed rock is really a protomylonite (Backlund, 1953). The augen structure mentioned previously was also noted in the brecciated granite, and the microcline augens are really cataclasts. As the cataclastic deformation increases, the rock loses its granitic appearance and becomes dense and cherty with only occasional fragments. Where this dense rock becomes the dominant rock it forms a mylonite zone. The passage from protomylonite to mylonite is generally gradual and irregular. A zone exists between the two where protomylonite and mylonite are intermixed in a lenticular fashion and interlayered. The lenses and layers are of variable size and thickness. The contact of the protomylonite with the mylonite was placed where the granitic texture is rarely visible on the outcrop; this seems to be corroborated by thin section studies.

The normal granite is composed mainly of quartz, albite–oligoclase, microcline perthite, and chlorite. Sphene, epidote, opaque material, zircon, apatite, and carbonate are also present in minor amounts. Table XXVI gives two average modes for this granite, based on eight specimens.

TABLE XXVI | *Average modes of granite in Cayzor unit*

	Average of six specimens	Average of two specimens
	Range %	Range %
Albite–oligoclase	36(23–44)	15(15–16)
Microcline	33(26–39)	60(59–60)
Quartz	24(12–37)	23(21–25)
Chlorite	5(0–11)	2(2–3)
Opaque	1(0–2)	
Others	1(0–2)	
Rock composition	quartz-monzonite	granite

Microcline is perthitic, and fresh and occurs in large to small grains. The larger grains, roughly lenticular, are up to 15 by 8 mm. Their grain boundaries are irregular, and where they are in contact with plagioclase, the plagioclase is in small myrmekitic grains forming re-entrants in microcline as if it had developed at its expense. Microcline also encloses occasional round grains of plagioclase and quartz. Plagioclase is generally slightly altered to sericite and carries no round quartz inclusions. Most of its grains are less than 1 mm across, but a few reach 4 by 3 mm.

Quartz has an undulatory extinction, is interstitial, and encloses other minerals. Most of it occurs in clusters of small round individuals exhibiting the imbricate structure mentioned previously (*see* section immediately before "Granites in the area . . . ABC fault"). In the normal granite, a few quartz grains are similar in size to those of plagioclase. Locally, some of it has recrystallized in slightly larger irregular patches with sutured boundaries, and some was even mobile, as shown by its flow structure.

Chlorite, interstitial to feldspars, occurs with quartz, and most of it has the anomalous deep blue and purple interference colours of penninite. Some chlorite is definitely pseudomorphous after hornblende and biotite. It is locally reddish brown. Much of it is probably a product of retrograde metamorphism, but some may have been introduced. Sphene is light brown, and locally it is all altered to leucoxene and black opaque material. Zircon grains are oval and slender with a ratio of 3:1. The opaque material is in part pyrite, but much of it is hematite, staining the boundaries of grains or occurring as scattered grains amongst the crushed material. Epidote is an alteration product and was probably introduced with carbonate.

Granite in Map-Unit 16 (Jean Lake Amphibolite)

The Jean Lake amphibolite (16) is crossed by several dykes, sills, and irregular masses of granitic material. These are locally very abundant, particularly near the contacts of the amphibolite masses with other rocks, where they may constitute as much as 50 per cent of the amphibolite masses. They may also be uniformly interbanded with amphibolite. The granite masses reach a size on surface of 400 by 1,000 feet, but a few are mere seams and veinlets, a few inches to a fraction of an inch wide. They may be almost flat lying or dip steeply with the foliation and gneissic structure of the amphibolite; in general they trend about parallel with the main trend of the amphibolite. In composition they are similar to the normal granite, being composed mainly of white to grey quartz, red feldspar, and minute amounts of chlorite. In addition to red feldspar the pegmatitic phase has buff and greenish white feldspars and some muscovite. A few masses weathering white, locally high in quartz and white feldspar, are massive or foliated and carry a great deal of mafic minerals. Such rocks grade into the normal granite and may represent masses of granitized quartzite.

TABLE XXVII | *Chemical analyses of granites northwest of Black Bay fault, in percentages*

	1	2	3	4
SiO_2	73.33	74.15	72.78	73.84
Al_2O_3	14.33	12.92	14.56	14.29
Fe_2O_3	.31	.54	.12	.34
FeO	.66	1.58	2.01	.75
CaO	.99	.52	1.73	.69
MgO	.34	.37	.92	.21
Na_2O	4.60	3.38	3.55	3.61
K_2O	4.00	5.21	2.94	5.21
H_2O^+	.47	.73	.76	.60
H_2O^-	.08	.07	.09	
TiO_2	.07	.26	.18	.16
P_2O_5	.09	.07	.09	.25
MnO	.01	.03	.02	.05
CO_2	.35			
Cr_2O_3				
Total	99.63	99.83	99.75	
Niggli Numbers				
al	47.1	43	46	
fm	7.4	17	17	
c	6.0	3	10	
alk	39.5	37	28	
si	411	423	358	
si^1	258	248	212	
qz	153	175	146	

1. Composite sample from dykes and irregular masses of granite in Jean Lake amphibolite in the area southwest of Jean Lake.
   Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
2. Red granite, Black Bay area, Sask. Hale (1953).
   Analyst: W. H. Herdsman, Glasgow, Scotland.
3. White Lake granite, Black Bay area, Sask. Hale (1953).
   Analyst: W. H. Herdsman, Glasgow, Scotland.
4. Average of six muscovite granites, Nockolds (1954, p. 1012).

Several hand specimens were collected from a few of the granite masses enclosed in the Jean Lake amphibolite within the area extending from the Leonard adit to the western boundary of the map-area. The analysis of a composite sample made of this group is given in Table XXVII and is fairly similar to one of an average muscovite granite (No. 4) made by Nockolds (1954) and presented in the same table. The main difference is in the ratio of soda to potash. The high soda–potash ratio of the granite in the amphibolite suggests an affinity with the feldspathic quartzite of this area and consequently to a metasomatic origin. Two other chemical analyses are included in the same table as they are of granites from the Black Bay area (Hale, 1953), the area adjoining the Beaverlodge area to the west. The iron content of the Black Bay red granite (No. 2) is, however, higher than that of the granite in the Jean Lake amphibolite. It may contain more hematite dust. The White Lake granite (No. 3) of the Black Bay area has apparently about 15 per cent biotite, and this may explain why it differs appreciably from the granite in the Jean Lake amphibolite.

Granite in Map-Unit 15 (Rix Unit)

A red to reddish white and purplish red granite is abundant over the area of the Rix unit (15). It occurs as sill-like layers, dykes, and irregular masses of various sizes. Some of the masses, which were large enough to be mapped separately, are shown on the map. The sill-like layers constitute an important part of the quartzitic layered gneiss; indeed, they and the dykes together constitute the bulk of the granitic layered gneiss. Most of the sill-like layers appear to be rocks derived by the granitization of pre-existing rocks. These layers are believed to represent relict bedding because they are interbedded with known quartzite beds and gneiss of clearly sedimentary origin. Furthermore, they grade along strike into rocks of probable sedimentary origin. The dykes crosscut the country rocks, and some are continuous with the sills. A few dykes and most of the sills also exhibit a fine colour foliation parallel with the layered structure. This may be a relict bedded structure but is probably a cataclastic and recrystallization effect. Since they grade into each other and are similar in composition and texture, both dykes and sills are assumed to have a common source. The dykes may be remobilized material derived locally from the sills or from the larger areas of intensely granitized country rock farther away.

The masses that were mapped separately are either large pegmatite dykes and sills or large areas of country rock completely or sufficiently granitized to be mapped as granite. The granite is of the normal type. The granite area north of Jean Lake and south of Boom Lake fault is regarded as a typical example. The rocks composing it grade to the south into granitic and quartzitic layered gneisses. The granite of the small masses is generally of the normal type; that of the larger ones, which are concordant with and derived from pre-existing rocks, shows some variations of grain size and exhibits many relict structures and many remnants of pre-existing rocks. The most common relict structure is a layering believed to represent bedding. The fine coloured layered structure or striped effect, the result of quartz and feldspar occurring in separate layers, may also be relict bedding but is probably in part a cataclastic effect.

The contacts of these granite areas are sharp to gradational. They are sharp across the strike of the rocks against mafic layers or glassy quartzite beds but are gradational along strike, either by passing almost imperceptibly into, or by fingering with, the other rocks, generally quartzitic or granitized layers. Where both these rock types are present interfingering is common.

The granite is made up mainly of quartz, oligoclase, and microcline perthite with generally less than 5 per cent mafic minerals. Oligoclase and perthite are uniformly distributed in anhedral grains up to 2 mm in size. Plagioclase is generally altered to sericite, whereas microcline is fresh. Where microcline is in small amount, it is later and interstitial to oligoclase. However, as there are tiny euhedral crystals of plagioclase in some large microcline grains and as some myrmekite may form at the expense of microcline, there seems to have been a late development of plagioclase. Quartz is in clusters of tiny (less than 0.1 mm) round grains, with the imbricate structure. It is interstitial. Chlorite is found associated with minor amounts of biotite and muscovite. There are also minor amounts of opaque minerals, carbonate, epidote, sphene, and apatite. The thin sections from the granite of this area display some cataclastic effects from granulation at localized spots to mortar structure.

Table XXVIII gives the mineral content of the granite from this area as determined in three thin sections.

TABLE XXVIII *Estimated mineral composition of granitic rocks in Rix unit, in percentages*

	Granitized quartzite	Dyke of normal granite (red-white) near Bushell	Dyke of normal granite (red) near Rix mine
	1	2	3
Oligoclase	55	11	36
Microcline	11	37	20
Quartz	27	51	42
Chlorite	5	1	1
Opaque	1		1
Carbonate	1		
Rock composition	granodiorite	granite	quartz-monzonite

Granitic Rocks of the Area North of Boom Lake Fault

Granite is abundant in this area, but most of it is in masses too small to be mapped separately or too indefinite and too gradational into the other rocks to be outlined with certainty in the field. It is a major constituent of the granitic layered gneiss where it occurs mainly as layers, sills, and dykes, or as irregular masses. It is the granitoid component. A few masses were sufficiently large and typical to be outlined and to be shown on the map, mostly north of Bush Lake. A belt of granitic rock was traced against and north of Boom Lake fault from Bush Lake to the northern boundary of the map-area, and several other areas were observed along the Bellegarde fault. The largest masses occur north of Bellegarde Lake and near the northern boundary of the map-area west of Smysniuk Lake. Most of the masses are elongated parallel with the foliation of the rocks or with the trend of the formations.

The granite that forms an integral part of the granitic layered gneiss is normal granite and has already been described with the rock-units in this general area (*see* Area between Boom Lake and Black Bay faults, map-units 15 to 17d). The granite of the masses shown on the map is of both normal and gneissic types. It is made up mainly of white quartz, red feldspar, and some chlorite, the chlorite being responsible for its gneissic structure. The rock grades along and across strike into the other rock types, and in many instances its gneissic structure seems to reflect the structure of these rocks. In a general way this granite appears to have formed at the expense mainly of the granitic layered gneiss, but possibly locally of the quartzitic layered gneiss.

The belt of granite against the Boom Lake fault is strongly gneissic, and some of this rock may be highly granitized chlorite-rich feldspathic quartzite. Most of the other masses were probably granitic layered gneiss, as throughout the areas of granite there were many patches of granitic layered gneiss not yet entirely granitized.

Some of the dykes and sills are pegmatitic. Pegmatites were noted almost everywhere in this area but are most abundant north of the main mass of amphibolite passing by Doreen and Leibel Lakes and south of the Powerline Creek unit. These pegmatites resemble the granite in composition; in general they are free of mafic minerals, or almost so, although they may carry up to 20 per cent black tourmaline, in tiny acicular crystals, and garnet.

In thin sections the rock is typical of the normal granite of the Beaverlodge area. Its texture is allotriomorphic granular, and its grain size is less than 1 mm. Albite, microcline, quartz, and chlorite or green biotite are its main minerals. Its mode is given in Table XXIX.

TABLE XXIX — *Mode of granite in area northwest of Boom Lake fault, in percentages*

Albite	40
Microcline	30
Quartz	25
Chlorite	4
Opaque and others	1

The albite is generally heavily altered to sericite whereas the microcline is fresh. Microcline and quartz are interstitial to albite. Some of the quartz is in large recrystallized masses. Granulation occurs locally on a small scale. Chlorite is an alteration product after biotite, and most of it is interstitial and is similarly oriented.

Martin Formation

(Map-Units 20 to 26)

History and Definition

In 1888, R. G. McConnell (1893), while travelling along the south shore of Lake Athabasca from Athabasca River to William Point, encountered a granular siliceous sandstone, which he named 'Athabasca sandstone.' A similar sandstone had been observed by M. Cochrane (McConnell, R. G., 1893) at the east end of the lake as early as 1882, when he was a survey assistant on a Topographical Survey party, but McConnell was the first to name and describe it. J. B. Tyrrell (1895) and C. Camsell (1916) mentioned that along the north shore of Lake Athabasca there were several small areas of Athabasca sandstone overlying unconformably all other rocks. F. J. Alcock (1914, 1916, 1920, and 1936a) used the term 'Athabasca series' not only for the flat-lying sandstone south of the lake but also for the somewhat similar lithologic formations, although somewhat more deformed, in the small areas north of the lake. These small areas lie along the shore and a few miles inland, and some are in the Beaverlodge area.

A. M. Christie (1949), who mapped the Goldfields – Martin Lake map-area in 1946, 1947, and 1948 on the scale of 1 mile to 1 inch, and Blake (1956), who made in 1952 a reconnaissance survey of most of the areas of Athabasca rocks north and south of Lake Athabasca, retained the term Athabasca series, implying that they accepted Alcock's correlation. W. C. Gussow (1957 and 1959) suggested the name Martin Lake series for the deformed Athabasca rocks north of Lake Athabasca, that is, for the part of the Athabasca series in the Beaverlodge area. He restricted the term 'Athabasca Formation' to the flat-lying sandstone south and north of the lake. In 1959 W. F. Fahrig (1961) proposed the name Martin Formation for all Christie's steeply dipping Athabasca rocks, that is, the Martin Lake series of Gussow, because these rocks are more deformed and in general are lithologically different from the Athabasca rocks south of the lake. The name Martin was used, because it had already been used by Gussow and because the Martin Formation appears to be best represented and exposed around Martin Lake.

In published preliminary maps and separate papers (*see* Bibliography), I used the term Athabasca Series or Group for these rocks, because an overall correlation between both rock types was believed to exist. However, the suggestion to give a formational name to these rocks, made by Gussow and Fahrig, is accepted here, and the previously known Athabasca rocks of the Beaverlodge area are referred to in this report as the Martin Formation.

Extent and Location

The rocks of the Martin Formation cover 32.4 square miles in the area under study. They are found only south of the Black Bay fault and mainly around Beaverlodge, Martin, and Fredette Lakes. They are assumed to underlie all of Beaverlodge Lake, for all drilling done by various mining companies from the ice on the lake cut rocks characteristic of the Martin Formation. Most of these rocks outcrop within a large continuous area extending from north of Fredette Lake to south of Beaverlodge Lake, but twelve smaller areas were mapped northeast of Melville Lake, west of Mic Lake, and southwest of Ace Lake. All seem to be small remnants or outliers.

The main area is bordered on the northwest by the Black Bay fault, and elsewhere by the trace of the unconformity plane that separates the Tazin rocks from Martin Formation rocks, except that the boundary between Melville and Ace Lakes is the St. Louis – ABC fault. The trace of the unconformity is fairly straight from the northern boundary of the map-area to Melville Lake but is very wavy or sinuous south from Ace Lake, the sinuous appearance being due to several small, narrow, long basins, forming re-entrants into the Tazin rocks and encircling Beaverlodge Lake.

Nature of Basal Unconformity

The rocks of the Martin Formation rest with a pronounced angular unconformity on the Tazin rocks, although at a few places the Tazin rocks pass gradually within a few feet into rocks of the Martin Formation. In the last-named instances, the first few inches or feet of Martin rocks are residual material derived from the Tazin rocks directly below and consolidated in place (*see* Pl. 17). This can be seen readily at most places along the unconformity south and west of the Fay shaft, where the detritus forming the first foot or so of the Martin rocks is material derived from the Tazin rocks directly below, in almost the same position as they were before being eroded. The fragments of the detritus, which are angular, may be partly or wholly broken away from the rock below and may have moved only very slightly or not

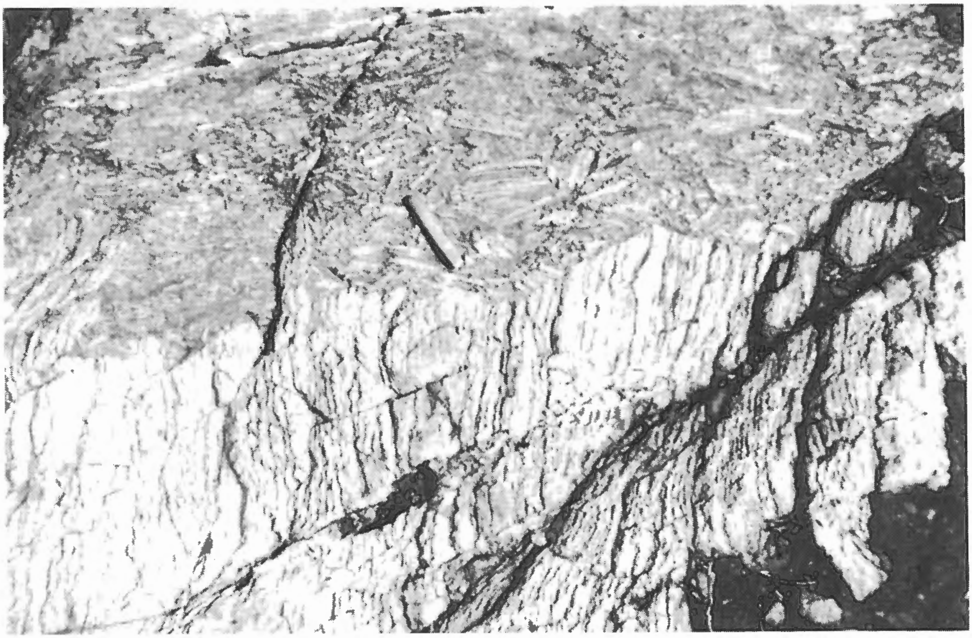


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PLATE 17. Tazin–Martin unconformity south of Fay shaft. Basal conglomerate immediately above unconformity made up of fragments derived from rocks immediately below. Locally fragments are still almost in original position (see left edge of photograph). Knife 3 inches long.

at all. In most places, however, the unconformity plane is sharp. Generally, on one side of the plane are Tazin rocks, on the other Martin rocks. Thus, on Umisk Island, in Beaverlodge Lake, the unconformity is represented by a contact between Tazin quartzite and Martin conglomerate; east of Fredette Lake by a contact between massive and brecciated granites and Martin conglomerate; and southwest of Murmac Bay by a contact between Tazin quartzite or hornblende schist and Martin siltstone and conglomerate.

In the area of Tazin rocks east of Fredette Lake are several small areas of seemingly remnants of Martin basal conglomerate. The fact that these show gradational contacts with the underlying granite and quartzite indicates that the present surface is very close, in this area at least, to the unconformity plane. In the area south and west of Nero Lake, the unconformity is also, in part, gradational, and there, too, it was not far from the present surface.

The angle of dip of the unconformity plane, as determined on outcrops, appears in most cases to be steep. Exceptions are where Martin rocks form a capping on tops of hills; there the dip is believed to be low. Steep dips would suggest either that the plane of unconformity was subsequently tilted or that the erosional surface on which these rocks were deposited was rugged. Probably both are partly true. It is believed that some tilting and folding of the Martin rocks took place, but if the trace of the unconformity plane is followed at surface, it can be seen that at a few places it ran over hills entirely disregarding the present topography; this suggests that the Martin rocks were deposited on a very rugged surface. This was observed west of Nero Lake, southwest of Ace Lake, north of ABC adit, and east of Fredette Lake. These features suggest that in some places in the Beaverlodge area, at least, very little of the Tazin rock was eroded since Precambrian time; it was protected by rocks of the Martin Formation. In other words, locally the erosion has reached the level of the unconformity.

The narrow layer of deeply weathered rocks, noted at several places immediately below the unconformity plane in the area south of Lake Athabasca, which was fully studied by Kirkland (1953) in the area of Black Lake, was nowhere seen in the Beaverlodge area.

Sections and Thickness

The Martin Formation, which occupies basins of various sizes (Fig. 4), can be subdivided on the basis of lithology into the following recognizable rock types: basal conglomerate, arkose, siltstone, andesite and basalt, interstratified conglomerate, and some sandstone. Some of these rock types form lithologic units or members that can be recognized whenever they occur. Others, because of lack of distinctive features, have to be grouped together within arbitrarily set limits, generally between the recognizable members, in which case they too can be considered as members. On this basis, sections have been prepared for the basins recognized: the Martin Lake, the Fredette Lake, and a few minor ones east of Beaverlodge Lake. All these basins are made up of similar rock types but in different proportions. In some, a certain rock type may be thick or thin or entirely missing. The sections are given in Table XXX, and those for the two main basins are composite sections, selected arbitrarily to give the most information. The Martin Lake section is believed to be the thickest and the most complete. The thicknesses given in Table XXX were determined from surface observations made during field work and, in the cases of the smaller areas near Fay, Ace, and Metal Uranium shafts, from underground exploration and drilling. The aerial distribution of the members of the Martin Formation is shown on Figure 4.

Map-Unit 20: Basal Conglomerate

In many places the rocks of the Tazin Group pass upward into a basal conglomerate without a definite break. In general, however, the unconformity is clear-cut. The basal conglomerate occurs as a lenticular mass or layer at the base of the Martin Formation. It may be very thick, as west of Nero Lake, east of Fredette Lake, on Umisk Island in Beaverlodge Lake, and north of it, or it may be very thin or missing, as on the peninsula southwest of Umisk Island. But wherever present, it is a typical, easily recognizable rock of massive appearance and highly resistant to weathering. It forms some of the highest hills in the area. A hill west of Nero Lake capped with this conglomerate reaches an elevation of almost 500 feet above the surrounding ground. A hill of about the same height and with, in part, the same relationship was noted on Umisk Island.

The basal conglomerate is a well consolidated reddish rock, formed of unsorted, angular to subangular fragments, generally cemented by a red arkosic matrix. The fragments are ordinarily so closely packed that they constitute about 65 per cent of the rock. In size, they are unsorted, varying up to 3 feet in diameter. Fragments of this size were noted only a few feet above the unconformity north of Umisk Island in Beaverlodge Lake and west of Nero Lake.

The fragments are derived entirely from rocks of the Tazin Group. All types of Tazin rocks are present, but quartzites, granites, and granitic gneisses predominate. Fragments of black and dark red ferruginous quartzites, and of brecciated and mylonitized rocks of amphibolite and mafic gneisses were a few types of rocks observed. In the conglomerate south of Umisk Island, fragments of black argillite were noted in a sandy matrix. In general, also, the fragments are predominantly of the type of rocks outcropping directly below the unconformity. In many instances, from a few feet to as much as about 20 feet above the unconformity plane, the fragments may be entirely or almost entirely of local origin, that is, made

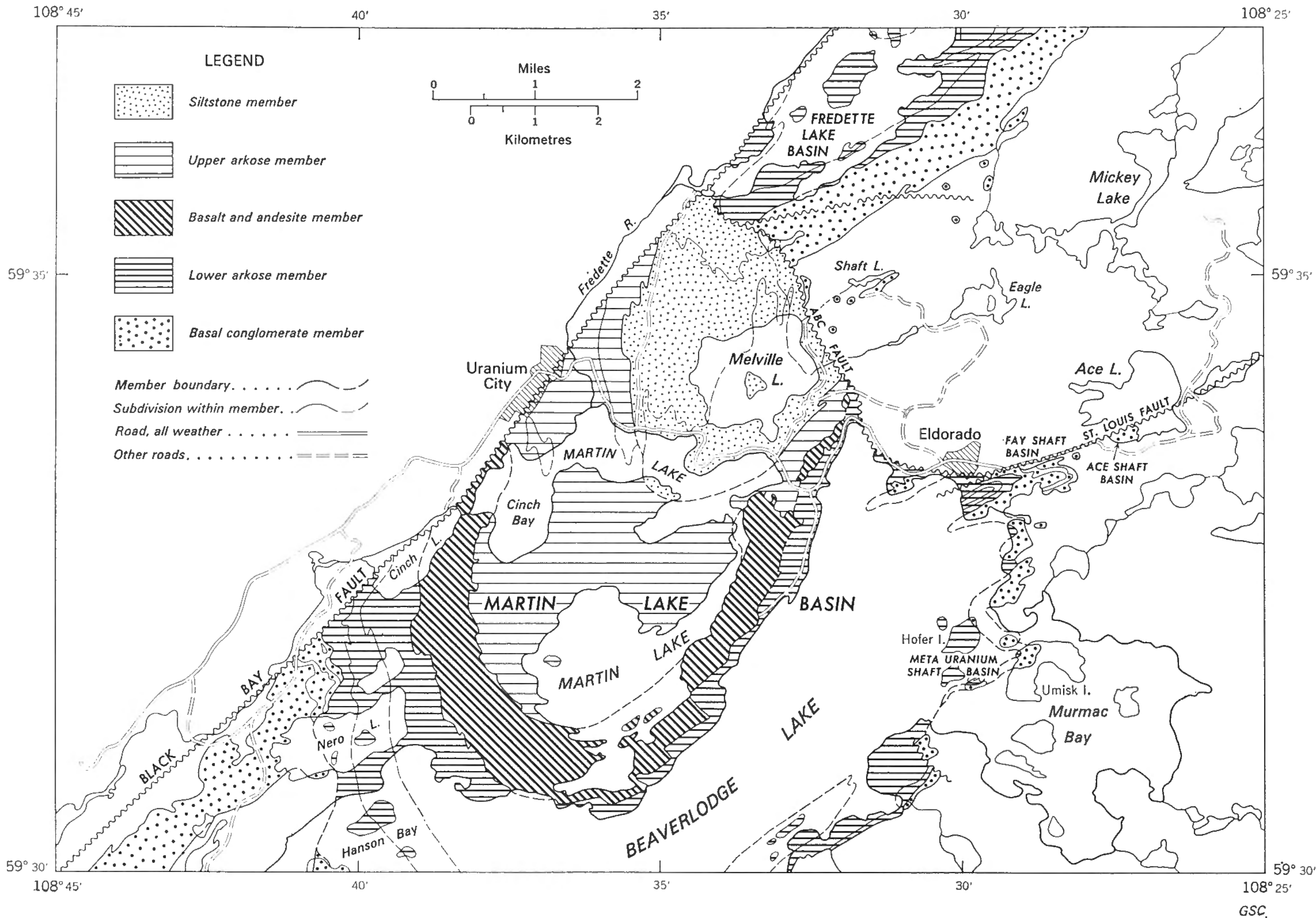

FIGURE 4. Distribution of rock types, Martin Formation.

TABLE XXX — *Columnar sections of the Martin Formation, Beaverlodge area*

Rock units or members	Martin Lake area		Fredette Lake area		Eldorado townsite	Fay shaft	Ace shaft	Meta Uranium shaft
SILTSTONE Mainly thinly bedded chocolate-red siltstone, interbedded with thin beds of arkose and conglomerate	From 13,000 to 19,500 feet thick	From 1,000 to 6,000 feet	Missing					
UPPER ARKOSE Mainly orange-red to salmon-pink arkose; locally includes thick lenses of conglomerate; near the top interbedded with siltstone and conglomerate		From 800 to 7,000 feet; on the west includes 1,000 feet of conglomerate	Missing					
AMYGDALOIDAL AND PORPHYRITIC BASALT AND ANDESITE interbedded with arkose; includes GABBRO SILLS near bottom		Up to 3,500 feet	Missing					
LOWER ARKOSE Mainly orange-red to salmon-pink arkose; includes locally some thinly bedded chocolate-red siltstone and / or thick lenses of conglomerate; minor grey arkosic sandstone near bottom in the Martin Lake area		From 3,000 in the west to 8,000 feet in the east, locally includes up to 250 feet of siltstone and / or 1,300 feet of conglomerate	From 4,000 to 6,500 feet thick	From 2,000 to 3,500 feet of arkose above, and 300 to 1,000 feet of siltstone below, interbedded with 600 feet of conglomerate	100 to 150 feet of arkose 50 to 100 feet of siltstone 75 to 125 feet of arkose	100 feet of conglomerate 50 feet of siltstone	100 to 150 feet of conglomerate 50 to 75 feet of siltstone	A few feet only of arkose
BASAL CONGLOMERATE (in the west part of the Martin Lake area it includes up to 1,000 feet of siltstone)		Up to 2,500 feet		From 1,500 to 2,000 feet	From 600 to 800 feet	100 feet	100 feet	From 600 to 800 feet

up of the rock or rocks directly below the unconformity. Thus, at one place about 500 feet due south of the Fay shaft, the conglomerate rests on massive white quartzite and the fragments are almost entirely of this quartzite (*see* Pl. 18). Similarly, the conglomerate west of Nero Lake rests on massive and brecciated red granite, and most of the fragments are of this type. The conglomerate west of Hanson Bay on Beaverlodge Lake and that east of Fredette Lake have a great number of grey quartzite fragments that were seen to rest on large areas of quartzitic rocks.

The matrix also, particularly for a few feet above the unconformity, may be made up of material partly of local origin and related to the rock or of rocks directly below the unconformity. Where dirty green, chlorite schist, amphibolite, and chlorite–epidote rocks are common in the Tazin rocks below the unconformity, this was noted west of Fredette Lake and in the

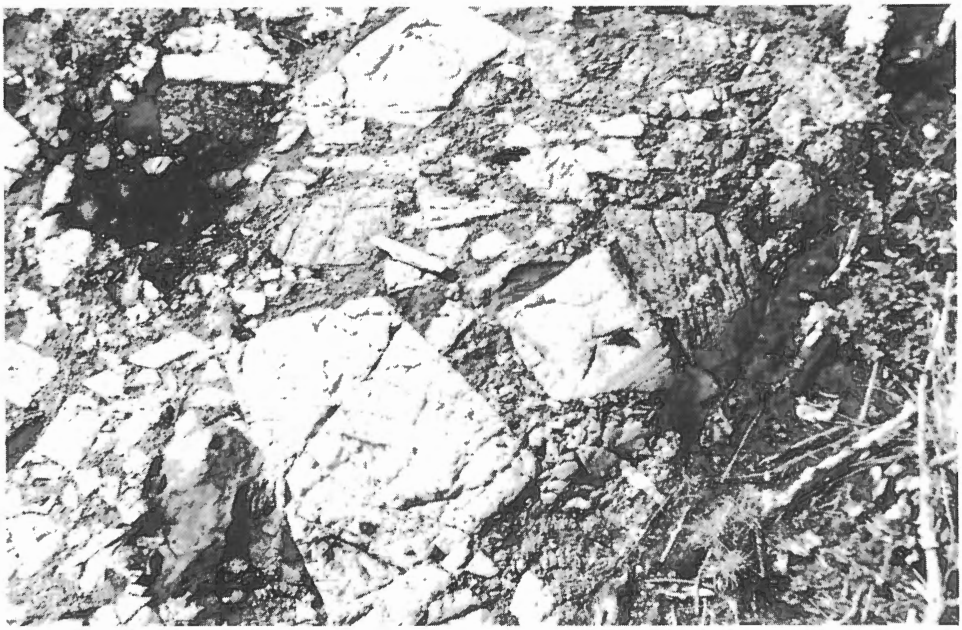

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PLATE 18. Typical basal conglomerate, Martin Formation, south of Fay shaft. Fragments are angular, of unsorted size and composition, and closely packed.

small mass near Eagle shaft. It is arkosic or chocolate-red and siltstone-like where the rocks below are reddish and mainly granitic, as in the area west of Nero Lake.

Although the fragments in this conglomerate are generally unsorted in size and composition, locally a certain amount of sorting may be present. West of Nero Lake, layers rich in unsorted fragments of a dark grey dense clastic siliceous rock (a rock composed of quartz grains in a chloritic matrix) could be roughly traced in the field and is believed to indicate bedding. These grey quartzitic fragments resemble the grey quartzite outcropping nearby on both sides of Black Bay fault. East of Fredette Lake at several places near the unconformity, layers with fragments of a definite size range were noted. Also, layers with only one kind of fragment, but unsorted as to size, were seen. A similar feature was noted in the conglomerate south of Ace shaft. Thus, although the basal conglomerate at first glance appears structureless, it is not entirely so. Very detailed mapping would probably outline several zones of slightly different composition and texture.

In thin sections the matrix may be similar to the arkose and siltstone described later, or it may be chloritic and composed of clastic grains of quartz and feldspar surrounded by chloritic material. Some carbonate, apatite, and zircon are ordinarily present, and iron oxide either forms clusters or is in tiny scattered grains.

This conglomerate may be locally interbedded with siltstone and arkose. A thick lens of siltstone was mapped in this conglomerate west of Nero Lake and south of Ace Lake; in it a narrow lens of siltstone was noted. In the area north of Umisk Island in Beaverlodge Lake and at the west end of Beaverlodge Lake, it is interbedded with layers of arkose, all of various thicknesses.

Seams of cryptocrystalline quartz and iron oxide, up to 6 inches wide but generally less than one quarter inch, were observed throughout areas of this conglomerate, particularly south and west of Nero Lake. A few narrow seams of pink feldspar were also noted in this conglomerate south of Ace shaft.

Map-Units 22 and 24: Arkose

Arkose is found at all levels above the basal conglomerate. In a few localities, such as north of Umisk Island in Beaverlodge Lake and northeast of Eagle shaft, it occurs also in beds within the basal conglomerate. Its main occurrence is in thin beds aggregating great thicknesses (*see* Pl. 19). Although such sequences have great lateral extent, rarely do individual beds extend far. Locally, the arkose may be in thick, massive, tough, structureless layers. The arkose along the east shore of Fredette Lake and a short distance east of Melville Lake are of this type. Much of the arkose is interbedded with siltstone near the upper part of the Martin Lake succession and with occasional narrow beds of conglomerate at all levels in the entire section. As shown on the accompanying map and on Figure 4, the arkose was subdivided into a lower and an upper arkose member.

The arkose is generally a well consolidated, hard rock, which weathers with a sandy appearance and breaks into rhombic blocks along well-defined joint planes. The colour is orange-red to red and light reddish brown in places. It may be purplish red, such as locally in the Fredette Lake area. It is fine to medium grained, the grain size varying between 0.1 and 2.0 mm, a size which puts the arkose in the sandstone group of Pettijohn. It is rather coarse on the islands in Fredette Lake. From a study of thin sections it is apparent that the

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PLATE 19. Gently dipping arkose, Martin Formation, on north shore of Hanson Bay, Beaverlodge Lake. View westward.

grain sizes fall into two main groups, one averaging about 1.0 mm, the other between 0.1 and 0.5 mm. The larger grains are few in number and generally are well distributed throughout the rock. They are either quartz or feldspar. Quartz grains may, in fact, be up to 2 mm in size whereas the feldspar grains are closer to 1 mm. The grains in general are subangular to subrounded and equant. Since they are usually very closely packed, there is very little matrix or cement. The angularity of the grains seems to be slightly more pronounced in the Fredette Lake basin than in the Martin Lake area. Within the Martin Lake basin the grains are more angular in the lower arkose member than in the upper and are also somewhat coarser, indicating longer transportation and better sorting for the upper arkose. The grains, which form almost 99 per cent of the rock, are of quartz, various kinds of feldspars (such as plagioclases, microcline, and perthite), interlocking quartz and feldspars (including myrmekite) and a few of opaque substances. There are practically no grains of chlorite and sericite. A few tiny flakes of brown and green biotite were recognized in two thin sections and were part of the matrix or cement. The grains are cemented by carbonate and iron oxide and rarely by small amounts of detrital material. No secondary quartz enlargement was noted. The red colour of the arkose is due to original red stain in the grains of quartz and feldspars and partly to the iron oxide cement.

Mineral grain counts in thin sections of arkose from the various basins of the Martin Formation in the Beaverlodge area have given the average mineral composition shown in Table XXXI. Details of these grain counts are presented in Table XXXII.

TABLE XXXI — *Average mineral composition of arkose and sandstone (map-units 22 and 24) of the Martin Formation, in percentages*

	Arkose Martin Lake basin	Arkose Fredette Lake basin	Grey sandstone Martin Lake basin	Sandstone dyke Martin Lake basin
Number of thin sections studied	15	5	3	1
Feldspars	60	58	41	10
Quartz	32	34	31	55
Opaque	6	2	2	matrix 24
Mafic minerals	1.5	6	8	8
Carbonate	0.5		18	3

A grey-white arkose was observed at several places on the islands in Beaverlodge Lake. It has generally as much quartz as, and more carbonate and fewer feldspars than, the ordinary arkose (Table XXXI). Another variety could be called a sandstone, it is composed almost entirely of quartz grains. This type occurs only near the southern margin of the Martin Lake basin, either as narrow beds within the arkose or in the conglomerate interbeds in Hanson Bay of Beaverlodge Lake. This sandstone is believed to be lithologically similar to the sandstone of the Athabasca Formation of the south shore of Lake Athabasca.

Two heavy mineral separations, one on six hand specimens from the arkose of the Martin Lake basin and the other on five hand specimens from the Fredette Lake area, were made. In these heavy fractions the following minerals were recognized: zircon, garnet, apatite, hematite, some hornblende, chlorite, quartz, and feldspars. Sphene, magnetite, and rutile are probably also present. Although tourmaline was reported by Christie, none was noted in the many thin sections studied and in the heavy fractions examined.

TABLE XXXII *Modes of arkose, Martin Formation, in percentages*

Location	Martin Lake basin																			Fredette Lake basin				
	West of synclinal axis							Centre			East of synclinal axis									East shore of Lake			Within Lake	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Specimen No.	S14-52	S15-52	S17-52	S18-52	S19-52	S26-52	T80-56	S22-52	C8-52	C13-52	S20-52	S21-52	S28-52	S29-52	R48	R1	T65-57	T36A	C5	1-C-56	5-C-56	T18-56	T16-56	T81-56
Feldspars	63	68	67	62	40	61	70	47	37	39	67	69	60	55	54	57	52	42	10	60	56	67	57	52
Quartz	33	30	29	34	42	23	26	44	46	19	27	25	29	29	35	34	35	30	55	30	38	25	34	44
Opaque	3	2	4	4	3	8	4	4	12	1	5	6	6	10	10	5	5	2			2	3	2	1
Mafic minerals	1					1		5	5	13	1		5	2	1	4	3	13	8	10	4	4	7	3
Carbonate					15	7				28				4				13	3					
Matrix																	5		24					

Specimens 5, 10, and 18, are grey arkoses.
Specimen 19 is of a sandstone dyke.

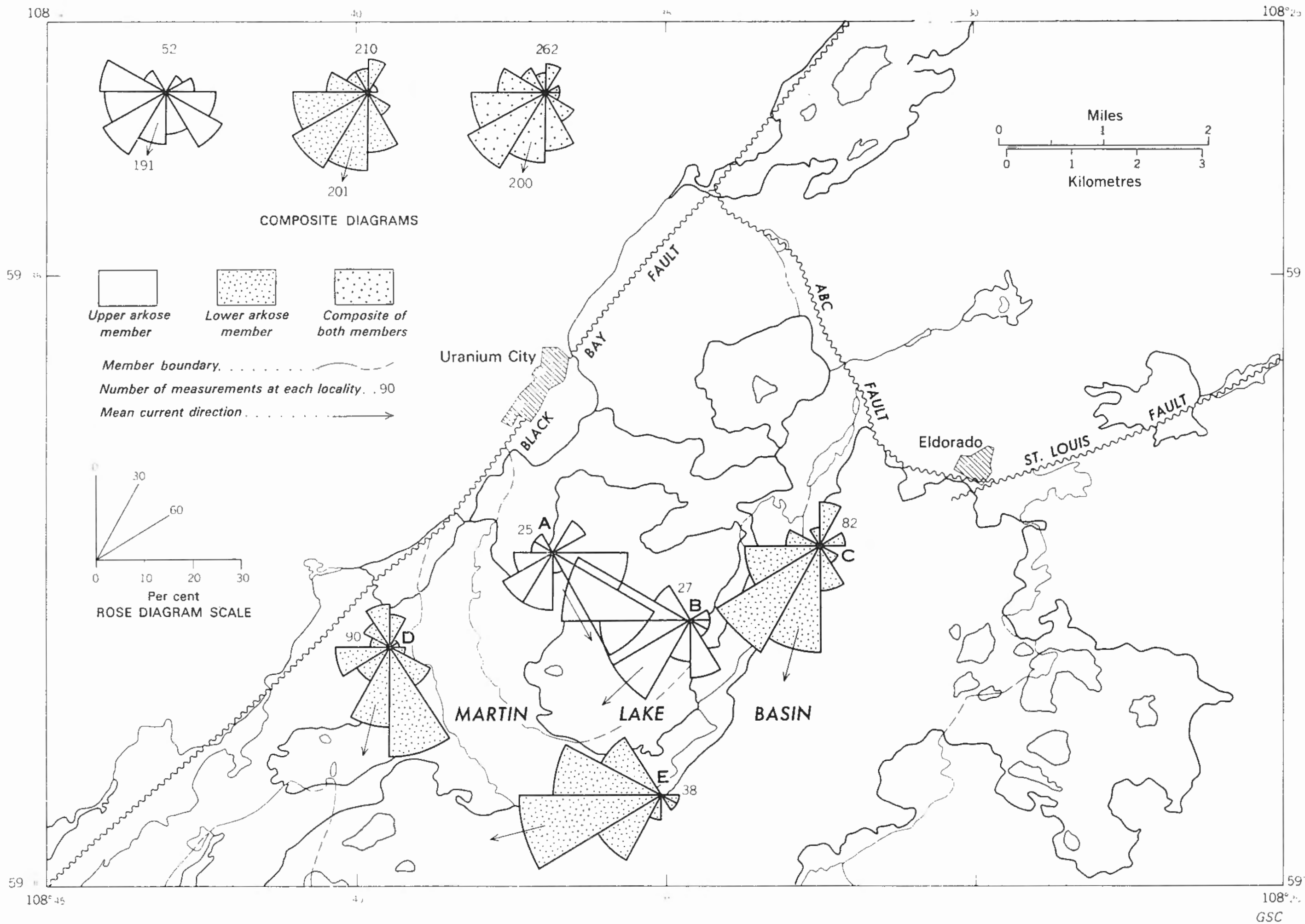

FIGURE 5. Rose diagram showing percentage distribution of current direction based on crossbedding in Martin Lake basin.

Two specimens of arkose from the Martin Lake basin were stained for feldspar. Although it was not possible to determine the total feldspar content in these two stained specimens, their potassic feldspar content could be evaluated very readily; in both specimens it was about 31.5 per cent. The plagioclase content is then probably about 28.5 per cent.

Where the arkose is well bedded, a few minor structural features were observed. The most common one is lateral grain variation within beds, but rarely graded bedding, so common in greywacke. It is merely a variation in grain size along strike and up or down dip. Graded beds however, were, noted at a few places, particularly in the fine arkose. Crossbedding is another common and widespread feature. It is from microscopic to very large in size and usually of the planar type, although locally the trough type was recognized. Crossbedding was observed almost everywhere in the Martin Lake basin but is not so common north of Martin Lake and is more difficult to measure there. In the area south of and around Martin Lake 262 readings indicate that the probable source of the material for this basin is from north-northeast, a direction which contrasts sharply to the east and southeast one measured by Fahrig (1961, p. 26) for the Athabasca Formation south of this area. The results of these

PLATE 20

Large fragments of granite or granitized rock widely scattered in fairly uniform grained arkose. Fragments have well rounded edges and appear to be faceted. West shore of Lake Beaverodge near south boundary of map-area.

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readings, after correction for tilt, are shown in Figure 5. In the Fredette Lake basin, the arkose on the islands show good crossbedding, but to the east shore of the lake only microscopic crossbedding of the planar type was seen and was insufficiently well exposed to allow readings in three dimensions.

In addition to these features, ripple-marks were also observed. They are generally of the wavy type and occur mainly where the rock is thinly bedded.

In several places an occasional large fragment of Tazin rock was observed in the arkose (*see* Pl. 20). On the east shore of Beaverlodge Lake, Tazin rocks can readily be seen in the arkose and are also common in areas of massive arkose. Tazin rock fragments are up to 10 inches in diameter and are mainly of granitic composition. They may also occur in groups of two or three. Their peculiar occurrence in rather uniform-grained rock suggests that they may have been dropped by drifting ice. They are rounded to subrounded, but when two such fragments were removed from the surrounding arkose they seemed to be partly faceted.

Another peculiar feature of the arkose was noted in the area where it is interbedded with volcanic flows. There, some of the beds that directly overlie the flows contain occasional fragments of the underlying volcanic rocks in a few places; also, the fact that many of the grains forming the arkose appear to be derived from the underlying volcanic rocks themselves is an indication that erosion of the flows took place before they were covered again with arkose. Although there definitely was a time break, it was probably one of local or minor significance only.

A group of specimens was collected from the main arkose area (mostly from the upper arkose member) of the Martin Lake basin. These specimens were formed into a composite sample that was chemically analyzed, and the analysis is believed to be representative of the arkose of the area (Table XXXIII). The great similarity in composition of the arkose to the normal granite (Table XXVII, No. 1) of the area is apparent. The somewhat higher content of iron, lime, and magnesia in the arkose is probably due to its cement, which is mainly iron oxide and carbonate.

Sandstone dykes were noted at a few places in the volcanic rocks (23). These dykes are almost vertical and suggest that the fractures were filled from above when the arkoses and volcanic rocks were exposed to erosion. These dykes are more often composed of a quartz-rich sandstone rather than an arkose. Similar dykes, though not of the same composition, were also noted in the Tazin rocks, usually at a short distance from the Martin Formation. The latter, however, are made up of much finer grained material than the sandstone dykes in the flows and have a much higher content of iron oxide. They are siltstone dykes.

The arkose is generally red, but locally, in addition to its normal red colour, it shows a deep red coloration that varies in intensity from bed to bed and also from place to place within a bed. This coloration is in layers parallel either with or across the bedding planes and in patches of irregular size and shape, all irregularly distributed throughout the arkose. The patches may even cross from one bed to the next, above or below. Such occurrences suggest that this coloration took place after the consolidation of the arkose; but where the variation of colour is accompanied by a change in grain size, it is possibly a depositional feature. Where it is found as a thin film along and for narrow widths on both sides of joint planes, it is definitely a late feature, either surficial only or hydrothermal. In all cases, the red coloration is believed to be due to hematite. These colour effects are probably due to a combination of processes. One of them, not mentioned above, may be the bleaching of the red colour of the arkose by surficial waters charged with organic material, leaving behind red unbleached patches. This suggests an oxidation-reduction reaction.

TABLE XXXIII *Chemical analyses of arkose and siltstone, Martin Formation, in percentages*

	1	2	3	4	5	6	7
SiO_2	74.41	73.33	74.15	65.91	65.44	64.00	58.10
Al_2O_3	11.15	14.33	12.92	15.86	13.88	14.00	15.40
Fe_2O_3	0.87	0.31	0.54	0.35	3.70	1.30	4.02
FeO	.83	.66	1.58	3.77	0.88	4.1	2.45
CaO	2.13	.99	0.52	2.63	2.34	3.4	3.11
MgO	0.61	.34	.37	1.49	1.54	2.9	2.44
Na_2O	3.67	4.60	3.38	3.07	4.04	3.5	1.30
K_2O	3.84	4.00	5.21	4.43	4.04	2.1	3.24
H_2O^+	0.23	0.47	0.73	1.12	0.93	2.0	{ 5.00
H_2O^-	.09	.08	.07	0.15	.23	0.1	
TiO_2	.16	.07	.26	.53	.47	.5	0.65
P_2O_5	.08	.09	.07	.20	.16	.1	.17
MnO	.03	.01	.03	.07	.06	—	C .80
CO_2	1.57	.35	nil	.16	2.06	1.5	2.63
S						—	$SO_3$0.64
Total	99.67	99.63	99.83	99.74	99.77		
Na_2O/K_2O	0.96	1.14	0.75	0.69	1.0	1.66	0.40
$Fe_2O_3+FeO+MgO/CaO$	1.08	1.34	4.78	2.13	2.61	2.44	2.86

Niggli Numbers

	1	2	3	4	5	6	7
si	437	411	423	278	285	258	252
al	39	47	43	39	36	33	39
fm	13	7	17	24	25	33	31
c	13	6	3	12	11	15	15
alk	35	40	37	25	28	19	15
si	241	258	248	199	213	176	160
qz	196	153	175	79	72	82	92
(al+fm) − (c+alk)	4	41	20	26	22	32	40

1. Arkose, Martin Formation, composite sample.
   Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
2. Normal granite, dyke, near Rix-Smitty mine shaft, composite sample.
   Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
3. Red granite, Black Bay area, west of Beaverlodge area.
   Analyst: W. H. Herdsman, Glasgow, Scotland (from W. E. Hale, 1953).
4. Foot Bay layered gneiss, Tazin Group, east of Donaldson Lake, composite sample.
   Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
5. Siltstone, Martin Formation, north of Martin Lake, composite sample.
   Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
6. Average greywacke, F. J. Pettijohn (1949, p. 271).
7. Average shale, F. W. Clarke (1924, p. 34).

Map-Units 21 and 26: Siltstone

The siltstone is a dense to fine-grained, chocolate-red rock that is found at several horizons in the various basins. It does not account generally for much of the total sections as it occurs mainly in much thinner beds with thicker beds of other rock types. Locally, however, it may have accumulated in layers of as much as 1,000 feet thick. This is so for the lens of siltstone north of Nero Lake and for the band along the southeast shore of Fredette Lake. As a rule, the siltstone forms thinner layers. In the centre of the Martin Lake basin and toward the upper part of the section, the siltstone occurs thinly interbedded with much arkose and some conglomerate. There it constitutes up to 60 per cent of the section. These interbedded sequences are up to 5,000 feet thick and are mapped with the siltstone member.

The chocolate-red colour of the siltstone, as seen in thin sections, is due mainly to uniformly distributed, fine-grained hematite, but in places to limonite. Where this is so it indicates hydration of hematite to limonite. Locally the siltstone seems to be bleached of its red colour, or of some of it, as it is buff or spotty buff. Interbedded with the ordinary red siltstone are a few thin beds that are entirely light greenish grey or only patchy grey, suggesting reducing conditions when these beds were deposited. These greenish beds and patches are finer grained than the red siltstone and have much sericite. The grains forming the red siltstone are generally angular, and many of them are slender, longer in one dimension, just as the grains in greywacke. The slender grains are generally oriented similarly. Sericite and chlorite are most commonly longer in one dimension, as are some of the quartz and feldspar grains. The grains are generally very closely packed. The interstitial clastic material and the cement constitute only a small part of the rock. The average grain size is between 0.02 and 0.05 mm, but there are a few larger grains up to 0.15 by 0.01 mm in size. These occur uniformly distributed within the rock.

Bedding is not always obvious but where present is indicated by slight colour variations, small grain size changes, and even by faint thin lines of different compositions. In thin sections, a local rough stratification is indicated. Graded bedding was recognized only under the microscope, the grains passing from 0.04 mm at the base to 0.02 mm at the top of a bed. Mudcracks are a common feature in the siltstone of the Martin Lake basin but are rare in the Fredette Lake area. They are generally filled with arkosic material. A few ripple-marks were seen. Pock marks, possibly resulting from rain drops, were noted in the area around Melville Lake. Although a faint slaty structure has developed along rare bedding planes, nowhere could one regard the rock as a slate. This slaty structure is due to the presence of numerous tiny flakes of mica and chlorite on some planes parallel with the bedding planes.

The results of grain counts on thin sections of the siltstone are given in Table XXXIV. The quartz grains are generally clear. Feldspar grains are clear to somewhat dusty due to iron oxide; otherwise they are not altered. Staining tests suggest a total feldspar content somewhat similar to the one given above for the arkose and indicate also the presence of plagioclase and potassic feldspar. The potassic feldspar content is high. As the mineral composition of this siltstone is close to that of the arkose, the rocks are probably related to each other, the siltstone representing a rock with a better sorted grain size. Therefore, this rock is probably an arkosic siltstone as described by Christie (1953, p. 49). Other minerals, recognized in thin section but generally in small amounts, are muscovite, chlorite, green biotite, zircon, and apatite.

Specimens were collected from the siltstone beds of the succession of interbedded siltstone, arkose, and conglomerate north of Martin Lake. This composite sample was chemically analyzed with the results shown in Table XXXIII, No. 5. This analysis compares well with the analysis for the arkose and approaches that of an average greywacke (Table XXXIII). Its higher content of iron, lime, and magnesia is an indication of the greater amount of hematite and carbonate as cement in the siltstone and also of the larger amount of mafic minerals in this rock as a whole. Its alkali content and its ratio of soda to potash, if compared to those of the Foot Bay gneiss (Table XXXIII, No. 4), indicate that this rock was derived by weathering from the Tazin rocks.

TABLE XXXIV | *Modes of siltstone, Martin Formation, in percentages*

Location	Martin Lake basin			Fredette Lake area		Average
	Nero Lake area	Area north of Martin Lake				
Specimen No.	1 T46-57	2 S32-52	3 4-R	4 2-C-56	5 15-C-56	All specimens
Feldspars	65	69	63	55	60	60
Quartz	7	8	13	10	10	10
Opaque	15	12	22	25	20	20
Mafic minerals	13	11	2	10	10	10

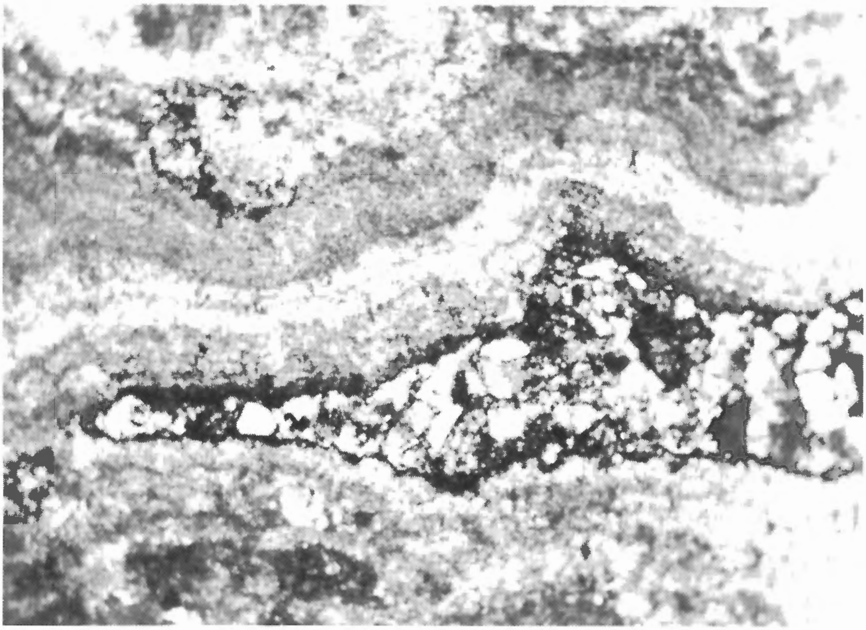

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PLATE 21. Concentric algal structure observed in conglomerate interbed near top of siltstone member of Martin Formation. South of ABC adit and shaft. Crossed nichols, enlarged about 30 times.

A layer of clastic rock displaying some concentric zoning was traced for at least 200 feet in the area of siltstone east of Melville Lake, due north of Martin Lake. This layer may extend farther north and south; however, due to poor exposures it could not be traced. It is therefore not shown separately on the map. The layer is only 5 feet wide and occurs where the siltstone is thinly interbedded with arkose and conglomerate. It is characterized by irregular masses that display a peculiar concentric zoning, expressed by bands, a few millimetres wide, concentric about a nucleus (generally a few clastic grains or a pebble) (*see* Pl. 21). These masses are irregularly distributed along and within the layer and serve to define it. They are generally less than a foot across. Individual bands may be fairly uniform and concentric, forming almost a circle, or may pinch out rapidly, but generally they are very irregular in shape, length, and width. Some end abruptly against other zones or against clastic material as if truncated by erosion. New bands form on these truncated pieces as a result of subsequent reactivation. The bands are made up mainly of carbonate and seem to have grown amongst clastic materials; locally they enclose a few clastic grains. Under the microscope, a few small irregular areas with the same zoning were noted in clastic material. They look like fragments from larger masses, possibly the product of erosion. They seem also to have moved about and to have been deposited with the other clastic material, probably due to wave action. Some of the zones are wavy on the outside as if they had grown outwards. The carbonate of these structures is believed to be material washed over some organisms and trapped by them during their life processes. This explains why some of the zones enclose a few clastic grains. This type of structure probably belongs to the stromatolites (Hofmann, 1971, p. 86). The organisms, algae, responsible for this structure generally require shallow water, and it is believed that their deposits were subjected to erosion and once in fragments were free to move. This would explain how some of the zones are truncated and how fragments of the zoned structures were found.

Map-Unit 23: Volcanic Rocks and Gabbroic Sills

The andesite and basalt flows and their associated gabbroic sills are found only in the Martin Lake basin, where they occur in a horseshoe-shaped belt, extending from the Black Bay fault slightly north of Cinch Lake around Martin Lake and pinching out slightly east of Melville Lake before reaching the ABC fault. The thickness of this belt at the south end of Martin Lake is about 3,800 feet. Everywhere the volcanic rocks and the sills are found they are interlayered with wide bands of arkose and some conglomerate, and, as a result of this, at least six different periods of volcanic eruption are indicated, each separated by the arkose zones. Each period probably also represents more than one outpouring of lava. Thus, south of Martin Lake, at one locality at least, three different outpourings were recognized in one period of eruption. Features such as pillowed and flow structures, brecciated flow tops, wide zones of amygdaloidal lava alternating with zones of massive lava, and fragments of volcanic rocks in arkose directly above the volcanic rocks, all suggest that these volcanic rocks are surficial deposits and that each period of eruption was followed by an inter-period of arkosic deposition. The associated gabbroic sills are found below the volcanic rocks in the succession, and, as with the flows, they are interlayered with arkose and conglomerate. Most of them occur west and south of Martin Lake; only two small occurrences are known east of the lake. However, the sills may be as abundant to the east, for, if present, they would be under the waters of Beaverlodge Lake. The sills are up to 400 feet thick. South of Martin Lake, at least five of them were counted, and locally they may be more numerous. South of Cinch Lake only three gabbroic sills were mapped. The sills show crosscutting relationships with the arkose but not with the flows.

Map-Unit 23a: Volcanic Rocks

The volcanic rocks (23a) are massive and fine to medium grained. On weathered surfaces they are various shades of brown and green to very light brown; on fresh surfaces they are normally dark green to dark brown and black. Locally, their patchy brown, red, and green colour impart a broad mottled appearance to the rock, as in the adit of the Martin Lake mine. They are commonly porphyritic with laths of white feldspars occurring singly or in clusters and exhibiting bird-foot markings on weathered surface. They are also commonly amygdaloidal, the amygdules reaching 6 inches in size but being mostly smaller than an inch across. The distribution of the amygdules in the flows cannot be related to any particular structural feature of the flows, except that they appear to be more abundant and to occur over a greater distance downward than upward. In these places they occur most commonly in patches or pockets and in layers oriented about parallel with the trend of the flow; but generally the layers are not of uniform thickness. The shape of most of the amygdules is spherical or nearly so. Near the base of flows amygdules are locally pipe-like with the pipes oriented about at right angles to the base of the flows. In composition the amygdules are made up of chlorite, carbonate, a dense fine-grained siliceous material, or even of a mixture of chlorite and carbonate with locally some quartz, sphene, opaque minerals, and feldspars. When the amygdules are made up of a mixture, the minerals are cryptocrystalline and occur generally in spherical rhythmic bands, but in a few places there may be a cavity left in the centre of the amygdules where some euhedral minerals have formed, usually quartz, blades of specularite, and carbonate.

A pillowed structure (23d) was seen, but it is not a common feature. It was observed only near the Martin Lake adit on the Martin Lake side and south of the lake. The pillows are generally round or oval and may be up to 3 feet in diameter. The selvage zone of these pillows is rather narrow and is associated with a set of circular sheeted joints.

In thin section, the lava usually consists of large euhedral feldspar laths resting in a mesh of smaller euhedral feldspar laths, interstitial mafic minerals, and opaque substances. The large crystals of feldspar occur isolated or in groups of two or three and are up to 4 by 1.0 mm in size. The smaller feldspar crystals of the matrix average about 0.4 by 0.1 mm. Both the large and small feldspar laths proved to be andesine in composition about An_{35}, which agrees fairly well with the determination of Smith (1952) of An_{28-32}. Christie (1953) suggests a composition of An_{35-55} for the feldspars, which is probably a little high in anorthite for the feldspar of most of the volcanic rocks; but his volcanic rocks included the gabbroic sills, which have a more calcic feldspar. Edie (1951) called the feldspar of the volcanic rocks andesine. Locally, however, the feldspar has been found to be albite, and in such cases the mafic minerals are almost completely to entirely altered to chlorite, sphene, and even serpentinized material. The amygdules are represented in thin sections by oval and round masses. In a few places, large grains of mainly chlorite, up to 2 by 0.3 mm and with a general ragged appearance, are probably altered phenocrysts of hornblende and possibly pyroxene. These large grains rest in a matrix similar to the one described above, but here the interstitial mafic material is mainly chlorite and an isotropic brown substance. The opaque substance occurs as blades, small scattered grains, rims round other minerals, and dust particles. The texture of the rock is ophitic to diabasic.

Mineral counts on at least fourteen specimens of these rocks (Table XXXV) indicate two main trends of feldspar content (Table XXXVI). One group has a feldspar content of about 35 per cent, the other a feldspar content of about 65 per cent. They all have about 10 per cent opaque material; and if one assumes about 3 per cent for minerals such as carbonate, apatite, and quartz, the remainder is mafic material such as chlorite, sphene, an isotropic brown to green substance, epidote, and some relicts of hornblende and pyroxene.

TABLE XXXV *Modes of lavas (23a) and gabbroic sills (23c), Martin Formation, in percentages*

	Volcanic rocks																	Gabbroic sills						
Location	East of Martin Lake													West of Martin Lake	South of Martin Lake			East of Martin Lake	West of Martin Lake			South of Martin Lake		
	South of main road											North of road												
Specimen No.	1 S-50	2 11-V	3 1-V	4 S-47	5 2-V	6 T64-57	7 4-V	8 5-V	9 Flow 3	10 Flow 2	11 Flow 1	12 R-46	13 R-47	14 T60-52	15 5-1	16 C-2-52	17 C-7-52	18 S-51	19 S-12	20 S-10	21 S-9	22 S-4-52	23 S-6-52	24
Feldspars	40	38	25	26	46	30	39	62	29.2	74.8	60.2	60	67	67	43	63	31	20	72	49	35	24	30	72.3
Isotropic substance		1	47	51	45	44	20	1	41.5			20			1									
Opaque	3	10	8	18	5	5		18	17.3	9.1	18.1	13	11	10	4	4	10	14	10	5	5	7	6	5.7
Chlorite	31	44	13	3	3	7	14	16	6.5	10.9	11.2	7	13	23	39	31	57	16	16	7	18	1		5.1
Sphene	26	5	4			14	1	1								1		2	2	7			4	
Quartz		2	tr	2	1		1						6		6									
Apatite			4						0.9	tr	1.3		3			1	2.5		2					2.5
Carbonate								2		tr	2.3				7									0.4
Pyroxenes																				35	35	68	61	14.1
Epidote									4.6	5.2	4.9													tr
Biotite																								
Sericite											2.1													
Serpentine																		50						

Specimens 9, 10, 11, and 24 are from R. W. Edie (1951, p. 52).
The specimens 1 to 11 are from layers of volcanic rocks that are progressively higher in the succession, the specimens 1 and 2 being from the lowest layer, and specimens 8 and 11 from the highest one.
Specimens 1 and 2 are from one layer.
Specimens 4, 5, 6, and 9 are from another one.
Specimens 7 and 10 belong to one layer whereas the specimens 8 and 11 belong to another one.
Specimens 12 and 13 are from a layer that may be related to any of the above layers.

TABLE XXXVI | *Average modes of lavas and gabbroic sills, in percentages*

	Lavas		Gabbroic sills
Number of thin sections studied	9	5	7
Feldspars	36	63	(20–72)
Opaque	9	11	8(5–14)
Apatite, quartz, carbonate	3	3	3(2–7)
Mafic minerals and isotropic substance	52	23	(16–69)

R. W. Edie (1952), who has made mineral counts on these rocks, obtained the same trends in feldspar content. It would appear from the location of the specimens studied for this report and those of Edie (1952) that the feldspar content is higher in those flows that are high in the succession, suggesting that, with time, the lava became more acidic; that is, that differentiation was going on when these flows were ejected. These rocks, although they appear fresh in the hand specimen, are really highly altered. The feldspars generally have a dusty appearance or are sericitized rather heavily. Most of the mafic minerals are alteration products. Although it is not always possible to tell what the original mafic mineral was, it seems that there are a few partly altered remnants of pyroxene, possibly augite, and some hornblende. The brown and light green isotropic substance is possibly chlorite or a glass, that is, material not yet recrystallized.

Specimens were collected from the various layers of volcanic rocks in the area east of Martin Lake and south of the Martin Lake adit. These specimens were cleaned of all visible amygdules and chemically analyzed. The results are presented in Table XXXVII. This rock, if it is compared with the world's average basalt and dolerite, is found to contain half as much lime and magnesia and twice as much potash and soda, indicating some spilitic tendencies. This suggests that the feldspars in these rocks are relatively acidic and are probably quite abundant. Three other chemical analyses of these rocks were presented by Dawson (1956) and are from specimens not far from radioactive veins. These show an increase in the total iron and lime content and a marked decrease in the silica content when compared with analysis No. 1, Table XXXVII. These changes possibly result from the alteration associated with the uranium mineralization. R. W. Edie (1952) made chemical spectrographic analyses of three separate layers of volcanic rocks above the Martin Lake adit. His results checked in part with those of analysis No. 1, Table XXXVII.

Locally the volcanic rocks are crossed by fractures, now mainly filled with detrital quartz though containing some clastic material derived from the volcanic rocks themselves. Some of these clastic-material-filled fractures are locally definite sandstone dykes. These were described with the arkose. In other places, the fractures are very narrow and appear to be related to a sort of columnar jointing. Such fractures which are usually filled with a dense mixture of microcrystalline silica and hematite, impart to the rock a box-like structure.

Map-Unit 23c: Gabbroic Sills

The gabbroic sills are massive, fine to coarse grained, and dark brown to dark green. They exhibit chilled, dense to fine-grained margins and locally show crosscutting relationships with the arkose interlayered with them; apophyses of gabbro extend into the arkose, and the gabbro near the contact contains occasional blocks of arkose. The rock has a general ophitic appearance. In places, particularly near the margins, it may be slightly amygdaloidal and porphyritic with large mafic minerals in a finer grained ophitic matrix.

In thin sections, this rock shows an ophitic or a diabasic texture and comprises randomly oriented euhedral feldspar laths of various sizes, resting in a mass of alteration products. Its mineral composition, shown in Table XXXV, was estimated from grain counts of seven

TABLE XXXVII *Chemical analyses of the lavas and gabbroic sills, Martin Formation, in percentages*

	1	2	3	4	5	6	7	8	9
SiO_2	51.51	46.07	40.93	47.97	50.83	49.1	53.7	49.4	52.6
Al_2O_3	15.22	16.29	15.94	16.41	14.07	13.1	13.7	14.3	13.0
Fe_2O_3	6.15	9.14	10.60	9.23	2.88	9.5	8.1	9.0	2.9
FeO	4.89	4.26	3.14	2.67	9.00	2.5	2.8	2.6	7.9
CaO	4.29	4.64	7.74	5.77	10.42	3.9	3.0	3.1	6.0
MgO	4.38	4.53	4.39	3.62	6.34	4.6	4.7	4.0	3.9
Na_2O	4.66	5.48	3.16	4.42	2.23	4.7	4.3	5.2	3.0
K_2O	1.67	1.56	1.69	1.54	0.82	2.0	3.0	1.7	4.0
H_2O^+	2.49	3.08	3.15	2.34	.91				
H_2O^-	0.42	0.40	0.31	0.76					
TiO_2	2.19	0.63	1.37	1.16	2.03				
P_2O_5	1.08	1.08	1.00	0.87	0.23				
MnO	0.14	0.01	0.04	.01	.18	0.1	0.1	0.1	0.2
CO_2	.60	3.30	6.10	3.10					
S		0.04	0.03	0.16					
Total	99.69	100.51	99.59	100.03					
Na_2O/K_2O	2.78	3.52	1.87	2.87	2.72	2.35	1.43	3.06	0.75
$Fe_2O_3+FeO+MgO/CaO$	3.6	3.87	2.34	2.69	1.75	4.26	5.2	5.04	2.45
Fe_2O_3+FeO/MgO	2.52	2.96	3.13	3.29	1.87	2.61	2.74	2.90	2.77

Niggli Numbers

	1	2	3	4
si	149	121	105	134
al	26	25	24	27
fm	45	45	44	41
c	13	13	21	18
alk	19	17	11	14
(al+fm) − (c+alk)	40	40	36	36

1. Volcanic rocks, amygdules removed, east limb of syncline and south of Martin Lake adit, composite sample. Analyst: John A. Maxwell, Geol. Surv. Canada, Ottawa.
2. Volcanic rocks, 18 inches from radioactive vein, above Martin Lake adit. Analyst: R. J. C. Fabry (K. R. Dawson, 1956, p. 35).
3. Volcanic rocks, 6 inches from radioactive vein, above Martin Lake adit. Analyst: R. J. C. Fabry (K. R. Dawson, 1956, p. 35).
4. Volcanic rocks, 12 inches from radioactive vein, above Martin Lake adit. Analyst: R. J. C. Fabry (K. R. Dawson, 1956, p. 35).
5. Normal tholeiitic basalt and dolerite (137 analyses). S. R. Nockolds (1954), p. 1021.
6. Volcanic rocks, flow No. 1, Martin Lake adit, R. W. Edie (1952, p. 686).
7. Volcanic rocks, flow No. 2, Martin Lake adit, R. W. Edie (1952, p. 686).
8. Volcanic rocks, flow No. 3, Martin Lake adit, R. W. Edie (1952, p. 686).
9. Gabbroic sill or coarse-grained lava, south of Martin Lake, R. W. Edie (1952, p. 686).

Remarks: Analyses Nos. 2, 3, and 4 are from the volcanic band corresponding to flow No. 2 of R. W. Edie.

R. W. Edie's analyses are spectrographic except for SiO_2 and FeO, which were chemically analyzed at the University of Minnesota.

thin sections. An average mode is given in Table XXXVI. The feldspar laths are up to 4 by 0.5 mm in size and locally are closely packed. They are generally fresh and are believed to be labradorite about An_{55}. Here, as in the flows, the feldspar content seems to fall into two main groups: one in which the feldspar content is about 27 per cent, the other in which it is about 60 per cent. The mafic minerals interstitial to or enveloping the feldspar laths are now mainly serpentine, chlorite, and a light brown to light grey almost isotropic substance, and possibly also some sphene. They are probably alteration products after pyroxene; in fact, a few light brown relicts with a large 2V suggest that they were once probably augite. A few of these relicts also show the schiller effect; that is, grains of opaque minerals are scattered on their surface. Chlorite not only is an alteration product after pyroxene but also occurs in crypto-crystalline masses in amygdules. The opaque mineral is probably magnetite as it occurs mainly as cubes and hexagones, or as blades and irregular patches in the alteration products. Sphene, apatite, carbonate, and interstitial felsic minerals are accessory minerals.

There is no complete chemical analysis of these sills, except for a spectrographic analysis made by R. W. Edie (1952), presented in Table XXXVII. This analysis shows that the soda and potash content is high in these rocks as it is in the flows, suggesting consanguinity. To ascertain this relationship, two more specimens were partly analyzed for CaO, Na_2O, and K_2O (Table XXXVIII). The K_2O and CaO results compare well with those of Edie but not the Na_2O data. Similar partial analyses were obtained on four specimens of late gabbro dykes and sills. The results of these suggest that the spilitic tendencies recognized in the volcanic rocks are not present in the gabbro intrusions. This may indicate that the high soda content of the volcanic rocks is due to an alteration that took place when the lava being extruded came into contact with sea-water and may not be a feature related to the original

TABLE XXXVIII | *Partial chemical analyses[1] of lavas and gabbroic sills, Martin Formation, and of four basalt dykes cutting Tazin rocks, in percentages*

	1	2	3	4	5	6	7
CaO		5.03	2.16	5.58	4.35	2.87	6.30
Na_2O	3.44	2.32	2.74	2.43	3.20	2.22	3.14
K_2O	1.40	1.68	2.41	2.00	3.08	2.32	1.11
Na_2O/K_2O	2.43	1.38	1.14	1.22	1.04	0.96	2.83

1. Volcanic rocks, Martin Formation shore of Beaverlodge Lake, just over half a mile southeast of portal of Martin Lake adit on Martin Lake.
   Analyst: R. J. C. Fabry (Christie, 1953, p. 52).
2. Gabbroic sill, Martin Formation, about halfway between Nero Lake and Martin Lake.
   Analyst: O. C. Wickremasinghe.
3. Gabbroic sill, Martin Formation, about 2,000 feet, south of Cinch Lake.
   Analyst: O. C. Wickremasinghe.
4. Late basalt or gabbro dyke (late dyke), about 3,000 feet, southwest of Frank Lake and 3,000 feet, northwest of Martin Lake.
   Analyst: O. C. Wickremasinghe.
5. Late basalt or gabbro dyke (late dyke), about halfway between Schmoo Lake and the east end o Foot Bay on Donaldson Lake.
   Analyst: O. C. Wickremasinghe.
6. Late basalt or gabbro dyke (late dyke), about 300 feet north of the southwestern end of Mickey Lake.
   Analyst: O. C. Wickremasinghe.
7. Late basalt or gabbro dyke (late dyke), about 1,000 feet east of Sailie Lake.
   Analyst: O. C. Wickremasinghe.

[1]Semiquantitative spectrographic analyses were made on these samples. In all of them, manganese, zirconium, barium, strontium, and locally chromium were present in amount varying from 0.1 to 0.01 per cent. Copper, chromium, and locally nickel occur in amount less than 0.01 per cent. Beryllium was not detected.

composition of the lava. Nevertheless the flows, sills, and late gabbro dykes are all high in potash and low in lime if compared with a normal basalt (Table XXXVII, No. 5), and, based on their chemical analyses and on their mineral composition, they are therefore probably all related. However, from their textures and structures it is obvious that they have formed under different environmental conditions. No late gabbro dykes were seen cutting the flows or the sills, and none was observed above them in the Martin Lake succession. Christie (1953, p. 50) reported that "an amygdaloidal flow toward the base of the section was seen to be cut by a trap dyke 3 inches wide doubtless related to the flows." The field relationship therefore suggests a common time and space relationship and consequently a common source for the flows, sills, and late gabbro dykes. Whole rock K-Ar ages (Wanless *et al.*, 1965, pp. 72–73) obtained on these rocks, are as follows: volcanic flow, 1,630 m.y.; gabbroic sill, 1,410 m.y.; and late gabbro dyke, 1,490 m.y.

Map-Unit 25: Conglomerate Interbeds

This conglomerate (25), which is interbedded with arkose and siltstone at various levels above the basal conglomerate, occurs as narrow beds and thick lenticular masses, generally of short lateral extent. Locally, it includes narrow beds of arkose and siltstone.

It is a conglomerate that has some distinctive features, such as rounder fragments and a better sorting of fragments as to size and composition, characteristics which serve to distinguish it readily in the field from the basal conglomerate. It is generally massive and well consolidated. A wide belt of it, extending from Martin Lake almost to Fredette Lake slightly east of Uranium City, is a hard, well indurated, massive rock. But in a few other localities, as on the shore of Beaverlodge Lake in Hanson Bay, south of Nero Lake, and to the southwest of Murmac Bay, it does not seem to be so well consolidated, as it has broken rather rapidly under wave action. It is generally red or shading from red to reddish brown. It is composed of well rounded, fairly well sorted fragments, most of which are less than 6 inches in diameter. However, occasional fragments are known to be 14 inches across. The fragments were derived mainly from the Tazin rocks, but a few are definitely fragments of rocks from the Martin Formation. Arkose and siltstone fragments were noted throughout. Fragments of porphyritic and amygdaloidal basalt, probably related either to the flows and gabbroic sills of the Martin Formation or to the late gabbro dykes, were recognized in this rock, slightly south of Fredette Lake near the Black Bay fault. And finally, near Murmac Bay, fragments of probably the basal conglomerate were seen in it. In a few places, so closely are the fragments packed that they constitute about 65 per cent of the rock, as is common in the basal conglomerate. In most cases, however, the matrix is as abundant as the fragments; that is, it forms about 50 per cent of the rock. This matrix is mostly arkosic but locally is mainly detrital quartz, as on Hanson Bay in Lake Beaverlodge, where the conglomerate is also interbedded with a grey siliceous sandstone, believed to be lithologically somewhat like the main sandstone of the Athabasca Formation.

The conglomerate on the peninsula east of Padget Bay in Beaverlodge Lake is mapped with this conglomerate, although it is slightly different in appearance. It grades upward and to the northwest into silicified arkose. The conglomerate is also, though to a lesser extent, heavily silicified, with seams and patches of white silica. It is made up of closely packed subrounded fragments, mainly of red granite and granitic gneiss and some fragments of quartz and quartzite, but little matrix. The fragments are up to 12 inches in diameter. The matrix becomes gradually more chloritic toward the lake shore.

The conglomerate in the area south of and near the juncture of Black Bay and ABC faults is locally almost a coarse arkose, for it is composed of widely dispersed, rounded to subangular fragments in an abundant arkosic matrix. Near the Black Bay fault it is interbedded with siltstone and arkose. To the east near the ABC fault it interfingers with arkose. The fragments in this conglomerate are less than 8 inches in diameter.

The conglomerate on the northern islands in Fredette Lake is interbedded with orange-red arkose and is composed of well-worn unsorted fragments closely packed in an arkosic matrix. As a result of deep erosion by waves, it was possible to take out a few of the fragments. All were fairly flat, suggesting that they were water-worn.

The conglomerate on the peninsula on the west shore and almost at the south end of Fredette Lake becomes more arkosic northeasterly away from the Black Bay fault, suggesting a gradation into arkose easterly. On the eastern outcrops, it is bedded and interbedded with arkose. Most of the fragments are small, but a few were noted up to a foot in diameter. This rock is badly weathered locally, probably the result of wave action when the level of Fredette Lake was much higher in Pleistocene time, shortly after the retreat of the glaciers.

Late Gabbro

(*Map-Unit 27*)

The late gabbro intrudes the host rock with sharp contacts. It is most abundant in the area between Boom Lake and Black Bay faults. It is also common north of the Boom Lake fault but not so common as south of it. A few bodies were noted north of St. Louis fault but none south of it.

The late gabbro occurs as dykes, sills, and irregular masses. The dykes are the most common form and account for more than 90 per cent of these rocks. The sills were observed north of the Black Bay fault. Both dykes and sills are up to 150 feet wide, but most of them are less than 10 feet and average about 6 feet. The masses are generally wider than the dykes and sills, and most of them appear to be enlarged parts of these bodies. Most dykes and sills could not be traced for more than a few thousand feet, but few dykes west of Fredette Lake are up to 2 miles long. In general, the dykes and the sills are of uniform width along the strike but may pinch out abruptly. In places, too, they widen or narrow down very irregularly. Where they widen, they usually branch and enclose one or more blocks of country rocks. In relation to each other the dykes are commonly distributed in an *en échelon* pattern with some overlapping. Locally they may change direction very suddenly; this may account for some of their stepped contact. The changes in direction may also be gradual so that eventually a dyke may become a sill.

The strike of many gabbro dykes was measured from the detailed preliminary maps. These measurements were grouped into 10-degree sectors, and the percentage in each group was plotted on Figure 6. It is obvious from this figure that most of the dykes trend due east or S65°E. Too few sills were seen to show in this manner, but their strike is believed to be about N45°E. Both dykes and sills all dip steeply to vertically. In general the dykes are distributed in belts up to half a mile wide forming swarms. Locally, however, a belt may be represented by only one dyke. These belts, which trend parallel with the main trends of the dykes, occur regularly at intervals of 2 or 3 miles. The trends of these belts and those of the dykes within each belt suggest two conjugate sets of fractures. Four belts are believed to be present north of St. Louis fault, but they are not so well developed there as they are in the area north of the Black Bay fault where four belts were also recognized. One of the belts north of the Black Bay fault is particularly strong, for it extends from Fredette Lake to the northwest corner of the map-area.

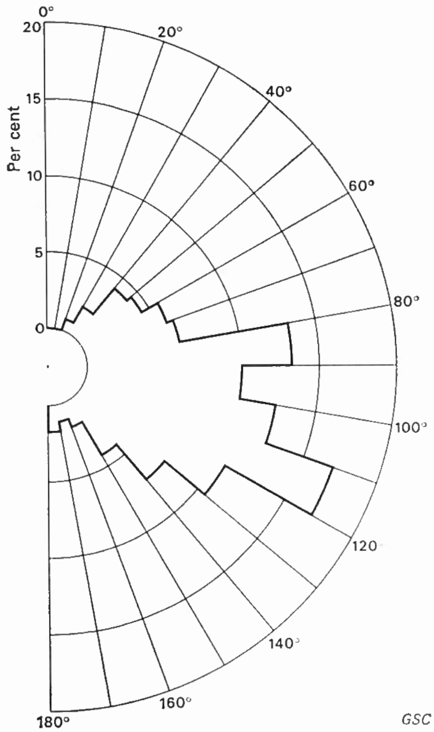

FIGURE 6

Strike of late gabbro and basalt dykes and sills, based on 1,300 readings. Beaverlodge area.

The late gabbro is a massive, fresh, locally well jointed rock. In general it is of uniform composition, and locally near its contacts it carries a few inclusions of the country rocks, generally gneisses and granites. The grain size varies from fine at the edges to relatively coarse in the centre, depending on the width of the bodies, but most of these are fine to medium grained, as none is very wide. It is really a basalt or a fine-grained gabbro. The weathered surfaces are brown, reddish brown, brownish grey, and greenish black; the fresh surfaces are black, dark green, and greenish black. Where the feldspar content is high and the grain is medium, the rocks locally display a diabasic texture. A few dykes are porphyritic with white feldspar laths and large prisms of a dark green mineral or with amygdules (generally less than one quarter inch wide) of white carbonate and chlorite. Others are deep red; these are generally more radioactive than the dark green ones. This red coloration is believed to be an alteration due to a late hematitic dissemination. It is probably mainly hydrothermal, for locally it is closely associated with pitchblende and carbonate–hematite veins and is restricted to a few joint planes within the dykes or to the contact zones of the dykes, the coloration affecting not only the gabbro but also the intruded rocks. This effect was observed in relation to a few dykes northwest of Bellegarde Lake and southwest of Mickey Lake.

Other dykes, such as those emplaced along the Pinky fault and a few others near the Black Bay fault, are heavily chloritized and are traversed by seams of carbonate, quartz, and epidote. A few dykes south of Schmoo Lake have seams of epidote and hematite. Finally, a few vuggy quartz veins were seen locally to cross some of the dykes north of Ace Lake and in the area south of the Crackingstone River fault. All these may be late hydrothermal effects. As seen in thin sections, these dykes are generally altered; in rare cases they were fresh. The fresh dykes seem to occur at some distance from the areas of intense hydrothermal alteration. They are (Table XXXIX) composed mainly of plagioclase and pyroxene with

TABLE XXXIX — *Estimated mineral composition of late gabbro dykes (map-unit 27), in percentages*

Location	North of Black Bay fault						North of Saint Louis fault										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Plagioclase	54	{55		59	60	25	29	29	55	43	52	49	47	47	61	45	44
Albite			75														
Pyroxene						52	59	63									
Amphibole					trace				3							2	
Chlorite	27	15	6	29	10	16	X	X	25	{34	{33	{46	{49	30	2	12	{19
Biotite				X	7									6	18	1	X
Quartz and quartz-feldspar intergrowth	7	5	3	4	1	X	X	X	8	11	6	X	X	5	2	27	27
Iron oxides	9	9	16	8	7		12	8	6	12	9	5	4	7	5	5	4
Carbonates	2	13			2				2					2			
Sphene	X															1	X
Apatite	1	3							1					trace	trace	2	X
Epidote						X			trace	X			X	2	12		X
Groundmass					10												
Pyrite									trace								

1. In Uranium City, a few feet south of the road to Cayzor shaft.
2. Same location as 1, but showing red alteration.
3. About 1,200 feet north-northeast of Lake Cinch shaft near Crackingstone River.
4. About 2,000 feet southwest of Frank Lake.
5. After Christie (1953, p. 58) southwest of Fredette Lake.
6. Near west boundary of map-area, about 7,500 feet west of south end of Doreen Lake.
7. About 800 feet north of the southwest end of Mickey Lake.
8. About 2,500 feet west of the northwest end of Mickey Lake.
9. After Christie (1953, p. 58) south of Mickey Lake.
10. About 2,000 feet southwest of Schmoo Lake.
11. About 800 feet west of the west end of Schmoo Lake.
12. Near northern boundary of map 3,500 feet northeast of the north end of Donaldson Lake.
13. Near northern boundary of map 6,000 feet northeast of the north end of Donaldson Lake.
14. After Christie (1953, p. 58), south of Donaldson Lake.
15. After R. W. Edie (1952, p. 413), Emar claims, south of Donaldson Lake, slightly modified.
16. After Christie (1953, p. 56), on island in Fredette Lake.
17. Same location as 16.

small amounts of iron oxides, quartz, and a micrographic intergrowth of quartz and feldspar. Three thin sections showed an average feldspar content of about 30 per cent, an average pyroxene content, including some chlorite, of about 60 per cent, and an average iron oxide content of about 9 per cent. Other minerals, such as quartz or quartz-feldspar intergrowths, apatite, and carbonate, are either missing or together represent less than one per cent of the rock. In the altered dykes, the plagioclases are heavily altered to sericite and muscovite, the pyroxene having been almost entirely changed to an amphibole and/or chlorite; there are commonly small amounts of interstitial quartz or quartz–feldspar micrographic intergrowth, some apatite, and locally some carbonate. Seven thin sections of the altered rocks suggest an average content of feldspar about 50 per cent; of mafic minerals, mainly all alteration products after pyroxene, about 35 per cent; of iron oxides about 8 per cent; and of quartz and/or quartz-feldspar intergrowth about 5 per cent. The composition of these two main groups, linked to the degree of alteration, is probably due to hydrothermal effects but may also be an indication of different ages or of differentiation.

The plagioclase is a labradorite or an andesine and occurs in laths. In most, but not all, thin sections the laths are of two sizes, giving rise to the porphyritic texture observed in some hand specimens. The average size of the laths in the groundmass is around 0.4 by 0.04 mm, whereas the phenocrysts, which occur usually in clusters or radiating groups, are from 0.6 by 0.06 mm to many times that figure. The pyroxene is probably augite. It occurs in blocky grains about the same size as the feldspar laths. Its alteration products, amphibole and chlorite, have in many instances retained their shape; when they have not, their cleavage traces may be indicated by iron oxide grains. Quartz occurs as clear grains irregularly scattered throughout, or it forms, with potassic feldspar, a plumose micrographic intergrowth. The quartz and the intergrowth are interstitial and vary much in abundance. They seem to be present in fair amounts wherever these rocks are heavily altered; this suggests a genetic relationship between the alteration and the presence and content of the intergrowth and the quartz. The iron oxide occurs as irregular grains, fairly uniformly scattered all through the rock, and much of it is probably ilmenite; it is associated with leucoxene. There is also some hematite, much of which occurs as disseminated powder affecting all the minerals; this explains the red appearance of some of the dykes. It is a common occurrence where a dyke is cut by pitchblende veins. A few dykes near some of the main faults, such as the Black Bay, Crackingstone, and Pinky faults, have been so intensely altered that they now contain mainly albite, chlorite, and small amounts of carbonate and hematite. In most thin sections, large oval or round or irregular areas, made up entirely of either quartz, chlorite, or carbonate, or mixtures of all three in various proportions, are regarded as the amygdules recognized on weathered surfaces. These are fairly common but are not always large enough to be a striking feature in the hand specimen. Many of them are only 1 mm or less wide.

The gabbro dykes cut the Tazin rocks and all members of the Martin Formation below the volcanic rocks. Fragments or pebbles occur in the conglomerate interbeds of the Martin Formation above the volcanic rocks that may equally well have been derived from the gabbro dykes as from the volcanic rocks, since they are porphyritic with white feldspar laths but are not amygdaloidal. In other words, the fragments resemble either rock types. It is possible that there is more than one age for gabbro dykes, but this is also hard to ascertain because no crosscutting relationships between dykes were observed. The dykes cut across the main folded structures of the area; they cross the mylonite and brecciated zones but are themselves cut by the late faults, and in many instances they are offset against them. Most of the dykes mapped north of the Black Bay fault stop at this fault; they were not found south of it. It is the same along the Boom Lake fault. As the dykes are believed to have been emplaced along joints and late faults, most of these must have formed earlier than the dykes themselves.

The offset of many dykes against late faults may therefore represent only late movement on those faults. Many of the dykes also show some hydrothermal alteration; this suggests that the joints and faults they occupy were the loci for the circulation of hydrothermal solutions. This alteration however is not believed to represent the main period of hydrothermal alteration; it represents late ones, when there was renewed flow of hydrothermal solutions. As these dykes do not seem to have intruded rocks younger than the volcanic rocks of the Martin Formation, they may be genetically related to these volcanic rocks. This is also partly suggested by the chemical and mineralogical similarity of the volcanic rocks and the late gabbro. Both rock types fall into two main compositional groups: one high in feldspar, the other relatively low. The suggested relationship is furthei borne out by the striking resemblance of a few of the dykes and of some of the Martin volcanic rocks, by the presence of gabbroic sills as part of the Martin volcanic succession, and by the close spatial relationship of some of the dykes and the Martin volcanic rocks, an indication that the dykes may be the feeders of the flows. Christie reported a trap dyke, 3 inches thick, cutting an amygdaloidal flow toward the base of the section. Partial chemical analyses of four dykes are given in Table XXXVIII. The results cannot be compared with the chemical analyses of the volcanic rocks of the Martin Formation (Table XXXVII) nor with the spectrographic analyses of the late dykes by Edie (Table XL) since they are too erratic to be significant. The gabbro dyke on the large island in Fredette Lake (Table XXXIX, Nos. 16 and 17) has a K-Ar whole rock age of 1,490 m.y. (Wanless, 1965), which is less than the age of 1,630 m.y. for the Martin volcanic rocks and more than the age of 1,410 m.y. (Wanless, *et al.*, 1965) for the Martin gabbroic sills.

TABLE XL | *Spectrographic analyses of late gabbro (diabase dykes), in percentages (after R. W. Edie, 1952, p. 413)*

	1	2	3	4	5
*SiO_2	53.1	52.7	52.9	51.3	55.1
Al_2O_3	13.8	17.3	15.2	14.9	14.7
Fe_2O_3	3.3	4.6	1.4	3.4	2.0
*FeO	4.8	4.7	6.7	7.7	6.7
CaO	4.2	5.2	4.3	3.7	2.2
MgO	5.4	5.2	6.5	7.6	6.7
Na_2O	2.5	3.8	2.4	2.2	4.3
K_2O	6.3	5.6	1.6	2.0	0.5
MnO	0.1	0.1	0.1	0.1	0.1
Niggli Numbers					
si	163	144	159	146	173
al	25	28	27	25	27
fm	41	37	49	54	52
c	14	15	14	11	7
alk	20	20	10	10	14
si			140	140	152
qz			19	6	21
(al+fm) − (c+alk)	32	30	52	58	58

*SiO_2 and FeO were chemically analyzed at the University of Minnesota.

1. Ace mine area.
2. Emar claims, Donaldson Lake.
3. Eagle-Ato-Mic claims, Mic Lake.
4. Tamblyn group, south shore, Beaverlodge Lake. This is slightly south of the map-area.
5. Strike group, north of Ace Lake.

Chapter III

ALTERATION AND ORIGIN OF THE TAZIN GROUP AND THE MARTIN FORMATION

Metamorphism in Tazin Group

All the rocks of the Tazin Group in the Beaverlodge area have been regionally metamorphosed and granitized; that is, they have been subjected to deep-seated processes involving their recrystallization with the development of characteristic groups of minerals over a wide area and of granite where the composition and conditions were right. Subsequent to this regional metamorphism and granitization,[1] some of the rocks suffered strong repeated retrogressive dynamic metamorphism. Finally, in a few places they were affected by soda metasomatism and/or subjected to hydrothermal alteration; the metasomatism and the hydrothermal effect are regarded as phases of the granitization process. The time lapse between the beginning and the end of all these metamorphic events is believed to have been relatively short, although hydrothermal activities appear to have continued for a long time on a relatively small scale. This is suggested by the nature of the pitchblende, by the texture of some of the pitchblende veins, by the many ages of pitchblende, and by the calcite and quartz veins in the Tazin rocks and the Martin Formation. An age of 1,795 m.y. by the K-Ar method (Lowdon, 1963a, p. 64) was obtained on chloritized biotite of the Donaldson Lake gneiss, and although this date may be somewhat young, it is believed to give at least the youngest age for the regional metamorphism in the area. According to Stockwell's classification it would be Aphebian. All other dates in the area on either monazite, biotite, or muscovite from pegmatite dykes and many others on selected samples of pitchblende are of about the same order of magnitude.

As the rocks of this area are not alumina-rich, no metamorphic zones based on diagnostic minerals could be outlined. Nevertheless, even if some alumina-rich layers had been present, it is unlikely that any significant differences would have appeared in so small an area. Based on the mineral assemblages in the quartzo–feldspathic gneiss and the amphibolites, the area is believed to lie entirely or almost entirely within the almandine–amphibolite facies of Turner and Verhoogen (1960, p. 544). It is true, however, that Dawson (1956, p. 4) speaks of "metamorphism on a regional scale that has produced a wide range of metamorphic grades," and Christie (1953, p. 65) of low and moderately high grades of regional metamorphism. The writer believes that the staurolite–almandine subfacies, that is, the lowermost zone of the almandine–amphibolite facies, is the grade represented in this area, even if no staurolite was

[1]This term is used to denote the process by which a rock is converted into granite.

observed. In many parts of the area the mineral assemblages typical of this subfacies in both the quartzo–feldspathic gneiss and the amphibolites have been destroyed or obscured later by retrogressive effects related to dynamic metamorphism and late phases of granitization, such as metasomatic replacement and hydrothermal alteration. These late retrogressive effects explain mainly why Dawson and Christie spoke of high and low grades of metamorphism or of wide range of metamorphic grades.

The main rock types of the area, the quartzo–feldspathic gneisses and amphibolites, are the products of regional metamorphism, and in general each one is characterized by a distinct mineral assemblage.

In the quartzo–feldspathic rocks, the most diagnostic mineral assemblage is albite–oligoclase, microcline, quartz, biotite, and garnet, with minor amounts of muscovite, epidote, and sphene. Garnet is not present everywhere, for much of the rock did not contain the necessary components. It was most commonly observed in quartzitic rocks where it is fairly abundant locally. It was noted everywhere in the area north of the Boom Lake fault but is rare near the Boom Lake fault and south of Doreen and Betty Lakes. It is abundant in the quartzitic rock north of these lakes and also north of Bush and Liebel Lakes as far as the northern boundary of the map-area. It is present everywhere in the area between the Black Bay fault and the Boom Lake fault but is rare and generally difficult to recognize, because almost all of it has been altered to chlorite. In the area south of the St. Louis fault it is abundant in the quartz–biotite schist. In the area north of the St. Louis fault it was noted only near the Eagle shaft. Elsewhere it has not developed probably because of the unsuitable composition of the original rocks.

Biotite is the main mafic mineral of the quartzo–feldspathic rocks; locally some hornblende is associated with it. Biotite was noted everywhere in the map-area, but it is most abundant where garnet occurs. It is abundant in the area north of the Boom Lake fault. In the area north of Black Bay fault and south of Boom Lake fault it is abundant in the Rix unit south of Crackingstone River fault and also in the Cayzor unit in the area about Don and Pluton Lakes. Elsewhere in this area it is altered to chlorite. South of the St. Louis fault, it occurs widely in the area from south of Fookes and Fulton Lakes to the southern boundary of the map-area, and it is fairly abundant in the Foot Bay and Donaldson Lake gneisses north of the St. Louis fault. Elsewhere north and south of the St. Louis fault the biotite is altered to chlorite.

In the amphibolites and in the largest of the basic layers in the quartzo–feldspathic gneisses, the mineral assemblage has remained constant throughout most of the map-area, except where the rocks are intensely hydrothermally altered. In some cases the mineral assemblage has remained unchanged even in an area of intense dynamic deformation, like the one adjoining the Black Bay fault to the north. This assemblage is made up of hornblende, oligoclase–andesine, and minor epidote, quartz, biotite, and sphene.

Retrogressive metamorphism is here defined as the transformation of metamorphic minerals of the amphibolite facies into minerals characteristic of the greenschist facies. The features believed to indicate this type of metamorphism are as follows: a) the presence of much chlorite pseudomorphic after biotite, hornblende, and garnet, and relicts of these minerals in rocks where chlorite is the main mafic mineral; b) the presence of albite–oligoclase, where normally the feldspar would be oligoclase–andesine (this generally occurs in close association with the chloritization and was noted particularly in the amphibolites and basic layers); and c) the presence of much recrystallized quartz in the cataclastic rocks where chlorite is the only or the main mafic mineral.

Two agents are believed to be responsible for these retrograde effects. One agent is believed to be tectonic, presumably related to the cataclastic deformations responsible for the extensive brecciation and the development of many large mylonite zones in the Beaverlodge area. The second agent is hydrothermal. The uranium mineralization in the area is probably a phase of this hydrothermal action. These agents are suggested as there seemed in the field to be a relationship between the degree of brecciation and mylonitization or between the amount of hydrothermal alteration and the extent and the intensity of the retrogressive metamorphism.

The effects of retrogressive metamorphism were noted almost everywhere in the Beaverlodge area, but they vary greatly in intensity from place to place. Generally they are superimposed on minerals of the amphibolite facies. In the area north of the Boom Lake fault, retrograde metamorphism is indicated by the partial chloritization of biotite, garnet, and hornblende in most of the area, and by the almost total chloritization of the dark minerals in local areas, such as zones of breccia and mylonite and areas of granite.

South of the St. Louis fault much of the Murmac Bay Formation is unaltered, except in the vicinity of granitized areas where most of the mafic minerals have been partly to entirely chloritized. In the granite and granitized areas, chlorite is always the main mafic mineral. All this chlorite is regarded as being due to retrograde metamorphism, probably either by cataclastic or hydrothermal agents, since much of the area is brecciated and hydrothermally altered.

North of the St. Louis – ABC fault the effects of retrograde metamorphism are so extensive and so well displayed that the rock could easily be taken to be a normal metamorphic facies or succession of grades. But because relicts of the original mineral assemblage of the amphibolite facies can be recognized in thin sections from many places, except for a few areas in the immediate vicinity of the mines along the St. Louis fault, all this alteration is considered to be retrograde. Much of it, particularly in the Foot Bay and Donaldson Lake gneisses and also in the granite areas near the unconformity east of Fredette Lake, is probably due to tectonic and cataclastic effects. The alteration of the hornblende schist and gneiss along the St. Louis fault to chlorite–epidote–albite–quartz rock and that of the slate and argillite and of some of the schist to chlorite–sericite-bearing rock instead of biotite-rich rocks are retrograde effects, possibly due mainly to hydrothermal agents. It is possible, however, that some of the rocks in the area between Eagle, Berth and Tane Lakes because of their stratigraphic position have not reached the metamorphic grade characteristic of the Beaverlodge area as a whole and are not really retrograded rocks.

In the area between Black Bay and Boom Lake faults, chlorite is the main mafic mineral of most quartzo–feldspathic rocks. In some amphibolite masses, particularly those in mylonite zones, the hornblende is wholly or partly altered to chlorite. All granite areas and granitized rocks have chlorite as the main dark mineral. Since this chlorite is locally pseudomorphic after garnet, hornblende, and biotite, and since the area is intensely brecciated, the chlorite is considered to be retrograde and its development to be connected with the cataclastic effects. Some of it, however, may be hydrothermal, particularly in the immediate vicinity of Black Bay and Boom Lake faults, where some of the feldspars, particularly in the amphibolite, is now albite, and where much hydrothermal chlorite and some epidote, quartz, and albite have been introduced.

Metamorphism in Martin Formation

The rocks of the Martin Formation are fresh looking, hard and well consolidated. In general they do not appear to have been metamorphosed, and if they have been, the degree of metamorphism must have been very low. In the field, the clastic texture and depositional features such as bedding, crossbedding, ripple-marks, grain size variations, and mudcracks are still very apparent and very well preserved. Under the microscope no incipient quartz growths were noted in any of the rock types. The chlorite, the sericite, and the few flakes of biotite that were recognized in the matrix of the conglomerate, in the arkose, and in the siltstone, were found, in general, interstitial to detrital grains and are probably themselves detrital. Some of them may, however, be recrystallized material, especially the sericite or muscovite and some of the chlorite concentrated along planes in the siltstone. These minerals appear to have developed there in sufficient quantity to produce an occasional platy structure with a distinct sheen on the parting planes. The volcanic rocks in general are highly altered, but it is not the result of the retrograde metamorphism mentioned above. Rather it is an alteration that is probably deuteric or is related to the material in which the flows were ejected.

Types of Alteration

This is not intended to be a thorough study of the various types of alteration in the area, but only to mention and describe briefly those features that were readily noted, on outcrops or hand specimens, during field work and later in the general study of thin sections. These alterations may be due to various causes, and where these causes are readily apparent or where they can be distinguished fairly easily from each other, they were noted and are indicated in the short description that follows. Since some of them affect wide areas, they were recognized almost everywhere in the map-area, particularly hematization, chloritization, and epidotization. Affects are not, however, always striking and in many places may be overlooked if not sought. Other types of alteration, such as silicification, carbonatization, and albitization, are more localized and restricted in extent. Consequently they are minor features only, although locally they may be as striking and as intense as the main types.

Hematitization

Most of the rocks of the Beaverlodge area are red, due to disseminated hematite. In general the red coloration is restricted to the feldspars and, as such, is found in almost all rock types in the area. Locally, particularly near uranium deposits and in brecciated zones, this staining affects not only the feldspars but also all the other minerals, and in such areas it may be so intense that it masks the original nature of the rock. The resulting rock is deep red, and in such rock the hematite occurs in veinlets as well as being disseminated. The most common occurrence of this deep red rock is in close association with the uranium mineralization in the area. In fact, near uranium deposits the staining is so pronounced and so striking that it is generally regarded as one of the main characteristics of the uranium deposits of the Beaverlodge area. Indeed, most previous authors described it under the heading: Red Alteration of the Rocks in the Beaverlodge Area.

Not all the red colour in the area is believed to be due to hydrothermally introduced hematite, but at least some of it is thought to be due to hematite formed from the excess iron in the original rocks freed by regional metamorphism. This metamorphic hematite is believed to be responsible for most of the red coloration in the granites and gneisses of the Beaverlodge area. In these rocks the hematite is usually on the feldspars, mainly the plagioclase, and rarely on the quartz. This coloration is also never so intense that it hides the nature of the minerals. This origin is also believed to explain the specularite in the massive and thinly bedded white glassy quartzite at the south end of Doreen Lake, along the south shore of Moran and Zora Lakes, and in the area northeast of Beth Lake. It also probably explains the hematite in the ferruginous quartzite of the Murmac Bay Formation. A few geologists, however, may argue that the specularite in the glassy quartzite mentioned above is hydrothermal, because to them some of the quartzite-like rocks of the area are hydrothermally silicified rocks (Campbell, D.D., 1957, p. 313; Dudar, 1960, p. 70) and not real quartzites (*see* section on silicification below).

Hydrothermal hematite may be as widely distributed as metamorphic hematite, but its obvious and apparent characteristics are definitely more restricted in extent and more localized. They are particularly evident near the uranium deposits and in fractures and brecciated or mylonite zones. The amount of hematite present also varies from place to place, but in general, where evidence for hydrothermal hematite is clear, the amount is fairly high and the rock is a deeper red than elsewhere. Hydrothermal hematite may be present in small amounts in the red granite and gneisses of the area as a whole, but how much, if any, of the red colour of the rock it is responsible for is impossible to tell. Where it occurs as specularite and as the earthy type along fractures and cleavage planes, or where it fills spaces between grains and replaces the matrix between fragments in the brecciated zones, it is regarded as mainly of hydrothermal origin, although some in the matrix and around grains may be due to regional metamorphism. Along fractures it may occur as seams, veinlets, and veins, all a fraction of an inch thick; or it may form a coating only. Its presence along cleavage planes was recognized mainly in feldspar where it is accompanied by a hematite dust or stain in the adjoining material. Where this disseminated hematite is abundant, and where the impregnated cleavage planes are very closely spaced, the hematite may completely mask the nature of the original mineral and even the nature of the rock itself. Indeed, hematite may be so plentiful in the matrix that the true nature of brecciated rock or mylonite may be completely obscured. Generally, however, the deposition of hydrothermal hematite is accompanied by other hydrothermal effects, and then the end product may be a deep red rock, completely different from the original rock and cloudy to almost opaque in thin sections.

Hydrothermal hematitization was noted mainly in the Tazin rocks, but it occurs also on a minor scale in the Martin Formation, especially near pitchblende veins. Although the main hydrothermal effects are believed to have taken place shortly after the regional metamorphism of the Tazin rocks and before the deposition of the Martin rocks; later reactivation of hydrothermal solutions probably deposited some hematite in the Martin Formation. In fact, several periods of hematite deposition probably took place. Like most of the Tazin rocks, Martin Formation rocks are red. This colour is, however, probably not due to hydrothermally introduced hematite but may be a residual effect of the Tazin rock from which they are derived. The origin of this red colour is discussed with the origin of the Martin rocks but is probably related to their mode of deposition and the conditions of weathering at the time of deposition.

Chloritization

Chloritization was recognized almost everywhere in the Beaverlodge area. On most outcrops it could easily be overlooked, since it is nowhere very obvious, except possibly in rocks adjoining uranium deposits, in mylonite zones, and in brecciated rocks. In these rocks the mafic minerals are entirely chloritized, or almost so, and all rock types are crisscrossed by a network of chlorite veinlets and seams that vary in abundance from place to place. In thin section, it was recognized everywhere and was too obvious to overlook. This chloritization represents a retrogressive metamorphism due to cataclastic deformation or hydrothermal effect. In brecciated areas and mylonite zones, the chloritization is probably mainly cataclastic, but some may be hydrothermal. As suggested by the chlorite veinlets in thin sections, this alteration is probably later than the hematitization, although, like the hematite, there were several generations of chlorite (Dudar, 1960).

In the vicinity of uranium deposits, the chloritization of the rock is a very striking feature. If the deposit is a vein, there is much chlorite along the plane of the vein and for a few inches on each side of it. Where the deposit is of the disseminated type and large, the chlorite is interstitial and is in veinlets, all through the rock. The most striking example is in the vicinity of the Eldorado mines along the St. Louis fault, also at Rix Smitty mine and in the area of Lake Cinch mine. In these areas, amphibolite and hornblende schist are converted to chlorite rock for a fair distance from the deposit itself. The argillite is altered to a chlorite-sericite rock, and the granite and the granitic gneisses have all their mafic minerals entirely chloritized; they are also invaded locally by some chloritic material. The chloritization of the amphibolite and argillite decreases in intensity away from the deposit and presents a gradational and irregular contact with the relatively unchloritized rock. In the granite and gneisses, changes are not so apparent as in the amphibolites and argillites because the rocks generally contain much less chlorite or mafic minerals.

Epidotization

This alteration is almost as widespread as chloritization and hematitization but is not so intense, and in most places it does not change the nature of the rock. It occurs mainly as veinlets and seams throughout the rocks. In general, except in the amphibolite and hornblende schist, these veinlets are not closely spaced and form only a small percentage of the rock.

Epidotization is abundant in all masses of amphibolite and hornblende schist north of the St. Louis fault and northwest of Black Bay and Boom Lake faults but does not seem to be a common feature in the rocks south of St. Louis fault. It is also a common alteration of the granites and gneisses north of St. Louis and Boom Lake faults. In the amphibolite masses it occurs as irregular patches (up to a foot wide) at the junction of veins, or it occurs disseminated throughout the rock adjacent to the veinlets, seams, and patches. This type of epidotization, in patches, is particularly characteristic of those amphibolite masses converted to chlorite rocks near uranium deposits, and epidote is common all through these masses. Some of this epidote may be due to regional metamorphism, but most of it seems to be hydrothermal; it is yellowish green on weathered surfaces, generally fine grained, and is commonly associated with albite, chlorite, hematite, and quartz. Although epidotization occurs in all types of Tazin rocks, it was not recognized in rocks of the Martin Formation. It is therefore probably a product of the main hydrothermal metamorphism in the area and is closely related in time of formation to the regional metamorphism of the Tazin rocks. No widespread reactivation of epidote-bearing solutions seems to have taken place, as was the case for hematite, chlorite, and silica.

Silicification

Silicification has been reported (Buffam, 1957, p. 222; Campbell, 1957, p. 312; Chamberlain, 1958, p. 84; and Dudar, 1960, p. 70) as a major alteration of the rocks in the general area of the Eldorado shafts, that is, near the St. Louis – ABC fault. It was also suggested that this alteration may extend to other parts of the Beaverlodge area and that most of the rocks mapped as quartzite (by the writer) north of the St. Louis fault be ascribed to it. Dudar (op. cit.) suggested an epigenetic origin for these rocks and assumed that the silica came mainly from the surrounding sedimentary rocks. The main facts in support of this hypothesis are the apparent crosscutting relationship of the siliceous rock with other rocks, its cherty appearance, and its fine-grained nature. Campbell (op. cit.) described the siliceous rock as follows: "The silica is a glassy or cryptocrystalline massive or banded grey and/or white rock comprised almost entirely of quartz (90%) with minor mafic partings and detrital minerals. The texture of the silica (rock) is uniform with grains generally less than 0.1 mm in long dimensions and characteristically intricately sutured, elongate and oriented in a dense felted mosaic. Where the silica has replaced argillite it generally reflects the sedimentary bedding as thin even colour bands; where it has replaced gneiss the inherited colour banding is distinctly gneissic in appearance."

The writer believes that this quartzose rock is really a dense to fine-grained quartzite; that the fine-grained nature is either original or the product of intense crushing; that the gneissic structure is a relict feature, possibly bedding; that the rock is now mainly a mylonite or an ultra-mylonite; and that not only some recrystallization of the quartz took place but, locally, some of it was mobilized. Also, as indicated by thin section studies, some of this mylonitized quartzite is again brecciated suggesting a late deformation. This brecciation and the crosscutting relationship seen in the mine workings and assumed locally on surface in the mine area by the above-mentioned authors, are indications of late movement only and not of silicification, which is an earlier feature than this late deformation.

In summary, the writer believes that some silicification did take place in the Beaverlodge area and that it was fairly widespread, but that its effects are minor only and not as great as the above-mentioned authors seem to imply.

The silicification in this area is believed to be of two types. One type is represented by irregular patches of recrystallized quartz and by seams, veinlets, and patches of white, probably remobilized quartz. The patches have a sutured outline, are generally less than a few millimetres long, and rest in a matrix of fine-grained, partly recrystallized felsic material. This silicification is a product of cataclastic metamorphism. It is the commonest and the most widespread type of silicification in the area and is found in all mylonite zones, in all areas of brecciated rocks, and in many other places where cataclastic effects are fairly intense. This relationship is definitely diagnostic, and its association with uranium mineralization is probably more than coincidental.

The other type of silicification is a late effect and is probably hydrothermal. It alters locally some of the rocks near the major faults and occurs in cryptocrystalline form as fracture filling in many parts of the area. This fracture filling gave rise to veins of vuggy quartz, not only in the Tazin rocks but also in the Martin Formation, and to tiny seams and veinlets of quartz locally cutting the rocks in all directions.

Carbonatization

Carbonatization was noted almost exclusively in granite and granitized rocks. It is characterized by the development of carbonate minerals in a rock otherwise made up of quartz, feldspar, and chlorite. The amount of carbonate varies appreciably from outcrop to outcrop and also from place to place within an outcrop. The end product may be a rock made up almost entirely of carbonate and albite or oligoclase, and a little chlorite. On weathered surfaces a carbonatized rock is generally darker red than the ordinary rock and is vuggy or pitted as a result of the leaching of carbonate. Carbonatization is not so extensive nor so common as the types of alteration described above, but where it has affected the rock the outcrops are generally typical. It is probably a hydrothermal effect, as it seems to be related to the uranium mineralization, the carbonatized rocks generally being slightly more radioactive than the ordinary granite or granitized rock of the area. Furthermore, in many localities carbonatized rocks are cut by seams and narrow veins of pitchblende; carbonatization is more intense in brecciated areas or zones of intense crushing and near major faults, and it seems to proceed from fractures, decreasing in intensity gradually into the adjoining rocks.

These rocks have been described in some detail with the granites. Their main occurrences in the Beaverlodge area are as follows:

1. A wide belt, trending about parallel with the formation, that extends from the north shore of Verna Lake to Schmoo Lake. Its maximum degree of carbonatization is in the area south and east of Foot Bay, off Donaldson Lake.

2. The area between Yahyah Lake and Fish Lake. In this area carbonatization is not too extensive, but it is fairly typical and could be readily observed at many places.

3. The area between Boom Lake and Bertha Lake. This area includes the Rix Smitty mine and extends for a short distance on the northwest side of Boom Lake fault toward Jeff Lake. The carbonatization there is not always obvious.

Carbonatization is also indicated by veins of carbonate up to a foot wide, that cut all rock types and are found in small number everywhere in the area. The veins are of the fracture filling type. Some of these veins are pitchblende-bearing and constitute ore; others are barren or almost so.

Albitization

Albitization is suggested by veinlets of albite, or of albite and quartz, cutting the rocks in various directions in many parts of the Beaverlodge area. These veinlets are only a few millimetres wide and are not conspicuous in outcrop, but under the microscope they are readily noted. They are most abundant in areas that have been altered by hydrothermal solutions, particularly in areas adjoining major faults such as the St. Louis – ABC fault and the Black Bay fault, in mylonite zones, in areas of brecciated rocks, and in zones of close fracturing. Albitization is also suggested by the presence of euhedral grains of albite in rocks that are otherwise intensely altered and deformed. These albite grains are fresh, well twinned, and fairly abundant locally. Their outline suggests that they were late to form. These grains are common and occur in widely spaced clusters in the areas north of St. Louis – ABC fault and north of Black Bay fault. The grains are believed to be related in some ways to the veinlets mentioned above, since it is difficult to suggest that euhedral grains could be formed when the rocks were regionally metamorphosed. They are probably a metasomatic effect related to granitization and a part of complex hydrothermal alteration.

A rock described locally as a feldspar rock in the vicinity of some of the mines, particularly those on the Eldorado property, has been referred to by some writers (Buffam, Campbell, Smith, 1957, p. 222) as due to feldspathization. This type of rock, composed almost entirely of feldspar, is probably the result of a combination of several processes, the main ones being regional metamorphism and granitization with some late soda metasomatism of the type described in the preceding paragraph.

Origin of Tazin Rocks

Amphibolite

The amphibolite masses of the Beaverlodge area do not differ from most amphibolite masses in similar types of rocks in other parts of the world. They present the same problem; that is, it is difficult to assign to them a definite origin because more than one seems possible. The most probable origins are presented here, and a few specific masses are discussed.

The amphibolite occurs in masses of various shapes and sizes, and shape and size are believed to suggest the origin. The form of these masses and their occurrences may be summarized as follows:

1. Some of the masses are lenticular, a few inches to a few feet long, and fairly thin. These are generally distributed at irregular intervals along several irregularly spaced horizons.

They may be separate independent masses, but since many of them resemble boudins or locally seem to be the result of faulting followed by stretching, most of them are probably separated masses of once continuous beds or layers.

2. Other layers and lenticular masses are up to several hundred feet long by only a few feet thick. Interbedded with other rock types, these seem to be part of a normal sedimentary succession. The masses south of Boom Lake fault and southwest of Bertha Lake are of this type.

3. Some layers are thick and have the same relationship to the other rock types as the thin layers or beds mentioned above (2). The thick layers are locally very well bedded, for example, the masses between Colliei Lake and Virgin Lake. A few of them, however, are massive and gneissic but are not bedded, and consequently their origin possibly differs from that of the thinly bedded masses. These massive layers may belong in this group oi in group 4. The Jean Lake amphibolite probably belongs to this group since it is partly well bedded and partly massive.

4. Finally, there are thick lenticular bulky masses. These trend parallel with the formation and generally end very abruptly. Most vary in grain size and composition and are massive.

The small lenticular masses, the narrow layers, and some of the thick layers were most likely deposited in water, because they occur within, and are interbedded with, many kinds of sedimentary rocks. The small lenticular masses enclosed in and along the bedding planes of sedimentary rocks were probably concretions, whereas the layers were probably beds or groups of beds depending on their thickness. The small lenticular or concretion-like masses vary in texture and composition. Thus, their grain is fine to coarse; they are massive to highly foliated, and they may be composed entirely of feathery amphibole or of a mixture of amphibole, chlorite, epidote, sphene, feldspars, and/or quartz, in various proportions. All are generally high in amphiboles, chlorite, and epidote. These differences may reflect variations in their original composition but probably indicate that they were limy sediments.

The thick layers of amphibolite, at least those between Collier Lake and Virgin Lake, are locally well bedded and in general are fairly uniform in grain size and composition, except for minor variations within the layers or from bed to bed. They are interbedded with many types of sedimentary rocks such as quartzite, schist, and argillite. Single beds of these rocks locally lie between layers of amphibolite; occasional beds or fairly thick lenses of these rocks are enclosed within the amphibolite layers. This was observed in several places in the large amphibolite masses north and south of Verna Lake, southwest of Ace Lake, and south of Eagle Lake. In addition, parts of the layers north of Eagle Lake are fragmental and massive and resemble pyroclastic rocks. These structureless or massive layers are neither pillowed nor amygdaloidal, but their mineral composition is similar to that of the bedded and fragmental layers; they are probably thick beds. Chemical analyses of both the well bedded and massive types suggest a close relationship to basalts or to the basic end of the normal differentiation sequence of a normal basaltic magma (*see* Ternary diagrams, Figs. 7 and 8). This suggests that these amphibolites were probably pyroclastic rocks of basaltic composition.

The thick lenticular bulky masses (group 4) were probably also pyroclastic rocks, but some may have been gabbroic sills, since they are massive and show broad compositional variation. The amphibolite masses of Uranium City and of the Powerline creek belt are probably of this type. The amphibolite masses south of St. Louis fault are partly of sedimentary origin; some of them are well bedded and closely interbedded with quartzite, quartz-biotite schist, and dolomite. Others are massive, show wide variation of composition and texture, and resemble gabbro. The large mass between Murmac Bay and Kram Lake and the one south of Sells Lake were probably gabbroic sills.

All this suggests that most of the amphibolite masses and layers are a normal part of the Tazin Group succession and were formed at about the same time as the sedimentary rocks with which they are interbedded. However, as the sills are intrusive, they may be slightly later, but as they are metamorphosed to about the same degree and are overlain by the Martin Formation, they are still part of the Tazin Group as a whole.

TABLE XLI | *List of chemical analyses used for Figures 7 and 8*

			Page[1]
1.	Arkose, Martin Formation		119
2.	Siltstone, Martin Formation		119
3.	Amygdaloidal basic volcanic rock, fresh, Martin Formation	Table XXXVII, No. 1	126
4.	Basic volcanic rock, Martin Formation, altered	No. 2	126
5.	Basic volcanic rock, Martin Formation, altered	No. 4	126
6.	Basic volcanic rock, Martin Formation, fresh	No. 3	126
7.	Jean Lake amphibolite, Tazin Group		70
8.	Amphibolite, Murmac Bay Formation, Tazin Group		44
9.	Quartzite, Murmac Bay Formation, Tazin Group		40
10.	Mildly reddened quartzite, Tazin Group, area north of St. Louis – ABC fault		28
11.	Reddened quartzite, Tazin Group, area north of St. Louis – ABC fault		28
12.	Argillite, black to grey, Argillite-hornblende schist unit, Tazin Group		35
13.	Hornblende schist, Argillite-hornblende schist unit, Tazin Group		35
14.	Hornblende schist, Argillite-hornblende schist unit, Tazin Group		35
15.	Brecciated-feldspathized argillite, Tazin Group, area north of St. Louis – ABC fault		35
16.	Fresh argillite, Tazin Group, area north of St. Louis – ABC fault		35
17.	Fresh argillite, Tazin Group, area north of St. Louis – ABC fault		35
18.	Red granite, Jean Lake amphibolite, Tazin Group		103
19.	Red granite, Black Bay area		103
20.	White granite, Black Bay area		103
21.	Red granite, Donaldson Lake gneiss		95
22.	Foot Bay, layered gneiss, Tazin Group		95
23.	Donaldson Lake, layered gneiss, Tazin Group		95

[1]Page in this report where chemical analysis and petrographic details are given.

Quartzo–Feldspathic Gneiss

The nature of the pre-existing rocks from which the quartzo–feldspathic gneisses were derived is not definitely known. However, the study of these gneisses in the field and in thin sections has provided a few features that suggest that the pre-existing rocks were mainly sedimentary, some probably of pyroclastic and tuffaceous material. The following features are regarded as diagnostic: the presence of remnants of pre-existing rocks at several places in the gneisses; the striking resemblance of the foliation in the gneisses with the bedding and stratification of these remnants and the continuity of the structures in the two rocks; and the close similarity of the mineral and chemical composition of the gneisses and of the remnants of pre-existing rocks with those of known rocks.

The various areas of the Beaverlodge area outlined in the chapter on General Geology are now briefly discussed to indicate the types of pre-existing rocks possibly present as remnants in these gneisses in each area and to outline their main occurrences.

In the area south of the St. Louis fault, particularly in the Murmac Bay area, the original nature of the pre-existing rocks is fairly obvious; many of the rocks are not granitized at all.

White glassy quartzite, ferruginous quartzite, dolomitic quartzite, dolomite, limestone, garnetiferous quartz–biotite schist, and argillite were recognized over large areas. These were mapped as the Murmac Bay Formation. The rocks are locally well bedded. They are in general broadly interbedded, and their occurrence suggests a normal sedimentary succession. The same type of succession, but with some differences in the original composition of the rocks, was probably also present east of Fookes Lake where the rocks are granitized. Among the granitized rocks, there are many remnants of well-bedded white glassy quartzite, and of other types of quartzite and a few patches of carbonate rocks. The structure is also apparently continuous from the remnants through the granitized rocks to the main area of the Murmac Bay Formation; many of the contacts are gradational. A chemical analysis of a sample from one of the quartzite layers in the Murmac Bay area (Table X) when it is plotted on the ternary diagram (Fig. 7) falls in the field of orthoquartzite and suggests a related rock. This indicates that the sources of the gneisses in this area were probably sedimentary rocks.

In the area north of St. Louis – ABC fault, rocks normally mapped as quartzite, dolomitic quartzite, argillite, and schist were recognized and mapped at several localities. On the west

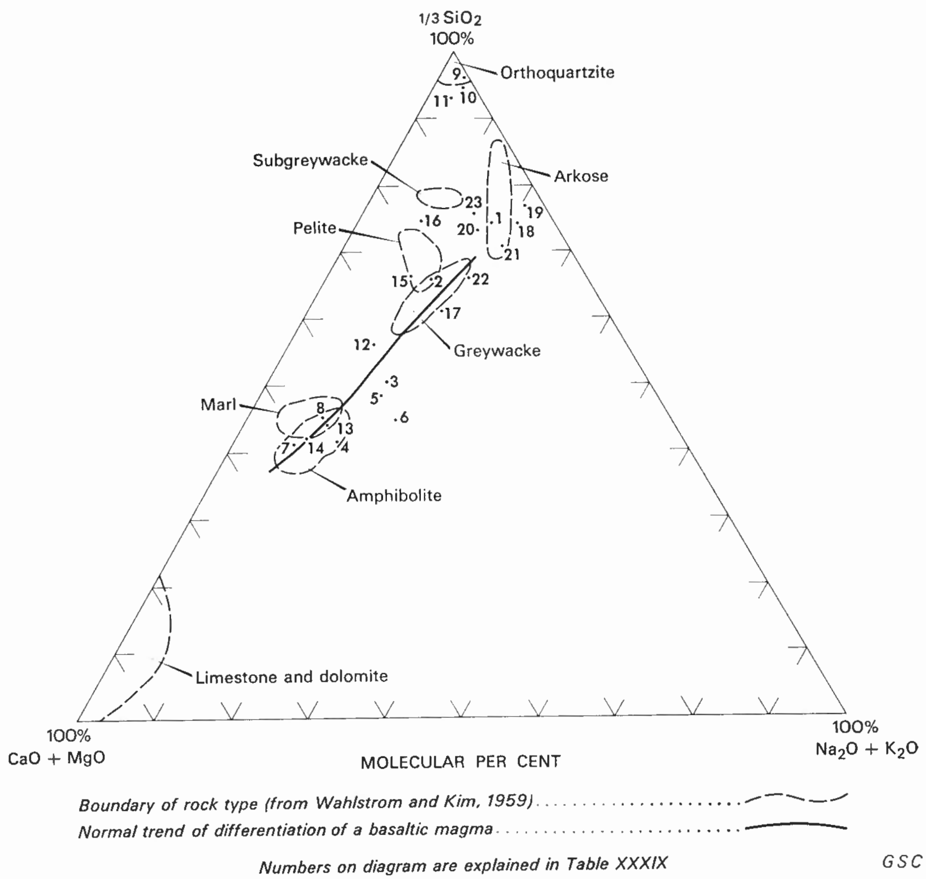

FIGURE 7. Relative percentage 1/3 SiO_2: $CaO + MgO$: $Na_2O + K_2O$ of rocks from Beaverlodge area.

shore of Donaldson Lake, single beds or perhaps small groups of quartzite beds were noted; some were mapped. In the area southeast of Virgin Lake, thinly interbedded quartzite and chlorite schist overlain by, and partly interbedded with, thinly bedded tuffaceous material were widely recognized and traced. In the area north of Ace Lake a thinly bedded mixture of quartzite, argillite, and dolomitic quartzite was mapped. Finally, south of Eagle Lake, the succession is almost flat lying and comprises quartzite, slate, argillite, and tuffaceous material. In general these rocks are ungranitized remnants in a very large area of granite and granitized rocks. The remnants seem to lie in their normal position and to form part of a normal succession of gently to closely folded sedimentary rocks. They generally have gradational contacts with the gneisses and exhibit a distinct bedding. They are all interbedded and mixed with one another and with the gneisses. These remnants are also mineralogically and chemically characteristic of sedimentary rocks and suggest the nature of the pre-existing rocks, which were the source of the gneisses. Two chemical analyses of the quartzites from this area and four analyses of the argillites are fairly typical, for, when plotted on the ternary diagrams (Figs. 7 and 8), they fall within or near the field of orthoquartzite or pelites and greywackes.

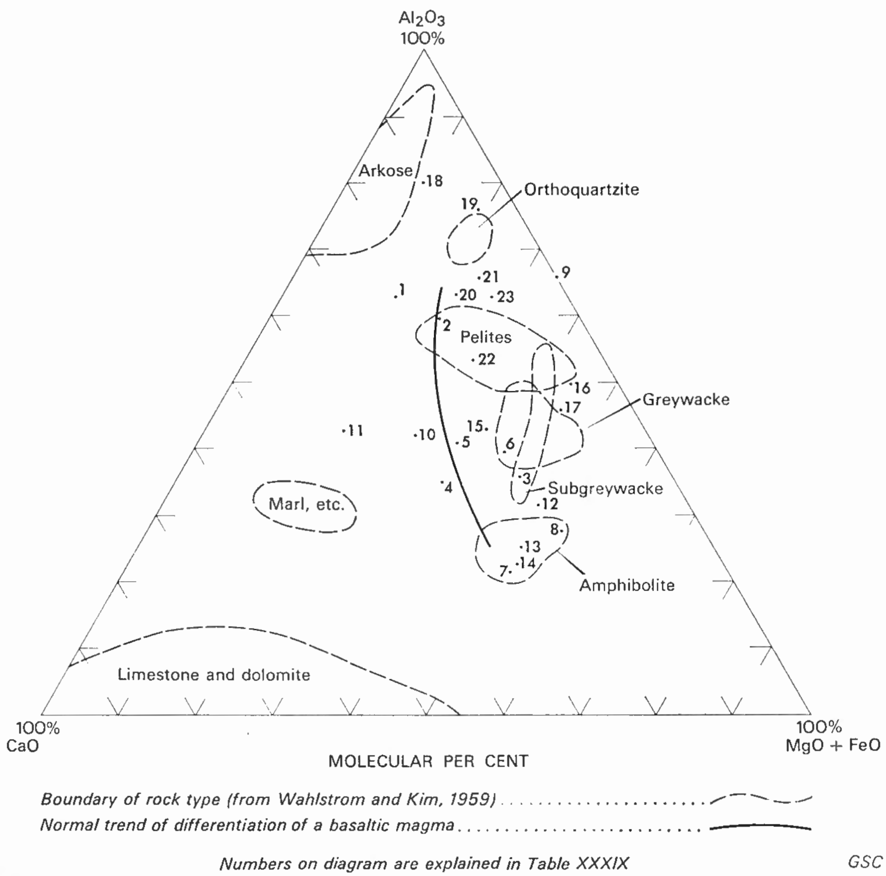

FIGURE 8. Relative percentage Al_2O_3: CaO: MgO + FeO of rocks from Beaverlodge area.

North of the Black Bay fault very few indications concerning the nature of the pre-existing rocks were recognized. Rocks that can be mapped as quartzite, feldspathic quartzite, and chlorite schist were recognized in the areas south and east of Bertha Lake, in the area east of Don Lake, and in the area south of Pluton Lake. Relict bedding is also believed to be present in those localities. Moreover, some thinly bedded quartzites were noted on the west shore of Fredette Lake and along Fredette River. All these occurrences are remnants of sedimentary rocks within granitized rocks or gneisses. Locally these remnants could be mapped separately, but most of them are too small. The nature of the remnants in general, their bedded appearance, their gradational contacts, and the continuity of their structure with that of the granitized rocks all suggest that they were once part of a sedimentary succession, probably the source rocks of the gneisses. Chemical analyses of these remnants are not available, but chemical analyses of the granites derived from these gneisses suggest an affinity with pelites and arkoses (Figs. 7 and 8).

North of the Boom Lake fault, indications concerning the nature of the original rocks are very scanty. Quartzite is believed to be present in the vicinity of Doreen and Liebel Lakes and round Betty Lake. Most of the quartzose rocks of the Powerline Creek belt were mapped as quartzites, and southwest of Pig Lake and round Smysniuk Lake some rocks were mapped as biotite schist and are probably metasediments. These, as occurrences in the other parts of the Beaverlodge area, show the same characteristics and are probably remnants of the pre-existing rocks from which the gneisses were derived.

As already mentioned, bedding or bedded structure was observed in many localities throughout the Beaverlodge area, not only in the ungranitized parts and the remnants but also in the gneisses or granitized rocks themselves. In general, also, the foliation of the gneisses is locally so strikingly similar in appearance and attitude to the bedding in the remnants that one is forced to conclude it is relict bedding. Even in those areas in the gneisses where both assumed bedding and foliation are present, the two have the same attitude. Both features exhibit the same general structural pattern. This can scarcely be a coincidence but rather indicates that the foliation is really relict bedding.

Many of the gneisses are fine grained and granoblastic or granular in the outcrop and thus texturally resemble a fine-grained recrystallized sedimentary rock. Their mineral composition, as determined in thin sections, has been described in detail in the chapter on General Geology, and, locally at least, this composition and those of known gneisses derived from sedimentary rocks are similar.

The chemical composition of these gneisses also resembles those of sedimentary rocks, as indicated by the only two available chemical analyses of these gneisses. When these two analyses are plotted with the chemical analyses of the pre-existing rock types of the Beaverlodge area on the two ternary diagrams (Figs. 7 and 8), even those of the gneisses, but not those of the amphibolite, fall within or near the assumed fields of greywacke, subgreywacke, pelites, and orthoquartzites or arkose. This statement, made earlier, suggests that most of the gneisses were once either large bodies of fairly pure and homogeneous sandstone, feldspathic sandstone, and arkose, or large areas of thinly bedded and interstratified shales, greywackes, and sandstone or arkose. This thinly bedded mixture was probably particularly abundant in those areas where the foliation is now well developed and is as regular as in stratified rocks.

Metasomatic Granite

The origin of the granite of the Beaverlodge area has been discussed by many workers whose views are clearly presented in Christie's report (1953, pp. 69–70). It is apparent from Christie's study and from the results of the writer's field work that the divergence of opinion is mainly due to the nature of the contacts, the appearance of the granite, the size of the granite masses and of the area mapped, and the scale of mapping. Some contacts are sharp, others are gradational, and a few masses have both kinds. Some granite outcrops look igneous; others have a hybrid appearance. Some workers have mapped only very small areas, and in such areas all the granite may occur in small masses with apparent intrusive relationships only, or the area may be entirely granite or mixtures where the nature of the granite is obscure or impossible to define. This explains the differences of opinion and demonstrates the complexity of the problem, which may be seen, from the following description, by Alcock (1935), of his old granite:

> It would appear that the intrusion of these granites combined a number of processes. There was a granitization of Tazin rocks due to solutions and mineralizers supplied by an underlying magma. There was the intimate injection of the older beds by magmatic material, giving combinations of hybrid and igneous masses in all proportions, and there may have been also an actual melting of older rocks resulting in the production of granitic rocks. (p. 16)

This statement suggests that the granite masses in the area may be of several origins.

Christie was more explicit when he wrote:

> The granites are believed to have been emplaced mainly by a granitization or replacement process, but various small bodies . . . . may have been emplaced as a molten magma. (1953, p. 72)

His granitization process implies the deposition of material from "tenuous fluids."

The writer has distinguished two granites: a metasomatic and an intrusive. The metasomatic granite is the more common in the area and includes most of the granite masses shown on the map. It is believed to have formed mainly at the expense of pre-existing rocks by recrystallization, with the possible addition and with the possible removal of material. The nature of the material added and removed is not definitely known since no chemical data are available on this subject; but the study of some rocks from north of the Black Bay fault in thin sections suggests that the original rock (map-unit 17: impure quartzite) was rich in oligoclase, quartz, and biotite or chlorite and that the main metasomatic effect was the addition of microcline, or potassium that subsequently formed microcline. The intrusive granite occurs only as small masses and dykes, a few of which are pegmatitic. The dykes (*see* Pl. 22), but not all the masses, have crosscutting relationships. Lack of these is typical of the sills and lenticular masses parallel with the foliation, and many of them may be metasomatic and may not be intrusive. The small masses, intrusive or not, and the dykes were noted everywhere in the area except in the Martin Formation, but in general they are too small to be mapped separately. Those that are mapped are not distinguished on the map from the metasomatic granite. Indeed the intrusive granite is not a major mappable unit. It is, however, probably related to the metasomatic granite defined below, and both granites were probably formed about the same time and possibly by the same process, the intrusive granite being the molten and mobilized parts of the metasomatic granite. The small masses parallel with the foliation may have formed directly from pre-existing beds, and the changes may have taken place without deformation or apparent changes in volume.

The following features support a metasomatic origin for most of the granite of the area:

1. The shape of most of the granite masses reflects the trend of the rocks and in general the structure of the area. This suggests that the granitization is a selective process, that it has developed at the expense of certain rock types, and that it has followed in its development the trend of these rocks and consequently outlined the main structures of the area. Thus, in the area north of the Eldorado townsite near the apex of and along the Ace Lake – Donaldson Lake anticline, the granitized rocks seem to have developed mainly at the expense of quartzitic

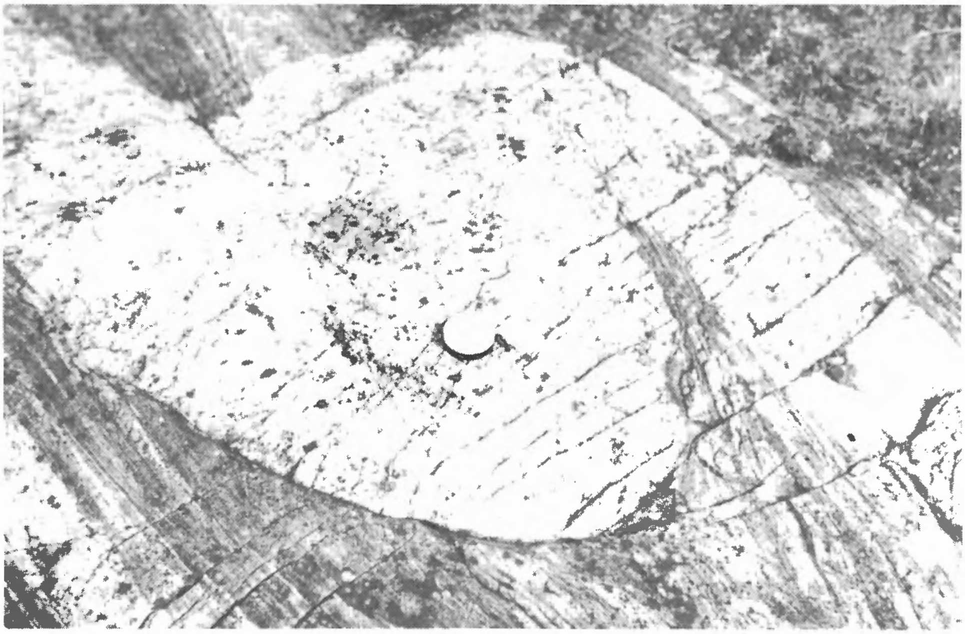

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PLATE 22. Granitic layered gneiss, Rix unit. A large granite dyke is seen cutting the gneiss and passing at both extremities into sills parallel with the foliation or the layered structure.

rocks and to have followed in their development fairly closely the trend of these quartzites, and consequently now outline the nose of the anticline. The same selective process is believed to explain the trend and the shape of the large mass of granite north of the Black Bay fault that extends from between Pluton and Fredette Lakes to Cinch Lake. The same selective nature of the granitization explains the large areas of granitized rocks east of Fookes Lake. There, the process is related to a gradual change in composition of the original rock from west to east, that is, from glassy quartzite to impure quartzite. As seen on the outcrop, it is even more apparent that the shapes of the granite masses are due to this selective process. Thus, on the outcrop, a bed or layer may be completely granitized whereas the ones on either side may be untouched or only irregularly granitized. The granitized bed may be altered for a great distance along the strike without any apparent deformation or warping of the adjoining rocks, suggesting that the process is a quiet one without any change of volume or shape.

2. Many of the contacts are gradational. The gradation within a rock type usually takes place over a short distance, generally only a few inches. A few of these gradations were described in the chapter on General Geology. There are areas, however, where the pre-existing rocks and the granite are closely mixed. This is also a form of gradation, as it represents the selective nature of granitization, and the degree of efficiency of the process; it is not *lit-par-lit* intrusion. Some rocks are granitized at a much later stage than others merely because they are relatively refractory to the process. This is to be expected if it is assumed that the process proceeds through the rock like a wave. It is however apparent that locally it may proceed simultaneously from different centres, and then the gradation may seem to

be very irregular. In summary the nature of the contact is believed to be controlled primarily by the selective nature of granitization. Good examples of gradational contacts can be readily seen almost everywhere in the area, but particularly east of the Tazin–Martin unconformity east of Fredette Lake, west of Fredette Lake in general, and north of the east end of Murmac Bay. Other contacts are very sharp, and these are usually with refractory rocks such as amphibolite and glassy quartzite, although rock types that normally have gradational contacts may exhibit sharp contacts. These contacts are usually parallel with the trend of the formation, and it seems that the bedding and foliation, being discontinuity planes, were obstacles too great for the granitization to cross.

3. A few layers or remnants of the pre-existing rocks were traced along the strike from areas of ungranitized rocks into areas of granite, and in passing from one area to the other they have retained all or at least some of their characteristic features. In places the nature of the pre-existing rocks may be readily recognized, and some layers or remnants may be only slightly altered. Other layers have been so intensely granitized locally that their extension into the granite can be recognized only by small remnants or relict minerals. The position of some former amphibolite layers in the Foot Bay gneiss was thus indicated by small lenses and larger pockets of amphibole crystals in the gneiss. Quartzite occurs in many irregular masses of all sizes in the granite in the area north of Mic Lake and south of Virgin Lake. These remnants show a continuity of structure and suggest that the process took place without destroying the structure of the rock being granitized.

4. Some of the main structures outlined in granite areas are probably relict, since they are continuous with structures in adjoining areas of ungranitized rocks. This was recognized in the area west of Fredette Lake where closed folding was traced in both the pre-existing rocks and the granite.

5. Many of the granites vary greatly in grain size from place to place, and many also vary in texture and composition. The variations appear to be related to the nature of the pre-existing rocks, since similar variations can be seen in remnants of pre-existing rocks; furthermore they are features typical of the pre-existing rocks. Thus, the fine-grained appearance of some of these rocks, their fine bedding and lamination, and their variation in composition from bed to bed may be preserved in part in the granite. Similarly the low mafic content of some of the granite in certain areas is believed to reflect the low mafic content of some of the quartzites.

6. Some of the amphibolite masses have white feldspar metacrysts and may exhibit a strong development of biotite in areas near intense granitization. The biotite generally forms at the expense of hornblende and is now commonly associated with chlorite, which is probably late. This development of biotite and feldspar is believed to represent a step toward the granitization of the amphibolite and possibly to indicate the addition of some potassium. A step further in the granitization of the amphibolite masses (*see* Pl. 23) is the stage at which the feldspar metacrysts are plentiful enough to change the nature of the original rock, in this instance the amphibolite into a hornblende-feldspar gneiss. Some of the large feldspars are oligoclase and may be metacrysts developed as a result of granitization, but as some are highly altered, they may represent original phenocrysts altered by the granitization.

7. Most of the layered gneisses are made up of alternating layers of granite and intensely granitized rocks (Fig. 3). The granite layers are locally very uniform in width, and their distribution suggests a bedded structure. Many of them, however, are lenses, irregular masses, veins, and dykes. The layers of highly granitized rocks also contain a small amount of granite, similar to the granite of the granite layers. It occurs in these granitized layers in tiny lenses, patches and round masses or augen (*see* Pl. 24). The main granite layers and the small masses

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PLATE 23. Hornblende schist and gneiss, north of St. Louis fault. Lenses, streaks, seams, and lines of granitic material, all oriented parallel with the foliation, are regarded as a step in granitization.

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PLATE 24. Granitic layered gneiss, Rix unit. Augen structure of the dark biotite-bearing layers is regarded as the first step in granitization.

within the highly granitized layers may represent material moved there from an outside source as pegmatitic and granitic solutions rich in water; such solutions generally are regarded as having high penetrating power at the temperature of granitization. It is, however, possible that most of the layers and small masses may have developed in situ from the pre-existing rocks without any addition of material. Actually it is impossible to say how much material was derived from the rock in place and how much was brought there from outside, that is, from nearby rocks, but it seems probable that much of it was developed from the rocks in situ and that such changes generally took place without apparent deformation or volume changes of the rock as a whole.

8. In thin sections a few other interesting and diagnostic features are visible. The feldspars are generally unzoned; myrmekite locally is very abundant; and many of the plagioclase grains have numerous embedded round quartz inclusions. The rocks in many instances display a mosaic texture where sequence of crystallization is not evident; but where a sequence is suggested, the plagioclase appears to be veined or replaced by K-feldspar and quartz, and therefore is early. Some of the accessory minerals, such as apatite, may be aligned as if they were remnants of a bedded structure. The micas also occur in some rocks in streaks and shreds, indicative of an old sediment.

9. Where granite dykes cross structures in the pre-existing rocks they do not seem to force the walls apart, since the structures are not dislocated but rather seem to replace the rock without disturbing its original structure. Locally the structure of the pre-existing rock is faintly preserved in the dyke itself.

The end product of this recrystallization and metasomatic effect is a fairly homogeneous coarse-grained red granite, mentioned earlier in this report. In places it much resembles an igneous rock, but, as stated previously, it seems to have formed directly from the rocks in situ. It is probable that most of it was never in a fluid state and had never moved, except for the dykes, which represent locally molten and mobile parts of the granite. In one instance, however, in the area north of Flack Lake and west of Raggs Lake, the granite appears to have been plastic enough to have moved slightly and rotated a little some of the ungranitized remnants, in this case, amphibolite. In all cases the end result of granitization is a rock fairly different in appearance and structure, if not always in composition, from the original rock from which it evolved. Two chemical analyses of granite from the Beaverlodge area and two from the Black Bay area to the west are given in Tables XXIV and XXVII. When these analyses are plotted on ternary diagrams (Figs. 7 and 8), they seem to be slightly more siliceous and richer in alumina and alkalis than a normal igneous granite, findings that suggest a possible derivation from quartzite.

The various rock types react differently under the effects of granitization. The term granitization, as used here, means the process by which a rock is converted into granite, or at least into a rock resembling granite mainly by recrystallization in situ, although a few elements—mainly potassium—could be introduced by metasomatic processes or from nearby rocks. If there were additions and removals of material, they probably took place without apparent change in volume. It is not believed that the process involved the addition of granitic fluids in large quantity from a magmatic source somewhere deep below the area granitized. No simple basic or acidic fronts, as suggested by Doris Reynolds (1949), were recognized. The process seems to have been controlled mainly by a rise in temperature and possibly pressure. This increase implies a transfer of energy from depth or perhaps not too far away from the area granitized. This rise in temperature and pressure is assumed to move through the rock like a wave and to reach values below which no granitization of any rock is possible, but above which a few rock types are readily granitized, whereas others, being more resistant, are granitized only slightly or not at all. Granitization is a selective and conditional process, in which some rocks react more readily and more completely under certain temperature–pressure conditions than others, the degree depending on the nature and composition of the rock.

There are many rock types in the Beaverlodge area. Some types were more common in certain parts than others, and this is the main reason for the variations in the extent and intensity of granitization from place to place. As suggested earlier, the original rocks of the Beaverlodge area that were converted the most readily into the red granite were greywacke and impure feldspathic sandstone, and probably these constituted the most abundant rocks in those parts of the Beaverlodge area that are now mainly granite and granitized rocks. This is probably what happened in most of the area north of the Black Bay fault and in areas where it seems obvious that these were the rocks that changed most readily into granite. Probably this is also true for the area north of St. Louis fault, and indeed for the entire Beaverlodge area, for remnants of pre-existing rocks in most granite areas have the general appearance of greywacke or impure feldspathic sandstone.

Quartzites, such as the glassy white quartzite of the Murmac Bay Formation, some of the quartzites low in feldspar such as those near Eagle shaft and Eagle Lake, or some of the glassy transparent quartzites near Doreen and Collier Lakes and along the Fredette River, are in general resistant to granitization, and even if all the adjoining rocks are heavily granitized, they are left almost completely unaffected. Where the quartzite is high in feldspar and has few dark minerals, it is readily and extensively granitized. Much of the quartzite southeast of Virgin Lake and northwest of Mic Lake, or much of the quartzite east of the Tazin–Martin unconformity east of Fredette Lake is of this type, and much of it has been completely granitized.

The argillaceous rocks are usually associated with tuffaceous and pyroclastic rock and also in part with glassy quartzite. These rocks are commonly either highly siliceous or in part mafic-rich and are not always readily granitized. Where they are granitized, it seems that the process was slow, gradual, and very selective. This is apparent a short distance northeast of Eagle Lake and halfway between Mickey Lake and Eagle Lake.

The amphibolites are in general very resistant and are rarely granitized, even in part. As they are composed mainly of hornblende and feldspar, mere recrystallization is not sufficient to produce a granite. Some addition and subtraction of material are necessary. This is obvious when one compares the chemical analyses of amphibolites from this area with those of the red granite and even the gneisses. The abundance of amphibolites and related rocks may explain why the area is not a uniform mass of granite and why the geology appears so complex.

It has been shown that the formation of the metasomatic granites of the Beaverlodge area is probably closely related to the regional metamorphism of the Tazin rocks, since they are regarded as the possible end products of this process, at least in places. The metasomatic granites thus are relatively younger than all the other regionally metamorphosed rocks. The granite dykes, however, and some of the small masses, which are the molten parts of the metasomatic granites, are probably still younger, since they cut large areas of granitized rocks. Some of the dykes are coarse grained, pegmatitic, and fresh looking, and although these show results of strain and some brecciation like the granite dykes, they are probably the latest granitoid rocks to have crystallized.

All the granite masses and dykes are overlain unconformably by the Martin Formation and are cut by the late gabbro or basalt dykes. The 1,795 m.y. K/Ar age obtained on biotite from the Donaldson Lake gneiss is believed to be a reasonable lower limit for the formation of the metasomatic granite. This is close to the age of 1,815 m.y. on muscovite from a pegmatite dyke on Crackingstone peninsula, south of the area of this report.

Environment of Deposition

It has been shown that most of the rocks of the Beaverlodge area were once named sediments, except for the amphibolites, which were probably mainly composed of pyroclastic and tuffaceous material. As indicated by the mapping, the nature of the quartzite seems to change from a fairly well sorted white glassy quartzite in the Murmac Bay area, south of the St. Louis fault, to feldspathic impure quartzite and greywacke north of the Black Bay fault, passing through a transition zone north of the St. Louis fault where the white glassy quartzite and the impure quartzite and greywacke are closely interbedded. Also in the Murmac Bay area south of the St. Louis fault there are fairly large masses of crystalline, silica-bearing dolomite and limestone. North of the St. Louis fault and in general north of the Black Bay fault, limestone and dolomite are represented only by minor lenticular masses or narrow beds, most of them too small to be mapped separately. Gneisses believed to have formed from greywacke, shale, and shaly sandstone seem to become increasingly more abundant to the northwest across the map-area, at least as far as the Powerline Creek belt (map-units 11 and 12). This suggests a change of facies and of environment. The amount of amphibolite does not seem to vary appreciably throughout the area, but it is possible that those layers or masses that are of volcanic origin or are sills are more common south of the St. Louis fault than north of it.

All the rocks of the Beaverlodge area are folded and faulted to various degrees. It seems that the folding or deformation is less complex and more open south of the St. Louis fault than north of it and north of the Black Bay fault. Faulting is a common feature north of the St. Louis and Black Bay faults but seems rare south of the St. Louis fault. For the area north of the St. Louis and Black Bay faults, these features (i.e., the types of sedimentation and the types of deformation) seem to suggest environments of deposition different from those for the area south of the St. Louis fault. In the latter area the rock association and the simplicity of folding seem to be typical of the platform type of deposition, or at least of the proximal zone of a geosyncline, whereas north of the St. Louis fault, and especially north of the Black Bay fault, the rock association and the complexity of deformation are typical of a geosynclinal environment. And, as is common in many parts of the world, a period of geosynclinal deposition is often followed by some orogenic movements, which locally bring about the development of red clastic beds at a later period, generally after extensive block faulting. This seems to be so in this area, since red beds occur abundantly in the Martin and Fredette Lake basins where such beds are represented by the arkose and siltstone of the Martin Formation (*see* origin of Martin Formation below).

Origin of Martin Formation

Conditions During Deposition

The Martin Formation in the Beaverlodge area was deposited under continental, not marine, conditions on a rugged weathered surface. Continental conditions are indicated by the nature of the rocks, by the minor structural features observed in them, and by the spatial position of some of the rocks in the basins. The rocks of these basins are almost entirely clastic (green beds of possible shales, though rare, were seen), and locally there are some interbedded volcanic flows. Limestone or carbonate rocks were not seen. The rocks of this formation are very similar to those of the Newark series (New Jersey) and to red beds in many other parts of the world that are regarded to be of continental origin. Crossbedding, rain-drop markings, mud-cracks, and variations of grain size within the arkose are typical of continental environment. The stromatolitic structure indicates the action of some organisms but does not necessarily imply marine conditions. These clastic rocks also cover large areas and form thick deposits, two features ordinarily incompatible with marine deposition of such rocks.

Shallow conditions of deposition are indicated by minor depositional features, such as wave ripple-marks and crossbeds in the arkose, mudcracks and rain-drop markings in the siltstone, and beds and lenses of conglomerate at several horizons and in many localities in these basins. The stromatolitic structure also generally develops under shallow water conditions.

There are indications that the material was not transported very far from its source and that generally it was deposited very rapidly. In some instances, the material was moved only a few feet, if at all, from its original position. Thus, at a few places it was observed that the basal conglomerate was made up of rock fragments derived from the Tazin rocks directly underneath. This type of rock passes gradually into a rock where the fragments have moved slightly from their original position but are still very angular; then, farther up, into a rock where the fragments have definitely moved; and finally into a conglomerate, composed of fragments of a mixture of Tazin rocks. Other indications of short transportation and rapid deposition are the angularity of the fragments in the basal conglomerate and of the grains in the arkose and the siltstone; the coarseness of the fragments in the basal conglomerate and the poor sorting, not only of the fragments in the basal conglomerate but also of the grains in the arkose and the siltstone; the freshness and the great abundance of feldspars in the arkose and siltstone and, in part, in the matrix of the conglomerates; the small variety of heavy minerals in the arkose, principally zircon, garnet, apatite, hematite, chlorite, hornblende, sphene, and rutile (?); the widespread and common occurrence of crossbedding; the thick lenses of conglomerate at all levels in the sections and throughout the area; and the rapid changes in the grain sizes within beds and from bed to bed of the arkose and siltstone.

The red colour of most of the rocks of the Martin Formation is due to hematite, which forms the cement for the grains in the arkose and siltstone and in the matrix of the conglomerate, and acts as a colorant for the feldspar grains and also for some of the quartz grains. This iron oxide is believed to be derived from the Tazin rocks mainly by mechanical weathering. However, it may be partly the product of oxidation or the result of hydrothermal action. It is too uniformly and too widely distributed to be an hydrothermal effect. Hydrothermal action would concentrate its effects along definite zones and planes. If it be due to oxidation, it would imply periods of moderate rainfall alternating with periods of semi-aridity in a hot environment. This was suggested by Alcock (1936a, p. 24), Christie (1953, p. 54), and Blake (1956, p. 9). However, as the arkose and the siltstone have a high content of relatively unaltered feldspars, it is hard to visualize how the feldspars could stay fresh if the climatic conditions were wet and hot, even if the deposition were rapid. It is possible that some feldspar would be preserved, but wet conditions would facilitate the hydration of hematite, and the formation of brown limonite, which does not appear to be a common mineral in the Martin Formation, except possibly in the siltstone. Siltstone, of course, implies conditions of better sorting and slightly longer transportation. Oxidation is not believed to be essential to explain the presence of hematite; it is known that the oxide is already present in the Tazin rocks but may have been none the less effective. In conclusion, it is suggested that low temperatures and semi-arid conditions would help to preserve the feldspars and the red colour of the Tazin rocks during their disintegration. The presence of large faceted fragments (Pl. 20) of Tazin rocks at various horizons in the arkose suggests that ice may have acted as an agent for their transportation and deposition; this would support the hypothesis of a cold climate.

The pillowed structure in the volcanic rocks at a few places suggests that these rocks formed under water. Also, the lava may have been ejected in shallow water, because the presence of fragments of volcanic rocks in the arkose immediately above some of the flows shows that shortly after its ejection it was subjected to erosion.

Source Area

All the basins of Martin rocks in the Beaverlodge area are elongated in a northeasterly direction. This applies also to the small basins that form re-entrants in Tazin rocks along the eastern margin of the main Martin Lake basin. This northeasterly trend of all the basins is an indication that the material deposited in them was transported in a southwesterly direction from a source to the northeast and north. The tongue-like body of basal conglomerate in the southwest corner of the main Martin Lake basin suggests that some of the material in that particular area may have come from the southwest. Other indications for the direction of transport and for the probable position of the source are the nature of some of the rocks and the statistical studies on minor structures such as crossbeds. The fragments in the basal conglomerate and most of the fragments in the conglomerate interbeds are derived from the Tazin rocks. The large number of granitic fragments suggests a large granitic terrain as their source. To the northeast, there are such large areas. Relatively large granitic areas are known to occur to the southeast, south, and southwest, but in these areas, granitic rocks are so intermixed with quartzite and amphibolite that the scarcity of these rocks fragments makes it unlikely that the source of the Martin sediments lay in these directions. The arkoses and siltstones are made up mainly of clastic grains of feldspar and quartz in about the same amount and proportion as one finds them in the granitic rocks of the Tazin Group, indicating a granitic terrane for the source area. If, however, quartzite and amphibolite had been abundant in some parts of the source area, the composition of the arkose and siltstone should vary with the abundance of quartzite and amphibolite in the source area; locally they should be almost a pure sandstone, in other places almost a greywacke. Their uniform composition suggests a uniform source, mainly granitic rocks. The red colour of the arkose, siltstone, and conglomerate indicates a relationship to the granitic rocks of the Tazin Group. This colour is a direct product of the disintegration of the granitic rocks, not of the quartzites, which are commonly white, nor of the amphibolites, which are usually dark green.

As mentioned previously, the arkose of the Martin Lake basin is commonly crossbedded. A total of 262 measurements of the attitudes of these crossbeds were obtained from five localities in the Martin Lake basin. These localities, called A, B, C, D, E, appear on Figure 5. The readings from each locality were corrected for tilt and then plotted in circular histograms. They strongly suggest that the source for the material deposited in the Martin Lake basin was to the north and northeast and that the material was transported in a south to southwesterly direction. This corresponds to the direction presented by Fahrig (1961) for the Martin rocks based on forty-one readings. No similar measurements were made on crossbeds in the Fredette Lake basin; but a few measurements in the conglomerate interbeds north of Uranium City suggest the same source.

The basal conglomerate has already been shown to have been largely derived from the Tazin rocks directly below it.

In summary, the source of the basal conglomerate seems to be the rocks immediately below and the source of the sediments in the main Martin basin seems to be the Tazin granitic rocks immediately to the north and northeast. Near Nero Lake, some material may have come a short distance from the south.

History of Deposition

The history of deposition of the Martin Formation, as suggested by the information obtained in the field and in thin sections, is summarized in chronological order:

1. At the start of deposition of the Martin rocks the land surface was rugged and typical of a block faulted terrain. This is indicated by the nature of the basal conglomerate, which locally is a talus, or possibly a fan; by the trace of the unconformity; and by the present fault pattern.

2. The source area was one of unweathered Tazin rocks, mainly granites and granitic rocks, located to the north and northeast of the present area of Martin rocks. Erosion was mainly mechanical, no apparent weathering of the detritus having taken place; the grains have retained their red colour, and the feldspars are very fresh and abundant.

3. The detritus was removed shortly after its formation and transported by swift rivers down the steep fault scarps under the conditions of a cool, rather dry climate.

4. The accumulation of the detritus was rapid because it was near its source and under shallow water. This rapid accumulation soon filled the basin, and since great thicknesses of material had accumulated, the rapid filling was accompanied by a down-warping of the basin.

5. During the early accumulation of the Martin rocks, there were periods of volcanism that gave rise to outpourings of lava and injection of gabbroic sills in the Martin Lake basin.

6. Erosion contemporaneous to the deposition of the Martin rocks produced fragments of the early Martin rocks that were included in the late Martin rocks.

7. Subsequent tectonic events, to be described later, modified and shaped the basin to its present form.

Correlation and Age

In this report the rocks of the Martin Formation are correlated with those of the Athabasca Formation south of Lake Athabasca, following the usage established by Alcock and continued later by Christie and Blake. Gussow (1959) and Fahrig (1961), however, do not accept this correlation, indeed Fahrig (1961, p. 32) goes so far as to suggest a period of erosion between the deposition of the two sequences.

It is true that there is no lithological similarity between the two formations. The rocks of the Athabasca Formation "are composed almost entirely of well-rounded quartz grains. With few exceptions, conglomerate beds and feldspar grains are virtually absent and the red colour so prevalent north of the lake (Athabasca) is lacking" (Blake, 1956, p. 9). This is in sharp contrast to the rocks of the Martin Formation, which are predominantly arkoses, being made up of angular grains. This contrast indicates that the source rocks and the conditions of transportation and deposition were not the same for the two formations, but it does not preclude the possibility that the material was deposited at the same or about the same general geological time. However, Gussow and Fahrig regarded these features as sufficiently diagnostic to state that, in the light of knowledge so far, no correlation exists between the two formations. In fact it is now commonly accepted that the Martin Formation is overlain unconformably by the Athabasca Formation even if both formations were never seen in contact. The following of this section is retained since it is pertinent to the correlation problem of the Martin Formation.

About six late basalt and gabbro dykes were mapped in the area underlain by the Martin Formation. Two similar dykes have been reported to cut the Athabasca Formation south of Lake Athabasca. In the Fredette Lake basin, gabbro dykes cut all the exposed Martin rocks; that is, the basal conglomerate, the siltstone, and the arkose lying above it. In the Martin Lake basin, one dyke is along the unconformity plane, partly in the basal conglomerate;

another is in the arkose above the basal conglomerate; and a third, as reported by Christie (1953) and possibly related to the gabbro dykes, apparently cuts the base of one of the volcanic flows. Thus, in the Beaverlodge area, the late basalt and gabbro dykes do not appear to cut rocks younger than the volcanic flows of the Martin Formation. Of the dykes in the Athabasca Formation, Tyrrell in 1895 described one gabbro dyke 200 feet wide on Cree Lake, Saskatchewan. Fahrig (1961, p. 15), who looked at this dyke, stated: "it is likely that the dyke is intrusive into the sandstone." Blake (1956) mentioned a 5-foot-wide dyke cutting the Athabasca sandstone on the south shore of Lake Athabasca. These dykes and those in the Martin rocks are very similar in appearance and mineral composition and seem to be related to each other. However, K-Ar whole rock age determinations on a dyke in the Fredette Lake basin and one on Cree Lake south of Lake Athabasca suggest that these dykes are not of the same age, and the two formations cannot therefore be correlated on this evidence. The Fredette Lake dyke gave an age of 1,490 m.y. (*see* last part of section under "Conditions during Deposition"), whereas the age of the one on Cree Lake is about 1,230 m.y. (Burwash *et al.*, 1962). This difference appears to be too great to be an analytical error, and until more determinations are available the evidence is therefore not conclusive.

The best evidence of correlation of the two formations appears to be a transition zone between the north shore of Lake Athabasca and the south shore of Beaverlodge Lake where rocks characteristic of both formations appear to be interbedded, the quartz-rich sandstone increasing in abundance to the south, the arkose increasing to the north. This Christie (1953) described and later Blake (1956); from what the writer saw on the few outcrops of the Martin Formation at the southwest end of Beaverlodge Lake in the area mapped, this transition zone does appear to exist. Even Fahrig (1961, p. 32), who does not think the two formations should be correlated, agrees that on the basis of a rapid facies change the Martin rocks could grade into the Athabasca Formation within the short distance that separates their outcrop areas on Crackingstone Peninsula in Lake Athabasca. During the mapping no attempts were made to outline this transition zone, which indeed is mostly outside the area mapped, or to see if the progression does, in fact, exist and if it is gradual. However, there is some evidence in its favour. On Beaverlodge Lake a few 18-inch beds of a white, seemingly highly siliceous sandstone interbeds were noted in both the conglomerate and the arkose. These, which may represent the first stage of the transition zone, could be regarded as the best evidence for correlating the two formations.

All workers in the area, even Gussow (1959) and Fahrig (1961), assign a Precambrian age for the Martin Formation because these rocks have been broadly folded into synclines trending northeasterly, because they are intensely faulted, and because they are cut, at least in part, by late basalt and gabbro dykes known to be Precambrian. The many ages tabulated in Chapter V on Economic Geology seem to date, at least in part, the Martin Formation. From K-Ar and Pb-U ages of about 2,000 m.y. on biotite and uraninite in pegmatite of the Tazin gneisses, from Pb-U ages of about 1,600 m.y. on pitchblende occurring as veins and fracture fillings in volcanic rocks of the Martin Formation, and from the K-Ar whole rock age of 1,630 m.y. on the same volcanic rocks, it appears that the lower part of the Martin Formation, including the volcanic rocks, were deposited between 2,000 and 1,650 m.y. ago. A K-Ar age on biotite from a large gabbro dyke at the northeast end of Neeley Lake, northwest of Black Bay fault, outside the map-area, was determined as 1,830 m.y. (W.F. Fahrig, pers. com.). This dyke appears to be cut by the Black Bay fault and does not seem to intrude the Martin rocks east of the fault. This age may therefore put an upper limit on Martin rocks and may limit their deposition from and below the volcanic rocks to a shorter period, that is, between 1,830 m.y. and 1,630 m.y. This would place these Martin rocks in the Aphebian (Early Proterozoic) (1,640–2,440 m.y.) of Stockwell (1964). Nevertheless no upper limit can be placed on the Martin Formation above the volcanic rocks. The Martin Formation is regarded here to be between 1,830 m.y. and 1,650 m.y., that is very late Aphebian or very early Helikian (Fraser, 1970).

A correlation is proposed (McGlynn, 1971) with rocks of the Nonacho Group, as rocks of each group have lithologic similarities and occur only about 125 miles apart. The Nonacho Group is made up mainly of conglomerates, shales, arkoses, sandstones, and greywacke. These rocks grade into one another, are interbedded, and are grey to buff. The conglomerate, which is found mainly at the base, is composed of closely packed, angular, unsorted fragments, mostly of granite or granitic rocks in an arkosic matrix. Crossbedding, mudcracks, ripple-marks, and grain gradation are common. Volcanic rocks are not present and the group is cut by late gabbro dykes. The rocks of the group are relatively unmetamorphosed and are not cut by granite. They are folded into northeasterly trending open folds with steeply dipping limbs, and are cut by faults. These lithologic and tectonic similarities to the Martin rocks suggest a correlation between both groups.

The Martin rocks are also correlated with the rocks of the Kazan Formation of the Dubawnt Group (Donaldson, 1965). Both are similar lithologically. Like the rocks of the Martin Formation, the rocks of the Kazan Formation are red, feldspar-rich, and mainly conglomerate and arkose. Included in them are some volcanic rocks; they are folded into open folds and cut by faults and gabbro dykes. The volcanic rocks, however, are somewhat more acidic than rocks of the Martin Formation. A K-Ar whole rock age determination on a gabbro dyke, outcropping slightly to the north of the area underlain by the Dubawnt Group, is 1,350 m.y., and K-Ar ages on biotite from the Dubawnt volcanic rocks average 1,716 m.y. (Fraser, *et al.*, 1970). These ages and similarities of lithologic and tectonic histories suggest a correlation between the Martin Formation and the Kazan rocks of the Dubawnt Group.

Chapter IV

STRUCTURAL GEOLOGY

The rocks of the Tazin Group have been extensively and intensely folded, faulted, and fractured. Many wide areas of brecciated rocks and mylonites. related to faulting and possibly to folding, occur. In the complexly folded areas, there is some repetition of the rock units. Most of these trend northeasterly, but locally, due to folding, they trend easterly. The total thickness of Tazin rocks in the Beaverlodge area is about 20,000 feet but may reach 30,000 feet. These figures were obtained from a composite section and are believed to represent only a fraction of all the Tazin rocks north of Lake Athabasca. Christie (1953, p. 20) estimated the thickness of Tazin rocks at 30,000 feet in the area extending from Lake Athabasca to Beaverlodge Lake, most of which is outside the area of this report. Most of the rocks of the Tazin Group in this area are foliated. The foliation is regarded as bedding, as relict bedded structure partly accentuated by metamorphism, and as a metamorphic effect. Lineation was measured on wrinkles, crenulations, minor folds, and drag-folds and appears to be related to the main fold axes of the area. Two periods of folding, two periods of faulting, and several sets of joints, all interrelated, were recognized. Most of the folds shown on the map are early folds; late folds are rare. The early faults are represented on the map by the mylonite and brecciated zones mentioned above, and it is the late faults that are shown on the map. The Martin Formation has also been folded, faulted, and fractured, and locally it is even a little brecciated. The Martin folds are gentler than those of the Tazin rocks; they trend northeasterly about parallel with those in the Tazin rocks and are probably late. The faults are all late and abundant. Numerous joints also occur. The main structural features of the Beaverlodge area are described in some detail below, and where possible they are explained.

Bedding

Bedding was recognized in the Tazin rocks at many places in the Beaverlodge area, and in some parts, as around Murmac Bay, it is characteristic and almost ubiquitous. In other parts of the area, as north of the Black Bay fault or north of the St. Louis fault, it can be recognized with certainty only where recognizable remnants of sedimentary rocks are found. In general, bedding is indicated by a sharp change in the composition of the rocks from one side of the bedding plane to the other. This is generally accompanied by colour differences and locally by a slight variation or a marked difference in size of mineral grains. In rocks that are highly metamorphosed it is indicated locally by the unusual abundance of certain metamorphic minerals, such as garnet or white feldspar, along or within certain bands or layers.

In granitized rocks, it may be represented by narrow layers of granite and gneiss. Beds may be fairly thick, as north and south of the St. Louis fault, or very thin as is common north of the Black Bay fault, north of Ace Lake, and in general in the area of Ace and Fay shafts. Many of the beds north of the Black Bay fault are less than an inch thick, but they reach 20 feet locally. In general no attempts were made to measure the thickness of beds as the rocks are too intensely deformed, too badly altered, and too widely covered with overburden and lichens. Tops could not be determined because features such as grain gradation, cross-bedding, ripple-marks, mudcracks, or other characteristic features, were not seen or recognized anywhere. These features may be present, but if so, they are so rare or so marked by metamorphism and granitization that they were not recognizable, even in rocks of the Murmac Bay Formation, except in the few layers of quartz-pebble conglomerate that show some grain variation.

Bedding in the Martin Formation is clear and common and was discussed with the description of the Martin Formation.

Foliation

Most of the rocks of the Tazin Group in this area are foliated. Though mainly a layered structure, the foliation is also gneissic and in rare cases a schistosity. A layered structure is here defined as one in which the layers have a visible thickness on the outcrops; a gneissic structure, as one characterized by the orientation of acicular and platy minerals in a common direction without apparent layering; and a schistose structure, as one characterized by a concentration and alignment of mainly platy minerals along closely spaced planes, permitting the rocks to part with greater ease than those with gneissic or layered structures only. Most of the foliation in the Tazin Group is believed to be a relict bedded structure that may or may not have been accentuated by metamorphism, but some of it is definitely a metamorphic feature due to recrystallization, rock flowage under stress, cataclastic deformation, and possibly metamorphic differentiation.

As the layers are of different colours, different grain sizes, and different compositions, foliation is generally readily recognized on the outcrops. The contacts between layers are sharp to gradational. This type of foliation is most common and is best represented in granitized rocks derived from sedimentary rocks. It is also fairly common in areas of more lightly metamorphosed sedimentary rocks but is rare in the granite areas. It is marked in the periphery of the granite areas where not all rocks were entirely granitized or changed into the normal red granite. In all these areas the layered structure is believed to be a relict bedded one, and in some cases it was shown on the map as bedding. Most granite areas, however, are not layered but are gneissic or massive. In many places the gneissic structure of these granite areas is believed to be a phase of the layered structure and to represent bedding so heavily modified by granitization and metamorphism that only a gneissic structure is left, the layered structure being almost obliterated. Some layered structure was also recognized in a few amphibolite masses. Where it resembles bedding, it may indicate that the amphibolite was a tuffaceous rock; where it is found only in the contact zones of the amphibolite with the enclosing rocks, it may represent a depositional gradation, that is, a change of facies from one rock type to another, that is, from enclosing rock to amphibolite; or it may be a metamorphic feature. Some of the layered structure of the mylonite zones is probably due to cataclastic deformation accompanied by mobilization of some of the material of the rocks under differential stress.

Gneissic structure is generally present where the layered structure is found, but it also occurs in rocks that are not layered. It is common in large unlayered amphibolite and granite masses where it is usually parallel with the layered structure in adjoining rocks. However, in a few amphibolite masses the gneissic structure was so intricately contorted and folded that it appears certain it was related to the bedding and that it represented a closely folded rock, the gneissic structure having formed as a result of folding, recrystallization, and flowage along the bedding plane under great confining pressure.

The schistose structure is nowhere pronounced and was noted only in beds high in mica or chlorite. It was produced in rare places in quartzite by the development of much sericite.

No foliation, except for bedding and a faint slaty structure in the siltstone, was noted in the Martin Formation.

Lineation

Lineation was recognized at many places in the Tazin rocks of the area, but it is neither common nor obvious. In most instances it was difficult to determine a reliable direction. It is represented by streaks and wrinkles on the foliation planes, by the axis of the crests and troughs of the crenulations and minor folds, and even locally by drag-folds along the foliation. The streaks and wrinkles are due to mineral elongation and alignment and possible crenulations and were recognized mainly in the area south of the St. Louis fault. The crenulations and minor folds are the result of flexing and are the best developed lineations in the area. Drag-folds which were also used locally in the same way as the minor folds, in most cases gave the same results as the minor folds and crenulations. Streaks and wrinkles were also noted locally in the siltstones of the Martin Formation but are related to the folds in the Martin Formation.

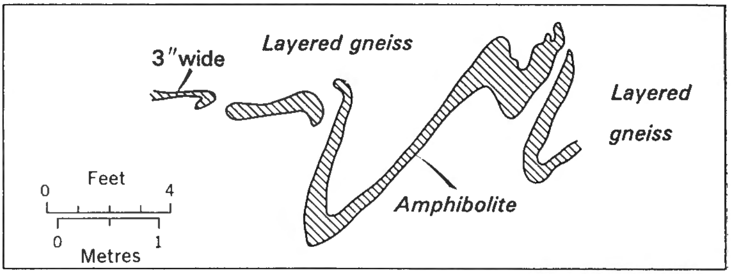
South of the St. Louis fault the lineation trends southerly and plunges 30 degrees south. It is probably related to the Goldfields synclinorium of Christie (1953, p. 21). North of the St. Louis – ABC fault, the lineations trend northeasterly and plunge either north or south. North of the Black Bay fault the bearing and plunge of the lineation are the same as north of the St. Louis – ABC fault. However, there, northerly plunges seem to characterize anticlines and southerly plunges synclines. In general all lineation plunges between 15 and 60 degrees, averaging 30 degrees. The lineation seems to trend parallel with the trend of the main fold axes of the area. This is very obvious in the areas south of Eagle Lake and northeast of Ace Lake and south and east of Bertha Lake, and in the vicinity of the Rix Smitty shaft. There, the lineations were numerous (and fairly good) and are all closely related to folded structures. This is also true of the rare lineation in rocks of the Martin Formation since they were parallel with the fold axis of the Martin strata wherever seen.

Rock Flowage Features

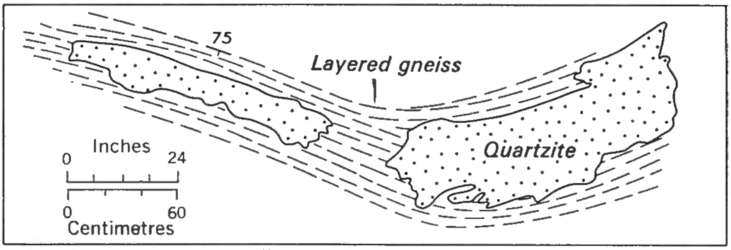
There are indications in the area that the rocks have moved under great pressure, that the various rock types have reacted differently under such conditions, and that the nature and the intensity of movement have varied with the competency of the rocks. The degree of competency varies not only with the nature of the rock and the thickness of the bed or mass, but also with the nature of the adjoining beds. Furthermore, on its competency may depend the nature of the movement and the types of deformations that result from the applied stress.

The massive glassy quartzite is the most competent rock in the area. The amphibolite is in general less so and in many instances the two have reacted in exactly the same way. The impure quartzite, the greywacke, and the chlorite- or biotite-rich gneisses generally behave like incompetent rocks except where interbedded with the even less competent carbonate-rich rocks.

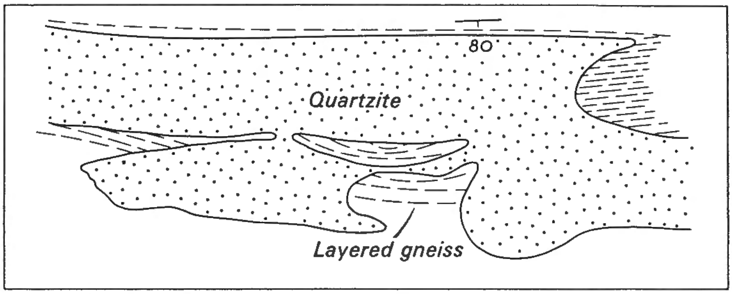
The features that indicate movement under great pressure are as follows: boudinage structures, intricate flowage structures in carbonate-rich rocks and locally in granitized quartzitic rocks, flowage in the zones of contact of amphibolite with quartzite and gneisses, and drag-folds.



Amphibolite bed showing drag folding and thickening of beds at the nose of folds. About 2500 feet northwest of Bushell.



Quartzite bed showing difference in thickness of the boudins may be due to stretching or thickening due to drag folding. About 1000 feet due west of southern end Smysniuk Lake.



Quartzite displaying rock flowage, drag folding and possibly a rude boudin of layered gneiss. About 1000 feet due west of southern end of Smysniuk Lake. Size of area shown about 12 feet by 3 feet.

GSC

FIGURE 9. Sketches of boudinage structures.

Boudinage structure is developed extensively in the amphibolites at all stratigraphic levels but is most common in amphibolite in granitized rocks. The presence of this structure, which was recognized on the scale of the outcrop in a series of boudins, explains the lenticular appearance of many of the large amphibolite layers and masses. Thus, the large irregular masses of amphibolite a short distance south of the St. Louis fault in the area south of Ace and Fay shafts are probably large boudins and parts of several beds of amphibolite that have been stretched and squeezed and then broken and pulled apart. Quartzites and granitized quartzites locally also exhibit boudinage structure. Sketches made in the field of boudinage structures are shown in Figure 9.

The carbonate rocks along the Boom Lake fault northeast of Chance Lake, those in the Powerline Creek belt near the western boundary of the map-area, and the dolomitic rocks east of Bushell and north of Ace Lake, all show intricate patterns of rock flowage. Some of the granitized quartzite, particularly those in the area north of Bushell, shows much rock deformation and flowage in the form of irregular folds and drag-folds. These are described as nebulites. Rock flowage was also indicated by the many drag-fold-like structures, seen here and there throughout the area, particularly in some of the faintly schistose quartzite and tuffaceous rocks.

Some flowage is also suggested at the contact of amphibolite with quartzite and granitized quartzite (Fig. 10). The irregularity of these contacts, the protrusion of the amphibolite into short, irregular, and bulbous forms, and some accentuation of the gneissic or layered structure in the amphibolite near the contacts suggest a certain amount of flowage.

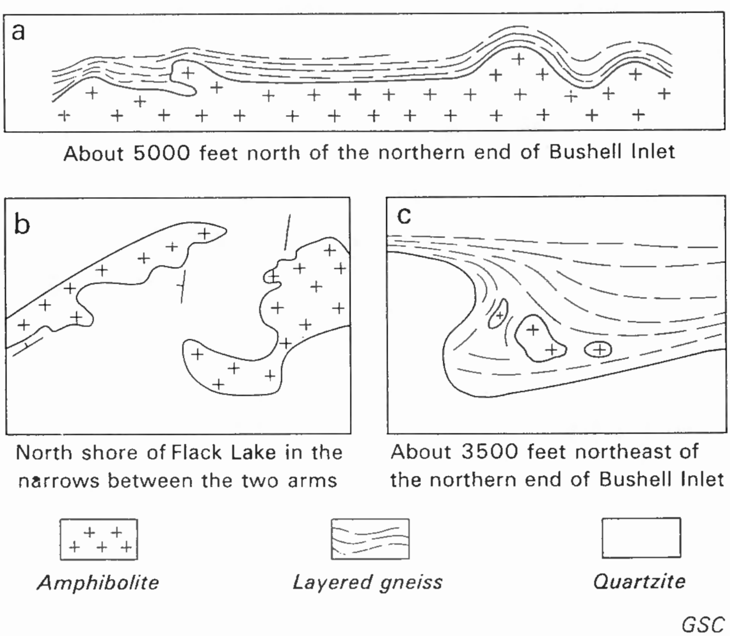


FIGURE 10. Features along contacts between three different amphibolite masses and layered gneisses or quartzite. Wavy nature of contacts, bulbous protuberances, and drag-folding effects suggest that the amphibolite flowed under heavy load at great depth. Sketches are not drawn to scale.

Folds

Tazin Group

Changes in direction of strike and dip of the many rock units in the area indicate that the rocks of the Tazin Group have been intensely and complexly folded. However, where the dips are fairly gentle and where the rocks are recognized as sedimentary, the beds are assumed to lie in their normal attitudes. Moreover, most foliation is regarded as relict bedded structures, and in most instances these are assumed to indicate the normal attitudes of the rocks.

Based on these assumptions, the location of many fold axes on the map is made possible. From their positions it is apparent that some rock types are folded more closely than others, and that disharmonious folding is common in this area. This is true of the area extending on the west from Padget Bay to Hab Lake and on the east to the north end of Donaldson Lake. In this area, broad folds seem to characterize the quartzites and granitized quartzites, whereas the thinly bedded argillaceous, quartzitic, and tuffaceous rocks form small, intricate, close folds.

The sinuous traces of some fold axes and the transverse trends of a few minor folds indicate more than one period of folding. Sinuous traces were noted at several places throughout the area. This can readily be seen on Figure 11. It is not suggested that all the sinuous traces are due to a second period of folding, but at least some are. A few transverse trends, which were recognized east of Verna Lake and within the workings of Verna mine, are considered to be a good indication of a late period of folding.

Two periods of folding are therefore apparent in the Beaverlodge area, and each varies appreciably in importance and intensity. The early period probably took place after deposition of the sedimentary rocks or about the time these were granitized. It comprises most of the fold axes that trend northeast and north; it is definitely the main period of folding. The second period is represented by small folds only. Although these are present everywhere in the area, they are not common. They are later than the first period and are probably related to the deformations responsible for the late faulting, or they may be due to the stresses that caused the mylonitization (*see* p. 174). Since they are local features only, they cannot be distinguished in most instances from the other folds unless their trend is at a pronounced angle to the trend of the early folds.

Figure 11 shows the position and trends of most known fold axes. It can be seen that the trend of most fold axes northwest of both the St. Louis – ABC fault and the Black Bay fault is northeasterly, whereas south of the St. Louis fault it is northerly. The writer's interpretation of the structure of the area is depicted on the structure sections (*in pocket*). These structure sections show that major folds are rare, but that these are places where the formations on a broad scale are almost flat lying though in detail are complexly folded. This is a characteristic feature of the area as a whole and shown in Figure 12.

Area north of St. Louis – ABC Fault

In the area north of the St. Louis – ABC fault the many folds recognized all trend between N10°E and N80°E, averaging N50°E. Most of the folds appear to be open and upright. Folds in the thinly interbedded mixture of argillaceous and tuffaceous rocks are small in relation to the large, broad folds of the quartzites and granitized rocks. This indicates disharmonious folding, a characteristic feature of this area. Based on the trend of the rock units, the major folded structure here appears to be the Ace Lake – Donaldson Lake anticline. This structure may in fact be a large drag on a much larger fold, but this could not be ascer-

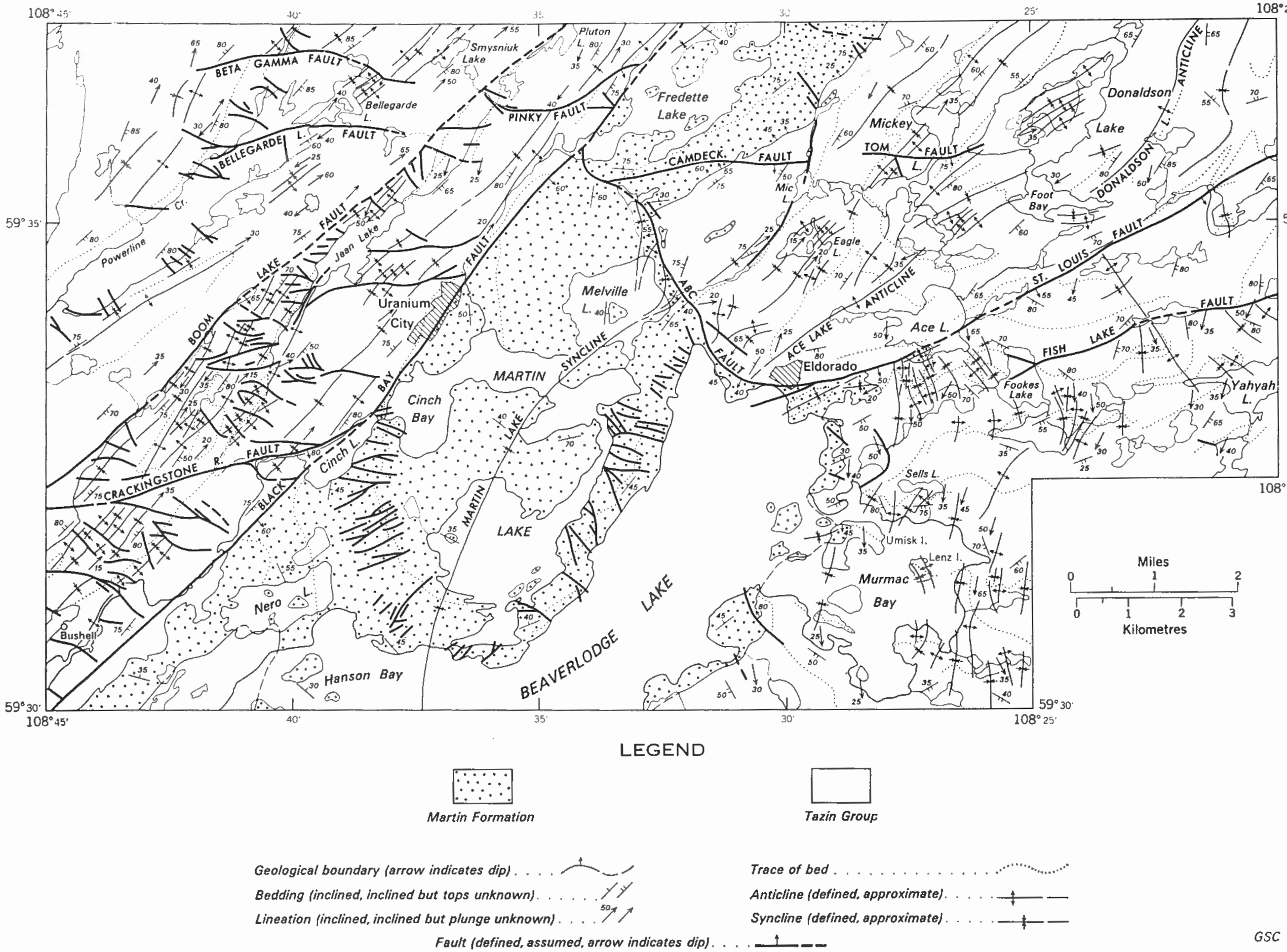


FIGURE 11. Main structural features, Beaverlodge area.

tained because the nature of the folds and the broad trend of the rocks west of the Ace Lake – Donaldson Lake anticline suggest that the axis of this larger fold should be east of the map-area. The axis of the Ace Lake – Donaldson Lake anticline extends from the ABC fault east of Padget Bay to about three-quarters of a mile north of Ace Lake. The position of its extension to the northeast as far as Foot Bay on Donaldson Lake is uncertain because it is difficult to determine which of the minor fold axes in this area represents the main structure. North of Foot Bay the anticlinal axis lies east of Donaldson Lake. Based on about six lineation readings in the vicinity of the fold axis, this anticline is believed to plunge between 40 and 60 degrees southwesterly. As a result of this plunge, a fairly complete cross-section of rocks is exposed along the crest line, the oldest rocks in the succession occurring in the northeast corner of the map-area, the youngest ones occurring near the Tazin–Martin unconformity east of Fredette Lake. This anticlinal trend line was one of the main elements used in working out the stratigraphy, not of this part of the area only but of the Beaverlodge area as a whole.

The other folds in the area north of the St. Louis – ABC fault appear to be either subsidiary folds or undulations on the limb of this anticline where the formations, if taken as a whole, are almost flat lying but which are in detail complexly and closely folded. This is the type of structure shown in Figure 12. The east limb of the Ace Lake – Donaldson Lake anticline shows drag-folding on a large scale and gentle rolls of the rock units. The gentle rolls can be seen on the slope north of Flack Lake and on the hills south of the east end of Foot Bay. Drag-folding was recognized not only on outcrops but also from the trends plotted on the map. The west limb of the Ace Lake – Donaldson Lake anticline is not deformed to the same extent as the east limb, but it passes gradually westerly into a zone where the formations on a broad scale are flat lying but in detail are closely folded (Fig. 12), giving rise to open and complex folds. No overturning was recognized. This flat-lying feature extends west as far as the syncline passing by Hab Lake, and by a point about 2,500 feet west of Eagle Lake. This syncline appears to be a structure comparable in importance to the Ace Lake – Donaldson

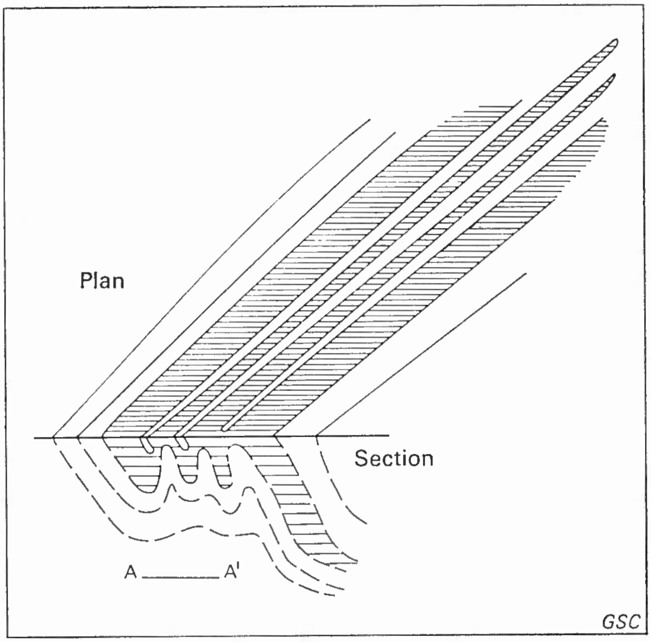


FIGURE 12

Folding characteristics of thinly layered rocks in Beaverlodge area. General attitude of the rock unit may be almost flat lying for miles (A-A′), but in detail component layers are isoclinally folded. These folds are so tight that the layers on each limb are almost parallel, even near the nose of folds.

Lake anticline. These structures appear on structure sections A–B and C–D (*in pocket*). The major syncline seems to plunge south with the anticline, but in the flat-lying area most of the folds plunge gently north, as suggested by lineation on drag-folds.

Area south of St. Louis Fault

In the area south of the St. Louis fault the general trend of the rock units is easterly, but being complexly folded, they trend in many directions. They are believed to be near the trough and on the east limb of the Goldfields synclinorium (Christie, 1953, p. 21), which in this area passes gradually eastward into what appears to be a major anticline. Neither of these structures could be recognized fully in this area as their axes are outside it. The synclinorium trends north, and its axis passes slightly west of or by Umisk Island. The position of the major anticline cannot be defined, but its trend is northeast. All the folds mapped are believed to be subsidiaries of the major structures. They trend between N60°W and N35°E and average due north, in sharp contrast to the average trend of N50°E for the folds north of the St. Louis – ABC fault. In detail the formations are extensively drag-folded, and here, too, disharmonious folding was recognized. Thus, south of Ace Lake, there is a wide belt of interbedded amphibolite and granitized rocks. The amphibolite layers of this belt are intricately and complexly deformed into small, tight drag-folds. This belt of complex folding was recognized also east of Fookes Lake and north of Yahyah Lake. The rocks south of this belt, in this instance mainly the quartzite of the Murmac Bay Formation, are also complexly folded, but in contrast to the tight folds of the northern belt the folds there are gentle, open, and large. Since all the small folds and drag-folds that were mapped in this area trend about parallel with the trend of the Goldfields synclinorium mentioned above, they are believed to be related to it. Also about thirty measurements on the lineation indicate that they trend about parallel with the trend of the fold axes and plunge at about 40 degrees (30–60°) south. This is believed to be the average plunge of all folds south of the St. Louis fault. The wide fanning out of the trend of the lineation is probably due to their positions on the Goldfields synclinorium and indicates that lineation and folds are related. Christie described the same pattern (1953, p. 24). The type of fold reported by Christie (1953, p. 23), characterized by the thinning of the less competent rock near the apex of the fold, was not recognized by the writer. In fact the folds appear to be of the usual type, thickening at the nose. Structure sections E–F and G–H (*in pocket*) summarize the writer's interpretation of the structure of this area.

Area north of Black Bay Fault

In the area between Black Bay and Boom Lake faults, the rocks trend mainly northeasterly, except in a few places where they are, if regarded as a unit, almost flat lying (*see* structure sections X–Y and V–W, *in pocket*). Such areas, however, are in detail folded just as complexly as the rest of the area. In general all folds are believed to be tight and isoclinal, and locally very complex. They trend about N50°E, which is parallel with the main trend of the folds north of the St. Louis – ABC fault. Near Bertha and Boom Lakes, the folds trend N35°E, which is slightly different from the normal trend of N50°E. This is believed to be due to a major S-type drag-fold that forms an anticline on the east side of Bertha Lake. This drag-fold was recognized from the trend of the rock units in the large area of granitized quartzites east and south of Bertha Lake and by the broad bend in the general trend of the Jean Lake amphibolite layer. The plunge of this drag-fold, as suggested by numerous lineation measurements, is 25°NE. This drag-fold suggests that the southeast side of the Boom Lake fault moved southwest, that is, a right-hand lateral displacement.

The folds north of the Boom Lake fault are similar in general to those described above (*see* structure sections M–N and R–S). There, also, they are mainly tight, isoclinal, and complex, with probably some overturned folds locally. In general the rocks trend northeasterly or in the same direction as the trend of the folds. These rocks probably form part of the major structure at Fold Lake to the north, outside the map-area not yet fully defined.

Lineation measurements north and south of the Boom Lake fault and in general immediately north of the Black Bay fault are very erratic. They plunge between 30 and 60 degrees, either north or south. They suggest isoclinal folding with synclines plunging southwest and anticlines plunging northeast.

Martin Formation

The rocks of the Martin Formation are well bedded. Tops of beds were obtained from mudcracks in siltstone, ripple-marks and crossbeds in arkose, and locally from grain gradation and stratification in siltstone and conglomerate. Tops of flows were indicated by pillowed structures, by the location and shape of amygdules in the flows, and by erosional features near the upper surface of flows. All top determinations suggest that the Martin Rocks are nowhere overturned, even in areas where they are now steeply dipping.

Two major and several smaller synclines were recognized in the Martin rocks of the Beaverlodge area. The main syncline, with probably the thickest section, is the Martin Lake syncline. This syncline, which trends northeasterly, is truncated on the northwest by the Black Bay fault and on the northeast by the St. Louis – ABC fault. Near the south end of Martin Lake, it plunges northeasterly at about 35 degrees. A short distance north of the ABC adit on Melville Lake it closes and plunges southerly, suggesting that the Martin Lake syncline may be an elongate basin. There, the fold axis branches and fans out into several minor folds; this may be due to movement along the ABC fault. The location of these minor folds are shown on Figure 11 and on the geological map. The other major syncline is in the Fredette Lake area. It also trends northeasterly, and the approximate position of its axis is a short distance east of the Black Bay fault and is almost completely covered by Fredette Lake. The west limb of this syncline has been truncated by the Black Bay fault; this explains why its axis is so close to the fault. This syncline also plunges gently to the northeast. Smaller synclines were recognized about Ace, Fay, and Meta Uranium shafts. The syncline at Ace shaft appears to plunge to the northeast, whereas those at Fay and Meta Uranium shafts plunge to the southwest. The plunge of the Fay shaft syncline is about 20 degrees, as indicated by lineation in siltstone. The thickness of the rocks deposited in these synclines is given in Table XXX.

Minor features such as mudcracks in siltstone, ripple-marks and crossbeddings in arkose, some stratification in the conglomerates, and amygdules and vugs in the volcanic rocks suggest that the rocks of the Martin Formation were laid down on an almost flat surface; it is unlikely that these features would have formed on very steep slopes. Moreover, readings on crossbeds (Fig. 5), when corrected for tilt, as indicated by the dip of the bedding, gave a common direction of transport, indicating that these crossbeds were tilted at about the same time. Similarly, Smith (1952), from observations on the locations and shapes of the amygdules in the flows and on the positions of the fillings of the amygdules and of the vugs in the flows after correction for tilt, as indicated by the dip of the flows, concluded that the flows were laid down horizontally. This was also indicated by the pillowed structures noted by the writer.

In the Martin Lake area, dips of 60 degrees are not uncommon east and west of the lake. In the Fredette Lake area, dips as high as 85 degrees were measured in the siltstone band above the basal conglomerate east of the lake. These dips and folds, mentioned above in the Martin Formation, suggest that the rocks were folded from their original horizontal position to their present steeply dipping position. On the other hand, the apparent great thicknesses of sediments in the interior of the synclines, the major faults that more or less bound the basins, and the volcanic flows, which presuppose supply channels (or major faults), all suggest possible subsidence. This may be regarded as a main cause of the tilting, but it is most unlikely that subsidence alone can be responsible for the amount of tilt involved. Folding seems to have been necessary.

The problems involved in the development of these basins can be stated as follows:

1. Both the Martin Lake and the Fredette Lake synclines are confined to relatively small areas. The Martin Lake syncline is at least 13,000 feet thick and includes a fair thickness of volcanic and intrusive rocks. The Fredette Lake syncline is at least 4,000 feet thick.

2. Both synclines are closely associated with major normal faults.

3. Both are bordered on the northwest by the Black Bay fault, and where the two meet at the south end of Fredette Lake they are bordered by the St. Louis – ABC fault.

The relatively small size of these basins, the great thicknesses of sediments accumulated in them, and their close association with major faults, all suggest block faulting as the probable reason for their development. Block faulting alone, however, could not readily explain the large synclinal structures recognized in these basins, the steep dips on their limbs, and the circular outline of the formations as seen on the outcrops, particularly the horseshoe outline of the volcanic rocks in the Martin Lake basin. Therefore, in addition to the downward movement on the major faults and the subsidence of the basins, a compressive stress in a northwest–southeast direction seems to be evident. Moreover, the northwesterly bend in minor fold axes in the Martin rocks north of Melville Lake and in the Tazin rocks south of Ace Lake also seems to indicate a strike–slip movement on the St. Louis – ABC fault.

Therefore, the probable conditions of development of these basins can be summarized in these words. At the beginning of the deposition of the Martin Formation, several fault scarps and basins existed, now occupied by Martin and Fredette Lakes. The topography was of the block faulted type. Clastic material was transported to and deposited in these water-filled basins, first at their margins as talus and alluvial fans, and later in the interior of the basins, where it was deposited by rivers as lenticular bodies and beds. As the water in these basins was fairly shallow, the basins filled rapidly. Subsidence permitted accumulation of the great thicknesses of sediments now present. This was brought on by repeated movements on the faults, later partly by the weight of the sediments themselves in the basins and partly by volcanic activity. Subsidence increased the depth of the water in the basins, but as erosion continued, more material was carried into the basins. This cycle was repeated several times until late in the deposition of the sediments when the basins were compressed laterally in a northwest–southeast direction, possibly as a result of a major downward movement on the main faults. The latest deposited sediments are almost flat lying. This downward movement was responsible for the steep dips measured on both major synclines and may have been in part strike–slip. It may also have affected locally the Tazin rocks, as indicated by the fold axes south of the St. Louis fault in the area south of Ace shaft. The major synclines already present became more pronounced as a result of the compression and movement on the faults. Subsequent erosion left the basins as they are now.

The smaller basins or synclines along the eastern margins of the Martin Lake basin are probably minor features that developed on the original surface on which the Martin Formation was deposited. Their shape may have been slightly accentuated by later compressive forces.

Faults

Faults are numerous in the Beaverlodge area. Field mapping has indicated at least two major periods of faulting, one early and one late. Field work has also shown that faulting was a discontinuous and slow process, carried on over a long period of time, and that it was reactivated many times within a relatively short period, giving rise, locally and at least during the second period of faulting, to faults trending in many directions, some younger than others. Thus, the Black Bay fault seems to have followed the approximate position of an old zone of faulting and to have been active several times since the initial break. Similarly, detailed mapping at the Martin Lake mine has revealed that fractures striking N25°E are probably younger than those trending N70°E or NW. This had already been suggested by Smith (1952) in his underground studies at the Martin Lake mine.

Early Faults

The early faults were characterized in the field by wide zones of mylonitic and brecciated rocks, by narrow mylonite zones associated with irregular areas of variously brecciated rocks, and by seemingly unoriented patches or areas of brecciated rocks. They are found only in rocks of the Tazin Group. Brecciation in the Martin Formation, occurring only over narrow zones, is related to the late faults.

The mylonite and brecciated masses in the Tazin rocks constitute true, wide fault zones but are not shown on the map by the ordinary fault symbol, because it was not possible to show such wide zones and irregular areas by this means. Instead, they are shown as a cataclastic phase of the rock type concerned and have been given a subunit number. Also, as most of these zones and areas could not be traced and outlined with great accuracy because of their gradational contacts and locally because of the thick overburden, it was not always possible to measure their main trend or strike. It was also not possible in most cases to determine their dip. Thus, little is known about their general attitudes, although there are a few exceptions. The mylonite zone adjoining the Black Bay fault on the northwest and the few narrow mylonite zones southeast of Eagle shaft, which could be traced through the bush for a few hundred feet, indicate trends similar to those of the late faults.

Unlike the late faults, the mylonite zones and areas of brecciated rocks rarely form depressions in the land surface and therefore do not show as lineaments on air photographs. Consequently, prior to field work there is no way of knowing of their presence except that a lineament indicating a late fault may also mark the trend of a mylonite or brecciated zone caused by an early fault. However, these zones or early faults are cut at many places by late faults. In some instances the apparent trend of the breccia zones and their general shape suggest that they may be a product of the main period of folding and that their locations were controlled by the folds and the nature of the rocks involved. Some of these brecciated zones may therefore not be true faults but rather are fold breccias. They would then be the loci of intense cataclastic effects, in part due to folding. Most of the brecciated zones of this area, however, probably represent major faults. Their significance is discussed below.

Figure 13 shows all the main mylonite and brecciated zones of the areas north and south of the St. Louis fault and the main one north of the Black Bay fault. Most were outlined in the field, except that the mylonite zone northwest of the Black Bay fault was partly outlined by the aid of thin sections. However, it is believed that their shape and the position of their contacts are fairly accurately portrayed. The most important of the known late faults are also shown and can be mapped much more precisely.

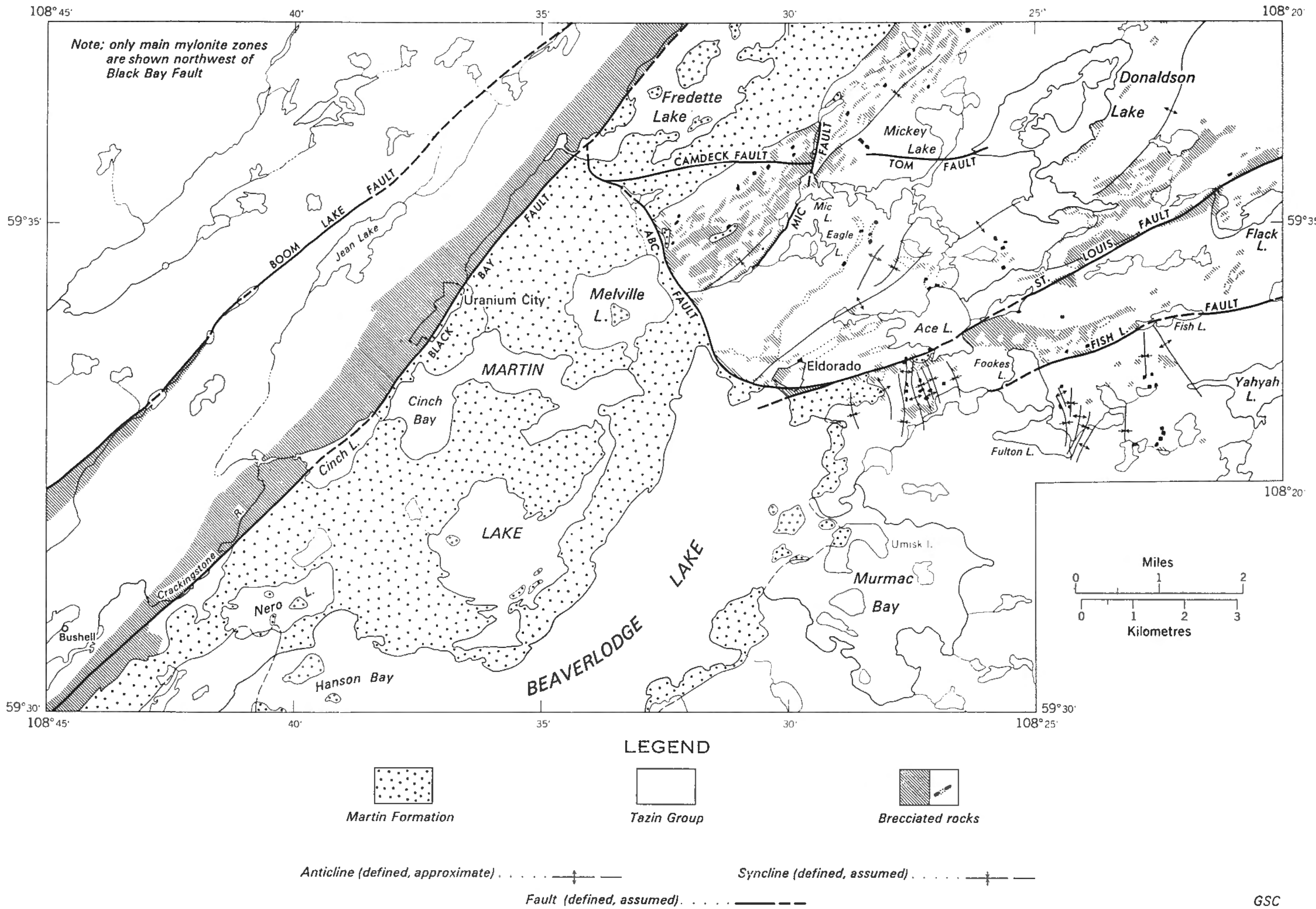


FIGURE 13. Areas of brecciated rocks observed east of the Martin Formation. Main faults and some fold axes are shown. Note that the faults seem to be later than the brecciated rocks, but the fold axes suggest that certain rock types were more readily brecciated than others.

From a study of Figure 13 it is apparent that no relationship exists between the brecciated and mylonite zones as mapped and some of the late faults. Moreover, the fact that the mylonitized rocks along the St. Louis and Black Bay faults have been rebrecciated along these faults, indicates that the mylonites are earlier than the faults, a conclusion that was substantiated by thin section studies. This at least suggests that the old structures were the loci of late movement and that they may be parallel with the late faults, though this is not necessarily true for all of them.

For example, there are many large bodies of brecciated and mylonitized rocks in the immediate vicinity of the St. Louis fault, and the writer believes that they may be due to the St. Louis fault as mapped, except that the trend of some of these brecciated bodies, the variations in their widths along the St. Louis fault, and their distribution on each side of it, all indicate that they were offset by the St. Louis fault and are earlier features. It is difficult to explain the following otherwise: 1, the position of the brecciated areas north and south of the St. Louis fault, west and north of Flack Lake; 2, the wide northwesterly trending brecciated zone extending from Fish Lake to Ace Lake, south of the St. Louis fault; 3, some of the brecciated rocks occurring north of and adjoining the St. Louis fault between Ace Lake and Beaverlodge Lake; and 4, the narrow mylonite and brecciated zones, mapped very carefully underground by the mine geologists at Eldorado, which trend at a sharp angle to the strike of the fault and are apparently displaced by it (pers. com. from mine geologists).

The wide zone of brecciated rocks south of the Tazin–Martin unconformity, east of Fredette Lake, trends northeasterly. It includes a few narrow northeasterly trending mylonite zones that are probably faults, but the wide zone itself is not associated with any major known late fault like the St. Louis. The zone is cut off on the south by the ABC fault. About Mic Lake, it is crossed by the Camdeck fault, which strikes easterly or almost at right angles to the trend of the zone, and it, too, seems to be offset by the probable Mic fault. This suggests two periods of faulting: an early one, represented by the wide breccia zone, and a late one, represented by the late faults that cut it. In stratigraphic position it is believed that this zone corresponds to the wide zone of brecciation that extends from Fish Lake to Ace Lake, south of the St. Louis fault. If so, this would suggest that rock type and folding are probably responsible for the position of this breccia zone and that it is possibly part of a fold structure, although it may be a folded fault. If it is part of a fold structure, it is difficult to explain the presence of fractured granitized rocks, since granitization is assumed to be synkinematic, or a late phase of the folding, which must have preceded mylonitization. The breccia zone then is probably the result of some type of deformation active later than, or in the late stage of, folding and is closely related to the nature and the position of the rocks on the folds.

Many of the small breccia patches in the area north and south of the St. Louis fault do not seem to be associated with any known faults, and their distribution in relation to some of the folds seems to suggest that they may have developed as a late phase of folding (Fig. 13). On the other hand, the wide zone of brecciated, carbonitized, and pyritized rocks south of Foot Bay and Schmoo Lake is another zone apparently not associated with any known late fault, but it nevertheless represents a zone of faulting, presumably early.

In summary, in the areas north and south of the St. Louis fault, the mylonite and brecciated zones may be the results of three main causes:

1. Early faulting, producing wide zones of mylonitized and brecciated rocks; for example, the zone southeast of the Tazin–Martin unconformity, which is so broad that it probably represents a deformation involving crustal blocks.

2. Deformations that took place at the nose and on the flanks of folds and within selected rock types. In part, the rock that resulted may be regarded as fold breccia. This deformation was also early, probably during or shortly after granitization.

3. Effects of movement along the late faults. Breccia zones produced by this means are nowhere so extensive nor so common as those produced by the other two causes. They are localized in the immediate area of the fault plane and are commonly superimposed on other cataclastic features, for example, the rebrecciation of mylonitized rocks near the St. Louis fault.

The mylonite zone adjoining the Black Bay fault to the northwest is in places almost a mile wide, too wide to represent a single fault despite its continuity. Generally a mylonite zone due to a single fault varies greatly in intensity along the strike. The width and uniformity of this zone would indicate that it is due to several faults or perhaps to a major stress; in any case it is due to a large scale deformation probably involving the movement of large blocks of the earth's crust. This deformation may be a very late phase of the deformation responsible for the folding and may have taken effect subsequent to granitization, since both granite and granitized rocks are greatly mylonitized. Other features that indicate that the Black Bay fault as mapped is not responsible for this mylonite and brecciated zone are as follows:

1. Southwest of Cinch Lake the main trend of the mylonite zone forms an angle of 10 degrees to the strike of the Black Bay fault;

2. The rocks on both sides of the Black Bay fault, including the mylonite and to a lesser extent the rocks of the Martin Formation, have been brecciated and coarsely fractured;

3. The Black Bay fault is too distinct a feature to be directly the cause of so wide a zone of mylonite; rather, in this belt, being a natural zone of weakness, the fault formed along and within the belt; and

4. The mylonite zone itself is cut by numerous late faults trending westerly and northwesterly, and no apparent genetic relationship seems to exist between the two.

Other mylonite zones (most of which were not mapped individually) were recognized between Black Bay and Boom Lake faults. They probably are fault zones since they are narrow, short, and local. They are generally difficult to trace because most of them are partly hidden or are covered with overburden.

As the zone of mylonitic rocks along the Boom Lake fault is locally fairly intense and generally surprisingly continuous, and as the wide zone of shearing described from the underground work at Rix mine (*see* p. 239) is probably related to it and is part of it, it was probably formed in the same way as the one against the Black Bay fault.

Late Faults

The late faults in contrast to the early ones are represented by fairly clean-cut fractures. All the faults shown on the map are of this type. In the field they generally appear as long narrow depressions or small gullies that show up as pronounced lineaments on air photographs. The depressions and gullies vary in length and width with the size of the faults. Some, like the one associated with the Black Bay fault, can be seen for many miles; others, like those crossing the trend of the formations, can be traced for only a few hundred feet. Still others are represented by discontinuous lineaments that may be decidedly pronounced locally but elsewhere along the strike are almost unnoticeable on air photographs. Many of the faults trending across the formations north of the Black Bay fault show the last two features very well. In a few places, particularly in the Martin Formation, the depression does not always correspond with the trace of the fracture itself but is a few feet on the side of the rock most easily eroded away due to differential weathering of the rocks on each side of the fault.

Most of the late faults cannot be seen at the surface because they are covered with overburden, but where they are not or where they are exposed underground they are clean-cut fractures, generally with gouge and some hydrothermal alteration products and with some brecciation for a few inches on either side of the fracture. Most of these faults were mapped fairly accurately since their positions are indicated by offset of rock types across the faults, by variations and contortions in the strike of the rocks near them, by narrow zones of finely brecciated rock on each side of the fracture, and by some hydrothermal alteration that resulted particularly in the deep red coloration and silicification of the brecciated walls. In the Martin rocks, offsets along volcanic flows, siltstone bands, and conglomerate lenses were used to locate these faults. Fault traces are straight or sinuous. The sinuous shape is not due to folding but to other causes such as the heterogeneous nature and differences in competency of the rocks traversed.

The strikes of the late faults in the Tazin and Martin rocks have been plotted on Rose diagrams (Fig. 14). They are strikingly similar and suggest that like and probably regional forces were responsible for their formation. The main fault directions can be determined more readily on the diagram for the faults in the Martin Formation, possibly because the number of measurements that fall into one sector does not completely dominate other preferred directions as it does in the Tazin rocks where faults with a northwesterly trend greatly predominate over faults trending otherwise. The main fault directions recognized in the Tazin rocks, in their order of abundance, are: N50°W, N75°W, N85°E, N5°E and northeast or between N40°E and N65°E. Rare faults strike about north. In the Martin Lake syncline, the faults seem to radiate from a centre in Martin Lake and to be normal to the

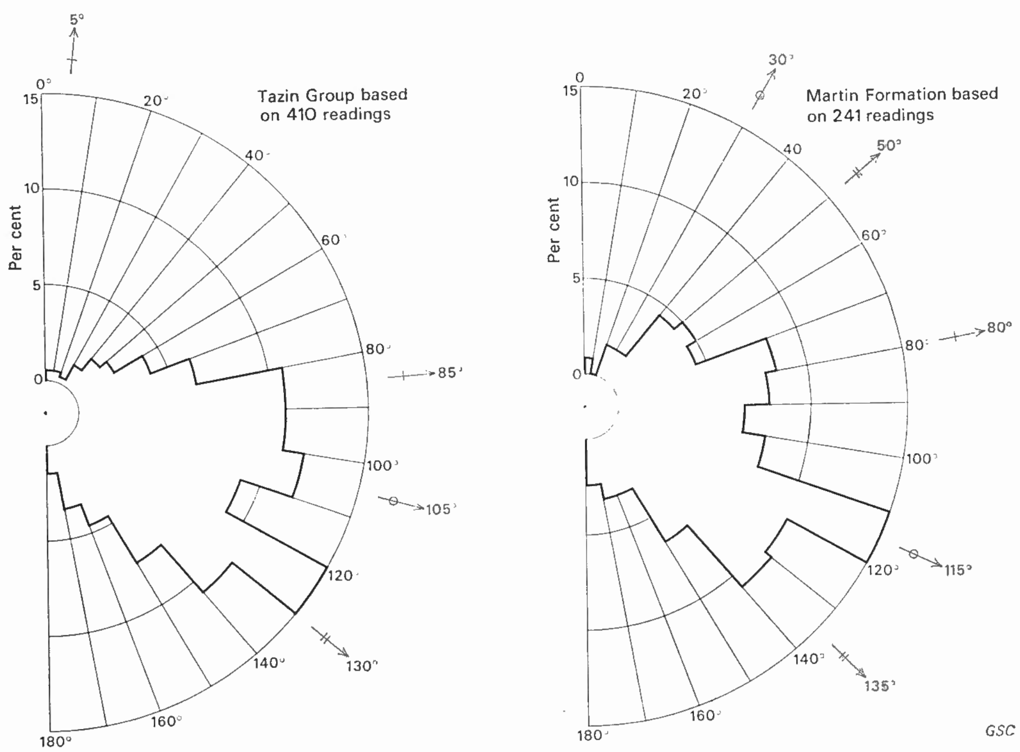


FIGURE 14. Strike of late faults, Beaverlodge area. Arrows and figures at their extremities indicate directions considered by the writer to be the directions of the main faults in the area. Three conjugate sets are shown, which also correspond to the directions of the principal joints.

horseshoe-like pattern determined by the volcanic rocks. Nevertheless, the same main directional groups were recognized as in the Tazin rocks (Fig. 15). These directions in the order of abundance are N45°W, N65°W, N80°E, N50°E, and N30°E.

In general, as can be seen in Table XLII, faults and joints have similar strikes, and the two features are probably related. Dips vary between 50 degrees and vertical and are generally steep. A few minor faults have fairly flat dips, that is, dips from 15 to 35 degrees. The northeast-trending faults are about parallel with the trends of the rocks, whereas the other faults are normal or are at a pronounced angle to them.

The late faults were developed late in the tectonic history of the Beaverlodge area. Locally they cut the late gabbro dykes, but in general they are believed to have been emplaced along faults. It therefore seems probable that the offsets observed were due to late movements along the faults.

Several of the late faults are major features. They have been studied in detail and are discussed at some length here, but the direction and the amount of movement along them are not yet fully known. Examples are the St. Louis fault, the ABC fault, the Black Bay fault, the Boom Lake fault, and the Fish Lake fault, descriptions of which follow.

Other faults such as the Camdeck, the Tom, the Crackingstone, the Pinky, the Bellegarde, the Beta Gamma, and a few other probable faults are also described, but as a group, not individually.

St. Louis Fault

The St. Louis fault was traced in the map-area from Beaverlodge Lake to Raggs Lake, a distance of 5 miles. Blake (1955, p. 39) suggested that its northeast extension passes through Prince Lake. This assumes a sharp easterly bend in its strike before reaching the northeast end of Prince Lake, beyond which it apparently resumes its original strike to pass by Alces and Hamilton Lakes. Its extension to the west is still unknown, although there are indications that it may fan out westerly into several branches, one of them being the ABC fault; however, this would involve an almost 90 degree bend in strike. That this fault is the western extension of the St. Louis fault was suggested by the author as early as 1955, a suggestion provisionally accepted by several other geologists, particularly Chamberlain (1958). However, even if the ABC fault is an extension, it is now regarded as one of the main branches only, which, together, with several others, combine to form the westward extention of the St. Louis fault. This is suggested because many other faults that could be the westward extension of the St. Louis fault have been recognized. Some of these, near the Martin Lake mine and north of it, may be branches of the fan effect mentioned above; another may lie in the gully that crosses the strip of land separating the north ends of Beaverlodge and Martin Lakes, southeast of Melville Lake, may extend easterly from there under the waters of Martin Lake to Cinch Lake, and possibly may eventually pass into the Black Bay fault in much the same manner as the ABC fault. The existence of this branch fault has not yet been proved, and it is not shown on the map, but a few features suggest it. Thus, the main synclinal axis of the Martin Lake basin seems to be offset across the north arm of Martin Lake; drilling by Eldorado company (pers. com.) in Beaverlodge Lake south of the point east of Padget Bay and on the peninsula south of the Eldorado townsite west of the Fay shaft has indicated the presence of a second fault additional to the ABC fault (this fault is shown on the map); drilling on the south shore of the north arm of Martin Lake has encountered much alteration, several vugs or cavities, and much carbonate; a few dips on arkose blocks (assumed to be in place or almost so) near Beaverlodge Lake are reversed and plunge steeply east instead of west; and, finally, there is a sharp decrease in the amount of volcanic rock on the north side of the above-mentioned gully. There is no evidence that other major southwesterly trending faults that could be branches of the St. Louis fault lie under the waters of Beaverlodge Lake. Neither field work on the north and west shores of Beaverlodge Lake by the writer nor electrical geophysical surveys carried on over the waters of the lake in the winter by private companies (B. Macdonald, pers. com.) have suggested any such possibility, at least not near the western shore of the lake. The western extension of the St. Louis fault is then still a complex problem not entirely clarified.

The St. Louis fault itself, as mapped in the field, seems to be a composite feature. There are indications that it comprises two sets of *en échelon* faults, so closely spaced that they are almost one unit, one main set trending between N60°E and N65°E and the other about N55°E. These two sets are responsible for some of the bends along the strike of the St. Louis fault. Three bends were recognized from Ace Lake to Flack Lake, one north of Verna shaft, another west of Collier Lake, and a third north of the west end of Flack Lake. These bends are at irregular intervals and may be due to variations in the types of rocks cut by the fault. To the west, the fault turns gradually into the ABC fault and probably also into its many other branches. In general the fault is parallel with the trend of the formations except near Flack Lake and toward Beaverlodge Lake where it cuts them. Dips on the fault are uniformly between 50 and 55 degrees south, but where the dip passes into the ABC fault, as determined by underground drilling, it is as low as 40 degrees.

At surface the fault is represented by a strong lineament and a relatively straight depression, but in outcrops it is not prominent. Locally it is marked by some hydrothermal alteration products and by fine to coarse breccia for not more than a few inches on one or both sides of the fault plane. Thus, some of the rocks near Ace Lake are slightly silicified and strongly hematitized, but not so much as along the ABC fault east of Padget Bay. East of Verna Lake and almost as far as Raggs Lake, much of the rock is carbonatized. Underground, the fault is usually characterized by up to 6 inches of gouge, and by a small amount of sheeting up to 2 feet wide, and locally by some coarse brecciation or fracturing over a width of rock up to several feet thick, but apparently by no true mylonite. Much chloritization and silicification are usually associated with the brecciation and sheeting.

The movement on the St. Louis fault is not known for sure, but attempts have been made to determine its direction and amount. The direction of movement is suggested by matching certain geological features on opposite sides of the fault, but this has led to conflicting conclusions. Christie (1949, p. 14) suggested a right-lateral movement of 1,100 feet, based on offset of an amphibolite contact across the fault. This is not believed to be valid, since the mode of occurrence of this amphibolite is in lenses or masses that finger out easterly, and what appears to be the offset end of a mass on the north side of the fault is believed to be, in fact, the end of an independent finger. The feature used by the writer is the boundary between quartzite successions with different degrees of granitization. The positioning of this boundary on each side of the fault is somewhat subjective, and indeed the beds on either side of the fault may not be dislocated parts of the same series at all; however the two successions match well, and the writer feels that the hypothesis is possibly correct. If this is true, it indicates a left-hand displacement of 1,200 feet. Smith (1952, p. 28) thought that the separation of the Martin (his Athabasca) rocks west of Ace Lake also suggested an apparent left-lateral movement on the St. Louis fault. A similar movement is suggested by the general trend and curvature (concave westerly) of the minor fold axes not only in the Tazin rocks south of the St. Louis fault in the vicinity of Ace Lake but also in the Martin Formation north of Melville Lake. However, these folds may be much later features.

The writer, therefore, is not certain what the main direction of movement on the St. Louis fault was, nor what the degree of movement was, but in order to explain the curvature on the minor fold axes south of ABC and St. Louis faults, it seems necessary for the hanging-wall (south side) to have moved in relation to the footwall (north side) to the east and either up or down. If so, the movement on this fault was not only normal but also lateral, and it probably was to the left. The last movement on this fault was, however, definitely normal, and this is what is seen now in the field as the Martin rocks on the south side are down-faulted in relation to the Tazin rocks on the north side.

Chamberlain (1958) made a special study of the St. Louis fault and tried to determine the amount of movement on it. By assuming, a) that the St. Louis and the ABC faults are a single fault; b) that all movement along the St. Louis – ABC fault is later than the deposition of the Martin Formation; c) that the direction of movement on this fault is rigidly controlled by the sharp bend in the strike of the St. Louis fault where it passes into the ABC fault; and d) that the location of the traces of the Tazin–Martin unconformity plane are as on Christie's map and that their dips are 40 degrees east of Beaverlodge Lake and 70 degrees east of Fredette Lake, he was able to calculate a net slip component of about 3.9 miles for the St. Louis fault, comprising a dip slip component of 3 miles with a right-hand strike slip component of 2.1 miles for the St. Louis fault and a left-hand component along the ABC fault. The apparent left-hand displacement along the ABC fault is in agreement with the arguments presented above but not so the right-hand component on the St. Louis fault, which interpretation does, however, agree with Christie's.

As the St. Louis fault fans out into several large branches westerly, a calculation of the amount of movement that uses only one of these branches and ignores completely all others will give results that are not likely to be too significant. Furthermore, the nature of the basal conglomerate, its structure, and its position near and against such major faults as the St. Louis suggest that this fault began to form before the deposition of the Martin Formation and is not entirely a late feature, as assumed by Chamberlain. Christie (1953, p. 54) and Joubin (1955) assumed an early age for it because they thought that this fault was partly responsible for the deposition of the Martin rocks. Furthermore, field work has left in doubt the actual dip of the unconformity east of Fredette Lake. In fact, there are indications that this unconformity was almost flat for a wide distance east of its present position, to at least as far as a few hundred feet east of Eagle shaft. The figure of 70 degrees used by Chamberlain is therefore questioned not only on this ground but also on the evidence of actual dip readings on the unconformity plane measured during the present field work and shown on the geological map.

ABC Fault

The ABC fault is believed to extend from where the St. Louis fault bends into it east of Padget Bay on Beaverlodge Lake to the south end of Fredette Lake where it appears to swing north into the Black Bay fault, a distance of about 3½ miles.

In the field, the fault is marked for almost its entire length by a pronounced sinuous depression, with Martin rocks on the southwest side and Tazin rocks on the northeast, except at the south end of Fredette Lake where Martin rocks are present on both sides. The fault is also marked, particularly east of Padget Bay, by a characteristic brecciation of the Martin rocks, a strong silicification of the arkose near the fault, and an intense red hematitization of the rocks on both sides of the fault. Some of the rocks are purple as a result of this hematitic alteration. Up to 14 inches of gouge, as well as some shearing in places, was seen along this fault in the underground workings of the ABC adit.

The fault strikes across the rock units. It strikes about N30°W between the north end of Padget Bay and approximately where the Tazin–Martin unconformity comes to the fault, and about N60°W south of this to the St. Louis fault and north to the Black Bay fault. The dip is 40 to 55 degrees southwest.

As mentioned above, the ABC fault is now regarded as a branch of the St. Louis fault, although, as the alteration along it east of Padget Bay is similar to the type of alteration found along the St. Louis fault near Ace Lake, it was thought for a while to be the western extension of the St. Louis fault.

The fact that it has Martin rocks on both sides south of Fredette Lake is an indication that it is later than the Martin rocks. This, however, like the last movement on the St. Louis fault, is regarded as a result of the last movement on the fault, which is believed to have been normal. As the normal movement has taken place on both of them at about the same time, one may assume that the two faults are related.

As suggested previously, the displacement on the ABC fault appears to be left-handed, but the amount of displacement is unknown.

Black Bay Fault

The Black Bay fault was traced for a distance of 11 miles in the west half of the area. Its extension outside the map-area to the southwest is along the east shore of Black Bay on Lake Athabasca (Fraser, 1960) and to the northeast as far as Anne Lake (Christie, 1953, p. 66). It may be assumed therefore that the Black Bay fault is at least 30 miles long.

In general the fault is a prominent feature. It is marked by the straight east shore of Black Bay southwest of the map-area, by a deep depression between Bushell and Fredette Lakes and beyond Fredette Lake, and by the straight west shore of Fredette Lake near the north boundary of the map-area.

Its strike is in general about parallel with the main trend of the rock units, except in the area between Uranium City and Cinch Lake, where the fault is seen to make an angle of about 20 degrees with the trend of the rock units. Its strike is about N45°E in the area southwest of Cinch Lake, but it is N40°E from Cinch Lake to the northern boundary of the map-area. There also appears to be slight bends in the strike of the fault: one where the fault is under the waters of Cinch Lake, approximately where the Crackingstone River fault meets the Black Bay fault; and another at the south end of Fredette Lake, about where the ABC fault meets the Black Bay fault. There are possibilities that some other faults reach the Black Bay fault about where the ABC fault swings into it, but these westerly trending faults could not be traced as far as the Black Bay fault. The dip of the Black Bay fault, as indicated by diamond drilling, is fairly constant at about 60°SE.

A wide zone of mylonite and ultramylonite is closely associated with the fault as mapped. It is almost a mile wide northwest of Uranium City and is shown on the geological map. The rocks in this zone have already been described fully, and the significance of the zone has been discussed (p. 174). In general, the zone appears to be too wide and too continuous to result from a single fault. It is crossed in many places by clean-cut fractures of the late fault types, and right against the Black Bay fault much of the mylonite is itself brecciated or broadly fractured. Outcrops near the fault south of Cinch Lake also show some brecciation of the mylonite, and in the area between Uranium City and Cinch Lake some outcrops, only a few feet from the fault plane, are a true breccia, being made up of mylonite fragments in a matrix of fine-grained crushed material. West of Fredette Lake most of the rocks adjoining the fault are coarsely brecciated, and there, again, all fragments are mylonitic and have practically no matrix but are cemented with chlorite- and carbonate-filled fractures. All these features suggest that the fault as mapped is a late feature, but one that is believed to follow along an old structure. The fault mapped appears to be due to renewed movement along the old structure, now marked by the wide mylonite zone.

Neither the direction nor the amount of movement along the Black Bay fault could be determined. Many gabbro and basalt dykes are cut by the fault but cross the mylonite zone. If the extensions of these dykes could be recognized on the southeast side of the fault, the amount of displacement and its direction on the Black Bay fault could be computed. A few granite masses seem to be displaced by the Black Bay fault, but they cannot be used to measure displacement because their true boundaries southeast of the fault are not known. However, the last movement on the fault was normal, the Martin rocks having been down-faulted to the southeast with respect to the Tazin rocks to the north. The amount of this normal movement is at least as much as the thickness of the Martin rocks adjacent to the fault. However, the nature of the Martin rocks in the vicinity of the Black Bay fault, particularly the basal conglomerate in the Nero Lake area, suggests that this fault was active at the beginning of the deposition of the Martin rocks, so that the normal movement suggested above is the last-known movement on the Black Bay fault.

Boom Lake Fault

The Boom Lake fault was traced for 8 miles in the west half of the map-area, passing through Chance, Emu, and Boom Lakes. South of Chance Lake it may divide into several branches that extend to Lake Athabasca; to the northeast it probably extends for some distance past Pluton Lake, but its position has not been located there.

The fault is represented by a marked depression extending from southwest of Boom Lake to the western boundary of the map-area. The writer believes that its position has been fairly accurately established from Boom Lake north to the road going to Beta Gamma shaft. North of this road its trace is indicated by local truncation of rock units, but its position is difficult to pinpoint because there are no physical features to help in locating it. Probably it passes along the west shore of Pluton Lake.

The strike of Boom Lake fault is between N45°E and N55°E southwest of Chance Lake. From Chance Lake to Boom Lake, its trend is N40°E; from Boom Lake to the northern boundary of the map-area it is again about N50°E. The fault strikes about parallel with the rock units on the north side of it but makes an angle of about 20 degrees with the rock units south of the fault, except northwest of Jean Lake and toward Pluton Lake, where it is about parallel with the rock units on both sides. At Rix Athabasca mine (Smitty), where it was intercepted underground, its dip is between 30 and 65 degrees southeast. It is represented there by a wide zone of fracturing and shearing. At surface, it is commonly associated with much brecciated rock and mylonite. The relationship of these mylonitized and brecciated rocks to the fault is believed to be the same as for similar rocks and the St. Louis and Black Bay faults, a relationship which has already been described.

The direction and the amount of movement on this fault are not known, and indications that could be informative are rare and not too reliable. Thus, the pattern of the rock units in the area south of the Boom Lake fault and north of the Black Bay fault seems to indicate that the block north of the Boom Lake fault moved northeasterly relative to the mass south of it. However, a few gabbro or basalt dykes in the area extending from Pluton Lake to as far southwest as Jean Lake were traced across the Boom Lake fault without any significant displacement. This then suggests very little movement along the fault north of Jean Lake. On the other hand, in the area between Boom and Chance Lakes, the displacement may have been greater, as a right-hand lateral displacement of about 5,000 feet seems to be indicated by zones of quartzitic, amphibolitic, and dolomitic rocks on each side of the fault. Perhaps the amount of movement along this fault varies from place to place.

On the 4-mile compilation geophysical map (GSC Aeromagnetic Series, Map 70206, 1964), the Boom Lake fault shows up as a strong lineament, and the rocks northwest of the Boom Lake fault seem to be much more magnetic than those south of it. This may be due to the strong retrograde metamorphism affecting the rocks southeast of the fault.

Fish Lake Fault

This fault was traced from Billo Lake to the north end of Fookes Lake. It is indicated by the truncation of rock units and by differences in the complexity of folding between the rocks north and south of the fault. Its extension to the west may be marked by the gully between the north end of Fookes Lake and Ace Lake. It is also probable that its westward extension is represented by another branch passing under the waters of Tailings Lake to extend to the north end of Murmac Bay near Umisk Island. It is also possible that the junction of the north branch of this fault with the St. Louis is marked by the wide zone of brecciation, trending northwest from Fish Lake to the St. Louis fault at Ace Lake.

Other Faults

All the other faults shown on the map were indicated by the truncation of formations or offsetting of rock types. Many others could probably have been shown if all lineaments visible on air photographs had been studied on the ground. Moreover, of those shown on the map very few were actually seen, because they are generally covered with overburden. Those that were seen, either in outcrops, as in the case of Tom, Pinky, and Camdeck faults; or underground, as in the Crackingstone River fault, seem to have a steep dip (between 70 and 90 degrees) to the south and to be clean-cut fractures. The extension of a few of these faults was inferred locally, particularly where they trend toward a known fault.

There are also zones where faults may exist but where no clean-cut fault planes could be seen. Such zones are generally characterized by much brecciation, and partly by carbonitization, hematitization, and pyritization in varying degrees. They are probably related to the mylonite zones described earlier. Several of these zones were recognized in the area south of Schmoo Lake and north of St. Louis fault. One zone may be found along the east shore of Donaldson Lake. Others are believed to exist in the area north of the Boom Lake fault, most of them trending parallel with the formations. All these are probably the loci of early faults.

Joints

Joints were recognized everywhere and in all types of rocks in the Beaverlodge area. Locally they are a prominent feature of the rocks, and there they are closely spaced and are abundant and remarkably continuous. Most of the joints are believed to be of the tension type, since they are open clear-cut fractures. They appear to be best developed in granitized or intensely altered rocks.

More than 8,000 readings of joint directions were made on the rocks of the Beaverlodge area. Small outcrop areas were selected at fairly regular intervals all through the entire map-area, and on these all fractures were measured. The map-area was then divided into four major units, and the joint readings from each of these were plotted together on a Rose diagram (Fig. 15). A composite Rose diagram for the entire map-area is also included in Figure 15. The readings on joints in the Martin rocks were kept separated from those in the Tazin rocks, and a Rose diagram made from them is also shown on Figure 15.

In general, in the Tazin rocks a prominent set of joints runs parallel with the foliation or stratification of the rocks and another set is at right angles to this direction, or about northwest. Other important directions are about east, slightly south of east, and northeast.

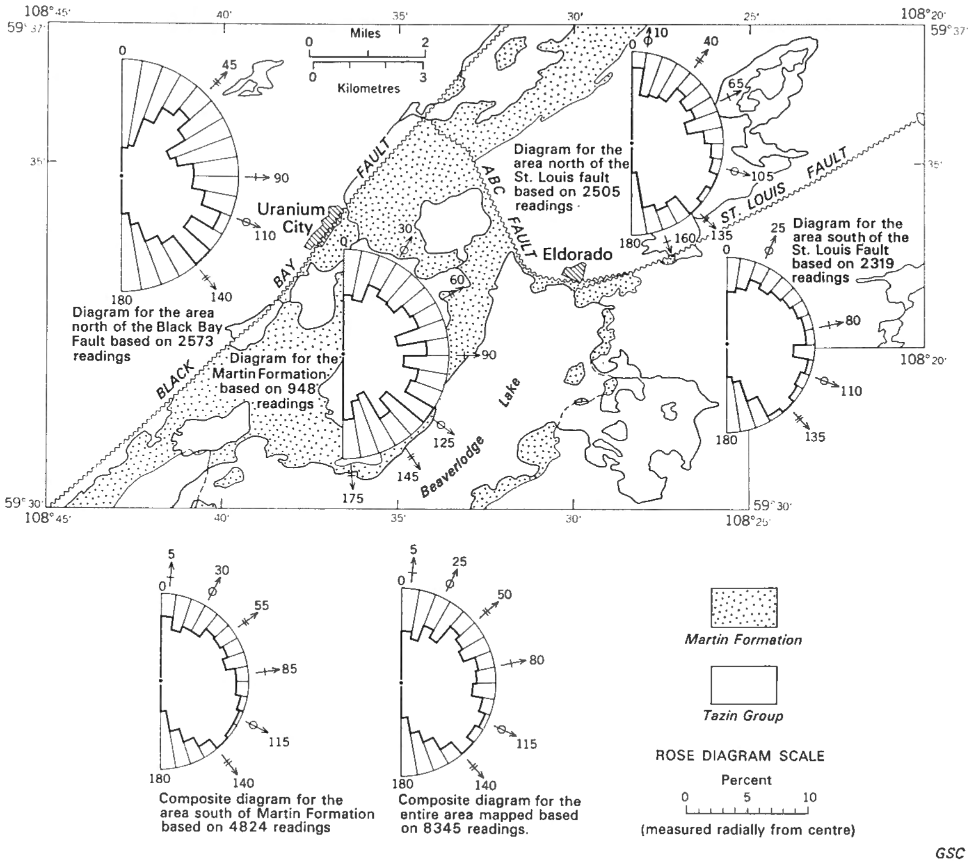


FIGURE 15. Rose diagrams illustrating directions of joints, Beaverlodge area. Arrows and figures at their extremities indicate the directions considered by the writer to be the directions of the main joints. Three conjugate sets are shown, which also correspond to the directions of the late faults.

Another but weaker direction is about due north. Groups of joints with other directions may be present, but as they are probably local features, not regional, they are difficult to determine.

In the Martin Formation the joints appear to be better developed and to be more common in the arkose than in the conglomerate and volcanic rocks. Thus, in the arkose in the central part of the Martin Lake basin, three main directions of joints were recognized, one parallel with the strike and dip of the bedding plane; another parallel with the strike of the beds but dipping almost at right angles; the third perpendicular to the strike of the bedding plane and dipping in either direction, mainly steeply. These three directions give rise to angular rhombic blocks in the outcrop. In the volcanic flows and gabbroic sills, the joints may be columnar, but in general their directions correspond to those in the arkose.

The main directions of joints, as shown by the Rose diagrams on Figure 15, are summarized in Table XLII. From a study of this Table, it is apparent that the main directions of joints are about the same from one end of the area to the other and that they are also the same in both the Tazin rocks and the overlying Martin Formation. This suggests that they were probably formed by the same cause and at about the same time, and that they are regional

TABLE XLII *Main directions of joints and faults in Beaverlodge area as suggested by Rose diagrams (Figs. 14 and 15)*

Joint directions (from Fig. 15)						Fault directions (from Fig. 14)		Fracture directions at Verna (Chamberlain, 1958)		
		North of St. Louis fault	South of St. Louis fault			In		In		
Entire area	North and south of St. Louis fault			North of Black Bay fault	Martin Formation	Tazin rocks	Martin rocks	Altered tuffaceous rock (ore rock*)	Tuffaceous rock (argillite)	Quartzite (silica)
5	5	160	?	?	175	5	?	150	160	0
80	85	65	80	90	90	85	80	80	70	90
25	30	10	25	?	30	?	30			
115	115	105	110	110	125	105	115		Others	
50	55	40	?	45	60	?	50			
140	140	135	135	140	145	130	135			

*Names used by Chamberlain.

features rather than local effects only. Six main directions are indicated; these can be grouped into three sets. Each set is composed of two directions, about at right angles to each other. The two directions are not always equally strong, and one may even be missing or be so weak as not to show on the diagram. Thus, in the rocks of the Martin Formation, joints striking N30°E and N55°W are always common. Joints striking N60°E and N35°W are almost as common but may be missing in a few localities. Finally, joints striking east and N5°W have rarely been observed in the Fredette Lake syncline but occur almost everywhere in the Martin Lake basin. The main directions of joints in the area north of the St. Louis fault are slightly different from those in the other areas of Tazin rocks in the Beaverlodge area. It is possible that this effect results from one of the movements on the St. Louis – ABC fault, and that the movement responsible was in part rotational. A reverse direction of rotation may be suggested by those in the Martin Formation, but this is uncertain.

For comparative purposes the main fault directions of the Beaverlodge area, as suggested by the Rose diagrams of Figure 14, are included in Table XLII. It is evident from these fault directions that, even if those of the major faults such as the St. Louis are given little weight, they correspond to those of the joints and that a close relationship must exist between the deformations that produced the two. It is interesting to note here that the late gabbro dykes (Fig. 6) follow the east and the slightly south of east-trending joints, and that these joints may therefore be more distinctly tension fractures than the others.

Finally, the results of Chamberlain's (1958) measurements on 1,600 fractures in the Verna mine are incorporated in Table XLII to show that detailed studies within a limited area give approximately the same main joint directions. Chamberlain observed that about 80 per cent of the fractures measured were less than 20 feet long and about 95 per cent of them were less than 40 feet long. None of the joints less than 20 feet long had any gouge, and gouge was rare even in the joints under 40 feet long. The fractures were also more abundant in the altered tuffaceous rocks than in the other rocks.

Dips were measured in the field as often as possible. Most of them were over 70 degrees in either direction, and many were vertical, but about 15 per cent had dips lower than 70 degrees. Chamberlain (1958) reports a vertical dip for the fractures trending 150, 160 and 0 degrees and a dip varying between horizontal and vertical, but mainly near 40 degrees south, for the fractures striking at about 80 degrees.

All the joints of the Beaverlodge area were probably formed at about the same time, but as those cutting across the trend of the formations offset joints in other directions locally, they are possibly slightly younger. It was not possible to get other or better age relationships between the various groups of joints.

Chamberlain (1958) regarded the fractures trending northwest and having vertical dips as tension fractures, whereas the ones striking about parallel with the St. Louis fault or roughly east he regarded as due to shearing. These, he assumed, were subsequently dilated by the normal movement on the St. Louis fault. This relation does not correspond to the one indicated above (*see* 20 lines above) in relation to the late gabbro dykes.

Tectonic History

In order to coordinate the various structural elements described in this chapter, to place them in their proper position in the long and complex geological history of the Beaverlodge area, and to correlate them with each other and with the metamorphic events and the alteration processes described in Chapter III, I have given below a summary of the succession of events and have shown them in diagram form in Figure 16. The events vary in importance and duration, and partly in vertical extent; some overlap.

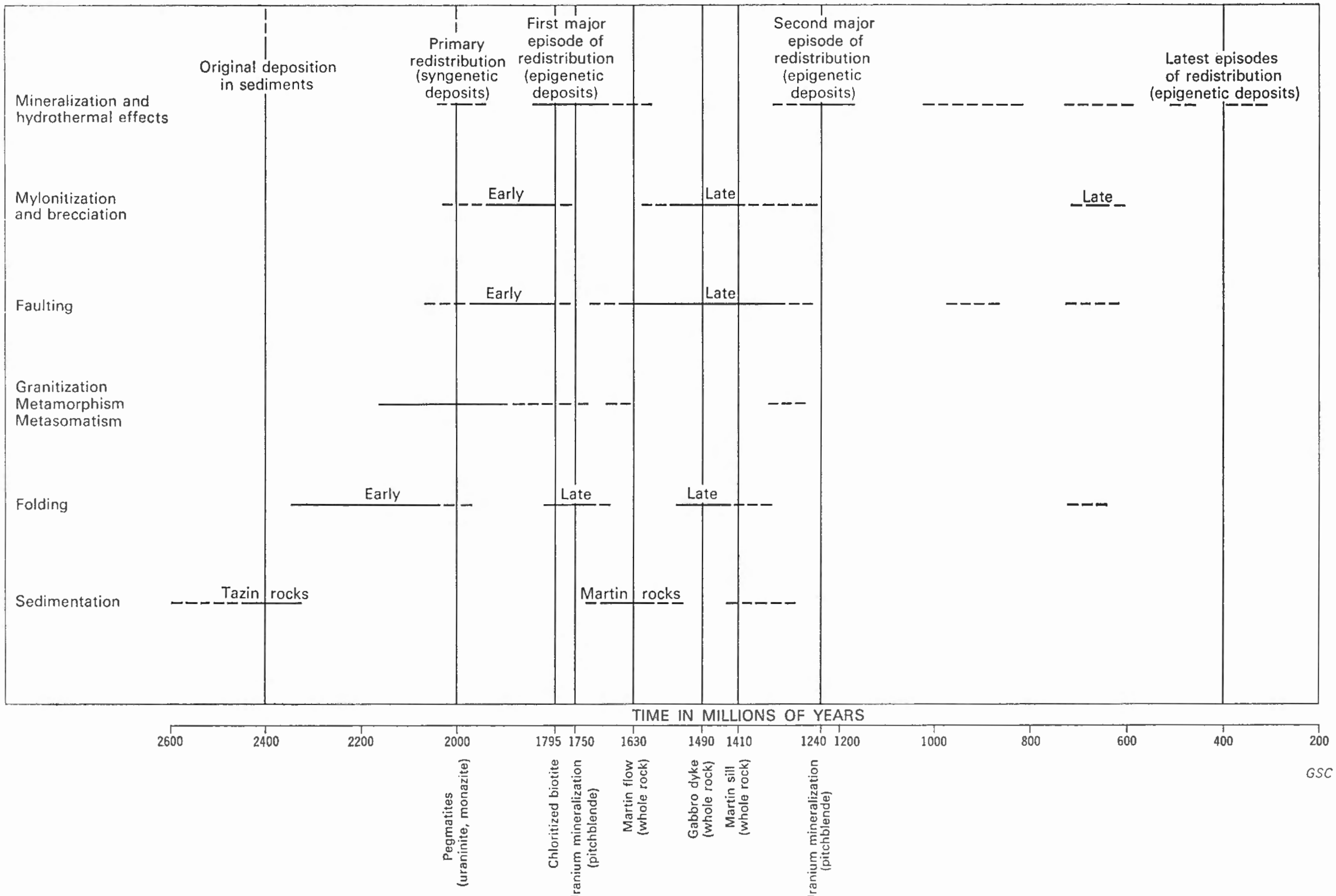


FIGURE 16. Diagram showing time sequence of geological events, Beaverlodge area.

1. The recognizable event was the deposition of the Tazin sedimentary and tuffaceous material over a large area, probably between 2,200 and 2,600 m.y. ago. North of the Black Bay fault and to a lesser degree in part north of the St. Louis fault these were thinly bedded and mainly impure sandstones and shales with minor accumulations of limy shales and basic tuffs. South of the St. Louis fault and partly north of it, the sedimentary and tuffaceous materials were thickly bedded and included abundant pure sandstone and shales with some dolomite. As suggested by the nature of these rocks and by their distribution in the Beaverlodge area, one may assume that the basins of deposition were probably fairly shallow or platform-like in the late stage of the succession and about Murmac Bay, and very deep or geosynclinal in the early stage of the succession and toward the northwest corner of the map-area.

2. This sedimentary and tuffaceous material, particularly that deposited in deep water and corresponding to the early part of the succession, was buried to great depths where it was involved in complex folding and where the temperature was high enough to permit the development of bedding foliation, boudinage structure, and rock flowage. The folds formed at this stage represent the early and main period of folding. Most of the folds in the Tazin rocks of the Beaverlodge area are believed to belong to this stage.

3. At the time these deeply buried rocks were being complexly folded they were also regionally metamorphosed. All the rocks of the area were recrystallized, and mineral associations characteristic of the amphibolite facies were developed. Large areas were granitized. Granite was formed abundantly, and many of the rocks were changed into quartz-feldspar gneisses. This change was metamorphic and took place without appreciable addition of material from outside, but some material may have moved from place to place within limited areas.

4. Following, or possibly as a late effect of, the deformation responsible for the folding and the metamorphism, probably due to the fact that the folded and metamorphosed rocks had been brought to a higher level in the earth's crust, that is, into the zone where the rocks break instead of flow, large masses of rocks of the Tazin Group were brecciated. This brecciation developed wide zones of mylonite and brecciated rocks along fault zones (probably thrust faults), along bedding planes on the limbs and at the apex of folds where slippage and movement were possible, and at many other places where similar movements occurred. This was a period of mylonitization and brecciation rather than of shearing. Some of the minor folds in the Tazin rocks regarded as late folds may actually have formed at this stage as a result of movements associated with these cataclastic effects. The cataclastic effects of this stage were accompanied by recrystallization and mobilization of some of the quartz and a few retrograde metamorphic effects, such as the transformation of biotite and garnet into chlorite and of andesine and oligoclase into less calcic plagioclase. This deformation, at least the main effects of it, probably ended about 1,750 m.y. ago.

5. At a later time when much of the rock involved in the folding and metamorphosing had been eroded away, the Tazin rocks were again deformed by faulting. This period of faulting lasted a long time, from about 1,700 m.y. to about 1,300 m.y.; it was reactivated several times and locally was characterized by block faulting. In some of the basins resulting from this block faulting the Martin rocks were deposited. The reactivation of the movement on these faults was repeated several times over a long period and is believed to be responsible for the diverse attitudes of the many sets of faults in both the Tazin and Martin rocks, striking in all directions for the folds in the Martin rocks, and possibly also for some of the minor folds in the Tazin rocks that trend differently from the main folds. This extensive

period of faulting that was accompanied by widespread fracturing accounts for all the joints in the area. Locally the movement on some of these faults was mainly normal, but in general it followed any direction.

6. Some retrograde metamorphism, due to hydrothermal alteration and hydrothermal features, was later than all the above events. Hydrothermal alteration was active however for a long period and was probably a continuation of the granitization (event 3). It is localized mainly along and near major faults and characterized by the formation of minerals such as hematite, chlorite, carbonate, and pitchblende.

Chapter V

ECONOMIC GEOLOGY

Uranium is the only metal that has been found in commercial quantity in the area and is now (1966) being mined at the Fay–Ace–Verna mine of Eldorado Mining and Refining Company Limited. In 1957 it was produced from at least four other but smaller mines, which ceased to operate in April 1960, due to termination of sales contracts or exhaustion of ore. Up to the end of 1965 uranium production from the area amounted to almost twenty-five million pounds of U_3O_8. Table XLIII gives details of the production from the various sources in the area as obtained from the literature, government files, and annual mine reports. The production data for the mines other than the Eldorado, which is still operating, represent the total production of those mines to the time they were shut down.

TABLE XLIII | *Production of uranium to end of 1965*

	Ore, in tons	U_3O_8, in pounds
Black Bay (Murmac Bay)	1,375	6,500[1]
Bolger, Eagle, and Martin Lake	9,000[1]	60,000[1]
Cayzor	90,391	484,686
Eagle–Ace (Nesbitt)	20,000[1]	75,000[1]
Eldorado	5,873,505	22,093,488
Lake Cinch	139,205[2]	731,257
National Exploration	28,759[3]	143,677
Rix	283,073	1,400,000[1]
Leasers (Beaverlodge area only)	2,000[1,4]	14,000[1]
Total	6,447,308	25,008,608

[1]Estimated.
[2]Tonnage in 1960, estimated at 14,000 tons, is included.
[3]Two thousand tons of ore shipped in 1955 is included in this number and has been estimated to contain 9,000 lb U_3O_8, which is included in 143,677.
[4]This total was estimated from data in the files of the Saskatchewan Government Office in Uranium City in the fall of 1962.

Other metals are known to occur in the Beaverlodge area or slightly to the south, east, and west of it. They are iron, copper, gold, nickel, and vanadium, but none except gold has been found in sufficient quantity to be mined profitably. Most of these metals occur along the north shore of Lake Athabasca in the region south of the Beaverlodge area; presumably, when the region along the north shore of Lake Athabasca was prospected for these metals, the Beaverlodge area was also examined. Iron has been known to occur since 1895 near Fish Hook Bay. These deposits were assessed before 1920 and were found to carry less than 38 per cent iron. Copper was recognized on the Consolidated Nicholson property in 1930, and a few copper stains were noted during the mapping of the Beaverlodge area. Gold was found in the vicinity of Neiman Bay in 1934 and was mined from June 1939 to May 1942 at the low grade Box Mine of the Consolidated Mining and Smelting Company of Canada, Limited near Goldfields. High costs and shortage of labour forced it to shut down. Nickel showings have been investigated in the Dinty Lake area, slightly to the east of the Beaverlodge map-area. Vanadium, which was determined from several of the uranium deposits of the Beaverlodge area, occurs mainly as nolanite (Robinson, 1955a, p. 68). In the Eldorado Ace mine it was found in fairly large amounts on some levels, but its extent is not yet fully known.

History of Prospecting and Mining for Uranium

Pitchblende was reported by Alcock (1936a, pp. 36–37) from two showings in the region between Cornwall Bay and Fish Hook Bay on Lake Athabasca. Thucholite was also apparently (Lang, 1962, p. 146) identified by Ellworth in 1942 in a specimen sent to the Geological Survey from the Box mine. In 1944, when uranium became of strategic importance, a Crown Company, Eldorado Mining and Refining (1944) Limited, was organized to take control of the Eldorado mine at Great Bear Lake and to prospect for uranium in Canada, a right then reserved by this company. Apart from the pitchblende occurrences of the Great Bear Lake area, those of the Lake Athabasca region were at that time the only occurrences definitely known in Canada, although one uncorroborated occurrence of pitchblende was reported from Ontario, and pegmatitic and supergene uranium minerals were known to occur at several localities. When the Crown Company began to look for uranium, the Lake Athabasca region, because of the presence of pitchblende there, was regarded as a promising uranium-bearing region and was one of the first to be prospected. In 1945 prospecting was extended from the known pitchblende occurrences near the shores of Lake Athabasca north to the Beaverlodge area. In general, the results were very successful. Many new pitchblende occurrences were found, and large blocks of claims were staked for the Crown Company.

Late in 1947, the ban on private prospecting and staking for uranium and for its mining was lifted by the Canadian Government. This resulted in some private prospecting and staking in the Beaverlodge area in 1948 and 1949. During this period the Crown Company drove its Martin Lake adit and began its inclined Ace shaft. Some of the future privately owned mines were staked at that time.

In 1949 the Saskatchewan Government withdrew all prospective land not then staked and subdivided it into forty-two concessions of approximately 25 square miles each; these were sold at auction. Each concessionaire was required to spend at least $50,000 in working the concession. Failure to do so within a certain period resulted in forfeiture of the concession and the Saskatchewan Government would again declare the area open to public prospecting and staking. Those who fulfilled their contract were allowed to retain 20 per cent of the concession as claims, but they had to abandon the rest, which became open for prospecting and staking on August 4, 1952. During this period of concessioning, thousands of radioactive occurrences were found, but only a few deserved further investigation. A great deal of surface mapping and diamond drilling was done on the best occurrences. This was followed by shaft sinking, adit drifting, and underground exploration on some. The Eagle shaft, the Eagle–Ace shaft, the Rix–Leonard adit, the Rix–Smitty shaft, the Fay shaft, the National Exploration inclined shaft, and a few others were then sunk. Some of these prospects, such as the Eagle, were closed down about that time; others later became producers.

When most of the concessioned ground became open to public prospecting in August 1952, the Beaverlodge area as a whole experienced a renewal of intense prospecting and staking. The discovery of the important Gunnar mine deposit, slightly south of the map-area, dates from this period. Other deposits explored underground in the four years following this date, were: the Beta Gamma and Verna in 1953, Black Bay Uranium, Cayzor, and National Explorations in 1954; Lake Cinch and St. Michael in 1955; and Rix–Leonard in 1956. By 1957, when production in the area was at its peak, several thousands of minor uranium occurrences were known.

In 1952, a townsite, later named Uranium City, was laid out by the Saskatchewan Government on a sand plain near Fredette River on the north shore of Martin Lake. This site became the trading centre of the area, and at the time of maximum activity, about 1957, the town had a population of about 1,500 people. About the same time the Crown Company established a housing development at the north end of Beaverlodge Lake for its employees.

In 1949 Eldorado leased a hydroelectric plant, installed by Consolidated Mining and Smelting Company of Canada Limited at Wellington Lake on the Wellington River, about 20 miles west of the Ace mine, to supply power to the former Box gold mine. Its power capacity was doubled in 1959 by raising the dam and installing an additional turbine.

Two large treatment plants were installed in the area. One, near the Fay shaft on the property of the Eldorado Company, was built to treat the ore from the Fay–Ace–Verna mine and, when desirable, a certain amount of custom ore from nearby private properties. The other was installed near the west end of Nero Lake and was controlled by Lorado mine. It was designed as a custom mill to treat ore from the Lorado mine and also from the other small mines in the area not sufficiently high in ore to justify their having treatment plants of their own. The Eldorado plant, which began operation in 1953, was enlarged twice thereafter. In the last change, 1957, its capacity was increased to 2,000 tons a day. The Lorado plant had a capacity of 700 tons a day and began operation in 1957. It was closed in April 1960 when the Company sold its contract to Eldorado. As a result of this transaction, the companies shipping to Lorado had to stop operations and were closed down soon after. The mines involved were Rix Athabasca Uranium, Lake Cinch Uranium, and Cayzor Uranium. Black Bay Uranium mine, National Exploration mine, and Eagle–Ace mine had already been closed down due to depletion of ore. This left Eldorado the only producer in the area, apart from the Gunnar mine, which is outside the map-area under consideration. This curtailed trade at Uranium City, and the population dwindled to about 800. As there is at present (1964) an oversupply of uranium, prospecting in the area is at a standstill.

Types of Uranium Deposits

As recognized by Robinson (1955a, p. 47) there are three distinct types of uranium deposits in the Beaverlodge area: 1, epigenetic, those that formed at a later time than the enclosing rocks but possibly from them; 2, syngenetic, those that formed during the time the enclosing rocks crystallized; and 3, supergene, those that are due to surficial secondary enrichment.

The epigenetic deposits are the most common, and as far as known they are the only ones large enough to be economic. Their main characteristics are described below.

The syngenetic deposits were not studied by the writer because they are rare in the area and not economic. They may, however, be genetically important as they may be the ultimate source of the epigenetic deposits. Three main groups were noted: deposits that are coarse-grained pegmatitic bodies; deposits that are granite masses, slightly more radioactive than most; and remnants of country rocks somewhat richer in radioactive minerals than the enclosing granitized rocks.

In general the radioactive mineral content of the syngenetic deposits is erratic and low. According to Robinson (1955a, p. 47), the uranium-bearing minerals in these deposits are "uraninite, monazite, cyrtolite (a zircon), and less commonly, uranothorite, pyrochlore-microlite, and xenotime. All these minerals contain thorium and rare earth elements in addition to uranium. In some of these deposits thorium exceeds uranium in amount. Red alteration of the country rocks and of these radioactive rocks themselves is relatively rare. It is generally true, however, that red granites or red facies of granite are more radioactive than the normal grey to pink facies."

The supergene deposits are generally superimposed on, and transitional downward into, the other types of deposits. They were recognized in the area almost everywhere there was uranium mineralization; but they were not economic, probably mainly because most were formed in the short space of time since the Pleistocene. Earlier and possibly much larger deposits of this type were undoubtedly removed by the glaciers.

These deposits are all characterized by secondary uranium minerals, the most common ones being, according to Robinson (1955a, p. 47), uranophane and liebigite. Most of them now form only a thin zone at the surface, but in rare cases, particularly near the main fault zones, secondary minerals have been found to depths of almost 1,000 feet. At the Ace mine the ore mined above the second level was somewhat richer than the ore below; this was attributed (E. E. N. Smith, pers. com.) to secondary enrichment from the surface.

A striking example of secondary enrichment near the surface, which may date from before the Pleistocene, is the uranium-rich earth-like mass of loose material above the Bolger showing. About 1,500 tons of this material averaging 0.7 per cent U_3O_8 were scooped out of a hollow on the Bolger showing east of Verna Lake and milled (E. E. N. Smith, pers. com.). This was, however, practical because epigenetic deposits were being mined in the vicinity.

It should be mentioned, however, that important supergene ore was mined at Gunnar south of the map-area, and it is not impossible that large supergene deposits await discovery within the map-area.

Characteristics of Epigenetic Deposits

The epigenetic deposits may be classified as disseminations or fracture fillings, or combinations of both. In the disseminated deposits the pitchblende is scattered through the rocks in fine grains or particles, although in places the grains may be close enough to form large patches and bodies of massive pitchblende. The fracture fillings are mainly either pitchblende or pitchblende grains and patches scattered through such vein material as quartz, carbonate, and chlorite. The fractures may be tiny irregular cracks or clear-cut, fairly straight fissures. The tiny cracks may locally be so closely spaced and so numerous that they form a tight network of veinlets. The clear-cut fissures give rise to true fissure veins that may be fairly extensive. Generally, where there is some disseminated pitchblende there is also some fracture

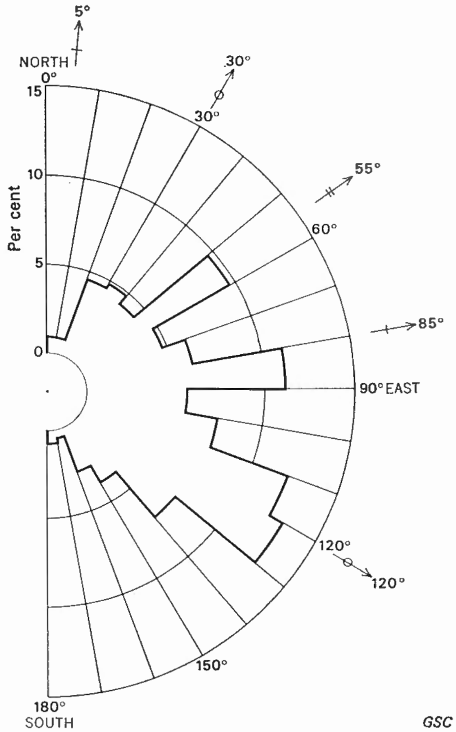


FIGURE 17

Strike of radioactive fractures, Beaverlodge area. Diagram based on 263 readings obtained during field work. Arrows and figures at their extremities indicate directions considered by the writer to be the directions of the main radioactive fractures. Three conjugate sets indicated, which also correspond to the directions of the late faults and joints.

filling. Most of the main deposits exhibit both types of deposit, and it is indeed very likely that fracture filling may be a local product of dissemination. On the other hand, much fracture filling has been noted where disseminated pitchblende is almost absent. This is particularly true of the minor deposits, which are generally true fissure veins or fracture fillings. The main directions of the radioactive fractures are shown in Figure 17 and will be discussed later.

Based on the shape of the known ore zones and partly on the structure of the enclosing rocks, the epigenetic deposits can be classified as breccia, stockwork, network and dissemination, dissemination, and vein, or any combination of these.

Breccia Deposits

Breccia deposits were observed in the Ace mine against and below the St. Louis fault. They are tabular bodies elongated along the plane of the fault. They are up to 50 feet thick, up to 800 feet long along the strike of the fault, and at least 3,000 feet long down the plunge of the ore zone. Many are, however, much smaller. They are all characterized by large to small fragments of mylonitized and brecciated highly granitized rocks, with pitchblende in fine grains disseminated throughout or in fairly large masses forming the matrix surrounding the fragments. Fracture fillings in the form of tiny irregular cracks are rare in this type of deposit, and generally not very noticeable. According to reports, however, some breccia deposits are cut by vein type deposits. The breccia ore zones are very important because they have supplied large tonnages of ore.

Stockworks

Stockwork deposits were observed only in the Fay–Ace–Verna mine. They are lenticular to pipe-like bodies that pinch out up and down the plunge. They are all at short distances above or below the St. Louis fault. Up to 400 feet long by 60 feet wide, they have been traced for at least 1,000 feet down plunge. They consist of a large number of fine, closely spaced fractures, filled with pitchblende, calcite, and chlorite. These fractures are considered to represent a much shattered area or a system of closely spaced joint fractures along which pitchblende has been deposited, as a coating only or a filling for the open space. Pitchblende disseminated in the rocks between the fractures is not a noticeable feature and does not appear to be important.

Networks and Disseminations

Networks of tiny irregular pitchblende veinlets with much pitchblende disseminated in the rocks adjoining and separating the veinlets were found in highly brecciated rocks, as at the Rix mine, where both fragments and matrix are impregnated and cut by the veinlets. The Verna ore zones are probably also mainly of this type, although they are also locally of the vein type. These deposits are tabular in shape and much longer down plunge than in other directions. They pinch out up and down the plunge, and if several are present they are disposed in an *en échelon* pattern. All are related to slightly larger fractures, which may or may not be mineralized with pitchblende. They are not far from a major fault and may represent shattered zones.

Disseminations

Fairly large deposits made up entirely of disseminated pitchblende are rare. They are represented by the Main Fault ore zone at Lake Cinch mine.

Veins

Veins are the most common type of deposit. They are found not only near major faults but also at great distances from them and mostly occupy joint-type fractures or shear zones. They may be very large, as those mined in the Ace mine, but most of them, particularly those some distance from the major faults, are small, both along strike and down dip. Locally, the vein deposits may form a system in which the veins are disposed *en échelon*. One such system was traced in the Ace mine at least 3,000 feet down the plunge. Where several veins are closely spaced, they have been known to constitute lenticular masses up to 50 feet thick, branching along the strike and down dip, the veins converging and diverging.

All these types have supplied large tonnages of ore, but the breccia, the stockwork, and the network and dissemination deposits are the most important.

It is possible that some types of deposits are earlier than others. There are a few features that suggest that the vein types are the latest to form, and crosscutting relationships indicate that most of the deposits involving dissemination and filling of numerous tiny cracks may be the earliest. Apparently, in the Ace mine some deposits of the vein types were seen cutting deposits of the breccia and stockwork types. This is also suggested by the results of absolute age determination.

Mineralogy

The mineralogy of the Beaverlodge deposits will not be described here in detail; this has already been done by Robinson (1955a). Pitchblende is the main and the most common uranium mineral in all these deposits. Thucholite has been identified from a few deposits, but it is present in only very small quantity. Gummite and several other secondary uranium-bearing minerals were identified (*see* supergene deposits) from the outcrops of most deposits, but in general they are not found in large amounts. Robinson stated that pitchblende is generally cryptocrystalline. In the hand specimen, it is massive, colloform, and occasionally earthy, but euhedral grains that were regarded as pitchblende were seen locally. The other common metallic minerals are hematite and pyrite, which locally are fairly abundant. Hematite occurrences range from minute disseminations to masses. The variety specularite is fairly common. Chalcopyrite, galena, sphalerite, and clausthalite were also seen but appear to be present only as traces or in minor amounts. Robinson has identified several selenides from these deposits, the main one being nolanite and tiemannite. These generally occur in very small amounts, and only locally are they visible. All these deposits are low in thorium. This is in contrast to the syngenetic deposits, which are generally high in thorium. It suggests that the thorium was dispersed during the metasomatism, whereas the uranium was concentrated, as suggested in this report.

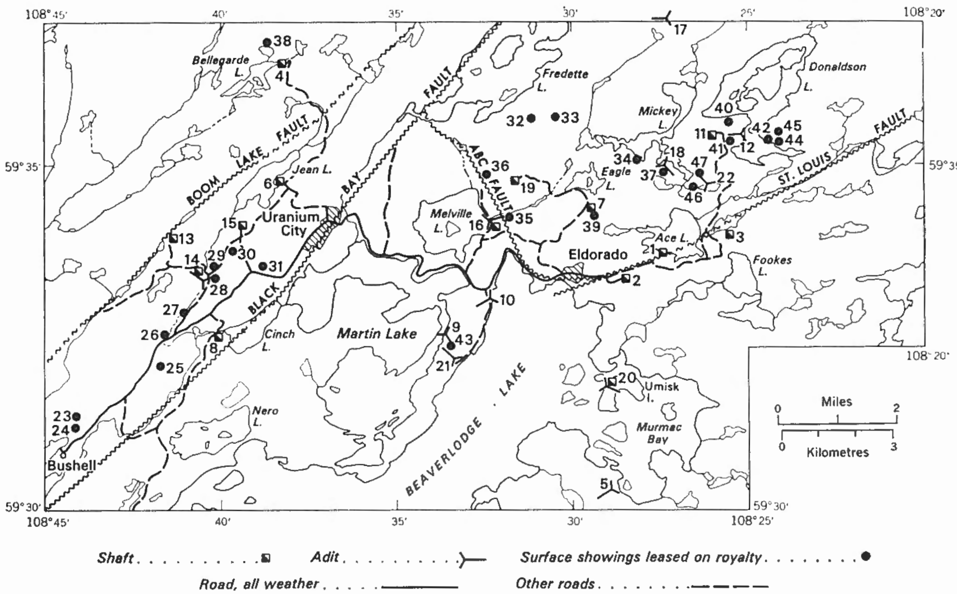
The principal gangue minerals are calcite, chlorite, and quartz. Albite–oligoclase occurs locally in small amounts. In some deposits the gangue minerals constitute a very small proportion of the deposits; elsewhere they are the main constituents.

According to Robinson there were several generations of hematite, calcite, quartz, and pitchblende. Although these minerals began to deposit in the order given above, their deposition was carried on simultaneously for a long period of time, almost to the end of deposition. Several generations of chlorite (Dudar, 1960) were deposited over a long period of time.

Relationship to Structure

The spatial distribution of the main epigenetic deposits is illustrated in Figure 18. From this figure it is apparent that most of the deposits are in the area north of the St. Louis – ABC fault and in the area between Black Bay and Boom Lake faults. These areas are characterized by extensive mylonitization, much brecciation, and, locally, close fracturing. This is in sharp contrast to the areas south of St. Louis fault and north of Boom Lake fault where mylonitization, brecciation, and fracturing are relatively uncommon. Thus, there probably is a relationship between the amount of brecciation, mylonitization, and fracturing, and the intensity of mineralization. This relationship is probably mainly structural, that is, physicochemical, but it is possible that it is also genetic and chemical. This is discussed in the section dealing with the origin of the deposits.

It is also shown in Figure 18 that the largest deposits are near major faults. The Fay–Ace–Verna mine is near the St. Louis fault; the Lake Cinch deposits are near Black Bay fault; and the Rix–Smitty showings are near Boom Lake fault. In no place is the ore zone in the fault itself, except possibly at the Rix–Smitty mine, where a few small ore zones of the vein type were found in what appears to be the sheared zone of Boom Lake fault. These ore zones are small and insignificant and do not disprove the statement that the main ore zones are not in the faults themselves. In fact, the main ore zones are generally at some distance from the fault zones, although locally, as in the Ace mine, they are partly against it. They seem to be located also at places along the fault where there is a change in the strike. This change is generally slight and gradual over a distance of several thousand feet, as in the area between the Fay and Ace shafts. Locally this change is sharper, as seen along the Black Bay fault in the area east and northeast of the Lake Cinch mine. A change in strike is also apparent along Boom Lake fault near the Rix–Smitty shaft. These changes in strike would normally favour the development of close fracturing, intense shattering, and brecciation for some dis-



LIST OF DEPOSITS

MINES WITH PLANT

1. Ace shaft (Eldorado)
2. Fay shaft (Eldorado)
3. Verna shaft (Eldorado)

SHIPPING MINES

4. Beta Gamma shaft, very small shipment
5. Black Bay adit, very small shipment
6. Cayzor shaft
7. Eagle - Ace shaft (Nesbitt Labine)
8. Lake Cinch shaft
9. Martin Lake adit (Martin Lake side) (Eldorado)
10. Martin Lake adit (Beaverlodge Lake side) (Eldorado)
11. National Exploration shaft
12. National Exploration adit, very small shipment
13. Rix Smitty shaft
14. Rix Leonard adit and shaft
15. St. Michael shaft, shipment from surface dump by leasers.

PROSPECTS WITH UNDERGROUND EXPLORATION

(No shipments except possibly by leasers on a very small scale)

16. ABC adit and shaft (Nesbitt Labine)
17. Baska adit (Virgin Lake)
18. Beaver Lodge adit (Mickey Lake)
19. Eagle shaft (Eldorado)
20. Meta Uranium adit and shaft, no shipment
21. Pitch - Ore adit
22. Strike adit

SURFACE PROSPECTS LEASED ON A ROYALTY BASIS

(Very small shipments were made from most of them. Most of these prospects are not described in this report)

23. 59°31′20″–108°44′10″
24. 59°31′10″–108°44′10″
25. 59°32′4″–108°41′40″
26. 59°32′27″–108°41′35″
27. 59°32′50″–108°41′00″
28. 59°33′18″–108°40′15″
29. 59°33′25″–108°40′10″
30. 59°33′45″ 108°39′45″
31. 59°33′25″–108°38′50″
32. 59°35′30″–108°31′10″
33. 59°35′30″–108°30′35″
34. 59°35′12″–108°28′30″
35. ABC surface showing
36. Baska property, ABC fault
37. Beaver Lodge Uranium, hill showing
38. Beta Gamma, No. 6 showing
39. Eagle - Ace mine area, Nesbitt Labine
40. National Exploration, Donaldson Lake
41. National Exploration, Donaldson Lake
42. National Exploration, Donaldson Lake
43. Pitch - Ore group, Martin Lake
44. Reno group, Donaldson Lake
45. Reno group, Donaldson Lake
46. Strike group, Ace Lake
47. Strike group, Ace Lake

GSC

FIGURE 18. Location of main uranium deposits, Beaverlodge area. Leased surface showings included.

tance in the walls of the fault as a result of movement along the fault; in other words, they would favour the development of numerous openings. They may have also helped in the formation of wide sheared zones, like the ones along Boom Lake fault near the Rix–Smitty mine. Many of the main deposits are at least closely associated spatially with such areas of fracturing, shattering, and brecciation.

In general, the major deposits are also located near the major faults where a subsidiary (2nd order structure) fault branches from the major fault, but again the deposits generally are not in such subsidiary faults but in still smaller fractures and fissures. The Crackingstone River fault, near the Lake Cinch deposit, seems to branch from the Black Bay fault, but so far, only a little mineralization has been found in it. The Smitty fault is near the Rix–Smitty mine. Several other faults, possibly extending from Black Bay fault to Boom Lake fault, pass in the general vicinity of the Cayzor and Rix–Leonard deposits. Near the Fay–Ace–Verna mine, it is very likely that a branch of the Fish Lake fault swings northward to join the St. Louis fault at the south end of Ace Lake and continues north of the fault under the sand plain west of Ace Lake. Similar types of structures, known locally as the Verna faults but not mapped by the writer, may exist in the vicinity of Verna deposits.

Most of the minor deposits or showings are found near and within similar subsidiary faults or are closely associated with much smaller ones (3rd order structures) and with joint-like fractures. These smaller faults are probably due to the stresses responsible for both the subsidiary faults and the major ones. The main directions of these mineralized smaller faults or joint-like fractures in the Beaverlodge area are contained in Figure 17. This is based on all radioactive fractures (faults or not) that could be measured on outcrops during the mapping. It is apparent from this figure that the main strike directions correspond with those of all the faults and joints in the Beaverlodge area as a whole. These are divisible into three conjugate sets of two directions each, except that one is missing or not recognized. The main directions are N5°E, N30°E, N55°E, N85°E, and N60°W. Their dips are mainly steep.

It appears also that slight changes in the strike of the subsidiary and smaller faults or fractures mark favourable places for mineralization. These changes generally take place where the faults or fractures cross rocks of different types or at least of different competency, particularly the contact zones between different rock types. The contact itself is generally a favourable spot for mineralization, particularly if it is irregular, due to rock facies changes, deformation, alteration such as granitization, and hydrothermal or cataclastic effects.

A few writers (Joubin, 1955; Robinson, 1955a, p. 73) have suggested a relationship between the epigenetic deposits and the Tazin–Martin unconformity or contact. Most of the deposits were thought by Joubin to be surface phenomena and were tentatively related to this contact. It is true that in the area north of the St. Louis – ABC fault and also in a few places south of it and elsewhere in the Beaverlodge area, the unconformity was close to the present surface. However, it is difficult to postulate the same relationship for the area between Black Bay and Boom Lake faults where no remnants of Martin rocks and no features characteristic of the unconformity were found during detailed mapping. The great thickness of Martin rocks south of Black Bay fault suggests that some Martin rocks were removed north of it. Nevertheless, as stated by Robinson (1955a, p. 74), the Beaverlodge area as a whole remains one where residual masses of Martin rocks can be found, and this would suggest that the Tazin–Martin unconformity even north of Black Bay fault was only a few thousand feet or less above the present surface. This, however, would assume that the mineralization is later than much of the deposition of the Martin rocks. It could be related to the second episode of uranium redistribution discussed under age below.

Mineralization at Ace mine was encountered down to a depth of 4,000 feet near the St. Louis fault where the Tazin–Martin unconformity was probably close to the present surface. The Martin Lake mine deposits are possibly about the same distance vertically above the unconformity. If there is a relationship between the unconformity and the location of the deposits, these observations suggest that the mineralization could take place to at least 4,000 feet, above and below the unconformity, provided there were deep channelways like the St. Louis fault. Furthermore, the unconformity may have itself acted as a channelway for the solutions, just as the major faults of the area have, and may therefore be regarded as a structural feature as economically important as the major faults. This concept is contrary to the one that considers groundwater to be the mineralizing agent and would very likely place a depth limit for the deposits north of Black Bay fault. It is contrary also to the time of mineralization advanced in this report.

Relationship to Rock Types

A detailed study of the main known epigenetic deposits of the Beaverlodge area, made during the course of mapping, showed that the uranium was deposited in many rock types; that certain rock types or rocks rich in certain minerals seem to favour the precipitation of uranium; that the concentration of uranium generally occurs where two or more rock types are in contact or are interbedded; and that the concentration seems to be higher where several rock types are thinly interlayered. Where the interlayering is broad, the rock seems to behave as an independent unit. The areas where several rock types are closely and thinly interlayered could be referred to as heterogeneous zones and may be representative of loci of lower chemical potential. This would then explain the greater concentration of uranium in these zones.

Uranium deposits were found in rocks of the Tazin Group, in rocks of the Martin Formation, and, in rare instances, in late basalt and gabbro dykes and sills. In rocks of the Tazin Group, they were noted in hornblende schist and amphibolite, in argillite and slate, in graphitic and dolomitic quartzites, in carbonatized, chloritized, and brecciated granites, and in a great variety of granitized and brecciated or mylonitized rocks. In rocks of the Martin Formation, they were seen in the basal conglomerate and in the basalt or andesite. The principal rock types acting as host to the main deposits of the area are listed in Table XLIV.

Christie (1953, p. 83) and Robinson (1955a, p. 49) have stated that certain types of host rocks appear to be more favourable than others for the deposition of pitchblende. Basalt or andesite are more common host rocks than arkose at Martin Lake mine; amphibolite and hornblende schist are more favourable than quartzitic rocks at Beaverlodge uranium prospect; and in general basic rocks are more common hosts than acidic rocks in many other small occurrences. Pitchblende prefers hematitic and graphitic quartzite to white quartzite at Black Bay Uranium mine. At Fay–Ace–Verna mine the preference seems to be not for hornblende schist and amphibolite, which occurs in the immediate vicinity of the deposits, but rather for chlorite-rich argillaceous rock and for highly brecciated chloritized feldspathic quartzite; and at Verna, glassy quartzite is definitely not a favourable host rock. At Lake Cinch and Rix-Smitty mines, pitchblende prefers highly granitized, brecciated, roughly layered rocks. At Lake Cinch mine, however, the host rock is more siliceous, less chloritic and less carbonaceous than at Rix-Smitty. From the evidence presented above, it seems difficult to specify the rock type most favourable for pitchblende deposition for the area as a whole. However, the following conclusion of Robinson (1955a, p. 49) is believed to be fully

TABLE XLIV | *Main host rock of principal deposits*

Deposit	Host Rock
Ace	Mylonitized feldspathized, quartzite, argillite
Fay	Granitized layered rocks and basal conglomerate of Martin Formation
Verna	Brecciated feldspathized argillite
Beta Gamma	Granitized layered rocks
Black Bay (Murmac Bay)	Hematitic and graphitic quartzite
Cayzor	Granitized chlorite schist and quartzite
Eagle-Ace	Argillite and slate
Lake Cinch	Mylonitized granitized layered rocks
Martin Lake	Basalt and andesite of Martin Formation
National Exploration	Grey, roughly banded, granite-like gneiss
Rix-Smitty	Red, brecciated, banded granitized rocks
Rix-Leonard	Amphibolite and granitized layered rocks
St. Michael	Granitized chlorite schist and quartzite
ABC	Granitized layered rocks
Baska (Virgin Lake)	Brecciated granitic gneiss
Beaver Lodge (Mickey Lake)	Amphibolite or hornblende schist
Eagle	Chloritic masses and granitized rocks
Meta Uranium	Basal conglomerate of Martin Formation and granite gneiss
Pitch-Ore (Martin Lake)	Basalt and andesite of Martin Formation
Strike	Amphibolite or hornblende schist

corroborated: ". . . observations indicate that under equivalent structural conditions, rocks rich in iron, magnesium, and in carbonate minerals are markedly more favourable to pitchblende deposition than acidic rocks." Acidic rocks as used in this report are those low in mafic minerals, such as chlorite, or in other minerals such as graphite and carbonate.

It is evident, therefore, that the deposition of the pitchblende is probably partly for chemical reasons, but as shown earlier in the section on relation to structure, it is to a large extent for physical reasons. However, it is believed that the heterogeneity mentioned previously and exemplified below was a much more important factor in the concentration of uranium than the presence of a single rock type, however favourable it may seem.

This feature was suggested from a study of the major deposits of the area and is believed to indicate that the different rock types of a thinly interlayered succession have an interrelated chemical effect on each other, and on the uranium-bearing solutions as these pass through them. These heterogeneous zones were recognized in all major deposits, and the following short descriptions of a few of these deposits will illustrate this feature.

1. The large deposits of Fay–Ace–Verna mine are found near the St. Louis fault where several rock types are closely interbedded. Argillite, hornblende schist, and feldspathic quartzite, all interlayered and all granitized or altered to various degrees, are abundant in the outcrops and underground. Farther to the northeast along the strike of the St. Louis fault, away from the mine area (that is, northeast of Collier Lake), only one rock type, granite or highly granitized rock, was recognized, and ore deposits are lacking. The apparent absence of the requisite heterogeneity there perhaps explains why deposits do not seem to occur.

2. The Lake Cinch deposits occur in a locality where rock types are varied and closely interlayered. Granitized chlorite schist, granitized quartzite, and granitic-layered gneiss are all closely interlayered. Also the Black Bay fault is a feature comparable in size to the St. Louis fault. Southwest of Cinch Lake along the fault, the rocks are very uniform, and no areas of heterogeneous rocks seem to be present. No uranium deposits were located there. The fact that to the northeast of Cinch Lake there is a greater diversity of rock types suggests favourable chemical conditions for uranium deposition, although as yet no deposits have been found. Perhaps other known critical requirements are absent or were not detected during the mapping.

3. The Rix-Smitty deposit is also in a region where highly altered and granitized rocks of various compositions are closely interlayered. Indeed, heterogeneity of the rock masses appears to be a widespread feature along the south side of Boom Lake fault and particularly in the immediate area of the mine as it is seen on the geological map.

4. Most of the deposits described later in this chapter are also associated with diverse rock types. Where a fracture traverses these, dilatant zones may be created. This is undoubtedly a significant factor in the deposition of uranium, but the chemical diversity of rock types is believed to be just as significant, particularly if this diversity is represented by zones of several diverse rock types.

In summary the main ore controls, in order of importance, are: 1, structure; 2, favourable rock; and 3, zone of thinly interlayered rocks or heterogeneous zones.

Age of Deposits

Since Nier published his work on isotopic lead ages in 1939, a great deal of information has become available on the use of radioactive decay of uranium and other elements to determine the age of minerals and rocks and on how to interpret the results. As the Beaverlodge is a major uranium area, it was widely known when the isotopic lead age investigations started, consequently many of the samples used for these studies came from or near this map-area. For this reason many ages are available for this area.

Most of the ages are on pitchblende, but a few are on uraninite, monazite, feldspar, biotite, and other minerals. Eighty-nine ages on pitchblende alone are available, but unfortunately many of these are duplicates; they were made on the same material or on material from the same deposit. There are, for example, nineteen ages on the Martin Lake mine alone. Thirteen ages have been determined on uraninite, monazite, biotite, and feldspar; twelve of them were on specimens from slightly outside the actual map-area. These thirteen determinations give ages ranging between 1,800 and 2,100 m.y. (Table XLV) and date the syngenetic deposits mentioned previously, that is, the final stage of regional metamorphism in the area, the last phase of granitization and recrystallization.

TABLE XLV *Ages of biotite, muscovite, uraninite, monazite, and feldspar from the Beaverlodge area and vicinity*

Sample No.	Mineral	Description of deposits	Location	Ages in millions of years						References
				Pb^{207}/Pb^{206}	Pb^{207}/U^{235}	Pb^{206}/U^{238}	Pb^{208}/U^{232}	K/Ar	Rb/Sr	
1	Biotite, 40% chloritized	Donaldson Lake gneiss	East shore of Mickey Lake					1,795		Lowdon (1963a, p. 64)
2	Muscovite	pegmatite	Gunnar Mine					1,815		Lowdon (1961)
3	Biotite	pegmatite	Viking Lake					1,850	1,970	Davis, *et al.* (1955–56)
4	Biotite, 50% chloritized	pegmatite	Viking Lake					1,950	2,350	Aldrich, *et al.* (1956)
5	Biotite	pegmatite	Viking Lake					1,780	1,970	Aldrich, *et al.* (1958)
6	Biotite, slightly altered to chlorite	pegmatite	Near Viking Lake					2,015		Lowdon (1960)
7	Feldspar	pegmatite	Viking Lake					1,810 ± 130		Cumming, *et al.* (1955)
8	Uraninite	pegmatite	Near Viking Lake	1,925	1,945	2,000	2,120			Lowdon (1960)
9	Uraninite	pegmatite	Viking Lake	1,850	1,830	1,790	1,600			Aldrich, *et al.* (1958)
10	Uraninite	pegmatite	Viking Lake	1,870	1,830	1,790	1,640			Wilson, *et al.* (1956)
11	Uraninite	pegmatite	Viking Lake		1,880	1,850	1,670			Wasserburg, *et al.* (1955)
12	Monazite	pegmatite	Desjarlais Lake NW of Beaverlodge Lake	1,950	1,775	1,705	1,615			Robinson (1955a)
13	Monazite	pegmatite	Oldman River	2,220	1,780	1,450	1,705			Robinson (1955a)

The first published ages connected with the Beaverlodge area or, more precisely, the general area north of Lake Athabasca, were on pitchblende from slightly south of the present map-area and were based on uncorrected lead–uranium analyses. These analyses were published by Ellsworth in 1950 and can be found in Lang (1952a, p. 123). The first isotopic ages on pitchblende from the actual map-area were published in 1952 by Kerr and Kulp and the specimen used was from the Martin Lake mine. Since then, thirty-two isotopic ages have been published by Collins, *et al.* in 1954, thirty by Robinson in 1955, and five others by various workers at various times (Tables XLVI and XLVII). Twenty-two new ages (A.D. numbers and R149) not published previously are added in this report (Table XLVII). The ages tabulated in Tables XLVI and XLVII are believed to represent all the known ages on pitchblende from the area, that is, all the known ages on the epigenetic deposits. In these two tables, the ages are grouped first by the subdivisions of the map-area used throughout this report and then by deposits.

The R and the A.D. specimens were all analyzed in the laboratories of the Geological Survey. The total lead and uranium contents were determined by X-ray fluorescence, except in a few cases where they were obtained by quantitative chemical analysis. These are indicated in Table XLVII. Most of the R samples were also chemically analyzed, but outside the Geological Survey Laboratories. As these analyses were made available to check the X-ray data, the name of the analyst is given in the table. In all cases the results obtained by X-ray fluorescence apparently checked very closely with those of the chemical analyses. Only rarely did corrections have to be made. In all cases, except R632, the X-ray results were used in calculating the ages presented in Table XLVII. The isotopic analyses (also done in the Geological Survey Laboratories) were corrected for ordinary lead using the samples shown in Table XLVII, the analyses for which are given in Table XLVIII. All the results of Table XLVII were taken directly from the files of the Geological Survey Laboratories.

Where lead isotopic analyses were available, three ages were calculated for each sample. This was possible for all samples analyzed in the Geological Survey Laboratories, since isotopic determinations were made in all cases. The calculations were made by using the "Tables for the Calculations of Lead Isotope Ages" published by the USGS (Prof. Paper 334-A, 1959). The ages are listed in Table XLVII. The ages obtained from the three ratios Pb207/Pb206, Pb207/U235, and Pb206/U238 are rarely identical or even within a few million years of one another. In general, indeed even the order of magnitude is only approximate for the three ratios. In fact for only five samples (A.D. 108, A.D. 111, R631, R632, and A.D. 348) were the results for the three ratios in about the same order of magnitude. The other samples in general show the following relationship: Pb207/Pb206 > Pb207/U235 > Pb206/U238, which is generally regarded as indicating a loss of lead from the minerals of the samples during their lifespan.

When the ratios Pb207/U235 are plotted against the ratios Pb206/U238 (Fig. 19), all points are below the theoretical Concordia line (Wetherill, 1956). This also is believed to indicate a loss of lead at some time during the life history of the minerals and to suggest that the ratio Pb207/Pb206 gives the best age of the three ratios: Pb207/Pb206, Pb207/U235, and Pb206/U238. The Pb207/Pb206 ages would theoretically be less affected by loss of lead if it can be assumed that both lead isotopes were removed in an amount proportionally equivalent to their amounts in the minerals. The Pb207/Pb206 ages are consistently the highest; this also is regarded as a good indication that they are the most reliable of the three ages, although this may not be true for the ages of the latest or other episodes due to too much reworking. When the ages from the three ratios are each plotted as histograms, they all give diagrams of similar appearance to the one for Pb207/Pb206 ages (Fig. 20), although the peaks of Pb207/U235 ratios are slightly to the left of those of the Pb207/Pb206

TABLE XLVI *Published ages of pitchblende from the Beaverlodge area excluding Robinson (1955a)*

Reference	Analyst	Deposit	Location	Ages in millions of years grouped within their probable episodes of mineralization								
				1750			1240			Latest		
				207/206	207/235	206/238	207/206	207/235	206/238	207/206	207/235	206/238
1954	Collins, *et al.*	Ace	North of the St. Louis – ABC fault	1,820								
1955	Giletti & Kulp	Eagle	North of the St. Louis – ABC fault	1,530	1,450	1,425						
1957	Eckelmann & Kulp	Eagle	North of the St. Louis – ABC fault	1,610	1,480	1,375						
1957	Eckelmann & Kulp	Eagle	North of the St. Louis – ABC fault				1,140	975	895			
1954	Collins, *et al.*	Eagle	North of the St. Louis – ABC fault	1,700								
1954	Collins, *et al.*	Eagle	North of the St. Louis – ABC fault	1,630								
1954	Collins, *et al.*	Eagle	North of the St. Louis – ABC fault	1,620								
1954	Collins, *et al.*	Eagle	North of the St. Louis – ABC fault	1,430								
1954	Collins, *et al.*	Mic Zone	North of the St. Louis – ABC fault				1,210					
1954	Collins, *et al.*	Mic Zone	North of the St. Louis – ABC fault				1,160					
1954	Collins, *et al.*	Beth Zone	North of the St. Louis – ABC fault							970		
1954	Collins, *et al.*	Strike Group	North of the St. Louis – ABC fault	1,780								
1954	Collins, *et al.*	Donaldson Lake	North of the St. Louis – ABC fault							850		

1954	Collins, *et al.*	Tam Lake	North of the St. Louis – ABC fault							945		
1954	Collins, *et al.*	ABC	North of the St. Louis – ABC fault							920		
1954	Collins, *et al.*	Bolger	South of St. Louis fault							400	437	444
1954	Collins, *et al.*	Martin Lake	South of St. Louis fault	1,580	630	400						
1954	Collins, *et al.*	Martin Lake	South of St. Louis fault				1,110					
1954	Collins, *et al.*	Martin Lake	South of St. Louis fault	1,670								
1954	Collins, et *al.*	Martin Lake	South of St. Louis fault	1,660								
1954	Collins, *et al.*	Martin Lake	South of St. Louis fault	1,660								
1954	Collins, *et al.*	Martin Lake	South of St. Louis fault	1,650								
1954	Collins, *et al.*	Martin Lake	South of St. Louis fault	1,620								
1954	Collins, *et al.*	Martin Lake	South of St. Louis fault	1,620								
1954	Collins, *et al.*	Martin Lake	South of St. Louis fault	1,610								
1954	Collins, *et al.*	Martin Lake	South of St. Louis fault	1,580								
1954	Collins, *et al.*	Martin Lake	South of St. Louis fault	1,570								
1954	Collins, *et al.*	Martin Lake	South of St. Louis fault	1,530								
1954	Collins, *et al.*	Martin Lake	South of St. Louis fault	1,410								
1955	Cumming, *et al.*	Martin Lake	South of St. Louis fault				1,150	930	840			
1952	Kerr and Kulp	Martin Lake	South of St. Louis fault							900	980	860
1954	Collins, *et al.*	Cinch Lake	North of Black Bay fault and south of Boom Lake fault				1,120					
1954	Collins, *et al.*	Cinch Lake	North of Black Bay fault and south of Boom Lake fault				1,070					
1954	Collins, *et al.*	Cinch Lake	North of Black Bay fault and south of Boom Lake fault				1,030					
1954	Collins, *et al.*	Rix-Smitty	North of Black Bay fault and south of Boom Lake fault				1,310					
1954	Collins, *et al.*	Rix-Smitty	North of Black Bay fault and south of Boom Lake fault				1,210					
1954	Collins, *et al.*	Rix-Smitty	North of Black Bay fault and south of Boom Lake fault				1,590					

TABLE XLVII *New ages of pitchblende from the Beaverlodge area and ages published by Robinson (1955a)*

Sample No.	Method of analysis		Deposit	Location		Rock type	Nature of deposit and pitchblende
	X-ray	Chemical		General	Detail		
A.D. 108	..		Ace Mine	North of St. Louis – ABC fault	2nd level. 60′ north of St. Louis fault. Outside and below Main Ore Zone No. 01	In Tazin rocks and granite	Vein
A.D. 109			Ace Mine		2nd level. Main Ore Zone No. 01. West of Ace shaft		Disseminated in mylonite
A.D. 111	..		Ace Mine		3rd level. 60′ north of St. Louis fault. Outside and below Main Ore Zone No. 01. East of No. 01		Fracture filling
A.D. 232	..		Ace Mine		4th level. 150′ north of St. Louis fault. Stope 420 east of Ace shaft		Vein, cut by pyrite and carbonate
A.D. 235	..		Ace Mine		7th level. In Main Ore Zone No. 01. West of Ace shaft		Disseminated and in blebs in mylonite cut by pyrite
R149	..		Ace Mine		1st level. 145X cut north. 32′ north of main drift. Outside Main Ore Zone No. 01		Vein (?), nodular
R546	..		Ace Mine		Eldorado		
R618	..	X	Ace Mine		Between 5th and 6th levels. 60′ north of St. Louis fault		Vein (?), massive
R620	..		Ace Mine		3rd level. 100′ north of St. Louis fault. West of Ace shaft		Vein (?), intergrowth with calcite
R622	..	X	Ace Mine		1st level. 126′ north of St. Louis fault. West of Ace shaft		Vein (?), massive and ragged
R623	..	X	Ace Mine		1st level. 109′ north of St. Louis fault. West of Ace shaft		Vein (?), massive

Sample used for isotope corrections	Ages in million years grouped within their probable episodes of mineralization								
	1750			1240			Latest		
	207/206	207/235	206/238	207/206	207/235	206/238	207/206	207/235	206/238
R457	1,605	1,590	1,560						
R457	1,710	1,550	1,455						
R457	1,755	1,750	1,780						
R457							710	470	405
R457	1,660	1,415	1,290						
R457	1,810								
1,000 m.y.				1,270	1,100	1,030			
R457							100	142	173
R457				1,090	820	720			
R457	1,575	1,280	1,145						
R457	1,780	1,570	1,450						

TABLE XLVII (cont.) | *New ages of pitchblende from the Beaverlodge area and ages published by Robinson (1955a)*

Sample No.	Method of analysis		Deposit	Location		Rock type	Nature of deposit and pitchblende
	X-ray	Chem-ical		Gen-era!	Detail		
R624	..	X	Ace Mine	North of St. Louis – ABC fault	1st level. 80′ north of St. Louis fault. West of Ace shaft	In Tarzin rocks and granite	Vein (?), residual
R625	..	X	Ace Mine		1st level. 171X cuts north. 18′ north of main drift. West of Ace shaft		Vein (?), mixed with calcite
R626	..	X	Ace Mine		1st level. 22′ north of St. Louis fault. West of Ace shaft		Disseminated (?), massive
R627	..	X	Ace Mine		1st level. Near St. Louis fault plane. West of Ace shaft		Disseminated (?), granular
R628	..	X	Ace Mine		1st level. 45′ north of St. Louis fault. East of Ace shaft		Vein (?), massive
R629	..	X	Ace Mine		1st level. 7′ north of St. Louis fault. East of Ace shaft		Vein (?), massive
R630	..	X	Ace Mine		3rd level. 90′ north of St. Louis fault. West of Ace shaft		Vein (?), ragged
R631	..	X	Ace Mine		3rd level. 30′ north of St. Louis fault. West of Ace shaft.		Disseminated (?), massive
R632		X	Ace Mine		2nd level. In a N–S fracture, East of Ace shaft		Vein, intergrowth with chalcopyrite
R633	..		Ace Mine		2nd level. In a E–W fracture 60′ north of St. Louis fault. East of Ace shaft		Vein, intergrowth with chalcopyrite
R636			Ace Mine		2nd level. 90′ north of St. Louis fault. West of Ace shaft		Vein (?), massive

Sample used for isotope corrections	Ages in million years grouped within their probable episodes of mineralization								
	1750			1240			Latest		
	207/206	207/235	206/238	207/206	207/235	206/238	207/206	207/235	206/238
R457	1,580	800	575						
R457	1,670	1,410	1,310						
R457	1,795	1,450	1,225						
R457	1,730	1,385	1,190						
R457							570	225	205
R457							450	245	232
R457				1,280	890	775			
R457	1,680	1,610	1,620						
R457							800	750	710
R457							740	620	623
R457	1,905	1,630	1,465						

TABLE XLVII (cont.) *New ages of pitchblende from the Beaverlodge area and ages published by Robinson (1955a)*

Sample No.	Method of analysis		Deposit	Location		Rock type	Nature of deposit and pitchblende
	X-ray	Chemical		General	Detail		
R639	..	X	Ace Mine	North of St. Louis – ABC fault	2nd level. 5′ north of St. Louis fault. West of Ace shaft	In Tazin rocks and granite	Disseminated (?), two generations
R150	..	V	Eagle		2nd level, central		Vein (?), replacing
R420	..	X	Eagle		1st level, west end		Vein (?), massive
R611			Camdeck (?)		GG. No. 2 trench		Vein, residual
R508			Bar Group Beaverlodge Uranium (?)		No. 5 zone		Vein, massive
A.D. 233					4,200′ due west of National Exploration camp on Foot Bay and 600′ NE of shore of Mickey Lake		Fractured filling against gabbro dyke and cut by carbonate
A.D. 237			National Exploration		1st level. Upper shear drift 102, near corner X cut from shaft		Vein, massive, weathered
R608			Eagle–Ace		2nd level		Vein, massive
R609	..	X	Eagle–Ace		1st level		Vein, massive
A.D. 103	..		Eagle–Ace		2nd level, vein 213		Vein, mixed with carbonate
R646	..	X	Eagle–Ace		Near ABC fault in adit		Vein, massive
A.D. 113	..		Radiore	South of St. Louis – ABC fault	4,000′ east of North and of Fookes Lake		Fracture filling
A.D. 230	..	..	Verna Mine		Main Verna. 4th level 630′ east of shaft and 260′ south of it		Disseminated pitchblende and fracture filling. Late quartz epidote and pyrite
A.D. 231	..		Verna Mine		Main Verna. 4th level. 330′ east of shaft and 100′ south of it		In fracture massive pitchblende in dark red dense rock

Sample used for isotope corrections	Ages in million years grouped within their probable episodes of mineralization								
	1750			1240			Latest		
	207/206	207/235	206/238	207/206	207/235	206/238	207/206	207/235	206/238
R457	1,670	1,345	1,185						
R530	1,622	1,465	1,385						
R530				1,060	950	860			
R642							530	260	250
R642							535	360	333
R530							640	370	325
R530							400	140	145
R457							360	240	237
R457							690	350	325
R457							<100	<100	225
R530							510	330	310
R530				1,055	810	715			
R530							345	210	175
R530							960	595	505

TABLE XLVII (cont.) *New ages of pitchblende from the Beaverlodge area and ages published by Robinson (1955a)*

Sample No.	Method of analysis		Deposit	Location		Rock type	Nature of deposit and pitchblende
	X-ray	Chemical		General	Detail		
A.D. 352		..	Verna Mine	South of St. Louis – ABC fault	West Verna Ore Zone. 6th level. 6,500 drift east	In Tazin rocks and granite	In fractures in deep red rock
A.D. 353		..	Verna Mine		West Verna Ore Zone. 6th level. 6B, 23A stope		In fractures in deep red rock
A.D. 104	..		Bolger		1,200′ east of Verna Lake and 1,200′ south of St. Louis fault		Vein, massive and weathered
R218			Martin Lake Mine		Rock dump, Martin Lake side	In Martin rocks	Vein
R535	..	X	Martin Lake Mine		Bottom of No. 2 flow		Vein, colloform
R536	..	X	Martin Lake Mine		Top of No. 2 flow		Vein, colloform
R537	..	X	Martin Lake Mine		No. 1 flow (above No. 2 flow in succession)		Vein, colloform
R532	..	V	Pitch-Ore		Trench No. 10		Vein, massive
A.D. 112	..		Cinch Lake	Between Black Bay and Boom Lake faults	400′ north of west end of lake	In Tazin rocks and granite	Fracture filling, massive (?)
A.D. 129	..		Cinch Lake				Vein
A.D. 347		..	Cinch Lake		2nd level. Main Ore fault zone. Stope 2-north		Fracture filling and disseminated Massive (?)
A.D. 348		..	Cinch Lake		2nd level. Main Ore fault zone. Stope 1-south		Fracture filling, massive (?)
A.D. 234	..		Cayzor		1st level. No. 76 vein		
A.D. 350		..	Rix-Smitty		4th level. Smitty West extension. Stope W550		Fracture filling and disseminated

Sample used for isotope corrections	Ages in million years grouped within their probable episodes of mineralization								
	1750			1240			Latest		
	207/206	207/235	206/238	207/206	207/235	206/238	207/206	207/235	206/238
1,000 m.y.				1,025	695	590			
1,000 m.y.				1,150	916	828			
R530							730	340	275
R530	1,570								
R530				1,160	930	835			
R530	1,575	1,335	1,210						
R530				1,090	940	885			
R530				1,270	1,055	975			
R530				1,165	910	810			
R530				1,040	830	740			
500 m.y.							510	355	310
1,000 m.y.				1,185	1,110	1,095			
R530				1,150	860	720			
A.D. 354							170	273	285

TABLE XLVII (cont.) *New ages of pitchblende from the Beaverlodge area and ages published by Robinson (1955a)*

Sample No.	Method of analysis		Deposit	Location		Rock type	Nature of deposit and pitchblende
	X-ray	Chemical		General	Detail		
A.D. 351		..	Rix–Smitty		2nd level. Smitty West extension. Stope 62–120 along fracture at 1 to Smitty fault		Fracture filling, massive (?)
R547	..	X	Rix–Leonard		In adit		Vein, colloform

.. Analysis done in the laboratories of the Geological Survey of Canada
X Analysis done by Kulp
V Analysis done by Kulp and U.S.G.S.

ratio, and those of Pb206/U238 ages are still farther to the left. This would suggest that the mechanism that brought about the loss of lead was uniformly operative. It is known that lead was lost, since galena and clausthalite high in radiogenic lead have been found all through these deposits.

If the Pb207/Pb206 ages are assumed to be the most reliable, and if those that seem to fall within a definite range or group, as shown on the histogram of Figure 20, are selected and plotted as ratios on a Concordia graph (Fig. 19), their distributions are such that straight lines can be drawn through two sets of points. One line starts at 1,750 m.y., the other at 1,240 m.y., and the two lines cut the Concordia curve just below the 300 m.y. mark, whereas theoretically they should meet at the zero mark. The Concordia graph of Figure 19, prepared by R. D. Stevens under the guidance of R. K. Wanless of the Geological Survey, suggests that the loss of lead can be attributed to volume diffusion from pitchblende deposited during two different periods of uranium mineralization, one at 1,750 m.y. ago, the other at 1,240 m.y. It is, however, possible that it indicates (Tilton, 1960) only one period of mineralization at 1,750 m.y. followed by normal volume diffusion to 1,300 m.y., at which time there was a period of activity that brought about an almost complete dissipation of lead from the minerals, moving the diffusion line closer to the theoretical Concordia line. At about 1,240 m.y. normal volume diffusion was resumed; this would explain the second straight line. At a later time, probably in the last few hundred million years, another period of activity accompanied with lead loss took place, which would explain the scattering of points near the zero mark on the Concordia graph. This scheme implies only one period of uranium mineralization but several episodes of uranium redistribution, and this is accepted here. The first major episode of uranium redistribution would correspond to the period of uranium mineralization and is the most important one. It took place about 1,750 m.y. or shortly after the regional metamorphism and the granitization in the area and is probably closely related to the cataclastic

Sample used for isotope corrections	Ages in million years grouped within their probable episodes of mineralization								
	1750			1240			Latest		
	207/206	207/235	206/238	207/206	207/235	206/238	207/206	207/235	206/238
A.D. 354							136	316	351
R313				1,210	930	805			

R Robinson samples. All information on these samples taken directly from Robinson (1955a) or from GSC files
A.D. Samples collected by the writer

effects responsible for the widespread mylonitization and brecciation. Age of 1,795 m.y. in chloritized biotite and ages of about 2,000 m.y. (Table XLV) on uraninite, monazite, muscovite, and feldspar from pegmatites, which are regarded as the last products of granitization, suggest this relationship. The second episode of uranium redistribution due to the period of activity at about 1,300 m.y. probably corresponds to the period of intense fracturing characterized by the development of the many late faults and joints in the area. This second episode was associated locally with some uranium concentration. The latest period of uranium redistribution, which took place around 300 m.y., probably corresponds to minor and late movements on the major faults of the area, such as the St. Louis, ABC, and Black Bay faults.

The ages based on the Pb207/Pb206 ratios from the Beaverlodge area vary erratically (*see* Fig. 21). Minerals from the main two episodes of uranium redistribution are found everywhere; a few of the more thoroughly investigated deposits present even a wider range of ages (Fig. 22). No definite pattern in the spatial distribution of the various ages can be recognized, nor does each episode of uranium redistribution and concentration seem to have favoured any particular part of the area. It appears, however, that if there are centres of the first episode of redistribution or mineralization that these centres are located within or near major zones of mylonite and breccia and that they may be the Ace mine, the Eagle deposit, and the Rix–Smitty mine. The same centres were probably active during the second episode of uranium redistribution, as some ages corresponding to the second episode were obtained from them. Most of the other important deposits, such as Verna mine, Radiore showing, Lake Cinch mine, Rix–Leonard adit, Cayzor mine, and others including the Martin Lake mine, were probably formed during the second episode. Furthermore, it appears that at subsequent irregular intervals all these deposits were reactivated, that material was added or removed, and that younger pitchblende was deposited either in or near the deposits, this pitchblende representing reactivated material.

TABLE XLVIII *Composition of leads from galena and clausthalite used for corrections*

Sample No.	Location			Rock types		Mineral	Isotopic lead ratios		
	General	Deposit	Detail	General	Detail		206/204	207/204	208/204
A.D. 354	North of Black Bay fault	Rix-Smitty	4th level. Smitty west Extension. Stope west 450 near top	Tazin Group	Mylonitized quartz feldspar gneiss	Galena	9.07	7.26	17.89
R313		Rix-Leonard	In adit—footwall of vein	Tazin Group	Hornblende schist cut by granite dykes	Galena	58.10	21.90	37.72
R457	North of St. Louis fault	Ace mine	6th level	Tazin Group	Mylonitized granitic rock (?)	Clausthalite	43.95	20.08	39.14
R530	South of St. Louis–ABC fault	Pitch-Ore	trench 8	Martin Formation	Basalt	Clausthalite	19.90	15.57	37.06
R642	North of St. Louis fault	Bar group	Zone 1A	Tazin Group	Hornblende schist cut by granite dykes (?)	Clausthalite	26.33	17.21	36.11
500 m.y. Pb							17.93	15.75	38.05
1,000 m.y. Pb							17.00	15.66	37.00
1,750 m.y. Pb							15.43	15.45	35.36

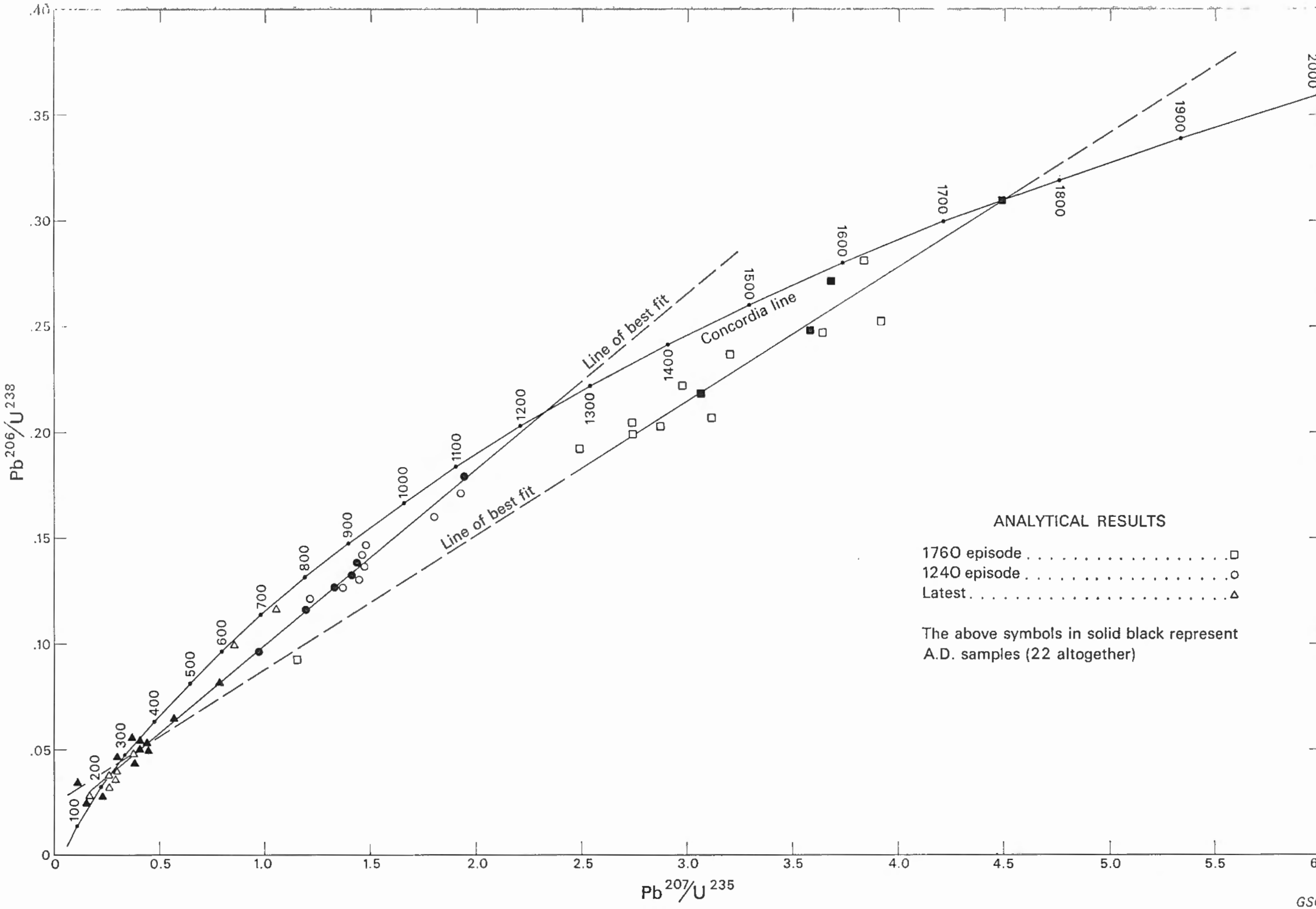


FIGURE 19. Concordia graph prepared from original plot by R. D. Stevens, Geological Survey, based on analytical information given in Table XLVII, excluding samples R149, R218, and R620. Lines of best fit obtained by method of least squares fall approximately on the solid diffusion lines as calculated by the method explained by Tilton (1960).

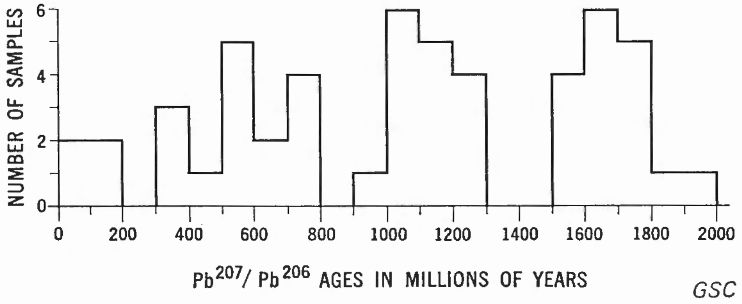


FIGURE 20. Histogram based on fifty-two Pb^{207}/Pb^{206} ages given in Table XLVII.

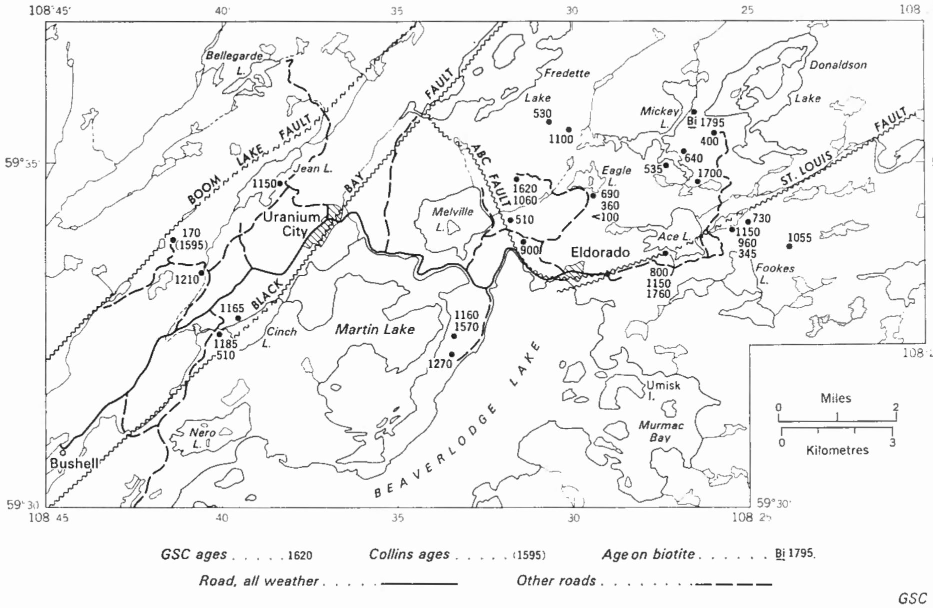


FIGURE 21. Spatial distribution of Pb^{207}/Pb^{206} age determinations, Beaverlodge area.

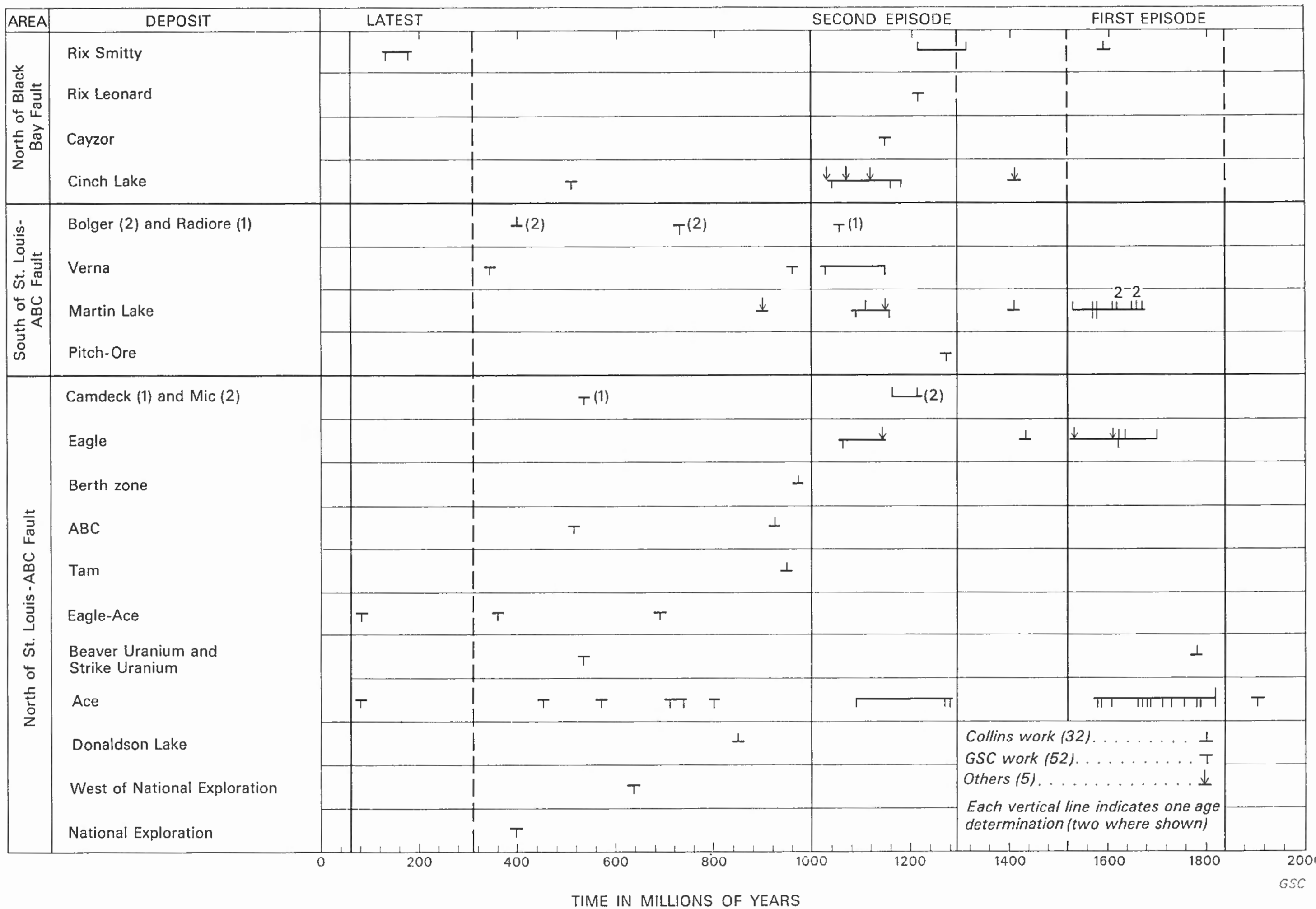


FIGURE 22. Pb^{207}/Pb^{206} ages of uranium deposits in Beaverlodge area, based on all available determinations.

Origin of Deposits

Uranium minerals have been found in almost every rock type in the Beaverlodge area, and their spatial distribution does not seem to correspond to that of any igneous rock type or to the shape of any particular igneous or igneous-like mass. A few small uranium showings were seen in the late gabbro or basalt dykes and sills, but no genetic connection is believed to exist between this gabbro and the uranium mineralization, since the distribution of the pitchblende occurrences within the area is not related in any way to the distribution of the gabbro dykes. The largest concentration of gabbro dykes is in an east-west belt near the northern boundary of the map-area, whereas the greatest concentration of uranium is near the major faults of the area and at some distance from this belt. In addition, the amount of gabbro dykes and sills is small compared to the large number of pitchblende occurrences. Finally, from the age of 1,490 m.y. on the northwesterly trending dyke cutting the basal conglomerate and the lower arkose of the Martin Formation in Fredette Lake and from the absolute age determinations on pitchblende it appears that the late gabbro dykes of the Beaverlodge area are somewhat younger than the main pitchblende mineralization or the first main episode of uranium redistribution. The pitchblende along fractures in the dykes is therefore probably redistributed pitchblende.

Similarly no genetic connection is likely between the gabbro and basalt of the Martin Formation and the uranium deposits, as this gabbro was dated 1,410 m.y. and the basalt 1,630 m.y.; both are somewhat younger than 1,750 m.y., which is the first major episode of uranium redistribution or the period of uranium mineralization. Furthermore, there are no spatial relationships between them.

All granites in the area are metasomatic. Even the granite dykes are considered metasomatic since they are held to represent the mobile, possibly molten part of the large metasomatic granite areas. Thus, if the uranium mineralization is related to granite, it is not related to an igneous granite, for none was recognized during the mapping. Actually, the general characteristics of the deposits and their spatial distribution does suggest that they are related to the metasomatic granite of the area and not to some outside or unrecognized igneous granite. Thus, Robinson (1955a, p. 101) wrote: "Evidence... indicates that syngenetic deposits are probably the products of metasomatism and the epigenetic deposits... the products of hydrothermal solutions." It is true that the syngenetic deposits can best be explained as late products of the granitization process and that they represent a phase of the molten mobile part of the metasomatic granite. If this process, that is, the conditions accompanying the development of the metasomatic granite, had been carried a step further than the formation of the granite dykes, then some sort of hydrothermal solutions could have been released from the granitized material, in this instance at a time later than the formation of the granite and pegmatite dykes or the syngenetic deposits, and the solutions could have leached the uranium from these deposits and the source rock, carried it some distance away, and concentrated it in some of the places where it is found now. Sullivan (1957, p. 600) regarded the uranium deposits of this area as syngenetic accumulations in sediments with reconcentration during the granitization. In other words, the mechanism of uranium concentration and redistribution is a complex and multiple one. It could be summarized as follows.—The uranium from the source rocks was locally reactivated during the granitization and concentrated in the syngenetic deposits and granitized areas (Primary redistribution). These areas were the immediate source of uranium at a still later time when mylonitization remobilized the uranium and reconcentrated (first main episode of redistribution) it in the mylonitized zones themselves, that is, in those places where most of the epigenetic deposits are now found. This episode, that is, when the rocks were mylonitized, corresponds to the oldest period of pitchblende formation or 1,750 m.y. There was a further episode of major uranium redistribution at 1,240 m.y. with much concentration of pitchblende and several minor ones later (Fig. 16).

The uranium content of fifty-seven samples of various rock types from the area was determined by the Chemistry Section of the Geological Survey of Canada. The results suggest that the granites or granitized rocks have a higher uranium content than the other measured rock types and that some granites have more uranium than others. This supports the suggestion made above that the uranium made available from the source rock by granitization was probably concentrated, possibly in some of the more granitized parts of the granitized rocks. The granitized areas can therefore be regarded as the immediate source of the uranium for most of the epigenetic deposits in the area. As all granites in the Beaverlodge areas are metasomatic, presumably the uranium came from the pre-existing rocks, some of which may have been particularly rich in uranium. The argillaceous rocks or their metamorphic derivatives have a somewhat higher uranium content than the associated white quartzite and amphibolite (Table XLIX). These rocks could therefore be regarded as the ultimate source of the uranium in the area. The possible nature of the original or pre-existing rocks is discussed below, and was discussed at great length in a paper by Tremblay (1970).

The following elements, U, Fe, Ca, Cu, Pb, V, Se, Co, Ni, and As, were reported by Robinson (1955a, p. 78) from the epigenetic deposits of the Goldfields area (which include the Beaverlodge area). Locally some of these elements are fairly abundant. Thus, vanadium is abundant at Ace mine, and cobalt and nickel at the Nicholson mine, south of this map-area. In general, however, the elements enumerated above are in small amounts.

TABLE XLIX | *Uranium content of main rock types in Beaverlodge area*

Rock types	Number of specimens analyzed		Uranium PPM	
Amphibolite	15		0.8 (0.3–2.7)	
Argillite	6		4.6 (3.0–8.8)	
Chlorite schist	3	14	4.4 (3.6–5.5)	4.5 (3.0–8.8)
Impure quartzite	5		4.3 (3.4–6.8)	
White quartzite	7		3.0 (1.6–4.7)	
Layered gneiss (white quartzite and chlorite schist)	6		3.7 (1.2–5.3)	
Granite	15		5.4 (1.0–13.0)	

Certain associations, such as Co–Ni–U, are known to occur in deposits in basic rocks. Deposits of this type, however, which generally have a low uranium content, are not associated with extensive granitization. This is in contrast to the deposits in the Beaverlodge area, which have a high uranium content and occur in an area of widespread granitized rocks. Furthermore, if the uranium deposits of the Beaverlodge area were concentrations of uranium derived from basic rocks, concentrations of such metals as nickel and cobalt, and probably also bismuth, tin, and tungsten, should be present. As concentrations of these elements have not been reported from the area, except for minor and rare occurrences of nickel, cobalt, and vanadium, then some rock other than a gabbro or basalt must be the source of the uranium. In other words, the hornblende schist and the amphibolite masses of the area, mainly those that were probably originally gabbro, basalt, or pyroclastic rock, cannot be regarded as the source rock, particularly since most masses, even the largest, are not heavily granitized. Their uranium content (Table XLIX) is, in fact, so much lower than in the other rock types that it is unlikely they are the source rock.

The elements reported by Robinson and listed above are known to be present in some sediments elsewhere on the earth's surface. Generally such sediments are rare in nature and highly reducing conditions must have been present for their formation; such conditions are encountered only in very special environments. However, there is no reason to suppose that such conditions never existed in Precambrian time and that this type of sediment was not deposited. It is also likely that such sediments had a higher uranium content in Precambrian time than similar sediments deposited later, because the earth's crust at that time was probably richer in uranium than it is now.

The presence of thucholite, identified from a few deposits in the map-area, suggests that the source rock may also have been carbon-rich. Indeed, Sullivan (1957, p. 600) referred to "carbon-rich shales and allied sediments" as the source rocks for the uranium deposits of this area.

In summary, the above association of elements, including uranium and carbon, can be found in carbon-rich sediments of the black shale type, and uranium concentration could be the result of their granitization. If such sediments were present in this area, they could have been the source rock. Indeed they may be represented by the chlorite-rich argillite-like rocks that were recognized in the vicinity of the deposits at Fay–Ace–Verna, Lake Cinch, and Rix–Smitty mines, which are the largest known deposits in the map-area. They could also be represented by some of the chlorite-rich granitoid gneisses recognized throughout the area. See paper by Tremblay (1970) for more information on this.

As mentioned earlier, the granitized areas (primary redistribution at about 2,000 m.y.) are considered by the writer to have been the immediate source of uranium. The particular parts of these areas that supplied the uranium for the epigenetic deposits seem to have been the mylonitized and brecciated zones, since most of the epigenetic deposits are in or close to these cataclastic zones. It seems that the cataclastic effects responsible for the development of the mylonite zones were sufficiently effective to reactivate the uranium already concentrated by the granitization in the granitized rocks, to put it into solution, and to make it available for transportation. This reactivation corresponds to the first major episode of redistribution at about 1,750 m.y. The cataclastic zones seem to have been the channelways along which the uranium was leached from the rocks by hydrolytic processes, transported probably in carbonaceous waters and deposited in its present position. These mylonite zones are naturally preferential zones of circulation, since as tectonically they are potentially active. That this is so is shown by the many cracks, fractures, faults, and breccias found in them that represent late movement along these zones and that are superimposed on the mylonitic rocks. These cracks, fractures, and breccias formed the dilatant zones in which uranium, dissolved from the earlier deposits by solutions mobilized as a result of this later tectonic activity, was deposited to form orebodies of the second major episode of redistribution, dated 1,240 m.y.

In summary, the events of mineralization or of mobilization and deposition are as follows:

1. Deposition of uranium-bearing sediments.
2. Mobilization of uranium and its concentration during granitization.
3. Remobilization of uranium and its concentration during mylonitization.
4. Remobilization and concentration during late fracturing, following the same zones of weakness as 3. The episodes of 3 and 4 have produced workable deposits, and they correspond to the two main episodes of uranium redistribution shown on Figure 16.

The mylonite zones are then not only transportation zones but also the loci of deposition, the deposition having taken place under the physico-chemical conditions described in the section on relation of deposits to structure and rock type. The deposits of both major episodes, having formed from solutions, naturally have all the characteristics of hydrothermal deposits. This hypothesis explains not only the variations in the intensity of mineralization throughout the Beaverlodge area but also the large range of absolute ages; each episode may have had a long and complicated history. The many tectural and structural variations of the deposits can also be attributed to the nature of the original rocks. In other words, this hypothesis by which the mylonite zones can be regarded as the source of the uranium, the loci of transportation, and the place of deposition, is a logical and practical one. It has already been suggested by Geoffroy and Sarcia (1958) for some deposits in France. The mylonitization is thus an index to mineralization.

Suggestions for Further Exploration

According to the views expressed in the earlier part of this chapter, further prospecting in the area and the exploration of the known occurrences, if and when more uranium is required, should be restricted to the mylonitized and brecciated zones and their immediate vicinity.

The mylonite zones to be prospected and explored should be those near major faults, such as the St. Louis, the Black Bay, and the Boom Lake, and possibly also the Fish Lake and Camdeck-Tom. Only such large structures will be deep enough to permit extensive circulation of mineralizing solutions and to allow the possibility for workable deposits to be formed.

The most favourable parts along the major faults are where subsidiary faults, much fracturing, shattering, and widespread brecciation are superimposed on the mylonitized zones and are in close association with rocks of several different types. As discussed earlier, the fracturing and brecciation provide suitable physical conditions for circulation and deposition, and the diversity of rock types provide chemical conditions that favour uranium precipitation. An additional encouraging circumstance is the presence of the source rock defined above, although these cannot always be recognized.

Also favourable, is the occurrence of the above-mentioned features in an area of highly granitized rocks of several rock types. Finally, rocks to be favourable should exhibit a pronounced retrograde metamorphism, that is, chlorite, epidote, hematite, and possibly albite (as an alteration product of more basic feldspar) and should be present in various amounts in all rock types.

As a general conclusion, the conditions mentioned may be found in places over the entire area north of Lake Athabasca, and it is very likely that regional investigations anywhere in this large area may show a relationship of deposits and mylonitic rocks (Beck, 1964) similar to that in the Beaverlodge area. This relationship is believed to be more than coincidental.

Description of Deposits

Deposits described in this section include only those that have been explored underground by drifts and crosscuts from a shaft or through an adit. All other deposits, those that have been investigated only by stripping, trenching, and/or diamond drilling, or have been recognized only by using a geiger counter, are not described or even listed here for the reason that all or most of them have already been described by Christie and Lang (Christie, 1953; Lang, 1952a and 1962). Most of the claims on the properties described here, except those on the Eldorado property, have lapsed since this was written.

Mines with Plants

Fay–Ace–Verna Mine

References: Allen (1950); Allen, Macdonald, and Smith (1954); Beaverlodge (1957); Buffam, Campbell, and Smith (1957, p. 223); Campbell (1957); Christie (1953, p. 93); Dawson (1956); Dudar (1957 and 1960); Eldorado (1960); Lang (1952a, p. 77; 1962, p. 153); Macdonald (1954); Macdonald and Kermeen (1956); Robinson (1955a, p. 19); Tremblay (1957b; and 1958b).

The Fay–Ace–Verna mine is operated by Eldorado Mining and Refining Limited (a Crown corporation wholly owned by the Canadian Government, now known as Eldorado Nuclear Limited), which has a large block of claims at the north end of Beaverlodge Lake. This block of claims, which extends northeasterly for a distance of about 6 miles from the lake to Donaldson and Raggs Lakes, is crossed by a major structural feature, the St. Louis fault. The Ace orebodies are on the northwest or footwall side of this structure whereas the Fay ore zones and the Verna orebodies are on the southeast or the hanging-wall side.

History

Several occurrences of pitchblende were found on these claims by P. St. Louis and E. Larum (two prospectors working for Eldorado) in 1946. The occurrence that became the Ace mine seemed to be more interesting than the others, for it was near a topographic feature that suggested the presence of a major fault, later named the St. Louis fault. Subsequent geiger-counter surveys, trenching, and diamond drilling done in the vicinity of this occurrence gave results encouraging enough to warrant underground exploration. The inclined Ace shaft was sunk in 1949 at an inclination of 50 degrees parallel with the St. Louis fault. This was followed by drifting, further deepening of the shaft, more drifting, and the opening of new levels.

By 1950 sufficient ore had been outlined to warrant going into production. A vertical five-compartment production shaft, the Fay, was collared and completed to a depth of 1,200 feet by 1952. A treatment plant with an initial capacity of 500 tons of ore a day, using a carbonate-leaching method, was designed and built in the vicinity of the Fay shaft. The acid-leaching method was added later on. Milling started in April 1953.

As a result of drilling to the east in the vicinity of Verna Lake, a third shaft, the Verna, was sunk in 1953 to a depth of 925 feet. These shafts were deepened later, and in 1962 the Fay reached a depth of 4,000 feet; the Ace 800 feet, and the Verna 1,350 feet. The three shafts served underground operations over a distance of more than 14,000 feet along the St. Louis fault. They are connected underground by two haulage-ways, one on the 9th level and one on the 13th, and still another is planned for the 19th level. In addition to these shafts and haulage-ways, the mine is served by an internal shaft, sunk in 1961 from the 6th to the 9th level, about 3,000 feet southwest of the Verna shaft in the hanging-wall of the fault. There are also several miles of drifts and crosscuts and twenty-seven levels in use or provided for. All mining operations at the end of 1962 were above the 15th level. The mill capacity has been increased to 2,000 tons of ore a day and has been running at or somewhat below this capacity since April 1957.

Total production at the end of 1965 amounted to 22,093,488 lb of U_3O_8 from the treatment of 5,873,505 tons of ore, averaging 0.23 per cent U_3O_8 a ton. Published ore reserves (proved and probable) were estimated in 1965 at 1,500,000 tons, averaging 0.21 per cent U_3O_8 a ton. In early 1962, about 4,000,000 tons of ore, averaging 0.23 per cent U_3O_8 a ton, had passed through the mill. Of this amount, about 5 per cent was custom ore.

Geology

The rocks in which the mines are found belong to the Tazin Group. In the area extending southwesterly from Ace Lake to Beaverlodge Lake, south of the St. Louis fault, they are overlain unconformably by two small synclinal areas of Martin conglomerate, arkose, and siltstone.

The most common Tazin rocks in the vicinity of the mines are hornblende schist, argillite, and quartzite (map-units 3, 4, and 5). Most of these rocks are fine grained and thinly bedded. Much of the hornblende schist is now highly epidotized and chloritized, and much of the argillite is a fine-grained, faintly schistose, chlorite–sericite rock. In part, the argillite carries much epidote. The quartzite is white to pink and grey, and much of it is feldspar-rich. All these rocks are feldspathized to varying degrees. They grade into one another along and across the strike and down dip, and locally it is very difficult to distinguish either the quartzite or the hornblende schist from the argillite. South of the fault, there are large areas of granitized rocks and granites. All the above-mentioned rocks are hematitized to varying degrees in the vicinity of the orebodies and are also extensively mylonitized and brecciated in the general area of the St. Louis fault.

Northwest of the fault, the hornblende schist, the argillite, and the quartzite outcrop as a belt that extends almost from Beaverlodge Lake to northeast of Verna Lake, a distance of about 20,000 feet. Rocks in this belt dip about parallel with the St. Louis fault. The Ace shaft is near the middle of the belt, and all the known ore zones in the footwall of the fault are in it. This belt is bordered on the southeast by the St. Louis fault and in all other directions it tapers out, grading into granitized rocks and granite, or having sharp contacts. Its thickness, which is about 1,200 feet on the surface near Ace shaft is fairly constant to a depth of about 1,200 feet. At this depth it narrows down appreciably to about 200 feet, which is maintained down to at least 2,200 feet.

This belt is made up of three units:

1. Against the fault there is a layer of siliceous rock, here called a feldspathic quartzite but known at the mine as 'feldspar rock.' This was traced all the way from the surface down to the lowest levels. Dawson (1956, p. 22) described this rock as an oligoclasite and pointed

out that most of it is highly mylonitized. It also appears to have been rebrecciated locally along the fault. This layer varies in thickness both along the strike and down dip, a variation which suggests rapid changes of facies from quartzite to impure quartzite and argillite. Here the rock is regarded as a feldspathized and mylonitized siliceous argillite or feldspathic and impure quartzite. The brecciated and shattered parts of this layer are partly mineralized and ore bearing. These parts contain some of the best types of orebodies, that is, the breccia and stockwork types.

2. North of and immediately below the quartzite or 'feldspar rock' layer is a fairly wide zone of thinly bedded, thinly to coarsely interbedded argillite and hornblende schist (map-unit 4). The hornblende schist appears to be the dominant rock type in this zone, but both rocks are so similarly altered and locally so closely alike in hand specimens or outcrops and so intimately mixed, that in most instances it is practically impossible to map them separately. This zone is almost 700 feet wide in the area west of Ace Lake and may be about 1,200 feet wide in the Verna Lake area. At surface the outcrop areas of this zone are lenticular. The zone was traced down to the lowest levels in the mine, but below 1,200 feet it is less than 200 feet wide. The contacts between this zone and the quartzite or 'feldspar rock' layer above, and also the contacts between the argillite and the hornblende schist within the zone, appear to be important loci of mineralization.

3. North of and below the above zone is another layer of quartzite (map-unit 3), interbedded locally with much chlorite schist. Both rock types, which are thinly bedded, grade north, east, and west into pink to red quartz–feldspar layered gneiss and metasomatic granite. As this layer of quartzite and schist has been entirely altered to layered gneiss and granite, it may be missing at depths greater than 1,000 feet.

Southeast of the St. Louis fault, in the area between Verna, Collier, and Fish Lakes, a wedge-shaped area of rock types similar to those described above was mapped. This area is regarded as the southward extension of the belt north of the fault. It is bordered on the northwest by the St. Louis fault. In it the rocks have the same characteristic features as those in the belt north of the fault except that they are somewhat coarser grained toward the east and that the quartzite in general is more glassy and less feldspathic. The succession is also slightly different; at least three layers of quartzite, possibly four, were mapped (many of the mine geologists refer to parts of this siliceous rock as zones of hydrothermal silica along faults). The lenticular masses of argillite and hornblende schist are bordered on the north and south by two of these quartzite layers. These grade to the north and south into granitic-layered gneisses and granites and pinch out gradually eastward into gneisses and granites. The Verna shaft is near the western end of this body, and the main ore zones (the Verna orebodies) south of the fault are within the belt of hornblende schist and argillite that outcrops about 600 feet east of Verna shaft and near its upper contact with quartzite. The ore zones, however, do not outcrop. At depth this belt is locally intensely chloritized, hematitized, feldspathized, and highly fractured, and it is in these altered rocks that the ore zones are found. Such altered rocks are known locally as 'ore rock.'

In the area south of the fault, extending from slightly west of Verna shaft to west of Fay shaft, all the rocks are granitized. These rocks are locally mineralized, but the extent of their mineralization is not completely known. So far, little production has come from them.

Structure

In the belt on the northwest side of the St. Louis fault, the general trend of the formations is northeasterly about parallel with the fault, which strikes N70°E and dips 50°SE near Ace shaft. The dip of the rocks, too, is about the same as of the fault, but it may be somewhat steeper near the surface and slightly flatter at depth, particularly at about 1,000 feet where a change in dip is indicated by the change in the thickness of the belt. This suggests a truncation of the formations by and along the fault down the dip. But on the outcrop both hornblende schist and argillite exhibit many flexures and intricate minor folds. Even a few of the quartzite beds 3,500 feet southwest of Ace shaft show minor folds. Lineation strikes southwest and plunges at around 45 degrees. On a larger scale, this belt is regarded as being on the southeast limb of the Ace Lake–Donaldson Lake anticline, whose axis passes about 4,000 feet northwest of Ace shaft. The flexures or drag-folds and the minor folds mentioned above are regarded as minor features on the limb of this major fold and are believed to be directly related to it and not to the fault. Many of the ore zones seem to occur in these minor structures.

In the wedge-shaped area southeast of the fault, the formations trend southeasterly to easterly. Where they are against the fault they are truncated at a sharp angle and trend southeasterly; away from the fault, or east of Verna shaft, their trend is mainly easterly. Readings on the attitudes of the formations at surface and underground by the mine geologists have indicated the presence of many flexures, rolls, and minor folds. An anticlinal structure trending about parallel with the fault and plunging southwesterly was traced in the underground workings from east of Verna shaft to at least 1,200 feet west of it. The south limb of this structure shows a complex succession of rolls or minor folds. All these features were interpreted as rolls or minor folds on the limb of the much larger, Ace Lake–Donaldson Lake anticline—the major structure north of the fault—which is believed to control the structure of this region. Some of the structures in the general Verna area, particularly those trending northwesterly, may be related to the Goldfields synclinorium (*see* structure section). All the Verna ore zones are related to the minor anticline described above or to other structures subsidiary to it. This minor anticline is "overturned to the north with the axial plane roughly paralleling the St. Louis fault." It is known to plunge 35 degrees southwest above the 5th level, to "flatten to 8 degrees between the 5th and 6th levels and to 'steepen' to 30 degrees between 6th and 9th levels" (Eldorado, 1960, p. 16).

In the vicinity of both the Ace and Verna shafts, the St. Louis fault varies slightly in strike, two broad bends being faintly indicated. In the Ace shaft area, sufficient underground work has been done to show that one of the bends corresponds to a broad convex bulge (Eldorado, 1960, p. 15) to the south that extends for a distance of about a mile from slightly east of Fay shaft to about the south end of Ace Lake. This bulge plunges about 50 degrees southwesterly. The bends in the strike of the fault and the bulges, if they occur at both places, are probably important structural features in the localization of all the structural features described below, such as the breccia zones against the fault, the shattered zones near the fault, and the joint-type fractures in both walls of the fault and a few hundred feet away from it.

Some of the quartzite ('feldspar rock') layer, against and northwest of the St. Louis fault in the Ace shaft area, is a mylonitized brecciated rock. These zones of mylonite and breccia grade into relatively massive rock in which the original texture of the rock is still visible or suggested. They are very irregularly distributed, and some of them appear to have been locally rebrecciated near the fault plane. Detailed underground mapping in the areas at the west end of Verna Lake, north of the fault and south of Ace Lake south of the fault, has shown that much of this mylonitized rock has been shattered over large stretches in the general vicinity of the St. Louis fault. These zones of rebrecciated and shattered mylonite are locally mineralized with pitchblende, some of the largest orebodies being in such zones.

Joint-type fractures were measured underground in both the Ace and Verna shaft areas (Eldorado, 1960, p. 15) and at surface by the writer in the vicinity of the shafts. Near

Ace shaft, four sets of fractures were recognized. Two sets strike about parallel with the St. Louis fault, one dipping between 45 and 70 degrees south, the other 20 to 35 degrees south. The other two sets strike about at right angles to the strike of the fault, one set dipping 80 to 90 degrees east or west, the second between 20 and 60 degrees west. These transverse sets of joints are probably later than the parallel sets as they offset them. The parallel joints are ore bearing. In the vicinity of the Verna shaft, fractures appear to be more common in the argillite–hornblende schist (unit 4) (Chamberlain, 1958). Two main sets were recognized, one parallel with the St. Louis fault in strike and dip, the other at right angles to it and almost vertical. The latter set partly follows the attitude of the formations, and near the fault they trend southeasterly. Fractures with other directions were recognized in this area but are minor features only. All the ore zones in the Verna area are associated with some of the fractures mentioned above.

Footwall Ore Zone

The ore zones so far found in the footwall of the St. Louis fault, that is, north of it, are distributed over a distance of 10,000 feet, from about 5,000 feet west of the Ace shaft to 5,000 feet east of it. All are within 300 feet of the fault; some are in the immediate footwall of the fault, but most are some distance away.

For descriptive purposes the ore zones in the footwall may be grouped as follows: 1, breccia type; 2, stockwork of fine fractures; and 3, vein type. All three types are accompanied by some pitchblende disseminated in the surrounding rocks.

Breccia ore zones are entirely within the brecciated and mylonitized feldspathic quartzite ('feldspar rock') layer against the St. Louis fault within the bulge in the fault plane mentioned above. Their plunge is about 50°SW (Fig. 23, *in pocket*) or about the same as that of the bulge. Their upper boundary is the non-radioactive gouge of the fault. Their other boundaries are generally gradational and are determined by geiger counter or visual inspection. The ore zones are composed of angular fragments of the mylonitized feldspathic quartzite ('feldspar rock') and pitchblende in fine grains disseminated in the matrix surrounding the fragments of the breccia or in the fairly large groundmasses forming it. The pitchblende is generally black and metallic, but some in the large masses is reddish brown and hematitic and contains many impurities, probably remnants of the matrix. The pitchblende is generally associated with chlorite, calcite, and quartz. Pyrite is also present in individual grains and veinlets and is fairly abundant locally. In width these orebodies "vary from 1 foot to 50 feet but average 10 feet" (Eldorado, 1960, p. 15). Their horizontal and vertical extent can be estimated on Figure 24. It is reported that they are cut by a few short, discontinuous pitchblende-filled fractures. Examples of these ore zones are the "01" and "06" orebodies, which are the main examples of breccia type ore in the Ace shaft area.

Stockworks may be a variety of the breccia ore zones. They are represented by the "44" ore zone located about 1,500 feet west of Verna shaft north of the fault, and by the "L" orebody south of Ace Lake south of the fault. The "44" orebody is entirely in feldspathic quartzite and consists of "fine fractures filled by pitchblende, calcite, pyrite, and chlorite" (Eldorado, 1960, p. 15). It is believed to be in a place where the feldspathic quartzite has been shattered and where it coincides with the location of a minor change in the strike of the fault at surface. This may indicate a bulge on the plane of the fault in the Verna shaft area. A few crystals of brannerite were apparently identified from this orebody. "This orebody is an elongated, wedge-shaped pipe dipping 50° southwest and raking 45° southwest. It pinches out 50 feet above 3rd level, enlarges to 60 feet wide by 250 feet long on 6th level and diminishes to 30 feet by 100 feet on 9th level" (Eldorado, 1960, p. 15). It has been recognized on the 13th level.

Vein type ore zones are mainly along fractures subparallel with the St. Louis fault, although a few have a lower dip. The transverse fractures are generally not mineralized, and some of the youngest displace the main ones of these ore zones. The vein type ore zones, like the other ore zone types are in the general area of the bulge in the fault. Their rake as a whole is between 30 and 60 degrees southwest, that is, parallel with that of the other ore zones and the plunge of the bulge. Some of these ore zones "consist of one well defined, irregular fracture with local diverging branches" (Eldorado, 1960, p. 15). Other ore zones are made up "of an interconnected network of subparallel veins spread over a horizontal distance of up to 200 feet" (Eldorado, 1960, p. 15). These ore zones are composed of pitchblende, calcite, chlorite, and locally a few fragments of the wall-rocks. They contain also variable (generally very small) amounts of pyrite, clausthalite, and nolanite. Figure 23 gives a rough idea of the size of these orebodies.

Robinson (1955a, p. 21), who made a detailed study of the mineralogy of the Ace mine, identified in trace or minor amounts the following additional metallic minerals: chalcopyrite, galena, bornite, ilmenite, marcasite, and sphalerite.

Hanging-wall Ore Zones

The known ore zones on the south side of the fault are distributed from an area about 2,000 feet east of Verna shaft to about 3,000 feet west of Fay shaft for a distance of almost 15,000 feet. The largest ore zones south of the fault are the Verna orebodies. All these are at least 400 feet away from the fault and are concentrated in an area extending 800 feet east of the Verna shaft to an unknown distance west of the shaft; exploration is not complete in that direction. They are in the wedge-shaped mass of argillite, hornblende schist, and quartzite south of the fault. They could be classified as combination vein and stockwork deposits, because they are all fracture controlled and because abundant minute mineral-bearing cracks permeate the fracture walls. There is also some disseminated pitchblende in the rocks immediately adjoining the cracks, almost all of which are in altered argillite. No ore shoots have been found in the hornblende schist, but rare small ones occur in the quartzite. In these orebodies pitchblende is associated with much carbonate and locally much pyrite. They are crossed by veins of cryptocrystalline quartz. For descriptive purposes they have been grouped into what is known locally as the 'Main Verna ore zone,' that is, orebodies associated with the steeply plunging part of the anticline as recognized in the underground workings, and the 'West Verna ore zone,' that is, orebodies associated with the more gently plunging part of the same anticline. The plunge of this anticline is slightly steeper in the east than in the west, as described previously under structure.

The Main Verna ore zone, located east of Verna shaft, does not extend above the 2nd level or below the 7th. The horizontal extent of this zone can be seen on Figure 23. It is entirely in the highly altered, faintly schistose argillaceous rocks. Here the ore occurs in sheets, lenses, and locally in complex irregularly branching and interconnecting masses. In plan, the area that encompasses the ore shoots, as seen on Figure 24a, is arc-shaped, concave northeasterly, and fairly thick at the apex of the arc. It is part of the anticline mentioned above. The west arm of the arc (note area) trends slightly west of north whereas its east arm trends about S60°E. In section the ore zone as a whole plunges 30 to 45 degrees at about S20°W. The sheets and lenses forming the orebodies appear to be mainly fracture-controlled. They are distributed in an *en échelon* pattern down the plunge and dip of the ore zone and intermittently along its strike. The irregular masses are at the apex of the structure and appear to be due to a complex system of closely spaced fractures striking in several directions. The dip and plunge of most ore shoots are in general fairly low, except at the apex of the structure where they dip and plunge much more steeply or vertically. The orebodies "range in width from three to 60 feet but average 15 feet . . . lengths are extremely variable but average 150 feet" (Eldorado, 1960, p. 16).

The West Verna ore zone is separated from the Main Verna by a narrow crosscutting zone of barren rock about 100 feet wide and is situated mainly west of the shaft. Although the West Verna orebodies do not extend above the 5th level, they were traced as far down as the 13th level (present bottom level in this part of the mine). They occur, as do the Main Verna orebodies, in highly altered faintly schistose argillaceous rocks, which are the extension of the Main Verna band. The ore similarly occurs in sheets, lenses, and pods. In plan, the ore zone follows the anticlinal structure, and the dip and plunge are also essentially the same as those of the anticline. The plunge of the zone as a unit ranges between 15 and 30 degrees southwest. The dip of the west limb is about 15 degrees, whereas that of the south limb is more variable, being flat to almost vertical due to rolls on the southeast limb of the anticline. In the West Verna ore zone the ore shoots are distributed in an *en échelon* fashion not only down the dip but also down the plunge of the fold. In width the orebodies vary "from 3 to 40 feet and average 10 feet; lengths are variable and reach 800 feet" (Eldorado, 1960, p. 16). Figure 23 gives an idea of the size of these ore zones.

In the West Verna ore zone a few minor fractures dip north instead of south. Their dip is about 55 degrees, which is much steeper than the dip of the main ore fractures in the West Verna in general. Some of these steeply dipping fractures are mineralized and locally form ore shoots, but most of them are small compared with the main ore shoots. They are generally short vertically but may be extensive along strike.

Other Ore Zones

All the other known ore zones south of the fault are under development. They are as follows: The "L" ore zone is in granitized rocks or granite, the Bolger orebody is in hornblende schist and argillite, and the Ura ore zones are in Martin basal conglomerate and granitized rock near the unconformity. The Bolger orebody is the only one east of Verna shaft; all the others are west of it.

The "L" orebody is probably the largest in this group. It is about 300 feet south of the fault, immediately south of Ace Lake. It is also near the eastern boundary of the bulge on the fault plane in the Ace shaft area. The deposit is believed to extend at least from the 9th to the 13th level. It consists of a network of fine fractures filled with veinlets and seams of pitchblende or with only a coating of it on the walls of the fractures. It appears to be of the stockwork type. The granitized rock in which it is found is a highly brecciated and mylonitized rock that appears to have been subsequently much fractured.

The Bolger orebody is similar to the Verna orebodies but appears to be small and shallow.

The Ura ore zones are of the fracture-filling type with some disseminated pitchblende in the immediate vicinity of the fractures. The fractures are horizontal to steeply dipping. Extending for short distances above and below the Martin–Tazin unconformity, they are concentrated in the trough of the unconformity.

Shipping Mines

Beta Gamma Mine

References: Christie (1953, p. 109); Lang (1952a, p. 81); Robinson (1955a, p. 13).

Beta Gamma Mine Limited, which owned this mine, was reorganized in April 1956. It became Consolidated Beta Gamma Mine Limited. In early 1959 the property was sold to

Lavant Mines Limited. The mine site is at the north end of Bellegarde Lake, 2½ miles north and west of Uranium City. By road it is almost 4 miles to Uranium City.

Acquired in the late summer of 1952, the property comprised the Chum group of forty-five claims. In the fall of 52 and the winter of 1953 the claims were prospected, with much stripping and some trenching. Eight radioactive zones were found. Some of these were drilled, and by the spring of 1953 the information gathered warranted the sinking of a three-compartment vertical shaft to test the No. 1 and No. 2 zones. The shaft was started in August 1953 and completed to a depth of 150 feet by the end of January 1954. A level was established. In 1954 and early 1955, about 1,500 feet of drifting and crosscutting was done in the area of No. 1 and No. 2 zones as well as further drilling. As the ore values were not consistent, work was suspended and the mine was closed down at the end of June 1955. All work at the property ceased in July 1955. In early 1959, Lavant Mines Limited reopened the shaft and dewatered the mine. Some mining was done and some ore was recovered, and when the mine was closed down again in November 1959, about 200 tons of ore had been shipped to the the Lorado Custom Mill.

In the vicinity of the mine, the rocks are mainly medium- to coarse-grained layered gneiss (map-unit 13), locally grading into red granite (map-unit 19). These rocks are traversed by a few dykes or sills of red granite, partly pegmatitic, and are locally mafic-rich. There are also a few narrow dykes of late gabbro. Much of the known mineralization appears to be associated with mafic-rich bands or zones in the gneiss or with the rock near late gabbro dykes.

The formations in the mine area trend northeasterly and dip steeply in either direction. In general the rocks are closely folded and much faulted and fractured. An anticlinal axis lies about 200 feet north of the shaft and a syncline about 200 feet east of it. A fault passes a few feet south of the shaft. It strikes northwesterly, west of the shaft; and about east, east of it. The dip appears to be steeply north. If the fold axes and the formations are traced south of the fault, they seem to be offset to the right and to indicate an apparent right-hand displacement along the fault. The fact that south of the fault the two fold axes are only 250 feet apart is an indication of much tighter folds south of the fault than north of it.

All the rocks in the mine area are much fractured. Fractures of the joint-type trend mainly N50°E, N75°E, N70°W, N45°W, and N15°W. Most of the dips are steep in either direction. The mineralization is commonly along some of these fractures, mainly those trending about N75°E.

On surface the No. 1 zone is about 150 feet south of the shaft and lies entirely south of the above-mentioned fault. The zone strikes about N70°E, or parallel with the formations, and dips steeply south. It is along the contact between red granitic layered gneiss on the north and garnetiferous quartz-rich granitic gneiss on the south. A late gabbro dyke also marks this contact for a hundred feet or so, immediately south of the fault. The zone itself is very narrow, mainly a fracture with some pitchblende, calcite, and chlorite along it. Although some radioactivity was observed for a few hundred feet along the zone, pitchblende was recognized only in a few places and is abundant only locally. The rocks near the fracture are generally altered deeply red.

The No. 2 zone is north of the fault and about 150 feet north of the shaft. Its strike and dip are about the same as those of No. 1 zone. The No. 2 zone is entirely in garnetiferous, quartz-rich granitic gneiss with granite phases locally. The zone is represented by several closely spaced fractures that branch, curve, diverge, converge, and die out in an irregular fashion. Many of the fractures contain some pitchblende, calcite, and chlorite. The distribution of pitchblende appears to be spotty, although some radioactivity was recognized along much of the fracture zone.

All the other zones are along fractures where radioactivity has been detected with geiger counters; no pitchblende was recognizable in outcrops. All these zones were stripped, and a few of them were trenched and diamond drilled, but in general the results were not encouraging.

In the underground workings the ore values are also reported to be erratic, and the only orebody encountered was a small one in No. 1 zone near the surface. The pitchblende in all these cases was along fractures subparallel with the mafic-rich bands of the gneiss and near mafic sills or dykes. It forms ore only where the fractures pass down dip from the granitized rock into the mafic-rich bands or the gabbro masses.

Black Bay Uranium Mine

Reference: Lang (1962, p. 163).

The Gretta group of fourteen claims owned by Black Bay Uranium Limited is south of Murmac Bay on Beaverlodge Lake. It is reached by boat or plane in summer and on the ice in winter. The campsite is half a mile east of the mine site. Both sites are on the shore of Murmac Bay and a road half a mile long connects them.

In 1953–54 the property was prospected, and the promising showings were trenched. One area, about 500 feet long by 100 feet wide and about 1,000 feet west of the shore of Murmac Bay and half a mile east of Kram Lake, warranted more exploration since trenching gave the following results; "45 feet by 3 feet, 0.47 per cent U_3O_8; 75 feet by 4.8 feet, 0.72 per cent U_3O_8; and 20 feet by 15 feet 0.91 per cent U_3O_8" (Lang, 1962, p. 163). An adit begun in 1954 was driven 560 feet to intercept this area at depth. Up to 6,000 feet of crosscutting, drifting, and raising were done on it, and a winze was sunk. A great deal of diamond drilling was also done from the surface and underground. As a result of all this, the zone was investigated to a depth of 500 feet. In 1956, when the operations at the mine were suspended, all the known ore had been mined. In 1958, 1,375 tons of stockpiled ore were shipped to the Lorado Custom Mill for a return value of $21,283.

The rocks at the mine site are white glassy quartzite (map-unit 6) overlain by amphibolite (map-unit 7) and quartz–biotite schist (map-unit 8). These rocks have been described with the Murmac Bay Formation. They trend mainly southeast and dip about 50 degrees southwest.

The quartzite–amphibolite contact in the mine area is wavy and irregular and shows much shearing and fracturing. At the mine site itself, the contact has the shape of a drag-fold (S-type) and plunges steeply to the southeast and south. All the orebodies found so far are closely related to this drag-like structure. Along the contact and for a short distance on both sides of it, the rocks are schistose and carry a fair amount of graphite Joint-like fractures are also common on both sides, all along the contact. These fractures trend in two main directions, N50°W and N60°E. A small group trending N5°W, as well as possibly another one trending about N80°W, was recognized. Although the dip of these fractures is mainly vertical, they may be as low as 45 degrees in either direction, but mainly south. Fractures trending parallel with the two main directions of strike are mineralized, but not to the same extent everywhere. Generally the fractures parallel in strike with the contact are best mineralized, except near the drag-like structure where fractures of both major groups carry some mineralization. Locally these mineralized fractures are spaced close enough to form small orebodies. These were mined during underground exploration.

Cayzor Athabaska Mine

Reference: Lang (1962, p. 164).

The Azor group of eighteen claims, owned by Cayzor Athabaska Mines Limited (now New Cayzor Athabaska Mines Limited), straddle almost all of Jean Lake. The mine site is about 1¼ miles northwest of Uranium City, but by road it is about 1½ miles from Uranium City or 6 miles directly from Bushell.

These claims were first prospected, surveyed by geiger counter, and trenched for W. N. Millar between 1949 and 1951. In 1951, Azor Mines Limited was organized to evaluate the most promising pitchblende occurrences. Some diamond drilling was then done to the east of the present mine site with very erratic results. In 1952 the claims were acquired by Cayzor Athabaska Mine Limited, and a program of diamond drilling was initiated on the ice of Jean Lake to investigate the ground under this lake and the swampy ground along the east shore of it, that is, to find the possible extension of the known showing at the present mine site. Several high-grade fractures were intersected; further drilling proved some continuity. In 1954, a three-compartment production vertical shaft was started and sunk to a depth of 670 feet. Four levels were also established. A contract was obtained with the Lorado Custom Mill whereby the mine agreed to supply the mill by February 28, 1962, with ore containing a total of 2,909,000 lb U_3O_8. Production and shipment of ore started in May 1957. As a result of difficulties in finding ore due to the erratic nature of the ore zones, shipments to the mill were not constant and were somewhat lower than anticipated. In the hope of finding more ore, the shaft was deepened in 1959 to 900 feet, and two new levels were added. In November 1959, however, Lorado served notice to Cayzor of default in its ore shipment. In March 1960 an agreement was reached, satisfactory to both Lorado and Cayzor, whereby Lorado sold its contract. All operations at the Cayzor mine were suspended. By April 1960 the mine was closed. Altogether 90,391 tons of ore containing 484,686 lb U_3O_8 were shipped from the mine.

In the mine area, the rocks are mainly granitized chlorite–sericite schist and quartzite (map-unit 17), both interlayered with, and grading imperceptibly into, each other. Locally there are bands of a dark green amphibolite and of a coarse-grained white to red granitic rock. All these rocks were probably sediments and have been described with map-unit 17. The ore zones are in both the granitized chlorite schist and the impure quartzite.

The trend of the formation is N50°E, and the dip is steeply southeast. In general, the formations are regarded as being on the northwestern limb of a major syncline whose axis trends northeasterly and passes about 1,000 feet southeast of the shaft with probable overturning of the fold to the northwest.

The wide mylonite zone northwest of and along the Black Bay fault does not include the mine area, but as the mine lies in the margin of the zone the rocks show some brecciation in thin sections. Two prominent easterly trending faults were recognized and traced in the mine area. One passes about 200 feet south of the shaft, the other about 2,000 feet south of it. It is possible that they bear some relationship to the mineralization since all ore zones lie in the area between the two faults and in the immediate vicinity of the first one. The so-called 'Jean Lake shear,' mapped apparently in the underground workings of St. Michael mine to the south of this property, was not recognized at the Cayzor mine. Its assumed extension under the waters of Jean Lake was drilled but without success.

Joint-type fractures are common in the area, and all the known ore zones are related to them. Three principal sets were recognized, striking northwest across the formations, northeast parallel with the formations, and easterly. The northwesterly fractures dip in both directions; the fractures striking in the other directions dip mainly south. Dips are at all angles but mainly between 40 and 80 degrees. Most fractures do not extend far along strike or down dip, and very few keep a constant dip. A fracture traced on one level is rarely found on the level above or below. Only one fracture, known locally as the No. 17 zone, was traced from surface down to 550 feet. Fractures are tight, although gouge and a little graphite are generally present. Most of them are represented by several closely spaced slips. The rock between the slips is somewhat more schistose, but it is still the granitized chlorite schist and impure quartzite with impregnated pods, pockets, and lenses of granite. Narrow veins of pink carbonate may be present along certain slips, but some in the No. 17 zone are a few feet wide.

All ore zones occur along fractures of the three sets. They are generally small but may be 300 feet in length. They consist of pitchblende and some thucholite, forming pods, pockets, and lenses along the fractures. They are generally less than 2 inches thick and commonly no more than thin films or seams on slip planes. Zones of closely spaced slips may be up to 12 feet wide. Ore zones are generally very irregular and erratic along the fractures; the most continuous are those at the intersection of two fractures. Carbonate is generally present with the pitchblende, but the red alteration, so common in the ore zones of the Beaverlodge area, was rarely observed. The No. 17 zone is the only one that has some red alteration and it also contains much more carbonate.

Eagle–Ace Mine

References: Christie (1953, p. 109); Lang (1952a, p. 92; 1962, p. 165); Robinson (1955a, p. 38).

Nesbitt Labine Uranium Mines Limited, which owned the Eagle–Ace mine, was amalgamated in November 1960 with Gunnar Mines Limited, and both are now known as Gunnar Mining Limited. The mine site is about 1,500 feet south of Eagle Lake, or 4½ miles due east of Uranium City. By road, it is 7½ miles to Uranium City and about 2 miles to the Eldorado townsite to the south.

The property includes the JAM-MAJ group of eighteen claims and extends south and east from Eagle Lake to Ace Lake. The claims were staked in 1949 by J. Nesbitt. They were acquired in 1950 by Nesbitt Labine Uranium Mines Limited, which prospected them extensively in 1949 and 1950. Several uranium occurrences were found, three of which, known locally as the Riley zone, the Eagle Lake zone, and the No. 3 zone, were promising. A three-compartment shaft was begun in November 1951; subsequently two levels were established. Underground exploration was carried on through 1952–53. In 1953–54 the shaft was deepened to 640 feet, and two new levels were added. Some continuity in the ore zones had been encountered above the 2nd level, but below it very little ore was found. When the operations were suspended in June 1956, all the known ore had been mined. While the exploration was going on, the ore was stockpiled on surface, and when a contract with the Eldorado Custom Mill was obtained in 1954, about 20,000 tons of ore were shipped from September 1954 to the end of 1955, when the contract expired. In 1959 leasers shipped to the Lorado Custom Mill about 280 tons of fairly high grade ore from the dump and showings near the mine site. The mine is still inactive.

In the mine area, the main rock types are hornblende schist, argillite, slate, and quartzite, described previously as map-units 3 and 4. They are underlain by granite and gneiss, and in the shaft area a stratigraphic thickness of at least 640 feet of them was crossed. Stratigraphically, at the top is a thick layer of hornblende schist, which is underlain by a thick succession of interbedded and thinly bedded slate, argillite, and hornblende schist. Below that, is a glassy white quartzite, which passes gradually into granite and gneiss below. This great thickness of hornblende schist, argillite, slate, and quartzite is near the eastern margin of a large remnant of relatively ungranitized sediments and tuffs. On a large scale this remnant may be regarded as a flat-lying mass, but within it the rocks are both openly and tightly folded and extensively fractured. About 1,000 feet west of the shaft a synclinal axis was traced from Eagle Lake southwesterly for almost 4,000 feet. An anticlinal axis was also located a few feet east of the shaft; it is possibly a major drag-fold on the eastern limb of the syncline. All the ore zones investigated are within the area bordered by the two fold axes.

The contact between the thick layer of hornblende schist and the succession of interbedded slate, argillite, and hornblende schist below it may be a fault. Referred to at the mine as the 'Eagle fault,' it passes close to the shaft on the surface. It dips about 50 degrees northwest near the surface but flattens rapidly at depth or rolls with gentle undulations in the rocks on either side of the contact. These undulations, regarded as minor folds or drag-folds, plunge gently northeasterly. This fault contact (?) is believed to bear some relation to the ore zones, as it is mineralized for several feet along the strike on surface.

About 200 feet west of this contact and southwest of the shaft, a thin layer of quartzite was mapped within the upper thick layer of hornblende schist with which it appears to be interbedded. Locally somewhat schistose, it is known in the mine as the 'Riley shear.' It pinches out to the north but may extend south into the Eldorado ground. This shear may also bear some relationship to the ore zones.

All the rocks in the general vicinity of the shaft are traversed by numerous fractures of the joint-type. The main directions of these fractures, as measured in the field, are: N50°W, N45°E, N65°W, N10°E, N85°E, and N15°W. Their dip is steep to vertical, but a few of them tend to flatten at depth. The fractures trending N50°W and N45°E and lying between the two fold axes are locally mineralized, particularly near the 'Eagle fault' and 'Riley shear,' and where they cut the argillite and the slate, but not the hornblende schist. In general the mineralization is very erratic, and it is only in a few places that it makes ore. Most of the orebodies are small but have been reported to reach a length of 150 feet locally. In thickness they are up to 12 inches and are confined to the fractures. Within the fracture they consist of narrow zones made up of carbonate, blocks of wall-rocks, pyrite, hematite, chlorite, and pods and stringers of pitchblende. Quartz is also present. Robinson has identified the following additional minerals: chalcopyrite, bornite, and magnetite, and traces of galena, covellite, and tin. There is very little, if any, red alteration near these ore zones and fractures. In summary, these deposits are of the vein-type with carbonate filling.

Lake Cinch Mine

References: Christie (1953, p. 92); Lang (1952a, p. 92; 1962, p. 166); Robinson (1955a, p. 15); Turek (1962).

In 1960, Lake Cinch Mines Limited became Dickenson Mines Limited. The Jam group of eight claims owned by the company covers almost all of Cinch Lake and extends for a short distance to the southwest of it. The mine site is near the shore and at the southwest end of the lake and is 2½ miles in direct line from Uranium City, 3¼ miles by road.

The claims were staked in 1948 for Charles Swenson, who sold them in 1950 to Cinch Lake Uranium Mines Limited. In 1951–53, they were optioned to Mining Corporation Limited, which had the property mapped in detail and a few showings thoroughly diamond drilled. As a result of this work, a few small high grade orebodies were outlined south of the Crackingstone River. In October 1954, Lake Cinch Mines Limited, controlled by Violamac Mines Limited, took possession of the property and did 22,500 feet of diamond drilling on two promising showings north of the Crackingstone River. Results warranted the sinking of a vertical production shaft. The shaft was started in September 1955 and sunk to a depth of 548 feet. Two levels were established. Shortly afterwards, a contract to ship 1,500,000 lb U_3O_8 in ore by February 28, 1962, was obtained with the Lorado Custom Mill. Production and shipments began in May 1957. In 1958, the shaft was deepened to 867 feet and again in

1959 to 1,080 feet. By then, four new levels had been established. In March 1960, production stopped as a result of the termination of the contract with the Lorado Mill, which had sold its contract to Eldorado. The mine was closed, and all operations were stopped in May 1960. From May 1957 to the time the production stopped (March 1960), 731,257 lb of U_3O_8 were produced from 139,205 tons of ore mined. Ore reserves have not been published.

The rocks in the vicinity of the shaft are mainly granitic and quartzitic layered gneisses (map-unit 17) of probable sedimentary origin. A wide belt of quartzitic layered gneiss, locally resembling a foliated granite, was seen about 400 feet north of the shaft in contact with chlorite-bearing granitic layered gneiss on the north. South of the shaft it is in contact with a belt of granitized chlorite schist. The north contact of this quartzitic gneiss is about 1,400 feet north of and below the Black Bay fault. At depth the quartzitic gneiss near this contact is coarsely interbanded with some granitic gneiss. It is near this contact and north of Crackingstone River at depths greater than 200 feet and within the area of coarse interbanding that all the ore zones mined have been found. All the rocks of this area are coloured red with hematite, and near the ore zones they are bright red to chocolate-red.

Near the shaft the general trend of the formations is northeasterly about parallel with the Black Bay fault, which there strikes N45°E and seems to bend sharply to the east in the Cinch Lake area. The Black Bay fault on this property separates the Martin Formation on the south from the Tazin rocks on the north. The dip of the formations is steep in either direction, but underground it appears to be mainly southerly. Although no top determinations were made in the mine area, there are indications that this area is on the southeast limb of a syncline whose axis passes about 800 feet north of the shaft and trends about parallel with the formations. A broad flexure in the form of a large drag-fold (S-type) was mapped about half a mile northeast of the shaft. Although in the mine area this flexure was not recognized, it appears to have given way to numerous sheared zones and fractures. The ore zones are associated with some of these shears and fractures. Also, the area as a whole is within the wide mylonite zone near the Black Bay fault. The rocks show widespread cataclastic effects, and many are mylonites. The ore zones are within these cataclastic rocks and probably where the rocks have been refractured or rebrecciated.

Two main faults, the Crackingstone River fault and another one about 500 feet north of it, were mapped north of and near the shaft. The Crackingstone River fault strikes N75°E, dips about 80°SE, and is a wide zone of shearing and alteration that appears to converge easterly into, and merge with, the Black Bay fault. The other fault strikes about east, dips south, and probably also merges easterly into the Black Bay fault. Several minor faults between the two main ones were followed underground. The known ore zones are associated with them. One of these faults is known locally as the 'Main Ore fault;' the others are steeply dipping fractures extending from the Main Ore fault toward the Crackingstone River fault and striking east to southeast (Fig. 24). The Main Ore fault is parallel with the Black Bay fault, converges westward into the Crackingstone River fault, and dips from 45 to 70 degrees southeast. It is approximately along the north contact of the wide belt of quartzitic gneiss. This fault is really a zone of intense fracturing, made up of chloritic masses, large blocks of granitized rocks, granite patches, and several slip planes. Within the Main Ore fault zone is a 2- to 10-foot band of dark red mylonite, and it is through this rock that the pitchblende is disseminated in fine feathery spots and rims. Calcite, chlorite, and abundant reddish brown earthy and specular hematite are intimate associates of pitchblende. Along strike this ore shoot, having been traced from slightly below the first 300-foot level to an unknown distance below the 500-foot level, is at least 300 feet long and at least as long down dip.

The steeply dipping fractures are probably tension cracks, now made up of fragments of the wall-rocks cemented together with specular hematite, carbonate, and pitchblende. The

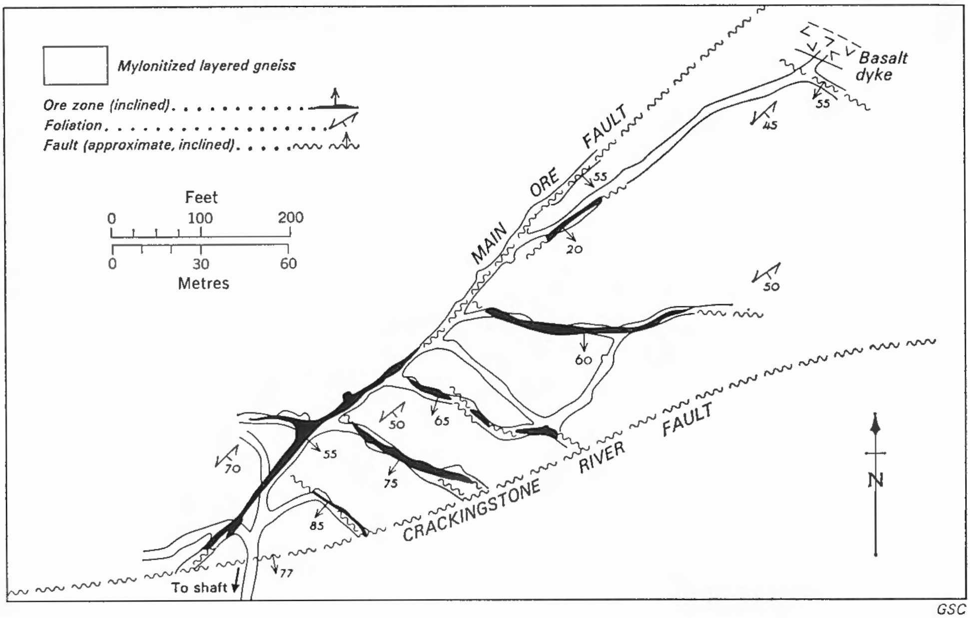


FIGURE 24. Second level, Lake Cinch Mines Limited. Prepared from a figure in booklet "Beaverlodge 1957" (p. 45) and from mine information. Size and shape of ore zones may not be accurate.

pitchblende "ranges from microscopic, to irregular veinlets and breccia fillings, ½ inch in width . . .Ore shoots range between 1 foot and 7 feet in width and between 50 feet and 250 feet in length" (Beaverlodge, 1957, p. 45).

Martin Lake Mine

References: Allen (1950); Buffam (1957, p. 232); Christie (1953, p. 104); Dawson (1956); Lang (1952a, p. 99; 1962, p. 167); Robinson, (1955a, p. 28).

This property is owned by Eldorado Mining and Refining Limited. It was the first uranium deposit developed in Saskatchewan. The property straddles the narrow strip of land that separates the northern part of Martin Lake from Beaverlodge Lake.

The original mine site is on the east side of Martin Lake, toward the south end of the narrows that connect the two halves of the Martin Lake. The site is 2½ miles southeast of Uranium City and may be reached by plane on floats or by canoe. Another mine site on the Beaverlodge Lake side of the property was established in 1954. It was connected to the original mine site by underground work and also to the main Uranium road by a spur road. This new mine site is only 2 miles by road from the Eldorado townsite.

In 1946 pitchblende mineralization was discovered on this property. The discoveries were trenched in 1947, and the presence of five veins was indicated. In 1948 an adit was driven from the east side of Martin Lake northeasterly. This underground work (the first on the property) was followed by much drilling. In 1952–53 by connecting the original adit to a new one started on the west shore of Beaverlodge Lake it was possible to reach the original mine site by both road and underground workings. In 1954 trial stoping was commenced, and some shipments were made to the Eldorado Custom Mill. This work showed, however, that large scale mining was not possible, and the operation was discontinued. Altogether, about 6,500 feet of underground work was done on this property.

The rocks in the vicinity of the mine sites are amygdaloidal and porphyritic basaltic flows (map-unit 23) intercalated with arkose (map-unit 22) and minor conglomerate. They trend north-northeast and dip about 50 degrees northwest. They are on the east limb of the Martin Lake syncline and about 6,000 feet east of its axis. Faults trending easterly to north-easterly, across or at an angle to the formations, are abundant in the area of the uranium mineralization. They dip about 50 degrees south and on them "displacements have all been dip-slip and rarely exceed 100 feet" (Buffam, *et al.*, 1957, p. 232). Slight flexures, of local extent only, in the trend of the rocks were observed and are the result of movement on these faults. There are also in the area many joint-type fractures. These strike mainly N35°E, N60°E, N60°W, N15°W, and due east. Most of them have dips steeper than 55 degrees in either direction. As the fractures and faults trending N35°E displace the others, they are the youngest.

The mineralization occurs entirely along faults and joint-type fractures. It is fracture filling, and most of it has been found where the fractures cross volcanic rocks. It is rare along fractures in the Martin arkose or conglomerate.

Mineralization consists mainly of pitchblende and carbonate with minor quartz and chlorite. The pitchblende is not uniformly distributed along the fractures and faults but is concentrated in pods and lenses. Smith (1952) believed that the pitchblende occurs not along the main faults and fractures, but rather along minor shear planes within the fault zone that dip parallel with the main fault. For a few inches to a couple of feet from the fractures the wall-rocks are stained red with hematite and are also widely carbonatized with disseminated grains of calcite. Other minerals reported from the veins or the fractures are hematite, umangite, berzelianite, klockmannite, clausthalite, chalcopyrite, bornite, native copper, and barite (Robinson, 1955a, p. 29). These are found in minor to trace amounts.

National Explorations Mine

References: Lang (1962, p. 170); Robinson (1955a, p. 36).

National Explorations Limited acquired the Pat group of twelve claims in 1951. These claims straddle the southwest end of Donaldson Lake, and in a straight line they are 6½ miles east of Uranium City and 3½ miles northeast of Eldorado townsite. They are connected to the Eldorado road by a truck road 3 miles long. By road the mine site is 11 miles from Uranium City and 5½ miles from the Eldorado townsite. The living quarters are at the west end of Foot Bay on Donaldson Lake, about one mile south of the mine site.

In 1951, the claims were explored using geiger counters, and the best occurrences were trenched and a few were diamond drilled. In 1952, the 'C' showing having proved most encouraging, an inclined shaft was sunk on it to a depth of 40 feet. By 1954, enough ore apparently had been outlined by underground explorations from the inclined shaft to warrant sinking a three-compartment production vertical shaft. This shaft was started in September 1954 and sunk to a depth of 360 feet. Three levels were established. Production started in 1955 and was intermittent up to October 1958, when ore was exhausted and the mine was shut down. From August 1955 to early 1956, 2,000 tons of ore carrying 0.22 per cent U_3O_8 were shipped to the Eldorado Custom Mill. No shipments were made in the remaining part of 1956. From January 1957 to October 1958, when the mine was closed, 26,759 tons of ore with a content of 134,677 lb U_3O_8 were shipped, mostly to the Lorado Custom Mill.

At the mine site on the 'C' showing, the main rock is a coarse-grained, grey, massive and foliated, granitic rock, probably derived from quartzite by granitization and described previously as the Donaldson Lake gneiss (map-unit 2). There are also narrow layers and small lenses of a dark green amphibolite and belts of the Foot Bay gneiss (map-unit 1). Most of the ore zones are associated with rocks resembling the Foot Bay gneiss.

The trend of the formations about the shaft is N45°E, and the dip is 65° SE. Broadly, these formations are on the northwest limb of a northeasterly trending syncline that plunges to the southwest and whose trough is about 700 feet southeast of the vertical shaft. Variations in the strike and dip of the foliation were noted locally. Although no marker beds were traced, these variations in strike and dip are probably flexures or crenulations and drag-folds or minor folds on the limb of the syncline. The drag-folds plunge to the southwest.

Fractures of two types, shallow-dipping and steep-dipping, were recognized in the mine area. Two of the shallow-dipping fractures, known locally as 'the upper shear' and 'the lower shear,' are of some significance and have been traced underground. At surface the upper shear is known as the 'C' showing and was traced along the side of an east-facing cliff, where it appears as a pronounced rusty sheared zone. This shear, as indicated by underground workings, strikes northwest from east of the shaft to a point north of the shaft, where it swings westerly. Its dip is between 20 and 35 degrees south. The lower shear strikes northwest and dips 20 degrees southwest. These two shears are generally less than a hundred feet apart. Locally, they converge and may stay parallel for a fair distance before they diverge again. The band between these two shears, where they are close to each other, trends southeasterly and plunges 15 degrees southwest. The two shears are actually zones characterized by numerous narrow veins of carbonate, lenticular masses of country rocks, and irregular layers or streaks of chloritic material with some graphite and gouge. They are generally narrow and locally may be tight. Their traces in detail are very sinuous. The main ore zones are found along these two shears, particularly where they converge and are parallel.

The steep-dipping fractures are probably of the tension type and were noted above, below, and between the two shears. They are tight fractures that strike easterly and dip between 55 and 80 degrees south and west. A few ore zones were found along them.

The ore zones along the shallow, steep-dipping fractures rake either with the dip of the fractures, that is, gently or steeply south and west, or with the plunge of the band between the two shears. They consist of concentrations of pitchblende, gummite, and some pyrite with traces of chalcopyrite and galena (Robinson, 1955a, p. 36) in pods, pockets and lenses. These concentrations are irregularly distributed along the length of the fractures, and their location may be structurally controlled. Locally, particularly in some of the shallow-dipping fractures, the pitchblende may also be disseminated for a short distance in the adjoining rock. Late quartz streaks were noted. The orebodies vary from a foot to 4 feet wide and are as much as 125 feet long.

Underground the two shears are along zones of red granitic layered gneiss. They probably follow layers of rock that could fracture and shear more readily than the adjoining layers. Near the ore zones this red gneiss has become dark red to chocolate-red due to intense hematitization. If these zones or layers of reddish gneiss represent original layers, then there is a relationship between the shears and the minor folds and flexures found along the foliation planes. Consequently, there probably is also a relationship between the flexures along the shears and the location of the ore zones on them.

A short adit was driven in 1957 on an easterly trending fracture on the west shore of the narrows connecting the main part of Donaldson Lake to Foot Bay.

Rix Mine

References: Christie (1953, pp. 115–116); Lang (1952a, p. 82; 1962, p. 173); Robinson (1955a, p. 44).

Rix Athabasca Uranium Mines Limited owns a large group of claims west of Uranium City. The claims extend northeasterly for 5 miles from Black Bay on Lake Athabasca almost to Jean Lake.

Radioactive occurrences were first found on these claims in 1949. Four promising occurrences, including the Smitty showing and the Leonard fractures, were investigated by trenching and diamond drilling. In early 1951, a 381-foot adit was driven on the most promising fracture of the Leonard system. However, more encouraging results on the Smitty showing shifted the interest to it, where a three-compartment vertical shaft was sunk in late 1952. Later two levels were established. In 1953, sufficient ore had been outlined to warrant production. No treatment plant was planned, but a contract to ship ore to the Eldorado Custom Mill was negotiated. When Rix began shipment of ore at the rate of 100 tons a day in April 1954, it became the first privately owned Canadian uranium producer. In 1956, the shaft was deepened, and two new levels were added. In 1957 it was deepened again to a depth of 760 feet and by the end of 1957 was servicing seven levels. Late in 1959 or early 1960, the mine was closed due to depletion of ore. A small part of the ore mined came from ground belonging to Goldfield Uranium Mines Limited, that is, from that part of the ore zone west of the Boom Lake fault.

On the Leonard showing, a small and very high grade ore shoot was mined in 1955 from and above the adit level. This work indicated that exploration of this system of fractures at depth was warranted. Accordingly, in 1956 the adit was widened near the entrance, an internal shaft was sunk, and two levels were opened. In 1959, the Leonard shaft was deepened to 872 feet, and two new levels were added. As a result of an agreement with the Lorado Custom Mill, and this was in addition to the contract already existing with the Eldorado Custom Mill in regard to the Smitty deposit, shipment of ore to the Lorado mill was initiated in February 1958. All exploration stopped at both shafts in 1960. In May 1960, as the ore was depleted or almost so, the mine stopped production and shut down shortly afterwards.

During the period the mine was in operation, 283,075 tons of ore were shipped for a value of $7,265,137, the average grade of which has been estimated to be slightly over 0.20 per cent U_3O_8. Most of this ore came from the Smitty showing.

In 1959, "under a royalty payment basis, Rix made arrangements with several independent leasers to allow them to mine several small but high-grade surface showings on the Rix claims. The leasers shipped a combined total of 566 tons of ore to the Lorado Custom Mill" (Griffith, 1960, p. 37). None of these small showings turned out to be large deposits.

Smitty Showing

The main mine buildings are situated near the Smitty shaft. The mine site can be reached by road, a distance of 6 miles from either Uranium City or Bushell on Lake Athabasca.

The geological formations in the Smitty shaft area belong to map-unit 15. They are mainly chlorite-bearing granitic layered gneiss, with narrow bands of amphibolite and hornblende–feldspar gneiss, and a few layers of quartzitic layered gneiss. All were once sedimentary and tuffaceous rocks. They are all of various shades of red due to disseminated hematite powder. In and near the ore zones they are coloured dark red to chocolate red and are generally impregnated with fine carbonates.

The trend of the formations is N30°E, and the dip is steeply southeasterly, but locally it is steeply northwesterly; this may be an indication of local rolls in the formations and possibly tight close folding. Broadly, the formations are believed to be on the eastern limb of a syncline whose axis in the mine area is probably to the west of the shaft and is truncated to the north by the Boom Lake fault. Drag-folds and crenulations were noted at several places in the rocks southwest of the mine area; they indicate a northeasterly trend and a plunge of about 30 degrees southwest. This plunge is believed to be that of the syncline. It is also the rake of the known ore zones in the mine. A plunge to the northeast, however, was noted on drag-folds slightly east of those mentioned above and may be related to an anticline slightly east of the Smitty shaft.

Several faults are known near the shaft. Two of them, the Smitty fault and its assumed western extension, and the Boom Lake fault are important features.

The Smitty fault is a tight fracture with a few inches of grey to red gouge and also locally some adjoining schistose chloritic material. Locally along the strike and down the dip, it splits into several closely spaced tiny fractures. Its strike is between N30° and 60°W, but in detail it may be very wavy. It dips 30 to 40 degrees southwesterly. About 200 feet east of the shaft the fault appears to swing easterly, to branch and fan out and to give rise to a set of minor fractures all dipping between 40 and 70 degrees southeast. The explored part of the Smitty fault extends from 400 feet east of the shaft, at least to the Boom Lake fault west of the shaft, and, so far, to a depth of about 500 feet. This fault is a strong feature above the 2nd level. On the 1st level, at a point about 260 feet west of the shaft, it is apparently cut by the Boom Lake fault, and its western extension appears to have been displaced northward for a distance of about 450 feet. This western extension was traced westward for about 300 feet and down dip for about 700 feet. It has a similar strike and dip to the Smitty fault. Although the Smitty fault itself, its western extension, and the rocks for a few inches near both features are only weakly or not at all radioactive, most of the ore zones follow these fractures very closely. The rocks near the Smitty fault and its assumed western extension are intensely and widely brecciated and mylonitized. These mylonitized rocks extend for an unknown distance away from the fault and its extension, and they are locally finely and closely fractured or shattered. Although the mylonitized and brecciated rocks are closely associated with the Smitty fault and its western extension, there does not appear to be any genetic relationship between them, for the Smitty fault and its western extension cut the mylonite in a very irregular way. The Smitty fault and its western extension are probably late features, and the fine fracturing or shattering imposed on the mylonite or breccia is also a late feature, perhaps produced by the same deformation as produced the Smitty fault.

Since the mylonitized and brecciated rocks are the loci for most of the ore zones in the area and since the ore zones are known to trend and plunge about parallel with the drag-folds measured on the surface southwest of the shaft, the mylonitized zones may have about the same attitude as the drag-folds; consequently they may be related to them rather than to the Smitty fault and its western extension. These rocks would thus follow the trend of the folds and may indicate beds of a particular competency or nature.

The Boom Lake fault is a zone of shearing and fracturing at least 140 feet wide in the mine area. It strikes N40°E and dips about 65°SE near the surface down to 250 feet and about 30 degrees at a depth of 500 feet. A few small ore zones conforming in strike and dip to the attitude of the fault were found in this structure below the 250-foot level.

The ore zones in the Smitty area are known locally as the original Smitty ore zone and the Smitty western extension ore zone. The original Smitty ore zone is entirely east of the Boom Lake fault and was traced from the surface down to the 2nd level. It was not found below this level. Three relatively small shoots, all closely associated with the Smitty fault, were mined in this area.

The Smitty western extension, having been traced from the surface down to the 4th level, was the most profitable ore zone. It lies west of the Boom Lake fault.

The ore zones are of two types: stockworks of fine fractures with much disseminated pitchblende in the adjoining rocks and vein type deposits. The stockworks are associated with the Smitty fault and its western extension and are the more important type. In shape they are flattened pipe-like bodies that trend about S15°W and rake about 35°SW. They may be up to 800 feet long down dip, 300 feet wide along the strike of the Smitty fault, and at least locally 30 feet thick.

The ore zones are made up of pitchblende and gummite, filling an irregular network of tiny cracks or fractures in a mylonitized or highly brecciated rock with much pitchblende disseminated in the rocks adjoining the cracks. The mylonitized rock is dark red due to abundant hematite, and there is also abundant carbonate and chlorite in the mineralized zone. Other metallic minerals recognized include pyrite, chalcopyrite, sphalerite, and galena. None of these is abundant but all occur locally in small blebs.

The ore zones in the Boom Lake fault are small and lenticular and consist of pitchblende and carbonate filling tight fractures. They are of the vein type.

Leonard Fractures

This deposit is 3,800 feet southeast of the Smitty showing, on the road leading to the main mine site. By road it is about a mile southeast of the Smitty area.

This showing is within map-unit 16 and at a place where the amphibolite is interlayered with abundant granitized siliceous rocks and red granite or pegmatite dykes and sills.

The formations trend northeasterly and dip steeply east. They are traversed by many tight fractures, one set of which trends westerly and dips steeply south to vertical. The original showing consisted of seven such subparallel, closely spaced fractures, all radioactive to varying degrees. Only one, however, the No. 1 fracture was thoroughly investigated.

The deposit is of the vein type. The pitchblende, which is mixed with carbonate, quartz, chlorite, and fragments of the wall-rock, occurs along the fracture. It is also disseminated for a few feet in the wall-rock of the vein. Thus, the small ore shoot mined above the adit consisted of several closely spaced radioactive fractures over a total width of 30 feet, a length of 40 feet, and a vertical distance of 110 feet. In general, the distribution of radioactive minerals is erratic along these fractures, and where they are sufficiently concentrated to constitute ore the orebodies are small. The principal ones appear to be mainly in the siliceous rocks, not in the amphibolite.

From this deposit, Robinson (1955a, p. 44) recognized galena, chalcopyrite, hematite, and pyrite, in addition to pitchblende. Dolomite, calcite, and quartz were also identified.

St. Michael Mine

The St. Michael deposit is 1½ miles due west of Uranium City, or about halfway between Cayzor shaft and Leonard adit (Rix). The mine site is 2½ miles by road from Uranium City. In September 1958 St. Michael Uranium Mines Limited became Cadamet Mines Limited as a result of a merger of the original owners with three other companies.

The Raz group of seven claims was acquired late in 1954 by St. Michael Uranium Mines Limited. Prospecting by trenching and diamond drilling was done in 1954 and 1955, and several mineralized zones were intersected. Thirty-three intersections gave an average value of 0.4 per cent U_3O_8 over 1.55 feet of core. In September 1955, a three-compartment production shaft was started, and in early 1956 it was completed to a depth of 427 feet. Two levels were established, and during most of 1956 about 7,000 feet of drifting and crosscutting, as well as some raising, was done on both levels to assess the values obtained from the surface drilling. In the meantime a contract to ship ore to the Lorado Custom Mill was obtained, and a mining plant was installed. Late in 1956, due to inconclusive results from the underground work and the lack of money, the operations were suspended and the contract with the Lorado Custom Mill was cancelled. The mine has been idle ever since. In 1958–59, leasers shipped to the Lorado Custom Mill about 250 tons of ore carrying less than 0.2 per cent U_3O_8 from the ore stockpiled near the shaft.

In the vicinity of the mine, the rocks (map-unit 17) are mainly granitized chlorite-rich feldspathic quartzite and granitized chlorite–sericite schist. There are also a few relatively small pegmatite masses and sills. All these rocks are cut by narrow gabbro and basalt dykes, particularly in the area immediately north of the shaft. The stratigraphic succession is as follows: beginning a few feet south of the shaft and extending much farther south is a wide zone of granitized chlorite–sericite schist and granitized impure quartzite, these interlayered with and grading imperceptibly into each other. North of this zone is a lenticular mass, about 700 feet wide, of massive granitized impure or feldspathic quartzite. This mass is followed on the northwest by a wide zone of augen-like chlorite schist.

The formations trend northeasterly. They are believed to be on the southeastern limb of an anticline whose axis passes about 800 feet northwest of the shaft or slightly to the east of the main valley at the southwest end of Jean Lake. Two faults may have some importance on this property. One, which was mapped on Cayzor ground to the northeast, passes a few feet south of the southeast end of Jean Lake. It strikes mainly east. To the west this fault seems to swing southwesterly into the main valley at the southwest end of Jean Lake to join the assumed Jean Lake shear zone, which was not mapped but was apparently recognized in the drilling and encountered underground. This shear zone trends northeasterly parallel with the trend of the formations. The intersection of these two faults may account for the wide shear zone encountered underground. The northeastern extension of this shear was not picked up underground on Cayzor grounds to the northeast.

Joint-type fractures are common on this property. Three principal sets are believed to be present: one trending northwest across the trend of the formations; a second trending northeast parallel or almost parallel with the trend of the formations, and a third trending easterly. Their dip is mainly south and steep. Most fractures do not extend far along strike or down dip. In fact, many seen on one level do not occur on the next.

The mineralization may be related to the two main faults mentioned above, but all of it lies along the joint-type fractures. In the Jean Lake shear zone the mineralization is along a few fractures trending easterly and N75°W. Their dip is about 80 degrees north and south. Away from this shear zone, the mineralized fractures trend mainly N80°E and N65°W, but N55°E striking fractures were also observed. In all cases, the mineralized bodies consist of pods and veins of pitchblende, erratically distributed along a tight fracture, or grouped in closely spaced, short, tight fractures. They also consist of pitchblende erratically distributed in the spaces between fragments of narrow brecciated zones or brecciated quartz veins. All the fractures and brecciated zones are coloured red where mineralized. In general the mineralization is spotty; most veins are less than half an inch wide and are of short horizontal and vertical extent. No definite pattern in the distribution of the mineralization could be outlined from the underground work.

On this property some mineralization also occurs in pegmatite bodies. This radioactivity is probably, however, due to monazite and uraninite, and not pitchblende, and is erratic and low. This type of mineralization was not investigated underground.

Prospects Explored Underground

ABC Prospect

References: Christie (1953, p. 111); Lang (1952a, p. 72); Robinson (1955a, p. 37).

Nesbitt Labine Uranium Mines Limited, which owned the ABC prospect, is now known as Gunnar Mining Limited since its amalgamation with Gunnar Mines Limited in November 1960. The working site is 2½ miles due east of Uranium City and about 2 miles due west of the Eagle–Ace mine, also owned and operated by the same company. By road it is 4 miles from Uranium City or 2 miles from the Eagle–Ace mine. The workings are on the east shore of Melville Lake and are serviced from the Eagle–Ace camp site.

The ABC group of nine claims was acquired by Nesbitt Labine Uranium Mines Limited in 1950. Prospecting revealed four interesting radioactive zones, the main one of which was traced for 80 feet along strike on surface. In 1952 an adit was driven 950 feet easterly to intersect it at a depth of 235 feet. In 1953, drifting, crosscutting, raising, and a sub-level at the 120-foot horizon were driven on it. No ore was found at a depth greater than 30 feet from the surface. Deep drilling done from the adit in 1953–54 gave encouraging results at depth of about 500 feet below the adit level. An internal shaft, located about 300 feet east and south of the main adit portal, was begun in late 1955 and completed to a depth of 798 feet in early 1956. Five levels were established. In November 1956 the results were disappointing, and operations were therefore suspended. In 1959 about 70 tons of high grade ore from this deposit, partly from the surface showings, were shipped by leasers to the Lorado Custom Mill.

In the working area, a major fault, the ABC, separates Martin arkose (map-unit 25) and siltstone (map-unit 26) on the west from quartzite (map-unit 5), argillite, hornblende schist (map-unit 4), and granite on the east. The ABC fault here strikes about N40°W and dips 40 to 45 degrees southwest. The strike of the fault changes appreciably both to the north and south. These changes in strike may be significant in the location of the mineralization.

West of the fault both arkose and siltstone trend northeasterly into the fault. Their dips are steeply west but are much shallower not far to the west. These rocks are on the eastern limb of the Martin Lake syncline near its northern apex where the syncline is closing. East of the fault in the immediate area of the workings, the stratigraphic succession consists of a thick layer of hornblende schist overlain by a glassy white quartzite, which passes northwesterly gradually into granite. They all dip steeply west. Near the ABC fault, the above-mentioned granite–quartzite contact strikes to about north, but a few feet away from the fault it swings sharply to the northeast to trend northeasterly for several hundred feet. This contact dips about 80 degrees northwest. In the working area and near the ABC fault this contact is the locus of much shearing and fracturing. It is at the intersection of this zone of shearing and fracturing with the ABC fault and in the rocks (quartzite and granite) below this fault that most of the mineralization has been found, although some was also found along fractures seemingly parallel with the ABC fault.

This deposit is believed to be of the vein-stockwork type. The pitchblende occurs along fractures and seams in pods and stringers, with abundant hematite and some chlorite, carbonate, and quartz. Pyrite was also noted. The main ore zone was not found at a depth greater than 30 feet and was restricted to a block about 30 feet wide extending from the granite–quartzite contact to the hornblende schist but entirely within quartzite or granitized rocks. Smaller ore zones were found at greater depths but were erratically distributed and were small or without any apparent continuity along strike. They were all below the ABC fault and a few feet from it, within quartzite and granitized rock.

Baska Prospect (*Virgin Lake*)

The workings on the Baska prospect are about 300 feet northeast of the southwest end of Virgin Lake and on the west shore of the lake. They are about 250 feet north of the northern boundary of the map-area. The prospect was visited in July 1956 and is described here because it is regarded as within the framework of this project. The property is 6.5 miles northeast of Uranium City and can be reached by plane or by tractor trail.

The deposit is owned by Baska Uranium Mines Limited. It is on the Dot group of thirty claims, which were acquired late in 1953. In 1954 the group was prospected and trenched, and the A zone should give interesting values. In 1955 much drilling was done to assess the surface deposits, and in October 1955 an adit was started. In early 1956, when the adit was completed to about 1,200 feet, about 1,900 feet of drifting, crosscutting, and raising had been done. Further drilling was done in the spring of 1956, and when operations were suspended in June 1956, 13,200 tons averaging 0.28 per cent U_3O_8 had been indicated, and about 1,800 tons of ore averaging 0.3 per cent U_3O_8 were stockpiled on the property. At one time it was planned to ship ore to the Lorado Custom Mill in early 1957, but the idea was abandoned pending better market conditions.

The rocks near the adit portal and to the west of it for at least 1,000 feet are mainly granite and granitized rocks. Near the west shore of the lake a narrow (about 3 feet wide) zone of chlorite schist was traced southwesterly for an appreciable distance along the pronounced valley at the south end of the lake. To the east the granite and granitized rocks pass gradually into buff quartzite near Hab Lake. To the west they are overlain unconformably by the basal conglomerate (map-unit 20) of the Martin Formation, which here may be 1,500 feet thick. Carbonate disseminated through the rock and white quartz veinlets were noted near the deposit.

Southwest of Virgin Lake the formations trend northeasterly. Immediately south of the lake they exhibit an S-shaped drag and are probably on the western limb of a major syncline, whose axis passes about 2,500 feet east of Virgin Lake.

Joint-type fractures are abundant in the area. The main strike directions are N45°E, N55°W, and about N85°W. They all dip steeply in either direction. These fractures are short, both horizontally and vertically, but the system probably extends to an appreciable depth. Locally they are fairly closely spaced.

As there is some indication of movement along the chlorite schist zone mentioned above, its location may be a fault zone. However, it does not appear to be a major structure. The movement responsible for the wide zone of brecciation and mylonitization that has affected most of the granite and granitized rocks in the vicinity of the deposit may also have been responsible for this chlorite schist zone. Joint-type fractures are abundant in the brecciated zone.

The mineralization is found entirely along joint-type fractures, and most commonly along fractures trending N55°W and N85°W. Occasional fractures trending about N50°E and N25°W are also mineralized. The dip of all mineralized fractures is around 75 degrees south; a north dip is rare. The mineralization consists of pitchblende veins or pods up to an inch thick but generally less than half an inch thick. Along some fractures, pitchblende constitutes only a film or a coating on the walls of the fractures. Pitchblende is associated with some carbonate, and in general the wall-rock of the mineralized fracture is heavily coloured with hematite. The pitchblende concentration seems to be greatest where the granite is fine grained and dense, or in what appears to be mylonitized granite or incompletely granitized quartzite.

The mineralized fractures are concentrated within an area about 1,000 feet long, west from the west shore of Virgin Lake and over a width of about 300 feet. This was referred to locally as the A zone, and the adit was driven on it to assess it at a depth of about 100 feet. It is not known if the tonnage mentioned above was concentrated into one large ore zone only or into several small scattered ones.

Beaver Lodge Uranium Prospect

References: Christie (1953, p. 91); Robinson (1955a, p. 12).

The camp-site on this property is on the south shore at the southeast end of Mickey Lake about 6 miles east of Uranium City and 1½ miles northeast of the Eagle–Ace mine shaft. The property was acquired by Beaver Lodge Uranium Mines Limited in 1951 and comprised five claims of the Bar group. In April 1959 the company was renamed Beaver Lodge Mines Limited.

In 1951 the claims were prospected and trenched, and some interesting showings along a fault zone were uncovered. In 1952, these were drilled, an adit was driven 400 feet to intersect them at depth, and an internal shaft was started to explore the zone at a vertical depth of 100 feet. Although all underground work was suspended in early 1953 due to a change in management, surface prospecting was intensified. The property has been idle since 1954. However, in 1958 and 1959 some leasers apparently recovered approximately 75 tons of ore from the adit and from a few surface showings on this property. This they shipped to the Lorado Custom Mill.

The adit portal is almost on the contact between hornblende schist (map-unit 4) above and granitized chlorite schist and granite–gneiss (map-unit 2) below. The contact dips gently southeast and may also mark the position of a fault, as a layer of chlorite schist directly below the hornblende schist indicates movement along it. The hornblende schist is part of a gently rolling but much larger body of hornblende schist, which plunges gently south and southwest. The schist is overlain, about 1,500 feet to the south, by a thinly bedded mixture (map-unit 3) of quartzite and chlorite–sericite schist. All these rocks are cut by a few pegmatite masses and late basalt dykes.

In the area of the adit the hornblende schist forms a narrow syncline with a northeasterly trending axis. The dip on each limb is around 45 degrees northwest and 45 degrees southeast respectively. This schist is crossed by numerous joint-type fractures, some of which are true faults. A few of these fractures or faults are transverse to the synclinal axis and trend about N45°W. One of these transverse faults was mapped because it is indicated by offsets of the contact and formations. Its dip is 80 degrees either way. This fault was the structure followed in the adit.

The mineralization occurs mainly along this fault, particularly where the fault is in hornblende schist and seemingly where it branches or changes slightly in direction. It occurs also along the fault where the main mass of hornblende schist is cut by occasional dykes of granite and basalt or where it includes beds of quartzite. In general the mineralization is sporadic. It consists of pitchblende in pods or veins along the fault, as a filling around blocks of the wall-rock or of the vein material within the fault, and as a mere coating on the blocks within the fracture and on the walls of the fracture. Pyrite is a common associate, and red alteration due to hematite is fairly characteristic where present. In general the wall-rocks are not much altered. Carbonate is the main non-metallic mineral and occurs chiefly as fracture fillings. Chlorite and quartz are also present. Robinson (1953a, p. 12) recognized the following additional minerals: chalcopyrite, galena, clausthalite, bornite, and marcasite.

This deposit is really a carbonate pitchblende-bearing vein along a recognizable fault.

Eagle Prospect

References: Allen (1950); Christie (1953, p. 96); Lang (1952a, p. 85); Robinson (1955a, p. 23); Smith (1949).

This property, which is owned by Eldorado Mining and Refining Limited, comprises the Eagle group of claims. The Eagle shaft area is near Shaft Lake about 3,000 feet northeast of the northeast end of Melville Lake. By road it is 4 miles northwest of Eldorado townsite and 9 miles from Uranium City which lies 3 miles in a direct line to the southwest.

Uranium mineralization was discovered on this property in 1947. In 1948 and 1949 a few showings were trenched, and two, known locally as the Spur zone and the Lost Mine zone, were drilled. Late in 1949 plans were made to assess the potentialities of these two zones by underground work. A vertical shaft was started in January 1950 and sunk to a depth of 300 feet. The shaft was located about 300 feet northwest of the Lost Mine zone and 800 feet southeast of the Spur zone. Two levels were established, and lateral work was carried on. In the early summer of 1951, the shaft timbering and the headframe were destroyed by fire. By that time much drilling and about 7,000 feet of drifting and crosscutting had been done on the two levels, most of it on the first level. All underground work was then stopped, and the mine has been closed ever since.

The rocks in the vicinity of the shaft are granite and brecciated granite with remnants of the country rocks in all stages of alteration and granitization. The remnants are either dense, siliceous, and quartzitic or schistose, chloritic, and amphibolitic. They are mixed and are partly interbanded with granite or granitized rocks. Their contacts with the granite are irregular and gradational or locally fairly sharp. The brecciated granite occurs in wide northeasterly trending belts surrounding and enclosing large masses of massive, relatively unbrecciated granite. The brecciated granite itself is made up of large to small blocks of unbrecciated granite in a well-cemented matrix of finely crushed granite. No remnants of the country rocks were recognized on the surface near the shaft, but apparently a few were exposed in the underground workings. On the surface a few feet southeast of the shaft, a contact between brecciated granite on the south and massive granite on the north, was mapped. The Lost Mine zone is in the brecciated granite near this contact on the surface, but the underground extension is apparently in a chloritic remnant. A couple of hundred feet north of the shaft another mass of brecciated granite is in contact with massive granite on the south and may join the mass of brecciated granite in the underground workings south of the shaft, previously described.

The north mass of brecciated granite extends as far as the Spur zone and includes a few mappable remnants of massive granite. The Spur zone is entirely in brecciated granite near the contact of one of these remnants.

In the shaft area the formations trend northeasterly and dip gently southeasterly but may be almost flat lying locally. They are probably on the east limb of a small anticline, whose axis passes about 500 feet northwest of the shaft. A northeasterly trending syncline was recognized about 2,500 feet southeast of the shaft, and in part the shaft area may be related to this syncline. Joint-like fractures trending in several directions were recorded. Some of these directions are subparallel with the apparent trend of the formations; others are at right angles to it or almost so. The main directions are N30°E, N65°E, N85°E, N65°W, N45°W, and N20°W. Most joints dip steeply south; north dips and shallow dips are rare. Some of the above trends may be trends of fault zones, but so far very few definite faults were recognized in the immediate shaft area.

The mineralization is of the vein-type and is fracture filling. It is entirely along a few of the joint-type fractures, especially along some of the fractures striking N85°E, N65°W, and N65°E. The mineralized fractures occur in swarms and within each swarm they are *en* *échelon*, widely to closely spaced, their number varying appreciably from swarm to swarm and from place to place within each swarm. The Lost Mine zone and the Spur zone are two such swarms. On the Eagle property the swarms occur in a zone about 500 feet wide that trends N65°W and extends from the southwest end of Shaft Lake to the southeast end of Eagle Lake. In this zone the swarms are spaced at distances of 500 to 1,000 feet. Only two of these swarms are in the shaft area and are described here.

The mineralized fractures have calcite and/or pitchblende with minor quartz. A few have more quartz and less calcite. In general the pitchblende is irregularly distributed along the fractures. It occurs in pods and veins or forms only a seam on the walls of the fractures. Hematite is also present, and locally the veins and the walls are heavily red coloured. Chlorite was recognized in most veins. Other minerals, identified by Robinson (1955a, p. 23), are chalcopyrite, bornite, pyrite, and galena. The mineralized fractures are generally less than half an inch in width and are rarely more than 100 feet long.

As a rule it appears that the nature of the rock plays an important role in the concentration of the pitchblende along the fractures. It seems that it is greatest along fractures in areas of massive granite entirely enclosed in brecciated granite and also in remnants of the country rocks in and near granite masses.

Meta Uranium Prospect

References: Christie (1953, p. 95); Lang (1952a, p. 79).

Meta Uranium prospect is on the west shore of Umisk Island in Beaverlodge Lake. The workings are 5.5 miles southeast of Uranium City and 2 miles south of Eldorado townsite. This prospect is the property of Meta Uranium Mines Limited. According to reports it was leased on a royalty basis to other interests in 1960.

The property comprises the Tor group of ten claims. It was acquired in November 1952, the claims were prospected in 1952–53, and the main showings, such as the Lake Shore zone, were drilled in 1953. In order to evaluate the Lake Shore zone more accurately, a crosscut adit was driven easterly from the west shore of Umisk Island and was completed to 291 feet in mid-November 1953. Drifting on the zone was not carried very far because results were discouraging. In 1953 much drilling was done from the adit level to investigate the known faults and contacts at depth and to evaluate a few erratic values. As a result of this drilling an internal two-compartment shaft was sunk from the adit level to a depth of 375 feet in late 1954. A level was established at 340 feet, and when the mine was closed down in November 1955, about 850 feet of drifting, crosscutting, and raising, and some additional drilling, had been done from this level. Two small orebodies had been found. The small size of the orebodies and the market conditions did not warrant further work on the property, which is still idle.

The site of the working is near the centre of a large circular area of Martin conglomerate (map-unit 20) and arkose (map-unit 21) that overlie unconformably Tazin quartzite (map-unit 6), amphibolite (map-unit 7), and granitized rocks. These Tazin rocks are included in the Murmac Bay Formation. The conglomerate and arkose here reach a thickness of 600 to 800 feet and are an eastern extension of the Martin Lake basin or syncline. As suggested by the attitudes of bedding, this extension is believed to represent a small basin or trough filled with Martin rocks within the old eroded Precambrian surface.

The unconformity plane is not generally visible on the surface in this area, but from its position in drill holes and its approximate position at surface it is believed to dip 30 to 40 degrees south, north of the adit portal; to dip west, east of it; and to dip steeply north, south of it. This plane was traced for almost 300 feet on the 340-foot level. It passes a few feet south of the shaft, and its trace is wavy. Underground some shearing was seen along this unconformity plane for part of its length on both sides of the shaft. The shearing almost dies out in Tazin rocks a short distance from the unconformity plane, or it passes into a fracture.

All the rocks in the workings are cut by joint-like fractures, which locally may exhibit some shearing. These fractures strike mainly N55°E, N35°W, N75°W, N10°E, and N55°W, and all dip steeply.

All radioactive occurrences at the surface found so far are in the conglomerate and arkose, and most of them are near the southern and eastern margins of the circular mass of Martin rocks or near the unconformity plane. The main occurrence, however, known as the Lake Shore zone, is about 100 feet northwest of the adit portal. At depth this zone may be represented by the orebodies located near the unconformity. The mineralization is in all cases closely associated with the zones of shearing along the unconformity, with the unconformity plane itself, and with fractures trending N55°W, N75°W, and N20°W. Surface drilling had indicated a mineralized zone up to 85 feet long. Underground, two small ore shoots were outlined in the zone of shearing at the unconformity in the shaft area, mainly above the level of the workings. These shoots had little lateral or vertical extent. The fractures are filled by carbonate veins and stringers with minor radioactivity and some red alteration. Rare fractures with carbonate and some radioactivity were found in the granitized rocks as much as 40 feet below and away from the unconformity plane, but most of them were in Martin rocks. Pitchblende is the main ore mineral.

Pitch-Ore Prospect

References: Christie (1953, p. 114); Lang (1952a, p. 98); Robinson (1955a, p. 42).

This deposit is on the west shore of Beaverlodge Lake about 3 miles southeast of Uranium City and 2 miles southwest of Eldorado townsite. By road the camp-site is 5 miles from Uranium City. The prospect was owned by Pitch-Ore Uranium Mines Limited, and in 1959 was apparently leased to other interests on a royalty basis. The camp-site was near the water's edge, and the adit portal was about 100 feet above the lake on the east slope of the high ridge between Martin and Beaverlodge Lakes.

The property which was acquired in 1950 by Pitch-Ore Uranium Mines Limited, included the Pitch-Ore group of twelve claims. In 1951 and 1952 it was prospected. Many trenches were dug, and several holes were drilled. Several mineralized zones were found, the No. 1 zone being the most promising. An adit was driven northwesterly on it from the west shore of Beaverlodge Lake, at an elevation of about 100 feet above lake level. Started in October 1952, it was completed to 1,000 feet by October 1953. About 16,500 tons of ore, averaging 0.10 per cent U_3O_8, were blocked out. Late in 1953 operations were suspended, and the prospect has been idle ever since. About 50 tons of the best ore was apparently shipped to the Eldorado Custom Mill.

The property is underlain by wide belts of basaltic flows, intercalated with arkose and conglomerate, all of the Martin Formation. The belts trend northeasterly, and all dip about 60 degrees northwest. They are on the east limb of the Martin Lake syncline whose axis passes about 8,000 feet northwest of the adit portal. Several faults and many joint-like fractures were recognized in the area. A major branching fault with an apparent left-handed horizontal displacement of the order of 600 feet passes by the adit portal, along which the adit was driven. The fault strikes N30°W and dips about 50 degrees southwest. This fault was traced across the strip of land separating Martin Lake from Beaverlodge Lake, and its dip appears to be somewhat steeper to the north and flatter to the south. As seen underground it is either a pronounced feature with gouge and fragments of the wall-rocks along it or a series of minor interlocking cracks giving rise to horse-like blocks along the fault. Many other faults were recognized on the surface. These are either branch faults, subsidiaries of the main fault, or subparallel features. All are small, and in many instances could be referred to as joint-like fractures. Measurements on fractures seen underground and in the outcrops gave the following main strike directions: due north and due east, N40°E and N65°W, and N65°E, and N30°W. All dip steeply to about 30 degrees either way, the steeper fractures being the more common.

Most of the mineralization is along the main fault and its branches, but it also occurs along minor fractures subparallel with the main fault and at some distance from it, and along a few of the contacts of volcanic rocks with arkose. It has even been found in the massive parts of flows at some distance from any recognizable fracture. In all instances, the mineralization was restricted to the volcanic rocks or to the part of the fracture within the volcanic rocks, only very rarely it is in the arkose. Even in the contact zone it is confined to the lava, the highest concentration generally being at some distance from the arkose. All these deposits show some red coloration, but it is particularly marked in the massive mineralized parts of the flows.

Most of these deposits are of the vein-type with calcite, chlorite, quartz, and pitchblende or some other radioactive minerals along fractures, faults, and contact zones. In addition, to the above minerals, Robinson (1955a, p. 43) identified the following minerals in order of abundance: hematite, chalcopyrite, clausthalite, pyrite, bornite, and covellite. Rutile is apparently also present.

Strike Prospect

References: Christie (1953, p. 116); Lang (1952a, p. 103).

This prospect is on the north shore of Strike Lake about half a mile north of Ace Lake and about 3 miles northeast of Eldorado townsite. It is less than 1,000 feet from a point on the road to National Exploration camp.

It comprises the Strike group of four claims, owned in 1953 by Strike Uranium Mines Limited. In 1955 the property was bought by Rock Hill Uranium Limited, which in late 1955 was purchased, in turn, by Imperial Mines and Metals Limited. This company became New Imperial Mines Limited in 1957.

Prior to 1952 the claims were prospected, and several radioactive occurrences were discovered, some of which had visible pitchblende. In 1952 and 1953, stripping, trenching, and shallow diamond drilling were done on the property by Strike Uranium Mines Limited. In 1953 a short adit was driven northwesterly from the north shore of Strike Lake. Further surface work was done in 1955 by Rock Hill Uranium Limited, but no work has been done since. However, in 1958–59 about 60 tons of ore was shipped to the Lorado custom mill from the surface showings.

The rocks in the vicinity of the adit and the showings are mainly hornblende schist (unit 4), quartzite, and chlorite–sericite schist (unit 3). The quartzite and chlorite schist, which are thinly interbedded, occur in large zones and lenses interbanded with massive to thinly bedded hornblende schist. These rocks are cut by a few irregular granite masses and northwesterly trending gabbro or basalt dykes.

The beds trend northeasterly, dip steeply southeast, and are on the southeastern limb of the Ace Lake – Donaldson Lake anticline. The axis of this anticline passes about 1,000 feet northeast of the adit portal and trends northeasterly. Farther to the northwest the formations are gently folded and locally almost flat lying.

No major faults were recognized in the vicinity of the adit, but the area is traversed by numerous joint-type fractures. These trend similarly to those near the Beaver Lodge Uranium adit: N20°E, N60°E, due east, N45°W, and N25°W. The fractures crossing the trend of the formations are the most common and the strongest.

Most of the mineralization on this property has been found along the joint-type fractures trending N45°W and due east, and dipping steeply northeast or southwest, but some mineralization is along the fractures trending N60°E. It appears also that the mineralization is restricted to the parts of the fractures within the hornblende and chlorite schist and gabbro. It is typically fracture filling and consists of pods, lenses, and seams of pitchblende with carbonate, quartz, and hematite irregularly scattered along the fractures. The vein material rarely exceeds a few inches in width, and the veins or lenses of massive pitchblende are generally less than half an inch wide.

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