GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

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THE PRECAMBRIAN GEOLOGY OF FOND-DU-LAC MAP-AREA (74-O), SASKATCHEWAN

(Report, 1 figure and Map 20-1968)

A. J. Baer

CANADA

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Price: $1.50 Catalogue No. M44-68-61

Price subject to change without notice

The Queen's Printer
Ottawa, Canada
1969

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ABSTRACT

The map-area is in northern Saskatchewan, east of Uranium City. South of Lake Athabasca the map-area is underlain by flat-lying sediments of the Athabasca Formation, whereas granitic rocks and gneisses occupy the area north of the lake. The gneisses form two groups. One group forms a broad belt closer to Lake Athabasca and is in the granulite facies or has undergone retrograde metamorphism from the granulite facies to the amphibolite facies. The other group, associated with granodiorite and migmatite, covers most of the area north of the first. These rocks are in the amphibolite facies. Rocks of the first group represent supracrustal rocks of various origins raised to granulite facies. They were deformed by a generally easterly trending gentle folding. A second period of metamorphism, associated with emplacement of abundant granitic rocks, caused a retrograde metamorphism of these granulites and was accompanied by formation of a northeasterly trending foliation. Faulting and mylonitization are probably related to the last stages of granite and granodiorite emplacement. All known mineral showings are confined to rocks in the granulite facies of metamorphism.

THE PRECAMBRIAN GEOLOGY OF FOND-DU-LAC MAP-AREA (74-O), SASKATCHEWAN

INTRODUCTION

Fond-du-Lac map-area is situated in northern Saskatchewan, 20 miles east of Uranium City, and can be easily reached by air or by water from Uranium City or Stony Rapids, a settlement on Lake Athabasca, a few miles to the east. Fond-du-Lac, a small village on the north shore of Lake Athabasca, is the only permanent settlement in the area. It was founded in 1845 to replace a series of earlier trading posts held by the Hudson's Bay Company and by the North West Company (Tyrrell, 1896).

Travel in the area in summer is by float plane or on foot. Small boats and canoes can be used on the larger lakes, but rivers are not navigable.

Considerable morphological contrast exists between areas on either side of Lake Athabasca. To the south, relief is low and the topography slopes gently towards the lake from 1,500 feet at the centre of the southern margin of the map-area to 700 feet on the lake. Maximum relief north of the lake does not reach 1,000 feet above lake level, but topography is commonly rugged except in the northern and eastern parts of the map-area.

Pleistocene deposits north of Lake Athabasca are extensive in areas of low relief (Carcoux, Chappuis, Scott and Fontaine lakes) but negligible elsewhere. By contrast, areas south of Lake Athabasca are extensively drift covered, with the exception of several low hills along the eastern end of the lake. Raised beaches are well developed in the southwestern part of the map-area at about 250 feet above present level of Lake Athabasca. South of the east end of Pine Channel, Mawdsley (1949) reported raised beaches at a maximum elevation of 392 feet above lake level. Sand dunes occur in the southwestern part of the map-area and represent the eastern extremity of a large sandy area that extends 45 miles west of the map-area.

The first geological report on the map-area was published by Tyrrell (1896) as a result of his exploration of the north shore of Lake Athabasca in 1892 and 1893. Although Camsell (1916) checked a reported occurrence of silver near Fond-du-Lac in 1915, the next important regional description was by Alcock (1936) who, with a large party, covered in one season the whole area between Lake Athabasca and the sixtieth parallel.

More recent work has been limited to small parts of the map-area, essentially along its western margin (Blake, 1955, Koster, 1965b) and at the eastern extremity of Lake Athabasca (Mawdsley, 1949, Colborne, 1962, Colborne and Rosenberger, 1963). Studies of the Athabasca Formation by Blake (1956) and Fahrig (1961) cover that part of the map-area situated south of Lake Athabasca.

The present work was undertaken in 1967, with the able assistance of C. Crosbie, P. Greene, W. Palmer and J. Pirie. D. P. Smith helped to prepare the

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GSC Project: 660010
Manuscript received: 30 September, 1968
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map and examined many thin sections. H. H. Burry piloted a Cessna 180 float-plane attached to the party, and his knowledge of the area as well as his personal qualities contributed to the successful accomplishment of the field work.

GENERAL GEOLOGY

South of Lake Athabasca, subhorizontal, light-coloured sandstone is overlain by a thick cover of drift. This is a tree-covered area of gentle hills, large lakes and broad swampy depressions.

North of the lake, gneisses and granitic rocks are complexly deformed and the lack of drift accentuates the relative ruggedness of the landscape. Drainage is mainly controlled by the structure of the bedrock. No stratigraphy has yet been established in this terrain. The map-units are arranged in the legend on the basis of structural and petrological criteria. Gneisses on the one hand (map-units 1-9) and plutonic rocks on the other (map-units 10-12) have been grouped together. This does not imply that all plutonic rocks are younger than all supracrustal rocks. Numbering of the gneisses corresponds approximately to a gradual retrogressive metamorphism from granulite facies to amphibolite facies (see map-legend). It seems that gneisses of the area were first brought up to the granulite facies grade of metamorphism and with later granitization, were partly reduced to the amphibolite facies. All gneisses are considered to be supracrustal rocks of comparable age (Archean), but the granulite facies of metamorphism belongs to an older orogenic period than the amphibolite facies. Granodiorite (11), which is by far the most common plutonic rock in the area, is coeval with the amphibolite facies of metamorphism.

Major faults in the area presumably formed during the final stages of the second metamorphism, but movement may also have occurred later.

Considerable prospecting for radioactive minerals has taken place in the map-area because of the proximity of Uranium City. Geological considerations indicate that only one third or possibly one half of the area north of Lake Athabasca is favourable ground for mineral deposits.

Pyroxene-garnet gneiss (map-unit 1)

Pyroxene-garnet gneiss is most common immediately north of Lake Athabasca, in particular near Camille Bay, Sucker Bay and Grease Bay. A continuous band northwest of Fond-du-Lac village, some smaller areas on Scott and Premier lakes, and one along Straight River, are the only other regions where it has been mapped.

A fine-grained to medium fine grained, dark grey to black rock is typical. Foliation is only visible on the weathered surface. Because of the dark colour, and the small grain size, garnet is commonly the only mineral that can be recognized in the field. Massive or banded varieties of the rock alternate without evident order, and where layering is present, it is due to variable proportions of feldspar in the rock. Different mineralogical associations have been recognized by previous workers (Kranck, 1955, Colborne, 1962) but none are sufficiently consistent to be mapped separately. Massive areas (1a) have the same mineralogy as gneissic areas (1). Common minerals are orthopyroxene, clinopyroxene, plagioclase, quartz and antiperthite. Biotite and apatite are accessory minerals.

Judging from its mineralogical association, the rock is now in the granulite facies of metamorphism. Evidence of retrograde metamorphism is abundant in specimens from Scott Lake and northwest of Fond-du-Lac village, where biotite or hornblende commonly rims pyroxene crystals and in some samples replaces them entirely. Rocks in the southeastern part of the area however are relatively free of such retrograde effects. All gneisses included in this map-unit probably represent metamorphosed supracrustal rocks. Many outcrops bordering Lake Athabasca have been mapped previously as "norite". Tyrrell (1896, p. 65) who introduced the term, mentions "a highly garnetiferous orthorhombic pyroxene gneiss or foliated norite". Because of the prominent gneissic character of the rock and because no evidence for an intrusive origin has been found, the writer prefers the term pyroxene-garnet gneiss for all similar rocks in the map-area.

Leucocratic garnet (-pyroxene) gneiss (map-unit 2)

The main area of outcrop of this map-unit is a ten-mile-wide strip extending northwest from Fond-du-Lac village to near Nevins and Neiman lakes. Map-unit (2) is also interlayered with (1) along Grease Bay and east of it, along Fond-du-Lac Lake. Another thin band occurs between Turnbull Lake and Straight River, and some minor lenses exist on Scott Lake.

Leucocratic garnet (-pyroxene) gneiss is commonly well foliated and characterized by thin leucocratic ribbons of quartz and feldspar interlayered with darker, fine-grained bands. Garnets commonly attain 3 to 5 mm in diameter. The rock in hand specimen appears to be quartz-rich, but thin sections show that plagioclase, and less commonly potash feldspar, are also present. The latter minerals are not recognizable with the unaided eye, because of the intense deformation to which the rock has been subjected. Garnet is the only ferromagnesian mineral in the most leucocratic varieties and these rocks have the appearance of pink to white garnet-bearing quartzites. Other varieties contain biotite and hornblende and are dark grey.

Included in map-unit 2 are layers or lenses of glassy quartzite up to 500 feet thick and rare ribbons of iron-formation up to 10 feet wide that outcrop east of Nevins Lake. A few lenses of map-unit (6) are also interlayered with map-unit (2).

In thin section leucrocratic garnet (-pyroxene) gneiss shows complete recrystallization of quartz into small clear grains aligned in lenses defining the foliation. Plagioclase (An_{36-38}) forms subhedral to anhedral crystals. Microcline nowhere forms more than a few per cent of the rock. Garnet is abundant and many grains are mantled by biotite. The rock is in the granulite facies of metamorphism because of the quartz-plagioclase-garnet-potassium feldspar assemblage. Biotite is due to later alteration associated with a strong deformation parallel with the present foliation. Presence of rare muscovite with biotite indicates retrogressive metamorphism.

Map-unit (2) is probably derived from leucocratic sedimentary rocks (arkose and quartzite) or acid volcanic rocks (tuff?) closely associated with rocks of map-unit (1). Both probably have had a similar history of deformation and metamorphism.

Garnet-sillimanite (-pyroxene) (-biotite) gneiss (map-unit 3)

This map-unit extends principally along the southwestern extremity of map-unit (2), west of Fond-du-Lac village and towards Nevins Lake, where it splits into a number of divergent 'arms'. Garnet-sillimanite (-pyroxene) (-biotite) gneiss in the Neil Bay area, 12 miles west-northwest of Fond-du-Lac, is typical. There the unit is a medium grained, granular, gneissic assemblage of blue quartz, feldspar, garnet, sillimanite and subordinate biotite. Rare pyroxene crystals are visible with the unaided eye. Sillimanite is less abundant in the northwestern part of the map-unit, and hypersthene is found rarely. Biotite content is greater in the well foliated rocks than in the poorly foliated representatives. The intensity of deformation is probably also greater in the well foliated rocks. Texture is commonly allotriomorphic granular, except where modified by later shearing and recrystallization.

Quartz which forms 20 to 40 per cent of the rock seems to be recrystallized into large anhedral grains with complex amoeboid texture. Plagioclase forms antiperthite and irregular grains smaller than either mafic minerals or recrystallized quartz grains. Garnet is poikiloblastic and surrounded by rims of biotite, whereas sillimanite is in thick stubby prisms. Hypersthene, where present, is mantled by biotite. Biotite, apatite, magnetite and zircon are accessory minerals. Fragments of garnet surrounded by reddish biotite are present in one thin section, indicating that biotite formed after fragmentation of the garnets.

Although most of the rocks in this map-unit are probably in the amphibolite facies (garnet-sillimanite-biotite assemblage), the distribution of biotite in coronas around garnet and the presence of relict hypersthene shows these rocks to have undergone retrograde metamorphism from the granulite facies. These rocks were probably originally argillaceous sediments.

Blake (1955) mapped many of these gneisses as migmatites because of an alternation of thin quartzofeldspathic lenses and mafic lenses visible in hand specimen. This crude layering, however, is not general or characteristic. From the few available observations, it might in fact be limited to areas surrounding granodioritic rocks. The term gneiss is more representative of the map-unit as a whole.

Pyroxene amphibolite (map-unit 4)

Rocks of this map-unit only occur in the Adair Bay – Natukam Peninsula area, southeast of Nevins Lake. The rock is generally medium-grained and dark green or black. Alternation of feldspar-rich zones and pyroxene- or hornblende-rich zones gives a layered appearance to some outcrops, but others are massive. Minerals recognizable in hand specimen include a greenish, grey or brownish feldspar, reddish-brown pyroxene, dark green hornblende and rare garnet crystals. Moderately altered samples show, in thin section, an allotriomorphic to hypidiomorphic granular texture. Plagioclase is anhedral, locally displays patchy extinction (by recrystallization?) and is poikiloblastic in some thin sections. Clinopyroxene showing large amounts of exsolved magnetite is common. Oxidation of magnetite to hematite is responsible for the red colour of the pyroxene. Hornblende is pleochroic in shades of brown or green, and replaces clinopyroxene. Orthopyroxene, which is extremely rare, is rimmed by a light coloured mineral which is probably amphibole. Interstitial quartz forms up to 15 per cent of some sheared rocks, but is generally less abundant. Garnet, chlorite, biotite, magnetite and hematite are minor minerals and apatite and zircon are accessory minerals.

As recognized by Blake (1955) the pyroxene amphibolite is in the granulite facies, although parts of it have been metamorphosed later to the amphibolite facies, especially along shear zones.

Amphibole - pyroxene-biotite gneiss (map-unit 5)

This rock is limited to the Scott Lake area and to the northwestern corner of the map-area, northwest of Tazin River. The unit includes a variety of closely related rock types, characterized by the presence of amphibole, orthopyroxene and clinopyroxene, by the fact that amphibole was commonly formed from pyroxene, and by a generally granular texture. Included are those rocks described by Koster (1965b) as "biotitic granulite", "felsic grey granulite", "felsic to mafelsic granulite" and "holofelsic granulite", all of which are gradational with one another. Similar rocks are present in the Scott Lake area where all gradations exist from rocks containing 60 per cent mafic minerals to those containing only 10 per cent mafic minerals.

Map-unit (5) is continuous with rocks mapped as gneissic granite and granodiorite in Wholdaia Lake map-area (Taylor, 1959), and is lithologically similar to some samples collected by H. H. Bostock and the writer in the southwestern part of the Wholdaia Lake area. It might also be in part correlative of hornblende-pyroxene gneisses described by Johnston (1961) from Astrolabe Lake area to the east. Gneisses of the Tazin River area extend into Ena Lake map-area (Koster, 1965a).

Rocks are commonly fine- to medium-grained. The leucocratic varieties are light grey to light pink whereas mafic varieties are greenish grey to dark green, according to the proportion of amphibole and pyroxene. The weathered surface is grey and finely pitted by weathering of mafic minerals. Except where rocks have been foliated by later deformation, no foliation is generally visible, although a pronounced lineation is present.

In thin section, quartz is seen to have recrystallized in ribbons or clusters of grains, locally with amoeboid sutures. Anorthite content of the plagioclase varies from 31 to 44 per cent and tends to decrease towards the outside of many crystals. This zoning however, is not related to the ideal crystalline form of the crystal, but is parallel to its external form, even where this is due to fracturing. The zoning is thus probably due to metamorphism of the rock after formation of plagioclase grains. Microcline is commonly present and locally contains rod perthite, apparently older than the microcline perthite. Light green and poikiloblastic amphibole is the most common mafic mineral. Two types are present - one is an alteration product of pyroxene, and the other, darker green variety grades into biotite. Pyroxene is common in specimens from the Tazin River area but is much scarcer on Scott Lake. Biotite is generally present and parallel to the visible foliation. It is highly pleochroic, with X almost colourless, and $Y \approx Z$ reddish brown. Magnetite, apatite and zircon are accessory minerals.

Composition of the rock and its association with map-units (1) and (2) indicate that it is now in the amphibolite facies, but had previously reached the granulite facies. Some parts might still be in the granulite facies but if biotite is taken as an index mineral of the amphibolite facies (Winkler, 1965) its widespread occurrence in rocks of map-unit (5) would exclude most of the map-unit from the granulite facies.

Mesocratic quartz-rich biotite gneiss (map-unit 6)

Although the mafic mineral content of these rocks varies from 15 to 25 per cent, they are called 'mesocratic' because they are intermediate between leucocratic and melanocratic gneisses. They are widely distributed throughout the map-area and form a broad continuous belt from Oldman Lake through Fond-du-Lac village to the eastern limit of the map-area. They are also associated with map-unit (4) at the south end of Scott Lake, and form less important layers of lenses northwest of Oman Lake, north of Nevins Lake and west of Narrow Bay on Lake Athabasca.

Map-unit (6) corresponds in part to biotite gneisses mapped by Colborne (1962) and Colborne and Rosenberger (1963) in the Wiley Lake map-area, and to some 'migmatite' described by Blake (1955) from Oldman River map-area.

The rocks are light to dark grey, generally well foliated with locally a good granular texture. Quartz forms 20 per cent or more of the rock and is characteristically milky blue. Quartzofeldspathic lenses, 2 to 3 mm thick occur rarely.

Thin sections show quartz to be recrystallized in clusters of clear crystals or in long thin lenses parallel with the foliation. Plagioclase An_{25-46} forms stubby anhedral crystals. Calcic plagioclase is more altered than sodic plagioclase and is found in samples where the granular texture is best visible. Destruction of the granular texture and recrystallization of more sodic plagioclase are probably due to the same phenomenon. Antiperthite is present in one thin section. Where present, potassium feldspar is chiefly intersertal and forms replacement perthite. More rarely it occurs as large crystals of microcline. Long thin parallel flakes of biotite determine foliation. They are pleochroic in shades of pale yellow and reddish brown. Muscovite, sillimanite and hornblende are minor minerals, whereas zircon, magnetite, sphene, apatite, and carbonates are accessory minerals.

From its mineralogical associations the rock is in the amphibolite facies. These rocks may have been granulites as shown by the granular texture of some samples, their close association with rocks containing relict of the granulite facies and the reported occurrence of hypersthene from the Wiley Lake map-area (Colborne and Rosenberger,1963). Retrogressive metamorphism has affected this map-unit more intensely than those previously described.

Leucocratic quartz-rich biotite gneiss (map-unit 7)

On the average, leucocratic quartz-rich biotite gneiss contains less than 15 per cent mafic minerals and more than 20 per cent quartz. It occurs in one large outcrop area between Thicke Lake, Lowe Lake and Grease Bay and in a few small bands on Train Lake, Carcoux Lake and northeast of McConville Lake.

Rocks of this map-unit are in many respects similar to some of map-unit (2), with the exception that garnet or pyroxene has been almost entirely replaced by biotite and that foliation is better marked. The rock is commonly fine- to medium-grained, white or slightly pink, and biotite forms clusters up to 5 mm across, or augen-like lenses parallel with the foliation. Foliation is good to excellent, and underlined by millimetre-thin sheets of quartz and feldspar. Occasional fragments of garnet are visible in the core of some biotite knots. The weathered surface is light grey and pitted because of differential weathering of the biotite knots.

In outcrop, map-unit (7) is commonly interlayered with minor amounts of map-units (2) and (6) and is gradational with them. It appears to be an equivalent of (2) strongly affected by retrograde metamorphism, presumably in part because of a more intense deformation.

Hornblende gneiss (map-unit 8)

Hornblende gneiss is most abundant in the central part of the map-area where it forms a number of large contorted strips. It also probably occupies much of a drift-covered area along the eastern margin of the map-area. Lesser amounts are present in the northwestern part of the map-area.

Hornblende gneiss is divided into two types, one a light coloured rock with less than 25 per cent mafic minerals (8a), and another darker rock with more than 25 per cent mafic minerals (8b). A further subdivision of the darker rock is not possible at the present scale of mapping although locally amphibolite is recognizable in the field.

Hornblende gneiss is commonly a foliated and layered alternation of thin quartzofeldspathic stringers with thicker hornblende-rich layers. The rock is fine or medium grained, allotriomorphic granular and dark green or black. Leucocratic varieties are light grey where they are fine grained, and typically mottled where they are coarser grained. Hornblende forms anhedral, locally poikiloblastic crystals, with a pleochroism from straw-yellow on X to dark green on Z. Plagioclase (An_{33-63}), which is locally antiperthitic, is anhedral. Green biotite commonly accompanies hornblende and probably replaces it. Small anhedral grains of quartz form up to 10 per cent of the rock, and microcline is present in some specimens. Epidote and sphene are common minor minerals and garnet and clinopyroxene occur sporadically. Apatite, magnetite, zircon, and in one specimen chlorite, are the accessory minerals. According to its mineralogy, the rock is in the amphibolite facies. Hornblende gneiss was probably derived from a mafic extrusive or intrusive rock, but no direct evidence exists as to the exact nature of the primary rock. Map-unit (4) may be the equivalent rock in the granulite facies.

Biotite gneiss (map-unit 9)

Biotite gneiss (9) is common in the central and northern parts of the map-area where it represents the most abundant rock type. This rock is commonly medium grained, well foliated, and shows various shades of grey according to the relative abundance of biotite. Arbitrary subdivisions have been made between leucocratic gneiss containing less than 15 per cent biotite, mesocratic gneiss with 15 to 25 per cent biotite and rare melanocratic gneiss with more than 25 per cent biotite. Millimetre-thin interlayers of quartz and feldspar are the rule, and in this respect most rocks of this map-unit could be named granitic gneisses. Their homogeneity and their granitic character clearly distinguish them from all other biotite-rich rock types. No trace of retrograde metamorphism is visible in hand specimen, and biotite is evenly distributed in layers parallel with the foliation. Some hornblende and garnet are locally present. In the northern part of the area, biotite gneiss (9) grades into gneissic granodiorite (11) and there the distinction between the two rests entirely on the greater continuity and persistence of gneissic layering in biotite gneiss.

Examination of thin sections shows an allotriomorphic granular texture with good foliation. Quartz forms small anhedral grains often crystallized in ribbons parallel with the foliation. Plagioclase crystals (An_{27-42}) are anhedral and little altered. Biotite is pleochroic in shades of brown (light brown on X and reddish brown to black on $Y \approx Z$). Muscovite, potassium feldspar, garnet and green hornblende replaced by biotite occur locally. Clinopyroxene is rare and zircon, magnetite, apatite, sphene, epidote and carbonates are accessory minerals. Biotite gneiss is in the amphibolite facies of metamorphism and presumably represents the metamorphosed equivalent of argillaceous sediments.

Pyroxenite (map-unit 10)

Pyroxenite is present in Fond-du-Lac Lake area in the extreme eastern part of the map-area, and forms minor lenses and pods too small to be mapped in the amphibolitic band southeast of Nevins Lake.

Minor pyroxenite lenses are also interlayered with map-unit (1) between Axis Lake and Lake Athabasca (Kranck, 1955) and similar lenses occur with pyroxene amphibolite of the Adair Bay – Matthews Lake area. The eastern part of the pyroxenite body on Fond-du-Lac Lake has been described by Colborne (1960). The rock is commonly massive, dark green or reddish brown and weathers black. Pyrite, pyrrhotite and, in the Axis Lake area, nickeliferous pyrrhotite are present in small amounts.

Kranck (1955) reports 85 per cent pyroxene, mainly hypersthene, 5 per cent plagioclase and 10 per cent sulphides with bright red biotite as an accessory mineral. Colborne (1960) described hypersthene, clinopyroxene, brown hornblende, plagioclase and epidote from the same rock, immediately east of the map-area.

Contacts with bordering rocks are conformable and gradational. Kranck (1955) has suggested that the pyroxenite is probably the result of metamorphic segregation, although it might represent remnants of pyroxenite sills.

Granodiorite (map-unit 11)

Granodiorite occupies a large part of the territory northwest of the Straight River Fault and northeast of the Saint Louis Fault. A gneissic rock is most common and massive granodiorite occurs only in the immediate surroundings of Fontaine Lake. Granodiorite grades imperceptibly into biotite gneiss (9) and the boundary between them is locally arbitrary and subjective. The rock is generally medium grained in shades of light grey or pink. The pink colour is related indiscriminately to alteration of all feldspars so that it is not a reliable index of potassium feldspar content. Biotite is a common mafic mineral and forms schlieren, bands and streaks in variable amounts. Hornblende is a common associate.

In thin section, granodiorite displays a hypidiomorphic, more rarely allotriomorphic, granular texture. Quartz forms clear, large grains with amoeboid sutures and undulose extinction. Plagioclase crystals are subhedral, stubby and occasionally rounded off by formation of replacement perthite. Anorthite content is about 24 per cent but rims of more sodic composition exist in some samples. Potassium feldspar occurs as small crystals of microcline as well as some string perthite and replacement perthite. Biotite laths are pleochroic in shades of green (yellowish on X, greenish on $Y \approx Z$) or more rarely brown. Where it is present, hornblende forms small, green, pleochroic crystals locally altered to biotite. Sphene, apatite, magnetite, chlorite and zircon are accessory minerals.

Radiometric age determinations (Rb/Sr whole rock isochron method) have been made by L. S. Beck (personal communication, 1967) on some granodiorites of the area. Samples from Chappuis Lake and from northwest of Nicholson Lake form an isochron indicating a 2,200 $\pm$ 100 m.y. age for these rocks.

Granite (map-unit 12)

Although rocks of granitic composition are associated with granodiorite (11) in the area, only one granite body, lying immediately south of Straight River is of sufficient extent to be shown on the map. The granite is white, massive, and medium- to coarse-grained. Numerous pegmatite dykes cut the bordering rocks and in some areas, pegmatite and gneiss are in about equal proportion, so that in these areas the boundary between the granite and the gneiss is arbitrarily drawn. Muscovite is the common mica, but minor biotite is generally present. Tourmaline-bearing pegmatites are also associated with the granite.

Radiometric age determination (Rb/Sr whole rock isochron) of this granite indicate an age of 1,820 $\pm$ 100 m.y. (Beck, personal communication, 1967).

Athabasca Formation (map-unit 13)

The Athabasca Formation has been described by Fahrig (1961) and defined by him as: "the generally flat-lying, predominantly sandstone sequence occurring south of Lake Athabasca ... and at isolated points on the northwestern shore of the lake" (Fahrig, 1961, p. 1).

The Athabasca Formation probably underlies all the area situated south of Lake Athabasca in Fond-du-Lac map-area. No sandstone outcrops are known on the north side of the lake. The Athabasca Formation in the map-area is commonly a white to beige, medium-grained sandstone. Isolated quartz pebbles up to 25 mm in diameter and beds of gravel are interlayered with the sandstone in many places. Crossbedding is common. In the Poplar Point – Brochet Bay area, the lower part of the formation is hematite-stained and includes beds of red shale.

The basal unconformity of the Athabasca Formation is exposed twelve miles east of Poplar Point (Blake, 1956) where the sediments lie on steeply dipping glassy quartzite similar to minor constituents of map-unit (3) in the Adair Bay – Nevins Lake area. Two sections were measured in that area. The first is on the west side of a small bay twelve miles east of Poplar Point (58° 20'30"; 107° 39'00").

Unit	Description	Thickness in centimetres
5	Sandstone, reddish, fine-grained; shaly hematite-rich lenses; isolated tabular quartzite pebbles about 2.5 cm by 7.5 to 10 cm lying in the bedding planes	29
4	Sandstone, red, coarse; grain size about 1 mm; a few quartzite pebbles from 5 mm to 10 cm in diameter	9
3	Micro-conglomerate and breccia, red; sandy matrix; average size of the pebbles 1 cm, maximum size 5 cm . . .	15
2	Sandstone, red, coarse-grained; grain size about 1 mm; thin red shaly lenses; rounded to subrounded quartzite pebbles in the lower 12 cm	21
1	Quartzite, highly crystalline, glassy, fine-grained; (map-unit 3); intense fracturing and hematite staining along fracture planes	82
	Base of section.	

Another section is exposed about 300 metres west of the previous one.

Unit	Description	Thickness in centimetres
4	Sandstone, red and rusty brown; crossbedded	210
3	Conglomerate; subangular, tabular quartzite pebbles; one block of quartzite 45 cm in diameter is imbedded in the conglomerate	21

2	Conglomerate; angular, tabular quartzite pebbles; shaly red matrix	15
1	Quartzite, highly crystalline, glassy, fine-grained (map-unit 3); intense vertical jointing stained red by hematite. This jointing appears to be parallel to compositional layering of the quartzite	59
	Base of section.	

Observations in this general area show that the most common basal sequence of the Athabasca Formation is – from top to bottom –

(1) Sandstone, white, grey or beige, with abundant crossbedding;
(2) Sandstone, red, purple, orange or rusty-brown, with abundant crossbedding;
(3) Sandstone, red, containing lenses or beds of red shale a few centimetres thick;
(4) Basal breccia or conglomerate, varying in thickness from a few centimetres to more than a metre.

Thickness of the basal conglomerate and size of the cobbles vary considerably over short distances. For instance, red shales containing pebbles up to 7 cm across are present only 300 metres away from a conglomerate with boulders 120 cm long. Elsewhere a breccia of angular block occurs within 7 metres of well-rounded cobbles of quartzite 15 to 30 cm in diameter. Most blocks and pebbles are similar in composition to quartzite (map-unit 3) present beneath the unconformity, but rare blocks of gneisses of unknown origin also occur.

Mylonite (map-unit 14)

Where faulting has so thoroughly brecciated rocks that their original nature is no longer recognizable, they have been mapped as mylonite (14), but where a rock is still recognizable as the sheared equivalent of another it has been grouped with the undeformed rock type. Mylonite (14) is thus limited to the immediate vicinity of the Black Bay Fault, the Saint Louis Fault in the Oldman Lake sector and the Straight River Fault.

Mylonite along the Black Bay Fault is bright pink, red or orange and has been mapped as red gneisses by Koster (1965b). A parallel layering is commonly visible because of recrystallization of thin quartz lamellae but massive outcrops without planar structure also occur. Fragments of quartz (with Boehm lamellae) plagioclase and hornblende crystals are visible under the microscope. Some potassium feldspar, chlorite and probably epidote have crystallized after mylonitization. Mylonites from Oldman Lake or from the Straight River area are grey to black, very fine grained to medium grained, according to the degree of fragmentation. A large part of the Straight River mylonite is well lineated but poorly foliated. Pink or white dots of feldspar are recognizable in most samples but the matrix contains minerals distinguishable only microscopically. The matrix includes fragments of garnet, biotite, sphene, zircon and apatite. Quartz grains are recrystallized and show rare undulose extinction. Undeformed euhedral brownish green tourmaline is present in one specimen from Simons Lake.

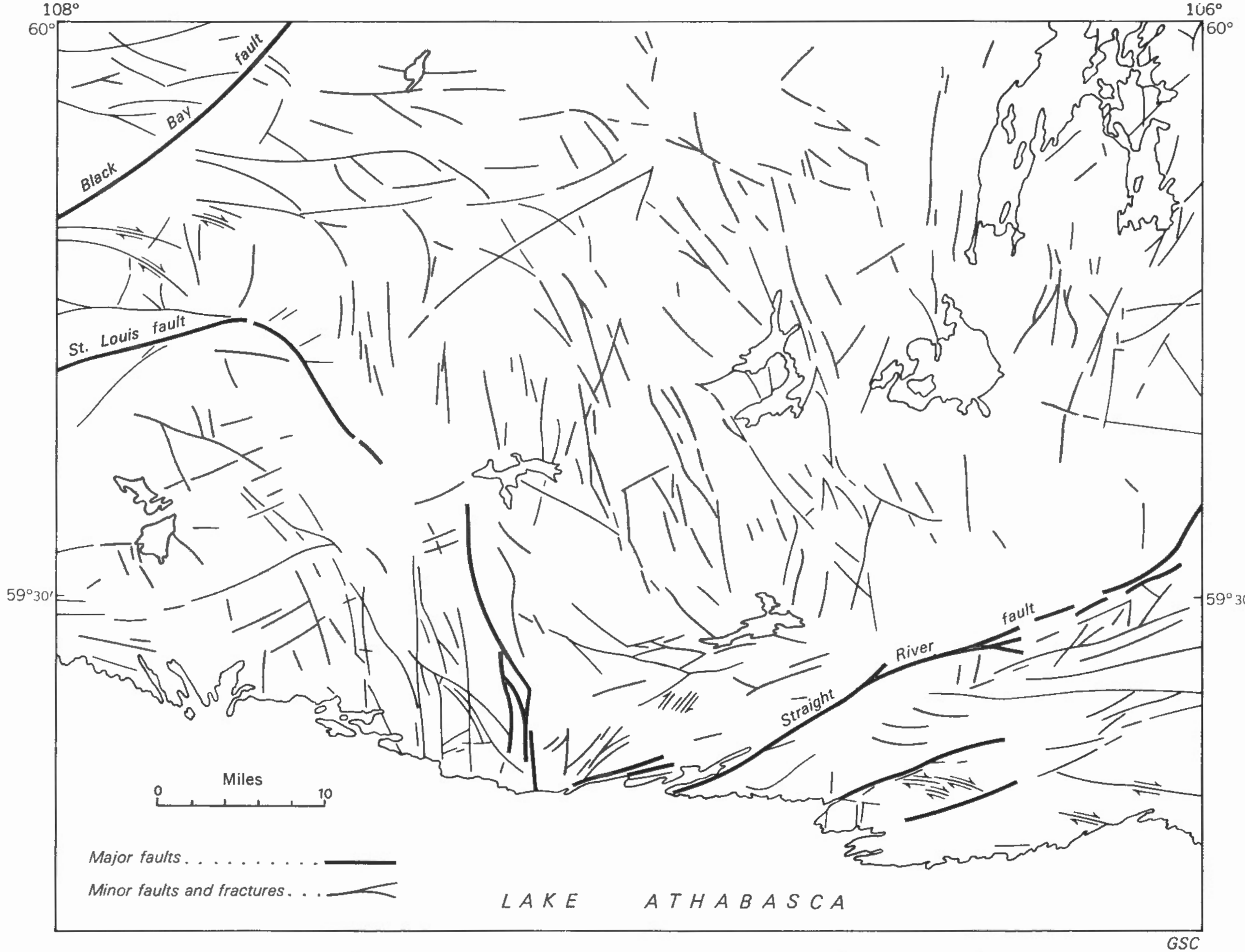

Figure 1. Fracture pattern in the Fond-du-Lac map-area, north of Lake Athabasca.

Major faults probably first formed at a late stage of the deformation that accompanied the emplacement of granodiorite (11). Although the relative age of the mylonite (14) and the Athabasca Formation (13) is not known, evidence from the Uranium City area (Tremblay, 1968) suggests that faults may have been reactivated at least until about 1,300 million years ago.

STRUCTURAL GEOLOGY

Because drift cover is sparse, much structural information can be obtained from air photographs and topographic maps. A marked contrast is apparent for instance between the topography of areas south and north of Grease River or southwest and northeast of Oldman Lake. From both the structure and lithology, the map-area can be divided into three blocks. One, south of Lake Athabasca is covered by flat-lying, Athabasca Formation and will not be discussed further. The two blocks north of Lake Athabasca are separated from each other by faults running along Oldman River and Oldman Lake (Fig. 1). The boundary crosses Bulyea Lake and more or less follows Sinclair and Thicke lakes. It is again represented by a fault along Grease and Straight rivers.

The northern block includes large complex masses of granodiorite (11), and has a northeasterly or northerly dominant structural trend. The structural style of the block is controlled by granodiorite bodies around which hornblende gneiss (8) and biotite gneiss (9) are wrapped in broad open folds. Occurrences of granodiorite vary from large irregularly shaped migmatitic masses in the north, through broad domes, as on Fagan Lake and on Train Lake, to smaller crosscutting plutons (McConville Lake) in the south.

By contrast, gneisses of the southern block commonly dip steeply in isoclinal folds (see map). Lithological units are long continuous ribbons or lenses that trend northwesterly in the western part of this block, easterly in the central part, and northeasterly in the eastern part of the block. Although there are lithological differences, the block is a distinct structural unit.

Northwesterly and easterly trending structures of the southern block are older than northeasterly structures of the northern block, because of refolding on all scales of northwesterly trending folds along northeasterly trending axes (Natukam Peninsula area, for instance). There is no evidence that northeasterly structures south of the Straight River Fault are older than other northeasterly trending structures north of the fault, but by their style of deformation, their composition and their metamorphic grade, rocks south of the Straight River Fault are closely related to other parts of the southern block. Some of the northeast trends south of the fault are possibly contemporaneous with easterly trending structures to the west, and older than northeasterly trending structures north of the Straight River Fault.

It is thus not everywhere possible to sort out ages of structures (and of deformation phases) by their intersection pattern alone. However if it is assumed that where rocks were retrometamorphosed from the granulite facies into the amphibolite facies, penetrative structures found in rocks of the granulite facies are older than those that accompanied formation of the amphibolite facies, then an older structural trend is dominant in the southern block and a younger structural trend is dominant in the northern block. The older trend has been named F_1 and the younger F_2.

The older (F_1) structures

Southwest of Publicover Lake, where they are best preserved, these structures appear to be isoclinal folds with steep limbs and gently plunging axes. They have been variously affected by more recent events in at least three different ways.

In Natukam Peninsula region, they have been refolded along northeasterly trending, southwest plunging (about 25 degrees) axes. The older foliation is bent around the folds and a younger one is locally present. South of Straight River intense shearing along steep northeasterly trending planes parallels the compositional layering. Effects of this shearing decrease to the south and are not noticeable east of Camille Bay on Lake Athabasca. In this area, compositional layering dips at shallow angles (10 – 20 degrees) to the northwest but steepens rapidly to near vertical attitudes in Camille Bay.

In the Publicover Lake – Forsyth Lake area, about 20 miles northeast of Natukam Peninsula, northwesterly trending gneisses are deformed into broad open folds along generally northeast trending, southwest plunging axes. The situation differs however from that in Natukam Peninsula area, in that layering dips at shallower angles (20 – 40 degrees) to the southwest, lithology is different, and the proportion of interlayered granitic material is locally considerable (map-unit 9). The northeasterly foliation is better displayed in granodiorite (11).

The younger (F_2) structures

F_2 structures affect essentially the northern and northeastern parts of the map-area. The structural style of these regions differs considerably from that of other areas. Gneisses are pinched between and apparently wrapped around broad irregular domes of granodiorite. Gneisses themselves contain a large proportion of quartzofeldspathic material and granitization is common. A northeasterly trending foliation is prominent everywhere.

In the central part of the area, west of Fontaine Lake, formerly northwesterly trending gneisses have been bent into the younger northeasterly foliation as indicated by the map-pattern and by intersections of minor structures. Dip of foliation planes varies considerably, from steep to horizontal, with the exception of the northwestern corner of the map-area where it is regularly steep. Fold axes plunge from 20 to 80 degrees to the southwest.

Foliation trends are more northerly around Scott Lake than in any other part of the area. This trend might represent a local deviation from the F_2 pattern, or an inherited pattern related to older (F_1) structures. Presence in that area of rocks displaying retrograde metamorphism from the granulite facies would suggest that the structural trend is probably inherited from the F_1 deformation.

Faults and mylonite zones

Because mylonitic zones accompany faults along which cataclasis has been particularly intense, they supply an easy distinction between major faults (with mylonite) and minor faults (without mylonite) (Fig. 1).

Three major faults extend beyond the limits of the map-area. They are the Saint Louis Fault, the Straight River Fault, and the apparent extension of the Black Bay Fault.

The Saint Louis Fault lies along Oldman River and turns to the southeast on Oldman Lake. It is almost continuous with a set of north-northwesterly trending fractures that extend south along Publicover and Schlater lakes, Bulyea River, southward to Lake Athabasca near the settlement of Fond-du-Lac. Because it is followed by Oldman Lake, this fault zone is more accessible than most faults so that its exact location is well defined. The fault plane generally dips steeply to the southwest and to the west, as observed by Blake (1955). Direction of movement, which Tremblay (1968, pp. 305-307) has discussed for the western extension of the fault, is not known.

The Straight River Fault zone extends northeast from Grease Bay on Lake Athabasca to well beyond the map-area. Dips are generally more than 60 degrees to the northwest along the southern part whereas they are more variable farther to the east. Colborne (1962) and Colborne and Rosenberger (1963) have indicated that movement along the fault was right-handed with a relative down-dropping of the southern block. A right-handed displacement is suggested in the Lower Lake area by the apparent drag of map-unit (7) along the fault, but there is no evidence of any vertical displacement. The northeasterly trending fractures south of Straight River, and between Grease Bay and Fond-du-Lac village, probably belong to the same zone, although they do not show any mylonite.

Another major fault marks the southeastern limit of map-unit (5) in the northwestern corner of the map-area. Koster (1965a) suggested that it represents the extension of the Black Bay Fault of the Uranium City area, righthandedly displaced along easterly trending faults in the Ena Lake map-area to the west. The sense of relative displacement on the Black Bay Fault in the present map-area has not been determined.

Minor faults and fractures are abundant and four sets are recognizable (Fig. 1). One trends east-west and is present south of Straight River as well as in the northwestern part of the map-area. Right-handed displacement is indicated in both areas. The Scott Lake area contains a north-trending set for which no sense of displacement has been established. A less apparent northeasterly trending set extends from Scott Lake along a narrow zone to the southwest and right-handed displacement has been observed in some places. Finally, a widespread northwesterly trending set is common in the central and western parts of the map-area.

ECONOMIC GEOLOGY

Mineral showings are confined to rocks in the granulite facies and those containing relicts of granulite facies (map-units 1 to 7).

Radioactive minerals

Although all specimens were checked for radioactivity, and most traversing teams carried either a scintillometer or Geiger counter, no new radioactive occurrences were discovered. Lang et al. (1962) and Koster (1965b) have discussed previously known occurrences. One radioactive boulder reported by a prospector to be south of Fond-du-Lac village could not be examined because of the high water level of Lake Athabasca.

The distribution of radioactive showings suggests that the western, southern and possibly eastern parts of the map-area north of Lake Athabasca, particularly along fault zones such as the Saint Louis Fault, would be the most rewarding for the prospector. No evidence of radioactivity was located in the Athabasca Formation.

Copper-nickel

The Dinty Lake 'norite' close to the western margin of the map-area, and the Axis Lake – Currie Lake 'norite' along the eastern margin of the area contain nickeliferous pyrrhotite. The Dinty Lake deposit that also contains some chalcopyrite was discovered in 1936. It has been described by Cooke (1937). According to Blake (1955) there are 1,500,000 tons of ore, containing up to 0.6 per cent nickel.

Sulphide mineralization in the Axis Lake area has been known since 1910. Four groups of occurrences contain nickeliferous pyrrhotite and have been described by Colborne (1962). Beck (1959) has summarized available information on all these deposits up to 1959. No new information is available.

Gold

Gold-bearing quartz veins of the Pine Channel area have been thoroughly described by Mawdsley (1949) and by Beck (1959). The veins contain arsenopyrite, pyrrhotite, pyrite and gold. A well mineralized sample assayed 3.36 oz. Au/ton, but most samples indicated less than 1 oz. /ton (Beck,1959).

CONCLUSION

Age and correlation

Biotite from retrometamorphosed gneiss near Fond-du-Lac has given an age of metamorphism of 1,740 m.y. (K-Ar method) (Stockwell in Lowdon,1961) and a sharply intrusive, structurally 'late' granite body near McConville Lake has been dated at 1,820 ± 100 m.y. (Beck, personal communication 1967, Rb/Sr whole rock isochron). Two samples from granodiorite domes fit on another Rb/Sr isochron at 2,200 ± 100 m.y. (Beck ibidem). Dates of the two thermal events indicated by the Rb-Sr data do not correlate with those accepted by Stockwell (1965) for the Kenoran (2,390 m.y.) and the Hudsonian (1,735 m.y.) orogenies, and it would not be wise at this point to try to force them into the existing framework.

Gneisses that are present in the granulite facies of metamorphism or that have obviously been retrograded from that facies belong in the Tazin gneisses. These rocks have been variously defined (see Tremblay, 1968, pp. 23-26). Christie's definition (1953) excluding granitic or granitized rocks from the Tazin Group is best applicable to Fond-du-Lac map-area. The group of rocks thus defined would presumably be Archean metasediments and metavolcanics little or not affected by later granitization.

Evolution of the area

Structure and metamorphism are so closely associated in the map-area that the grade of metamorphism can be deduced from the structural style or the structural style from the grade of metamorphism. Gneisses can be grouped into two categories, those that have reached the granulite facies (map-units 1-7) and those that may have reached it but do not show any indication of it (map-units 8-9). Whereas rocks of the first group are generally not associated with granodiorite bodies, the opposite is true of those of the second group. Ample evidence indicates that the amphibolite facies was imposed on rocks of the area after the granulite facies and that its imprint coincides with granitization phenomena. The map and sections demonstrate the difference in structural style between the two groups of rocks.

We can imagine part of the evolution of the area, starting at the time at which granulites formed. This first recognizable metamorphism was presumably accompanied by gentle to isoclinal folding along more or less easterly or northwesterly trends (F_1). Evidence of this first event is now essentially limited to a belt on the north shore of Lake Athabasca. A more recent orogenic event is indicated by the emplacement of large granodioritic masses and by the presence of the amphibolite facies. This metamorphism is accompanied by a northeasterly trending foliation (F_2) the effects of which decrease away from areas that are in the amphibolite facies. Retrograde effects on the earlier granulite metamorphism decrease in the same direction. Because gneisses of the second group (8) and (9) trend northwest where they are closest to rocks of the first group, they are thought to have belonged to the same series as map-units (1) to (7) although no petrological arguments are available to confirm this hypothesis. The Scott Lake area appears to be an 'island' of partly retrometamorphosed rocks isolated in a 'sea' of granodiorite, biotite gneiss and hornblende gneiss.

Major faults tend to follow boundaries between the two groups of rocks, and presumably correspond to deformation at a higher structural level accompanying final phases of granodiorite emplacement.

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