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GEOLOGY OF THE ANDREW LAKE, SOUTH DISTRICT, ALBERTA

by

John D. Godfrey

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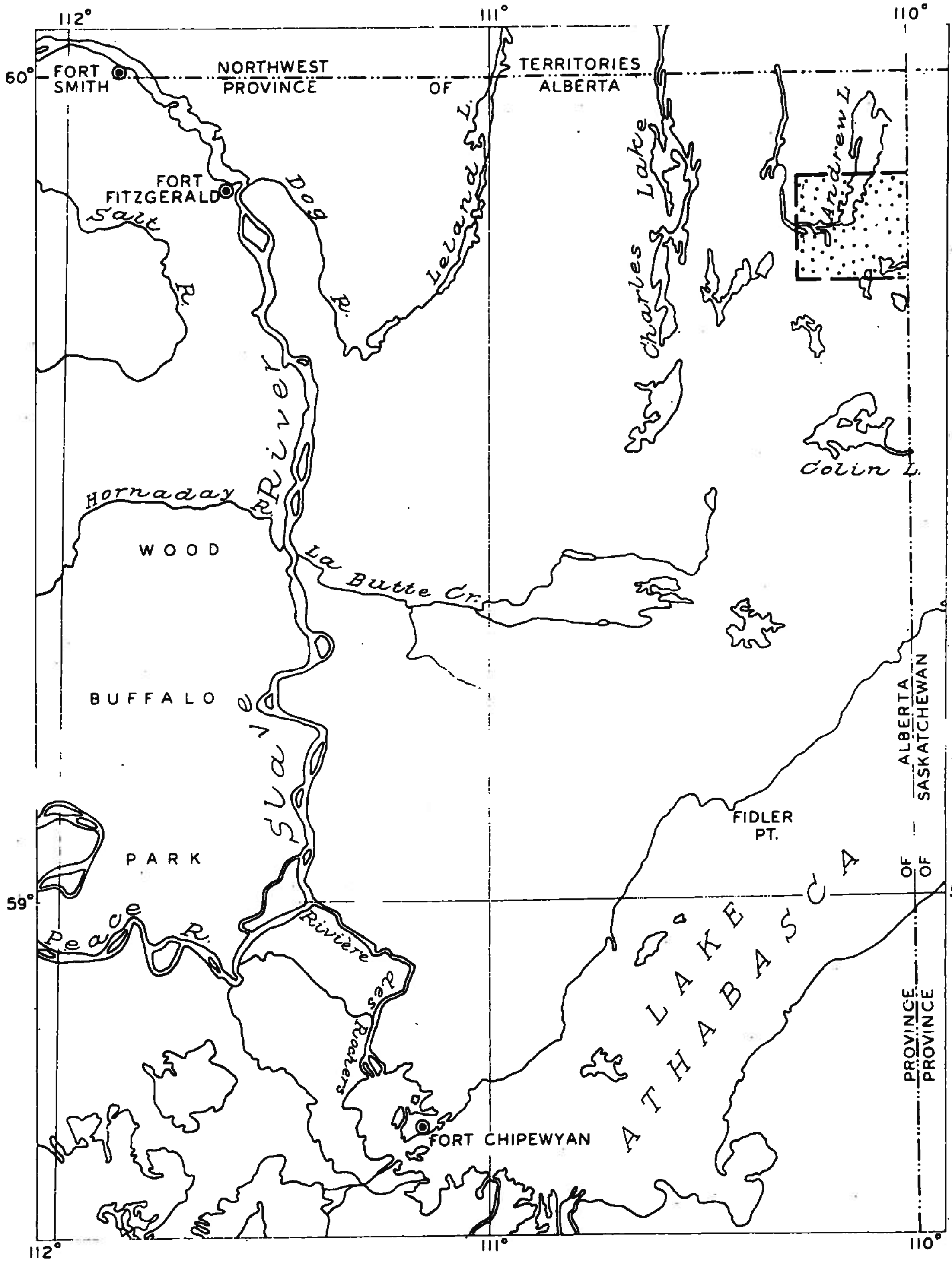

FIGURE 1

LOCATION OF MAP-AREA

SCALE IN MILES

4 0 4 8 12 16 20 24

GEOLOGY OF THE ANDREW LAKE, SOUTH DISTRICT, ALBERTA

Abstract

The geology of a 72 square-mile area in the Precambrian Shield of northeastern Alberta is shown on a colored map of scale 2 inches to 1 mile.

The western part of the area is underlain by granite gneiss containing isolated bands and patches of high-grade metasedimentary rocks, and the eastern part by a low-grade metasedimentary-volcanic complex associated with porphyroblastic biotite granites and with abundant massive biotite and leucocratic granites and pegmatites. Nineteen rock types are described with respect to hand-specimen characteristics, field occurrence, contact relations, and chemical and modal analyses.

Schistosity and foliation are well developed in most of the rock units, and small-scale folds and shear zones are common. A set of north- to northwest-trending faults is superimposed on the structural pattern, cutting across the prevailing northerly strike of the major rock units.

Minor radioactive anomalies and evidence of mineralization were observed in relation to metasedimentary rocks and fault zones.

INTRODUCTION

General Statement

This publication constitutes part of a series dealing with the geology of the Precambrian Shield in northeastern Alberta, north of Lake Athabasca. It deals with the general geology and mineralization of the Andrew Lake, South district which adjoins the Andrew Lake, North district (Godfrey, 1961).

Vertical aerial photographs are of considerable help in prospecting, exploration, and geological mapping, and are available for this area in two complete sets, both on a scale of 1:40,000. The more recent set of photographs (1955) can be obtained from the National Air Photographic Library, Topographic Survey, Ottawa, Ontario. Another set of photographs (1949) is available from the Technical Division, Department of Lands and Forests, Government of Alberta, Edmonton, Alberta.

Location and Access

The Andrew Lake, South district, is situated in the northeast part of Alberta (Fig. 1). It lies between longitudes 110 degrees and 110 degrees 15 minutes west, and between latitudes 59 degrees 45 minutes and 59 degrees 52 minutes 30 seconds north.

Uranium City, Saskatchewan, is situated 45 miles east of Andrew Lake and has regularly scheduled commercial airline flights from and to Edmonton, Alberta, via Fort Smith. Pontoon-equipped planes may be chartered from either Uranium City or Fort Smith into the map-area, where many scattered lakes are suitable for landing these craft.

Andrew Lake is 36 miles north of Lake Athabasca, the nearest commercially utilized water route. Tugs and barges of the Northern Transportation Co. Ltd. operate along this route from Fort McMurray, Alberta, to supply settlements towards the east end of Lake Athabasca, principally Uranium City, Fond du Lac, and Stony Rapids, Saskatchewan.

Physiography

The peneplained surface of the area is typical of the Precambrian Shield. Pleistocene glacial scouring has left numerous rock-basin lakes, low rounded hills, striae and giant grooves and a locally rugged surface with a maximum relief of about 300 feet. The general elevation is from 1,100 to 1,400 feet above sea-level. Over two thirds of the land surface of the map-area is bedrock with a small proportion of muskeg. Glacial sandy plains, such as at the south end of Andrew Lake have an open parkland-type vegetation. The lakes are mainly either disconnected or poorly connected, and cross-country canoe travel involves portaging. The principal drainage is west to Charles Lake.

The distribution and shapes of lakes are controlled by structural and lithological features and have been modified by ice erosion. Many narrow elongate bays are related to the erosion of fault zones, and straight shorelines suggest fault-line features. Fractured zones or structurally weak rocks have been plucked out by ice erosion, particularly on the west and southwest lake-shores, giving rise to irregular shorelines. Exceptionally clean, fresh bedrock surfaces are found as low, wide aprons bordering some rock-basin lakes, and such water-washed surfaces exhibit details of the bedrock geology.

* Previous Work

Tyrrell (1896) made the initial traverse along the north shore of Lake Athabasca in 1892 and 1893 and was followed in 1914 and 1916 by Alcock (1915, 1917). In 1929 and 1930 Cameron and Hicks (Cameron, 1930; Cameron and Hicks, 1931; Hicks, 1930, 1932) conducted a reconnaissance survey north of Lake Athabasca, including a traverse from Andrew Lake.

After gold was discovered at Goldfields, Saskatchewan, Alcock (1936) mapped the extreme northwest corner of Saskatchewan, adjoining the Andrew Lake district to the east on a scale of 1 inch to 4 miles. Mapping of the Fort Smith, N.W.T. area which adjoins the Andrew Lake district to the north, was completed in 1938 (Wilson, 1941) on a scale of 1 inch to 4 miles.

By 1953, uranium-prospecting activities had spread to the Precambrian Shield of Alberta, and Collins and Swan (1954) spent several weeks examining mineralization at a number of points in the northeastern corner of the province. Low-grade uranium mineralization was found in the course of this prospecting and exploration activity (e.g. Ferguson, 1953).

In 1959 the Geological Survey of Canada carried out a reconnaissance survey of the Precambrian Shield in Alberta north of Lake Athabasca and published a map on the scale of 1 inch to 4 miles with marginal notes (Riley, 1960).

In 1960 the Saskatchewan Department of Mineral Resources (Koster, 1961) carried out a mapping program on a scale of 1 inch to 1 mile in an area adjacent to the Andrew Lake map-area.

Present Study

Field work was carried out during 1957 and 1958. The accompanying map (61-2A) is based on parallel pace and compass traverses generally spaced at one-third mile intervals. Anomalous compass readings were obtained mainly in the vicinity of hornblende granite gneisses and amphibolites. Magnetite was observed at some granite gneiss localities, and its presence was confirmed by laboratory investigations, thus accounting for some magnetic anomalies.

The pattern of magnetic anomalies and contours outlined on an aeromagnetic survey by the Geological Survey of Canada, Ottawa (1958), can be correlated both with regional structures and the distribution of the principal rock groups indicated on the map 61-2A.

Acknowledgments

The field parties were composed of J. M. McLelland, E. Overbo and B. E. Henson in 1957; J. M. McLelland, E. W. Peikert, D. Clements, R. Jull, J. Steiner, J. G. Tansey and G. Wysocki in 1958.

The assistance of the pilots and staff of McMurray Air Service Ltd., Uranium City, Saskatchewan, is gratefully acknowledged.

GENERAL GEOLOGY

Precambrian igneous, sedimentary, and metamorphic rocks form the rock complexes of the Andrew Lake, South district.

The map-area can be divided into two approximately equal parts. The western part is underlain by a mixture of granite gneiss and high-grade metasedimentary rock and the eastern part by a series of porphyroblastic biotite granites, massive to foliated biotite and leucocratic granites and pegmatites, and low-grade metasedimentary rocks containing intercalated flows and tuffs. The distribution of the constituent rock types amongst the four principal rock groups - granite gneiss, porphyroblastic biotite granites, massive to foliated granites and pegmatites, and metasedimentary rocks - is shown in table 1.

The area is cut by three sets of faults, with orientations approximately northwesterly, northerly, and easterly. All rock types show some effects of deformation, such as crushed, sheared, and plastic-flow structures, and many exhibit features of an ultra-mylonitic or migmatitic character. The regional strike of the foliation ranges from north 0 to 30 degrees east and dips at high angles, mainly to the west.

Geological History

A tentative outline of the geological history is as follows: initial development of the granite gneiss complex as a coherent structural unit of predominantly biotite and hornblende granite gneisses. In this development rocks of sedimentary and volcanic origin probably underwent several cycles of metamorphism accompanied by mobilization and redistribution of material. The structural relations of bands and lenses of high-grade metasedimentary rocks to the remainder of the complex is uncertain; however, they probably represent either the untransformed remnants of an early cycle, or metasedimentary rocks incorporated during a late phase in the development of the gneissic complex.

The second distinct historical phase involved the formation of the low-grade metasedimentary rocks of Waugh Lake and their metamorphic equivalents - the porphyroblastic biotite granite group, including the biotite microgranite. These rocks structurally overlie the biotite and hornblende granite gneiss complex. The silty quartzitic sediments with their abundant intercalated extrusive materials suggest a history of rapid erosion and transportation, possibly in a geosynclinal environment. A southward increase in metamorphic grade in the Waugh Lake metasedimentary rocks coincides with a gradual change in mineralogy and texture from the metasedimentary rock complex through biotite microgranite to granites C and D. North from Waugh Lake, the biotite granites A and B are largely in fault contact with the Waugh Lake metasedimentary rocks and the petrogenetic relationships of these granites is less certain.

Late in the metamorphic cycle, granites and pegmatites intruded or replaced portions of all pre-existing rock types to form the abundant massive to foliated, biotite and leucocratic granites and pegmatites. These rocks are concentrated in a zone between the granite gneiss complex to the west and the low-grade metasedimentary rocks and associated porphyroblastic biotite granites to the east. The field and petrologic relationships of the porphyroblastic biotite granites and the massive to foliated, biotite and leucocratic granite group (Peikert, 1961) are summarized in figure 2.

Much of the transverse faulting and the associated features post-dates the

Table 1. Principal Rock Groups, Constituent Rock Types, and Their Field Associations

Granite Gneiss (30.8%)*	Massive to Foliated Granites and Pegmatities (13.9%)*	Metasedimentary and Associated Rocks (15.3%)*	Porphyroblastic Biotite Granites (9.5%)*
Biotite granite gneiss	Sheared, leucocratic granite	Quartzite	Biotite granite A
Hornblende granite gneiss		Biotite-sericite schist and phyllite	Biotite granite B
		Biotite feldspar-augen schist and phyllite	Biotite granite C
		Slaty argillite	Biotite granite D
		Basic rocks	Biotite micro-granite
		Sericitic, porphyroclastic phyllonite — — —	— — — —
	Muscovite granite and pegmatite — — —	— — — —	— — — —
	Feldspar pegmatite — — —	— — — —	— — — —
— — — — — — —	Massive biotite granite, biotite 'p' granite and granite pegmatite — — —	— — — —	— — — —
— — — — — —	— — — — — —	Amphibolite** — — —	— — — —

* Per cent outcrop of total map-area.

** Outcrop area included with each rock group as appropriate.

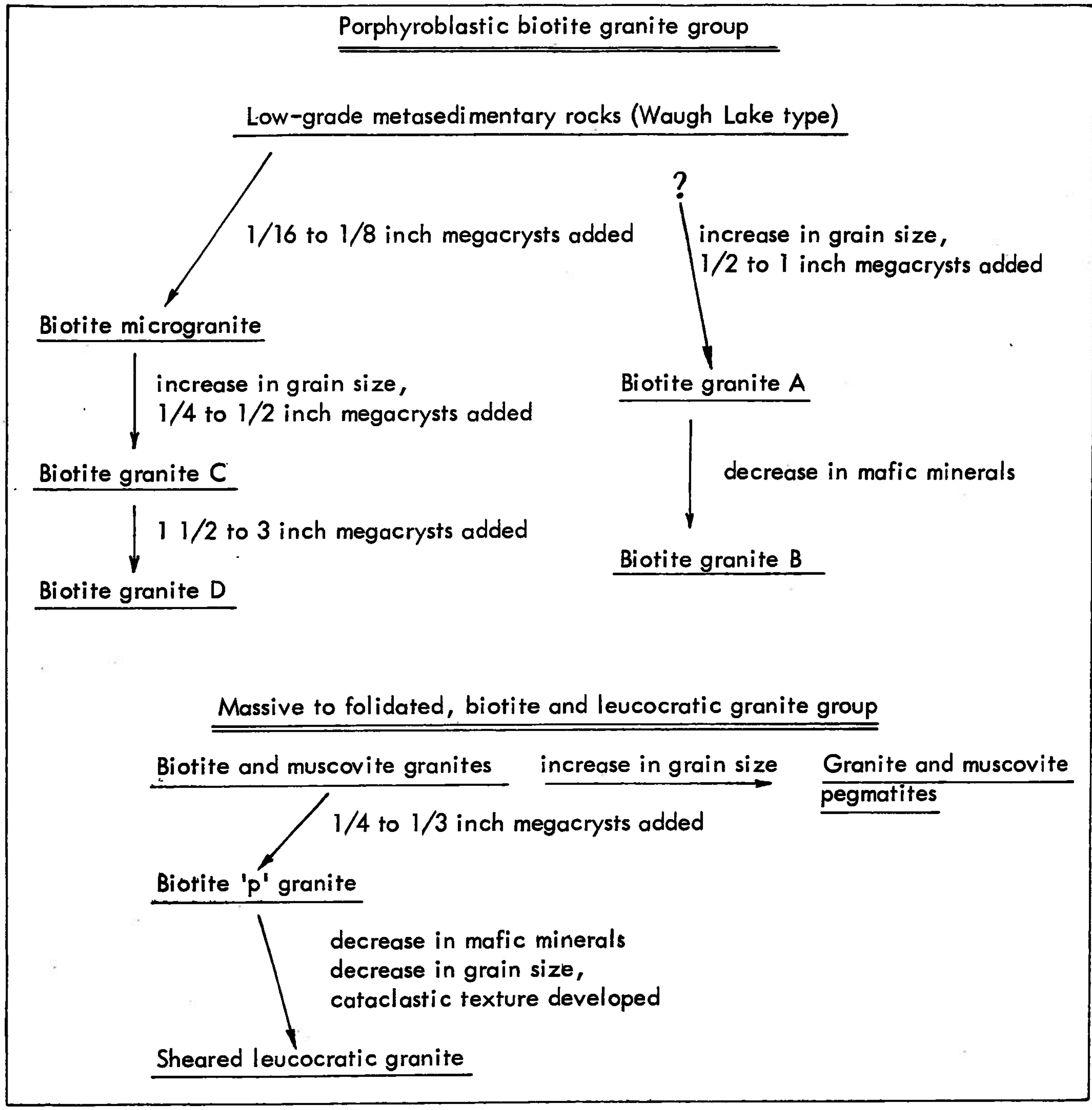

Figure 2. Relationships between members of the porphyroblastic biotite granite group, and amongst the massive to foliated, biotite and leucocratic granite group.

formation of all major rock units. At the east side of Andrew Lake in particular, deformation outlasted recrystallization, as parts of the normally massive biotite granite are distinctly foliated to gneissose and parts of the porphyroblastic biotite granite A are also gneissose.

Rock-Type Classification

The definition of some rock types and of some lithologic boundaries is not always clear and obvious in view of the many serial changes of mineralogy and texture from one rock type to another. In addition, metamorphism, intrusion, and deformation has obscured most original structures and contact zones and has resulted in extensive mixed rock assemblages. Thus only the predominant rock type is shown on much of the map, finer details being excluded.

In order to standardize the rock classification, selected hand-specimens were chosen as standard reference samples to represent as nearly as possible the typical lithology of each map-unit. The standard samples are listed in table 3 with their modal and chemical analyses and locations are shown on the geological map.

MAP-UNITS

Metasedimentary and Associated Rocks

The map-area is situated on the western edge of a belt of metasedimentary rocks outlined by Henderson (1939a, 1939b), Wilson (1941), Mulligan (1956), and Taylor (1956) in the Northwest Territories, and which extends southward on both sides of the Alberta-Saskatchewan boundary. In the north these rocks have been divided into the pre-Nonacho, Nonacho, and post-Nonacho series, and in the south have been referred to as the Tazin group (Camsell, 1916; Alcock, 1936; Christie, 1953). The metasedimentary rocks of the Andrew Lake, South district are not at present assigned to a specific stratigraphic division[1], and regional correlations are not attempted. Metasedimentary rocks are less erosion-resistant than other principal rock types, and hence are disproportionately exposed compared to their actual amount in total bedrock.

The metasedimentary rocks of the map-area fall into two distinct divisions: high-grade quartzites and schists which are present in the western part of the map-area and low-grade metasedimentary rocks which form a broad band near Waugh Lake in the east.

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1 The potassium-argon dates of biotite and muscovite from several of the principal rock types in this and adjoining map-areas are 1.8 billion years (Godfrey and Baadsgaard, 1962).

Waugh Lake Metasedimentary and Metavolcanic Rocks

The band of metasedimentary and metavolcanic rocks of the Waugh Lake area are of comparatively low grade, and similar rocks have not been found elsewhere in northeastern Alberta. This band is composed of interlayered, impure quartzite, siltstone, and biotite schist, sericitic porphyroclastic phyllonite, and intercalated basaltic flows and tuffs. Adjacent porphyroblastic biotite granites and biotite microgranite are probably metamorphic equivalents to this band of rocks, and they are described separately.

The Waugh Lake metamorphic rocks underlie 11.9 per cent of the map-area, the volcanic portion being 3.4 per cent, or about one-third of the Waugh Lake complex.

Laminated and graded bedding are best preserved in the quartzites located just west of the northern part of Waugh Lake (Sec. 1, Tp. 125, R. 1), and though this band of low-grade metasedimentary and metavolcanic rocks typically lacks all small-scale feldspar, pegmatite, and migmatite associations, small pegmatites and massive granite bodies are present towards the southern end of the Waugh Lake band. The presence of these bodies, plus the fact that the southern limits of the band interfinger with and grade into porphyroblastic biotite granite rocks, and the presence of garnet in the attenuated southern extremity of the band west of Johnson Lake, are interpreted as indications of a southward increase in metamorphic grade.

Within most of the Waugh Lake metasedimentary rocks the metamorphic grade ranges from the quartz-albite-muscovite-chlorite subfacies to the quartz-albite-epidote-biotite subfacies of the greenschist facies. The grade in the extreme southern section probably passes into the almandine-amphibotite facies (Fyfe, Turner, and Verhoogen, 1958). Effects of dynamic metamorphism - crushed, sheared, and mylonitic zones - are common. Such effects are particularly evident in the sericitic, porphyroclastic phyllonite and in the sericite-chlorite schist which extends for one mile south of Doze Lake and passes into the lineament of Waugh Lake.

The distribution of tourmaline-quartz veins and stringers throughout most of the Waugh Lake metasedimentary rocks, with a decided concentration inside the elbow of the lake, is unique in the Shield area of Alberta. They are discussed in greater detail in the mineral occurrences section.

Quartzite. Three subtypes recognized within the quartzite map-unit of the Waugh Lake area (Watanabe, 1961) are quartzose siltstone, mica-quartz arenite, and feldspathic wacke (Williams, Turner, Gilbert, 1958). Modal and chemical analyses of these three subtypes are presented in table 3, (samples 26, 28, and 34 respectively), however, they are grouped together as the quartzite map-unit for purposes of field description.

The quartzite map-unit is the major unit of the Waugh Lake band. This unit is typically interfingered or interlayered with all other rocks of the Waugh Lake area. The quartzite is light to medium grey when fresh, but weathers medium to dark grey. It may be massive-bedded and compact, or thinly bedded with well-developed bedding-plane joints. The quartzites are largely fine grained, but range from medium to very fine grained. Minor phyllite and biotite-sericite schist are almost ubiquitous and form narrow layers in the quartzite; the phyllitic - schistose rocks become predominant in the biotite schist map-unit.

In places good relict sedimentary bedding is recognizable, commonly graded in the thinner beds, with individual strata ranging from 1/8 to 10 inches in thickness. Unequivocal cross bedding was not observed. The finely laminated quartzites tend to be contorted, showing drag-fold structures, whereas coarser-grained and thicker beds have more open folds and apparently were more competent. Many of the thicker beds also possess good fracture cleavage.

The contacts of the quartzite map-unit with adjacent map-units are typically gradational, but superimposed shear contacts are common. Contacts along strike are interlayered and transitional with the biotite microgranite, are intrusive or faulted with the massive biotite granite, and faulted, but possibly transitional in part, to porphyroblastic biotite granites A and B.

Biotite Schist. This map-unit includes all fissile, finely foliated, micaceous rocks, typically interlayered on a small scale with minor impure quartzite. This unit, forming a minor but widespread component of the Waugh Lake metasedimentary complex, generally grades into and intertongues with the adjacent quartzite map-unit. Rock subtypes within the map-unit include phyllite, phyllonite, slaty argillite and schist, with chloritic, biotite-rich, sericitic, and ferruginous varieties. Distributions of these rocks are not outlined on the map, except for the south-trending sericite-chlorite schist zone at the south end of Doze Lake. Both fresh and weathered surfaces are dark grey, and chloritic varieties are dark to medium green. These rocks range in character from phyllitic to schistose and are fine- to medium-grained. The principal megascopic mineralogical features of the biotite schist include biotite, sericite, and chlorite in varied proportions, and many of the phyllites are obviously siliceous.

Milky quartz veins, in places sheared and boudinaged so as to produce lenticular or rounded pods, form tectonic or crush "quartz-pebble" pseudo-conglomerates. True conglomerate may be present in some outcrops, particularly those in SE. 1/4, Sec. 1, Tp. 125, R. 1, but they may prove to be of tectonic origin. Koster (1961, p. 17) described a "Western Conglomerate" from that part of the Waugh Lake metasedimentary band in Saskatchewan, and this appears to be similar to the rocks described above.

A chlorite-sericite phyllonite with hematite (sample 25) and a biotite-sericite schist (sample 27) were selected for chemical and modal analyses - see table 3.

Structures in the biotite schist map-unit include small-scale drag folds, near-vertical crenulations and lineations, and boudinaged or pinch-and-swell quartz veins. Mineralogical layering is evident, but primary structures are generally confined to the quartzites.

Contacts with other rock types are similar in character to those of the quartzite map-unit.

The effects of dynamic metamorphism are seen as highly sheared and deformed zones with abundant chlorite and sericite, and are particularly notable in the extensive shear zone at the south end of Doze Lake (Sec. 12, Tp. 125, R. 1).

Basic Rocks. The basic rocks of the Waugh Lake area are mainly volcanic in origin, consisting of basaltic flows and tuffs, with minor intrusive bodies. Metamorphism in deformation zones has resulted in the formation of minor greenstones, and recrystallization of some basic rocks, mainly in the south, has produced rocks more properly termed amphibolites. As indicated on the map, the basic rocks are intercalated with the metasedimentary units and make up about 30 per cent of the complex.

The flows and their amphibolitic equivalents are dark green or black where fresh, and weather to lighter shades of green, whereas the tuffs are greenish-grey and are lightest colored on the weathered surface. The flows and amphibolites are compact, dense, homogeneous rocks with an imperfect streaky foliation, and the tuffs are compact, massive to slightly foliated. The fine-grained, dark-colored texture of the flows and tuffs prevents recognition of the constituent minerals megascopically, but hornblende, biotite, and plagioclase were noted in the amphibolite. Chemical and modal analyses of two flow samples (24, 29) and one tuffaceous sample (23) are given in table 3.

Structures such as pillows, amygdules, and layering were not observed in the basic rocks. Chilled contacts and scoriaceous zones are not evident, and contacts with the metasedimentary units are generally partly covered or obscure. It is, however, likely that the basic rocks are mostly concordant with the surrounding rocks, and are predominantly composed of flows, with minor intercalated tuffaceous metasedimentary material. Field evidence has been corroborated by petrographic study in these identifications. One tabular gabbroic body, possibly a dyke up to 80 feet thick, cuts the metasedimentary rock foliation just north of Waugh Lake, (Sec. 12, Tp. 125, R. 1).

Minor alteration of some basic rocks to greenstone has taken place in zones of shear. Peikert (1961) has shown that metasomatism of basic tuffs and tuffaceous metasedimentary rocks has given rise to rocks of the porphyroblastic biotite granite group found on strike to the south of the Waugh Lake complex.

Sericitic, Porphyroclastic Phyllonite. This map-unit is confined to the Waugh Lake region and the adjoining area of porphyroblastic biotite granites. It forms distinct, mappable bands and lenses throughout this general area, and is intimately mixed with either the metasedimentary rocks or the porphyroblastic biotite granites A and B and the biotite microgranite. Both fresh and weathered surfaces are generally mottled and light colored, with darker streaks or bands. This rock readily splits along well-developed foliation planes and crumbles fairly easily with a hammer. Pink potash feldspar augen, "pebbles" and fragments of quartz, granite, and metamorphic rocks are set in a quartzo-feldspathic matrix streaked with biotite and chlorite. The texture is cataclastic, with about 50 per cent of the fragments being greater than 0.5 mm. Rounded feldspar augen and "pebbles" invariably have tails which trail off into a crushed, sheared, or mylonitic matrix. Chemical and modal analyses of typical samples (30 and 32) appear in table 3.

Structures are related to a cataclastic history, with rolled and sheared fragments or pebbles of quartz, quartzite, schist, argillite, and granite lying in a crushed matrix. Minor pegmatites and quartz veins which cut these rocks are commonly deformed to produce discontinuous, en échelon, or boudinage structures.

Contacts with adjacent rocks are predominantly sheared - a feature compatable with a cataclastic origin for this map-unit, but which may have arisen from a late dynamic metamorphism.

The mode of origin of these rocks is open to speculation. The cataclastic features of the rock largely obscure the critical information needed to determine its origin and history. The large fragments and pebbles may be of clastic origin, but cataclastic deformation of a granitic phase, such as porphyroblastic biotite granites A and B, could also give rise to crush conglomerates and to a sericitic, porphyroclastic phyllonite. A combination of these modes of origin is also possible.

High-grade Metasedimentary Rocks

Bands and lenses of quartzite and biotite schist are scattered throughout the granite gneiss terrain of the western part of the map-area. Four principal bands are present - west of Andrew Lake, west of Split Lakes, at Spider Lake, and east of Spider Lake.

These metasedimentary rocks are probably equivalent to the almandine - amphibolite facies.

Quartzite. The major rock type in these metasedimentary rocks is quartzite, which is commonly associated with minor phyllitic and schistose phases. Many features are similar to those of the low-grade Waugh Lake metasedimentary rocks and only the principal differences are emphasized below. Fracture cleavage is much less evident and though graded bedding is absent, layering representing relict bedding remains. The presence of graphite, pink to red garnet, and feldspathic material in the high-grade rocks constitute the main mineralogical differences. Feldspar augen, pegmatites, migmatitic phases and small granite bodies are common expressions of the feldspathic phases and are especially abundant in the Spider Lake band. Minor amphibolite and basic phases were noted in some metasedimentary bodies and are particularly conspicuous towards the north end of the Spider Lake band. Representative mineralogical or chemical compositions have not been established for these highly varied metasedimentary-migmatite complexes.

Structures tend to be of a plastic deformational character, and include open and tight folds, drag folds, and migmatitic structures in areas rich in feldspar.

All contacts are with granite gneiss and are typically transitional over distances from 10 to 100 feet across strike. The rocks on each side of the contact zone tend to be highly contorted, and the contact zone may be further complicated by subsequent small-scale faulting.

Biotite Schist. Bands and lenses of highly metamorphosed biotite schist form a closely associated minor constituent interlayered with quartzite. Gradations from schist to phyllite and phyllonite are very common in all of the major metasedimentary bands. The general characteristics of the high-grade schist are similar to those of the low-grade schists with primary sedimentary features being absent, but with garnet, graphite, and feldspar concentrations being present.

Structures and contacts of the biotite schist are similar to those of the quartzite unit and the equivalent low-grade schist.

Porphyroblastic Biotite Granites and Associated Rocks

The group of porphyroblastic biotite granites[1] comprises biotite microgranite and porphyroblastic biotite granites A, B, C, and D. The outstanding feature which distinguishes these rocks is their porphyroblastic feldspar texture. The gradation of mineralogy and texture between these rocks and their intimate association strongly indicate a common close genetic relationship. A summary of the petrographic features of all granites and pegmatites from the map-area are listed in table 2. Special features, the nature of contacts, and other structures are discussed under the individual rock types.

Biotite Microgranite

Biotite microgranite is closely associated with both the Waugh Lake metasedimentary rocks and the porphyroblastic biotite granites and related biotite granites. It is less abundant than other members of the porphyroblastic biotite granite group and is restricted to the area near Waugh Lake. This rock has the highest percentage of

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1 In order to emphasize the common textural characters which embrace the members of this porphyroblastic biotite granite group, it has been necessary to include rock types which do not conform to the strict definition of the term "granite". Thus, our working definition includes biotite granites A, B, C, and D, and the biotite microgranite (a fine-grained phase). Precise petrological nomenclature for these rock types is used in the section dealing with chemical and modal analyses.

Table 2. Systematized Description of Petrographic Properties of Granite and Pegmatite Map-units

Rock-unit		Color	Texture	Composition[1] Porphyroblasts[2]	Composition[1] Matrix
Biotite microgranite		porphyroblasts: white to grey; matrix: dark	porphyroblastic (1/16 to 1/8"), foliated, fine grained	plagioclase, minor microcline (20 to 35%)	quartz, plagioclase, biotite, hornblende minor epidote
Biotite granite A		porphyroblasts: white to grey; matrix: medium grey	porphyroblastic (1/2 to 1"), foliated, medium grained	microcline perthite (25 to 60%)	quartz, plagioclase, biotite, minor hornblende
Biotite granite B		porphyroblasts: white to grey; matrix: grey	porphyroblastic (1/2 to 1"), poorly foliated, medium grained	microcline perthite (30 to 60%)	more feldspar and less mafic minerals than A, minor microcline
Biotite granite C		porphyroblasts: white to grey; matrix: medium grey	porphyroblastic (1/4 to 1/2"), foliated, fine to medium grained	plagioclase (40 to 65%)	quartz, biotite, plagioclase, minor microcline, epidote, hornblende
Biotite granite D		porphyroblasts: grey to pink; matrix: medium to light grey	porphyroblastic (1 1/2 to 3"), foliated to massive, medium to coarse grained	microcline perthite (35 to 55%)	quartz, biotite, plagioclase, minor hornblende, epidote, microcline
Massive granite	equigranular biotite phase	pink to reddish	massive, equigranular, medium grained	none	quartz, microcline, perthite, plagioclase, biotite, minor muscovite, chlorite, locally garnet
Massive granite	muscovite phase	white to light grey	massive, equigranular, medium to coarse grained	none	quartz, perthite, plagioclase, muscovite, minor biotite, chlorite, locally garnet
Massive granite	biotite 'p' phase	pink to reddish	massive, medium grained, porphyroblastic (1/4 to 1/3")	microcline perthite (25 to 45%)	quartz, plagioclase, microcline perthite, biotite, minor chlorite, muscovite
Sheared leucocratic granite		light grey to pink	foliated, crushed, equigranular, fine to medium grained	none	quartz, microcline perthite, plagioclase, minor sericite, biotite, chlorite
Pegmatite	equigranular granite phase	pink to red	massive, equigranular, coarse grained	none	quartz, microcline perthite, plagioclase, minor biotite
Pegmatite	feldspar phase	white	massive, equigranular, very coarse grained	none	quartz, microcline perthite, plagioclase, minor biotite, chlorite, muscovite
Pegmatite	muscovite phase	white to light grey	massive, equigranular, very coarse grained	none	quartz, plagioclase, microcline, muscovite, locally garnet

1 Color is not a reliable guide for the identification of feldspars in the field. Color relations of the two feldspars vary within the area and the opposite of the usual relation is commonly observed (i.e. potash feldspar is usually pink to red, and plagioclase is white to grey). Mention of a specific feldspar is made only after laboratory checks on field observations, and caution is advised in the field identification of feldspars except where invariant properties are noted.

2 Percentages refer to amount of porphyroblasts in rock.

total mafic constituents and is the finest-grained member of the group. The rock is generally fairly uniform, but locally grades to porphyroblastic biotite granite C or to amphibolite, and in some outcrops large plagioclase crystals tend to be concentrated in bands to produce a faint gneissosity. Modal and chemical analyses (samples 33 and 38) are presented in table 3. On the basis of hand specimen textures, sample 38 probably represents a phase of biotite microgranite which is gradational toward porphyroblastic biotite granite C.

The contact between biotite microgranite and massive biotite granite is generally gradational in both textural and mineralogical characters. This contact is apparently similar to that between biotite granite C and massive biotite granite which is described below.

The north side of the biotite microgranite body west of Waugh Lake has an intertonguing contact with low-grade metasedimentary rocks. At one place the abundant plagioclase porphyroblasts gradually disappear towards the contact, and over a distance of one-quarter of a mile the microgranite passes on strike into quartz-sericite-chlorite phyllite. The contact between biotite microgranite and phyllite is sharp and parallels the sedimentary bedding, with the microgranite dipping beneath the phyllite at a high angle. (The tops of the sedimentary beds could not be determined near the contact.) The contact can be followed for several hundred feet until it becomes a faulted contact trending parallel to the regional strike. At a second place the biotite microgranite becomes finer-grained, more biotite-rich, more sheared, and less porphyroblastic along strike as the contact with metasedimentary rocks is approached. After an unexposed interval of 250 feet, massive metasedimentary rocks are exposed, containing plagioclase and quartz grains up to about 1/10 inches in diameter. Petrographic studies (Peikert, 1961) have shown that these metasedimentary rocks are tuffaceous, and are regarded as the parental materials of the porphyroblastic biotite granite group.

Biotite Granite A

Biotite granite A, closely associated with biotite granite B, adjoins the north and west sides of the Waugh Lake metasedimentary complex. The major outcrop area of this unit lies to the north and was outlined previously (Godfrey, 1961).

In addition to the white porphyroblastic feldspars (some with red rims), small red feldspars from 1/16 to 1/8 inch in diameter may be present in the matrix. Schistose-biotite rich lenses commonly a few inches wide and several feet in length are scattered throughout, but these may be inclusions of biotite schist rather than discrete segregations.

Internal structures are expressed as a matrix foliation and as alignments of schistose-biotite lenses or feldspar porphyroblasts. The porphyroblasts are generally parallel or subparallel to the matrix foliation, especially near metasedimentary rock contacts where they may show also augen-flow structure. Small shear zones occur mainly in the biotite-rich areas where the porphyroblastic feldspars typically develop augen structure, are fractured and are elongated in the direction of shear, all in contradistinction to the euhedral, tabular porphyroblasts of a relatively undeformed section.

The small red feldspars are distributed close to the small mylonitic shears (one-eighth inch thick) thus indicating their formation is linked with the deformational history.

Biotite Granite B

The boundary between biotite granites A and B is gradational, and its location is arbitrarily chosen dependent upon a hand-specimen classification. This gradation is not a simple change of lithology, as in detail biotite granites A and B interfinger and are arranged irregularly; however, a general gross change of rock type does occur across a composite band of these granites.

Loss of biotite, chlorite and hornblende, and increase in the feldspar content of the matrix marks the gradation from biotite granite A to biotite granite B. Mineralogically and texturally these two rocks are otherwise alike. Further increase in the feldspathic content of biotite granite B groundmass gives rise to a massive or slightly foliated, grey granite. Feldspar megacrysts of 1/2 to 1 inch diameter in the grey granite are apparently similar to those of biotite granites A and B.

Minor shear zones in biotite granite B and the grey granite are expressed in the same way as those in biotite granite A.

Small, massive, relatively leucocratic granitic bands and lenses are dispersed throughout biotite granites A and B. In hand specimen the only visible change between the leucocratic granitic masses and the enclosing porphyroblastic biotite granites is a difference in the biotite contents. The composite leucocratic granitic bands consist of varied amounts of aplite, microgranite, pegmatite, and include siliceous phases which in part resemble sugary-textured quartzite. In biotite granite A the leucocratic granite bodies attain a maximum of 10 per cent of the total rock and average about 5 per cent; in biotite granite B they make up about 1 per cent. The bodies may be almost straight sided with simple dyke-like forms or, less commonly, have irregular shapes. These bands range in width from a fraction of an inch to over 10 feet, average from 1 to 2 feet, and generally cross the foliation at small angles. Development of foliation in the porphyroblastic biotite granite either postdates or is synchronous with emplacement of much of the composite aplite-pegmatite masses for the foliation is mainly common to both. However, a small amount of the aplite-pegmatite appears massive adjacent to well-foliated porphyroblastic biotite granites A and B. Small strike separations may appear on cross-slips, where leucocratic granitic bands are offset by a few inches. Also, adjacent to mylonitic stringers the coarse-grained and porphyroblastic feldspars are generally extensively fractured in a zone several inches wide. A few mylonitic zones attain widths of 2 feet and appear as hard, siliceous, grey to green bands.

Biotite Granite C

This unit is found only in the southeastern section of the map-area, principally between Johnson and Cherry Lakes, although small masses are also present in the adjoining rock units. Biotite granite C is situated at the southern end of the Waugh Lake metasedimentary band associated with biotite granite D and massive granites and pegmatites. Modal and chemical analyses of biotite granite C (sample 41) are presented in table 3.

Internal structures of biotite granite C are simple and are expressed by an obvious biotite foliation, accompanied by a common alignment of porphyroblastic feldspars.

The contact between biotite granites C and D can be accurately defined because of the contrast in textures: feldspar porphyroblasts in C are from 1/4 to 1/2 inch in size, and in D are from 1 1/2 to 3 inches. Lenses of one rock type in the other are common near the contact but not away from the contact zone.

Contacts of biotite granite C with leucocratic granite, pegmatite, and aplite are all sharp, and are also distinct because of textural and mineralogical contrasts between the rocks. Though the contact zone may be complicated by inter-lensing of the two rock types, in places the leucocratic granitic masses appear to cut the foliation of the biotite granite C.

Near the contact between massive biotite granites and biotite granite C, the latter is cut by small veins and patches of rock mineralogically similar to massive biotite granite, i.e. with less biotite and more potash feldspar than biotite granite C. Although these rocks appear to be in sharp contact because of the difference in mineralogy, nevertheless the small veins and patches possess the texture of biotite granite C. This relationship was particularly noted on the south boundary of the biotite granite C body located in Sec. 25, Tp. 124, R. 1. About 250 feet from the contact biotite granite C changes to a poorly foliated biotite granite with 35 per cent pink potash porphyroblasts about 1/3 inches in diameter, and across strike towards the contact further changes produce a massive texture and a higher proportion of potash feldspar porphyroblasts. The contact of biotite granite C and massive biotite granite west of Johnson Lake is a complex zone one-half mile wide. Within this zone biotite granite C shows sharp contacts with dykes and irregularly shaped bodies of massive biotite granite and pegmatite, which include blocks of biotite granite C re-taining a foliation aligned with that in the main body to the east.

North of Johnson Lake a 50-foot wide band of slightly sheared biotite granite C encloses a lens of impure quartzite 35 by 7 feet, thus emphasizing the close interrelation of the metasedimentary rocks with biotite granite C. Both porphyroblastic biotite granite C and biotite microgranite are interlayered with, and are transitional into, the metasedimentary rocks along strike.

Biotite Granite D

This unit is found principally south of Johnson Lake, but small patches also occur in the adjacent biotite granite C to the west. The major expression of this map-unit is in the adjoining area to the south (Godfrey, 1963).

Modal and chemical analyses are included in the report covering the adjoining area to the south (Godfrey, 1963).

Internal structures have a simple form and from the compilation of rock foliation data are evident as parallel northerly striking structural lines. The tabular porphyroblasts are commonly aligned in the foliation of the coarse-grained matrix produced by biotite and lenticular quartz.

Contacts of biotite granite D with biotite granite C are characteristically interlensed and were described in more detail above (p. 16). In addition, however, the abundance of large porphyroblasts in biotite granite D increases rapidly across strike away from the contact: from 2 to 5 per cent at the contact to 15 to 30 per cent a few hundred feet away.

Though not observed completely, the contact zone of biotite granite D with sheared leucocratic granite is believed to be transitional and similar to the contact of biotite granite C with massive biotite granite. The large amphibolite body (Sec. 13, Tp. 124, R. 1) in sharp contact with biotite granite D is believed to be an intrusion, as there is no change of texture in either rock type near the contact, and as blocks of biotite granite D are present in the amphibolite.

Granite Gneiss

The western half of the map-area is underlain predominantly by granite gneiss with small areas of interspersed high-grade metasedimentary rocks. The granite gneiss terrain has a general red coloration and is characterized by rocks intermixed on a small scale to provide a great variation in texture and composition both within and between outcrops. The different rock types present include: biotite- and hornblende-granite gneiss and minor granite, ferromagnesian-poor granite, quartz monzonite, pegmatite, and a highly siliceous (quartzose) granitic or pegmatitic phase, any of which may contain porphyroblasts. Numerous amphibolite, hornblendite, and metasedimentary rock bands are scattered throughout the granite gneiss, many too small to be shown on the accompanying map. Most amphibolite bodies are found in the granite gneiss terrain; they have a well-dispersed distribution such that at least one body is found in most outcrops. Plastic deformation is a further characteristic of the granite gneiss terrain and is commonly expressed as swirls, ptygmatic and drag folds, and complex contortions. The alternation and variation of rock types over distances of tens of feet or less presents difficulties in delimitation of large areas of a predominating rock type, and serves to emphasize that this is a terrain of intimately mixed lithologies and structural complexities.

Biotite Granite Gneiss

Fresh and weathered surfaces of biotite granite gneiss are pink to red - red predominating on a weathered surface - with thin dark green or brown bands. Broken surfaces are irregular except rarely where biotite is concentrated in layers. Typical biotite granite gneiss contains up to 10 per cent biotite, about 30 per cent quartz, with potassic feldspar and plagioclase making up most of the remainder of the rock. Other minerals present are chlorite, epidote, garnet, hematite, magnetite, and allanite. Where chlorite is the common ferromagnesian mineral it is typically associated with alteration in a deformation zone and is presumed to be secondary after either biotite or hornblende. Epidote veinlets commonly 1/16 to 1/8 inch thick cut the granite gneiss foliation, and more rarely epidote is disseminated throughout the body of granite gneiss. Red garnets from 1/8 to 1/4 inch in diameter make up to 5 per cent of the total rock in certain zones of the granite gneiss. Hematite and magnetite occur locally in small concentrations, and dispersed allanite crystals average between 1/16 to 1/8 inch in diameter, and attain a maximum size of 1/4 inch.

The rocks are generally of medium to coarse grain. Potassic feldspar porphyroblasts from 1/4 to 3/4 inch in diameter may be sheared, crushed, and elongated within granite gneiss, mylonitic gneiss, or flaser-gneiss, and local concentrations form small irregular masses of pegmatite. Granitic pegmatites, with or without biotite and uncommonly with hornblende, predominate in places. A layered structure prominent in most areas consists of alternating quartzo-feldspathic and biotite-hornblende-rich layers ranging in thickness from 1/8 to 2 inches, the felsic layers being generally thicker.

Small areas of rock are sufficiently massive to be called biotite granites, and although they are outlined in the southern part of the map-area only, their distribution is known to be more general in the granite gneiss. In areas poor in ferromagnesian minerals (about two per cent dark minerals), the rocks may show either a massive or a slightly foliated texture, principally due to the alignment of elongated quartz grains. Small bands and lenses of pure and impure quartzite with minor biotite schists and migmatites are interspersed throughout the granite gneiss, but less commonly than similar bodies of amphibolite and hornblendite.

The banded structure of the gneissic rocks is typically swirled and drag-folded, and in some areas the rocks have been classed as migmatites. The study of minor structures in terms of elucidating larger forms has not yielded any pattern, and only the general direction of elongation shows any consistency on a regional scale. Contact relations of granite gneiss with metasedimentary rocks are transitional and have been discussed previously (p.12).

Hornblende Granite Gneiss

Hornblende granite gneiss forms an integral part of the granite gneiss terrain, being intimately mixed with biotite granite gneiss. Hornblende granite gneiss forms up to about 50 per cent of the rocks west and northwest of Spider Lake. This rock type is distinguished by the presence of 5 to 10 per cent hornblende but otherwise includes the common constituents of the biotite granite gneiss. Hornblende granite gneiss displays the typical textural and structural features of the granite gneiss terrain.

Amphibolite

Amphibolites[1] form a minor component of every major lithologic unit. Large amphibolite bodies are most characteristic of the porphyroblastic biotite granites C and D; in other associations they commonly appear as dispersed small bands and lenses. The lenticular amphibolites shown on the map are diagrammatic only: most bodies are smaller than actually depicted, and many bodies are too small for representation.

Amphibolites are dark green when fresh and medium greenish-grey on a weathered surface. They are compact with an irregular to rudely planar fracture. Principal minerals are hornblende and feldspars, with biotite and some quartz. The rocks are normally medium-grained, although fine- and coarse-grained phases have been noted, and they may be relatively massive or banded.

In the granite gneiss and high-grade metasedimentary rocks amphibolitic masses are generally bordered by coarse-grained biotite granite or biotite pegmatite or by biotite-rich schistose layers. Boudinaged amphibolite bands and groups or zones of angular amphibolite blocks are typically set in a pegmatite matrix.

In the gneissic terrain rocks of intermediate character form a complete sequence from hornblendite to amphibolite to hornblende granite gneiss. Amphibolites are massive to layered on a scale of a fraction of an inch to a few inches. Individual bodies range from a few inches to several hundred feet in thickness, but rarely exceed 200 feet and are commonly from 5 to 20 feet thick. Some contain sufficient biotite to impart a foliation to the rock. Amphibolite bands and lenses may be associated with hornblende-bearing phases of the granite gneiss, and some groups of lenses can be followed along strike for a mile or more. Around the amphibolite bands or groups of bands the granite gneiss is particularly contorted. Contacts of amphibolite with country rocks are generally sharp and conformable, and in places the contacts appear to be sheared.

Within the biotite granites C and D, and less commonly in granites A and B, many small basic bodies (not outlined on the map) are altered to sheared hornblende-plagioclase-biotite-chlorite rocks classed as amphibolites.

Small amphibolitic lenses, stringers, and bands up to 100 feet thick, associated with similar masses of metasedimentary rock, are found in the massive biotite and muscovite granites east of the south end of Andrew Lake (Sec. 34, Tp. 124, R. 1, and Sec. 4, Tp. 125, R. 1). These rock bodies are contorted and otherwise plastically deformed, and commonly have indefinite boundaries against the

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[1] The term "amphibolite" as used in this report includes both amphibolite and hornblendite. Shaw's (1957) definition 6A is preferred for amphibolite, i.e. "a metamorphic rock of medium to coarse grain, containing essential amphibole and plagioclase", whereas hornblendite is simply "a rock containing more than 90 per cent hornblende". Both of these rock types are found in the several terrains referred to, but hornblendite is generally less common.

host rock.

Towards the south end of the Waugh Lake metamorphic complex, some of the basic flows and basic, nonporphyroblastic phases of the biotite microgranite appear to grade into a medium- to fine-grained, foliated amphibolite.

Two large, fairly massive amphibolitic bodies crop out in the map-area, one in association with biotite granite C, and the other with biotite granite D. The former, located on the south shore of Waugh Lake, has a plug-like topographic expression and is made up of coarse-grained hornblende, feldspar, quartz, and biotite, the mafic minerals composing about half of the rock. The second body is tabular and is located south of Ney Lake. The rock is of medium to fine grain, of uniform foliation, and is essentially composed of hornblende and plagioclase.

Massive to Foliated, Biotite and Leucocratic Granites and Pegmatites

This group of rocks occupies a band between the granite gneiss terrain to the west, and the porphyroblastic biotite granites and Waugh Lake metasedimentary-metavolcanic complex to the east. These rocks are also present in minor amounts within all other major groups except the low-grade metasedimentary rocks. Members of this group represent rocks of varied association, age, and undoubtedly origin. However, because of their common textural and mineralogical characters and lack of distinguishing features in the field, they are mapped as one rock type. Rocks of this group tend to be coarse-grained and leucocratic, containing from 95 to 99 per cent felsic minerals. The massive granites contrast with the porphyroblastic biotite granite in terms of their equigranular texture, leucocratic nature, and poorly developed or absent foliation.

Muscovite granite, muscovite pegmatite, and feldspar pegmatite are present in small irregular bodies commonly ranging in width from 5 to 50 feet. Biotite granite is found in masses from a few feet to several miles in diameter, and granite pegmatite in minor bodies of a few feet in width.

Foliation or gneissic structure, simple in form, is locally present in otherwise homogeneous bodies.

Contacts of large, massive granite bodies tend to be sharp in detail but interfinger with the adjacent porphyroblastic biotite granite or metasedimentary rock, whereas small granite and pegmatite masses may exhibit simpler and more definite margins. Shreds and lenses of matted biotite flakes are incorporated into these rocks close to contacts with metasedimentary rocks. South of Waugh Lake one contact of the porphyroblastic phase of the massive biotite granite with biotite granite C proved gradational over a distance of several hundred feet. With loss of biotite and an increase in feldspar content the typically well-foliated biotite granite C grades into a poorly foliated porphyroblastic biotite granite and then into a massive biotite granite. More specific characters and associations of each member of this group are noted below.

Biotite Granite

This rock type constitutes the principal member of the massive granite and pegmatite group in both large and small bodies. The heterogeneous nature of the mass of biotite granite just southeast of Andrew Lake is evident in the scattered pegmatites, porphyroblastic biotite granite, amphibolites, and metasedimentary rock schlieren. In conjunction with this heterogeneity a foliated or gneissic structure is developed in the normally massive biotite granite.

Muscovite Granite

This granite is found in association with massive biotite granite, porphyroblastic biotite granites, and in the high-grade metasedimentary rocks of the gneissic terrain. The texture locally gives way to muscovite pegmatite. A "raisin structure" (p. 26) is developed where the granite is sheared, giving rise to rounded and crushed feldspars and garnets in a finer-grained cataclastic matrix.

Biotite 'p' Granite

The biotite 'p' phase of the massive biotite granite is found to the south of Waugh Lake, west of Cherry Lake, and in the granite gneisses. Though generally massive this rock may be foliated near contact zones.

Granite Pegmatite

This pegmatite is found in all major rock groups except the low-grade metasedimentary rocks. In the biotite and hornblende granite gneisses the granite pegmatite is not distinguished on the map because of the intimate mixture and the general small size of the dispersed bodies.

Feldspar Pegmatite

Feldspar pegmatite is of ubiquitous occurrence. The most striking characteristic on both fresh and weathered surfaces, is the abundant large, white feldspar crystals, commonly from 4 to 6 inches in diameter. Both feldspar and muscovite pegmatites are particularly abundant in the massive and porphyroblastic biotite granites around Sederholm Lake and farther west towards Andrew Lake.

Muscovite Pegmatite

Muscovite pegmatite is similar to muscovite granite and feldspar pegmatite with respect to field association, composition, and texture. The crystals of perthite and graphic intergrowths of feldspar with quartz reach a maximum diameter of about 6 inches, average about 3 inches, and are set in a groundmass of finer-grained feldspar, quartz, and muscovite.

Sheared Leucocratic Granite

This rock type is confined to a single large body in the extreme southeast corner of the map-area. North of Ney Lake it forms a dome rising to over 1400 feet, one of the highest points in northeastern Alberta. It is of uniform mineralogical and textural character except for common, poorly defined, small, irregular bodies and lenses of biotite granite C and massive biotite and muscovite granites. The typical rock has a crushed appearance, with the minerals generally aligned in the foliation plane produced by folia of sericite. The modal and chemical analyses of a typical sample (number 39) are given in table 3.

Internal structures are simple; no plastic deformation was noted, and small shears commonly parallel the foliation. Contacts with the porphyroblastic phase of the massive biotite granite are generally gradational and not easily defined because of the similarity in mineralogy. Contacts with biotite granite D are sharp, concordant and well defined by the contrast in texture.

CHEMICAL AND MODAL ANALYSES

The chemical and modal analyses (Table 3) were obtained from standard reference samples representing the major rock types mapped. These samples include 5 porphyroblastic biotite granites, 4 massive granites, 2 pegmatites, 3 granite gneisses, 6 low-grade metasedimentary rocks, 2 quartz basalts, and 2 porphyroclastic phyllonites from the Waugh Lake complex.

Biotite granites A (Sample 2) and B (Sample 17) retain the essential features noted for these rock types in the area to the north (Godfrey, 1961). They have a low silica content, a high (CaO+ MgO content), and a maximum of 7 per cent hornblende, although biotite persists as the major ferromagnesian mineral. The rocks differ in that quartz is higher in granite B and total ferromagnesian minerals are higher in granite A. These rocks lie in the "porphyroblastic" quartz monzonite to granodiorite division (Moorhouse, 1959, p. 154). Biotite microgranite (Samples 33 and 38) and biotite granite C (Sample 41) are of intermediate composition with respect to silica; they have less silica than biotite granites A and B, but their (CaO+ MgO) contents are distinctly higher. The mean (CaO+ MgO) contents for biotite microgranite, and biotite granites C, A, and B, calculated from data of Godfrey (1961) and the present report, are 7.25 ± 0.85, 5.82, 4.40 ± 0.29, and 3.29 ± 0.55 per cent, respectively. The (FeO+ MgO) contents for these rocks have the same relative pattern. Such a progression emphasizes the close genetic relationship between these rock types which are regarded as a petrogenetic group. Biotite microgranite and biotite granite C, following Moorhouse (ibid.) are classed as porphyroblastic microgranodiorite and porphyroblastic quartz diorite, respectively.

Massive biotite 'p', muscovite biotite, muscovite, and leucocratic granites (Samples 35, 31, 21 and 39) have low iron, calcium, magnesium, and titanium values, and are correspondingly high in alkalis and silica content. Pegmatites (Samples 14 and

Table 3. Chemical and Modal Analyses of Standard Rock Type Samples (Chemical analyses by H. A. Wagenbauer)

Sample	2*	17*	33	38	41	35	31	21*	39	14	40	37
SiO_2	67.40	67.43	62.85	60.35	63.71	72.16	65.25	73.43	76.71	75.60	73.58	65.63
TiO_2	0.47	0.42	0.59	0.81	0.57	0.13	0.47	0.06	0.05	0.06	0.03	0.41
Al_2O_3	13.72	14.61	14.99	15.07	15.57	14.36	15.95	14.99	12.88	13.50	15.77	15.70
Fe_2O_3	4.16	3.82	5.77	6.87	4.95	1.75	5.15	1.51	1.33	1.19	1.31	4.34
MgO	1.86	1.96	3.06	4.61	2.71	1.57	1.73	0.48	0.27	0.24	0.24	2.00
CaO	2.34	2.19	3.34	3.49	3.11	0.90	3.36	0.53	0.65	0.98	0.57	3.17
Na_2O	2.67	3.00	2.36	2.15	2.68	3.79	3.65	3.46	4.05	3.09	5.86	4.06
K_2O	4.52	5.14	3.69	4.28	2.42	4.81	2.72	4.64	3.83	7.16	1.82	3.27
L.O.I.	1.04	0.47	1.25	1.25	1.33	0.47	0.51	0.77	0.09	0.14	0.63	0.47
P_2O_5	0.20	0.14	0.17	0.20	0.21	0.05	0.17	0.02	0.05	0.09	0.15	0.14
MnO	0.08	0.10	0.12	0.09	0.08	0.07	0.09	0.03	0.03	0.02	0.01	0.08
Total	98.46	99.28	98.19	99.17	97.34	100.06	99.05	99.92	99.94	102.07	99.97	99.27
Quartz	14.7	23.0	30.3	18.4	36.3	23.1	31.1	28.8	30.8	18.4	33.5	24.5
Potash feldspar	29.3	37.5	5.9	9.3	2.4	38.8	27.1	18.5	32.1	45.5	10.9	24.1
Plagioclase	31.9	22.2	30.0	32.9	40.8	32.0	33.4	46.6	34.4	34.1	44.8	35.0
Biotite	14.1	8.7	26.2	30.3	19.9	3.5	1.8	0.4	1.0	1.5	0.0	6.6
Chlorite	0.0	0.9	0.0	0.0	0.0	1.0	0.3	0.3	0.5	0.4	0.0	0.5
Hornblende	6.9	4.6	1.0	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7
Epidote	2.7	0.6	5.4	0.6	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.8
Muscovite	0.0	1.6	0.0	0.0	0.0	1.0	6.1	5.4	1.1	0.0	10.4	0.0
Garnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calcite	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Accessories	0.4	0.9	1.0	1.2	0.3	0.6	tr.	tr.	0.1	0.1	0.3	0.8
No. of Points	3500	3000	2000	2000	2000	2000	2000	2000	2000	2000	3000	2000

Sample	5	36	28	26	34	25	27	23	24	29	30	32
SiO_2	71.00	73.00	80.45	76.04	73.47	67.93	57.56	62.20	58.67	53.96	75.12	75.50
TiO_2	0.26	0.12	0.47	0.21	0.49	0.46	0.71	0.64	0.72	0.84	0.25	0.32
Al_2O_3	14.41	14.88	10.39	12.68	13.02	16.10	21.30	16.22	15.96	14.62	12.59	12.16
Fe_2O_3	2.97	1.83	3.00	1.94	3.86	6.43	7.09	5.87	7.25	8.99	2.28	3.00
MgO	0.80	0.30	1.02	1.20	1.42	1.66	2.53	3.17	4.46	6.04	0.81	1.19
CaO	1.62	1.50	0.22	1.40	0.86	0.25	0.21	4.33	6.89	7.12	1.35	0.10
Na_2O	4.52	3.80	0.54	2.19	3.05	0.56	0.43	2.78	2.26	2.38	2.56	0.17
K_2O	3.79	4.51	2.22	2.62	2.53	3.67	6.24	2.76	2.17	3.29	4.17	5.30
L.O.I.	0.59	0.41	1.74	1.17	1.04	2.89	3.45	2.09	1.23	1.44	0.70	1.63
P_2O_5	0.08	0.12	0.04	0.04	0.07	0.08	0.12	0.10	0.09	0.27	0.06	0.06
MnO	0.05	0.02	0.01	0.03	0.05	0.05	0.07	0.10	0.12	0.19	0.04	0.02
Total	100.09	100.49	100.10	99.52	99.86	100.08	99.71	100.26	99.82	99.14	99.93	99.45
Quartz	31.4	35.6	68.8	49.4	54.4	36.7	23.7	21.0	7.1	2.1	47.8	46.3
Potash feldspar	24.9	22.1	0.0	0.3	0.0	0.0	0.0	8.2	0.0	1.7	28.4	11.2
Plagioclase	35.6	30.2	2.3	17.7	15.9	0.5	0.6	36.6	40.3	28.4	10.6	18.0
Biotite	3.3	5.6	1.0	10.1	15.3	0.0	21.4	21.6	18.6	33.2	0.8	0.0
Chlorite	2.2	0.5	3.6	0.4	0.0	8.7	0.4	0.1	0.0	0.0	1.1	1.9
Hornblende	0.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	20.2	28.0	0.0	0.0
Epidote	1.2	2.6	0.1	0.0	0.0	0.0	0.0	11.0	13.6	4.9	0.8	0.0
Muscovite	0.0	1.6	22.3	20.8	13.0	50.7	49.6	0.7	0.0	0.0	10.0	22.3
Garnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calcite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0
Accessories	0.9	1.1	1.9	1.3	1.4	3.4	4.3	0.7	0.2	1.6	0.5	0.3
No. of Points	2000	2000	1000	1000	1000	1000	1000	1000	1000	1000	1000	2000

2 Biotite granite A with small red feldspars and hornblende
17 Biotite granite B with hornblende
33 Biotite microgranite
38 Biotite microgranite
41 Biotite granite C
35 Massive, biotite 'p' granite
31 Massive, muscovite biotite granite
21 Massive, muscovite granite (sheared)
39 Sheared, leucocratic granite
14 Feldspar pegmatite
40 Muscovite pegmatite
37 Hornblende granite gneiss
5 Biotite granite gneiss
36 Biotite granite gneiss
28 Quartzite (Mica-quartz arenite)
26 Quartzite (Quartzose siltstone)
34 Quartzite (Feldspathic wacke)
25 Chlorite-sericite phyllonite
27 Phyllonitic biotite-sericite schist
23 Tuffaceous siltstone
24 Quartz basalt
29 Quartz basalt
30 Sericitic, porphyroclastic phyllonite
32 Sericitic, porphyroclastic phyllonite

* Analyses of these samples published (Godfrey, 1961).

40) have much the same composition as the foregoing rocks which are true granites.

The hornblende granite gneiss (Sample 37) has a low silica content, whereas the biotite granite gneisses (Samples 5 and 36) are more acidic. The presence of hornblende explains the higher values of calcium, iron, magnesium, and lower values of total alkalis and silica plus alumina. The variation in chemical composition of rocks from the gneissic terrain reflects the complexity of rock mixtures found there. Petrographically, these three gneiss samples fall in the field of quartz monzonites.

The six metasedimentary rocks (Samples 28, 26, 34, 25, 27, and 23) have very varied chemical compositions, pointing possibly to materials of different sources and depositional environments. Silica-rich samples 28, 26, and 34 fall in the arenite, siltstone, and feldspathic wacke[1] categories, respectively, whereas the alumina-rich samples 25 and 27, referred to as phyllonite and phyllonitic schist, represent more pelitic primary sediments which have suffered a high degree of deformation. Sample 23 is probably a tuffaceous sedimentary rock containing plagioclase, biotite, and epidote of igneous origin. The high iron and (CaO+ MgO) contents of sample 23 strongly indicate a contribution from an igneous source allied to the quartz basalts (samples 24 and 29).

The quartz basalts (samples 24 and 29) are typically basic to intermediate in composition and are high in iron, calcium, magnesium, and the alkalis. They are high in mafic minerals with 50 to 65 per cent combined biotite, hornblende, and epidote, and the feldspars are almost exclusively plagioclase.

The sericitic, porphyroclastic phyllonite samples (30 and 32) are high in silica and have some resemblance chemically to the massive biotite and muscovite granites. Though the origin of these rocks is still in doubt it is tentatively considered a deformed equivalent of some local granites.

STRUCTURAL GEOLOGY

The rocks of the map-area represent materials of widely differing physical properties, and consequently their response to stress is correspondingly different. Although folds of regional dimensions have not been recognised, major faults are not uncommon. These faults parallel the strike of the rocks, or transect them, generally in a northwesterly direction. The regional foliation strikes northerly and mainly dips steeply to the west.

The Bonny fault and its branches forms the principal transecting fault system in the map-area, associated structural features indicating that it is a fault of regional significance. The main fault plane grades into a fan-shaped fault zone on entering the present map-area from the north (Godfrey, 1961), which suggests a

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[1] Williams, Turner, and Gilbert (1958).

dissipation of magnitude to the southeast. Northwest of Andrew Lake the Bonny fault strikes north 27 degrees west and it dips 80 degrees southwest at the east end of Hutton Lake. In a well-exposed section on the west shore of Andrew Lake the fault becomes a brecciated fault zone filled with quartz and hematite, up to 500 feet in width. Marginal to the breccia zone, parallel shears grade outwards into the country rock. Hematization and chloritization of the country rock are common along the Andrew - Hutton Lakes section of the Bonny fault.

Branches of the Bonny fault to the southeast of Andrew Lake trend from southeasterly to easterly. Many branches have apparent horizontal displacements in that bands and bodies of several rocks terminate against the faults. Breccia, mylonite, and mylonitic sheeted structures have been noted in sections along the branch faults.

All the principal rock groups of the map-area are cut by minor transecting faults, which are marked by lineaments commonly occupied by muskegs or sandy areas. Where bedrock can be examined either within or adjacent to the lineament, evidence of small-scale fault features may be found, such as breccias—quartz-filled or hematized—ultra-mylonite or mylonitized country-rock, fractures and shears, and chlorite and red feldspar alteration in the wallrock.

Several faults parallel to the regional foliation trend are shown on the accompanying map; however, because of the difficulty in defining such faults, particularly in the weak metasedimentary rocks, those that are noted should be regarded as a minimum. A considerable amount of faulting parallel to strike in the Waugh Lake metasedimentary rocks is indicated by the widespread mylonitized and cataclastic nature of this rock complex. Deformation has obscured some of the important petrogenetic relationships between rock types, and the problem of the role of cataclastic processes in the genesis of the sericitic, porphyroclastic phyllonite remains to be evaluated. Koster (1961), working in Saskatchewan, has described similar features to those found in the Waugh Lake complex and refers to the intense folding and dynamic metamorphism in this metasedimentary and metavolcanic complex.

In the southeast quadrant of the map-area an imperfect system of complimentary shear and tension fractures is developed, where southeast extensions of the Bonny fault represent shears, and north to north-northeast faults represent tension fractures.

Joints and shears are present in every major rock. Many shears grade into sheeting, and some are directly related to faults. Though some fracture systems can be related to deformation features, the structural meaning of other fractures remains uncertain.

Planar structure is evident in most rocks except the massive granites and pegmatites, though even in these rocks a late deformation may have produced a foliation. In a few places lineation has been observed in combination with foliation or gneissosity in the metasedimentary rocks and granite gneiss.

The density of foliation, gneissosity, and schistosity orientation data permits ready extrapolation between adjacent field traverses and the construction of continuous structural lines; the interpreted structural forms represented on the map are conservative in their complexity. The density of foliation lines on map 61-2A is a rough measure of the degree of foliation in a particular rock type or rock body. A marked contrast in character is evident on the geological map between the structural pattern of the granite gneiss terrain and that of the massive and porphyroblastic biotite granites. The internal structural pattern indicates the presence of many large isoclinal and saddle folds in the gneissic terrain and in outcrop small-scale drag folds, contorted and crenulated structures, are also related to an intense plastic deformation. In contrast, very little folding is evident on any scale within the porphyroblastic biotite granites and the massive biotite granites and pegmatites.

A number of small-scale megascopic features which represent both plastic and cataclastic deformation may be summarized here. Mullion and rod structures are uncommon and confined to the metasedimentary rocks; drag folds, crenulations, totfalten (Fairbairn, 1949, p. 178), and fracture cleavage are common small-scale structural features in these rocks, especially in the slaty argillites, phyllonites, and biotite-sericite schists.

Boudinage amphibolite structures are characteristic of the granite gneiss where plastic flow has deformed many of the boudins into lenses, pods, and other related forms, and the enclosing well-banded granite gneiss exhibits extremes of contortion. Migmatite structures are more commonly found in the basic granite gneisses, at granite gneiss-metasedimentary rock contacts, and in highly feldspathized metasedimentary rocks. Structures include tight isoclinal or chevron folds, drag folds, and other more complicated forms indicative of plastic flowage; such features appear migmatitic in character and are plotted on the map (⟋). Rocks having more open folds and swirls are regarded as being contorted and are also indicated on the map (ζ). Despite the high degree of deformation, as a rule it is possible to distinguish a trend or "elongation" of the structure in an outcrop, and the map symbol is oriented accordingly. Such structural features may have significance on a regional scale.

Cataclastic structures found throughout the area include crushed augen (porphyroclastic) structure, mortar structure, flaser structure, and bands and stringers of mylonite. Augen structures are especially well developed in the sheared sections of porphyroblastic biotite schist and biotite granites A and C. Many of the augen-feldspar grains are fractured, and evidently where the effect of shear was more pronounced their typical euhedral form has been modified and rounded. Under conditions of intensive shear, mylonitization of the groundmass is obvious and augen structure grades to mortar or flaser structure. In such rocks where the proportion of cataclastically rounded grains is high relative to the mylonitic groundmass and other constituents (i.e. essentially consists of rounded, coarse grains packed in a fine-grained, mylonitic matrix), the rock has a "raisin'structure". This structure is found mostly in sheared rocks of coarse, equidimensional-grain size, such as in the porphyroblastic and massive biotite granites just east of Andrew Lake.

Mylonites and mylonitic rocks occur in all of the major rock types of the map-area. Minor mylonitic bands and stringers filled with green epidote are most common in the granite gneiss, are less abundant in the group of porphyroblastic biotite granites, and are rare in the massive biotite granites and metasedimentary rocks. These stringers average from 1/16 to 1/8 inch in thickness and a few feet in length, though groups of anastomosing stringers may extend for tens of feet along strike.

In summary, deformational features of both a plastic and cataclastic nature have shaped many of the dominant textural and structural characters of the rocks in this map-area. All major rock types show some degree of deformation, most have evidence of shear, and many contain areas of mylonitization.

MINERAL OCCURRENCES

Mineralization was noted in the course of systematic traverses and no attempt was made to prospect favourable areas between these traverses.

A description of mineralization of a large area which includes the present map-area (Godfrey, 1958b) contains further detail. The distribution of mineral showings indicates that areas of economic interest are most likely to be found in bands of metasedimentary rocks and in faults. Zones of radioactivity are associated with metasedimentary rocks, massive biotite granites, and faults, whereas sulfide mineralization other than pyrite is associated only with metasedimentary rocks.

Small gossan and rusty zones parallel to foliation are commonly found in the high-grade metasedimentary rocks, e.g. the Spider Lake band. Pyritization is common in the high-grade metasedimentary rocks, and other sulfides such as arsenopyrite, smaltite, and pyrrhotite may be present. In the Waugh Lake metasedimentary band small amounts of arsenopyrite, pyrrhotite, galena, molybdenite, and chalcopyrite have been noted. Unique to this band is the extensive presence of tourmaline-quartz composite veins which are concentrated on the north shore of the elbow of Waugh Lake. A sample of a composite tourmaline-quartz-arsenopyrite vein in the metasedimentary rocks located just east of the fourth meridian north of Waugh Lake yielded small amounts of gold, silver, and nickel.

Hematization, feldspathization, and chloritization with the breccia and marginal shears of the Bonny fault has the typical appearance of zones associated with uranium mineralization, such as that found in the Beaverlodge district of Saskatchewan to the east. Many zones of high radioactivity were traced over a total strike length of about two miles within the feldspathized high-grade metasedimentary band at Spider Lake. Radioactivity is concentrated in the pegmatitic phases of this metasedimentary band, where minor flakes of molybdenite are also found. Many low-level radioactive anomalies occur over an area of four square miles north and west of Cherry

Lake. These are found in massive biotite granites, pegmatites, granite gneiss, and lenses of high-grade quartzite and biotite schist.

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RESEARCH COUNCIL OF ALBERTA

LEGEND

PRECAMBRIAN*

Quartzite, *pure and impure, grey, green, pink and blue; including phyllite, biotite sericite schist, minor milky quartz pods, feldspar augen, granite and pegmatite lenses, ferruginous, garnetiferous, and graphitic zones.*

Biotite schist, *with abundant quartz, some sericite; including slate, phyllite, phyllonite, quartzite, minor milky quartz pods, feldspar augen, granite and pegmatite lenses, ferruginous, garnetiferous, and graphitic zones. Sericite, chlorite schist (sc) with quartzite lenses, fragments; phyllonitic; minor quartz pods, crush conglomerate and conglomerate?*

Basic rocks, *various basic rocks including greenstone, amphibolite, basalt, gabbro, and possibly metatuffs.*

Sericitic, porphyroclastic phyllonite, *feldspar augen; typically sheared, mylonitic to crushed matrix; with phyllite, quartzite, crush conglomerate, and minor conglomerate?*

Biotite granite A, *with white to grey, euhedral feldspar megacrysts, one-half to one inch in size, in a foliated biotite-rich matrix; including minor aplite, microgranite. Hornblende-bearing biotite granite (H).*

Biotite granite B, *with white to grey, euhedral feldspar megacrysts, one-half to one inch in size; including minor aplite, microgranite and massive grey granite. Hornblende-bearing biotite granite (H).*

Biotite microgranite, *with white to grey augen feldspar megacrysts, one-sixteenth to one-eighth inch in size, in a well-foliated biotite-rich matrix; including very minor aplite.*

Biotite granite C, *with white to grey subhedral to anhedral feldspar megacrysts, one-quarter to one-half inch in size, in a foliated matrix; including minor aplite, microgranite, and pegmatite.*

Biotite granite D, *with grey to pink to red euhedral feldspar megacrysts, one and one-half to three inches in size, in a foliated to massive matrix; including minor aplite, microgranite, and pegmatite.*

Biotite granite gneiss, *with some hornblende, chlorite; including minor massive granite, porphyritic granite, granodiorite, alaskite, pegmatite; lenses of biotite, quartzite, amphibolite; garnetiferous zones.*

Hornblende granite gneiss, *with some biotite, chlorite; including minor massive granite, porphyritic granite, granodiorite, pegmatite, and amphibolite.*

Amphibolite, *including biotite amphibolite, hornblendite; banded to massive.*

Biotite granite, *with white to pink to red feldspars, minor sericite; massive. Muscovite granite (m), with abundant white to pink feldspars, minor biotite; massive. Phases with abundant feldspar megacrysts (p), one-quarter to one-third inch in size.*

Granite pegmatite, *with white to pink to red feldspars, sparse biotite; massive. Feldspar pegmatite (f), with abundant very coarse white feldspar, quartz, sparse muscovite, biotite; massive. Muscovite pegmatite (m), with abundant white and pink feldspars, quartz; massive.*

Sheared leucocratic granite, *with white to pink feldspars; medium to fine grain, typically sheared; minor biotite, muscovite, sericite.*

*Note: Rock units are not arranged chronologically.

Geological boundary (defined, approximate, assumed)
Geological boundary, gradational
Bedding (dip and top known, dip known top unknown) 83 76
Bedding (dip unknown top known, overturned, dip unknown, top unknown) 85
Schistosity, gneissosity, foliation (defined, dip known, dip vertical; assumed) 75
Lineation (plunge known) 75 88
Extreme contortion (structural trend)
Tight folds (structural trend)
Fault (defined, approximate, assumed)
Shear zone
Breccia
Mylonite
Gossan
Joint
Sample location 32 o
Glacial striae (direction of ice movement known)
Radioactivity
Mineral occurrence (arsenopyrite) X asp
Molybdenite mol
Garnet G
Graphite R
Tourmaline T
Epidote E

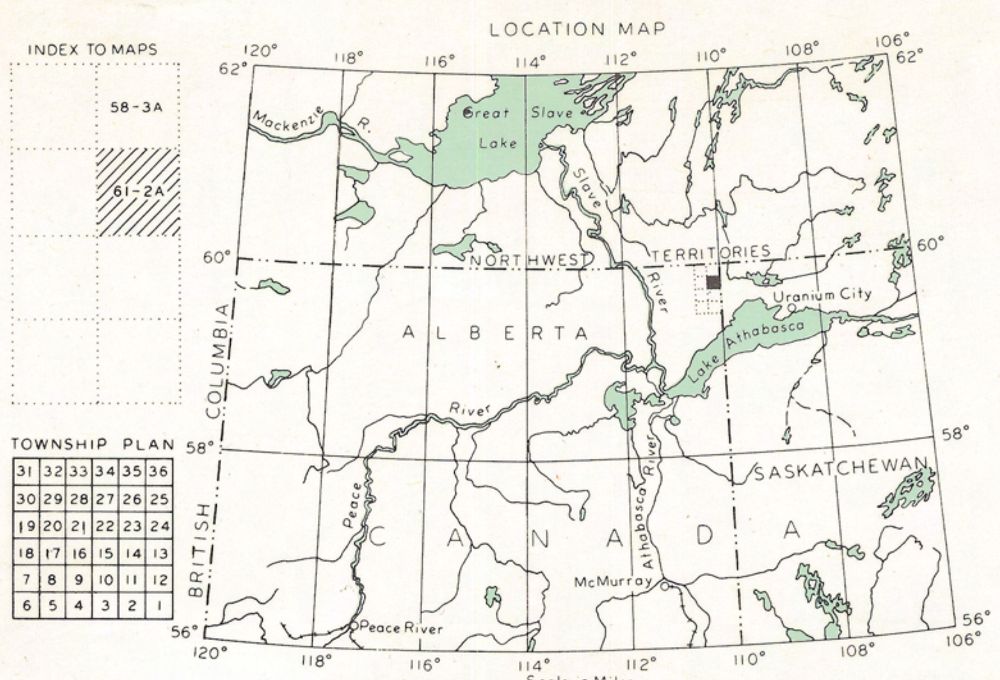
Geology by John D. Godfrey, 1957, 1958

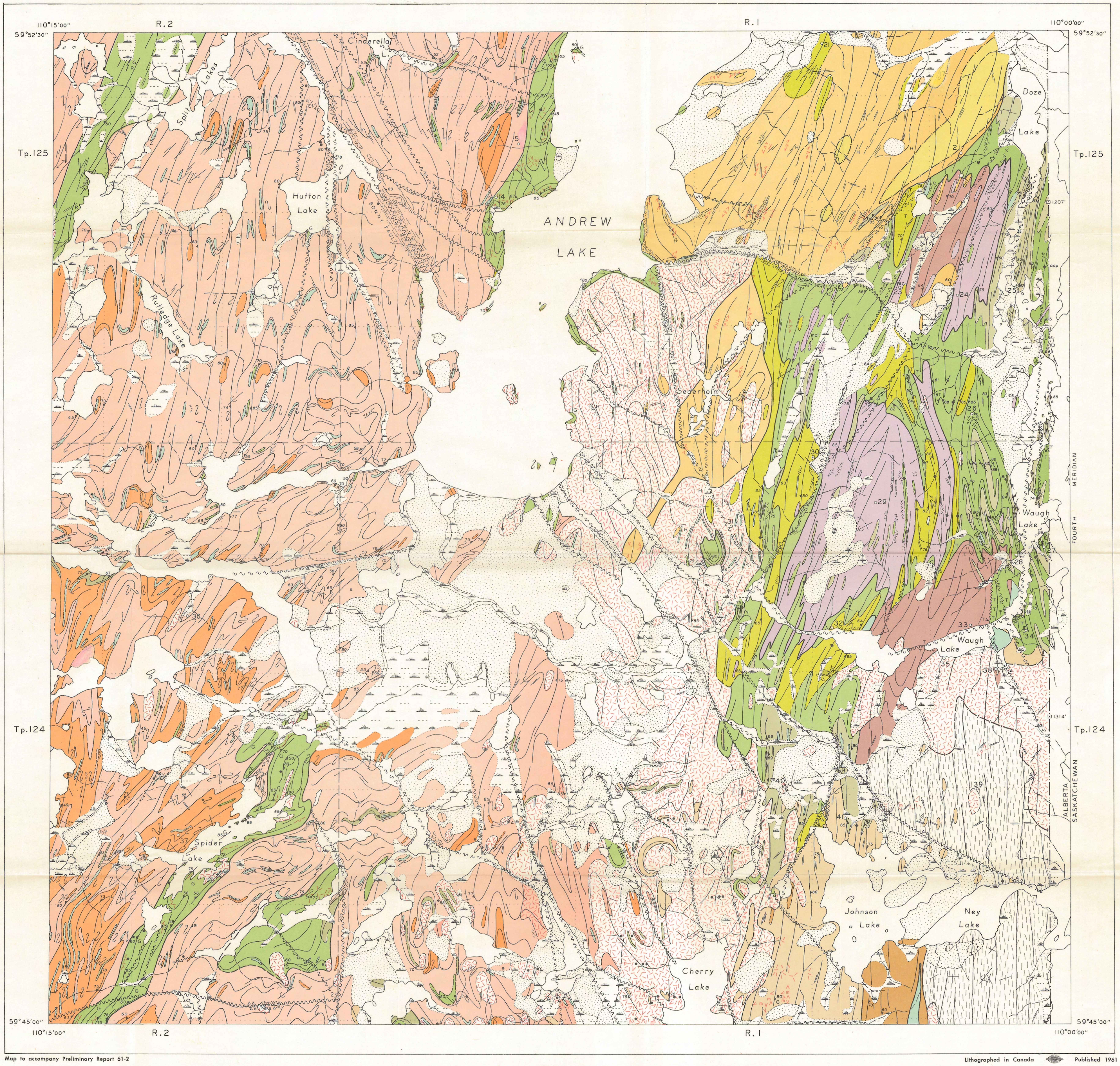
Drainage (permanent, intermittent)
Muskeg
Sand-covered area
Spot elevation, height in feet above mean sea-level 1314′
Provincial boundary
Township boundary
Section line

Base map compiled from planimetric sheet 74 $\frac{M}{16}$ SE. quarter, published by Government of Alberta, Department of Lands and Forests, Edmonton.

Air photographs covering this area are obtainable from the Technical Division, Department of Lands and Forests, Government of Alberta, Edmonton, and the National Air Photographic Library, Topographical Survey, Ottawa.

Approximate magnetic declination 26° 4′ East in 1961, decreasing 6′ annually.





Map to accompany Preliminary Report 61-2

Lithographed in Canada

Published 1961

MAP 61-2A

ANDREW LAKE, SOUTH

WEST OF FOURTH MERIDIAN

Scale: Two Inches to One Mile $\frac{1}{31,680}$