Geology of the Andrew Lake, North District

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GEOLOGY OF THE ANDREW LAKE, NORTH DISTRICT

by

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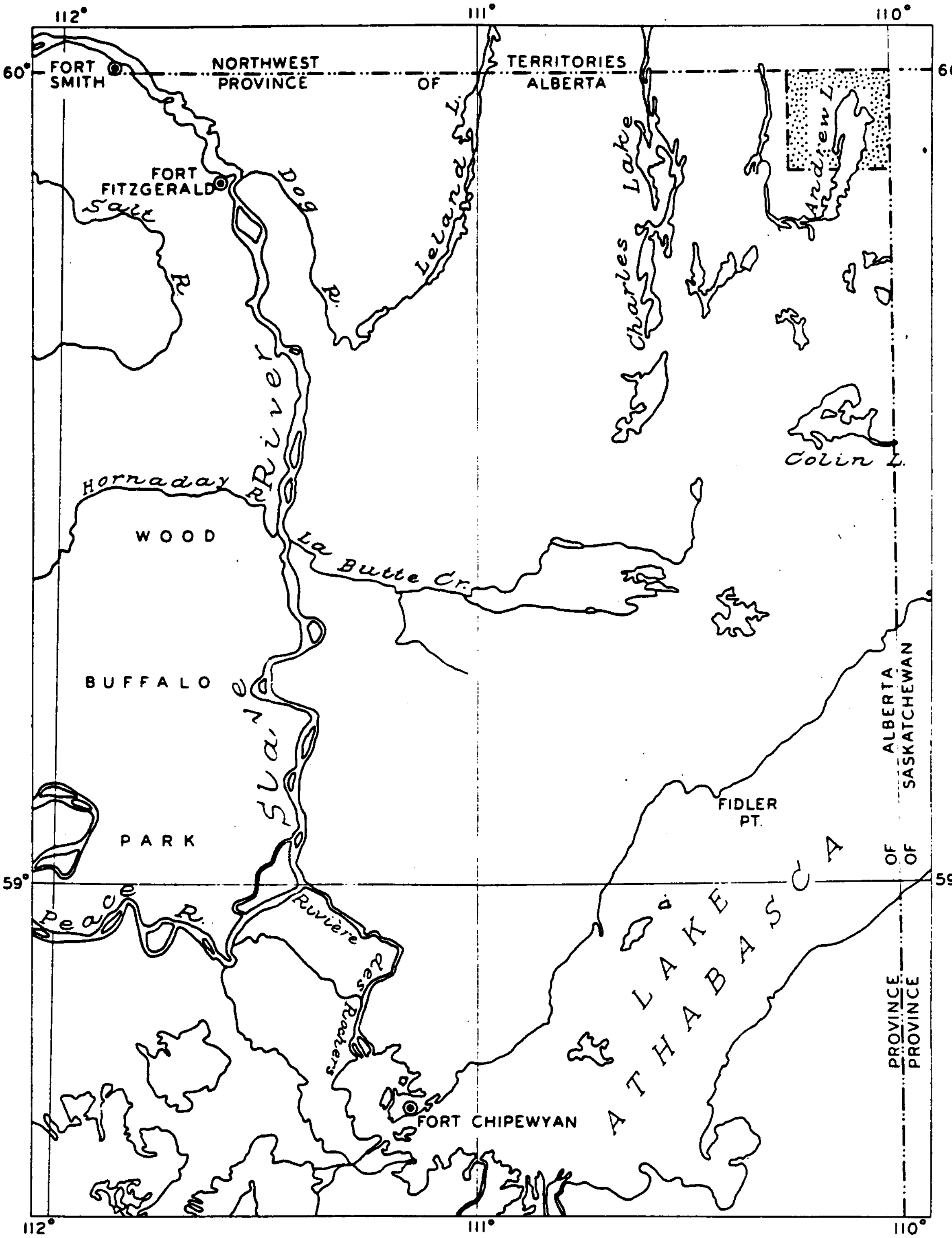

FIGURE 1

LOCATION OF MAP-AREA

SCALE IN MILES

4 0 4 8 12 16 20 24

GEOLOGY OF THE ANDREW LAKE, NORTH DISTRICT

ABSTRACT

A map on a scale of two inches to one mile is presented on which 12 map units are distinguished. These units constitute three principal rock groups: meta-sedimentary and associated rocks, porphyroblastic biotite granites, and granite gneiss. Each map-unit is described in terms of its distribution, hand specimen properties, structural characteristics, and contact relationships. Chemical and modal analyses are given for the granitic and gneissic rock units. The usefulness of aeromagnetic surveys and aerial photographs is indicated in the determination of regional bedrock structures and the distribution of principal rock types. Minor sulfide mineralization and radioactivity are noted.

INTRODUCTION

General Statement

This report and accompanying map provide preliminary information on the general geology and on mineralization in the district of Andrew Lake, North. About 3,600 square miles of Precambrian Shield rocks crop out in Alberta north of Lake Athabasca, and an additional 1,500 to 2,500 square miles lie on the south side of the lake.

Vertical aerial photographs are of considerable help in prospecting, exploration, and geological mapping, and are available 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 of District

Andrew Lake, North district, is situated in the extreme northeast corner of Alberta, and adjoins the Province of Saskatchewan and the Northwest Territories (Fig. 1). It lies between longitudes 110 degrees and 110 degrees 15 minutes west, and between latitudes 59 degrees 52 minutes 30 seconds and 60 degrees north.

Uranium City, Saskatchewan, is situated 45 miles east of Andrew Lake, and has regularly scheduled commercial flights from and to Edmonton, Alberta. Pontoon-equipped planes may be chartered from Uranium City 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 commerically utilized water route. Tugs and barges of the Northern Transportation Co. Ltd. operate along this route from McMurray, Alberta, to supply settlements towards the east end of Lake Athabasca, principally Uranium City, Fond du Lac, and Stony Rapids.

Topography

The peneplained surface of the area is typical of the Precambrian Shield. Pleistocene glacial scouring has left numerous rock-basin lakes and a locally rugged surface with a maximum relief of about 350 feet. The general elevation is from 1,000 to 1,350 feet above sea-level. Over two-thirds of the land surface of the map-area is bedrock with a small proportion of muskeg (see plate 1, in pocket). In some places a sandy glacial deposit has prevented much growth of low bush and these areas consequently have a parkland-type vegetation. The lakes are mainly either disconnected or poorly connected bodies of water, and cross-country canoe travel involves portaging. Principal drainage is west to Charles Lake.

The distribution and shapes of lakes are controlled by structural and lithological factors with modification by ice erosion. Narrow elongate bays are associated with erosion of fault zones and straight shorelines suggest fault-line features. Zones of fractured or structurally weak rocks have been plucked out by ice erosion, particularly on the west and southwest lake-shores, giving rise to an irregular shoreline. At one or two localities exceptionally clean, fresh, bedrock surfaces are found in the form of low, wide aprons bordering rock-basin lakes. Such water-washed surfaces afford a particularly good opportunity for detailed examination of the bedrock geology.

Previous Work

In 1892 and 1893 Tyrrell (1896) made the initial canoe traverse along the north shore of Lake Athabasca and was followed by Alcock at the time of the First World War (1915, 1917). In 1929 and 1930 Cameron and Hicks (Cameron, 1930; Cameron and Hicks, 1931; Hicks, 1930, 1932) conducted a reconnaissance survey of the Shield area north of Lake Athabasca; one of their canoe traverses began from Andrew Lake.

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

In 1954 uranium prospecting activities spread to the Precambrian Shield of Alberta and Collins (1954) of the Research Council of Alberta spent several weeks examining mineralization at a number of points. Principally low-grade uranium miner ization was found in the course of this prospecting and exploratory activity (e.g. Fe 1953).

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

Present Study

In 1957 an area of over 100 square miles was mapped on the Precambrian Shield in the extreme northeast corner of the Province; 72 square miles of this area are covered in the accompanying map. This map is based on parallel pace and compass traverses which were generally spaced at one-quarter to one-third mile intervals. Anomalous compass readings were experienced in places but were noted mainly in the vicinity of hornblende granite gneisses and amphibolites. Magnetite was observed at some granite gneiss localities and it has since been confirmed in the course of laboratory examination, thus accounting for those deviations.

Acknowledgments

The field party was composed of J. M. McLelland, senior assistant, and E. Overbo and B. E. Henson, junior assistants.

The co-operation and assistance of the pilots and staff of McMurray Air Service Ltd. contributed greatly towards an effective and efficient field operation.

The drafting of the final map 58-3A was carried out by S. J. Groot, and compilation of the aerial photographic mosaic for plate 1 was made by the Technical Division, Alberta Department of Lands and Forests, Edmonton.

GENERAL GEOLOGY

Precambrian igneous, metamorphic, and sedimentary rocks combine to form the rock complexes of the Andrew Lake, North, district where metamorphism has played a major role in the geologic history.

The geology is complex from the point of view of both lithologic and structural diversity. The dominant feature is the alternation of northerly trending major bands from tens of feet to three miles in width made up of three principal rock groups: granite gneiss, porphyroblastic biotite granites, and metasedimentary rocks with associated granites and pegmatites. Constituent rock types of these three principal rock groups are shown in table 1. The regional strike is north 10 to 20 degrees east and dips are either vertical or at high angles, mainly to the west.

Several major faults pass through the area; some trend northerly, as does the strike of the rock bands, and most transverse faults trend to the northwest. Most rocks in the area show some effects of deformation, and these include crushing, shearing and plastic flowage, which in extreme cases range to the formation of ultra-ylonite and rocks of migmatitic character.

Table 1. Principal rock groups, constituent rock types, and their field associations

Granite Gneiss (39%)*	Porphyroblastic Biotite Granites (22%)	Metasedimentary (6.5%) and Associated Rocks (1.5%)
Biotite granite gneiss	Biotite granite A	Quartzite
Hornblende granite gneiss	Biotite granite B	Biotite-sericite schist and phyllite
Amphibolite		Biotite feldspar-augen schist and phyllite
		Slate, argillite
	←———	Muscovite-granite and -pegmatite
	←———	Feldspar pegmatite
←———	———	Massive biotite granite and granitic pegmatite

* Per cent outcrop of total map-area

The distinction between lithologic units is not always clear and obvious, as a serial change in mineralogic character from one rock type to another can be found in many places in the map-area. Thus, problems exist in the definition of rock types and the establishment of some lithologic boundaries. Further, a high degree of deformation combined with metamorphism and the obliteration of most original structures has developed a complex of intricately mixed rock types over much of the area. Thus, three or four different rock types may be present in an outcrop, and map presentation of lithologic units shows only the predominant lithology in a specific rock body.

In view of the nomenclatorial problems created by gradation in mineralogic character of many granites and granite gneisses, and by textural variations induced by structural factors, certain hand-specimens were chosen as standard reference samples to represent the "normal" or "average" lithologies of the map-units. The standard samples, selected from about 1,000 hand-specimens, are listed in table 2 and their localities are shown on the map sheet. The standard samples, representing the rock types have been studied and classified on the basis of thin section, modal analyses, and wet chemical analyses.

Foliation, gneissosity and schistosity data are summarized on map 58-3A by extrapolation between adjacent field traverses to produce continuous structural lines. The density of field orientation data permits such extrapolation, and interpreted structural forms are conservative in their complexity.

The glacially smoothed outcrops have either clean or lichen-covered surfaces, while numerous rock basin lakes, sand plains, drumlins, eskers, highly polished striated rock surfaces, and glacial erratics also remain as evidence of a recent glaciation.

MAP-UNITS

Metasedimentary and Associated Rocks

The map-area is situated on the western edge of the southerly extension of a belt of metasedimentary rocks outlined by Henderson (1939a, 1939b), Wilson (1941), Mulligan (1956),and Taylor (1956) in the Northwest Territories. The metasedimentary and associated rocks of this extension are distributed on both sides of the Alberta-Saskatchewan boundary. To the north they 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). At this preliminary stage the metasedimentary rocks that crop out in the Andrew Lake, North, district have not been assigned to a specific stratigraphic division[1] and regional correlations are not proposed. Metasedimentary rocks occur as the narrowest of the major rock bands, are the least erosion-resistant, and hence are observed on surface less frequently than other principal rock types in the map-area. Though many of the bands of metasedimentary rocks have similar gross characteristics, detailed study of the constituent mineralogy and lithology may serve to distinguish individual bands. Megascopic features of bands are best displayed by the amount of feldspathic (pegmatitic-granitic) material in the metasedimentary rocks, the proportion of quartzite to schist, and the abundance and distribution of minerals such as garnet and graphite, and more rarely sillimanite and tourmaline. Metasedimentary rocks have absorbed much of the stress adjustment in the area because of their comparative weakness and they commonly exhibit extremes in degree of contortion, crenulation, and shear structures. Probably a number of faults, in addition to those noted on the map, lie within or are marginal to metasedimentary bands.

Primary sedimentary bedding is reflected on a major scale (few feet) by interlayered quartzite and biotite-sericite schist, and on a minor scale (few inches) by color banding in quartzite.

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[1] The potassium-argon age dates of biotite from biotite granite A and feldspar pegmatite were given as 1.9 and 2.0 billion years (Burwash, 1958). Calculations using constants now believed to be more accurate would modify these ages to 1.7 and 1.9 billion years, respectively.

Quartzite, and Associated Rocks

Quartzite; rocks of the quartzite map-unit crop out in clearly defined bands which influence the formation of northerly trending linear depressions, many of them occupied by lakes. Most of these bands can be referred to by the lake occupying the particular linear, namely:

Harker Lake	West of Holmes Lake
Sedgwick-Lindgren Lakes	Holmes Lake
Swinnerton Lake	Spur Lake
Murchison Lake	Andrew Lake

These metasedimentary rocks underlie 6.5 per cent of the map-area and the major rock bands have widths from 300 feet to 2 miles. Metasedimentary rocks probably underlie large parts of the muskeg, lake and sandy areas. In addition to the major metasedimentary rock bands, numerous lenses will be noted on the map which contribute to the heterogeneous and varied character of the granite gneiss terrain. Quartzite and quartzose phyllite make up most of the metasedimentary rock in these small lenses, many of which are only a few feet in width, and thus the map representation is diagrammatic rather than precise in actual dimensions.

Quartzite, the most abundant of the rock types in the quartzite map-unit, includes both pure and impure varieties. Fresh surfaces are typically light to dark grey, but may also exhibit light shades of blue, pink,and green, which are attributed to the presence of different impurities. Weathered surfaces may be iron-stained. Pure quartzites are compact, almost flinty, and impure quartzites, particularly biotite and sericite quartzites, tend to have a rude foliation and a cleavage fracture. The mineralogic composition ranges from that of orthoquartzite to that of greywacke; biotite, sericite, and minor chlorite are common in the latter. Minor minerals include garnet and hematite.

As the amount of sericite - and less commonly biotite and chlorite - increases, the quartzite grades to phyllite and schist. Garnetiferous zones are prominent in some quartzite layers and individual crystals or knots of crystals attain a maximum diameter of one inch. The lavender, pink, and red-colored garnets make up a maximum of 10 per cent of the rock within restricted layers; they weather out preferentially against a siliceous matrix to leave a distinctive pitted surface on outcrops. Though garnets have been found in most metasedimentary rock bands, they are particularly evident in the band which encloses Lindgren and Sedgwick Lakes. Hematite is found locally and probably reaches a maximum of about 10 per cent of the rock. Gossans and rusty zones are characteristic of the metasedimentary bands and result from weathering of hematite and pyrite in minor shear zones. Quartzites are typically sugary textured, medium grained, and have color banding that ranges in thickness from a fraction of an inch to 1 or 2 feet.

Biotite-sericite schist and phyllite are invariably present in an interlayered relationship with quartzite, and constitute from 10 to 40 per cent of the total rock. Fresh surfaces are medium to dark grey in the absence of chlorite, but shades of gree are apparent where chlorite is present. Weathered surfaces may be iron-stained. Depending on the proportion of micaceous material these rocks have moderate to excellent foliation, and cleave readily. Quartz and biotite are the principal constituents, sericite is common, with minor amounts of chlorite, garnet, and graphite. Most of these rocks are very siliceous and hence are more properly referred to as phyllites. Chlorite in particular is developed in zones of extensive shear and alteration, and sericite is also associated with such zones. Graphite[1] may be present in the more schistose sections of metasedimentary bands, and garnetiferous zones in siliceous schists are associated with adjacent garnet-bearing layers of quartzite. Quartz veins, lenses and pods are found in the schists, and to a lesser degree in the adjacent quartzite layers. The texture is fine to medium grained with a dominant schistose structure in layers from a few inches to several feet wide.

Granitic material in the quartzite map-unit; by changes in relative percentages of metamorphic feldspar to quartz, the quartzite grades to feldspathic quartzite, siliceous granite or pegmatite, and locally attains a granitic or pegmatitic composition. Feldspathic or "granitic" material may also be mixed with the interlayered schists as in the case of the quartzite. The metamorphic feldspar may be dispersed in a metasedimentary rock as single crystals (porphyroblasts and porphyroclasts), up to two inches in diameter, or be concentrated in association with quartz to form discrete "granitic" or "pegmatitic" lenses, pods, or stringers. Both types of feldspar distribution can be readily observed in the many exposures of metasedimentary rocks around the north shore of Andrew Lake (Sec. 27, Tp. 126, R. 1).

Masses of granitic material normally range in width from a fraction of an inch to several feet, though a few bodies are considerably larger and these are shown individually and outlined on the map, e.g. one-half mile south of Holmes Lake, (Sec. 26, Tp. 125, R. 2). A red dash or "V" map symbol has been used where small, dispersed bodies of granite or pegmatite make up a significant granitic content of the metasedimentary rock (over about 20 per cent). Granitic material comprises up to 50 per cent of the metasedimentary rock south of Dumbell Lake (Sec. 26, Tp. 126, R. 2), south of Holmes Lake (Sec. 26, Tp. 125, R. 2), and in the two larger islands of Andrew Lake (Sec. 4, Tp. 126, R. 1; Sec. 33, Tp. 125, R. 1).

The granite and pegmatite bodies within metasedimentary rocks may be concordant or discordant, have sharp or gradational contacts over a few inches, and have irregular or planar (but undulating) margins particularly for dyke-like forms. The mixing of granitic lenses, pods, and stringers with metasedimentary material typically forms a contorted migmatite complex. Such lenses, pods, and stringers are commonly interconnected and a single body may exhibit several of the features described above.

The contrast in weathering resistance between metasedimentary rocks and

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1 In the field, graphite is commonly confused with the economic mineral molybdenite, especially where present in fine-grained form.

well-defined masses of granites and pegmatites results in large bodies of the latter to stand out boldly as hills against the low lying metasedimentary rocks; in fact, most peninsulas, islands,and hills within major metasedimentary rock bands can be assumed to have a granitic core. The main peninsula and the larger islands of Andrew Lake are excellent examples, and can be noted on the aerial photographic mosaic, plate 1.

Internal structures of the quartzite map-unit are both primary and secondary in origin. Alternating quartzite and biotite-sericite schist layers are attributed to original sedimentary mineralogical differences, and bands differing in shades of grey, most commonly found within quartzite, are believed to represent sedimentary bedding. No evidence of graded bedding, crossbedding, minor erosion surfaces, and similar features was found. Small-scale deformation structures are common in these rocks and the schistose sections especially exhibit features such as crenulations, tight drag folds, shear-folds, and cross-shears. These features do not appear to conform to a general structural pattern that could point either to larger structural forms or to the imposed stress conditions.

The field relations between metasedimentary rock bands and granite gneiss, exclusive of faulted and sheared contacts, were not commonly noted. All contacts were concordant in the sense that foliation and gneissosity on both sides of the contact were parallel. Aside from shear contacts, others are gradational either through a migmatic mixed-rock zone from 30 to 300 feet wide (e.g. northwest of Sedgwick Lake), or through alternating bands of granite gneiss and metasedimentary rock over cross-strike distances of about 500 feet (e.g. inshore, southwest Andrew Lake). The western margin of the Sedgwick-Lindgren Lakes band in typical contact with granite gneiss is fairly well exposed, and apparently only moderately sheared. Characteristically,a cross-section through this contact shows that metasedimentary rock increases in feldspathic ("granitic" and "pegmatitic") content, mainly as pods and lenses rather than as dispersed grains, and in degree of deformation, towards the contact. In the contact zone of mixed rocks, gneissose granites and sheared, chloritic metasedimentary rock form contorted migmatities. The gneissose granites of this migmatitic zone are probably a mixture of granite gneiss and metamorphic feldspathic concentrations in the metasedimentary rock. Away from the contact zone, the granite gneiss and metasedimentary rocks may be contorted and sheared for widths of 20 to 60 feet. Most metasedimentary rock-granite gneiss contacts are of this type, but with various degrees of shearing range to a true faulted contact. In general, migmatization in these contact zones has masked the original nature of the contact relationships.

Contacts of metasedimentary rock with biotite granite A are of a gradational nature except where faulted. The 300- to 500-foot wide gradational zone from metasedimentary rock to biotite granite A shows an increase of porphyroblastic and augen feldspar and a complementary decrease of biotite and quartz. Feldspar pegmatite is particularly evident in the contact zone, and in the adjacent rocks. The granitic-bearing metasedimentary rocks may appear to be of a migmatitic nature; however, this is more likely due to deformational effects rather than to contact relations with biotite granite A. The contact zone is not a simple lithologic gradation but is varied in its nature, though commonly consisting of interlensed rock types. These relationships are typical for both bands of biotite granite A in contact with metasedimentary rock.

The contact zone of metasedimentary rock with massive granite and pegmatite is commonly made up of contorted, mixed rock types, where lenses and pods of one rock type are interfingered with the other. Good exposures of this zone are on the main peninsula (Sec. 15, Tp. 126, R. 1) at the northern end of Andrew Lake and on the two large islands.

The main Andrew Lake metasedimentary band within a mile of the Northwest Territories boundary contains appreciable amounts of porphyroblastic feldspar and biotite granites A and B. The granites are present as small masses, mixed in part with metasedimentary rock, and where sheared and gneissic a fault zone is suggested.

Biotite Schist

This map-unit which is found only in the southeast corner of the map-area is part of a band of metasedimentary rocks that shows little metamorphism in contrast to that of other bands.

The biotite schist unit includes sericite schist, phyllite, slate, phyllonite - all with quartzose phases - and impure quartzite. Fresh surfaces are dark grey and weathered surfaces are medium grey or iron-stained. A little sericite and chlorite is associated with conspicuous quartz and biotite. Noticeably lacking[1] are the garnetiferous zones, feldspar-augen schists, numerous quartz veins and pods, and intimately mixed small lenses and pods of granitic and pegmatitic material, so typical of other metasedimentary bands. One granitic boss about three-quarters of one mile in diameter protrudes through the metasedimentary rocks (see plate 1). However, the major portion of this boss lies in Saskatchewan and only part of the periphery, shown by red dashes, is found in Alberta. The metasedimentary rocks are fine grained and give little indication of primary bedding featues, probably as a consequence of obliteration in the course of extensive shearing.

Internal small-scale structures include ptygmatically folded quartz veinlets in slaty phyllite, good foliation with fine-scale crenulations giving rise to a steeply inclined lineation, and shear planes outlined by sericite and chlorite. Considerable shear-deformation is evident throughout most of the biotite schist, especially close to the granitic boss, and through a mylonitic contact zone into biotite granite A. Biotite schist appears to be in shear contact with biotite granite A to the west, and to be intruded by the large granitic boss.

Porphyroblastic Biotite Granites

The major bands of biotite granite A represent a gradational lithologic unit, intermediate in both composition and location between granitic quartzite bands and

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[1] The map legend for biotite schist includes minor milky quartz pods, feldspar augen, granite and pegmatite lenses, ferruginous, garnetiferous, and graphitic zones. These features do not apply to the small area of biotite schist on map 58-3A but to biotite schist on adjoining unpublished maps.

biotite granite B. The recurrent field relationship suggests a close genetic connection between these three rock types. Biotite granite A with biotite granite B make up texturally and mineralogically homogeneous bands of rocks, a notable feature amongst the varied and complex rock groups of this region.

Biotite Granite A

Biotite granite A is closely associated with biotite granite B in the two major bands of the map-area; one,east of Andrew Lake and the other west of Swinnerton Lake.

A fresh rock surface has the appearance of white spots on a dark grey background and a weathered surface has white spots on a medium grey background. The rock has a fair to good foliation which imparts a rough cleavage to a broken surface.

White to grey, generally euhedral, feldspar megacrysts[1] from 1/2 to 1 inch in size, some showing simple twinning, are set in a foliated matrix. The feldspar megacrysts make up from 15 to 30 per cent of the total rock in a medium- to coarse-grained matrix of about 30 to 50 per cent feldspar, 20 to 30 per cent quartz, 5 to 15 per cent biotite, and minor hornblende. In addition to the white porphyroblastic feldspars (some red at the rim), small red feldspars from 1/16 to 1/8 inch in diameter may be present in the groundmass. Biotite schistose layers a few inches wide and several feet in length are scattered throughout the biotite granite A; these may be otherwise described as inclusions of biotite schist.

Internal structures are evident as a matrix foliation, as concentrations of biotite or biotite schist inclusions, and as alignment of porphyroblasts. The porphyroblasts are generally aligned parallel or sub-parallel to foliation of the groundmass, especially where close to the metasedimentary rock contact, and they may show augen-flow structure. Good alignment of porphyroblasts is particularly evident in the area just east of the northern one-third of Andrew Lake (Secs. 14, 23, 26, Tp. 126, R. 1) though it becomes noticeably less perfect 500 to 1,000 feet eastward from the faulted metasedimentary rock contact where the texture is so massive locally that foliation determination is difficult. Local concentrations of biotite within the main bands of granite A seem to have lowered its competence and allowed formation of small shear-zones. In such zones the porphyroblastic feldspars 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. Careful examination of hand specimens shows that the small red feldspars are distributed close to very small mylonitic planes in biotite granite A. Deformation of biotite granite A west of Wells Lake has produced a gneissic structure and although the rock is defined on the map as biotite granite gneiss, it should not be confused with the major granite gneiss areas.

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[1] The term "megacryst" is used for descriptive purposes only; all data point to a metamorphic origin of the large feldspar grains found in metasedimentary rocks, biotite granites A and B, and granite gneiss.

Biotite Granite B

A fresh surface has the appearance of white spots on a medium-grey background and a weathered surface has white spots on a medium- to light-grey background The rock has a poor but noticeable foliation which provides a rude cleavage on a broken surface.

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

Minor zones of shear in the grey granite are evident as streaked or elongated porphyroblasts aligned in biotite schistose layers with mylonitic stringers, a feature similar in character to expressions of shear in both biotite granites A and B. The Swinnerton Lake biotite granites A and B band tends to be more sheared throughout than the Andrew Lake band.

The boundary between biotite granites A and B is gradational, and its location is dependent upon an arbitrarily chosen hand specimen classification. Field information alone is inadequate to make a quantitative study of the nature of this gradation, and although on a detailed scale complications arise from the interfingering or mixing of biotite granites A and B, the regional field data indicate a gross general change of rock type across a composite band of these granites.

Massive, relatively leucocratic granite bands and lenses are found dispersed throughout biotite granites A and B. On a megascopic scale the only apparent mineralogic difference between the granitic masses and the enclosing biotite granites is a change in biotite content. The composite granitic bands are made up of aplite, microgranite, pegmatite, and include siliceous phases which in part resemble sugary textured quartzite. In biotite granite A they 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 of pegmatite, microgranite, and aplite may be almost straight and dyke-like, or have irregular shapes; the former are more common. The granitic 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. Small strike separations on cross-slips are readily traced by granitic bands offset a few inches. Other minor deformation includes mylonite stringers where adjacent coarse-grained and porphyroblastic feldspars are extensively fractured in a zone several inches wide. A few mylonite zones attain widths of two feet and appear as hard, siliceous grey bands.

Granite Gneiss

The major bands of granite gneiss and associated rock types vary greatly in texture and composition on a local scale, but still maintain definite group characteristics. The different rock types combined in this rock group include: biotite - and hornblende-granite gneiss and granite (minor), ferromagnesian-poor granite, granodiorite, and a highly siliceous (quartzose) granitic or pegmatitic phase, any of which may have porphyroblasts, and a general red to pink coloration. Numerous small amphibolite and hornblendite lenses are scattered throughout the granite gneiss, and are essentially absent in the remainder of the map-area with the exception of a few in the metasedimentary rock bands. Another characteristic of rocks in the granite gneiss terrain is the high degree of plastic deformation as illustrated by the common swirls, ptygmatic folds, and complex contortions. The alternation and variation of rock types over distances of tens of feet or less, present difficulties in defining areas of a predominant rock type. In fact, mixed rock types are prevalent throughout the granite gneiss terrain and can be regarded as another of its characteristics.

Biotite- and Hornblende-granite Gneiss

The abundant biotite granite gneiss contains minor patches of hornblende granite gneiss in a rock complex which forms the principal rock group in the western part of the map-area. Fresh and weathered surfaces of biotite granite gneiss are pink to red, the latter predominating on a weathered surface, with thin dark green or brown layers. Hornblende granite gneiss is of similar color but tends to be darker in overall appearance. Only exceptional concentrations of biotite in layers markedly affects the irregular nature of a broken surface. Typical biotite granite gneiss contains not more than 10 per cent biotite, about 30 per cent quartz, with potassic feldspar and plagioclase making up most of the remainder of the rock. Hornblende granite gneiss differs only in containing 5 to 10 per cent hornblende. Minor mineralogic variations include the appearance of chlorite, epidote, garnet, hematite, magnetite, and allanite. Where chlorite is the common ferromagnesian mineral it is presumed to be secondary after either biotite or hornblende, and is probably associated with a deformation zone. Epidote veinlets commonly of 1/16- to 1/8-inch thickness cut the granite gneiss foliation, mostly as a fracture filling, and more rarely epidote is present throughout the body of granite gneiss. Certain zones of granite gneiss are rich in red garnets, from 1/8 to 1/4 inch in diameter, which make up to 5 per cent of the total rock, as on the easterly of the two large islands on Andrew Lake (Secs. 33, 34, Tp. 125, R. 1). Hematite and magnetite occur locally in small concentrations, and dispersed allanite crystals have diameters averaging 1/16 to 1/8 inch, attaining a maximum of 1/4 inch. The rock is of medium to coarse grain, though fine-grained phases are not uncommon. 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. A layered structure is dominant in most granite gneiss areas and consists of alternating quartzo-feldspathic and biotite-hornblende-rich layers, ranging in thickness from 1/8 to 2 inches. However, small areas within the gneisses are sufficiently massive to be called biotite- and hornblende-granites. In areas poor in ferromagnesian minerals (about two per cent dark minerals), the rock may show either a massive texture or a foliation due to the alignment of elongated quartz grains. Small metasedimentary bands and lenses of pure and impure quartzite with minor biotite schist and migmatite are interspersed throughout the granite gneiss, though less commonly than the bands and lenses of amphibolite and hornblendite. The proximity of small metasedimentary bands may be indicated by an increase in the biotite content of the granite gneiss and by a more massive, homogeneous, medium-grained texture.

The banded structure of the gneissic terrain is typically swirled and drag-folded and in some areas the rocks have been classed as migmatitic in character. Little use can be made of minor structures in terms of elucidating larger forms as only the general direction of elongation shows any consistency on a regional scale. Contact relations of granite gneiss with metasedimentary rocks have been discussed previously (p. 12).

Amphibolite

The numerous dispersed lenses of amphibolite[1] and hornblendite are a characteristic feature of the granite gneiss and are common in some metasedimentary rock bands. Amphibolites appear dark green on a fresh surface and medium greenish-grey on a weathered surface. They are compact with an irregular to rudely foliated fracture. Principal minerals are amphibole and feldspar, with quartz and biotite. Textures are normally medium grained but fine- and coarse-grained phases have been noted. Amphibolitic masses are generally bordered by coarse-grained granite or pegmatite having biotite crystals up to four inches in diameter, or by biotite-rich schistose layers. Boudinaged amphibolite and groups or zones of angular amphibolite blocks are typically set in a pegmatite matrix. Intermediate rock types from the gneiss terrain form a sequence from hornblendite to amphibolite to hornblende granite gneiss. Amphibolites are massive to thinly layered, on a scale of a fraction to a few inches, and range in thickness from a few inches to several hundred feet. Some contain appreciable amounts of biotite which imparts a foliation to the rock. Amphibolite bands and lenses may be associated with hornblende-bearing phases of the granite gneiss and some can be followed along strike for a mile or more. Around the amphibolite bands or groups of bands the granite gneiss layered structure is particularly contorted. Contact relations of amphibolite with country rocks are generally sharp and conformable, and in places the contacts appear to be sheared.

Massive Granites and Pegmatites

These rock types are present in minor quantities in the map-area and are associated with each of the three principal rock groups as small, scattered masses. More specific associations are noted under each rock type of this section. The granites and pegmatites of this group tend to be leucocratic in character containing in the order

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1 Hereafter, for general reference "amphibolite" is used to include the two petrologically distinguished terms "amphibolite" and "hornblendite". Definition 6A (Shaw, 1957) 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 of hornblende". Both of these rock types are found in notable quantities in the granite gneiss terrain.

of 95 to 99 per cent felsic minerals.

Biotite Granite

This granite is found in all of the major rock groups but more particularly in the granite gneiss and metasedimentary rocks. In granite gneiss areas biotite granite is not distinguished on the map because of the problem of outlining individual bodies. Both fresh and weathered surfaces are pink to red colored; the granite contains pink to red feldspar, abundant quartz, up to about 5 per cent biotite, minor garnet, and sericite where incipient shears and foliation are developed. The texture tends to be medium grained and massive. The heterogeneous nature of the larger masses of biotite granite in the Andrew Lake metasedimentary band is evident in the mixing of pegmatites and metasedimentary rock schlieren. These masses also show a tendency towards a foliated or gneissic structure.

Muscovite Granite

This granite is found only in association with metasedimentary rocks. All surfaces are white or light colored. Highly feldspathic, it is composed of 50 to 70 per cent white to pink feldspar, 5 to 15 per cent muscovite with minor biotite in contrast to all other granites in the map-area. The remainder is made up of quartz, partly in the form of graphic intergrowths, and minor pink or red garnets. The texture is massive and medium to coarse grained, locally giving way to muscovite pegmatite. A "raisin structure" (see page 27) is developed where the granite appears to be sheared so that feldspars and garnets are crushed and rounded.

Granite Pegmatite

This pegmatite is found in all major rock groups though it is especially typical of the granite gneiss terrain. In the latter association the granite pegmatite is not distinguished on the map because of the intimate mixture and small size of the dispersed bodies. All surfaces of the rock are pink to red colored, and it is composed of pink to red feldspar, abundant quartz, and about 5 per cent biotite. The texture is massive and coarse grained, the feldspars average from 1 to 2 inches in diameter.

Feldspar Pegmatite

Feldspar pegmatite is present mainly within and adjacent to major metasedimentary bands though minor amounts are associated with biotite granite A. The most striking field characteristic is the dominant white mass of large feldspar crystals on both fresh and weathered surfaces. This pegmatite is typified by an unusual abundance of white feldspar with graphic-intergrowths of quartz, and minor amounts of biotite or muscovite. The texture is massive with white feldspar crystals commonly from 4 to 6 inches in diameter.

Muscovite Pegmatite

Muscovite pegmatite is similar to muscovite granite and closely allied to feldspar pegmatite with regard to field association, mineralogic composition, highly felsic nature, and texture. The rock is composed of abundant white to pink feldspar, quartz, generally less than 5 per cent muscovite, and very little garnet. 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 smaller feldspar, quartz, and muscovite.

Muscovite granite, muscovite pegmatite, and feldspar pegmatite occur in bodies of irregular shape that range in width from 5 to 50 feet. Biotite granite is found in masses from a few feet to one mile in diameter, and granite pegmatite in minor bodies of a few feet in width. Close to contacts with enclosing metasedimentary rocks, shreds and lenses of matted biotite are incorporated into the granites and pegmatites.

Internal structures depend on the formation of a foliation or gneissic structure in an otherwise homogeneous texture. Such structures tend to be simple in form, especially when viewed on a regional scale.

Contacts of large, massive granite bodies tend to be mixed and interfinger with the enclosing metasedimentary rock, whereas small granite and pegmatite masses may exhibit simpler and more definite margins.

Chemical and Modal Analyses

Metasedimentary rocks are clearly distinguished as a petrologic group in the field. The heterogeneous, layered nature of these rocks, and the lithologic gradation and alternation create a difficulty in obtaining a representative sample suitable for chemical analysis, which therefore has not been carried out at this time. Petrological classification, distinction, and geologic boundaries are more problematical in the granite, granite gneiss, and porphyroblastic biotite granite terrains. Chemical and modal analyses of those hand specimens chosen as the reference standards of the map-units are given in table 2.

The standard granite, granite gneiss, and porphyroblastic biotite granite rock types show acidic characteristics in the analyses presented in table 2. On the basis of these analyses the 12 samples can be divided into three groups which coincide fairly well with their field classification and relationships. The first group of four sample (1, 2, 3, 4) belongs to the porphyroblastic biotite granites A and B. The second group of five samples (6, 7, 8, 9, 10) is from the granite gneiss terrain. In the third group, one sample (11) represents the relatively massive biotite granite, and two samples (12, 13) the muscovite granite, all of which are found in the metasedimentary rocks and porphyroblastic biotite granites.

Table 2. Chemical and modal analyses of standard rock type samples
Chemical analyses by H. A. Wagenbauer

Sample	1	2*	3	4	6	7	8	9	10	11	12	13
SiO_2	68.51	67.40	68.10	69.24	71.71	67.68	71.24	70.03	71.50	70.40	73.76	74.81
TiO_2	0.38	0.47	0.39	0.32	0.23	0.55	0.28	0.63	0.20	0.44	0.04	0.04
Al_2O_3	15.45	13.72	14.89	13.59	13.56	15.03	14.35	13.28	14.66	13.99	14.68	14.86
Fe_2O_3	3.46	4.16	3.55	3.60	2.93	4.21	2.39	5.19	2.30	3.47	1.57	1.12
MgO	2.31	1.86	2.28	1.79	0.71	1.19	0.77	0.86	0.43	1.23	0.36	0.09
CaO	2.68	2.34	1.96	2.39	1.06	0.96	0.90	2.25	1.20	0.45	0.55	0.51
Na_2O	2.77	2.67	3.00	4.37	4.10	2.32	5.10	4.00	3.41	3.43	3.43	7.97
K_2O	4.51	4.52	4.64	3.66	5.04	7.16	5.52	4.03	5.04	6.00	4.12	0.73
L.O.I.	0.71	1.04	0.92	1.03	0.34	0.77	0.59	0.35	0.75	1.05	0.55	0.23
P_2O_5	0.16	0.20	0.03	0.14	0.03	0.06	0.03	0.15	0.03	0.07	0.03	0.03
Total	100.94	98.36	99.76	100.13	99.71	99.93	101.17	100.77	99.52	100.53	99.43	100.39
Quartz	21.8	14.7	15.9	25.1	32.2	33.5	31.6	22.2	30.6	25.6	37.6	30.9
Potash Feldspar	33.7	29.2	35.4	21.6	23.7	35.1	19.6	27.1	19.1	44.9	27.8	**
Plagioclase	25.6	31.8	29.4	33.2	35.6	18.3	42.2	32.1	42.2	22.3	20.6	64.7
Biotite	16.0	14.1	15.1	4.9	7.3	10.4	6.1	9.0	0.7	5.8	-	-
Chlorite	-	-	-	6.2	-	-	0.4	-	5.8	1.2	-	1.1
Hornblende	1.2	6.9	-	-	-	-	-	7.6	-	-	-	-
Epidote	1.1	2.7	2.9	8.5	-	0.2	-	-	1.0	-	-	-
Muscovite	-	-	-	-	-	1.9	-	-	-	-	12.6	3.3
Garnet	-	-	-	-	-	-	-	-	-	-	1.1	-
Calcite	-	-	0.8	-	-	-	-	-	-	-	-	-
Accessories	0.6	0.4	0.3	0.4	1.2	0.6	0.05	1.9	0.3	0.7	0.3	-
Number of points	3,000	3,500	3,200	4,000	2,000	2,000	2,000	2,000	2,000	2,000	1,000	1,500

1 Biotite granite A
2 Biotite granite A with small red feldspars and hornblende
3 Biotite granite B
4 Biotite granite B with small red feldspars
6 Biotite granite gneiss
7 Biotite granite gneiss
8 Biotite granite gneiss
9 Hornblende granite gneiss
10 Porphyroblastic granite gneiss
11 Biotite granite, fine-grained phase
12 Muscovite granite, garnetiferous
13 Muscovite granite

* Sample located one mile south of map-area, three-quarters of one mile west of the Alberta-Saskatchewan Provincial Boundary.

** The small amount of potash feldspar is grouped with plagioclase.

Table 3. Chemical analyses of rock samples
Analyses by H. A. Wagenbauer

Sample	15	16	17*	18	19	20	21**	22
SiO_2	66.44	68.75	67.43	68.35	64.37	69.97	73.43	89.23
TiO_2	0.46	0.33	0.42	0.34	0.90	0.38	0.06	0.13
Al_2O_3	14.41	13.21	14.61	13.78	14.90	14.43	14.99	4.62
Fe_2O_3	5.20	3.61	3.82	3.13	6.16	3.11	1.51	2.39
MgO	1.84	2.18	1.96	1.05	1.28	0.66	0.48	0.69
CaO	1.12	1.35	2.19	1.47	1.82	0.53	0.53	0.43
Na_2O	3.68	3.04	3.00	3.07	2.89	2.33	3.46	0.32
K_2O	3.32	4.78	5.14	5.32	4.76	6.69	4.64	2.10
L.O.I.	0.72	0.49	0.47	0.56	0.71	0.34	0.77	0.24
P_2O_5	0.16	0.09	0.14	0.09	0.17	0.05	0.02	0.03
Total	97.35	97.82	99.82	97.16	97.96	98.49	99.89	100.18

15 Biotite granite A

16 Biotite granite B with small red feldspars and hornblende

17 Biotite granite B

18 Biotite granite B

19 Hornblende granite gneiss

20 Porphyroblastic granite gneiss

21 Sericitic granite, crushed and sheare

22 Mylonite

* Sample located three-eighths of one mile south of the map-area, one mile west of the Alberta-Saskatchewan Provincial Boundary.

** Sample located one-eighth of one mile south of the map-area two miles west of the Alberta-Saskatchewan Provincial Boundary.

There seems to be little difference between biotite granites A and B from the point of view of chemical analyses. They are characterized by a relative uniformity of analyses, and by a high (calcium + magnesium) total. The chief difference between biotite granites A and B in the modes is shown by a higher (biotite + hornblende + chlorite) content in granite A, and by a slightly higher average quartz content in granite B. A maximum of 7 per cent hornblende may be present in biotite granite A, though biotite remains the predominant ferromagnesian mineral. Petrographical classification[1] would place this rock group in the "porphyroblastic" quartz-monzonite to granodiorite division.

The complex of rock mixtures in the granite gneiss terrain provides a wide range of analyses as shown in table 2. Potassium is consistently high except in the hornblende granite gneiss where calcium becomes significant. The total (calcium + magnesium) for the granite gneiss group is intermediate between high values of the porphyroblastic biotite granite group and low values of the muscovite granites. Consideration of the modal analyses places most of these rocks in the quartz-monzonite division; however, samples 8 and 10 have sufficient plagioclase to make them marginal to the granodiorite field.

Although the field relationships of biotite granite (11) associated with metasedimentary rocks are similar to those of the muscovite granite, biotite granite shows strong chemical affinities to the granite gneiss group. Petrologically it is classed as granodiorite, which fringes on the field of true granites.

The muscovite granite group (12, 13) is very distinctive with high silica values and low iron, calcium and magnesium values. These rocks are believed to represent true granites which locally have undergone extensive sodium metasomatism.

Chemical analyses of samples 15 to 20 in table 3, given for comparative purposes, confirm the coincidence of chemical and geological classification as set out in table 2. Samples 15, 16, 17, 18 from the porphyroblastic biotite granites A and B maintain the same chemical characteristics which are shown in table 2, i.e. high (calcium + magnesium) values and a relative uniformity of chemical analyses (except for iron in sample 15). The nonparametric Mann-Whitney U-test[2] (Siegel, 1956, p. 116) was applied to determine differences between biotite granites A and B using the eight analyses given in tables 2 and 3. Statistically significant differences at the .05 level were found for P_2O_5 and the combined $K_2O + Na_2O$ content between the two granites. Greatest use can be made of the difference in combined alkali content in terms of petrogenetic interpretations, though any conclusions based on this data would be tentative at this time. It should be kept in mind that differences amongst other important oxides could possibly be detected by increasing the number of analyses. Samples 19 and 20 from the granite gneiss group fall in the

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1 Based on the recent outline given by Moorhouse (1959, p. 154).

2 Suggested by G. B. Mellon, Research Council of Alberta.

range of values established for this group in table 2. The chemical analysis of sample 21 indicates that it belongs in the muscovite granite group, but the rock is markedly crushed, sheared, slightly mylonitic, and it contains sericite flakes in foliation planes rather than the usual blocks and books of muscovite. Sample 22 represents a mylonite tending toward ultra-mylonite, and the analysis suggests that significant silicification has accompanied mylonitization. The advanced deformation evident in sample 21, which shows cataclastic textures exclusively, was insufficient to induce any silicification such as that which accompanied mylonitization in sample 22. This rock (sample 21), in fact, retains the definite chemical characteristics of the massive muscovite granites.

PLEISTOCENE GEOLOGY

The major effect of the Pleistocene glaciers which covered this area has been to scour the bedrock leaving smooth, polished,and striated surfaces. The deposition of minor amounts of glacial debris, which was brought in from the east-northeast, indicates that the wasting ice-sheet must have been largely composed of clean ice.

Principal expressions of ice erosion on the general topography are seen as low rounded hills and overdeepened valleys in which rock-basin lakes and muskegs are situated. Typical of the erosional features in the area are the striae and grooves of dimensions ranging from those which can be observed on single outcrops to the giant grooves (or flutings) sometimes several miles in length that have been described by Smith (1948), and Gravenor and Meneley (1958).

Glacial deposits in the map-area include sand plains, drumlins, eskers, and erratics. Some sand plains are extensive, such as those mapped on the north end and on the southeast shore of Andrew Lake. Composed of sorted, medium-grained sand, the flat-lying plains are covered by widely spaced, tall poplars, birch,or pine trees and have no brush undergrowth. The few drumlins and eskers are composed mainly of sand, though the latter also contain gravel. The eskers tend to be short in length and have a winding path, many of them lying in valleys close to lakes. Eskers are not indicated on the present map 58-3A but they are readily distinguished on vertical aerial photographs (plate 1). Erratic boulders are a common feature, many being precariously perched on the tops and slopes of hills.

Frost heave is evidenced by the opening of some joint planes to one foot or more, and by the upheaval of blocks of bedrock weighing many tons above the general bedrock surface. The gaping joints and heaved blocks were particularly noticeable in shallow muskeg areas, though the phenomenon is not uncommon on the sides and tops of hills. A large open network pattern observed on the bottom of some shallow lakes has probably originated from the effect of frost heaving and movement along joint planes. Other expressions of frost action are seen as angular boulder pavements, sometimes marginal to lakes, such as the pavement formed along the northeast shore of Andrew Lake (Sec. 23, 26, Tp. 126, R. 1).

STRUCTURAL GEOLOGY

Rock types and rock associations of the map-area represent materials of widely differing physical properties and their response to stress is correspondingly different and distinct. Regional folds have not been established in the map-area. The regional trend is northerly, parallel to the foliation which is steep and generally dips to the west. Primary structures in the metasedimentary rocks other than color banding have not been observed. Major faults in the district are of regional dimensions and may either transect the strike of the rocks, generally to the northwest, or parallel the strike. Many of the principal features can be observed on the aerial photographic mosaic (plate 1), and some of them have been illustrated in a study of aerial photographs (Godfrey, 1958a).

The Bonny fault (Godfrey, 1958b) is the most notable fault to transect the rock strike. Its valley lineament (plate 1) strikes north 27 degrees west, passing under Sedgwick, Murchison, Holmes, and Split Lakes. An apparent dip of 80 degrees southwest was determined in the vicinity of Andrew and Hutton Lakes, just south of the map-area. On aerial photographs the fault can be traced to the northwest outside the map-area and beyond the northern boundary of the Province of Alberta. Southeast of Murchison Lake the Bonny fault branches into several planes, possibly an expression of its diminishing significance as a major fault zone. At the south end of Sedgwick Lake the Bonny fault occupies a zone of chloritized, silicified, feldspathized, and phyllonitic metasedimentary rock. Mylonite and vertical shear-fractures which strike from north 23 to 35 degrees west are expressions of the fault movements. Within the apex contained between the two principal shears of the Bonny fault at Murchison Lake the rocks have been considerably fractured, crushed, and generally deformed. As distinct from most other areas in the district, the foliation and gneissosity here do not show a continuous pattern from one outcrop to the next, and it is difficult to outline lithologic trends or patterns. Bands of mylonite and areas with prominent chlorite and red feldspar (both typically associated with fault zones) are characteristic features of this disturbed area. On the south shore of Murchison Lake a ramifying network of quartz veins is laced through a zone of breccia and chloritized, feldspathized mylonite at least 40 feet wide. Continuing to the southeast the main expression of the Bonny fault is marked by a scarp on the northwest shore of Holmes Lake. The Bonny fault subdivides several times at Split Lakes, where most of the branches are on the footwall side of the principal shear and swing to a more easterly strike. Chlorite, red feldspar, and mylonite are common features within the wallrock adjacent to the fault, and hematized, silicified breccias are present at intervals in this section of the fault.

The Bonny fault is a major structural feature of this district, as illustrated by the termination and lack of obvious fit of the different lithologic bands on each side of the fault. Consideration of this and other observations noted above suggests that substantial movement and alteration have taken place along this fault; however, the relative motion could not be determined in the field.

A fault sub-parallel to the Bonny fault passes through the north end of Andrew Lake where its average strike is north 39 degrees west, and dips steeply, probably to the southwest. Small-scale features associated with the fault include mylonite and shear-fractures with chloritization and feldspathization. Hematized quartz-cemented and quartz-veined breccia is notably absent. A scarp in biotite granite A marks the location of this fault on the northeast shore of Andrew Lake and controls the shape of the shoreline for over a mile (Sec. 14, Tp. 126, R. 1). Northwest of Andrew Lake the projected fault line disappears under an area of muskeg and water and is then traced in granite gneiss to the northern provincial boundary, though as a less prominent structural feature. Strike separation along the fault is indicated from the map and a displacement is suggested; small-scale structural features, however, suggest that this fault is not as important as the Bonny fault.

Fault structures parallel to the regional trend in the map-area have been located but assessment of their structural significance is difficult. As expected, the mechanically weak metasedimentary bands have been the principal control in fault development parallel to the regional trend. The determination of the displacement and significance of these faults is generally complicated by three factors: lack of adequate exposure due to erosion of the weak metasedimentary rocks, especially in the more sheared and faulted sections; the ready deformation and shear of biotitic, graphitic, sericitic, and chloritic schists in response to stress; and the general absence of suitable geologic markers.

The wide, sheared metasedimentary rock band at the north end of Andrew Lake which is mostly obscured by muskeg and sand, probably contains a system of north-trending faults. A faulted easterly contact of the metasedimentary band against biotite granite A is evident. For the most part the fault-shear surfaces have an attitude similar to that of the foliation in the metasedimentary rocks. Metasedimentary rocks are particularly sheared in the vicinity of the largest island in Andrew Lake. On the mainland just west of the island a prominent fault-scarp striking north 25 degrees east and dipping steeply to the east marks the contact between metasedimentary rocks and granite gneiss. The Sedgwick and Swinnerton Lakes bands in particular have small shear zones within them in which single planes of movement cannot be traced for more than a few feet. In the contact zone west of Pythagoras Lake a cross-shear has interwedged the metasedimentary rocks and granite gneiss. The Swinnerton Lake metasedimentary band and its associated shears terminate against the northernmost branch of the Bonny fault, suggesting that movements on the Bonny fault branch post-date those in the Swinnerton Lake metasedimentary band.

A planar structure can be readily measured in most of the major rock types of the map-area. In the metasedimentary rocks alternation of layers (from 1 inch to 2 or 3 feet wide) of differing lithologies has produced a typically banded appearance parallel to the foliation. The granite gneiss terrain is typically layered for the most part, though areas of homogeneous, massive texture are not uncommon. Lineation, combined with foliation or gneissosity of the principal constituent minerals - quartz, feldspar, biotite, and hornblende - have been observed at a few points. Muscovite granite and muscovite pegmatite are fairly massive except for foliation resultant from shear features, such as mortar structure, flaser structure, mylonitization, and sheared wisps and lenses of biotite schist. Porphyroblastic biotite granites A and B show good foliation by parallelism of biotite and porphyroblastic feldspar. Gradation to the porphyroblastic grey granite, however, introduces areas of more massive-appearing texture and consequently a decrease in the degree of foliation.

A contrast in character is exhibited in the internal structural patterns of the granite gneiss and of biotite granites A and B. In granite gneiss many tight isoclinal folds have been reconstructed from the field traverse data, which is compatible with observations of drag folds, highly contorted, crenulated structures, and other forms indicating plastic deformation. In contrast, very little folding is evident on any scale within biotite granites A and B, and only simple foliation features were observed.

Joints are common, and in places are difficult to distinguish from fault fractures so that the tectonic significance of some fractures is problematical. The joints and shears in the granitic core of the large island in Andrew Lake appear to be related to stress conditions which also resulted in shearing of the enclosing metasedimentary rocks.

A number of small-scale megascopic features which represent both plastic and cataclastic deformational phenomena may be summarized here. Mullion and rod structures are rare except in the metasedimentary rocks. 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 (typically hornblende granite gneiss and amphibolite), 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 (Z) (in pocket). Rocks having more open folds and swirls are regarded as being contorted and are also indicated on the map (ↄ). 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 have been plotted as they may have significane on a regional scale.

Drag folds, crenulations, totfalten (Fairbairn, 1949, p. 178), fracture cleavage, and slaty cleavage are common small-scale structural features in the metasedimentary rocks, especially in the slaty argillites, phyllonites, and biotite-sericite schists.

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 granite A. Many of the augen-feldspar grains are fractured, and where the effect of shear is more pronounced the augen feldspars lose their euhedral form and become rounded. Under conditions of extensive shear the amount of mylonitization in the groundmass becomes more significant and augen structure grades to mortar or flaser structure. In a rock with flaser or mortar structure where the proportion of cataclastically rounded grains is high compared to the mylonitic groundmass and other constituents (i.e. essentially consists of rounded, coarse grains packed in a fine-grained, mylonitic matrix), the rock gives the appearance of a "raisin-structure". This structure is found mostly in sheared rocks of coarse, equidimensional, grain size, such as in the biotite granite core of the largest island in Andrew Lake (Sec. 4, Tp. 126, R. 1).

Mylonites have been noted in all the major rock types of the map-area. Many mylonitic zones can be related to obvious fault scarps, but some zones in the granite gneiss terrain occur in a fairly massive, unsheared body of rock having margins which grade into the wall rock and without other indications of a fault. Bands of mylonite are commonly developed in the granite gneiss terrain and minor bands and stringers less commonly in biotite granites A and B. Most mylonitic bands seem to be siliceous, and a typical sample taken from the major northwest fault at the north end of Andrew Lake contained over 89 per cent silica (see table 3, number 22). Some bands of mylonite (tens of feet wide) in granite gneiss have no related topographic expression and where these siliceous mylonite bands appear homogeneous or regularly layered, they can be mistaken in the field for quartzite. A means of distinction involves examination of weathered surfaces, which are most likely to reveal the texture and structure of a mylonite; adjacent and parallel to a mylonite zone, rocks may exhibit moderate shear, brecciation, crushing, and flaser and mortar structure. The attitude of siliceous bands may offer a clue to their true nature: a quartzite band should conform to the general strike and dip of the local area, whereas a siliceous band with a marked divergence from the local structure may well prove to be of a mylonitic nature. Mylonite stringers partially filled with green epidote are most common in the granite gneiss, biotite granite B, and porphyroblastic grey granite areas. These stringers average from 1/16 to 1/8 inch in width and a few feet in length, though groups of anastomosing stringers may extend for tens of feet along strike.

Metamorphism of the sediments that make up the recognizable metasedimentary rock bands has obliterated most of the original sedimentary structural features. The least-altered, though highly sheared, metasedimentary rock is the small area of biotite schist, phyllite, and phyllonite, found in the southeast corner of the map-area. In general, textural and mineralogic variations in the quartzite unit evident as interlayered quartzite and phyllite bands a few inches to several feet in thickness, and color banding, may well be expressions of original sedimentary bedding.

In short, 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 zones of mylonitization.

A sequence of the history of deformation is not presented at this time in view of the apparent complexities involved and the limited area of study completed to date.

GEOPHYSICAL SURVEYS AND AERIAL PHOTOGRAPHS

The Geological Survey of Canada has recently published 15 aeromagnetic maps on a scale of one inch to one mile of an area centred around the uranium district of Beaverlodge, Saskatchewan, and extending into Alberta. Four of these maps (Geological Survey of Canada, 1958) cover about 940 square miles in the extreme northeast corner of Alberta, including the Andrew Lake district. Ground control in a limited part of the area enables aeromagnetic data to be of considerable help in extending and deciphering major structures, attitudes, and types of rocks in adjacent areas. A comparison of bedrock geology with the pattern of anomalies on the aeromagnetic map of the Andrew Lake district reveals some interesting correlations. Bands of metasedimentary rock and biotite granites A and B consistently show low values of magnetic susceptibility whereas the readings over granite gneiss are generally high. As the biotite granites A and B occupy broad bands (from one to two miles wide) in the map-area, they appear as flat-bottomed, wide valleys on the contoured aeromagnetic maps. On the other hand, metasedimentary rock bands are usually narrow and where associated with granite gneiss they give rise to a linear pattern of sharply defined ridges and valleys. Where metasedimentary rocks are associated with biotite granites A and B a clear distinction is difficult as they are characterized by similar magnetic susceptibility values. Transverse faults, such as the Bonny fault, show up as aeromagnetic valleys where granite gneiss terrain is the wallrock, otherwise the magnetic susceptibility values are similar to those over metasedimentary rocks. The higher magnetic susceptibility values of the granite gneiss terrain correspond with a generally higher magnetite content of these rocks as noted in hand specimen and laboratory studies.

The interpretation of anomalies obtained by airborne scintillometer surveys in this general area should be made with caution. Preliminary information suggests that the mass effect of some slightly radioactive but large biotite granite and granite gneiss bodies may be adequate to produce anomalies equivalent to those found over some zones of uranium mineralization. At least a reconnaissance of the bedrock geology is important in the accurate interpretation of the significance of radiation anomalies.

The known mineralization in the map-area is associated with either a fault structure, a particular rock type, or both. It would be useful if such features could be readily extended or recognized beyond the boundaries of the map-area. Many of the major structural and lithologic features described in this report and figured on the accompanying map can be delineated on the aerial photographic mosaic (plate 1, in pocket). The photographic mosaic (plate 1) is made up of between 25 and 30 photographs and is reproduced on the same scale as map 58-3A. Tonal changes between adjacent photographs should not be confused with those due to bedrock, structural, or vegetational differences. Comparison of bedrock features with topographic expression as outlined on the photographic mosaic, or in stereoscopic coverage, can be useful in the interpretation of similar features from aerial photographs of adjacent areas.

Specific features which can be noted in a comparison of geological map 58-3A and the photographic mosaic, plate 1, are:

(1) Features associated with major faults:
- (a) Well-marked valley linears,
- (b) Scarps parallel to fault lines.

(2) Features associated with metasedimentary rock bands:
- (a) Bands coincident with the northerly trending valleys,
- (b) Enclosed granitic bodies forming prominent islands, peninsulas, and domes,
- (c) Termination of the Swinnerton Lake band by a fault at the south end of Henson Lake.

(3) Features of granite gneiss areas:
- (a) Formation of the rocky uplands, e.g. southeast of Swinnerton Lake,
- (b) The fine northerly lineation corresponding to the foliation trend, especially in the area east of Swinnerton Lake, which is not found in areas of porphyroblastic biotite granites.

(4) Features of glaciation:
- (a) Giant grooves and patchy debris over much of the map-area which are aligned east-northeast, the direction from which ice advanced,
- (b) Extensive sand plains with their uniform vegetation cover,
- (c) Rare, large drumlins as southwest of Dumbell Lake and north of the northern tip of Andrew Lake, aligned in the direction of ice movement,
- (d) Winding eskers as at the south end of Inkster Lake, north end of Dumbell Lake, and the east end of Split Lakes.

(5) Features of burnt-over areas:
- (a) Recent burnt areas appearing as dark north-northeast trending bands situated between Swinnerton Lake and the lake connected to the north end of Andrew Lake (Sec. 33, Tp. 126, R. 1),
- (b) Narrow, light lines in the burnt areas representing lines of unburnt vegetation parallel to the wind direction.

MINERAL OCCURRENCES

As noted previously the region has been mapped along traverse lines ideally spaced one-quarter of a mile apart and no attempt was made to prospect favorable areas. Any mineralization reported was noted in the course of these systematic east-west traverses.

The distribution of mineral showings indicates that areas of economic interest are more likely in bands of metasedimentary rocks and in faults. Some zones of radioactivity are associated with faults, and sulfide mineralization is associated with metasedimentary rocks. A description of mineralization of a large area which encompasses the present map-area has been published (Godfrey, 1958b) and should be referred to for further detail. Subsequent staking activity after release of this report in August, 1958, led to the filing of about 150 mineral claims.

Small gossan and rusty zones parallel to the rock strike are commonly found in metasedimentary rock bands, and are particularly evident in the Sedgwick-Lindgren Lakes band. Pyritization is a common feature of most metasedimentary rock bands, and other sulfides such as arsenopyrite, smaltite, and pyrrhotite were noted at several points in the Sedgwick-Lindgren Lakes band. Quartzite and biotite schist exposed on the southwest shore of Lindgren Lake showed sulfide mineralization within a gossan which yielded small values of nickel, silver, and gold.

The related minor features of the Bonny fault - brecciation, quartz stockwork, mylonitization, hematization, chloritization, and marginal shears - mark this fault as a major structure, and radioactivity of several times background was found at a number of places along the fault. Radioactive background varies over the different rock types, for example the counts over granite, granite gneiss, pegmatite, and some metasedimentary rocks may be twice as high as over some schists. The radioactive anomalies were recorded adjacent to the main Bonny fault zone rather than within it, and are coincident with bands of metasedimentary rocks as they abut against the fault. Some 45 miles to the east in the Beaverlodge district, Saskatchewan, uranium mineralization is associated with metasedimentary rock adjacent to major fault structures which generally exhibit hematization, feldspathization, and chloritization, i.e. those petrologic features typical of the Bonny fault zone.

Secondary alteration products of uranium minerals and those of molybdenite may be confused. Thin films or stains of either type of secondary alteration appear very similar as a pale, lemon-yellow color; on the other hand, thicker skins of secondary alteration products of uranium tend to be a canary yellow or to show a tinge of orange. The geiger counter provides a diagnostic test as secondary uranium products are inherently radioactive.

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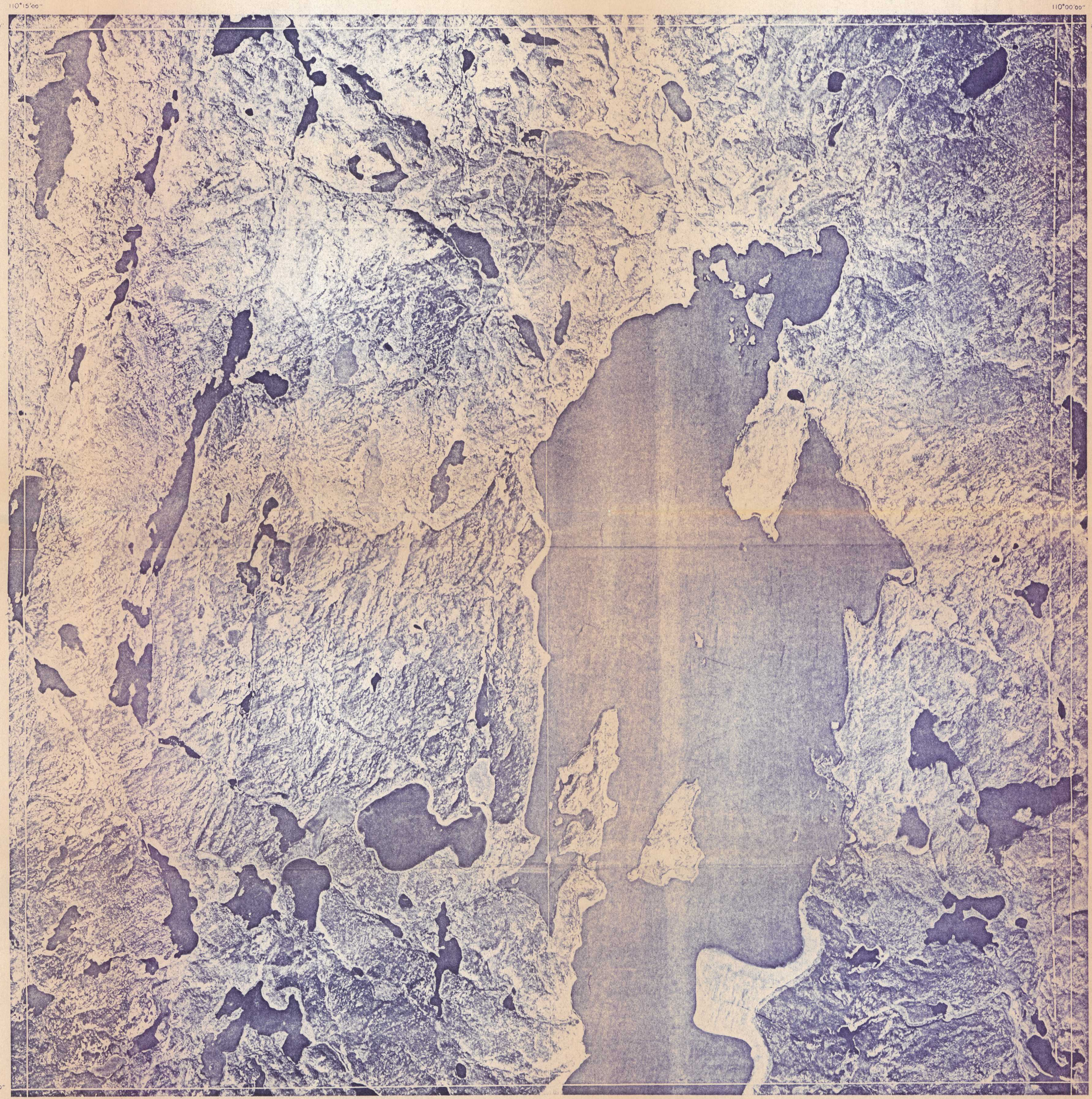

PLATE 1

AERIAL PHOTOGRAPHIC MOSAIC

ANDREW LAKE, NORTH

WEST OF FOURTH MERIDIAN

ALBERTA

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

½ ⅜ ¼ ⅛ 0 ½ 1 1½ 2

Mosaic to accompany Preliminary Report 58-3
Lithographed in Canada Published 1961

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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.*
- Biotite granite A, *with white or 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 or 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 granite gneiss, *with some hornblende, chlorite; including minor massive granite, porphyritic granite, granodiorite, alaskite, lenses of biotite, quartzite, amphibolite, garnetiferous zones.*
- Hornblende granite gneiss, *with some biotite, chlorite; including minor massive granite, porphyritic granite, granodiorite and amphibolite.*
- Amphibolite, *including biotite amphibolite, hornblendite; banded to massive.*
- Biotite granite, *with pink and red feldspars, minor sericite; massive. Muscovite granite (m), with abundant white and pink feldspars, minor biotite; massive.*
- Granite pegmatite, *with pink and red feldspars, 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.*

**Note: Rock units are not arranged chronologically.*

Geological boundary (defined, approximate, assumed)
Geological boundary, gradational
Schistosity, gneissosity, foliation (defined, dip known, dip unknown; assumed) 80
Extreme contortion (structural trend)
Tight folds (structural trend)
Fault (defined, approximate, assumed)
Shear zone
Breccia
Mylonite
Gossan
Vein
Joint
Sample location 9o
Glacial striae (direction of ice movement known)
Mineral occurrence (nickel) .... X Ni
Radioactivity .... ●
Arsenopyrite .... asp
Molybdenite .... mol
Garnet .... G
Graphite .... R

Geology by John D. Godfrey, 1957.

Drainage (permanent, intermittent)
Muskeg
Sand-covered area
Spot elevation, height in feet above mean sea-level .... 1248′ ⊡
Provincial boundary

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

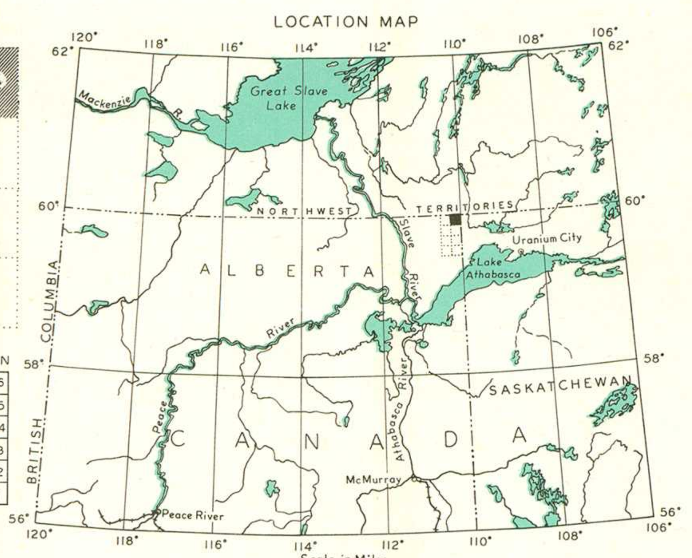
Air photographs covering this area are obtainable from the Technical Division, Department of Lands and Forests, Government of Alberta, Edmonton, and the National Air Photographic Library, Topographical Survey, Ottawa.

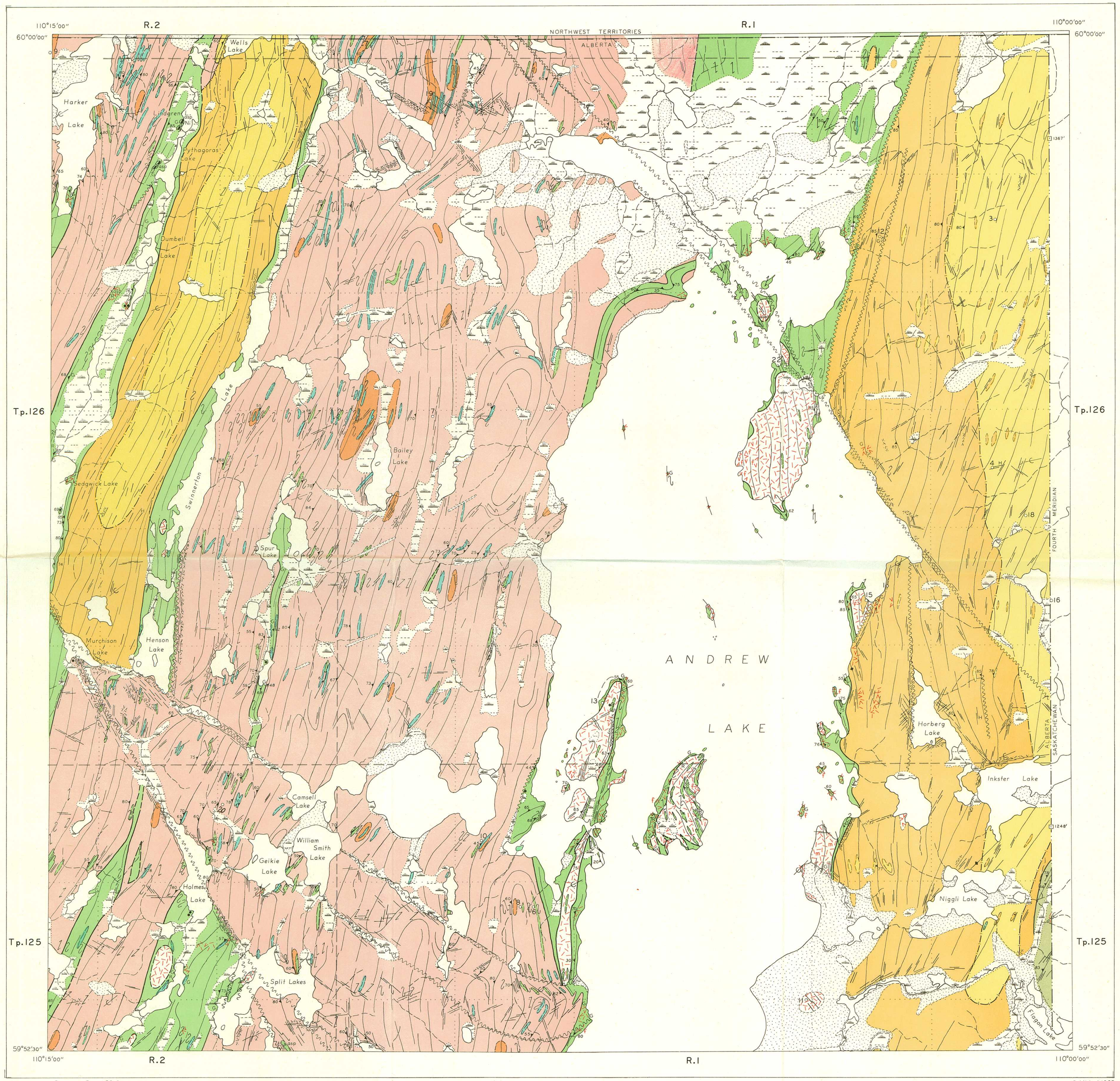
Approximate magnetic declination 26°10′ East in 1960, decreasing 6′ annually.

INDEX TO MAPS

TOWNSHIP PLAN

LOCATION MAP





Map to accompany Preliminary Report 58-3

MAP 58-3A

ANDREW LAKE, NORTH

WEST OF FOURTH MERIDIAN

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

½ ⅜ ¼ ⅛ 0 ½ 1 1½ 2

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