69-21

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 69-21

GEOLOGY OF THE PRECAMBRIAN ROCKS OF THUBUN LAKES MAP-AREA IN RELATIONSHIP TO THE McDONALD FAULT SYSTEM, DISTRICT OF MACKENZIE

(75 E/12 and parts of 75 E/13 and 85 H/9)

(Report, 2 figures and P.S. Map 9-1969)

E. W. Reinhardt

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ABSTRACT

The petrological and structural history of metasedimentary, metavolcanic, and granitic rocks within an area affected by the McDonald Fault system were examined during the course of one mile to one inch geological mapping. Petrographic studies were made on approximately 150 thin sections.

The oldest recognized rocks show relict stratiform foliation and consist of pelitic and pyroxene-bearing gneisses, marbles and calc-silicate rocks, amphibolite, hornblende-bearing gneisses, meta-gabbro and meta-diorite, and metamorphosed acidic volcanics. These rocks probably represent Yellowknife-type sediments and volcanics that have been subjected to higher-grade regional metamorphism than commonly found in the Slave Province. The grade of primary metamorphism is indicated by the association of sillimanite and K-feldspar. The typical mineral assemblages of quartzo-feldspathic representatives are presented on an <u>AFM</u> projection (Thompson diagram).

The granitic rocks are divisible into three mappable types distinguished by colour, mineralogy, texture, and structure. Evidence for assimilation of metasedimentary material was found. Granitic rocks rank as the dominant component in layered migmatites which form two broad northeastward-trending belts.

The above mentioned rocks were subjected to penetrative shear related to northeastward-trending transcurrent faulting (McDonald system) which produced widespread mylonites, cataclasites, and secondary foliation subsequent to high-grade metamorphism and granitic intrusion. This deformation was accompanied by retrograde metamorphism of relatively low grade. K-Ar ages from micas and hornblende are influenced by this deformation.

Transcurrent faulting was followed by vertical faulting along essentially the same fracture pattern. Later northeastward-striking faults of minor displacement are partly occupied by diabase dykes and quartz veins.

A general assessment of observed low-grade mineralization in the area is included. The common sulphide minerals are pyrite, pyrrhotite, chalcopyrite, sphalerite, and galena.

GEOLOGY OF THE PRECAMBRIAN ROCKS OF THUBUN LAKES MAP-AREA IN RELATIONSHIP TO THE McDONALD FAULT SYSTEM, DISTRICT OF MACKENZIE

INTRODUCTION

The primary objectives of this preliminary account are to describe and interpret the petrological, structural, and economic geology of the Thubun Lakes map-area in order to assess better the character of transcurrent faulting and associated mylonitization of the McDonald Fault system*. Many of the interpretations lack full documentation and in certain cases may have to be revised in the light of more comprehensive studies of specific problems. The report and accompanying geological map are based on geological field work done mostly in 1966 by C. J. Dodds and the writer. A small part of the mapping represents work done in the area by the writer in 1965. Most of the map-area is covered by earlier reconnaissance geological maps by Stockwell (1936a) and Henderson (1939). The present study is part of a program initiated in 1965 to evaluate the nature of the boundary between the Slave and Churchill Structural Provinces and to investigate the paragenetic and structural history of migmatitic gneisses that occur between the McDonald Fault and Nonacho Lake. Summary accounts of progress in this program have been published (Reinhardt, 1966, 1967).

Thubun Lakes map-area is 100 miles southeast of Yellowknife and borders the southeast shore of Great Slave Lake at the entrance to the East Arm. The area is accessible throughout most of the year by chartered aircraft from Yellowknife, Hay River, and Uranium City. Break-up takes place about mid-June and freeze-up begins about mid-October. In 1966 break-up was early and float-equipped aircraft were able to land in the vicinity of Simpson Islands and Hornby Channel, Great Slave Lake, during the first week in June. Thubun River provides a canoe route between Great Slave Lake and Thubun Lakes as previously described by Stockwell (1933, p. 39c). Rocher River, the closest settlement to the map-area, lies to the southwest on Taltson River, 2 miles south of Taltson Bay, Great Slave Lake.

Local relief most places within the map-area is less than 200 feet, but the tops of the highest hills reach altitudes of 500 feet above the level of Great Slave Lake.

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* The McDonald Fault system herein denotes the major system of faulting that forms a wide northeastward-trending zone along the southeast side of the east arm of Great Slave Lake. The system is named after the McDonald Fault which passes through McDonald Lake (<u>see</u> Reinhardt, 1966, Fig. 1, p. 35).

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An estimated 75 per cent of the land surface is exposed bedrock, the structure of which is largely responsible for the configurations of lakes and the pattern of drainage. Long linear depressions commonly mark zones of faulting and brecciation. The depth of erosion is greatest in those parts of the area underlain by metasedimentary schists and is least in those parts of the area underlain by granitic rocks. Planar bedrock structures are accentuated because their general strike corresponds to the southwesterly direction of ice movement during continental glaciation. Bedrock cover consists mainly of till and muskeg; deposits of sand and gravel are minor in both number and extent but provide several good campsites on Thubun Lakes as well as along the shore of Great Slave Lake.

Forest cover is thin to moderate. The growth is least in areas of high outcrop density underlain by granitic and migmatitic rocks, and heaviest in low-lying, wet areas such as along streams that follow faults or in swampy areas underlain by metasedimentary or metavolcanic rocks. Spruce is most abundant; other common varieties are birch, pine, poplar, tamarack, willow and alder. A large part of the area has been burned over at various times and one small forest fire was active in the summer of 1966. Secondary growth and deadfall in the older areas of burn make walking more difficult than in areas not burned over or recently burned over. There is, however, some compensation where the trees have been burned off in that running water has removed a larger proportion of the moss cover over the outcrops and lichen is usually thin or absent.

The writer is appreciative of the able assistance provided by H. L. Mellish and R. C. Morgan in 1965, and Alain Bernier, P. G. Pilch, and D. L. Austen (cook) in 1966.

C. J. Dodds deserves special thanks both for his excellent contribution to the geological mapping in 1966 and for worthwhile discussions concerning the geology of the area.

The writer is grateful for consultations with J. C. McGlynn whose familiarity with the geological problems in the area was of considerable value in planning the field investigations in 1965 and 1966.

DESCRIPTION AND RELATIONSHIP OF MAP-UNITS

General Remarks

The map-units are described on the basis of field observations and preliminary examination of about 150 thin sections. This information is used to make certain petrogenetic interpretations which are included with the petrographic descriptions.

With the exception of quartz veins (11), diabase dykes (10), and the rocks included in unit 9, the primary fabrics of igneous and metamorphic rocks have been obscured or modified by extensive mylonitization and cataclasis that accompanied the development of large-scale, northeastward-striking, steeply-dipping faults. The character of secondary textures and structures produced by this penetrative deformation is a function of the following main factors: the orientation of primary gneissosity or stratiform foliation with the direction of preferred shear; the mineralogy and bulk chemistry of the rocks involved; the nature of primary igneous and metamorphic textures; the homogeneity of a given mappable rock-unit over the extent of its occurrence; and the proximity to both major and minor faults or zones of mylonitization. Thus, the textural relationships of minerals can be attributed to both the competence of the given rock in the stress system as well as the intensity of local deformation. Also, the mechanical deformation of these rocks appears to have been accompanied by an incomplete secondary low-grade metamorphism which will be referred to as 'retrograde metamorphism' in this paper. As most rocks in the area have experienced at least two periods of crystallization, a distinction between primary igneous and metamorphic mineral associations and secondary or retrograde recrystallization is desirable in discussing the petrology.

Pelitic and Associated Quartzofeldspathic Pyroxene-bearing Gneisses and Schists (unit 1)

This unit comprises metasedimentary rocks that have been subdivided in the field into garnetiferous (1a) and nongarnetiferous (1b) subunits. The schists do not differ greatly from the gneisses in chemical composition but normally contain higher proportions of micaceous minerals and exhibit greater evidence of shear.

The gneisses and schists vary in colour from light to dark grey, depending on the proportions of mafic minerals of which biotite is the most abundant. Quartz and feldspar are the dominant light-coloured minerals in the gneisses and muscovite is commonly a major light-coloured constituent of the schists. Both gneisses and schists locally weather rusty due to the presence of minor amounts of disseminated graphite, pyrite, and pyrrhotite.

Typical outcrops of leucocratic gneisses that contain more than 75 per cent quartz and feldspar are found north of La Loche River. These gneisses are essentially granitic in composition and are characterized by light grey feldspar in contrast to the pink feldspar of the granitic migmatite (5a). Mafic-rich gneisses occur north of Doucet Lake in isolated bands surrounded by quartz monzonite (7a). They appear to have resisted total assimilation and granitization by virtue of their relatively high proportions of iron, magnesium, and calcium.

Original stratiform foliation is not readily discernible in individual outcrops of gneiss or schist because planes of compositional layering have either themselves acted as movement planes or are cut by movement planes. However, large-scale compositional banding is revealed by minor differences in erosional resistance. This feature can be evaluated from air photographs and is well exemplified by the folded gneisses between Doucet Lake and the northeast end of south Thubun Lake. The stratiform structure of the gneisses was also determined by delineating bands interstratified with and parallel to other lithologies such as marble (2a) and amphibolite (3). A schistose structure is well-developed in the metasedimentary rocks exposed along the shoreline of south Thubun Lake where the dominant lithology is muscovite-chlorite schist whose original high-grade metamorphic character has been destroyed by cataclasis and retrograde crystallization. In places these rocks actually resemble shales and have been locally mapped as such in the adjacent O'Connor Lake map-area to the south (Irwin and Prusti, 1955).

The rocks in unit 1 are medium grained except for those which experienced extensive cataclastic comminution without subsequent recrystallization. Sheared potassium-rich representatives contain catacrysts of quartz, feldspar, and porphyroblastic garnet in a matrix of fine-grained muscovite and chloritized biotite. The apparent mafic content is often exaggerated by the cataclastic redistribution of biotite.

Assemblages made up of biotite, garnet, cordierite, and occasionally sillimanite in addition to the common mineral phases quartz, alkali feldspar, plagioclase, and opaque oxides, are characteristic of the pelitic or more aluminous gneisses and schists of unit 1. In these rocks garnet is common and appears either as porphyroblasts or as smaller, well-distributed, equidimensional grains. Inclusions are mainly fine-grained, needle-like sillimanite and sieve quartz. In a few garnets the orientation of strings of quartz inclusions suggest that the host has been slightly rotated during recrystallization. Some minor alteration to biotite along fractures was noted in some garnet.

Reddish brown biotite is present in almost all the pelitic rocks and, as observed in thin sections, tends to be oriented parallel to the foliation. It is altered in varying degrees to chlorite, clinozoisite, sphene, opaque minerals, and second generation biotite.

Cordierite is commonly altered to chlorite and white mica and in some gneisses occurs in porphyroblasts or knots. Other minerals observed microscopically either as inclusions in, or as 'breakdown' products of, cordierite are sillimanite, andalusite, green spinel, and opaque oxides. Only a few specimens of the more aluminous gneisses contain sillimanite as a primary metamorphic phase. Normally it is considered to be either of prograde or retrograde derivation and appears as fine-grained alteration of biotite or as inclusions in garnet and cordierite. Sillimanite appearing with secondary andalusite is always finer grained than the associated andalusite.

Most of the quartz in the pelitic gneisses is fine grained and occurs in lenticular aggregates parallel to the secondary foliation suggesting recrystallization during retrograde metamorphism. K-feldspar is interstitial and also probably experienced some recrystallization. Plagioclase compositions range from An_{25} to An_{35} and bent and fractured grains indicate negligible recrystallization during penetrative deformation. Both feldspars are altered to white mica and in some places abundant coarse muscovite was presumably formed at the expense of K-feldspar. Some plagioclase is considerably altered to clinozoisite. The characteristic accessory constituents include apatite, graphite, sulphides, and opaque oxides.

Certain pyroxene-bearing gneisses are included in unit 1 because they are compositionally and spatially related to the pelitic varieties. They occur either intercalated with pelitic gneisses or as dark strand-like inclusions in granitic rocks such as are commonly observed in the southeastern part of the area. They are less abundant than the pelitic gneisses and have slightly higher ($CaO + Na_2O + K_2O$) : Al_2O_3 ratios which also suggests a compositional relationship to the metasedimentary hornblende-bearing gneisses (3) and calc-silicate rocks (2b). Hypersthene is more common than diopside and in places has been partly altered to chlorite. Diopside is partly altered to actinolite, hornblende, and clinozoisite. Plagioclase ranges in composition from andesine to bytownite. The anorthite content is probably a function of the availability of CaO rather than a reflection of variable metamorphic grade. Quartz, K-feldspar (microcline) and biotite have similar modes of occurrence to that in the pelitic gneisses. Accessory constituents include apatite, opaque minerals, and sphene.

The primary mineral assemblages recognized in gneisses and schists of unit 1 are indicative of an approximate uniform grade of regional metamorphism, the intensity of which is marked by the stable association of sillimanite and K-feldspar in rocks of appropriate composition. The most useful assemblages for evaluating metamorphic phase relations are found in rocks that always contain quartz, K-feldspar, plagioclase, opaque oxides, and one or more ferromagnesian silicate minerals. These assemblages can be conveniently portrayed on AFM projections (Fig. 1). The detailed method of application and the theoretical implications of the AFM representation have been dealt with by Thompson (1957) and with reference to cordierite-bearing gneisses by Reinhardt (1968). Minerals common to all assemblages do not appear directly on this type of diagram but sillimanite, cordierite, garnet, biotite, hornblende, hypersthene, and diopside do appear as the distinctive or 'indicator' mineral phases. These combinations or 'abbreviated assemblages' are taken to represent the effect of bulk chemical composition in terms of the A, F, and M components for approximately constant conditions of temperature, load pressure, and partial pressures of volatile constituents. Chemically analyzed mineral compositions might show that there was some variation in the partial pressure of water from place to place at the time of recrystallization and for this reason the AFM projection (Fig. 1) must to some extent, be regarded as a model representing constant physical conditions of metamorphism.

Petrographic examinations of the pelitic gneisses indicate that the most common primary mineral assemblages are cordierite-garnet-biotite, and garnet-biotite and hypothetical compositions representing these assemblages in terms of components A, F, and M are shown in Figure 1. The less common assemblages sillimanite-cordierite-garnet, sillimanite-garnet, and sillimanite-cordierite were locally developed in rocks containing relatively high proportions of alumina. It is also probable that sillimanite-garnet-biotite and sillimanite-cordierite-biotite were compatible stable associations at approximately the same temperature and load pressure as the assemblages mentioned above but formed under slightly different water pressures. Such variations in water pressure might be expected from place to place in a terrane undergoing regional metamorphism (see Reinhardt, 1968). The association cordierite-biotite is less common in the area as a whole but is representative of the nongarnetiferous schists (1b) of south Thubun Lake.

On the basis of microscopic study the pyroxene-bearing gneisses can be divided into those assemblages containing two feldspars and those which contain only plagioclase. Only the two feldspar-bearing assemblages can be represented on the AFM diagram in Figure 1. Those that are deficient in K-feldspar include the associations biotite-hypersthene, hypersthene-diopside, biotite-hypersthene-diopside, and diopside alone. One rock from Doucet Lake contains only plagioclase (An_{85}), hypersthene, and opaque minerals and another from the southeast corner of the map-area contains plagioclase (An_{40}), biotite, hypersthene, diopside, and hornblende. Cummingtonite was tentatively identified in three thin sections of quartz-plagioclase-bearing gneisses; the other minerals present were biotite, hornblende and/or hypersthene, garnet, and diopside. The compatible associations in these rocks is not clear and require further investigation.

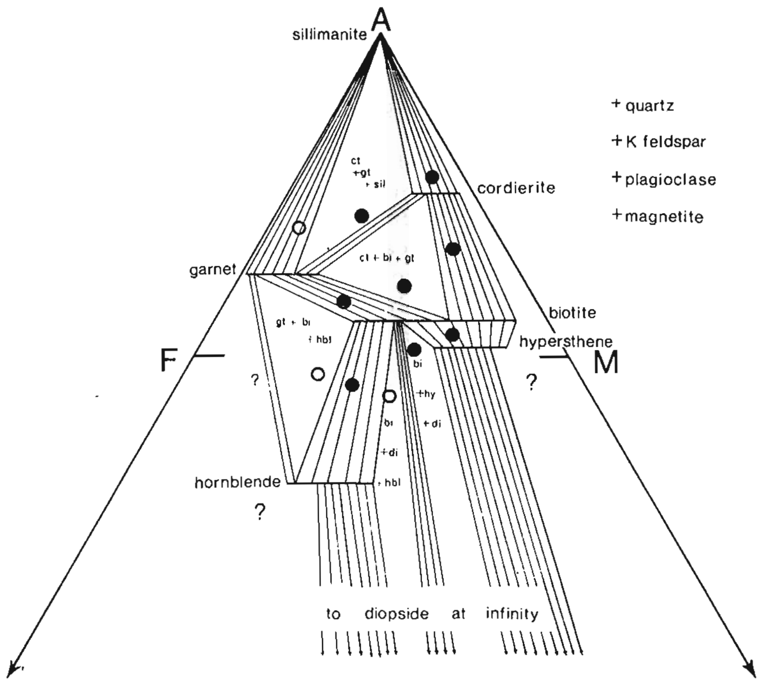

Figure 1. AFM projection showing some of the high-grade metamorphic phase assemblages recognized in Thubun Lakes map-area. The diagram is derived from compatibility tetrahedra by successive projections through the common phases quartz, K-feldspar, plagioclase, and magnetite such that A = Al_2O_3-K_2O-Na_2O-CaO, F = FeO-Fe_2O_3, and M = MgO. The method and assumptions involved in constructing this type of projection are discussed by Reinhardt (1968) and the general application of this form of representation to metamorphic assemblages was devised by Thompson (1957). The phases common to all assemblages are listed to the right of the diagram and associations of indicator minerals appear directly on the projection. The assumed positions of phases (minerals) of variable composition are shown by heavy horizontal lines except for diopside which lies at infinity. Three-phase associations of indicator minerals are represented by triangles and two-phase associations by tie-lines. The assemblages observed in thin sections are indicated by solid circles which represent hypothetical or assumed bulk rock compositions appropriate to each observed assemblage. Similarly, open circles indicate assemblages inferred from associations noted in hand specimens or from outcrops.

Marble and Calc-silicate Rocks (unit 2)

The rocks comprising this map-unit are of minor occurrence and are usually interstratified with metasedimentary gneisses of unit 1. The two small masses of marble enclosed by homogeneous quartz monzonite (7a) north of north Thubun Lake are probably inclusions. Several bands of marble are too small to be shown on the accompanying geologic map and, in a few places, rusty graphitic biotite schist occurring with marble or calc-silicate rocks could not be separated. Small bodies of white pegmatite containing tourmaline are found adjacent to marble.

The marbles (2a) are medium grained, light grey to buff rocks composed essentially of carbonates along with diopside, phlogopite, graphite, and antigorite after olivine. They show stratiform foliation wherever layers containing significant concentrations of calc-silicate minerals are present. The calc-silicate rocks that occur with marble were not examined microscopically but are known to contain diopside, hornblende, phlogopite, and tremolite. They appear to be gradational into the pyroxene gneisses of unit 1.

Amphibolite, Hornblende-bearing Gneiss, and Meta-gabbro (unit 3)

The typical lithologies of this map-unit are medium- to fine-grained amphibolite and hornblende-biotite gneiss. The meta-gabbros and meta-diorites (3b) are distinguished by their relict igneous textures but do not differ significantly in mineralogy from the amphibolites or hornblende-bearing gneisses. Amphibolites and gneisses exhibit faint layering in some outcrops but the dominant foliation appears to have been produced by a process involving shear and a parallel alignment of elongate hornblende crystals is common. In general, the extent of retrograde crystallization is less obvious than that observed in the pelitic gneisses (1a) although rocks of both units are spatially related and interbanded. These relations, however, are not characteristic of meta-gabbro and meta-diorite.

The amphibolites are essentially composed of hornblende (greater than 40 per cent) and plagioclase. They alternate with, and in some places grade into, more leucocratic hornblende-bearing gneisses. The plagioclase compositions for the amphibolites and gneisses as a group range between An_{20} and An_{40}. The plagioclase may be appreciably altered to sericite and clinozoisite. In thin sections, typical hornblende is green and shows varying degrees of replacement by actinolite, chlorite, and clinozoisite or epidote. The more leucocratic representatives also contain quartz, microcline, and biotite. The microcline is interstitial to other primary minerals; biotite is greenish brown, shows extensive chloritization, and exhibits evidence of post-crystallization deformation. Accessory minerals are apatite, opaque minerals, and sphene.

Amphibolites and hornblende-bearing gneisses are considered to have been derived from both lime-rich sediments and basic volcanic rocks. If the metagabbros are assumed to represent near-surface sills, it is probable that some of the source magma reached the surface and was extruded as volcanic flows. Some of the medium-grained rocks displaying subophitic textures may, in fact, represent the central parts of thicker flows. On the other hand, gradational contacts between pelitic gneisses and hornblende-biotite gneisses and intimate associations of marble with amphibolite and hornblende-bearing gneisses suggest a sedimentary origin for many bands of amphibolite and compositionally related rocks.

The main occurrence of meta-gabbro and meta-diorite (3b) is north of Thubun River; other scattered small-scale occurrences were found elsewhere in the map-area. Considerable variation in grain size and mafic content was noted in the mass north of Thubun River and there granitic rocks in amounts as great as 30 per cent locally accompany meta-diorite. The contact shown on the map marks a gradation from meta-gabbro and meta-diorite to migmatite. No thin sections of either meta-gabbro or meta-diorite were examined but the relict subophitic textures of these rocks and their general lack of foliation is indicative of an igneous origin. Contact relationships show that these rocks were intruded by the granitic component of the migmatite (5).

The common metamorphic assemblages recognized in thin section examinations of amphibolite and hornblende-bearing gneiss are: plagioclase-hornblende (-biotite) and quartz-plagioclase-hornblende (-biotite). Hornblende, biotite, and garnet were observed together locally in outcrops along the north shoreline of south Thubun Lake. This association is compatible with the proposed phase relations presented in Figure 1. A hypothetical composition representing the observed assemblage quartz-microcline-plagioclase-hornblende-biotite is also given in Figure 1 and the compositional relationship to the pelitic gneisses becomes apparent.

Quartzofeldspathic Chlorite-Muscovite (-Biotite) Cataclasite and Schist; Minor Fine-grained Amphibolite (unit 4)

These rocks have experienced intense granulation and often contain significant amounts of secondary micaceous minerals. Primary structures and textures are either indefinite or indistinguishable from those produced during shear and cataclasis.

As indicated on the accompanying geological map, most boundaries between this and adjacent map-units are fault contacts. The nature of the remaining contacts, and particularly part of the southern contact, could not be satisfactorily determined. Three possibilities were considered for the nature of the contact separating rocks of unit 4 and migmatite (5a) between longitudes 111° 55'W and 112° 15'W: (i) a fault which follows the stratiform foliation in the north and transgresses it in the south; (ii) an unconformity, and (iii) a continuous sequence of layered metamorphic rocks that have been locally transgressed in the south by granite that accompanied migmatization. Although shearing is notable throughout the width of unit 4, a major fault is not obvious anywhere along the southern contact. Conclusive evidence for an unconformable relationship is lacking, although towards the southwest end of the contact, the pattern obtained by mapping and plotting of lineaments from air photographs, suggests discordance. No confirming evidence suggestive of an unconformity in this locality was obtained during the examination of outcrops near the contact and conformable relationships appear to exist over the remainder of the contact distance. On traversing the contact from north to south, one passes gradationally through layered amphibolite into amphibolite intercalated with granitic rocks, and finally into typical layered granitic migmatite (5a). These changes may be observed over distances as short as 300 feet. Granitic interbands were occasionally seen across the width of the belt defined by unit 4 and this, in addition to the features already discussed, supports the explanation that the contact in question represents a migmatite front. However, a brief examination was made in 1966 of rocks which occur a few miles to the west of the map-area in the vicinity of Petitot Islands and which were assigned to the Wilson Island Group by Stockwell (1936). Some of these rocks resemble rocks of unit 4 suggesting a possible correlation. If this were the case, some discontinuity might be expected on passing from Wilson Island-type strata into the typical metasedimentary and metavolcanic strata occurring elsewhere in the Thubun Lakes map-area. Further field work is planned to evaluate the feasibility of such a correlation.

The contact between rocks of unit 4 and rocks of unit 9 in the northeast corner of the area is poorly exposed and could be a fault. Evidence was found for a fault separating the same map-units on the shoreline of Great Slave Lake in the vicinity of longitude 112° 15'W. This fault may represent relatively minor movement along an unconformity.

The greater portion of unit 4 consists of rocks that are probably of volcanic origin. The basic varieties, which have been metamorphosed to amphibolite, are commonly laminated but some display massive structure and faint subophitic texture. The acidic varieties are more extensively deformed and are either cataclasites or quartzofeldspathic chlorite-mica schists depending on the extent of secondary recrystallization. The content of chlorite and mica is less than 5 per cent in many cataclasites and a thin section of one such specimen showed euhedral plagioclase and rounded quartz aggregates in a fine-grained matrix of quartz and feldspar. This example is the only indication of volcanic origin found in the examination of a suite of leucocratic rocks having the same appearance in both hand specimens and outcrops. Presumably the primary textures have been entirely destroyed by cataclasis in virtually all these rocks. Augen-schist probably also of volcanic origin, occurs in several outcrops bordering the shore of Great Slave Lake. The mortarcrysts consist of quartz and feldspar as well as large composite fragments of these minerals. The matrix is composed of quartz, feldspar, chlorite, and mica. At one location layers several feet thick of light greenish quartzose rock were noted; although these could represent beds of quartzite, they are more likely zones of finely mylonitized and silicified acidic volcanics. They are gradational with darker rocks, considered to be intermediate volcanics, containing 30 per cent chlorite and biotite.

The origins of other lithologies in this map-unit are even more obscure. Some are tentatively regarded as sediments and examples are found along the shoreline of Great Slave Lake at several locations both to the northeast and southwest of the prominent crescent-shaped peninsula located due north of La Loche River. The rocks in these locations are dark grey and contain angular to subrounded, coarse, individual grains and composite fragments of quartz, and feldspar in a matrix consisting mainly of randomly oriented chlorite and biotite. Plagioclase is granulated, bent, and often extensively altered. In many outcrops, these rocks resemble unmetamorphosed clastic sediments but cataclastic textures are evident in thin sections and any original clastic texture that was present has been destroyed.

As in the case of the pelitic gneisses and schists of unit 1, a partial retrograde metamorphism appears to have accompanied the severe cataclasis of the rocks in unit 4. Any estimate of the primary grade of regional metamorphism is therefore bound to be uncertain but the occurrence of amphibolite in the sequence can be taken as a rough guide. It is also possible that the metamorphic grade decreases sharply to the north and away from the contact with the migmatite (5a) but this is merely an impression that cannot be confirmed by assemblages of primary minerals.

Migmatite (unit 5)

The bulk of the migmatitic rocks are granitic and occur in two broad northeastward-trending belts that are separated by the La Loche River Fault. These belts may represent different parts of the same belt that have been brought into coincidence and repeated (through faulting). This, however, cannot be adequately demonstrated without additional field work outside the map-area but certain similarities and differences evident within the map-area deserve brief mention. In regard to differences, marble (2a) and calc-silicate rocks (2b) are present in the north belt but absent from the south belt. The migmatites of unit 5c, which are more akin to the metamorphic rocks already described in that they include 60 per cent or more amphibolite and metasedimentary gneiss, are only mappable in the north belt. On the other hand, the granitic migmatites (5a) are similar in both belts and typically contain more than 60 per cent granitic component that varies in composition from granite to quartz diorite with hornblende and biotite as the characteristic ferromagnesian minerals. The elongate zone of granitic augen-gneiss (5b), which has been roughly delineated in the south belt, is probably a mylonitized equivalent of the porphyritic quartz monzonite (8) of the north belt, suggesting further similarity between the belts.

The granitic migmatite (5a) forms a terrane of well-exposed resistant outcrops. Large-scale compositional layering is reflected topographically by continuous ridges up to 15 miles in length. Undoubtedly, several of these features represent pseudo-layering produced by mylonitization which is most intense in these rocks and some transposition of the original compositional layering could be recognized in some outcrops. Less persistent, thinner layers down to inch-scale banding were also observed during mapping. The mylonitization was superimposed on the stratiform foliation mainly along or subparallel with steeply dipping planes of compositional layering so that the primary and secondary foliations are often difficult to differentiate in the field.

As previously noted, a large proportion of the granitic migmatite (5a) has been mylonitized subsequent to the process of migmatization so that a large measure of the description must be devoted to mylonitized representatives. The granitic rocks of this map-unit that escaped severe cataclasis were not examined in detail, but they resemble the gneissic border facies of the quartz monzonite (6).

The comprehensive classification of mylonitized rocks proposed by Hsu (1955, p. 252) is adopted in this paper for the description of those cataclastically deformed rocks that exhibit 'fluxion' structure but lack extensive contemporaneous recrystallization. Protomylonite (less than 50 per cent fine-grained matrix) is the most abundant type, particularly in the south migmatite belt where an estimated 60 per cent or more of the rocks are mylonitized. Almost all migmatitic rocks show some evidence of cataclasis and the intensity of granulation varies from one layer to another with mylonite foliations and lineations characterizing zones of most intense shearing. True mylonites (50 to 95 per cent fine-grained matrix) are less abundant than protomylonites and are developed in narrower zones, measuring from a few feet to several tens of feet in width. Ultramylonites (with more than 95 per cent fine-grained matrix) are found chiefly in zones adjacent to major faults such as along La Loche River. The zones are narrow and transitional (across strike and over a few feet) into mylonites (sensu stricto) and protomylonites. The typical pink weathering of feldspars in the granitic portions of the mylonitized migmatites can be attributed to hydrothermal activity accompanying cataclasis and zones displaying the most intense mylonitization weather brick red. The granitic rocks in these zones have a flinty appearance and break along intersecting planes of cleavage and jointing to produce a rubble of sharp angular fragments. In certain places, it is virtually impossible to procure a hand specimen that is not bounded by planar surfaces. The fresh surfaces of granitic mylonites are darker than the weathered surfaces and present a false impression of the mafic content. This is largely because the dark minerals, and in particular biotite, are so thoroughly dispersed. Large cataclasts of porphyroclasts of plagioclase and microcline show rounding and rotation and commonly appear as augen. Hornblende, where present, has a lesser tendency to maintain original grain size. The matrix consists of a mixture of quartz, feldspar, biotite, hornblende, chlorite, and white mica. The last named appears to be a product of neocrystallization. Aggregations of fine-grained quartz arranged in lenses or streaks in the plane of mylonite foliation impart a flaser structure to some rocks and the elongation of quartz streaks defines a shallow-plunging lineation.

Thin sections of granitic mylonites show dusty plagioclase porphyroclasts that have been bent and rounded through mechanical grinding without significant recrystallization. Similar features are displayed by microcline porphyroclasts but in places this mineral appears to have experienced partial recrystallization and was observed in fractures in plagioclase. Both feldspars occur in the matrix. Biotite is normally bent, shredded, and redistributed along the foliation so as to define a weak megascopically visible lineation parallel to the direction of quartz smears. There is also some alteration to chlorite which may completely replace some grains of biotite. Quartz shows much evidence of recrystallization and is invariably fine grained, having dimensions in the order of 0.01 mm. Aggregates of quartz show 'stream around' enclosures about feldspar porphyroclasts and coarser quartz occupies pressure shadows both fore and aft the feldspar grains. The opaque minerals are both oxides and sulphides, and some of the oxides appear to be a by-product of biotite breakdown to chlorite. Some of the disseminated pyrite and pyrrhotite was probably derived from permeating hydrothermal solutions that presumably accompanied cataclasis.

The nongranitic fractions of the migmatite are mainly amphibolites with subordinate metasedimentary gneisses. These rocks occur in layers or strands that often fade imperceptibly along, as well as across strike, into granitic rocks. Some strands are disjointed into rotated block-like inclusions forming agmatite. Hornblende-rich clots and schlieren attest the assimilation and digestion of amphibolite by a more mobile granitic fraction. Although the supporting evidence is incomplete, the author interprets the granitic fraction of the migmatite as mainly having originated from anatexis at depth supplemented by local anatectic derivatives at higher levels. The granitic portion generated at depth could have migrated by rising along the stratiform foliation of the pre-existing rocks. This would account for the relatively undisturbed nature of the layering and explain the assimilation of amphibolite and layered gneiss.

Hornblende-Biotite Quartz Monzonite (unit 6)

The rocks belonging to this map-unit occur in a single concordant mass located north of La Loche River. The border facies of this sill-like body are gneissic and generally transitional into granitic migmatite (5a). Some minor cross-cutting relationships in the vicinity of the boundaries indicate that the body is of magmatic derivation. The similarity of this border facies to the granitic fraction of the enclosing migmatite (5a) may be indicative of a common parentage and contemporaneous emplacement. The central part of the body is dominantly homogeneous, massive, medium-grained quartz monzonite. Hornblende schlieren as well as a few partially digested inclusions were observed in places. On the basis of field examinations, it appears that cataclastic deformation within the mass was slight.

Three thin sections of the central facies were examined. In general, they show equal amounts of quartz, microcline, and plagioclase, each in the order of about 30 per cent with microcline slightly in excess of plagioclase. Optically determined plagioclase compositions are all close to An_{32} and slight alteration to sericite and clinozoisite was found in one section. Dark brown biotite shows some alteration to chlorite. Hornblende, in amounts equal to that of biotite, shows minor alteration to epidote group minerals. Accessory minerals are sphene and opaque oxides. Slight cataclasis was noted in one specimen whereas the remaining two others showed hypidiomorphic equigranular textures.

Quartz Monzonite and Granite; Minor Granodiorite and Quartz Diorite (unit 7)

This map-unit includes a widespread assemblage of granitic rocks of diverse lithologies. More detailed mapping and petrographic work would probably result in better definition of the rock types and their distribution but even then some heterogeneity of petrographic types might be expected.

In the southeast corner of the map-area, salmon-pink weathering, gneissic to massive granite with minor quartz monzonite (7b) forms a core zone enclosed by other granitic rocks (7). Isolated minor occurrences of petrographically similar granitic rocks (7b) were recognized north of the core zone. The distinctly concentric pattern of the core zone is well-expressed in its outer parts by remnant gneissosity and screens of metasedimentary gneiss. Towards the central part the granites are progressively more massive and strands of gneiss and mafic schlieren are less abundant although they still reflect the concentric shape typical of the zone. Within the concentric mass, the quartz content, about 35 per cent, is similar to other granitic rocks of the map-unit but the ratio of microcline to plagioclase is generally greater. Microcline occurs in phenocrysts up to 2 inches across and the plagioclase is either oligoclase or andesine. Reddish brown biotite is always present in minor proportions and is accompanied by garnet and/or cordierite. Chlorite and muscovite are alteration products of cordierite and biotite and are best developed in zones of cataclasis. Small concentrations of sillimanite, hercynite, and opaque oxides occur with cordierite and they are interpreted as 'breakdown' products of the latter mineral. Some aggregation or clustering of ferromagnesian minerals was noted but biotite typically has uniform distribution. Dark orthopyroxene was seen in a few hand specimens but was not observed in any thin sections. The granites of the core zone, compared with other rocks of unit 7, are slightly coarser grained and show more widespread development of porphyritic texture, but otherwise maintain similar granitic fabrics which have subsequently been modified to mortar textures in varying degrees. In places a secondary foliation derived by shearing is present, but in the majority of outcrops the degree of cataclasis and accompanying recrystallization is difficult to judge.

Rocks of unit 7 that surround the core zone and that lie south of a line roughly along the axis of south Thubun Lake are mainly light grey to pink, gneissic to massive quartz monzonites. They are characterized by greater diversity in the content and association of mafic and micaceous minerals than granitic rocks of this unit observed elsewhere in the area. They may also contain sizable ingested strands of metasedimentary rocks, especially south of Doucet Lake. In mapping these rocks, one gets the impression that the mafic mineral association is governed by both the type and amount of metasedimentary material ingested. Mafic and aluminous minerals form small segregated masses in some places. The grain size of the granitic rocks shows considerable variation and some are porphyritic. Many of the outcrops directly southeast of south Thubun Lake show rough weathered surfaces on which the feldspars stand out imparting a 'pebbly appearance' to the rock. This feature is thought to reflect granulation and cataclasis. Mylonitization is only locally recognizable.

Petrographically, many of the granitic rocks in this area are similar to those in the core zone and to the north. They consistently contain about 35 per cent quartz and their plagioclase composition ranges from An_{18} to An_{33} in the thin sections studied. Microcline is more abundant than plagioclase, is usually perthitic showing a pattern of oriented rods or strings, and in some thin sections appears to have replaced plagioclase. Biotite is always present and may be accompanied by garnet, cordierite, and occasionally hornblende. Garnet and cordierite are sometimes found together in the same specimen. Muscovite occurs as a secondary mineral in some specimens, but is lacking in many. Minor amounts of sillimanite, andalusite, and green spinel (hercynite?) appear in a minority of the cordierite-bearing granitic rocks. Opaque minerals are sparse and mainly associated with leucoxene. Much of the parallel alignment of minerals, which defines the foliation of these rocks, results from shear and recrystallization.

The granitic rocks of unit 7 that occur north of south Thubun and Doucet lakes are typically biotite-garnet (-muscovite) quartz monzonite (7a). They display much less variation in composition, texture, and structure than the granitic rocks of this unit that have already been described. They are light grey to buff and biotite and euhedral pink garnet are the common varietal minerals. Muscovite is most abundant north of north Thubun Lake and is sporadic in its occurrence west of Doucet Lake and the inter-Thubun Lake locality. Hornblende occurs locally but was not commonly recognized in the field. Biotite and garnet, as well as hornblende where present, occur in small, evenly distributed streaky segregations, which in combination with lenticular quartz, impart the gneissic foliation to these rocks. Muscovite is aligned in the same foliation plane but is uniformly distributed in the rock. Marked lineations of mineral streaks are best displayed north of north Thubun Lake.

Thin section examination of the quartz monzonite (7a) indicates a rather uniform quartz content of about 35 per cent, plagioclase ranging from An_{20} to An_{25} in amounts of 30 per cent, and 25 to 35 per cent microcline. The remaining 5 to 10 per cent is made up mostly of biotite, garnet, and muscovite.. Accessory minerals are sphene, apatite, and sparse opaque oxides. Two ages of biotite are present: a first generation reddish brown variety and a less prevalent second generation greenish brown variety. Both are altered to chlorite. The dominant texture of these rocks is granitic but variably modified by cataclasis or recrystallization.

Some minor zones of migmatite, mostly in the area between the Thubun Lakes have been included in this map-unit. These consist of intercalated quartz monzonite and metamorphic rock and because of their small size and sporadic occurrence they could not be shown separately on the accompanying geological map.

The granitic rocks of unit 7 are thought to have formed during a single magmatic event. The presence of cordierite, garnet, and sillimanite probably resulted from contamination of the granitic magma with metasedimentary material. The similarity of the ferromagnesian mineral associations with those of the surrounding and included metamorphic rocks and the congregation of mafic minerals into lenticular aggregates in the granitic rocks, suggest that the more refractory parts of the original host rocks resisted complete melting whereas the less refractory parts were incorporated in the granitic melt. This would further suggest that the granitic rocks were emplaced during high-grade regional metamorphism of the gneisses and may have actually contributed to this metamorphism.

Porphyritic Quartz Monzonite (unit 8)

The sill-like mode of occurrence of this rock gives the impression that it is younger than the granitic rocks already described. It is, however, possible that it represents a porphyritic derivative of the granitic component of the migmatites. The contacts with migmatite are sharp to gradational and those with metasedimentary gneiss are sharp and gently cross-cutting. The porphyritic quartz monzonite is commonly transitional into less distinctly porphyritic varieties which ultimately grade into equigranular granitic rocks that are virtually indistinguishable from the granitic component of the migmatite (5a). This type of gradation is rare across sill-like masses but common near terminations and tongue-like extensions of these masses. A particular type of migmatite, having porphyritic quartz monzonite as the granitic component, is developed near some of the blunt terminations. No recognizable contacts between quartz monzonite (8) and the more widespread granitic rocks of unit 7 were recognized within the map-area but at one locality to the southwest the latter appear to occur as a strand-like inclusion in the former.

The distinctive outcrop feature of the quartz monzonite (8) is the presence of pink elongate microcline phenocrysts up to 3 inches long. These phenocrysts display megascopically visible carlsbad twinning with the twin planes parallel to the long dimensions. Most phenocrysts in the central parts of sill-like bodies lack any preferred orientation whereas those near the margins show a crude planar orientation parallel to the contacts, which are in turn parallel to the regional foliation. This orientation is believed to have originated largely through shear movement at or near the contacts rather than through a primary igneous flow process. Substantiating evidence for this conclusion is provided by mild cataclasis near the contacts. The quartz content varies and locally syenitic phases are developed. The mafic minerals are biotite and generally hornblende. Some segregations of mafic minerals into stringers parallel to the length of the sill-like forms was noted near the zones of migmatite. Biotite is slightly altered to chlorite where cataclasis has been active. Optical measurements of plagioclase compositions from two specimens gave compositions of An_{22} and An_{25}.

Great Slave Supergroup, Union Island, and Et-then Groups (unit 9)

Rocks belonging to these groups are shown collectively as a single map-unit on the accompanying geological map and they are only shown within the limits of present mapping although they are known to exist throughout the East Arm of Great Slave Lake. Rocks belonging to the Great Slave Supergroup and Et-then Group were recognized by Stockwell (1936a) and Henderson (1939). P. F. Hoffman (1968, p. 42) has further suggested that some of the rocks in this vicinity also belong to the Union Island Group. For more information on the distribution and character of rocks belonging to the above groups, the interested reader is referred to the published accounts by Stockwell (1933, 1936a, b), Henderson (1939), and Hoffman (1967, pp. 36-39; 1968a, pp. 140-142; 1968b).

Diabase Dykes (unit 10) and Quartz Veins (unit 11)

The diabase dykes (10) range in width from a few inches to about 100 feet and occupy late, essentially vertical fractures most of which strike northwest. They are thought to belong to the Mackenzie dyke swarm whose average K-Ar age according to Fahrig et al. (1965, p. 287) is about 1315 m. y. A smaller number of dykes have northerly and northeasterly strikes and these are considered to belong to the same episode of dyke emplacement as the northwestward-striking dykes.

Quartz veins (11) occupy the same late fractures as the diabase dykes but are usually only a few inches wide and less than 100 feet long. One exceptionally large vein east of south Thubun Lake has an estimated width of 70 feet. Some of the veins contain ore minerals and carbonate gangue and these are subsequently described in this report. The quartz veins (11) are considered to be younger than the diabase dykes (10) because three miles west of Doucet Lake a quartz vein was observed to cut a diabase dyke.

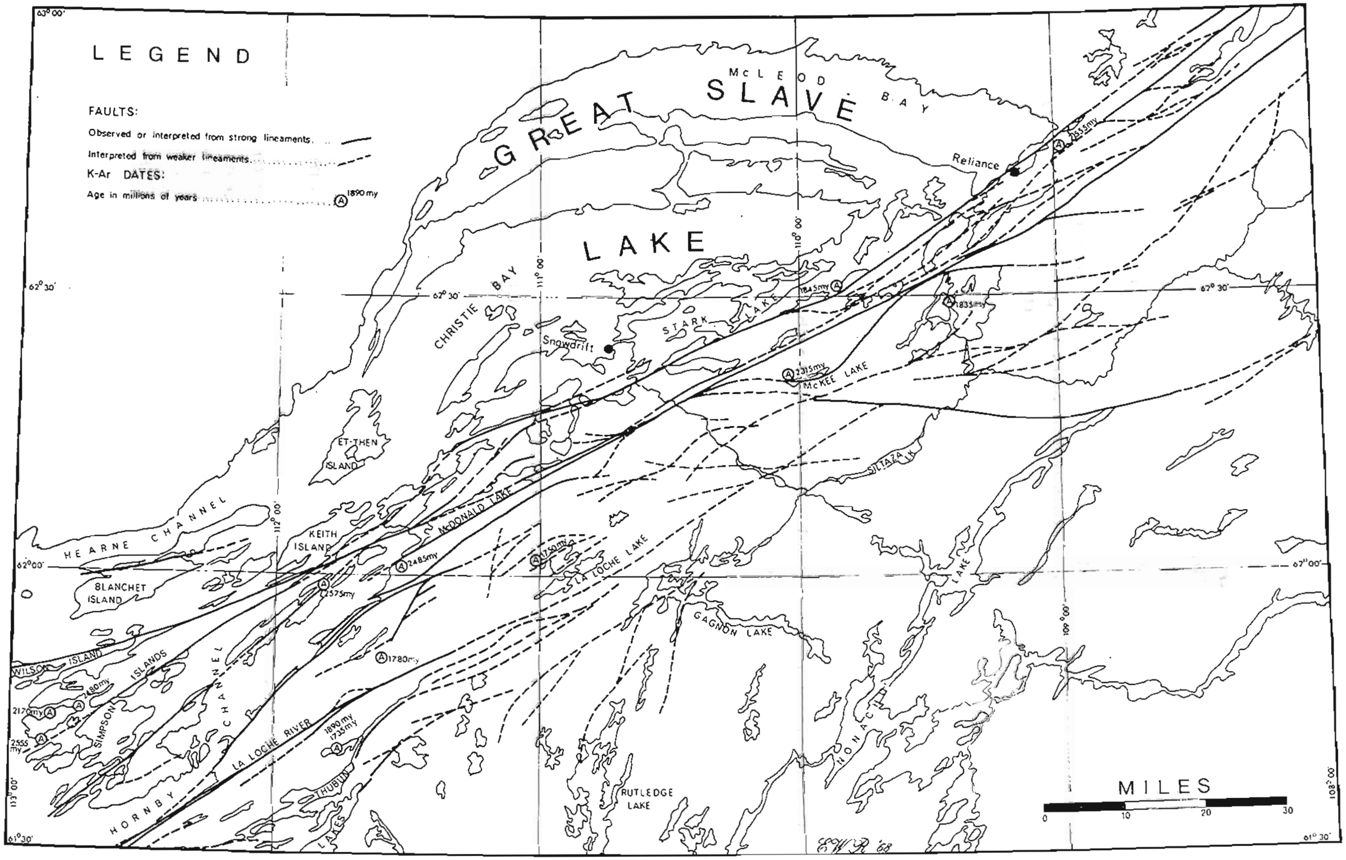

Figure 2. Compilation of northeastward-striking faults outlining the McDonald Fault system along the southeast side of Great Slave Lake. The pattern of early transcurrent faulting in the East Arm is emphasized by later vertical faulting along the same breaks. Selected K-Ar dates are included to illustrate the proposed effects of mylonitization and recrystallization associated with transcurrent faulting. The compilation was prepared from published geological and aeromagnetic maps; air photographs and field observations.

STRUCTURAL GEOLOGY

General Remarks

A detailed analysis of the structural geology in the map-area is not attempted in this report. All rocks have experienced a complex structural evolution much of which is difficult or impossible to decipher because of the obliteration by shear and recrystallization of most early formed, identifying features.

The most spectacular structures are northeastward-striking faults of the McDonald system (see Fig. 2) named herein after the McDonald Fault which passes through McDonald Lake directly northeast of the map-area. The McDonald Fault is marked by a prominent fault-line scarp from the south end of McDonald Lake as far as Reliance, at the northeast limit of the East Arm of Great Slave Lake. The McDonald Fault lineament can be traced for approximately 250 miles northeast of McDonald Lake and its extension probably offsets the Dubawnt Group (Donaldson, 1967, p. 23) near Hanbury River.

It is not certain, without detailed mapping outside the map-area, whether small-scale structural features such as foliations, fold axes, and lineations formed by intersecting surfaces belong to a regional pattern. On the other hand, mylonite lineations related to movement on northeastward-striking faults and perhaps some of the joint patterns, reflect regionally developed structures.

Foliation

As already mentioned in the description of map-units, there are at least two distinct types of foliation. The earlier or primary foliations are defined by compositional layering in the metasedimentary, metavolcanic, and migmatitic rocks, and by segregations of dark minerals in the granitic rocks. A later or secondary foliation has been developed largely through shear accompanied by recrystallization and appears as flow cleavage or schistosity in the metamorphic rocks, as planar streaks, mylonite or flaser structure in some of the migmatites and granites, and as crude, widely spaced, cleavage planes, local gneissosity or planar orientation of feldspar augen in many of the granitic rocks.

Over a large part of the map-area, the two ages of foliation appear to coincide in direction of strike making the distinction between them either difficult or impossible, and for this reason they are not differentiated on the accompanying geological map. In certain places, such as around the noses of folds, the primary foliation can be separately identified because of its high angle of intersection with the secondary foliation, recognizable compositional layering, and subparallel orientation with respect to the gross layering of map-units.

Lineations

Probably the most useful lineation is that formed during mylonitization of the granitic migmatite (5a). This lineation is mainly defined by streaks of quartz on planes of mylonitization and the plunge is at low angles to the northeast. This direction is considered to correspond with the linear direction of movement along planes of mylonitization but the sense of relative movement must be ascertained from other features. This type of lineation is best developed in the migmatite belt south of La Loche River.

A consistent lineation with a steep southwesterly plunge was observed in the quartz monzonite (7a) along the shoreline of the large lake north of north Thubun Lake. This lineation is defined by elongate quartz and streaky masses of biotite and is thought to represent the intersection of primary and secondary foliations. A similar lineation, having a somewhat shallower plunge, is developed in some of the granitic rocks northwest of Doucet Lake. Here, there is greater suggestion that the lineation arises from intersecting planar structures because the anticlinal structure defined by layers of metasedimentary gneiss has a subparallel, measurable, direction of plunge. The best example of a lineation derived from the intersection of original compositional layering and northeastward-striking cleavage is shown by the pelitic schists around the nose of the synclinal structure northeast of the northeast end of south Thubun Lake where the cleavage is essentially parallel to the axial plane of the fold such that the lineation defines the plunge. The axes of minor shear folds and elongation of mineral streaks have the same orientation.

Presumably most other recorded lineations in the map-area are a result of penetrative shear forming either intersections with primary foliations or tracing slip on planes of primary foliation.

Folding

Except for gentle bending, the rocks north of La Loche River display no appreciable folding although their steeply dipping layering would suggest that they were involved in regional folding. Well-developed folds are found south of La Loche River beyond the belt of granitic migmatite (5a). Although lithologic mapping has led to the recognition of most folds, the quantity of structural data that can be used to determine the nature and time of fold formation is meagre. Again this is attributed to the destructive effects of shearing and resultant secondary foliation. Furthermore, one cannot ignore the possibility that shearing itself may have played a role in the development of certain folds. As reference to the accompanying geological map will illustrate, folded metamorphic rocks are spatially related to the distribution of granitic rocks of unit 7 and this is interpreted to mean that folding was mainly a consequence of the mobility of granitic magma.

One of the most obvious folds in the map-area lies north of Doucet Lake. This fold is anticlinal, plunging to the southwest at 25 to 30 degrees, and has been disrupted along its north limb by northeastward-striking faults. The structure passes northward into a syncline having a similar plunge. A syncline also occurs northeast of the northeast end of south Thubun Lake and its plunge appears to be southwest at 15 to 20 degrees.

A major southeastward-plunging syncline immediately south of Thubun Lakes map-area was mapped by Irwin and Prusti (1955) who placed the axis of this structure through the Isle of Pines. The writer obtained a plunge measurement of about 40 degrees to the southwest on the Isle of Pines near the position of the axis shown on the map of Irwin and Prusti. It appears that this structure is a composite major syncline on which minor anticlines are developed. Northwest of the axis the pattern of primary foliation defines a minor anticline which passes into a second syncline farther to the northwest. Measurements of primary foliation along the northwest side of the Isle of Pines suggests a plunge for this syncline of from 30 to 40 degrees southwest.

A poorly defined anticlinal structure is indicated in the pelitic gneisses and amphibolites near where north Thubun Lake drains into Thubun River. Shear and migmatization are so intense near the structure that the only reliable evidence for its existence is a relatively thin amphibolite marker within the garnetiferous gneisses. Three measurements of primary foliation in or near the amphibolite suggest an axial plunge to the southwest.

There is a northeastward-plunging anticlinal structure just north of the portage between the north and south Thubun Lakes. The inclination of plunge is estimated at 10 degrees and garnet-bearing gneiss and amphibolite form an envelope about a granitic core. Minor folds in schists that outcrop on some of the larger islands in south Thubun Lake have similar plunges.

The available information does not provide much in the way of a satisfactory explanation for the divergence in axial plunge in and around Thubun Lakes. Certainly the southwesterly plunge is the more dominant and presumably this characterizes the major folding. Three possible explanations for the development of the observed folds are: (i) two periods of folding preceded mylonitization and faulting; (ii) major folding previous to the period of mylonitization and faulting with subsidiary warping during shear; (iii) non-uniform stress distribution during a single period of folding accompanying movement or emplacement of a granitic melt.

The grossly concordant nature of the granitic bodies, both in shape and internal foliation, to the enveloping layered and folded metamorphic rocks supports the third explanation.

Jointing

Most joints in the map-area have near-vertical dips and are probably akin to the last period of faulting. The statistical orientation of joint surfaces has not been evaluated but preliminary examination of a large number of measurements taken north of Thubun Lakes suggests a preference for a northwesterly direction of strike.

Faulting and Mylonitization

Examination of faulting in the Thubun Lakes map-area has provided a clearer understanding of the development of the McDonald Fault system along the southeast side of Great Slave Lake. The regional extent of this fault system is obvious from Figure 2, which is a compilation based on air photographs, aeromagnetic maps, geological maps, and observations made in 1965 and 1966. As previously reported (Reinhardt, 1967, p. 43), at least three main periods of faulting are recognizable both in the Thubun Lakes area and elsewhere to the northeast.

In the map-area, the first period of fracturing is marked by northeastward-striking faults such as the La Loche River Fault, faults paralleling the shoreline of Great Slave Lake, and a host of lesser faults of indefinite extent in the vicinity of Thubun Lakes. Deformation during this period probably initiated the pattern for the McDonald system. Movement was essentially transcurrent dextral and of considerable magnitude along the main breaks. Some measure of the scale of movement is suggested by the truncation of northeastward-trending stratiform foliation north of La Loche River Fault (see accompanying geological map). The direction of movement during this period is reflected by the gently northeastward-plunging mylonite lineations south of La Loche River and offsetting of the anticlinal structure northeast of Doucet Lake.

The first period of faulting is characterized by numerous splays that depart considerably in their direction of strike from the consistent north-eastwardly trend of the McDonald system. Field observations both in the map-area and elsewhere along the system, indicate that splay faulting was influenced and guided by earlier structures (such as steeply dipping layering) as well as by differences in rock competence. As indicated by the fracture pattern in Figure 2, the splays appear to break away and return in arcuate fashion from the straight northeastward-striking main faults such as the McDonald. Presumably the propagation of the transcurrent system took place with repeated splaying from the main faults so as to form a braided network of shear fractures in the adjacent rocks in a manner similar to that proposed by Kingma (1958, p. 270-271) for certain transcurrent faults in New Zealand. Movement could have been routed through splays from one main fault to another or taken up by a series of splays. Splays in the McDonald system appear better developed on the south sides of main faults, a good example of which is the curved fault through McKee Lake (Fig. 2). Here the rocks to the north of the fault are granites and typical Yellowknife-type metamorphic rocks, whereas the rocks to the south are more migmatitic and of higher metamorphic grade (Reinhardt, 1966, p. 34). An interesting possibility, evident from Figure 2, is that the splay fault branching off the main McDonald Fault and continuing towards Wilson Island to the west could have accommodated major transcurrent movement. If this were the case, the two main exposures of Wilson Island Group strata shown on Maps 377A and 378A (Stockwell, 1936a, 1936b) could be offset parts of the same original mass. This, however, must remain speculative until a detailed study of the Wilson Island Group in Great Slave Lake is complete. Where splay faults have branched into steeply dipping planes of stratiform foliation, they are extremely difficult to trace because the shear is distributed along numerous planes of layering. This is probably why such extensive mylonitization exists in many areas where the layering is appropriately oriented.

Examinations along the McDonald system reveal that mylonitization related to the first period of faulting is developed on a regional scale between the McDonald Fault scarp and Nonacho Lake. Mylonite zones up to four and five miles wide are known in this area and a survey of the literature on mylonites suggests that some of the widest zones of mylonitization so far recognized occur here. Evidence that the mylonitization was a consequence of transcurrent faulting is found in the increased intensity of mylonitization adjacent to these faults and the reasonably consistent orientation of mylonite lineations and foliations with the direction of shearing. Observations made in 1965 and 1966, in a few critical localities also suggest that the degree of mylonitization varies with the depth at which the rocks were sheared. Where different depth levels have been brought into coincidence through vertical components of fault movements (south side up) the deeper level or south sides show the more intense mylonitization. For instance, the fault that occurs a few miles south of McDonald Lake and strikes parallel to the McDonald Fault (Fig. 2) separates virtually unsheared granite and low-grade schist from highly mylonitized migmatite, granitic rock, and higher-grade gneiss to the south. One tentative explanation for this is that the higher-level expression of transcurrent shear was confined to definite fault planes spaced at regular intervals, whereas at greater depth, movement was translated by a myriad of closely spaced, subparallel planes of shear. In other words, there would be a tendency for planes of major faulting to branch into multiple shear planes at depth.

In the petrographic part of this report it has been more or less assumed that mylonitization and retrograde metamorphism were temporally related events; some evidence will not be offered to support this proposition. First of all, the textures of the sheared rocks are suggestive that recrystallization and neocrystallization were in response to the same stress that produced mylonitization. For example, the foliation formed by the parallel arrangement of muscovite and chlorite in low-grade schists of south Thubun Lake has the same orientation as northeastward-striking shear planes. The presence of minerals such as plagioclase, which did not suffer significant recrystallization, attests to the cataclastic nature of the deformation so that the development of schistosity cannot be attributed to mere flattening perpendicular to the plane of the foliation. In certain rocks, such as the foliated quartz monzonite and granodiorite (7a) north of Thubun Lake, biotite is bent but muscovite appears relatively undeformed. Quartz appears to have recrystallized in many of the rocks and the manner in which it forms lenticular rods between closely spaced shear planes can only be accounted for by recrystallization during shear.

Secondly, it is conceivable that a certain amount of frictional heat could have been generated during widescale mylonitization and this would foster recrystallization. No other exothermal process that affected the granitic and metamorphic rocks alike can be identified in the area.

A third reason for proposing concomitant mylonitization and retrograde metamorphism is that the states of fine aggregation produced by cataclasis renders the rocks more vulnerable to recrystallization than if the original grain size were maintained. Conditions for recrystallization would even be further improved if the crushing permitted access and permeation of water to act as a mineralizing fluid. The recrystallization process would be enhanced through continued shear such that newly formed mineral grains in translational movement would come in contact with those components required for its increased growth without a large dependence upon long-range element diffusion from elsewhere in the rock. This type of process could account for the development of the chlorite-mica schists of south Thubun Lake.

The second main period of faulting is thought to consist of dominantly vertical movements along the reactivated sites of the major northeastward-striking transcurrent faults. This vertical faulting definitely displaced strata of the Great Slave Supergroup and Et-then Group and permits recognition of the distribution of the earlier transcurrent system in parts of the East Arm of Great Slave Lake where successions of these strata attain considerable thickness. The vertical faulting also appears to follow a more linear course and occurs over a narrower zone than faulting of the transcurrent system. The topographic highland underlain by high-grade metamorphic and migmatitic rocks south of the McDonald Fault reflects the vertical uplift of the south side. Narrow zones of brecciation and quartz-carbonate infilling characterize this period of faulting. At several locations along the south shore of Great Slave Lake, the quartz and carbonate infilling is accompanied by minor sulphide mineralization.

The third period of faulting is marked by near vertical, northwestward-striking fractures and is better displayed in the Thubun Lakes area than to the northeast. Observed displacements of less than a mile indicate relatively small sinistral movements. Many of these fractures are occupied by diabase dykes (10) and quartz veins (11) and probably the northwestward-striking joints were developed during this period.

ECONOMIC GEOLOGY

The observed occurrences of sulphide mineralization in the map-area (most of which were previously discovered and examined by prospectors) are indicated on the accompanying map. Numerous claims were staked in the map-area in 1965 and 1966, mainly during the winter months. At least two prospectors were active in the area during the summer of 1966. Summary accounts of some of the early-known mineralization have been compiled by Lord (1951, p. 176) and descriptions of other properties are found in papers by Baragar and Hornbrook (1963, pp. 22 and 34), and Thorpe (1966, p. 29). Chalcopyrite, sphalerite, and galena were the most commonly observed ore minerals and they are usually associated with considerable quantities of iron sulphides as well as minor amounts of less common sulphides.

Sulphide localization is related to, and probably controlled by faulting. For example, scattered showings of chalcopyrite are found along La Loche River Fault where it defines the shoreline of Great Slave Lake and also in the vicinity of near-shore northeastward-striking faults farther to the northeast. Quartz veins containing sphalerite, galena, and chalcopyrite (in decreasing order of abundance) follow roughly the same fracture pattern as the late northwestward-striking faults. One possible exception is the sphalerite, chalcopyrite, and galena mineralization on the Bun group of claims (see Thorpe, 1966, p. 29) where mineralization appears to have partially replaced calc-silicate minerals along a stratigraphic horizon made up of both marble and calc-silicate rock. The writer is of the opinion that the ore-forming solutions gained access through fracture channels and the mineralization was merely concentrated in the calc-silicate-bearing horizon.

A second generalization is that the northwestward-striking quartz veins contain more sphalerite and galena (in that order of abundance) than chalcopyrite whereas quartz-carbonate stockworks formed along the northeastward-striking faults contain greater proportions of chalcopyrite than the combined proportions of sphalerite and galena. The ore mineralization is chiefly confined to the veins themselves and the amphibolites and metasedimentary gneisses are tentatively regarded as more favourable host rocks than the granitic types.

Ore mineralization along the northeastward-striking faults is almost always in quartz and carbonate that form stockworks or enclose breccia fragments. Although there may be a weak preference for mineralization to occur in meta-gabbro or amphibolite host rocks, the chief factor seems to be the extent of brecciation. The best mineralization may thus be expected in the widest breccia zones. This type of mineralization is well displayed on the south shore of Great Slave Lake near the southwest corner of the map-area (Bev group of claims). Systematic trenching and drilling was in progress in this location in 1966.

Native copper was observed in a small prospect pit on the shore of Great Slave Lake, two miles directly north of the outlet of La Loche River. The host rock has a highly altered and brecciated appearance and contains quartz, feldspar, and chlorite. The alteration appears to be partly a result of oxidation, and the emplacement of calcite and hematite probably accompanied the concentration of native copper. The native copper may have been derived from earlier formed copper sulphides by oxidation.

Several outcrops of amphibolite along the east shore of south Thubun Lake and elsewhere in the area weather rusty and contain disseminated iron sulphide minerals. Traces of chalcopyrite were found in one such occurrence near the south boundary of the map-area.

A useful first sign of copper sulphide mineralization in the map-area is the presence of haloes of malachite stain on outcrop surfaces. Some of the galena-bearing quartz veins display no galena on weathered surfaces but the presence of this mineral in the unweathered, deeper parts of the veins is indicated on the surface by cubic shaped casts. Major structural controls that may be considered in searching for mineralization are intersecting faults and zones of dilation along curved fault surfaces.

GEOLOGICAL HISTORY AND RELATED PROBLEMS

General Remarks

In this section an attempt is made to establish an approximate chronology for the major geological events in the map-area. Evidence both from the map-area and elsewhere is referred to in this presentation.

Age and Correlation of Oldest Known Rocks

The oldest recognized rocks in the map-area comprise units 1, 2, 3, 4, and the metasedimentary and metavolcanic components of the migmatite (5). It is assumed that rocks of unit 4 belong to the oldest sequence in the map-area although, as previously mentioned, their relationship to other layered rocks is uncertain. The order in which the sequence is presented on the accompanying map is not necessarily chronological because no top determinations could be made and as indicated on the map, units 1, 2, and 3 are interbanded. The sequence is composed dominantly of amphibolites, pelitic gneisses, metamorphosed acidic volcanics, marble and related calc-silicate rocks, and pryoxene-bearing gneisses. Lithologically these rocks show a greater resemblance to the less intensively metamorphosed rocks of the Yellowknife Group, which occur north of Great Slave Lake and elsewhere in the Slave Province*. Therefore, the oldest known rocks in the Thubun Lakes area are provisionally regarded as Yellowknife-type sediments and volcanics deposited in Archean time and subsequently metamorphosed to higher metamorphic grade than most of the Yellowknife Group rocks in the Slave Province. The evaluation of metamorphic phase relations summarized diagrammatically in Figure 1 has been instructive in assessing the metamorphic grade, and mapping and field examinations have provided a much clearer understanding of the character and extent of migmatization and assimilation both of which indicate a relatively deep-level metamorphic environment.

Because the oldest known sequence of rocks in the Thubun Lakes area is typical of the less migmatized and less altered deeper-level metasedimentary and metavolcanic rocks in the region south of the McDonald Fault, it is of interest to review the previous conclusions as to the origin of these rocks, both within the map-area and elsewhere to the northeast. This allows a comparison with the views of the present author and demonstrates the disagreement among workers in the region and the difficulty of making correlations where the degree of migmatization and metamorphism differ significantly.

In the first reconnaissance mapping of the Great Slave Lake area, Stockwell (1936a) made a few observations along the south shore and indicated on his map that the rocks in question, within the present map-area, belong to the Wilson Island Group. This may, in fact, still be the best interpretation, as previously discussed, for that part of the shoreline north of La Loche River. From the geological reconnaissance of Taltson Lake map-area, Henderson (1939) suggested that the metamorphosed volcanics and sediments occurring along this shoreline and also in the vicinity of Thubun Lakes are of the same age as the Tazin and Yellowknife Groups. Irwin and Prusti (1955), on their geological map of the O'Connor Lake area, suggested that amphibolites and metasedimentary gneisses and schists similar to those in south Thubun Lake, are of Archean age and equivalent to the Wilson Island Group. In the region to the northeast, Wright (1951, p. 4; 1952, p. 4) tentatively assigned the more altered schists and gneisses of the migmatitic terrane south of the McDonald Fault to the Yellowknife Group. He (1952, p. 4) also noted that there was a difference in degree of metamorphism in the vicinity of Schist Lake (lat. 62° 20'N, long. 110° 00'W). In 1965, the writer examined relationships in this vicinity and found considerable evidence of a faulting roughly along the axis of Schist and McKee Lakes (Reinhardt, 1966, pp. 34-35). The lower grade metamorphic rocks on the north side of the fault zone are Yellowknife-type quartz-mica schists containing staurolite, garnet, and cordierite; fine-grained amphibolite; and chlorite schist. The rocks on the south side are thoroughly migmatized granitic gneisses, in part similar to the migmatite (5a) of Thubun Lakes map-area. Farther to the northeast but still south of the fault, less altered, high-grade quartzo-feldspathic gneisses containing cordierite, garnet, biotite, and sillimanite were found. The mineral assemblages of these gneisses can be compared

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* For further information as to the lithology and stratigraphic succession of Yellowknife Group rocks north of Great Slave Lake, the interested reader is referred to recent work by Heywood and Davidson (in press) as well as the earlier reconnaissance investigations by Henderson (1941, 1944) and Folinsbee (1952).

directly with their counterparts in the Thubun Lakes area. The lower grade schists and amphibolites on the north side of the fault are extensively intruded by muscovite-biotite granodiorite and a K-Ar age* of the muscovite from a specimen collected near the north shore of McKee Lake, three miles south of the McDonald Fault lineament (see Fig. 2), gave 2,315 ± 65 m. y. This, therefore, establishes a minimum age for the sediments and volcanics. The foregoing suggests that all deep-level rocks south of the McDonald Fault lineament are similar to the oldest known rocks in the Thubun Lakes area and thus, if the writer's interpretation is correct, the metamorphic rocks in this region are Archean and may be equivalent to rocks of the Yellowknife Group in the Slave Province.

Age of Granitic Emplacement

The exact time interval over which the granitic rocks of the map-area were emplaced is indefinite and more than one period of granitic intrusion may be represented. The problem is further complicated by a lack of conclusive evidence as to the relative ages of the major granitic divisions (units 6, 7, and 8). By reference to the ages of major granitic intrusions in the Slave Province, Archean ages are tentatively assigned to the granitic rocks in the map-area. This interpretation is somewhat tenuous in the case of the porphyritic quartz monzonite (8) as partly suggested by its sill-like mode of occurrence and limited involvement with layered rocks to produce migmatite, therefore, the comments to follow apply mainly to units 6 and 7.

The grossly concordant relationships of granitic bodies to the folded enclosing rocks, suggest that granitic emplacement was syntectonic. The high proportion of granitic rocks in the area coupled with the presence of comparable high-grade mineral assemblages in both undigested strands and schlieren and the surrounding metamorphic rocks, suggest that primary metamorphism accompanied granitic introduction. All this may have been accomplished during the Kenoran Orogeny (Stockwell, 1964). Unfortunately these ideas must remain largely speculative because Archean ages do not appear in the available K-Ar dates from the granitic rocks within the map-area. Muscovite and biotite were dated* from a single specimen of granodiorite (7a) and the values are 1,735 ± 60 m. y. and 1,890 ± 55 m. y., respectively. A hornblende date* from a mafic segregation in quartz monzonite (6) gave 1,780 ± 60 m. y. At first sight, the above range of ages may be interpreted as conclusive evidence of Hudsonian granitic intrusion (Stockwell, 1964) but the discrepancy of the two different mica ages from the same specimen gives reason to suspect that the penetrative shear and accompanying retrograde recrystallization have altered the primary age of the biotite and that the muscovite is secondary. Furthermore, the writer is of the opinion that the latter interpretation can be extended to include most of the cataclastically deformed rocks in the region south of the McDonald Fault and the available K-Ar dates (see Fig. 2 and Wanless et al., 1967, Fig. 1) in this region reflect the age of penetrative deformation rather than granitic emplacement. Rare occurrences of older dates in this part of the western Churchill Province may be regarded as further evidence for this tentative conclusion.

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* Determination by the Isotope Geology Section, Geological Survey of Canada.

Age of Transcurrent Faulting, Mylonitization, and Retrograde Metamorphism

Transcurrent faulting with associated mylonitization and retrograde metamorphism followed the primary high-grade metamorphism and plutonic intrusion of granitic rocks in the map-area. The length of time spanned by this penetrative deformation is difficult to estimate but, if the writer's interpretation of the K-Ar dates from the sheared rocks is correct, mylonitization must have effectively ceased prior to 1,735 m. y. Further transcurrent displacements, however, may have continued without new crystallization of micas. This would suggest that mylonitization continued after deposition of the Great Slave Supergroup if the present available K-Ar age (1,845 m. y.; Lowdon et al., 1963, p. 47) determined from granite cutting the Great Slave Supergroup is meaningful. This, however, does not necessarily imply that transcurrent faulting did not commence prior to the deposition of the Great Slave Supergroup. Displacements and patterns typical of the transcurrent system appear to be weaker in localities where the Great Slave Supergroup is present suggesting that this assemblage has not experienced the complete duration of transcurrent faulting. Further work is planned to clarify these age relationships.

Later Faulting and Diabase Dykes

Later vertical faulting took place along the sites of the earlier transcurrent faults. This faulting outlasted the deposition of the Et-then Group because rocks of this group are cut by the southwestern extension of the La Loche River Fault along the shoreline of Great Slave Lake. Recent work by Hoffman (1967, p. 36; 1968a, p. 142) suggests that this faulting was also active during deposition of the Et-then Group. The northeastward-striking vertical faults are in turn cut by north-northwestward-striking faults that exhibit minor sinistral offset. In addition, these latter faults in some places are occupied by diabase dykes which also cut the Et-then Group. It follows, therefore, that both periods of later faulting probably fall between the time of Hudsonian Orogeny and the time of diabase emplacement (1,310 m. y.).

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