THE GEOLOGY OF THE CHURCHILL FALLS AREA, LABRADOR

by

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INTRODUCTION

The area mapped during the 1980 season comprised N.T.S. sheets 23H/10, 23H/9 and 13E/12W, and is an easterly extension of previous Mineral Development Division mapping in southwestern Labrador (Wardle, 1979; Noel and Rivers, 1979).

The area is located at the southeastern end of the Smallwood Reservoir and includes the hydroelectric townsite of Churchill Falls. Access to the townsite may be made by scheduled air service from Montreal or St. John's; by all weather road linking with the QNS & L Railway at Esker; or by tote road from Goose Bay.

Service roads connect Churchill Falls to dam sites at Orma Lake, 100 km north of the map area, to the south shore of the Forebay Reservoir, and also to the hydroelectric site of Twin Falls.

The map area is an undulatory plateau which has been deeply dissected by the east flowing Valley, Unknown, and Churchill Rivers. All of these rivers flow through deep rocky gorges and over several major waterfalls, the largest of which was Churchill Falls, which has now been divided to form the Churchill Falls hydroelectric development. Creation of the Forebay Reservoir as part of this scheme has resulted in extensive flooding of the plateau land. The accompanying map has been adjusted to show approximately the flooded areas.

Exposure on the plateau is generally very poor, with the exception of the southeast part of the area, which has a more rugged topography. Elsewhere in the area, good exposure is usually confined to the river valleys, some hill tops, and the numerous quarries and roadside outcrops created around the Forebay Reservoir.

The only previous geological mapping in the area was the reconnaissance work by Eade (1952) and Stevenson (1969) of the Geological Survey of Canada (G.S.C.). Eade shows the northwestern part of the area as underlain by banded granitic gneisses and gneissic granites and Stevenson mapped the southeastern part as paragneisses and gabbroic rocks. Some more detailed work was carried out by the British Newfoundland Exploration Company (BRINEX) during construction of the Churchill Falls site. (White, 1968; Barton and Barton, 1970; Callahan, 1968, 1969, 1973, 1980).

In the regional synthesis by Greene (1974), the gneisses in the northwest part of the area were assigned to the Churchill Province and those in the southeast to the Grenville Province. The Grenville Front was, therefore, inferred to extend diagonally across the area from southwest to northeast.

GENERAL GEOLOGY

The oldest rocks are various granitoid and metasedimentary gneisses of Unit 1 which are present as large inclusions within younger granitoid plutons. These are the only Hudsonian tectonites in an area previously considered to be dominantly underlain by such rocks (Greene, 1974).

Paleohelikian supracrustal sequences in the area are represented by the felsic volcanics and volcaniclastics of the Blueberry Lake Group (Unit 2). It is clear that most of the area is underlain

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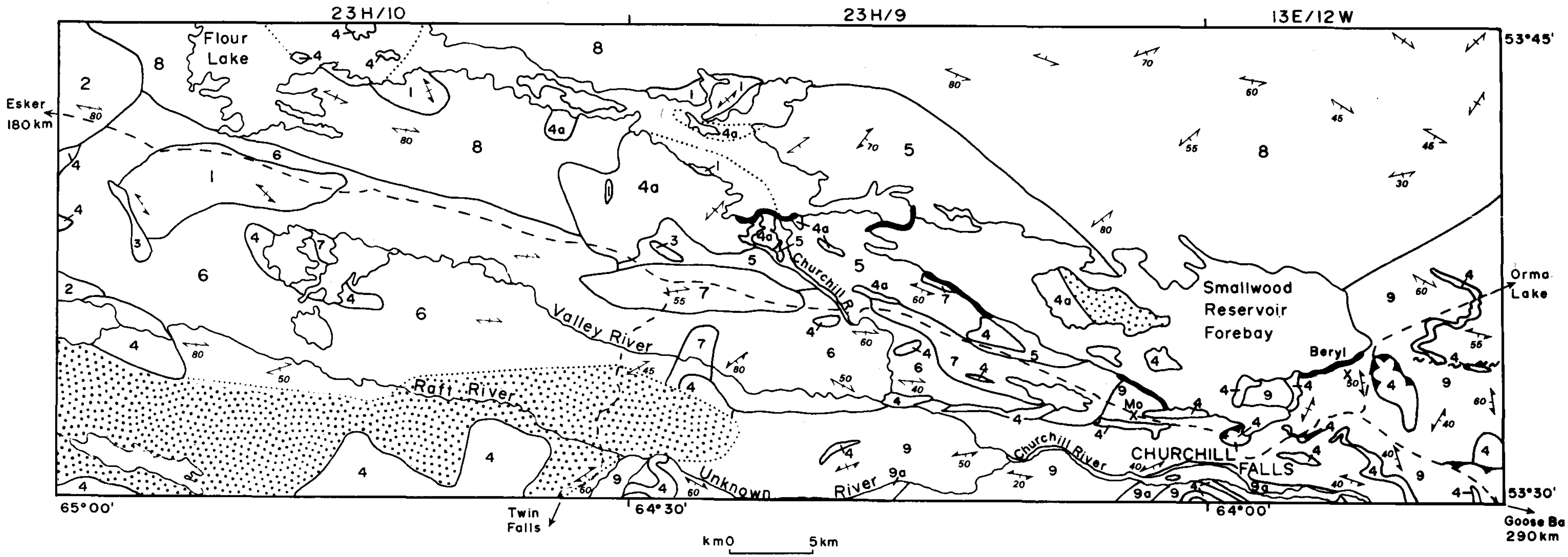

Road

Earth Dam

Cleavage schistosity

Gneissosity

Fault

Thrust

LEGEND

HELIKIAN

9	*Granitoid gneisses equivalent to units 6, 7 and 8;* **9a**, *quartz-feldspar sillimanite gneiss, quartz - feldspar garnet gneiss.*
8	*Coarse grained pink quartz monzonite; microgranite and aplite; minor diorite*
7	*Pink microgranite and equigranular granite*
6	*Gray quartz monzonite*
5	*Gray monzonite*
4	**SHABOGAMO INTRUSIVE SUITE:** *Gabbro, amphibolite;* **4a**, *biotite-hornblende gabbro*
3	*Mafic porphyry*
2	**BLUEBERRY LAKE GROUP:** *Felsic and mafic volcanics, volcaniclastics*

ARCHEAN OR APHEBIAN

1	*Tonalitic gneisses, minor amphibolite;* **1a**, *biotite-sillimanite pelitic gneiss*

by graintoid and gabbroid rocks of Paleohelikian age. These are represented by the gabbroid intrusives of Unit 3 and the Shabogamo Intrusive Suite (Unit 4), which in turn have been intruded by a range of granitoid plutons represented by Units 5-8.

The entire area was deformed during the Grenvillian Orogeny and, thus, by definition lies entirely within the Grenville Province. Deformation and metamorphism associated with this event increase in intensity from northwest to southeast. As a result, the granitoid plutons of Units 5-8 become progressively metamorphosed to granitoid gneisses in the southeastern part of the area (Unit 9).

Tonalite gneisses, minor amphibolite, and sillimanite-biotite-garnet gneiss (Unit 1)

This is a very poorly exposed unit, the extent of which is defined largely on the basis of aeromagnetic lows (G.S.C. aeromagnetic maps, 1972).

Most outcrops consist of white weathering, migmatitic, tonalitic gneisses with common bands of amphibolite. These were partially mylonitized and retrogressed prior to intrusion by Helikian plutons.

Also included in the unit is a small area of quartz + biotite + sillimanite + garnet + microcline pelitic gneiss (1a) which was subsequently intensely folded and partially migmatized.

Both types of gneiss have been intruded posttectonically by the younger granitoid plutons. The tonalite-amphibolite gneisses are similar to gneisses of probable Archean age in the Gabbro Lake area (Wardle, 1979), which adjoins the western boundary of the map area.

Blueberry Lake Group (Unit 2)

This is also a very poorly exposed unit; it is delineated on the basis of only four outcrops. These consist of rhyolite and plagioclase phyric, intermediate to mafic volcanics which could be of either intrusive or extrusive origin.

The unit represents the easterly termination of the Blueberry Lake Group, the type area for which is informally defined in the Gabbro Lake area (Wardle, 1979; Noel and Rivers, 1979) The group typically consists of felsic to intermediate pyroclastics, volcaniclastics and minor hypabyssal intrusives. The latter have been dated at 1540 ± 40 Ma (Brooks *et al.*, in press).

Mafic Porphyry (Unit 3)

Mafic porphyry is only exposed at two localities in the map area; however, abundant boulders in the glacial overburden indicate that it may be more widespread.

This rock type contains large (up to 3 cm diameter) euhedral plagioclase phenocrysts in a dark, purple-gray groundmass of intermediate appearance and locally displaying a weak flow alignment. Low grade metamorphism has saussuritized the phenocrysts, producing a green coloration, and has recrystallized the groundmass to a fine granular intergrowth of epidote, albite, opaque minerals, and actinolite.

The unit is intruded by granodiorite dikes of the Unit 6 pluton. It is uncertain, however, whether Unit 3 forms a hypabyssal component of the Blueberry Lake Group or the Shabogamo Intrusive Suite, or belongs to a separate intrusive episode.

Shabogamo Intrusive Suite (Unit 4)

Gabbroid bodies of varying size and metamorphic grade occur throughout the map area. The most typical lithology is a medium to coarse grained olivine gabbro which contains irregular zones of coarse pyroxene-plagioclase pegmatite. This is identical to the large mass of Shabogamo gabbro occurring in the Gabbro Lake area to the west (Wardle, 1979) which has been dated at 1400 Ma (Brooks *et al.*, in press).

A distinctive variety, prevalent along the southern side of the Forebay Reservoir is a melanocratic, two pyroxene-biotite gabbro (4a) in which biotite forms large 1-2 cm diameter poikilocrysts. Locally, hornblende is suspected to be an additional primary constituent and, in these instances, it is possible that the rock type has a dioritic composition.

In the southeastern part of the area, within Unit 9, the large gabbro bodies typically have coarse grained centres with clinopyroxene-garnet-spinel coronas developed around olivine and orthopyroxene. Smaller bodies of gabbro, and the margins of the larger bodies, have been converted to amphibolite schist and gneiss.

In most cases, where contact zones are exposed and well preserved (*i.e.* largely in the northeastern part of the area), the gabbro is practically always intruded by dikes of granite and pegmatite from the surrounding plutons. In the contact zones, the gabbro is also usually net veined and stoped by these younger granitoid plutons and, in many cases, there is a complete gradation over several tens of metres from granitoid crowded with xenoliths to gabbro net-veined by granitoid and pegmatite.

In many locations, however, the gabbro bodies become finer grained towards the contact zones and include zones of plagioclase phyric diabase and fine gabbro. The xenolith content of the granitoid plutons is also composed largely of diabase derived from these peripheral zones.

These relationshps could be interpreted to indicate that the gabbro is the younger unit and has produced rheomorphic remobilization ("back veining") by melting of the granitoid rocks. However, the net veined and stoped zones are extensively developed and bear no relationship to the size of the gabbro body. In fact, some of the smaller gabbroic bodies have been totally brecciated by net veining, a feature which would not be expected to result from rheomorphism. Furthermore, the granitoid plutons contain xenoliths of diabase in areas well away from exposed gabbro plutons, a feature that is also inconsistent with a rheomorphic model.

The preferred interpretation, therefore, is that in most cases the gabbros predate the granitoid intrusions. The possibility of some pre-gabbro granitoids cannot be discounted, however.

The gabbros have locally been intruded by several late, pretectonic mafic dikes which also intrude the monzonite of Unit 5.

Gray Monzonite (Unit 5)

This is a distinctive gray plutonic rock exposed in shoreline and quarry outcrops around the Forebay Reservoir. On the basis of field identification, the pluton is of monzonite composition but varies locally to monzodiorite, quartz monzonite and quartz diorite. The unit is typically gray on weathered and fresh surfaces but may be pink where it has been strongly deformed or affected by low grade alteration.

Vague compositional layering has also been observed locally within the unit.

The monzonite is generally medium to coarse grained and usually subequigranular in texture. Locally, however, microcline may form dark purple-gray phenocrysts up to 1 cm long. Otherwise, gray alkali feldspar occurs intergrown with gray plagioclase in granular texture and contains minor interstitial quartz, commonly with a blue tinge. Biotite and pyroxene (hypersthene?) are the main mafic mineral phases. Pyroxene has been partially replaced by biotite.

Gray Quartz Monzonite (Unit 6)

This is an extensive unit throughout the central part of the map area. It is usually a medium grained, white weathering quartz monzonite, gray on fresh surface, with a seriate texture in which dark purplish gray microcline forms phenocrysts up to 1 cm diameter. Granodiorite, microgranite, and microgranodiorite phases are also present locally, the latter being particularly prevalent near the Blueberry Lake Group. Biotite is the predominant mafic mineral, locally intergrown with hornblende or sphene, and commonly appears to be pseudomorphic, possibly after pyroxene.

Gray quartz monzonite intrudes Units 1, 2, 3 and 4; however, relationships to the Unit 5 monzonite are uncertain. In the only place at which the two plutons have been observed in contact, along the upper part of the Churchill River, both units have been strongly mylonitized and age relationships remain unknown.

Pink microgranite and equigranular granite (Unit 7)

This is a composite unit comprising various bodies of pink, medium grained, equigranular granite, quartz syenite, microgranite, and aplite.

Several bodies of this unit have been delineated on the accompanying map. Given the poor degree of exposure of this unit, however, it is not certain whether these represent single homogeneous plutons or zones of numerous minor intrusions.

Numerous small dikes and sheets of microgranite and aplite intrude all the other plutonic units of the area but are generally too small to be portrayed on the map. In general, these are correlated with Unit 7. It is possible, however, that in some locations they may represent late differentiates of Units 5 and 6.

A deformed variant of Unit 7 is a strongly foliated, fine grained, biotite granite exposed along the Valley River (7a).

Coarse grained porphyritic quartz monzonite (Unit 8)

This unit extends across the northern part of the map area and is contiguous with the granitic pluton of the Lake Michikamau area (Unit 3; Nunn, this volume). Exposure of the unit is generally very poor and the position of the southern boundary is based largely on aeromagnetic interpretations.

The unit is characteristically a coarse grained, pink, quartz monzonite with seriate texture. The megacrysts are mainly microcline and vary in length up to 1.5 cm. The matrix consists of white plagioclase, locally tinged green by saussuritization, intergrown with pink alkali feldspar and interstitial quartz, the latter often having a blue tinge. Biotite is the only mafic phase.

The unit also contains abundant microgranite and aplite, both as irregular masses and dikes, as well as several thin sheetlike bodies of diabase and diorite which are believed to be late dikes (8a).

Contact relationships with other units in the area have not been observed. On the basis of lithologic similarity, the unit could be correlated with the Unit 7 granites to the south. However, if the diorite dikes are part of the Shabogamo Suite, the unit must belong to a much earlier period of intrusion.

Granitoid gneisses (Unit 9)

South of Valley River, the plutonic rocks of Units 5, 6, 7 and 8 have been progessively metamorphosed to form the migmatitic granitoid gneisses of Unit 9. The contact of Unit 9 has been drawn at the first appearance of well developed migmatite fabrics and gneissic foliation in these rocks. In reality, this is a broad transitional zone in which areas of strongly foliated granitoid rocks interdigitate with migmatite and granitoid gneiss.

South of Churchill River, the predominant lithology within Unit 9 is a light gray to pink gneiss of quartz monzonite to granodiorite composition which is in a large part equivalent to Unit 6. Southeast and east of Forebay Reservoir, the gneisses are generally darker colored and appear to vary in composition from quartz diorite to monzonite and monzodiorite. There is little doubt that, in part, these are metamorphosed equivalents of Unit 5. Several zones within the gneisses, however, have been intruded by pretectonic dikes of amphibolitized diabase. If these dikes are related to the Shabogamo gabbros, formation of part of the gneiss protolith must have predated the intrusion of Unit 5.

To date, the various areas of gneisses have not been subdivided. In future petrographic studies, however, it should be possible to more closely define the extension of plutonic contacts into the gneiss terrains.

Scattered throughout the gneisses are abundant sheets and pods of pink granite gneiss and schistose aplite which are interpreted as metamorphosed equivalents of Units 7 and 8.

A feature of Unit 9 is the marked heterogeneity of development of migmatitic and gneissic fabrics. Throughout the gneiss terrain, numerous areas contain well preserved igneous features, *e.g.* mafic xenoliths and microcline phenocrysts, in a moderately foliated or lineated rock. These invariably grade laterally into areas of incipient migmatization in which mobilizate forms small elliptical pods or an intersecting vein system. In both cases, the leucosome veins are characteristically spotted with small biotite and/or hornblende porphyroblasts, possibly the product of incongruent melting.

These incipient migmatites often grade sharply, sometimes over distances of as little as 2 m, into zones of well banded, leucosome-rich migmatite. These zones are commonly associated with pre- or synkinematic pegmatite and aplite veins and may owe their development to the local introduction of fluids during metamorphism.

Also included within Unit 9 are several poorly defined screens of quartz + feldspar + biotite + sillimanite gneiss which may represent relict metasedimentary inclusions within the gneiss protolith (9a). The only one sufficiently large to be portrayed at map scale is located 1 km south of Churchill Falls (9a). Several areas of fine grained quartz + feldspar + biotite + garnet gneiss presently included within Unit 9 may also be of metasedimentary origin. These are largely confined to the area south of the Churchill and Unknown Rivers.

Late Dikes

Several thin dikes of olivine basalt and diabase were noted along the Valley and Upper Churchill River valleys. These dikes have approximate east-west trends and are completely post tectonic. Their age, other than being post-Helikian, is unknown.

STRUCTURE AND METAMORPHISM

All units, with the exception of the late dikes, have been varyingly affected by Grenvillian deformation. Reconnaissance studies indicate that the northwestern limit of this deformation, which was previously thought to transect the map area, lies approximately 40 km northwest of the center of the map area.

The only pre-Grenvillian structures recognized from the area are found within the gneisses of Unit 1. The larger bodies of this unit preserve gneissic and cataclastic fabrics of northwesterly trends which were probably inherited from the Hudsonian, and possibly even Kenoran, Orogenies.

The granitoid Units 5, 6, 7, and 8 have been affected by strong, zonally developed, Grenvillian deformation and metamorphism which increases in intensity from northwest to southeast.

In the northwest, the rocks vary from undeformed to moderately foliated with biotite or chlorite S_1 fabrics. Deformation is usually associated with shearing, and zones of protomylonite and mylonite schist are common. S_1 fabric trends have an overall east-west to northeast-southwest trend with steep southerly dips, and have been deformed into broad folds by later deformation.

To the southeast, in the general area of the Forebay Reservoir, the metamorphic grade rises to upper greenschist and amphibolite facies and the granitoids become more homogeneously foliated. Mylonite zones are still present but are seen as flaggy quartz + feldspar + biotite $\pm$ muscovite augen schists in which microcline usually forms augened porphyroclasts.

Within the area of Unit 9, the gneissic textures presumably indicate the development of upper amphibolite facies conditions. Zones of mylonite gneiss in this area appear to have developed at a late metamorphic stage and are associated with small scale F_2 folding and transposition of gneissic fabric. These folds generally have shallow plunges to the northeast and southwest and are associated with a strong southeasterly plunging mineral lineation. In some areas, this lineation is the dominant penetrative fabric. The style of this second deformation strongly suggests that it was associated with northwesterly directed overthrusting.

Several minor thrusts associated with F_2 folding have been observed at the base of reclined gabbro sheets in the southeastern part of the area. These are marked by progressive transposition of S_1 gneissic foliation into a flaggy S_2 mylonite fabric, then into ultramylonite and blastomylonite along the sole of thrusts.

Only one zone has been recognized which may represent a major thrust. This lies along the northern margin of the Unit 7 granite west of the Churchill River and is marked by a broad zone of intense mylonitization and foliation. The inferred thrust is drawn at the northerly limit of this deformation. Elsewhere in the map area, it appears that shortening has occurred along numerous minor thrust and ductile shear zones. This is particularly evident along the section provided by the Churchill River above its confluence with the Valley River. In this area, the Unit 6 quartz monzonite has been deformed by numerous closely spaced (50-100 m) mylonite and protomylonite zones which are separated by zones of weakly to moderately foliated quartz monzonite.

S_1 fabrics, F_2 fold axes, and thrusts have been refolded into north-south structural trends by an F_3 event that increases in intensity to the southeast. Numerous minor folds of north-south trend occur in the southeastern corner of the map area but, in general, it is uncertain whether these represent F_3 minor folds or rotated F_2 folds. The F_3 event does not appear to have been associated with the development of penetrative fabrics.

ECONOMIC GEOLOGY

Previous reports of mineralization in the area are restricted to a small occurrence of molybdenite in a gneiss boulder near Churchill Falls townsite (Callahan, 1969). The only mineralization found during the present mapping was an occurrence of green beryl in pretectonic pegmatites in migmatitic gneisses 5 km northeast of Churchill Falls. The beryl is associated with tourmaline and occurs as crystalline aggregates up to 3 cm in diameter and as single crystals 1-2 cm long.

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