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STRUCTURAL, METAMORPHIC AND INTRUSIVE RELATIONS IN THE HINTERLAND OF THE EASTERN CHURCHILL PROVINCE, WESTERN LABRADOR

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ABSTRACT

In western Labrador, the metamorphic–plutonic hinterland of the eastern Churchill Province is subdivided into two principal tectonostratigraphic elements, named the Central and Western zones. The Central zone consists primarily of metamorphosed supracrustal rocks, orthogneiss and variably foliated granitic rocks that are intruded by the Early Proterozoic De Pas batholith. The as yet undated pre-De Pas batholith units are inferred to be Archean, although the rocks may contain structural fabric elements developed concomitant with both Archean and Early Proterozoic (syn-De Pas batholith) regional metamorphic events. The Western zone includes a sequence of supracrustal rocks, consisting of interlayered quartzite, marble and metapelite, and tonalite gneiss and gabbro. Ages of the supracrustal rocks and tonalite gneiss in the Western zone are uncertain.

The Central and Western zones are separated by a regionally persistent ductile high-strain zone. The boundary is presumed to be a dextral transpressive structure that formed as a consequence of Early Proterozoic (ca. 1880 to 1830 Ma) construction of the hinterland and suturing with the foreland zone (New Quebec Orogen), although field kinematic evidence is lacking.

The Central zone also contains the anorogenic, Middle Proterozoic Michikamau Intrusion (anorthosite–gabbro suite) and associated, marginal bodies of ca. 1460 Ma granite and syenite.

INTRODUCTION

OBJECTIVES AND PREVIOUS WORK

In 1993, a 1:100 000-scale bedrock-mapping program was completed in the eastern Churchill Province in western Labrador. The study area is situated around the northern part of the Smallwood Reservoir, approximately 80 km northwest of the Churchill Falls town site, and is included within the Woods Lake map area, NTS 23I (Figure 1). Mapping in 1993 was accomplished using a combination of helicopter-supported ground traverses and boat-supported examination of the superb exposures around the Smallwood Reservoir. The field work was based from a camp located near the Lobstick Control Structure on the southern shore of the Smallwood Reservoir. The 1993 field season marked the completion of the field component of a Canada–Newfoundland Cooperation Agreement on Mineral Development that supported a regional mapping program initiated in 1992 (see James *et al.*, 1993a).

The purpose of this project is to improve understanding of the Archean and Early Proterozoic geology of the western part of the eastern Churchill Province. Prior to this project, this geology was known only from 1:250 000-scale maps dating from the early 1960s (see Wynne-Edwards, 1960; and Emslie, 1963) and from more detailed mapping that focused on the western margin of the Middle Proterozoic Michikamau Intrusion (Emslie, 1970). In contrast, Lower Proterozoic Labrador Trough rocks to the west, Labradorian rocks forming the northern margin of the Grenville Province to the south, and the Michikamau Intrusion and eastern Churchill Province rocks farther east are better known.

In addition to the regional mapping, part of the southern boundary of the study area was mapped in detail by G.A.G. Nunn with the aim of deciphering Early Proterozoic and Labradorian intrusive and tectonic relations. Results of this detailed study are reported separately (Nunn, 1993).

The mapping in NTS map area 23I and our understanding of some of the major, Early Proterozoic and Grenvillian structures in the region will benefit from detailed gravity surveys made by Gerry Kilfoil (Geochemistry, Geophysics

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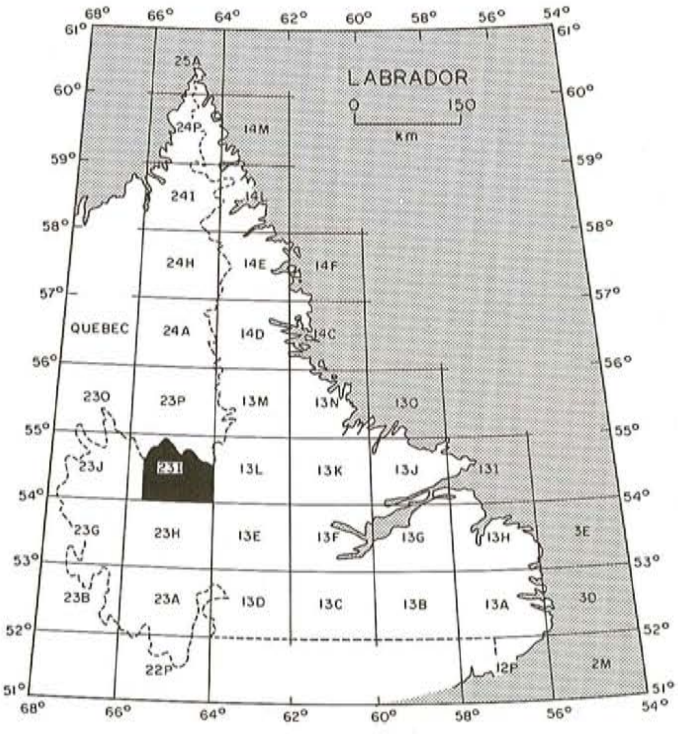


Figure 1. *NTS index map of Labrador showing the location of the study area, NTS 23I (patterned).*

and Terrain Sciences Section) in 1993. In total, approximately 650 km of new gravity data were acquired in three transects (see James *et al.*, 1993b, Figure 3). One of the transects crosses the study area, extending from the Superior Province to the eastern margin of the Michikamau Intrusion (in NTS map area 13L).

REGIONAL FRAMEWORK

The eastern Churchill Province in Labrador and contiguous northeastern Quebec separates the Archean Superior and Nain provinces (Figure 2) and contains three first-order tectonic elements; eastern and western foreland zones and a medial hinterland. The hinterland is considered to be a southeastern extension of the Rae Province (Hoffman, 1988) and is composed chiefly of reworked Archean rocks and Lower Proterozoic granitoid plutons (e.g., Ashwal *et al.*, 1986; Machado *et al.*, 1988; Ryan, 1990; Nunn *et al.*, 1990). The southwestern part of the hinterland is the focus of this study.

The hinterland is sutured against the Superior and Nain cratons by the Early Proterozoic New Quebec and Torngat orogens to the west and east, respectively (Wardle *et al.*, 1990b). These orogens, which contain Lower Proterozoic continental margin sequences, constitute the foreland zones. The foreland zones are transpressional orogens and have mirror-image craton-verging fold-and-thrust belts associated with dextral (west) and sinistral (east) transcurrent shear on their interior margins with the hinterland (Wardle *et al.*, 1990b). Hoffman (1990) proposed that accretion of the hinterland to the Superior Province, and contraction of the

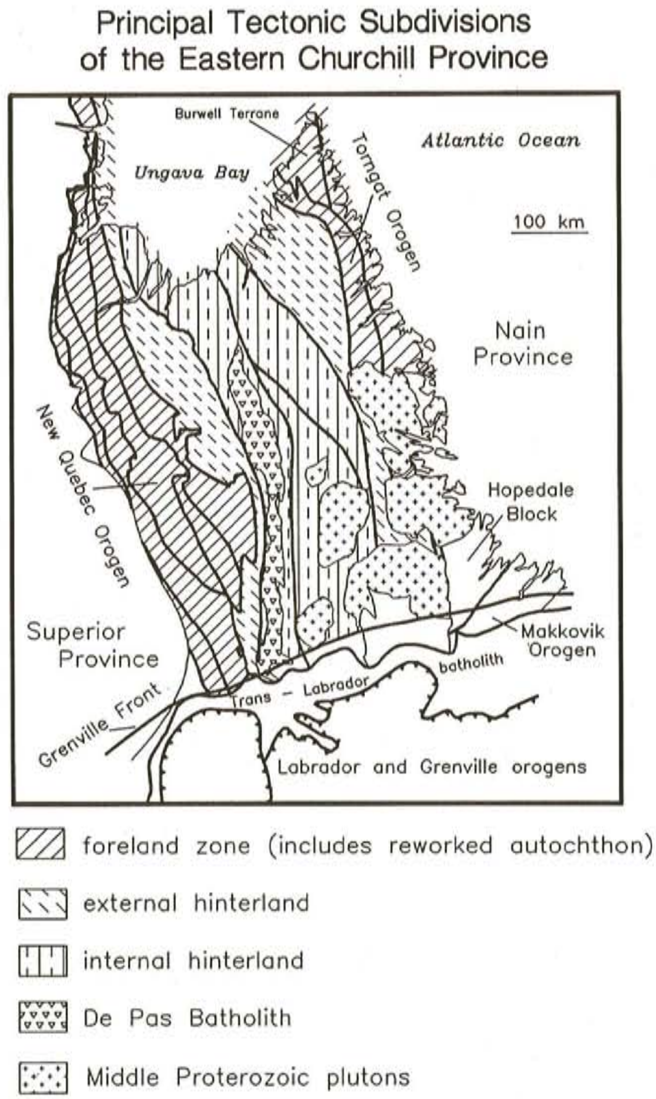


Figure 2. *Principal tectonic elements of the eastern Churchill Province. The subdivisions of the hinterland are provisional. Internal hinterland–Archean supracrustal and plutonic rocks and orthogneisses that are inferred to be only locally affected by Early Proterozoic regional metamorphism and penetrative deformation; includes the De Pas batholith. External hinterland–Archean and Lower Proterozoic supracrustal and plutonic rocks and orthogneisses that are more pervasively overprinted by Early Proterozoic regional metamorphism and penetrative deformation than rocks in the internal zones. The study area is located in the southwestern part of the hinterland.*

intervening Lower Proterozoic Labrador Trough rocks, occurred in the approximate interval from 1880 to 1840 Ma.

In the Smallwood Reservoir area, the hinterland can be subdivided into two zones, loosely following the previously defined zones of Wardle *et al.* (1990a) and van der Leeden *et al.* (1990). These are informally named the Central and Western zones (Figure 3).

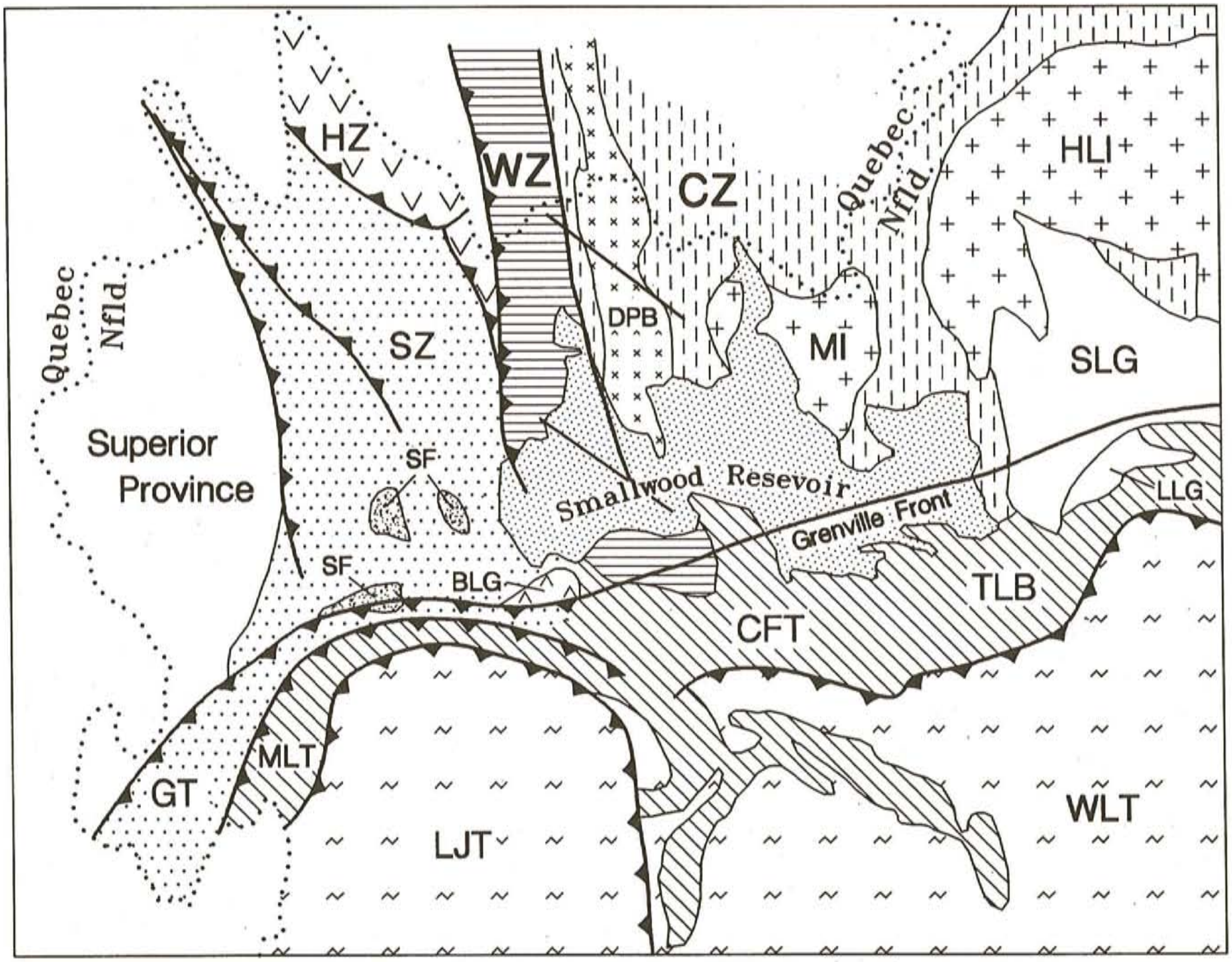


Figure 3. *Generalized geological map of western Labrador. The study area (Figure 4) includes the area between the Smallwood Reservoir and the Newfoundland–Quebec border. Tectonic units–eastern Churchill Province: WZ–Western zone, CZ–Central zone, SZ–Schefferville zone, HZ–Howse zone; Grenville Province: GT–Gagnon terrane, MLT–Molson Lake terrane, LJT–Lac Joseph terrane, CFT–Churchill Falls terrane, WLT–Wilson Lake terrane; stratigraphic units–BLG–Blueberry Lake Group, DPB–De Pas batholith, TLB–Trans-Labrador batholith, SF–Simms Formation, MI–Michikamau Intrusion, HLI–Harp Lake Intrusion, SLG–Seal Lake Group, LLG–Letitia Lake Group.*

CENTRAL ZONE

The Central zone consists of granitic orthogneisses and variably deformed tonalite to granite bodies that intrude supracrustal rocks. The supracrustal rocks, informally named the Overflow group, consist principally of biotite migmatite and minor amounts of mafic metavolcanic rocks. The orthogneisses, granitoid bodies and the Overflow group are intruded by several sets of amphibolite dykes. The ages of all of these rocks are uncertain, although they are considered to be Archean, based on isotopic data from correlative Central zone rocks, from east of the study area that have been examined by Nunn and Noel (1982). U–Pb zircon geochronology of four Central zone tonalite gneiss samples, which were collected from east of the present study area, indicates that the gneisses were emplaced in the range from 2690 Ma to 2655 Ma (Nunn *et al.*, 1990). Furthermore, the only post-Archean event isotopically recorded in these rocks, indicated by the resetting or growth of new titanite, is Labradorian in age (Nunn *et al.*, 1990). These data suggest that in the present study area, the medium- to high-grade metamorphic assemblages and structural fabric elements in Central zone rocks may be Archean and not related to Hudsonian tectonothermal events, although this model remains to be tested.

In the study area, the Central zone is intruded by granitic rocks belonging to the 500-km-long De Pas batholith. This is a composite batholith of K-feldspar porphyritic granite, charnockite and younger granite and granodiorite phases that display calc-alkaline trends (van der Leeden *et al.*, 1990). Field relations in the study area and elsewhere (see Wardle,

1985) demonstrate that intrusion of the De Pas batholith postdated development of gneissosity in the host Central zone gneisses, described in the preceding paragraph. U–Pb zircon ages of 1830 $^{+6}_{-5}$ Ma (Connelly, 1993) and 1811 ± 3 Ma (Krogh, 1986), determined from samples of granite collected near the southern end of the batholith, are interpreted to represent the age of emplacement.

WESTERN ZONE

The Western zone is in tectonic contact with the Central zone and the New Quebec Orogen. The Western zone is characterized by a series of prominent, linear magnetic anomalies but it is very poorly exposed. It consists of a minor amount of supracrustal rocks, informally named the Lobstick group, and younger tonalite gneiss and gabbro. All are undated. The gabbro is variably recrystallized and is locally fresh, and on this basis is inferred to be Early Proterozoic in age.

The Western zone has been overprinted by dextral transpressive shearing inferred to be related to the Lac Tudor shear zone (van der Leeden *et al.*, 1990). The contractional component of displacement on the Lac Tudor shear zone is thought to involve west-directed transport of Western zone rocks over the New Quebec Orogen. The boundary between the Western zone and the New Quebec Orogen is locally marked by an inflection in the regional Bouguer gravity anomaly (Mareschal *et al.*, 1990; Wardle *et al.*, 1990a) and has been proposed to be a suture by Thomas and Kearey (1980).

LOWER AND MIDDLE PROTEROZOIC ROCKS

The study area also contains a minor amount of Lower Proterozoic sedimentary rocks of the Petscapiskau Group and part of a major, Middle Proterozoic anorthosite and leucotroctolite intrusion and associated, marginal granitic bodies. The anorthosite–leucotroctolite is part of the Michikamau Intrusion (Emslie, 1970, 1978), determined by U–Pb zircon geochronology to have an igneous age of ca. 1460 Ma (Krogh and Davis, 1973). The igneous age of the marginal granitic intrusion has been determined to be 1459 ± 2 Ma (Krogh, 1993, unpublished data) using U–Pb isotopic methods on zircon and titanite. Locally, the Middle Proterozoic intrusions are unconformably overlain by clastic sedimentary rocks correlated with the Middle Proterozoic Seal Lake Group.

South of the study area, the hinterland is in intrusive and tectonic contact with granitoid rocks of the ca. 1650 Ma Trans-Labrador batholith (see Wardle, 1985). The Grenville Front, defined in the study area and areas to the east as the northern limit of east-northeast-striking Grenvillian structures, is considered to transect the southern part of the study area (see Nunn *et al.*, 1990).

LITHOLOGY AND CONTACT RELATIONS

Neither the contact relations nor the relative ages of units in the Central and Western zones are known, and geochronological data are lacking. Because of these uncertainties, the units cannot be listed in chronological order in the legend for Figure 4. The ensuing description of the units follows the numerical order listed in the legend.

Units 12 and 13, which occur in the New Quebec Orogen, were not mapped and thus are not described in the text.

CENTRAL ZONE: ARCHEAN AND LOWER PROTEROZOIC UNITS

Overflow Group (Unit 1)

The Overflow group, informally named after exposures of high-grade supracrustal rocks on the shores of Overflow Lake (Smallwood Reservoir), is inferred to be the oldest unit in the Central zone, based on intrusive relations observed in the field. It consists principally of biotite migmatite but contains very minor amounts of mafic gneiss, which are assumed to be derived from mafic volcanic rocks.

The most common rock type in the group is a brown-, rusty-, or black-weathering biotite migmatite. The rocks consist of a dark paleosome containing abundant biotite, common garnet and local sillimanite. There are a few occurrences of migmatite in which coexisting biotite, garnet and orthopyroxene occur. Locally, layering in the paleosome, defined by the percentage of biotite, represents relict sedimentary layering. The rocks contain white-weathering, K-feldspar-bearing leucosome that makes up approximately 40 percent of outcrops; locally the amount of leucosome exceeds 50 percent of the migmatite. Two phases of leucosome, distinguished on the basis of crosscutting relations, are locally present. The older of the phases is the most common and forms thin (<15 cm), roughly parallel to anastomosing layers containing minor amounts of biotite and garnet. The younger phase is somewhat coarser grained than the older.

The biotite migmatite is locally interlayered with iron formation. These are generally less than 1 m thick and consist of 10- to 15-cm-thick, alternating layers of quartz, which is inferred to be metamorphosed chert, and magnetite. Minor amounts of pyrite are common. Occurrences of iron formation are most common in the area 1 to 2 km west of Overflow Lake.

The biotite migmatite is intruded by mafic rocks, which appear to have been layered mafic intrusions. These are locally up to several tens of metres thick and contain 1- to 10-cm-thick layers defined by the percentage of hornblende and clinopyroxene. Relicts of the layered intrusions also occur as inclusions in some of the younger granitoid units. The biotite migmatite contains several generations of recrystallized and variably deformed granitic dykes. Metamorphosed mafic dykes of several ages, which are defined by crosscutting relationships, are common within the migmatite. The mafic dykes also intrude the younger granitoid bodies (Units 2 to 6).

The biotite migmatite is inferred to be derived from greywacke and interbedded greywacke and mudstone. The age of the sedimentary protolith is equivocal although it is thought to be Archean, and may be equivalent to similar metasedimentary rocks in Nunn *et al.'s* (1990) eastern Supracrustal unit. These rocks, which occur to the east of the study area, are of known Archean age.

The Overflow group contains a very minor amount of mafic gneiss, which is best exposed at 391379E, 6014185N. Contact relations between the biotite migmatite and the mafic gneiss are undefined. The mafic rocks are typically well layered and have a gneissosity defined by percentage of mafic minerals. The rocks are composed of variable amounts of hornblende, clinopyroxene, biotite, plagioclase and minor amounts of quartz. Garnet occurs locally. Outcrops contain up to 20 percent tonalitic leucosome that contains minor amounts of hornblende and biotite.

The mafic gneiss contains several occurrences of metamorphosed chert–magnetite iron formation and thin layers of white- to grey-weathering quartzofeldspathic gneiss. Locally, the unit is intruded by metadiorite dykes, which have a distinctive spotted texture, defined by coarse-grained porphyroblasts of hornblende that armour the clinopyroxene.

The mafic gneiss is presumed to be derived from mafic volcanic rocks based on its association with the biotite migmatite and the occurrences of interlayered iron formation. The layers of quartzofeldspathic gneiss are inferred to be derived from felsic volcanic rocks.

Tonalite–Tonalite Gneiss (Unit 2)

The tonalite–tonalite gneiss unit is a moderate heterogeneous division consisting of foliated and, in many cases, gneissic tonalite and lesser amounts of quartz diorite and diorite. The contact relations between the various phases are commonly undefined, although in some outcrops, it appears that the more mafic diorite and quartz diorite components are younger than the tonalite, and occur as inclusions and lenses within the tonalite. The unit also includes local inclusions of Overflow group metasedimentary rocks.

The tonalite is typically white- and black-weathering, fine to medium grained and has a granoblastic texture. Layering is defined by the percentage of mafic minerals. The rocks contain biotite, hornblende and local clinopyroxene. Locally, they are waxy olive-green and black on the fresh surface, a characteristic of granulite-facies rocks, and may contain orthopyroxene. The rocks are locally migmatitic and contain less than 40 percent, white-weathering leucosome.

Granitoid Gneiss and Migmatite (Unit 3)

The granitoid gneiss and migmatite unit is characteristically very complex and lithologically heterogeneous at all scales, and can perhaps be best described as being homogeneous in its heterogeneity. It consists chiefly of combinations of pink- and grey-weathering granitoid gneiss, but also includes foliated and variably gneissic granitic rocks. Some of the latter granitic rocks may be equivalent to rocks that elsewhere have been mapped as separate units (see Units 4 to 6). The age relations between the different rock types that make up the unit are uncertain, partly because the unit is poorly exposed, especially in areas west of the De Pas batholith and in the northeastern part of the study area, and partly because of the ambiguous nature of exposed contacts.

In the Overflow Lake area, the unit is mainly a pink and grey granitoid gneiss consisting of variable amounts of grey biotite-bearing paleosome, and layers and anastomosing sheets of pink or white leucosome of several ages (Plate 1). The rocks contain mafic xenoliths and deformed amphibolite dykes, and variably deformed granitic dykes. The granitoid gneiss contains biotite and commonly hornblende; locally orthopyroxene occurs.

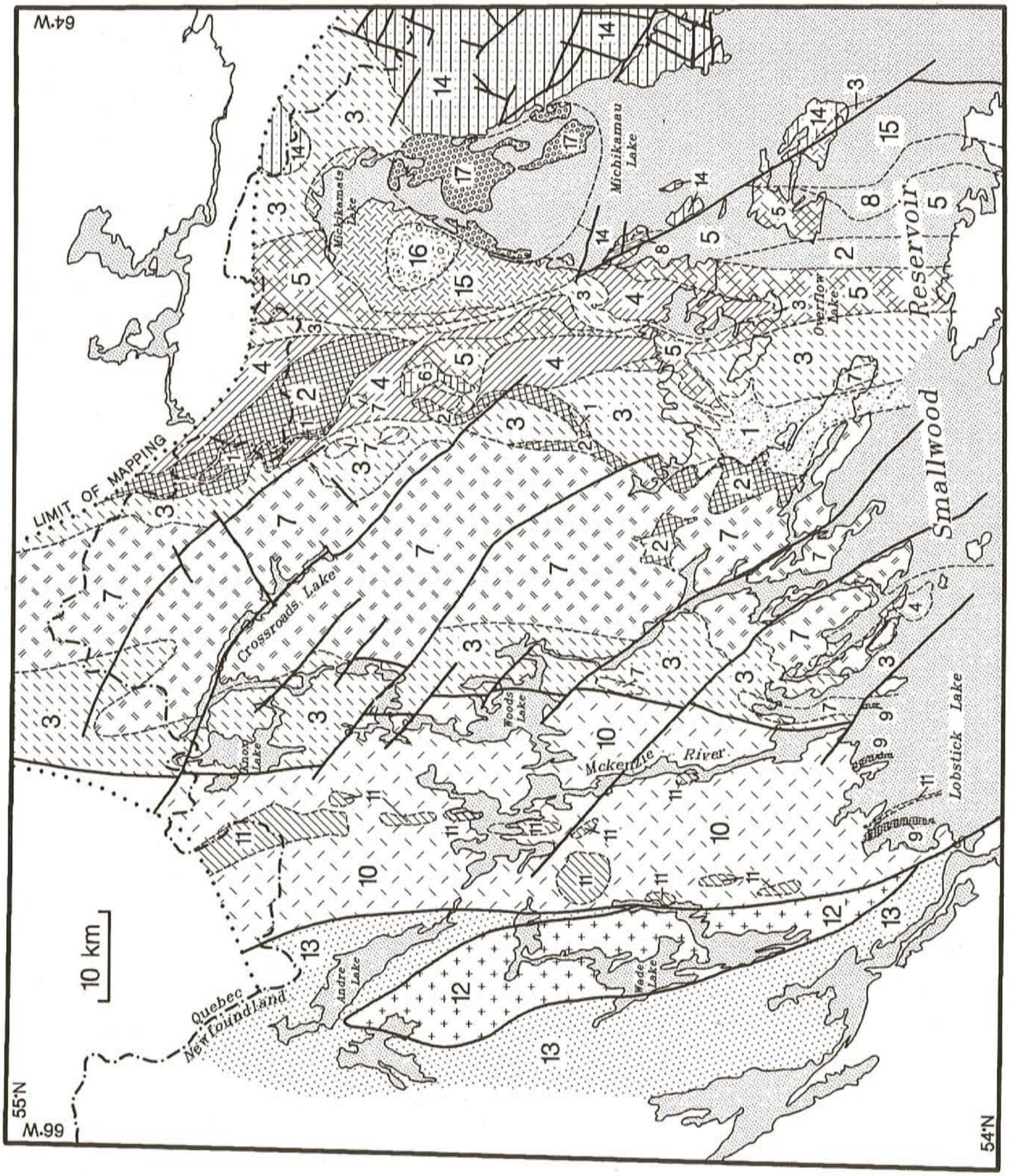
In the areas north and east of Michikamats Lake, the unit is principally a grey- to white-weathering monzogranite to granodiorite gneiss. The rocks consist of a grey paleosome containing biotite and local hornblende, and variable amounts of white leucosome. North of Michikamats Lake, where these rocks are highly strained, the unit is a grey, porphyroclastic gneiss.

West of the De Pas batholith, the unit is markedly heterogeneous and consists of pink and grey granitoid gneiss, foliated and gneissic granitoid rocks including granite, quartz monzonite and monzonite, and gneisses that contain a myriad of mafic inclusions, disrupted mafic dykes, pyroxenite blocks and biotite–garnet migmatite xenoliths. The gneisses that contain the abundant mafic blocks and dykes appear to be most common near the tectonic contact with the Western zone. North of Knox Lake and Crossroads Lake, the gneisses locally contain orthopyroxene. The ages of the rocks included in Unit 3, in the area west of the De Pas batholith, are unconstrained. It is possible that some of the foliated and gneissic granitoid units could be gneissic equivalents of De Pas batholith rocks.

Granite, Megacrystic Granite and Syenite (Units 4 to 6)

Three units of compositionally and texturally distinct foliated granitoid rocks have been mapped; these are granite (Unit 4), megacrystic granite (Unit 5) and syenite (Unit 6). Age relations between these three units are undefined, although it appears that the units are related, with only slight textural and compositional variations between units noted. The contacts between the units are diffuse zones in the field.

The rocks in the three units are pink-weathering, variably foliated and, locally, gneissic. The granite (Unit 4) is fine to medium grained and variably recrystallized but mainly has a granoblastic texture. It contains biotite and only local hornblende. The composition is moderately varied from monzogranite to syenogranite and the unit contains minor amounts of quartz monzonite. The megacrystic granite has a similar compositional variability and contains K-feldspar phenocrysts up to 4 cm in diameter. The phenocrysts are variably recrystallized, and where recrystallization and foliation is strongest, the rocks have an augenitic texture.


64°W
LIMIT OF MAPPING
Michikamats Lake
Michikamau Lake
Overflow Lake
Smallwood Reservoir
Crossroads Lake
Woods Lake
Knox Lake
Mckenzie River
Lobstick Lake
Andre Lake
Wade Lake
10 km
Quebec
Newfoundland
55°N
66°W
54°N

LEGEND

Middle Proterozoic – anorogenic
17 *Seal Lake Group*
16 *syenite*
15 *Michikamats granite*
14 *Michikamau Intrusion*

FORELAND ZONE – NEW QUEBEC OROGEN

Early Proterozoic
13 *Knob Lake Group*

Archean
12 *orthogneiss*

HINTERLAND ZONE – RAE PROVINCE

Western Zone

Archean and Early Proterozoic
11 *gabbro and amphibolite*
10 *Western Tonalite*
9 *Lobstick group*

Central Zone

Early Proterozoic
8 *Petscapiskau Group*
7 *De Pas batholith*

Archean
6 *syenite*
5 *megacrystic granite*
4 *granite*
3 *granitoid gneiss and migmatite*
2 *tonalite, tonalite gneiss*
1 *Overflow group*

geological contact
fault
bedding
principal foliation
minor shear zone

Figure 4. *Geological map of the study area.*

Plate 1. *Typical field aspects of an outcrop of granitoid gneiss (Unit 3) containing two phases of leucosome. The younger phase postdates the formation of folds in the older phase. (DJ-93-5232)*

The syenite (Unit 6) is also megacrystic, although there are some occurrences of medium-grained isotropic rocks in the unit. The syenite contains hornblende and, locally, biotite and clinopyroxene.

Other Intrusive Rocks

The Central zone also contains some other bodies of intrusive rocks that are not shown on the map because of their small size. These include pods of gabbroic anorthosite, mafic dykes of several ages, and small granitic bodies and dykes that postdate some of the mafic dykes.

The pods of gabbroic anorthosite are most common in the tonalite gneiss unit (Unit 2) in the northern part of the Central zone. The rocks are white-weathering, fine to coarse grained and composed of plagioclase and 10 to 20 percent hornblende that overgrows clinopyroxene. The pods are poorly exposed, but are considered to be several tens of metres wide and form lenticular bodies. They may represent structurally dismembered, elongate gabbroic anorthosite intrusions or they may be xenoliths. These rocks are not found within any of the younger units in the Central zone.

The Central zone includes at least two sets of amphibolite dykes that can be distinguished on the basis of composition and crosscutting relations. Both sets of dykes are foliated and deformed (Plate 2). The older set is typically black-weathering and fine grained. The younger set is grey-weathering and commonly has medium-grained hornblende porphyroblasts.

The Central zone also includes several occurrences of a pink, recrystallized biotite–monzogranite, which postdates the amphibolite dykes described in the preceding paragraph. The granite forms dykes and intrusions of uncertain dimension. This granite can only be distinguished from the Unit 4 granite where the former is observed to cut either the mafic dykes or folds that are recognized in Unit 4 granite.

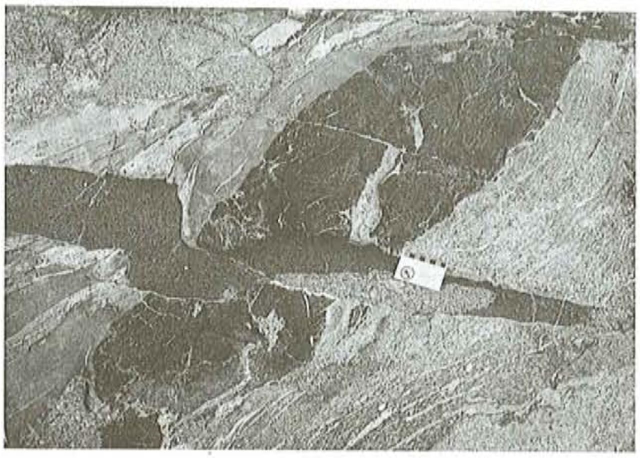


Plate 2. *Example of two mafic dykes, which postdate the gneissosity in the host gneisses (Unit 3), but are themselves deformed and metamorphosed by a post-dyke tectonothermal event. (DJ-93-2320)*

De Pas Batholith (Unit 7)

The Central zone includes the southern end of the De Pas batholith. In the study area, the batholith is a composite pluton that consists of variably recrystallized and foliated K-feldspar megacrystic granite and charnockite, isotropic granite and granodiorite, syenite, and megacrystic quartz monzonite and monzonite. The unit has not been further divided into subunits or individual intrusive bodies. Several small satellite plutons of megacrystic granite, located on either side of the main batholith, are correlated with the De Pas batholith on the basis of similarity of composition, texture and state of strain.

The unit mainly consists of grey- to pink- to orange-weathering, K-feldspar megacrystic syenogranite and monzogranite containing less than 10 percent biotite and hornblende. The rocks contain up to 25 percent, subhedral to anhedral, prismatic K-feldspar megacrysts, which are typically about 5 cm long, and have a fine- to coarse-grained groundmass (Plate 3). Magnetite is a common accessory mineral. In outcrops where recrystallization is extensive, rocks develop a weak gneissic or augenitic texture defined by aggregates of recrystallized and elongated K-feldspar megacrysts. Where rocks preserve a phaneritic texture, they locally contain a foliation, which is defined by alignment of the megacrysts, which is suspected to be a relict or accentuated igneous lamination.

Charnockitic rocks occur throughout the main batholith but they appear to be most common in its central and eastern parts. Petrographic studies and re-examination of the hand specimens will be required to delineate the areas underlain by charnockite and by the other rock types, with greater confidence.

The De Pas batholith is in intrusive contact with Units 1 to 3, and postdates formation of the gneissosity in these units. The western margin of the batholith has been overprinted by ductile, high-strain zones that deform the De Pas granite and the gneisses to the west. The age, kinematic sense and significance of the tectonic contact are unknown but the high strain may be coeval with the high strain along the boundary between the Central and Western zones.

Plate 3. *Example of massive, K-feldspar megacrystic quartz monzonite from the De Pas batholith. (DJ-93-5140)*

The rocks in the De Pas batholith are cut by two sets of weakly recrystallized and undeformed mafic dykes that have north-northeast and east-northeast strikes. The dykes could be Early or Middle Proterozoic in age.

Petscapiskau Group (Unit 8)

Metasedimentary rocks belonging to the Petscapiskau Group (Emslie, 1970) occur in several locations near the western margins of the Michikamau Intrusion (Unit 14) and the Michikamats granite (Unit 15). In the study area, the group consists of variably metamorphosed greywacke, pelite (mudstone), quartz wacke and quartzite. Greywacke is the most common rock type in the northern part of the area (approximately 408365E, 6025694N UTM coordinates, Plate 4), whereas quartz wacke, pelite and quartzite are the most common rocks in the southern part of the area (approximately 418079E, 5989970N UTM coordinates).

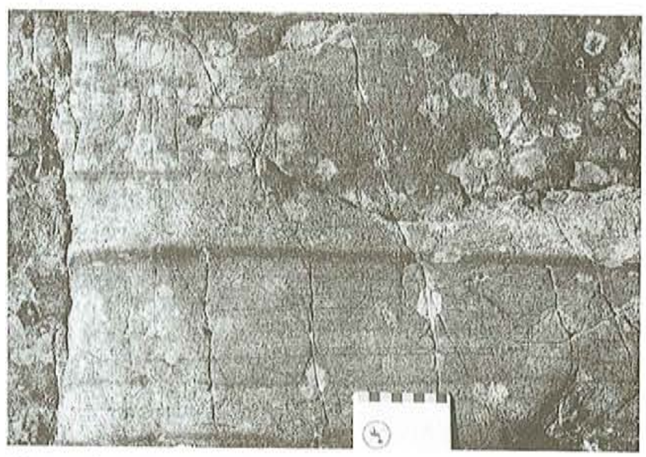


Plate 4. *Petscapiskau Group hornfelsic greywacke containing relict graded bedding. (DJ-93-5093)*

Where greywacke is adjacent to the Michikamau Intrusion, it is metamorphosed to black- to rusty-weathering cordierite–sillimanite–K-feldspar hornfels. Sillimanite forms acicular porphyroblasts up to 5 cm long. In the southern part of the area, where pelite is adjacent to the Michikamats granite, it is metamorphosed to produce silver- and black-weathering phyllites containing local, fine-grained biotite porphyroblasts. Accessory pyrite is common throughout the Petscapiskau Group.

Contact relations between the Petscapiskau Group and the Archean and Early Proterozoic intrusive rocks in the Central zone are undefined, although the sedimentary rocks are inferred to be Proterozoic based on $\in$Nd isotopic data obtained from a Petscapiskau Group metavolcanic rock (Kerr *et al.*, 1992). The Petscapiskau Group is intruded by the Michikamau Intrusion and the Michikamats granite.

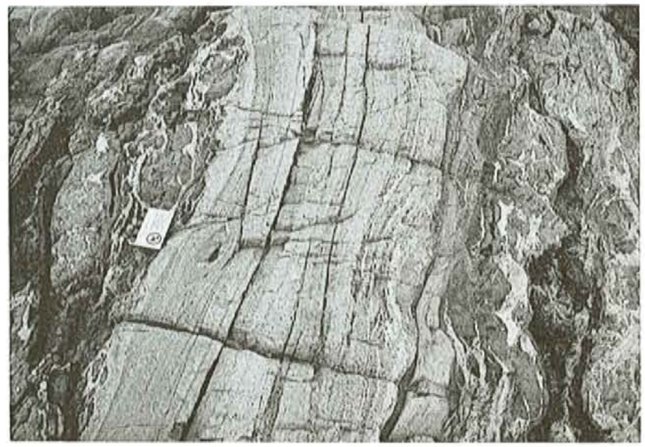


Plate 5. *Lobstick group quartzite (centre) interlayered with quartzofeldspathic rocks inferred to be derived from impure siliceous carbonate sediments. (DJ-93-5129)*

WESTERN ZONE: ARCHEAN AND LOWER PROTEROZOIC UNITS

Lobstick Group (Unit 9)

The Lobstick group occurs in the southwestern part of the study area and is named after exposures on shoreline outcrops in Lobstick Lake (Smallwood Reservoir). It consists of quartzite, pelitic gneiss, marble, impure siliceous carbonate, and a minor amount of amphibolite. The Lobstick group forms thin (<1 km) and locally highly strained belts that are bound by the Western Tonalite (Unit 10). Field relations between the supracrustal belts and the Western Tonalite unit were not observed, although the contacts are thought to be intrusive and locally tectonic.

Plate 6. *Recessive-weathering forsteritic marble (dark layer) containing disrupted layers of quartzofeldspathic gneiss. The marble is interlayered with quartzite (top left of photograph). (DJ-93-5129)*

All of the rock types that make up the Lobstick group can occur in a single outcrop, over several tens of metres. Quartzite occurs in 50- to 100-cm-thick beds (Plate 5). The rocks are completely recrystallized and they do not have relict sedimentary textures. The quartzite is locally interlayered with grey, fine-grained and delicately layered quartzofeldspathic gneiss containing carbonate and diopside. These grey rocks are inferred to be derived from impure siliceous carbonate. White- to brown-weathering marble occurs as layers up to 10 m thick within the quartzite and the grey gneiss (Plate 6). The marble contains local forsterite. Thinner (<5 m) layers of biotite–garnet pelitic gneiss and migmatite, and amphibolite occur throughout the unit.

The age of the Lobstick group is uncertain. These rocks are markedly different from the metasedimentary rocks in the Archean(?) Overflow group, although this does not preclude the Lobstick group from also being Archean. U–Pb zircon studies of the Western Tonalite unit (Unit 10) will provide a younger age limit for the Lobstick group.

Western Tonalite (Unit 10)

The Western Tonalite unit is best exposed on the shore of Lobstick Lake. Outcrops are very sparse in the central and northern parts of the Western zone. The unit typically consists of a white- and black-weathering, upper amphibolite-facies tonalite gneiss. It contains minor amounts of deformed granitic intrusions, amphibolite dykes and inclusions of biotite gneiss of uncertain affinity. The unit also consists of a minor amount of pink- and grey-weathering granitic gneiss.

The unit is moderately heterogeneous and locally consists of two compositionally distinct phases that locally display crosscutting relationships. These are an older, diorite gneiss phase and a younger, more widespread tonalite gneiss phase. The tonalite gneiss has a layering defined by the percentage of mafic minerals, including biotite, hornblende and local, minor amounts of clinopyroxene.

Gabbro and Amphibolite (Unit 11)

The Western zone contains areas of variably recrystallized and deformed gabbro and amphibolite that occur at all scales ranging from dykes (<10 m thick) to elongate bodies up to several kilometres wide. Some of the larger bodies underlie a series of prominent north-trending ridges (e.g., 335446E, 6010209N UTM coordinates) in the Western zone. The unit is poorly exposed and in some cases its presence is inferred from aeromagnetic data; the unit having a relatively high aeromagnetic signature. The gabbro is generally medium grained and non-foliated. Locally, the rocks have a weak igneous layering and a lamination fabric defined by plagioclase laths.

The amphibolite is inferred to be a more highly strained and recrystallized version of the gabbro. The rocks are black- to green-weathering, fine to coarse grained, foliated and locally gneissic. They are composed of hornblende, clinopyroxene and plagioclase.

MIDDLE PROTEROZOIC UNITS

Michikamau Intrusion (Unit 14)

Mapping of this unit in 1993 was restricted to a cursory examination of a small number of outcrops along the western margin of the Michikamau Intrusion. The intrusion has been studied in detail by Emslie (1963, 1970, 1978) and it was not a focus of study for this project. A small satellite pluton of gabbro and anorthosite, which occurs in the northeastern part of the study area, is inferred to be related to the Michikamau Intrusion and was also examined in 1993.

The western margin of the Michikamau Intrusion consists chiefly of undeformed anorthosite, gabbroic anorthosite and gabbro. Petrographic studies will be necessary to determine the amount of olivine that these rocks may contain. The rocks are mainly coarse grained, undeformed and, locally, layered.

The western contact between the Michikamau Intrusion and the older units is a fault in most places. There are only local examples of preserved intrusive relations.

Michikamats Granite (Unit 15)

The Michikamats granite (James *et al.*, 1993a) occurs in two separate bodies along the western margin of the Michikamau Intrusion in the northern and southern parts of the study area. The northern body was mapped in 1992 and the southern body was discovered in 1993. The contacts between the Michikamats granite and the older granitoid units in the Central zone appear to be sharp; the granite does not contain accidental inclusions of the country rocks. The granite does contain a few small inclusions of isotropic, fine-grained granite, which is marginally more mafic than the host Michikamats granite. The granite inclusions are interpreted to be cognate xenoliths.

The unit has a consistent texture and composition. It consists of massive, white- and pink-weathering, K-feldspar megacrystic syenogranite. The K-feldspar megacrysts are elongate to spherical (5 cm in diameter) and in many cases display concentric zoning defined by colour variations. Some of the megacrysts display rapakivi texture. Rocks contain distinctively blue-mauve quartz grains and approximately 10 percent combined biotite, hornblende and accessory magnetite.

Radiometric age dating of zircon and titanite collected from a sample of Michikamats granite (412309E, 6052830N UTM coordinates) yielded an age of 1459 $\pm$ 2 Ma (T. Krogh, unpublished data, 1993). This is interpreted to be the igneous age of the granite.

Syenite (Unit 16)

The central part of the northern body of Michikamats granite is underlain by isotropic syenite and quartz syenite. The rocks are pink- to white-weathering and medium to coarse grained. Commonly they contain K-feldspar megacrysts and approximately 10 percent hornblende that armours a clinopyroxene core. Occurrences of syenite, which contain clinopyroxene (5 percent), but do not contain hornblende, are less common. The rocks also contain minor amounts of biotite and magnetite.

Seal Lake Group (Unit 17)

Middle Proterozoic intrusions and granitic country rocks in the eastern part of the Central zone are unconformably overlain by clastic sedimentary rocks inferred to be equivalent to the Seal Lake Group. The unit is poorly exposed; all of the outcrops are low and flat, and occur chiefly along the shores of Michikamau and Michikamats lakes. The rocks are unmetamorphosed, although beds are slightly tilted and rocks locally contain a weak pressure-solution cleavage.

Outcrops along the west shore of Michikamau Lake consist of pink- to white-weathering quartz arenite and polymictic conglomerate. The arenite is medium grained and thin to medium bedded (2 to 20 cm), and contains local crossbeds and ripple structures. The conglomerate is immature, containing poorly sorted and variably rounded clasts of Michikamats granite and granite gneiss that are up to 30 cm in diameter.

Pink- and white-weathering quartz arenite also occurs on several islands in Michikamau Lake, in the northwestern part of NTS map area 13E/13. The rocks on these islands contain a vertical, east–northeast-striking pressure-solution cleavage that is interpreted to be a Grenvillian structure (see Nunn, 1982).

There are several outcrops of Seal Lake Group conglomerate occurring on islands in the north end of Michikamats Lake. The conglomerate and the unconformity occur mainly near the present level of Michikamats Lake but was also discovered on the peak of a hill (415547E, 6058984N UTM coordinates), approximately 60 m above the level of the lake. The polymictic conglomerate is a completely unsorted, framework supported conglomerate containing variably rounded, spherical to elongate clasts, locally up to 35 cm. Clasts are mainly foliated granite and granite gneiss inferred to be derived from Units 2 to 6. Clasts of mylonitic granitoid gneiss are common.

STRUCTURE AND METAMORPHISM

In the absence of more detailed geochronological and petrographic studies, determining the ages of fabric elements, structures and metamorphic assemblages in the study area is difficult. Rocks in the area may record the effects of Archean, Early Proterozoic (Hudsonian), Labradorian, and Grenvillian tectonothermal events. Hence, the following discussion concerning structural relations, and correlation of structures and metamorphic features, must be considered provisional.

CENTRAL ZONE

The oldest structures in the Central zone, apart from rare occurrences of relict bedding in metasedimentary rocks, are the principal foliation, defined by the metamorphic minerals and recrystallized mineral aggregates, and the metamorphic layering. The rocks in the Central zone (Units 1 to 6) are principally metamorphosed to upper amphibolite facies, although there are a few occurrences of orthopyroxene.

The principal foliation and gneissosity in Units 1 to 6 are mainly north to northeast striking. Several sets of superposed folds, inferred to have formed approximately synchronously with the metamorphic peak, deform the foliation and gneissosity. The youngest set of these folds is consistently southeast trending and moderately plunging. A southeast-trending mineral elongation lineation is common in Units 1 to 6 and, on the basis of its orientation, is inferred to be related to the youngest folding.

Intrusive relations in the Central zone (Figure 5) demonstrate that the gneissic rocks had attained their syn-metamorphic fabrics prior to ca. 1.84–1.81 Ga intrusion of the De Pas batholith. At present, this is the only relation that constrains the age of the syn-metamorphic fabric elements and structures in this zone. Radiometric age dating of gneisses in the Central zone (in progress) will help to resolve this problem.

From west to east across the Central zone, syn-metamorphic fabric elements and structures are progressively overprinted by approximately north-striking protomylonitic planar structures, culminating in a diffuse, poorly defined zone of ductile high-strain, which is centred approximately 2 to 3 km west of Petscapiskau Hill (see 1:250 000-scale topographic map of NTS 23I). No unequivocal kinematic indicators were observed in the high-strain zone. The highly strained rocks are extensively recrystallized and many of the high-strain fabrics are obliterated. The mineral elongation lineations in the zone have shallow to steep plunges. Based on field examinations, upper amphibolite-facies assemblages, which are recognized in lesser strained gneisses outside of the high-strain zone, are not retrogressed in the highly strained rocks. This relation suggests that the high strain was late syn-metamorphic with respect to upper amphibolite-facies metamorphism.

The high-strain structures described in the preceding paragraph lie along strike with the George River shear zone, and on this basis, are inferred to be part of the same structure. The George River shear zone is a dextral transcurrent structure, which persists for 500 km northward to the coast of Ungava Bay. If this correlation is correct, then the high-strain zones in the eastern part of the Central zone are Early Proterozoic and possibly related to final assembly of the hinterland and attendant dextral transpressive deformation along the contact with the New Quebec Orogen (foreland zone). The field relations suggest that deformation in the high-strain zones was synchronous with upper amphibolite-facies metamorphism, and by extension, may suggest that Early Proterozoic metamorphic effects may be more pervasive in some parts of the Central zone than previously appreciated. However, this does not preclude an Archean history of high-grade metamorphism and penetrative deformation.

The foliation in the De Pas batholith rocks is assumed to be Early Proterozoic. It must postdate ca. 1.81 Ga, although its younger age limit is unconstrained. The foliation is mainly north striking and variably developed but is consistently strong along the western margin of the batholith where a zone of protomylonite is developed. The foliation and the eastern contact of the batholith are folded by east- to southeast-trending, open to tight folds. Similar folds are also recognized in the Central zone where they deform small granitic bodies and granitic dykes that have discordant relations to the syn-metamorphic structures in the host gneisses. These folds are apparently unaccompanied by foliation development.

In the De Pas batholith there is a gradual, north-to-south rotation in foliation attitude from north to northwest to, locally, west striking. The change in structural orientation is also manifested by a swing in the regional-scale aeromagnetic anomaly pattern. This change in orientation of structures could be explained by passive reorientation of the Early Proterozoic foliation into an east–west attitude during either the Labradorian or Grenvillian orogenies. A loosely constrained, U–Pb zircon lower intercept age of 1000^{+125}_{-110} Ma from a sample of De Pas granite (Connelly, 1993), which occurs in the southern, 'reoriented' part of the batholith, suggests that the latter interpretation is the more probable.

WESTERN ZONE

Middle to upper amphibolite-facies rocks in the Western zone, including the Lobstick group and the Western Tonalite unit, contain a foliation defined by the metamorphic minerals and recrystallized mineral aggregates, and the metamorphic layering. The foliation is chiefly north to northwest striking, although there are some local variations in this trend. In the central parts of the zone, the foliation in the Western Tonalite unit is relatively shallow dipping and outcrops are commonly characterized by a gently rolling dome-and-basin structure

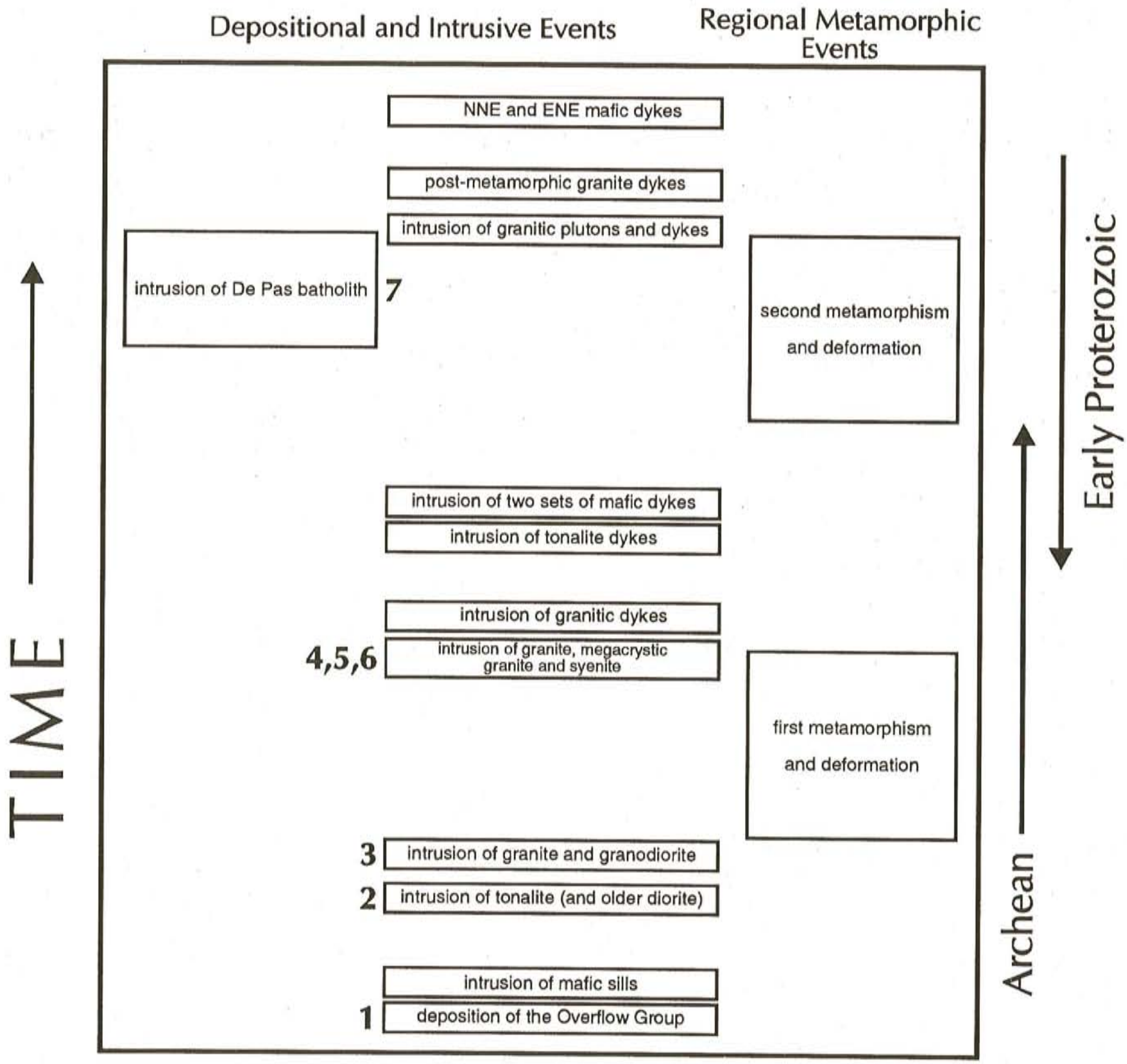


Figure 5. *A provisional, schematic representation of intrusive and tectonothermal events in the Central zone. In the centre and left columns are depositional and intrusive events whose chronological order is constrained by field relations and a minor amount of isotopic data (discussed in text). The De Pas batholith is listed in a separate column because field relations between it and the youngest granitic intrusions listed in the centre column are undefined. Regional tectonothermal events are listed in the right column. In the absence of detailed isotopic age determinations, there is a lot of uncertainty in the extent of Archean and Early Proterozoic events; this is represented by the overlap in the time-lines (right side of the diagram).*

Units 1 to 3 (bold numbers) are pervasively overprinted by a regional, high-grade event that is presumed to be Archean. Units 4 to 6 are thought to be late-syn metamorphic intrusions with respect to this event. Mafic dykes, which are discordant to fabric elements and structures in Units 1 to 6, are themselves deformed and metamorphosed to amphibolite facies. The age of this second metamorphism is unknown, but it may be related to an Early Proterozoic tectonomagmatic event, which resulted in intrusion of the De Pas Batholith and culminated in assembly of the various hinterland tectonostratigraphic elements and suturing with the foreland (New Quebec Orogen).

(Plate 7). From west to east, toward the tectonic contact with the Central zone, the shallow-dipping foliation and dome-and-basin structures are progressively overprinted by a steeply dipping, north-northwest- to north-striking foliation culminating in narrow zones of 'straight' gneisses (Plate 8), which form the contact with the Central zone. The straight gneisses represent extensively recrystallized mylonitic rocks in which high-strain fabric elements and kinematic indicators have been obliterated.

Plate 7. *Typical outcrop of Western Tonalite (Unit 10) containing upright, shallow-dipping down-and-basin structures. (DJ-93-5152)*

Plate 8. *Recrystallized ultramylonite developed in Western Tonalite near the contact between the Western and Central zones. The rocks contain a high-strain, planar fabric (340°/77°) defined by biotite, hornblende and the compositional layering, and a mineral elongation lineation (345°/23°) defined by quartzofeldspathic streaks. (DJ-93-5167)*

The age of the regional metamorphism and the syn-metamorphic fabric elements in the Western Tonalite unit and the Lobstick group are unknown. The age of the north-northwest- to north-striking foliation, which overprints the older structures in the Western zone, is thought to be Early Proterozoic and related to Early Proterozoic assembly of the hinterland and foreland (New Quebec Orogen) zones.

The kinematic sense and significance of the tectonic contacts between the Western zone and both the Central zone and the New Quebec Orogen are uncertain. The potential for these structures to be major, crustal-scale features will be examined using gravity models based on the detailed gravity data collected by G. Kilfoil.

GRENVILLIAN STRUCTURES

The study area contains several sets of structures of possible Grenvillian age apart from the aforementioned rotation in attitude of the foliation in the De Pas batholith rocks. One set includes northwest-striking sinistral faults that have displacements of up to several kilometres. The faults are not exposed and their position and the amount of displacement is inferred mainly from aeromagnetic and topographic lineaments and from offsets of aeromagnetic anomalies and lithologic contacts. The faults are inferred to deform all of the rock units in the study area, including the Michikamau Intrusion, and are tentatively interpreted to be Grenvillian structures. There are numerous examples of regionally persistent, northwest-striking Grenvillian faults in the Lac Joseph and Churchill Falls terranes to the south, and in the Ashuanipi Complex (Superior Province).

A second set of structures are minor, greenschist-facies, brittle to ductile faults, which occur in the southern part of the study area. The character of these structures suggests that they are late, and possibly Grenvillian.

The only penetrative structures thought to be of Grenvillian age were recognized 4 km to the southeast of the study area in NTS 13E/13. These consist of a vertical, east–northeast-striking pressure-solution cleavage in Seal Lake Group quartz arenite.

EXPLORATION POTENTIAL

Based on the rock types present and/or the presence of local occurrences of mineralization, there are five potential settings for economic mineral deposits in the study area.

1) There is the possibility of massive sulphide-hosted Ni–Co mineralization in the Michikamau Intrusion. Mineralization is most likely to occur in thin marginal zones consisting of layered troctolite, olivine gabbro and norite, which occur locally around the intrusion. Sulphide mineralization was observed in one locality (423428E, 6001638N UTM coordinates) near the margin of the intrusion.

2) Sedimentary exhalative (SEDEX) base-metal deposits could possibly occur in the Petscapiskau Group, which consists of clastic rocks and local occurrences of mafic volcanic rocks. There are numerous occurrences of sulphide gossans in the Petscapiskau Group (e.g., 408522E, 6025751N UTM coordinates). The Lobstick group may also have some potential for SEDEX deposits.

3) There is the possibility of gold mineralization associated with the iron formations in the Overflow group metasedimentary rocks. To date, reconnaissance sampling has not yielded any significant gold values from the study area, although this is the same type of environment that hosts small gold deposits in the Ashuanipi Complex, northwest of Schefferville (e.g., Lapointe, 1986).

4) Volcanic-hosted base- and precious-metal deposits may occur in the Overflow group volcanic rocks. The volcanic rocks do not appear to be common, although much of the area in which they occur has been flooded by the Smallwood Reservoir and there may be more volcanic rocks in the Overflow group than can be presently observed.

5) Some of the anorthosite in the Michikamau Intrusion is coarse grained and contains iridescent-blue Labradorite. Some of these rocks may have potential for the dimension-stone industry.

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