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THE ATIKONAK RIVER MASSIF AND SURROUNDING AREA, WESTERN LABRADOR AND QUÉBEC

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ABSTRACT

The Atikonak River massif is a suite of troctolitic, noritic and anorthositic rocks in southwestern Labrador. Spatially related pyroxene quartz monzonite and rapakivi-textured quartz syenite to granite occur with the anorthositic rocks in an association that is common to anorthositic suites elsewhere in Labrador. Areas of paragneiss and K-feldspar porphyritic granite also occur in and around the massif.

Magmatic structures and textures are well preserved in the Atikonak River massif and clearly demonstrate that intrusion of the basic magmas was not accomplished as highly crystalline mushes. Widespread development of mineralogical layering, including graded and cross-bedded varieties, attests to the presence of substantial amounts of liquid at the time of intrusion. Evidence of sub-solidus reaction between olivine and plagioclase is common in crystal cumulates in the massif. At present it is unclear to what extent such reactions took place during cooling of the massif from magmatic temperatures, or are the result of later regional metamorphism.

The massif is rimmed on the northwest side by monzonitic and rapakivi-textured rocks, which are in turn adjacent to paragneiss that is intruded by gabbronoritic and granitoid plutonic rocks. On the southeast side, the anorthositic rocks thermally affect part of a gabbronorite body. In the southeast of the map area, the anorthositic rocks and the amphibolite equivalents of the gabbronorite are intruded by a suite of predominantly equigranular or K-feldspar megacrystic granitoid rocks.

INTRODUCTION

The 1985 mapping program consisted of a joint project by the Geological Survey of Canada and the Newfoundland Department of Mines and Energy. The provincial group continued the regional mapping that was started in 1982 under a series of co-operative programs between the two government bodies. The 1985 field season was the first for this project under the present Canada-Newfoundland Mineral Development Agreement, 1984-1989, aimed at completing the regional mapping of southwestern Labrador. A Geological Survey of Canada team joined the program to assist in the mapping, and as a part of the ongoing study of the anorthositic bodies of eastern Canada.

The map area is equidistant (about 200 km) from Churchill Falls, Labrador City and Sept Îles (Figure 1), and includes approximately 5,900 km^2 of the southern tip of western Labrador. It encompasses NTS map areas 23A/1,2,7 and 8, 22P/15, most of 22P/16 and those parts of 22P/9 and 10 that lie north of the Gulf of St. Lawrence-Atlantic Ocean watershed; mapping was at 1:100,000 scale. The parts of the map area that fell within Québec were given a comparatively cursory examination, with the exception of a few traverses designed to aid in the geological interpretation of the Labrador side of the border.

Exposure throughout most of the upland-dominated, western and southern region is excellent, and in contrast to that in the predominantly lowlying, drift-covered areas in the northern and eastern parts of the map area. Access during this study was by float plane and helicopter.

The first geological description from the map area is given by Low (1896) who studied the area around the southeast corner of Atikonak Lake and the Romaine River in August of 1894.

No further work was done in the area until the 1950's, when BRINEX conducted an exploration program that included geological reconnaissance in 1953 and airborne

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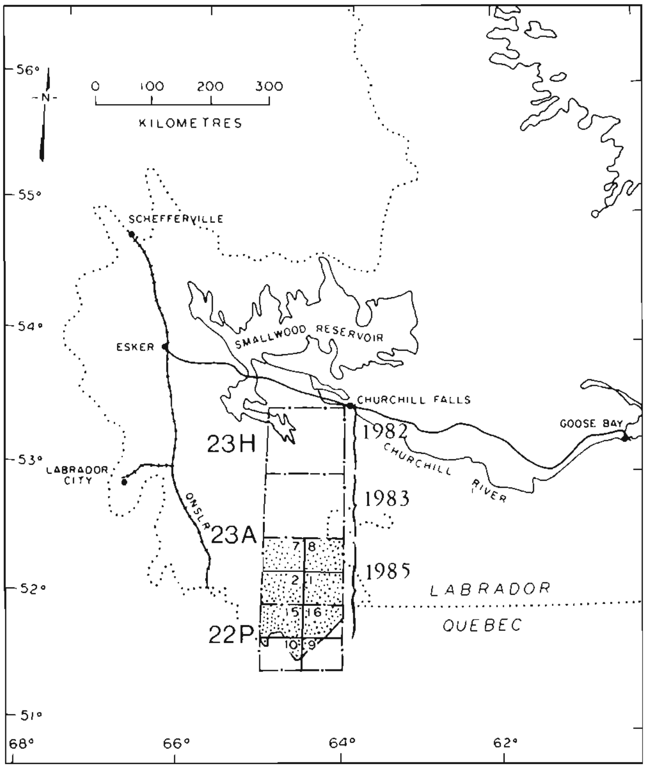

Figure 1: *Location map of the Atikonak River massif, southwestern Labrador.*

geophysics in 1954. Ground prospecting and follow-up work on several anomalies were done in 1956 and the whole program was summarized by Pyke (1956). The anomalies are underlain by anorthositic rocks and numerous, but minor, occurrences of Fe, Ti and Cu mineralization were found throughout the area.

Blais (1960) described similar rocks to those of the Atikonak River massif from the Waco area, 80 km to the southwest, which he called the Waco igneous complex. These rocks lie at the southwestern end of the Lac Fournier massif, which was described by Sharma and Franconi (1975). Earlier reconnaissance mapping of parts of the map area resulted in 1:250,000 scale maps by Stevenson (1968) of 23A and Sharma and Franconi (1975) of the Québec portion of 22P. These maps were incorporated into broader compilations at 1:1,000,000 scale by Greene (1972) and 1:1,500,000 scale by Avramtchev and Marcoux (1980).

The upland core of the map area is underlain mostly by the anorthosite-related suite and its associated granitoid rocks. Anorthositic massifs and their associated intrusions constitute major components of the northeastern Grenville Province (Emslie, 1985). The anorthositic rocks described here are collectively termed the Atikonak River massif, and are a northeasterly extension of the Lac Fournier massif of Sharma and Franconi (1975). The present mapping has shown that, in addition to forming a generally distinctive physiographic feature, the Atikonak River massif is almost completely isolated from similar rocks to the south by older paragneiss and younger granitic intrusions (Figure 3). The aeromagnetic map (Geological Survey of Canada, 1985) indicates that the exposure gap between the Atikonak River massif and the Lac Fournier massif may be underlain by paragneiss rather than anorthositic rocks (as shown on Figure 3) although structural data (Figure 3) suggest that the two massifs are continuous beneath the paragneiss. For these reasons, and to add precision to subsequent description, the new name is introduced in this publication and in a companion report by Emslie *et al.* (1986). Some of the description of the anorthositic rocks is taken directly from the latter report.

GENERAL GEOLOGY

Regional Setting

The map area lies within the Grenville Province between 175 km and 275 km south of the Grenville Front[1] (Figure 2). The bulk of the region to the north, between the Grenville Front and the map area, is composed of high-grade gneisses and temporally related plutonic rocks that are remnants of the late Early Proterozoic Labrador orogen (Thomas *et al.*, *in press*). These rocks were stacked into a parautochthon and a number of overlying allochthons during the Grenvillian orogeny (Rivers and Nunn, 1985) and are assigned, here, to an 'external' zone of the Grenville orogen (Figure 2). The allochthons are part of a chain of structures that form a more or less continuous zone along the strike length of the eastern Grenville Province (Wardle *et al.*, *in press;* Rivers and Chown, *in press*). Near the northern margin of the map area, the Grenvillian metamorphic grade is in upper amphibolite to granulite facies, however, the degree of Grenvillian reworking in the allochthonous terranes is still very uncertain.

The present area lies within an 'interior' zone of the Grenville orogen that stretches south to the Gulf of St. Lawrence (Figure 2), and consists of high-grade gneisses of unknown but pre-Grenvillian age (Wynne-Edwards, 1972; Bourne *et al.*, 1977; Loveridge, 1986), including abundant plutonic rocks. The tectonic and orogenic make-up of this area is poorly understood, but large volumes of massif-type anorthosites are characteristic, represented by the Atikonak River massif within the map area.

Supracrustal Gneisses (Unit 1)

The supracrustal gneisses comprise pelitic to semipelitic paragneiss and minor, thin layers of psammitic paragneiss and basic gneiss. The largest area of paragneiss occurs in the northwestern part of the map area (Figure 3) where it generally consists of a fine to medium grained migmatite that contains centimetre-scale, pink to buff, granitic layers and millimetre-scale, aluminous restite seams and schlieren (Plate 1). The respective mineralogies of the leucosomes and melanosomes consist of a feldspar + quartz ± biotite ± opaque oxide assemblage, and a sillimanite + opaque oxide ± biotite ± garnet ± quartz or plagioclase assemblage (subunit 1a). Biotite is commonly absent or minor in both

[1] Approximate northern limit of Grenvillian ductile deformation in supracrustal cover sequences (Rivers and Nunn, 1985).

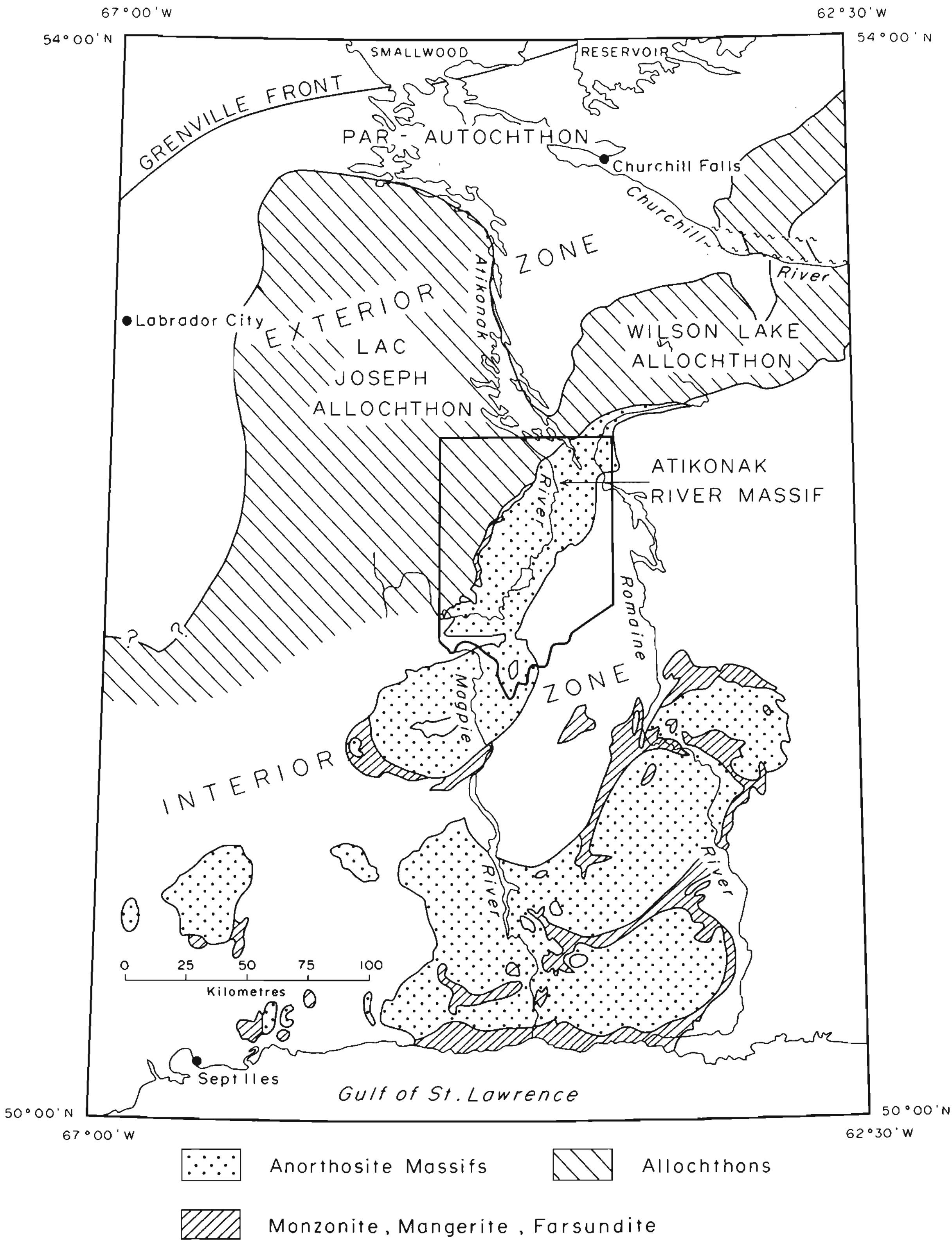

Figure 2: *Regional setting of the map area, within a section across the Grenville Province from the Grenville Front to the Gulf of St. Lawrence. Figure 3 area is indicated.*

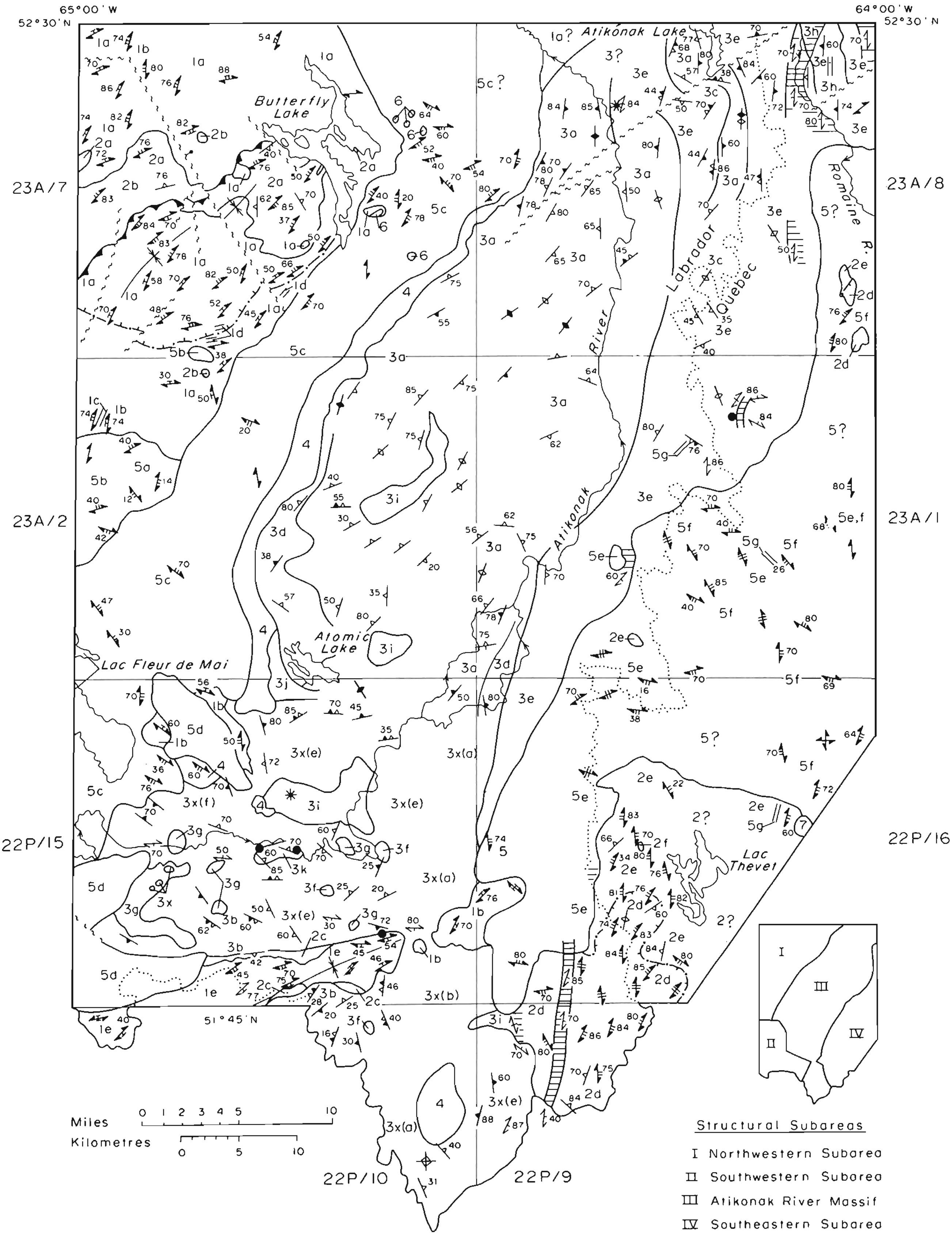

Figure 3: *Solid geology of the Atikonak River massif and its surrounding area.*

LEGEND

HELIKIAN or younger

7 Quartz feldspar porphyry.

HELIKIAN (no chronological order implied)

6 Gabbro.

5 **Granitoid plutonic suites.** 5a, seriate to equigranular, fine to coarse grained granite; 5b, K-feldspar megacrystic quartz monzonite; 5c, rapakivi-textured granite to quartz syenite; 5d, K-feldspar porphyritic,blue-quartz granite; 5e, equigranular, fine to coarse grained granite; 5f, K-feldspar megacrystic granite, quartz syenite and quartz monzonite; 5g, gray, granitic gneiss dikes.

4 Pyroxene monzonite (mangerite) and pyroxene quartz monzonite (farsundite).

3 **Atikonak River massif:** coarse to very coarse grained, mostly igneous and/or corona textured.

Troctolite association: 3a and 3b, layered and laminated troctolite, leucotroctolite and anorthosite.

Transition group: 3c, layered and laminated troctolite, hypersthene troctolite, leucotroctolite and anorthosite with layered and laminated or intergranular-textured norite and leuconorite.

Noritic association: 3d, layered and laminated norite, leuconorite and anorthosite; 3e, layered and intergranular-textured norite and leuconorite with layered (rarely laminated) anorthosite; 3f, seriate, medium to coarse grained, intergranular-textured norite and leuconorite; 3g, homogeneous, very coarse grained, intergranular-textured norite.

Anorthosite groups: 3h, layered and laminated anorthosite, magnetite anorthosite and hypersthene-magnetite anorthosite; 3i, isotropic anorthosite.

Small layered intrusions: 3j, Beaver Pond gabbro - medium grained olivine gabbro, troctolite and gabbro; 3k, medium grained ferrodiorite.

Uncertain association: 3x, structural and textural equivalents of the rest of the Atikonak River massif; complete replacement of ferromagnesian mineralogy by hydrous assemblages.

PALEOHELIKIAN and HELIKIAN

2 **Basic plutonic suites:** medium grained, mostly metamorphic textured. 2a, leuconorite, leucogabbronorite and quartz leuconorite; 2b, gabbro and leucogabbro; 2c, leuconorite and gabbronorite with minor biotite norite and magnetite anorthosite; 2d, leucogabbronorite; 2e, amphibolite and minor ultramafic amphibolite; 2f, serpentinized ultramafic rock.

PALEOHELIKIAN or older

1 **Supracrustal gneisses.** 1a, sillimanite-bearing, biotite-poor, granite-layered, pelitic to semipelitic paragneiss; 1b, more biotite-rich equivalent of 1a; 1c, psammitic paragneiss; 1d, basic gneiss; 1e, 1a-type paragneiss interlayered with sillimanite-free gneiss, commonly cordierite bearing.

SYMBOLS

Geological boundary (inferred)
Fault, tick on downthrown side (inferred)
Thrust, teeth in dip direction (uncertain)
Bedding, tops unknown (inclined)
Igneous layering, tops known (overturned, inclined, vertical)
Igneous layering, tops unknown (subhorizontal, inclined, vertical)
Igneous lamination (inclined, vertical)
Igneous layering and lamination parallel (overturned, inclined, vertical)
Gneissic layering (inclined, vertical)
Mineral foliation (subhorizontal, inclined, vertical)
Foliation and gneissic layering parallel (inclined, vertical)
Foliation in shear zones (inclined, vertical)
Subunit layers (1c, 1d, 5g)
Amphibolite-granulite facies boundary, tick on higher-grade side (approximate)
Shear zone
Synform (inferred)
Provincial boundary
Main mineral occurrences: labradorite
magnetite

the leucosome and the restite, but may also form discontinuous selvages between the two. Locally, in the northwest part of the map area and in gneiss pendants within the plutonic rocks elsewhere in the map area, the restite is characterized by a medium to coarse grained sillimanite + biotite + magnetite ± garnet assemblage (subunit lb).

Plate 1: *Strongly differentiated stromatic paragneiss; alternating layers of granite and sillimanite- and magnetite-rich restite (subunit la). The layering is both isoclinally and openly folded and a steeply pitching lineation associated with the tighter folds is evident. The clinometer is 10 cm long. M&E-GN85-CS8-32.*

The migmatitic paragneiss (subunits la and lb) varies from a rock that has a well defined layering (Plate 1) to one in which the restite forms a discontinuous location fabric (Turner and Weiss, 1963, pages 34-35) within the granitic leucosome. In places, the leucosome has coalesced to form a nebulitic rock or an inhomogeneous diatexite containing randomly scattered remnants of restite. All gradations occur between this and the stromatic migmatite. Later generations of migmatitic material are usually pink, coarse grained, discordant granite veins, but include fine to medium grained aplite or microgranite dikes and veins, and sheets of granodiorite. The discordant veins are commonly quartz rich (ranging to quartzolite), particularly in the northwestern parts of the map area.

Centimetre- to metre-scale layers of psammitic paragneiss occur within the pelitic and semipelitic paragneiss, either as homogeneous, quartzofeldspathic layers or as a finely layered (bedded ?), quartzofeldspathic gneiss containing very thin pelitic laminae. Discordant migmatite is less abundant in the psammitic layers and commonly is very quartz rich. In the west of NTS map area A/2, thinly bedded, quartzose psammites containing thin biotite- and muscovite-rich pelitic laminae occur in a layer 60 m or more thick (subunit lc).

Metabasic rocks are intercalated with the paragneiss sequence. Most commonly they form thin layers, strips, enclaves and boudin trains of green to brown weathering, plagioclase + clinopyroxene ± orthopyroxene metabasite. Several 5 to 50 m thick layers of black, massive to modally layered amphibolite or pyroxene-bearing metabasite are also present (subunit ld). A quartz vein segregation fabric is commonly developed, and at one locality the amphibolites display a discontinuous, pale-green, color banding. These metabasic rocks are thought to be derived from extrusive or hypabyssal protoliths within the supracrustal succession.

Plate 2: *Compositionally and leucosome-layered metabasic inclusions, veined and enclosed in an orthopyroxene-bearing neosome (subunit ld). The clinometer is 10 cm long. M&E-GN85-CS1-32.*

Thin layers of metabasic rock are commonly net veined or sheeted by granodioritic to tonalitic neosomes (Plate 2). In extreme cases, the neosome occurs as centimetre- to metre-scale sheets, which are interlayered with the paragneiss, and contains only scattered metabasite enclaves. The neosomes consist of feldspar + quartz + biotite ± garnet or feldspar + quartz + orthopyroxene ± biotite assemblages.

In the southwestern part of the map area, the paragneiss (subunit le) consists mostly of typical pelitic to semipelitic migmatite, similar to subunit la, which, in areas that are generally close to the contact with Unit 3, contains cordierite as well as sillimanite. This paragneiss is intercalated , on a scale of tens of metres, with sillimanite-free layers in which the restite appears to consist of magnetite and minor biotite and quartz. The sillimanite-free migmatite is either structurally similar to the normal, stromatic paragneiss or is broken up into zones of agmatite in which the layered and folded paragneiss is isolated as numerous, small, close-spaced blocks in a later generation of migmatite. Minor layers of psammitic to semipelitic composition in the paragneiss contain less developed location fabrics than the rest of the sequence, and the restite commonly consists only of cordierite ± magnetite. Many of the rocks are orthopyroxene bearing and are more distinctly brown weathering than the paragneisses in the rest of the map area. Cordierite is dark gray to black, or bluish, and commonly has a vitreous lustre.

The southwestern area of paragneiss contains thin layers of metabasite and discordant, metre-scale sheets of granitic migmatite. It structurally overlies the anorthositic rocks and may be a large roof pendant.

The paragneiss contains dimensionally oriented fabrics and/or polygonal recrystallization textures. The generally lineated, dynamic, restite mineralogy comprises sillimanite, opaques and biotite. In hand specimen, garnet appears to be posttectonic and may be associated with a largely mimetic crystallization of biotite selvages and scattered, coarse grained, sillimanite needles, up to 13 mm by 1 mm in size. The quartzofeldspathic layers are commonly polygonally recrystallized, but may also contain dynamic textural elements, either in the form of a mineral fabric or as shape aggregates.

Basic Plutonic Suites (Unit 2)

The unit consists of two suites that occur on each side of the Atikonak River massif, and a third area of metabasic rock flanking the paragneiss in the southwest part of the map area.

To the northwest is a suite (subunits 2a and 2b) of green and black gabbro (color index, 35-65) and gray leuconorite

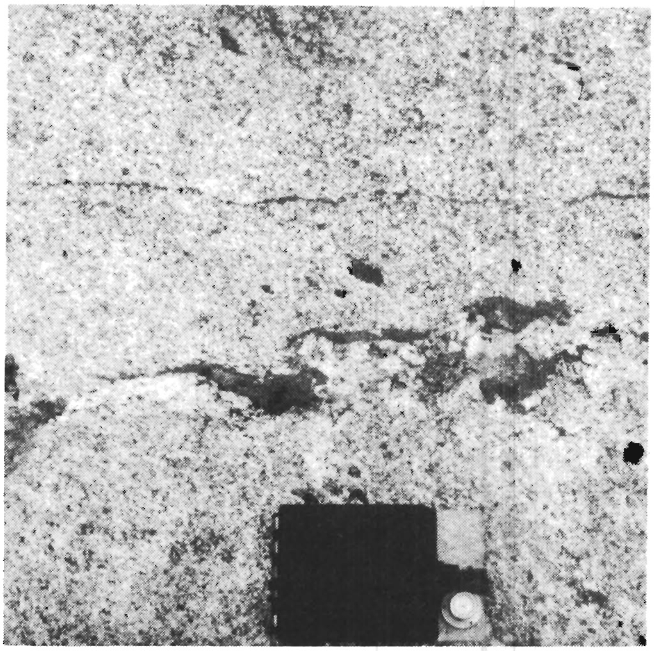

Plate 3: *Medium grained, equigranular leuconorite with a biotite- and orthopyroxene-bearing metamorphic segregation (subunit 2a). The clinometer is 10 cm long. M&E-GN85-CS2-35.*

(Plate 3), leucogabbronorite and quartz leuconorite (color index, 10-35). These rock types are medium grained, massive, and range in texture from relict igneous to strongly lineated. Rarely, the gabbroic rocks (subunit 2b) and the noritic rocks (subunit 2a) are layered. The gabbro contains clots of clinopyroxene that occur in knobbly weathering layers. The noritic rocks contain layers that have a range of textural, grain size and compositional variations, including fine grained, equigranular leuconorite, orthopyroxene porphyroblastic melanorite, and a websteritic rock, as well as layers of the more common rock types. The layering generally occurs on a metre scale. The noritic rocks commonly contain scattered to abundant, generally finer grained, cognate xenoliths, some of which may be disrupted dikes.

Relict igneous mineralogy is found in rare pegmatitic patches in gabbro, in a microgabbro, and in coarse grained anorthosite veins that cut a leucogabbronorite. The microgabbro may be olivine bearing and has an intergranular texture. It appears to grade into a medium grained, plagioclase-biotite metamorphic rock. The remaining mineralogies are metamorphic and generally form a plagioclase + pyroxene + biotite ± quartz assemblage that has a weak, linear, mineral fabric. The rocks commonly contain coarse grained, metamorphic segregations of similar composition to the host (Plate 3), locally containing quartz. Rarely, the leucogabbronorite contains a few, scattered K-feldspar porphyroblasts.

Granitoid veins cut the suite and range from alkali-feldspar granite to tonalite in composition, and include rare, layered, muscovite granite pegmatite. Veins at the granitic end of the spectrum locally contain tourmaline; those of granodioritic to tonalitic composition commonly contain orthopyroxene and, more rarely, garnet. Textures in the veins range from igneous to metamorphic. Parts of the veins, particularly the margins, are commonly strongly rodded and locally appear much more deformed than their metabasic host. The quartz leuconorite is more intensely foliated than the quartz-free noritic rocks, and flattening of the usually random or net-veined nature of the granite veins has produced a layered rock in places.

The presence of the quartz-bearing rock types suggests that the noritic part of the suite may represent a diorite - quartz diorite protolith.

The northwestern basic plutonic suite intrudes, and encloses xenoliths of, the supracrustal basic gneiss (subunit 1d), and is presumed also to intrude the paragneiss sequence since these gneisses are normally interlayered.

Metabasic rocks (subunit 2c) flank parts of the paragneiss in the southwestern pendant. They consist of fine to medium grained, equigranular leuconorite containing layers of gabbronorite and biotite norite. A distinctive layer of cumulate-textured magnetite anorthosite, containing centimetre-scale, oval augen of polygonal plagioclase in a discontinuous groundmass of magnetite, occurs in the metabasite sequence on the north side of the pendant. The metabasic rocks are concordant with the paragneiss in the pendant and are cut by leuconorite dikes of Unit 3.

The southeastern basic plutonic suite comprises a light-colored, dark-spotted leucogabbronorite (subunit 2d) and black amphibolites (subunit 2e), together with some minor rock types. The leucogabbronorite is fine to medium grained, equigranular, and contains a largely dynamic, metamorphic mineralogy, although relict igneous textures are preserved normal to the lineation in areas of low strain. Rare compositional variations in the leucogabbronorite consist of diffuse layers of slightly different color index (Plate 4) and more obvious layers of gabbronorite. Plagioclase-bearing pyroxenite layers seem to parallel these variations, and may be igneous layering or dikes. Dikes of mafic to ultramafic amphibolite cut the layering (Plate 4), and hairline fractures containing either felsic or mafic minerals are also present. These features are best preserved in the low-strain areas where they are folded and at high angles to the foliation; throughout most of the leucogabbronorite they are attenuated and subparallel to the foliation. In the southwest of its outcrop area, the leucogabbronorite is a dark gray, compact, equigranular rock and is thought to be a hornfels adjacent to the anorthosite.

Plate 4: *Diffusely layered and foliated leucogabbronorite with a crosscutting dike of foliated amphibolite (subunit 2d). The amphibolite contains an oriented shape fabric of polygonal plagioclase after plagioclase phenocrysts. The clinometer is 10 cm long. M&E-GN85-CS5-30.*

The amphibolite (subunit 2e) is a medium grained, foliated rock with a predominantly LS mineral fabric of hornblende and plagioclase (Plate 5). Rare compositional variations may represent relict dikes or layering (compare Plates 4 and 5). Finer grained, gray, more strongly foliated zones also occur. Locally, subunit 2e consists of plagioclase-biotite rocks and appears to grade into granitoid-layered, tonalitic gneisses. Outcrops of ultramafic and mafic amphibolite, and appinite dikes are rare rock types in the amphibolite assemblage. Two kilometres northwest of Lac Thevet, the amphibolite contains an area of approximately 250 by 150 m of serpentinized ultramafic rock containing clinopyroxene-rich patches and discontinuous layers (subunit 2f).

Plate 5: *Veined (white area above pencil) and foliated amphibolite (subunit 2e) containing an earlier compositional layering (compare with Plate 4). The pencil is 10.5 cm long. M&E-GN85-CS6-10.*

Subunits 2d and 2e underlie predominantly upland and lowland areas respectively. However, the relationship is not a simple spatial one, i.e., areas of gabbronorite occur within the amphibolite and amphibolite locally underlies the upland periphery.

Throughout its outcrop area the amphibolite is cut by dikes and net vein systems related to Unit 5.

The Atikonak River Massif (Unit 3)

Major rock types of the Atikonak River massif include leucotroctolite (color index, 10-25), troctolite (color index, 25-50), leuconorite (color index, 10-25), norite (color index, 25-50), and anorthosite (color index, <10). A preliminary division of the massif is made on the basis of ferromagnesian mineralogy, resulting in troctolitic and noritic associations. Within these associations further subdivision is attempted using composition, structure and texture, although relationships between and within each association are commonly very complex. Subsequent alteration of the primary ferromagnesian mineralogy makes division impossible in some areas. Large masses of true anorthosite are distinctly subordinate parts of the massif. Substantial parts of all subunits are essentially massive with little variation in mineral proportions or grain sizes.

Troctolite and leucotroctolite (subunit 3a), typically with more plagioclase-rich interlayers that include anorthosite (Plate 6), form dominant rock types in the better exposed

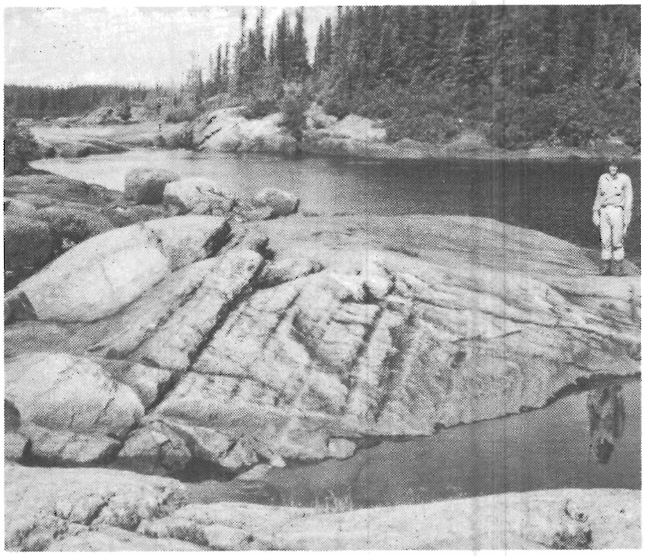

Plate 6: *Leucotroctolites (subunit 3a); layered section dipping westerly at a moderate angle in outcrops along the Atikonak River. GSC-203423-L.*

upland area north and west of the Atikonak River. These occur with separate leuconorite and norite layers and areas (subunit 3d) that also contain anorthosite interlayers. Both subunits exhibit a considerable variety of structures and textures; they are broadly characterized by modal layering (Plates 6 and 12) and variably developed igneous lamination (Plate 13), but massive and isotropic layers occur, particularly in subunit 3d to the north of Atomic Lake. Mineral layering several centimetres to several metres wide is widespread, and is displayed particularly well in burned-over areas and along larger rivers (Plate 6). Plagioclase is usually dark gray to black and the rocks are dark gray on both fresh and weathered surfaces. The feldspar forms mostly tabular crystals 1 to 5 cm across, but layers of considerably greater grain size are common. The grain size of individual mineral species is usually homogeneous throughout a layer but grain-size grading also occurs. Orthopyroxene is commonly a subordinate or minor constituent of the troctolitic association. Within any one layer, the ferromagnesian minerals are usually evenly distributed, however, mineral grading and more rarely cross-bedding and slump features are present in subunit 3a.

To the east of the uplands, topographically lower areas are underlain largely by rocks of noritic association (subunits 3e and 3h). A layer of troctolitic association rocks (subunit 3a), 1 to 4 km wide, occurs along a strike length of 18 km within the noritic rocks, about 6 km east of the main contact between subunits 3a and 3e. Locally, a transitional group (subunit 3c) occurs between this layer and subunit 3e. The transitional group consists of decimetre- to metre-scale interlayering of laminated troctolite and leucotroctolite, with anorthosite, leuconorite and norite that are either laminated or have an intergranular texture. Some layers contain both olivine and orthopyroxene.

The noritic association in the eastern part of the map area consists of layered norite, leuconorite and anorthosite (subunit 3e). Layering occurs on decimetre- to metre-scales but is commonly indistinct within an outcrop; rather, compositions vary between groups of outcrops, and in the better exposed northern parts of this subunit appear to relate to layering on a kilometre scale. Mineral grading is present in some of the more finely layered parts of the sequence. Anorthosite layers are locally laminated, but in contrast to subunit 3d, the orthopyroxene-bearing layers nearly everywhere have an intergranular texture and are very coarse grained (Plate 7). Plagioclase is commonly irridescent in subunit 3e and opaque oxide pods, clots and layers are most common in this subunit.

Plate 7: *Leuconorite (subunit 3e); randomly oriented, partly recrystallized plagioclase laths with intergranular orthopyroxene and scattered patches of coarser grained orthopyroxene. The hammer is 33 cm long. M&E-GN85-CS6-16.*

A 3 to 4 km thick, laminated anorthosite (subunit 3h) is intercalated with subunit 3e in the northeastern corner of the map area. The anorthosite is characterized by red-brown, 1 to 4 cm long plagioclase and sporadic, decimetre-scale, oval patches of intercumulus magnetite and minor orthopyroxene.

Alteration of the ferromagnesian minerals and corona development are abundant throughout the northern map sheets (NTS area 23A), particularly in the lower-lying northern and eastern parts. It is generally possible to differentiate between troctolitic and noritic association rocks using relict mineralogy, unaltered cores, differing types of coronas and pseudomorphs, and texture. In the south, however, these features are commonly not distinct enough, and large areas of unknown or uncertain affinity (subunit 3x) are indicated together with their possible protoliths (in parentheses on Figure 3).

Troctolitic association rocks are either similar to subunit 3a or form subunit 3b in the south of the map area (NTS map area 22P). Subunit 3b comprises anorthosite containing patches of troctolite or leucotroctolite, 5 to 20 cm across (giving this rock an overall leucotroctolite composition), and intercalated layers of anorthosite. Rarely, the patches coalesce to form a more or less continuous layering (Plate 8), and clinopyroxene occurs with olivine in one locality. Modal layering of anorthosite and leucotroctolite, containing varying concentrations of olivine-bearing patches, and plagioclase lamination are common; anorthosite generally forms the thicker layers.

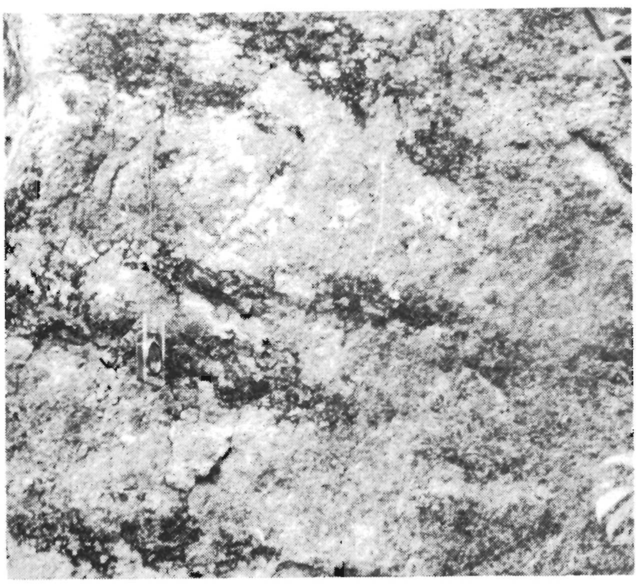

Plate 8: *Anorthosite containing isolated and coalesced patches of troctolite defining a discontinuous layering (subunit 3b). The clinometer is 10 cm long. M&E-GN85-CS4-5*

In subunits 3b, 3e and 3x, plagioclase is commonly bimodal in grain size, and rare, tabular megacrysts up to 40 cm long are scattered in a coarse to very coarse grained groundmass; the megacrysts are aligned parallel to the layering. Thick anorthosite layers, in which layering and lamination may be more common than is apparent because of the monomineralic composition, also occur in these three subunits, and may be related to subunit 3i (see below). These layers commonly contain residual patches of coarser grained, intergranular-textured leuconorite and norite, which suggests an affinity with the noritic associations. Rarely, blocks of leucotroctolite, and oxide pods and layers occur in subunit 3x(e).

Several anorthosite-related bodies occur in the other rocks of the massif. In its southwestern part, the massif is cut by medium to coarse grained, seriate, intergranular-textured norite and leuconorite (subunit 3f), and a very coarse grained, texturally similar, but homogeneous, noritic equivalent (subunit 3g, Plate 9). These rocks are common in and around the Atikonak River valley in this area. Every gradation occurs between isotropically-textured norite and leuconorite containing scattered xenoliths of subunits 3b, 3e and 3x (Plate 10), through increasingly xenolith-rich facies, to a host rock composed of subunits 3b, 3e or 3x that is cut by norite and leuconorite dikes or net-veins. The intrusive rock types are distinctly brown weathering in relation to their dominantly anorthositic xenoliths. Subunit 3i consists of a medium to coarse grained, generally isotropic, anorthosite containing gray to brown, commonly chatoyant plagioclase.

Plate 9: *Very coarse grained isotropically textured norite (subunit 3g); plagioclase is mostly polygonized, some of the orthopyroxene is kinked. The penknife is 9 cm long. M&E-SW85-CS1-34.*

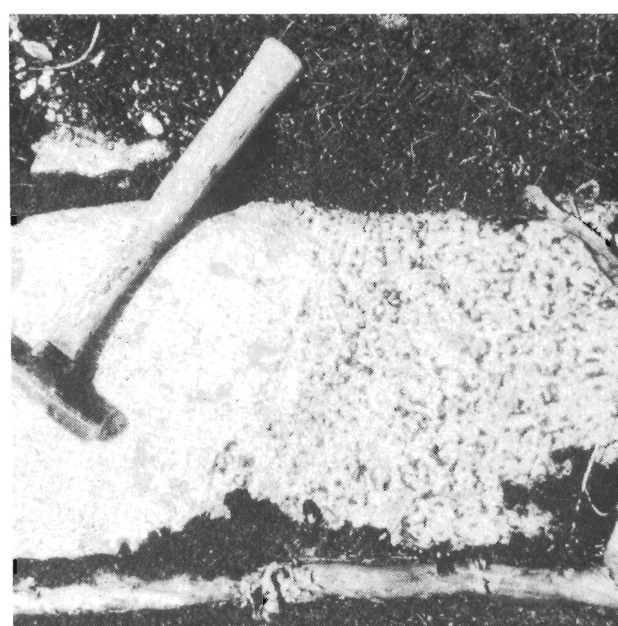

Plate 10: *Medium grained intergranular-textured leuconorite (subunit 3f) containing a laminated anorthosite xenolith. The hammer is 33 cm long. M&E-SW85-CS2-11.*

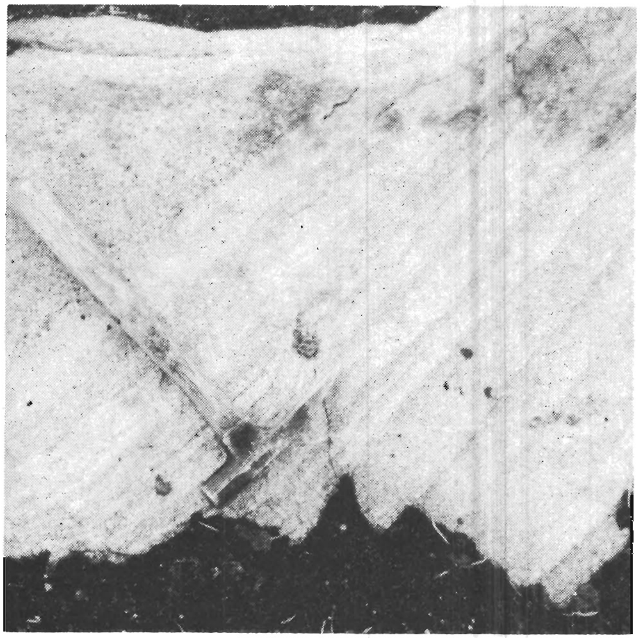

Plate 11: *Layered ferrodiorite (subunit3k), containing centimeter- to decimetre-scale layers of varying color index and rare mineral grading (tops toward the bottom right). The hammer is 33 cm long. M&E-SW85-CS2-9.*

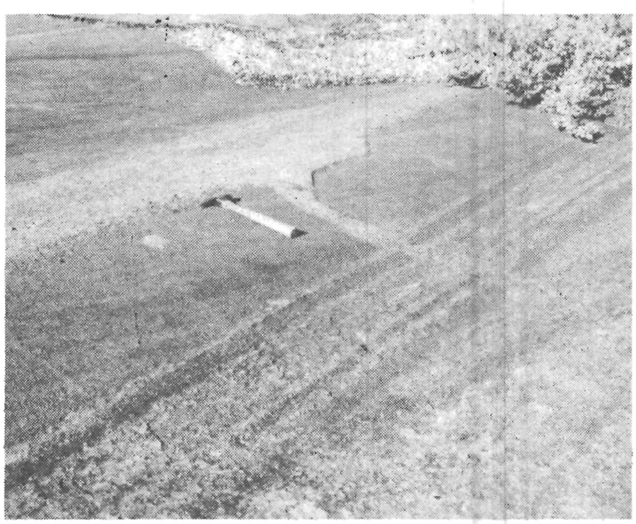

Plate 12: *An appendage from an anorthosite layer cuts across a layered sequence of leucotroctolites and dies out within it (subunit 3a). Layers dip about 55 degrees to the upper left (west); the relationship is consistent with a mild disturbance during bottom crystallization in which an overlying anorthositic cumulate penetrated already consolidated underlying cumulate rocks in a manner reminiscent of clastic dike formation. The hammer is 33 cm long. GSC-203423-M.*

The anorthosite is dark gray in the north (NTS map area 23A), but is light gray to white in the lower-lying exposures farther south (NTS map areas 22P/9 and 15). Lamination is rare and the anorthosite locally contains primary biotite. It is not

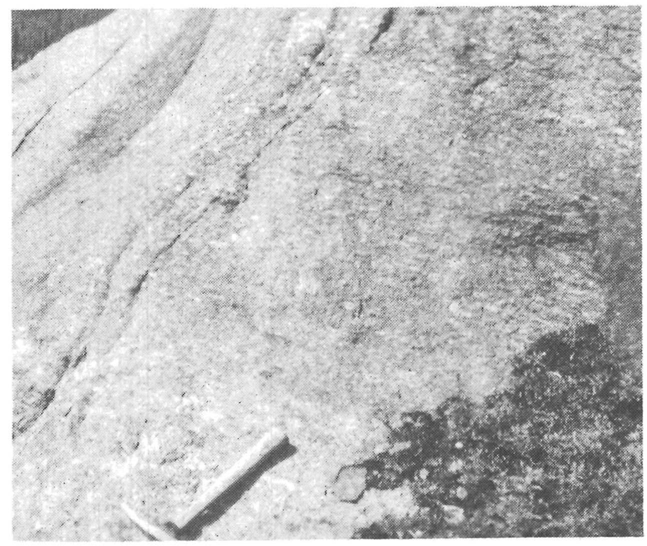

Plate 13: *Strong planar plagioclase orientation in a coarse grained troctolite layer overlying a very coarse grained anorthosite layer, also with marked planar plagioclase orientation (subunit 3a). The hammer is 33 cm long. GSC-203423-G.*

known whether this subunit is intrusive or whether some or all of the occurrences are large xenoliths.

A medium grained, layered intrusion containing olivine gabbro, troctolite, and gabbro is named the Beaver Pond gabbro (subunit 3j). Local pyroxene- and oxide-rich pods or disrupted layers in the intrusion contain up to several percent sulfides, including pyrrhotite and chalcopyrite. The Beaver Pond gabbro appears to intrude coarse grained leucotroctolite (subunit 3a) and is intruded by pyroxene monzonite (Unit 4).

Ferrodiorite forms another small, discrete pluton (subunit 3k, Plate 11). It is a fine to medium grained, light-brown weathering rock rich in magnetite and orthopyroxene, with a well developed, commonly contorted layering. The ferrodiorite contains a xenolith of anorthosite and is intruded by dikes of norite (subunit 3f).

Internal structures of the massif. Mineral layering, commonly accompanied by moderate to strong sub-parallel planar plagioclase lamination, is developed to some degree in nearly all of the subunits of the massif (Plates 6, 8, 10, 11, 12 and 13), excluding only subunits 3f, 3g and 3i. In addition, layers defined by differences in plagioclase grain size and shape occur independently and in association with mineral layers (Plate 13). Examples of mineral- graded layers (Plate 11), grain-size-graded layers, cross-bedded layers, and apparent slump features all occur in different localities. Modal contrasts between adjacent layers are commonly subtle, involving variations of less than 20 percent in amounts of mafic components present (e.g., lower right in Plate 12). Locally, however, stronger contrasts occur and melatroctolite (color index, >50) and oxide-rich layers are present in a few localities.

Mineral grading determinations consistently indicate tops to the east in the east part of the map area, within subunit 3e. This indicates that the orthopyroxene-bearing subunits 3e and 3h probably overlie subunits 3a and 3d, and that the transition group (subunit 3c) and rare layers of subunit 3a occur near the base of subunit 3e. The layered, equigranular-textured noritic rocks (subunit 3e) could either be a precursor to the cross-cutting noritic rocks in NTS map area P/15 (subunits 3f and 3g), or be fed by them.

Planar plagioclase orientation is commonly developed in rocks that lack mineral layering and is present in olivine- and orthopyroxene-bearing rocks, as well as nearly pure plagioclase rocks (Plate 13). Where sections subparallel to dip surfaces are exposed, it can be seen that plagioclase crystals are plate-like or discoidal, and in places are packed closely together like brickwork with only very small amounts of interstitial material. Planar plagioclase orientation occurs in rocks of grain sizes less than 1 cm to greater than 30 cm, and it locally occurs either throughout a layered section, or is limited to specific layers and is absent or much more weakly developed in intervening layers.

Oxide-rich pods, clots and layers (up to 1 m thick) occur locally, mostly in subunits 3e, 3j and 3k, and most are strongly magnetic, indicating a preponderance of magnetite over ilmenite. Opaque oxide minerals are usually the second most abundant mafic constituent present in any one lithotype and disseminated grains of oxide are visible in many specimens. In subunit 3h magnetite is the predominant mafic mineral; orthopyroxene is subordinate. Clots of massive opaque oxide up to 30 cm across occur sporadically in some noritic and leuconoritic outcrops, in places closely associated with coarse grained orthopyroxene and small amounts of sulfides.

Complex interrelationships occur among subunits on a local scale. A consistent relationship in the northwest, however, is that xenoliths of coarse grained to very coarse grained anorthosite and leuconorite are present in many outcrops of troctolite and leucotroctolite. Xenoliths range in size from less than 1 m to at least 10 m across and are possibly much larger. These relationships clearly show that orthopyroxene-bearing rocks predate and postdate the troctolite association, although the latter case is more common at the present level of exposure.

Very coarse grained to 'giant' orthopyroxene crystals occur widely in the massif, commonly ranging from 30 to 60 cm across (Plate 14). These include both rounded or nodular shapes, and crystals subophitically intergrown with plagioclase. Where these large orthopyroxenes are present within sections of olivine-bearing rocks, they occur within very coarse grained anorthosite or leuconorite that is commonly identifiable as xenoliths. Giant orthopyroxenes were not found in direct contact with troctolite or leucotroctolite, implying that they became unstable in silica-deficient magmas at crustal pressures and survived transport only where they are armored by an enclosing xenolith. Very coarse grained, commonly kinked, orthopyroxene crystals also occur in residual patches and as groundmass (heteradcumulate?) plates in subunit 3e.

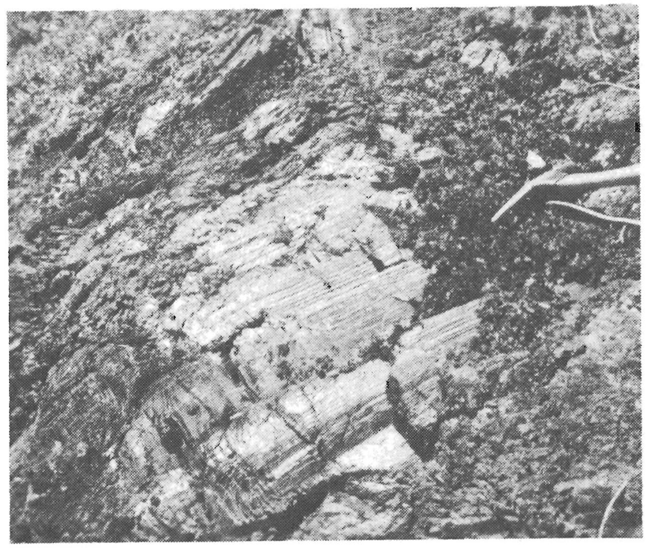

Plate 14: *Strong kink banding in a giant orthopyroxene crystal (subunit 3a); the crystal is over 40 cm across. GSC-203423-I.*

Although layered structures occur widely, the massif does not have an overall coherent pattern of layering. Areas up to 50 km² do show regular attitudes of layering. However, it is not possible to determine to what extent layer domains represent discrete intrusions, as opposed to disrupted, tilted or deformed parts of a larger intrusion because over considerable areas rock compositional changes are subtle. Intrusive relationships are visible in outcrop in many places (e.g., subunits 3f, 3g, 3j and 3k and the many examples of cognate xenoliths in subunit 3a), lending some support for interpreting the massif as a composite of numerous separate intrusions.

Aplite, fine to coarse grained granite and granite pegmatite dikes and veins are common in the massif, particularly in the northeastern and eastern parts of the map area. Some of these relate to the emplacement of the various granitoid plutonic rocks; most, however, probably relate to intrusion of partial melts, generated during regional metamorphism of the envelope to the massif, along tensile or shear fractures in the anorthositic rocks. At one locality the granite veins contain pyrogenetic sillimanite. Some dikes and veins have amphibolite facies alteration halos, up to 10 cm wide, in the anorthositic rocks.

Monzonite-Related Rocks (Unit 4)

Immediately adjacent to the northwestern margin of the Atikonak River massif, and in intrusive contact with it, is a rim of medium to coarse grained pyroxene monzonite, pyroxene quartz monzonite and minor quartz diorite. These rocks are typically brownish to rusty weathering, commonly with a color index of 20-30. Variable amounts of amphibole and biotite accompany, and locally exceed, pyroxene in these rocks. Perthite megacrysts, 1 to 3 cm across, become increasingly abundant away from the massif contact. At one locality, the unit contains a body of finer grained monzonite, which is chilled against the main phase, and a xenolith-rich facies. The xenoliths consist mostly of fine grained and porphyritic equivalents of the main phase in which the K-feldspar phenocrysts closely match those of the host, and also include granoblastic leucogabbroic clasts that look like deformed cumulate rocks. Several small, subequant areas of monzonite occur in southern parts of the map area. Dikes of pyroxene monzonite, ranging from 1 to 30 cm in width, intrude the Atikonak River massif to at least 5 km from the northwestern contact, and more locally around the southern monzonite intrusions.

Granitoid Plutonic Rocks (Unit 5)

Subunits 5a and 5b occur together in the west part of NTS map area A/2; their interrelationship is unknown. Subunit 5a consists mostly of equigranular, fine to coarse grained, pink or maroon, biotite granites that vary in color index from 0 - 10. Anhedral, seriate and saccharoidal primary textures are present and the granites range from undeformed to moderately foliated. Aplite veins are common and the fine to medium grained granites are locally riddled with quartz veins.

Subunit 5b comprises K-feldspar megacrystic granitoid rocks that are chiefly quartz monzonite in composition. The rocks are pink or buff (color index, 3 - 10) and range from undeformed to strongly foliated. Megacrysts, 1 to 3 cm across, occur in a groundmass of quartz, plagioclase, K-feldspar and biotite. Biotite is commonly intergrown with plagioclase, and quartz is commonly moulded on plagioclase in an otherwise anhedral fine to medium grained groundmass. Sphene and allanite are accessory phases; the former is locally abundant. The subunit contains veins of aplite and granite. The small area of megacrystic granite, 9 km northeast of the main outcrop area of subunit 5b, contains inclusions of paragneiss (subunit 1a).

A large mass of coarse grained biotite- and/or hornblende-bearing granite to quartz syenite (subunit 5c) that has a distinctive rapakivi texture formed by plagioclase-rimmed perthite ovoids of 4 cm or more in diameter, lies to the northwest of the monzonitic rim to the Atikonak River massif; in several places subunit 5c appears to be transitional into the pyroxene-bearing monzonitic rocks. Large parts of the rapakivi granite that occur close to the anorthositic massif are essentially massive with negligible deformation of original igneous textures (Plate 15) and variable polygonal recrystallization of the original mineralogy. Farther northwest, the rapakivi texture becomes increasingly obscure, biotite predominates over hornblende, and garnet, commonly associated with opaque oxide grains, is ubiquitous wherever the quartz syenite or granite is recrystallized. Within 6 to 12 km of the massif contact, subunit 5c is penetratively deformed and recrystallized with a shape fabric of polygonal K-feldspar and ferromagnesian-rich clots.

Subunit 5d consists of finely to coarsely K-feldspar porphyritic granite that is characterized by blue quartz. In the finer grained variety, 10 to 40 percent of tabular, gray, K-feldspar phenocrysts are either distributed with random orientation or form a primary foliation in an anhedral, medium grained granite groundmass. In the more abundant megacrystic variety, subequant K-feldspar phenocrysts are

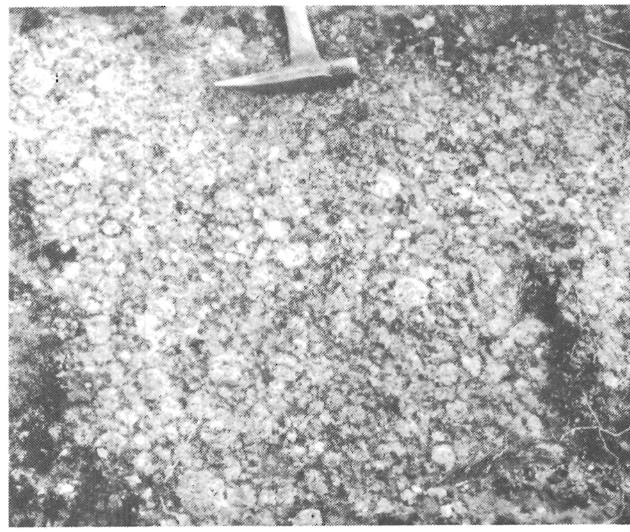

Plate 15: *Coarse grained, ovoid-rich, massive rapakivi granite (subunit 5c). The hammer head is 16 cm across. GSC-203423-J.*

generally a dark purplish gray, 1 to 4 cm across, and commonly form 30 to 60 percent of the rock. Locally, the megacrysts are concentrated in patches, in which the interstitial material is minor, and poorly developed rapakivi textures are also present. The groundmass is medium to coarse grained granite. The granite varies toward quartz-poor compositions and locally contains abundant, fine grained, ovoid xenoliths of dioritic to monzonitic composition. The subunit is cut by coarse to very coarse grained graphic granite dikes and aplite veins. Non-megacrystic, blue-quartz granite, probably related to subunit 5d, forms dikes in the adjacent anorthositic rocks.

Pink, equigranular, fine to coarse grained biotite granite (subunit 5e) is abundant southeast and east of the centre of the map area. The granite is rarely K-feldspar $\pm$ plagioclase porphyritic and ranges from undeformed to moderately foliated. Rare, equigranular to aplitic, granite layering may represent migmatization or the intrusion of veins. Locally the rock is seriate-textured or contains xenoliths of diorite or granite gneiss.

To the north and east of the equigranular granites, pink, K-feldspar megacrystic rocks (subunit 5f) are predominant, although the two rock types are intimately associated at map scale. The megacrystic rocks include granite, quartz monzonite and quartz syenite. K-feldspar megacrysts, generally 2 to 3 cm across, but locally up to 7 cm, occur in a medium to coarse grained groundmass of quartz, plagioclase and biotite, including minor magnetite and allanite. This subunit ranges from undeformed to gneissic, although the layering in the gneissic portion may be the result of extreme deformation of K-feldspar megacrysts rather than migmatization. Pink or white, coarse to very coarse grained alkali-feldspar granite, granite and quartz syenite sheets also occur in this area. They are commonly rich in allanite. The sheets cross-cut finer grained granitoid rocks, granitoid-layered amphibolite and tonalite gneiss.

Subunits 5e and 5f contain abundant enclaves and schlieren of amphibolite, and lesser, but morphologically similar, amounts of plagioclase-biotite rock and tonalite gneiss, all of which belong to subunit 2e. A K-feldspar porphyritic granite (part of subunit 5e) intrudes the anorthosite suite west of Lac Thevet, and granitic gneiss dikes (subunit 5g) cut the anorthosite suite, the tonalite gneiss and strongly foliated to gneissic portions of subunit 5f in various parts of this eastern area.

Gabbro (Unit 6)

Several patches of gabbro occur within the rapakivi-textured granitoid rock in the north part of the map area. Where the granitoid rock is undeformed, the gabbro is a dark, medium grained, intergranular-textured rock containing a largely primary mineralogy. Farther north, the gabbro patches consist of fine to medium grained, foliated amphibolite, commonly containing disseminated garnet. It is not known whether the patches are inclusions or intrusions in their rapakivi-textured host.

Quartz-Feldspar Porphyry (Unit 7)

This unit crops out as a single cliff exposure in the southeast part of the map area and is depicted as underlying the whole of the hill. The porphyry is an undeformed, fine grained, quartzofeldspathic rock containing quartz and feldspar phenocrysts approximately 0.5 cm across. Its contacts were not seen.

Diabase Dikes (not on Figure 3)

Diabase dikes are black, very fine grained and aphyric, and probably are of more than one generation. They are known only to occur in the areas underlain by paragneiss and anorthositic rocks in the map area. The dikes are generally less than 1 m wide, discordant to the gneissosity and rectilinear, but locally are subparallel to the fabric and more irregular in thickness. They commonly have chilled margins and rarely are backveined; bayonet and *en echelon* structures are developed in places. One example was found of a straight, discordant, apparently unmetamorphosed dike with a 1 cm wide foliated margin.

Surficial Geology (not on Figure 3)

The map area was completely covered by late Wisconsin ice of the Laurentide ice sheet. Numerous striae, grooves and roches moutonnées indicate that the advance was generally from a northwesterly direction. Till cover is still very extensive in the lowland parts of the map area, but the initially thinner or discontinuous cover in many of the upland areas is considerably depleted by erosion, particularly on the main plateau north and west of the Atikonak River, and in the east-trending section of the Atikonak River valley. The lowland till locally forms a complete cover, even of prominent hills, in the lee of the main plateau, and a till veneer occurs on some of the highest ground along the watershed in NTS map area P/10.

The till cover is punctuated by 1 to 4 km wide outwash plains and associated eskers that record the pattern of late Wisconsin deglaciation, mostly in a 150-trending direction. The outwash plains provide the source for extensive areas of aeolian sand. These deposits nucleate along short sections or lengthy bands of the outwash plains and extend eastward for up to 6 km, generally terminating in lobate forms. The aeolian sand is characterized by dune morphologies (M. Batterson, personal communication, 1985) indicating paleowind directions ranging from west-northwest to west-southwest. The dunes consist of angular-nosed, barchan-like forms that commonly interfinger to form obliquely longitudinal dune fronts. The dunes are in various stages of stabilization and are only rarely still active.

STRUCTURE AND METAMORPHISM

Units 3 and 5 separate and isolate several areas containing older structures, e.g., Units 1 and 2. As a result the map area is divided into four structural subareas (shown in an inset with Figure 3) between which firm correlations cannot presently be made.

I. Northwestern Subarea

The paragneiss contains a well developed migmatitic layering (Plate 1) that, locally, has coalesced to form a diatexite. The migmatization in the paragneiss sequence is the oldest tectonometamorphic event recognized in the map area. Relicts of the mineralogy associated with this initial metamorphic differentiation have escaped subsequent recrystallization, and consist of restite clots of sillimanite and opaques and coarse grained granite layers. The paucity of biotite in both the leucosome and the restite indicates an intense dehydration at this time and the general lack of ferrous iron-bearing phases (e.g., garnet, biotite and orthopyroxene), together with an abundance of magnetite, indicates a high oxygen fugacity during metamorphism (T. Rivers, personal communication, 1983). Low water pressure and high oxygen fugacity may have inhibited partial melting (Emslie, 1981) and the earliest recognized migmatitic layering may be an enhanced primary feature. The high oxygen fugacity may have resulted from high ferric iron contents in the depositional environment (A. Thomas, personal communication, 1984) and this condition has persisted, at least in part, through subsequent metamorphism.

In the northwest part of the map area, the formation of a gneissosity in the basic gneiss, and probably the supracrustal rocks as a whole, was followed by the emplacement of basic plutonic rocks (subunits 2a and 2b). Units 1 and 2 in this region were then deformed together during a major high-grade dynamothermal event. This resulted in tight folding and a largely penetrative, axial planar recrystallization in the paragneiss, which occurred at sillimanite grade (Plate 1). Minor hydration of the restite and a local lowering of the oxygen fugacity resulted in the formation of biotite seams and selvages and garnet crystallization, perhaps involving reactions such as:

$$\text{Ksp} + \text{mt} + \text{water} \rightarrow \text{bio} + \tfrac{1}{2}\,0_2$$

$$2\ \text{sill} + 2\ \text{mt} + 4\ \text{qz} \rightarrow 2\ \text{gt} + 0_2$$

The gabbroic and noritic rocks were heterogeneously deformed and their recrystallization produced two-pyroxene, biotite, plagioclase and quartz mineral fabrics.

The foliations strike mostly between 090 and 045, dip steeply toward the north-northwest and have steeply pitching lineations. High-strain zones are marked by mylonitic or porphyroclastic textures with higher biotite contents than those normally found in the paragneiss; they commonly occur in the paragneiss adjacent to the plutonic rocks.

Recrystallization outlasted the deformation and mimetic, posttectonic crystallization structures involving biotite, garnet and sillimanite are common in the paragneiss (see reactions above). Metamorphic sweats and granitic veins are mostly syn to posttectonic in the basic rocks and commonly contain orthopyroxene (Plate 3).

No distinction was made in the field between the biotite-poor, relatively anhydrous, paragneiss assemblage (subunit 1a) that occurs in both the northwestern uplands and in the adjacent lowland areas. However, the mineralogy of the basic plutonic rocks and, in particular, the orthopyroxene-bearing segregations and granitoid sheets within the basic rocks, indicate that the upland areas are underlain by granulite facies rocks. In contrast, the more hydrous, biotite-rich facies of the paragneiss (subunit 1b) is thought to be a middle to upper amphibolite facies assemblage and is found only in lowland areas. This is consistent with observations made to the north (1982 and 1983 areas in Figure 1), namely that the major changes in topography represent metamorphic facies changes (Stevenson, 1968; Nunn and Christopher, 1983; Nunn, Noel and Culshaw, 1984). In most cases it is not known if these facies boundaries also coincide with structural breaks.

Both the gneissic location fabric in the paragneiss and the axial planar mineral foliation throughout Units 1 and 2 in the northwest part of the map area are folded into a large, regional synform (Figure 3). Variations in the attitudes of the fabrics indicate that the structure is probably synclinorial and small-scale minor folds are common. The smaller-scale structures are locally coaxial with the earlier mineral lineation but little recrystallization is apparent during this later episode of folding.

Granitoid plutonic rocks (subunits 5a, 5b and 5c) underlying the lowlands in the northwestern part of the map area contain paragneiss inclusions and are weakly to strongly foliated. The foliation is defined by quartz, feldspar and biotite groundmass mineral fabrics, shape fabrics of ferromagnesian clots and polygonized feldspar aggregates, and, less commonly, megacryst alignment. Assemblages containing garnet biotite and hornblende occur in both deformed and undeformed (but recrystallized) rock and indicate amphibolite facies conditions.

The foliation in the granitoid rocks trends mostly between 100 and 050; in the west it generally dips moderately to the north whereas east of Butterfly Lake it dips moderately to the southeast and contains a down-dip linear component. The fabrics in the rapakivi-textured rocks become less pervasive southeastward and pass through a zone containing variably oriented, narrow shear zones into undeformed rock near the anorthosite suite contact. Locally, the undeformed rock is recrystallized and the ovoids are replaced by a polygonal aggregate of K-feldspar. There is no correlation between recrystallization of the ovoids and deformation, but there does appear to be a general relationship between the degree of deformation and the height of the terrain, i.e., the lower levels are underlain by the most deformed rocks and higher levels are underlain by undeformed rocks, near the anorthosite contact.

Perturbations in the foliation in the granitoid rocks appear to relate to cross-folding in the east part of NTS area A/7, and oval domes and basins in the west part of NTS area A/2; both structures have approximately 140-trending axial traces.

II. Southwestern Subarea

In the southwest (NTS map areas P/10 and 15), a similar relationship is thought to exist between the paragneiss (subunit 1e) and basic plutonic rocks (subunit 2c) as in the northwestern subarea. Here, however, the metabasic rocks were emplaced concordantly and are not known to cross-cut the paragneiss layering.

The paragneiss has a folded gneissosity to which there is a silllimanite-grade axial planar fabric. Rare agmatite zones are developed in the paragneiss and a plagioclase shape fabric occurs in a cumulate layer in the basic rocks; both are thought to be coeval with the axial planar fabric.

The main area of paragneiss in the southwest part of the map area (subunit 1e) is characterized by the anhydrous type of restite (cf. subunit 1a), which here contains orthopyroxene, and the metabasic rocks (subunit 2c) are at granulite or pyroxene hornfels grade. Fabrics in this paragneiss are oriented east-northeasterly and are generally steeply dipping; near the anorthosite contacts the paragneiss and metabasite structures dip gently away from the contact. Farther north in NTS map area P/15, the smaller pendants of paragneiss contain the more hydrous assemblage (subunit 1b).

Some paragneiss layers in subunit 1e contain abundant cordierite. The mineralogy appears isotropic in these layers, as well as in much of the quartzofeldspathic layers, some sillimanite-bearing restites and the adjacent metabasic rocks. This may be due to thermal recrystallization during emplacement of the anorthosite suite (Unit 3) with cordierite produced by replacement of the restite. Alternatively, the cordierite could be a product of compositionally controlled regional metamorphism, and the lack of pyroxene, sillimanite and quartzofeldspathic mineral fabrics may be related to posttectonic recrystallization. Cordierite probably formed from biotite-free, biotite-poor and biotite-rich assemblages respectively, according to the following reactions:

$$2 \text{ mt} + 6 \text{ sill} + 9 \text{ qz} \rightarrow 3 \text{ cord} + O_2$$

$$\text{bio} + \text{mt} + 6 \text{ sill} + 9 \text{ qz} \rightarrow 3 \text{ cord} + \text{Ksp} + H_2O + ½ O_2$$

$$2 \text{ bio} + 6 \text{ sill} + 9 \text{ qz} \rightarrow 3 \text{ cord} + 2 \text{ Ksp} + 2 H_2O + O_2$$

Orthopyroxene could also be the result of thermally induced reactions in the southwestern pendant.

The anorthositic rocks (Unit 3) were followed by emplacement of the granitoid suites 5c and 5d. In this area, Units 3 and 5 are rarely foliated. These deformation fabrics strike westerly in Unit 3 and northwesterly in Unit 5, and dip in either direction. The orientation (gently inward-dipping) of the paragneiss structures near the anorthosite contact around the southwestern pendant, and the undulating, gentle to moderate dips of the layering and lamination in the underlying anorthosite, suggest that the paragneiss is now a synformal cap resting upon the anorthosite suite (Figure 3).

III. Atikonak River Massif

Structures such as layering and igneous lamination in cumulate intrusions are generally regarded as primary features of initially low dip or subhorizontal attitude. In the Atikonak River massif, these features are now of very variable orientation and include large areas underlain by subvertical and even overturned layering. Strong deformation in the massif is confined to a number of shear zones (mostly narrow), and the absence of penetrative deformation in the massif indicates that much of the variation was achieved by brittle deformation, e.g., fracturing, block faulting or fracture-assisted buckling. The extent to which these structures may have been superimposed on original variations relating to possible multiple intrusion is unknown. A major 055-trending fault is inferred in the northeast part of the map area, based upon a sinistral displacement of 1 to 3 km of the interlayered subunits.

On a local scale, narrow, white-weathering, hairline fractures occur widely in the more massive rocks of the massif. The fractures are filled with altered material, including radiating crystal clusters that lie in the plane of the fracture and spaced garnet porphyroblasts up to 2 cm across that have nucleated along the fractures in some areas. Most of the fractures show little or no offset but relative displacements up to a few metres can be seen in places. The distribution of these fractures is not uniform throughout the massif and they appear to be more abundant toward the northwest margin of the body, and in the more pristine anorthositic rocks in southern parts of the map area (NTS map area 22P).

Throughout the massif, but far more commonly away from the northwestern upland plateau and the massive fractured areas, grain boundary recrystallization of plagioclase is evident and is locally penetrative. This feature makes some laminated anorthosites (e.g., parts of subunit 3h) look as if they contain strong, anastomosing, tectonic fabrics. Although the recrystallization is probably due to annealing of strains produced tectonically, e.g., by grain boundary sliding, the amount of strain may be negligible. This polygonization is probably responsible for the generally lighter gray or white weathering colors, and for a decreased resistance to erosion of rocks in the Atikonak River valley and lowland areas of the massif. The grain-boundary recrystallization and the hairline fracturing may be, respectively, ductile and brittle responses to the same tectonic stresses.

Shear zones in the Atikonak River massif are generally only several millimetres to a metre across, but are widespread. Within shear zones, plagioclase is recrystallized to fine to medium grained granular aggregates. In rocks of troctolitic association, olivine is replaced by a hydrous mineral fabric of amphibole and biotite; in noritic rocks, orthopyroxene is commonly enclosed in a sheath of biotite and is locally completely replaced by the biotite. Shear zones confined to granitic veins are common in the Atikonak River massif. The shearing occurs either throughout the veins, along the margins, or in the centre of the veins, and is evident as strong, steep, linear fabrics of quartz, feldspar and biotite.

The largest shear zone in the massif follows the Romaine River in the northeast corner of the map area (Figure 4). The zone strikes north-south, dips steeply to the west and is 1 to 3 km wide. Structures within the zone range from foliated rock with abundant lenticular relicts of gray or red-brown plagioclase, to a fine grained, white, anorthosite gneiss. In places, this lenticularity occurs at larger scales, and augen of undeformed and partly recrystallized rock occur in a mesh of anastomosing shear zones. Relict pyroxenes with biotite sheaths are common, and both shape fabrics and mineral lineations indicate an approximately down-dip extension.

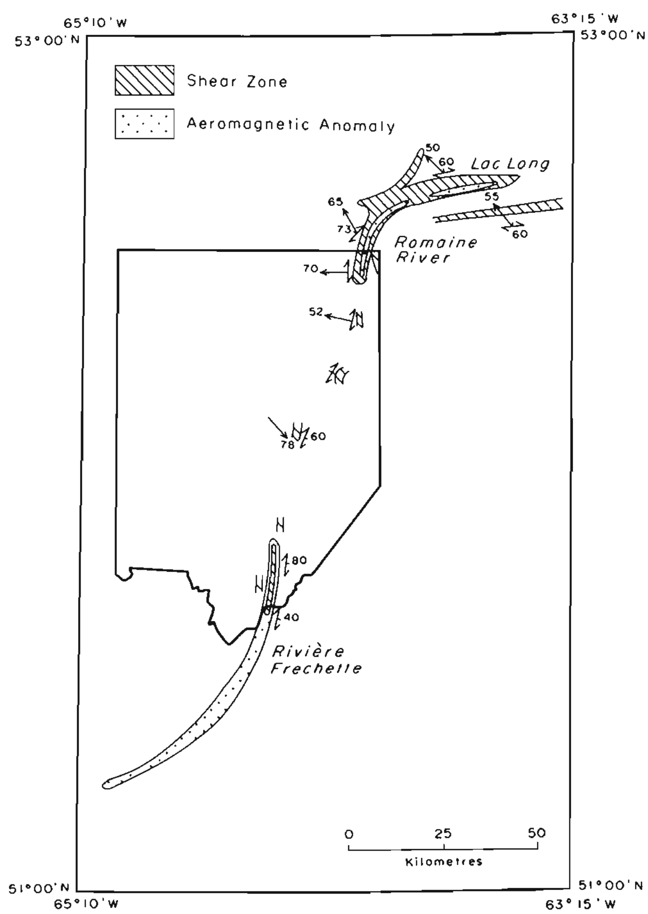

Figure 4: *The Lac Long/Romaine River shear zone system, the Rivière Frechette shear zone and its proposed aeromagnetically-interpreted extension, and a possible connection between the two shear zones [in part after Thomas et al. (1984) and Nunn et al. (1984); aeromagnetic data from Geological Survey of Canada, (1985)].*

Farther south, well spaced groups of outcrops containing similar strong fabrics occur more or less on line with the Romaine River zone, although the orientations of the fabrics are very variable. These outcrops are thought to represent folded continuations of the Romaine River zone, and are tentatively interpreted to join with the Riviere Frechette zone in subunit 2d (see below). Several smaller, subparallel shear zones are suspected in eastern parts of the map area.

Metamorphic overprinting is evident on rocks of the massif but its significance is not readily assessed. Whereas all the semi-brittle to ductile deformation of rocks in the massif is accompanied by metamorphism, the converse is not the case and large areas of undeformed rock are pseudomorphed by a metamorphic mineralogy. These areas are characterized by corona-forming reactions. Coronas separating olivine and plagioclase are nearly universal in olivine-bearing rocks, but it is unclear whether these are a consequence of subsolidus cooling of a deep-seated intrusion or result from younger regional metamorphism. Typical coronas are narrow and extremely fine grained; field examination suggests two pyroxenes and spinel are probably present. Locally, in the north part of the map area (NTS map area 23A), and usually adjacent to shear zones or pegmatitic granite dikes, reaction rims and coronas become broader and their mineralogy changes to fibrous amphibole, chlorite, and other hydrous minerals. In places, pyroxene or olivine are completely replaced, although they can usually be readily identified by their hydrous pseudomorphs. In southern areas (NTS map area 22P) such replacements are more complete and widespread, and identifiction of the protolith is more difficult (subunit 3x). The distribution of the hydrous type of coronas also correlates well with the generally lower-lying areas of the massif.

IV. Southeastern Subarea

The paragneiss is very poorly exposed in the southeastern part of the map area. It contains a gneissosity and a subparallel, sillimanite-bearing, mineral recrystallization of hydrous aspect (subunit lb).

The basic plutonic suite is moderately to strongly foliated, exhibiting granulite facies (subunit 2d, Plate 4) or amphibolite facies (subunit 2e, Plate 5) dynamic fabrics. The facies boundary is shown in Figure 3. Locally, subunit 2e consists of either tonalitic gneiss or amphibolite that is either veined or layered by granitoid rocks; these location fabrics are in the amphibolite facies. The foliation throughout the suite is mostly steep, oriented between 000 and 040; and in the gabbronorite (subunit 2d) it commonly contains a steeply north-plunging, linear component.

The consistency of the foliation throughout subunits 2d and 2e suggests that the facies boundary is synchronous with the foliation and not a result of structural reworking. The mapped facies boundary is close to a marked aeromagnetic change from high in subunit 2d to low in subunit 2e (Geological Survey of Canada, 1985). The presence of foliated amphibolite dikes (Plate 4) within the gabbronorite also indicates that the mineral assemblage is locally dependent upon the available water fugacity; in hand specimen, no reaction rims are visible at the dike margins.

Subunit 2d is intruded by the anorthositic rocks (Unit 3) but the relationship of Unit 3 to the fabrics in the metabasic rock is unknown. Both basic suites (subunits 2d and 2e and Unit 3) are intruded by granitoid rocks (subunits 5e and 5f) of which weakly to undeformed rocks cut the fabrics in subunit 2e.

Fabrics in subunit 5e range from isotropic, through quartzofeldspathic and biotite mineral foliations, to a spaced location fabric of aplitic veins. In subunit 5f, they range from isotropic, through mineral and shape aggregate foliations, to gneissic. Locally, a discontinuous layering, formed by attenuation of a replaced megacryst shape fabric, is folded. Rarely, subunits 5f and 2e and Unit 3 are cut by granitoid gneiss dikes (subunit 5g). All the structures in the southeastern granitoid plutonic suite are in the amphibolite facies. The structures strike mostly between 080 and 150 and are variably dipping.

A 0.5 to 0.8 km wide shear zone (the Rivière Frechette shear zone, Figure 4) cuts the gabbronorite in the southernmost part of subarea IV. The zone consists of varying sizes and concentrations of foliated, gabbronorite augen in an anastomosing mesh of fine grained, amphibolite facies shear zones. The shear zone grades into mylonite and ultramylonite but lacks a well developed linear fabric. Locally, the mylonite fabric is folded into outcrop-scale, angular-hinged folds. Less than 1 km north of the approximate facies boundary between subunits 2d and 2e (Figure 3), the shearing heterogeneously deforms amphibolite that is veined and diked by granitoid rocks. Five kilometres west of Lac Thevet, mylonitic granite containing rare, porphyroclastic feldspar relicts cuts granite-layered amphibolite (subunits 5e? and 2e), and is also folded.

The Romaine River - Rivière Frechette Shear Zone

The Lac Long lineament (Thomas *et al.*, 1984) occurs to the northeast of the map area (Figure 4), where it consists of a zone of straightened paragneiss and deformed anorthositic rocks. This shear zone trends southward near the boundary of the map area and follows the Romaine River as a 1 to 3 km wide zone of deformed anorthositic rocks. Despite the lack of exposure and opposing dip directions between the north and the south of the map area, it seems likely that this deformation zone is continuous with the Rivière Frechette shear zone (Figure 4). Both the Lac Long/Romaine River and the Rivière Frechette shear zones show as marked aeromagnetic lows, although a connection between the two is not obvious on the aeromagnetic map (Geological Survey of Canada, 1985). The significance of this potentially greater than 200 km long structure (Grenvillian?) is unknown.

Late Structures

Throughout the map area, foliations vary considerably in both dip and strike; this irregularity particularly applies to the southeastern granitoid rocks, which are the youngest of the main plutonic suites in the map area. Crenulations and fracture cleavages associated with these variations are very rare.

Brittle features also occur throughout the map area. They consist mostly of fault sets, of which northwest-trending fractures with a subvertical throw are prominent. Most rock types in the map area are cut by rare pseudotachylite and/or ultracataclasite veins.

MINERALIZATION

Disseminated metallic minerals occur throughout the map area. These consist mostly of magnetite, pyrite and pyrrhotite (Pyke, 1956) in the paragneiss (Unit 1); magnetite, ilmenite and pyrite in the Atikonak River massif (Unit 3); and magnetite in the basic plutonic suites (Unit 2), the monzonites (Unit 4) and the granitoid plutonic suites (Unit 5). The monzonite rim to the anorthositic massif shows as a prominent aeromagnetic ridge (Geological Survey of Canada, 1985), but large concentrations of magnetite were not found.

Concentrations of oxide and sulfide minerals occur in some rock types in the Atikonak River massif. Podiform or layered concentrations, up to 1 m across, of 30 to 100 percent magnetite occur in the noritic rocks (subunit 3e), particularly in the east part of the massif, and less commonly in subunits 3a and 3h. Magnetite-rich layers, containing orthopyroxene, occur in the ferrodiorite (subunit 3k). The Beaver Pond gabbro (subunit 3j) contains pods or layers rich in oxides and sulfides including pyrite, chalcopyrite and pyrrhotite.

Chatoyant feldspar is widepread in the plagioclase-rich rocks of the Atikonak River massif, principally in subunits 3e, 3i and 3x, displaying varying hues of blue, green, yellow and bronze. In some leuconoritic rocks of subunit 3e, irridescent plagioclase occurs in medium grained, granular, polygonally recrystallized, metamorphic derivatives of the host rock, as well as in the much coarser grained protolith.

Pure anorthosite suitable for alumina production is not abundant. Aggregate resources associated with outwash material are voluminous, however, accessibility precludes development.

DISCUSSION

The northwestern part of the map area appears to be a direct continuation of rock units mapped to the north (Nunn *et al.*, 1984) and lies within the Lac Joseph allochthon (Rivers and Nunn, 1985). The geochronology-based history set up for that area places the gneissic fabric development in the early Labradorian, the basic suites in a plutonic interval, and the major mineral recrystallization in both the upland paragneiss and the metabasic rocks in the late Labradorian (Nunn *et al.*, 1985). The Labradorian orogeny and the related plutonic interval occurred between 1700 Ma and 1600 Ma (Nunn *et al.*, 1985; Thomas *et al.*, *in press*). Foliations in the granitoid rocks, and perhaps the post-gneissosity foliation in the lowland paragneiss, are thought to be Grenvillian in age.

The age of the anorthositic rocks is poorly known. The Atikonak River massif has yielded a K-Ar (biotite) age of 854 ± 31 Ma (Wanless *et al.*, 1970, page 65). The massif and its associated granitoid rocks (subunits 5c and 5d) were emplaced between the Labradorian orogeny at ca. 1660 Ma and the Grenvillian orogeny at ca. 1000 Ma.

The generation of anorthosite magmas relates to mantle processes (Emslie, 1985).The tectonic setting of the Atikonak River massif at the time of intrusion is not understood at present. The rock assemblage, however, is virtually identical to anorogenic associations in Labrador north of the Grenville Front (Emslie, 1980). The massif resisted the development of extensive penetrative fabrics and the associated pyroxene monzonites and rapakivi granites were protected adjacent to the massif. Such fabrics are better developed away from the massif, or are confined to relatively narrow shear zones that appear to entirely postdate crystallization of the rocks and may be much later (Grenvillian?). The massif thus forms the core of a large, regional, low-strain augen. There is little doubt that the igneous suite intruded amphibolite to granulite grade rocks that had already been deformed in one or more previous events, and that the grade of subsequent regional metamorphism was in the amphibolite facies.

The complex variations in attitudes of layered sections in the massif, coupled with widespread evidence of xenoliths and intrusive relations among units, suggest that intrusion was prolonged and involved both partly crystallized rock and largely liquid magma. Proportions of each were probably variable in time and space within the massif. The extent to which different magma pulses are represented, as opposed to successive intrusive events, cannot be assessed on field evidence alone. The common presence of well defined mineral layers is clear evidence that the massif cannot be regarded as a simple intrusion of plagioclase-rich crystal mush.

Xenoliths of country rock are rare in all of the major rock units associated with the massif. They are essentially absent from the massif itself and only a few small inclusions of basic to intermediate composition were noted within the pyroxene monzonite and rapakivi granite. The lack of country rock xenoliths suggests that magma stoping was not an important process of emplacement, and constitutes permissive evidence in support of diapiric intrusion.

According to Thomas (1974), much of the Atikonak River massif is undistinguished by significant positive or negative Bouguer anomalies; this seems to imply that either olivine-bearing rocks at depth are less abundant than they appear at the surface or that the massif is a relatively thin slab.

The Atikonak River massif is the northernmost of a number of large anorthositic massifs in this part of the Grenville Province (Figure 2). It is flanked to the southeast by gabbronorite (subunit 2d), which appears to correlate with the northern tip of a large positive gravity anomaly (Figure 5). This feature is in contrast to the generally low relief and negative anomalies of the anorthositic rocks in the region (Figure 5), and suggests that the whole of the gabbro to anorthositic gabbro lobe of Sharma and Franconi's (1975) Lac Fournier massif may be a separate metabasic plutonic suite that is unrelated to the anorthositic rocks. At present, the potential age of these metabasic rocks, and of the granitoid plutonic suite (subunits 5e and 5f) that intrudes them, also ranges between the Labradorian and Grenvillian orogenies.

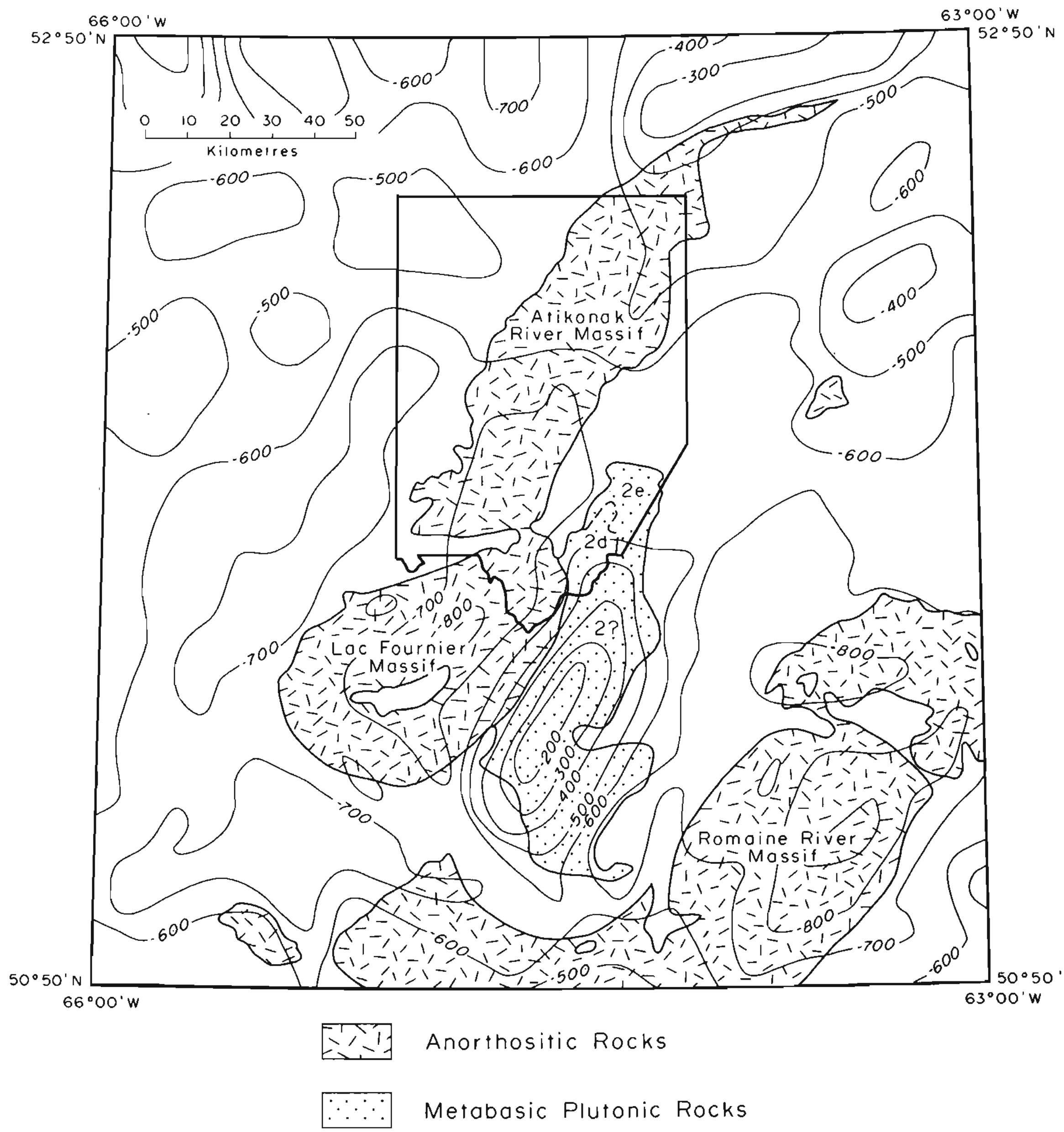

Figure 5: *Gravity anomalies in the region of the Atikonak River massif showing a possible extension (2?) of the metabasic plutonic suite (2d and 2e) coincident with a strong positive anomaly [in part after Sharma & Franconi (1975), Thomas et al. (1984) and Nunn et al. (1984); gravity data from Geological Survey of Canada, 1986)].*

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REFERENCES

Avramtchev, L., and Marcoux, P.
1980: Geological map of Québec. Québec Ministère de L'Energie et des Ressources, Direction générale de la recherche géologique et minérale, Carte DP-735, 1:1,500,000 scale.

Blais, R.A.
1960: Wacouno-Waco area, Saguenay electoral district. Quebec Department of Mines, Geological Surveys Branch, Geological Report 96, 58 pages.

Bourne, J.M., Stott, G., Borduas, B., and Lalonde, A.
1977: Lac de Morhiban and Natashquan River map area. *In* Current Research, Part A, Geological Survey of Canada, Paper 77-1A, pages 199-204.

Emslie, R.F.
1980: Geology and petrology of the Harp Lake Complex, central Labrador: an example of Elsonian magmatism. Geological Survey of Canada, Bulletin 293, 136 pages.

1981: Exceptionally high-grade metapelitic gneisses in the Red Wine Mountains, southern Labrador. Geological Association of Canada, Program with abstracts, Volume 6, page A17.

1985: Proterozoic anorthosite massifs. *In* The deep Proterozoic crust in the North Atlantic Provinces. *Edited by* A.C. Tobi and J.L.R. Touret. NATO Advanced Study Institute, Series C, Volume 158, pages 39-60. D. Reidel, Dordrecht, 603 pages.

Emslie, R.F., Lefebvre, C.E., Kjarsgaard, B. and Sherlock, R.
1986: Atikonak River massif, Labrador. *In* Current Research, Part A, Geological Survey of Canada, Paper 86-1A, pages 755-758.

Geological Survey of Canada
1968: Gravity map series, numbers 64 (Mingan-Cape Whittle), 65 (Clarke City-Mingan), 66 (North West River) and 67 (Ashuanipi), 1:500,000 scale.

1985: Preliminary magnetic anomaly map (residual total field), Maps NN-2O-M (Churchill Falls) and NM-20-M (Anticosti Island), 1:1,000,000 scale.

Greene, B.A.
1972: Geological map of Labrador. Mineral Resources Division, Department of Mines, Agriculture and Resources, Province of Newfoundland and Labrador.

Krogh, T.E.
1983: Report on U-Pb zircon geochronology, Labrador and Newfoundland. Private report submitted to Newfoundland Department of Mines and Energy, Mineral Development Division. On Open File, Mineral Development Division, Newfoundland Department of Mines and Energy, St. John's.

Loveridge, W.D.
1986: U-Pb ages on zircon from rocks of the Lac de Morhiban map area, Québec. *In* Current Research, Part A, Geological Survey of Canada, Paper 86-1A, pages 523-530.

Low, A.P.
1896: Report on explorations in the Labrador Peninsula along the East Main, Koksoak, Hamilton, Manicuagan and portions of other rivers in 1892-93-94-95. Geological Survey of Canada, Annual Report L, Volume VIII, 387 pages.

Nunn, G.A.G. and Christopher, A.
1983: Geology of the Atikonak River area, Grenville Province, western Labrador. *In* Current Research, Part A, Geological Survey of Canada, Paper 83-1A, pages 363-370. *Also in* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 83-1, pages 107-114.

Nunn, G.A.G., Noel, N. and Culshaw, N.G.
1984: Geology of the Atikonak Lake area, Grenville Province, western Labrador. *In* Current Research, Part B, Geological Survey of Canada, Paper 84-1B, pages 414-425. *Also in* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 84-1, pages 30-41.

Nunn, G.A.G., Thomas, A. and Krogh, T.E.
1985: The Labradorian Orogeny: Geochronological Database. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 85-1, pages 43-54.

Pyke, M.W.
1956: Report on exploration in areas G and K, Labrador, 1956. Unpublished assessment report, BRINEX G56015. Open File [Lab 181], 13 pages.

Rivers, T. and Chown, E.H.
1986: The Grenville Orogen in eastern Quebec and western Labrador - definition, identification and tectonometamorphic relationships of autochthonous, parautochthonous and allochthonous terranes. *In* New Perspectives on the Grenville Problem. *Edited by* J.M. Moore and A. Baer, Geological Association of Canada, Special Paper. *In press.*

Rivers, T. and Nunn, G.A.G.
1985: A reassessment of the Grenvillian orogeny in western Labrador. *In* The deep Proterozoic crust in the North Atlantic Provinces. *Edited by* A.C. Tobi and J.L.R. Touret. NATO Advanced Study Institute, Series C, Volume 158, pages 163-174. D. Reidel, Dordrecht, 603 pages.

Sharma, K.N.M. and Franconi, A.
1975: Magpie, Saint-Jean, Romaine Rivers area. Québec Ministère des Richesses Naturelles, Geological Report 163, 73 pages.

Stevenson, I.M.
1968: Geology of Lac Joseph map-area (23A), Newfoundland and Québec. Geological Survey of Canada, Paper 67-62 (Report, 4 pages, and Map 23-1967).

Thomas, A., Culshaw, N.G., Mannard, G. and Whelan, J.G.
1984: Geology of the Lac Ghyvelde-Lac Long area, Grenville Province, Labrador and Québec. *In* Current Research, Part A, Geological Survey of Canada, Paper 84-1A, pages 485-493. *Also in* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 84-1, pages 42-52.

Thomas, A., Nunn, G.A.G, and Krogh, T.E.
1986: The Labradorian orogeny; evidence for a newly identified 1600 to 1700 Ma orogenic event in Grenville Province crystalline rocks from central Labrador. *In* New perspectives on the Grenville problem. *Edited by* J.M. Moore and A. Baer. Geological Association of Canada, Special Paper. *In press.*

Thomas, M.D.
1974: The correlation of gravity and geology in southeastern Québec and southern Labrador. Geological Survey of Canada, Earth Physics Branch, Gravity map series and report, 49 pages.

Turner, F.J., and Weiss, L.E.
1963: Structural analysis of metamorphic tectonites. McGraw-Hill, New York, 545 pages.

Wanless, R.K., Stevens, R.D., Lachance, G.R. and Delabio, R.N.
1970: Age determinations and geological studies, K-Ar isotopic ages, report 9. Geological Survey of Canada, Paper 69-2A, 78 pages.

Wardle, R.J., Rivers, T., Gower, C.F., Nunn, G.A.G. and Thomas, A.T.
1986: The northeastern Grenville Province: New Insights. *In* New Perspectives on the Grenville Problem. *Edited by* J.M. Moore and A. Baer. Geological Association of Canada, Special Paper. *In press.*

Wynne-Edwards, H.R.
1972: The Grenville Province. *In* Variations in Tectonic Styles in Canada. *Edited by* R.A. Price and R.J.W. Douglas. Geological Association of Canada, Special Paper 11, pages 263-334.

Note: Mineral Development Division file numbers are included in square brackets.