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PRELIMINARY U–Pb GEOCHRONOLOGICAL DATA FROM THE MEALY MOUNTAINS TERRANE, GRENVILLE PROVINCE, SOUTHERN LABRADOR

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Regional Geology Section

ABSTRACT

Preliminary U–Pb geochronological studies of zircon and titanite collected from samples of gneissic monzodiorite, foliated quartz monzodiorite, and an undeformed monzonite that occur in the southwestern part of the Grenvillian Mealy Mountains terrane (MMT) give igneous emplacement ages of 1659 ± 5 Ma, 1650 ± 1 Ma and 1643 ± 2 Ma, respectively. Despite the significant textural and structural differences between the samples, the isotopic data suggest that all three of these pyroxene-bearing granitoid rocks are components of the Mealy Mountains intrusive suite (MMIS), a mid-Labradorian AMCG suite.

In contrast, zircons from a sample of foliated granite from the MMT give a 1514 ± 10 Ma age, interpreted to be the time of igneous emplacement. This data is significant because it demonstrates that the southwestern MMT includes Pinwarian intrusions, and that it has been overprinted by Mesoproterozoic, post-1514 Ma, deformation. Lower-intercept ages from the two deformed MMIS rocks and the Pinwarian granite are loosely constrained between 1050 and 940 Ma, suggesting the tectonothermal event overprinting these rocks is Grenvillian. However, the data do not eliminate the possibility that the region has been affected by overprinting Paleoproterozoic and Mesoproterozoic events. The fact that the ca. 1643 Ma monzonite is undeformed and has apparently escaped deformation is consistent with field observations that the state-of-strain in the area, at all scales, is heterogeneous, although there is a general increase in both the degree of recrystallization and tectonic fabric development toward the southern MMT.

INTRODUCTION

Precise age dating of rocks using U–Pb geochronological methods is an essential supplement to regional geological mapping studies in areas where intrusive and metamorphic ages are inadequately known, and unequivocal contact relationships between rock units are unexposed. As a part of 1:100 000-scale geological mapping of the southwestern Mealy Mountains terrane (MMT) in 1998 (James and Lawlor, 1999; James, 1999), four samples were collected from regionally important intrusive units and from outcrops containing critical relationships or features fundamental to the understanding of the history of the MMT. Fractions of zircon and titanite from these samples were analysed at the Jack Satterley Geochronology Laboratory, Royal Ontario Museum, Toronto. The results, as well as a brief discussion of their implications, are presented in this report. However, the geochronological ages should be considered as preliminary. Later, it may be necessary to collect additional mineral fractions from the same samples or to re-analyze certain fractions in order to refine the ages.

REGIONAL SETTING

The Kenamu River study area is situated in the southwestern part of the MMT (Gower and Owen, 1984) of the northeastern Grenville Province (Figure 1). The MMT consists primarily of Labradorian-age crust of the Mealy Mountains intrusive suite (MMIS) (*see* Emslie, 1976; Emslie and Hunt, 1990), minor amounts Paleoproterozoic pre-Labradorian crust, Pinwarian (1530 to 1450 Ma) and Grenvillian (ca. 980 to 950 Ma) intrusions (Krogh *et al.*, 1996). The MMIS mainly consists of an older group of anorthositic, leucogabbroic and leucotroctolitic rocks that occur in areas east of the study area (*see* Gower, 1999), and a younger group of pyroxene-bearing monzonite and quartz monzonite. A pyroxene monzonite and pyroxene granite, inferred to be from the younger group of rocks and occurring in the north-

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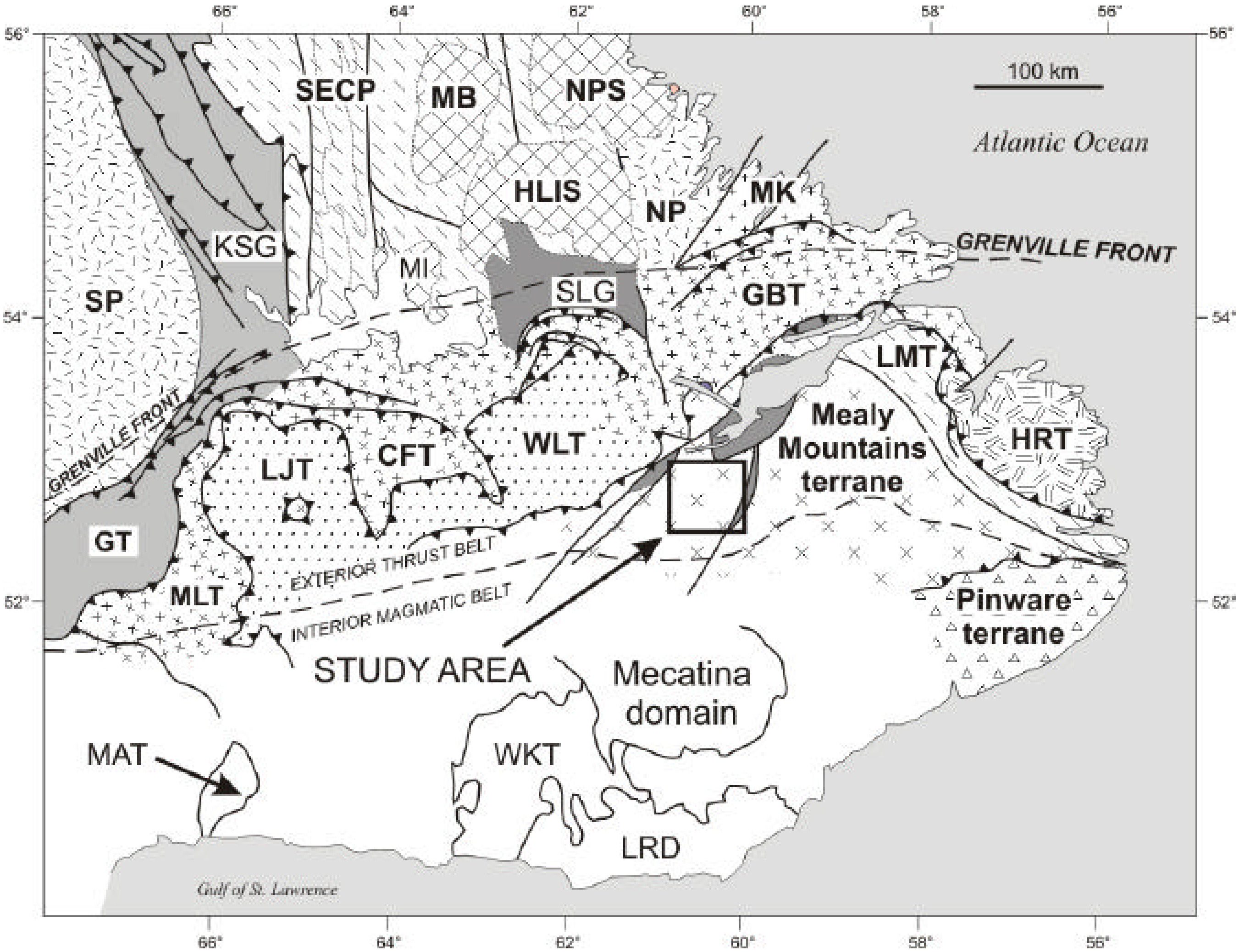

Figure 1. *Location of the Kenamu River study area in relation to the tectonic and major lithotectonic units of northeastern Laurentia. Grenville Province: HRT - Hawke River terrane, LMT - Lake Melville terrane, GBT - Groswater Bay terrane, WLT - Wilson Lake terrane, CFT - Churchill Falls terrane, LJT - Lac Joseph terrane, MLT - Molson Lake terrane, GT - Gagnon terrane, MAT - Matamec terrane, WKT - Wakeham terrane, LRD - La Romaine domain. Archean divisions: SP - Superior Province, NP - Nain Province (Hopedale Block). Archean and Paleoproterozoic divisions: MK - Makkovik Province, SECP - Southeastern Churchill Province (core zone), KSG - Kaniapiskau Supergroup (2.25 - 1.86 Ga). Mesoproterozoic units: NPS - Nain Plutonic Suite, HLIS - Harp Lake intrusive suite, MB - Mistastin batholith, MI - Michikamau Intrusion, SLG - Seal Lake Group.*

eastern part of the MMIS, have emplacement ages of 1646 ± 2 Ma and 1635 +22/ 8 Ma (Emslie and Hunt, 1990), respectively.

The MMIS is not an anorogenic AMCG suite. Emplacement ages overlap with regionally significant tectonothermal and magmatic events, defined as the Labradorian Orogeny that occurred in northeastern Laurentia between 1720 and 1600 Ma (*see* Gower, 1996). The Labrador Orogen has a broadly tripartite zonation consisting of northern volcanic and sedimentary belts (e.g., Blueberry Lake and Bruce River groups) that were deposited on the southern margin of pre-Labradorian Laurentia; a medial magmatic zone defined as the Trans-Labrador batholith and interpreted as a subduction-related continental magmatic arc (*see* Kerr, 1989), and a southern zone dominated by paragneiss, orthogneiss and mafic intrusions (e.g., Ossok Mountain intrusive suite; James, 1994). The MMIS occurs within the southern zone.

The MMT is a Grenvillian tectonic unit and is one of the thrust-stacked terranes that make up the northeastern Grenville Province (Figure 1). The terrane straddles the boundary between the Interior Magmatic Belt and Exterior

Thrust Belt (*see* Gower, 1996). The northwestern boundary of the MMT is a Grenvillian tectonic contact with the Wilson Lake terrane. The location and nature of the southern and western boundaries of the MMT are uncertain. The boundary between the MMT and the Pinware terrane (Gower *et al.*, 1988) occurring 200 km east of the study area, is a Grenvillian tectonic contact (Gower, 1996). The MMT has been variably affected by Labradorian, Pinwarian and Grenvillian (ca. 1000 to 950 Ma) tectonothermal events. The U–Pb geochronological studies will be crucial in determining the nature and extent of these overprinting events.

GENERAL GEOLOGY

The study area (Figure 2) is dominated by units of monzonite, and lesser amounts of gabbronorite, monzodiorite, quartz monzodiorite, quartz monzonite, and granite. Rocks are variably recrystallized and deformed, at all scales, although generally, rocks in the southern part of the study area are more highly strained and recrystallized than rocks occurring in northern areas. On the basis of field observations, the rocks occurring in the northern part of the study area were correlated with rocks in the MMIS, whereas correlation of the deformed rocks in the southern part of the area was uncertain. James and Lawlor (1999) presented three possibilities to explain the structural and textural differences between rocks in the southern and northern parts of the study area. The possibilities are: 1) that the rocks in the southern part of the area are pre-Labradorian (>1720 Ma) and significantly older than the MMIS rocks, 2) that rocks in the southern part of the area are early Labradorian (1720 to 1660 Ma) and only slightly predate emplacement of the MMIS rocks, or 3) that the rocks in the southern part of the area are the same age as, and part of, the MMIS. The principal goal of the geochronological study is to test these ideas by determining the emplacement ages for samples having different textures and structures from the southern and northern parts of the study area.

ANALYTICAL PROCEDURES

Zircon and titanite were separated from the rock samples using standard heavy liquid and magnetic separation techniques. All zircon fractions had an air abrasion treatment (*see* Krogh, 1982). Mineral dissolution and isolation of U and Pb from zircon follow the procedure of Krogh (1973), modified by using small anion exchange columns (0.05 mL of resin) that permit the use of reduced acid reagent volumes. Zircon fractions weighing less than 0.005 mg had no chemical separation procedures. The HBr method was used to extract U and Pb from titanite (*see* Corfu and Stott, 1986).

Lead and U were loaded together with silica gel onto outgassed rhenium filaments. The isotopic compositions of Pb and U were measured using a single collector with a Faraday or Daly detector in a solid source VG354 mass spectrometer. A mass fractionation correction of 0.1% per AMU for both Pb and U was used. The laboratory blanks for Pb and U were usually 1 to 3 pg and 0.2 pg, respectively, for zircon, and 10 and 2 pg, respectively, for titanite, which required larger anion exchange columns. In some instances, the laboratory blank was higher due to common Pb introduced by a contaminated HCl bottle; in such an instance, isotopic composition of the contaminant was measured and corrected for. Error estimates were calculated by propagating known sources of analytical uncertainty for each analysis including ratio variability (within run), uncertainty in the fractionation correction (0.015% and 0.038% (1 sigma) for Pb and U, respectively, based on long-term replicate measurements of the standards NBS981 and U-500), and uncertainties in the isotopic composition and amount of laboratory blank and initial Pb. Initial common Pb in excess of blank was corrected using Stacey and Kramers (1975) Pb-evolution model. Decay constants are those of Jaffey *et al.* (1971). All age errors quoted in the text and error ellipses in the concordia diagrams are given at the 95% confidence interval. Discordia lines and intercept ages were calculated using the regression program of Davis (1982).

SAMPLE DESCRIPTIONS

MONZODIORITE (P_{MM}mdq): DJ-98-1176

The sample was collected from an outcrop occurring along the east shore of Minipi Lake (UTM 640277E, 5818598N; NTS map area 13C/10), in the southern part of the study area. The outcrop is foliated, locally gneissic, and consists of alternating layers of fine- to medium-grained, white-, black- and pink-weathering monzodiorite to quartz monzodiorite and fine-grained, grey-weathering diorite (Plate 1). The diorite forms thin (<20 cm) layers and makes up less than 15 percent of the outcrop. This outcrop was sampled because in the field it appeared to be the most highly metamorphosed and deformed example of a pyroxene-bearing granitoid rock. Based on the field observations, it was uncertain if this rock should be correlated with the MMIS or if it was from an older, metamorphosed suite that predated MMIS intrusion.

The sample is taken from the monzodiorite component of the outcrop and consists of plagioclase, microcline, quartz and clinopyroxene (< 10%). The clinopyroxene is almost entirely replaced by very fine-grained amphibole. The rocks also contain fine-grained, green-pleochroic biotite, which on the basis of texture in thin section appears to be a relatively late, metamorphic mineral. The biotite is locally overgrown by minor amounts of chlorite. Accessory epidote, magnetite, apatite, zircon and titanite also occur. The rock has a relatively strong, northeast-striking foliation.

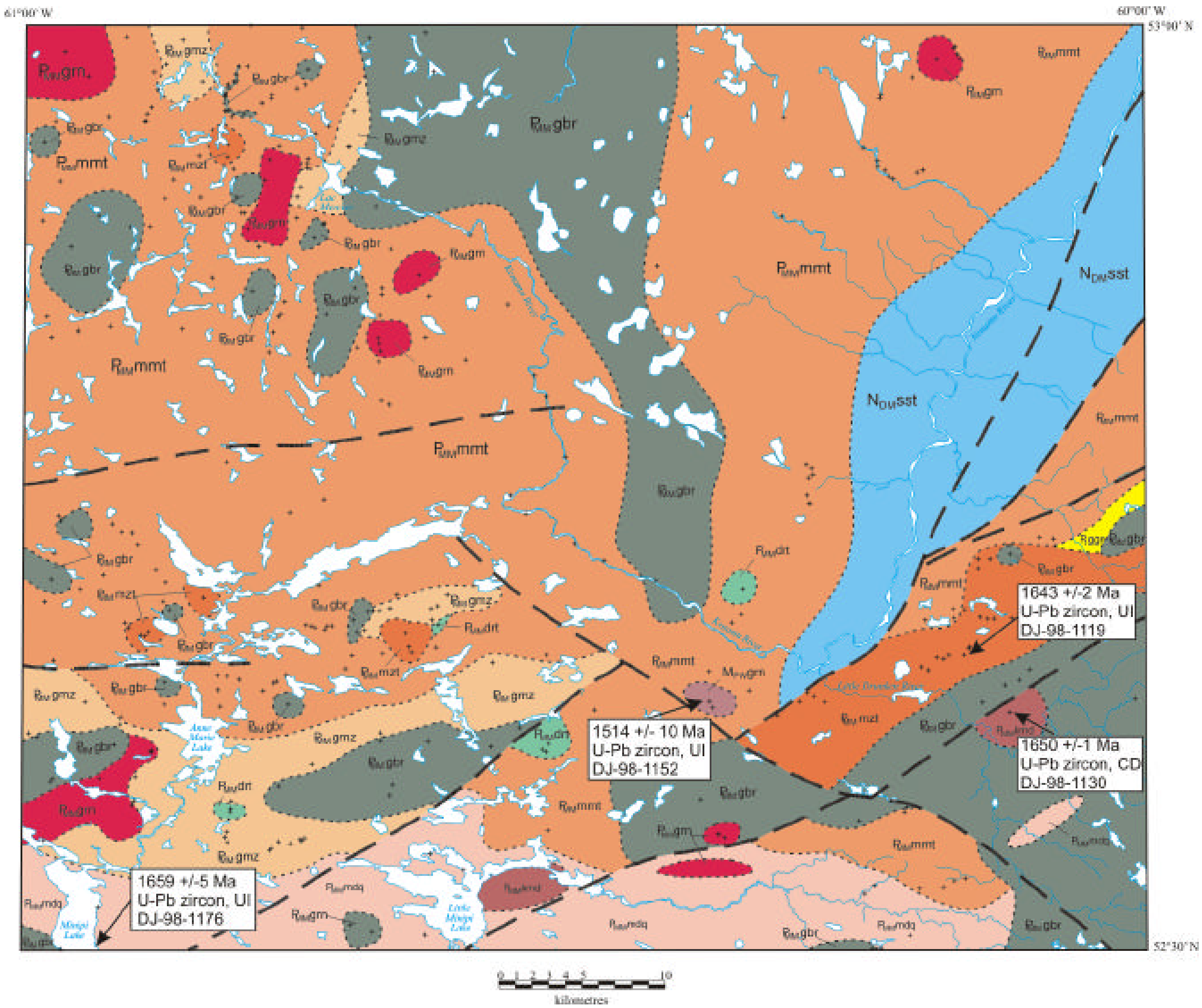

Figure 2. *General geology of the Kenamu River study area. Modified from James (1999).*

Abundant brown, 2:1 and 3:1 (length to width), subhedral, prismatic crystals characterize the zircon population in the sample. The grains are generally cracked and slightly rounded, possibly due to metamorphic rounding. Crystals average 100 to 250 microns in length. They have uranium concentrations between 200 and 300 ppm. Three near concordant data points from two single grains (fractions 2 and 3), and one fraction containing three zircons (fraction 1), overlap each other and have $^{207}Pb/^{206}Pb$ ages of 1654.6 ± 1.6, 1652.9 ± 1.5, and 1652.1 ± 1.3 Ma, and are 0.39%, 0.51% and 0.60% discordant, respectively (Figure 3 and Table 1). These data give an upper intercept age of 1659 ± 5 Ma and a Grenvillian lower intercept age of ca. 940 Ma. The 1659 ± 5 Ma age is considered the best estimate for the time of igneous crystallization.

QUARTZ MONZODIORITE (P_{MM}kmd): DJ-98-1130

The sample was collected from an outcrop of foliated, K-feldspar porphyritic quartz monzodiorite occurring in the southeastern part of the study area (UTM 694741E, 5834700N; NTS 13C/9). The rock is white- to grey- to locally pink-weathering, and grey and pink on fresh surfaces. It consists of >15% subhedral, K-feldspar (microcline) phenocrysts (to 1 cm) and a finer grained, granoblastic-textured groundmass consisting of plagioclase, quartz, clinopyroxene (10%) and minor orthopyroxene. The pyroxenes are variably overgrown by fine-grained, blue-green amphibole. The rock also contains approximately 10% brown biotite. On the basis of texture in thin section, the biotite appears to coexist with the pyroxene, although at

LEGEND

NEOPROTEROZOIC

N_{DM}sst	Double Mer Formation: flat-lying to gently east-dipping beds of mauve- to brown- to dull red-weathering arkose, sandstone, and pebbly sandstone

MESOPROTEROZOIC

M_{PW}gm	Granite: pink-weathering, foliated biotite monzogranite

PALEOPROTEROZOIC

Mealy Mountains intrusive suite

P_{MM}gbr	Gabbro - gabbronorite: fresh to variably deformed and metamorphosed gabbro and gabbronorite, but also includes minor amounts of leucogabbro, leucogabbronorite, diorite, olivine-bearing rocks, and amphibolite
P_{MM}drt	Diorite: fresh to variably deformed diorite and gabbro
P_{MM}grn	Quartz monzonite and granite: massive to foliated, fine- to medium-grained quartz monzonite and granite
P_{MM}mzt	K-feldspar porphyritic monzonite: pink- to grey-weathering K-feldspar porphyritic or coarse-grained (isotropic) pyroxene-bearing monzonite
P_{MM}gmz	Grey monzonite: grey-weathering, pyroxene-bearing monzonite; generally medium grained but locally K-feldspar porphyritic, massive to foliated
P_{MM}mmt	Monzonite: a heterogeneous division consisting mainly of pink- to grey-weathering, medium-grained pyroxene-bearing monzonite, but also includes porphyritic monzonite, and minor amounts of quartz monzonite and granite
P_{MM}kmd	Quartz monzodiorite: white- to grey to locally pink-weathering K-feldspar porphyritic quartz monzodiorite containing clinopyroxene and orthopyroxene
P_{MM}mdq	Monzodiorite - diorite - monzonite: a heterogeneous division consisting of foliated to locally gneissic, pyroxene-bearing monzodiorite, diorite, monzonite, and containing minor amounts of foliated granite, in par,t the unit may contain more highly strained and recrystallized versions of all Mealy Mountains intrusive suite monzonitic and granitic rock types

Gneissic rocks

P_1ggn	Orthogneiss: pink-weathering granitic orthogneiss and migmatite

geological contact: assumed

Neoproterozoic fault: assumed

outcrop

GEOCHRONOLOGICAL DATA

1659 +/-5 Ma	age
U-Pb zircon, UI	isotopic system and mineral analysed, UI - upper intercept age, CD - concordant age
DJ-98-1176	sample number

least locally it appears to have grown at the expense of pyroxene. The rock contains accessory magnetite, zircon and titanite. Biotite defines a weak foliation in the rock, and although the foliation is not very strong, the rock is more highly strained and recrystallized than massive MMIS monzonite that occurs only 3 km to the north (*see* sample DJ-98-1119).

Abundant, euhedral, pale brown to pink, mostly cracked, 2:1 (length to width) prismatic zircon grains (zircon fractions 1:4, Figure 4) give four concordant data points that have a mean $^{207}Pb/^{206}Pb$ age of 1650.5 ± 1.1 Ma (Figure 4 and Table 1), interpreted to be the best estimate for the age of igneous crystallization. In addition, the data indicate that titanite crystallizated about 10 m.y. later, or that it was reset to 1641.3 ± 8.7 Ma ($^{207}Pb/^{206}Pb$ age) by a later thermal event. This second event is within error of the emplacement age of a major, monzonite intrusion (*see* DJ-98-1119 below), which occurs 3 km to the north. The growth or resetting of titanite in the quartz monzodiorite is interpreted to be an expression of the thermal effects related to that intrusion.

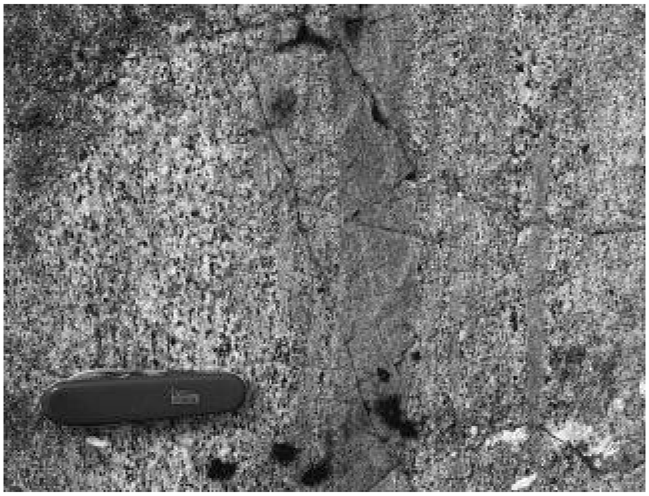

Plate 1. *Outcrop of gneissic P_{MM}mdq rocks consisting of foliated, pyroxene-bearing monzodiorite component (under the knife; DJ-98-1176 sample location) and grey-weathering diorite layer (centre).*

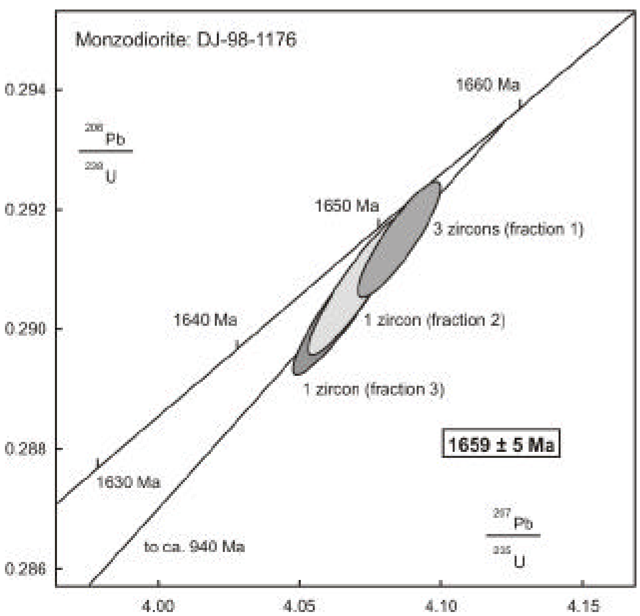

Figure 3. *U–Pb concordia diagram for sample DJ-98-1176.*

MONZONITE (P_{MM}mzt): DJ-98-1119

This sample, collected from the southeastern part of the study area (UTM 692138E, 5838460N, NTS map area 13C/9), is representative of the undeformed pyroxene-bearing monzonitic rocks, which dominate the study area and the western part of the MMIS. The sample is white to grey on the weathered surface and maple-sugar bronze on the fresh surface (Plate 2). It is dominated by medium- to coarse-grained K-feldspar phenocrysts surrounded by a lesser amount of fine-grained, recrystallized K-feldspar grains, which are derived from recrystallization of the phenocryst margins, plagioclase and minor quartz. The rock contains approximately 10% clinopyroxene, minor orthopyroxene and accessory magnetite and zircon. The pyroxenes define an intergranular texture. The rock also contains very minor amounts of amphibole and biotite that have clearly grown at the expense of the pyroxenes. The rock does not contain a tectonic fabric.

Abundant, high-quality zircons in the form of large fragments (broken during pulverization?) were concentrated from the sample. Three single-grain fractions give concordant (fractions 1 and 2) and near concordant (fraction 3) data (Figure 5 and Table 1). The mean ^{207}Pb/^{206}Pb age of fractions 1 and 2 is 1643.2 ± 2 Ma and is considered the best estimate for the age of igneous crystallization. This age is consistent with the 1646 ± 2 Ma age of emplacement determined for a pyroxene-bearing monzonite from the western MMIS (*see* Emslie and Hunt, 1990).

GRANITE (M_{PW}grn): DJ-98-1152

This sample of monzogranite was collected from the southern part of the study area (UTM 676622E, 5834825N; NTS map area 13C/9). In the field it was noted that the sample was well foliated, coarser grained, contained significantly more quartz (>20%) and appeared to be pyroxene-absent, as compared to the typically massive, fine- to medium-grained and pyroxene-bearing granite and quartz monzonite of the MMIS. A testable model based on the field data proposed that the sample was from a deformed granite intrusion that predated the MMIS.

The sample is light pink on the fresh and weathered surfaces. It is a fine- to coarse-grained, anhedral granular rock (Plate 3) having a southeast-striking foliation. The foliation is defined by recrystallized, lenticular quartz aggregates. It consists of relict, coarse-grained K-feldspar phenocrysts and very fine-grained, recrystallized K-feldspar (microcline), quartz and plagioclase. The rock contains less than 5%, fine-grained biotite that is variably pseudomorphed by chlorite. It also contains accessory magnetite and zircon.

The sample contains a population of brown to dark brown, euhedral, highly cracked and altered zircon. Most grains are large (200 to 500 microns), although the sample also contains a population of small needles (100 microns) that are relatively less cracked and altered compared to the large grains. The small needles were selected for analysis. They contain uranium concentrations between 100 and 300

Table 1. U-Pb Isotopic Results

	Weight (mg)	U (ppm)	Th/U	Common Pb (pg)	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{238}U$	2 sigma	$^{207}Pb/^{235}U$	2 sigma	Age (Ma) $^{207}Pb/^{206}Pb$	2 sigma	percent discordant
DJ-98-1176: Monzodiorite												
fraction 1: 3 zircon fragments,												
colourless to pale brown	0.001	295.52	0.91	0.89	642.01	0.29149	0.00048	4.0858	0.008	1654.60	1.6	0.4
fraction 2: 1 zircon, colourless	0.001	210.31	0.82	0.59	689.25	0.29077	0.00060	4.0718	0.009	1652.90	1.5	0.5
fraction 3: 1 zircon, brown	0.001	297.70	0.62	0.41	1394.73	0.29036	0.00056	4.0643	0.008	1652.10	1.3	0.6
DJ-98-1130: Quartz monzodiorite												
1 zircon	0.001	280.10	0.72	4.50	133.20	0.29168	0.00087	4.0823	0.015	1651.80	3.4	0.1
1 zircon	0.002	218.40	0.78	5.90	154.13	0.29173	0.00088	4.0809	0.014	1650.90	2.8	0.1
1 zircon, pink, euhedral	0.001	257.40	0.85	0.80	841.35	0.29139	0.00070	4.0739	0.012	1649.90	2.9	0.1
1 zircon, pink, euhedral	0.001	164.30	0.76	0.40	736.94	0.29174	0.00075	4.0772	0.012	1649.20	3.0	0.1
DJ-98-1119: Monzonite												
fraction 1: brown, very large fragment	0.033	223.60	0.63	2.70	5116.03	0.29043	0.00093	4.0455	0.012	1643.00	3.7	0.0
fraction 2: pale-brown fragment	0.012	206.90	0.69	0.60	6123.03	0.28946	0.00080	4.0326	0.011	1643.30	2.9	0.3
fraction 3: colourless, large fragment	0.012	86.80	0.68	1.20	1591.97	0.28861	0.00059	4.0135	0.010	1640.00	1.9	0.4
DJ-98-1152: Foliated granite												
fraction 1: 5 zircons,												
small grains and fragments	0.002	315.58	0.47	1.44	721.27	0.26477	0.00057	3.4676	0.007	1527.80	2.4	1.0
fraction 2: 2 zircons,												
colourless to pale brown	0.001	116.04	0.30	0.55	346.90	0.26181	0.00074	3.3871	0.010	1504.70	2.7	0.4
fraction 3: 2 zircons,												
colourless to pale brown	0.001	217.54	0.53	1.40	253.30	0.25670	0.00058	3.2924	0.009	1488.30	3.5	1.1

ppm. Three fractions of zircon (Figure 6 and Table 1) give $^{207}Pb/^{206}Pb$ ages of 1504.7 ± 2.7 (fraction 2), 1488.3 ± 3.5 (fraction 3), and 1527.8 ± 2.4 (fraction 1) Ma and were 0.42%, 1.16% and 1.00% discordant, respectively. The two fractions containing two grains each (fractions 2 and 3) define a chord having an upper intercept age of 1514 ± 10 Ma and a lower intercept age of ca. 1050 Ma. The upper intercept age is interpreted to be the best estimate for the age of igneous crystallization. The lower intercept age indicates the sample was overprinted by a Grenvillian thermal event. Data for fraction 1, containing five grains, plots to the right of the chord and may indicate that there is older inherited material in this population. Refinement of this age is needed through additional analyses.

DISCUSSION

The data indicate that the samples of gneissic monzodiorite (DJ-98-1176), foliated quartz monzodiorite (DJ-98-1130) and monzonite (DJ-98-1119) are mid-Labradorian intrusions, and all three units correlate with the MMIS. Thus, one of the models proposed by James and Lawlor (1999) that the variably deformed and metamorphosed rocks occurring in the southern part of the Kenamu River area (i.e., represented by samples DJ-98-1176 and DJ-98-1130) represented crust that predated emplacement of the MMIS, is not supported by the geochronological data. However, the timing of deformation and metamorphism in the gneissic monzodiorite and foliated quartz monzodiorite samples remains somewhat uncertain. It is possible that these rocks were overprinted by a mid-Labradorian tectonothermal event constrained between ca. 1659 and 1643 Ma, i.e., between the ages of emplacement of the most extensively overprinted and the freshest rocks, respectively. In this model, intrusion of the quartz monzodiorite, at 1650 Ma, would be synchronous with the tectonothermal event. This model may explain the textural and structural differences between the three MMIS samples. Conversely, the geochronological data also support other models.

The 1514 ± 10 Ma age of emplacement for the sample of foliated granite (DJ-98-1152) is the most surprising and significant result of the geochronological study. Provisional field-based interpretations suggesting that this rock did not correlate with the MMIS, turn out to be correct. However, this granite is not, as first speculated, an intrusion that predated emplacement of the MMIS. Rather it is a Pinwarian granite and it postdates the MMIS by more than 100 m.y.

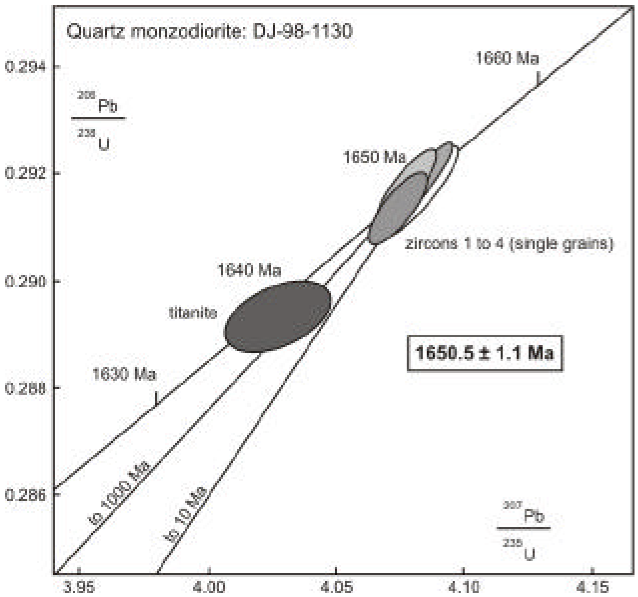

Figure 4. *U–Pb concordia diagram for sample DJ-98-1130.*

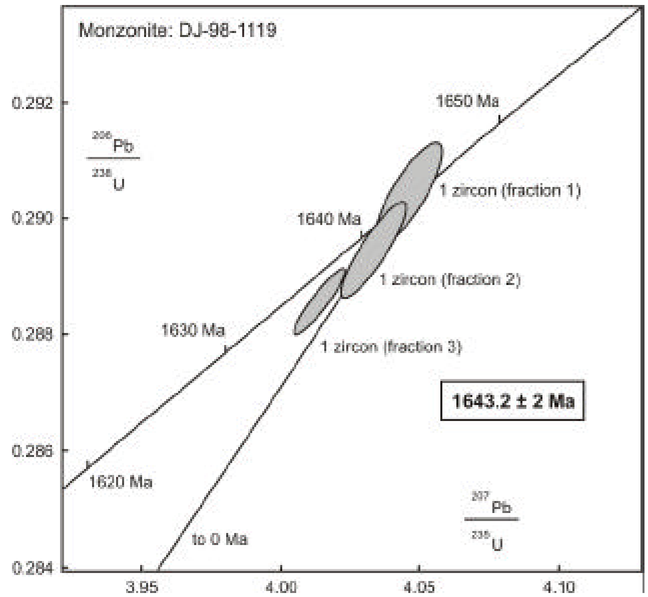

Figure 5. *U–Pb concordia diagram for sample DJ-98-1119.*

Plate 2. *Grey-weathering, massive K-feldspar porphyritic monzonite containing two pyroxenes. Sample DJ-98-1119 was collected from this outcrop.*

Plate 3. *Foliated, Pinwarian monzogranite (unit M_{PW}grn). Outcrop DJ-98-1152.*

The fact that this Pinwarian granite is deformed has important regional implications because it unequivocally demonstrates that the southwestern MMT has been overprinted by a post-1514 Ma event. This event could be Pinwarian (i.e., between 1514 and 1450 Ma) or Grenvillian, although the U–Pb data from the three samples of deformed rocks define Grenvillian lower intercept ages, albeit loosely constrained, between 1050 and 940 Ma suggesting that this event is Grenvillian. This interpretation does not eliminate the possibility of a mid-Labradorian (i.e., pre-1643 Ma) event, as discussed previously, although it does make that model less appealing. Nevertheless, it remains that some MMIS rocks have completely escaped penetrative strain, are essentially fresh and show only limited evidence of recrystallization.

Assuming that the area has been overprinted by only a Grenvillian tectonothermal event, the relatively close spatial relationship between deformed and undeformed MMIS rocks could be explained by a model of heterogeneous distribution of strain. The strain is heterogeneous from the map scale to the outcrop scale, although undeformed MMIS rocks occur mainly, but not exclusively, in the northern part of the Kenamu River study area. However, there is no well-

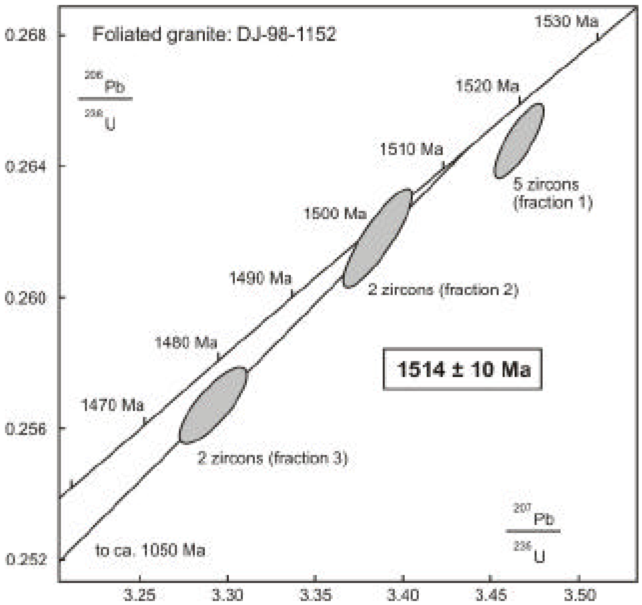

Figure 6. *U–Pb concordia diagram for sample DJ-98-1152.*

defined "structural front" that separates regions of deformed and undeformed rocks. The variations in strain and degree of recrystallization cannot easily be explained by a simple model invoking MMIS intrusions of several ages that predate and postdate a mid-Labradorian deformation. Rather, the development of tectonic fabrics may have been influenced by original textures or variations in grain size. Coarse-grained, isotropic rocks, like monzonite sample DJ-98-1119, may be less amenable to developing a tectonic foliation as compared to finer grained rocks containing an original igneous lamination. That said, additional geochronological studies are necessary to refine tectonic models for this region, which has been affected by Paleoproterozoic (>1660 Ma) to Neoproterozoic tectonic events.

REFERENCES

Corfu, F. and Stott, G.M.
1986: U-Pb ages for late magmatism and regional deformation in the Shebandowan belt, Superior Province, Canada. Canadian Journal of Earth Sciences, Volume 23, pages 1075-1082.

Davis, D.
1982: Optimum linear regression and error estimation applied to U-Pb data. Canadian Journal of Earth Sciences, Volume 19, pages 2141-2149.

Emslie, R.F.
1976: Mealy Mountains complex, Grenville Province, southern Labrador. *In* Report of Activities, Part A. Geological Survey of Canada, Paper 76-1A, pages 165-170.

Emslie, R.F. and Hunt, A.
1990: Ages and petrogenetic significance of igneous-charnockite suites associated with massif anorthosites, Grenville Province. Journal of Geology, Volume 98, pages 213-231.

Gower, C.F.
1996: The evolution of the Grenville Province in eastern Labrador. *In* Precambrian Crustal Evolution in the North Atlantic Region. *Edited by* T.S. Brewer. Geological Society Special Publication No. 112, pages 197-218.

1999: Geology of the Crooks Lake map region, Grenville Province, eastern Labrador. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey, Report 99-1, pages 41-58.

Gower, C.F. and Owen, V.
1984: Pre-Grenvillian and Grenvillian lithotectonic regions in eastern Labrador - correlations with the Sveconorwegian Orogenic Belt in Sweden. Canadian Journal of Earth Sciences, Volume 21, pages 678-693.

Gower, C.F., van Nostrand, T. and Smyth, J.
1988: Geology of the St. Lewis River map region, Grenville Province, eastern Labrador. *In* Current Research. Newfoundland Department of Mines, Mineral Development Division, Report 88-1, pages 59-73.

Jaffey, A.H., Flynn, K.F., Glendenin, L.E., Bentley, W.C. and Essling, A.M.
1971: Precision measurements of half-lives and specific activities of 235U and 238U. Physics Reviews: Nuclear Physics, Volume 4, pages 1889-1906.

James, D.T.
1994: Geology of the Grenville Province in the Lac Joseph and Ossokmanuan Lake areas (23A/NW and 23H/SW), western Labrador. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 94-2, 58 pages.

1999: Geology of the Kenamu River area (NTS 13C/NE), Grenville Province, southern Labrador. Newfoundland Department of Mines and Energy, Geological Survey, Open File 013C/0040, 1:100 000-scale map with descriptive notes.

James, D.T. and Lawlor, B.
1999: Geology of the Grenville Province, Kenamu River area (NTS 13C/NE), southern Labrador: Preliminary observations of Labradorian and Pre-Labradorian(?) intrusions. *In* Current Research. Newfoundland

Department of Mines and Energy, Geological Survey, Report 99-1, pages 59-70.

Kerr, A.
1989: Geochemistry of the Trans-Labrador granitoid belt, Canada: A quantitative comparative study of a Proterozoic batholith and possible Phanerozoic counterparts. Precambrian Research, Volume 45, pages 1-17.

Krogh, T.E.
1973: A low contamination method for hydrothermal decomposition of zircon and extraction of U and Pb for isotopic age determinations. Geochimica et Cosmochimica Acta, Volume 37, pages 488-494.

1982: Improved accuracy of U-Pb zircon ages by the creation of more concordant systems using an air abrasion technique. Geochimica et Cosmochimica Acta, Volume 46, pages 637-649.

Krogh, T.E., Gower, C.F. and Wardle, R.J.
1996: Pre-Labradorian crust and later Labradorian, Pinwarian and Grenvillian metamorphism in the Mealy Mountains terrane, Grenville Province, eastern Labrador. *In* Proterozoic Evolution in the North Atlantic Realm. *Compiled by* C.F. Gower. COPENA-ECSOOT-IBTA conference, Goose Bay, Labrador, Program with Abstracts, pages 106-107.

Stacey, J.S. and Kramers, J.D.
1975: Approximation of terrestrial lead iotope evolution by a two-stage model. Earth and Planetary Science Letters, Volume 26, pages 207-221.