Current Research (1997) Newfoundland Department of Mines and Energy, Geological Survey, Report 97-1, pages 1-7

THE AGE OF THE MOKAMI HILL ("OLD MOKAMI") QUARTZ MONZONITE, GRENVILLE PROVINCE, EASTERN LABRADOR

C.F. Gower and S. Kamo[1]
Labrador Mapping Section

ABSTRACT

"Old Mokami" is a song, well-known in Labrador, about Mokami Hill, which is a prominent feature situated 57 km north-northeast of Goose Bay in the eastern Grenville Province. A two-pyroxene quartz monzonite from near the peak of Mokami Hill has yielded an age of 1417 ± 5 Ma (U–Pb, zircon; 2σ error), meaning that "Old Mokami" is only middle-aged by geological standards. The date analytically overlaps with a 1426 ± 6 Ma age for the Michael Gabbro, found in the same region, thus providing the first indication that magmatism at this time was not entirely mafic. By occupying a previous gap in ages, the date emphasizes the continuum of AMCG (anorthosite–monzonite–charnockite–granite) magmatism in eastern Laurentia from 1500 to 1230 Ma.

INTRODUCTION

Mokami Hill has been immortalized in a song entitled "Old Mokami" (music composed by Gerald Mitchell and lyrics by Bryon Chaulk and popularized by singer Shirley Montague. *See* Appendix 1). The hill is located 57 km north-northeast of Goose Bay and 5 km north of the mouth of the Sebaskachu River (54°49'N; 60°8'W) where it forms a prominent geographical feature in the area, as it is steep sided and rises abruptly from the surrounding lowlands (50 m asl) to a height of 486 m. The hill is a local tourist attraction and can be reached by a trail from the shore of Sebaskachu Bay.

How old is "Old Mokami"? The question is answered here and some of the broader geological implications of the age are discussed.

GEOLOGICAL SETTING

Mokami Hill is situated in the southwest part of the Groswater Bay terrane in the eastern Grenville Province (Figure 1) and is included within the region mapped at 1:100 000 scale by Erdmer (1984). The bedrock surrounding Mokami Hill is described by Erdmer (*op. cit.*) as a medium-grained, grey, well-layered biotite and hornblende granodioritic gneiss. A sample of the gneiss, 19 km west-northwest of Mokami Hill (Figure 2), has yielded an age of $1677\ ^{+18}_{-11}$ Ma (Schärer *et al.*, 1986).

The southern side and peak of Mokami Hill is included as part of Erdmer's (1984) Unit *Hgmq*, which he described as "buff, resistant, massive to well foliated, coarse grained, hornblende granite to quartz monzonite". The crescent-shaped area on the northern flank of the hill was designated by Erdmer (*op. cit.*) as Unit *Hbm* and described as "massive, equigranular, coarse grained, brown biotite monzodiorite". Obvious topographic lineaments (Figure 2) suggest that the hill is surrounded by three intersecting faults and perhaps owes its existence to them. An east-trending lineament passes north of Mokami Hill, a northwest-trending lineament lies to the west, and a northeast-trending lineament to the southeast coincides with a major mylonite zone mapped by Erdmer (*op. cit.*).

A second, lithologically similar body was identified by Erdmer (1984) 5 km north-northeast of Mokami Hill (Figure 2). It is 3 km in diameter and was designated as Unit *Hqmg*, for which his description reads "pink, coarse grained, massive to weakly foliated biotite quartz monzonite and granite". He referred to the two bodies as nearly unstrained stocks, and noted that they are both characterized by coarse-grained zircon. This body does not form a prominent landmark like Mokami Hill, which may introduce some doubt that the two intrusions are correlative, but the contrast could simply reflect differing structural or glacial histories. Mokami Hill and the body to the north were grouped by Erdmer (*op. cit.*) with a much larger homogeneous, coarse-grained, pink to buff

[1] Jack Satterly Geochronology Laboratory, Geology Department, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario, M5S 2C6.

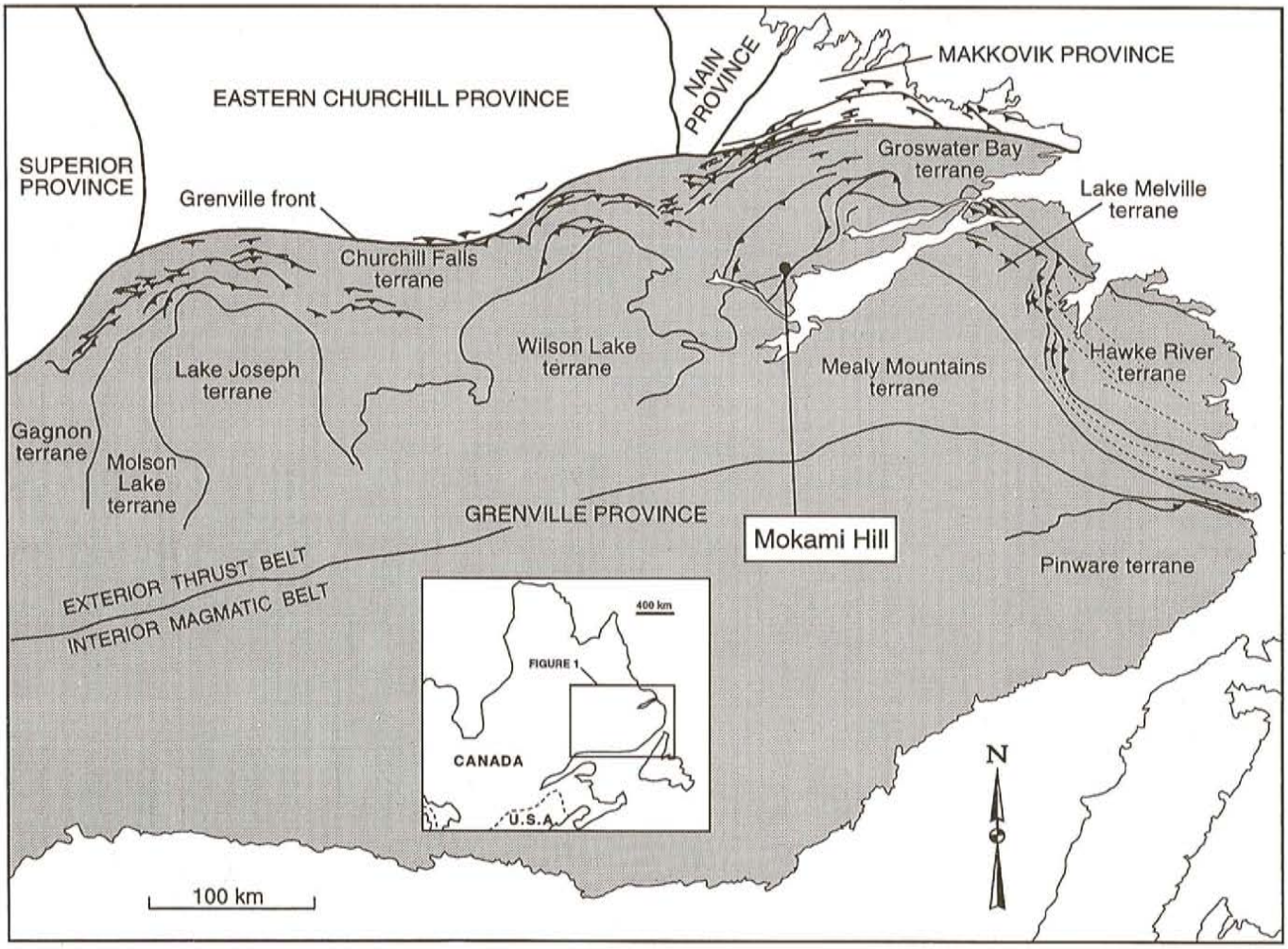

Figure 1. *Location of Mokami Hill in the eastern Grenville Province.*

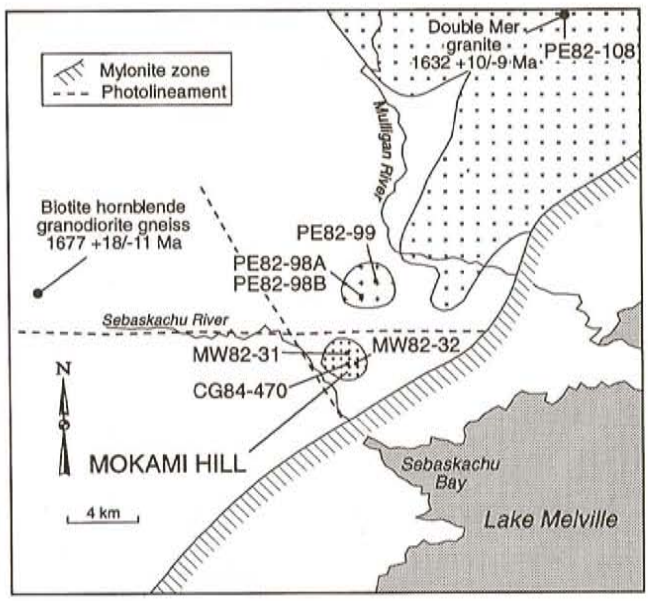

Figure 2. *Simplified geological sketch map of the Mokami Hill area. Patterned granitoid units discussed in text.*

biotite granite to the northeast forming an intrusion about 20 km across (his Unit *Hpxg*). The grouping was based on evidence indicating that all three bodies intrude the surrounding gneisses, show relatively weak strain, and are K-feldspar-rich rock types. The biotite granite (Unit *Hpxg*) was termed the Double Mer granite by Schärer *et al.* (1986) and dated to be 1632 $^{+10}_{-9}$ Ma from a site 25 km northeast of Mokami Hill. The age for the sample from Mokami Hill reported here now demonstrates that correlation of all three intrusions is not correct.

PETROGRAPHIC FEATURES

The dated sample (CG84-470, Figure 2) was collected from the western side of Mokami Hill, about 20 m below its summit. The outcrop is massive, not extensively recrystallized, and cut by minor granitoid intrusions. The rock is a coarse-grained quartz monzonite (hereafter termed the Mokami Hill quartz monzonite) containing orthopyroxene, clinopyroxene and amphibole. Orthopyroxene is sparse, forming elongate grains that are extensively altered to orange-brown bastite. The more abundant clinopyroxene forms stubby anhedral to subhedral light-green grains, having

exsolved opaque minerals along cleavage traces. The clinopyroxene resembles Fe-rich varieties that characterize AMCG suite monzonitic rocks. Dark-green amphibole is the most common mafic mineral; it forms anhedral clusters, with which other mafic and opaque minerals are associated. Accessory minerals include large, zoned allanite, an anhedral opaque mineral, common zircon, rare apatite and minor amounts of an orange-brown phyllosilicate, which is probably Fe-rich biotite. The zircons have thin rims. Felsic minerals are quartz, perthitic alkali feldspar (having coarse flame texture) and minor well-twinned sodic plagioclase.

A whole-rock geochemical analysis is not available for the dated sample of Mokami Hill quartz monzonite. However, Erdmer (1984) established two data stations on Mokami Hill (MW82-31 and MW82-32, Table 1); samples were collected at both sites, thin sections cut and whole-rock, major- and trace-element geochemical data obtained. As can be seen from Table 1, the two rocks are chemically distinct, thus provoking the questions, "Which rock compositionally represents the dated sample, and are two unrelated rock types present?". From comparison of thin sections, there is little doubt that the dated rock more closely resembles MW82-31. The most important characteristics in common are: i) large, anhedral, undulose, unpolygonized quartz grains, ii) coarse flame perthite, iii) 'sieved' texture in amphibole, iv) the presence of green clinopyroxene, v) minor orange-brown biotite, vi) similar accessory minerals, except that allanite is much less common in MW82-31.

In contrast, allanite in MW82-32 forms large, zoned grains similar to those in the dated sample and this feature may suggest genetic linkage. However, MW82-32 shows several significant contrasts, especially in being much more recrystallized and containing garnet. If MW82-32 is genetically related to the dated rock, it may be a less silicic phase of the intrusion. This would be consistent with Erdmer's (1984) suggestion that the monzodiorite (Unit *Hbm*) might be related to the central quartz-monzonite-granite (Unit *Hgqm*). It is reasonable to suppose that the monzodiorite is a border phase of the intrusion and that its recrystallization is attributable to Grenvillian deformation.

Thin sections of two samples (PE82-98B and PE82-99; Erdmer, 1984) from the small body to the north show some petrographic differences with the Mokami Hill quartz monzonite, especially higher biotite and plagioclase contents and more extensive recrystallization. Three whole-rock chemical analyses from this body (PE82-98A, PE82-98B, PE82-99; Erdmer, 1984) show compositional similarity with both MW82-32 and the 1632 $^{+10}_{-9}$ Ma Double Mer granite (PE82-108; Erdmer, 1984) (Table 1).

U–Pb ISOTOPIC RESULTS

A homogeneous population of clear, generally large (200 to 500 μm), pale-brown, equant to long prismatic zircon grains was recovered from the Mokami Hill quartz monzonite. The population is notable for its abundant yield of high-quality grains, many of which have surfaces that exhibit a small degree of rounding. Two single- and two multigrain-zircon fractions were analyzed for U and Pb (Table 2). Three data points (No. 1 to 3; Figure 3) are collinear and give an upper intercept age of 1417 ± 5 Ma (2 σ). Due to the limited spread in the three data points, it is useful to assume that Pb loss occurred between about 800 and 0 Ma, in order to approximate a reasonable estimate for the upper age error. This is consistent with lower intercept ages from previous U–Pb dating of samples from the surrounding region (Kamo *et al.*, 1996). A fourth data point indicates a slightly older $^{207}Pb/^{206}Pb$ age of 1422 ± 2 Ma (Table 2). It is interpreted that this multigrain fraction contained a small inherited component.

DISCUSSION

The 1417 ± 5 Ma age clearly distinguishes the Mokami Hill quartz monzonite from the 1632 $^{+10}_{-9}$ Ma Double Mer granite. It remains uncertain whether the small body north of Mokami Hill is related to the Double Mer granite or the Mokami Hill quartz monzonite.

The 1417 ± 5 Ma Mokami Hill quartz monzonite is the only known, late geon-14 granitoid body in the eastern Grenville Province (cf., Gower and Tucker, 1994; Gower *et al.*, 1995). Similar monzonitic rocks occur in the Upper Paradise River pluton, 200 km to the southeast (Figure 4), but U–Pb zircon age determinations of 1501 ± 9 Ma and 1495 ± 7 Ma (Wasteneys *et al., in press*) show that this intrusion is significantly older. Granitoid rocks emplaced in the Pinware terrane between 1490 ± 5 and 1472 ± 3 Ma (Tucker and Gower, 1994) are also older. Closer in age are the ca. 1470 to 1420 Ma Harp Lake, Michikamau and Mistastin AMCG suites, all of which are located north of the Grenville Province, but overlapping with metamorphism at 1450 $^{+15}_{-21}$ Ma in the Pinware terrane (Wasteneys *et al., in press*).

The 1417 ± 5 Ma age also distinguishes the Mokami Hill quartz monzonite from the Nain Plutonic Suite emplaced north of the Grenville front between 1350 and 1280 Ma. Rocks coeval with the Nain Plutonic Suite were emplaced in the northern part of the eastern Grenville Province. These include the Red Wine Intrusive Suite dated to be 1337 $^{+10}_{-7}$ Ma (Gandhi *et al.*, 1988) and the spatially associated Letitia Lake Group (1327 $^{+4}_{-2}$ Ma; Fryer 1983). Farther east, the Arrowhead Lake and Upper North River bodies have yielded ages of 1307 ± 28 Ma (Rb–Sr, whole rock; Fryer in Ryan *et al.*, 1982) and 1296 $^{+13}_{-12}$ Ma (Schärer *et al.*, 1986), respectively. In the southern regions of the eastern Grenville Province, the Rivière Pentecôte anorthosite has been dated to be 1354 ± 3 Ma (Martignole *et al.*, 1993) and 1365 $^{+7}_{-4}$ Ma (Emslie and

Table 1. Major- and trace-element whole-rock geochemical analyses and CIPW normative minerals from Mokami Hill and selected other rocks in the area

	Mokami Hill		North of Mokami Hill			Double Mer granite
Sample no.	MW82-31	MW82-32	PE82-98A	PE82-98B	PE82-99	PE82-08
Rock type	*Hgqm*	*Hgqm*	*Hqmg*	*Hqmg*	*Hqmg*	*Hpxg*
Major elements (Wt %)						
SiO_2	71.70	64.50	64.80	64.40	64.10	65.50
TiO_2	0.37	0.22	0.91	0.84	0.88	0.56
Al_2O_3	12.25	17.45	15.15	15.10	15.65	15.75
Fe_2O_3	1.26	0.97	1.76	1.70	1.48	1.18
FeO	2.63	1.81	3.79	3.47	3.34	2.27
$Fe_2O_3^t$	4.18	2.98	5.97	5.56	5.19	3.70
MnO	0.07	0.10	0.21	0.19	0.17	0.10
MgO	0.12	0.23	0.86	0.83	0.70	0.50
CaO	0.78	1.20	2.17	2.10	1.94	1.57
Na_2O	3.65	5.12	4.30	4.37	4.84	4.68
K_2O	5.43	6.53	5.23	5.35	5.69	5.81
P_2O_5	0.05	0.05	0.37	0.35	0.34	0.14
LOI	0.32	0.38	0.26	0.36	0.47	0.88
Total	98.63	98.56	99.81	99.06	99.60	98.94
Trace elements (ppm; n.d. - not detected)						
Li	21.9	12.6	15.2	15.7	16.6	20.2
F	554	283	979	870	242	414
V	n.d.	8	19	19	9	9
Ni	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cu	6	4	8	7	3	5
Zn	163	130	164	148	143	91
Zr	776	316	487	421	281	813
Cr	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ga	33	36	26	26	25	25
Rb	138	112	86	92	54	63
Sr	22	308	276	287	289	258
Y	71	71	70	68	45	41
Nb	69	52	31	29	18	20
Mo	5	4	5	3	2	3
Ba	196	1238	2091	2236	2594	1458
La	180	115	113	103	74	109
Ce	348	228	238	221	156	204
Th	n.d.	6	2	3	n.d.	4
Pb	24	27	23	23	19	27
U	0.5	0.8	1.1	1.0	0.5	0.8
Normative mineralogy (CIPW)						
Quartz	27.1	5.9	13.3	12.4	8.7	11.5
Zircon	0.2	0.1	0.1	0.1	0.1	0.2
Orthoclase	32.2	38.6	30.9	31.7	33.7	34.4
Albite	30.9	43.3	36.4	37.0	41.0	39.6
Anorthite	0.9	5.4	6.6	5.8	4.2	4.8
Diopside	1.8	0.3	1.4	2.0	3.5	2.1
Hypersthene	2.7	2.7	5.9	5.0	3.8	2.7
Magnetite	1.8	1.4	2.6	2.5	2.2	1.7
Ilmenite	0.7	0.4	1.7	1.6	1.7	1.1
Apatite	0.1	0.1	0.9	0.9	0.9	0.3
Fluorite	0.2	0.1	0.3	0.2	0.0	0.1
Spodumene	0.1	0.0	0.0	0.0	0.0	0.1
Total	98.6	98.5	100.1	99.2	99.6	98.4

Table 2. U-Pb zircon data for Mokami Hill quartz monzonite, eastern Labrador

No.	# of zircon	Weight (μg)	U (ppm)	Th/U	Pb^c	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	Age (Ma) $^{207}Pb/^{206}Pb$	%D
1	1	30	124	0.35	4.8	1070	0.24477 ± 0.00030	3.0198 ± 0.0041	1414.5 ± 1	0.2
2	1	12	114	0.39	6.1	321	0.24339 ± 0.00040	2.9990 ± 0.0051	1412.0 ± 2	0.6
3	21	321	141	0.35	8.6	7163	0.24255 ± 0.00135	2.9831 ± 0.0166	1408.5 ± 2	0.9
4	8	33	108	0.38	10.4	483	0.24413 ± 0.00057	3.0236 ± 0.0074	1421.9 ± 1	1.1

Note: All zircon fractions have been abraded (Krogh, 1982); Th/U ratio estimated from abundance of ^{208}Pb and U–Pb age; Pb^c is the total amount of common Pb from sample and laboratory procedures; $^{207}Pb/^{204}Pb$ is the measured ratio; Pb/U ratios are corrected for fractionation, blank, spike, and initial common Pb; %D is percent discordant assuming zero-age Pb loss; errors are 1 σ.

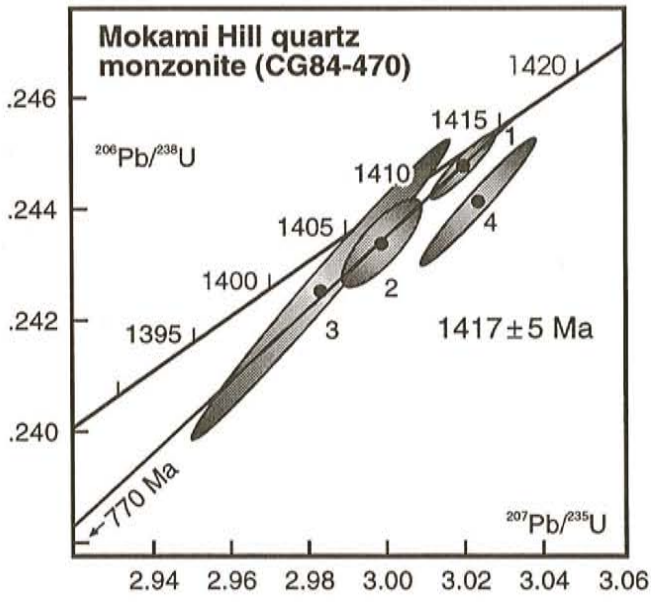

Figure 3. *Concordia diagram for the Mokami Hill quartz monzonite (CG84-470).*

Hunt, 1990) and a monzonite in the Havre–St. Pierre area has an age of 1322 ± 7 Ma (Martignole *et al.*, 1994).

The unit closest in age to the Mokami Hill quartz monzonite is the Michael Gabbro, which also occurs in the Groswater Bay terrane. It has an age of 1426 ± 6 Ma (Schärer *et al.*, 1986), which analytically overlaps with the age of the Mokami Hill quartz monzonite. Given their spatial proximity, the Michael Gabbro and the Mokami Hill quartz monzonite may belong to a single bimodal mafic–felsic intrusive event. The Michael Gabbro has been correlated with the Shabogamo Gabbro in western Labrador, where ages of 1459 $^{+23}_{-22}$ Ma (Connelly and Heaman, 1993) and 1452 $^{+15}_{-13}$ Ma (Connelly *et al.*, 1995) have been reported. These dates suggest that the Shabogamo Gabbro is slightly older than the Michael Gabbro, but concordant monazite ages between 1423 and 1403 Ma (Connelly and Heaman, 1993) from retrogressed metasedimentary gneiss in the Lac Joseph terrane appear to record a thermal event coeval with the emplacement of the Mokami Hill quartz monzonite.

The 1417 ± 5 Ma Mokami Hill quartz monzonite fills in a gap in ages for AMCG magmatism in eastern Laurentia, supporting the hypothesis that this activity was continual from ca. 1500 to 1230 Ma. As dating advances, it is probable that intrusions of similar age will be found elsewhere in the eastern Grenville Province. If they have similar topographic expression to Mokami Hill they are not easy to overlook, but if they do not, and are similar in size, they may escape detection.

CONCLUSION

The two-pyroxene quartz monzonite pluton that underlies the Labrador landmark known as "Old Mokami" has an age of 1417 ± 5 Ma. The age supports the notion that AMCG magmatism was continual from 1500 to 1230 Ma in eastern Laurentia.

ACKNOWLEDGMENTS

O'Briens Music Store of St. John's, Newfoundland, is thanked for supplying the information on the origins of the song "Old Mokami" reproduced here, from notes accompanying a compact disk entitled "Our Labrador", with permission from Phoebe Chaulk. The words of the song are given in Appendix 1. Philippe Erdmer is thanked for leaving a well-organized collection of thin sections and whole-rock geochemical analyses following the completion of his project, Double Mer–Lake Melville and for reviewing an earlier version of this manuscript.

REFERENCES

Connelly, J.N. and Heaman, L.M.
1993: U-Pb geochronological constraints on the tectonic evolution of the Grenville Province, western Labrador. Precambrian Research, Volume 63, pages 123-142.

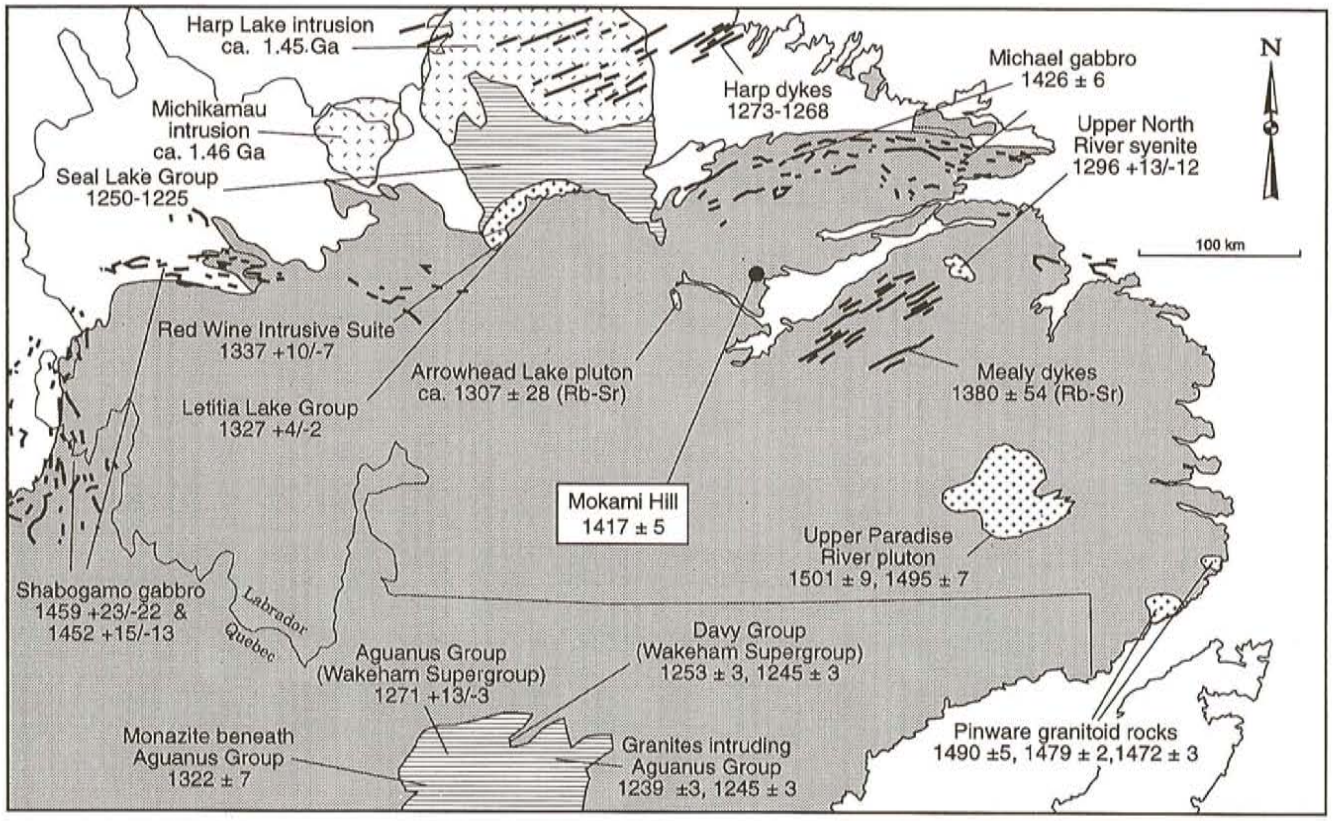

Figure 4. *Mokami Hill quartz monzonite in the context of 1500 to 1230 Ma AMCG and related magmatism in southeast Laurentia.*

Connelly, J.N., Rivers, T. and James, D.T.
1995: Thermotectonic evolution of the Grenville Province of western Labrador. Tectonics, Volume 14, pages 202-217.

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

Erdmer, P.
1984: Precambrian Geology of the Double Mer - Lake Melville region, Labrador. Geological Survey of Canada, Paper 84-18, 37 pages.

Fryer, B.J.
1983: Report of geochronology - Labrador mapping. Unpublished report to the Newfoundland Department of Mines and Energy, Open File Lab 617, 34 pages.

Gandhi, S.S., Krogh, T.E. and Corfu, F.
1988: U-Pb zircon and titanite dates on two granite intrusions of the Makkovik orogen and a peralkaline granite of the Red Wine Intrusive Complex, central Labrador. Geological Association of Canada - Mineralogical Association of Canada - Canadian Society of Petroleum Geologists, Joint Annual Meeting, St. John's, Newfoundland, Program with Abstracts, Volume 13, page A42.

Gower, C.F., James, D.T., Nunn, G.A.G. and Wardle, R.J.
1995: The eastern Grenville Province. *In* The Geology and Mineral Deposits of Labrador: A Guide for the Exploration Geologist. *Compiled by* R.J. Wardle and D.H.C. Wilton. Geological Survey of Newfoundland and Department of Earth Sciences, Memorial University of Newfoundland, pages 73-101.

Gower, C.F. and Tucker, R.D.
1994: The distribution of pre-1400 Ma crust in the Grenville province: Implications for rifting in Laurentia-Baltica during geon 14. Geology, Volume 22, pages 827-830.

Kamo, S.L., Wasteneys, H., Gower, C.F. and Krogh, T.E.
1996: Refinements to the timing of Labradorian and later events in the Grenville Province, eastern Labrador, based on new U-Pb data. Precambrian Research, Volume 80, pages 239-260.

Krogh, T.E.
1982: Improved accuracy of U–Pb dating by the creation of more concordant systems using an air abrasion technique. Geochimica et Cosmochemica Acta, Volume 46, pages 637-649.

Martignole, J., Machado, N. and Indares, A.
1994: The Wakeham terrane: a Mesoproterozoic terrestrial rift in the eastern part of the Grenville Province. Precambrian Research, Volume 68, pages 291-306.

Martignole, J., Machado, N. and Nantel, S.
1993: Timing of intrusion and deformation of the Rivière-Pentecote anorthosite. Journal of Geology, Volume 38, pages 498-547.

Ryan, B., Neale, T. and McGuire, J.
1982: Descriptive notes to accompany geological maps of the Grand Lake area, Labrador 13F/10, 11, 14, 15. Newfoundland Department of Mines and Energy, Mineral Development Division.

Schärer, U., Krogh, T.E. and Gower, C.F.
1986: Age and evolution of the Grenville Province in eastern Labrador from U-Pb systematics in accessory minerals. Contributions to Mineralogy and Petrology, Volume 94, pages 438-451.

Tucker, R.D. and Gower, C.F.
1994: A U-Pb geochronological framework for the Pinware terrane, Grenville Province, southeast Labrador. Journal of Geology, Volume 102, pages 67-78.

Wasteneys, H., Kamo, S., Moser, D., Krogh, T.E., Gower, C.F. and Owen, J.V.
In press: U-Pb geochronological constraints on the geological evolution of the Pinware terrane and adjacent areas, Grenville Province, southeast Labrador, Canada. Precambrian Research.

APPENDIX

OLD MOKAMI

Lyrics - Byron Chaulk • Music - Gerald Mitchell

Overlooking the waters of Lake Melville so grand,
One of the biggest in all this great land,
Proudly we watch as it flows to the sea,
From high on the mountain of Old Mokami.

The beautiful forest where the wildlife roams,
Where none but the free can ever call home,
Old mother Nature lets anyone see,
From high on the mountain of Old Mokami.

Our mighty old rivers are some of the best,
They flow from the North, the South and the West,
Their great dancing waters so lovely to see,
From high on the mountain of Old Mokami.

The tall Mealey Mountains off to the Southwest,
Where the caribou feed and the ptarmigan nest,
All these and more great wonders to see,
From high on the mountain of Old Mokami.

They can talk of their cities their riches unfold,
All the things that they bought with their silver and gold,
All the gold that they have couldn't buy what I see,
From high on the mountain of Old Mokami.

The song was originally recorded by Gerald in 1971 and is one of many musical collaborations with Byron Chaulk. Though the lyrics describe the view from the top of Mokami Mountain, the song conjures up images of the vast unspoiled wilderness common throughout Labrador.