Current Research (2013) Newfoundland and Labrador Department of Natural Resources
Geological Survey, Report 13-1, pages 223-232

NEW U–Pb ZIRCON GEOCHRONOLOGY FOR THE MEASLES POINT GRANITE, AILLIK DOMAIN, MAKKOVIK PROVINCE, LABRADOR (NTS MAP AREA 13O/03)

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ABSTRACT

Quartz–feldspar-porphyritic intrusions are present throughout the Aillik domain of the Makkovik Province. These intrusions are regionally extensive linear bodies that bisect the Aillik Group. One of these intrusions, the Measles Point Granite, is a fine-grained quartz–feldspar-porphyritic granite that is preserved in coastal outcrops along the western edge of Makkovik Bay. New U–Pb geochronological data from the Measles Point Granite yielded an igneous crystallization age of 1873 ± 10 Ma and a metamorphic overprinting age of 1787 ± 5 Ma. This new U–Pb date supports the interpretation that the Measles Point Granite is part of the Paleoproterozoic synvolcanic quartz–feldspar-porphyritic granite suite(s) that cut the Aillik Group. Previous studies had suggested that it may represent basement to the Aillik Group; however, this new U–Pb date, coupled with field evidence, indicates that this is not the case. The Measles Point Granite is interpreted to be part of the suite of sill-like bodies that intruded synchronous with deposition of the Aillik Group and was subsequently deformed and metamorphosed with the sequence during the compressional stages of the Makkovikian orogeny at ca. *1800 to 1780 Ma.*

INTRODUCTION

The Aillik domain, which is one of three domains that divide the Makkovik Province, is dominated by Paleoproterozoic metasedimentary and metavolcanic supracrustal sequence of the Aillik Group and by Paleoproterozoic intrusive suites (Kerr *et al.*, 1996; Figure 1). The Aillik domain is contained entirely within the Central Mineral Belt of Labrador (Ryan, 1984), an area known for its abundant and varied base-metal and uraniferous mineral occurrences. The Aillik Group, as originally mapped, was initially divided into the Upper and Lower Aillik Group (Kranck, 1939; King, 1963; Marten, 1977; Clark, 1979). However, recent work (Ketchum *et al.*, 2002), which included lithological, geochronological and geochemical studies, redefined the group as the Aillik Group (previously Upper Aillik Group) and the Post Hill Group (previously Lower Aillik Group). Recent geological mapping focused on characterizing the Aillik Group and the abundant Paleoproterozoic plutonic suites that intrude the group, including the Measles Point Granite (Hinchey, 2007; Hinchey and LaFlamme, 2009). The Aillik domain also contains abundant pre- and posttectonic mafic dykes.

This study presents *in situ* Sensitive High-Resolution Ion Microprobe (SHRIMP) U–Pb zircon geochronology from a sample of Measles Point Granite. Constraining the timing of crystallization of the Measles Point Granite is critical to evaluating tectonic models in the region. It has previously been suggested that the granite represents basement to the Aillik Group (Sinclair *et al.*, 2002). This interpretation was questioned by Hinchey (2007), who suggested that the Measles Point Granite was a synvolcanic intrusion based on more recent mapping and also that basement to the Aillik Group has not yet been identified in the field (Hinchey, 2007; Hinchey and LaFlamme, 2009). Understanding the relationship between the Aillik Group and the Measles Point Granite is critical to distinguishing between tectonic models for the formation of the Aillik Group and Makkovik Province.

REGIONAL GEOLOGY

OVERVIEW

The Makkovik Province is part of the Paleoproterozoic accretionary orogen that is bounded to the northwest by the Archean Nain Province and to the south by the Mesopro-

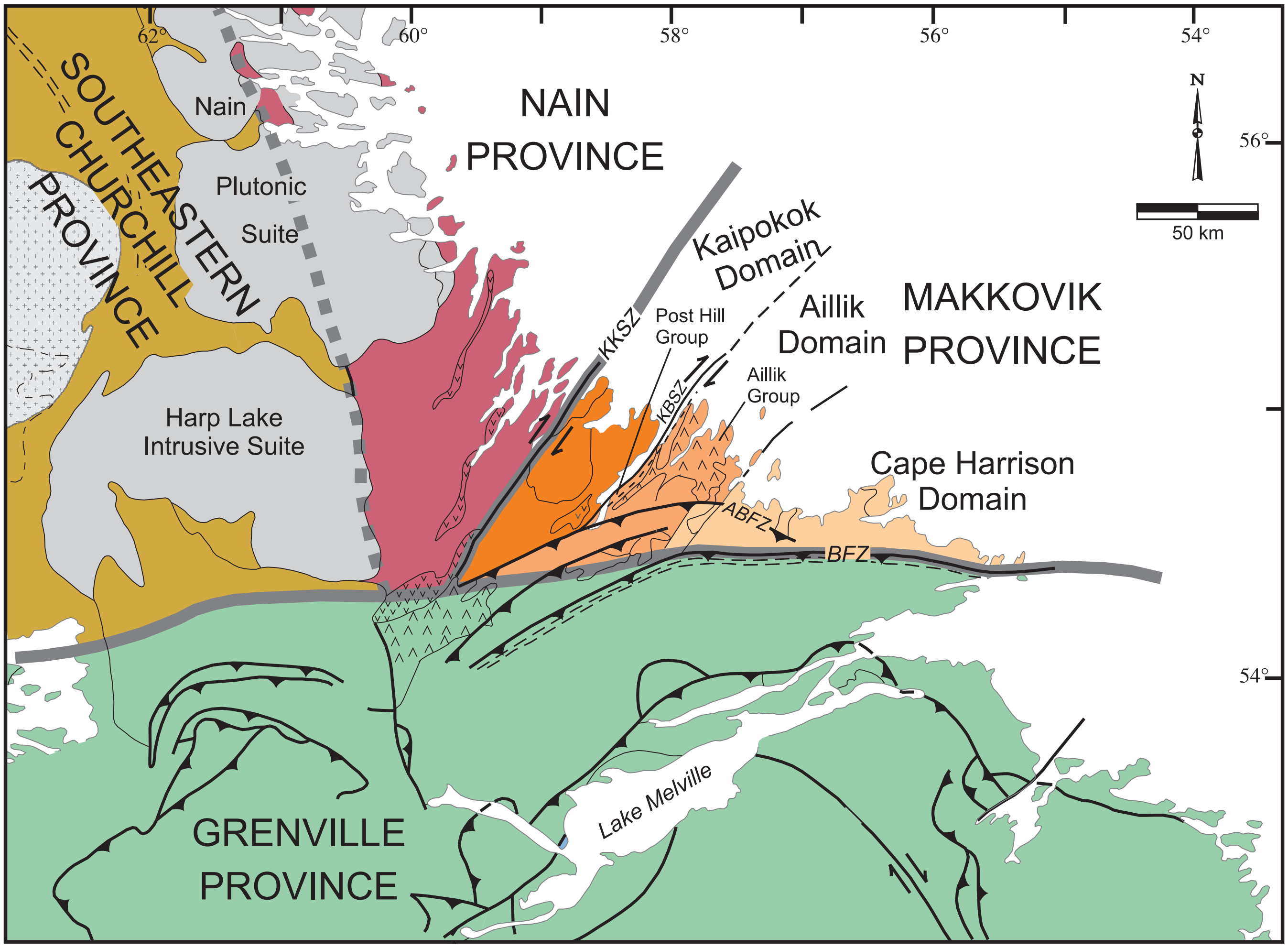

Figure 1. *A simplified tectonic framework of south-central Labrador; the map highlights the three domains of the Makkovik Province: the Kaipokok, Aillik and Cape Harrison domains (simplified after Wardle* et al.*, 1997). KBSZ – Kaipokok Bay shear zone; KKSZ – Kanairiktok shear zone; BFZ – Benedict fault zone; ABFZ – Adlavik Brook fault zone.*

terozoic Grenville Province (Figure 1). It is divided into three domains, namely (from northwest to southeast), the Kaipokok, the Aillik and the Cape Harrison domains (Kerr *et al.,* 1996). The Kaipokok domain consists of reworked Archean gneiss of the Nain Province, overlying Paleoproterozoic metavolcanic and metasedimentary supracrustal sequences of the Moran Lake and the Post Hill groups, and Paleoproterozoic granitoid intrusions (Kerr *et al.,* 1996; Ketchum *et al.,* 2001) and is interpreted to be the foreland zone of the Makkovik Province (Kerr *et al*., 1996). The boundary between the Kaipokok and Aillik domains is marked by several high-strain shear zones that cumulatively comprise the Kaipokok Bay shear zone (defined by Ketchum *et al*., 1997; *cf*., Kaipokok Bay structural zone of Kerr *et al*., 1996; Culshaw *et al*., 2000). The Aillik domain is dominated by Paleoproterozoic metasedimentary and metavolcanic supracrustal rocks (Aillik Group) and Paleoproterozoic intrusive suites (Kerr *et al.,* 1996). The Cape Harrison domain is dominated by syn- and posttectonic Paleoproterozoic intrusive suites, a package of reworked orthogneiss (Cape Harrison Metamorphic Suite), and rare enclaves of supracrustal rocks interpreted to be correlative with the Aillik Group (Gower and Ryan, 1986; Kerr *et al.,* 1996). The boundary between the Aillik domain and the Cape Harrison domain is obscured by abundant plutonic intrusions and the boundary may be transitional at deeper crustal levels (Kerr *et al*., 1996). The Aillik and Cape Harrison domains are interpreted to be part of a composite arc to rifted-arc terrane that formed prior to, and after, the start of accretion to the Nain cratonic margin (Ryan, 1984; Kerr *et al*., 1996; Culshaw *et al*., 1998). The accretion of this terrane marked the initiation of the 1.9–1.78 Ga Makkovikian orogeny, resulting in the development of a regional penetrative tectonic fabric, regional-scale shear zones and greenschist- to amphibolite-facies metamorphism (Gandhi *et al*., 1969; Sutton, 1972; Marten, 1977; Clark, 1979; Gower *et al*., 1982; Kerr, 1994; Ketchum *et al*., 1997, 2002; Culshaw *et al*., 2000). Syn- to postorogenic granitic plutons and a

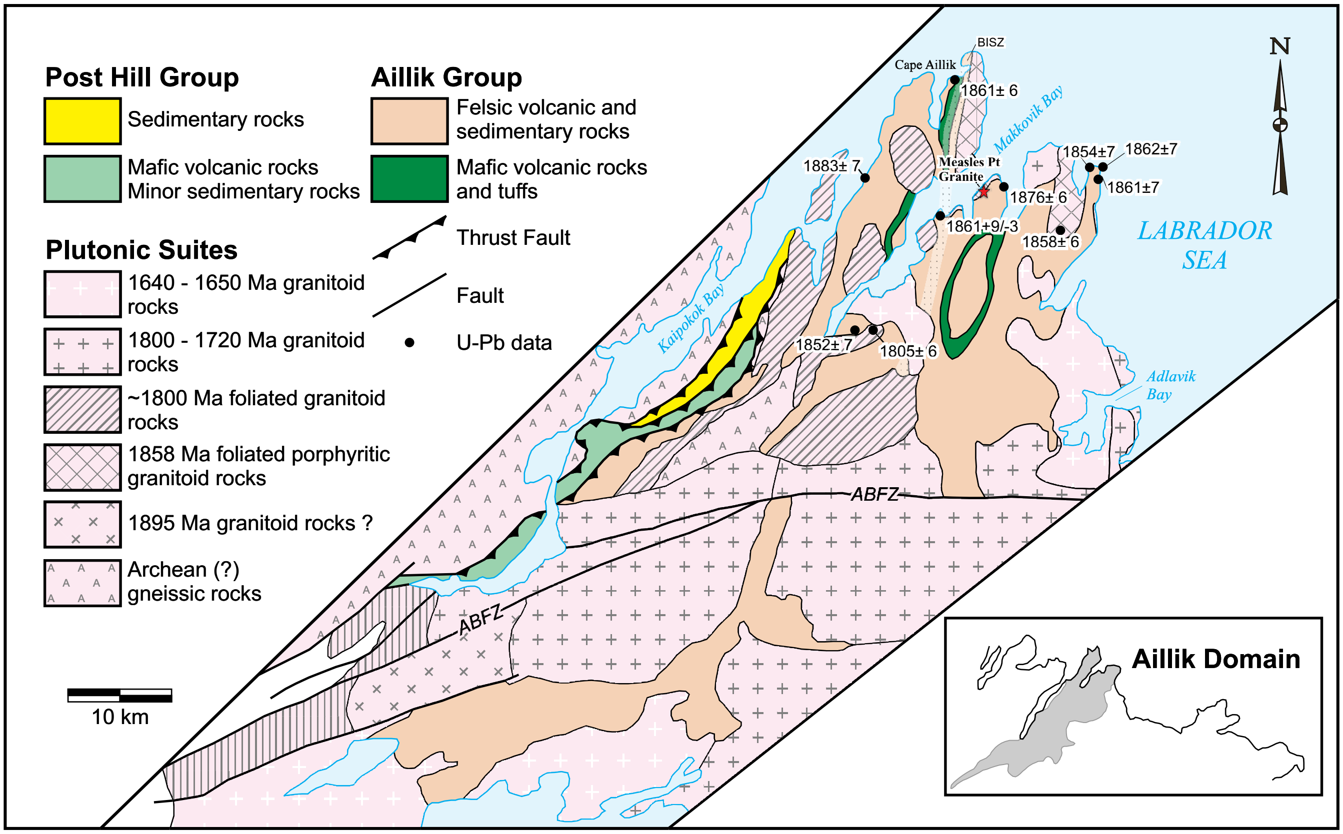

Figure 2. *A simplified geological map of the Aillik domain, Makkovik Province (modified after Kerr* et al.*, 1996). Locations of U−Pb zircon dates are plotted; data is from Schärer* et al. *(1988); Kerr* et al. *(1992), Ketchum* et al. *(1997, 2002); Sinclair* et al. *(2002); Cox* et al. *(2003); Hinchey and Rayner (2008) and LaFlamme et al. (2013). BISZ – Big Island shear zone; ABFZ – Adlavik Brook fault zone. The red star symbol marks the location of the U–Pb geochronology sample of the Measles Point Granite.*

number of late, major, east-trending faults are found throughout the Makkovik Province.

The Aillik domain is underlain mainly by the *ca*. 1883–1852 Ma Aillik Group (Schärer *et al.*, 1988; Hinchey and Rayner, 2008; LaFlamme *et al.*, 2013), which is a supracrustal assemblage of metavolcanic and metasedimentary rocks (Figure 2). The group is intruded by granitoid plutons, including *ca*. 1858 Ma synvolcanic intrusions (Hinchey and Rayner, 2008) and younger suites that range in age from *ca*. 1805 to 1630 Ma (Kerr, 1994). The Aillik Group structurally overlies the Post Hill Group. This latter group is a highly strained, amphibolite-facies, supracrustal sequence, which, in part, structurally overlies Archean gneiss that forms the basement to the lowest members of the Post Hill Group (Culshaw *et al.*, 1998, 2000; Ketchum *et al.,* 2001).

The Aillik Group comprises interbedded sandstone and siltstone, conglomerate, tuffaceous sandstone, felsic tuff, rhyolite, volcanic breccia, and lesser mafic volcanic rocks and volcaniclastic sedimentary rocks. The group is intruded by synvolcanic porphyritic granite sheets and is deformed and metamorphosed. The stratigraphy of the Aillik Group is complex because of the discontinuous lithological units and along with folding and thrusting, has resulted in the repetition of stratigraphy (Hinchey, 2007).

The U–Pb zircon ages for felsic volcanic rocks within the Aillik Group include an age of 1856 ± 2 Ma from an ash-flow tuff at Michelin Ridge, an age of 1861 +9/-3 Ma from a rhyolite flow at Ranger Bight, and a much younger age of 1807 ± 3 Ma from a quartz–feldspar porphyry, collected from White Bear Mountain (Schärer *et al.*, 1988; *see* Figure 2 for approximate locations of the U−Pb sample sites). The younger *ca*. 1807 Ma age suggests that not all of the porphyries are co-magmatic with felsic volcanism, and, in light of the widespread *ca*. 1800 Ma igneous activity in the area, it is likely that the dated porphyry is related to a younger magmatic event and is not part of the Aillik Group (Sinclair *et al*., 2002; Hinchey, 2007; Hinchey and Rayner, 2008). In addition, Hinchey and Rayner (2008) reported three U−Pb zircon dates from the Aillik Group, including, 1) a felsic tuff from Aillik Bay that yielded a date of 1861 ± 6 Ma; 2) a rhyolite from the eastern side of Kaipokok Bay that yielded a date of 1883 ±7 Ma; and 3) a rhyolite from Ford's Bight area that yielded a date of 1876 ± 6 Ma (Figure 2). These new dates for felsic volcanic rocks have extended the timing of the initiation of volcanism to *ca*. 1883 Ma. LaFlamme *et al*. (2013) reported U–Pb SHRIMP zircon geochronology from four felsic tuff samples from the Aillik Group collected from two different geographic areas yielding magmatic ^{207}Pb/^{206}Pb ages of 1852 ± 7 Ma, 1854 ± 7 Ma, 1861 ± 7 Ma, and 1862 ± 7 Ma. The ages fall within the range of previous U–Pb zircon dates reported for felsic volcanic rocks of the Aillik Group, which, taken together, indicate that felsic volcanism occurred over *ca.* 30 m.y. Volcanism was perhaps concentrated during the last 10 m.y. of that interval, based on the predominance of the younger ages; however, this may also represent a sampling bias.

Sinclair *et al*. (2002) reported a discordant, upper-intercept, ID-TIMS U–Pb zircon age of 1929 +10/-9 Ma for the Measles Point Granite, a deformed porphyritic granite exposed along the southeast coast of Makkovik Bay (Figure 2). The significance of this age has been questioned (Hinchey, 2007) because the Measles Point Granite is interpreted as a hypabyssal, foliated granite that is lithogeochemically similar to, and spatially associated with, the felsic volcanic rocks of the Aillik Group; the latter are reported (Hinchey and Rayner, 2008) to be approximately 70 Ma younger. Hinchey (2007) suggested that, based on field evidence, the intrusions are interfolded with the Aillik Group and the porphyritic granites are synvolcanic intrusions requiring them to have formed synchronous with, or shortly after, volcanism. A U–Pb date from a similar folded porphyritic granite occurring inland yielded an age of 1858 ± 6 Ma (Hinchey and Rayner, 2008) supporting this interpretation. New U–Pb geochronology from a sample of the Measles Point Granite, *per se*, is reported herein.

ANALYTICAL METHODS

Ion microprobe analysis of zircon was performed using the SHRIMP II at the Geological Survey of Canada, following the procedure described by Stern (1997), with standards and U–Pb calibration methods following Stern and Amelin (2003). Zircon grains were cast in 2.5-cm-diameter epoxy mounts (GSC #IP425) along with fragments of the GSC laboratory standard zircon (z6266), which has a ^{206}Pb/^{238}U date of 559 Ma. Internal sections of the grains were exposed by grinding and polishing using 9, 6, and 1 µm diamond compound. The internal features of the zircon grains (such as zoning, internal domains and alteration) were characterized using backscattered electron (BSE) imaging utilizing a Cambridge Instruments scanning electron microscope. Grain-mount surfaces were evaporatively coated with 10 nm Au of high purity. The SHRIMP analyses were conducted using an $^{16}O^-$ primary beam projected onto the zircons at 10 kV. The sputtered area used for analysis was *ca.* 16–25 µm in diameter with a beam current of *ca.* 2-5 nA. For the zircon analyses, the count rates of ten isotopes of Zr^+, U^+, Th^+, and Pb^+ were sequentially measured over 6–7 scans using a single electron multiplier and a pulse counting system that has a deadtime of 23 ns. Offline data processing was accomplished using SQUID version 2.23 software. A 1σ external error for ^{206}Pb/^{238}U ratios reported in the data tables incorporate a ± 1.0% error in calibrating the standard zircon (*see* Stern and Amelin, 2003). No fractionation correction was applied to the Pb-isotope data; common Pb correction utilized the Pb composition of the surface blank (Stern, 1997). Isoplot v. 3.00 (Ludwig, 2003) was used to calculate weighted means of the dates.

U–Pb GEOCHRONOLOGY

SHRIMP U–Pb data for each spot analysis of zircon, corrected for mass fractionation, are reported in Table 1. Uncertainties for the ^{207}Pb/^{206}Pb ratios and calculated ^{207}Pb/^{206}Pb dates for each analysis are quoted at 1σ. A concordia diagram (^{207}Pb/^{235}U versus ^{206}Pb/^{238}U) is shown in Figure 3 and individual analyses are plotted at the 2σ uncertainty level. Figure 4 plots Th/U ratios versus ^{207}Pb/^{206}Pb dates for individual analysis, where the bars represent 2σ uncertainty level. Figure 5 shows backscattered electron (BSE) and cathodoluminescence (CL) images of representative zircon grains and the SHRIMP pit locations.

SAMPLE DESCRIPTION

A sample of the Measles Point Granite (08AH247A03) was collected from a coastal outcrop in Makkovik Bay (Figure 2). The sample was collected from the same outcrop as the reported discordant, upper-intercept ID-TIMS U–Pb zircon date of 1929 +10/-9 Ma from Sinclair *et al.* (2002). The sample is from a massive, foliated magnetite–biotite–hornblende porphyritic monzogranite (Plate 1). The unit is fine to medium grained, weakly foliated, and contains plagioclase phenocrysts that are 1–3 mm in length. The unit is characterized by flattened mafic clots of intergrown hornblende and biotite, which define the foliation: the clots are 2–10 cm long, and represent 1% of exposure. Millimetre-scale discrete shear zones also occur throughout the outcrop.

The porphyritic monzogranite sample yielded a small amount of zircon. The zircon grains were generally of poor quality, containing abundant fractures and inclusions. Zircon grains range from stubby prisms to subrounded equant grains. In BSE images, many of the grains contain a weak, fine-scale oscillatory zoning, often rimmed by a micron-

Table 1. SHRIMP U–Pb data for each spot analysis of zircon, corrected for mass fractionation. Uncertainties for the $^{207}Pb/^{206}Pb$ ratios and calculated $^{207}Pb/^{206}Pb$ dates for each analysis are quoted at 1σ. Universal Transverse Mercator (UTM) location is from zone 21, NAD27. Excluded data are shaded grey

[a]Spot	U (ppm)	Th (ppm)	Th/U		$^{206}Pb^*$ (ppm)	$^{204}Pb/^{206}Pb$	% ±	[b]f(206)^{204} %	$^{208*}Pb/^{206*}Pb$	% ±	$^{207*}Pb/^{235}U$	% ±	$^{206*}Pb/^{238}U$	% ±	[c]Corr Coeff	$^{207*}Pb/^{206*}Pb$	% ±	$^{206}Pb/^{238}U$	±$^{206}Pb/^{238}U$	$^{207}Pb/^{206}Pb$	±$^{207}Pb/^{206}Pb$	[d]Disc. (%)
Sample 08AH247A03 - Porphyritic Granite (Measles Point Granite). UTM: 351604.0 E 6110816.0 N																						
Igneous crystallization - $^{207}Pb/^{206}Pb$ age = 1873 ± 10 Ma																						
9765-4.1	76	50	0.657		38	0.00007	37	0.11	0.193	1.7	17.32	1.2	0.5852	1.1	0.91	0.2146	0.50	2970	27	2941	8	-1
9765-13.1	46	16	0.340	0.017	13	0.00025	66	0.43	0.118	4.2	5.48	2.5	0.3341	1.2	0.48	0.1191	2.19	1858	19	1942	39	+5
9765-2.1	118	55	0.464	0.023	34	0.00024	24	0.41	0.148	2.1	5.39	1.4	0.3356	1.1	0.77	0.1166	0.91	1866	18	1904	16	+2
9765-33.1	224	106	0.472	0.024	63	0.00025	33	0.44	0.141	2.7	5.27	1.7	0.3301	1.1	0.67	0.1158	1.26	1839	18	1892	23	+3
9765-10.1	429	160	0.372	0.019	126	0.00008	23	0.13	0.113	1.4	5.47	1.1	0.3426	1.1	0.93	0.1157	0.42	1899	17	1891	7	-0
9765-12.1	235	132	0.561	0.028	68	0.00045	20	0.78	0.170	1.5	5.38	1.6	0.3377	1.1	0.68	0.1155	1.17	1875	18	1888	21	+1
9765-80.1	141	59	0.416	0.021	40	0.00018	20	0.31	0.132	2.0	5.28	1.4	0.3331	1.2	0.87	0.1150	0.70	1854	20	1879	13	+2
9765-33.1_A	245	129	0.525	0.026	69	0.00005	47	0.09	0.164	1.4	5.20	1.2	0.3290	1.1	0.90	0.1146	0.53	1834	17	1873	10	+2
9765-8.1	335	142	0.424	0.021	98	0.00012	21	0.20	0.134	1.4	5.36	1.2	0.3397	1.1	0.91	0.1145	0.49	1885	17	1873	9	-1
9765-30.1	578	323	0.559	0.028	164	0.00077	7	1.33	0.171	1.4	5.17	1.4	0.3292	1.1	0.77	0.1139	0.90	1835	17	1863	16	+2
9765-19.1	367	224	0.611	0.031	104	0.00251	4	4.35	0.194	1.0	5.20	1.7	0.3318	1.1	0.65	0.1137	1.28	1847	18	1860	23	+1
9765-81.1	141	67	0.478	0.024	39	0.00031	18	0.53	0.145	1.9	5.11	1.4	0.3260	1.1	0.78	0.1137	0.89	1819	17	1860	16	+3
9765-77.1	149	36	0.240	0.012	43	0.00017	24	0.29	0.076	2.5	5.25	1.4	0.3358	1.1	0.84	0.1135	0.73	1866	19	1855	13	-1
9765-45.1	126	74	0.589	0.029	36	0.00074	10	1.28	0.181	1.8	5.18	1.6	0.3319	1.2	0.71	0.1133	1.14	1847	19	1853	21	+0
9765-16.1	264	147	0.555	0.028	74	0.00011	35	0.19	0.168	1.6	5.12	1.3	0.3277	1.1	0.85	0.1133	0.68	1827	17	1853	12	+2
9765-30.1_A	438	231	0.528	0.026	119	0.00177	4	3.07	0.164	2.1	4.93	1.5	0.3159	1.1	0.72	0.1132	1.04	1770	16	1852	19	+5
9765-43.1_A	110	35	0.318	0.016	31	0.00019	27	0.34	0.097	2.6	5.04	1.4	0.3267	1.1	0.77	0.1119	0.91	1822	17	1830	17	+1
Metamorphism - $^{207}Pb/^{206}Pb$ age = 1787.0 ± 5.6 Ma																						
9765-6.1	478	26	0.055	0.003	132	0.00005	23	0.09	0.016	2.9	4.95	1.1	0.3224	1.1	0.95	0.1114	0.34	1802	17	1822	6	+1
9765-43.1	143	44	0.306	0.015	39	0.00103	22	1.79	0.078	5.6	4.84	3.6	0.3156	1.5	0.42	0.1112	3.26	1768	23	1818	59	+3
9765-74.1	40	8	0.193	0.010	11	0.00127	15	2.20	0.040	4.6	4.80	2.9	0.3142	1.3	0.43	0.1109	2.66	1761	19	1813	48	+3
9765-26.1_A	843	24	0.028	0.001	226	0.00063	4	1.10	0.009	2.6	4.76	1.2	0.3124	1.1	0.90	0.1105	0.52	1752	16	1807	9	+3
9765-31.1_A	1010	62	0.061	0.003	276	0.00006	14	0.10	0.037	2.5	4.84	1.1	0.3187	1.1	0.97	0.1101	0.24	1783	16	1801	4	+1
9765-26.1	881	19	0.022	0.001	246	0.00013	14	0.23	0.006	3.9	4.93	1.1	0.3248	1.1	0.94	0.1100	0.39	1813	17	1800	7	-1
9765-65.1	1007	52	0.051	0.003	275	0.00004	16	0.08	0.020	3.0	4.83	1.1	0.3181	1.1	0.98	0.1100	0.23	1780	16	1800	4	+1
9765-23.1	1011	44	0.044	0.002	281	0.00003	37	0.05	0.017	2.7	4.91	1.1	0.3240	1.1	0.96	0.1098	0.32	1809	17	1797	6	-1
9765-25.1_A	976	22	0.022	0.001	259	0.00002	27	0.03	0.007	3.4	4.68	1.1	0.3089	1.1	0.98	0.1098	0.24	1735	17	1797	4	+4
9765-23.1_A	982	48	0.049	0.002	261	0.00005	15	0.09	0.023	1.8	4.67	1.1	0.3088	1.0	0.97	0.1098	0.25	1735	16	1796	4	+4
9765-9.1	912	34	0.037	0.002	256	0.00004	22	0.07	0.012	2.7	4.93	1.1	0.3262	1.1	0.97	0.1097	0.27	1820	17	1795	5	-2
9765-62.1	704	66	0.093	0.005	189	0.00005	21	0.08	0.018	2.4	4.72	1.1	0.3124	1.1	0.96	0.1097	0.29	1752	16	1794	5	+3
9765-3.1_A	1243	138	0.111	0.006	345	0.00014	9	0.25	0.035	1.5	4.88	1.2	0.3227	1.2	0.97	0.1096	0.29	1803	19	1792	5	-1
9765-25.1	1116	24	0.021	0.001	308	0.00004	34	0.07	0.006	4.4	4.84	1.1	0.3211	1.1	0.95	0.1094	0.34	1795	17	1789	6	-0
9765-67.1	901	35	0.039	0.002	254	0.00008	12	0.14	0.013	2.2	4.96	1.1	0.3288	1.1	0.97	0.1093	0.26	1833	17	1788	5	-3
9765-41.1	988	36	0.037	0.002	258	0.00008	43	0.14	0.011	4.9	4.59	1.3	0.3044	1.1	0.87	0.1093	0.64	1713	17	1787	12	+5
9765-22.1	683	20	0.030	0.001	186	0.00007	23	0.13	0.008	4.2	4.77	1.1	0.3164	1.1	0.93	0.1092	0.40	1772	16	1787	7	+1
9765-49.1	797	21	0.026	0.001	212	0.00009	31	0.16	0.009	5.4	4.65	1.2	0.3094	1.1	0.88	0.1091	0.59	1738	16	1784	11	+3
9765-18.1	734	12	0.016	0.001	201	0.00005	26	0.09	0.004	4.3	4.78	1.1	0.3182	1.1	0.96	0.1090	0.31	1781	16	1783	6	+0
9765-45.2	607	14	0.024	0.001	162	0.00009	15	0.15	0.006	4.0	4.67	1.1	0.3114	1.1	0.95	0.1088	0.34	1748	16	1779	6	+2
9765-49.1_A	623	15	0.025	0.001	168	0.00001	57	0.02	0.009	3.7	4.71	1.3	0.3146	1.3	0.97	0.1086	0.29	1764	19	1777	5	+1
9765-50.1	1001	28	0.028	0.001	261	0.00008	44	0.13	0.011	5.8	4.54	1.3	0.3032	1.1	0.84	0.1085	0.68	1707	16	1775	12	+4
9765-50.1.2	771	17	0.023	0.001	202	0.00003	26	0.05	0.007	3.6	4.55	1.1	0.3046	1.1	0.97	0.1083	0.27	1714	17	1772	5	+4
9765-54.1	619	14	0.023	0.001	169	0.00006	18	0.10	0.007	3.8	4.72	1.2	0.3169	1.2	0.96	0.1081	0.31	1775	18	1767	6	-0
9765-22.1_A	637	31	0.049	0.002	164	0.00006	25	0.10	0.016	2.4	4.46	1.1	0.2998	1.1	0.96	0.1080	0.31	1690	16	1765	6	+5
9765-53.1	722	12	0.017	0.001	194	0.00004	31	0.07	0.007	3.5	4.65	1.2	0.3128	1.2	0.97	0.1078	0.30	1754	18	1762	6	+0
9765-24.1	557	10	0.018	0.001	151	0.00020	16	0.35	0.006	9.5	4.65	1.2	0.3157	1.1	0.89	0.1069	0.55	1768	17	1747	10	-1
9765-41.1	940	77	0.082	0.004	221	0.00010	11	0.17	0.020	2.0	4.04	1.1	0.2743	1.1	0.94	0.1069	0.39	1563	15	1747	7	+12
9765-24.1_A	469	8	0.017	0.001	122	0.00051	9	0.88	0.005	6.9	4.41	1.4	0.3025	1.2	0.86	0.1058	0.70	1703	17	1728	13	+2
9765-20.1	937	278	0.297	0.015	229	0.00011	13	0.19	0.143	32.8	4.07	3.2	0.2840	3.0	0.94	0.1040	1.05	1611	43	1697	19	+6
9765-73.1	1361	214	0.157	0.008	263	0.00038	7	0.66	0.047	2.0	3.14	1.2	0.2252	1.1	0.93	0.1011	0.44	1309	13	1645	8	+22

Notes (see Stern, 1997):

[a]Spot name follows the convention x-y.z; where x = sample number, y = grain number and z = spot number. Multiple analyses in an individual spot are labelled as x-y.z.z. The U-Pb fractionation behaviour in these deeper pits varies from the values used in the U-Pb calibration, as such only the Pb/Pb ages are considered accurate for these Uncertainties reported at 1σ percent and are calculated by using SQUID 2.23.08.10.21, rev. 21 Oct 2008. Ages reported at 1σ absolute.

[b]f206^{204} refers to mole fraction of total ^{206}Pb that is due to common Pb, calculated using the ^{204}Pb-method; common Pb composition used is the surface blank (4/6: 0.05770; 7/6: 0.89500; 8/6: 2.13840).[c]Corr Coeff = correlation coefficient; [d]Discordance relative to origin = 100 * (1-($^{206}Pb/^{238}U$ age)/($^{207}Pb/^{206}Pb$ age)).

* refers to radiogenic Pb (corrected for common Pb). Calibration standard 6266; U = 910 ppm; Age = 559 Ma; $^{206}Pb/^{238}U$ = 0.09059. Error in $^{206}Pb/^{238}U$ calibration 1.05% (included)

Standard Error in Standard calibration was 0.24% (not included in above errors but required when comparing data from different mounts/methods).

Analyses shaded grey are reported but not used in the calculation of weighted mean ages due to either high common Pb composition, inheritence, mixing or high discordance.

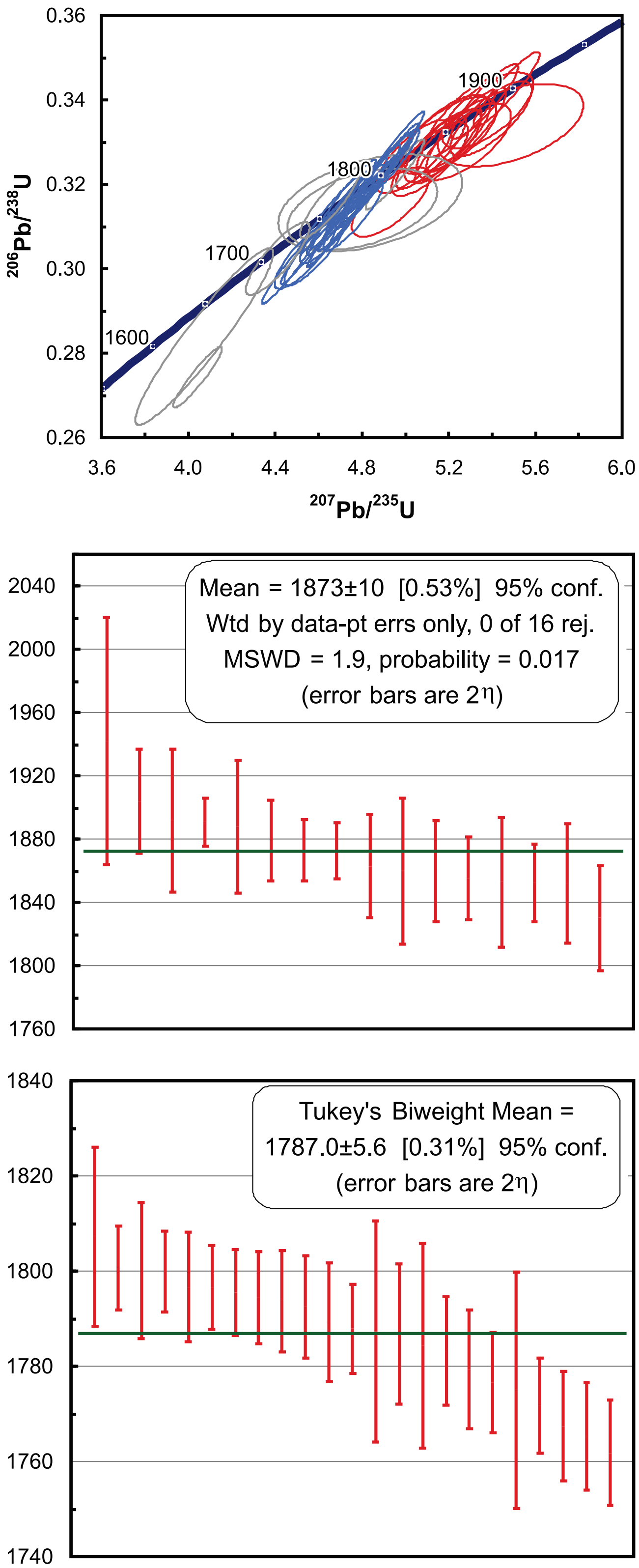

Figure 3. (opposite) *Sensitive High-Resolution Ion Microprobe (SHRIMP) U–Pb zircon analyses from a sample of Measles Point Granite, plotted on a concordia diagram ($^{207}Pb/^{235}U$ versus $^{206}Pb/^{238}U$) and as weighted averages. Individual analyses are plotted at the 2σ uncertainty level. Replicate spot analysis and data with more than 5.5% discordance were not included in age calculations. Igneous crystallization ages are in red, metamorphic recrystallization ages are in blue and excluded ages are in grey.*

scale homogenous rim (Figure 5). Other grains appear homogenous or have a patchy, irregular zoning in BSE images.

A total of 35 grains, varying in shape and internal structure, were analyzed. Forty-five analyzed resulted in two dominant age populations that correspond to distinct zircon textural types (Table 1). The first population consists of sixteen analyses, and has a $^{207}Pb/^{206}Pb$ date of 1873 ± 10 Ma (2σ error; weighted mean) (Figure 3). Thorium/uranium ratios range from 0.24–0.61 (Figure 4). These analyses are largely from grains having well-developed oscillatory zoning indicating magmatic growth (Figure 5), and, therefore, this date is interpreted as the igneous crystallization age of the monzogranite. One analysis has an Archean age of 2941 Ma that was excluded from the calculation and is considered to be inherited. The second population comprises thirty-one analyses, of which twenty-three were used to calculate a $^{207}Pb/^{206}Pb$ date of 1787 ± 5.6 Ma (2σ error, weighted mean;

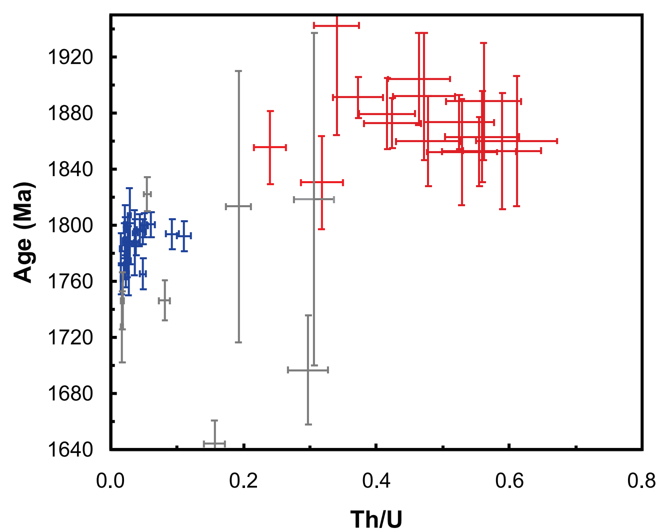

Figure 4. *Thorium/uranium ratios* versus *$^{207}Pb/^{206}Pb$ date for individual analysis, where the bars represent 2σ uncertainty level. Igneous crystallization ages are in red, metamorphic recrystallization ages are in blue and excluded ages are in grey.*

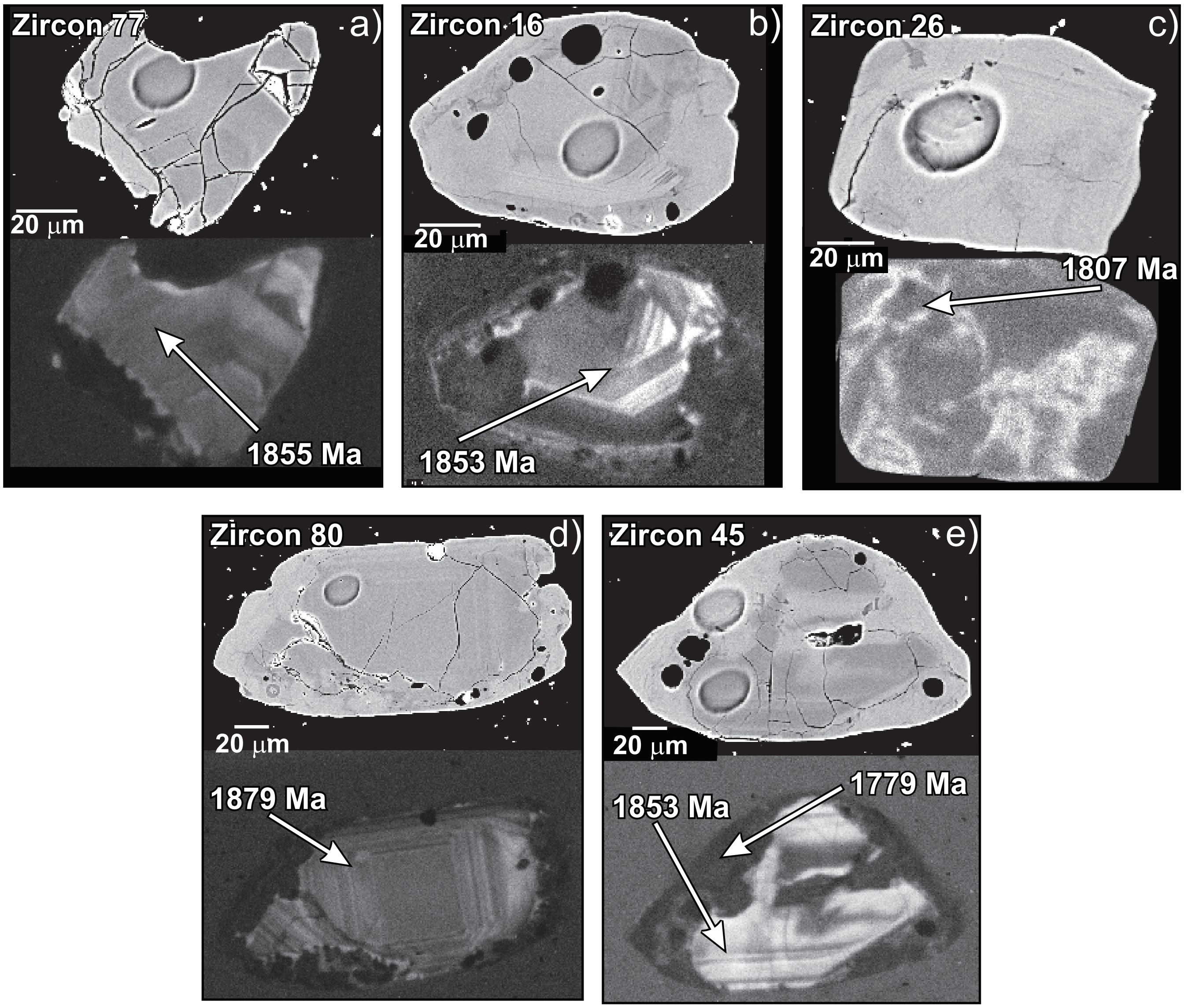

Figure 5. *Representative backscattered electron (BSE) images (top image) and corresponding cathodoluminescence (bottom image) of zircons dated using SHRIMP. The pit left by the ion beam is apparent most strikingly on the top BSE image. Zircon ages are reported as $^{207}Pb/^{206}Pb$ dates. Zircon number corresponds to spot numbers in Table 1. Zircon numbers are: a) zircon 77; b) zircon 16; c) zircon 26; d) zircon 80; and, e) zircon 45.*

Figure 3). Thorium/uranium ratios range from 0.01–0.11 (Figure 4). These analyses are from zircons that display an irregular, discontinuous or patchy zoning in BSE imaging (Figure 5). This phase of zircon is interpreted to be recrystallized during metamorphism. This interpretation is supported by the low Th/U ratios characteristic of metamorphically recrystallized zircon (Figure 4). Analyses with intermediate Th/U and Pb/Pb ages were excluded from the calculations and are interpreted to reflect incomplete recrystallization of older igneous zircon. Six analyses with the youngest ages (1747−1593 Ma) were excluded from the calculation and are assumed to have a significant component of a younger Pb-loss. Excluded data are presented in Table 1 and plotted in Figures 3 and 4, but are shaded grey.

DISCUSSION

A sample from the Measles Point Granite dated herein, has a complex zircon population. The $^{207}Pb/^{206}Pb$ date of 1873 ± 10 Ma is interpreted as the igneous crystallization age of the body. This is based on the internal zircon morphology and Th/U ratios with both being characteristic of igneous zircon (*see* Corfu *et al.*, 2003; Hoskin and Schaltegger, 2003). The granite also contains a second zircon pop-

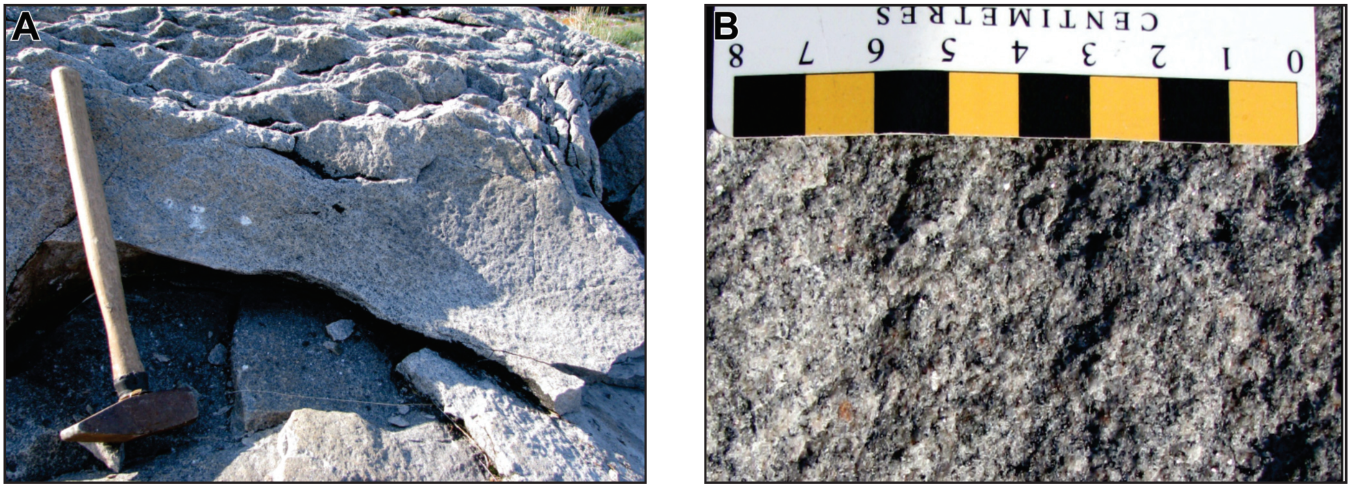

Plate 1. *Representative photograph of the Measles Point Granite in A) outcrop, and B) in hand held sample.*

ulation with a $^{207}Pb/^{206}Pb$ date of 1787 ± 5.6 Ma that is largely from recrystallized rims of the older zircon grains as well as from homogenous structureless grains. This date is interpreted as representing the timing of deformation and metamorphism of the Measles Point Granite.

The Measles Point Granite's chemical composition is similar to the felsic volcanic rocks of the Aillik Group (Hinchey, 2007). The Aillik Group and associated synvolcanic intrusion(s) were subsequently deformed and metamorphosed during the latter compressional stages of the Makkovikian Orogeny. The 1787 ± 5.6 Ma age of zircon recrystallization in the granite is coincident with the timing of regional Makkovikian metamorphism (Ketchum *et al.*, 2002).

Previous studies (Sinclair, 1999; Sinclair *et al.*, 2002) have suggested that the Measles Point Granite is *ca*. 1929 Ma and may represent the basement rocks of the Aillik Group. The age reported by Sinclair *et al.* (2002) was determined by linear regression of several, multi-grain, discordant, ID-TIMS analysis of zircon. The data are all greater than 10% discordant, and the linear regression yielded an upper intercept age of 1929 +10/-9 Ma and a lower intercept age of 956 +36/-35 Ma. Based on the complex zircon morphologies and mixed age populations reported above, it is apparent that the Measles Point Granite contains a complex zircon population not ideally suited for multi-grain ID-TIMS analysis. Based on the isotopic data presented above and field relationships, the previous age of *ca.* 1929 Ma is most likely inaccurate due to the combined effects of multiple zircon growth events and discordance, and that the best estimate of the age of the granite is 1873 ± 10 Ma, as reported herein.

The Measles Point Granite is part of a group of foliated porphyritic granites that occur throughout the Aillik domain (Hinchey, 2007; Hinchey and LaFlamme, 2008; Hinchey and Rayner, 2008). These intrusions have been infolded and metamorphosed with the Aillik Group. The intrusions are interpreted as being synvolcanic requiring them to have formed synchronous with, or shortly after, volcanism (Hinchey, 2007). A U–Pb age of 1858 ± 6 Ma (Hinchey and Rayner, 2008) from a similar folded porphyritic granite occurring inland, some 20 km to the southeast of the Measles Point Granite, supports the regional and contemporaneous distribution of these intrusions with felsic volcanism within the Aillik Group, which lasted from *ca.* 1883–1852 Ma (Schärer *et al.*, 1988; Hinchey and Rayner, 2008; LaFlamme *et al.*, 2013).

CONCLUSION

The Measles Point Granite has an igneous crystallization $^{207}Pb/^{206}Pb$ zircon age of 1873 ± 10 Ma, and is interpreted as a sill-like, hypabyssal, porphyritic granite. It is lithogeochemically similar to, and spatially associated with, the felsic volcanic rocks of the Aillik Group. It is part of a series of porphyritic bodies that intruded synchronously with formation of at least part of the Aillik Group and was subsequently deformed and metamorphosed during the Makkovikian Orogeny at *ca.* 1787 Ma.

ACKNOWLEDGMENTS

This manuscript benefited from thoughtful reviews by Lawson Dickson. Tom Pestaj is thanked for assistance at the J.C. Roddick Ion Microprobe Laboratory, Geological Survey of Canada.

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