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$^{40}Ar/^{39}Ar$ LASER DATING OF ZONED WHITE MICAS FROM THE LAKE LEWIS LEUCOGRANITE, SOUTH MOUNTAIN BATHOLITH, NOVA SCOTIA, CANADA

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ABSTRACT

We report $^{40}Ar/^{39}Ar$ data for zoned micas from three sampling sites in the Lake Lewis leucogranite in the South Mountain batholith (SMB) of Nova Scotia. Individual grains of mica contain oscillatory zones of Ms_{ss}, the main white mica, and IMP, a weakly pleochroic intermediate mica phase, in sufficiently large volumes to provide good targets for laser dating. The mean age of Ms_{ss} from the three sampling sites is 380 ± 2 Ma; the maximum age recorded is *ca.* 382 Ma. Data from IMP define a population that has about this same upper limit in age but a significantly younger lower limit. We observe only slight intragrain variations in age at all three sites, but detect significant (*i.e.,* ~2–3%) intergrain variations at two sites. We conclude that these primary micas cooled through the Ar closure temperature (nominally, 350°C) at 381 ± 1 Ma. Comparison with other geochronological data suggests that, within analytical uncertainty, this is the time of crystallization of the SMB. The younger argon ages, mainly from IMP, may reflect post-emplacement loss of argon resulting from pervasive *ca.* 370 Ma (and possibly later) magmatic or hydrothermal activity in the SMB. These new data provide a time-frame that permits a correlation of late-stage magmatic activity in the SMB (*e.g.,* at Lake Lewis) with some, but not all, of other known magmatic, alteration, and mineralization events.

Keywords: $^{40}Ar/^{39}Ar$, laser, ages, micas, epitactic growth, zoning, South Mountain Batholith, Nova Scotia.

SOMMAIRE

Nous présentons des données sur le rapport $^{40}Ar/^{39}Ar$ des micas zonés, échantillonnés à trois sites dans le leucogranite de Lake Lewis, faisant partie du batholite de South Mountain, en Nouvelle-Écosse. Les grains individuels de mica contiennent des zones oscillatoires soit de Ms_{ss}, le mica blanc principal, soit de IMP, un mica intermédiaire faiblement pléochroïque, en volumes suffisamment importants pour fournir des cibles adéquates pour une datation au laser. L'âge moyen du mica blanc, Ms_{ss}, à ces trois sites est 380 ± 2 Ma; l'âge maximum est environ 382 Ma. Les données pour le mica IMP définissent une population qui a à peu près la même limite supérieure d'âges, mais un seuil d'âges inférieurs plus jeune. Nous observons de légères variations à l'intérieur des grains à chacun des trois sites, mais les variations entre grains sont plus importantes (~2–3%) à deux des sites. Nous croyons que ces micas primaires ont refroidi au delà de la température de fermeture pour l'argon (qui serait de 350°C) il y a 381 ± 1 Ma. Une comparaison avec les autres données géochronologiques montre qu'il s'agit ici du temps de cristallisation du batholite de South Mountain, compte tenu de l'incertitude analytique. Les âges plus jeunes, surtout mesurés sur les grains du mica IMP, pourraient témoigner d'une perte d'argon après la mise en place, résultant d'une activité magmatique ou hydrothermale généralisée à environ 370 Ma (et peut-être plus tard) dans ce batholite. Les nouvelles données fournissent un encadrement temporel permettant la corrélation de l'activité tardi-magmatique (c'est-à-dire à Lake Lewis) dans ce batholite avec certains autres événements connus de magmatisme tardif, d'altération et de minéralisation.

(Traduit par la Rédaction)

Mots-clés: $^{40}Ar/^{39}Ar$, laser, âges, micas, croissance épitactique, zonation, batholite de South Mountain, Nouvelle-Écosse.

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Introduction

Conventional $^{40}Ar/^{39}Ar$ age-spectrum analysis of a bulk-mineral separate may not recover a primary cooling age because the primary age signature, along with any argon isotopic variation imposed by later geological events, are likely to be homogenized in the step-heating procedure (Fallon *et al.* 2001, Reddy *et al.* 1996). Laser-based spot dating, on the other hand, is an approach more likely to yield primary age information (Fallon *et al.* 2001, Hames & Cheney 1997). Using carefully selected material, such studies seek this information from observed intra- and intergrain age variations. In this paper, we present results from such a study carried out to constrain the age of a large batholith in southwestern Nova Scotia.

The South Mountain Batholith (SMB) is a large, late Devonian, highly fractionated, peraluminous granitic complex, with rock types ranging from biotite granodiorite to muscovite–topaz leucogranite (Clarke & Muecke 1985, Tate & Clarke 1997, MacDonald 2001). The most highly evolved rocks are rare (<1%), late leucogranites occurring as small, discrete, and texturally variable bodies in the interior of the batholith. The Lake Lewis leucogranite (Fig. 1) is a small (4–5 km^2), white- to cream-colored, fine- to medium-grained, generally equigranular but locally porphyritic, highly evolved pluton intruding the New Ross leucomonzogranite (Ham 1991).

In a previous study, Clarke *et al.* (1993) analyzed two bulk concentrates of muscovite from the Lake Lewis leucogranite by the $^{40}Ar/^{39}Ar$ step-heating method, and reported plateau ages of 370 ± 3 Ma for both samples. Clarke *et al.* (1993) interpreted this age as the time of leucogranite crystallization, a conclusion now seeming unlikely in the light of possible isotopic homogenization. The purpose of this paper is to use the recently discovered zoned magmatic white mica grains in the Lake Lewis leucogranite to provide more reliable and cross-referenced $^{40}Ar/^{39}Ar$ laser-probe age data for the SMB.

Background

Until recently, the age of emplacement of the SMB was considered to be *ca.* 372 Ma. This conclusion was based on a number of earlier studies, for example: (i) the 372 ± 2 Ma Rb/Sr combined whole-rock and mineral isochron age obtained by Clarke & Halliday (1980) for SMB granodiorites, (ii) a mean $^{40}Ar/^{39}Ar$ plateau age of 367 ± 7 Ma (maximum value = 380 Ma) obtained by Reynolds *et al.* (1981) for 17 samples of muscovite and biotite from the SMB, (iii) U/Pb ages of 374 ± 2 and 373 ± 2 Ma obtained by Harper (1988) for monazite from monzogranites and leucomonzogranites, respectively, in the New Ross area (northeastern SMB), (iv) a combined whole-rock and mineral Pb/Pb isochron age of 373 ± 3.6 Ma obtained by Chatterjee & Ham (1991) for a granodiorite from the SMB, and (v) $^{40}Ar/^{39}Ar$ plateau ages ranging between 369 ± 2 Ma and 375 ± 4 Ma for white micas from several leucogranite bodies, as reported by Clarke *et al.* (1993).

More recent data suggest that the age of SMB emplacement is significantly older than 372 Ma. Data supporting this conclusion include: (i) Re/Os ages of 377 ± 3 and 376 ± 3 Ma obtained by Carruzzo *et al.* (2003) for molybdenite from some mineralized areas in the SMB, (ii) U/Pb ages of 377 ± 4 (on monazite) and 385 ± 2 Ma (on zircon) obtained by Keppie *et al.* (1993) for granodiorite and leucomonzogranite, respectively, and (iii) well-defined $^{40}Ar/^{39}Ar$ single-grain laser-probe ages on white micas from mineral occurrences in the New Ross area ranging up to maximum values of ~380 Ma (Carruzzo 2003, Carruzzo *et al.* 2003).

The Lake Lewis leucogranite pluton contains four fluorine-rich mica phases: Bt_1, a rare early biotite occurring as inclusions in quartz, Bt_2, the main pleochroic brown mica, Ms_{ss}, the main white mica, and IMP, a weakly pleochroic brown intermediate mica phase. Clarke & Bogutyn (2003) argued that Bt_1, Bt_2, and Ms_{ss} are primary magmatic phases, and that IMP also crystallized from a magma, or from a fluid in equilibrium with a magma. The major-element compositions of IMP are intermediate between Bt_2 and Ms_{ss}, and this phase normally occurs in single crystals as layers alternating with Ms_{ss}. Because the repeated layers are in optical and crystallographic continuity, they are referred to as oscillatory epitactic-growth zones. Clarke & Bogutyn (2003) suggested that this zonation might be explained by the repeated build-up and release of overpressured fluid in the magma chamber.

The oscillatory-zoned Ms_{ss}–IMP micas described above occur as large (~1–4 mm) grains, providing excellent targets for dating the individual mica phases, and thus an opportunity to obtain laser-probe estimates of the time of their crystallization.

In addition to providing new and better data relating to the age of emplacement of the SMB, the current study has implications for the history of mineralization in the region. Clarke & Bogutyn (2003) suggested that the Lake Lewis magmatic–hydrothermal event may correlate with hydrothermal alteration, mineralization, and dyke intrusion elsewhere in the batholith. In this paper, we provide an estimate of the age of the Lake Lewis emplacement event, a datum required to make such correlations.

Analytical Methods

We carefully hand-picked cleavage fragments of micas from lightly crushed samples of rock collected from three sites in the leucogranite (Fig. 1), and selected at each site five of the largest grains that display well-defined oscillatory zoning involving Ms_{ss} and IMP; we did not target biotite phases in this study. We photographed each grain in plane-polarized light and with

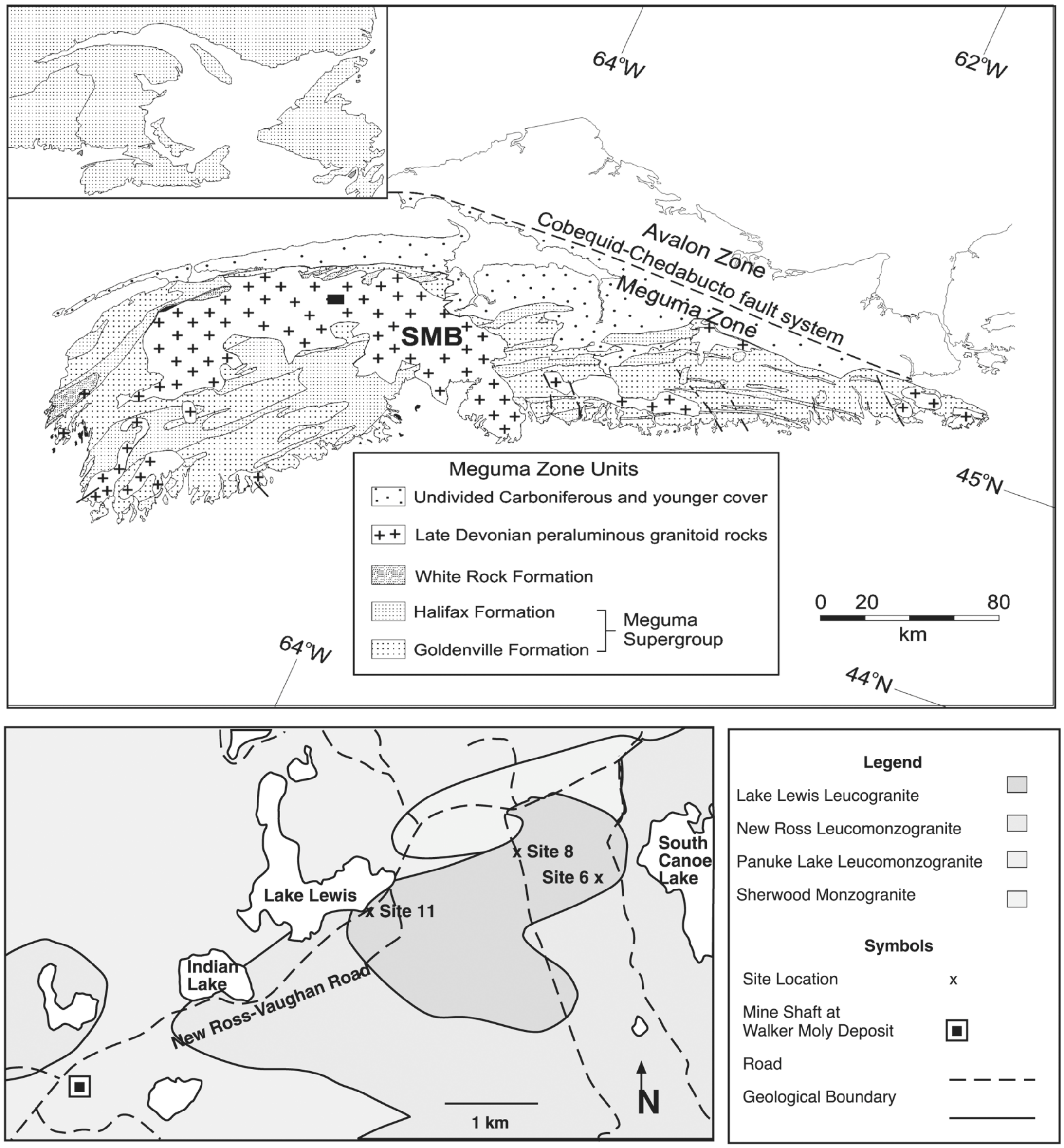

FIG. 1. General location map of the South Mountain batholith in southwestern Nova Scotia (above), showing the position of the Lake Lewis leucogranite (black rectangle). Geological map of the Lake Lewis leucogranite (below, simplified after Ham 1991), showing site locations and position of the Walker Mo–Cu mineral deposit.

crossed nicols. In plane-polarized light, Ms_{ss} is almost colorless, whereas IMP appears as variable shades of pale brown. We used the photographs with crossed nicols to help define crystal boundaries, and within each boundary, we selected targets for dating. The latter information was recorded on transparent overlays for subsequent reference and laser positioning during analysis. We expected the laser to sample the full thickness (~0.3 mm) of a given grain, and consequently, because of the oscillatory nature of the zoning, expected that some of the selected target-areas would yield gas from both mica phases. However, with careful selection of targets, we can minimize such contamination. Furthermore, because the two mica phases are closely similar in apparent age (see Results below), the effects of any likely contamination should be considerably less than our estimated analytical uncertainties.

For irradiation in the McMaster University nuclear reactor, selected grains were placed individually into holes machined in aluminum disks, each disk containing grains from only one site. The flux monitor was the hornblende standard MMhb–1 (assumed age: 520 ± 2 Ma; Samson & Alexander 1987). Laser-probe analyses were made with a Nd–YAG system operated in the pulsed mode (1–2 kHz). Several bursts of energy, each ~0.5 s in duration, were delivered to a given target to produce a laser pit with diameter between ~100 and ~500 μm depending on the size of the target area. All isotopic analyses were made using a VG 3600 mass spectrometer. We report the age data in Table 1 with their 1σ uncertainties, the latter not including the uncertainty in the irradiation parameter, J. This assumption is reasonable for analyses within grains and among grains from a given site, because the neutron flux gradient over the small (~1 cm diameter) sample disks is known to be low. Mean ages in the text are given with 2σ errors that include the uncertainty in J. We make no allowance in the error estimates for uncertainties in the assumed age of the flux monitor, nor in the values of the isotopic and decay constants.

TABLE 1. SUMMARY OF ANALYTICAL DATA FOR ZONED WHITE MICAS, LAKE LEWIS LEUCOGRANITE, SOUTH MOUNTAIN BATHOLITH, NOVA SCOTIA

Grain	Spot	Type	^{39}Ar mV	Age ±1σ Ma	% ATM	^{36}Ar/^{40}Ar	^{39}Ar/^{40}Ar	%IIC
Site 8: J = 0.002503 ± 0.00002 (2σ)								
1	3	IMP	53.5	377.1 ± 1.8	5.5	0.000186	0.010169	0.04
1	4	Ms_{ss}	31.5	374.9 ± 1.7	3.3	0.000113	0.010468	0.05
1	5	Ms_{ss}	15.3	374.5 ± 1.9	4.3	0.000146	0.010376	0.12
1	6	Ms_{ss}	35.8	377.4 ± 1.7	1.4	0.000049	0.010595	0.04
3	1	IMP	57.4	383.5 ± 2	9.7	0.000328	0.009536	0.04
3	2	IMP	63.6	384.4 ± 1.7	1.7	0.000057	0.010354	0.04
3	3	Ms_{ss}	32.4	381.3 ± 1.7	1.6	0.000056	0.010454	0.03
3	4	Ms_{ss}	30.8	382.0 ± 1.8	0.8	0.000028	0.01052	0.04
6	2	IMP	25.8	382.7 ± 2.2	13.5	0.00046	0.00915	0.03
6	3	Ms_{ss}	43.9	385.9 ± 1.7	1.1	0.000038	0.010372	0.08
6	4	Ms_{ss}	28.3	382.4 ± 1.8	1.4	0.000047	0.010447	0
4	3	IMP	8.7	373.3 ± 2.1	3.9	0.000132	0.010457	0.21
2	3	Ms_{ss}	95	379.8 ± 1.8	5.3	0.000181	0.010103	0.01
2	4	Ms_{ss}	61.1	376.3 ± 1.7	0.5	0.000019	0.010726	0.02
Site 11: J = 0.002509 ± 0.00002 (2σ)								
2	1	Ms_{ss}	30.1	373.2 ± 2.7	23.6	0.000798	0.008338	0.03
2	2	Ms_{ss}	23.5	372.7 ± 2.6	21.7	0.000737	0.008546	0.11
2	4	IMP	11.6	368.7 ± 2.6	17.6	0.000597	0.009108	0.16
4	2	IMP	59.7	378.0 ± 2.2	14.3	0.000486	0.009211	0.02
4	3	IMP	23.6	374.1 ± 2.1	12.6	0.000427	0.009507	0
1	2	Ms_{ss}	52.7	373.1 ± 2	11.2	0.000379	0.009692	0.06
1	3	IMP	16.1	367.8 ± 1.8	2.3	0.000079	0.010831	0.11
1	4	IMP	31	371.3 ± 1.7	0.7	0.000026	0.010889	0.06
3	2	IMP	29.1	377.6 ± 1.9	4.1	0.000141	0.010322	0.04
3	3	Ms_{ss}	28.2	379.5 ± 1.8	2.4	0.000081	0.010456	0.11
3	4	Ms_{ss}	185.7	382.6 ± 1.8	3.8	0.000131	0.010204	0.01
5	1	IMP	31.7	377.2 ± 2.3	17.7	0.0006	0.008871	0
5	2	IMP	22.5	370.0 ± 2.7	22.7	0.000769	0.008511	0.02
5	3	Ms_{ss}	62.6	381.5 ± 1.8	2.8	0.000096	0.010345	0.01
5	4	Ms_{ss}	56	380.9 ± 1.7	1.5	0.000051	0.010509	0.05
Site 6: J = 0.002485 ± 0.00002 (2σ)								
3	1	IMP	12.1	375.3 ± 2	10	0.00034	0.009661	0.14
3	2	IMP	17.4	378.5 ± 1.9	8.7	0.000296	0.009711	0.09
3	3	IMP	19.3	381.8 ± 1.8	2.8	0.000097	0.010237	0.18
3	4	Ms_{ss}	30.4	380.3 ± 1.8	4	0.000137	0.010154	0.04
3	5	Ms_{ss}	37.5	381.6 ± 1.7	1.2	0.000041	0.010416	0.09
4	2	IMP	10	379.6 ± 2.5	16.9	0.000574	0.008804	0.06
4	3	IMP	20.5	379.9 ± 1.8	4.8	0.000165	0.010082	0
4	4	Ms_{ss}	13.4	378.1 ± 2	8.8	0.0003	0.009707	0.11
4	5	Ms_{ss}	23.3	380.8 ± 1.8	4.4	0.000151	0.010097	0.06
5	1	IMP	13.8	379.7 ± 1.8	2.1	0.000071	0.010379	0.11
5	2	Ms_{ss}	10.7	378.9 ± 1.8	2.2	0.000077	0.010385	0.11

Data are corrected for mass-spectrometer discrimination, interfering isotopes, and system blank. % IIC: percent interfering isotopes correction; % ATM: percent atmospheric argon.

Results

Table 1 contains a summary of the argon age and isotopic data. Spot analyses that required large (>30%) corrections for atmospheric argon (generally the ones with low ^{39}Ar abundances) were considered unreliable and are not reported. Figure 2 shows photographs of representative grains from the three sites with the apparent ages and mica phases indicated. Figure 3 displays the data for each site in the form of an apparent age *versus* analysis number plot that shows the intragrain *versus* intergrain variations in age, as well as the observed differences in age between the two mica phases. We show apparent age *versus* ^{39}Ar abundance plots for all our age data in Figures 4a and 4b. The site represented by each data point is identified in Figure 4a. Figure 4b shows the distributions of the two mica phases and their corresponding relative probability *versus* age plots. We present the results for each site below.

Site 8, grains 1, 2, 3, 4, 6

No analytically significant intragrain variation in age exists; hence, Ms_{ss} and IMP cannot be distinguished on the basis of age. However, there are significant intergrain differences; the mean ages of grains range from 376 ± 3 Ma (grain 1) to 384 ± 3 Ma (grain 6). Some of these differences may be the result of neutron flux gradients. The mean ages (weighted according to ^{39}Ar abundance) are 380 ± 3 Ma (2σ including σ_J, $n = 9$ data points) for Ms_{ss}, and 382 ± 3 Ma ($n = 5$) for IMP.

Site 11, grains 1, 2, 3, 4, 5

The only significant intragrain variation in age occurs in grain 5, where spot 2 is significantly younger than the others, but here also there are significant intergrain differences, the mean ages of grains ranging between 372 ± 3 and 382 ± 4 Ma. The mean ages of Ms_{ss} and IMP are, respectively, 380 ± 3 Ma ($n = 7$) and 374 ± 3 Ma ($n = 8$), values suggesting a detectable difference between the two phases.

Site 6, grains 3, 4, 5

With one possible exception (spot 1 in grain 3), no significant intragrain or intergrain differences in age are apparent at this sampling site. The mean ages are 381 ± 3 Ma (n = 5) for Ms_{ss}, and 379 ± 3 Ma (n = 6) for IMP.

Discussion

Ages of Ms_{ss} and IMP

From the three sampling sites, the mean apparent age of Ms_{ss}, the main white mica in the leucogranite, is 380 ± 2 Ma; with the exception of one outlier, the maximum age recorded by Ms_{ss} is *ca.* 382 Ma (Fig. 4b). The relative probability plot (Fig. 4b) suggests that the most probable age is 381 Ma. It might be argued (Fig. 3) that two of the grains from Site 8 are significantly older (*ca.* 384 Ma) than the ages given above. However, the (2σ) uncertainties in these grain ages are ~3–4 million years, comparable to the age difference in question. Moreover, as noted above, these grains provided only one spot age for Ms_{ss} that can be classified as a high-age outlier. Consequently for Ms_{ss}, we estimate the time of initial cooling through the closure temperature of white mica (nominally, 350ºC; McDougall & Harrison 1999) to be 381 ± 1 Ma.

Data from IMP (Fig. 4b) define an age population that has about the same upper limit as the one for Ms_{ss}, but a significantly younger lower limit. This younging is particularly apparent at Site 11 which, on average, appears to be ~6 million years younger than the others. Clarke & Bogutyn (2003) noted that IMP typically has a variably mottled appearance in back-scattered electron images, suggesting heterogeneity with respect to iron that may be evidence of exsolution or breakdown of a possibly metastable IMP. If IMP quickly unmixes to Ms_{ss} and Bt_2 (in approximately a 5:1 ratio) at temperatures just below the granite solidus (~600ºC), and if argon retention in these phases is relatively low (owing to the presence of biotite and smaller effective grainsize), then IMP will be relatively susceptible to resetting by later magmatic or hydrothermal activity (*e.g.*, at *ca.* 370 Ma), and thus ages of IMP will tend to be lower than those of Ms_{ss}.

From textural and chemical evidence, Clarke & Bogutyn (2003) argued that Ms_{ss} is a primary magmatic phase. The ~380 Ma age obtained for Ms_{ss} in the current study may also be primary, and it contrasts with the *ca.* 370 Ma reset age obtained previously by the conventional step-heating method (Clarke *et al.* 1993), a discrepancy reasonably explained by the difference in analytical methods. The bulk separate prepared for step heating would have contained not only IMP as well as Ms_{ss}, but also potentially some domains of secondary white mica. As noted above, homogenization of age variations in the step-heating analysis is likely to produce the observed well-defined plateaus. On the other

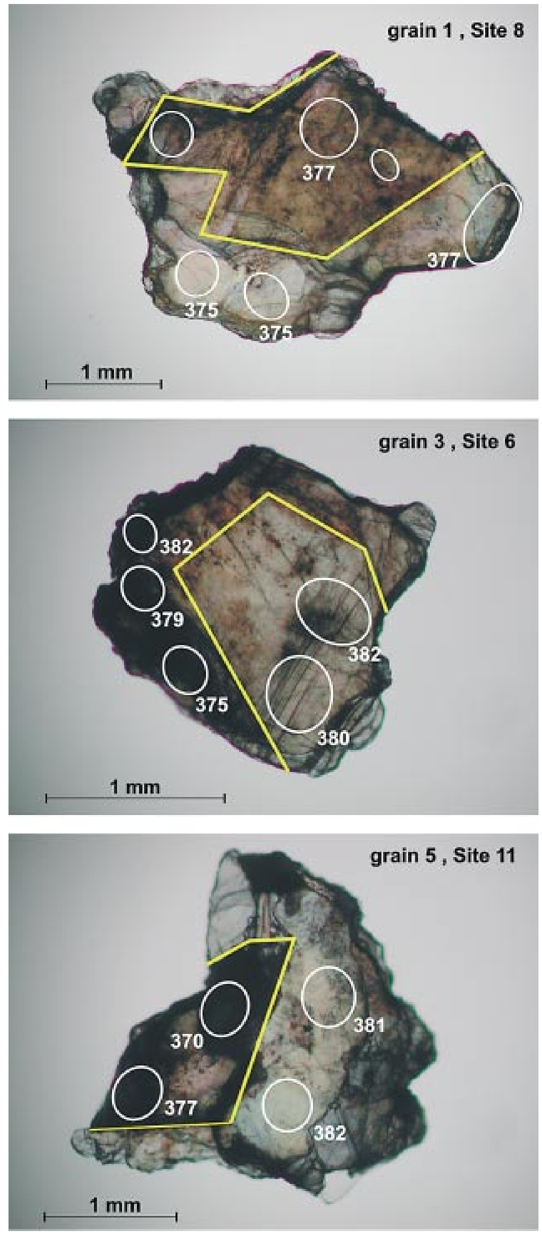

FIG. 2. Photographs of representative grains from the three sites, in plane-polarized light. White circles (ovals) with apparent ages noted identify the laser spots, *i.e.*, areas of total fusion; spots without ages were rejected because of high atmospheric corrections (see text).Yellow lines enclose the data from IMP (sites 8, 11), and Ms_{ss} (site 6).

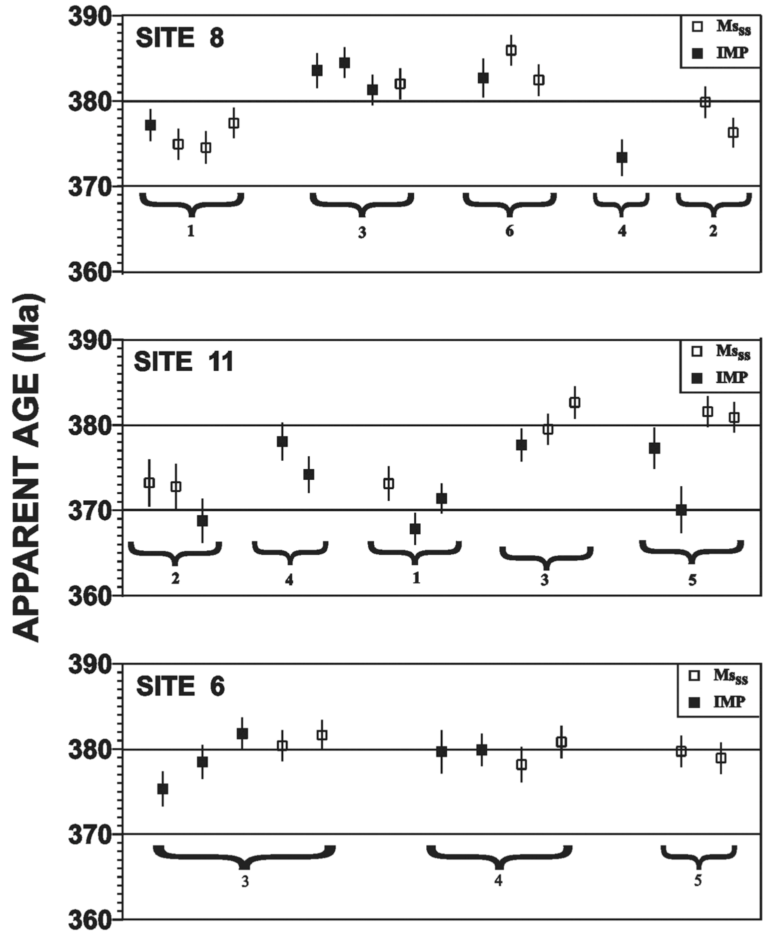

FIG. 3. Apparent ages for each site, grouped according to grain number (Table 1); the x axis is in arbitrary units and has no significance. Analytical uncertainties (1σ) and mica types are as indicated. Lines at 370 Ma and 380 Ma are shown for reference.

hand, the current laser-based study was carried out on carefully selected grains with specific targets selected, as much as possible, away from edges and phase boundaries. Hence, only a few spot ages, principally ones from IMP, record the apparent *ca.* 370 Ma event (Fig. 4b).

Regional considerations

Clarke & Bogutyn (2003) used the zoned white micas of the Lake Lewis leucogranite to make two inferences about magmatic and hydrothermal processes in the central part of the SMB. Firstly, they suggested that a build-up and release of H_2O pressure in the Lake Lewis pluton was responsible for formation of the zoned micas, and that the overpressures caused fracturing of the roof that provided pathways for the ascent of felsic magmas and descent of meteoric waters; secondly, they proposed that this process released hydrothermal fluids that were instrumental in forming mineral deposits. For these inferences to be correct, all magmatic and mineralization events must be coeval. Below, we examine both these inferences.

The rhyolite dyke, or "elvan", at the Turner tin deposit ~7 km to the west of the Lake Lewis leucogranite, is an extremely fine-grained felsic rock containing pristine microphenocrysts of quartz and muscovite. Single-grain ^{39}Ar data from these muscovite microphenocrysts yield a primary age of crystallization of *ca.* 380 Ma (Carruzzo 2003), in close accord with our Lake Lewis data. Thus the pressure variations in the Lake Lewis leucogranite, as recorded in its zoned micas, and the formation of "elvans", appear to be coeval events, lend-

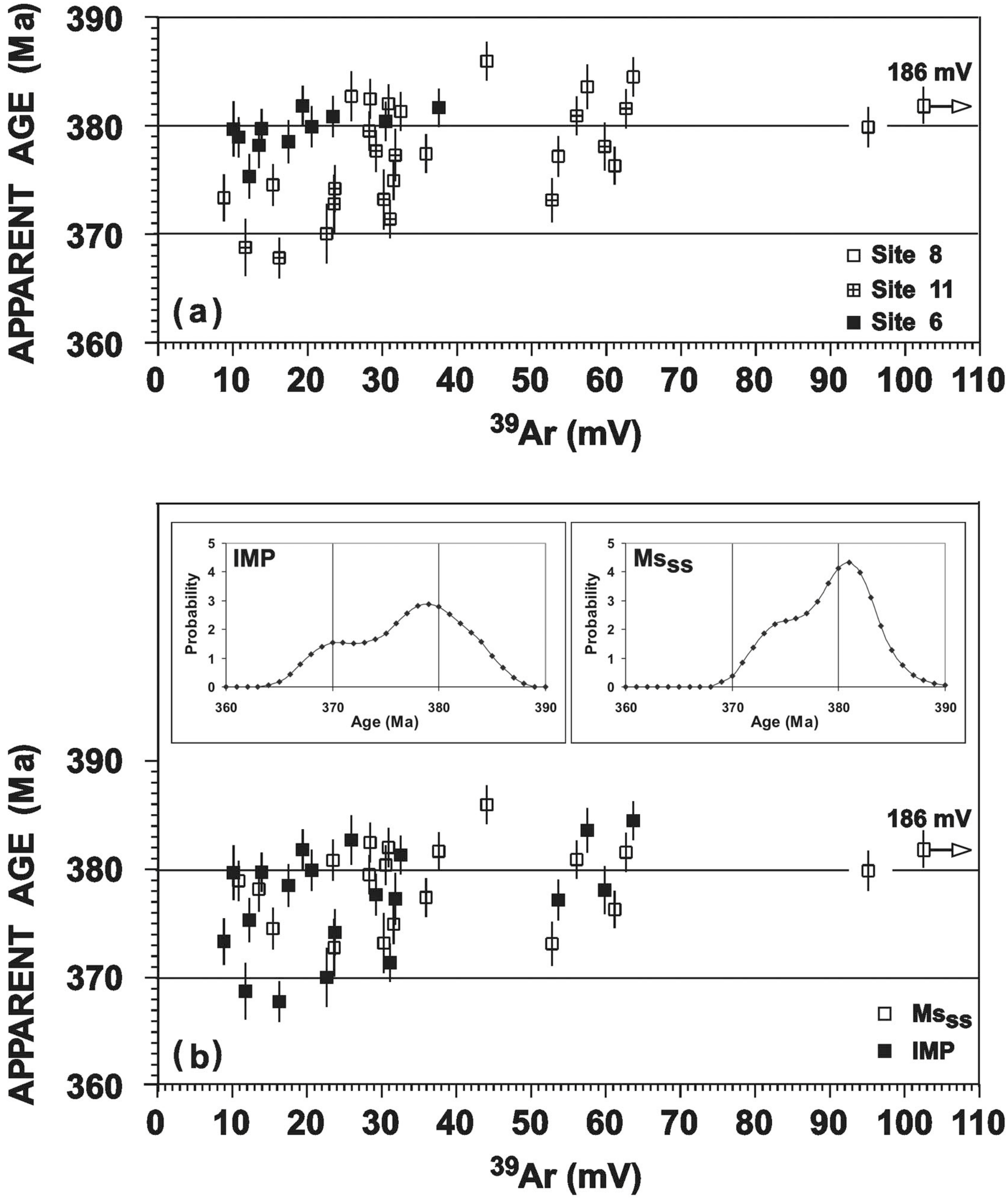

FIG. 4. Apparent ages plotted as a function of ^{39}Ar abundance (in mV, an arbitrary scale from the mass spectrometer output): (a) with site identification, (b) with mica phases identified. Uncertainties and reference lines are as in Figure 3. Relative probability plots for the two mica phases are shown in (b).

ing support to the idea that fluid overpressuring may have fractured the roof of the pluton, allowing some magma to ascend quickly and to undergo both temperature and pressure quenching. Also, if some of those magmas reached the surface, they would form the predicted volcanic rocks.

Mineral deposits from the central part of the SMB (Carruzzo 2003, Carruzzo *et al.* 2003) yield a range of apparent ages between *ca.* 380 and 320 Ma, data obtained chiefly from the analysis of whole grains of muscovite. In contrast, our ages from the Lake Lewis leucogranite fall principally within the 380–370 Ma interval (Fig. 4), the smaller range at least in part attributable to the selective analysis made possible by the high resolution provided by laser-probe spot-heating. A comparison of the data suggests that the Lake Lewis micas are coeval with most of the deposits (*e.g.*, Long Lake, Turner tin, and Mn mines), implying a possible genetic relationship among the fluids responsible. However, Clarke & Bogutyn (2003) believed that release of overpressured hydrothermal fluids from the Lake Lewis leucogranite might also be responsible for mineralization at the nearby Walker Moly deposit ~4 km to the southwest. On the basis of both Ar/Ar and Re/Os geochronology, the Walker Moly aplite – pegmatite – greisen suite appears to be significantly younger (*ca.* ~370 Ma). If so, it does not appear to be chronologically or genetically related to the Lake Lewis magmatic-hydrothermal fluid-circulation event. However, the Walker age of mineralization may be recorded in some of the youngest IMP grains at Lake Lewis. If so, this date can only be a resetting event of an older age. Work is under way to re-date the Walker greisen.

Conclusions

Recent and current work on zoned micas from the Lake Lewis leucogranite suggests that these micas are texturally and chemically the most convincing primary magmatic micas in the SMB. In the current $^{40}Ar/^{39}Ar$ study, laser-spot dating of the micas yields ages in the range *ca.* 380–370 Ma, the lower limit approximating conventional age-spectrum values previously reported. The principal conclusions of this study are:

1) From the upper age limit for the main white mica (Ms_{ss}), we conclude that the Lake Lewis leucogranites had cooled to ~350ºC by 381 ± 1 Ma. Because of the close agreement between this age and those recorded by U/Pb and Re/Os isotopic systems, which have higher closure temperatures, we believe that 381 Ma is a close approximation to the time of crystallization of the geologically *youngest* rocks in the batholith, and thus the age data recorded for the Lake Lewis micas are consistent with their deduced primary magmatic origin.

2) The Lake Lewis micas have recorded relatively minor post-emplacement loss of argon, mostly confined to the intermediate mica phase (IMP), and probably a reflection of a pervasive resetting events at *ca.* 370 Ma in the SMB.

3) The zoned muscovite of the Lake Lewis leucogranites is coeval with the muscovite phenocrysts of the Turner "elvan", lending support to the idea that fluid overpressure, zoned micas, fracturing, and magma ascent were genetically related.

4) The 381 ± 1 Ma age is equivalent to the oldest $^{40}Ar/^{39}Ar$ and Re/Os ages recorded in a number of mineral deposits in the central part of the SMB, suggesting that a connection between release of magmatic fluids from late leucogranites and the development of mineralization is plausible.

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