Uranium-lead ID-TIMS and LA-ICP-MS ages for the Cassiar and Seagull batholiths, Wolf Lake map area, southern Yukon

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ABSTRACT

The Cassiar and Seagull batholiths are mainly post-tectonic felsic intrusions emplaced into the North American miogeocline and Yukon-Tanana Terrane, respectively, near the British Columbia-Yukon boundary. The two bodies range in composition from granodiorite and quartz monzonite to granite. Previous studies reported K-Ar and Rb-Sr dates of ~100 Ma for Seagull batholith and about 110 Ma for Cassiar batholith. Two samples of massive quartz monzonite from the interior of the Cassiar batholith, and a strongly foliated and lineated augen gneiss within a ductile shear zone near the western margin of the batholith, yield overlapping U-Pb monazite and/or zircon ages of 112.3 ± 2.0 Ma, 113.2 ± 2.2 Ma, and 110.2 ± 1.0 Ma respectively, by ID-TIMS methods. Samples of aplitic biotite granite and megacrystic biotite granite from the Seagull batholith give distinctly younger U-Pb zircon ages of 99.3 ± 2.2 Ma and 95.7 ± 2.1 Ma, respectively, using LA-ICP-MS methods.

RÉSUMÉ

Les batholites de Cassiar et de Seagull sont principalement des intrusions felsiques post-tectoniques mises en place respectivement dans le miogéoclinal nord-américain et dans le terrane de Yukon-Tanana, près de la limite entre la Colombie-Britannique et le Yukon. La composition des deux masses varie de la granodiorite et de la monzonite quartzifère au granite. Des études antérieures ont établi par des méthodes de datation aux K-Ar et aux Rb-Sr des âges d'environ 100 Ma pour le batholite de Seagull et d'environ 110 Ma pour le batholite de Cassiar. Deux échantillons de monzonite quartzifère massive, prélevés près de la limite ouest du batholite de Cassiar, ainsi qu'un gneiss oeillé à structure fortement foliée et linéations marquées à l'intérieur d'une zone de cisaillement ductile près de la limite occidentale du batholite, indiquent un chevauchement des datations aux U-Pb de la monazite et/ou des zircons de 112,3 ± 2,0 Ma, 113,2 ± 2,2 Ma et 110,2 ± 1,0 Ma, respectivement, d'après des méthodes ID-TIMS. Des échantillons de granite aplitique à biotite et de granite mégacristallin à biotite provenant du batholite de Seagull livrent des âges U-Pb des zircons nettement plus récents de 99,3 ± 2,2 Ma et de 95,7 ± 1,7 Ma, respectivement, d'après des méthodes LA-ICP-MS.

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INTRODUCTION

Plutonic rocks are widespread in the Wolf Lake map area (NTS 105B) in southern Yukon (Fig. 1), where they intrude pericratonic terranes including displaced strata of the North American miogeocline (Cassiar Platform) on the east, and metamorphosed continental and arc rocks of the Yukon-Tanana Terrane on the west. Previous geochronology of plutons in this portion of the Cordillera have shown that most are Early Cretaceous in age, although Permian and Early Jurassic plutonic rocks are also present within the Yukon-Tanana Terrane, and scattered Late Cretaceous bodies have also been identified. All Early Cretaceous intrusions in the Cassiar Platform adjacent Yukon-Tanana Terrane southwest of the Tintina Fault in southern Yukon have mainly been assigned to the Cassiar plutonic suite (e.g., Mortensen *et al.*, 2000). This is based on scarce isotopic age information as well as overall lithology and geochemistry. Significant silver, tin and tungsten occurrences are thought to be temporally and genetically associated with the Cassiar suite intrusions in this area.

A detailed geochemical and isotopic study along the length of the Cassiar batholith constituted a M.Sc. thesis (Driver *et al.*, 2000). The nature of the Seagull batholith and intrusions to the northwest is discussed by Liverton and Alderton (1994), Liverton and Botelho (2001) and Liverton *et al.* (2001). Despite the metallogenic significance of the Early Cretaceous plutonism, available geochronological data consist mainly of K-Ar and Rb-Sr age determinations. In this paper, we report U-Pb zircon and monazite ages for three samples from the Cassiar batholith and two from the Seagull batholith. The 10- to 15-m.y. separation in age of these two batholiths warrants more complete distinction within the Cassiar suite. Forthcoming publications will address more fully the geological, tectonic and metallogenic significance of the new results.

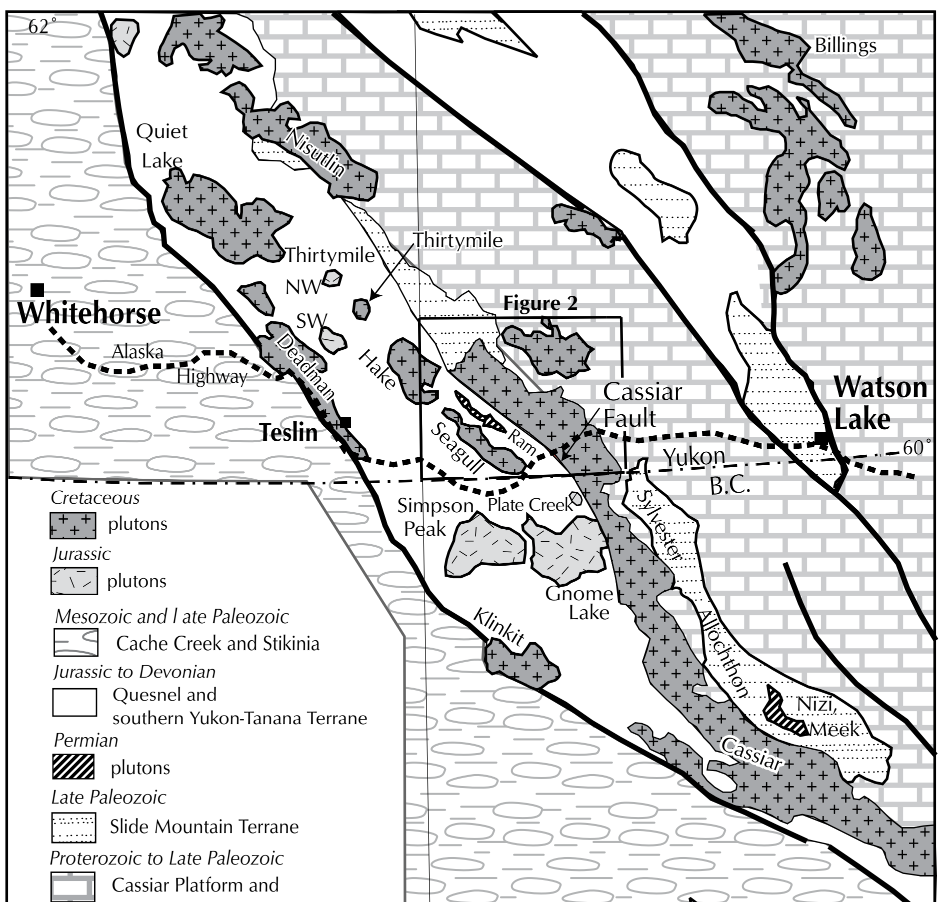

Figure 1. *Simplified geology of southern Yukon and northern British Columbia, with major plutons labelled. Box shows location of Figure 2.*

CASSIAR BATHOLITH

The Cassiar batholith is a northwest-trending, elongate body, approximately 350 km in length and from 5 to 40 km wide, that intruded the western shelf edge of Ancestral North America (Figs. 1 and 2). It is mainly felsic, comprising biotite ± muscovite quartz monzonite and granite with less abundant biotite ± hornblende granodiorite and monzodiorite. Geochemical and isotopic studies by Driver *et al*. (2000) indicate that the various phases in the batholith are subalkaline and typically weakly to moderately peraluminous, with evolved isotopic signatures (initial Sr ratios = 0.706 to 0.734; εND = -2.7 to -17.1). Driver *et al*. (2000) concluded that magmas that formed the Cassiar batholith represent partial melts of two distinct sources: one likely derived from Proterozoic metasedimentary and/or basement rocks of Ancestral North America; the other was a mafic source of uncertain age and origin.

Where the Alaska Highway crosses Cassiar batholith in southern Yukon, the western contact of the batholith is the Cassiar Fault, a northwest-trending dextral shear (Fig. 1). Roadcuts show that the degree of mylonitization decreases eastward over about 5 km (Poole *et al*., 1960; Gabrielse, 1969); farther south, where the fault crosses ridge spurs in northern BC, it is only tens of metres wide. Although brittle deformation clearly occurred after the Cassiar batholith had cooled, the elongated shape of the pluton suggests it intruded along a pre-existing zone of crustal weakness.

Previous age information for the Cassiar batholith consists of two K-Ar biotite ages of 103 ± 10 Ma and 101 ± 8 Ma for samples of massive granite (Baadsgaard *et al*., 1961; Lowdon, 1961), a single K-Ar age of 89 ± 4 Ma for muscovite from "cataclastic granite" near the western margin of the body (Wanless *et al*., 1972), and a Rb-Sr whole-rock isochron age of 112 ± 4 Ma for various fine-grained phases of the Cassiar batholith in southeastern Wolf Lake map area (G. Medford and R.L. Armstrong, unpublished data).

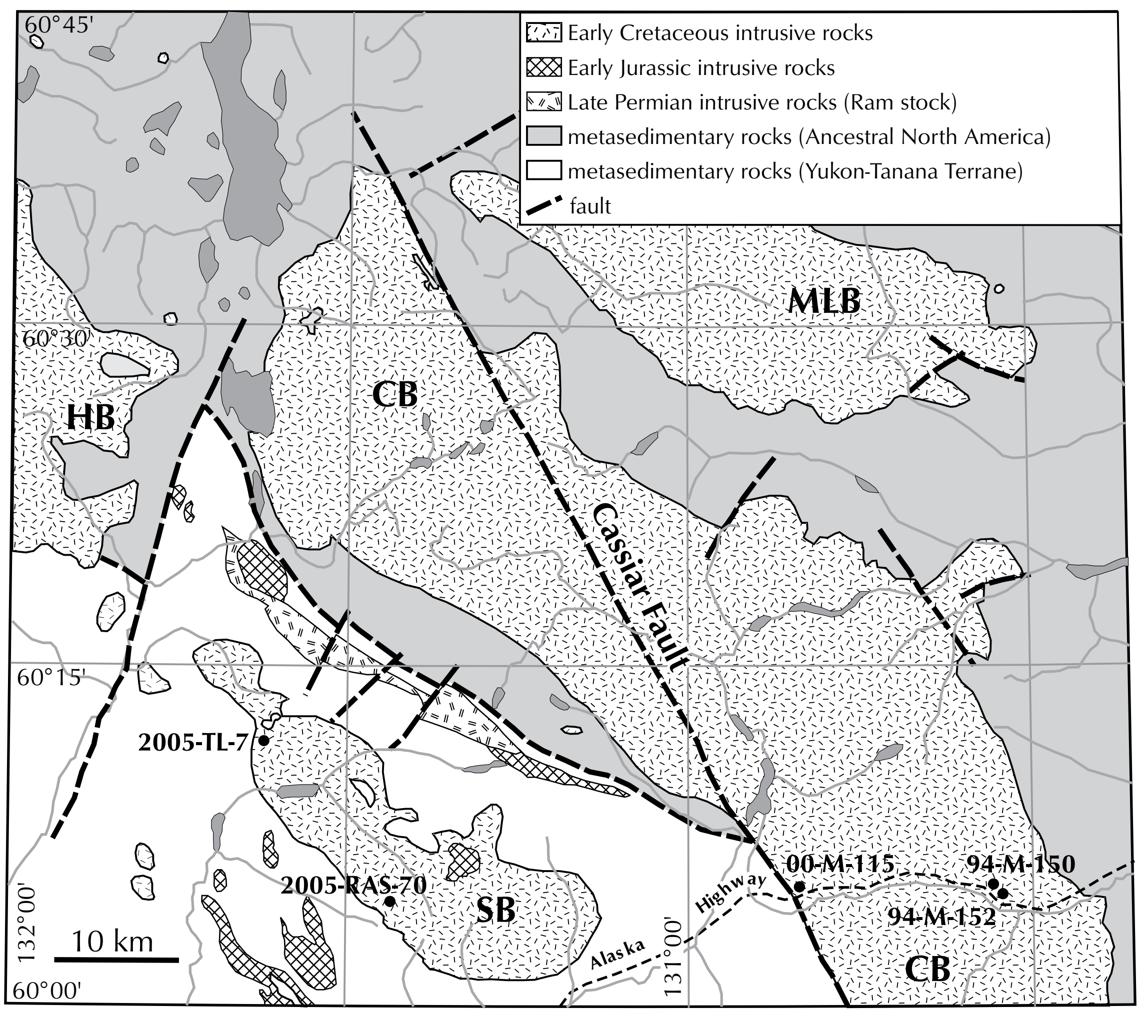

Figure 2. *Geology of southwestern Wolf Lake map area showing locations of geochronological samples. Plutons labeled as follows: CB = Cassiar batholith, SB = Seagull batholith, HB = Hake batholith, MLB = Marker Lake batholith.*

SEAGULL BATHOLITH

The Seagull and Hake batholiths (possibly joined beneath a 7-km-wide septum of metasedimentary host rock) are distinct one-mica granites with enriched biotite (Liverton *et al*., 2005). Northwest of Hake batholith are the Thirtymile and Ork stocks which contain some of the most evolved lithofacies reported in the northern Cordillera. These include zinnwaldite-topaz leucogranites with extreme Rb/Sr ratios, and range from metaluminous to peraluminous in composition. Trace element contents fall within the fields of within-plate ('anorogenic'), rather than arc-related granitoids. These plutons have a distinct metallogenic signature comprising pronounced Sn-B-F enrichments. The granites had previously been interpreted to represent a single intrusive suite on the basis of chemistry and metallogeny (Liverton and Alderton, 1994; Liverton and Botelho, 2001). The whole-rock chemical data for these intrusions, and their very Fe-rich mica chemistry, are consistent with being late-orogenic magmas derived from the middle crust. The Thirtymile, Hake and Seagull plutons were emplaced at a sufficiently shallow level in the crust to have allowed 'ultrafractionation'. This happens when the presence of fluorine facilitates fractionation by inhibiting nucleation in the magma chamber, depolymerizing silicates and depressing the solidus so that elements such as lithium and boron can move upward in the magma (C. Hart, pers. comm., 2003).

Isotopic studies yielded Rb-Sr ages of 101 ± 5.3 Ma for the Thirtymile stock, and an interpreted cooling age of 98.3 ± 2.9 Ma for the marginal phase of the Hake batholith (Liverton *et al*., 2001). Seven K-Ar biotite ages from various samples of the Seagull batholith itself range from 94 ± 4 Ma to 102.8 ± 1.1 Ma, and a single Rb-Sr whole-rock isochron age of 100.3 ± 2.8 Ma was reported for the Seagull batholith by Mato *et al*. (1983).

U-PB GEOCHRONOLOGY

In this study, we determined U-Pb crystallization ages for three samples from the Cassiar batholith and two samples from the Seagull batholith. Conventional thermal ionization mass spectrometry (TIMS) methods were employed to date zircons and monazites from the Cassiar batholith samples, and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) methods were used to date zircons from the Seagull batholith. All of the analytical work was done at the Pacific Centre for Isotopic and Geochemical Research (PCIGR) at the University of British Columbia.

METHODOLOGY

The methodology used for TIMS analyses at the PCIGR is as described by Mortensen *et al*. (1995). LA-ICP-MS dating has recently been established as a routine procedure at the PCIGR. Zircons are separated from their host rocks using conventional mineral separation methods. Approximately 25 of the coarsest, clearest, most inclusion-free grains are selected from each sample, mounted in an epoxy puck along with several grains of internationally accepted standard zircon (in this case we used FC-1, a ~1100 Ma zircon standard), and brought to a very high polish. The grains are examined using a stage-mounted cathodoluminescence unit, which makes it possible to detect the presence of altered zones or older inherited cores within the zircon. High-quality portions of each grain, free of alteration, inclusion, or cores, are selected for analysis. The surface of the mount is then washed for ~10 minutes with dilute nitric acid and rinsed in high purity water. Analyses are carried out using a New Wave 213 nm Nd-YAG laser coupled to a Thermo Finnigan Element2 high-resolution ICP-MS. Ablation takes place within a New Wave "Supercell" ablation chamber which is designed to achieve very high efficiency entrainment of aerosols into the carrier gas. Helium is used as the carrier gas for all experiments and gas flow rates, together with other parameters such as torch position, are optimized prior to beginning a series of analyses. A 25 micron spot with 40% laser power is used, making line scans rather than spot analyses in order to avoid within-run elemental fractions. Each analysis consists of a 7-second background measurement (laser off) followed by a ~28-second data acquisition period with the laser firing. A typical analytical session consists of four analyses of the standard zircon, followed by four analyses of unknown zircons, two standard analyses, four unknown analyses, etc., and finally four standard analyses. Data are reduced using the GLITTER software marketed by the GEMOC group at Macquarrie University in Sydney, Australia, which automatically subtracts background measurements, propagates all analytical errors, and calculates isotopic ratios and ages. Final ages for relatively young (Phanerozoic) zircons are based on a weighted average of the calculated $^{206}Pb/^{238}U$ ages for 10-15 individual analyses. Final interpretation and plotting of the analytical results employ the ISOPLOT software written by K.R. Ludwig.

SAMPLE LOCATIONS AND DESCRIPTIONS

Two samples of massive granite of the Cassiar batholith were collected from roadcuts on the north side of the Alaska Highway (Fig. 2). Sample 94-M-150 is a medium-grained, equigranular biotite-muscovite granite collected 2.6 km east of Canyon Creek (12.6 km east of the Upper Rancheria River) (UTM 6662082N, 411358E; all coordinates are NAD 1983, zone 9). Sample 94-M-152 was collected 3.1 km east of Canyon Creek (UTM 6661682N, 412008E), and consists of fractured and chloritized biotite granite with K-feldspar phenocrysts up to 3 cm in length. Both zircon and abundant monazite were recovered from this sample. A third sample (00-M-115) was collected near the western margin of the Cassiar batholith, from a zone of strongly foliated biotite granite with K-feldspar augen up to 1.5 cm long on the east side of Porcupine Creek, 3.4 km east of the Upper Rancheria River (UTM 6661394N, 387721E). This sample yielded only zircon.

Two samples were dated from the Seagull batholith (Fig. 2). Sample 2005-TL-7 is a fine-grained megacrystic biotite granite containing K-feldspar phenocrysts up to 1.5 cm in length, and was collected on a northeast-trending spur approximately 2 km south of Dorsey Lake (UTM 6669582N, 357865E). This sample contains ~15% fresh black biotite. Sample 2005-RAS-70 was collected on Peak 1727 m, approximately 4.5 km north of the outlet of Dorsey Lake (UTM 6676481N, 354299E). It is an aplitic biotite granite containing ~10% biotite. Both samples yielded abundant zircon and monazite.

ANALYTICAL RESULTS

The two samples of massive granite from the Cassiar batholith each yielded a small amount of zircon, which consisted of clear, pale yellow, equant to stubby prismatic grains, some of which contained visible cloudy cores. Three fractions of zircon were selected from sample 94-M-150, taking care to avoid grains with visible cores. The three analyses all yielded discordant analyses (Fig. 3a) with relatively old Pb/Pb ages (up to 1181 Ma), indicating that inherited cores were present in at least some of the grains in each fraction. The data do not define a linear array, and, therefore, meaningful upper and lower concordia intercept ages cannot be calculated. Both samples also yielded abundant monazite, occurring as

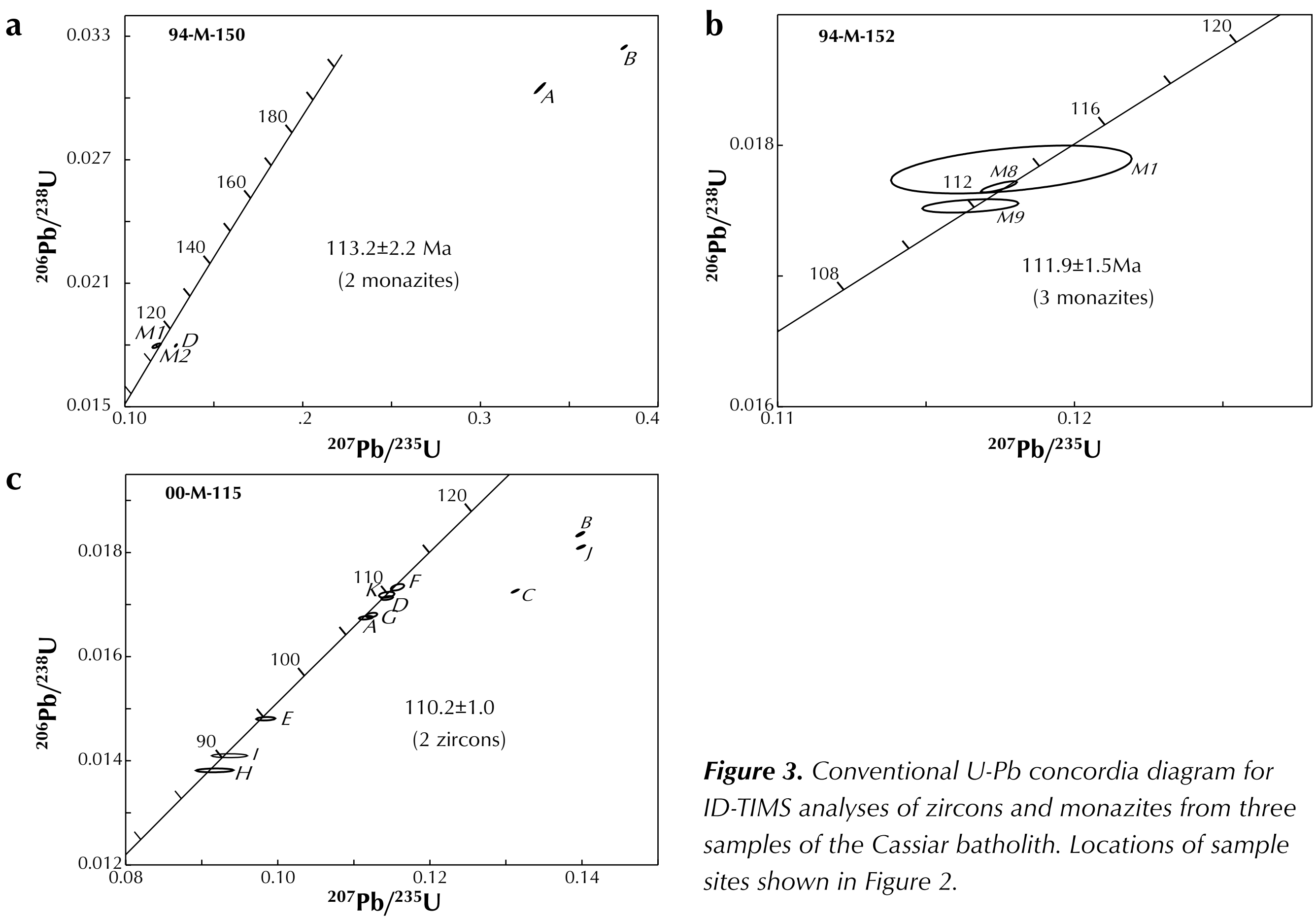

Figure 3. *Conventional U-Pb concordia diagram for ID-TIMS analyses of zircons and monazites from three samples of the Cassiar batholith. Locations of sample sites shown in Figure 2.*

equant, multifaceted pale yellow grains. Two fractions of monazite were analysed from sample 94-M-150, and both analyses lie slightly above concordia, presumably a result of disequilibrium amounts of ^{206}Pb present. The total range of ^{207}Pb/^{235}U ages of the two monazite fractions (113.2 ± 2.2 Ma) is taken as the best estimate for the crystallization age of the sample. Only monazite was analysed from the second sample (94-M-152). Three fractions lie on or immediately above concordia (Fig. 3b), and the total range of ^{207}Pb/^{235}U ages for the three fractions (111.9 ± 1.5 Ma) is taken as the best estimate for the crystallization age.

The sample of strongly foliated and lineated K-feldspar augen gneiss from near the western edge of the Cassiar batholith (sample 00-M-115, Fig. 2) yielded only zircon. Zircons from this sample include some grains that are similar in appearance to those in the previous two samples, along with a larger population of square elongate prisms with simple terminations. Previous work on zircon populations with significant inheritance has shown that this latter morphological population is less likely to contain inherited cores. A total of 12 strongly abraded fractions from the prismatic population were analysed, and a considerable amount of scatter is evident in the data (Fig. 3c). Three of the analyses (B, C and J) are strongly discordant with Pb/Pb ages up to 454 Ma and are interpreted to have contained a significant inherited zircon component. The rest of the analyses fall on, or immediately below, concordia with a considerable amount of scatter in the ^{206}Pb/^{238}U ages. This scatter is interpreted to reflect the effects of post-crystallization Pb-loss, which is not surprising in light of the very high U-contents of these samples (up to 3843 ppm; Table 1). The best estimate for the crystallization age of the sample is given by the total range of ^{206}Pb/^{238}U ages for fractions D, F and K, at 110.2 ± 1.5 Ma. There is a small degree of scatter between these three analyses, however, and we cannot preclude the possibility that some or all of these fractions have also experienced minor Pb-loss. The age should therefore be considered to be a minimum estimate for the crystallization age of the gneissic granite.

LA-ICP-MS methods were used to date the two samples from the Seagull batholith. Both samples yielded abundant zircon as well as abundant monazite. The zircon grains range from clear, pale yellow, stubby multifaceted prisms, some of which contain cloudy cores, to elongate square prisms, with simple terminations and rare to abundant clear inclusions. Twenty of the elongate prismatic population were selected from each of the two Seagull samples and mounted in epoxy pucks along with several grains of the FC-1 zircon standard. The grains were examined on a cathodoluminescence stage to confirm that no cores were present. A total of 11 analyses were done on sample 2005-TL-7 and 12 analyses on sample 2005-RAS-70. Results are shown in Figure 4, in the form of a compilation of measured ^{206}Pb/^{238}U ages. The individual analyses are relatively imprecise as compared to conventional TIMS analyses, and the assigned ages are based on weighted means of all or most of the ^{206}Pb/^{238}U ages. Results indicate an age of 95.7 ± 2.1 Ma for sample 2005-TL-7 (Fig. 4a; megacrystic biotite granite phase) and 99.3 ± 2.2 Ma for sample 2005-RAS-70 (Fig. 4b; aplitic biotite granite phase). All eleven analyses were included in the weighted average age for sample 2005-TL-7. However, two analyses from sample 2005-RAS-70 give significantly older ages than the rest, and are interpreted

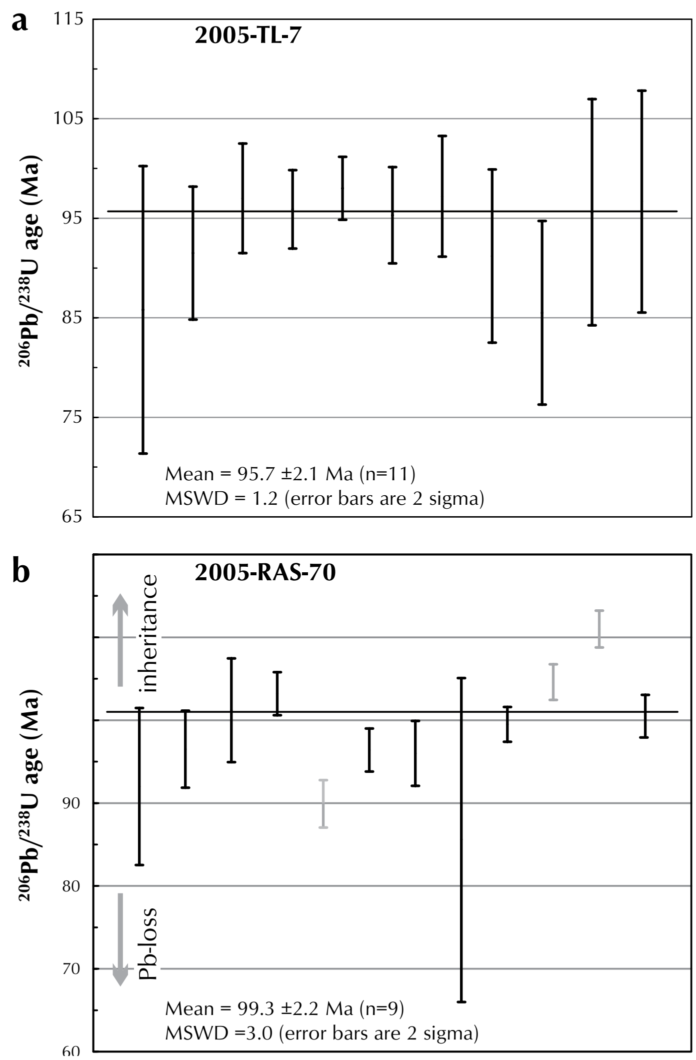

Figure 4. *Plot of ^{206}Pb/^{238}U ages for individual LA-ICP-MS analyses from two samples of the Seagull batholith.*

Table 1. *U-Pb analytical data for Cassiar Batholith samples (ID-TIMS).*

Sample description[1]	weight (mg)	U (ppm)	Pb[2] (ppm)	$^{206}Pb/^{204}Pb$ (measured)[3]	total common Pb (pg)	% ^{208}Pb[2]	$^{206}Pb/^{238}U$[4] (± % 1σ)	$^{207}Pb/^{235}U$[4] (± % 1σ)	$^{207}Pb/^{206}Pb$[4] (± % 1σ)	$^{206}Pb/^{238}U$ age (Ma; ± % 2σ)	$^{207}Pb/^{206}Pb$ age (Ma; ± % 2σ)
Sample 94-M-150											
A: N2,+104	0.080	834	25.4	14 490	9	7.1	0.08239(0.39)	0.3335(0.42)	0.07935(0.09)	193.6(1.5)	1181.0(3.4)
B: N2,+104	0.062	773	26.1	6517	15	10.2	0.03246(0.14)	0.3809(0.20)	0.08509(0.08)	205.9(0.6)	1317.7(3.2)
D: N2,+104	0.048	1033	18.2	5447	10	7.5	0.01798(0.16)	0.1287(0.23)	0.05191(0.11)	114.9(0.4)	281.4(5.1)
M1: +134,u	0.051	2691	352.4	231	710	87.5	0.01796(0.30)	0.1178(0.99)	0.04754(0.80)	113.0(2.1)5	76.6(38.2)
M2: +134,u	0.046	2647	385.7	437	326	88.8	0.01801(0.19)	0.1190(0.59)	0.04790(0.49)	114.1(1.3)5	94.4(23.0)
Sample 94-M-152											
M1: +104,u	0.009	1167	170.9	593	20	89.0	0.01782(0.51)	0.1179(1.72)	0.04799(1.56)	113.1(3.7)5	98.7(73.8)
M4: +104,u	0.019	2629	337.0	2200	24	87.7	0.01743(0.14)	0.1156(0.24)	0.04810(0.16)	111.0(0.5)5	104.4(7.6)
M8: +104,u	0.024	2010	250.2	1352	39	87.1	0.01768(0.12)	0.1175(0.26)	0.04818(0.17)	112.8(0.6)5	107.9(8.2)
M9: +104,u	0.035	1890	236.4	1185	62	87.3	0.01754(0.15)	0.1165(0.70)	0.04818(0.65)	111.9(1.5)5	108.1(30.9)
Sample 00-M-115											
A: N2,+134,p	0.050	840	15.2	3366	13	16.6	0.01675(0.10)	0.1116(0.41)	0.04832(0.38)	107.1(0.2)	115.1(18.2)
B: N2,+134,p	0.084	1318	25.3	5882	21	13.3	0.01835(0.12)	0.1398(0.19)	0.05524(0.10)	117.2(0.3)	421.9(4.4)
C: N2,+134,p	0.086	1516	27.4	8192	17	13.4	0.01726(0.09)	0.1312(0.16)	0.05514(0.09)	110.3(0.2)	417.8(3.8)
D: N2,+134,p	0.074	1226	23.2	6512	15	18.3	0.01713(0.10)	0.1144(0.34)	0.04844(0.31)	109.5(0.2)	120.8(14.4)
E: N2,+134,t	0.022	2840	42.9	2319	25	11.6	0.01480(0.11)	0.0994(0.21)	0.04869(0.13)	94.7(0.2)	133.1(6.0)
F: N2,+104,p	0.015	1472	28.2	3986	6	16.6	0.01771(0.17)	0.1190(0.21)	0.04870(0.16)	113.2(0.4)	133.5(7.4)
G: N2,+104,p	0.018	1725	31.9	4385	7	17.9	0.01680(0.13)	0.1123(0.34)	0.04850(0.31)	107.4(0.3)	123.6(14.4)
H: N2,+104,p	0.048	2413	34.2	576	177	12.0	0.01382(0.13)	0.0917(1.34)	0.04814(1.33)	88.5(0.2)	106.1(62.9)
I: N2,+104,p	0.042	3843	56.5	1253	114	13.5	0.01410(0.13)	0.0936(1.26)	0.04817(1.27)	90.3(0.2)	107.8(59.2)
J: N2,+104,p	0.018	1771	34.2	3425	10	14.9	0.01811(0.09)	0.1399(0.19)	0.05603(0.11)	115.7(0.2)	453.6(5.0)
K: N2,+104,p	0.015	1299	23.3	1679	12	14.3	0.01719(0.16)	0.1148(0.27)	0.04846(0.22)	109.8(0.4)	121.7(10.5)
L: N2,+104,p	0.037	658	12.8	1399	19	18.7	0.01751(0.10)	0.1178(0.25)	0.04879(0.18)	111.9(0.2)	137.8(8.2)

[1] N2 = non-magnetic at 2 degrees side-slope on Frantz magnetic separator; grain size given in microns; p = elongate square prisms; sp = stubby prisms; mf = equant multifaceted grains; t = tips broken off prisms; u = unabraded.

[2] radiogenic Pb; corrected for blank, initial common Pb, and spike

[3] corrected for spike and fractionation

[4] corrected for blank Pb and U, and common Pb

[5] $^{207}Pb/^{235}U$ ages given for monazite analyses

to have included a minor inherited component. In addition, one fraction gives a younger age and is interpreted to have experienced post-crystallization Pb-loss. These three fractions were excluded from the calculated average age.

DISCUSSION

The classification of plutonic rocks into suites is an important first step in assessing their role in regional tectonic history and metallogeny. Plutons of Early and mid-Cretaceous age in the northern Cordillera have been subdivided into various plutonic suites on the basis of age, lithology and geochemistry. Those southwest of the Tintina Fault, including the Cassiar and Seagull batholiths, comprise the Cassiar suite (Mortensen *et al.*, 2000), one of three suites included in the Anvil-Hyland-Cassiar belt by Hart (2004) and Hart *et al.* (2004). These three sites have mainly felsic, weakly to moderately peraluminous compositions.

Establishing common parentage between intrusions in the Cassiar Terrane and those intrusions northeast of the Tintina Fault is complicated by the ~450 km of early Tertiary dextral slip between them. Furthermore, the U-Pb ages for the Cassiar batholith reported here are identical to the 110-113 Ma age range obtained from several large intrusions that were emplaced into the Yukon-Tanana Terrane in the Finlayson Lake District of southeastern

Yukon (Mortensen, unpublished data); and those are included in the Anvil plutonic suite. The Seagull batholith is distinct in age and composition from both the Cassiar batholith and most bodies of the Anvil plutonic suite. Liverton and Alderton (1994), and Hart *et al*. (2004) considered it to represent an ultra-fractionated sub-suite of the Cassiar suite. We suggest that the Seagull batholith is akin to the Tungsten plutonic suite of eastern Yukon and southwestern Northwest Territories (Mortensen *et al*., 2000; Hart *et al*., 2004) because our new U-Pb ages for the Seagull batholith (99.3 ± 2.2 Ma and 95.7 ± 2.1 Ma) overlap with ages obtained for various intrusions of the Tungsten suite (Mortensen *et al*., 2000; Mortensen, unpublished data; Hart, 2004). At this point, however, there are insufficient data available for other intrusions within the Cassiar Terrane to further speculate on possible genetic linkages between the various intrusions.

Table 2. *U-Pb analytical data for Seagull Batholith samples (LA-ICP-MS)*

Sample number	$^{206}Pb/^{238}U$ age (Ma)	Error (Ma, 1 sigma)
	85.8	7.22
2005-TL-7a	91.5	3.34
2005-TL-7b	97	2.75
2005-TL-7c	95.9	1.97
2005-TL-7d	98	1.58
2005-TL-7e	95.3	2.42
2005-TL-7f	97.2	3.03
2005-TL-7g	91.2	4.35
2005-TL-7h	85.5	4.61
2005-TL-7i	95.6	5.68
2005-TL-7j	96.7	5.56
2005-RAS-70a	92	4.74
2005-RAS-70b	96.5	2.32
2005-RAS-70c	101.2	3.13
2005-RAS-70d	103.2	1.3
2005-RAS-70e	89.9	1.43
2005-RAS-70f	96.4	1.3
2005-RAS-70g	96	1.96
2005-RAS-70h	85.6	9.74
2005-RAS-70i	99.5	1.05
2005-RAS-70j	104.6	1.08
2005-RAS-70k	111	1.11
2005-RAS-70l	100.6	1.23

The age and origin of the strong ductile deformation that affected the western margin of the Cassiar bathlith remains unresolved. The deformation is presumably associated with the Cassiar fault; however, since contacts between massive phases of the batholith and ductilely deformed phases are not exposed, we cannot prove that the deformation is actually synplutonic. At this point, the minimum age for the fabric development is only constrained to be older than the 89 ± 4 Ma K-Ar muscovite age from the sheared Cassiar batholith granite that was reported by Wanless *et al*. (1972), and younger than both the Rb-Sr whole-rock isochron age of 112 ± 4 Ma (unpublished) and the 110 ± 1.5 Ma zircon age reported here.

A somewhat similar scenario was described by Mortensen and Hansen (1992) at the northwest end of the Nisutlin batholith in west-central Quiet Lake map area, approximately 200 km northwest of the current study area. At this locality, granodioritic orthogneiss yielded a U-Pb zircon and monazite crystallization age of 110.8 ± 0.4 Ma, and a $^{40}Ar/^{39}Ar$ cooling age for biotite of 100.0 ± 1.0 Ma. This orthogneiss unit was interpreted to represent an early phase of Cassiar suite magmatism that experienced ductile deformation prior to 100 Ma, and prior to the intrusion of the massive phases of the Nisutlin batholith, which cross-cut the ductile fabrics. Foliations in the gneissic rocks adjacent to the Nisutlin batholith dip gently to the northeast, and kinematic indicators record top-to-the-southeast (or dextral) displacement, which differs somewhat from that of fabrics in the western margin of the Cassiar batholith.

The Anvil-Cassiar suite is regionally associated with proximal tungsten (± molybdenum) and zinc-lead skarn mineralization, and more distal silver-lead-zinc veins (Mortensen *et al*., 2000; Hart, 2004). In southern and central Wolf Lake map area, there are numerous occurrences that are hosted within or immediately adjacent to the Cassiar batholith (Yukon MINFILE, Deklerk and Traynor, 2005). Most of these are polymetallic veins, along with several examples of tungsten, molybdenum and zinc-lead skarns. None of these occurrences have been dated thus far, and therefore we cannot confidently state that they are genetically associated with the Cassiar batholith.

The metallogenic signature of the Seagull batholith is very different from that of the Cassiar batholith. Mineralization within or immediately adjacent to the Seagull batholith consists of tin (± tungsten) skarns and greisens, along with several zinc-lead skarns. The most significant of these occurrences is the JC skarn system (105B 040, Yukon MINFILE, Deklerk and Traynor, 2005) with a drilled reserve of 1.25 Mt of 0.2% Sn (Layne and Spooner, 1991). The nature of the spatially associated mineralization near the Seagull batholith is consistent with its 'ultrafractionated' composition, and it has been assumed (although unproven) that most or all of the skarn and greisen mineralization is temporally and genetically related to the batholith.

CONCLUSIONS

- The age of the Cassiar batholith is now narrowly confined between 110 and 113 Ma, confirming an unpublished Rb-Sr age and revealing that the two K-Ar dates on biotite were too young.
- The U-Pb zircon age for the Seagull batholith confirms earlier K-Ar dates that suggest it is distinctly younger than the Cassiar suite. However, the older date for the less common aplitic phase (99.3 ± 2.2 Ma) and younger date on the common megacrystic phase (95.7 ± 2.1 Ma) are the converse of what is normally expected in a large batholith. The distribution and timing of phases within Seagull batholith warrant further investigation, and is a promising avenue of research in granite petrology and metallogeny.

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