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Article abstract

A tonalite dyke in the Benacadie Brook Formation in the Boisdale Hills of central Cape Breton Island yielded a U-Pb (zircon) age of 564.5 ± 5.1 Ma, interpreted to be the age of intrusion. The age is identical within error to the U-Pb (zircon) age of $564 \pm 3/-2$ Ma previously reported for a granodiorite sample from the nearby Shunacadie Pluton. Based on geographic proximity and identical age, as well as petrological similarities, the tonalite dyke is interpreted to be comagmatic with the granodiorite. Although the new date does not provide further constraint on the age of the Benacadie Brook Formation, it affirms the importance of ca. 560 Ma plutonism in the Bras d'Or terrene of Cape Breton Island.

A Late Neoproterozoic age for a tonalite dyke in the Boisdale Hills, Cape Breton Island, Nova Scotia

Sandra M. Barr¹, Sandra Kamo², and Chris E. White³

¹*Department of Geology, Acadia University, Wolfville, Nova Scotia B0P 1X0, Canada*

²*Royal Ontario Museum, 100 Queen's Park, Toronto Ontario M5S 2C6, Canada*

³*Department of Natural Resources, P.O. Box 698, Halifax, Nova Scotia B3J 2T9, Canada*

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A tonalite dyke in the Benacadie Brook Formation in the Boisdale Hills of central Cape Breton Island yielded a U-Pb (zircon) age of 564.5 ± 5.1 Ma, interpreted to be the age of intrusion. The age is identical within error to the U-Pb (zircon) age of $564 \pm 3/-2$ Ma previously reported for a granodiorite sample from the nearby Shunacadie Pluton. Based on geographic proximity and identical age, as well as petrological similarities, the tonalite dyke is interpreted to be comagmatic with the granodiorite. Although the new date does not provide further constraint on the age of the Benacadie Brook Formation, it affirms the importance of ca. 560 Ma plutonism in the Bras d'Or terrane of Cape Breton Island.

Un dyke de tonalite intrusive dans la formation de Benacadie Brook, dans les collines du centre de l'île du Cap-Breton, a révélé une datation au U-Pb (au zircon) de $564,5 \pm 5,1$ m.a. Cette datation est la même que celle obtenue au U-Pb (au zircon) de $564 \pm 3/-2$ m.a. signalée précédemment pour un échantillon de granodiorite de la formation plutonique adjacente de Shunacadie. Compte tenu de la proximité géographique, du même âge et d'autres similitudes pétrologiques, ce dyke de tonalite est réputé appartenir à la même province pétrographique que la granodiorite. Bien que cette nouvelle datation ne donne pas d'autres précisions sur l'âge de la formation de Benacadie Brook, elle n'en établit pas moins l'importance de l'activité plutonique survenue dans le terrane du Bras d'Or sur l'île du Cap-Breton il y a environ 560 m.a.

Traduit par la rédaction

INTRODUCTION

The Boisdale Hills of south-central Cape Breton Island (Fig. 1) are underlain by northeast-trending belts of Late Neoproterozoic or older metamorphic and plutonic rocks, and Cambrian to Ordovician volcanic, sedimentary, and minor plutonic rocks (e.g., Bell and Goranson 1938; Milligan 1970; Barr and Setter 1986; White *et al.* 1994). The purpose of this note is to present a new U-Pb (zircon) age, as well as petrographic and chemical data, from a tonalitic dyke in the metamorphic rocks. The dyke was dated in an attempt to better constrain the minimum age of the host metamorphic rocks, previously indicated by a U-Pb (zircon) age of $564 \pm 3/-2$ Ma from granodiorite of the Shunacadie Pluton (Barr *et al.* 1990). Although the age reported here is identical, within error, to that of the previously dated granodiorite and hence does not provide enhanced constraint on the age of its host rocks, it provides further corroboration for the age of plutonic units in the Bras d'Or terrane of Cape Breton Island (Fig. 1).

GEOLOGICAL SETTING

The metamorphic rocks of the Boisdale Hills were included in the George River Series of Milligan (1970) and George River Group of Keppie (1979). As a result of detailed petrographic study, Raeside (1989) and Raeside and Barr

(1990) divided the metamorphic rocks into two suites, a higher grade Frenchvale Road metamorphic suite and a lower grade Benacadie Brook Formation. The relationship between these two units is uncertain because they are everywhere separated by major faults and/or younger units (Fig. 1).

The age of these metamorphic units is also uncertain. The minimum age is constrained by the ages of plutonic units intruded into them, oldest of which is the U-Pb (zircon) age of granodiorite in the Shunacadie Pluton (Barr *et al.* 1990). The Benacadie Brook Formation, which mainly hosts the Shunacadie Pluton (Fig. 1), is similar to relatively low-grade metasedimentary units scattered throughout the Bras d'Or terrane, collectively termed the George River Metamorphic Suite by Keppie *et al.* (1998). The age of these metasedimentary rocks is mainly constrained by plutons similar in age to or younger than the Shunacadie Pluton (Raeside and Barr 1990; Keppie *et al.* 1998), although Keppie *et al.* (1998) reported detrital zircon ages as young as 637 Ma from volcanogenic units in the Creignish Hills (CH; Fig. 1) inferred to be part of the George River Metamorphic Suite. However, the depositional age of possibly correlative units in northern mainland Nova Scotia and southern New Brunswick has been suggested to be as old as middle Riphean (Hofmann 1974), and hence the age of units such as the Benacadie Brook Formation is important for regional correlations and tectonic reconstructions (e.g., Keppie *et al.* 1998).

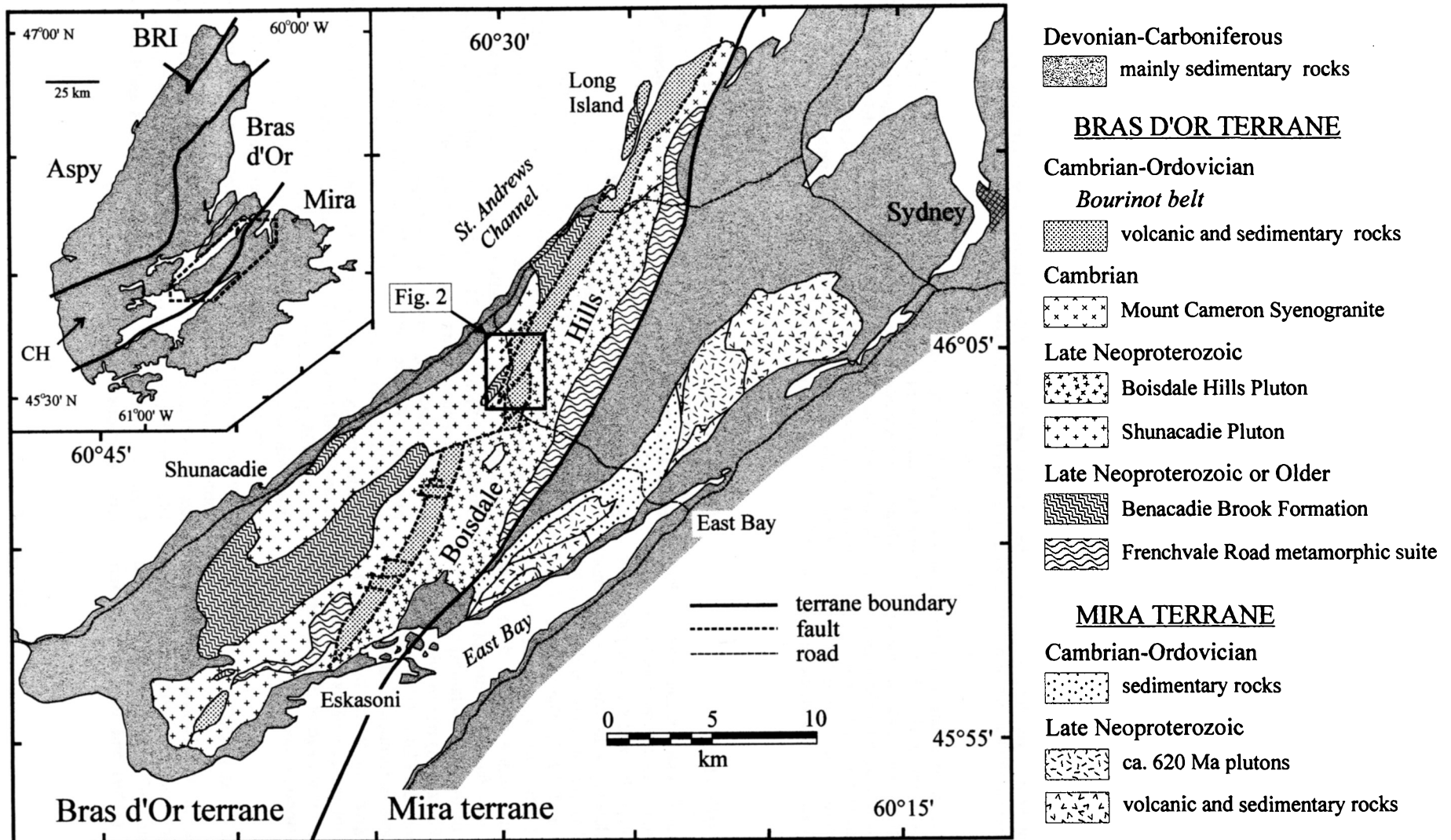


Fig. 1. Simplified geological map of the Boisdale Hills area, after White *et al.* (1984), showing the location of the more detailed map in Fig. 2. The inset map of Cape Breton Island shows the location of the larger map at the boundary between the Bras d'Or and Mira terranes of Barr and Raeside (1989); BRI is the Blair River inlier and the arrow labeled CH shows the approximate location of the Creignish Hills referred to in the text.

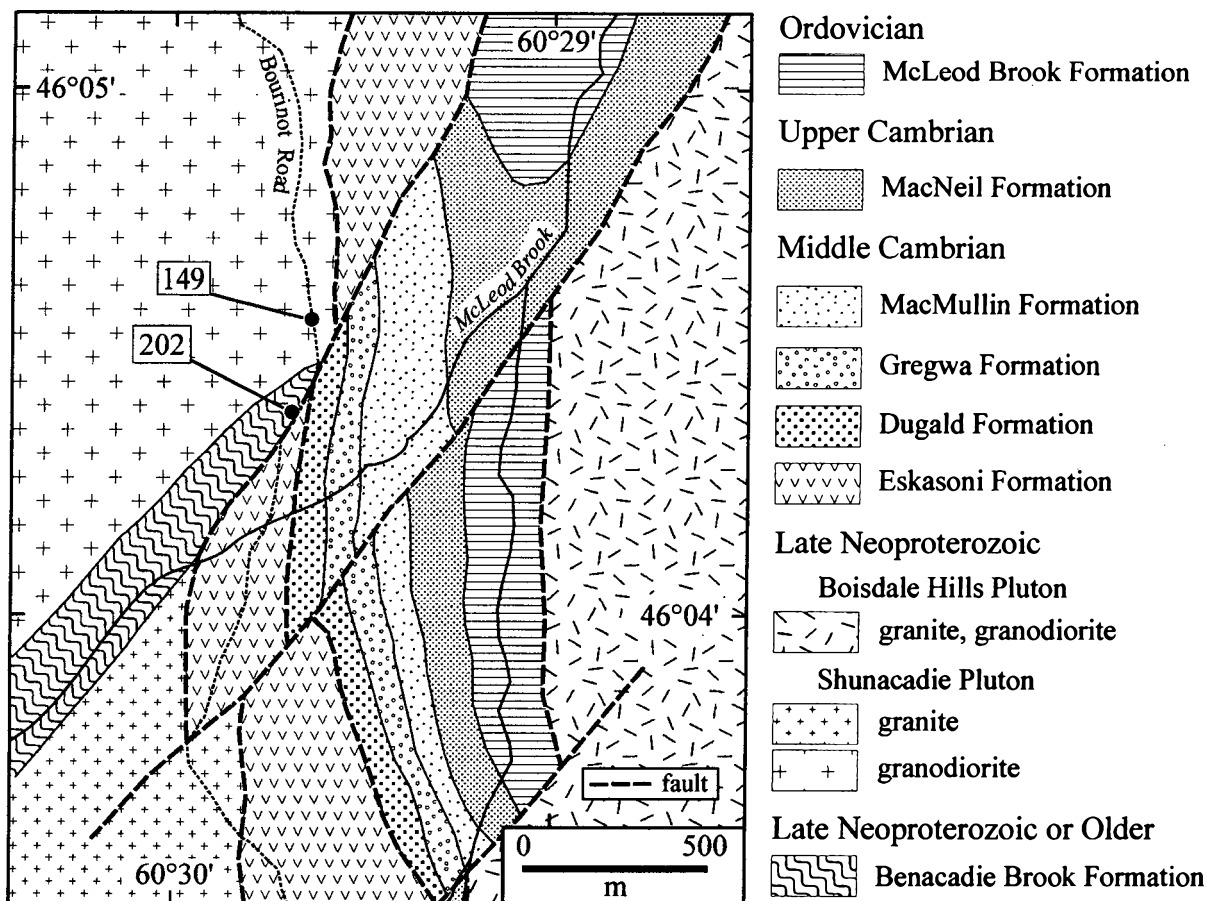


Fig. 2. Geological map of the central Boisdale Hills showing the location of the dated tonalite dyke (sample 202) and sample 149 from near the margin of the Shunacadie Pluton. Geology is after White *et al.* (1994); the Middle Cambrian to Ordovician formations listed in the legend constitute the Bourinot belt of Fig. 1.

Plutonic rocks of the Boisdale Hills were studied in detail by Barr and Setter (1986). They divided the rocks into two large plutons, Shunacadie and Boisdale Hills, separated by volcanic and sedimentary rocks of the Bourinot belt and by major faults (White *et al.* 1994). The Shunacadie Pluton consists mainly of biotite granodiorite, with minor areas of diorite, granite, and leucogranite. The age of the pluton is $564 \pm 3/-2$ Ma, based on U-Pb (zircon) dating of the biotite granodiorite unit (Barr *et al.* 1990). The components of the Boisdale Hills Pluton range from diorite, quartz diorite, and tonalite to granodiorite, monzogranite, and leucogranite (Barr and Setter 1986). The minimum age of the Boisdale Hills Pluton is constrained by $^{40}\text{Ar}/^{39}\text{Ar}$ cooling ages for hornblende of ca. 530 Ma (Keppie *et al.* 1990). Earlier Rb-Sr results ranging from ca. 502 to 563 Ma (e.g., Cormier 1972; Wanless *et al.* 1968) have large errors and are not considered reliable (Barr *et al.* 1990). Barr and Setter (1986) also included the Mount Cameron Syenogranite (Fig. 1) in the Boisdale Hills Pluton, but it was subsequently shown to be a petrologically distinct and younger pluton with a U-Pb (zircon) age of 509 ± 2 Ma (White *et al.* 1994).

TONALITE DYKES

The dyke that is the focus of the present study is one of

two dykes of tonalitic composition that intruded an outcrop of metasedimentary rocks about 100 m in extent along the Bourinot Road (Fig. 2). The metasedimentary rocks that host the dykes appear to form a large xenolith or roof pendant in the Shunacadie Pluton, and are correlated on the basis of lithology with the Benacadie Brook Formation of Raeside and Barr (1990). On the east, the metamorphic rocks are in faulted contact with rocks of the Eskasoni Formation, the lowermost unit of the Cambrian-Ordovician Bourinot Group (White *et al.* 1994).

The metamorphic rocks consist of fine- to medium-grained hornfels, containing mainly quartz and plagioclase together with about 15% scattered, randomly oriented biotite flakes. Garnet forms rare porphyroblasts.

The two tonalite dykes that cut the hornfels are each 5 – 10 m wide, and consist mainly of medium-grained anhedral plagioclase and quartz, and clusters of small biotite flakes. They contrast with the adjacent granodiorite of the Shunacadie Pluton, which has a well-preserved hypidiomorphic granular (igneous) texture. The texture of the dykes suggests that they have been recrystallized, together with their host metasedimentary rocks, by the thermal effects of the adjacent Shunacadie Pluton, and/or by interaction with hot fluids derived from the pluton or the host rocks.

Similar tonalitic dykes were also observed in a small area of metamorphic rocks north of Eskasoni, 12 km to the

Table 1. Chemical data¹

wt. %	BHC91-202	BHC91-149	Average ²
SiO ₂	67.03	70.35	67.53
TiO ₂	0.60	0.48	0.49
Al ₂ O ₃	16.19	15.93	15.49
Fe ₂ O ₃ ¹	4.64	3.43	3.87
MnO	0.10	0.08	0.09
MgO	2.38	1.57	1.45
CaO	2.05	1.00	2.80
Na ₂ O	4.04	5.42	3.77
K ₂ O	0.93	0.67	2.46
P ₂ O ₅	0.13	0.11	0.11
LOI	2.50	2.00	1.47
TOTAL	100.59	101.04	99.67
ppm			
Ba	275	122	397
Rb	42	26	78
Sr	223	236	217
Y	35	20	28
Zr	161	134	155
Nb	12	7	11
Th	10	10	11
Pb	15	10	10
Ga	15	12	15
Zn	133	42	60
Cu	91	7	8
Ni	17	14	16
V	94	57	69
Cr	30	33	45

¹Analyses by standard X-Ray Fluorescence techniques at the Regional Geochemical Centre, St. Mary's University, Halifax, NS, except major element data for calculation of the average for the Shunacadie granodiorite is taken from Barr and Setter (1986).

²Average of 22 analyses of samples from the granodiorite unit, Shunacadie Pluton; samples from Barr and Setter (1986).

southwest of the Bourinot Road section (Fig. 1). That area of metamorphic rocks was assigned to the Frenchvale Road metamorphic suite by Raeside (1989) and Raeside and Barr (1990).

Chemical analysis of a sample from the dated dyke (BHC91-202; Table 1) shows low K₂O (0.93%), consistent with its tonalitic modal mineralogy. Also shown in Table 1 is a chemical analysis of sample 149, collected from the granodioritic unit of the Shunacadie Pluton approximately 200 m north of the tonalite dyke (Fig. 2). Although superficially more similar in appearance to typical granodiorite of the Shunacadie Pluton, rather than to the tonalite dykes, sample 149 contains little or no K-feldspar and has chemical composition similar to that of dyke sample BHC91-202 (Table 1). The similarity is also illustrated on a multi-element variation diagram (Fig. 3). Compared to the average of 22

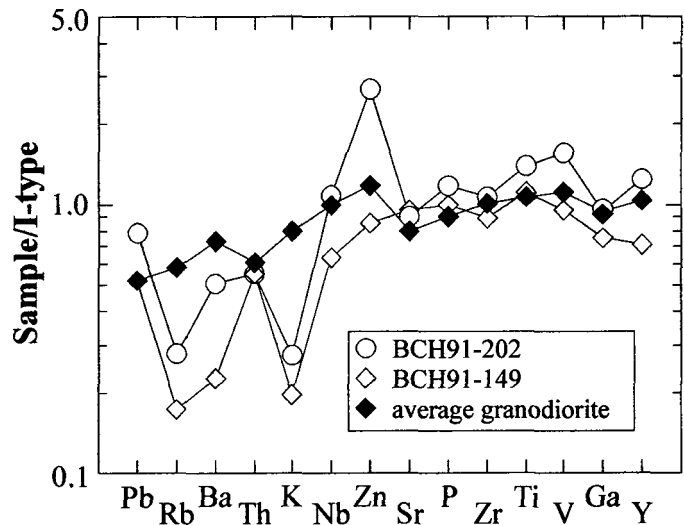


Fig. 3. Multi-element variation diagram with data from Table 1 normalized to average I-type granite of Whalen *et al.* (1987).

analyses of samples from the granodiorite unit of the Shunacadie Pluton (samples from Barr and Setter 1986), both the tonalite dyke sample and sample 149 have lower contents of the mobile elements such as K, Rb, and Ba, but have similar compositions in the generally less immobile elements such as P, Zr, and Ti (Fig. 3). It is suggested that in both cases, the chemical differences are the result of post-crystallization alteration and metasomatism.

GEOCHRONOLOGY

Analytical methods

Zircon was separated from the tonalite sample using standard heavy liquid and magnetic separation techniques. All zircon fractions, with the exception of #7, were air abraded (Krogh 1982). Mineral dissolution and isolation of U and Pb from zircon followed the procedure of Krogh (1973), modified by using small anion exchange columns (0.05 mL of resin).

Pb and U were loaded together with silica gel onto outgassed rhenium filaments. The isotopic compositions of Pb and U were measured using a single collector Daly detector in a solid source VG354 mass spectrometer. A mass fractionation correction of 0.1% per amu for both Pb and U was used. Error estimates were calculated by propagating known sources of analytical uncertainty for each analysis, including ratio variability (within run), uncertainty in the fractionation correction (0.038% and 0.026% at 1 sigma for Pb and U, respectively, based on long-term replicate measurements of the standards NBS981 and U-500), and uncertainties in the isotopic composition and amount of laboratory blank and initial Pb. Initial common Pb in excess of 10 pg was corrected using the Pb evolution model of Stacey and Kramers (1975). Decay constants are those of Jaffey *et al.* (1971). Age errors quoted in the text and table and error ellipses in the concordia diagrams are given at the 95% confidence level. Discordia lines and intercept ages were calculated using the regression program of Davis (1982).

Table 2. U-Pb isotopic data for zircon from tonalite dyke sample BHC92-202.

No.	# of grain fragments	Weight (mg)	U (ppm)	Pb (ppm)	Model Th/U	Pb ^C (pg)	Isotopic ratios			Apparent ages			% disc.
							²⁰⁷ Pb/ ²⁰⁴ Pb	²⁰⁶ Pb/ ²³⁸ U	²⁰⁷ Pb/ ²³⁵ U	²⁰⁶ Pb/ ²³⁸ U	²⁰⁷ Pb/ ²³⁵ U	²⁰⁷ Pb/ ²⁰⁶ Pb	
1	3	0.003	249	23	0.46	0.7	368.5	0.09094 ± 0.00035	0.7389 ± 0.0030	561.08 ± 2.09	561.77 ± 1.77	564.54 ± 5.74	0.6
2	33	0.010	441	41	0.43	16	106.9	0.09018 ± 0.00023	0.7325 ± 0.0033	556.61 ± 1.33	558.04 ± 1.95	563.87 ± 7.70	1.3
3	11	0.006	115	11	0.41	1.3	195.2	0.08943 ± 0.00026	0.7260 ± 0.0039	552.16 ± 1.57	554.22 ± 2.29	562.66 ± 9.90	1.9
4	10	0.008	209	20	0.47	16	53.7	0.09354 ± 0.00019	0.7731 ± 0.0071	576.43 ± 1.15	581.53 ± 4.06	601.48 ± 17.83	4.4
5	18	0.010	173	16	0.47	1.5	415.7	0.09104 ± 0.00022	0.7443 ± 0.0023	561.65 ± 1.33	564.91 ± 1.36	578.03 ± 4.89	3.0
6	42	0.018	369	35	0.49	2.1	1082.2	0.08992 ± 0.00044	0.7339 ± 0.0024	555.08 ± 2.59	558.86 ± 1.43	574.25 ± 8.71	3.5
7	35	0.028	496	46	0.47	4.4	1104.1	0.08966 ± 0.00022	0.7330 ± 0.0020	553.52 ± 1.29	558.30 ± 1.18	577.87 ± 2.57	4.4

Notes: Model Th/U from estimated Th concentration based on abundance of ²⁰⁸Pb and ²⁰⁷Pb/²⁰⁶Pb age. Pb^C is total common Pb from sample and laboratory procedures. ²⁰⁷Pb/²⁰⁴Pb ratios have been corrected for spike and fractionation. Pb/U ratios have been corrected for spike, fractionation, blank, and initial common Pb. % disc. is percent discordance assuming zero-age Pb loss. Absolute errors are 2 sigma.

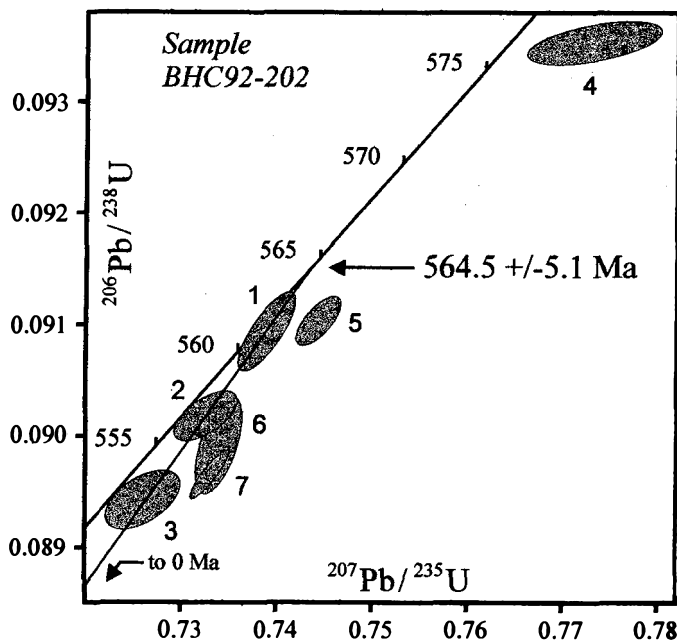


Fig. 4. Concordia diagram for zircon fractions 1 to 7, as described in the text. Data are from Table 2.

Results

Seven multigrain zircon fractions were analyzed for Pb and U and the data are presented in Table 2 and Fig. 4. The zircon fractions were selected from 2 morphologically distinct subpopulations: (1) colourless, skeletal fragments (i.e. flat, bladed shards), and (2) colourless, euhedral, elongate, doubly terminated, 4-sided prismatic grains.

Data points 1, 2, and 3 are collinear and give an upper intercept age of 564.5 ± 5.1 Ma (91% probability of fit), which is interpreted as the best estimate for the age of the tonalite dyke. The data points are 0.7%, 1.6%, and 2.4% discordant, respectively, along the Pb-loss line toward a zero-age lower intercept. These data were obtained from fragments of skeletal grains, as were data points 5, 6, and 7; however, the latter plot to the right of the Pb-loss line and it is suspected that these fractions contained minor inherited components in the form of colourless cores or as discrete grains. Data point

#4 was produced from the second subpopulation and contains older inherited zircons that were probably acquired during emplacement of the dyke into older crust.

IMPLICATIONS AND CONCLUSIONS

The age of metamorphic units in the Bras d'Or terrane is not well constrained (e.g., Raeside and Barr 1990; Keppie *et al.* 1998). The tonalite dyke was sampled for dating because its petrographic features suggested that it might be an older intrusion, age of which would constrain better the minimum age of the host metamorphic rocks than the Shunacadie Pluton (U-Pb age $564 \pm 3/-2$ Ma; Barr *et al.* 1990). However, the age obtained (564.5 ± 5.1 Ma) is identical to that of the Shunacadie Pluton, and hence does not provide further information about the minimum age of the Benacadie Brook Formation.

The apparent petrographic differences between the tonalite dykes and granodiorite of the Shunacadie Pluton, such as greater degree of recrystallization of the tonalite, may be related to its small size and interaction with the host metasedimentary rocks. This interpretation is consistent with inheritance apparent in zircon systematics in the tonalite. The overall chemical similarity between the tonalite dyke and sample 149 from near the margin of the Shunacadie Pluton suggests that interaction with the metamorphic rocks may have produced their compositional characteristics, which contrast with the average composition of granodiorite in the Shunacadie Pluton. The tonalitic dykes are inferred to be comagmatic with the granodiorite unit of the Shunacadie Pluton.

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