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**A 2169 Ma U-Pb baddeleyite age for the Otish Gabbro,
Quebec: Implications for correlation of Proterozoic
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Superior Province**

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Abstract

Otish Gabbro sills intrude sedimentary rocks in the Otish Basin of the southeastern Superior Province. Here, deposition of Otish Supergroup sediments had previously been thought to be older than K-Ar and Sm-Nd ages of ca. 1750-1710 Ma for Otish Gabbro sills, and younger than ca. 2515-2500 Ma U-Pb ages of underlying Mistassini dykes. However, a much older U-Pb baddeleyite age of 2169.0 ± 1.4 Ma is presented here for an Otish sill, indicating that they are coeval with, and likely genetically related to, the giant 2172-2167 Ma Biscotasing dyke swarm to the southwest and (or) the Cramolet sills and Payne River dykes to the north. The new date also indicates that the age of the Otish Supergroup falls between ca. 2515 Ma and ca. 2169 Ma, only a little different from the ca. 2450-2217 Ma bracket for the Huronian Supergroup of the Southern Province, and is consistent with both supergroups spanning the oxy-atmo inversion. The Otish Supergroup could also be coeval with the Sakami Formation to the north, but is likely older than the Richmond Gulf Group on the east coast of Hudson Bay.

Early paleomagnetic study of Otish sills yielded a remanence $\sim 20^\circ$ from that expected for Biscotasing-aged intrusions. This may indicate that too few distinct sills were studied to average out paleosecular variation, that demagnetization techniques failed to fully remove unstable magnetization components, or that the remanence is a stable secondary overprint, perhaps acquired during a fluid event related to uranium mineralization at ca. 1720 Ma.

Key words: Otish Gabbro, Otish Supergroup, Biscotasing dyke swarm, U-Pb baddeleyite age, paleomagnetism

Introduction

Gently dipping sedimentary rocks of the Otish Supergroup in the Otish Basin lie unconformably on Archean basement rocks of the Superior Province within ~100 kilometres of the Grenville Front (Figs. 1 and 2; Chown and Caty 1973, Rulhmann et al. 1986, Genest 1989a). The Otish Supergroup has been subdivided into a lower Indicator Group characterized by drab-coloured conglomerate and sandstone, and an upper Peribonca Group characterized by red sandstone, mudstone, dolomite and conglomerate (Bergeron 1957, Eade 1966, Chown and Caty 1973, Genest 1989a). Abundant Otish Gabbro sills and a few gabbro dykes (Figs 2 and 3; Fahrig and Chown 1973, Chown and Archambault 1987; Genest 1989) intrude both the Indicator and Peribonca Group sedimentary rocks. The sills also occur outside the basin in contact with basement rocks of the Superior Province. It is likely in these locations that overlying sedimentary rocks have been lost to erosion. Other sills intrude outliers of the Indicator Group. The sills were previously thought to be ca. 1750-1710 Ma in age (e.g., Ruhlmann et al. 1986, Chown and Archambault 1987, Höhndorf et al. 1987, Gatzweiler 1987, Genest 1989a, Beyer et al. 2012). Based on the supposed age of the sills, it has generally been assumed that the Otish Supergroup sedimentary rocks may be as young as ca. 1710 Ma.

The Otish Basin is only one of a number of Paleoproterozoic basins in the eastern Superior and Southern provinces (Fig. 1). Others include the nearby Mistassini Basin, the Huronian Basin, a series of small basins hosting the Sakami Formation sedimentary sequence, and the Richmond Gulf Graben. There has been much speculation about

whether sedimentary units of one or other of these basins may be correlated with the Otish Supergroup (e.g., Chown and Caty 1973, Genest 1989b, Beyer et al. 2102). Establishing accurate correlations or non-correlations between these basins has implications not only for understanding the extensional and break-up history that affected the Superior craton, but also for metallogenic potential within and across depositional basins, particularly as the Otish Basin is host to several uranium prospects (e.g. Beyer et al. 2012).

In this study we investigate the U-Pb geochronology of the Otish sills in order to determine their emplacement age, clarify their relationship with other mafic magmatic events in the Superior Province, better constrain the age of deposition of the sedimentary units of the Otish Basin, and re-evaluate the age relationship between the Otish Basin and other Paleoproterozoic basins of the eastern Superior and Southern Provinces. In addition, we reassess earlier paleomagnetic data for the sills to determine if it is reliable and, hence, if it can be used for the construction of the Superior Province apparent polar wander path (APWP).

Previous Studies

Otish Gabbro sills and feeder dykes

Three principal Otish sills (Fahrig and Chown 1973, Chown 1979, Chown and Archambault 1987) consisting of olivine gabbro have been recognized in the northern

part of the Otish Basin (Fig. 3), where the sedimentary host rocks dip gently (typically 0°-15°) to the south. The Novet sill is found near the unconformity with Archean basement rocks. Successively higher in the sedimentary sequence are the Margat and Conflans sills.

Chown and Archambault (1987) interpreted poorly dated dykes within the Otish Basin as feeders for the Otish sills. Beyond the Otish Basin, they proposed a correlation with a swarm of northeast-trending dykes of regional extent.

Geochronology

Prior to the present study Otish Gabbro sills and dykes were thought to have been emplaced at ca. 1750-1710 Ma. Sm-Nd ages of 1730 ± 10 Ma (minerals) and 1710 ± 30 Ma (whole rock) were obtained from Otish Gabbro within the basin (C. Brooks in Ruhlmann et al. 1986). Chown and Archambault (1987) suggested a minimum age of ca. 1750 Ma based on poorly constrained K-Ar dates of northeast-trending dykes within and outside of the Otish Basin (Stevens et al. 1982, p. 43), and on interpretation of ages (Fryer 1972, T.E. Krogh in Chown and Caty 1973) associated with thermal events in the region that they suggested might be related to intrusion of the sills. In addition, uranium mineralization in the basin, which has been thought to be associated with emplacement of the Otish Gabbro, has been dated at 1723 ± 16 and 1717 ± 20 Ma (pitchblende and secondary U-ore U-Pb age; Höhndorf et al. 1987) and 1721 ± 20 Ma (uraninite $^{207}\text{Pb}/^{206}\text{Pb}$ age; Beyer et al. 2012).

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108 Although Chown and Archambault (1987) proposed that prominent northeast-trending
109 dykes of the southeast Superior craton, which extend for 900 km, fed the Otish sills,
110 precise U-Pb dating (and associated paleomagnetic studies) of northeast-trending dykes
111 to the southwest and west of the Otish Basin has not yet identified a ca. 1750-1710 Ma
112 dyke swarm. Instead, three prominent swarms of other ages have been recognized –
113 namely, the $2216 \pm 8/-4$ Ma Senneterre swarm (Buchan et al. 1993), the 2172-2167 Ma
114 Biscotasing swarm (Buchan et al. 1993, Halls and Davis 2004) and the 1141 ± 1 Ma
115 Abitibi swarm (Krogh et al. 1987). However, many northeast- to north-northeast-trending
116 dykes, especially those close to the Otish Basin, have yet to be studied and, hence, are of
117 unknown age. The Paleoproterozoic Senneterre and Biscotasing dyke swarms and coeval
118 units elsewhere in the Superior craton are illustrated in Figure 1.

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120 Senneterre dykes have been interpreted as part of the giant radiating Ungava swarm (Fig.
121 1) that extends across the eastern Superior Province from the Grenville Front to the Cape
122 Smith Belt (Buchan et al. 1998, Buchan et al. 2007) and has a focus southeast of Ungava
123 Bay, a possible mantle plume centre. Senneterre dykes likely fed the coeval 2219-2210
124 Ma Nipissing sills of the Huronian Basin (Corfu and Andrews 1986, Noble and Lightfoot
125 1992, Buchan et al. 1998). Biscotasing dykes are recognized over a wide area of the
126 eastern and western Superior Province, on either side of the Kapuskasing Structural Zone
127 (Fig. 1; Halls and Davis 2004). Recent U-Pb dating, in the North Spirit Lake area of
128 northwestern Ontario, suggests that the known span of these dykes may extend an
129 additional 600 km west of the established western Biscotasing swarm (e.g. 2175 ± 3 Ma

Margot Lake dyke, Hamilton and Stott 2008). Biscotasing dykes are coeval with the Cramolet sills which intrude the lower portion of the Seward Supergroup in the New Quebec Orogen (Fig. 1) and are dated at 2169 ± 2 Ma (Rohon et al. 1993), as well as the Payne River dykes of the extreme northeastern Superior Province (Fig. 1) dated at 2170-2160 Ma (U-Pb baddeleyite, S. Pehrsson, pers. comm. 2000).

Paleomagnetism

In an early paleomagnetic study, Fahrig and Chown (1973) sampled the Otish sills at nine sites (Fig. 3). Seven sites are in the upper Conflans sill. One site is in one of the small “satellite” sills which Chown and Archambault (1987, p. 113) describe as offshoots of the Conflans sill “which can be traced back into the main sill along strike”. Another site is in the middle Margat sill. A tenth site is in a dyke that was interpreted to feed the lower Novet sill.

Fahrig and Chown (1973) reported a near vertical down natural remanent magnetization (NRM) ($D = 242^\circ$, $I = 87^\circ$), and a steep west-southwest remanence ($D = 250^\circ$, $I = 73^\circ$) upon alternating field (AF) demagnetization. Two specimens at each site were demagnetized in stepwise fashion to 80 mT. The remaining specimens were then blanket cleaned at two steps between 10 and 25 mT. No thermal cleaning experiments were carried out. Baked contact tests were not attempted. Fahrig and Chown (1973) reported a mean paleomagnetic pole of 35°N , 107°W , $A_{95} = 9^\circ$.

Current study

Geochronology

In the current study, a U-Pb baddeleyite age was determined for a sample of the Conflans sill at site FA71-57 (Figure 3) from the paleomagnetic collection of Fahrig and Chown (1973) archived at the Geological Survey of Canada in Ottawa. Mineral separations and isotopic analyses were carried out at the Jack Satterly Laboratory at the University of Toronto, following the methods outlined in Hamilton and Buchan (2010). Abundant, fine-grained, fresh baddeleyite was recovered from approximately 0.75 kg of medium-grained gabbro.

U-Pb analytical results for four fractions, comprising a total of nine grains, are listed in Table 1 and shown in Figure 4. The data for all fractions are collinear, only slightly discordant (0.5-1.4%), and regress to yield an upper intercept age of 2169.0 ± 1.4 Ma (95% conf.), which we interpret to represent the age of emplacement of the Conflans sill. This age is indistinguishable from that of the widespread Biscotasing dykes to the southwest, and more localized Payne River dykes and Cramolet sills to the north (Fig. 1). Subsequent to the completion of the U-Pb baddeleyite dating described in this paper for the Conflans sill, further sampling of the Otish Gabbro was carried out by Milidragovic et al. (2015) as part of a broader, separate petrological and geochemical study. They briefly describe similar, but preliminary, U-Pb ages of 2172-2164 Ma for two other sills and a

dyke, which confirm the results herein, although their analytical results have yet to be published.

Paleomagnetism revisited

As noted earlier, Fahrigh and Chown (1973) calculated a magnetic pole at 35°N, 107°W, ($A_{95} = 9^\circ$) corresponding to the mean cleaned Otish remanence direction with unit weight to each of the ten sampling sites. As the data are derived from only two independent sills and one dyke, secular variation will not have been averaged out, and the pole should be considered as a virtual geomagnetic pole (VGP).

It is current practice, when sites can be assigned to individual sills or dykes, to calculate mean directions based on unit weight to each intrusion, because each intrusion will likely have cooled through its blocking temperatures in a short time relative to secular variation of the geomagnetic field. Recalculating the data of Fahrigh and Chown (1973) on this basis, yields a mean direction for the cleaned data in the Conflans and Margat sills of $D = 264^\circ$, $I = 74^\circ$ and corresponding VGP at 41°N, 111°W. If the dyke is included, one obtains a mean direction from the three intrusions (two sills and one dyke) of $D = 246^\circ$, $I = 74^\circ$, $\alpha_{95} = 14^\circ$ and corresponding VGP at 34°N, 105°W, $dm = 26^\circ$, $dp = 23^\circ$ (34°N, 105°W, $A_{95} = 25^\circ$ based on the mean of the three intrusions' VGPs).

The Otish NRM pole and the recalculated cleaned VGP (including the dyke) are plotted in Figure 5 for comparison with the APWP for the Superior craton between ca. 2.22 Ga

and ca. 1.88 Ga, and for Laurentia at 1.74 Ga following its assembly. This APWP has been developed since the Otish data were published by Fahrig and Chown (1973). It consists entirely of key paleomagnetic poles (Buchan 2007) that have been demonstrated primary with field tests and are precisely dated. Of particular note, given the age correlation described in this paper for the Otish sills and Biscotasing dykes, is the pair of primary 2.17 Ga Biscotasing dyke paleopoles obtained in the eastern and western Superior craton (Buchan et al. 1993, Halls and Davis 2004). The Biscotasing paleopoles differ slightly because the western Superior craton has been rotated 10-20° counterclockwise relative to the eastern Superior craton across the Kapuskasing Structural Zone as documented in ca. 2.45 to 2.07 Ga key paleomagnetic poles (Halls and Davis 2004, Buchan et al. 2007, Evans and Halls 2010).

There are three possible explanations of the apparent discrepancy between the paleopoles for the coeval Otish sills and Biscotasing dykes. Firstly, the Otish VGP, based only on three intrusions, is unlikely to average out paleosecular variation. A comparison of the Otish and Biscotasing remanence directions (Fig. 6) suggests that the two data sets are not widely discordant. However, the mean direction for the Otish gabbro intrusions is ~20° away from the well-defined direction for the Biscotasing dykes. Secondly, the position of the cleaned Otish VGP, between the Otish NRM pole and the Biscotasing poles (Fig. 5), could indicate that the low-stability component of NRM was not completely removed in the original AF cleaning experiments, which employed more primitive instruments and experimental procedures (e.g., blanket cleaning) than are used today. Thirdly, because no test has been done to demonstrate that the Otish remanence is

primary, it could be a stable secondary overprint, perhaps acquired at ca. 1720 Ma during fluid events associated with uranium mineralization (e.g., Höhndorf et al. 1987, Beyer et al. 2012). Indeed, the Otish VGP falls a relatively short distance from the primary 1740 $\pm 5/-4$ Ma Cleaver dyke paleopole (Fig. 5). Further paleomagnetic study is required to distinguish between these three possible explanations.

It should be noted that other explanations of the discrepancy between the Otish and Biscotasing paleomagnetic data, such as overprinting during the nearby Grenville orogeny or structural tilting of the sills, seem unlikely. Although the Otish Basin is close to the Grenville Front, there is no evidence of magnetic overprinting during the Grenville orogeny on the Otish sills that have been sampled in the northern portion of the basin. In particular, the Otish paleopole is quite distinct from paleopoles related to the Grenville orogeny which form a track running north in the western Pacific Ocean (Brett and Dunlop 2008). Tilting of the sills and their paleomagnetic remanence is also considered an unlikely explanation of the discrepancy, because correcting for the slight tilt of the sampled sills, as recorded in approximate fashion by Fahrigh and Chown (1973), moves the Otish VGP about 10° south, but not significantly closer to the Biscotasing pole.

Discussion

Age of Otish Gabbro and potential correlation with Superior Province magmatic events

The age of 2169.0 ± 1.4 Ma reported herein (and previously in an abstract by Hamilton and Buchan 2007) for the Conflans sill of the Otish Gabbro indicates that Otish sills are coeval with the widespread Biscotasing diabase dyke swarm to the southwest and the Cramolet sills and Payne River dykes to the north. We suggest that the Otish sills are related to one or more of these units. We find no evidence for ca. 1750-1710 Ma mafic magmatism within the Otish Basin as has been proposed by earlier workers. These younger age determinations, based upon Sm-Nd and K-Ar systems, appear to have been affected by isotopic exchange and/or re-equilibration at the whole-rock and mineral scale during a subsequent fluid or thermal event. Mafic dykes of the Biscotasing swarm trend northeast toward the basin and could be feeders of the sills. As yet, however, the Biscotasing dykes have not been traced as far as the basin, although there are large undated and unclassified northeast-trending dykes in the vicinity (Fig. 1).

Age of Otish Supergroup and potential age correlation with other sedimentary basins

Deposition of the Otish Supergroup sedimentary rocks (or at least those stratigraphically below the Conflans sill) is now constrained between ca. 2515 Ma and 2169 Ma, bracketed by the age for the intruding Otish sills reported herein and the ca. 2515-2500 Ma age (Heaman 2004, Hamilton 2009) for the northwest-trending Mistassini dykes, which are not observed to cut the Otish Supergroup (e.g., Figure 5 of Gatzweiler 1987). Given the age bracket for the Otish Supergroup, the presence of ca. 2217 Ma Nipissing sills or ca. 2216 Ma Senneterre dykes in the Otish Basin cannot be ruled out. Indeed, Senneterre dykes have been observed to the southwest, northwest and northeast (Fig 1).

The presence of Nipissing-Senneterre intrusions would place further constraints on the age of sedimentation in the basin. However, the limited paleomagnetic work that has been published for two Otish sills and one dyke (Fahrig and Chown 1973) did not reveal the remanence direction that characterizes Nipissing and Senneterre intrusions (shallow up to the north or shallow down to the south). Further geochronological and paleomagnetic studies are needed to clarify whether Nipissing-Senneterre sills and dykes are present.

The new age constraint on the Otish Supergroup has the following important implications for the correlation of sedimentary basins in the eastern Superior and Southern provinces (Figs. 1, 7):

(1) *Richmond Gulf Group of Richmond Gulf Graben*. The Richmond Gulf Group is preserved within the Richmond Gulf Graben which extends inland from the southeastern coast of Hudson Bay (Fig. 1; Chandler and Schwarz 1980). A correlation in age between the Otish Supergroup and the Richmond Gulf Group appears to be unlikely (Fig. 7) because Richmond Gulf Group sedimentary rocks are thought to be no older than ca. 2025 Ma based on a U-Pb and Pb-Pb analysis of diagenetic apatite cement from sandstone at the base of the Group (Chandler and Parrish 1989). However, additional geochronological studies are needed to confirm this age constraint.

(2) *Huronian Supergroup of Huronian Basin*. An age correlation between the Otish Supergroup and the Huronian Supergroup of the Southern Province (Fig. 1) is more likely because the latter is bracketed between the 2446 Ma age of underlying Matachewan

dykes (Heaman 1997) and the 2219-2210 Ma age of intruding Nipissing sills (Corfu and Andrews 1986, Krogh et al. 1987, Noble and Lightfoot 1992). Thus, the age brackets for these two sequences are rather similar (Fig. 7). This supports earlier interpretations of an Otish-Huronian correlation based on a comparison of the four sedimentary cycles in each basin, and the observation that in each case they span the oxy-atmo-inversion transition from lower grey beds to upper red beds in alluvial units of similar depositional strata (Roscoe, 1969, 1973; Cloud 1972; Genest 1989a, 1989b), a shift which is thought to have occurred prior to 2.32 Ga (Hannah et al. 2004; Bekker et al. 2004). The rather similar age brackets for the Otish and Huronian sequences also bring into question the interpretation of Beyer et al. (2012), who do not favour an Otish-Huronian correlation because of contrasting styles of uranium mineralization in the two basins.

(3) *Sakami Formation of Sakami basins.* The Otish Supergroup age bracket is also not greatly different from that of the Sakami Formation sedimentary rocks of the central eastern Superior Province (Figs. 1, 7) which are older than the crosscutting 2216 Ma Senneterre dykes, but younger than probable Mistassini dykes (2515-2500 Ma), as discussed in Goutier et al. (2001) and Buchan et al. (2007).

(4) *Mistassini Group of Mistassini Basin.* The Mistassini Basin is located along the Grenville Front a short distance southwest of the Otish Basin (Fig. 1). Mistassini Group sedimentary rocks, dominated by an upper sequence of shallow marine carbonates and iron formation and a lower sequence of siliciclastic beds, are younger than underlying ca. 2515-2500 Ma Mistassini dykes. Chown and Caty (1973) considered the lower

sedimentary units of the Mistassini Group, which are only found in the extreme northeast corner of the basin, to be equivalent to the Otish Supergroup. Unfortunately, few sills or dykes intrude the Mistassini Group so that establishing a younger age limit is difficult. Therefore, the age relationship between the Otish and Mistassini sedimentary rocks remains unclear (Fig. 7).

Implications for earlier correlation of uranium mineralization in the Otish Basin and emplacement of Otish Gabbro sills

Earlier studies (Beyer et al. 2012, and references therein) have linked uranium mineralization in the Otish Basin, which has been dated at ca. 1720 Ma, to the emplacement of Otish sills. However, the much older age obtained herein for the Otish Gabbro sills indicates that if the age of ore deposition is accurate, mineralization significantly postdates, by ~450 m.y., emplacement of the sills.

Conclusions

(1) Otish Gabbro sills were emplaced at 2169.0 ± 1.4 Ma, rather than at ca. 1750-1710 Ma, as previously thought.

(2) Otish Gabbro sills are indistinguishable in age from, and likely related to, the widespread Biscotasing dyke swarm, and (or) the more localized Cramolet sills and Payne River dykes.

(3) Otish Supergroup sedimentary rocks are >2169 Ma in age, compatible with being roughly contemporaneous with the Huronian Supergroup of the Southern Province which is older than ca. 2219-2210 Ma Nipissing sills and Senneterre dykes, and consistent with both supergroups spanning the oxy-atmo inversion. The Otish Supergroup may also be roughly contemporaneous with the Sakami Formation of the eastern Superior Province which is also older than Senneterre dykes.

(4) The interpretation of early published paleomagnetic data of Fahrig and Chown (1973) is uncertain. We conclude that the Otish VGP is not reliable and should not be used for APWP construction, since the corresponding Otish paleomagnetic remanence is $\sim 20^\circ$ from that of the expected direction based on well-defined primary data from the coeval Biscotasing dyke swarm. This may simply reflect the fact that paleosecular variation has not been averaged out in the three intrusions that were studied. Alternative explanations include incomplete removal of viscous components, or a stable secondary overprint, perhaps acquired during a fluid event at ca. 1.72 Ga. There is no evidence of an overprint related to the nearby Grenville orogeny.

(5) Assuming that the best estimate of the timing of U ore mineralization is accurately constrained at ca. 1720 Ma (Beyer et al. 2012), the much older 2169 Ma age constraint on Otish gabbro sills from the present study demonstrates unambiguously that the two events are widely spaced in time, and unrelated.

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Figure Captions

Figure 1: Paleoproterozoic sedimentary basins and selected Paleoproterozoic dyke swarms and sills of the Superior and Southern provinces. Dykes and sills are modified after Buchan and Ernst (2004). Ca. 2.22 Ga dykes appear to form a radiating pattern whose focus (star) locates a probable mantle plume centre (Buchan et al. 2007). The portion of the Superior Province west of the Kapuskasing Structural Zone (W Superior) has been rotated 15° clockwise (see large arrow) relative to the eastern Superior (E Superior) to undo a rotation of 10-20° that is believed to have occurred after 2069 Ma on the basis of paleomagnetic studies by Halls and Davis (2004), Halls et al. (2005), Buchan et al. (2007) and Evans and Halls (2010). NQO = New Quebec orogen; CSB = Cape Smith Belt.

Figure 2: Geology of the Otish Basin region (simplified after Genest 1989a).

Figure 3: Otish Gabbro sills of the northern Otish Basin (modified after Fahrig and Chown 1973). Solid circles are paleomagnetic sampling sites of Fahrig and Chown (1973). Paleomagnetic site FA71-57 in the Conflans sill is also the U-Pb dating site of the present study.

Figure 4: Concordia U-Pb diagram showing baddeleyite analyses from gabbro at site FA71-57, in the Conflans sill of the Otish Basin. Inset shows representative baddeleyite

crystals chosen for analysis. Error ellipses and regression age calculation errors are shown at 2σ level of uncertainty.

Figure 5: Otish Gabbro VGP in comparison to key paleopoles for other Paleoproterozoic units from the Superior Province and the key pole for the Cleaver dykes of Laurentia. Ellipses of 95% confidence are shown for each pole. Ages are in Ma. Question mark associated with Otish VGP reflects uncertainty in primary or secondary nature of the pole. Light grey arrows indicate the time progression of Superior Province and Laurentia poles. The black arrow indicates the direction in which the Otish paleopole moved upon AF demagnetization (Fahrig and Chown 1973). The dark grey dotted arrow indicates the direction in which the Otish would move if further demagnetization were to result in more complete removal of the viscous component (as discussed in the text).

Figure 6: Comparison of paleomagnetic remanence directions from Otish sills and a feeder dyke (Fahrig and Chown 1973) and Biscotasing dykes of the eastern Superior Province (Buchan et al. 1993). Directions are plotted on the lower hemisphere of an equal area net. Sites from a single dyke or sill are grouped. The six Biscotasing dyke groupings are labelled B1-B6. Biscotasing directions have been recalculated (assuming a geocentric axial dipole field geometry) for a reference locality of 52.3°N, 71.0°W to allow a direct comparison with the Otish directions.

Figure 7: Comparison of the age constraints on sedimentary sequences of the eastern Superior and Southern provinces. The rise in atmospheric oxygen and earliest redbeds are

595 thought to have occurred prior to 2.32 Ga (references in the text). Fm, Gp and SGp are
596 Formation, Group and Supergroup respectively.

597

598 **Table**

599

600 Table 1: Baddeleyite U-Pb isotopic data for Conflans gabbro sill, Otish Basin.

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Table 1. Baddeleyite U-Pb isotopic data for Conflans gabbro sill, Otish basin.

Fraction	Description	Weight (μg)	U (ppm)	Pb ^T (pg)	Pb _C (pg)	Th/U	Ages (Ma)												Disc. (%)	
							²⁰⁶ Pb/ ²⁰⁴ Pb	²⁰⁶ Pb/ ²³⁸ U	± 2σ	²⁰⁷ Pb/ ²³⁵ U	± 2σ	²⁰⁷ Pb/ ²⁰⁶ Pb	± 2σ	²⁰⁶ Pb/ ²³⁸ U	± 2σ	²⁰⁷ Pb/ ²³⁵ U	± 2σ	²⁰⁷ Pb/ ²⁰⁶ Pb		± 2σ
FA71-57; summit, gently dipping plateau between Lac Pollet and Lac Manet; approx. 52.298 N, 71.081 W																				
Bd-1	3 fresh, med brn blade fr	0.3	189	34.8	0.3	0.060	7647	0.39346	0.00093	7.3207	0.0204	0.13494	0.00013	2138.9	4.3	2151.3	2.5	2163.3	1.7	1.3
Bd-2	1 fresh, drk brn, blocky	0.2	187	14.6	0.5	0.027	1808	0.39767	0.00136	7.4150	0.0331	0.13523	0.00032	2158.3	6.2	2162.8	4.0	2167.0	4.2	0.5
Bd-3	2 fresh, med brn blade fr	0.3	289	34.0	0.5	0.093	4103	0.39328	0.00090	7.3175	0.0211	0.13495	0.00017	2138.0	4.2	2151.0	2.6	2163.3	2.2	1.4
Bd-4	3 fresh, med-drk brn blade fr	0.3	399	39.2	0.7	0.075	3761	0.39534	0.00090	7.3622	0.0215	0.13506	0.00018	2147.5	4.2	2156.4	2.6	2164.8	2.3	1.0

Notes:

All analyzed fractions represent best available optical quality baddeleyites.

Abbreviations: med - medium; drk - dark; brn - brown; fr - fragments.

 Pb^{T} is total amount (in picograms) of Pb. Pb_{C} is total measured common Pb (in picograms) assuming the isotopic composition of laboratory blank: 206/204 - 18.221; 207/204 - 15.612; 208/204 - 39.360 (errors of 2%).

Pb/U atomic ratios are corrected for spike, fractionation, blank, and, where necessary, initial common Pb; 206Pb/204Pb is corrected for spike and fractionation.

Th/U is model value calculated from radiogenic 208Pb/206Pb ratio and 207Pb/206Pb age, assuming concordance.

Disc. (%) - per cent discordance for the given 207Pb/206Pb age.

Uranium decay constants are from Jaffey et al. (1971).

Figure 1

Figure 2

Figure 3

Figure 4.

Figure 5

AGE CONSTRAINTS ON SEDIMENTARY BASINS
OF EASTERN SUPERIOR & SOUTHERN PROVINCES

Figure 7