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ON RECENT GEOCHRONOLOGICAL STUDIES IN THE NAIN PROVINCE, CHURCHILL PROVINCE AND NAIN PLUTONIC SUITE, NORTH-CENTRAL LABRADOR

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ABSTRACT

U−Pb geochronology has been undertaken on a variety of rocks between Voisey Bay and the Quebec border. The gneisses along the coast maintain some attributes of their Archean, Nain Province heritage, but an Early and Middle Proterozoic isotopic overprint is obvious. Rocks within the Churchill Province yield zircon, titanite and monazite that point to Archean protoliths overprinted by high-grade metamorphism ca. 1830-1800 Ma. Early Proterozoic juvenile crust is subordinate to Archean crust in the suite of rocks examined from the Churchill Province. Posttectonic granitoid plutons yield ages consistent with their field interpretation as Elsonian intrusions.

INTRODUCTION

A four-year mapping program, from Voisey Bay westward to the Quebec border, was completed in 1988. The 60-km-wide transect covers Archean gneisses of the Nain Province, Early Proterozoic and reworked Archean gneisses of the Churchill Province and Middle Proterozoic plutonic rocks of the Nain Plutonic Suite (Figure 1). Since only limited geochronological data, in the form of potassium−argon mineral ages, were available from this area, a U−Pb zircon program was initiated in order to obtain some idea of the absolute age of specific rock units and to establish a relative chronology of events determined from field studies. This paper summarizes some of the results from the geochronological program, conducted over a 3-year period, mostly at the zircon-dating laboratory of the Royal Ontario Museum (ROM), Toronto. The less-complete data referred to herein arise mainly from work still in progress by U. Schärer and S. Philippe. Geological details relevant to the following discussion may be found in papers by Ryan and Lee (1986), Ryan *et al.* (1987, 1988) and Ryan (1990). Data and graphical representations of the age studies carried out at the ROM are on file at the Geological Survey Branch of the Newfoundland Department of Mines and Energy (Krogh and Schärer, 1987; Krogh and Heaman, 1989; Krogh and Oliver, 1990). More discussion of the data and the regional significance of the results of these studies will be presented in papers to be published elsewhere.

The capitalized letters following the sample reference numbers in the text below and also in Table 1 refer to the sample sites shown on Figure 1.

RESULTS

NAIN PROVINCE

Rocks assigned to the Nain Province occupy the coastal strip north of Voisey Bay. These have been overprinted by Early Proterozoic tectonothermal activity, a conclusion initially proposed on the basis of field observation that mafic dykes of Early Proterozoic age within these gneisses are deformed and are metamorphosed to amphibolite facies. Study of samples from a coastal outcrop of grey migmatite containing a folded amphibolite dyke gave the following results:

Zircon from one sample (Nain 2,A) of the grey migmatite defines a mixing line with an upper intercept age of 2843 ± 11 Ma and a lower intercept age of 1805 Ma. The older age is considered to reflect the Archean protolith age of the migmatite, whereas the 1805 Ma falls within the range of a metamorphic episode in the Churchill Province (see below).

Preliminary analysis of another sample (US.87.21,A) from the same outcrop has yielded a thorite(?) population that gives a much younger age, namely 1310 ± 5 Ma. This appears to reflect thermal resetting and/or new growth caused by a nearby rapakivi granite pluton (see below).

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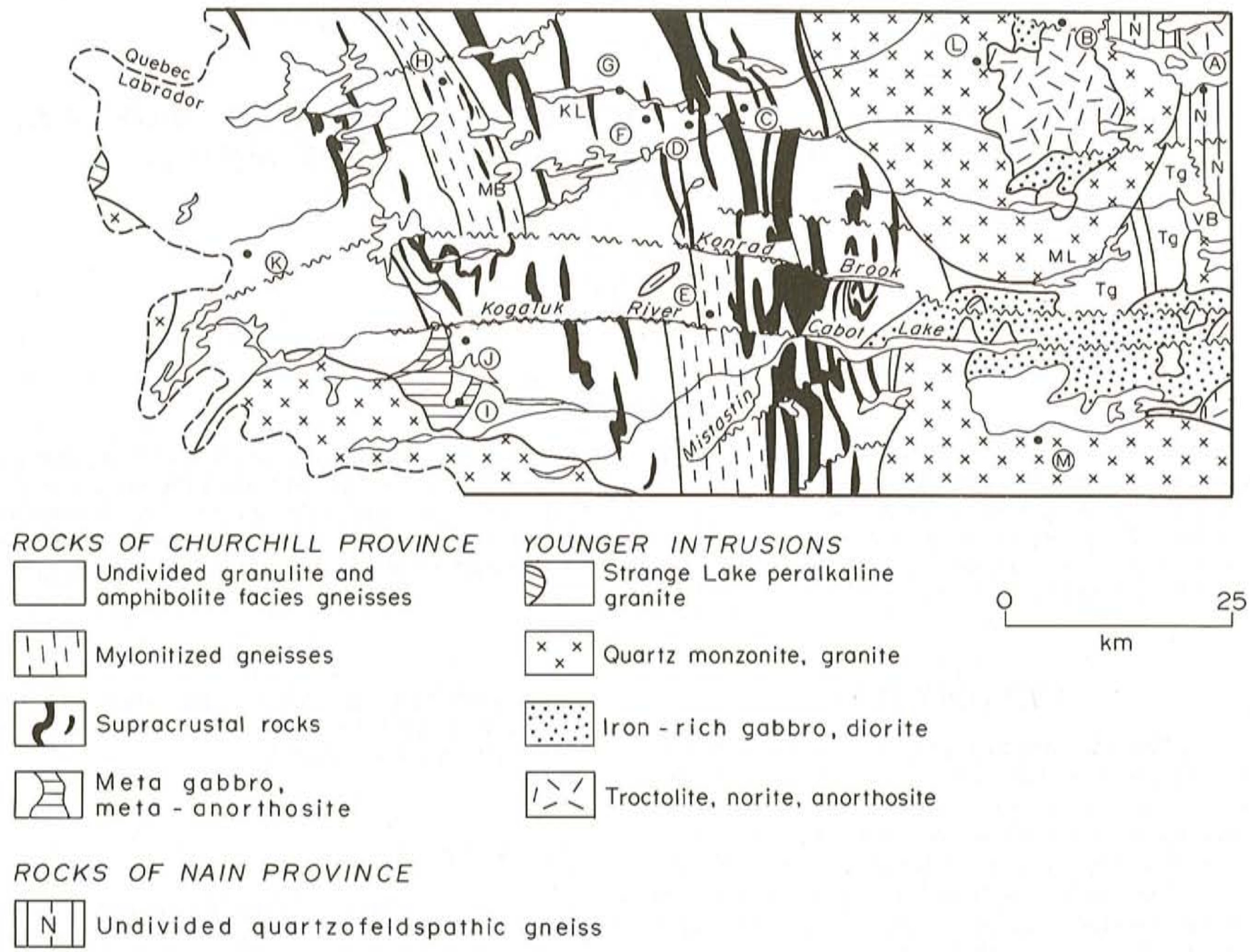

Figure 1. *Sketch map of the Nain Province–Churchill Province transect showing sample sites for geochronology studies. Circled letters with dot refer to sample locations and numbers listed in text and Table 1. Tg = Tasiuyak gneiss, VB = Voisey Bay, ML = Makhavinekh Lake, KL = Khongnekh Lake, MB = Moonbase Lake.*

The folded amphibolite dyke (Nain 3,A) yielded three zircon fractions, which define a line with upper intercept of 2100 ± 100 Ma and lower intercept of 1434 ± 4 Ma. Titanite from the same sample gives an age of 1256 ± 6 Ma. It is probable that the older zircon age from the dyke marks the age of intrusion, and that the titanite age marks the waning thermal effects of the rapakivi intrusion. The significance of the 1434-Ma age is somewhat obscure at present, but it is of interest to note that it falls within the time frame of some of the earliest Elsonian intrusions in central Labrador (for example 1448 to 1447 Ma for Harp Lake 'adamellite', 1426 Ma for Snegamook granite; see Stockwell, 1982, p. 63) and may be a record of resetting during this early phase of the Elsonian anorogenic magmatism. Alternatively, the older zircons may be xenocrystic and the younger ones give the actual age of the dyke emplacement.

CHURCHILL PROVINCE

The Churchill Province includes the 30-km-wide Tasiuyak gneiss and its intercalated enderbitic units that lie immediately west of Nain Province, and the polylithologic complex of gneisses and foliated charnockitic rocks that lie to the west of Tasiuyak gneiss. The Churchill Province contains a significant proportion of Hudsonian-reworked Archean crust, the Rae Province of Hoffman (1988). A suite of layered gneisses and foliated plutonic rocks from the Churchill Province has been investigated by U–Pb geochronology. Results are as follows:

A schlieric-layered, lineated, enderbitic gneiss occurs north of a polyphase Elsonian intrusion in eastern Churchill Province. Three zircon fractions from a sample (BR.85.259,B) of this rock plot on a line with an upper intercept of 1909^{+33}_{-21} Ma and a lower intercept of 1507^{+64}_{-61} Ma. Both these ages are somewhat difficult to explain in light of the known regional geology, since they do not correlate with any known metamorphic or intrusive events in this part of Labrador. It may be that the overprinting pyroxene–hornfels contact metamorphism from nearby anorthositic and granitic plutons has disturbed the P–Ub zircon systematics and these dates do not represent meaningful geological events.

Table 1. Summary of geochronological results. See text for discussion of data. Letters refer to sample localities on Figure 1

Locality (Figure 1)	Sample	Minerals	Age (Upper Intercept / Lower Intercept) Ma	Comments
A	Nain 2 qtz-felds gneiss	zircon	$\frac{2843 \pm 11}{1805}$	mixing line, Archean protolith, Hudsonian overprint
A	US.87.21 qtz-felds gneiss	thorite(?)	1310 ± 5	preliminary data, Middle Proterozoic thermal resetting
A	Nain 3 amphibol. dyke	zircon titanite	$\frac{2100 \pm 100}{1434 \pm 4}$ 1256 ± 6	older age may be time of intrusion; younger ages reflect thermal disturbance
B	BR.85.259 opx-qtz-felds gneiss	zircon	$\frac{1909^{+33}_{-21}}{1507^{+64}_{-61}}$	thermal disturbance of zircon by granite?
C	Geo.89.4 noritic pegmatite	zircon, monazite	$\frac{1831 \pm 2}{1803}$	older age may be pegmatite crystallization age
D	Geo.89.3 massive charnockite	zircon, monazite	$\frac{2597^{+27}_{-15}}{1823}$	Archean intrusion?
E	Geo.89.5 mylonitized gneiss	zircon, titanite	$\frac{2572^{+20}_{-18}}{1806}$	mylonitized Archean gneiss
F	Geo.89.2 sillimanite-biotite augen gneiss	zircon, monazite	$\frac{2574 \pm 8}{1824}$	Archean intrusion?
G	Geo.89.1 qtz-felds gneiss	zircon, monazite zircon	$\frac{2657 \pm 18}{1824}$ 1975	Archean migmatite with Proterozoic overprint
H	US.87.29 mylonitized gneiss	thorite(?)	1857 ± 3	preliminary data, Proterozoic metamorphism?
I	US.87.27 qtz-felds gneiss	zircon	2807^{+45}_{-27}	preliminary data
J	DD.87.48b pegmatite	zircon	1854 ± 1	intrusion age
K	BR.87.336 pink granite	zircon, monazite	$\frac{1859^{+5}_{-3},\ 1990}{231 \quad 1760}$ 1841 1837	complex zircon population
L	DL.85.201 rapakivi granite	zircon	$\frac{1322 \pm 1}{117}$	older age is time of intrusion
M	US.87.26 granite	zircon	1292 ± 4	preliminary data intrusion age

A weakly foliated, pegmatitic leuconoritic dyke (Geo.89.4,C) intrudes a metamorphosed and gneissose anorthositic and noritic layered intrusion, and is probably related to the larger layered body itself. Low U zircons from a sample of this dyke indicate a primary (intrusion ?) age of 1831 $\pm$ 2 Ma. Monazite growth occurred at around 1803 Ma. If the dyke is genetically related to the larger layered unit in which it occurs, it implies basic magmatism at about 1830 Ma in this area. Monazite and titanite from other rocks in this general area (see below) suggest high-grade metamorphism around this time as well, indicating a coeval magmatic–metamorphic episode whose influence may have lasted until ca. 1800 Ma.

Weakly foliated, fairly homogeneous, medium-grained charnockite is not uncommon in parts of central Churchill Province. One sample (Geo.89.3,D) was collected from a fairly extensive unit of this rock type. This rock differs radically from well-layered migmatite in the same general area, and was considered, on the basis of its weakly foliated character, to be a late kinematic Hudsonian intrusion. The line defined by the zircon populations (which fall well off concordia) may be interpreted to suggest an Archean protolith (upper intercept) of 2597^{+17}_{-15} Ma, which has been subjected to high-grade metamorphism in the Early Proterozoic (lower intercept of 1823 Ma controlled by a monazite analysis), or else inherited zircons in a Proterozoic intrusion.

One sample (Geo.89.5,E) of mylonitized gneiss from a broad amphibolite facies, high-strain zone near Mistastin River has been investigated. An upper intercept age of 2572^{+20}_{-18} Ma is obtained, when projected to the titanite age of 1806 Ma, and is interpreted to provide more evidence of Archean crust affected by metamorphism and mylonitization during the Early Proterozoic.

Zircon fractions isolated from sillimanite–biotite augen gneiss (Geo.89.2,F), associated with rusty garnetiferous pelitic gneiss, cluster near concordia. It is not possible to determine in the field if this is a highly deformed porphyritic granite within the paragneiss or a porphyroblastic variety of the metasedimentary rocks. A line, hinged on 1824 Ma monazite from the same rock, gives an upper intercept age of 2574 $\pm$ 8 Ma. The simple single-zircon population from this rock is consistent with the interpretation that this unit is a simple granite, although this poses some problems in interpreting the significance of the older age here. Although not ruling out the existence of Archean supracrustal rocks, it is assumed that most of the supracrustal rocks within the inner Churchill (Rae) Province are Lower Proterozoic cover that have been interleaved with reworked basement. However, the simple-zircon population for this rock seems to indicate that this granite could have been derived from the surrounding paragneiss during the late Archean, and then deformed and metamorphosed during Hudsonian events. Again, as with some of the other rocks, the data may indicate inherited zircons of Archean age in a granite emplaced at 1824 Ma, but it would seem unlikely that inherited zircons would produce a well-defined cluster near concordia, as the population from this rock does, unless they are all from the same original source.

Grey, amphibolite-facies migmatite, containing generally concordant amphibolite dykes, occupies much of the region east of the Moonbase Lake mylonite zone. One sample of grey migmatite (Geo.89.1,G) was collected from this region. Six zircon fractions, with an extrapolated line from an 1824 Ma monazite (from Geo.89.2), give an upper intercept of 2657 $\pm$ 18 Ma. A line through the zircons alone suggests growth around 1975 Ma, the significance of which is unclear. Neosomal zircons from the sample plot farther down the discordia line than paleosomal zircons, suggesting new growth during metamorphism.

Highly strained, regularly banded, grey gneiss and parallel amphibolite-mafic granulite dykes characterize the northern part of the Moonbase Lake mylonite zone. Grey gneiss (US.87.29,H) from this zone has yielded thorite(?) that suggests high-grade metamorphism at 1857 $\pm$ 3 Ma, 50-million years older than the age determined for metamorphism in the Mistastin River zone noted above.

West of the Moonbase Lake mylonite zone, it is not uncommon to find metamorphosed, highly discordant dykes in the gneisses. These gneisses and pre-dyke metamorphosed leucogabbro–anorthosite units within them, were postulated, on the basis of field relations and comparison with Nain Province geology, to be Archean in age. Preliminary results from poor-quality zircons from one sample (US.82.27,I) of gneiss that hosts leucogabbro fragments yields an imprecise age of 2807^{+45}_{-27} Ma.

A weakly deformed biotite pegmatite dyke (DD.87.48b,J), discordant to gneisses that contain leucogabbro fragments and that are cut by basic granulite dykes, has yielded large equant zircon grains that are nearly concordant at 1854 $\pm$ 1 Ma, and this is interpreted as the time of dyke emplacement. This dyke is identical to pegmatites that form an intrusive network in a large granulite-facies mafic dyke in a nearby outcrop, and is therefore assumed to have been emplaced after the peak of granulite-facies metamorphism. It should be noted that this age corresponds to the time of high-grade metamorphism in the Moonbase Lake mylonite zone, but here appears to signify granitic intrusion that postdates an earlier granulite-facies event.

A small, weakly foliated pink granite (BR.87.336,K), concordant to gneissosity on a regional scale and assumed to be late kinematic with respect to Hudsonian deformation and metamorphism, yielded a complex population of zircon and monazite. Two zircon fractions fall well off concordia and define a line with upper intercept of 1859^{+5}_{-3} Ma and lower intercept of 231 Ma. Two monazite fractions plot close to concordia at 1851 Ma and 1837 Ma; a line through these gives 1990 Ma and 1760 Ma as upper and lower intercepts, respectively. Two explanations for these relationships are possible: (i) the upper monazite age is the time of emplacement and the younger is the time of metamorphism, the zircons having been moved off the line by recent Pb loss and hence giving meaningless ages, or (ii) the 1760 Ma age is the time of granite emplacement and both the older monazite and the zircon population are inherited, making the similarity in age between the above pegmatite (1856 Ma) and this granite (1859 Ma) purely fortuitous.

ELSONIAN PLUTONS

A rapakivi granite, characterized by the diagnostic plagioclase-mantled potassium feldspars, forms an ovoid pluton west of Voisey Bay. A group of good quality low-uranium zircon from a sample (DL.85.201,L) of this granite defines a discordia line between 1322 ± 1 and 117 Ma. The 1322 Ma age represents the time of crystallization of the zircons, and quite probably the age of emplacement of the pluton.

A sample (US.87.26,M) of similar granite, lacking mantled ovoids, south of Kogaluk River, has yielded an age of 1292 ± 4 Ma, slightly younger than the rapakivi granite above, but still within the time frame of Elsonian intrusions in this part of Labrador.

SUMMARY

The U−Pb geochronology confirms the Archean age for coastal gneisses of the Nain Province, indicates mafic dyke intrusion between 2200 and 2000 Ma, and provides evidence for contact metamorphism ca. 1300 Ma. It has established the Late Archean age of gneisses within the Rae Province and suggests that Early Proterozoic metamorphism, responsible for reworking of the Archean gneisses, reached its peak ca. 1830 to 1800 Ma. However, there is some indication that high-grade metamorphism was also imposed upon parts of this area prior to ca. 1855 Ma. The suite of rocks examined to date indicate that there has been limited growth of zircon in the Archean gneisses of Rae Province during the Lower Proterozoic metamorphic overprint. Elsonian granitoids were emplaced at ca. 1325 to 1290 Ma, apparently generating some new thorite (?) and titanite growth, but at the same time causing significant Pb-loss in zircon. Zircon studies are still being conducted in an attempt to further refine the geological evolution of this area of Labrador.

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NOTE: Geological Survey Branch file numbers are included in square brackets.