Current Research (2003) Newfoundland Department of Mines and Energy
Geological Survey, Report 03-1, pages 35-45

THE SOUTHEASTERN CHURCHILL PROVINCE REVISITED: U–Pb GEOCHRONOLOGY, REGIONAL CORRELATIONS, AND THE ENIGMATIC ORMA DOMAIN

D.T. James, G.A.G. Nunn[1], S. Kamo[2] and K. Kwok[2]
Regional Geology Section

ABSTRACT

The Orma domain is a Paleoproterozoic tectonic division of the Core Zone, Southeastern Churchill Province (central Labrador), consisting principally of late Archean orthogneisses, deformed intrusions, and relicts of Archean supracrustal gneisses. Emplacement ages, determined by U–Pb age dating of zircon and titanite, for intrusions of orthopyroxene granodiorite and K-feldspar porphyritic granite that occur in the northern Orma domain are 2581 +10/-8 and 2571 +6/-5 Ma, respectively. On the basis of field relationships and composition, the orthopyroxene granodiorite is interpreted to be a diatexite derived from the substantial anatexis of tonalite and granodiorite orthogneisses that dominate the Orma domain. Thus, the high-grade metamorphism of the Orma domain was late Archean. Emplacement of the porphyritic granite, containing pyroxene and garnet, was synchronous with high-grade metamorphism and attendant deformation.

A granitic pegmatite was intruded into host Orma domain tonalite at 2628 ± 13 Ma and was subsequently mylonitized. The age of the mylonitization is undetermined; it could be either Archean or Paleoproterozoic.

The data presented here are consistent with the interpretation of the Orma domain as a relatively pristine Archean block that apparently escaped 1820 to 1775 Ma high-grade metamorphism and deformation that are pervasive in contiguous tectonic domains of the Core Zone, and in most parts of the Southeastern Churchill Province. The factors influencing this enigmatic escape remain unknown.

INTRODUCTION

In July 2001, a brief field excursion was made to examine several critical exposures in the Southeastern Churchill Province (SECP), in the area northeast of Michikamau Lake, central Labrador (Figure 1). The purpose of this excursion was to collect samples for U–Pb geochronology studies, and to attempt regional correlation of Archean and Paleoproterozoic units mapped separately in the SECP by James (*see* James *et al*., 1993; James and Mahoney, 1994) and Nunn (1993, 1994) in areas west and east of Michikamau Lake, in NTS map areas 23I and 13L, respectively. The age dating was carried out by K. Kwok and S. Kamo at the Royal Ontario Museum, Toronto, and was completed in March 2002. The purpose of this report is to present and interpret the results of the geochronology, and to comment on regional correlations in the SECP.

The report includes a brief overview of some aspects of the geology of the SECP, to provide a regional context for the geochronological data, and to highlight the problems. A comprehensive review of the SECP is beyond the scope of this paper, and readers seeking detailed discussions are directed to papers by James and Dunning (2000) and Wardle *et al*. (2002).

REGIONAL GEOLOGY

The SECP is a 300-km-wide, north-trending composite tectonic belt of Archean and Paleoproterozoic rocks that is one segment of a system of Paleoproterozoic orogens linking Archean cratons in northeastern Laurentia (Figure 2). It is principally a continuation of the Trans-Hudson Orogen, which can be traced around the western, northern and eastern margins of the Superior craton. The SECP formed as a

[1] Mineral Lands Division

[2] Geochronology Laboratory, Royal Ontario Museum, Toronto, Ontario

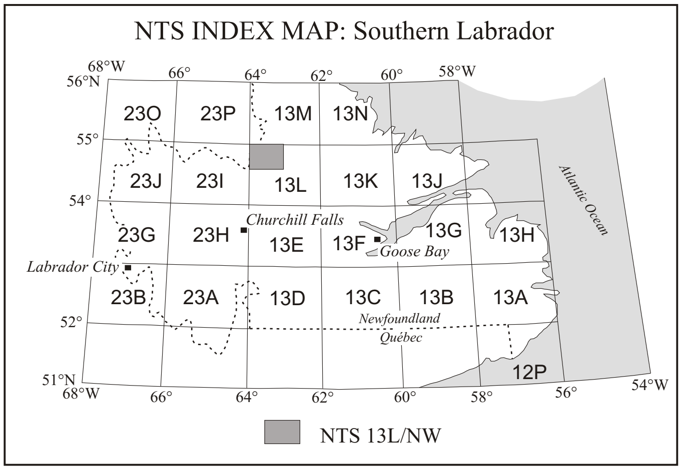

Figure 1. *NTS index map for southern Labrador showing location of the study area.*

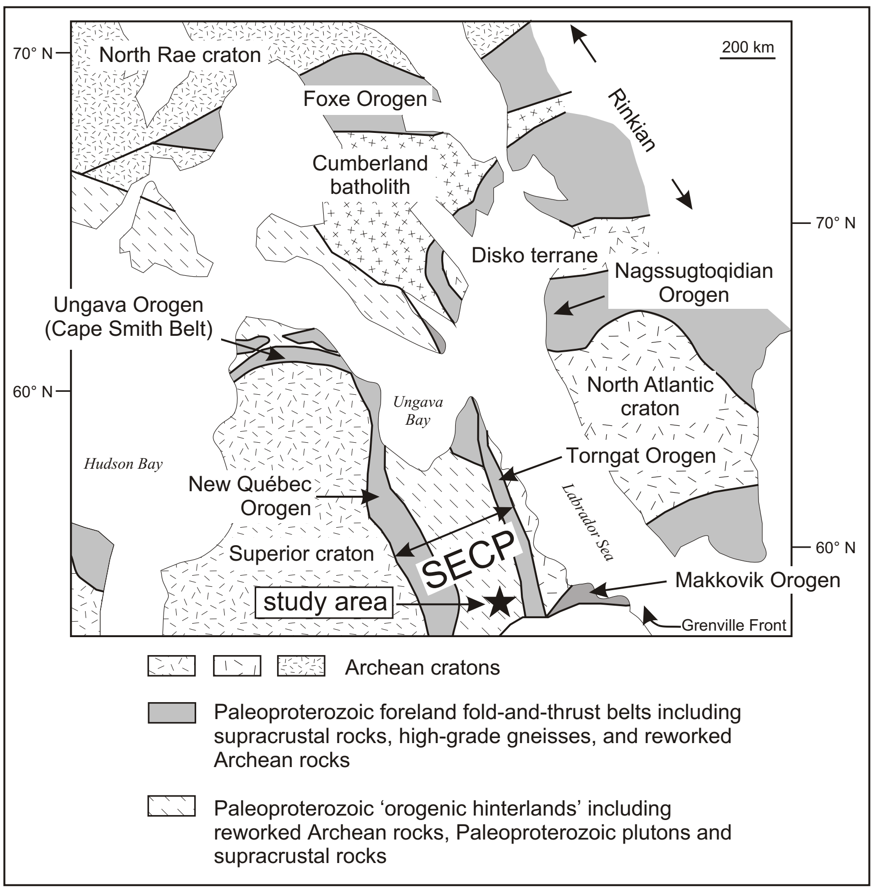

Figure 2. *Schematic "pre-drift" reconstructed diagram showing principal tectonic elements of northeastern Laurentia including areas in northeastern North America and western Greenland.*

result of relative northward movement and sequential collision of Archean North Atlantic (Nain) and Superior cratons, and attached Paleoproterozoic supracrustal sequences, with an Archean craton(s) that resided to the north (*see* Hoffman, 1990; Van Kranendonk *et al.*, 1993; Wardle, 1998; James and Dunning, 2000; Wardle *et al*., 2002). Also involved in the collisions were Archean crustal blocks of suspect parentage that are now confined to the intervening regions between the intact Archean cratons.

The SECP can be broadly subdivided into three fundamental tectonic divisions. From west to east, the divisions include: 1) a west-verging fold-and-thrust belt (New Québec Orogen) mainly developed in 2.17 to 1.86 Ga sedimentary and volcanic rocks, but also involving Superior craton basement, 2) a composite terrane, termed the Core Zone (James and Dunning, 1996; James *et al*., 1996), having Archean and Paleoproterozoic components; and 3) a doubly verging, fan-shaped wedge (Torngat Orogen) developed primarily in juvenile (<1.95 Ga) Paleoproterozoic sediments and inferred to represent an accretionary complex along the suture between the Core Zone and the North Atlantic craton (Figure 3). Dextral (west) and sinistral (east) transcurrent shear zones, which are syn- to posttectonic with respect to thrusting in the New Québec and Torngat orogens, respectively, separate the bordering foreland orogens from the Core Zone. The Core Zone is a mosaic of variably reworked Archean crustal blocks (Van der Leeden *et al*., 1990; Wardle *et al*., 1990; Nunn *et al*., 1990; James *et al*., 1996; Isnard *et al*., 1998), ca. 2.3 Ga and <1.95 Ga supracrustal rocks (e.g., Van der Leeden *et al*., 1990; Girard, 1990; Scott and Gauthier, 1996), and 1.84 to 1.81 Ga granitoid rocks belonging to the De Pas and Kuujjuaq batholiths (Perreault and Hynes, 1990; Dunphy and Skulski, 1996; James *et al*., 1996).

The southwestern part of the Core Zone, in central Labrador, consists of the McKenzie River, Crossroads, and Orma domains (James *et al*., 1996; James and Dunning, 2000). The domains are separated by major, Paleoproterozoic high-strain zones. The McKenzie River domain consists mainly of Archean (ca. 2776 Ma) tonalite gneiss and lesser amounts of inferred Paleoproterozoic supracrustal gneisses. The Crossroads domain contains relicts of high-grade Archean (>2700 Ma) granite–greenstone terrane crust and Paleoproterozoic (ca. 1835 to 1810 Ma) granitoid intrusions, which are part of the >500-km-long De Pas batholith. The

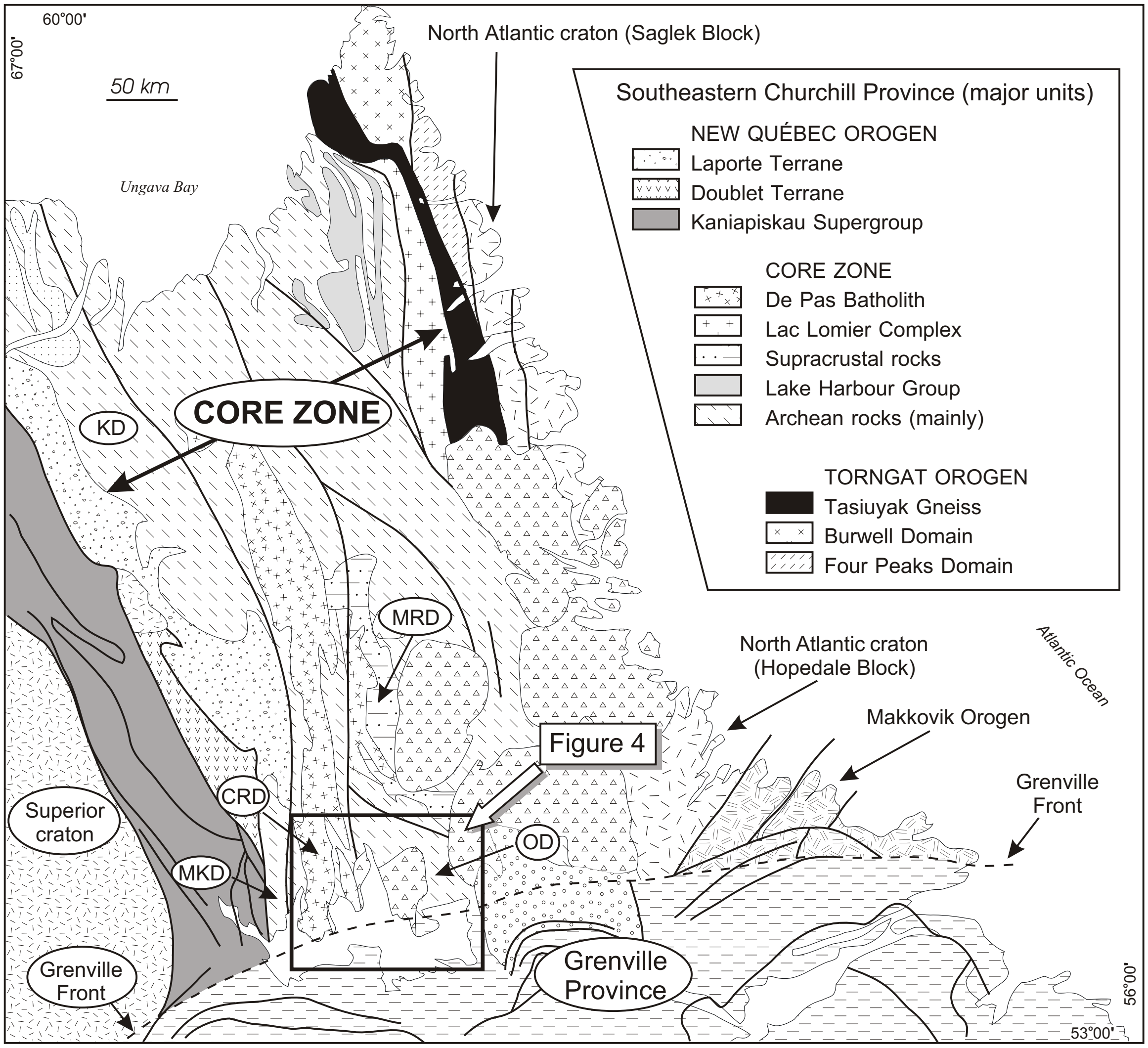

Figure 3. *Tectonic elements of Labrador and northeastern Québec. MKD - McKenzie River domain, CRD - Crossroads domain, OD - Orma domain, MRD - Mistinibi–Raude domain, KD - Kuujjuaq domain. Mesoproterozoic intrusions are indicated by the open triangle pattern.*

De Pas batholith intrusions are variably deformed and recrystallized, demonstrating the Crossroads domain has been overprinted by a Paleoproterozoic tectonothermal event that partially overlapped and postdated their emplacement. The Orma domain (Nunn *et al.*, 1990; Nunn, 1994), which is the focus of this study, contains late Archean, high-grade orthogneisses and older relicts of supracrustal rocks, deformed intrusive rocks of undetermined age, and a minor amount supracrustal rocks belonging to the Petscapiskau Group.

Mapping and geochronology have demonstrated that McKenzie River and Crossroads domains were overprinted by high-grade Paleoproterozoic (ca. 1820 to 1775 Ma) metamorphism and attendant deformation (*see* James and Dunning, 2000). In marked contrast, available geochronological data from the Orma domain rocks (e.g., Nunn *et al.*, 1990) suggest that they escaped the Paleoproterozoic tectonothermal and intrusive event that is so pervasively expressed in the domains to the west and north. However, geochronological data from the Orma domain are sparse.

This study adds significantly to the age data from the Orma domain, and tests the model that the Orma domain is a relatively pristine Archean block, with respect to pre-1750 Ma thermotectonic and intrusive events. This study also tests the hypothesis proposed by James and Dunning (2000) that the Orma and Crossroads domains have a similar Archean history. The samples analysed include a deformed, K-feldspar porphyritic granite (Sample 1), which has similar field characteristics to rocks of the Paleoproterozoic De Pas batholith, a pyroxene-bearing granodiorite (Sample 2), inferred on the basis of field relationships to be a diatexite emplaced at or near the peak of high-grade metamorphism, and a mylonitic granitic pegmatite (Sample 3) contained in a southwest-striking high-strain zone.

ORMA DOMAIN

The Orma domain (Figure 4) contains Archean metavolcanic and minor metasedimentary rocks. These are intruded by tonalite and granodiorite orthogneisses, pyroxene-bearing granitoid rocks (diatexite), deformed K-feldspar porphyritic granite, and lesser amounts of metamorphosed granite and gabbro. In general, the grade of Archean metamorphism increases from south to north, from upper amphibolite to granulite facies. The Orma domain is separated from the Crossroads domain by the George River shear zone and from the Mistinibi–Raude domain by an unnamed shear zone. The bordering shear zones are Paleoproterozoic structures.

The tonalite orthogneisses, which intrude the supracrustal rocks introduced in the preceding paragraph, have igneous crystallization ages between 2682 and 2663 Ma, as determined by U–Pb age dating of zircons (Nunn *et al.*, 1990). Titanite data from the same rocks suggest that they underwent high-grade metamorphism in the late Archean. Notably, the U–Pb data show no evidence that the Archean rocks were overprinted by high-grade Paleoproterozoic thermal events prior to the ca. 1720 to 1600 Ma Labradorian Orogeny; all Pb-loss in the titanites is younger than ca. 1640 Ma (Nunn *et al.*, 1990). Based on these data, the Orma domain has been considered to have mainly escaped the high-grade Paleoproterozoic tectonothermal event that overprinted the Crossroads and McKenzie River domains. The Orma domain also includes a sequence of greenschist-facies wacke, quartz wacke, quartzite, tuffaceous rocks, and metamorphosed basalt, named the Petscapiskau Group (Emslie, 1970). The age or ages of Petscapiskau Group rocks are unknown, although they are thought to be mostly Paleoproterozoic.

ANALYTICAL PROCEDURES

Zircon and titanite were separated from the samples using heavy liquid and magnetic separation techniques. All zircon fractions had an air abrasion treatment (Krogh, 1982), although titanite was not abraded. Mineral dissolution and isolation of U and Pb from zircon follow the procedure of Krogh (1973), modified by using small anion exchange columns (0.05 ml of resin) that permit the use of reduced acid reagent volumes. However, in cases where the weight of the grain, or grains, was 5 micrograms or less, no chemical separation procedure was followed, and the bulk dissolved sample was analyzed. Titanite was dissolved in HF and HNO_3 in capsules at about 60°C for 3 to 4 days, and U and Pb were isolated by using HBr chemistry.

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 with a Daly pulse counting detector in a solid source VG354 mass spectrometer. Data are corrected for a mass discrimination of 0.07%/AMU and a deadtime correction of 21.5 nsec. The thermal source mass discrimination correction is 0.1%/AMU. The laboratory blanks for Pb and U are usually less than 1 and 0.1 pg, respectively. In this study, the total common Pb for most zircon analyses varied from 0.3 to 1.0 pg, a few were 3 to 10 pg, and this was attributed to laboratory Pb; thus no correction for initial common Pb was necessary. For titanite analyses, initial common Pb corrections were made using the model of Stacey and Kramers (1975).

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 0.015% (1s) for Pb and U, respectively, based on long-term replicate measurements of the standards SRM982 and CBNM72-6), uncertainties in the isotopic composition, amount of laboratory blank, and initial Pb. Decay constants are those of Jaffey *et al.* (1971). All age errors quoted and error ellipses in the concordia diagrams are given at the 95% confidence interval. Zircon and titanite were analyzed for Pb and U by IDTIMS (isotope dilution thermal ionization mass spectrometry) methods.

U–Pb ISOTOPIC RESULTS

SAMPLE 1: K-FELDSPAR PORPHYRITIC GRANITE (DJ-01-1089)

The Orma domain contains a generally northwest- to north-trending, somewhat arcuate-shaped intrusion of deformed K-feldspar porphyritic granite (Unit 8, Figure 4) that is in excess of 20 km long (Figure 4). The emplacement age of the porphyritic granite is unknown. The unit, which has been described in some detail by Nunn (1994), consists mainly of grey- to dark-brown-weathering, variably deformed and recrystallized, pyroxene biotite monzogranite having K-feldspar phenocrysts up to 5 cm (Plate 1). Commonly, the pyroxene is rimmed by hornblende or garnet. Garnet also occurs as discrete grains. The porphyritic granite has very similar mineralogy and field characteristics to K-feldspar porphyritic granite, which forms a major component of the Paleoproterozoic De Pas batholith in the contiguous Crossroads domain. The Orma domain porphyritic granite intrudes the Archean supracrustal rocks and orthogneisses, and is moderately deformed. Based on its obvious similarities to the De Pas porphyritic granites, a

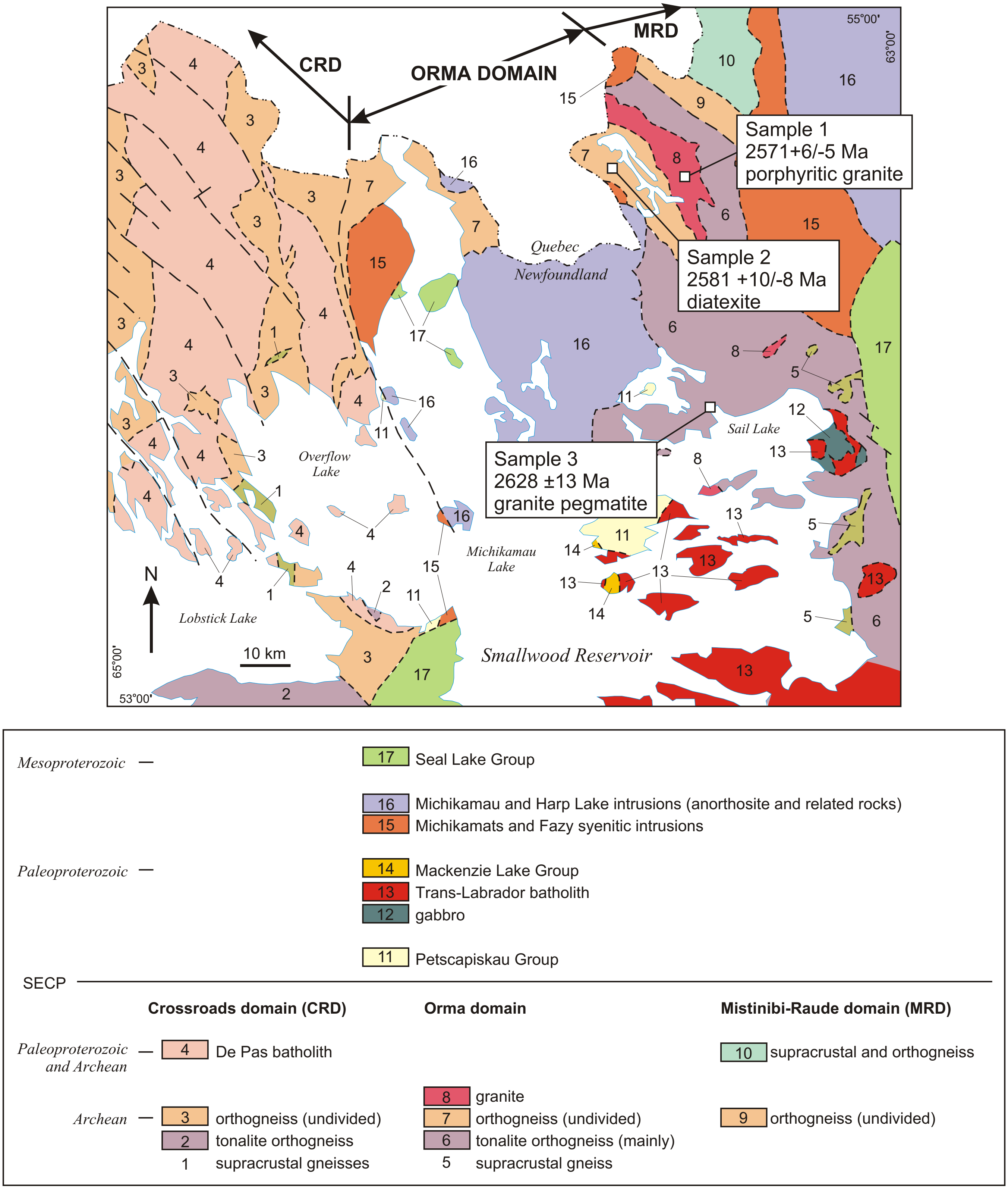

Figure 4. *General geology of the SECP in the Smallwood Reservoir area, central Labrador.*

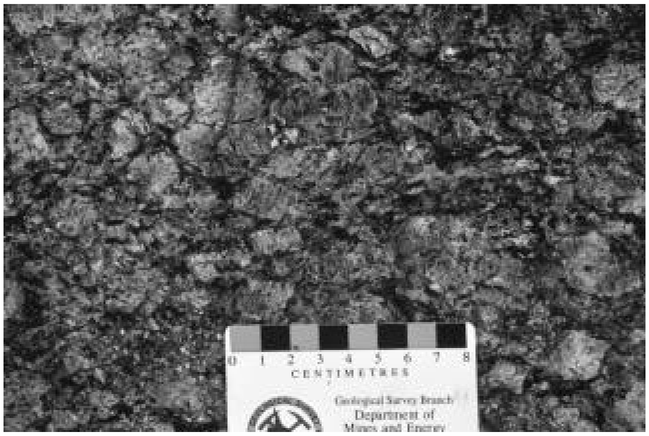

Plate 1. *K-feldspar porphyritic monzogranite (Sample 1) having coarse-grained K-feldspar phenocrysts and a fine-grained granoblastic groundmass consisting of quartz, plagioclase, minor amounts of clinopyroxene, orthopyroxene, hornblende, and garnet.*

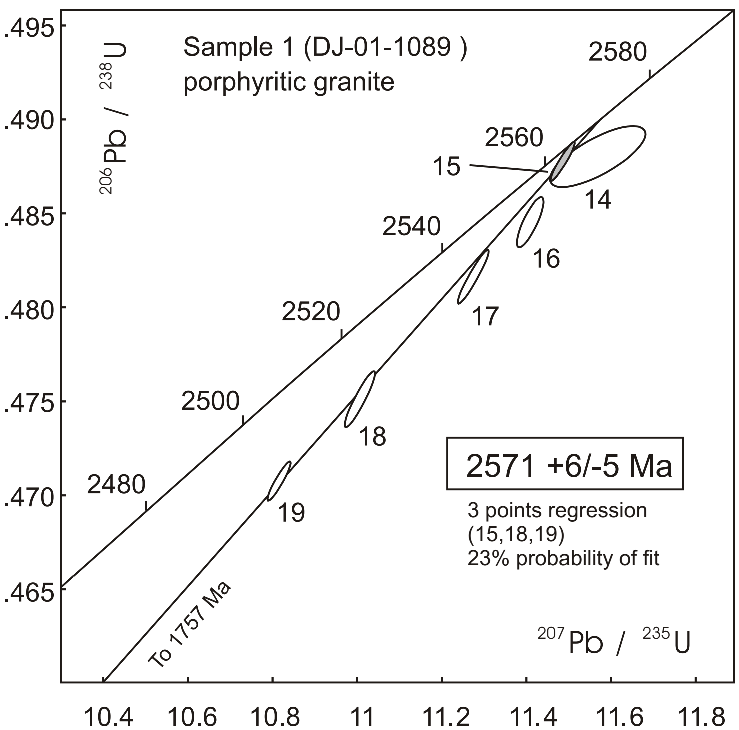

Figure 5. *U–Pb concordia diagram for Sample 1.*

Paleoproterozoic age for the Orma domain granite was predicted by the first author.

Sample 1 (Field sample: DJ-01-1089, UTM 451235 E, 6076951 N, NTS map area 13L/13) is a foliated, K-feldspar porphyritic monzogranite having a fine-grained granoblastic groundmass consisting of quartz, plagioclase, <10 percent clinopyroxene, minor amounts of orthopyroxene, hornblende, and very fine-grained, granular garnet. On the basis of texture, hornblende and garnet appear to postdate the pyroxene. The rock also contains relict, coarse-grained and slightly perthitic K-feldspar phenocrysts, coarse-grained plagioclase, and aggregates of medium-grained unrecrystallized quartz.

The sample contains an abundance of euhedral, clear, pale-brown, prismatic zircon crystals. Six, single-zircon analyses gave near-concordant and discordant data that are generally colinear (Figure 5, Table 1). Fractions 15, 18, and 19 are colinear and give an upper intercept age of 2571 +6/-5 Ma and a poorly constrained lower intercept age of 1757 +95/-84 Ma. Three fractions (14, 16 and 17) plot just to the right of the line and were excluded from the calculation; these fractions are interpreted to be biased by minor, inherited components in the rock.

The data indicate that the rock was emplaced in the latest Archean at 2571 +6/-5 Ma, and was subsequently affected by a Paleoproterozoic thermal event, which induced Pb loss in the zircons. The data unequivocally demonstrate that the Orma domain porphyritic granite does not correlate with the De Pas batholith. The significance of the Pb-loss event recorded by the zircons, which could be as old as ca. 1.85 Ga or as young as ca. 1.67 Ga, is uncertain. One possible interpretation is that the Orma domain was at least weakly overprinted by the same Paleoproterozoic event that affected Crossroads and McKenzie River domains. Alternatively, the thermal event could be Labradorian. The second interpretation is broadly consistent with titanite data from the southern Orma domain that indicate a post-1640 Ma Pb-loss event (*see* Nunn *et al*., 1990), although samples from the the southern part of Orma domain and are significantly closer to known Labradorian or younger intrusive complexes.

SAMPLE 2: ORTHOPYROXENE GRANODIORITE (DJ-01-1090)

The northern Orma domain contains composite bodies of clinopyroxene- and orthopyroxene-bearing granitoid rocks having compositions gradational from granodiorite to monzogranite. The granitoid rocks are variably gneissic; they have a local, diffuse layering defined primarily by biotite concentration that is gradational at all scales into a massive, homogeneous rock (Nunn, 1994). These rocks are interpreted to be diatexites, and are thought to be the product of the nearly complete anatexis of Archean tonalite and granodiorite orthogneisses that make up a significant part of Orma domain (Nunn, 1993). Partially melted metasedimentary and metabasic rocks, which are intruded by the tonalite and granodiorite orthogneisses and

Table 1. U–Pb isotopic data for zircon and titanite, Orma domain, Southeastern Churchill Province

Fraction No.	Analysis No.	Description	Weight (mg)	U (ppm)	Th/U	PbCom (pg)	207/204	206/238	2 sigma	207/235	2 sigma	207/206 Age (Ma)	2 sigma	% Disc.
	Sample 1:DJ-01-1089, porphyritic granite, Orma domain, Southeastern Churchill Province													
14	p38tk40	1 Ab zr	0.0015	95	0.41	10.1	92	0.4880	0.0016	11.568	0.113	2576.4	12.8	0.7
15	p1tk40	1 Ab zr euh	0.0010	518	0.48	0.27	10118	0.4878	0.0010	11.486	0.029	2565.3	1.4	0.2
16	p36tk40	1 Ab zr rod incln	0.0080	94	0.51	3.03	1328	0.4845	0.0013	11.409	0.032	2565.2	2.8	0.9
17	p2tk40	1 Ab zr	0.0010	148	0.51	0.48	1644	0.4816	0.0014	11.274	0.037	2555.4	1.7	1.0
18	p37tk40	1 Ab zr lpr	0.0100	111	0.48	0.44	12816	0.4751	0.0015	11.006	0.036	2537.9	2.1	1.5
19	p125tk39	1 Ab zr sl resorbed crk	0.0100	124	0.46	0.50	12410	0.4708	0.0010	10.815	0.027	2524.0	1.6	1.8
	Sample 2:DJ-01-1090, diatexite, Orma domain, Southeastern Churchill Province													
20	p42tk40	1 Ab zr bubble incln	0.0025	90	0.47	0.61	2156	0.5040	0.0017	12.473	0.045	2648.2	1.7	0.8
21	p3tk40	1 Ab zr resorbed	0.0015	104	0.63	0.32	2757	0.4986	0.0028	12.195	0.069	2628.6	1.8	1.0
22	p41tk40	1 Ab zr rnd	0.0020	92	0.34	0.28	3705	0.4979	0.0012	12.102	0.032	2618.4	1.9	0.6
23	p123tk39	1 Ab zr rnd	0.0020	20	6.58	0.56	398	0.4875	0.0022	11.490	0.058	2566.9	3.3	0.3
24	p122tk39	1 Ab zr resorbed	0.0050	115	0.27	1.21	2528	0.4853	0.0011	11.406	0.031	2562.3	1.5	0.6
25	p22tk40	2 Unab titanite yel	0.0200	510	168.7	24.9	1782	0.4550	0.0018	10.130	0.040	2471.1	2.7	2.6
	Sample 3:DJ-01-1092, mylonitic granite pegmatite dyke, Orma domain, Southeastern Churchill Province													
26	p7tk40	1 Ab zr sl resorbed incln	0.0010	141	0.48	0.21	3831	0.5000	0.0016	12.179	0.042	2621.8	1.9	0.4
27	p9tk40	1 Ab zr sl resorbed incln	0.0010	128	0.43	0.35	2100	0.4992	0.0021	12.158	0.052	2621.7	2.2	0.5
28	p8tk40	1 Ab zr sl resorbed	0.0010	112	0.41	0.41	1516	0.4944	0.0016	11.975	0.042	2612.5	1.8	1.1

FOOTNOTES TO TABLE
Titanites are picked from M1.7 Amp frantz fraction.
Ab - abraded; zr - zircon grain; spr - short prismatic; lpr - long prismatic; euh - euhedreal; rnd - round; sl - slightly; incl - inclusion; yel - yellow;
dk - dark brown, sl - slightly; incl - inclusion; yel - yellow; dk brn - dark brown; crk - cracked
PbCom - Common Pb, assuming all has blank isotopic composition
Th/U 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).

occur as large rafts in the diatexite, and relict inclusions contained in the orthogneiss, may also have contributed to formation of the orthopyroxene-bearing granitoid rocks. The orthopyroxene, which is interpreted to be primary, as opposed to being a relict mineral, demonstrates that formation of the granitoid rocks occurred at granulite facies.

Sample 2 (Field sample: DJ-01-1090, UTM 449403 E, 6068757 N, NTS map area 13L/13) is a white-weathering orthopyroxene granodiorite (Plate 2). The rock is fine- to medium-grained, variably recrystallized, and is massive. It contains medium-grained anti-perthitic plagioclase, quartz, K-feldspar, less than 10 percent fine-grained orthopyroxene, minor biotite, and unidentified opaques. Orthopyroxene is locally overprinted by biotite and minor amounts of very fine-grained amphibole, and is variably pseudomorphed by bastite.

The sample contains abundant, rounded and cracked, pale-brown zircons. The zircon grains are mainly elongate and prismatic, having length to width ratios of 3:1 and 4:1, although three populations can be defined on the basis of morphology. The main population consists of elongate, slightly rounded to prismatic grains. A second population consists of very highly resorbed grains, which are slightly larger than the main population, some having cores and mantle overgrowths. A third population is made up of very small and equant (approximately 50 microns) grains. The sample also contains clear, honey-brown titanite.

Two of the single-grain zircon fractions analysed, including a rounded grain (Fraction 23) and a resorbed grain (Fraction 24), and one titanite fraction (Fraction 25), are colinear and give $^{207}Pb/^{206}Pb$ ages of 2566.9 ± 3.3, 2562.3 ± 1.5, and 2471.1 ± 2.7 Ma, respectively (Figure 6, Table 1). The analyses are 0.3%, 0.6%, and 2.6% dis-

Plate 2. *Typical field aspects of white-weathering, medium-grained and massive orthopyroxene-bearing diatexite (granodiorite; Sample 2).*

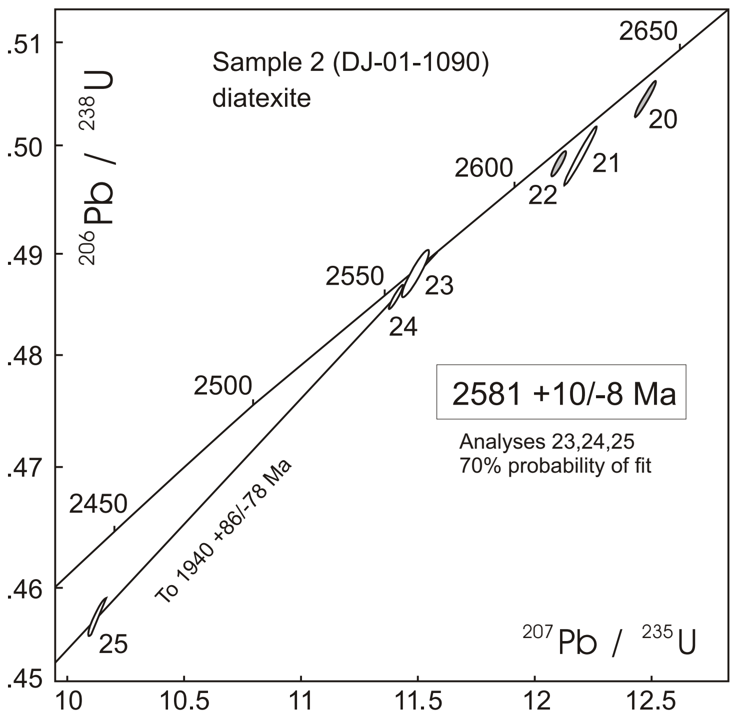

Figure 6. *U–Pb concordia diagram for Sample 2.*

cordant, assuming zero-age Pb loss. A regression line, calculated using Fractions 23 to 25, gives an upper intercept age of 2581.2 +9.9/-7.5 Ma, and a poorly defined lower intercept age of 1940 +86/-78 Ma with a 70% probability of fit. The fact that the youngest zircon grains (Fractions 23 and 24) are colinear with the titanite data (Fraction 25) suggests the zircons (Fractions 23 and 24) represent new grains related to igneous emplacement of the rock, and are not inherited. Alternatively, if Fractions 23 and 24 were interpreted as inherited grains, it would imply that the titanite was also inherited, which is considered unlikely. On the basis of Fractions 23 to 25, the best estimate for the emplacement age of the orthopyroxene granodiorite is 2581 +10/-8 Ma. The significance of the lower intercept age is uncertain.

Data for zircon Fractions 20 to 22 give $^{207}Pb/^{206}Pb$ ages of 2648.2 ± 1.7, 2628.6 ± 1.8, and 2618.4 ± 1.9 Ma, that are 0.8%, 1.0%, and 0.6% discordant, respectively (Figure 6, Table 1). Fractions 20 to 22 are interpreted to be inherited grains from the pre-existing rock that were incorporated during anatexis. This interpretation is broadly consistent with ca. 2704 to 2620 Ma igneous emplacement ages for intrusive units in Orma and Crossroads domains (*see* Nunn *et al*., 1990; James *et al*., 1996; James and Dunning, 2000).

SAMPLE 3: MYLONITIC GRANITIC PEGMATITE (DJ-01-1092)

Along the north shore of Sail Lake (Figure 4), the Orma domain includes mylonitic tonalite orthogneiss tentatively correlated on the basis of lithology with the late Archean Orma dyke tonalite (*see* Nunn, 1993). At Sail Lake, the mylonitic tonalite includes mylonitized granitic pegmatite dykes. The mylonitic fabric has a southwest strike, moderate (30°) dip to the northwest, and an intense, shallow, northeast-trending mineral elongation lineation. The mylonitic fabrics were developed at amphibolite facies. Sample 3 (Field sample: DJ-01-1092; UTM 473218 E, 6025392 N, NTS map area 13L/06) was collected from a mylonitic pegmatite dyke (Plate 3).

Sample 3 is a pink-weathering, mylonitic and strongly lineated granitic pegmatite. The rock has a simple mineralogy, consisting almost entirely of fine-grained microcline, quartz, and plagioclase. The rock contains very minor amounts (<2%) of very fine-grained muscovite, chlorite, and accessory zircon.

Three single zircons (Table 1; Fractions 26 to 28) were collected from a homogeneous population that consisted of small (80 to 100 microns), clear, yellow zircon grains. The grains are mainly short, 2:1 (length to width) prismatic crystals that are slightly rounded to euhedral. U–Pb analyses of Fractions 26 to 28 are colinear, nearly concordant, and give $^{207}Pb/^{206}Pb$ ages of 2621.8 ± 1.9, 2621.7 ± 2.2, and 2612.5 ± 1.8 Ma, that are 0.4%, 0.5%, and 1.8% discordant, respectively (Figure 7). A regression line calculation gives an upper intercept age of 2628 ± 13 Ma and a very imprecise lower intercept age of 1486 ± 770 Ma with a probability of fit of 64%. Emplacement of the pegmatite is interpreted to be at 2628 ± 13 Ma.

DISCUSSION

Emplacement of orthopyroxene granodiorite (Sample 2) and K-feldspar porphyritic granite (Sample 1) at 2581 +10/-8 and 2571 +6/-5 Ma, respectively, postdate emplacement of the igneous precursor of Orma domain tonalite orthogneiss by approximately 100 Ma. Field relationships and mineralogy suggest that the orthopyroxene granodiorite represents a diatexite that was generated by substantial anatexis of Orma domain tonalite and granodiorite orthogneiss, and contained inclusions of supracrustal rocks. Thus, ca. 2580 Ma is interpreted to represent a time of granulite-facies metamorphism in Orma domain. Emplacement of the K-feldspar porphyritic granite is identical, within error, to the orthopyroxene granodiorite. The mineral assemblage, including clinopyroxene, orthopyroxene, and garnet, contained in the porphyritic granite is interpreted as an Archean metamorphic assemblage.

The data from Samples 1 and 2 are consistent with a model of late Archean high-grade metamorphism presented by Nunn *et al.* (1990). The intrusive ages of the two samples are the youngest, late Archean ages in the SECP. The data from the K-feldspar porphyritic granite (Sample 1) demonstrate that this unit does not correlate with the De Pas batholith.

The data presented herein neither supports nor negates the model proposed by James and Dunning (2000) that the Orma and Crossroads domains have similar Archean histories. Archean high-grade metamorphism of >2620 Ma orthogneisses and supracrustal rocks in Crossroads domain could be ca. 2580 Ma, and be the same high-grade event expressed in Orma domain. (Crossroads domain is polymetamorphic, and was metamorphosed from amphibolite to local granulite facies in the Paleoproterozoic.) However, the Archean pyroxene-bearing granitoid rocks and porphyritic granite that occur in the Orma domain are not present in the Crossroads domain.

A granitic pegmatite (Sample 3) was intruded into host Orma domain tonalite at ca. 2628 Ma, almost 50 Ma before the peak of metamorphism. The U–Pb data only constrain the mylonitization of the pegmatite to be younger than 2628 Ma. The mylonitization could be Archean and occur somewhere in the range from 2628 to 2580 Ma. Alternatively, the deformation could be related to Paleoproterozoic (ca. 1775 to 1820 Ma) deformation in the SECP, or <1660 Ma and related to Labradorian deformation. However, a Grenvillian (ca. 1040 to 980 Ma) age for the high strain is not favoured as all known Grenvillian effects in the area occurred in the greenschist-facies or lower.

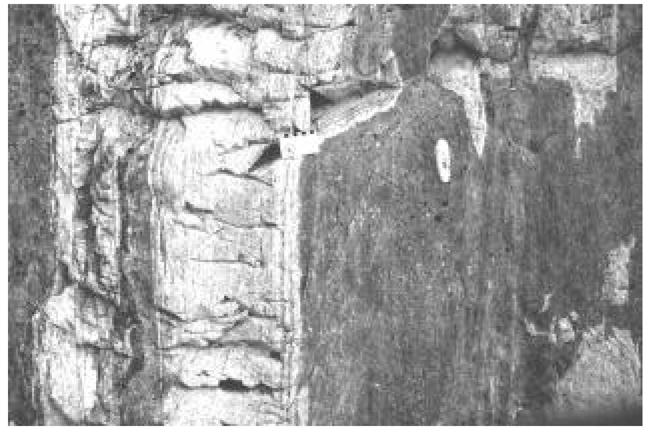

Plate 3. *Mylonitic granite pegmatite (left-centre of photograph; Sample 3) contained in southwest-striking mylonitic tonalite orthogneiss (Unit 6, Figure 4).*

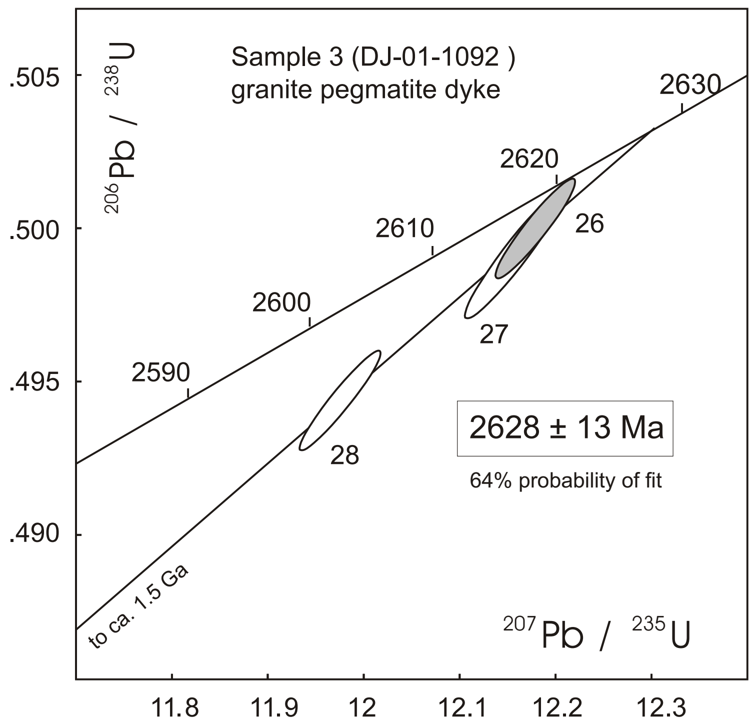

Figure 7. *U–Pb concordia diagram for Sample 3.*

The significance of the poorly defined lower intercept ages for the three samples is uncertain. The lower intercept ages suggest the Orma domain was affected by a Paleoproterozoic thermal event, which induced Pb loss in zircon, although the timing and degree of the proposed thermal event are unknown. The lower-intercept ages notwithstanding, the striking feature of the data is the absence of unequivocal evidence for 1850 to 1775 Ma intrusive rocks, pervasive deformation, or metamorphism in Orma domain. The enigma of how and why Orma domain remained a relatively pristine Archean block in the core of a major Paleoproterozoic orogen remains unsolved.

ACKNOWLEDGMENTS

Léopold Nadeau (GSC Québec) and Sharon Parsons (INRS Québec) accompanied James and Nunn on the sample-collecting excursion in 2001. Sincere thanks to S. Colman-Sadd for his support of this project. Our thanks to John Danby of Canadian Helicopters, for providing reliable transportation. Andrew Kerr reviewed a preliminary version of this report.

Finally, the first two authors wish to salute the work and lasting accomplishments of Tom Krogh, Sandra Kamo, and the staff of the geochronology laboratory at the Royal Ontario Museum. Their interest and efforts have contributed significantly to our knowledge of Labrador geology. Precise U–Pb geochronology, whose practices and standards were pioneered and established by Tom Krogh and the ROM laboratory, may have provided the greatest single contribution in advancing Precambrian geoscience in the last 20 years.

REFERENCES

Dunphy, J.M. and Skulski, T.
1996: Petrological zonation across the De Pas batholith: a tilted section through a continental arc? *In* Eastern Canadian Shield Onshore-Offshore (ECSOOT) Transect Meeting, 1996. *Edited by* R.J. Wardle and J. Hall. The University of British Columbia, Lithoprobe Secretariat, Report 57, pages 44-58.

Emslie, R.F.
1970: The geology of the Michikamau Intrusion, Labrador (13L, 23I). Geological Survey of Canada, Paper 68-57.

Girard, R.
1990: Evidence d'un magmatisme d'arc proterozoique inferieur (2.3 Ga) sur le plateau de la rivière George. Geoscience Canada, Volume 17, pages 265-268.

Hoffman, P.F.
1990: Dynamics of the assembly of northeast Laurentia in geon 18 (1.8-1.9 Ga). Geoscience Canada, Volume 17, pages 222-226.

Isnard H., Parent, M., Bardoux, M., David, J., Gariépy, C. and Stevenson, R.K.
1998: U-Pb, Sm-Nd and Pb-Pb isotope geochemistry of the high-grade gneiss assemblages along the southern shore of Ungava Bay. *In* Eastern Canadian Shield Onshore-Offshore (ECSOOT) Transect Meeting, 1998. *Edited by* R.J. Wardle and J. Hall. The University of British Columbia, Lithoprobe Secretariat, Report 68, pages 67-77.

Jaffey, A.H., Flynn, K.F., Glendenin, L.E., Bentley, W.C. and Essling, A.M.
1971: Precision measurement of half-lives and specific activities of 235U and 238U. Physical Review, Volume 4, pages 1889-1906.

James, D.T., Connelly, J.N., Wasteneys, H.A. and Kilfoil, G.J.
1996: Paleoproterozoic lithotectonic divisions of the southeastern Churchill Province, western Labrador. Canadian Journal of Earth Sciences, Volume 33, pages 216-230.

James, D.T. and Dunning, G.R.
1996: New data from the Southeastern Churchill Province, western Labrador. *In* Eastern Canadian Shield Onshore-Offshore Transect (ECSOOT) Meeting, 1996. *Edited by* R.J. Wardle and J. Hall. The University of British Columbia, Lithoprobe Secretariat, Report 57, pages 133-149.

2000: U–Pb geochronological constraints for Paleoproterozoic evolution of the Core Zone, southeastern Churchill Province, northeastern Laurentia. Precambrian Research, Volume 103, pages 31-54.

James, D.T., Johnston, D.H. and Crisby-Whittle, L.
1993: Geology of the Eastern Churchill Province in the Smallwood Reservoir area, western Labrador. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 93-1, pages 35-49.

James, D.T. and Mahoney, K.L.
1994: Geology of the eastern Churchill Province in the NTS 23I map area, western Labrador. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 94-1, pages 371-385.

Krogh, T.E.
1973: A low-contamination method for hydrothermal decomposition of zircon and extraction of U and Pb for isotopic age determinations. Geochimica Cosmochimica Acta, Volume 37, pages 485-494.

1982: Improved accuracy of U-Pb zircon ages by the creation of more concordant systems using an air abrasion technique. Geochimica Cosmochimica Acta, Volume 37, pages 637-649.

Ludwig, K.
2000: Isoplot/Ex version 2.2: A geochronological toolkit for Microsoft Excel, Berkeley Geochronology Center, Special Publication 1A.

Nunn, G.A.G.
1993: Geology of the northeastern Smallwood Reservoir (NTS map area 13L/SW), Labrador. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 93-3.

1994: Reconnaissance geology of the Kanairiktok River headwaters, Labrador. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 94-1, pages 429-446.

Nunn, G.A.G., Heaman, L.M. and Krogh, T.E.
1990: U-Pb geochronological evidence for Archean crust in the continuation of the Rae Province (eastern Churchill Province), Grenville Front Tectonic Zone, Labrador. Geoscience Canada, Volume 17, pages 259-265.

Perreault, S. and Hynes, A.
1990: Tectonic evolution of the Kuujjuaq terrane, New Québec Orogen. Geoscience Canada, Volume 17, pages 238-241.

Scott, D.J. and Gauthier, G.
1996: Comparison of TIMS (U-Pb) and laser ablation microprobe ICP-MS (Pb) techniques for age determinations of detrital zircons from Paleoproterozoic metasedimentary rocks from northeastern Laurentia, Canada, with tectonic implications. Chemical Geology, Volume 131, pages 127-142.

Stacey, J.S. and Kramers, J.D.
1975: Approximation of terrestrial lead isotope evolution by a two-stage model. Earth and Planetary Science Letters, Volume 26, pages 207-221.

Van der Leeden, J., Bélanger, M., Danis, D., Girard, R. and Martelain, J.
1990: Lithotectonic domains in the high-grade terrain east of the Labrador Trough (Quebec). *In* The Early Proterozoic Trans-Hudson Orogen of North America. *Edited by* J.F. Lewry and M.R. Stauffer. Geological Association of Canada, Special Paper 37, pages 371-386.

Van Kranendonk, M.J., St-Onge, M.R. and Henderson, J.R.
1993: Paleoproterozoic tectonic assembly of northeast Laurentia through multiple indentations. Precambrian Research, Volume 63, pages 325-347.

Wardle, R.J.
1998: The Southeastern Churchill Province: towards synthesis. *In* Eastern Canadian Shield Onshore-Offshore (ECSOOT) Transect Meeting, 1998. *Edited by* R.J. Wardle and J. Hall. The University of British Columbia, Lithoprobe Secretariat, Report 68, pages 224-244.

Wardle, R.J., James, D.T., Scott, D.J. and Hall, J.
2002: The southeastern Churchill Province: synthesis of a Paleoproterozoic transpressional orogen. Canadian Journal of Earth Sciences, Volume 39, pages 639-663.

Wardle, R.J., Ryan, B., Nunn, G.A.G. and Mengel, F.C.
1990: Labrador segment of the Trans-Hudson Orogen: crustal development through oblique convergence and collision. *In* The Early Proterozoic Trans-Hudson Orogen of North America. *Edited by* J.F. Lewry and M.R. Stauffer. Geological Association of Canada, Special Paper 37, pages 353-369.