The Earliest Neoproterozoic Magmatic Record of the Pearya Terrane, Canadian High Arctic: Implications for Caledonian Terrane Reconstructions

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Abstract

Succession I of the exotic Pearya terrane, northernmost Ellesmere Island, includes voluminous granitoid orthogneiss units that form the presumptive basement to this displaced crustal fragment. Previous whole rock Rb/Sr and multigrain zircon U/Pb geochronology revealed ages in a range from the latest Mesoproterozoic to earliest Neoproterozoic. This study presents new single grain zircon U/Pb geochronology from a suite of 7 samples that defines a relatively narrow range of earliest Neoproterozoic ages, from 962 ± 6 Ma to 974 ± 8 Ma. Whole rock trace element geochemistry reveals LILE enrichment decoupled from low to depleted HFSE values, suggestive of a subduction zone origin. Nd and Hf isotope geochemistry supports input from both juvenile and evolved materials, with $\epsilon\text{Nd}_{(t)}$ values between -1 and -4.6, and a similar

range for ϵHf values microsampled from zircon age domains consistent with the crystallization of the protolith.

Documentation of abundant earliest Neoproterozoic magmatic ages reinforces correlations between Pearya Succession I and areas of the North Atlantic-Arctic Caledonides containing a tectonothermal record of earliest Neoproterozoic magmatism. The Northwestern, Northeastern, and Southwestern terranes of Svalbard record magmatic events in the c. 965 Ma to 920 Ma range. Likewise, the lower Kalak Nappes of Norway and the East Greenland Caledonides preserve slightly older and younger magmatism and metamorphism, respectively. Slightly older ages occur in orthogneiss units of the south central Brooks Range and Farewell terrane, Alaska. The geochemical and isotopic data from the Pearya terrane orthogneiss units support links between these regions in terms of subchondritic $\epsilon\text{Nd}_{(i)}$ and Paleoproterozoic depleted mantle model ages. The Pearya Terrane orthogneiss units and similar units dispersed in the Arctic are interpreted to have originated near or on the northeastern margin of Greenland, and record a continental arc later carried out of the Caledonide orogen into the Circum-Arctic realm. These data permit models for an exotic origin to the Pearya terrane as part of a later strike-slip orogenic system.

1. Introduction

The Pearya terrane of northernmost Ellesmere Island, Canada (Fig. 1), is identified as an exotic terrane in part by the contrast of its Mesoproterozoic to Neoproterozoic orthogneiss units with Paleoproterozoic to Archean basement units of the northern Canadian and Greenland Shield (e.g. Trettin, 1987, Trettin, 1991a, Trettin, 1998). The timing of Paleozoic arc activity and deformation allowed Trettin (1987) to infer a Caledonian affinity for Pearya, but the pre-Caledonian affinity and tectonic setting of the older Pearya terrane units remains poorly documented and thus poorly understood (cf. Trettin, 1998 and Hadlari et al., 2014). Early Neoproterozoic tectonothermal events observed in East Greenland, Finnmark (Norway), and the Northwestern and Northeastern terranes of Svalbard define the Renlandian orogen which is

thought to have marked initiation of subduction along the greater Rodinian margin (Cawood et al., 2010). Previous geochronology of the Pearya terrane orthogneiss units yielded a range of ages from c. 1080 Ma (Sinha and Frisch, 1976a, b) to c. 965 Ma (Trettin et al., 1992), allowing inclusion of Pearya in the Renlandian orogen, but suggesting magmatism may have started much earlier. Evidence of Neoproterozoic magmatism in the Arctic Alaska and Farewell terranes of Alaska (Amato et al., 2014, Bradley et al., 2014) combined with models for large-scale translation of Caledonian terranes through the Arctic (Colpron and Nelson, 2009, Nelson et al., 2013, McClelland et al., 2015), suggest that the Pearya terrane is an important link for reconstructing pre-Caledonian paleogeography.

This study builds on the previous U/Pb zircon geochronology of Trettin et al. (1987, 1992) to refine our understanding of the timing of magmatism recorded in the Precambrian orthogneiss units of the Pearya Terrane. Secondary Ion Mass Spectrometry (SIMS) microsampling and cathodoluminescence (CL) imaging is utilized to separate magmatic and inherited xenocrystic components in evaluating the significance of older ages identified in the earlier studies (Trettin et al., 1992). Whole-rock and zircon trace element geochemistry provides insight into the tectonic setting of the orthogneiss protolith. Whole-rock Nd and Pb as well as zircon Hf isotopic analyses indicate a contribution from crustal assimilation in their petrogenesis. The combined data strengthen ties between the Pearya Terrane orthogneiss units and similar units in the Arctic and North Atlantic, and provide constraints for paleogeographic association of the Pearya terrane basement with the northeastern Greenland margin in the Neoproterozoic.

1.1 Regional Geology

The Pearya Terrane is located on northernmost Ellesmere Island outboard of the late Neoproterozoic to Devonian Franklinian Basin. On the basis of recognized Caledonide affinities Trettin (1987) postulated that the Pearya Terrane was correlative with Svalbard and represented a fragment that escaped from the Caledonian orogen. Accretion of the terrane against the northern margin of Laurentia (Franklinian Basin) was proposed have occurred in the Silurian, based on

the appearance of Pearya-sourced clasts in conglomerates in deep-water basinal rocks of the Danish River formation (Trettin, 1991c). The various units of the Pearya Terrane were emplaced as fault bound slices along a series of sinistral strike-slip faults that terminate into arcuate thrusts at the southwest end of the terrane (Trettin, 1991b, von Gosen et al., 2012).

Trettin (1998) divided the Pearya terrane into five tectonostratigraphic assemblages referred to as Succession I to V (Fig. 2). Succession I includes Mesoproterozoic to Neoproterozoic orthogneiss and minor metasedimentary units that are inferred to represent depositional basement of the terrane. Succession II consists of Neoproterozoic siliciclastic rocks and limestone overlain by variably metamorphosed Cambrian to Ordovician clastic units, limestone and lesser volcanic rocks. Zircon from a felsic volcanic unit near the top of the section gave an U/Pb age of $503 \pm 8/-2$ Ma (Trettin et al., 1982). Succession III is interpreted as an early Paleozoic arc sequence that contains a plagiogranite dated at $481 \pm 7/-6$ Ma (Trettin et al., 1982) and was amalgamated with Successions I and II during the Ordovician M'Clintock orogeny (Trettin, 1991c). Succession IV and V are post-M'Clintock sedimentary units with variable deformation and little evidence of metamorphism. Upper Silurian sedimentary rocks in the Clements Markham Fold Belt to the southeast of the Pearya terrane record proximity of the terrane to the Laurentian margin and subsequent Late Silurian to Early Carboniferous accretion-related deformation (Trettin, 1998). This deformation has been assigned to the Ellesmerian Orogen. Its final stage took place in (?) Late Devonian to Early Carboniferous times (compare, e.g., Okulitch, 1991, Soper and Higgins, 1991, Trettin, 1991d, Mayr et al., 1998, Piepjohn et al., 2013, 2015).

The crystalline basement of Pearya Succession I outcrops in three main belts (Fig. 2) referred to as the Cape Columbia, Deuchars Glacier, and Mitchell Point belts and as small outliers in the western half of the terrane (Trettin, 1987). The Cape Columbia Belt, a 39 km by 6 km exposure in the northeastern Pearya terrane consists of amphibolite-facies garnet biotite quartzofeldspathic gneiss with subordinate granitic and pegmatitic dikes, amphibolite, schist and marble (Trettin, 1998). Foliation roughly strikes east-west and complex isoclinal folds with

steep to overturned axial planes are common (Frisch, 1974, von Gosen et al., 2012). Retrograde greenschist-facies metamorphism is evident by albitic plagioclase compositions and replacement of garnet by biotite, quartz, muscovite and chlorite (Trettin, 1998). The Deuchars Glacier Belt is a crescent shaped 37 by 12 km exposure dominated by massive to foliated granitic orthogneiss (Trettin, 1998). This unit is separated from the Neoproterozoic-Lower Ordovician metasedimentary rocks of Succession II by the northeast-dipping Deuchars Thrust. The west-central Mitchell Point Belt is the largest area of basement exposure at 127 by 15 km, composed primarily of quartz diorite to quartz monzonite orthogneiss, minor schist, and other intrusive units (Trettin, 1998). Klaper and Otha (1993) noted a dominantly southwest-striking foliation that is axial planar to common isoclinal folds. In its western part, the Mitchell Point belt is bound by the Mitchell Point Fault Zone and Peterson Bay Fault to the northwest and southeast, respectively (von Gosen et al., 2012, Piepjohn et al., 2013). Along the Petersen Bay Fault Succession I units were carried over strata of the Clements-Markham Fold Belt (compare Piepjohn et al., 2013, with further references therein) and represent the northernmost part of the deformed Franklinian Basin. Further northeast, the southeast boundary of the Mitchell Point Belt is marked by the Pearya Shear Zone (von Gosen et al., 2012).

Initial geochemical data and the presence of inherited zircon suggested a likely arc origin for the Pearya orthogneisses, with at least partial derivation from older crust (Trettin, 1987, Trettin et al., 1992). Previous geochronology indicated a late Mesoproterozoic to early Neoproterozoic protolith age for the gneisses. Early single grain zircon analyses yielded U/Pb ages for granitoid orthogneisses of the Cape Columbia Belt of 926 and 980 Ma, and a Rb/Sr isochron age of 1060 ± 18 Ma (Sinha and Frisch, 1976, recalculated in Trettin, 1991b). Multigrain zircon analyses of a granitic sample from the Deuchars Glacier Belt yielded an upper intercept U/Pb age of $1037 \pm 25/-20$ Ma (Trettin et al., 1987). U/Pb zircon upper intercept ages of 1150 ± 300 Ma, 1300 ± 300 Ma, and 1450 ± 400 Ma from Paleozoic intrusions were assumed to reflect the age of zircon xenocrysts inherited from the basement (Trettin, 1991b). Bulk U/Pb zircon analyses from the Philips Inlet Pluton in the western Pearya terrane yielded one

concordant zircon fraction with an age of 965 ± 2 Ma (Trettin et al., 1992). This difference in age occurrences was interpreted by Trettin (1998) to represent different magmatic events through the late Mesoproterozoic and in the early Neoproterozoic.

2. Sample locations and descriptions

Samples in this study were collected from the three major basement exposures of the Pearya terrane during a CASE expedition in 2008. Outcrop photographs and photomicrographs of the samples are presented in Figs. 3 and 4. Table 1 summarizes the locations and lithologic descriptions for each sample.

2.1 Cape Columbia Belt

Three samples were collected in close proximity to one another from the Cape Columbia belt at Cape Columbia (Fig. 2). The outcrop area includes megacrystic orthogneiss and equigranular orthogneiss, both with a penetrative foliation and well developed mineral lineation related to the Pearya Shear Zone (McClelland et al., 2012a, von Gosen et al., 2012). Sample 08-153 was collected from a plagioclase and K-feldspar megacrystic garnet two-mica granodioritic orthogneiss (Fig. 3a). The sample is compositionally zoned at the mm scale, with plagioclase + quartz + white mica domains alternating with biotite dominated domains. Garnet, plagioclase and K-feldspar form sigma porphyroclasts that deflect the white mica and biotite defined foliation (Fig. 4a). In contrast, sample 08-154 was collected from a finer grained equigranular garnet two-mica granitic orthogneiss with a penetrative foliation defined by mica and recrystallized quartz ribbons (Figs. 3b and 4b). Numerous xenoliths and larger screens of metasedimentary rock are present in both of the orthogneiss occurrences. A third sample collected from a weakly deformed leucocratic pegmatite dike that cuts the foliation in the equigranular orthogneiss yielded a U-Pb zircon (SHRIMP) age of 453 ± 4 Ma (McClelland et al., 2012a).

2.2 Deuchars Glacier Belt

A sample (08-178) of two-mica granitic mylonitic orthogneiss in the Deuchars Glacier Belt was collected approximately 50 meters above the Deuchars Thrust (Fig. 2). The orthogneiss has a well-developed foliation defined both by mica shape-preferred orientation and quartz ribbons (Fig. 4c). Larger quartz grains show extensive subgrain development, characteristic of grain boundary migration recrystallization (Stipp et al., 2002), and fine grained quartz makes up the bulk of the mylonitic matrix. Plagioclase and perthite occur as fresh to somewhat altered, c.25 mm – 50 mm wide porphyroclasts with embayed edges.

2.3 Mitchell Point Belt

Sample 08-102 is a coarse grained biotite granodioritic orthogneiss taken from Mitchell Point, just west of Yelverton Inlet (Fig. 2). The sample contains large (> 30 mm in width) plagioclase porphyroclasts (Fig. 3d) with additional plagioclase occurring as abundant blocky grains in the remainder of the rock. Plagioclase grains are partially sericitized. Quartz displays embayed and serrated subgrain boundaries (Fig. 4d) that are evidence of dynamic recrystallization via grain boundary migration (Stipp et al., 2002). Biotite, locally altered to chlorite, is the dominant mafic phase and defines a weak foliation.

A sample of garnet biotite tonalitic orthogneiss (sample 08-103) was collected adjacent to the Pearya Shear Zone at the southeastern extremity of Petersen Bay. The rock is a L-S tectonite, with a penetrative foliation defined by biotite and ribbons of recrystallized quartz (Figs. 3e and 4e) and lineation defined by elongate quartz aggregates and aligned white mica, biotite, and feldspar. Garnet occurs as heavily fractured 20-30 mm grains. Plagioclase is blocky and partly altered. Larger grains often form sinistral sigma structures that provide kinematic data for ductile deformation associated with Pearya Shear Zone (von Gosen et al., 2012).

Sample 08-191 was collected from a two-mica granitic orthogneiss exposed adjacent to the Pearya Shear Zone, in Milne Fiord, approximately 20 kilometers along strike to the northeast

of sample locality 08-103 (Fig. 2). Biotite, white mica, and quartz ribbons define a well-developed foliation that is deflected around porphyroclasts of plagioclase and quartz (Fig. 4f).

Finally, two samples were collected from the Petersen Bay Pluton, a composite body exposed south of the Mitchell Point Belt and Pearya Shear Zone. The pluton is surrounded by metasedimentary rocks of Succession II (Trettin, 1998), however the contacts are not exposed and intrusive relationships are uncertain. Trettin et al. (1992) sampled a monzodiorite dominated by sodic feldspar, some K-feldspar, and minor biotite, and obtained U/Pb ages from abraded zircon and titanite fractions of 334.5 ± 1.5 Ma. Sample 08-134 is a two-mica granodioritic orthogneiss with a foliation defined by biotite and white mica (Fig. 3g). This foliated orthogneiss is cut by an undeformed leuco-syenite, dated by the zircon U/Pb method to 332 ± 2 Ma (McClelland et al., 2012b).

3 Methods

3.1 Zircon analyses

Representative samples of the seven Pearya Succession I orthogneisses were crushed and pulverized at the University of Iowa. A heavy mineral concentrate was extracted from these resulting material by conventional density and magnetic susceptibility methods. Zircon was hand-picked from this concentrate, mounted with natural zircon standards on 2.54 cm epoxy round mounts, and polished. Cathodoluminescence (CL) imaging of the grains revealed intra-grain complexities such as zonation, and was used in sample spot selection. Zircon U-Pb and trace element analyses were conducted at the USGS-Stanford University Ion Probe Laboratory, following routines outlined in Barth and Wooden (2006) and Mazdab and Wooden (2006). The data were reduced using the SQUID-2 add-in to Microsoft Excel (Ludwig, 2005), with U-Pb ages and concordia plots generated using the Isoplot ver. 3.0 add-in to Microsoft Excel (Ludwig, 2003). These data are presented in Appendix A (U-Pb) and Appendix B (trace element). Lu-Hf isotopic analysis of zircon utilized additional grains from the heavy mineral separate. These

were mounted in 2.54 cm epoxy round mounts, polished, and CL imaged. U-Pb analysis at the University of Arizona LaserChron center identified age domains in the grains, and domains within error of the SHRIMP U-Pb ages were selected for further Lu-Hf analysis following the protocols outlined in Gehrels et al. (2006, 2008), Cecil et al. (2011). Lu-Hf data are presented in Appendix C, and additional details for all zircon analyses are presented in Appendix D.

3.2 Whole-rock analyses

An aliquot of rock chips from each crushed sample was powdered for whole-rock geochemical and isotopic analyses. Major element analysis (Si, Al, Ca, Na, K, Mg, Fe, Mn, Ti and P) was conducted by inductively coupled plasma optical emission spectrometry (ICP-OES). Additional analysis of trace and Rare Earth Elements (REE) utilized 0.1 g of powder, digested in HNO₃-HF in Parr bombs. This solution was analyzed by inductively coupled plasma mass spectrometry (ICP-MS). Nd and Pb isotopic analysis was conducted using multi-collector ICP-MS at the University of Illinois, Champagne-Urbana. Additional details for the whole-rock analyses are presented in Appendix D.

4. Results

4.1 Zircon analysis: U/Pb geochronology, trace elements, Hf isotopes

The seven orthogneiss samples yielded abundant stubby to elongate, subhedral to euhedral zircon. CL imaging revealed relatively simple grains characterized by oscillatory zoning indicative of magmatic zircon (Fig. 5). Overgrowths are rare, but rims up to several microns thick are observed on some grains. Concentrations of Th range between 4 ppm to 704 ppm, with most values below 100 ppm; likewise, U concentration ranges from 48 ppm to 4582 ppm, with the majority of values <500 ppm. All of the samples yield a spread in U/Pb ages that reflect the effects of inherited zircon and/or Pb-loss in individual grains. Concordia ages for magmatic zircon from the seven samples range between 962 ± 7 Ma to 972 ± 4 Ma (Fig. 6).

Zircon grains yielding older ages ($>1,000$ Ma) are interpreted as xenocrystic zircon, noted in all samples except for 08-134. $^{207}\text{Pb}/^{206}\text{Pb}$ ages range from 1025 Ma to 1797 Ma, with two broad clusters occurring between 1025-1300 Ma and 1540-1800 Ma. Fig. 6a illustrates the sample-by-sample distribution of these inherited ages, with sample 6b displaying all 29 inherited ages from this study as a histogram and probability distribution function.

Hf concentrations in zircon varied between 9465 to 17,603 ppm, with Th/U typically decreasing with increasing Hf concentration. Despite scatter in the data, some samples show inflection in low Th/U samples as Hf ppm reaches 12,000-14,000 ppm. The majority of analyzed zircon recorded REE patterns typical of igneous zircon (Fig. 8), i.e. positive Ce anomalies, negative Eu anomalies and increasing concentration relative to chondritic values from the light rare earth elements (LREE) to heavy rare earth elements (HREE) (Hoskin and Schaltegger, 2003). Deviation from the typical magmatic signature aids in interpretation of the U/Pb data; for example, enrichment in LREE is an indicator of metamictization and disturbance of the zircon structure (Belousova et al., 2002, Hoskin, 2005). Some grains exhibit flattened HREE patterns and low Th/U ratios (<0.1) suggestive of the involvement of garnet during zircon crystallization, either as a co-crystallizing phase or a residue in the source (Rubatto, 2002).

The two orthogneiss samples from the Cape Columbia Belt display different zircon age distributions. Augen orthogneiss sample 08-153 has minimal inheritance and a relatively simple age distribution (Fig. 6a). Assuming one older analysis of an inherited core (Fig 7a) and two younger analyses due to Pb-loss, the sample gives a concordia age of 972 ± 7 Ma (MSWD = 1.3; $n = 12$ of 15). In contrast, sample 08-154 yields a spectrum of zircon ages. 21 of 39 analyses from sample 08-154 are interpreted as xenocrystic zircon due to their much older ages (Fig7a), as well as the presence of metasedimentary xenoliths observed at outcrop scale. Excluding the older ages presumed to be premagmatic and the 6 youngest ages as reflecting Pb-loss the remaining 12 ages define a weighted mean age of 972 ± 6 Ma (MSWD = 1.3). The weighed mean was used to identify a subset of analyses from this group give a concordia age of 969 ± 6 Ma (MSWD = 1.2; $n = 7$ of 39) which is interpreted as the emplacement age for this body.

Three of the youngest ages that have low Th/U ratios and lower Yb/Gd_N (ranges from 3.5 to 5.2); Fig. 8b) may reflect post emplacement Pb loss or recrystallization during a Devonian metamorphic event, suggested by titanite growth in the Cape Columbia belt at 372 Ma (Ward et al., 2015).

Oscillatory zoned zircon from Deuchars Glacier Belt sample 08-178 gives a Concordia age of 972 ± 4 Ma (MSWD = 1.0) on the basis of 12 of 15 analyses (Fig. 6c). Two analyses reflect xenocrystic zircon (Fig 7a) due to their older ages relative to the main population, and the youngest analysis is interpreted to record Pb-loss. Six analyses with lower Yb/Gd_N (ranges from 5.0 to 10.0) patterns and low Th/U ratios (<0.1) are interpreted to reflect involvement of garnet during zircon crystallization (Fig. 8c).

All samples from the Mitchell Point Belt show a spread in U/Pb ages, with most zircon yielding earliest Neoproterozoic ages. Analyses from sample 08-102 range from 950 to 1500 Ma with the two oldest analyses interpreted as xenocrystic zircon (Fig 7a). The next two older analyses are interpreted to reflect a mix of inherited and magmatic signatures, with possible cores observed in CL, and the youngest analysis is interpreted to record Pb-loss (Fig. 6d). The remaining 10 analyses give a weighted mean $^{206}\text{Pb}/^{238}\text{U}$ age of 968 ± 6 Ma (MSWD = 1.1; n = 10 of 15). Rejecting the oldest age of this group due to discordance (analysis 6.1), the calculated concordia age for this sample is 964 ± 6 Ma (MSWD = 1.0; n = 9 of 15). Sample 08-103 also defines a significant age range but with more analyses skewed toward younger ages (Fig. 6e). A concordia age of 966 ± 5 Ma (MSWD = 1.5; n = 5 of 14) is interpreted as the emplacement age for the sample, assuming two analyses are from inherited cores (Fig 7a) and seven younger analyses reflect Pb-loss or recrystallization. Sample 08-191 yielded ages ranging from 941 to 985 Ma with a weighted mean age of 962 ± 10 Ma (MSWD = 11.9; n = 10 of 15) excluding one young analysis attributed to Pb-loss and two analyses from xenocrystic zircon (Fig. 6f). Assuming the large age spread is due to a combination of analysis of mixed domains and Pb-loss, 6 analyses give a concordia age of 965 ± 5 Ma (MSWD = 1.6; n = 6 of 15) which is interpreted as the emplacement age for this sample. Zircon ages from the Petersen Bay Pluton

sample 08-134 range from 925 to 985 Ma, with REE patterns typical of igneous zircon (Figs. 6g and 8g). Attributing the 5 youngest ages to Pb-loss or recrystallization, 15 analyses give a weighted mean age of 965 ± 7 Ma (MSWD = 0.7; n = 15 of 20). Concordant analyses define a concordia age of 964 ± 6 Ma (MSWD = 1.3; n = 10 of 20) which is the interpreted emplacement age for the sample.

4.2 Zircon Hf isotopic results

Measured $^{176}\text{Hf}/^{177}\text{Hf}$ ratios for zircon age domains within error of the crystallization age calculated from SHRIMP analysis range from 0.281703 to 0.282753, with most falling between 0.282100 and 0.282300. Calculated epsilon Hf values at the crystallization age for all samples ($\epsilon\text{Hf}_{(i)}$) range from +5.8 to -17.2, with most values occurring between +2.3 and -6.5 (Fig. 9a). Zircon from samples 08-102 and 08-153 both show tight clusters of $\epsilon\text{Hf}_{(i)}$ between +1.7 to -1.1 and +1.7 to -2.2 respectively, with three analyses characterized by $\epsilon\text{Hf}_{(i)} < -10$ (Fig 9b). Other sample's $\epsilon\text{Hf}_{(i)}$ values span a similar range near $\epsilon\text{Hf}_{(i)} = 0$.

4.3 Whole-rock geochemistry

The samples analyzed in this study range from tonalitic to granitic in mineralogical composition, with biotite forming the dominant mafic phase in all seven samples. Muscovite $\pm$ garnet is present in several samples. Weight percent (wt. %) values for major elements are recalculated to an anhydrous total of 100% and presented in Table 2. Wt % SiO_2 ranges from a low of 61.81 and a high of 72.51, consistent with the tonalitic to granitic mineralogy of the samples. Wt % values of Al_2O_3 show less variation, ranging between 13.95 and 16.53. The alkali and element oxide contents vary between the samples as well. K_2O varies between 0.59 and 5.81. In contrast, Na_2O shows a narrow range of variation, ranging between 2.33 and 6.79. Wt. % CaO varies between 0.37 and 8.63. In general, higher wt % SiO_2 correlated to higher alkali and alkali earth values.

Sample values for whole-rock trace element geochemistry are presented in Table 2. Trace element patterns in all seven samples show overall enrichment in incompatible elements relative to mid-ocean ridge basalt (MORB) values (Fig. 10). Th and Pb enrichment coupled with negative Nb and Ta anomalies are typical of granitoid rocks. Negative Eu anomalies (Eu/Eu^* ranging from 0.2 to 0.7) seen in six of seven samples, indicate that most of the precursor magmas were affected by shallow level fractionation effects and/or residual plagioclase in the source. Sample 08-103 is the sole exception, with $\text{Eu}/\text{Eu}^* = 1.1$, suggesting that plagioclase fractionation was not significant. REE ratios are consistent with fractionation effects for the samples, with $\text{La}/\text{Sm}_\text{N}$ values ranging from 6.9 to 2.4, $\text{Dy}/\text{Lu}_\text{N}$ values ranging from 1.1 to 1.6, and $\text{La}/\text{Yb}_\text{N}$ values ranging from 26.2 to 4.2. Samples 08-103 and 08-134 show lower $\text{Dy}/\text{Lu}_\text{N}$ values, from 1.1 to 1.3, which may indicate garnet in the magma source area (e.g. Gromet and Silver, 1987).

Whole rock isotopic data are summarized in table 3. $^{143}\text{Nd}/^{144}\text{Nd}_{(t)}$, calculated to the crystallization age of each sample, ranges from 0.511158 to 0.511346 with a range in $\epsilon\text{Nd}_{(t)}$ of -4.61 to -0.97. Depleted mantle model ages (DePaolo, 1981) calculated for each sample vary, with sample 08-178 yielding an age of 2.7 Ga, and the rest falling in a Paleoproterozoic range of 2.1-1.6 Ga. Measured Pb isotopic compositions deviate from the crustal evolution of Stacy and Kramers (1975). Age corrected $^{207}\text{Pb}/^{204}\text{Pb}$ for the samples are lower than upper crustal values, clustering around c. 15.0. $^{206}\text{Pb}/^{204}\text{Pb}$ varies from 17.1 to 17.4, with one sample (08-191) characterized by a low value of 13.9. $^{208}\text{Pb}/^{204}\text{Pb}$ for five samples plot between 36.4 and 37.5, with two samples (08-134 and 08-191) displaying far lower values (33.3 and 31.7, respectively).

5. Discussion

5.1 New geochronologic constraints

Zircon U/Pb ages from the seven Pearya Succession I orthogneiss samples range from 972 Ma to 962 Ma. The U/Pb ages are interpreted to reflect the crystallization of the granitoid protoliths, suggested both by the simple oscillatory zoned grains as well as trace element patterns

consistent with an igneous origin (Hoskin and Schaltegger, 2003). The ages are consistent, within measurement errors, between the three major exposures of orthogneiss sampled. On the basis of the xenocrystic zircon observed in 6 samples, the older age of $1037 \pm 25/-20$ Ma determined by Trettin et al. (1987) is interpreted to reflect the presence of inherited xenocrystic zircon in the multigrain fractions that were analyzed, rather than evidence for late Mesoproterozoic magmatism in the Pearya terrane. The new ages considerably narrow the time range of pre-Paleozoic magmatism observed in the Pearya terrane and allow more definitive comparisons with magmatic events in other regions.

5.2 Origins of Pearya Succession I

5.2.1 Tectonic setting

Traditional granitoid classification schemes, such as those of Chappell and White (1974, 2001) and those outlined by Frost et al. (2001) may be difficult to apply to metamorphosed granitoid rocks, due to the presumed mobility of elements such as Na, K, and Ca during metamorphism. This issue can be mitigated by the application of less mobile elements and trace element data from zircon sensitive to tectonic setting. Whole-rock trace element patterns (Fig. 10) show decoupled LILE and HFSE elements. This includes high concentrations of the fluid-mobile elements such as Pb, non-enrichment to depletion of HFSE, and Nb-Ta anomalies generally diagnostic of a subduction modified mantle source (e.g. Rogers and Hawksworth, 1989). Tectonic discrimination diagrams developed by Pearce et al. (1984) provide additional insight. Previous studies from Trettin (1998) included immobile trace element data, which allows for a comparison between this study and the pre-existing data in terms of Nb versus Y space. The Y vs. Nb (Fig 11a) places six of seven samples in the VAG+SynCOLG field of Pearce et al. (1984). Post Collision granites (PostCOLG; Pearce et al., 1984, Pearce, 1996) are difficult to distinguish on these plots, as they vary with crustal source chemistry. Th-Hf-Ta ternary diagrams (Wood et al., 1979, Wood, 1980) provide additional discrimination between silicic magmas generated at subduction zones versus anorogenic settings. The orthogneiss

samples plot in the volcanic arc field with calc-alkaline affinity (Fig. 11b), as defined by samples in the volcanic arc field with $\text{Hf/Th} < 3$ (Wood, 1980). These trace element data suggest a volcanic arc origin for the orthogneiss samples; however, discriminating between granitoids produced in the volcanic arc proper and those related to syn- and post-collisional magmatism is difficult using immobile elements. Zircon trace element geochemistry provides additional insight into the tectonic setting as well as petrogenesis (discussed fully in section 5.3). Fig 12a plots U/Yb against Gd/Yb , providing a useful discriminant between continental arc and post-collisional granitoids (Grimes et al., 2007, 2015). Virtually all of the zircon compositions analyzed from c. 965 Ma age domains from this study overlap the empirically derived continental arc compilation of Grimes et al. (2007, 2015), with none occurring in the post-collisional field.

5.2.2. Source characteristics

Isotopic data from whole-rock samples suggest that much of the material incorporated into the orthogneiss protolith originated from recycled lower crustal materials. Time corrected $^{206}\text{Pb}/^{204}\text{Pb}$, plotted against $^{143}\text{Nd}/^{144}\text{Nd}_{(i)}$ for six of seven sample fall near the approximate values expected for a time corrected enriched mantle (EM) sources (Fig 13). One sample, 08-191, has an anomalously low $^{206}\text{Pb}/^{204}\text{Pb}$ value out of the range of any reservoirs. The reason for this discrepancy is unclear, although the value is similar to those observed in Archean granulite basement from southeastern Greenland (Taylor et al., 1992). Both of the EM I and EM II reservoirs proposed by Zindler and Hart (1986) incorporate supposed crustal materials, and are characterized by similar $^{143}\text{Nd}/^{144}\text{Nd}_{(i)}$ values in the modern setting. Pb isotopes provide a more sensitive discrimination between these sources, as the EM I reservoir is characterized by low U/Pb and correspondingly lower $^{206}\text{Pb}/^{204}\text{Pb}$ values, whereas the EM II reservoir has high U/Pb and $^{206}\text{Pb}/^{204}\text{Pb}$ values. While it is unlikely that the orthogneiss protolith was derived purely from a mantle source, the correlation between the EM I and EM II reservoirs provides some insight into the source of the magma. EM II isotopic ratios are typically consistent with

subducted sediments derived from upper crustal materials. In contrast, EM I seems to represent either lower crustal materials or metasomatized mantle (Zindler and Hart, 1986). The EM I-like source signal may reflect the remobilization of lower to mid-crustal materials, rather than an enriched mantle source, for several reasons. Nd depleted mantle model ages (T_{DM}) for the samples are generally Paleoproterozoic to earliest Mesoproterozoic, with sample 08-178 yielding a T_{DM} of 2.7 Ga. The subchondritic $\epsilon Nd_{(i)}$ values, and model ages in excess of the calculated crystallization ages for the orthogneiss samples, support a remobilization of material from lower to mid-crustal levels. The range of $\epsilon Hf_{(i)}$ values for the majority of zircon analyzed (+2.3 to -6.5; Fig. 8) overlaps the whole-rock $\epsilon Nd_{(i)}$ values. The observed spread in $\epsilon Hf_{(i)}$ values from the zircon also suggests input from older mafic lower crustal material that was then partially melted at c. 967 Ma. Xenocrystic zircon serve as an additional line of evidence indicating a crustal source, and are present in low abundances in five samples. Once sample (08-134) lacks inherited zircon, and one sample (08-154) contains a large inherited population that contrasts with the immediately adjacent and older sample 08-153. This may simply reflect different phases of magmatism in the area, as both samples share whole-rock isotopic characteristics. Interestingly, the abundance of inherited zircon in sample 08-154 does not correspond to more radiogenic Pb isotopic values. This may further support a lower crustal source, where fluid mobile U and Th would be lost during metamorphic reactions that occurred prior to magma generation. The isotopic observations are consistent with models for arc magma generation, where lower crustal rocks are heated and eventually melted by underplated basaltic magma rising from the mantle wedge above a subduction zone magma (e.g. Annen et al., 2006 and references therein).

5.3 Petrogenesis

Whole-rock trace element data reveal the variable role of fractionation in melt genesis. Most samples display prominent Eu, Sr, and Ti anomalies consistent with the fractional crystallization of plagioclase, titanite and ilmenite. Two samples, 08-103 and 08-134, lack strong Eu anomalies and recorded lower magnitude Sr and Ti anomalies, indicating a reduced

fractional crystallization of Ca and Ti-bearing phases. La/Yb_N values for five of seven samples fall between 4.2 and 12.8, indicating relatively minor fractionation of light to heavy REE occurred. Two samples (08-103 and 08-134) with Dy/Lu_N values < 1.3 likely reflect HREE fractionation related to residual garnet in the source.

Trace element analysis of zircon provides an additional avenue to investigate petrogenesis based on comparison with detailed studies (Claiborne et al., 2006, 2010, Wooden et al., 2006, 2007, Grimes, 2007, 2015, Barth and Wooden, 2010). This discussion focuses on trace element data analyzed from zircon age domains consistent with the crystallization age of the sample, and omits data from xenocrystic zircon. These REE patterns are typically consistent with the characteristics of igneous zircon (Hoskin and Schaltegger, 2003). This includes variable positive Ce anomalies, negative Eu anomalies, and steep positive REE trends. As noted above, most of the zircon compositions from this study overlap the continental arc compilation of Grimes et al. (2007, 2015). In addition, zircon from samples 08-178, 08-154 and 08-102 show a “garnet signature” in U/Yb versus Gd/Yb space (Fig. 12a; Grimes et al., 2015). This suggests that the magmas for these samples formed at depth in the garnet stability field, lending support to a lower crustal source area for these samples. Hf concentrations and Yb/Gd values serve as useful indicators of magma differentiation (Madzab et al., 2007), and can be plotted against other values to trace changes in the magma over time. Th/U is sensitive to fluid input from the original magma, versus anatectic fluids, and generally decreases as differentiation progresses towards a “magmatic” and “anatectic” boundary at $\text{Th/U} = 0.1$ shown in Fig 12b (Barth and Wooden, 2010, Claiborne et al., 2010). Samples 08-134, 80-153, and 08-154 show no clear trend in increasing Th/U as differentiation progresses; indeed, 08-134 zircon do not cross the $\text{Th/U} = 0.1$ that indicates a transition into more water rich anatectic fluids. Four samples, 08-102, 08-103, 08-178, and 08-191, all display decreasing Th/U values as Hf concentration increases (Fig 12b). Samples 08-154 and 08-134 record decreasing Eu/Eu^* with increasing Hf trends that are consistent with co-crystallization of zircon and plagioclase or derivation from a source characterized by a Eu anomaly (Wooden et al., 2006, Barth and Wooden, 2010, Fig. 12c).

The other five samples show very low Eu/Eu^* and little variation with increasing Hf, suggesting zircon crystallization after significant plagioclase growth or low oxidation conditions. Ce/Sm as a function of Yb/Gd (Fig. 12d) provides information regarding magma oxidation state as differentiation progresses. Samples 08-102, 08-134, 08-153 and 08-178 have relatively constant Ce/Sm values (Fig 12d) as differentiation progressed, indicating that oxidation did not vary significantly during zircon crystallization (Barth and Wooden, 2010, Claiborne et al., 2010). Samples 08-103 and 08-191 showed an increase in Ce/Sm as differentiation progressed (Fig 12d), possibly indicating an increase in magma oxidation related to the anatectic fluids detected by their increasing Th/U values (Fig 12b). Ce/Sm values for sample 08-154 decreased over the course of differentiation, likely affecting the slope of the Eu/Eu^* trend observed in Fig 12c as reduced Eu^{2+} became more favorable over Eu^{3+} . Finally, the negative trend of increasing U/Ce and decreasing Th (Fig. 12e) for the low Th/U samples (Samples 08-102, 08-153, 08-154, 08-178; Fig 12b) may support input from anatectic melting (e.g. Castiñeiras et al., 2011). The other samples fall into the magmatic field. The presence of anatectic fluids in the petrogenesis of these rocks, in addition to their trace element and isotopic character, are consistent with typical granitoid evolution and crustal melting.

5.4 Connections with Early Neoproterozoic magmatism in the Caledonides

Our new data allow for robust links to be drawn between the Pearya Terrane, the Northwestern and Eastern terranes of Svalbard, and the Caledonides of East Greenland and Scandinavia. Trettin (1987) tentatively linked the Pearya terrane orthogneisses to North Atlantic occurrences of Grenville-Sveconorwegian (*sensu lato*) tectonometamorphic activity. Connections between Pearya Succession I and the Arctic Caledonides are reinforced by the abundant earliest Neoproterozoic crystallization ages (see Fig. 14) and 1.60 - 2.01 Ga Nd T_{DM} model ages from this study, as discussed below.

5.4.1 Svalbard

Early Neoproterozoic magmatic activity is preserved on Nordaustlandet in the Eastern terrane, Albert I Land of the Northwestern terrane, and in Oscar II Land and Wedel Jarlsburg Land of the Southwestern terrane. Turbiditic metasedimentary rocks in Nordaustlandet contain late Paleoproterozoic to late Mesoproterozoic detrital zircon (Johansson et al., 2005) are overlain by c. 960 Ma volcanic rocks and intruded by c. 960 Ma to 930 Ma granitoids (Gee et al. 1995, Gee and Teben'kov 1996, Johansson et al., 2005). The granitoids are peraluminous and fall within the VAG+SynCOLG and VAG fields on Nb-Y and Ta-Yb tectonic discrimination plots (Johansson et al., 2004, 2005). Whole rock Nd isotope analysis of four c. 950 Ma samples yields Nd T_{DM} model ages ranging from 1.69 Ga to 1.98 Ga and $\epsilon Nd_{(950\text{ Ma})}$ from -2.6 to -3.4. Johansson et al. (2005) suggest a Mesoproterozoic metasedimentary source as the magmatic precursor to these granitic rocks, using a biotite schist metamorphosed in the early Neoproterozoic with an $\epsilon Nd_{(950\text{ Ma})}$ of -4.1 (T_{DM} model age of 1.75 Ma) as a point of reference.

The Northwestern terrane of Svalbard preserves early Neoproterozoic U/Pb ages as well, documented in Albert I Land and the Biskayarhalvøya-Hotedahlfonna horst to the east. SIMS U/Pb analysis of orthogneiss samples range from 956 ± 6 Ma to 966 ± 10 Ma (Pettersson et al., 2009a). The orthogneiss samples are characterized by abundant modal quartz and K-feldspar, contrasting somewhat with the bulk of the Pearya terrane samples. A calc-alkalic, peraluminous I type granite gave a Pb/Pb evaporation age of c.960 Ma (Ohta and Larionov, 1998). Discordant TIMS analyses yielded intercept ages of c.960 Ma for samples of K-feldspar rich porphyritic garnet biotite metagranite and corona gabbro (Peucat et al., 1989). The $^{87}\text{Sr}/^{86}\text{Sr}$ and $^{143}\text{Nd}/^{144}\text{Nd}$ isotopic data indicate that these units possess a crustal component, interpreted as juvenile at 1800 Ma to 1900 Ma by Peucat et al. (1989). Initial $^{87}\text{Sr}/^{86}\text{Sr}$ values are 0.7117 for the metagranite, and 0.7069 for the gabbroic unit; likewise, the $\epsilon Nd_{(i)}$ for these units are -2.1 and -1.5 respectively (Peucat et al., 1989) with both sets of data suggesting input of a more evolved component.

Recent data from the southwestern terrane of Svalbard continues the trend of early Neoproterozoic granitoid magmatism. Majka et al. (2014) investigated the felsic augen gneiss of

the Berzeliuseggene Igneous Suite, Wedel Jarlsberg Land. Two ages were generated from this sample: Zircon cores yielded an age of 950 ± 5 Ma, with metamorphic rims recording a younger tectonothermal event at 635 ± 10 Ma. Gasser and Andresen (2013) also report an age of 927 ± 3 Ma from an augen orthogneiss collected from Oscar II Land; however, the field relationships between the sample and the host sedimentary units are unclear. These earliest Neoproterozoic ages documented in the Southwestern terrane help reinforce previously inferred ties to the other terranes of Svalbard, as well as to the Succession I orthogneiss units of the Pearya terrane.

5.4.2 Svaerholt Terrane (lower nappes), Kalak Nappe Complex, Finnmark

Kirkland et al. (2006) presented zircon U/Pb ages from a suite of granitic rocks from the lower units of Kalak Nappes, obtaining crystallization ages between 981 ± 7 Ma to 973 ± 4 Ma. The Repvåg granite is described as a peraluminous S-type monzogranite and Kirkland et al. (2006) note that it is petrographically similar to the structurally lower granitoids. Sm/Nd isotope geochemistry from this sample yield a Nd T_{DM} model age of 1.731 Ga, and a corresponding $\epsilon Nd_{(i)}$ of -2.57 (Kirkland et al., 2006). The dated units cut a series of metapelites and metapsammities with Nd T_{DM} model ages ranging from 1.7 Ga to 2.1 Ga, with no correlations between Nd values and metamorphic grade observed (Kirkland et al., 2006, 2008).

5.4.3 East Greenland

The East Greenland Caledonides contain granitoid rocks of both S and I type affinities that are hosted within the Krummedal Sequence and record both early Neoproterozoic and Paleozoic tectonothermal events (Kalsbeek et al., 2008). Pre-Caledonian biotite granites and granitic gneisses yield U/Pb zircon ages from 915 ± 18 Ma to 947 ± 19 Ma (Kalsbeek et al., 2000, Leslie and Nutman, 2003). Narrow metamorphic rims on detrital zircon in the Krummedal metasedimentary rocks give an age of 955 ± 13 Ma (Strachan et al., 1995). Field relationships and patterns of ages from inherited zircon from many of the granitic bodies (Kalsbeek et al., 2008) implicates anatexis of the enclosing Krummedal Sequence as a dominant source of melt.

Kalsbeek et al. (2000) propose crustal thickening followed by orogenic collapse as the cause of c. 950 Ma - 920 Ma magmatism in this region, with melt generation facilitated by the fertile lithologies of the Krummedal metasediments. These ages are significantly younger than those observed in the Pearya Succession I orthogneiss and the Svaerholt granites, as well as most observed from Svalbard. This discrepancy may be due to the East Greenland Caledonides recording a different tectonothermal event, an occurrence of age progression, or Pb-loss affecting the crystallization ages due to Caledonian metamorphism.

5.4.4 Links to central Alaskan terranes and Arctic Alaska-Chukotka?

The southern Brooks Range of Alaska hosts a suite of Proterozoic to Paleozoic metasedimentary rocks variably intruded by granitoid metaigneous units. Amato et al. (2014) report a weighed mean $^{206}\text{Pb}/^{238}\text{U}$ age of 968 ± 5 Ma from a granitoid orthogneiss near Ernie Lake in the Arctic Alaska terrane, southern Brooks Range. Similar, although slightly older, c. 979 Ma ages are reported by Bradley et al. (2014) from the Farewell terrane of Alaska. The ages of Neoproterozoic units from the Arctic Alaska and Farewell terranes fall within the range of those documented in the North Atlantic Caledonides. Detrital zircon similarities between Neoproterozoic units of Peary Land, northern Greenland (Kirkland et al., 2009) and Arctic Alaska (Macdonald et al., 2009) suggest links between these regions as well. Correlation of the earliest Neoproterozoic igneous rocks with those of the Pearya terrane supports translation of the Arctic Alaska and Farewell terranes from the North Atlantic Caledonides into the circum-Arctic realm by Paleozoic tectonic events (Colpron and Nelson, 2009). Further support of these links is provided by O'Brian and Miller (2014) and Brumley et al. (2015) studied crystalline rock dredged from the Chukchi Borderland, part of Arctic Alaska-Chukotka, in the western Arctic Ocean. U-Pb geochronology of potassium feldspar augen gneiss samples sampled by Brumley et al. (2015) revealed zircon core ages from 880–980 Ma and 1100–1825 Ma, consistent with possible derivation from the crystalline basement of the Pearya Terrane (Succession I, Trettin et al., 1987, Trettin et al., 1992, this study, and Succession II, Hadlari et al., 2014, Malone et al.,

2014). Other samples revealed evidence of igneous activity in the Late Neoproterozoic , with Cambrian-Ordovician metamorphism (O'Brian and Miller, 2014, Brumley et al., 2015). Both studies propose that these data, in addition to c. 430 Ma crystallization ages consistent with those observed Caledonian granitoids in Svalbard, include the Chukchi Borderland as part of the peri-Laurentian igneous arc terranes outboard of the Franklinian Basin margin and adjacent to both the Pearya and Svalbard terranes.

5.5 Paleogeographic implications

Succession I forms the presumed basement to the Pearya terrane (Trettin, 1998), and as such plays an important role in understanding the terrane's origin. Trettin (1987, 1991a, 1998) favored an exotic origin for the terrane on the basis with correlation to similar units in the Caledonides. In contrast, Hadlari et al. (2014) have proposed a pericratonic origin for the Pearya terrane and a model in which the Pearya terrane was separated from the Franklinian Basin margin by crustal necking that ultimately lead to the development of the Deep Water Basin. Early Neoproterozoic magmatic and tectonothermal activity recorded by Pearya Succession I then should have occurred in an intracratonic setting in the pericratonic model. This model contrasts to models proposing Early Paleozoic subduction south of Pearya (Klaper, 1992a, b) or subduction beneath Pearya in the Early Silurian (Bjørnerud and Bradley, 1994). Furthermore, the north Laurentian margin in the Canadian Arctic Islands and north Greenland is underlain by Paleoproterozoic basement rocks (Hoffman, 1988, Davidson, 2008, St. Onge et al., 2009) that lack any evidence of early Neoproterozoic magmatism (e.g., Frisch and Trettin, 1991). We follow correlations summarized by Trettin (1998) that link the Pearya terrane with North Atlantic Caledonian terranes of Svalbard, northern Norway, and East Greenland as outlined in the previous section.

Widespread Neoproterozoic metamorphism and deformation as observed in Scandinavia, Greenland and Svalbard has been attributed to an accretionary orogen formed along the northeastern margin of Laurentia (Cawood et al., 2010). Early Neoproterozoic magmatism in

Svalbard and Norway records subduction beneath the Laurentian margin in the initial phases of the Valhalla orogen (Cawood et al., 2010, Kirkland et al., 2011). Early Neoproterozoic magmatism of the Pearya terrane is interpreted here to record a similar arc setting along the Laurentian margin (Fig. 14). Magmatism of similar age in the Farewell and Arctic Alaska terranes suggest the arc system extended to the Siberian and Baltica margins, respectively. Emplacement of younger (c. 950-915 Ma) S-type granites in eastern Svalbard and East Greenland may reflect extension on this margin, possibly related to post orogenic collapse. Alternating contractional and extensional events along the northeast Laurentian continental convergent margin account for magmatism, deformation and sedimentation in the Valhalla orogen as summarized by Cawood et al. (2010). This reconstruction is consistent with recent detrital zircon provenance data from Proterozoic rocks of Pearya Succession II (Hadlari et al., 2014, Malone et al., 2014), which support correlations with similar units in Svalbard (the Brennevinsfjorden and Helvetesflya Groups of Northeastern Svalbard, Lorenz et al., 2012, the Krossfjorden Group, Northwestern Terrane, Pettersson et al., 2009b; the St. Jonsfjorden Group, Drudmannsodden Unit, and Comfortlessbreen Units of the Southwestern Terrane, Gasser and Andresen, 2013). Interestingly, the pattern of inherited ages observed from the orthogneiss samples (Fig 7) resembles age spectra from Proterozoic units observed in Svalbard as well, particularly in the abundant c. 1600 Ma ages and lack of Archean ages observed. This detrital zircon data also correlates well with Proterozoic units in the East Greenland and Norwegian Caledonides (see summary in Malone et al., 2014), reinforcing previously suggested ties to the wider Caledonian Orogen (e.g. Gee and Teben'kov, 2004).

6. Conclusions

New U/Pb zircon geochronology from the Pearya Succession I orthogneisses reveals a far wider extent, but narrower age range of earliest Neoproterozoic magmatic activity than previously documented (Trettin et al., 1987, 1992). These data reinforce links between the Pearya Terrane and other areas of earliest Neoproterozoic magmatism: Northwest Svalbard,

Northeast Svalbard, and the Svaerholt succession of the Kalak Nappe Complex. Elements of the Arctic Alaska and Farewell terranes, currently dispersed into the Circum-Arctic realm, may share contemporaneous magmatic activity as well. Geochemical evidence from whole-rock and zircon grains indicates that the Pearya terrane orthogneiss formed as part of a continental igneous arc system. Whole rock Nd and zircon Hf isotopic data reveals juvenile components in the parental magma, possibly related to the remelting of mafic lower crustal materials. This juvenile source may be related to Paleoproterozoic igneous materials observed as basement in the Caledonian foreland of East Greenland, possibly part of a larger province prior to Paleozoic thrusting (Kalsbeek et al., 2008). These data suggest that the Pearya Terrane restores southeast of its current position along the northeastern margin of Greenland, with the other Caledonian terranes such as those in Svalbard (e.g. Gee and Teb'enkova, 2004), as part of the proposed active convergent margin of Cawood et al. (2010) and Kirkland et al. (2011). This reconstruction allows Pearya Succession I to escape from the margin during Caledonian orogenesis with Svalbard and similarly aged Circum-Arctic terranes, and later accrete against the Franklinian Basin margin as part of the exotic, composite Pearya terrane by the mid-Paleozoic.

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References

- Amato, J.M., Aleinikoff, J.N., Akinin, V.V., McClelland, W.C., and Toro, J., 2014. Age, chemistry, and correlations of Neoproterozoic–Devonian igneous rocks of the Arctic Alaska–Chukotka terrane: An overview with new U-Pb ages, in: Dumoulin, J.A., and Till, A.B. (Eds.), *Reconstruction of a Late Proterozoic to Devonian Continental Margin Sequence, Northern Alaska, Its Paleogeographic Significance, and Contained Base-Metal Sulfide Deposits*. Geological Society of America Special Paper 506, 29-27.
- Anders, E., Grevesse, N., 1989. Abundances of the elements: meteoric and solar. *Geochimica et Cosmochimica Acta* 53, 197-204.
- Annen, C., Blundy, J.D., Sparks, R.S.J., 2006. The genesis of intermediate to silicic magmas in deep crustal hot zones. *Journal of Petrology* 47, 505-539.
- Baker, J., Peate, D.W., Waight, T., Meyzen, C., 2004. Pb isotopic analysis of standards and samples using a ^{207}Pb - ^{204}Pb double spike and thallium to correct for mass bias with a double focusing MC-ICP-MS. *Chemical Geology* 211, 275-303.

- 670 Barth, A.P., Wooden, J.L., 2006. Timing of magmatism following initial convergence at a
671 passive margin, southwestern U.S. Cordillera, and ages of lower crustal magma sources.
672 *Journal of Geology* 114, 231-245.
- 673 Barth, A.P., Wooden, J.L., 2010. Coupled elemental and isotopic analyses of polygenetic zircons
674 from granitic rocks by ion microprobe, with implications for melt evolution and the
675 sources of granitic magmas. *Chemical Geology* 227, 149-159.
- 676 Belousova, E.A., Griffin, W.L., O'Reilly, S.Y., Fisher, N.I., 2002. Igneous zircon: trace element
677 composition as an indicator of source rock type. *Contributions to Mineralogy and*
678 *Petrology* 143, 602-622.
- 679 Bjørnerud, M.G., Bradley, D.C., 1994. Silurian foredeep and accretionary prism in northern
680 Ellesmere Island: Implications for the nature of the Ellesmerian Orogeny. 1992
681 *Proceedings of the First International Conference on Arctic Margins (ICAM-92,*
682 *Anchorage, Alaska, September 2-4, 1992), OCS Study MMS 94-004, 129-133.*
- 683 Black, L.P., Kumo, S.L., Williams, I.S., Mundil, R., Davis, D.W., Korsh, R.J., Foudoulis, C.,
684 2003. The application of SHRIMP to Phanerozoic geochronology; a critical appraisal of
685 four zircon standards. *Chemical Geology* 200, 171-188.
- 686 Bradley, D.C., McClelland, W.C., Friedman, R.M., O'Sullivan, P., Layer, P.W., Miller, M.L.,
687 Dumoulin, J.A., Till, A.B., Abbot, J.G., Bradley, D.B., Wooden, J.L., 2014. Proterozoic
688 geochronological links between the Farewell, Kilbuck, and Arctic Alaska terranes.
689 *Journal of Geology* 122, 237-258.
- 690 Brumley, K., Miller, E.L., Konstantinou, A., Grove, M., Meisling, K.E., Mayer, L.A. 2015. First
691 Bedrock samples dredged from submarine outcrops in the Chukchi Borderland, Arctic
692 Ocean. *Geosphere* 11, 76-92.
- 693 Castiñeiras, P., Navidad, M., Casas, J.M., Liesa, M., Carreras, J., 2011. Petrogenesis of
694 Ordovician magmatism in the Pyrenes (Albera and Canigó Massifs) determined on the
695 basis of zircon minor and trace element composition. *Journal of Geology* 119, 521-534.

- 696 Cawood, P.A., Nemchin, A.A., Strachan, R., Prave, T., Krabbendam, M., 2007. Sedimentary
697 basin and detrital zircon record along the East Laurentia and Baltica during assembly and
698 breakup of Rodinia. *Journal of the Geological Society, London* 164, 257-275.
- 699 Cawood, P.A., Strachan, R., Cutts, K., Kinny, P.D., Hand, M., Pisarevsky, S., 2010.
700 Neoproterozoic orogeny along the margin of Rodinia: Valhalla orogen, North Atlantic.
701 *Geology* 28, 99-102.
- 702 Cecil, M.R., Gehrels, G., Ducea, M.N., Patchett, P.J., 2011. U-Pb-Hf characterization of the
703 central Coast Mountains batholith: Implications for petrogenesis and crustal architecture.
704 *Lithosphere* 3, 247-260.
- 705 Chappell, B.W., White, J.R., 1974. Two contrasting granite types. *Pacific Geology* 8, 173-174.
- 706 Claiborne, L.L., Miller, C.F., Walker, B.A., Wooden, J.L., Madzab, F.K., Bea, F., 2006. Tracing
707 magmatic processes through Zr/Hf ratios in rocks and Hf and Ti zoning in zircons: An
708 example from the Spirit Mountain Batholith, Nevada. *Mineralogical Magazine* 70, 517-
709 543.
- 710 Claiborne, L.L., Miller, C.F., Wooden, J.L., 2010. Trace element composition of igneous zircon:
711 a thermal and compositional record of the accumulation and evolution of a large silicic
712 batholith, Spirit Mountain, Nevada. *Contributions to Mineralogy and Petrology* 160, 511-
713 531.
- 714 Colpron, M., Nelson, J., 2009. A Paleozoic Northwest Passage: incursion of Caledonian,
715 Baltican and Siberian terranes into eastern Panthalassa, and the early evolution of the
716 North American Cordillera, in: Cawood, P.A., and Kroner, A. (Eds.), *Earth accretionary
717 systems in space and time. Geological Society of London Special Publications* 318, 273-
718 307.
- 719 Davidson, A., 2008. Late Paleoproterozoic to mid-Neoproterozoic history of northern Laurentia:
720 An overview of central Rodinia. *Precambrian Research* 160, 5-22.
- 721 DePaolo, D.J., 1981. Trace element and isotopic effects of combined wallrock assimilation and
722 fractional crystallization. *Earth and Planetary Science Letters* 53, 189-202.

- 723 Frisch, T., 1974. Metamorphic and plutonic rocks of northernmost Ellesmere Island, Canadian
724 Arctic Archipelago. Geological Survey of Canada Bulletin 229, 1-87.
- 725 Frisch, T., Trettin, H.P., 1991. Precambrian successions in the northernmost part of the
726 Canadian Shield, in: Trettin, H.P. (Ed.), Geology of the Innuitian Orogen and Arctic
727 Platform of Canada and Greenland. Geological Society of America Geology of North
728 America E, 295-341.
- 729 Frost, B.R., Barnes, C.G., Collins, W.J., Arculus, R.J., Ellis, D.J., Frost, C.D., 2001. A
730 geochemical classification for granitic rocks. Journal of Petrology 42, 2033-2048.
- 731 Gasser, D., Andresen, A., 2013. Caledonian terrane amalgamation of Svalbard: Detrital zircon
732 provenance of Mesoproterozoic to Carboniferous strata from Oscar II Land, western
733 Spitsbergen. Geological Magazine 150, 1103-1126.
- 734 Gee, D.G., Johannsson, Å., Ohta, Y., Teben'kov, A.M., Krasil'schikov, A.A., Balashov, Y.A.,
735 Larionov, A.N., Gannibal, L.F., Ryungenen, G.I., 1995. Grenvillian basement and a
736 major unconformity within the Caledonides of Nordaustlandet, Svalbard. Precambrian
737 Research 70, 215-234.
- 738 Gee, D.G., Teben'kov, A.M., 1996. Two major unconformities beneath the Neoproterozoic
739 Murchisonfjorden Supergroup in the Caledonides of central Nordaustlandet, Svalbard.
740 Polar Research 15, 81-91.
- 741 Gee, D.G., Teben'kov, A.M., 2004. Svalbard: a fragment of the Laurentian margin, in: Gee,
742 D.G., Pease, V. (Eds.), The Neoproterozoic Timanide Orogen of Eastern Baltica.
743 Geological Society of London Memoir 30, 191-206.
- 744 Gehrels, G.E., Valencia, V., Pullen, A., 2006. Detrital zircon geochronology by laser-ablation
745 multicollector ICPMS at the Arizona Laserchron Center. Geochronology: Emerging
746 Opportunities, Paleontological Society Short Course. Paleontological Society Paper 12,
747 67-76.

- 748 Gehrels, G.E., Valencia, V.A., Ruiz, J., 2008. Enhanced precision, accuracy, efficiency and
749 spatial resolution of U-Pb ages by laser ablation-multicollector-inductively coupled
750 plasma-mass spectrometry. *Geochemistry Geophysics Geosystems* 9, 1-13.
- 751 Grimes, C.B., John, B.E., Kelemen, P.B., Mazdab, F.K., Wooden, J.L., Cheadle, M.J., Hanghøj,
752 K., Schwartz, J.J. 2007. Trace element chemistry of zircons from oceanic crust: A
753 method for distinguishing detrital zircon provenance. *Geology* 35, 643-646.
- 754 Grimes, C.B., Cheadle, M.J., Wooden, J.L., John, B.E. 2015. "Fingerprinting" tectono-
755 magmatic provenance using trace elements in igneous zircon. *Contributions to*
756 *Mineralogy and Petrology* 170, 46
- 757 Hadlari, T., Davis, W. J., and Dewing, K. 2014. A pericratonic model for the Pearya Terrane as
758 an extension of the Franklinian margin of Laurentia, Canadian Arctic. *Geological Society*
759 *of America Bulletin* 126, 182–200.
- 760 Harris, N.B.W., Pearce, J.A., Tindle, A.G., 1986. Geochemical characteristics of collision zone
761 magmatism, in: Coward, M.P., Ries, A.C. (Eds.). *Collision Tectonics*. Geological Society
762 of London Special Paper 19, 67-81.
- 763 Hoffman, P.F., 1988. United plates of America, the birth of a craton: Early Proterozoic growth
764 and assembly of Laurentia. *Annual Review of Earth and Planetary Sciences* 16, 543-603.
- 765 Hoskin, P.W.O., 2005. Trace-element composition of hydrothermal zircon and the alteration of
766 Hadean zircon from the Jack Hills, Australia. *Geochimica et Cosmochimica Acta* 69,
767 637-648.
- 768 Hoskin, P.W.O., Schaltegger, U., 2003. The composition of zircon and igneous and metamorphic
769 petrogenesis, in: Hanchar, J.M., Hoskin, P.W. (Eds), *Reviews in Mineralogy &*
770 *Geochemistry Volume 53: Zircon*, 27-62.
- 771 Johansson, A., Larionov, A.N., Teben'kov, A.M., Gee, D.G., Whitehouse, D.G., Vestin, J., 2000.
772 Grenvillian magmatism of western and central Nordauslandet, northeastern Svalbard.
773 *Transactions of the Royal Society, Edinburgh: Earth Sciences* 90, 221-254.

- 774 Johansson, A., Larionov, A.N., Gee, D.G., Ohta, Y., Teben'kov, A.M., Sandelin, S., 2004.
 775 Grenvillian and Caledonian tectono-magmatic activity in northeasternmost Svalbard, in:
 776 Gee, D.G., and Pease, V. (Eds.), *The Neoproterozoic Timanide Orogen of Eastern*
 777 *Baltica*. Geological Society of London Memoir 30, 207-232.
- 778 Johansson, A., Gee, D.G., Larionov, A.N., Ohta, Y., Teben'kov, A.M., 2005. Grenvillian and
 779 Caledonian evolution of eastern Svalbard – a tale of two orogenies. *Terra Nova* 17, 317-
 780 325.
- 781 Kalsbeek, F., Thrane, K., Nutman, A.P., Jepsen, H.F., 2000. Late Mesoproterozoic to early
 782 Neoproterozoic history of the East Greenland Caledonides: Evidence for Grenvillian
 783 orogenesis? *Journal of the Geological Society, London* 157, 1215–1225.
- 784 Kalsbeek, F., Higgins, A.K., Jepsen, H.F., Frei, R., Nutman, A.P., 2008. Granites and granites in
 785 the East Greenland Caledonides, in: Kalsbeek, F., Thrane, K., Higgins, A.K., Gilotti,
 786 J.A., and Smith, M.P. (Eds.), *The Greenland Caledonides: Evolution of the northeast*
 787 *margin of Laurentia*. Geological Society of America Memoir 202, 227-249.
- 788 Kirkland, C.L., Daly, J.S., Whitehouse, M.J., 2006. Granitic magmatism of Grenvillian and late
 789 Neoproterozoic age in Finnmark, Norway – Constraining pre-Scandian deformation in
 790 the Kalak Nappe Complex. *Precambrian Research* 145, 24-52.
- 791 Kirkland, C.L., Daly, J.S., Whitehouse, M.J., 2007. Provenance and terrane evolution of the
 792 Kalak Nappe Complex: Implications for Neoproterozoic paleogeography and tectonics.
 793 *The Journal of Geology* 115, 21-41.
- 794 Kirkland, C.L., Daly, J.S., Whitehouse, M.J., 2008. Basement-cover relationships of the Kalak
 795 Nappe Complex, Arctic Norwegian Caledonides and constraints on Neoproterozoic
 796 terrane assembly in the North Atlantic region. *Precambrian Research* 160, 245-276.
- 797 Kirkland, C.L., Pease, V., Whitehouse, M.J., Ineson, J.R., 2009. Provenance record from
 798 Mesoproterozoic-Cambrian sediments of Peary Land, North Greenland: Implications for
 799 the ice-covered Greenland Shield and Laurentian paleogeography. *Precambrian Research*
 800 170, 43-60.

- 801 Kirkland, C.L., Bingin, B., Whitehouse, M.J., Beyer, E., Griffin, W.L., 2011. Neoproterozoic
802 palaeogeography in the North Atlantic Region: Inferences from the Akkajaure and Seve
803 Nappes of the Scandinavian Caledonides. *Precambrian Research* 186, 127-146.
- 804 Klaper, E.M., 1992a. The Paleozoic tectonic evolution of the northern edge of North America: a
805 structural study of northern Ellesmere Island, Canadian Arctic Archipelago. *Tectonics* 11
806 (4), 854-870.
- 807 Klaper, E.M., 1992b. Correction to "The Paleozoic tectonic evolution of the northern edge of
808 North America: A structural study of northern Ellesmere Island, Canadian Arctic
809 Archipelago" by E. M. Klaper. *Tectonics* 11 (6), 1433-1437.
- 810 Klaper, E.M., Ohta, Y., 1993. Paleozoic metamorphism across the boundary between the
811 Clements Markham Fold Belt and the Pearya Terrane in northern Ellesmere Island,
812 Canadian Arctic Archipelago. *Canadian Journal of Earth Sciences* 30, 867-880.
- 813 Leslie, A.G., Nutman, A.P., 2003. Evidence for Neoproterozoic orogenesis and early high
814 temperature Scandian deformation events in the southern East Greenland Caledonides.
815 *Geological Magazine* 140, 309-333.
- 816 Li, Z.X., Bogdanova, S.V., Collins, A.S., Davidson, A., De Waele, B., Ernst, R.E., Fitzsimons,
817 I.C.W., Fuck, R.A., Gladkochub, D.P., Jacobs, J., Karlstrom, K.E., Lu, S., Natapov, L.M.,
818 Pease, V., Pisarevsky, A.A., Thrane, K., Vernikovsky, V., 2008. Assembly,
819 configuration, and break-up history of Rodinia: A synthesis. *Precambrian Research* 160,
820 179-210.
- 821 Lorenz, H., Gee, D. G., Larionov, A. N., and Majka, J. 2012. The Grenville-Sveconorwegian
822 Orogen in the high Arctic. *Geological Magazine* 149, 875–891.
- 823 Ludwig, K.R., 2003. User's manual for Isoplot 3.00: A geochronological toolkit for Microsoft
824 Excel. Berkley Geochronology Center Special Publication 4, 1-70.
- 825 Ludwig, K.R., 2005. Squid version 1.13b: A user's manual. Berkley Geochronology Center
826 Special Publication 2, 1-22.

- 827 Macdonald, F.A., McClelland, W.C., Schrag, D.P., Macdonald, W.P., 2009. Neoproterozoic
828 glaciation on a carbonate platform margin in Arctic Alaska and the origin of the North
829 Slope subterranean. *Geological Society of America Bulletin* 121, 448-473.
- 830 Madzab, F.K., Wooden, J.L., 2006. Trace element analysis in zircon by ion microprobe
831 (SHRIMP-RG): technique and applications. *Geochimica et Cosmochimica Acta* 70,
832 A405.
- 833 Majka, J., Be'eri-Shlevin, Y., Gee, D.G., Czerny, J., Frei, D., Ladenberger, A., 2014. Torellian
834 (c. 640 Ma) metamorphic overprint of Tonian (c. 950 Ma) basement in the Caledonides
835 of southwestern Svalbard. *Geological Magazine* 151, 732-748.
- 836 Malone, S.J., McClelland, W.C., von Gosen, W., Piepjohn, K., 2014. Proterozoic evolution of
837 the North Atlantic Caledonides: Insights from detrital zircon analysis of metasedimentary
838 rocks from the Pearya terrane, Canadian High Arctic. *Journal of Geology* 122, 623-648.
- 839 Maniar, P.D., Piccoli, P.M., 1989. Tectonic discrimination of granitoids. *Geological Society of*
840 *America Bulletin* 101, 635-643.
- 841 Mattinson, J.M., 2010. Analysis of the relative decay constants of ^{235}U and ^{238}U by multi-step
842 CA-TIMS measurements of closed-system natural zircon sample. *Chemical Geology*
843 275, 186–198.
- 844 Mayr, U., de Freitas, T., Beauchamp, B., Eisbacher, G., 1998. The Geology of Devon Island
845 north of 76°, Canadian Arctic Archipelago. *Geological Survey of Canada Bulletin* 526, 1-
846 500.
- 847 Mazdab, F.K., Wooden, J.L., 2006. Trace element analysis in zircon by ion microprobe
848 (SHRIMP-RG): technique and applications. *Geochimica et Cosmochimica Acta*, 70,
849 A405.
- 850 McClelland, W.C., Kusky, T., Bradley, D.C., Dumoulin, J., Harris, A.G., 1999. The nature of
851 Nixon Fork “basement”, west-central Alaska. *Geological Society of America, Abstracts*
852 *with Programs* 31, A-78.

- 853 McClelland, W.C., Malone, S.J., Gosen, W. von, Piepjohn, K., and Läufer, A., 2012a. The
 854 timing of sinistral displacement of the Pearya Terrane along the Canadian Arctic Margin.
 855 *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften (German Journal of*
 856 *Geosciences)* 163, 251-259.
- 857 McClelland, W.C., Malone, S.J., Gosen, W. von, Piepjohn, K., and Läufer, A., 2012b, Sinistral
 858 Displacement of the Pearya Terrane along the Canadian Arctic Margin: Abstract T34A-
 859 07 presented at 2012 Fall Meeting, AGU, San Francisco, Calif., 3-7 Dec.
- 860 McClelland, W.C., Schmidt, J.M., Till, A.M., 2006. New U-Pb SHRIMP ages from Devonian
 861 felsic volcanic and Proterozoic plutonic rocks of the southern Brooks Range, AK.
 862 *Geological Society of America, Abstracts with Programs* 38, 12.
- 863 McClelland, W.C., Strauss, J.V., Ward, W.P., Malone, S.J., Colpron, M., Piepjohn, K., Gosen,
 864 W. von, Macdonald, F.A., Gehrels, G., Gilotti, J.A., 2015. Evidence for a Paleozoic
 865 strike-slip orogen on the North American Arctic margin. *GSA Annual Meeting*
 866 (Baltimore, 1-4 November 2015), *Abstracts with Programs* 47, 7, p. 445.
- 867 Nelson, J.L., Colpron, M., Israel, S., 2013: The Cordillera of British Columbia, Yukon, and
 868 Alaska: Tectonics and metallogeny. *Society of Economic Geologists Special Publication*,
 869 17, 53-109.
- 870 O'Brien, T., Miller, E., 2014. Continuous zircon growth during long-lived granulite facies
 871 metamorphism: A microtextural, U-Pb, Lu-Hf, and trace element study of Caledonian
 872 rocks from the Chukchi Borderland, Arctic Ocean. *Contributions to Mineralogy and*
 873 *Petrology* 168, 1-19.
- 874 Ohta, Y., Larionov, A.N., 1998. Grenvillian single-grain zircon Pb age of a granitic rock from
 875 the southern island of Hesteskoholmen, Liefdefjorden, northwestern Spitsbergen,
 876 Svalbard. *Polar Research* 17, 147-154.
- 877 Ohta, Y., Larionov, A.N., Tebenkov, A.M., Lepvrier, C., Maluski, H., Lange, M., Hellebrandt,
 878 B., 2002. Single-zircon Pb-Evaporation and $^{40}\text{Ar}/^{39}\text{Ar}$ dating of the metamorphic and
 879 granitic rocks in north-west Spitsbergen. *Polar Research* 21, 73-89.

- Okulitch, A.V., 1991. Chapter 12. Silurian - Early Carboniferous deformational phases and associated metamorphism and plutonism, Arctic Islands. F. Late Devonian - Early Carboniferous deformation of the Central Ellesmere and Jones Sound fold belts, in: Trettin, H.P. (Ed.), *Geology of the Innuitian Orogen and Arctic Platform of Canada and Greenland*. Geological Society of America, *Geology of North America E*, 318-320.
- Pearce, J., 1996. Sources and settings of granitic rocks. *Episodes* 19, 120-125.
- Pearce, J.A., Harris, N.B.W., Tindle, A.G., 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. *Journal of Petrology* 25, 956-983.
- Pettersson, C.H., Teben'kov, A.M., Larionov, A.N., Andresen, A., Pease, V., 2009a. Timing of migmatization and granite genesis in the Northwestern Terrane of Svalbard, Norway: implications for regional correlations in the Arctic Caledonians. *Journal of the Geological Society, London* 166, 147-158.
- Pettersson, C. H., Pease, V., and Frei, D. 2009b. U-Pb zircon provenance of metasedimentary basement of the northwestern terrane, Svalbard: implications for the Grenvillian-Sveconorwegian Orogeny and development of Rodinia. *Precambrian Research* 175, 206–220.
- Peucat, J.J., Ohta, Y., Gee, D.G., Bernard-Griffiths, J., 1989. U/Pb, Sr and Nd evidence for Grenvillian and latest Proterozoic tectonothermal activity in the Spitsbergen Caledonides, Arctic Ocean. *Lithos* 22, 275-285.
- Pidgeon, R.T., Furfaro, D., Kennedy, A.K., Nemchin, A.A., van Bronswijk, W., Todt, W.A., 1994. Calibration of zircon standards for the Curtin SHRIMP II. Eighth International Conference on Geochronology, Cosmochronology and Isotope Geology. Berkeley, June 5-11, Abstracts, 251.
- Piepjohn, K., Gosen, W. von, Läufer, A., McClelland, W.C., Estrada, S., 2013. Ellesmerian and Eurekan fault tectonics at the northern margin of Ellesmere Island (Canadian High Arctic). *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften (German Journal of Geosciences)* 164 (1), 81-105.

- 907 Piepjohn, K., Gosen, W. von, Tessensohn, F., Reinhardt, L., McClelland, W.C., Dallmann, W.,
 908 Gaedicke, C., Harrison, J.C., 2015. Tectonic map of the Ellesmerian and Eurekan
 909 deformation belts on Svalbard, North Greenland, and the Queen Elizabeth Islands
 910 (Canadian Arctic). *Arktos*, 1 (12), 1-7.
- 911 Rogers, G., Hawkesworth, C.J., 1989. A geochemical traverse across the North Chilean Andes:
 912 evidence for crustal generation from the mantle wedge. *Earth and Planetary Science*
 913 *Letters* 91, 271-285.
- 914 Rubatto, D., 2002. Zircon trace element geochemistry: Partitioning with garnet and the link
 915 between U-Pb ages and metamorphism. *Chemical Geology* 184, 123-138.
- 916 Schaltegger, U., Fanning, C.M., Günther, D., Maurin, J.C., Schulmann, K., Gebauer, D., 1999.
 917 Growth, annealing, and recrystallization of zircon and preservation of monazite in
 918 highgrade metamorphism: conventional and in-situ U-Pb isotope, cathodoluminescence,
 919 and microchemical evidence. *Contributions to Mineralogy and Petrology* 134, 186-201.
- 920 Shand, S.J. 1943. *The Eruptive Rocks*, 2nd Ed. John Wiley, New York. 444p.
- 921 Sinha, A.K., Frish, T., 1976a. Whole rock Rb/Sr and zircon U/Pb ages of metamorphic rocks
 922 from Northern Ellesmere Island, Canadian Arctic Archipelago I. The gneiss region
 923 between Ayles Fiord and Yelverton Inlet. *Canadian Journal of Earth Sciences* 12, 90-94.
- 924 Sinha, A.K., Frish, T., 1976b. Whole rock Rb/Sr and zircon U/Pb ages of metamorphic rocks
 925 from Northern Ellesmere Island, Canadian Arctic Archipelago II. The Cape Columbia
 926 Complex. *Canadian Journal of Earth Sciences* 13, 774-780.
- 927 Soper, N.J., Higgins, A.K., 1991. Chapter 11. Devonian - Early Carboniferous deformation and
 928 metamorphism, North Greenland. A. Deformation, in: Trettin, H.P. (Ed.), *Geology of the*
 929 *Innuitian Orogen and Arctic Platform of Canada and Greenland*. Geological Society of
 930 America, *Geology of North America E*, 283-288.
- 931 Stacey, J.S., Kramers, J.D., 1975. Approximation of terrestrial lead isotope evolution by a two-
 932 stage model. *Earth and Planetary Science Letters* 26, 207-221.

- 933 Stipp, M., Stünitz, H., Heilbronner, R., Schmid, S.M., 2002. The eastern Tonale fault zone: a
 934 'natural laboratory' for crystal plastic deformation of quartz over a temperature range
 935 from 250 to 700°C. *Journal of Structural Geology* 24, 1861-1884.
- 936 Strachan, R.A., Nutman, A.P., Friderichsen, J.D., 1995. SHRIMP U/Pb geochronology and
 937 metamorphic history of the Smallefjord sequence, NE Greenland Caledonides. *Journal of*
 938 *the Geologic Society, London* 152, 779-784.
- 939 St.-Onge, M.R., Van Gool, J.A.M., Garde, A.A., Scott, D.J., 2009. Correlation of Archaean and
 940 Paleoproterozoic units between northeastern Canada and western Greenland:
 941 Constraining the pre-collisional upper plate accretionary history of the Trans-Hudson
 942 orogeny, in: Cawood, P.A., and Kroner, A. (Eds.), *Earth accretionary systems in space*
 943 *and time. The Geological Society, London, Special Publication* 318, 193-235.
- 944 Sun, S.S., McDonough, W.F., 1989. Chemical and isotope systematics of oceanic basalts:
 945 implications for mantle composition and processes, in: Saunders, A.D., Norry, M.J.
 946 (Eds.), *Magmatism in the Ocean Basins. Geological Society, London, Special Publication*
 947 42, 313-345.
- 948 Taylor, P.N., Kalsbeek, F., Bridgwater, D., 1992. Discrepancies between neodymium, lead and
 949 strontium model ages from the Precambrian of southern East Greenland: Evidence for a
 950 Proterozoic granulite-facies event affecting Archaean gneisses. *Chemical Geology* 94,
 951 281–291.
- 952 Thompson, J.A., 2011. Uranium series analysis of 2006 Augustine volcanics: an investigation
 953 into the timescales of magmatic processes. M. Sc. Thesis. University of Iowa, 79-97.
- 954 Trettin, H.P., 1987. Pearya: A composite terrane with Caledonian affinities in northern Ellesmere
 955 Island. *Canadian Journal of Earth Sciences* 24, 224-245.
- 956 Trettin, H.P., 1991a. Chapter 4. Tectonic Framework, in: Trettin, H.P. (Ed.), *Geology of the*
 957 *Innuitian Orogen and Arctic Platform of Canada and Greenland. Geological Society of*
 958 *America, Geology of North America E*, 59-66.

- 959 Trettin, H.P., 1991b. Chapter 12. Silurian-Early Carboniferous deformational phases and
 960 associated metamorphism and plutonism, Arctic Islands, in: Trettin, H.P. (Ed.), Geology
 961 of the Innuitian Orogen and Arctic Platform of Canada and Greenland. Geological
 962 Society of America, Geology of North America E, 295-341.
- 963 Trettin, H.P., 1991c. Chapter 9. The Proterozoic to Late Silurian record of Pearya. In Trettin,
 964 H.P. (Ed.), Geology of the Innuitian Orogen and Arctic Platform of Canada and
 965 Greenland. Geological Society of America, Geology of North America E, 241-259.
- 966 Trettin, H.P., 1991d. Chapter 12. Silurian - Early Carboniferous deformational phases and
 967 associated metamorphism and plutonism, Arctic Islands. E. Middle Devonian to Early
 968 Carboniferous deformations, northern Ellesmere and Axel Heiberg Islands, In: Trettin,
 969 H.P. (Ed.), Geology of the Innuitian Orogen and Arctic Platform of Canada and
 970 Greenland. Geological Society of America, Geology of North America E, 309-317.
- 971 Trettin, H.P., 1998. Pre-Carboniferous geology of the northern part of the Arctic Islands.
 972 Chapter 4: Geology of Pearya. Geological Survey of Canada Bulletin 425, 108-192.
- 973 Trettin, H.P., Loveridge, W.D., Sullivan, R.W., 1982. U/Pb ages on zircons from the M'Clintock
 974 West massif and the Markham Fiord pluton, northernmost Ellesmere Island. Current
 975 Research, Part C, Geological Society of Canada Paper 82-1C, 161-166
- 976 Trettin, H.P., Loveridge, W.D., Sullivan, R.W., 1982. U/Pb ages on zircons from the M'Clintock
 977 West massif and the Markham Fiord pluton, northernmost Ellesmere Island, in: Rb-Sr
 978 and U-Pb isotopic age studies, Report 5. Current Research, Part C, Geological Survey of
 979 Canada Paper 82-1C, 161-166.
- 980 Trettin, H.P., Parrish, R.R., Roddick, J.C., 1992. New U-Pb and ^{40}Ar - ^{39}Ar age determinations
 981 from northern Ellesmere and Axel Heiberg islands, Northwest Territories and their
 982 tectonic significance, in: Radiogenic age and isotopic studies: Report 6. Geological
 983 Survey of Canada Paper 92-2, 3-30.

- 984 von Gosen, W., Piepjohn, K., McClelland, W.C., Läufer, A., 2012. The Pearya Shear Zone in
 985 the Canadian High Arctic: kinematics and significance. *Zeitschrift der Deutschen*
 986 *Gesellschaft für Geowissenschaften (German Journal of Geosciences)* 163, 233-249.
- 987 Watt, G.R., Kinny, P.D., Fridrichsen, F.D., 2000. U/Pb geochronology of Neoproterozoic and
 988 Caledonian tectonothermal events in the East Greenland Caledonides. *Journal of the*
 989 *Geological Society, London* 157, 1031-1048.
- 990 Watt, G.R., Thrane, K., 2001. Early Neoproterozoic events in East Greenland. *Precambrian*
 991 *Research* 110, 165-184.
- 992 Whitney, D.L., Evans, B.W., 2010. Abbreviations for names of rock-forming minerals.
 993 *American Mineralogist* 95, 185-187.
- 994 Williams, I.S., 1998. U-Th-Pb geochronology by ion microprobe, in: McKibben, M.A., et al.
 995 (Eds), *Applications of microanalytical techniques to understand mineralizing processes.*
 996 *Reviews in Economic Geology* 7, 1-35.
- 997 Wood, D.A., 1980. The application of a Th-Hf-Ta diagram to problems of tectonomagmatic
 998 classification and establishing the nature of crustal contamination of basaltic lavas of the
 999 British Tertiary Volcanic province. *Earth and Planetary Science Letters* 50, 11-30.
- 1000 Wood, D.A., Joron, J.L., Treuil, M., 1979. A re-appraisal of the use of trace elements to classify
 1001 and discriminate between magma series erupted in different tectonic settings. *Earth and*
 1002 *Planetary Sciences Letters* 45, 326-336.
- 1003 Wooden, J.L., Madzab, F.K., Barth, A.P., Miller, C.F., Lowery, L.E., 2006. Temperatures (Ti)
 1004 and compositional characteristics of zircon: Early observations using high mass
 1005 resolution on the USGS-Stanford SHRIMP-RG. *Geochimica et Cosmochimica Acta* 70,
 1006 A707.
- 1007 Wooden, J.L., Mazdab, F.K., Barth, A.P., 2007. Hafnium and temperature (from titanium)
 1008 variations in zircons: A potential new tool to evaluate petrologic processes in magmas.
 1009 *GSA Abstracts with Programs* 39, 406.

- 1010 Zindler, A., Hart, S., 1986. Chemical Geodynamics. Annual Review of Earth and Planetary
1011 Science 14, 493-571.
1012

Table 1: Sample locations

Sample	Lithology	Latitude	Longitude	Belt
08-153	Garnet two-mica granodioritic orthogneiss	83.10651	-70.24366	Cape Columbia
08-154	Garnet two-mica granitic orthogneiss	83.10632	-70.02512	Cape Columbia
08-178	Two-mica granitic mylonitic orthogneiss	82.27776	-80.94899	Deuchers Glacier
08-102	Chlorite biotite granodioritic orthogneiss	82.22451	-82.65575	Mitchell Point
08-103	Garnet biotite tonalitic orthogneiss	82.44505	-81.63486	Mitchell Point
08-191	Two-mica granitic orthogneiss	82.60574	-81.38544	Mitchell Point
08-134	Two-mica granodioritic orthogneiss	82.472921	-81.39229	Petersen Bay pluton

Table 2. Orthogneiss major oxide and trace element composition data.

	08-153	08-154	08-178	08-102	08-103	08-191	08-134
Major element oxide (wt %)							
SiO₂	63.9	63.3	72.5	61.8	72.5	74.0	62.3
TiO₂	0.89	1.1	0.25	0.87	0.39	0.19	0.94
Al₂O₃	15.87	16.53	14.02	15.54	13.95	14.69	16.18
FeO*	6.69	6.81	2.20	6.62	2.93	1.41	6.03
MnO	0.12	0.09	0.03	0.16	0.03	0.02	0.11
MgO	1.90	2.34	0.46	1.43	1.89	0.86	1.58
CaO	4.11	2.24	1.27	8.63	1.66	0.37	5.74
K₂O	2.79	4.44	5.81	0.59	2.12	1.39	2.54
Na₂O	2.88	2.33	2.86	3.27	4.11	6.79	3.82
P₂O₅	0.09	0.05	0.35	0.36	0.14	0.17	0.09
Total	99.25	99.24	99.76	99.26	99.67	99.84	99.33
Trace elements (ppm)							
Li	19.1	29.2	-0.3	3.5	5.9	0.4	0.9
Sc	7.1	7.7	2.8	6.9	7.4	3.2	3.9
Ti	5518.3	6369.9	1519.6	5893.9	5748.2	1080.9	2237.9
V	142.2	134.2	79.0	105.0	186.6	49.4	98.2
Cr	34.1	74.6	5.3	28.6	20.1	3.6	12.3
Ni	22.4	34.0	6.8	20.4	12.5	4.6	39.1
Cu	31.8	29.6	14.4	27.7	28.4	9.9	11.7
Zn	92.0	134.7	31.8	86.7	80.0	20.4	26.0
Ga	21.9	22.7	20.8	22.6	22.0	20.2	20.5
Rb	38.4	148.5	179.5	67.5	35.3	50.8	76.6
Sr	184.4	143.4	79.3	201.3	218.1	26.3	93.6
Y	32.7	38.8	32.9	27.9	25.3	8.6	8.4
Zr	378.8	282.9	128.7	387.6	438.0	105.8	143.6
Nb	16.1	20.8	10.2	19.3	18.6	7.8	11.8
Cs	2.1	4.6	2.2	3.0	2.2	0.8	1.8
Ba	557.1	531.3	275.7	795.5	557.4	35.7	189.5
Hf	9.8	7.6	3.9	10.0	10.7	3.3	3.8
Ta	0.8	0.9	0.8	1.0	0.9	0.8	0.8
Pb	19.9	20.3	25.6	26.4	12.1	2.6	4.7
Th	19.9	18.4	7.6	29.3	5.2	7.1	11.9
U	1.1	2.3	2.0	1.5	1.3	1.8	1.5
Rare Earth elements (ppm)							
La	56.8	43.0	16.0	71.7	33.4	15.7	36.6
Ce	123.0	94.8	36.5	156.0	70.0	45.0	75.9
Pr	15.2	11.6	4.1	19.3	8.4	4.0	7.3
Nd	59.8	44.9	15.6	75.0	34.2	14.1	23.6
Sm	11.4	9.2	4.0	14.6	6.3	2.5	3.3
Eu	1.5	1.0	0.3	1.7	2.0	0.1	0.5
Gd	7.8	6.6	3.5	9.4	4.4	1.3	1.4
Tb	1.3	1.2	0.8	1.3	0.8	0.3	0.3
Dy	6.5	6.8	5.6	6.1	4.5	1.8	1.8
Ho	1.2	1.4	1.2	1.1	0.9	0.3	0.3
Er	3.2	3.8	3.1	2.6	2.6	1.0	0.9
Yb	3.0	3.5	2.6	2.5	2.6	0.9	0.9
Lu	0.5	0.5	0.4	0.4	0.4	0.1	0.1

Table 3: Orthogneiss whole-rock Nd and age corrected Pb isotope data. Please see Appendix D for analytical details.

Sample	Sm ppm	Nd ppm	$\frac{^{147}\text{Sm}}{^{144}\text{Nd}}$ (0)	$\frac{^{143}\text{Nd}}{^{144}\text{Nd}}$ (0)	$\frac{^{143}\text{Nd}}{^{144}\text{Nd}}$ 1 σ error	T _{DM} (Ma)	$\epsilon\text{Nd (i)}$	$\frac{^{208}\text{Pb}}{^{204}\text{Pb}}$	$\frac{^{207}\text{Pb}}{^{204}\text{Pb}}$	$\frac{^{206}\text{Pb}}{^{204}\text{Pb}}$
08-153	11.41	59.76	0.120260	0.5119209	0.000005	1998	-4.54	36.506	15.503	17.354
08-154	9.18	44.92	0.128693	0.5119732	0.000004	2102	-4.61	36.424	15.495	17.145
08-178	4.01	15.64	0.161697	0.5122234	0.000005	2700	-3.74	36.772	15.497	17.329
08-102	14.63	75.01	0.122864	0.5119485	0.000004	2009	-4.36	37.327	15.506	17.391
08-103	6.34	34.16	0.116880	0.5119354	0.000005	1906	-3.93	37.579	15.498	17.418
08-191	2.53	14.14	0.112750	0.5120579	0.000007	1645	-0.97	31.711	15.245	13.939
08-134	3.31	23.60	0.088372	0.511833	0.000006	1598	-2.40	33.285	15.495	17.201

Table 4: Summary of data from this study.

Sample	Lithology	Belt	Concordia Age (Ma)	Age Err.	$\epsilon\text{Nd (i)}$	$\frac{^{206}\text{Pb}}{^{204}\text{Pb}}$	Tectonic setting
08-153	Garnet two-mica granodioritic orthogneiss	Cape Columbia	972	± 7	-4.54	17.3541	Volc. Arc
08-154	Garnet two-mica granitic orthogneiss	Cape Columbia	969	± 6	-4.61	17.1454	Volc. Arc
08-178	Two-mica granitic mylonitic orthogneiss	Deuchers Glacier	972	± 4	-3.74	17.3293	Volc. Arc
08-102	Chlorite biotite granodioritic orthogneiss	Mitchell Point	964	± 6	-4.36	17.3913	Volc. Arc
08-103	Garnet biotite tonalitic orthogneiss	Mitchell Point	966	± 5	-3.93	17.418	Volc. Arc
08-191	Two-mica granitic orthogneiss	Mitchell Point	965	± 5	-0.97	13.9385	Volc. Arc
08-134	Two-mica granodiorite	Petersen Bay pluton	964	± 6	-2.40	17.201	Volc. Arc

Appendix A: Zircon SHRIMP U-Pb data

Spot Name	U (ppm)	Th (ppm)	$^{232}\text{Th} / ^{238}\text{U}$	^{206}Pb c	$^{238}\text{U} / ^{206}\text{Pb}^*$	% err.	$^{207}\text{Pb}^* / ^{206}\text{Pb}^*$	% err.	^{207}Pb corr. ^{206}Pb / ^{238}U Age	1 σ err.	^{204}Pb corr. ^{207}Pb / ^{206}Pb Age	1 σ err.
SAMPLE: 08-153. Garnet two mica granodioritic orthogneiss, Cape Columbia belt												
08153-1.1	1573	58	0.04	0.05	6.32	0.9	.0710	0.4	945.9	8.2	958	7.8
08153-2.1	193	4	0.02	-0.16	6.15	1.0	.0698	1.2	973.7	9.9	923	24.2
08153-3.1	211	80	0.39	-0.17	6.05	1.0	.0704	1.1	987.7	9.8	940	22.0
08153-4.1	253	27	0.11	-0.02	6.20	1.1	.0706	1.1	965.4	10.5	945	22.2
08153-5.1	341	35	0.10	-0.04	6.09	1.0	.0713	0.8	981.2	9.0	966	16.9
08153-6.1	127	51	0.42	0.15	6.10	1.1	.0730	1.3	977.9	10.2	1013	27.1
08153-7.1	147	24	0.17	0.12	6.28	1.1	.0715	1.3	952.4	10.1	971	26.9
08153-8.1	285	24	0.09	0.14	6.60	1.0	.0703	0.9	908.7	8.5	939	19.4
08153-9.1	210	115	0.57	-0.12	3.47	1.0	.0995	0.7	1632.7	16.0	1614	13.5
08153-10.1	339	59	0.18	-0.03	6.05	1.0	.0718	0.9	987.0	9.3	979	17.9
08153-11.1	195	112	0.60	0.07	6.08	1.1	.0710	1.5	982.6	10.3	957	30.1
08153-12.1	2205	69	0.03	0.06	6.24	0.9	.0715	0.4	957.6	8.3	973	7.4
08153-13.1	221	22	0.11	0.05	6.16	1.0	.0718	1.1	969.8	9.6	981	22.7
08153-14.1	153	125	0.84	-0.14	6.03	1.1	.0703	1.5	991.7	10.4	938	30.5
08153-15.1	327	157	0.50	-0.05	6.19	1.1	.0709	0.9	965.8	10.6	953	19.1
SAMPLE: 08-154. Garnet two mica granodioritic orthogneiss, Cape Columbia belt												
08154-1.1	549	178	0.34	0.27	3.22	0.3	.1088	0.8	1741.2	5.5	1780	14.6
08154-2.1	414	13	0.03	0.01	6.21	0.4	.0664	2.0	968.5	3.7	818	42.0
08154-3.1	300	11	0.04	0.16	6.40	0.5	.0682	1.8	938.7	4.1	875	38.0
08154-4.1	839	511	0.63	0.37	3.54	0.3	.1016	0.4	1598.2	4.0	1653	6.9
08154-5.1	386	18	0.05	0.28	6.07	0.4	.0732	1.3	981.6	3.9	1020	27.3
08154-6.1	437	76	0.18	0.39	3.50	0.4	.1027	1.4	1616.1	6.7	1673	26.7
08154-7.1	183	99	0.56	0.02	6.21	0.6	.0698	1.9	964.4	5.3	923	38.5
08154-8.1	90	66	0.75	0.15	3.65	0.9	.0944	2.6	1565.8	14.0	1516	48.3
08154-9.1	491	9	0.02	0.25	6.47	0.4	.0696	1.8	927.0	3.3	916	36.7
08154-10.1	325	13	0.04	0.10	6.38	0.5	.0687	1.4	940.2	4.7	889	29.1
08154-11.1	1074	415	0.40	0.23	4.74	0.2	.0829	0.4	1231.5	2.8	1267	8.1
08154-12.1	449	17	0.04	0.22	6.29	0.4	.0706	1.2	951.1	3.4	946	25.3
08154-13.1	254	25	0.10	1.18	6.29	0.6	.0704	3.0	951.1	5.5	939	62.2
08154-14.1	48	21	0.46	-0.09	5.36	1.4	.0591	10.7	1124.3	12.2	570	233.5
08154-15.1	200	25	0.13	-0.14	6.13	0.6	.0683	2.8	977.2	5.5	879	57.1
08154-16.1	369	13	0.04	0.01	6.33	0.4	.0704	0.8	946.2	3.8	940	16.6
08154-17.1	283	46	0.17	0.04	3.26	0.5	.1061	2.0	1725.6	9.4	1733	36.1
08154-18.1	193	134	0.72	0.18	4.23	0.6	.0874	1.6	1366.3	8.0	1370	30.3
08154-19.1	421	110	0.27	0.66	3.36	0.4	.1077	0.5	1669.6	6.3	1761	8.9
08154-20.1	364	77	0.22	0.26	4.92	0.4	.0812	0.9	1190.2	4.9	1226	17.8
08154-21.1	417	91	0.23	0.19	5.70	0.4	.0743	0.9	1041.2	4.0	1051	17.8
08154-22.1	60	12	0.21	-0.07	6.36	1.2	.0595	7.9	952.9	9.9	585	171.7
08154-23.1	512	115	0.23	-0.04	3.15	0.4	.1080	1.3	1778.6	7.4	1766	23.0
08154-24.1	112	39	0.36	0.52	3.94	0.7	.0944	1.4	1452.9	10.3	1516	25.8
08154-25.1	306	7	0.02	-0.01	6.21	0.5	.0696	1.4	964.3	4.4	918	28.4
08154-26.1	150	36	0.25	0.14	6.11	0.7	.0712	1.7	977.0	6.6	964	34.1
08154-27.1	70	26	0.38	0.11	6.34	1.1	.0645	5.2	951.2	9.5	759	108.7
08154-28.1	161	61	0.40	0.31	5.04	0.7	.0782	1.6	1166.7	7.5	1152	31.3
08154-29.1	312	52	0.17	0.40	6.06	0.6	.0726	1.3	983.4	5.3	1001	27.3
08154-30.1	584	193	0.34	0.92	3.74	0.3	.1018	1.6	1514.0	5.5	1657	29.2

08154-31.1	127	95	0.77	0.69	3.63	0.8	.1023	0.8	1558.0	12.2	1666	15.6
08154-32.1	307	32	0.11	-0.08	5.80	0.5	.0721	0.9	1027.7	4.9	987	18.6
08154-33.1	436	80	0.19	0.46	5.86	0.4	.0761	1.2	1011.9	4.1	1097	23.4
08154-34.1	585	186	0.33	0.23	3.17	0.3	.1095	0.4	1766.9	5.5	1792	7.1
08154-35.1	472	344	0.75	-0.06	6.06	0.5	.0707	0.8	985.8	4.3	948	15.7
08154-36.1	195	123	0.65	0.09	3.68	0.7	.0965	0.9	1550.1	11.1	1557	16.6
08154-37.1	547	140	0.26	0.16	6.22	0.4	.0711	1.0	960.5	3.5	959	20.4
08154-38.1	268	234	0.90	0.29	5.74	0.5	.0742	1.7	1034.1	4.9	1048	34.2
08154-39.1	408	98	0.25	0.07	6.22	0.4	.0700	1.0	962.5	3.8	927	20.8

SAMPLE: 08-178. Garnet two mica granitic orthogneiss, Deuchers Glacier belt

08178-1.1	874	57	0.07	0.05	6.28	1.0	.0712	0.6	951.9	9.5	963	11.4
08178-2.1	184	98	0.55	0.04	6.18	1.2	.0708	1.4	967.0	11.3	951	27.9
08178-3.1	185	32	0.18	0.19	6.26	1.2	.0719	1.3	954.8	11.1	982	26.5
08178-4.1	1059	61	0.06	0.05	6.17	1.0	.0717	0.5	968.3	9.5	978	10.0
08178-5.1	205	53	0.27	0.14	6.18	1.2	.0713	1.6	966.9	11.2	966	32.2
08178-6.1	432	33	0.08	0.01	6.16	1.1	.0719	0.8	969.3	10.1	984	16.9
08178-7.1	687	47	0.07	-0.01	6.09	1.0	.0717	0.6	979.7	9.9	978	12.8
08178-8.1	847	51	0.06	0.04	6.13	1.0	.0715	0.6	974.7	9.7	972	12.4
08178-9.1	345	53	0.16	-0.03	6.11	1.1	.0713	0.9	977.4	10.6	967	19.0
08178-10.1	324	63	0.20	0.09	6.12	1.1	.0729	1.0	974.0	10.6	1012	20.5
08178-11.1	496	48	0.10	0.15	6.15	1.1	.0719	1.0	970.7	10.3	983	20.3
08178-12.1	1142	70	0.06	0.84	6.15	1.0	.0716	1.5	971.8	9.5	974	29.6
08178-13.1	958	117	0.13	0.05	6.15	1.0	.0715	0.6	971.0	9.6	972	11.3
08178-14.1	118	64	0.57	0.26	3.47	1.3	.1021	1.0	1627.3	20.0	1662	17.7
08178-15.1	437	137	0.32	0.93	4.00	1.1	.0960	1.0	1430.2	14.8	1549	18.3

SAMPLE: 08-102. Chlorite biotite tonalitic orthogneiss, Mitchell Point belt

08102-1.1	198	41	0.21	-0.02	6.18	1.2	.0701	1.4	967.7	11.2	930	28.9
08102-2.1	150	42	0.29	0.25	6.17	1.3	.0734	1.3	966.7	11.7	1024	26.1
08102-3.1	125	35	0.29	-0.27	6.05	1.3	.0685	1.8	990.3	12.7	884	36.3
08102-4.1	198	28	0.14	-0.08	6.20	1.2	.0706	1.1	965.2	11.1	945	23.1
08102-5.1	174	24	0.14	0.17	6.22	1.2	.0720	1.3	959.8	11.6	985	27.2
08102-6.1	655	12	0.02	-0.13	6.14	1.0	.0702	0.7	974.5	9.9	933	13.8
08102-7.1	200	28	0.14	0.02	6.16	1.2	.0713	1.2	969.7	11.2	967	24.3
08102-8.1	312	38	0.13	-0.13	5.96	1.1	.0718	1.0	1001.5	10.8	981	19.4
08102-9.1	196	68	0.36	-0.07	6.16	1.2	.0701	1.3	970.8	11.3	930	26.7
08102-10.1	146	28	0.20	-0.15	6.17	1.3	.0695	1.5	970.3	12.0	915	31.9
08102-11.1	143	80	0.58	0.66	3.80	1.2	.0989	1.3	1499.3	17.5	1603	23.3
08102-12.1	362	68	0.19	0.00	6.25	1.1	.0715	0.9	956.9	10.5	970	18.1
08102-13.1	308	42	0.14	0.48	5.20	1.1	.0809	1.1	1130.3	12.1	1218	21.7
08102-14.1	187	44	0.24	-0.15	6.15	1.2	.0709	1.3	971.2	11.2	954	27.3
08102-15.1	123	32	0.27	-0.24	6.31	1.3	.0675	2.5	951.4	12.0	854	52.0

SAMPLE: 08-103. Garnet biotite granodioritic orthogneiss, Mitchell Point belt

08103-1.1	206	68	0.34	0.01	6.38	1.1	.0705	1.1	938.8	10.2	942	22.1
08103-2.1	257	82	0.33	0.10	6.28	1.1	.0710	1.0	952.5	10.1	958	21.4
08103-3.1	138	77	0.57	-0.08	6.24	1.2	.0692	1.5	959.6	11.0	906	30.3
08103-4.1	341	90	0.27	0.12	6.40	1.1	.0716	0.9	934.8	9.7	973	18.0
08103-5.1	297	103	0.36	0.08	6.18	1.1	.0719	0.9	966.5	10.2	982	18.8
08103-6.1	222	87	0.41	0.02	6.32	1.1	.0708	1.1	947.4	10.3	952	21.9
08103-7.1	89	63	0.73	-0.07	5.38	1.3	.0762	1.6	1099.6	14.0	1100	31.1
08103-8.1	216	114	0.55	0.43	6.78	1.1	.0715	1.3	884.2	9.8	972	26.9
08103-9.1	593	128	0.22	0.72	3.73	1.1	.1008	0.6	1519.9	15.6	1639	10.3
08103-10.1	230	104	0.47	0.00	6.19	1.2	.0713	1.0	965.7	11.4	965	21.4

08103-11.1	306	153	0.52	0.47	6.53	1.1	.0727	1.0	915.3	9.8	1006	21.0
08103-12.1	288	81	0.29	-0.16	6.17	1.1	.0701	1.0	970.4	10.5	932	20.5
08103-13.1	665	429	0.67	0.01	6.15	1.0	.0714	0.6	971.0	9.8	970	12.5
08103-14.1	289	73	0.26	0.15	6.33	1.1	.0721	1.0	943.9	10.2	990	19.3

SAMPLE: 08-191. Two mica granodioritic orthogneiss, Mitchell Point belt

08191-1.1	749	195	0.27	-0.02	6.16	1.1	.0712	0.6	970.1	9.9	963	13.2
08191-2.1	258	206	0.82	0.04	6.05	1.2	.0721	1.0	985.4	11.4	989	20.7
08191-3.1	519	195	0.39	-0.02	6.36	1.1	.0705	0.8	941.4	9.8	944	16.4
08191-4.1	2298	668	0.30	0.06	6.22	1.0	.0716	0.4	960.7	9.3	975	7.4
08191-5.1	4582	704	0.16	0.26	6.85	1.0	.0691	0.6	877.4	8.6	902	13.2
08191-6.1	279	191	0.71	0.06	6.21	1.1	.0723	1.2	960.6	10.6	995	25.0
08191-7.1	189	132	0.72	-0.09	6.27	1.2	.0693	1.4	956.0	11.2	909	29.2
08191-8.1	226	65	0.30	0.06	6.26	1.2	.0718	1.1	955.0	10.9	980	23.3
08191-9.1	1158	172	0.15	-0.23	5.84	1.0	.0712	0.6	1021.5	10.1	964	11.4
08191-10.1	1320	205	0.16	-0.08	6.12	1.0	.0705	0.5	976.8	9.6	943	10.7
08191-11.1	600	387	0.67	-0.02	6.13	1.1	.0714	0.7	974.7	9.9	968	14.3
08191-12.1	234	105	0.46	-0.06	6.19	1.1	.0700	1.6	966.5	10.6	930	31.9
08191-13.1	187	294	1.62	0.22	4.04	1.1	.0917	0.8	1421.3	15.7	1462	14.7
08191-14.1	501	234	0.48	0.06	3.61	1.0	.0979	0.4	1577.0	15.9	1585	8.3
08191-15.1	625	138	0.23	0.11	6.34	1.0	.0713	0.8	943.3	9.5	966	17.0

SAMPLE: 08-134. Two mica granodioritic orthogneiss, Petersen Bay Pluton

08134-1.1	69	37	0.55	0.40	6.32	1.0	.0700	3.8	947.7	8.8	929	77.8
08134-2.1	168	42	0.26	-0.02	6.28	0.6	.0679	2.2	956.2	5.8	866	45.2
08134-3.1	72	32	0.47	0.09	6.21	1.1	.0637	4.9	970.2	10.2	731	103.9
08134-4.1	151	84	0.57	-0.27	6.24	0.7	.0649	2.5	965.7	6.2	771	53.3
08134-5.1	133	78	0.61	-0.01	6.24	0.9	.0696	1.8	960.2	8.2	915	36.7
08134-6.1	158	95	0.62	0.21	6.43	0.8	.0672	3.7	935.4	7.4	843	76.7
08134-7.1	52	22	0.43	0.16	6.21	1.2	.0703	5.0	963.1	10.9	936	101.6
08134-8.1	177	91	0.53	0.12	6.33	0.7	.0661	3.7	950.5	5.6	811	77.6
08134-9.1	48	25	0.54	0.02	6.36	1.6	.0449	19.1	968.8	11.2	-61	466.8
08134-10.1	137	101	0.76	-0.09	6.18	0.7	.0679	2.7	970.9	6.6	866	56.5
08134-11.1	287	166	0.60	0.17	6.45	0.5	.0685	1.8	930.9	4.3	883	36.5
08134-12.1	142	67	0.49	0.14	6.39	0.7	.0648	3.4	942.6	6.3	769	71.5
08134-13.1	100	71	0.74	-0.21	6.18	0.9	.0689	1.7	969.0	8.0	895	35.6
08134-14.1	97	54	0.58	0.25	6.25	0.9	.0712	2.9	955.9	7.7	962	58.9
08134-15.1	118	72	0.63	0.15	6.37	0.8	.0694	2.3	941.7	6.8	911	47.3
08134-16.1	235	172	0.76	0.21	6.51	0.6	.0687	2.7	922.8	5.4	890	56.1
08134-17.1	288	178	0.64	-0.07	6.09	1.1	.0693	1.4	983.1	10.4	908	29.7
08134-18.1	236	143	0.63	-0.10	6.24	0.6	.0694	1.2	959.7	5.7	909	24.5
08134-19.1	150	79	0.54	0.12	6.24	0.7	.0687	1.9	960.9	6.4	890	39.5
08134-20.1	118	82	0.71	0.42	6.25	0.8	.0720	2.1	956.3	7.6	987	42.5

Notes:

All analyses were performed on the SHRIMP-RG Ion Microprobe at the United States Geological Survey-Stanford Microanalytical Center at Stanford University. The analytical routine followed Williams (1998) and Barth et al. (2001). Data reduction utilized the SQUID program of Ludwig (2005).

Pb* denotes radiogenic Pb; Pb_c denotes common Pb; $f^{206}\text{Pb}_c = 100 \cdot ({}^{206}\text{Pb}_c / {}^{206}\text{Pb}_{\text{total}})$.

Calibration concentrations and isotopic compositions were based on replicate analyses of CZ3 (550 ppm U) and R33 (419 Ma, Black et al., 2004). Reported ratios are not corrected for common Pb. Errors are reported in parentheses as percent at the 1 σ level.

Ages were calculated from $^{206}\text{Pb}/^{238}\text{U}$ ratios corrected for common Pb using the ^{207}Pb method (see Williams, 1998). Initial common Pb isotopic composition approximated from Stacey and Kramers (1975). Uncertainties in millions of years reported as 1σ .

Appendix B: Zircon SHRIMP trace elements data. Note: Only sample 08-153 included Lu during the analytical routine.

Spot	Y	La	Ce	Nd	Sm	Eu	Gd	Dy	Er	Yb	Lu	Hf
SAMPLE: 08-153. Garnet two mica granodioritic orthogneiss, Cape Columbia belt												
08153-1.1	4857.884	0.012	0.709	0.451	3.408	0.042	58.419	453.596	699.561	1065.206	156.835	15405
08153-2.1	1035.701	0.011	0.253	0.110	0.553	0.059	10.672	89.050	120.720	175.202	27.706	13507
08153-3.1	2382.862	0.039	1.854	1.168	4.490	0.079	54.646	234.441	375.868	564.902	96.920	12563
08153-4.1	2116.652	0.095	1.125	0.543	2.252	0.066	32.311	189.120	344.580	583.203	103.217	14003
08153-5.1	3458.727	0.017	1.871	0.461	2.365	0.108	38.188	279.194	618.393	1099.507	192.973	13583
08153-6.1	1401.863	0.010	2.366	1.042	3.261	0.155	34.371	138.302	245.393	409.905	73.617	11808
08153-7.1	1920.839	0.025	0.890	0.459	2.127	0.051	28.770	168.368	332.067	566.245	100.899	13067
08153-8.1	971.537	0.114	1.377	0.187	0.717	0.031	9.920	76.666	180.836	348.945	64.683	14614
08153-10.1	2084.443	0.005	1.605	0.881	3.826	0.142	48.812	217.701	316.364	484.980	83.176	13466
08153-11.1	2940.987	0.061	2.517	1.664	6.175	0.082	73.933	300.602	470.151	687.448	118.460	12602
08153-12.1	4896.783	0.712	4.385	1.006	3.769	0.031	59.302	483.684	603.862	772.519	103.627	17603
08153-13.1	2684.482	0.005	0.617	0.357	1.971	0.029	29.756	220.906	488.371	882.199	155.498	14148
08153-14.1	3983.748	0.030	5.572	2.479	8.170	0.144	84.492	374.528	706.002	1178.976	209.212	12444
08153-15.1	4078.035	0.053	3.182	3.118	8.427	0.148	93.293	396.670	671.177	1016.650	173.740	13283
Spot	Y	La	Ce	Nd	Sm	Eu	Gd	Dy	Er	Yb	Hf	
SAMPLE: 08-154. Garnet two mica granodioritic orthogneiss, Cape Columbia belt												
08154-27.1	699.602	0.022	4.307	0.534	1.683	0.888	16.817	68.583	127.350	253.154	10406	
08154-15.1	551.803	0.020	5.182	0.304	0.927	0.335	9.477	47.134	105.451	237.460	10365	
08154-16.1	719.527	0.023	0.753	0.192	0.942	0.089	16.213	86.884	88.094	99.608	12306	
08154-22.1	406.219	0.020	3.441	0.267	0.672	0.300	7.584	40.640	77.851	162.552	11381	
08154-	583.616	0.025	1.242	0.174	0.900	0.111	14.782	72.706	69.015	78.030	12897	

10.1											
08154-25.1	531.240	0.029	0.499	0.180	0.965	0.078	15.664	79.153	61.682	63.667	13282
08154-2.1	686.003	0.799	2.346	0.305	0.733	0.100	11.037	67.575	97.100	164.062	11058
08154-7.1	1380.276	0.016	10.776	1.526	4.060	0.747	36.296	141.625	246.273	409.418	9465
08154-39.1	1570.032	0.021	12.819	2.343	4.889	1.355	41.363	168.640	280.029	527.082	13249
08154-3.1	520.637	2.386	2.581	1.440	2.139	0.482	20.075	74.353	60.681	71.112	11924
08154-35.1	2857.435	0.051	21.385	4.073	9.486	1.120	88.712	324.494	501.446	762.061	12705
08154-37.1	3790.631	0.029	7.536	0.913	3.977	0.402	53.829	339.335	706.407	1234.246	13704
08154-12.1	985.050	0.037	1.154	0.150	0.840	0.117	14.349	96.631	159.317	270.993	13020
08154-26.1	852.905	0.205	5.464	1.035	2.275	1.068	20.409	85.377	153.842	300.463	10832
08154-5.1	634.887	0.028	1.636	0.224	1.286	0.076	18.267	75.873	93.147	176.977	12775
08154-13.1	876.890	0.151	1.892	1.126	0.022	0.336	16.095	85.200	187.409	493.264	12314
SAMPLE: 08-178. Garnet two mica granitic orthogneiss, Deutchers Glacier belt											
08178-6.1	1722.667	0.009	1.316	0.465	2.752	0.124	41.861	196.669	204.731	253.018	13692
08178-1.1	2837.468	0.009	0.591	0.496	2.932	0.033	47.083	306.255	282.134	234.994	14566
08178-9.1	4587.799	0.007	1.191	0.791	3.660	0.060	56.258	385.426	844.938	1458.015	13129
08178-7.1	3728.058	0.014	0.725	0.466	2.788	0.036	41.482	326.771	592.352	975.618	13726
08178-4.1	3280.241	0.012	0.672	0.386	2.790	0.033	46.924	341.740	363.035	362.349	14922
08178-13.1	4332.343	3.413	10.827	3.218	4.785	0.349	57.392	428.871	506.261	423.467	13366
08178-8.1	2814.898	0.070	0.725	0.414	2.525	0.040	42.753	300.171	278.635	232.624	15001
08178-10.1	3460.499	0.012	1.463	0.750	3.737	0.053	52.021	311.960	602.676	968.126	12904
08178-2.1	1582.450	0.031	6.258	1.991	4.435	0.679	44.727	164.125	285.916	448.971	10518
08178-5.1	2976.419	0.014	1.251	0.777	3.612	0.071	47.629	270.816	531.623	870.114	12379

08178-3.1	1643.381	0.015	0.901	0.426	1.887	0.050	26.388	152.482	291.387	495.426	12432
08178-11.1	3743.497	0.103	1.351	0.534	2.446	0.041	38.672	317.445	671.004	1156.707	13413
08178-12.1	3260.667	1.248	4.464	1.201	2.643	0.125	38.794	330.919	368.148	397.018	16053
SAMPLE: 08-102. Chlorite biotite tonalitic orthogneiss, Mitchell Point belt											
08102-15.1	1464.727	0.010	1.032	0.574	2.246	0.046	29.039	143.309	249.194	397.168	12582
08102-8.1	2642.085	0.011	0.855	0.449	2.434	0.041	33.403	232.512	482.115	831.793	12940
08102-10.1	753.014	0.005	0.876	0.576	2.398	0.057	28.964	82.383	111.229	161.515	13270
08102-14.1	348.988	0.010	0.942	0.808	3.974	0.067	45.732	83.865	26.999	16.500	12569
08102-9.1	2352.442	0.021	1.606	1.169	4.267	0.079	51.572	232.336	386.701	587.943	12630
08102-6.1	320.750	0.006	0.472	0.252	1.529	0.060	22.040	57.232	31.736	20.726	15280
08102-2.1	1666.043	0.005	1.161	0.658	2.693	0.058	35.161	166.286	271.467	404.213	12629
08102-3.1	610.900	0.018	1.030	0.635	2.769	0.054	31.934	93.549	76.709	85.494	13012
08102-7.1	287.144	0.011	0.775	0.619	3.032	0.078	33.050	50.449	32.693	37.737	14245
08102-4.1	133.963	0.005	0.715	0.472	2.444	0.049	26.249	33.270	11.065	7.056	13057
08102-12.1	3711.408	0.009	1.259	0.866	3.764	0.088	47.221	316.885	701.547	1249.170	12817
08102-5.1	2439.735	0.005	0.649	0.390	1.894	0.045	28.122	207.223	464.283	822.793	13695
08102-1.1	3011.053	0.011	0.936	0.681	3.161	0.049	45.566	278.035	568.558	961.389	12644
SAMPLE: 08-103. Garnet biotite granodioritic orthogneiss, Mitchell Point belt											
08103-3.1	1407.890	0.013	9.523	1.223	3.596	0.403	36.310	139.404	245.908	397.132	10550
08103-12.1	1091.096	0.007	9.336	0.388	1.362	0.113	18.183	97.508	206.847	380.500	12090
08103-6.1	1329.602	0.009	10.146	0.629	2.269	0.179	25.305	123.602	246.523	441.276	11419
08103-1.1	1092.800	0.006	8.453	0.484	1.693	0.106	18.851	97.997	201.022	360.118	11753
08103-4.1	1273.106	0.007	9.193	0.473	1.920	0.114	21.901	115.154	237.839	428.570	12749

08103-2.1	1180.714	0.011	8.979	0.410	1.528	0.120	19.747	104.595	221.678	400.319	11908
08103-5.1	1322.640	0.013	11.620	0.533	1.806	0.147	22.953	118.263	247.796	452.912	12180
08103-13.1	3341.815	0.013	18.171	1.789	6.077	0.842	71.764	327.732	616.983	1031.480	12246
08103-8.1	1507.698	0.214	11.836	1.506	3.383	0.432	35.209	148.655	267.472	441.366	10412
08103-10.1	1252.453	0.004	12.307	0.693	2.389	0.203	26.500	118.629	231.322	400.199	11415
08103-14.1	1214.202	0.007	7.450	0.369	1.494	0.089	19.485	107.921	230.471	420.468	12756
08103-11.1	1879.487	0.033	13.586	1.659	4.454	0.330	42.651	181.205	333.531	557.863	9624
SAMPLE: 08-191. Two mica granodioritic orthogneiss, Mitchell Point belt											
08191-3.1	1974.637	0.019	14.230	1.014	3.427	0.283	37.491	182.739	352.967	602.674	12565
08191-15.1	2705.677	0.006	8.308	0.731	3.219	0.158	41.147	232.261	476.081	834.047	12772
08191-4.1	3309.587	1.561	181.857	4.893	8.158	0.740	64.142	298.870	590.115	1015.458	14373
08191-10.1	2156.935	8.008	20.185	1.981	0.293	0.247	30.472	192.393	440.723	859.603	11984
08191-2.1	2922.777	0.088	11.724	5.285	10.701	1.413	90.135	309.670	499.961	749.304	9627
08191-8.1	1196.837	0.008	7.865	0.406	1.602	0.168	19.573	105.488	221.683	403.635	12893
08191-12.1	1280.125	0.148	11.860	0.747	2.331	0.195	25.048	119.281	234.202	406.856	11237
08191-7.1	1846.024	0.014	12.367	3.239	6.747	0.950	55.287	187.052	317.629	491.442	10052
08191-6.1	2079.489	0.023	20.462	2.469	6.319	0.880	56.099	214.202	360.674	552.853	9991
08191-11.1	2909.265	24.986	67.925	11.763	9.105	0.624	73.548	300.427	533.723	850.764	10926
08191-1.1	1510.042	1.240	16.337	0.829	0.203	0.155	25.527	146.573	306.110	565.101	16437
SAMPLE: 08-134. Two mica granodiorite, Mitchell Point belt											
08134-1.1	505.254	0.020	10.348	0.275	0.899	0.265	9.786	47.055	94.998	181.772	9669
08134-2.1	624.379	0.011	6.712	0.234	0.968	0.171	11.137	56.654	118.141	222.444	10955
08134-3.1	435.936	0.015	10.097	0.201	0.667	0.205	7.314	38.381	83.444	165.590	9588

08134-4.1	724.939	0.024	18.245	0.460	1.273	0.325	13.682	64.325	135.769	264.103	10597
08134-5.1	900.382	0.011	18.329	0.503	1.630	0.451	17.210	82.265	168.992	322.966	10721
08134-6.1	954.180	0.019	19.778	0.602	1.692	0.426	18.556	91.491	184.068	348.779	10798
08134-7.1	313.760	0.023	8.733	0.149	0.497	0.114	5.772	29.083	59.336	115.817	11477
08134-8.1	559.381	0.029	16.445	0.336	0.946	0.260	9.211	48.127	106.553	241.144	10810
08134-9.1	373.091	0.020	8.664	0.201	0.622	0.181	7.225	36.153	69.973	135.400	10372
08134-10.1	890.994	0.020	15.521	1.087	2.619	0.966	21.438	83.805	163.988	329.040	9835
08134-11.1	814.249	0.020	19.302	0.401	1.217	0.303	12.666	64.405	149.236	330.955	10933
08134-12.1	676.392	0.012	16.892	0.262	0.878	0.193	11.185	59.183	127.697	253.967	12809
08134-13.1	818.851	0.019	13.555	0.700	2.037	0.499	19.021	77.788	148.369	267.377	10406
08134-14.1	531.068	0.019	15.587	0.248	0.898	0.258	10.125	50.094	99.700	190.378	10712
08134-15.1	697.965	0.017	18.049	0.470	1.411	0.363	14.352	65.499	129.112	238.752	10234
08134-16.1	569.926	0.016	19.456	0.328	0.915	0.229	9.032	48.318	106.313	227.419	11255
08134-17.1	932.530	0.027	27.054	0.637	1.753	0.432	17.831	83.329	178.966	383.094	12979
08134-18.1	1015.130	0.189	21.655	1.082	1.969	0.496	19.496	88.151	193.828	408.432	11757
08134-19.1	592.763	0.032	15.804	0.391	1.020	0.291	9.920	51.668	112.559	242.856	12083
08134-20.1	929.876	0.083	16.441	0.765	1.945	0.575	20.193	88.843	170.005	306.225	11410

Note: All analyses were performed on the SHRIMP-RG Ion Microprobe at the United States Geological Survey-Stanford University Microanalytical Center, Stanford, CA following procedure outlined in Mazdab & Wooden (2006). All trace element abundances expressed in ppm. Sample 08-153 included Lu analyses. The remaining samples did not.

Appendix C: Zircon Lu-Hf isotopic data

	$\frac{(^{176}\text{Yb} + ^{176}\text{Lu})}{^{176}\text{Hf}} (\%)$	$\frac{^{176}\text{Hf}}{^{177}\text{Hf}}$	$\pm (1\sigma)$	$\frac{^{176}\text{Lu}}{^{177}\text{Hf}}$	$\frac{^{176}\text{Hf}}{^{177}\text{Hf}} (\text{T})$	$\epsilon\text{Hf} (0)$	$\epsilon\text{Hf} (0) \pm (1\sigma)$	$\epsilon\text{Hf} (\text{T})$	U/Pb age T (Ma)
SAMPLE: 08-153. Garnet two mica granodioritic orthogneiss, Cape Columbia belt									
08-153-1	40.2	0.282194	0.000041	0.002071	0.282156	-20.9	1.4	-0.6	972
08-153-2	8.4	0.281842	0.000048	0.000489	0.281833	-33.3	1.7	-12.0	972
08-153-4	29.7	0.282199	0.000036	0.001670	0.282169	-20.7	1.3	-0.1	972
08-153-5	40.9	0.282217	0.000036	0.002327	0.282174	-20.1	1.3	0.1	972
08-153-6	25.3	0.282189	0.000036	0.001383	0.282164	-21.1	1.3	-0.3	972
08-153-7	28.0	0.282234	0.000040	0.001600	0.282205	-19.5	1.4	1.1	972
08-153-8	61.2	0.282230	0.000045	0.003404	0.282168	-19.6	1.6	-0.2	972
08-153-9	26.5	0.282220	0.000050	0.001525	0.282192	-20.0	1.8	0.7	972
08-153-12	58.9	0.282192	0.000052	0.003133	0.282134	-21.0	1.8	-1.4	972
08-153-13	46.5	0.282244	0.000053	0.002702	0.282195	-19.1	1.9	0.8	972
08-153-14	18.6	0.282141	0.000059	0.001114	0.282120	-22.8	2.1	-1.9	972
08-153-15	18.4	0.282187	0.000065	0.001108	0.282167	-21.1	2.3	-0.2	972
08-153-16	11.1	0.281880	0.000048	0.000758	0.281866	-32.0	1.7	-10.9	972
08-153-17	33.2	0.282255	0.000046	0.001917	0.282220	-18.7	1.6	1.7	972
08-153-18	26.7	0.282137	0.000046	0.001493	0.282110	-22.9	1.6	-2.2	972
08-153-19	18.5	0.282190	0.000046	0.001052	0.282171	-21.0	1.6	-0.1	972
SAMPLE: 08-154. Garnet two mica granitic orthogneiss, Cape Columbia belt									
08154-2	132.4	0.282252	0.000070	0.007549	0.282116	-18.8	2.5	-2.1	969
08154-4	23.9	0.282365	0.000049	0.001375	0.282340	-14.8	1.7	5.8	969
08154-5	19.2	0.282105	0.000036	0.001100	0.282085	-24.1	1.3	-3.2	969
08154-6	40.9	0.282070	0.000040	0.002341	0.282027	-25.3	1.4	-5.3	969
08154-9	12.1	0.282174	0.000049	0.000658	0.282162	-21.6	1.7	-0.5	969
08154-10	19.7	0.282243	0.000043	0.001142	0.282222	-19.2	1.5	1.6	969
SAMPLE: 08-178. Garnet two mica granitic orthogneiss, Deutchers Glacier belt									
08-178- 1	38.8	0.282160	0.000048	0.001978	0.282123	-22.1	1.7	-1.6	972
08-178- 6	26.4	0.282187	0.000043	0.001320	0.282163	-21.1	1.5	-0.2	972
08-178- 8	27.9	0.282154	0.000052	0.001371	0.282129	-22.3	1.8	-1.5	972
08-178- 9	44.3	0.282116	0.000040	0.002489	0.282071	-23.6	1.4	-3.5	972
08-178- 11	47.3	0.282199	0.000050	0.002798	0.282148	-20.7	1.8	-0.8	972
08-178- 12	50.7	0.282197	0.000056	0.002546	0.282150	-20.8	2.0	-0.7	972
08-178- 13	19.6	0.282151	0.000047	0.000952	0.282133	-22.4	1.7	-1.3	972
08-178- 15	27.8	0.282164	0.000052	0.001533	0.282136	-22.0	1.8	-1.2	972
08-178- 16	29.6	0.282192	0.000066	0.001688	0.282161	-21.0	2.3	-0.3	972
08-178- 17	33.7	0.282133	0.000068	0.001728	0.282102	-23.0	2.4	-2.4	972
08-178- 18	15.1	0.282163	0.000049	0.000787	0.282149	-22.0	1.7	-0.7	972
08-178- 19	45.9	0.282196	0.000056	0.002601	0.282148	-20.8	2.0	-0.8	972
SAMPLE: 08-102. Chlorite biotite tonalitic orthogneiss, Mitchell Point belt									
08-102-3	31.5	0.282203	0.000041	0.001815	0.282170	-20.6	1.5	-0.2	964
08-102-4	15.2	0.282164	0.000038	0.000813	0.282150	-21.9	1.3	-0.9	964
08-102-5	22.0	0.282222	0.000071	0.001347	0.282197	-19.9	2.5	0.8	964
08-102-9	23.4	0.282225	0.000047	0.001284	0.282202	-19.8	1.7	0.9	964
08-102-10	45.5	0.282265	0.000054	0.002477	0.282220	-18.4	1.9	1.6	964
08-102-13	14.7	0.282238	0.000054	0.000830	0.282223	-19.4	1.9	1.7	964
08-102-17	28.8	0.282175	0.000063	0.001674	0.282145	-21.6	2.2	-1.1	964

08-102-18	25.6	0.282213	0.000050	0.001496	0.282186	-20.2	1.8	0.4	964
08-102-19	12.6	0.281703	0.000061	0.000764	0.281689	-38.3	2.1	-17.2	964
08-102-20	14.7	0.282183	0.000038	0.000839	0.282167	-21.3	1.3	-0.3	964
SAMPLE: 08-103. Garnet biotite granodioritic orthogneiss, Mitchell Point belt									
08-103 -4	19.6	0.282016	0.000068	0.001143	0.281996	-27.2	2.4	-6.5	966
08-103 -8	31.9	0.282175	0.000062	0.001856	0.282142	-21.6	2.2	-1.3	966
08-103 -10	14.7	0.282104	0.000109	0.000852	0.282089	-24.1	3.9	-3.2	966
08-103 -11	18.9	0.282178	0.000055	0.001136	0.282157	-21.5	2.0	-0.8	966
08-103 -16	23.3	0.282168	0.000056	0.001399	0.282142	-21.8	2.0	-1.3	966
08-103 -17	28.5	0.282241	0.000089	0.001796	0.282209	-19.2	3.1	1.1	966
08-103 -18	18.1	0.282113	0.000057	0.001053	0.282094	-23.8	2.0	-3.0	966
SAMPLE: 08-191. Two mica granodioritic orthogneiss, Mitchell Point belt									
08-191-1	10.1	0.282156	0.000047	0.000626	0.282145	-22.2	1.7	-1.1	965
08-191-4	23.7	0.282266	0.000045	0.001413	0.282240	-18.4	1.6	2.3	965
08-191-5	25.6	0.282177	0.000044	0.001481	0.282150	-21.5	1.6	-0.9	965
08-191-5	23.9	0.282076	0.000054	0.001390	0.282051	-25.1	1.9	-4.4	965
08-191-7	24.3	0.282178	0.000049	0.001451	0.282152	-21.4	1.7	-0.8	965
08-191-8	24.0	0.282133	0.000043	0.001432	0.282107	-23.1	1.5	-2.4	965
08-191-9	15.6	0.282191	0.000046	0.000962	0.282173	-21.0	1.6	-0.1	965
08-191-10	51.8	0.282285	0.000056	0.002961	0.282232	-17.7	2.0	2.0	965
08-191-11	39.7	0.282229	0.000068	0.002306	0.282187	-19.7	2.4	0.4	965
08-191-12	18.5	0.282157	0.000043	0.001094	0.282137	-22.2	1.5	-1.4	965
08-191-14	34.6	0.282219	0.000056	0.002105	0.282181	-20.0	2.0	0.2	965
08-191-15	29.6	0.282258	0.000047	0.001640	0.282228	-18.6	1.7	1.9	965
08-191-16	25.2	0.282202	0.000046	0.001485	0.282175	-20.6	1.6	0.0	965
08-191-17	25.9	0.282227	0.000047	0.001547	0.282199	-19.7	1.7	0.8	965
08-191-19	12.4	0.282033	0.000053	0.000765	0.282019	-26.6	1.9	-5.5	965
08-191-20	36.4	0.282180	0.000057	0.002179	0.282141	-21.4	2.0	-1.2	965
SAMPLE: 08-134. Two mica granodioritic orthogneiss, Petersen Bay Pluton									
08134-1	16.8	0.282107	0.000039	0.001007	0.282088	-24.0	1.4	-3.2	964
08134-3	17.6	0.282147	0.000050	0.001040	0.282128	-22.6	1.8	-1.7	964
08134-4	19.2	0.282095	0.000044	0.001209	0.282073	-24.4	1.6	-3.7	964
08134-5	17.5	0.282053	0.000043	0.001078	0.282034	-25.9	1.5	-5.1	964
08134-6	15.0	0.282127	0.000050	0.000910	0.282111	-23.3	1.8	-2.4	964
08134-7	18.6	0.282123	0.000037	0.001233	0.282100	-23.4	1.3	-2.7	964
08134-8	12.9	0.282123	0.000050	0.000791	0.282109	-23.4	1.8	-2.4	964
08134-9	10.3	0.282145	0.000047	0.000628	0.282134	-22.6	1.7	-1.5	964
08134-10	34.7	0.282072	0.000040	0.001940	0.282037	-25.2	1.4	-5.0	964
08134-11	13.7	0.282219	0.000038	0.000880	0.282203	-20.0	1.4	0.9	964
08134-12	13.4	0.282143	0.000043	0.000856	0.282127	-22.7	1.5	-1.8	964
08134-13	15.3	0.282059	0.000041	0.000935	0.282042	-25.7	1.5	-4.8	964
08134-14	18.7	0.282109	0.000038	0.001092	0.282089	-23.9	1.3	-3.1	964
08134-15	15.8	0.282127	0.000040	0.000947	0.282110	-23.3	1.4	-2.4	964
08134-16	27.8	0.282143	0.000048	0.001652	0.282114	-22.7	1.7	-2.3	964
08134-17	19.5	0.282077	0.000042	0.001146	0.282056	-25.1	1.5	-4.3	964
08134-18	30.1	0.282119	0.000040	0.001829	0.282086	-23.6	1.4	-3.3	964
08134-19	12.6	0.282203	0.000039	0.000765	0.282190	-20.6	1.4	0.4	964
08134-2	19.2	0.282149	0.000043	0.001106	0.282129	-22.5	1.5	-1.7	964
08134-20	22.8	0.282068	0.000036	0.001350	0.282043	-25.4	1.3	-4.8	964
08134-21	14.6	0.282110	0.000042	0.000908	0.282093	-23.9	1.5	-3.0	964

Appendix D: Details of sample preparation and analytical procedures.

Zircon analyses

Two to four kilogram samples were crushed and pulverized, and heavy mineral concentrate was separated on a Gemini water table. Zircon grains were purified from this concentrate via magnetic and heavy liquid (Methylene Iodide; S.G. = 3.30-3.33 @ 20°C) separation techniques, and relatively inclusion and fracture-free grains were picked in alcohol for analysis. Selected grains were mounted in epoxy resin with a natural zircon standard and polished to expose grain interiors. Cathodoluminescence (CL) imaging was performed to reveal intra-grain complexities and aid in analysis spot selection (Fig 5). Zircon grain mounts were imaged and analyzed at the U.S. Geological Survey-Stanford University Ion Probe Laboratory using the sensitive high-resolution ion microprobe-reverse geometry (SHRIMP-RG) instrument following the routines established by Barth and Wooden (2006) for U/Pb analysis, and Mazdab and Wooden (2006) for concurrent trace element analysis. The data collected by SHRIMP analysis are presented in Appendix A (U/Pb) and B (trace elements). Data reduction utilized the SQUID-2 add-in to Microsoft Excel (Ludwig, 2005), with concordia plots generated using Isoplot version 3.00 (Ludwig, 2003).

Additional zircon grains from each sample were mounted in 2.54 cm rounds and CL imaged for additional analysis by laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) at the Arizona Laserchron Center. U/Pb analyses were completed to characterize the age of CL domains. Grains for Hf analysis were selected from grains within error of the crystallization age determined by previous SIMS analysis. Isotopic composition and fractionation corrections were calibrated by replicate analysis of the natural zircon standard R33 (421 Ma; Black et al., 2004, Mattinson, 2010), and U concentrations were calibrated with Madagascar Green (MAD; 4196 ppm U, Barth and Wooden, 2010). Analysis occurred over three separate sessions on four different mounts, with 2σ calibration errors for the R33 $^{206}\text{Pb}/^{238}\text{U}$ ratios ranging between 0.32% and 0.64%. The rare-earth element (REE) routine analyzed ^{139}La , ^{140}Ce , ^{146}Nd , ^{147}Sm , ^{153}Eu , $^{157}\text{Gd}^{16}\text{O}$, $^{163}\text{Dy}^{16}\text{O}$, $^{166}\text{Er}^{16}\text{O}$, $^{172}\text{Yb}^{16}\text{O}$, $^{175}\text{Lu}^{16}\text{O}$, and $^{180}\text{Hf}^{16}\text{O}$, with concentrations calibrated

against zircon standards MAD and CZ3 (Mazdab and Wooden, 2006, Barth and Wooden, 2010). The data collected by SHRIMP analysis are presented in Appendix A (U/Pb) and B (trace elements).

Additional grains from each sample were mounted in 2.54 cm rounds and CL imaged for additional analysis by laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) at the Arizona Laserchron Center. U/Pb analyses were completed to characterize the age of CL domains. Grains for Hf analysis were selected from grains within error of the crystallization age determined by previous SIMS analysis. The spot size was 40 μm , either overlapping the previous age spot or adjacent to it in the dated CL domain. Each analysis consisted of a 40 second background measurement followed by a 60 second acquisition of one-second integrations during ablation. Five standards (SL, R33, FC1, Mud Tank, and Plesovice) were analyzed at the beginning and end of the session and after 20-25 unknowns. Hf solutions and standards from the Hf analytical session were pooled for establishing isotope and mass inference correction values. Analytical details for U/Pb and Hf isotopic analysis are available in Gehrels et al. (2006, 2008), Cecil et al. (2011) and the Arizona Laserchron Center website (<https://sites.google.com/a/laserchron.org/laserchron/home>).

Whole rock geochemistry

A fraction of each sample was set aside for geochemical analysis after being passed through the jaw-crusher. A 40 g aliquot of rock chips was screened for alteration and powdered in an alumina ball mill. Beads for major element analysis were made from 0.1g of whole-rock powder fused with 0.4g of ultra-pure LiBO_2 flux in a graphite crucible at 1050 $^{\circ}\text{C}$. Glass from this process was dissolved in 50 mL of 5% HNO_3 . 10 mL aliquots of each sample and two rock standards were diluted in 70 mL of 2% HNO_3 for analysis. Analyses were performed on a Varian ICP-OES 720 ES system at the University of Iowa, Department of Chemistry. Analysis of Si, Al, Ca, Na, K, Mg, Fe, Mn, Ti and P was conducted simultaneously, and the final intensities

were calculated by the Varian program software. Drift correction utilized a drift solution run after each three unknowns. Sample calibration used runs of pre-dissolved rock standards AC-E and BVHO2, with values recovered from the GeoReM database (<http://georem.mpch-mainz.gwdg.de/>) used to generate calibration curves for converting intensity to concentration. Major element data are outlined in Table 2, and full procedural details follow Thompson (2011). Trace elements analyses were determined from 0.1g of whole rock powder that was digested in HNO₃-HF in Parr bombs, diluted to a factor of 5000 in 2% HNO₃, and spiked with an internal standard of Be, Rh, In, Re, and Bi. Major element reproducibility for reference standards BVHO2 and AC-E are as follows:

	Accuracy for BVHO2	Accuracy for AC-E
Al ₂ O ₃	-1.35	-0.79
CaO	-8.84	-0.85
Fe ₂ O ₃	-1.42	-0.86
K ₂ O	11.97	-0.86
MgO	3.32	-0.81
MnO	-0.99	-0.87
Na ₂ O	5.51	-0.85
P ₂ O ₅	6.14	-1.05
SiO ₂	3.19	-0.86
TiO ₂	-0.05	-0.85

ICPMS analysis for trace elements was conducted on a Thermo X-Series II mass spectrometer at the University of Iowa Department of Earth and Environmental Sciences. Data reduction included corrections for machine drift, reagent blank values, interferences due to oxide formation, and overlaps due to isobaric interference. Data calibration utilized the following rock standard reference materials: BIR-1, AGV-2, RGM-1, BCR-2, ACE-1, and STM-1. The GeoReM database (<http://georem.mpch-mainz.gwdg.de/>) records the preferred values for these standards. Rock standard QLO-1 was processed with the unknowns to provide a measure of

precision and accuracy, with accuracy relative to GeoReM values $\leq 5\%$ for most elements except for Ti (-5.9%), Cu (-9.1%), Ga (-21.48%), Gd (19.33%), and Tb (12.63%).

Whole rock Pb and Nd isotope analysis

Whole-rock sample powders for Pb analysis were leached in hot 6M HCl for two hours prior to digestion in HNO₃ and HF in the University of Iowa clean lab facility. Each digested sample was loaded into a column with AG1 X-8 100-200 mesh anionic exchange resin and flushed through twice. Pb-bearing solutions were collected, dried and reconstituted in HNO₃. A Thallium solution (NIST SRM 997) was added to each sample to correct for mass fractionation during analysis using the measured ²⁰⁵Tl/²⁰³Tl ratio (Baker et al., 2004). Samples for Nd analysis were separated from the solution prepared for trace element geochemistry. Rare earth element (REE) separation utilized cation exchange AG 50Wx8 resin, and Nd was separated from the other REE with Eichrom Ln-spec resin. Instrumental mass fractionation was corrected using a ¹⁴⁶Nd/¹⁴⁴Nd value of 0.7219. Reproducibility was assessed using the Ames Nd metal standard (± 0.000032 ; 2 σ , n=8), and the ¹⁴³Nd/¹⁴⁴Nd data are presented relative to an Ames Nd metal ¹⁴³Nd/¹⁴⁴Nd value of 0.51213. This value is equivalent to a La Jolla Nd standard ¹⁴³Nd/¹⁴⁴Nd value of 0.51185. Accuracy was assessed by analyzing the BHVO-2 USGS rock standard, yielding a ¹⁴³Nd/¹⁴⁴Nd = 0.512989, within the range of data for this standard (GeoReM database: <http://georem.mpch-mainz.gwdg.de/>). Both Pb and Nd isotope analyses were performed at the University of Illinois at Urbana-Champaign using the Nu Plasma MC-ICP-MS instrument.

Figure Captions

Fig. 1. Polar view of the Arctic Caledonides (cross-hatched pattern) and Circum-Arctic region, illustrating the locations of areas discussed in this paper. CB = submerged Chukchi Borderland; EGC = East Greenland Caledonides, EL = location of the Ernie Lake orthogneiss; NF = Nixon Fork terrane; KNC = Kalak Nappe Complex; specifically areas recording earliest Neoproterozoic tectonothermal activity: NES = Northeastern Svalbard (Nordaustlandet); NWS = Northwestern Svalbard; PT = Pearya Terrane, Succession I units; SWS = Southwestern Svalbard.

Fig. 2. Simplified geologic map of the Pearya Terrane (modified from Trettin 1987, 1991b, 1991c, 1998). This study focuses on the three main belts of Proterozoic metaigneous rocks of the Mitchell Point, Deuchars Glacier, and Cape Columbia belts (Pink). See text for a review of the terrane stratigraphy.

Fig. 3. Outcrop and hand sample photographs of (A) feldspar megacrystic granodioritic orthogneiss (sample 08-153) and (B) equigranular granitic orthogneiss (sample 08-154) from the Cape Columbia Belt, (C) granitic orthogneiss (sample 08-178) of the Deuchars Glacier Belt, (D) granodioritic orthogneiss (sample 08-102), (E) tonalitic orthogneiss (sample 08-103), (F) two mica granitic orthogneiss (08-191), Mitchell Point belt, (G) the two-mica granodioritic orthogneiss (sample 08-134) of the Petersen Bay Pluton.

Fig. 4. Representative photomicrographs of the orthogneiss samples. Mineral abbreviations after Whitney and Evens (2010). (A) Plane polarized light (PPL) image of 08-153 showing distribution of quartz-rich, feldspar and white mica, and biotite-rich domains, (B) PPL image of 08-154 with garnet porphyroclasts, quartz ribbons, and aggregates of biotite and white mica that define the foliation, (C) Cross-polarized light (XPL) image of 08-178 which exhibits quartz recrystallization and foliation defined by biotite-white mica. (D) XPL image of 08-102 characterized by recrystallized quartz with embayed grain boundaries that are consistent with

grain boundary migration recrystallization (Stipp et al., 2002), (E) PPL image of 08-103 showing recrystallized quartz ribbons, feldspar and garnet porphyroblasts and biotite aggregates that defined foliation, and (F) PPL image of 08-191 with a large recrystallized quartz porphyroblast surrounded by finer grained foliated biotite, white mica, plagioclase and quartz in the foliation.

Fig. 5. Representative cathodoluminescence (CL) images of zircon analyzed for U/Pb and trace element data at the USGS/Stanford SHRIMP-RG facility. Spot indicates analysis location. Data for each grain's analysis is presented in Appendices A and B.

Fig. 6. Tera-Wasserburg plots of SHRIMP-RG data from samples of the (A-B) Cape Columbia Belt, (C) Deuchars Glacier Belt, (D-F) Mitchell Point Belt, and (G) Petersen Bay Pluton. Black ellipses indicate data used for age calculations. All analyses are plotted as 1σ error ellipses uncorrected for common Pb. Gray ellipses indicate analyses rejected due to Pb loss, inheritance or other factors as discussed in text. Some older analyses interpreted as inherited components are omitted.

Fig. 7. (A) Diagram showing the sample by sample breakdown in xenocrystic zircon ages with error bars showing 1σ error in Ma. (B) Histogram and probability distribution function of pooled xenocrystic zircon ages from the orthogneiss samples. Note the abundance of Mesoproterozoic age peaks and lack of observed Archean ages.

Fig. 8. Chondrite normalized trace element data for all zircon analyzed concurrent with U-Pb analysis by the SHRIMP-RG instrument. Normalization values used from Anders and Grevesse (1989).

Fig. 9. Hf isotopic data from zircon age domains within error of the sample's Concordia age. (A) Histogram and normalized probability plot of $\epsilon\text{Hf}_{(t)}$ values from all c. 967 Ma basement

zircon. Dashed gray line is the depleted mantle trend for this time. (B) $\epsilon\text{Hf}_{(t)}$ values for each sample, plotted against crystallization age. Note the dominance of values near the gray CHUR reference line, with a few outliers observed. Error bars not included for clarity, but are generally ± 2 epsilon units.

Fig. 10. Whole-rock trace element geochemistry of the basement orthogneiss samples. (A) MORB-Normalized trace element diagram. (B) Chondrite normalized REE plot. Normalized using values of Sun and McDonough (1989).

Fig. 11. Trace element tectonic discrimination diagrams based on whole-rock data. (A) (after Pearce et al., 1984). VAG = volcanic arc granite; Syn-COLG = Syn-collisional granite; WPG = Within plate granite; ORG = Ocean ridge granite. The gray fields plot previous geochemistry for the Deuchars Glacier Belt (lighter) and the Philips Inlet Pluton (darker) (from Trettin 1998). (B) Hf-Th-Ta ternary diagram (after Wood 1980). a = calc-alkaline affinity; b = tholeiitic affinity; c = N-MORB; d = E-MORB and within plate tholeiites; e = alkaline, within plate affinities. Note that the Pearya Terrane samples dominantly plot as volcanic arc related granitoids, supporting a supra-subduction zone origin for Succession I.

Fig. 12. Trace element variations in zircon related to magma evolution effects. (A) Gd/Yb vs U/Yb, a monitor of crustal setting; (B) Th/U vs Hf concentration, recording Th/U variation as differentiation progresses; (C) Hf vs Eu/Eu*, a monitor of plagioclase fractionation influence against differentiation; (D) Yb/Gd vs. Ce/Sm, monitoring magma oxidation against differentiation; (E) Th concentration verses U/Ce, a monitor of melt water content and anatectic input. Plots after Barth and Wooden (2010), Claiborne et al. (2010), and Grimes et al (2015). See text for further discussion.

Fig. 13. $^{143}\text{Nd}/^{144}\text{Nd}$ versus $^{206}\text{Pb}/^{204}\text{Pb}$ isotope correlation diagram (after Zindler and Hart, 1986). Sample isotopic values are age-corrected to their crystallization age, and the approximate mantle reservoirs are age corrected to c. 967 Ma, the average age of the orthogneiss samples for comparison. BSE = Bulk silicate Earth; MORB = Mid Ocean Ridge Basalt; EM-I = Enriched Mantle I (“recycled lower crustal material”); EM-II = Enriched Mantle II (“subducted sediment / upper continental crustal affinity”). See text for discussion.

Fig. 14. Comparison chart of early Neoproterozoic zircon SIMS and conventional U/Pb ages from the Pearya terrane, northern Svalbard, and Ernie Lake, Alaska. The dashed box outlines the range of ages that overlap with those of the Pearya terrane basement. Letter in parentheses indicates the reference: Pearya – (a) this study, (b) Trettin et al. (1992); Alaska – (c) McClelland et al. (2006); Northwestern Svalbard – (d) Pettersson et al. (2009), (e) Peucat et al. (1989); Northeastern Svalbard -); (f) Johansson et al. (2000), (g) Gee et al. (1995) (h) Johansson et al. (2004).

Fig. 15: Proposed reconstruction of the Pearya Succession I orthogneiss units and other areas of earliest Neoproterozoic igneous activity in the Arctic Caledonides, highlighted by black ovals. Laurentia, Baltica, and Amazonia reconstruction after Li et al. (2008). Abbreviations after Fig. 1.

A. 08-153

B. 08-154

C. 08-178

D. 08-102

E. 08-103

F. 08-191

G. 08-134

La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

Steep HREE

- zircon with Pb-loss
- magmatic zircon
- xenocrystic zircon

Flat HREE

- △ zircon with Pb-loss
- ▲ magmatic zircon
- ▲ xenocrystic zircon

KEY	
08-102	◆
08-153	▲
08-154	○
08-178	◇
08-103	■
08-134	▲
08-191	●

KEY

08-102	◆
08-153	△
08-154	○
08-178	◇
08-103	■
08-134	▲
08-191	●

c. 970 Ma

SIBERIA

LAURENTIA

Farewell
(NF)

Pearya terrane
Succession I
intrusions

Kap Hansteen
(NES)

Krummedal
(EGC)

EL

Sørøy
(KNC)

AMAZONIA

BALTICA

Collisional orogen
(Grenville-Sveconorwegian-Sunsas)

Back-Arc/Foreland basins

Early Neoproterozoic igneous arc