Earth and Planetary Science Letters 503 (2018) 95–107

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

Hydrothermally-altered mafic crust as source for early Earth TTG: Pb/Hf/O isotope and trace element evidence in zircon from TTG of the Eoarchean Saglek Block, N. Labrador

A. Vezinet [a,*], D.G. Pearson [a], E. Thomassot [b,c], R.A. Stern [d], C. Sarkar [a], Y. Luo [a], C.M. Fisher [a]

[a] Department of Earth & Atmospheric Sciences, University of Alberta, Edmonton, Alberta, Canada
[b] Centre de Recherches Pétrographiques et Géochimiques, Université de Lorraine, 54501 Vandoeuvre-Lès-Nancy, France
[c] Institute for Geochemistry and Petrology, ETH Zürich, Clausiusstrasse 25, 8038 Zürich, Switzerland
[d] Canadian Centre for Isotopic Microanalysis, University of Alberta, T6G 2E3, Canada

ARTICLE INFO

Article history:
Received 3 May 2018
Received in revised form 26 August 2018
Accepted 13 September 2018
Available online xxxx
Editor: M. Bickle

Keywords:
Early Earth
Eoarchean Saglek Block
zircon U–Pb/Hf/O isotope
zircon trace element
low-T alteration

ABSTRACT

The North Atlantic craton hosts extensive exposures of Eoarchean crust, spread through areas of Western Greenland and Northern Labrador (Canada). Of these two areas, the crust of the Saglek Block of Northern Labrador has received far less attention from the scrutiny of modern analytical methods than its better documented Western Greenland equivalent, the Itsaq Gneiss Complex. Here, we present the first coupled trace element and U–Pb/Hf/O isotope dataset for zircon from an early TTG component of the Saglek Block. The combination of textural, elemental and isotopic *in-situ* analyses enables selection of the least disturbed zircon domains. From these it is demonstrated that the oldest felsic remnants exposed in the Saglek Block were emplaced 3.86 ± 0.01 billion yr (Ga) ago through partial melting of basaltic protoliths. The Hf isotope signature of the oldest zircon domains from the Saglek Block TTG indicates derivation from sources that did not undergo substantial Lu/Hf fractionation, resulting in initial Hf isotope compositions that are chondritic within uncertainty. The oxygen isotope ratios of the least disturbed zircon portions vary from 5.38 ± 0.16‰ to 6.64 ± 0.19‰ and document the interaction of the TTG protoliths with Earth's early hydrosphere at low temperature (≤150–200 °C) prior partial melting in the Eoarchean. The results support TTG production in the Eoarchean from variably hydrated basaltic protoliths.

1. Introduction

The scarcity of exposed ancient rocks limits our ability to decipher the geodynamic history of the early Earth. The timing of generation of Earth's early silicate reservoirs (crust, enriched mantle and depleted mantle) is of prime importance in understanding the evolution of the outer layers of the early Earth and, in particular, in constraining at what stage the crust became dominated by the evolved silicic compositions that we see today. The most controversial and persistent issues concerning the early Earth revolve around the nature, origin, extent and fate of the Hadean/Eoarchean crust (e.g. Blichert-Toft and Albarède, 2008; Harrison et al., 2008; Kemp et al., 2009, 2010, 2015; Bell et al., 2014; Reimink et al., 2016).

One approach to addressing these questions is to study the elemental abundances and isotopic composition of ancient accessory minerals since isotopic compositions and trace element concentrations yield constraints on the differentiation processes and timing of rock crystallization. Zircon, owing to its resilience to higher metamorphic grades, is an ideal candidate to probe early silicate Earth magmatic and metamorphic processes. The Hf- and O-isotope composition of zircon have long been proven effective tracers in ancient rocks, so long as these isotopic signatures can be correctly correlated with the crystallisation age (e.g. Payne et al., 2016; Vervoort and Kemp, 2016). Such integrated zircon Hf/O studies have been applied to detrital zircon populations to determine early Earth crustal and exogenous processes (Blichert-Toft and Albarède, 2008; Harrison et al., 2008; Bell et al., 2011, 2014; Bell and Harrison, 2013; Zeh et al., 2014; Bolhar et al., 2017). Fewer coupled Hf/O isotope data have been published for Earth's oldest igneous rock suites despite such data being critical in assessing the nature of the source from which these earliest continental rocks were derived (Hiess et al., 2009, 2011; Næraa et al., 2012; Reimink et al., 2016). Since the igneous Tonalite–Trondhjemite–Granodiorite suite (TTG) occurs as the dominant rock type in exposed Archean terranes, determin-

* Corresponding author.
E-mail address: vezinet@ualberta.ca (A. Vezinet).

https://doi.org/10.1016/j.epsl.2018.09.015
0012-821X/

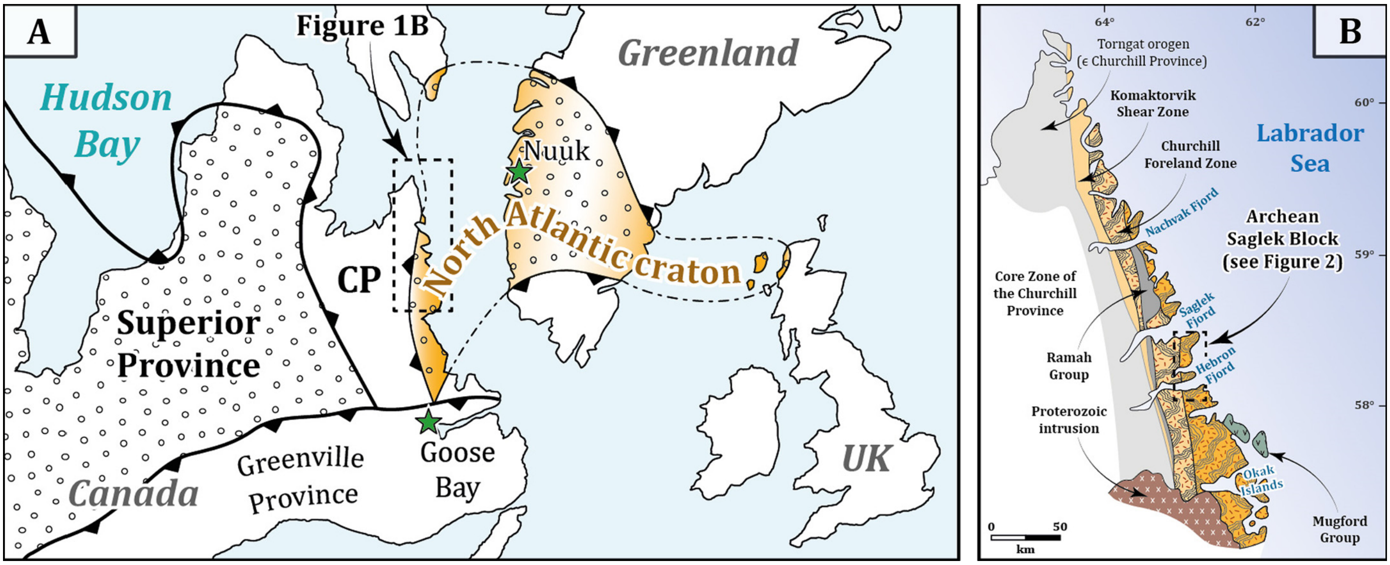

Fig. 1. A. Pre-drift reconstruction of the North Atlantic craton (yellow area on the map), dotted areas are pre-2.5 Ga terranes; green stars represent towns. CP: Churchill Province **B.** General geological map of the north-eastern Labrador and Québec (modified after Ryan and Martineau, 2012). (For interpretation of the colours in the figure(s), the reader is referred to the web version of this article.)

ing the isotopic composition of zircon hosted by these suites is a cornerstone of any model addressing the generation of the first continental nuclei.

The chemical and isotopic composition of zircon populations preserved in igneous rock suites from the *ca.* 4.02 Ga-old Acasta gneiss complex, the *ca.* 3.8 Ga-old from the Itsaq Gneiss Complex and the *ca.* 3.8 Ga-old Nuvvuagittuq felsic crust are well documented (Hiess et al., 2009, 2011; Iizuka et al., 2009; Kemp et al., 2009; Guitreau et al., 2012; Næraa et al., 2012; O'Neil et al., 2013; Reimink et al., 2014, 2016; Bauer et al., 2017; Fisher and Vervoort, 2018), unlike those from the Eoarchean Uivak Gneiss complex exposed in the Saglek Block (Labrador, Canada) that have thus far been studied via U–Pb isotope measurements (Schiøtte et al., 1989a, 1989b; Schiøtte et al., 1990, 1992, 1993; Krogh and Kamo, 2006; Shimojo et al., 2016; Komiya et al., 2017; Kusiak et al., 2018; Sałacińska et al., 2018). In an attempt to develop insights into the formation of Earth's early crust, we conducted the first combined *in-situ* chemical and U–Pb, Lu–Hf and O (Pb/Hf/O) isotope study of zircons from felsic lithologies of the Uivak Gneiss complex. In this study, U–Pb/Hf isotope analysis was achieved through the laser-ablation split-stream (LASS) protocol, that allows constant monitoring of the U–Pb and Hf isotope composition during ablation to ensure that initial Hf isotopic ratios are calculated using appropriate U–Pb ages (Fisher et al., 2017). These U–Pb–Hf analyses are complemented by trace element analyses and ion-probe oxygen-isotope measurements carried on the same zircon domains. This approach provides additional constraints on the nature of the magma from which zircon crystallized, or the fluids that may have interacted with the parent rock.

We show that the oldest Eoarchean TTGs of the western-most extension of the North Atlantic Craton are consistent with derivation from partial melting of a chondritic to mildly depleted basic igneous source rocks that experienced low-T hydrothermal alteration prior to burial and partial melting.

2. Regional geology

The North Atlantic craton is an Archean terrane disrupted during Atlantic Ocean opening (e.g. Bridgwater et al., 1973). Today, this craton is exposed in eastern Canada, Greenland and northern Scotland (Fig. 1A). The Canadian part of the craton, known as the Nain Province, is sub-divided into the southern Hopedale Block and the northern Saglek Block. The latter is a 10–50 km-wide band of Archean rocks exposed between the coast of the Labrador Sea and the Proterozoic Churchill Province (Fig. 1B) and has long been identified as an equivalent to the early-Archean Akulleq terrane exposed onto the Greenlandic part of the craton (Bridgwater et al., 1973). The Archean Saglek Block is largely dominated by rocks of granulite-facies metamorphic grade. High-grade conditions have been recognized as two discrete events: a Paleoarchean (*ca.* 3.5–3.6 Ga) event and a Neoarchean (*ca.* 2.7–2.8 Ga) event (Barton, 1975; Schiøtte et al., 1989a, 1989b; Sałacińska et al., 2018). Notably, the north-eastern part of the Saglek Block (dotted area in Fig. 2) is the only zone of the study area where peak metamorphic equilibration remained below granulite facies conditions (Bridgwater et al., 1975). The western edge of this amphibolite facies sub-area is shaped by the N–S trending Handy Fault, locally delineating the metamorphic boundary with the granulite facies area (Fig. 2).

The Archean Saglek Block is dominated by two main rock associations: supracrustal lithologies and a composite grey gneiss complex (Fig. 2). The supracrustal assemblage includes the following lithologies: (i) ultramafic rocks, (ii) both mafic and felsic metavolcanics; (iii) clinopyroxene-bearing hornblendites; (iv) iron formations; (v) carbonate-rich rocks and (vi) clastic meta-sediments. This varied assemblage has been classified into two sub-units: the Eoarchean Nulliak Supracrustal assemblage and the Mesoarchean Upernavik Supracrustal assemblage (Collerson and Bridgwater, 1979; Bridgwater and Schiøtte, 1991). The mafic and ultramafic units of the Nulliak Supracrustal have provided Nd and W isotope evidence of early (>4.0 Ga) mantle differentiation (Collerson et al., 1991; Liu et al., 2016; Morino et al., 2017).

Two units of the grey gneiss complexes are recognized within the Saglek Block. The oldest unit comprises deformed Na-rich granitoids and was first recognized as the Uivak grey gneiss complex (Hurst et al., 1975). Zircon populations from these felsic lithologies show an intricate and polyphase record with U–Pb crystallization dates up *ca.* 3.9 Ga (Schiøtte et al., 1989a; Shimojo et al., 2016; Komiya et al., 2017) making these rocks some of the oldest intact lithologies exposed on Earth. Younger grey-gneiss units, also with Na-rich granitoid affinities, are thought to be either newly formed felsic bodies (e.g. the *ca.* 3.2 Ga-old Lister gneiss, Schiøtte et al., 1989a) or the migmatized high-grade equivalent of the Uivak lithologies (e.g. the Neoarchean Kiyuktok gneiss, see