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Crustal growth and reworking during Lapland–Kola orogeny in northern Fennoscandia: U–Pb and Lu–Hf data from the Nattanen and Litsa–Aragub-type granites

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ABSTRACT

In this paper we present new zircon U–Pb, Lu–Hf and REE data for Palaeoproterozoic intrusions (Nattanen– and Litsa–Aragub-type granites) of the Fennoscandian shield, to obtain a more detailed understanding of their petrogenesis. The intrusions form a chemically homogenous group of SiO_2-rich A-type, post-kinematic granites that were emplaced between 1.79 and 1.76 Ga. The Hf isotopes indicate that the source was dominated by an Archaean crustal component although a mantle contribution cannot be ruled out. The isotopic data further constrain the evolution of the Archaean and Palaeoproterozoic crust and the assembly of the Nuna (Columbia) supercontinent. The Nattanen– and Litsa–Aragub-type granites are part of a voluminous phase of granitoid magmatism in Fennoscandia at 1.8–1.75 Ga, reflecting large-scale processes at the margin of the Nuna supercontinent.

1. Introduction

The continental crust has evolved by repeated events of growth and reworking through time. Some old shield areas contain evidence of processes spanning most of the Earth's history. Geological mapping combined with major and trace element geochemical studies and dating of exposed rocks provides an overview of the distribution of rocks at the present surface, and of the age of the processes that formed or modified them, but such a picture will be unable to distinguish between processes that involve reworking of pre-existing continental crust, and those in which new material has been introduced from the upper mantle. Unraveling the relative contributions of juvenile material and components with a crustal history to the source of granitic magmas requires the use of radiogenic isotope tracer systems (Sm–Nd, U–Th–Pb, Lu–Hf).

Whole-rock radiogenic isotope data record the final, locally homogenized product of possible mixing processes; neither the nature of the end-members involved, nor their relative contributions can be unambiguously identified from such data. Since the Lu–Hf isotope system of magmatic zircon is robust against modification by post-crystallization processes, Lu–Hf data from single, dated, magmatic zircon crystals can provide a resolution in time and space that is unattainable by whole-rock methods (e.g., Hawkesworth and Kemp, 2006). Since the initial $^{176}Hf/^{177}Hf$ ratio of a magmatic zircon records the composition of the magma at the time of crystallization, single-zircon Hf isotope data are well-suited to detect heterogeneities produced by mixing of melts of different provenance, or by crustal contamination of mantle-derived melts (e.g., Griffin et al., 2002).

In Fennoscandia, Lu–Hf data from single crystals of zircon have been used successfully to identify the sources of subduction-related and intraplate late-Archaean and Proterozoic magmas (e.g., Andersen et al., 2009a; Kurhila et al., 2010; Lauri et al., 2011, 2012b; and references therein). The present study focuses on members of a suite of Palaeoproterozoic granitic intrusions in N Finland and NW Russia known as the Nattanen (Haapala et al., 1987; Heilimo et al., 2009; Mikkola, 1928, 1941) and Litsa–Aragub granites (Vetrin et al., 1975, 2006). They intrude different Archaean and Palaeoproterozoic rock complexes and constitute a minor but potentially important part of the Palaeoproterozoic Fennoscandian granite magmatic history. Earlier conventional radiogenic isotope studies of these granites (Heilimo et al., 2009; Huhma, 1986; Patchett et al., 1981; Vetrin and Rodionov, 2008) indicate an origin by anatectic melting of Archaean crust, but the nature and prehistory of the crustal source rocks involved, and their relationship to the amalgamated blocks of the Archaean domain of Fennoscandia remain unknown.

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We present new in-situ zircon U–Pb and Lu–Hf isotope analyses by laser ablation multicollector inductively coupled plasma mass spectrometry (LA-MC-ICPMS) as well as rare earth element (REE) analyses for zircon, and whole-rock geochemical data from the Nattanen- and Litsa–Aragub-type granites from Northern Finland, and Kola Peninsula, Russia, of the northern Fennoscandian shield. The data strengthens the constraints on the origin of the northern part of Fennoscandia. Our new results, combined with previously published isotopic data, will help to form an integrated model of crust formation history and granitic magmatism of the northern part of the shield.

2. Geological setting

In the Fennoscandian (Baltic) Shield, evidence of Archaean rocks at the surface or in the deep crust is confined to an area north of a line running roughly from lake Ladoga in Russia to the Lofoten archipelago of Norway (Fig. 1, inset). The NE parts of the shield comprise mainly Meso-Neoarchean cratonic materials (3.5–2.6 Ga), whereas the central and western parts of the shield consist of the Palaeoproterozoic 2.0–1.8 Ga Svecofennian domain, the 1.8–1.65 Ga Transscandinavian Igneous Belt (TIB) and the Meso-Neoproterozoic 1.2–0.9 Ga Sveconorwegian Province. Neoproterozoic to Phanerozoic sedimentary basins and the Caledonian nappes form younger cover sequences on the Precambrian basement.

The geographic target of this paper (Fig. 1) is located in the northern part of the shield where several mainly Meso- to Neoarchean domains are situated close to each other: the Karelia Province, Belomorian Mobile Belt and Kola Province (e.g., Hölttä et al., 2012; Slabunov et al., 2006). Some poorly known, smaller Archaean crustal fragments are also exposed: the Norrbotten domain (e.g., Lundqvist et al., 2000; Mellqvist et al., 1999; Öhlander et al., 1987), and the Inari terrain and Suomujärvi complex (Evins et al., 2002; Meriläinen, 1976; the latter two are not separated in the map).

The Karelia and Kola provinces of the Archaean domain of Fennoscandia underwent rifting around 2.44 Ga and 2.50 Ga, respectively, as shown by mafic layered intrusions and felsic A-type granites (e.g., Balashov, 1996; Bayanova et al., 2009; Lauri et al., 2012a; Zozulya et al., 2001). Rifting created gradually deepening basins that were filled with volcanic rocks and minor sediments (e.g., Hanski and Huhma, 2005; Lehtonen et al., 1998). The Lapland–Kola orogeny (1.93–1.91 Ga) caused the accretion of the Kola and Karelia Provinces, with the allochtonous Lapland granulite belt being sandwiched in between the Kola and Karelia Provinces (e.g., Daly et al., 2001, 2006). Almost simultaneously, the Norrbotten domain collided from the northwest around 1.92 Ga (Berg et al., 2012; Lahtinen et al., 2005). During these orogenies, supracrustal units were thrust together (e.g., Hanski, 2001) and granitic complexes intruded in central Finnish Lapland, with ages ranging from 1.95 Ga (pre-orogenic) to 1.76 Ga (post-orogenic) with the highest intensity of intrusive activity at ca. 1.81–1.76 Ga (Ahtonen et al., 2007; Bergman et al., 2001; Lauri et al., 2012b; Lehtonen et al., 1998; Nironen, 2005). The area between the central Lapland granite complex and supracrustal units is occupied mainly by porphyritic granites with a 2.1 Ga age and negative whole-rock ε_{Nd}, and zircon ε_{Hf} values, but their relation to the regional evolution is not

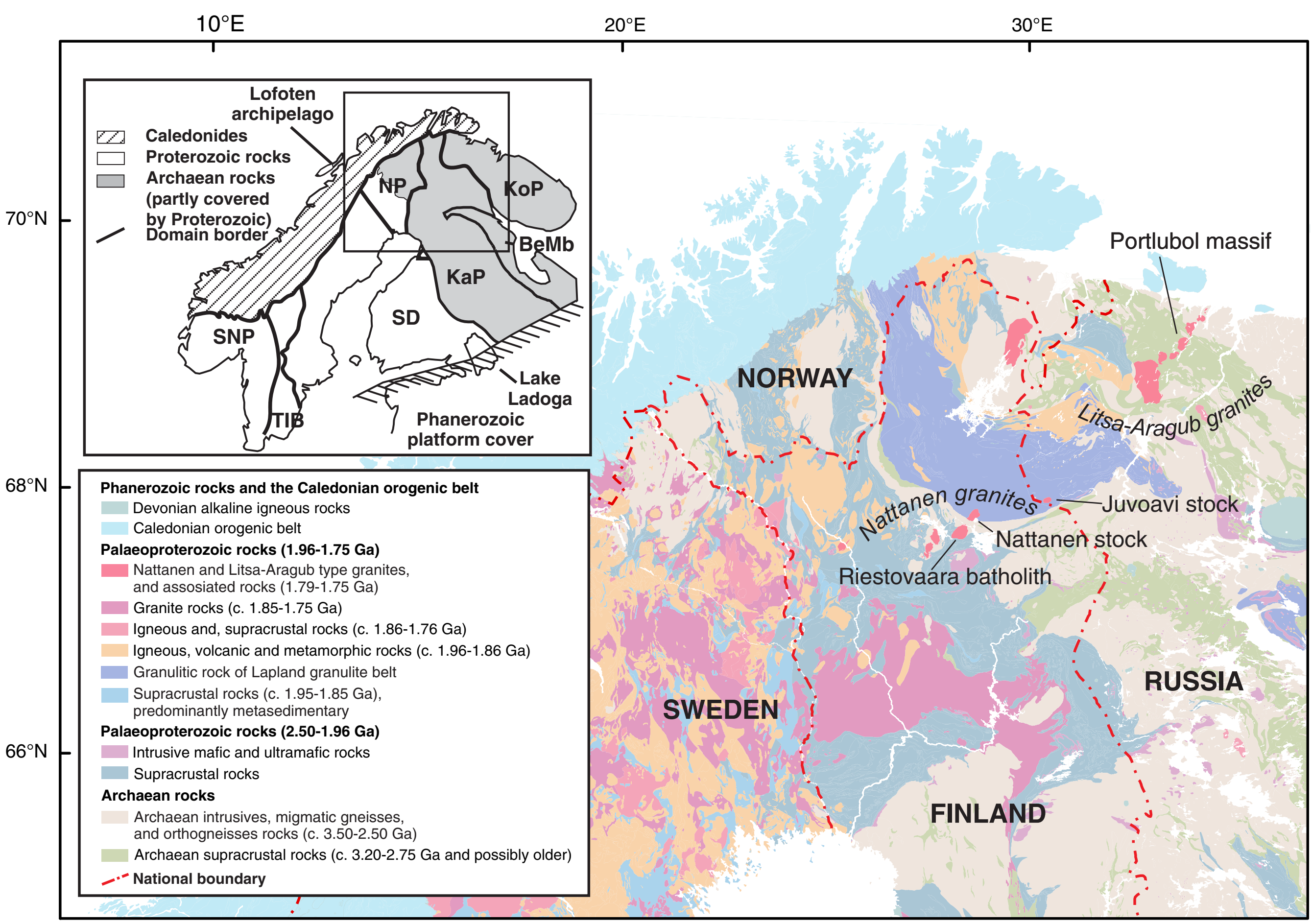

Fig. 1. Geological map of the northern part of the Fennoscandian shield after Koistinen et al. (2001), showing studied granites. Abbreviations in inset map: BeMb — Belomorian Mobile belt, KaP — Karelia Province, KoP — Kola Province, NP — Norrbotten Province, SD — Svecofennian domain, TIB — Trans Scandinavian Igneous Belt, and SNP — Sveconorwegian Province.