INSTITUTE OF SEISMOLOGY
UNIVERSITY OF HELSINKI

REPORT S-65

LITHOSPHERE 2016

NINTH SYMPOSIUM ON THE STRUCTURE, COMPOSITION AND EVOLUTION OF THE LITHOSPHERE IN FENNOSCANDIA

Geological Survey of Finland,
Espoo, November 9-11, 2016

PROGRAMME AND EXTENDED ABSTRACTS

edited by

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Helsinki 2016

Post-kinematic mafic dykes in southern part of Central Svecofennia, Finland

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The geochemical composition of seven post-kinematic mafic dykes in southern part of Central Svecofennia have been studied. Two dykes have been selected for in situ zircon U-Pb geochronology and one for in situ zircon Lu-Hf isotope analysis. These c. 1.86 Ga dykes can be divided into two subgroups by their geochemical characteristics: i) an enriched type with Nb contents up to 42 ppm, high contents of certain fluid mobile elements such as F, Ba, Sr, K_2O and LREE and elevated contents of Fe_2O_3, Ti_2O and P_2O_5, and ii) a primitive type with high MgO and Cr content. The primitive dyke exhibit positive, average c. +3, initial εHf values. The geochemical data combined with the petrological and the field observations suggest that the dykes are juvenile and derived from a subduction-enriched mantle source in a within-plate environment during the post-kinematic stage of the Svecofennian orogeny.

Keywords: Svecofennian orogeny, Lu-Hf, U-Pb, geochemistry, mafic dykes

1. Introduction

The Svecofennian orogen in southern Finland is proposed to consist of two terranes: Central Svecofennia (CS) in the north and Southern Svecofennia (SS) in the south (Korsman et al. 1997; Figure 1a). Central Svecofennia is characterized by the large Central Finland Granitoid Complex (CFGC) in the north, followed by the volcanic arc-type Tampere schist belt (TSB) on its southern fringe (Kähkönen 2005). South of the TSB is the Pirkanmaa migmatite belt (PB), metamorphosed at c. 1.88 Ga (Mouri et al. 1999). Southern Svecofennia consists of two separate volcanic arc-type belts, the Häme (HB) and Uusimaa (UB) belts (Kähkönen 2005; Figure 1b). Southern Svecofennia is characterised by the late-Svecofennian high heat flow and production of granites and migmatites, which formed the Late Svecofennian Granite Migmatite zone (LSGM) at c. 1.84-1.81 Ga (Ehlers et al. 1993, Väisänen et al. 2002, Mouri et al. 2005).

The age difference in metamorphic processes between Central Svecofennia and Southern Svecofennia is evident indicating different tectonic processes within a short distance. In this study, we present petrological, geochemical, zircon U-Pb and Lu-Hf isotope data from mafic dykes cross-cutting the Pirkanmaa migmatites, a few kilometres north of the proposed terrane boundary, in order to evaluate their petrogenesis and tectonic significance. We also compare these dykes with a dyke of the same age in Southern Svecofennia.

2. Geological setting

The study area straddles the proposed terrane boundary between Central Svecofennia and Southern Svecofennia (Figure 1b). The northern part of the study area, belonging to Central Svecofennia, consists of the PB high-grade sedimentary rocks (Mouri et al. 1999, Kähkönen 2005; Figure 1b). The PB is characterised by migmatized psammitic supracrustal rocks and gneisses of a turbiditic origin (Kähkönen 2005) but it also includes some mafic to ultramafic volcanic rocks with MORB to WPL affinities (Peltonen 1995) and various synorogenic granitoids (Mouri et al. 1999). It has been interpreted to represent the forearc sediments of a volcanic arc complex (Lahtinen 1996, Kähkönen 2005).

The southern part of the study area consists of the c. 1.88 Ga HB comprising mafic, intermediate and felsic volcanic and plutonic rocks (Vaasjoki 1994, Nironen 1999, Kähkönen 2005, Saalmann et al. 2009). The volcanics are well-preserved and have been metamorphosed at amphibolite facies. The HB is considered to have formed in a subduction-related volcanic arc setting and the volcanic rocks show mature volcanic arc affinities (Hakkarainen 1994, Lahtinen 1996, Kähkönen 2005).

In between the terranes is a proposed terrane boundary that is not straightforwardly observable in the field (Korsman et al. 1997, Sipilä et al. 2011). Within the study area the boundary is demarcated by various syn to post-kinematic granitoids and an E-W trending shear zone.

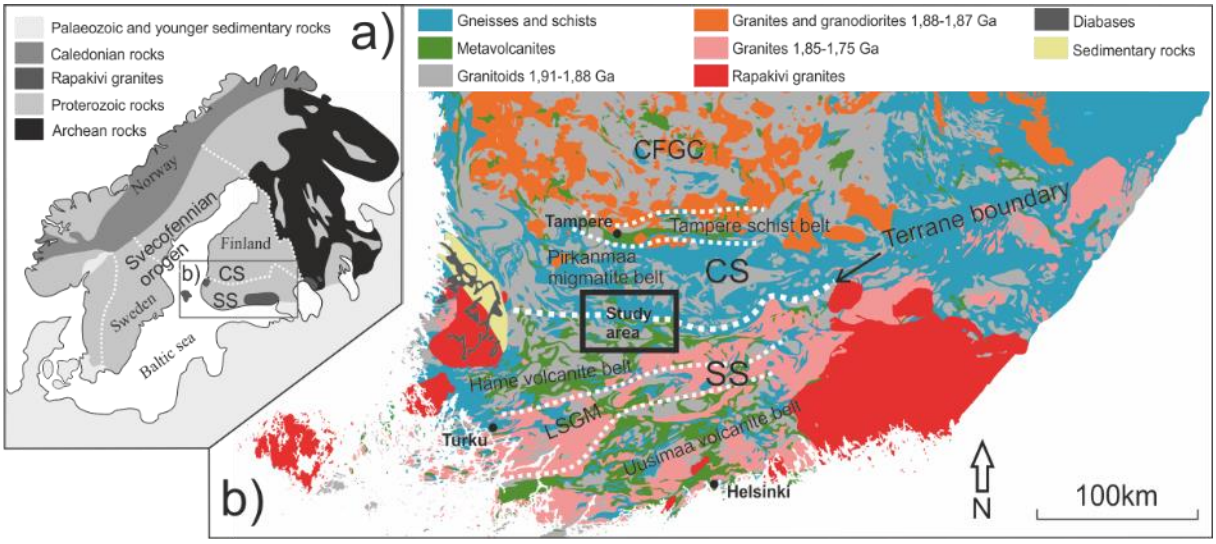

Figure 5. a) Geological overview of the Fennoscandian shield, modified after Koistinen et al. (2001). b) Lithological map of southern Finland, modified after Kallioperä - Bedrock of Finland 1:200 000. The study area is indicated by a black rectangle. See text for abbreviations.

3. Petrology and geochemistry of the mafic dykes

The dykes occur as elongated intrusions a few to tens of metres wide and tens to hundreds of metres long which cut the migmatisized metasedimentary country rocks in the NWW-SEE direction with an apparent gentle NNE dip. The country rock is partially melted on the upper contact of the mafic dyke and the veins of tonalitic leucosome cut the dykes in places. Otherwise the dykes are undeformed and exhibit an ophitic to subophitic texture of plagioclase laths and intergranular hornblende and primary and secondary biotite (Figure 2b and c). Prismatic apatite is the most common accessory phase (Figure 2d) with minor pyroxene. The grain size ranges from a rapidly cooled fine-grained contact zones (Figure 2b) to slowly cooled medium-grained interiors (Figure 2c).

Geochemically the dykes can be divided into two subgroups, although they share some common features. The first group is characterized by Nb, F, Ba, Sr and LREE enrichment, and show elevated Fe_2O_3, K_2O, P_2O_5 and Ti_2O contents. In the TAS diagram this group is classified as monzogabbro and the K_2O content shows a shoshonitic composition. The second group, a gabbro in the TAS diagram, is calc-alkaline and exhibits a more primitive nature by higher MgO and Cr contents but also shows slightly elevated Ti_2O, and F values. Both groups show distinct subduction zone characteristics with LILE enrichment and Nb and Ta depletion in the NMORB normalized multielement diagram. However, the overall trace element concentrations are higher in the enriched type, especially the Nb and Ta contents.

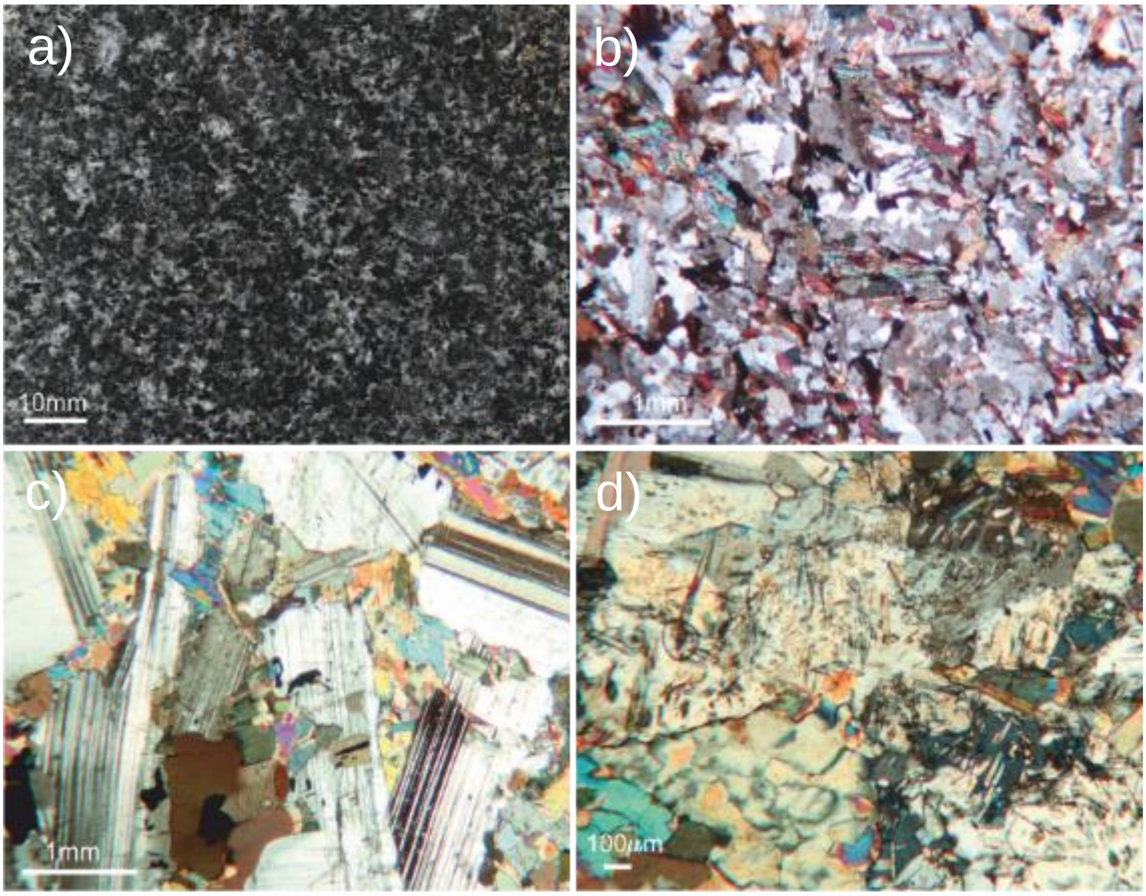

Figure 6. a) A photograph from a cut surface of a medium-grained dyke. Photomicrographs of a thin section from a fine-grained variety (b), medium-grained dyke (c) and apatite inclusions in plagioclase (d).

4. Isotope characteristics

The zircon U-Pb ages of two of the dykes, one of each type, were determined by the laser ablation inductively coupled mass spectrometry (LA-ICP-MS) in the Finnish Geoscience Research Laboratory at GTK, Espoo, Finland. A concordia age of c. 1.86 Ga was obtained for both of the dykes. The Lu-Hf isotope composition was determined for one of the primitive dykes on the previously dated zircons using the same LA-ICP-MS facility. 36 analyses on 29 zircons show an average initial $\varepsilon Hf_{(1.86\ Ga)}$ of c. +3.

5. Discussion and conclusion

Nevalainen et al. (2014) have described c. 1.86 Ga intra-orogenic enriched monzogabbros from Southern Svecofennia which are deformed in the late Svecofennian stage at c. 1.83 Ga. The mafic dykes of the same age in this study show many similar geochemical features, e.g. LILE, LREE, F, K_2O and P_2O_5 enrichment, but lack signs of structural deformation.

Both dyke types in this study show WPL affinities (e.g., Pearce 1982; Schandl and Gorton 2002). However, the magmas have been enriched by a subduction-related metasomatism. According to the Hf isotopes the primitive type is juvenile, although it displays a large variation in initial εHf values. Although the initial eHf values are scattered, its average value indicates a dominantly mantle derived primitive source for these dykes. Whether the dyke types are derived from the same magma source is still unknown.

The field observations, the emplacement age and the geochemical signature support the post-kinematic nature of the dykes. This suggests that cratonization had already started in Central Svecofennia at 1.86 Ga and that the tectonic regime had changed from an active continental margin to a within-plate environment.

Acknowledgements

This study was funded by the Finnish Cultural Foundation, the Turku University Foundation and the Finnish Society of Sciences and Letters.

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