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Metamorphic zones in SW Finland: monazite and zircon U-Pb dating of leucosomes in paragneisses

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The Central Svecofennian Arc Complex (CSAC) and the Southern Svecofennian Arc Complex (SSAC) show different ages of peak metamorphism: ~1.88 Ga in the CSAC and ~1.83 Ga in the SSAC. In the present project we study the age of the metamorphism in SW Finland. We have collected two samples. Of these the Eurajoki leucosome zircons were > 1.92 Ga, i.e.,inherited, but monazites show two populations: ~1.83 Ga and ~1.7 Ga. The zircons from the Rauma leucosome yielded two populations: ~1.86 Ga and ~1.83 Ga. The monazites show ages of ~1.83 Ga and ~1.7 Ga. We interpret that the ~1.86 Ga zircons represent the older metamorphism and the 1.83 Ga zircon and monazite group to represent the younger metamorphism. The 1.7 Ga group is unusual and needs further investigation.

Keywords: Paragneiss, U-Pb, Geochronology, Svecofennian orogeny, southern Finland

1. Introduction

At 1.92-1.77 Ga, the present day central and southern Finland was affected by the Svecofennian orogeny (Gorbatschev & Bogdanova, 1993; Lahtinen et al., 2005). In Finland, the orogen is divided in two inferred terranes: The Central Svecofennian Arc Complex (CSAC) and the Southern Svecofennian Arc Complex (SSAC). These are shown in Figure 1.

A key difference between these is the age of the peak metamorphism. In the southernmost part of the CSAC, the Pirkanmaa belt, the metamorphism peaked at c. 1.88 Ga, while in the SSAC the highest metamorphic temperatures were reached at c. 1.83 Ga. This difference is shown in Figure 1.

It is not known whether the age of peak metamorphism changes sharply or gradually across the terrane boundary.

We have started a project to determine the age of metamorphism in the CSAC and SSAC. We will perform U-Pb zircon and monazite geochronology from leucosomes in paragneisses sampled from the Pirkanmaa belt in the north to the Åland archipelago in the south. Here we present some of our preliminary results from the Rauma region where we have gathered two samples denoted as the Eurajoki leucosome and the Rauma leucosome.

2. Methods

Zircons and monazites were separated by crushing, panning, heavy liquid, magnetic separating and hand picking. Grains were BSE-imaged with the SEM at the Department of Physics and Astronomy at the University of Turku. The U-Pb dating was carried out with the TM AttoM High Resolution ICP-MS in the Finnish Geosciences Research Laboratory at the Geological Survey of Finland, Espoo.

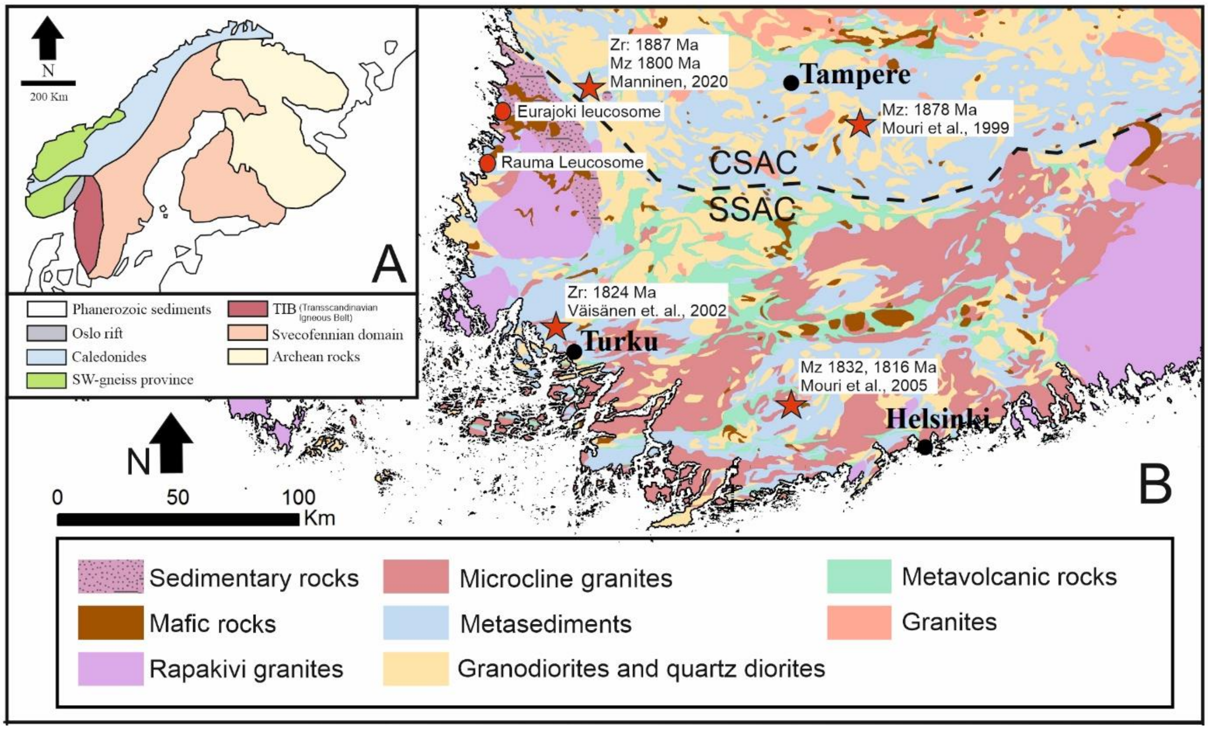

Figure 1. A: Simplified geological division of Fennoscandia. B: Simplified geological map of South Finland with selected previous U-Pb age determinations indicated by red stars. Sample locations of this study are indicated by red circles. Modified from Nironen et al., (2016). CSAC= Central Svecofennian Arc Complex, SSAC= Southern Svecofennian Arc Complex, Mz= monazite, Zr= zircon.

3. Results

Eurajoki Leucosome

The zircons of the sample show only Archean 2.7-2.6 Ga and Paleoproterozoic 2.1-1.92 Ga ages. These are therefore interpreted to be inherited.

The monazites show two concordant populations. The older one contains six analyses and has a concordia and $^{207}Pb/^{206}Pb$ ages of ~1.83 Ga. The younger population of 13 analyses yields a concordia age of ~1.7 Ga with a similar weighted average $^{207}Pb/^{206}Pb$ age.

Rauma Leucosome

The zircons yield two distinct populations. The older concordant population consist of four grains and has a U-Pb concordia age of ~1.86 Ga with a similar weighted average $^{207}Pb/^{206}Pb$ age. The younger age comprises only one analysis and yields a concordia age of ~1.83 Ga and a similar $^{207}Pb/^{206}Pb$ age.

The monazite ages show two populations. The older one contains 14 analyses and has concordia and weighted average $^{207}Pb/^{206}Pb$ ages of ~1.83 Ga. The younger population comprises 11 analyses and yields a concordia age of ~1.7 G with a similar weighted average $^{207}Pb/^{206}Pb$ age.

4. Discussion

We have analysed both monazites and zircons from the leucosomes in the migmatitic paragneisses. It is assumed that the anatectic melting of water- and aluminium-rich metasediments and their subsequent crystallisations occur during the peak temperature. Therefore, leucosomes are the best rock type for dating ancient high-T metamorphic events.

Zircon is a very robust mineral and has a high closure temperature (Corfu et al., 2003). It crystallises readily from the magma but may retain its U-Pb composition during the later metamorphism. Not even melting completely destroy zircon and their U-Pb system. This is proven by abundant inherited zircon populations that are often present in the Svecofennian rocks, including this study. Monazite has a lower closure temperature and recrystallises more readily in subsequent metamorphism (Kohn, 2017). This can be seen in the behaviour of the two minerals in Manninen (2020), where zircon yielded an age of 1885 Ma and monazite 1800 Ma. In that case the zircon was inferred to represent the melt formation and the monazite the later hydrothermal metamorphic event.

The oldest age group of ~1.86 Ga was found in zircon from the Rauma leucosome but the same age was not found from monazite of the either sample. This age represents the oldest metamorphism so far found in S-Finland and it is older than the previous findings (Hölttä et al., 2020). The ~1.86 Ga. period contains magmatism in the SSAC (Mänttäri et al. 2006; Väisänen et al., 2012; Nevalainen et al., 2014). The absence of ~1.86 Ga ages in monazites is most likely due to its readiness to recrystallise: the ~1.86 Ga monazites, if they ever existed, have been reset by later thermal events.

The ~1.83 Ga age is present in zircon from the Rauma leucosome and the Rauma and Eurajoki monazites. This age group represents the well-documented 1.83 Ga peak metamorphism in the SSAC, which resulted in formation of large volumes of anatectic melts (Väisänen & Hölttä 1999; Mouri et al., 2005; Kurhila et al., 2010). The later high T- low P-metamorphism was not able to destroy all the evidence from an earlier thermal event in the zircons, but no older monazites are present in the samples.

The ~1.7 Ga concordant age group, present in both Eurajoki and Rauma monazites is the most surprising result and the previously published youngest monazite ages from southern Finland are much older (Hölttä et al., 2020). The reason for these young monazites remains to be solved.

The preliminary data does not give a clear answer to the variation of the peak metamorphic ages between the CSAC and the SSAC: The ~1.83 Ga age group fits perfectly with the known c. 1.83 Ga age for the late-orogenic event in the SSAC and would therefore indicate a sharp change in the age of the peak metamorphism. The presence of the ~1.86 Ga ages, however, complicates the matter. The nature of the age difference between the two terranes depends whether the ~1.86 Ga age group represents the oldest metamorphism in the SSAC or the onset of the younger 1.83 Ga metamorphism.

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