Temperature and fluid variations in metamorphic rocks in Nautanen, Gällivare, Sweden

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Introduction

This study focuses on the metamorphic geology of the Nautanen deformation zone. It is part of the SGU-financed project, Metamorphic Map of Sweden. The first aim of the study is to investigate the pressure (P)-temperature (T)-fluid history, specifically estimating the P-T conditions of the metamorphic event in the deformation zone and outside the zone. The second aim of the study is to explain any difference between these P-T estimates and to seek evidence of chemical mobility in the area.

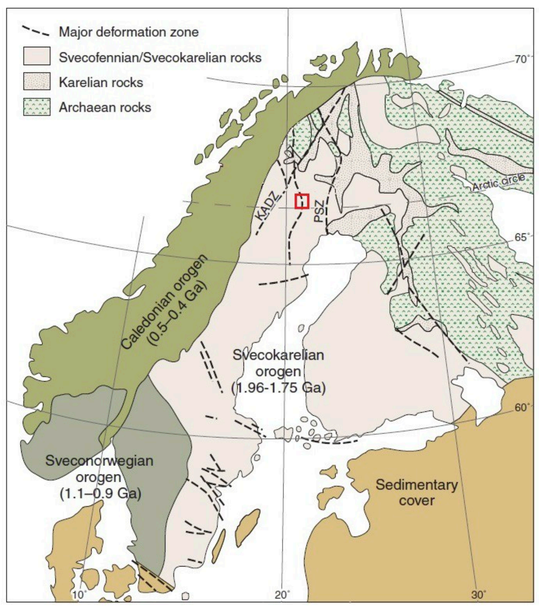

Fig 1. Major geological units in the Fennoscandian Shield and surrounding areas. Modified from Gorbatschev & Bogdanova (1993), Olesen & Sandstad (1993), Stephens et al. (1994), Korsman et al. (1997) and Bergman et al. (2001). KADZ = Karesuando-Arjeplog deformation zone, PSZ = Pajala shear zone. The study area is shown by a red square.

Geological setting

The study area is situated on the Fennoscandian Shield, which is the exposed Precambrian part of the larger East European craton (Fig 1). The main metamorphic event in the Nautanen area is the Svecokarelian orogen (1.96 – 1.75 Ga). The samples from the study area are metamorphosed sedimentary and volcanic rocks, which were surrounded by mafic intrusions and a later granite intrusion. The supracrustal rocks are folded and the Nautanen Deformation Zone (NDZ) crosscuts the folded rocks in a NW to SE direction (Fig.3).
The NDZ is a lineament detected from magnetic field data, electromagnetic data and an independent analysis of digital land altitude data. The lineament has little or no displacement and has been interpreted as a ductile deformation zone.

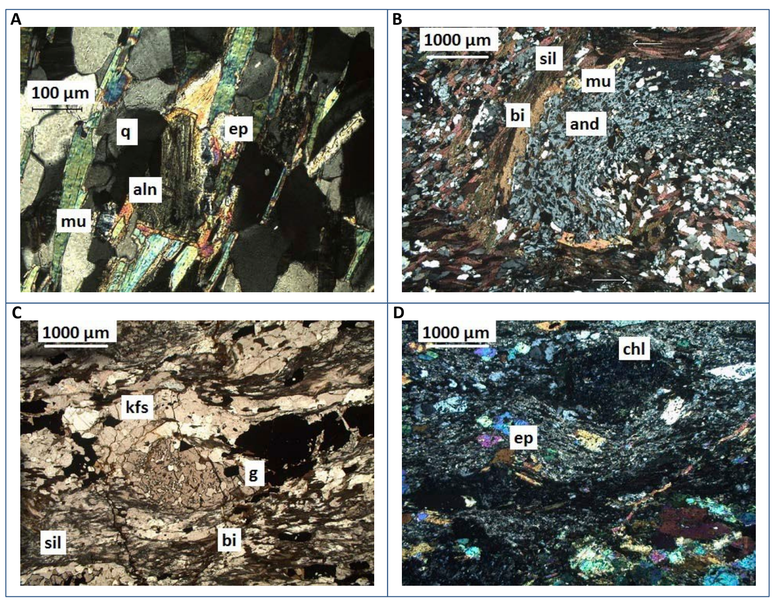

Fig 2. A) Thin section from sample 11GV07 east of NDZ with quartz, muscovite, epidote and allanite-Ce. B) 11GV28 west of NDZ close to the granite with andalusite, biotite, muscovite and sillimanite. C) 11GV36 in the NDZ close to the granite with garnet, biotite, k-feldspar and sillimanite. D) 11GV05 in the NDZ with chlorite replacing garnet and epidote. Photo A, B and D are in CPL and photo C is in PPL.

Methods

The mineralogy, texture and structural relationships in the thin-sections were studied using a petrographic microscope. Mineral chemistry was determined by Electron Microprobe analysis.
XRF analysis was conducted to obtain whole rock chemistry. Major elements and 16 trace elements were analyzed. The software AX and THERMOCALC 3.33 were used to estimate pressure and temperature.

Results

The samples were organized as follow; in the NDZ, west of NDZ and east of NDZ. We have delineated NDZ according to SGU's geological map (Fig 3). Variation in mineral composition and alteration was found in several thin-sections, which could be related to whether the sample was from the NDZ or from outside NDZ. Garnet (Fig 2 C, D) was found in 14 thin-sections within the NDZ and was not present outside the NDZ. Andalusite (Fig 2 B) was found in three thin-sections east of the NDZ. Porphyroblasts of metamorphic allanite-Ce (Fig 2 A) were found in two thin-sections west of the NDZ. Sillimanite (Fig 2 B, C) was found in four samples close to the granite intrusion. The samples from within the NDZ (Fig 2 C, D) were more altered with serecite, epidote and/or K-feldspar.

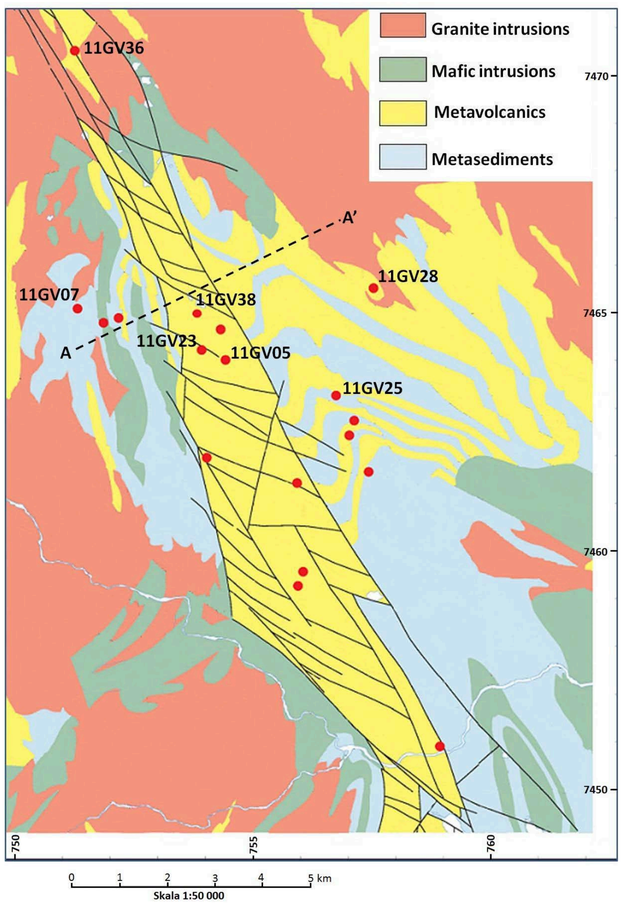

Fig 3. Simplified bedrock map over Nautanen. Red dots mark sample localities . The Ba profile is indicated by the dotted line across the NDZ. Modified from SGU bedrock map Ai 100.

To compare the concentration of trace elements (LIL and HFS), a spider diagram was used. The samples were normalized to the North American shale composite (NASC). In Fig 4 most element abundances are similar to NASC. However, several samples have high concentration of Ba. The Ba concentration was plotted along a 5.5 km profile perpendicular to the NDZ in Fig 5.

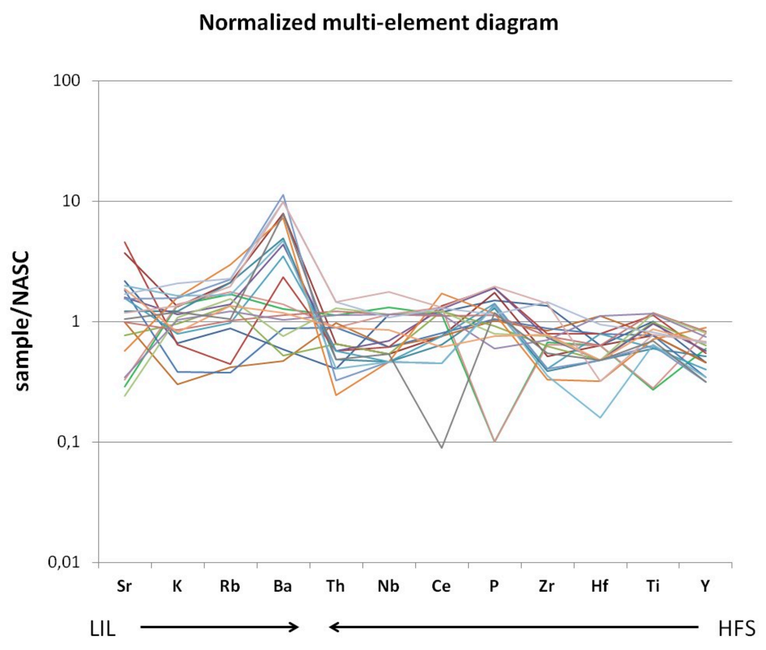

Fig 4. Multi-element diagram normalized to NASC. The arrows indicate the direction for higher mobility of the elements.

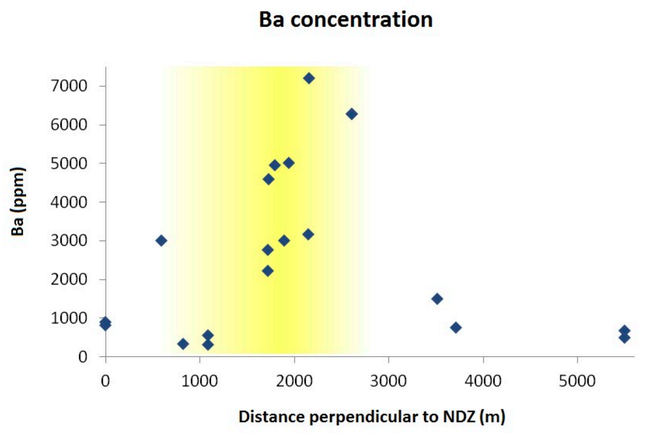

Fig 5. Ba concentration across profile A-A'. The yellow color indicates the deformation zone.

Average temperature was calculated with THERMOCALC (Tab 1). The pressure was assumed to be below 400 MPa as andalusite was present in three samples, thus the pressure for the calculations were set to 350 MPa. The highest temperatures were found close to the granite intrusion.

West → East							
sample	11GV07	11GV36	11GV38	11GV23	11GV05	11GV25	11GV28
T (˚C)	606 ±35	673 ±13	591 ±17	520 ±61	500 ±44	553 ±7	687 ±19

Tab 1. Average temperatures along a west-east constructed perpendicular to the NDZ. The average pressure was assumed to be 350 MPa.

Conclusions

The increasing temperature towards the granite intrusion suggests prograde contact metamorphism that needs not to be related to the NDZ. In Fig 2 B a poikiloblastic andalusite is wrapped around by muscovite, biotite and sillimanite. This could indicate an earlier regional metamorphic event with the growth of andalusite and a later second contact metamorphic event with the growth of sillimanite around the andalusite. The high concentration of mobile elements (e.g. Ba) indicates fluid controlled retrograde metamorphism in the NDZ. This is visible in thin-section (Fig 2 D) a garnet porphyroblast is replaced by chlorite and the matrix with serecite and epidote.

References
Bergman S., Kübler L., Martinsson O., 2001. Description of regional geological and geophysical maps of northern Norbotten county (east of the Caledonian orogen). Sveriges Geologiska Undersökningar. Ba 56

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