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$^{40}Ar/^{39}Ar$ hornblende geochronology from the Forsmark area in central Sweden: Constraints on late Svecofennian cooling, ductile deformation and exhumation

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ABSTRACT

At Forsmark, ca. 120 km north of Stockholm in central Sweden, ductile high-strain belts with WNW to NW trend anastomose around tectonic lenses with an inferred lower degree of ductile strain. Previous studies of ductile deformation zones with WNW to NW trend, elsewhere in the western part of the Svecofennian orogen in central Sweden, have yielded estimates for the timing of at least one phase of discrete ductile deformation that fall in the time interval 1.82–1.78 Ga. Most of these ages were determined by the U/Pb dating of titanite and, for this reason, provide no information on the thermal evolution. In this paper, we make use of $^{40}Ar/^{39}Ar$ hornblende geochronology to address late Svecofennian cooling, ductile deformation and exhumation. The data demonstrate the presence of three $^{40}Ar/^{39}Ar$ hornblende age generations. All ages have been adjusted to take account of ca. 1% systematic bias between $^{40}Ar/^{39}Ar$ and U/Pb ages recently reported in the literature. The oldest age, ca. 1.87 Ga, and the intermediate age generation, 1.85–1.84 Ga, are spatially restricted to the tectonic lenses. By contrast, the youngest age generation, 1.83–1.81 Ga, occurs both within the tectonic lenses and the enveloping high-strain belts. One explanation for the structurally controlled age distribution involves regional cooling beneath the closure temperature for argon isotopic mobility around or above 500 °C by 1.84 Ga, as represented in the oldest and intermediate age generations, followed by resetting of the argon isotope system in hornblende between 1.83 and 1.81 Ga, as represented in the youngest age generation. This resetting occurred in response to retrograde, lower amphibolite- to upper greenschist-facies deformation along discrete high-strain zones within the broader high-strain belts and was associated with regional exhumation. An alternative explanation involves no resetting of the ages. Instead, it is suggested that a period of slow cooling of hornblendes with slightly different closure temperatures, from ca. 1.87 to 1.82 Ga, may have caused the age variation observed within the tectonic lenses, whereas locally maintained higher temperatures, due to activity along the discrete high-strain zones, can explain the consistently younger ages in the broad, enveloping high-strain belts. In this explanation, an increase in cooling rate, in response to regional exhumation, finally closed the argon isotope system in hornblende throughout the area at 1.83–1.81 Ga. It is suggested that the regional exhumation at 1.83–1.81 Ga, which is included in both explanations, is related to far-field effects of the deformation that ended an accretionary tectonic cycle in adjacent tectonic domains.

1. Introduction

Ductile deformation zones with WNW to NW trend and a dextral strike-slip kinematic component are a common feature in the western part of the Svecofennian orogen in central Sweden (Figs. 1 and 2a). At least one phase of ductile deformation in a few of these zones has been dated, mainly by the U/Pb technique on titanite, yielding ages in the time interval 1.82–1.78 Ga (Högdahl et al., 1995, 2001; Högdahl, 2000; Högdahl and Sjöström, 2001; Beunk and Page, 2001). The consistency in ages suggests that they have a common history. However, with one exception (Högdahl et al., 1995), all recorded ages come from the northernmost and southernmost areas in this part of the Svecofennian orogen and the control on the timing of deformation over the region as a whole is therefore limited.

The Forsmark area, ca. 120 km north of Stockholm in the central part of Sweden (Fig. 1), is situated within a tectonic domain (domain 2; Fig. 2a), which consists of broad belts of highly deformed

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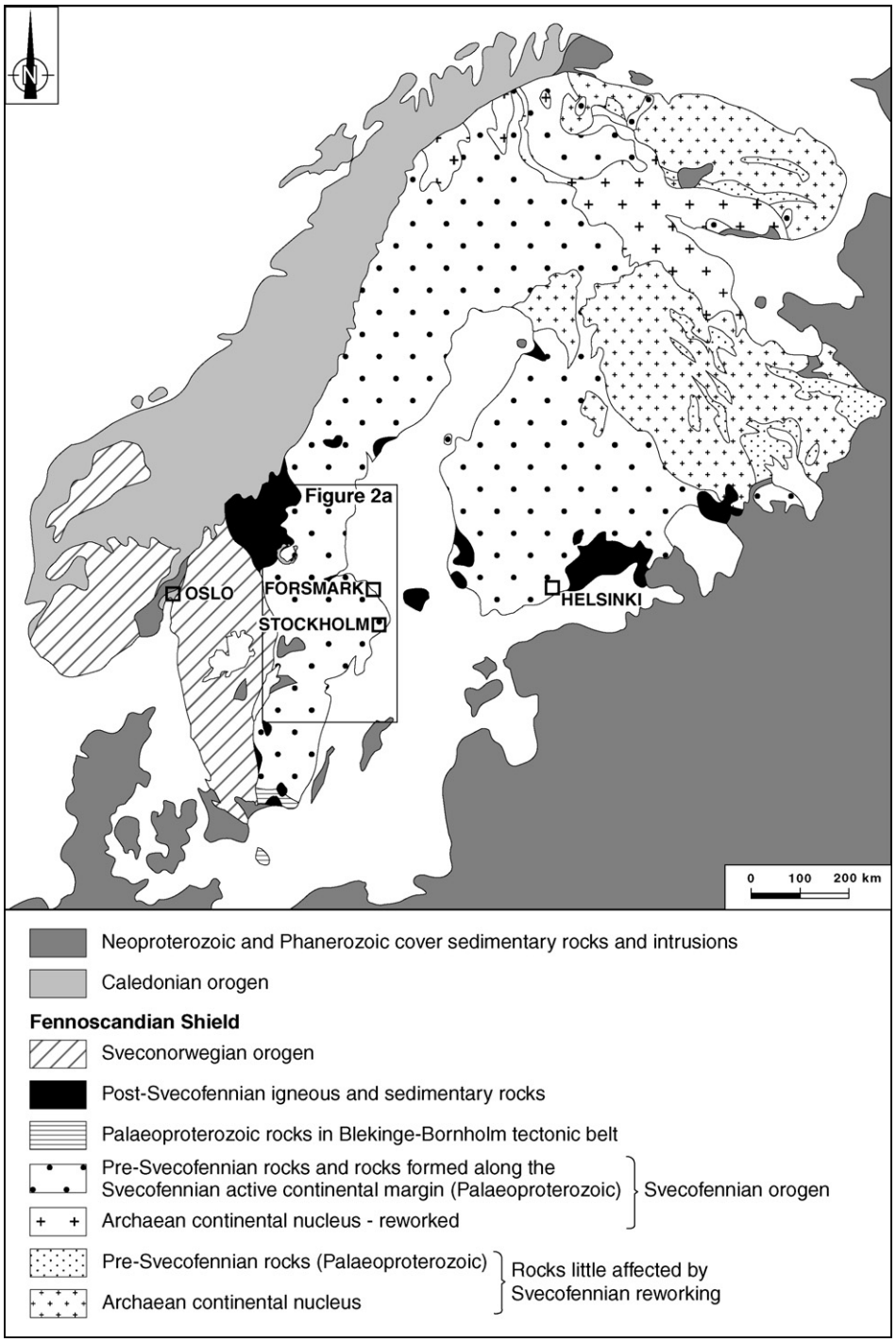

Fig. 1. Map showing the major tectonic units in the Fennoscandian Shield (modified after Koistinen et al., 2001). The location of the Forsmark area is also indicated.

rocks that trend WNW to NW and anastomose around tectonic lenses (Hermansson et al., 2007). The area has been chosen as a potential site for the disposal of highly radioactive nuclear waste (SKB, 2000) and, for this reason, has been mapped in considerable detail. In two previous studies in the Forsmark area (Hermansson et al., 2007, 2008), igneous crystallisation and subsequent penetrative ductile deformation under amphibolite-facies metamorphic conditions, has been tightly constrained using U/Pb geochronology on zircon and titanite. From these results, it was concluded that penetrative ductile deformation and the formation of the ductile high-strain belts occurred as early as 1.87–1.86 Ga, and that this event was regional in character and affected tectonic domain 3 to the south (Fig. 2a). It was also inferred that ductile deformation continued to be active after 1.85 Ga along discrete deformation zones in the area.

A study of the tectonothermal evolution along the deformation zones with WNW to NW trend at Forsmark is important, since the area's early history with respect to penetrative ductile deformation is well understood and there is good control on the field relationships between structures in the bedrock and dated igneous suites. Moreover, because of its intermediate geographic location, geochronological information from Forsmark can be used to link