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Direct dating of ductile deformation within the Caledonian nappe stack: Rb-Sr mineral data and element mapping from the COSC-1 drill core

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The Scandinavian Caledonides are a prime example of a well preserved and deeply exhumed orogenic belt, which allows insight into deep crustal deformation processes. The COSC drilling project (Collisional Orogeny in the Scandinavian Caledonides) provides access into one of the prominent thrust sheet stacks as it truncates a major portion of the so-called Middle Allochthon, the high-grade metamorphosed Seve Nappe together with the underlying lower grade metamorphic rocks. The upper 2350 m of the borehole consist of alternating layers of variably deformed felsic and calc-silicate gneisses and amphibolites, while a less metamorphosed meta-sedimentary unit prevails below. Surprisingly, both units are marked by the presence of abundant, cm- to m-wide, subhorizontal mylonitic bands from about 1700 m to the final borehole depth of 2500 m depth which point to a pervasive high strain zone of at least 800 m thickness affecting likewise both tectonic units.

We applied high-resolution element mapping techniques using XRF and LIBS (laser-induced breakdown spectroscopy) core scanning to elucidate the structure, composition and origin of different rocks from the strongly deformed lower Seve Nappe and the underlying unit. The dominating medium-grained gneissic to migmatitic, leucocratic rocks are structurally and compositionally different from more mica- and quartz-rich, fine-grained and subhorizontally deformed mylonitic rocks. We suggest that pre-metamorphic compositional differences, possibly alternation of clay-rich vs sandy layers, control the rock rheology during syn-metamorphic deformation. Fluid-driven element exchange can largely be ruled out.

In order to understand the temporal evolution of metamorphism and deformation, we dated the two major, texturally distinct metamorphic episodes using the Rb-Sr multi-mineral internal isochron approach. Gneisses were formed during the last high-grade, amphibolite facies metamorphism, and were partially reworked during subsequent mylonitizing deformation. The amphibolite-grade metamorphism dominating the Seve Nappe unit gneisses in the borehole and the surrounding region shows an early Silurian Rb-Sr mineral age of about 438 Ma, regarded as an age for a late stage of the high-grade overprint. In contrast, the mylonitic overprint that largely strained the lower 800 m borehole section occurred at about 429 Ma. The new Rb-Sr mineral age data fit well with existing age estimates for high-grade metamorphism in the overlying, nearby Åreskutan unit based on U-Pb zircon and monazite data. The new Rb-Sr mylonite age is the first direct dating of ductile deformation from the COSC drillcore. The age of ~429 Ma is consistent with U-Pb zircon data from pegmatites cutting the dominant Caledonian foliation in nearby surface outcrops. It appears that within the regional Caledonian allochthonous units metamorphism, incipient exhumation, nappe stacking, and emplacement of the nappe stack onto the continental platform followed each other in a dynamic and geologically rapid process.