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Partitioning of metamorphism and deformation at the nappe scale and implications for nappe-stacking mechanisms: The example of the Kalak nappe complex (north-Norwegian Caledonides)

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The Kalak nappe complex (KNC) is the largest tectonic unit of the northern Norwegian Caledonides. It consists of a slice of mid-lower crustal rocks forming part of the Middle Allochthon of the northern Norwegian Caledonides. A large part of the KNC is derived from lower crustal rocks belonging to the Seiland Igneous Province (SIP) and its country rocks. The SIP was emplaced at the base of the lower crust during the time span from 570 to 520 Ma, and consists of a deep-seated alkaline magmatic suite of dominantly gabbroic composition. During the intrusions, the host rocks were contact metamorphosed and partially molten (by dehydration melting of biotite), and subsequently recrystallized under granulite facies conditions (700°C–750°C and 0.5–0.7 GPa). Contact metamorphism, partial melting, and granulite facies re-equilibration were accompanied by the development of a gneissic to mylonitic foliation in both the mafic rocks and the migmatitic metasediments. Dehydration melting and removal of aqueous fluid in the form of melt resulted in the formation of a restitic lower crust dry enough to be mechanically strong.

The aim of this study is to investigate how such a dry and strong lower crust is subsequently overprinted during the Caledonian Orogeny, and what the implications for the internal structures of nappes and for the nature of nappe boundaries are. A systematic study in the nappe interior and along the nappe thrust contacts indicates that the rock sequence consists of lenses of high grade relicts (preserving high grade mineral assemblages, partial melting features, and granulite foliation) embedded in a deformed matrix of the same composition but with a retrograde overprint. The sheared and retrograded rocks contain hydrated mineral assemblages, which have equilibrated under amphibolite- and greenschist facies conditions. Thus, deformation and thrusting of the KNC was facilitated by hydration of dry lower crust, which previously was mechanically strong as a consequence of dehydration partial melting.

These observations indicate that fluid infiltration during continental collision resulted in large-scale weak zones, which acted as major decoupling horizons within the orogenic wedge, representing major thrusts and nappe boundaries. Thrust zones may represent domains, in which different amounts of shear strain have been acquired at different metamorphic grades and at different times (i.e. at the time of deformation). Thus, the metamorphic overprint was acquired during thrusting and does not necessarily represent an example of transported metamorphism, which is commonly considered as the typical setting resulting from continental collision and nappe stacking.

Many of the different structural units of the northern Scandinavian Caledonides are distinguished on the basis of their metamorphic grade (P, T, and thus their crustal structural level). The new interpretation of a partial hydration and partitioning of deformation and metamorphic overprint requires a partial re-interpretation of the character and significance of nappe boundaries. Our results indicate that nappe-stacking mechanisms and the internal structure of nappe boundaries are critically dependent on the availability of aqueous fluid during deformation and metamorphism.