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Constraints on the thermal evolution of the Scottish Caledonides by combined thermochronology

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Orogenic wedges are classically described as frictional wedges with localized deformations. This view works well with sedimentary wedges and the upper crust, but as soon as deeper parts of the crust are involved in the wedge, ductile and widespread deformations are observed and the analogy with frictional wedges is thus less relevant. Wedge construction and its later evolution are controlled by many factors: rheology, strain rates and erosion. The thermal evolution is also controlled by these same factors and in turn influences rheology and the way strain is accommodated. Thus, understanding the thermal history of the wedge may help to better understand its architecture. In the Western Alps, for example, recent studies show that (greenschist) collisional deformations occured first in a distributed mode during the thermal peak before being localised on major crustal thrusts. To document the thermo-structural evolution at deeper crustal levels, we chose the Scottish Caledonides examples where a crustal collisional wedge deformed in the amphibolite facies is exposed.

The Scottish Caledonides is a collisional wedge involved in the closure of the Iapetus Ocean through two tectonic events: the Grampian phase (480-440 Ma) and the Scandian phase (430-400 Ma) that culminated in the stacking of major ductile nappes (Moine, Ben Hope, Naver, Skinsdale). Despite being a largely studied wedge, the detailed sequence of deformation is still unknown and the complex thermal history suffers from the lack of thermochronological data.

The aim of this work is to constrain the thermal evolution of the nappes and their thrusts to better understand how this ductile wedge forms. To do so, combining different thermochronological and geochronological methods is crucial to describe refined Temperature-time (T-t) paths. Therefore, the T-t path of each unit must be evaluated by combining thermochronometers from the high crystallization temperature of syn-orogenic plutons (∼800°C), to the deforming temperature range (∼400-700°C) and finishing with the exhumation history to lower temperatures (<200°C). Hence, in this study we couple U-Pb dating on zircon and apatite with 204Pb correction, 40Ar/39Ar dating on muscovite and biotite and U-Th/He dating on zircon. We also use 40Ar/39Ar to attempt to date deformation along two major ductile shear zones: The Ben Hope and the Naver thrusts.

The U-Pb on apatite data range from 325.7 ±7 Ma in the west and 428.2 ±8.4 Ma in the east. The 40Ar/39Ar on muscovite ranges from 413 ±1.1 Ma to 436.5 ±3.5 Ma. We thus document a fast cooling event at about 420-425 Ma after a metamorphic (thermal) peak at 425 Ma that also corresponds to a distributed deformation and partial melting phase. However, the data also suggest that the ductile thrusts are still active until around 400 Ma, which is very young. This dataset is finally used to discuss the complex thermo-structural evolution of crustal orogenic wedges from different natural examples.