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Investigating heat transfer through the Lepontine Dome (Central European Alps) with a combined petrological, structural, dating and modelling approach

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Heat transfer during and after the emplacement of tectonic nappes within an orogeny is controlled by three fundamental processes: advection, diffusion and production of heat. Production is mainly caused by radioactive decay and shear heating. The relative importance and timing of these processes is often contentious. For example, in the Lepontine Dome of the Central European Alps the timing of the thermal evolution and the relative importance of advection, diffusion and shear heating is disputed. To better constrain and understand heat transfer in the Lepontine Dome, we apply a combined approach of petrological and structural analysis, zircon dating of migmatites and theoretical modelling.

We use data from an almost vertical transect (in the Ticino's valleys) cutting from bottom-to-top the Simano, Cima Lunga and Maggia gneissic nappes. These nappes show an extremely pervasive mineral and stretching lineation (NW-SE directed) indicating non-coaxial deformation during shearing at amphibolite facies metamorphic conditions. The transition from the Simano to the Cima-Lunga nappe is marked by a progressive change in the texture of gneisses, in which the porphyroblasts become more stretched from the bottom to the top. Locally, at the tectonic contacts, syn-tectonic migmatites have been found. Their leucosomes contain metamorphic zircons with ages spreading from 40 to 31 Ma (U-Pb dating).
The widespread paragneisses frequently contain garnets of different sizes and internal microstructure. Published and own petrological data of these garnet-bearing rocks attest an inverted metamorphic gradient from ca. 700°C to 650-600 °C at intermediate pressures below the Cima Lunga unit during the peak-T amphibolite facies condition.

Overall, the field data depict a major km-scale shear zone that generated an inverted metamorphic gradient during the peak-T amphibolite facies condition between 40 and 31 Ma. These results hint that fast advection of heat or shear heating (or both component contempraneously) contributed to imprint the regional amphibolite facies metamorphism during nappe emplacement.

To take another step towards unravelling the controlling heat transfer processes in the Lepontine

Dome and to test the relative importance of production, diffusion and advection, we employ three theoretical approaches with increasing complexity. First, we perform a dimensional analysis estimating dimensionless numbers, such as Peclet and Brinkman, for a range of reasonable parameters for the Lepontine Dome. Second, we apply numerical 2D thermo-kinematic simulations of trishear thrust-ramp evolution to test, for example, the impact of temperature-dependent viscosity and the geometrical relationship between temperature isogrades and nappe boundaries. Third, we apply state-of-the-art numerical 2D thermo-mechanical simulations of subduction and collision to investigate heat transfer and the resulting metamorphic facies distribution during the formation of an orogenic wedge.

Finally, we combine our modelling results with the available structural, age and metamorphic results to discuss potential scenarios for the heat transfer through the Lepontine dome.