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3D thermal structure of the Helvetic nappes, Central Alps: implications for collisional processes

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Understanding the rheology of orogenic wedges requires data on the structural and thermal evolution of collisional units. In this study, we document the maximum temperature reached by the Helvetic Nappe Complex, which formed the sedimentary cover of the European basement, by Raman Spectroscopy of the Carbonaceous Material (RSCM). This study area is an ideal natural case to assess the relationship between the thermal structure, its evolution through time and the deformation in the orogenic wedge, because 1) the constant dip of fold axes allows for the lateral projection of map data points to a single cross section, thus visualizing the thermal structure both in map view and in cross section over a depth range of nearly 8 km; 2) existing thermo-chronological data in the basement units (ECM) of the Helvetic nappes allow for the determination of syn-collisional T-t paths of the lower part of the wedge; 3) the well-suited lithologies of the Helvetic nappes allowed us to obtain 120 maximum temperatures with the RSCM method, hence depicting the 3D geometry of syn-collisional isotherms with a detail that has never been attained in previous literature.

Maximum temperature reached by the Upper Helvetic nappes lies in a range spanning between 193 °C and 350 °C ± 50 °C. For the Lower Helvetic nappes, the temperatures spread in a range of 232 °C and 358 °C ± 50 °C. In the Mont Joly nappe (Mont Blanc sedimentary cover), temperature ranges between 226 °C and 356 °C ± 50 °C. Interpolation of the data in map view shows a regular pattern of orogen-parallel isotherms, with T decreasing towards the foreland. Only at the western boundary of the Aar Massif, isotherms rotate around it, hence striking NW. Fold-axis-parallel projection of these data in cross sections, shows the geometry of the isotherms from the uppermost to the lowermost nappe of the Helvetic stack.

These results show that the isotherms are less folded than the layers suggesting that the thermal peak was attained after the accommodation of significant amounts of deformation. Moreover, the isotherms are not offset by the thrusts between the upper and the lower nappes, also suggesting their early stacking.

Nevertheless, the isotherms are nearly vertical in the core of the Morcles nappe, implying a significant post peak temperature deformation, that occurred during the rock exhumation due to the initiation of underlying crustal thrusts.

From these data, we propose that stacking of the Helvetic nappes initiated before thermal peak but deformation continued during and after this peak. This supports recent finding that most of the distributed shortening in the external zone was accommodated during a 5 to 10 Myrs long thermal peak before the localization of the deformation on frontal crustal thrusts.