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Thermomechanical constraints for the buoyancy-driven exhumation of the ultrahigh-pressure unit of the Dora-Maira Massif (Western Alps)

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The exhumation of UltraHigh-Pressure (UHP) rock units and their incorporation into orogenic wedges exhibiting significantly smaller peak pressures is still incompletely understood. The Dora-Maira Massif in the Western Alps includes the Brosassco-Isasca unit (BIU) whose metamorphic conditions peak at ∼40 kbar and ∼730 ˚C. Current estimates suggest decompression from the peak conditions to ∼10 kbar within ∼2 Ma. The BIU has a thickness of ∼1 km and a width between 10 and 20 km. The BIU is sandwiched between the San Schiaffredo unit (below) and the Rocca-Soleil unit (above) which both exhibit significantly lower peak metamorphic conditions of ∼15 kbar and ∼530 ˚C. All three units are usually considered to be from the same pre-alpine paleogeographic domain (i.e. Briançonnais domain). Assuming that metamorphic peak pressures were close to the lithostatic pressure, the San Schiaffredo and Rocca Solei units were buried to ∼50 km and the BIU to ∼130 km. The exhumation of UHP units is usually explained by buoyancy-driven flow, and two models are frequently considered: 1) Overall return flow of rocks within a distinct subduction channel and 2) upward flow of individual, lighter rock units within a heavier material (termed Stokes flow). However, both models fail to explain the formation of the Dora-Maira Massif and the BIU because model 1) predicts considerably larger volumes of UHP rocks than observed in the Dora-Maira Massif, and model 2) usually incorporates the UHP unit in the overriding plate and not within the orogenic wedge. Here, we present simple two-dimensional thermomechanical numerical models of exhumation by Stokes flow. We performed systematic simulations for linear viscous flow without temperature to constrain the general conditions for which exhumation by Stokes flow is applicable to the Dora-Maira Massif and the BIU. We assumed a dip of the subduction zone of 45 degrees. This requires that the UHP rocks not only exhume vertically by 80 km but also move horizontally over 80 km in order to be placed between the units at 50 km (15 kbar) within the orogenic wedge. Our main criteria for the applicability of a Stokes flow simulation to the Dora-Maira Massif are 1) fast exhumation within a few million years, 2) significant horizontal displacement during exhumation such that the UHP unit can reach the lower pressure units from the same paleogeographic domain at the base of the orogenic wedge, and 3) little internal deformation of the UHP unit. The results of the systematic simulations were used to perform specific simulations with more complex laboratory derived flow laws and temperature dependent viscosity. The final results show that exhumation for specific thermomechanical conditions of the UHP units by Stokes flow can be a feasible model for the Dora-Maira Massif and the BIU. The application of the modelling results to field observations is discussed.