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Using subsidence and P-T-t history on the Alpine Tethys margin to constrain lithosphere deformation modes during continental breakup

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Mantle exhumation and hyper-extended crust, as observed on the Iberia-Newfoundland conjugate margins, are key components of both present-day and fossil analogue magma-poor rifted margins. Conceptual models of the Alpine Tethys paleogeography evolution show a complex subsidence history, determined by the nature and composition of sedimentary, crustal and mantle rocks in the Alpine domains (Mohn et al., 2010). The relative timing of crustal rupture and decompressional melt initiation and inherited mantle composition control whether mantle exhumation may occur; the presence or absence of exhumed mantle therefore provides useful information on the timing of these events and constraints on lithosphere deformation modes and composition. A single mode of lithosphere deformation leading to continental breakup and sea-floor spreading cannot explain observations. We have determined the sequence of lithosphere deformation modes for the fossil Alpine Tethys margin using a numerical model of the temporal and spatial evolution of lithosphere deformation; the model has been calibrated against observations of subsidence and P-T-t history for the Alpine Tethys margin.

A 2D finite element viscous flow model (FeMargin) is used to generate flow fields for a sequence of lithosphere deformation modes, which are used to advect lithosphere and asthenosphere temperature and material. FeMargin is kinematically driven by divergent deformation in the topmost 15-20 km of the lithosphere inducing passive upwelling beneath that layer; the upper lithosphere is assumed to deform by extensional faulting and magmatic intrusions, consistent with observations of deformation processes occurring at slow spreading ocean ridges (Cannat, 1996). We also include buoyancy enhanced upwelling in the kinematic model as proposed by Braun et al. (2000). We generate melt by decompressional melting using the parameterization and methodology of Katz et al. (2003).

In the modelling of the Alpine Tethys margin, lithosphere deformation starts with simultaneous lithosphere extensional events to create both Valais and Piemont-Liguria rift basins. Buoyancy enhanced upwelling is required to generate uplift and emergence of the Briançonnais which is located between the Valais and Piemont-Liguria basins. Rifting in the Valais then ceases and the axis of extension and buoyant upwelling is focussed on the Piemont-Liguria basin leading to hyper-extension (e.g. Err and Bernina domains) and then to mantle exhumation (e.g. Platta domain). We explore the cause of the rapid post-uplift subsidence of the Briançonnais and show that this cannot be explained by thermal subsidence alone; crustal thinning (possibly depth-dependent) is also required. Particle tracking is used to predict P-T-t histories, which are tested against observations. Initial continental crust thickness and lithosphere temperature structure are important in controlling initial elevation and subsequent subsidence and depositional histories.