# Growth of Continental Plateaus by Channel Injection: Constraints and Thermo-Mechanical Consistency

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Recent interpretations suggest that weak, possibly partially molten, middle crust beneath plateaus plays a significant role in the dynamics of plateaus (Fig. 1a; Royden, 1996; Shen *et al*., 2001; Beaumont *et al*., 2001, 2004). How the edges of growing plateau connect to the foreland in the transition zone is, however, not entirely clear. Observations and numerical models suggest several mechanisms. The focus of our recent research is a Channel Injection (CI) mode, in which the plateau mid-crustal channel continues into the transition zone, brings material to thicken transitional crust, and widens plateau (Fig. 1b).

Simple modelling is used to improve our understanding of the first-order controls on the growth of continental plateaus and the interactions that occur within the transition zone. The simplified approach of this study also helps us to gain more insight into the results of numerical models which produce realistic looking results but are difficult to interpret in terms of the basic physical controls (Beaumont *et al*., 2001, 2004; Jamieson *et al*., 2004).

We developed successively more complete approximations to the evolution of a continental plateau and adjacent transition zone by the CI mode. CI-1, the simplest approximation (based on Clark and Royden, 2000), assumes a constant viscosity and thickness channel in which excess material accretes in zones above and below the channel. While the predictions of this model compare well with some natural examples, this model does not consider relations between plateau and transition zone. CI-2 includes a decrease in channel viscosity, predicted to occur on melt weakening or at high temperatures, when the crustal thickness exceeds a critical value, $D^*$ This model completes the connection between plateau and transition zone, but relies on the arbitrary chosen critical thickness of the crust. CI-3 is more realistic and considers the channel viscosity and thickness to be temperature dependent. CI-3 includes an associated thermal model which accounts for radioactive self-heating of the transition crust and for the heat advection as channel material flows from beneath the plateau. CI-3 demonstrates self-consistent plateau widening if the channel viscosity decreases when its temperature exceeds the critical value $T^*$.

The simplicity of the models allows analytical solutions for some cases and provides direct estimates of the parameters that control channel flow. Acceptable results for the topography of Tibet, for example, are achieved by CI-3 model when the channel viscosity is in the range $10^{18}$–$10^{19}$ Pa·s beneath Tibet and $10^{19}$–$10^{22}$ Pa·s beneath the adjacent areas and the critical temperature for the onset of partial melting is in the range 700–750 °C. These values agree with those determined from fully coupled thermal-mechanical models. Analysis of topographic data of the Central Andes with CI-2 model shows that the critical thickness of transitional crust in Andes plateaus is approximately 62 km.

The importance of CI-3 is that it can provide a consistent explanation in terms of both the mechanical and thermal evolution of the plateau and its transition. Additional analysis is used to determined the range of parameter values for which CI models are both internally consistent, and consistent with observations..

1. The thermal consistency test, asks whether the channel temperature is sufficient for viscous flow in quartz-rich rocks, and whether the temperature reaches the melting point, thereby initiating melt weakening, at the appropriate place and time. Comparison of the thermal evolution of CI-3 with a model in which transitional crust tectonically thickens uniformly shows that CI is a much more effective mechanism for heating the transitional crust.
2. Transient consistency test assesses whether the development of the melting conditions in the transitional crust coincides with the end of thickening. Premature melt weakening will, for example, result in the flattening the transitional zone topography before it reaches the level of plateau, and that is incompatible with lateral growth of plateau. The requirement for consistency significantly restricts the range of compatible parameter values.
3. Rheological consistency compares the channel viscosity in the conditions of the transitional crust with viscosity estimates from the laboratory experiments. Modelling of wide ($1.5–2\times10^3$ km) transitional zones, for example, with CI-3 requires channel viscosity to be about $10^{18}$ Pa·s which is incompatible with laboratory data.
4. Compatibility with the models of the upper crust was also checked. The CI models assume that the crust overlying the channel acts as a passive load. We compare CI with the models in which upper crust deforms viscously and show that viscously deforming upper crust can change estimates of crustal viscosity by up to two orders of magnitude. We also consider brittle upper crust and estimate the range of strength properties of this crust that are compatible with the CI models.

We demonstrate the consistency of the CI model using generic and natural (Tibet, Altiplano) parameters.

**References:**

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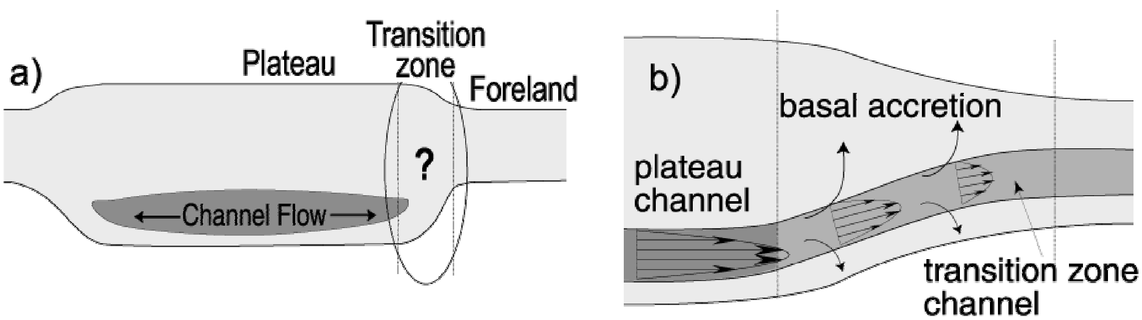


**Figure 1:** General view on the model of continental plateau (a), and the channel injection (CI) model for transition zone (b).