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Channelled flow of lava with temperature dependent pseudoplastic rheology: condition for tube formation

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Conditions for crust and tube formation are studied assuming for lava a pseudoplastic rheology dependent on temperature (*Sonder, pers. Comm.*).

The pseudoplasticity is the rheological model which, from recent laboratory studies, better describes the behaviour of basaltic lava (e.g. *Sonder et al.*, 2006). The pseudoplastic rheology belongs to the power law rheology and the constitutive equation for a power law fluid is the following:

$$\sigma_{ij} = 2k\dot{e}^{n-1}\dot{e}_{ij} \tag{1}$$

where k is the fluid consistency, n is the power law exponent and e depends on the second invariant of the deformation rate tensor. For a pseudoplastic fluid we have that n <1.

The equation of the motion for a gravity driven channelled flow of lava with power law rheology was recently solved with the finite volume method (*Filippucci et al.*, 2010).

The authors concluded that the assumption of the power law rheology introduces consistent variations in the velocity field respect to the newtonian case and this difference grows with increasing of the channel slope.

Starting from these results, we studied the effect of the cooling of a lava channel with pseudoplastic rheology with the aim of understanding the difference with the newtonian case, regarding both the superficial crust formation in the central region open channel and the transformation of an open channel in a lava tube.

The surface crust formation seems to depend on several factors as the flow rate, the ground slope, the surface cooling rate, and the rheology of the flowing fluid; the transition to a lava tube also depends on thermal, dynamical and rheological properties of the flow and on topography (*Dragoni et al.,* 1995; *Cashman et al.*, 2005). *Valerio et al.* (2008) investigated the condition of crust and tube formation assuming lava with newtonian rheology. We are interested now in understanding which variations can arise from changing the assumption on rheology and considering a pseudoplastic rheology with temperature dependence.

We describe the crust formation by the cooling of the open channel and found that the rapidity of the crust growth strongly depends on the non-linearity of the lava rheology. The description of the tube formation is accomplished by studying the variation in the superficial shear stress due to morphological and topographical changes, as described by *Valerio et al.* (2008).

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