Solidification effects on sill formation: An experimental approach

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Abstract

Sills represent a major mechanism for constructing continental Earth's crust because these intrusions can amalgamate and form magma reservoirs and plutons. As a result, numerous field, laboratory and numerical studies have investigated the conditions that lead to sill emplacement. However, all previous studies have neglected the potential effect magma solidification could have on sill formation. The effects of solidification on the formation of sills are studied and quantified with scaled analogue laboratory experiments. The experiments presented here involved the injection of hot vegetable oil (a magma analogue) which solidified during its propagation as a dyke in a colder and layered solid of gelatine (a host rock analogue). The gelatine solid had two layers of different stiffness, to create a priori favourable conditions to form sills. Several behaviours were observed depending on the injection temperature and the injection rate: no intrusions (extreme solidification effects), dykes stopping at the interface (high solidification effects), sills (moderate solidification effects), and dykes passing through the interface (low solidification effects). All these results can be explained quantitatively as a function of a dimensionless temperature θ, which describes the experimental thermal conditions, and a dimensionless flux φ , which describes their dynamical conditions. The experiments reveal that sills can only form within a restricted domain of the (θ,φ) parameter space. These experiments demonstrate that contrary to isothermal experiments where cooling could not affect sill formation, the presence of an interface that would be a priori mechanically favourable is not a sufficient condition for sill formation; solidification effects restrict sill formation. The results are consistent with field observations and provide a means to explain why some dykes form sills when others do not under seemingly similar geological conditions.

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