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Magma differentiation in dykes: from field evidence to numerical study

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Mechanisms active during magma ascent in dykes are not still well quantified. From field observations, it is apparent that most dykes actually contain a crystalline load. The presence of a crystalline load modifies the effective rheology of such a system and thus the flow behaviour. For example, increasing both the density and viscosity of each crystal, compared to the melt, will cause a reduction of the ascent velocity and will modify the shape of the velocity profile from "Poiseuille like" to "Bingham-like".

One issue related to the introduction of a crystalline load concerns the possibility for crystals to be segregated from a viscous granitic melt phase during magma ascent. The implications of such a process on magmatic differentiation have not previously been considered, nor has such a process been previously investigated via numerical models. In this study, we examine the flow dynamics of a poly-crystal bearing granitic melt ascending in a dyke via numerical models.

Results showed that the melt phase can be squeezed out from a crystal-rich magma when subjected to a given pressure gradient range and that crystals behaviour is strongly dependant on their size and density. This demonstrates that crystal-melt segregation in dykes during granitic magma ascent constitutes a viable mechanism for magmatic differentiation.

In order to quantify such a mechanism, results have been compared to two well-characterized granites from the Armorican Massif (France). Geochemically, these two granites originate from the same magmatic source, but the shallowest one (Questembert granite) can be derived from the deepest (Lizio granite) by a larger amount of crystal segregation during magma ascent in dykes. In our numerical models, we therefore use as initial conditions, the volume fraction and geochemical properties of the "Lizio-type" magma and compute the vertical distance required to end up with the "Questembert-type" magma. The comparison of the results allowed us to estimates the parameters such as pressure gradient, distance, viscosity, etc… needed, to explain their different degrees of geochemical differentiation.