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# Model experiments on magma migration in a viscoelastic host rock : effect of viscosity

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Magma generated from partial melting ascends upwards by its buoyancy to the magma chamber, some of which erupt at the Earth's surface. Magma is considered to ascend in the form of diapir in the asthenosphere and transforms to dykes in the lithosphere (Rubin, 1995) . These two end member cases have been studied in detail, but the mechanism of magma ascent in the transitional regime is still poorly known. We have been studying the ascent mechanism in the transitional regime by model experiments using a viscoelastic agar (Sumita and Ota, 2011). Here we report the results of experiments which focus on the effect of fluid viscosity on the magma migration in a viscoelastic medium.

We conducted (1) rheology measurement of agar and (2) fluid injection experiments. We inject magma (CsCl solution to which a thickener is added) using a syringe from the top of a cylindrical acrylic tank (height of 250 and 500 mm). The fluid has a volume of 1ml, density difference with the agar of 0.108 g/ml, and is injected at a constant rate of 0.1 ml/s. We vary the agar concentration in the range of 0.04-0.5 wt% and the fluid viscosity in the range of 10ˆ-3 - 650 Pas. As we increase the agar concentration in this range, we find that the yield stress and the rigidity of the agar increases by 3 orders of magnitude. By shearing the sample under a constant stress (creep test) we find that the agar can be approximated by a Voigt model to which a spring is connected in series. The experiments are recorded using video cameras from two sides and from the bottom of the tank.

From the injection experiments, we find that as the agar rigidity (G) decreases, the crack shape transforms from 2D (blade-like) to 3D (having a bulged head). The critical rigidity (Gc) of the 2D-3D transformation is around Gc=10 Pa, and this value becomes smaller when a high viscosity fluid is injected. The value of Gc is consistent with the rigidity estimated from the balance between the elasticity and buoyancy at which the strain becomes 1. The crack consists of a bulged head and a thin sheet-like tail, and the head becomes thinner and smaller as the crack elongates. When a stiff agar is used as the host, or when a high viscosity fluid is injected, the crack propagation stops within a certain distance from the injection point. We find that this propagation distance becomes shorter as we increase the agar yield stress or the viscosity of the injected fluid, and this result can be associated with the transformation of the crack shape to 2D. We fit the time-distance data to a power-law relation, and find that the exponent varies from 1/3 to 1. An exponent of 1/3 corresponds to the scaling obtained for a 2D crack which thins uniformly as it elongates (Taisne et al, 2011). An exponent larger than 1/3 corresponds to the crack shape becoming more 3D. To conclude, we find that the magma viscosity not only slowers its migration velocity, but also controls the crack shape, its deceleration, and the propagation distance until it stops.

References:

Rubin, A. M., 1995, Ann. Rev. Earth Planet. Sci, 23, 287-336.
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