Quantifying mineral dissolution andxenolith digestion rates

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Minerals and xenoliths dissolve in magma as it falls or risesrelative to the magma. Such convective dissolution rates areoften higher than diffusive dissolution rates and can be quantifiedusing the theory Kerr (1995) and Zhang and Xu (2003). In thiswork, I use the theory to carry out a parametric investigation ofzircon dissolution rate and xenolith digestion rate. The digestion rate of a xenolith is given as -dr/dt = bD/dwhere -dr/dt is the dissolution rate, D is diffusivity of the maindiffusing component (such as MgO for olivine-rich xenolith), d isthe boundary layer melt thickness for a xenolith sinking freelyrelative to the melt, and b is a dimensionless compositionalparameter (C0-C∞)/(Cx-C0) where C is the concentration of themain diffusing component and the unit is mol/L, C0 is the interfacemelt concentration, C∞ is the initial melt concentration, and Cx isthe concentration in the xenolith. Given temperature, xenolithcomposition and melt composition, the parameter b can beestimated from thermodynamics of the melt, and diffusivity D canbe found from literature. Hence the calculation of xenolithdigestion rate becomes the problem of calculating the boundarylayer thickness d. The results show that the boundary layerthickness does not change significantly with increasing xenolithsize, and is roughly proportional to the (1/3) power of viscosity.We are constructing a viscosity model that is able to calculateviscosity of all natural melts. The density difference betweenxenolith and melt also affects the boundary layer thickness. Forexample, at 1300°C, assuming D = 10-11 m2/s, viscosity η = 10Pa·s for a Hawaiian basalt, b = 0.08 for olivine and 0.16 forpyroxene, the boundary layer thickness is about 0.072 mm, and thedissolution rate is about 0.04 mm/hr for olivine and 0.08 mm/hrfor pyroxenes. The ascent velocity of magma must be more than0.19 m/s to entrain a xenolith of radium 50 mm to bring it to thesurface. Zircon dissolution rate and “immortality” of zircon willalso be investigated.

References:

1. Kerr (1995) Contrib. Mineral. Petrol., 121, 237-246.2. Zhang & Xu (2003), Earth Planet. Sci. Lett., 213, 133-148.