Viscosity and atomic structure of CO_2-bearing magmas in the Earth's interior

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Magmas that form by low-degree of partial melting of mantle rocks play a leading role in the mobilization of deep carbon from the interior to the feeding system of active volcanoes. These magmas are, however, exposed to variations of the SiO_2/CO_2 ratio and degree of polymerization during their ascent with important implications for their rheological properties and, in turn their migration towards the crust. The aim of this study was to determine the viscosity of synthetic CO_2-bearing melts and investigate their atomic structure at pressures (P) and temperatures (T) of the Earth's upper mantle in order to formulate a model of rheology as function of depth, melt composition and mantle redox state. We determined the viscosity of several synthetic molten glasses with variable CO_2 (2.5-40 wt%) and SiO_2 (5-40 wt%) contents as representative of natural carbonatitic, melilititic and kimberlitic magmas at pressures between 0.5 and 7 GPa at 1200-2000 °C using the Paris-Edinburgh press available at the 16BMB beamline at the Advanced Photon Source (USA). The starting materials consisted of glasses synthesized at high P and T using both the multi anvil press and piston cylinder apparatus from either a mixture of oxides and carbonates or from natural ultrabasic rock powders. The viscosity at each run was determined in situ from the fall velocity of a Pt sphere according to the Stokes' equation, followed by structural measurements of the liquids at HP-T by multi angle-energy dispersive X-ray diffraction. In addition, micro-Raman and micro-FTIR spectroscopy were used to investigate the speciation and polymerization of C-O molecules in the recovered quenched glasses. Our results show that the viscosity varies from 0.001 to 1 Pa·s from pure carbonatitic to foiditic melt compositions and appears strongly dependent on SiO_2 content. These viscosity data are used to model the mobility and ascent velocity of primitive CO_2-bearing magmas considered to have been parental magmas in some volcanic areas.