Effects of crystallization and bubble nucleation on the elastic properties of magmas

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Seismic tomography of potentially hazardous volcanoes is a prime toolto assess the physical state of magma reservoirs. Processes occurring in the magma conduit or chamber, such as crystallization, bubble exsolution and growth, control the magma rheology, hence the style of volcanic eruptions. Elastic parameters of vapor-saturated, partially molten systems are thus providing fundamental information for the identification of such reservoirs under active and seemingly dormant volcanoes. This knowledge will potentially serve to assess their risk.

For this investigation we selected a chemically simplified melt analogous to andesite and trachyte, in the system CaO-Na2O-Al2O3-SiO2-H2O-CO2 (Picard et al, 2011), which undergoes plagioclase crystallization and bubble exsolution upon cooling and/or decompression. Seismic velocities of such a system are of prime importance as plagioclase is the principal microlite phase crystallizing during ascent-driven decompression (e.g. Cashman and Blundy, 2000).

Phase equilibria of the considered system are computed for various pressure, temperature and water contents using PerpleX (Connolly and Kerrick, 2002). These thermodynamic data are used to estimate variation of elastic moduli and density, and thus wave propagation velocities.

The theoretically computed values are compared to laboratory measurements of compressional and shear wave propagation velocities on synthetic melts. Ultrasonic velocities are simultaneously measured in a Paterson-type internally-heated gas pressure apparatus at confining pressures up to 300 MPa and temperatures up to 1000degC. Using the pulse transmission technique, the experiments are performed at frequencies ranging from 0.1 to 3 MHz. Variations in the elastic parameters induced by the presence of bubbles or dissolved water in super-cooled liquids and glasses are discussed for various pressures and temperatures. As the investigated melt undergoes plagioclase crystallization, a thermal plateau is maintained over a specific duration in order to measure the changes in seismic properties associated with in-situ crystallization of the magma. This maintained temperature varies between 800 and 1000degC depending on the amount of dissolved water in the system.

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