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Determination of the influence of pressure and dissolved water on the viscosity of highly viscous melts: Application of a new parallel-plate viscometer

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ABSTRACT

A parallel-plate viscometer has been designed for use in an internally heated pressure vessel (IHPV) at pressures up to 350 MPa and at temperatures up to 900 °C. The viscosity of a melt is determined by measuring the rate of deformation of a cylindrical sample as a function of an applied, constant stress at a fixed temperature. The viscometer consists of a small furnace with two independent heating resistors, a moveable load by which the stress is applied to the sample, and a pressure-resistant transducer (LVDT) that measures the deformation of the sample. The accessible viscosity range covers three orders of magnitude from $10^{8.5}$ Pa·s to $10^{11.5}$ Pa·s.

Calibration measurements on the standard melt DGG1 at 0.1MPa demonstrated the precision of the viscometer to be within ±0.08 log units. Subsequent measurements at elevated pressure on DGG1-melt, Di_{100}-melt (Di = $CaMgSi_2O_6$), and $Ab_{55}Di_{45}$-melt (Ab = $NaAlSi_3O_8$, composition in weight percent) showed a pronounced increase of viscosity with pressure. Comparison with literature data on the pressure dependence of the transformation temperature of Di_{100}-melt (Rosenhauer et al. 1979) confirmed the reliability of these findings. The dependence on pressure becomes smaller with increasing temperature for these depolymerized melts; e.g., in the case of Di_{100}-melt (NBO/T = 2) from $d\eta/dP$ = +0.23 log units/100 MPa at 751 °C to $d\eta/dP$ = +0.18 log units/100 MPa at 770 °C. In contrast to the depolymerized melts, a polymerized melt of haplotonalitic composition (NBO/T = 0) shows a decrease by –0.12 log units/100 MPa in the pressure range 50–350 MPa at 889 °C.

Possible application of the new viscometer to study rheological properties of volatile-bearing melts was tested successfully with a hydrous haplotonalitic melt. Addition of 3.80 wt% of water to the anhydrous melt strongly shifts the viscosity-temperature relationship toward lower temperatures; e.g., at a viscosity of $10^{10.5}$ Pa·s from 883 to 515 °C. The measured viscosities did not drift during the run, indicating that water loss is negligible within the time scale of the experiments, as confirmed by IR-microspectroscopic analysis.