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An updated calibration of the plagioclase-liquid hygrometer-thermometer applicable to basalts through rhyolites

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Abstract

An updated and expanded data set that consists of 214 plagioclase-liquid equilibrium pairs from 40 experimental studies in the literature is used to recalibrate the thermodynamic model for the plagioclase-liquid hygrometer of Lange et al. (2009); the updated model is applicable to metaluminous and alkaline magmas. The model is based on the crystal-liquid exchange reaction between the anorthite ($CaAl_2Si_2O_8$) and albite ($NaAlSi_3O_8$) components, and all available volumetric and calorimetric data for the pure end-member components are used in the revised model. The activities of the crystalline plagioclase components are taken from Holland and Powell (1992). Of the 214 experiments, 107 are hydrous and 107 are anhydrous. Four criteria were applied for inclusion of experiments in the final data set: (1) crystallinities <30%; (2) pure-H_2O fluid saturated; (3) compositional totals (including H_2O component) of 97–101% for hydrous quenched glasses and 98.5–101 for anhydrous quenched glasses; and (4) melt viscosities ≤5.2 $\log_{10}$ Pa·s. The final data set spans a wide range in liquid composition (45–80 wt% SiO_2; 1–10 wt% Na_2O+K_2O), plagioclase composition ($An_{17–95}$), temperature (750–1244 °C), pressure (0–350 MPa), and H_2O content (0–8.3 wt%). The water solubility model of Zhang et al. (2007) was applied to all hydrous experiments. The standard error estimate on the hygrometer model is 0.35 wt% H_2O, and all liquid compositions are fitted equally well. Application of the model as a thermometer recovers temperatures to within ±12°, on average. Tests of the hygrometer on anhydrous piston-cylinder experiments in the literature, not included in the regression, show that the model is accurate at all pressures where plagioclase is stable. Applications of the hygrometer are made to natural rhyolites (Bishop Tuff, Katmai, and TobaTuff) with reported H_2O analyses in quartz-hosted melt inclusions from the literature; the results show agreement. Applications of the hygrometer/thermometer are additionally made to natural rhyolites from Iceland and Glass Mountain, California. The updated model can be downloaded either as a program in Excel format or as a MatLab script from the Data Repository.

Keywords: Plagioclase-liquid hygrometer, hygrometer, thermometer, plagioclase, liquid