

A thermodynamic model for the plagioclase-liquid hygrometer/thermometer

REBECCA A. LANGE,* HOLLI M. FREY, AND JACOB HECTOR

Department of Geological Sciences, University of Michigan, 1100 North University Avenue, Ann Arbor, Michigan 48109-1005, U.S.A.

ABSTRACT

A new thermodynamic model for the plagioclase-liquid exchange reaction between the albite ($\text{NaAlSi}_3\text{O}_8$) and anorthite ($\text{CaAl}_2\text{Si}_2\text{O}_8$) components is presented, which can be used as a plagioclase-liquid hygrometer or thermometer. The model incorporates calorimetric and volumetric data for the pure liquid and crystalline components, which permits the effect of temperature and pressure on the exchange reaction to be calculated independently from the effect of composition. This allows a more accurate assessment of the effect of melt composition (including dissolved water concentration) on the exchange reaction from plagioclase-liquid equilibrium experiments. Activity-composition relations for the plagioclase solid solution are taken from Holland and Powell (1992). The new hygrometer is calibrated on 71 plagioclase-liquid experiments, of which 45 are hydrous and 26 are anhydrous. Three filters were applied to the phase-equilibrium data: (1) crystallinities <30%; (2) pure H_2O fluid-saturated; and (3) compositional totals (including H_2O component) of 97–101% for hydrous quenched glasses. The final data set spans a wide range of liquid compositions (46–74 wt% SiO_2), plagioclase compositions (An_{93} - An_{37}), temperatures (825–1230 °C), pressures (0–300 MPa), and dissolved melt water concentrations (0–7 wt% H_2O). The standard error of estimate (SEE) for the model is ± 0.32 wt% H_2O , and all liquid compositions are fitted equally well. When the model is used as a thermometer, all measured temperatures are recovered equally well within ± 14 °C on average. The model is only recommended for applications that fall within the compositional bounds of the calibration data set (i.e., metaluminous basalts through rhyolites in equilibrium with An_{95} - An_{35}). It is not yet calibrated for rhyolites crystallizing plagioclase more sodic than An_{30} , owing to an absence of phase-equilibrium experiments on rhyolites that pass the required filters. The new plagioclase-liquid hygrometer/thermometer is available as a Visual Basic program that runs on Excel 2004.

Keywords: Thermodynamics, anorthite, albite, magmatic water concentrations, geothermometry, H_2O speciation