

VARIATION OF VISCOSITY WITH TEMPERATURE AND COMPOSITION IN THE PLAGIOCLASE SYSTEM; W. Hummel and J. Arndt, Mineralogisch - Petrographisches Institut der Universität Tübingen, 7400 Tübingen, Federal Republic of Germany

Knowledge of the viscosity of silicate liquids is a fundamental prerequisite for the successful development of petrologic models involving kinetic and transport phenomena. For example, for understanding the lunar anorthosite forming event as the result of diapiric intrusions (Longhi and Ashwal 1984), the viscosities of anorthite rich plagioclase melts must be known. In the present study the viscosities of thirteen different plagioclase compositions have been measured in the viscosity range  $10^{4.3}$  to  $10^8$  dPas using a micro-penetration viscometer (Arndt and Hummel 1983). The viscosity data obtained are shown in Fig.1. Application of the most common empirical and theoretical viscosity-temperature models to these data showed that the configurational entropy theory (Richet 1984) represents the best approach. According to this theory the relation between viscosity and temperature is given by

$$\log(\eta) = A_e + B_e / T \cdot S_{conf} \quad (1)$$

where  $\eta$  is the viscosity (dPas),  $T$  is the temperature (K),  $S_{conf}$  is the configurational entropy (J / mol·K), and  $A_e$  and  $B_e$  are adjustable parameters.

For the calculation of the configurational entropy of the end-members albite and anorthite all thermodynamic data required are available (Richet 1984). From the plots of the present viscosity data and available literature data versus  $1 / T \cdot S_{conf}$  shown in Fig.2, the values of the two adjustable parameters have been determined:

$$\text{Albite: } A_e = -1.260 \pm 0.035, \quad B_e = (5.659 \pm 0.018) \cdot 10^5$$

$$\text{Anorthite: } A_e = -2.126 \pm 0.030, \quad B_e = (5.676 \pm 0.022) \cdot 10^5$$

As is seen from Fig.2, all experimental data plot very well on the regression lines calculated from equ. (1). The identical slopes of the two lines indicate that the elementary steps in viscous flow are the same in both the albite and anorthite melts.

The configurational entropy approach is as yet the only theory that allows the calculation of the dependence of viscosity on composition. However, the calculation of the isothermal viscosities of intermediate plagioclase compositions solely from the pertinent data of the end-members albite and anorthite requires in addition the evaluation of an entropy of mixing term that adds to the configurational entropy of the pure end-members. A realistic mixing model for aluminosilicate melts is represented by the "two-lattice" model (Weill et al. 1980) which has been modified by the present authors in order to account for local charge balance in the plagioclase melts. The resulting entropy of mixing term is given by:

$$\Delta_m S = -R \left( \frac{Y}{2} \cdot \ln \left\{ y \left( 1 + \frac{Z}{2} \right)^2 \left( 1 - \frac{Z}{2} \right)^2 \right\} + \frac{Z}{2} \cdot \ln \left\{ z \left( 1 + y \right) \left( 1 - \frac{Y}{3} \right)^3 \right\} \right) \quad (2)$$

where  $y$  and  $z$  are the mol fractions of anorthite and albite, respectively, and  $R$  is the gas constant.

The isothermal viscosities of intermediate plagioclases have been calculated with

$$\log(\eta)_T = y \cdot \log(\eta)_{T,An} + z \cdot \log(\eta)_{T,Ab} \quad (3)$$

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The values of  $\log(\eta)_{T,An}$  and  $\log(\eta)_{T,Ab}$  are calculated from equ. (1) for a temperature  $T$  with the parameters for anorthite and albite, whereby the configurational entropy is varied by the addition of the entropy of mixing term (equ. 2). The results are shown as solid lines in Fig. 1. Taking into consideration the experimental errors, the agreement between measured and calculated viscosity data is excellent.

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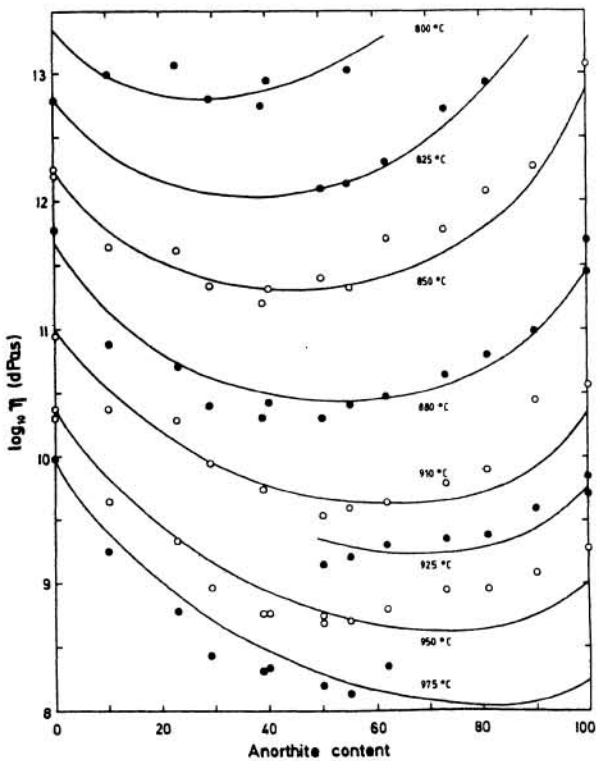


Fig. 1 Isothermal log viscosities of plagioclases. The circles are experimental data and the solid lines have been calculated from equ. (3).

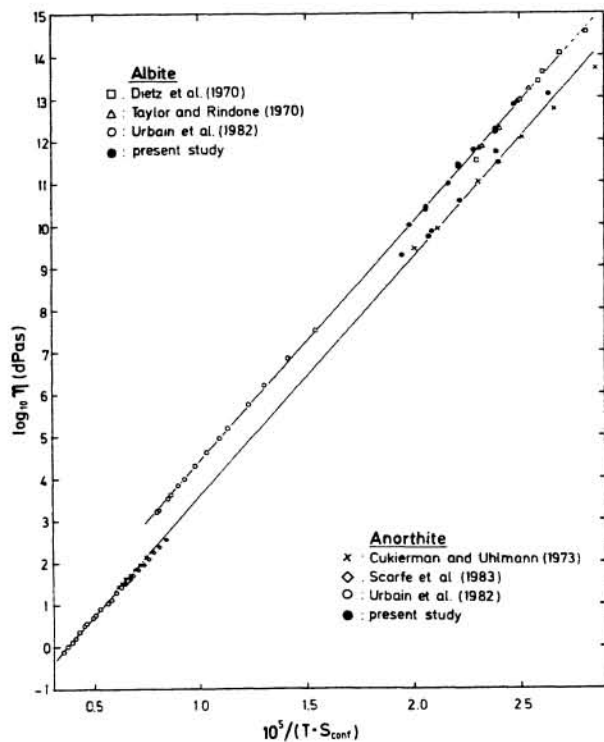


Fig. 2 Log viscosity versus  $1/TS_{conf}$  for albite and anorthite. The solid lines have been determined by linear regression.