Re-examination of viscosity evaluation model by Goto (1997)

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In the last half century, many viscosity prediction models for magmatic silicate melts have been proposed. Among them the popular and classical one by Shaw (1972) gives good evaluation of viscosity above liquidus temperature, but below liquidus it underestimates the viscosity. This is due to the incorrect supposition that logarithmic viscosity of silicate melts increases linearly against reciprocal absolute temperature (Arrhenius relation).

Goto (1997) applied Williams-Landel-Ferry (WLF) equation, theoretically supported one to express non-Arrhenian behavior of glass forming liquids, to evaluate the viscosity (*vis*) against absolute temperature (T) by determining the composition dependency of four parameters in the equation:

$\log vis = \log vis_{Tg} + A(T-T_g)/(B+T-T_g)$

vis_{Tg}: viscosity at glass transition temperature; A, B: adjustable constant; T_g: glass transition temperature

Measuring viscosity from 10^1 to 10^{14} Pa s and glass transition temperature for five volcanic rocks from basaltic andesite to rhyolite, he showed vis_{Tg} and A does not depend on chemical composition, and expressed the compositional dependency of B and T_g using the parameter S that gives Arrhenian slope in viscosity model by Shaw (1972). The application of WLF equation, together with evaluated compositional dependency/independency of four parameters, succeeded in evaluating the literature viscosity for five magmatic melts in wide temperature range. Furthermore, additional experiments for basaltic and rhyolitic melts to heighten the correctness of the model have finalized the four parameters to be:

$T_g = 48S^2 - 251S + 1248$

$\log vis_{Tg} = 12.8$

$A = 17.9$

$B = 26S^2 + 42S + 114$

However, scarcities of experimental samples and literature data for confirmation prevented this model from being published, except the appearances before revision in the proceedings of international meeting (Goto et al., 1997) and the article for lava flow simulation by Hidaka et al., (2005).

In about the recent decade a large amount of viscosity data in wide temperature and compositional ranges from literatures have become available to re-examine the above-mentioned revised model (Goto model). These viscosity data also have been applied to construct some new viscosity models. In the present study we re-examine Goto model by comparing the calculated viscosity with literature data and evaluations by Giordano and Dingwell (2003) (G&D model).

The used 608 viscosity data for 37 samples covers almost all types of volcanic rocks, including some synthetic samples without iron nor some alkaline earth elements. Among them 314 data for 19 samples were used to construct G&D model; it is self-evident this model predicts these viscosity correctly.

Overall the calculated viscosity by both models agree well with literature data below 10^5 Pa s, but become less precise above it. To compare the correctness of the two models, histograms for calculated viscosity minus measured viscosity were drawn for both viscosity data used and not used for G&D model construction, divided into low and high viscosity region, respectively, together with standard deviations. For the data used in G&D model, Goto model also predicted their viscosity almost the same level as G&D model, although the standard deviations were slightly larger. For the data not used in G&D model, both model predicted their viscosity better than for the former data. The standard deviations from Goto model became closer to, and became smaller than those from G&D model at low and high temperature regions, respectively. It is noteworthy although Goto model used only seven samples for its construction, it evaluates the viscosity with almost the same correctness of G&D model. These universality may be due to the application of parameter S by Shaw (1972) that reflects the compositional effect on viscosity satisfactory at high temperature, and theoretical base of WLF equation.