ELECTRONIC SUPPLEMENT

Study-by-study comparisons of the previous models

Over the last four decades, over ten models have been reported to calculate the viscosity of various silicate melts. Shaw (1972) and Bottinga and Weill (1972) were the pioneers in developing viscosity models on the basis of an Arrhenian temperature dependence for melt viscosity to predict the viscosity of geologically-relevant silicate melts at atmospheric pressure, with the viscosity range of $10^{-0.4}$-10^{5} Pa s (abbreviated as S-B-W model in the following descriptions). This model was used to predict the viscosity at high temperature, but the standard deviation is up to 0.99 log units when compared with the experimental data of high iron-bearing basaltic melts (Toplis et al., 1994) in the temperature range of 1572-1873 K. Baker et al. (1996) proposed an empirical equation to calculate the viscosity of rhyolitic melts (Baker model), covering a valid *T*-*P*-H_2O range of 973-1173 K, 0.001-10 kbar and 0-12.3 wt%, with the standard deviation of 0.54 log units on average. Based on the Arrhenius equation, Schulze et al. (1996) presented a specific model (S-B-H model) to predict the viscosity of rhyolitic melts in a wide *T*-*P*-H_2O range of 1073-1673 K, 0-10 kbar and 0-8.21 wt%, but it overestimates the experimental data (Persikov, 1991) by up to 1.62 log units. Following the method of the VFT (Vogel-Fulcher-Tammann) equation, Richet et al. (1996) developed a specific model to predict the viscosity of andesitic melts with the H_2O contents up to 3.5 wt% at 1 atm and 721.5-1978 K (R-L-H model). The modeling results are in good agreement with their fitting data (Richet et al. (1996), but the standard deviation is up to 1.72 log units when compared with the

experimental measurements (Liebske et al., 2003). With the adoption of the Arrhenius equation, a model for predicting viscosity of rhyolitic melts in the *T-H_2O* range of 900-1073 K and 0-7 wt% at 1atm was proposed by Scaillet et al. (1996), but it is not satisfactory in predicting the experimental data (Stevenson et al., 1995) with a maximum deviation up to 1.60 log units. Based on the VFT equation, Hess and Dingwell (1996) (H-D model) presented a model for hydrous leucogranitic melts with H_2O content up to 12.5 wt%, with the standard deviation of 0.72 log units on average. Giordano et al. (2003a) proposed an empirical model to calculate the viscosity of anhydrous melts at 0.001 kbar and 973-1873 K, but it deviates a lot from the experimental data (Liebske et al., 2003) with the standard deviation of more than 2 log units. Based on the kinetic of hydrous species reactions in the melt upon cooling, Zhang et al. (2003) (Z-H-L model) proposed an empirical model for hydrous melts from 570 K to 1920 K and 0.0006 wt% to 8.2 wt%. This model is in good agreement with experimental data of rhyolitic melts from 973 K to 1173 K, but it is not satisfactory between 895 K and 965 K, where the standard deviation is up to 3.55 log units. Based on the method of Giordano et al. (2003a), Giordano et al. (2006) proposed a model to predict the viscosity for various metaluminous, peraluminous and peralkaline melts at 0.001 kbar over a wide of temperature range (886-2538 K). However, the standard deviation for the viscosity of rhyolitic melts is up to 2.31 log units in comparison with the experimental data of Stevenson et al. (1995). Hui and Zhang (2007) (H-Z model) developed an advanced model for various natural melts at 1 atm over a wide range of *T-H_2O* range (573-2003 K, 0-5 wt% H_2O or 0-12.3 wt%

H_2O for rhyolitic melts). Nevertheless, there are 37 fitting parameters in the H-Z model, and this model doesn't perform relatively well for the iron bearing melts, especially for high iron-bearing melts, with the standard deviation of over 1.0 log units when compared with the experimental data of basaltic melts (Toplis et al., 1994). Vetere et al. (2006) and Vetere et al. (2008) used the modified VFT equation to model the viscosity of andesitic melts, covering a valid *T-P-H_2O* range of 1006-1796K, 0.001-10 kbar and 0-6 wt% H_2O (V-B-S model). The modeling results are in good agreement with the experimental data. On the basis of the modified VFT equation, Vetere et al. (2007) developed a model to predict the viscosity of shoshonitic melts, covering the temperatures from 733 K to 1673 K, pressures from 0.001 kbar to 5 kbar and H_2O contents from 0 wt% to 4.75 wt% (V-B-M model). Although the modeling results are good agreement with their fitting data, this model cannot be applicable into other mafic system (e.g., basalt). Based on the VFT equation, Misiti et al. (2006) and Misiti et al. (2011) developed a model to predict the viscosity of various melts (e.g., latite; shoshonite; trachyte) in the *T-P-H_2O* range of 840-1870 K, 0.001-5 kbar and 0-3.3 wt% (M-V-F model). It is worthy to note that only the data for shoshonitic melts can be used for comparison with M-V-F model in this study due to lack of information on the iron oxidation state for both latitic and trachytic melts that are available in the literature. The M-V-F model is in good agreement with the experimental data at temperatures above 1000 K, but not satisfactory at temperatures below 1000 K, where the standard deviation is up to 1.46 log units. Based on the Adam-Gibss (AG) equation, Avramov (2007) proposed a model to predict the viscosity of various melts

based on the synthetic melts, but this model is not valid in calculating the viscosity of natural melts, with the standard deviation of more than 3 log units in comparison with the experimental data of rhyolitic melts. Nevertheless, the model of Aramov (2007) was the first one to consider the pressure effect on the viscosity, which is fundamental to well understanding the pressure dependence of melt viscosity. Ardia et al. (2008) adopted the modified VFT equation to calculate the viscosity of rhyolitic melts in a valid *T*-*P*-H_2O range of 853-1913 K, 0.001-25 kbar and 0-5.24 wt% (A-G-S model). Although this model accounts for the pressure effect on viscosity, its standard deviation is up to 0.94 log units at pressures from 0.5 kbar to 2 kbar. By incorporating the compositional effect into the VFT equation, Giordano et al. (2008) developed a general model to predict the viscosity of various natural melts at the atmospheric pressure in a wide *T*-H_2O range of 518-1853 K and 0-8 wt% (G-R-D model). However, this model is not satisfactory in predicting the viscosities of iron-bearing melts, especially for high iron-bearing melts, with the standard deviation of over 1.0 log units in comparison with the experimental data of andesitic melts (Richet et al., 1996). Nevertheless, the G-R-D model is the mostly updated general model currently available for predicting the viscosity of variety of melts. Based on the Z-X-L model, Hui et al. (2009) proposed an empirical model to reproduce their experimental data of rhyolitic melts and claimed the model was valid in the *T*-*P*-H_2O range of 500-2000 K, 0.001-25 kbar and 0-12.3 wt% (H-Z-X model). However, the standard deviation of the model for the viscosity of rhyolitic melts in the *T*-*P* range of 973-1173 K and 0.5-2 kbar is about 0.70 log units in comparison with the experimental data of Persikov

(1991).