

## Modelling the Non-Arrhenian Rheology of Silicate Melts: Preliminary Results from the Anorthite-Albite-Diopside System

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**Introduction:** Viscosity is probably the single most important physical property governing the formation, transport and eruption of naturally-occurring silicate melts or magmas. It is over 25 years ago, since Shaw (1972) and Bottinga & Weill (1972) independently published two models for calculating the viscosities of hydrous silicate melts. The two models provided the first means to predict melt viscosities as a function of T and composition; their limitations are mainly a result of the experimental data that were available. The database on melt viscosities was inadequate in three main ways. Firstly, the entire database was small and comprised less than 1,000 experimental measurements. Secondly, the experimental data represented only a small proportion of the total compositional space occupied by natural melts. Thirdly, almost all of the experimental data derive from experiments at liquidus or higher temperatures where most melts show near Arrhenian temperature dependence.

**Towards a new model:** The extraordinary increase in the number of published measurements of melt viscosity for an expanding range of compositions has demonstrated the inadequacies of the existing models. However, the quality and volume of these data suggest that it is now possible to construct a new empirical model for describing the viscosities of natural systems. To be truly applicable to natural systems, future models must:

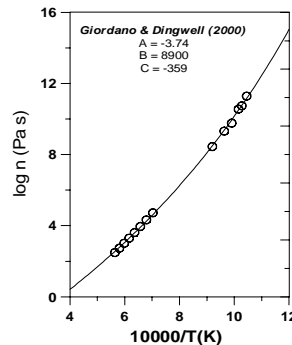
- be capable of describing melts that show Arrhenian and non-Arrhenian behaviour
- predict as a function of composition whether a melt will be Arrhenian or non-Arrhenian
- accurately reproduce the experimental database and predict results from future experiments.

The main challenge in building such models will be to find a means of partitioning the effects of composition across a system that shows both Arrhenian and non-Arrhenian temperature dependence. In the short term, the decisions governing how to expand the non-Arrhenian parameters in terms of composition will probably derive from empirical study.

**Numerical Considerations:** The non-linear character of the non-Arrhenian models ensures strong numerical correlations between model parameters that transcend the effects of composition. These correlations arise independent of the constitutive equation used (e.g., Vogel-Fulcher-Tammann VTF; Adam-Gibbs; Mode coupling theory).

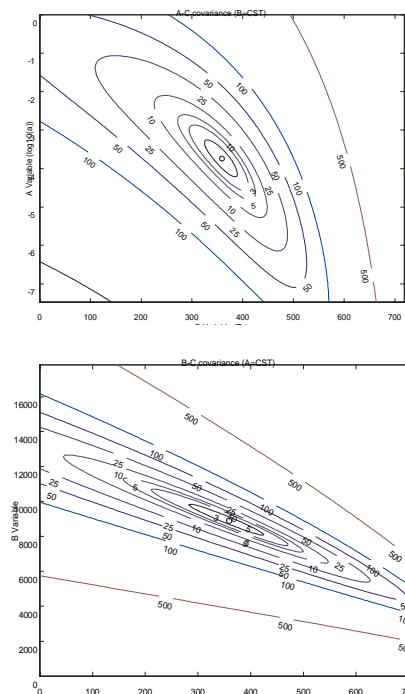
We present a numerical analysis of the nature and magnitudes of model-induced correlations arising from fitting the VTF model to published measurements of melt viscosity. We also show the extent to which the quality and distribution of experimental data can affect covariances between model parameters. These numerical correlations obscure the effects of composition and,

therefore, are critical to understand prior to deciding how to partition composition across non-Arrhenian melt models.



**Fig. 1** An example viscosity - T(K) dataset that is fitted to the VTF function. Fit parameters A, B and C are also given and their correlation is shown below.

**Fig. 2.** Contour plots of solution surface to fit of data in Fig. 1 to VTF equation. Surface is shown as two-dimensional projections of parameters A-C (upper) and B-C (lower).



**Application to An-Ab-DP:** We have applied these concepts to the simple anhydrous system An-Ab-Dp. This system has the attributes that: i) it is described fully by 3 components, ii) there are a large number of experiments spanning the entire system, and iii) the system contains melt compositions that are both strong and fragile, which makes it a good analogue for natural systems. On this basis, the system should provide a rigorous test of our strategy for modelling the compositional controls on viscosity.