

# SPECIALIZED GRANITIC SYSTEMS: A PHYSICO-CHEMICAL DESCRIPTION

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Specialized granites are associated with a wide range of ore deposits. The exact extremes of element enrichment in specialized granitic magmas are currently debated but it appears clear that minor element abundances of many components typically present in the trace element range of most granitic magmas are achieved. The enrichment of such elements in granitic melts influences the properties of the magma in two ways: 1) direct influence of the components on the melt properties through their partial molar properties as a consequence of their structural roles in the melt phase and 2) indirect influence of melt properties via the influence of these components on the phase equilibria of the magma. Many components of specialized granites lead to strong decreases in the temperature range of liquidus-solidus and as a result different physical and chemical melt properties can be expected. Additionally, a different thermal and mechanical relationship to the host rocks of igneous intrusion might be expected. The brittle-ductile transition will certainly be affected.

In order to understand the properties of magmas present during magmato-hydrothermal ore deposition, the influence of such enrichments on the physicochemical properties of granitic magmas have been experimentally investigated. The direct and indirect influences of minor components on melt viscosity, density, solubility of water and surface tension will be reviewed.

The viscosity of multicomponent specialized granitic melts is a complex, non-linear function of the temperature and composition of the melt. Existing calculational schemes for the estimation of melt viscosity are not capable of dealing with the chemical compositions of specialized granitic magmas in the temperature range of interest to the magmato-hydrothermal transition. A non-Arrhenian multicomponent model has been proposed for leucogranitic granitic melts where no significant specialization has occurred (Hess and Dingwell, 1996). This model appears to be sufficient for moderately intermediate normative Anorthite contents (Dingwell et al., 1999) but not for specialized granitic melts. Thus much effort has been spent on extending the data base for such viscosity models in future. The components investigated that exhibit the greatest influence on melt viscosity are excess alkalis (peralkalinity), F and H<sub>2</sub>O (Hess et al., 1995, 1996, Dingwell et al., 1996), less significant but measurable influences are seen for P<sub>2</sub>O<sub>5</sub> and for B<sub>2</sub>O<sub>3</sub> and Li<sub>2</sub>O and excess alumina, i.e. peraluminosity (Dingwell et al., 1985, 1992, 1993, 1998). Chlorine has little effect (Dingwell and Hess, 1998). Hydrous peralkaline silicic melts have extraordinarily low viscosities (Dingwell et al., 1998).

The surface tension of granitic melts is significantly reduced by the addition of excess alkalis and water. In contrast, P<sub>2</sub>O<sub>5</sub> increases the surface tension. The reduction of surface tension in the presence of up to several weight percent water is a factor of 4 in comparison to the dry melt (Bagdassarov et al., 2000).

The description of the density of specialized granitic melts has received a great boost from the application of dilatometric methods at temperature just above the glass transition (Dingwell, 1993). As a result partial molar volumes are available for SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, K<sub>2</sub>O, Rb<sub>2</sub>O, Cs<sub>2</sub>O, Li<sub>2</sub>O, BaO, SrO, CaO, MgO, TiO<sub>2</sub>, B<sub>2</sub>O<sub>3</sub>, P<sub>2</sub>O<sub>5</sub>, F<sub>2</sub>O, Ta<sub>2</sub>O<sub>5</sub>, Nb<sub>2</sub>O<sub>5</sub>, and WO<sub>3</sub> in granitic melts (Knoche et al., 1992, 1995, Dingwell et al., 1993). The partial molar volume of water has also been accessed using dilatometric methods (Ochs and Lange, 1997).

The chemical interdiffusion of major and trace components in haplogranitic and specialized granitic melts has revealed that the specializing components of specialized granitic melts have tracer diffusivities that are proportional to the viscosity of the melt, but with individual proportionality relationships. There is promise from this work that a general model for component diffusivities may be able to be linked to melt viscosity (Mungall and Dingwell, 1997, Mungall et al., 1994, 1998, 1999).

The solubility of water in granitic and specialized granitic melts has been intensively investigated in the past few years. The compositional dependence within the albite-orthoclase-quartz normative (haplogranitic) system is not large (up to 10% relative) (Holtz et al., 1992, 1994). In contrast some specializing components lead to significant increases in water solubility (e.g. B<sub>2</sub>O<sub>3</sub> (Holtz et al., 1993), excess alkalis (Dingwell et al., 1997). The situation can be complex as is the case for Li<sub>2</sub>O which increases water solubility as a network modifier in peralkaline systems but decreases it as a networkformer in calcalkaline systems (Romano et al., 1996).

One aspect of specialized granitic systems that probably is a control on ore distribution and concentration is the ductile-brittle transition in these systems, at variable degrees of crystallinity. The rapid application of stresses will lead to brittle-like behavior of highly crystallized specialized granitic cupolas and apophyses that is only partially quantifiable at present in terms of temperature, texture and strain rate (Dingwell, 1997, 1998, 2000). A better understanding of this transition in ore-forming magmatic systems is an important research goal for the future.

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