Volatiles and viscosity

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The physical properties of magmatic melts are notably influenced by the presence of dissolved volatiles. The influence of volatiles on the PVT-equation-of-state of silicate melts is slowly being mapped out in terms of the molar volume and its temperature- and pressure derivatives. The influence on transport properties is , to date, better constrained, and indeed the effects are even more dramatic for some volatiles. In both cases a wide range of complementary experimental techniques are being applied and it is often the case that proxy methods for property determinations yield results where direct determination is experimentally hindered.

Perhaps the most exhaustively investigated example of the influence of volatiles on properties is the case of the influence of water on viscosity. Its extensive investigation in the past 20 years contains many examples of experimental foresight and advance, as well as a number of pitfalls. Using this example, together with the allied determinations of transport properties in melts, a sketch of the state-of-the-art will be attempted.

An example of fluid immiscibility during the subvolcanic emplacement of a boron-rich acidic melt: The Capo Bianco aplite (Elba Island, Italy)

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Very unusual melts rich in boron and other volatile and rare elements are produced during partial melting of continental crust as well as by differentiation of granitoid plutons. Commonly these melts crystallize at plutonic depths producing typical coarse-grained rocks (pegmatites) that are industrial sources for rare elements (e.g. Ta, Li). Sometimes, such melts produce intrusive bodies showing a fine grained microgranite-aplite texture. In both cases the final equigranular isotropic texture reached by these rocks masks the original structure of magma (e.g. presence of early phenocrysts) and the eventual dynamic patterns experienced during transfer and emplacement of magma.

The Capo Bianco aplite sill (Elba Island, Italy) was emplaced at shallow depth (≈ 2.6 km) in the Late Miocene, recording very peculiar petrographic (layered and oriented texture) and geochemical features that recall a fluid immiscibility process between silica-rich and boron-rich melts. The rapid crystallization of the peraluminous, boron-rich Capo Bianco aplite allowed the preservation of the original structure of the acidic magma with a small percentage of early, millimetric phenocrysts (quartz, K-feldspar, oligoclase, muscovite) into a very fine-grained quartz-feldspatic groundmass. The groundmass also hosts a large number of spherical-ellipsoidal tourmaline orbicules ranging in size between few mm up to 15 cm. The tourmaline orbicules are made up by fibrous-radiating schorl-elbaite needles and quartz. Their textural relationships with the host, internal textural and chemical-isotopic features suggest that they represent an early character of the magma and excludes their formation by late- to post-magmatic processes. This observation coupled with geochemical composition of the rock and available experimental data on silicatic melts/glasses indicate that tourmaline orbicules can represent the product of rapid crystallization of boron-rich silicate melt bubbles earlier separated from the acidic magma before the final emplacement. Capo Bianco aplite can thus be regarded as a serendipitous occurrence of a boron-rich magma that escaped the source region and stopped/crystallized in a subvolcanic setting, just at the right depth for maintaining a snapshot of the silicate-liquids immiscibility processes and the emplacement dynamic.