Forum Comment
doi: 10.1130/G36512C.1

Magmatic life at low Reynolds number

J.D. Clemens
Department of Earth Sciences, University of Stellenbosch, Private Bag X1, Matieland 7602, South Africa

Glazner (2014) is to be commended for his analysis of the role of inertia in the development of textural features, such as layering, that are present in many bodies of granitic rock. The point is well made that the high viscosities of granitic liquids prevent flow within any plutonic granitic magmas from entering the turbulent régime (though the same cannot be said for explosive volcanic eruption of felsic magmas). The general demise of analogies between processes responsible for structures in water- or wind-lain sediments and superficially similar-appearing features in granites is long overdue, but there are many more phenomena in magmas than those related to Reynolds numbers and inertia.

Glazner writes (p. 937) that "in silicic systems the stiffness of the enclosing magmatic liquid does not allow for inertial movement of crystals relative to the liquid" and that "Crystals in such high-viscosity liquids are bound to the enclosing liquid by viscous forces and do not move independently of it". These apparently correct statements may hold the clue to the observation that granitic magmas do not appear to differentiate by crystal settling, and indeed only seem to differentiate at all on local scales (Clemens et al., 2010). That small apparent degree of crystal-liquid separation in granitic magmas is certainly due to differential movement of the solid and liquid portions of the magma, and we need to think of forced processes such as flow differentiation (viscous drag) and filter pressing (under subsiding solid blocks, for example) as possible causes of what we observe. As Glazner points out, gravity settling of crystals is quite unlikely. However, it seems worth mentioning a few notes of caution lest we take the new, non-sedimentary paradigm too far.

Glazner correctly notes (p. 936) that "Formation of apparent crossbedding…by erosion and redeposition is…precluded by the high viscosities of silicic liquids, and interpretation of such relationships in terms of sedimentary processes is incorrect". In this connection it seems worth asking whether erosion and related features could still occur in non-turbulent flows. Plutonic granitic magmas do flow and, if they contain regions of contrasting viscosity (due to differing degrees of solidification, differing silicate compositions, or differing dissolved volatile contents) then the rates of flow of adjacent, contrasting regions should differ, inducing shear at the boundaries and possible erosive and depositional effects that are not due to gravity or inertia.

Glazner writes (p. 935) that "The key to the mystery of layering in intermediate to felsic plutonic rocks must lie in geochemical self-organization and related processes". Later, on page 937, we read: "Layered features in granodiorites likely result from chemical processes, such as diffusion and advection …, self-organization…, crystal ripening …, and crystal growth in thermal gradients…, or from physical forced-mixing processes …". Self-organization could be the origin of some of these features, but it cannot be the origin of all. Glazner intimates this by including the phrase "or from physical forced-mixing processes". There is no doubt that potent structure-forming effects in felsic plutonic magmas can be due to nothing more dramatic than differential flow rates of adjacent magma packages. As a graphic illustration of this, Figure 1 shows a scroll-like structure, defined by concentration of crystals (notably garnet, plagioclase, biotite, and large alkali feldspar phenocrysts) along with both magmatic enclaves and country-rock xenoliths. This structure clearly cannot have been formed through pure diffusion and self-organization in the magma concerned. There are several of these scrolls, each ~2 m across, lined up just under the floor of an earlier-intruded and solidified phase of the pluton. The hypothesis proffered here is that the large and high-density solids in this flowing magma were accreted to the margin of the flow, where cooling and crystal content made this into a high-viscosity but still plastic layer. Continued viscous drag from the solidifying but flowing magma below then broke apart the enclave-rich layer and rolled pieces of it along the upper solid interface, to create scroll-like features that are analogous in shape to a jam sponge roll cake. Self-organization plays an important role in processes such as crystal growth, zoning, and the formation of some ripening textures in many natural systems, including granitic magmas (e.g., Ortoleva, 1994). Indeed, self-organization may play a role on a grand scale in orogenic belts (Brown and Solar, 1998). However, it would seem rash to neglect the likely roles of flow and compaction simply because the magmas concerned cannot flow in the turbulent régime and the incorrect application of analogies with sedimentary processes. There is a good deal more to think about.

Figure 1. An example of one of a series of scroll-like structures developed in an S-type porphyritic monzogranite of the Wilsons Promontory batholith of southeastern Australia, exposed along a coastal section in Norman Bay. Large K-feldspar phenocrysts and elongate enclaves define the structure, which also contains concentrations of biotite, magmatic garnet, and plagioclase (Wallis, 1981).

REFERENCES CITED

Brown, M., and Solar, G.S., 1998, Shear-zone systems and melts: Feedback relations and self-organization in orogenic belts: Journal of Structural Geology, v. 20, p. 211–227, doi:10.1016/S0191-8141(97)00068-0.

Clemens, J.D., Helps, P.A., and Stevens, G., 2010, Chemical structure in granitic magmas—A signal from the source?: Geological Society of America Special Paper, v. 472, p. 159–172, doi:10.1130/2010.2472(11).

Glazner, A.F., 2014, Magmatic life at low Reynolds number: Geology, v. 42, p. 935–938, doi:10.1130/G36078.1.

Ortoleva, P.J., 1994, Geochemical Self-Organization: Oxford, UK, Oxford University Press, 411 p.

Wallis, G.L., 1981, The geology of the Wilson's Promontory Batholith, Victoria [unpubl. MSc thesis]: Clayton, Australia, Monash University, 396 p.