Concentrating Sulfide Melts in Active Magma Pathways Using Chaotic Mixing

Jess Robertson,[1,*] Steve Barnes,[1] and Guy Metcalfe[2]

[1]CSIRO Minerals Resources National Research Flagship, Australian Resources Research Centre, Perth, WA, Australia
[2]CSIRO Manufacturing National Research Flagship, Highett Laboratories, Melbourne, Australia

*E-mail, jesse.robertson@csiro.au

Most magmatic deposits require a high ratio of magma to ore to achieve high ore tenors. Additionally, many deposits appear to form in long-lived, focused, and active magma pathways. These observations suggest that there are efficient mechanisms for concentrating and recovering sulfide droplets and crystals from actively flowing magmas. However, the physical mechanism for this concentration remains unresolved, particularly since small particles (both droplets and crystals) in active magma flows are expected to mostly track flow streamlines rather than clustering, especially in a steady laminar flow.

However, most magma flows are unlikely to be steady. When the flow rate in the magma varies with time, then the magma can exhibit chaotic mixing, in which a fluid element is stretched and folded until throughout the entire volume of the flow. Two kinds of chaotic flow structure can form under these conditions: (1) well-mixed chaotic zones of the flow and (2) unmixed islands of stability within the chaotic flow, known as Kolmogorov-Arnold-Moser (KAM) regions.

We report on analogue experiments designed to examine the effects of these regions on the distribution of dense particles. Concentration and trapping of particles occurs when they are scattered from high-strain regions in the chaotic zones and become trapped in the KAM regions, leading to a rapid concentration of particles relative to their original distribution. Larger and denser particles are concentrated preferentially, providing a mechanism to create concentrations of a single phase from the mixture of phases which are typically present in a magma. We describe the onset of secondary density-related instabilities and the effects of increased particle-particle interaction within the clustered particles, and highlight the impact of particle clustering on the dynamics of magma ascent and emplacement.