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Interactions Between Rhyolitic and Basaltic Melts Unraveled by Chaotic Magma Mixing Experiments

D. Morgavi (1), D. Perugini (1,2), C. De Campos (1), W. Ertl-Ingrisch (1), Y. Lavallee (1), and L. Morgan (3)

(1) Dept. Earth and Environmental Science, Ludwig Maximilian University (LMU) München Germany, (2) Dept. Earth Science, University of Perugia, Perugia Italy, (3) U.S. Geological Survey, Denver USA

Magma mixing is extensively documented in both intrusive and effusive igneous environments and can occur at any stage in the evolution of an igneous system. The occurrence of magma mixing structures is strongly modulated by the dynamics arising during the mixing process. Their understanding and interpretation requires detailed analytical and experimental studies.

Here, in order to shed new light on the complexity of magma mixing processes, we study experimentally the interplay of physical dynamics and chemical exchanges between basaltic and rhyolitic natural melts. In particular, we present the results of the first mixing experiments performed under controlled chaotic dynamical conditions, using high-temperature natural melts.

Results indicate that the mixing process is governed by the heterogeneous development of stretching and folding processes between the basaltic and the rhyolitic melt and produces a wide variety of flow patterns coexisting at the same time in the same system. These different patterns strongly modulate the chemical exchanges between the two melts and lead to sample segments having extremely variable degrees of homogenization. We have quantified the mobility of both major and trace elements by analyzing the rate of decay of the concentration variance during the mixing process. We show that elements diffuse in the mixing system with different efficiencies and, therefore, the attainment of the hybrid compositions requires different times for the different elements.

The conceptual approach presented in this work can be in principle applied to natural outcrops for a variety of purposes, ranging from estimate of the time-scales of magma mixing in volcanic rocks to the petrologic study of the impact of chaotic mixing processes on the compositional variability of natural rock samples.