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Influence of Landscape Morphology and Vegetation Cover on the Sampling of Mixed Igneous Bodies

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A plethora of evidence indicates that magma mixing processes can take place at any evolutionary stage of magmatic systems and that they are extremely common in both plutonic and volcanic environments (e.g. Bateman, 1995). Furthermore, recent studies have shown that the magma mixing process is governed by chaotic dynamics whose evolution in space and time generates complex compositional patterns that can span several length scales producing fractal domains (e.g. Perugini et al., 2003). The fact that magma mixing processes can produce igneous bodies exhibiting a large compositional complexity brings up the key question about the potential pitfalls that may be associated with the sampling of these systems for petrological studies. In particular, since commonly only exiguous portions of the whole magmatic system are available as outcrops for sampling, it is important to address the point whether the sampling may be considered representative of the complexity of the magmatic system.

We attempt to address this crucial point by performing numerical simulations of chaotic magma mixing processes in 3D. The numerical system used in the simulations is the so-called ABC (Arnold-Beltrami-Childress) flow (e.g. Galluccio and Vulpiani, 1994), which is able to generate the contemporaneous occurrence of chaotic and regular streamlines in which the mixing efficiency is differently modulated. This numerical system has already been successfully utilized as a kinematic template to reproduce magma mixing structures observed on natural outcrops (Perugini et al., 2007). The best conditions for sampling are evaluated considering different landscape morphologies and percentages of vegetation cover. In particular, synthetic landscapes with different degree of roughness are numerically reproduced using the Random Mid-point Displacement Method (RMDM; e.g. Fournier et al., 1982) in two dimensions and superimposed to the compositional fields generated by the magma mixing simulation. Vegetation cover is generated using a random Brownian motion process in 2D. Such an approach allows us to produce vegetation patches that closely match the general topology of natural vegetation (e.g., Mandelbrot, 1982).

Results show that the goodness of sampling is strongly dependant on the roughness of the landscape, with highly irregular morphologies being the best candidates to give the most complete information on the whole magma body. Conversely, sampling on flat or nearly flat surfaces should be avoided because they may contain misleading information about the magmatic system. Contrary to common sense, vegetation cover does not appear to significantly influence the representativeness of sampling if sample collection occurs on topographically irregular outcrops.

Application of the proposed method for sampling area selection is straightforward. The irregularity of natural landscapes and the percentage of vegetation can be estimated by using natural landscapes extracted from digital elevation models (DEM) of the Earth's surface and satellite images by employing a variety of methods (e.g., Develi and Babadagli, 1998), thus giving one the opportunity to select a priori the best outcrops for sampling.

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