INVESTIGATING PETROLOGIC INDICATORS OF MAGMATIC PROCESSES IN VOLCANIC ROCKS

Intrinsic conditions of magma genesis at the Lunar Crater Volcanic Field (Nevada), and implications for internal plumbing and magma ascent†

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ABSTRACT

The northern part of the Lunar Crater Volcanic Field (central Nevada, U.S.A.) contains more than 100 Quaternary basaltic cones and maars and related eruptive products. We focused on four informal units of different ages and locations in the field to test the compositional variability and magma ascent processes within the time span of an individual eruption and the variability between very closely spaced volcanoes with different ages. Based in whole-rock chemistry, mineral chemistry and the calculation of intrinsic properties (pressure, temperature, and oxygen fugacity) we found that individual magma batches were generated in the asthenospheric mantle from a heterogeneous garnet lherzolite/olivine websterite source by ~3–5% partial melting. Each magma batch and temporary deep reservoir was a separate entity rather than part of a continuous long-lived reservoir. Magmas ascended relatively fast, stalled and crystallized in the uppermost several kilometers of the mantle near the base of the crust and some also stalled at mid-crustal levels with minor or no geochemical interaction with surrounding rocks. Our data also suggest that volcanoes erupting within certain time windows had similar source characteristics and ascent processes whether they were located within a few hundred meters of each other or were separated by many kilometers.

Keywords: Lunar Crater Volcanic Field, monogenetic volcanism, whole-rock chemistry, mineral chemistry, geothermobarometry

INTRODUCTION

Most of Earth’s volcanism occurs at plate boundaries, in association with rifting or subduction, or in high magma-flux intraplate hotspots. However, substantial volcanism also occurs within continents and ocean basins, forming intraplate volcanic fields with relatively low-magma fluxes and commonly consisting of small-volume mafic volcanoes with alkaline affinities. Continental intraplate volcanic fields can consist of one to several hundred individual volcanoes, most of which are monogenetic (erupt in a single episode lasting weeks to years), and have lifespans of a few million years (Connor and Conway 2000). Unlike “hotspot” systems, these fields tend to have a diffuse spatial distribution of eruptive centers and in many cases have no clear migration of eruptive activity with time. Volcanic landforms in intraplate fields are dominated by scoria cones, spatter/agglomerate ramparts, lava fields, maars, and tuff cones, in proportions that depend upon the relative dominance of explosive vs. effusive activity and the local hydrologic environment (Valentine and Gregg 2008; White and Ross 2011; Brown and Valentine 2013).

Petrologic studies of intraplate volcanism have tended to focus on “big picture” questions such as the nature of the mantle, or the broad evolution of regional magmatic activity over millions of years; however, recent studies have begun to explore the details of volcanic fields with much higher spatial and temporal resolution, including the complexities often recorded within individual monogenetic volcanoes. An advantage of a study of low magma-volume monogenetic volcanoes is that they may display compositional complexities that are closely related to mantle source characteristics, which may be totally overprinted by crustal reservoir processes in higher volume-flux, long-lived volcanoes. Geochemical and volcanological data from the Pleistocene Southwest Nevada Volcanic Field in the western U.S.A. for example, suggest that individual volcanoes tap domains of partial melt that are progressively decreasing in volume and degree of partial melting with time (Valentine and Perry 2007). The domains are inferred to reflect local enrichments in volatile components within the lithospheric mantle source that has been subjected to repeated metasomatic events over ~1 Ga. Valentine and Perry (2006, 2007) suggested that the length scales of the partial melt domains are on the order of kilometers in size and the size of each volcano is proportional to its melt domain.