GEOCHEMICAL DIVERSITY WITHIN MONOGENETIC BASALTIC SYSTEMS MAY BE MAGMATIC ANALOGS FOR SMALL-SCALE INTRUSIONS IN FLOOR-FRACTURED CRATERS.

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Introduction: Floor-fractured craters (FFCs), are widely recognized on the Moon and Mars [1-3]. Recent investigations of lunar FFCs indicate a likely association with small-scale, shallow magmatic intrusions [4-7]. Spectral signatures of lunar pyroclastic deposits [8] as well as geophysical evidence of FFC crustal dynamics [6, 9] suggest complex igneous processes. Terrestrial analogs are not readily apparent; however, sill-like intrusions [e.g., 10, 14] are evident with basaltic magmatism in Idaho, USA, and geochemical variations within widespread monogenetic, mostly basaltic, lava fields on Earth [11-13] provide implications for magmatic models of lunar FFCs and related small intrusions.

Analog Rationale: Compositional variations in fissure eruptions and low-shield lavas [11-13] provide evidence for possible mechanisms that produce geochemical diversity in relatively small magma batches. This study examines geochemical variations in basaltic lavas within a relatively small region of the eastern Snake River Plain (ESRP), Idaho, USA along two adjacent rift zones (Fig. 1).

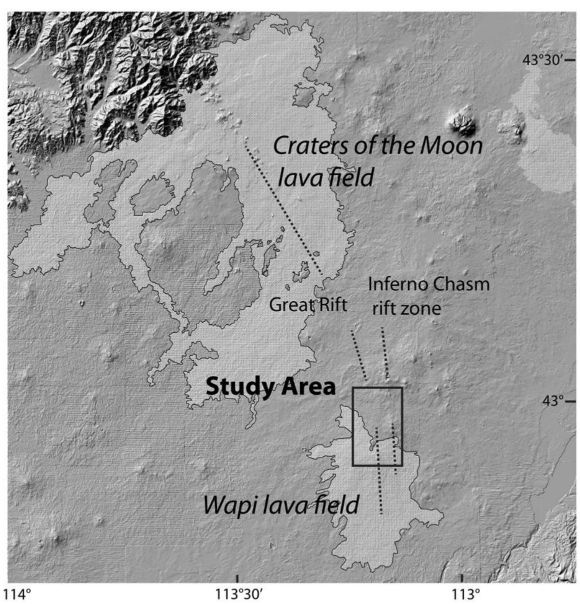

Fig. 1 Regional map of the study area within the eastern Snake River Plain, USA. Sampling focused on small-scale volcanic systems along the Great Rift and Inferno Chasm rifts zones.

The region is appropriate as a potential FFC analog considering the accepted view that ESRP magmatism is inextricably associated with a complex, chemically evolved mid-crustal sill [e.g., 14]. Geochemical samples were obtained from four separate (late Pleistocene – Holocene) basaltic episodes along these rift zones (Fig. 2): Kings Bowl lava field, Wapi lava field, pre-Kings Bowl lava flows, and Inferno Chasm lava flows. All of these features are being investigated by our team as planetary analogs. The intention is to assess geochemical, mineralogic, eruptive, and morphologic diversity within planetary magma systems, regardless of magma volume.

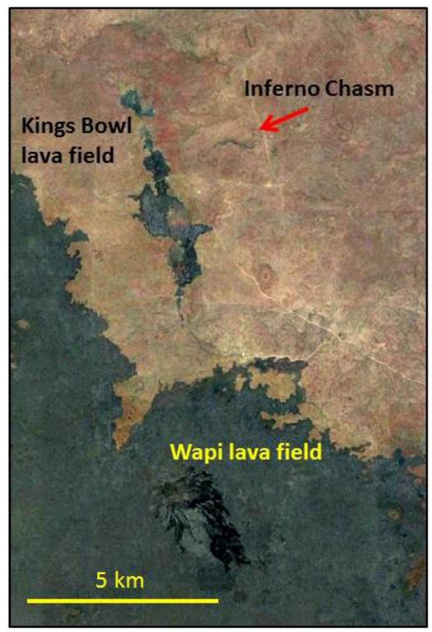

Fig. 2. Detail image (from Google Earth ®) showing locations of targeted basaltic features. Kings Bowl and Wapi lava fields represent the latest low-shield eruptions on the ESRP.

Compositional Diversity: Volcanism on the ESRP is dominated by olivine tholeiite lava flows that build coalescent low-shield volcanoes [15,16]. Analyses of hundreds of samples reveal significant variability within individual lava fields and between major lava flow groups [e.g. 13] from primitive to evolved compositions. Much of this chemical diversity is evident within the relatively small region of this study, illustrated by wide variation of TiO_2 vs. MgO (Fig. 3), whereas SiO_2 shows only meager variation (46.0 – 48.2 wt. %) over the entire sample set. Notably, each system has a unique geochemical signature.

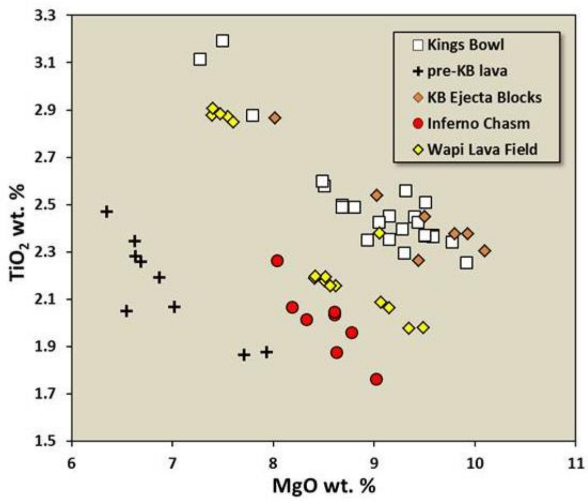

Fig. 3 Co-variation plots of Zr vs. MgO and TiO_2 vs. MgO exemplify the geochemical variability between small-scale eruptive episodes and within a relatively small region on the eastern Snake River Plain. Several Kings Bowl samples were collected from the ejecta block field on the flow surface, and pre-Kings Bowl samples were obtained from lava flow lobes exposed in a large phreatic pit along the eruptive fissure.

Compositional diversity among ESRP lavas and many other small basaltic systems is largely attributed to magmatic processes in the source region, open-system assimilation, or extreme fractionation of primary magma [e.g. 12-14,17,18]. The interpretations of regional variations among ESRP basalts [13,14,17], which are grossly mimicked by variations in Great Rift and Inferno Chasm rift zone volcanics (Fig. 3), suggest possible involvement of multiple sill-like intrusions in the shallow to middle crust, or other complex processes related to magma evolution. These studies also demonstrate that simple magma fractionation or assimilation, even in extreme cases, cannot produce the observed trends. Much of the chemical diversity can be attributed to crystal fractionation and/or mixing between primitive and fractionated components of a single small batch of magma. Magma mixing would entail multiple injections of primary magma that differentiate in a sill-like shallow chamber [14], which would enable co-mingling of end-member compositions produced by fractional crystallization. This model is supported by analyses of the Graveyard Point shallow differentiated sill [10] that provides geochemical evidence for end-member compositions on the ESRP.

Analog for FFC Magmatism: We propose a scenario that may help pave the way for more extensive modeling of FFC igneous processes (Fig. 4). Primary magma that is injected into the shallow crater subsurface begins to undergo extreme fractionation as a layered intrusion leading to chemically evolved compositions rich in elements (e.g., Zr, Th, REE, Ti, K, P, etc.), which are concentrated in residual liquids. Elements that are compatible to fractionating solid phases (e.g. Mg, Ca, Cr, Ni, etc.) are diminished in residual liquids, yet replenished by multiple injections of fresh magma. Magmas derived from mixing evolved and primitive compositions (a form of variable “auto-assimilation”) are then erupted or injected as dikes above the fractionating sill. This hypothesis can be tested with igneous rocks once compositional data are obtained.

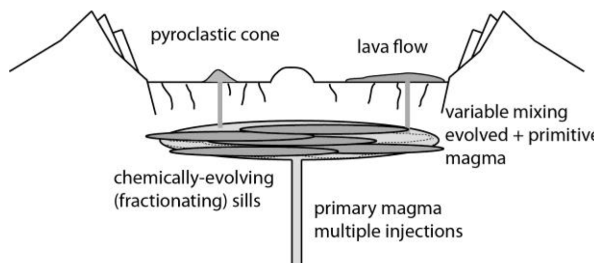

Fig. 4. Schematic diagram of proposed “auto-assimilation” model of magmatism associated with lunar floor-fractured craters.

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