

CHEMICAL VARIABILITY BETWEEN LAVA VENTS AND LAVA SURFACES—MARGINS: BLACK CRATER AND ROSS FLOW, LAVA BEDS NATIONAL MONUMENT, CALIFORNIA, USA. Z. F. M. Burton^{1,2} and E. L. Rader¹; ¹Department of Earth and Spatial Sciences, University of Idaho (Moscow, ID 83844, USA), ²Department of Geological Sciences, Stanford University (Stanford, CA 94305, USA; zburton@stanford.edu)

Processes of igneous differentiation, including fractional crystallization within the magma chamber, have been studied for over a century (e.g., early 1900s work by Norman L. Bowen), and are fundamental concepts to the field of petrology. However, despite abundant work on magmatic differentiation, little work has been done on chemical differentiation across the surface of a single lava flow—and yet, extrusive surface features are typically the only igneous products accessible to remote sensing or rover-based investigation of planetary surfaces (e.g., on the Moon, Mars, Mercury, etc.). Here, we analyze the surface chemistry of basalt flows in California to investigate chemical variability between lava vents and lava flow surfaces and margins.

Study Site: Black Crater (BC) and Ross Flow (RF) lie within Lava Beds National Monument, on the north flank of Medicine Lake Volcano, a large (~750 km³) Quaternary shield volcano in southern Cascade Range [1] (Fig. 1). BC and RF cover a small area of ~0.4 km², comprise an erupted volume of ~0.001 km³, and represent numerous ~3,000-year-old basaltic spatter events [1]. Sample locations included relatively smooth, alteration-free glassy surfaces in the middle and along the margins of lava flows, and spatter clasts near the vents.



Figure 1. (A) Location of Lava Beds National Monument on the North American continent; red box shows study area. Map source: WorldAtlas.com. (B) Zoomed-in location of Lava Beds National Monument in California, USA. Map source: Google Maps, Dec. 2022.

Methods: X-ray fluorescence (XRF) analyses were performed at three distinct parts of the Black Crater and Ross flows: (1) at lava vents, $n=27$ BC, $n=21$ RF; (2) on the surface of lava flows, $n=26$ BC, $n=36$ RF; and (3) at margins of lava flows, $n=27$ BC, $n=22$ RF.

Field measurements of lava-surface elemental compositions were collected with a portable, handheld Bruker Tracer IV-SD[®] XRF spectrometer. Default operating conditions were an anode current of 44 μ A at a voltage of 40 kV [2]. An Rh target thin window produces the X-ray beam, while a 10-mm² XFlash[®] silicon drift detector counts the secondary electrons [2]. Spot size was ~3 mm in diameter, equating to a total excitation area of ~7 mm² [2]. The analysis time was set at 30 s, and three replicate analyses were made at each sample site. Detailed XRF methods are available in reference [2].

Results: Vent samples yield mostly basalt and basaltic andesite plus some andesite compositions (Fig. 2) (SiO₂ 47–53 wt.%, $\bar{x}=51$ wt.% for BC; 49–58 wt.%, $\bar{x}=53$ wt.% for RF vents), while surfaces and margins yield basalt, basaltic andesite, andesite, dacite, trachyandesite, trachydacite, and several other evolved com-

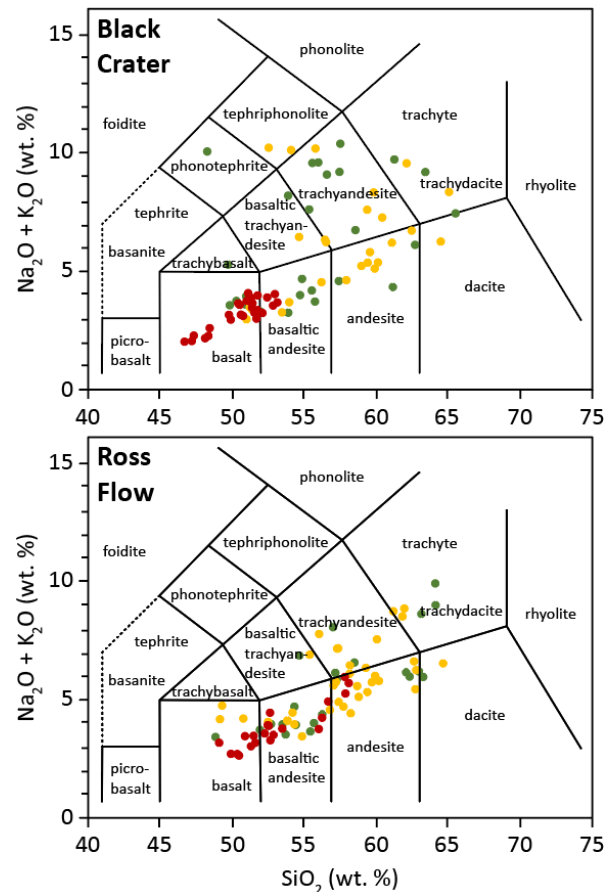


Figure 2. Total alkali-silica (TAS) diagrams displaying portable XRF data from lava vents (red circles), lava flow surfaces (yellow circles), and lava flow margins (green circles) at Black Crater and Ross Flow.

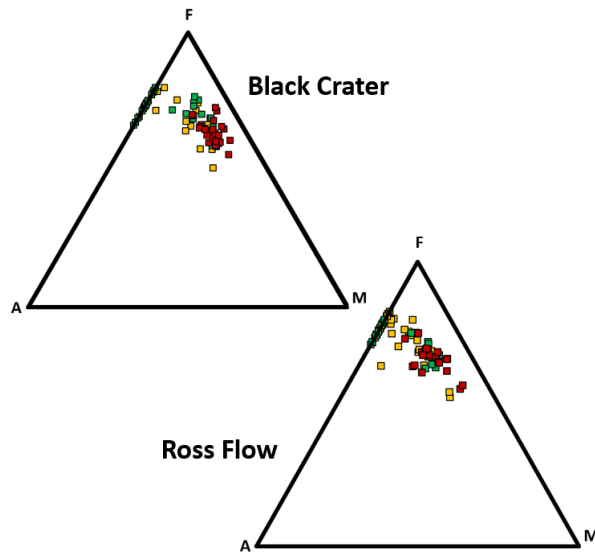


Figure 3. AFM ternary diagrams displaying portable XRF data from lava vents (red squares), lava flow surfaces (yellow squares), and lava flow margins (green squares). $A=Na_2O+K_2O$; $F=Fe_2O_3+FeO$; $M=MgO$.

$\bar{x}=3.5$ wt.%, FeO 8.2–16, $\bar{x}=12$ wt.%, Na_2O+K_2O 3.0–10, $\bar{x}=6.3$ wt.% for BC; MgO 0–12, $\bar{x}=2.4$ wt.%, FeO 9.2–16, $\bar{x}=12$ wt.%, Na_2O+K_2O 3.4–9.9, $\bar{x}=5.7$ wt.% for RF) than for vents (MgO 5.0–11, $\bar{x}=8.5$ wt.%, FeO 9.4–16, $\bar{x}=11$ wt.%, Na_2O+K_2O 2.0–4.1, $\bar{x}=3.2$ wt.% for BC; MgO 2.6–12, $\bar{x}=6.5$ wt.%, FeO 9.2–11, $\bar{x}=10.4$ wt.%, Na_2O+K_2O 2.6–6.0, $\bar{x}=3.8$ wt.% for RF) (Fig. 3). Surfaces and margins are enriched in Na and K and somewhat enriched in Mn, Fe, and Si relative to vents, while vents are enriched in Al, P, and Mg (Fig. 4).

Interpretation: The cause of observed chemical variability between lava vents and flows is unknown, but possible explanations could include intraflow chemical fractionation, differential weathering, vents and flows being sourced from different melts, or instrument artifacts due to factors like surface roughness.

Implications for Extraplanetary Study: Intraflow chemical variability carries implications for bulk geochemical studies, including of parent magma compositions and quantities (e.g., determining the number of parent magmas for lunar basalts [3]). Improved understanding of lava flow chemical heterogeneity can help

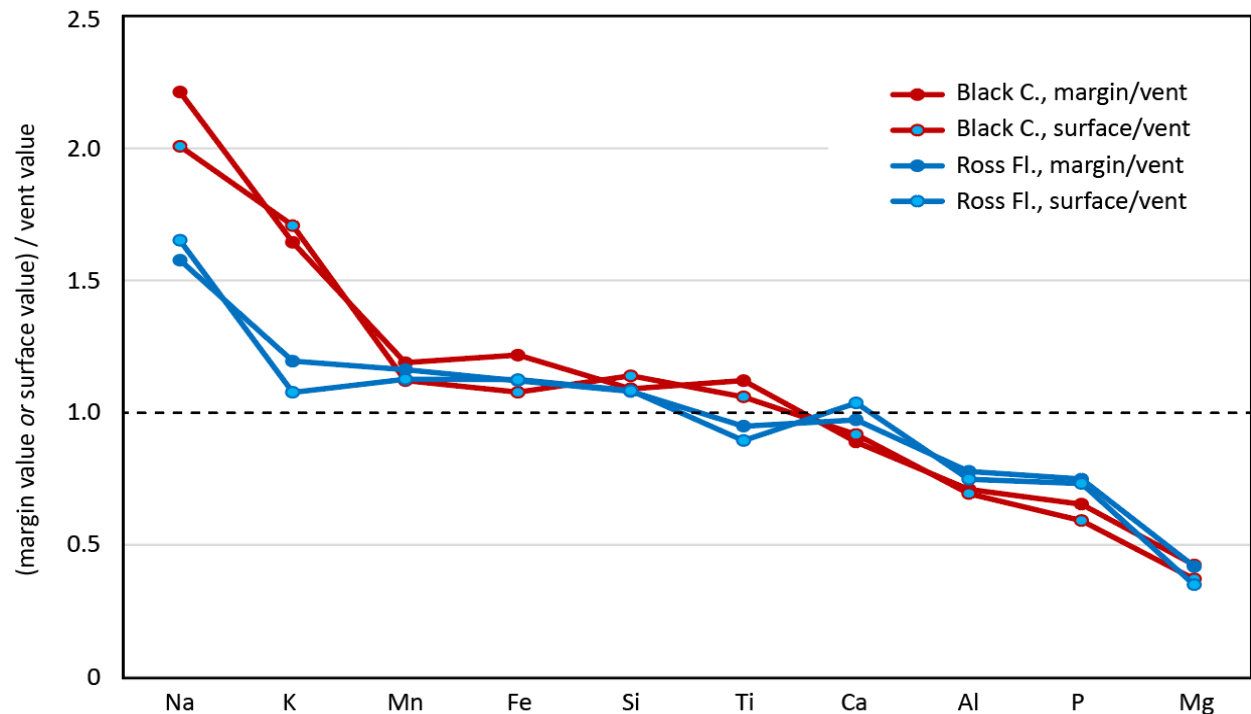


Figure 4. Plot of average surface and margin oxides normalized to average vent values. The x-axis is ordered by decreasing avg. enrichment of oxides in surfaces or margins vs. vents. The dashed line separates enrichment (above the line) from depletion (below).

positions (Fig. 2) (SiO_2 48–65 wt.%, $\bar{x}=57$ wt.% for BC; 49–65 wt.%, $\bar{x}=58$ wt.% for RF surfaces and margins). AFM ternaries similarly suggest more evolved compositions for surfaces and margins (MgO 0–12,

inform and guide investigation of planetary surfaces.

References: [1] Donnelly-Nolan et al. (1990) *JGR* 95, 19693–19704. [2] Sehlke et al. (2019) *Astrobiology* 19, 401–425. [3] Haskin et al. (1978) *LPSC* 9, 468–470.

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