LINKS BETWEEN ERUPTIVE STYLES, MAGMATIC EVOLUTION, AND MORPHOLOGY OF BASALTIC SHIELD VOLCANOES: SNAKE RIVER PLAIN, IDAHO

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Introduction: Despite their similar ages and geographic locations, two low-shield volcanoes on the Snake River Plain, Idaho, Kimama Butte (87 Ka [1]) and Rocky Butte (95 Ka [2]), have strikingly different profiles (Fig. 1). Kimama Butte has a diameter of 9 km and a height of 210 m with only a small elongate crater at the main vent. In contrast, Rocky Butte has a broad 12 km topographic shield that rises 140 m with less than 1-degree slopes. The summit is marked by a shallow, slightly elongated crater about 1 km across.

In this study, these two volcanoes are examined to determine the connections between chemical composition, eruption style, and topographic features of basaltic shield volcanoes. If such interrelationships can be understood on Earth with these two low-shield volcanoes, information can be unlocked about the many other shield volcanoes in the solar system.

Methods: Existing geologic maps of the area [1], [2], [3], [4], [5], were modified during field exploration and sampling (Fig. 2). Samples were collected around each shield from the distal flow margins, the flanks of the shield, and near the summit vents. Additionally, lava flow types (olivine-rich, intermediate, plagioclase-rich) were mapped. At Rocky Butte, strike and dip measurements were recorded for slabby ramparts along with flow descriptions (spatter, lava flow, spatter-fed flow, etc.) at points around the rim and inside the lava lake. Sample locations and other field information were compiled on detailed geologic and topographic maps in ArcGIS using aerial photographs

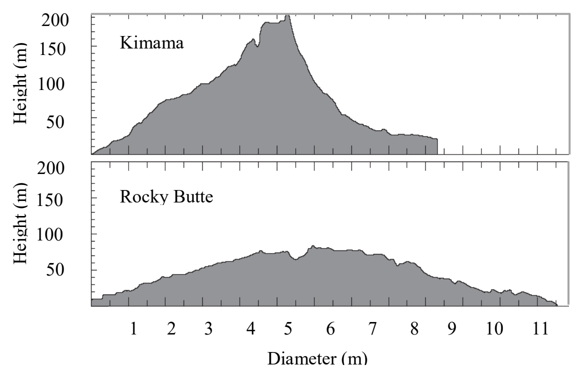

Figure 1. Profiles of Kimama Butte and Rocky Butte from east to west. Vertical exaggeration approximately 18:1.

and new digital elevation models derived photogrammetrically. Whole-rock major and trace element analyses by X-ray fluorescence spectrometry and major elemental analysis of pre-eruptive phases by electron microprobe were performed at Brigham Young University. Trace-element abundances in olivine and plagioclase were analyzed by LA-ICP-MS at the University of Utah.

Results: The summit regions of the two volcanoes are quite different. The vent crater at Rocky Butte developed as a large lava blister that inflated and then collapsed. The variably tilted rims of the blister are preserved. A lava lake then developed in the crater. Little spatter was erupted. In contrast, high spatter mounds flank the main summit crater at Kimama

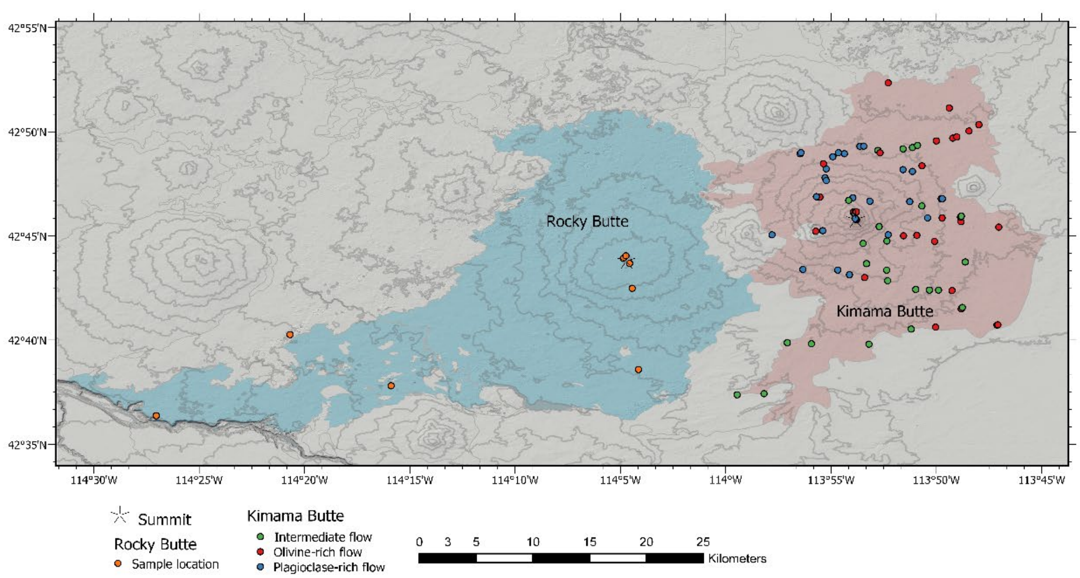

Figure 2. Geologic map showing the Kimama Butte and Rocky Butte lava fields. Sample locations are shown by colored circles for Rocky Butte. Sample locations and flow types are shown for Kimama Butte with colored circles. Modified from [1], [2], and [4].

Butte. Moreover, the vent region is dominated by short (5 to 300 m) spatter-fed plagioclase-rich lava flows. These lavas have calculated log viscosities of 2.0-3.0 Pa·s with 26-33% plagioclase phenocrysts. In contrast, near-vent lavas at Rocky Butte have calculated log viscosities of 1.5-2.0 Pa·s with 19-21% plagioclase phenocrysts.

Major- and trace-element variation diagrams show that the eruptive products of the two shields are very similar, but distinct in Ni and Al_2O_3 (Fig. 3). The olivine tholeiites range in TiO_2 concentrations from 2.6-4.5 wt% for Kimama Butte and 2.6-4.3 wt% for Rocky Butte. These ranges can be related to magma evolution

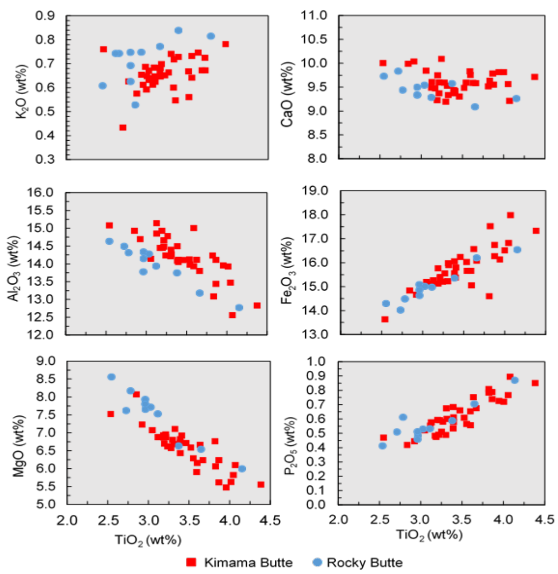

Figure 3a. Major-element variation diagrams for lavas from Kimama Butte and Rocky Butte.

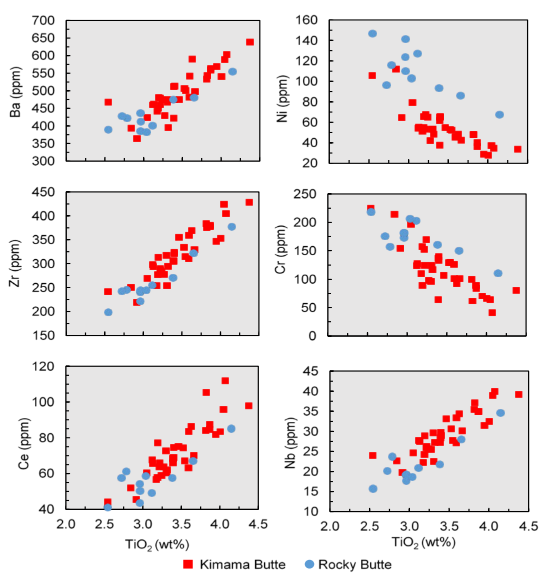

Figure 3b. Trace-element variation diagrams for lavas from Kimama Butte and Rocky Butte.

suggesting eruptive products with compositions probably controlled by fractional crystallization.

Compositions of the pre-eruptive phenocrysts, olivine and plagioclase, are similar across both shields but show variation with evolution. Olivine cores in the more primitive samples are more Mg-rich (Fo_{80-72}) than those in the evolved rocks (Fo_{65-55}). In both cases, thin Fe-rich rims are often present. Ni, Cr, and Al concentrations are higher in the olivine in the more primitive lavas than in the evolved. Plagioclase cores are similarly more calcic in the more primitive flows (An_{78-68}) than in the evolved ones (An_{65-52}). Plagioclase in the primitive rocks typically have less Ti, Ba, and Fe and more Mg than evolved samples.

Like other olivine-tholeiites on the Snake River Plain, the fO_2 and fH_2O were probably low with fO_2 at -1△QFM and 0.1 wt% H_2O [6]. Pressure of crystallization estimated from MELTS models seems to be around 1 to 2 kbar (about 7-8 km deep) [7]. Temperatures and calculated log viscosities of phenocryst-bearing magma overlap at Kimama (1147-1301°C and 1.0-2.4 Pa·s) and Rocky Butte (1145-1326°C and 0.5-2.2 Pa·s) [8][9]. Higher viscosities correlate with phenocryst-rich lavas, while higher temperatures are associated with the more primitive lavas.

Discussion: Because lava temperature and chemical composition overlap at the two volcanoes, they are probably not important controls of shield volcano morphology. It is not a simple function of more silicic and higher viscosity lavas producing higher steeper shields. However, Rocky Butte lacks late-stage, plagioclase-rich, high-viscosity lavas and the high spatter ramparts found at the summit of Kimama Butte. Thus, we conclude that eruption style plays the most important role in developing a low-shield volcano's summit. Where eruptions shifted from lava lake overflow and tube development to late fountaining with short spatter-fed phenocryst-rich flows with higher viscosities, a steeper, higher shield developed. Further work is needed to understand the factors that control eruption style at these two low shield volcanoes such as conduit geometry, volatile content, and exsolution history.

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