



# *Petrology of Volcanic Rocks*

**Example: Volcanic Processes at Lunar Crater, Nevada**

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## **Lunar Crater Volcanic Field, Nevada**

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### **Introduction**

Much of the latest volcanic activity in the southern Basin and Range Province produced basaltic lava fields. Consisting of scattered lava flows and cinder cones, most of which erupted only once, the fields stretch from central Nevada, between Tonopah and Ely, to south central California, south of Baker (Figure 1). The fields fit in an area roughly 400 x 400 km. Older fields pre-date the Basin and Range faulting; remnants of the flows rest atop tilted fault blocks (Shoshone Field, Figure 1). Others are partly covered by alluvial fans (Southern Death Valley Field, Figure 1, Figure 2). The youngest are only a few hundred years old (Ubehebe Field, Figure 1, Figure 3).

Lunar Crater Volcanic Field in Central Nevada contains several dozen basaltic cinder cones and lava flows (Figure 4). Lunar Crater, itself (Figure 5), formed by a phreatic explosion and is the only phreatic feature in the volcanic field.

Scott and Trask (1971) recognized three volcanic episodes; the episodes were separated in time by intervals long enough to produce erosional features. Shepard, *et al.* (1995) estimated an emplacement age of 38,000 ( $\pm 10,000$ ) years for the youngest event, which produced a basaltic flow that retains some original flow-top features (Figure 6). The oldest eruption occurred around 600,000 years ago (Kargel, 1986; cited by Shepard, *et al.*, 1995). A lava flow from the oldest event crops out in the wall of Lunar Crater itself where it rests on older sedimentary rocks. Events of intermediate age produced cinder cones, which have been slightly modified by erosion, and lava flows, the tops of which stick above the eolian cover (Figure 7).

The rocks contain phenocrysts of olivine, augite, and plagioclase. Plagioclase phenocrysts are smaller than the olivine and augite phenocrysts and more closely approach anhedral shapes than the mafic phenocrysts (Figure 8).

### **Rock Chemistry and Volcanic Processes**

Two sets of rock analyses can be found in the literature: Scott and Trask (1971) and Lum, *et al.* (1989). Figure 9 displays transformations of these data. The red ellipses mark the data from Scott and Trask (1971). The black crosses mark

data from Lum, *et al.* (1989).

When plotted on a Pearce element diagram designed to show the effects of sorting (fractionation or accumulation) of plagioclase, olivine, augite, and Fe-Ti oxide (Figure 9), the data fall in a narrow band with a slope of one. The trend with a slope of one indicates sorting can be a partial explanation of the chemical diversity. The scatter, however, exceeds that expected if the data came from rocks generated from a single magma batch. Consequently, either more than one melting episode generated the Lunar Crater magmas or the chemical diversity arose through assimilation of country rock. Magma mixing could be a factor in generating the chemical diversity but, again, at least two melting episodes would be required to generate at least two magmas to mix.

The chemical data collected by Scott and Trask (1971) segregate by age. The data belonging to the older data plot lower on the diagram (Figure 9) than do the data belonging to the younger lava flows. If the Lunar Crater magmas formed by repeated melting in the source region, then the systematic change in chemistry with age of eruption suggests the chemistry of the source region systematically changed over time. We think it less likely that a systematic change in chemistry could be generated by assimilation.

The ages assigned to the lava flows in the field indicate eruptions occurred over half a million years or so (Shepard, *et al.*, 1995). Magma batches erupt on a decade long time scale at Kilauea volcano in Hawaii (Nicholls and Russell, 1991). If magma batches were produced at the same time scales at the Lunar Crater field as they are in Hawaii then it is likely that the Lunar Crater data contain evidence of multiple melting episodes.

The Scott and Trask (1971) data contain linear clusters when plotted on a Pearce element diagram (Figure 6, red ellipses). Numbers 1, 3, and 5, for example, fall within analytical error on a line with a slope of one. Numbers 7, 8, 9, and 10 fall on another line, again with a slope of one. Each line can be interpreted as evidence that the analyses come from magmas with a common precursor, a single magma batch. The chemical variations in each linear cluster can be explained by sorting of olivine, plagioclase, augite, and Fe-Ti oxide (Figure 6). The chronologic constraints are not tight enough however, to rigorously test this speculation.

## Depths of Origin

One of the more primitive lava flows (No. 3, Figure 9) has the composition of a melt that would be in equilibrium with olivine and orthopyroxene at a pressure of 0.68 GPa (Figure 10). Orthopyroxene is not a phenocryst in the

lava flows and cinder cones forming the Lunar Crater Volcanic Field, however. Consequently, one infers that a relatively primitive magma reached the composition we see in the lava flow at a depth of 20-25 kilometers or less. One feature consistent with this interpretation is the compositions of the olivine phenocrysts. Thermodynamic modeling predicts an olivine composition of Fo90 for the liquidus phenocrysts. The optical properties indicate a 2V near 90° (Figure 3), which corresponds to an olivine composition of Fo88.

## Conclusion

Multiple melting episodes seems to be the best explanation for the chemical diversity in the analyses of the Lunar Crater rocks. If the youngest eruption is typical, then the lava that erupted at the surface came from a magma whose composition was modified at depths corresponding to 0.68 GPa (Figure 10) or less. Otherwise, the residual from the partial melting episode would have been orthopyroxene and the magma under saturated in olivine.

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