Physical volcanology and melt inclusion chemistry of Cinder Cone, Lassen Volcanic National Park, California: Implications for eruption styles and the plumbing systems of monogenetic volcanoes

Kristina J. Walowski[1], J. Katie Marks[1], Paul J. Wallace[1], Michael A. Clynne[2], and Katharine V. Cashman[1]

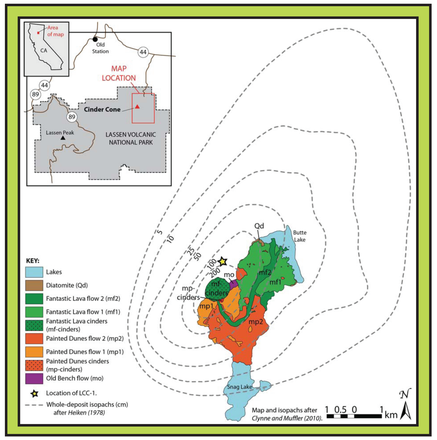
[1]University of Oregon; [2]United States Geological Survey

please contact: walowski@uoregon.edu (melt inclusion chemistry) or marks3@uoregon.edu (physical volcanology)

Introduction

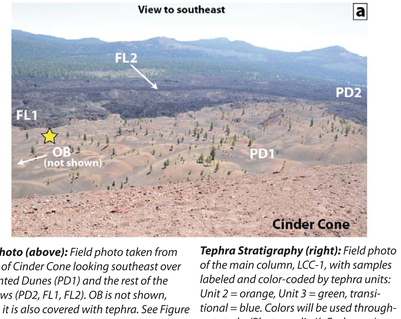
Monogenetic basaltic cinder cones are the most abundant volcanic landforms on Earth. Although their eruptions are short-lived (weeks to years), cinder cones display a wide range of eruptive styles including explosive violent Strombolian activity. However, the mechanisms driving explosive cinder cone eruptions are still poorly understood. In this study we investigate physical characteristics and measure the volatile (H_2O, CO2, Cl, S), major, and trace element compositions of olivine-hosted melt inclusions from the tephra deposit of 'Cinder Cone,' in the northern California Cascades, to better understand cinder cone eruption styles and the plumbing systems of monogenetic volcanoes.

Cinder Cone - Background

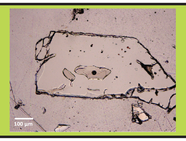


Location and Geologic Map (above): *Map of Cinder Cone, the distribution and geology of the lava flows, and the whole-deposit tephra isopachs. The main column of this study, LCC-1, is shown as the yellow star. The three phases of the lava flows are colored here; these colors will be used to denote tephra Units and will be utilized throughout the rest of the study. Purple = Old Bench (tephra Unit 1), orange = Painted Dunes (tephra Unit 2), and green = Fantastic Lava (tephra Unit 3).*

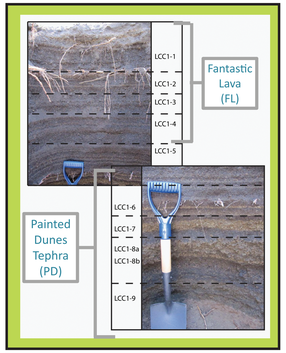
- Erupted in 1666 C.E., it is a young unvegetated cone found in the NE corner of Lassen Volcanic National Park (the Lassen Peak area represents the southernmost active volcanism in the Cascade Arc)
- ~200 m tall scoria cone built on top of an earlier cone
- Previous workers: Heiken (1978) and M.A. Clynne



Field Photo (above): *Field photo taken from the top of Cinder Cone looking southeast over the Painted Dunes (PD1) and the rest of the lava flows (PD2, FL1, FL2). OB is not shown, though it is also covered with tephra. See Figure 1 for a geologic map. Photo credit: J.K. Marks*

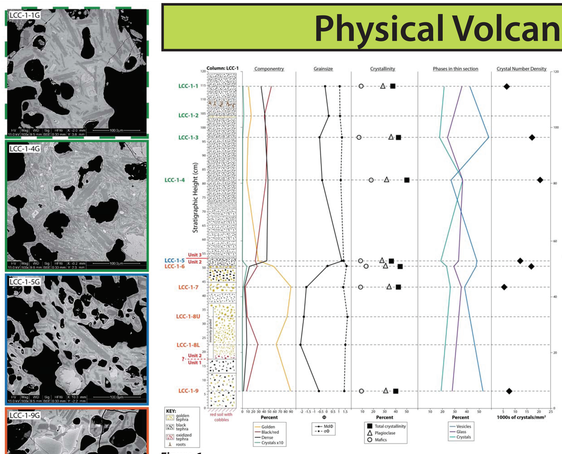


Melt Inclusion (above): *Transmitted light photo of an olivine-hosted melt inclusion from LCC-9 (Unit 3).*



Tephra Stratigraphy (right): *Field photo of the main column, LCC-1, with samples labeled and color-coded by tephra units: Unit 2 = orange, Unit 3 = green, transitional = blue. Colors will be used throughout study. (Photo credit: K. Cashman.)*

Physical Volcanology



SEM images (above): *Stratigraphic comparison of SEM images showing a sample from Unit 2 (LCC-1-9G, orange), the transition sample (LCC-1-5G, blue) and two samples from Unit 2 (LCC-1-4G and LCC-1-1G, green). Notice that LCC-1-4G, interpreted here to be the first sample of Unit 3, is highly crystalline compared to the other samples shown. Scale for each image is 100 µm.*

Figure 6:

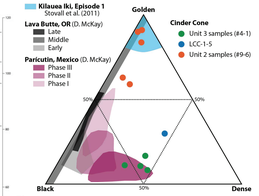
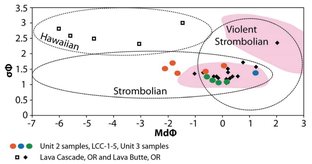


Figure 7:

- Unit 2 was created by less explosive Hawaiian and Strombolian styles whereas Unit 3 resembled a more explosive violent Strombolian eruption.
- Distinct transitional phase between Unit 2 and 3.



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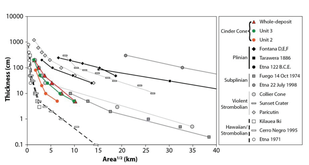
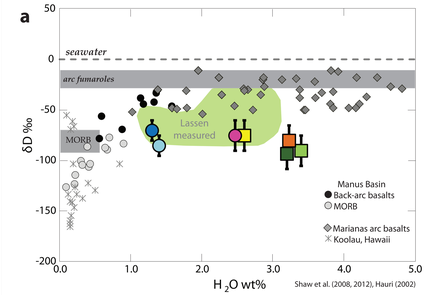
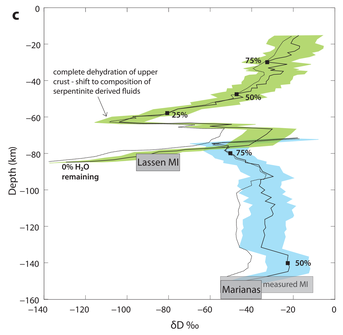


Figure 9

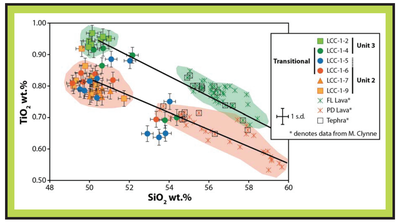
Other work - Waning dehydration of subducted mantle serpentinite drives slab melting beneath the Cascade Arc



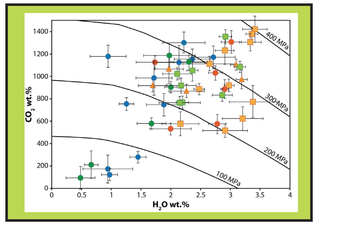
- Strong fractionation of D/H during slab dehydration forms a D-enriched hydrous slab component and a complimentary D-depleted residual slab.
- Measured and modelled δD values in the Cascades are more negative than those in the Marianas, suggesting a more dehydrated plate source.
- Fluids dehydrating from the hydrated upper mantle should rise through the slab, flux melting the upper oceanic crust which is above the MORB+H_2O solidus.



Melt Inclusion Chemistry

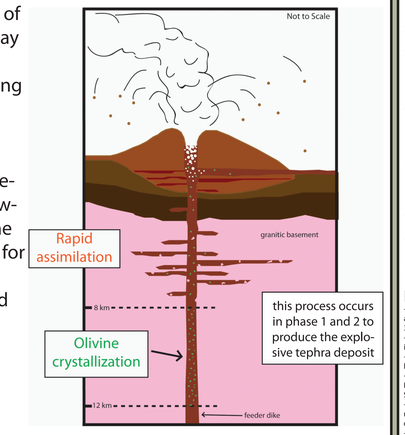


- Melt inclusions trapped two distinct batches of primitive basaltic magma, correlating with Units 2 and 3.
- Bulk lava and tephra are contaminated compared to MI compositions
- Transitional units appear highly contaminated by granitic basement rocks, similar in composition to bulk tephra and lava (quartz xenocrysts also present).
- Maximum water contents (3-3.4 wt %), are similar to those from Central Oregon, which have lower average volatile contents than other arcs.
- Primitive olivine crystallized at 200-350 MPa or ~8-12 km depth, while transitional units appear to be more degassed (trapped shallowly) and experienced more diffusive H-loss.



Conclusions

- Two major pulses of eruption that display distinct magma batches and differing eruption styles.
- Between the two major pulses, our results indicate a slowing or stalling of the eruption, allowing for shallow residence, contamination, and degassing of the transitional units.



Future Work

- Determine the order of tephra and lava flow emplacement by using field relations and bulk tephra geochemistry.
- Correct melt inclusions for CO_2 loss (to the vapor bubble) to better understand crystallization depths and magma storage history.
- Use olivine zonation, trace element diffusion, and stable isotope fractionation to better understand timescales of residence times and assimilation.

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