New Cosmogenic and VML Dates and Revised Emplacement History of the Ice Springs Volcanic Field in the Black Rock Desert, Utah

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Introduction/Background

The development of robust dating methods (Cosmogenic Dating & Varnish Microlamination (VML)) makes it possible to more accurately determine the date of young lava flows in the Ice Springs Volcanic Field (ISVF) in the Black Rock Desert, Utah. ISVF is hypothesized to be a compound polygenetic volcano due to multiple cinder cones (Miter, Terrace, Pocket, & Crescent), eruptions, and magma batches. This study aims to determine the flows' emplacement sequence and ages in order to place the ISVF in geologic context and improve understanding of its eruption history.

Ice Springs Volcanic Field (ISVF)

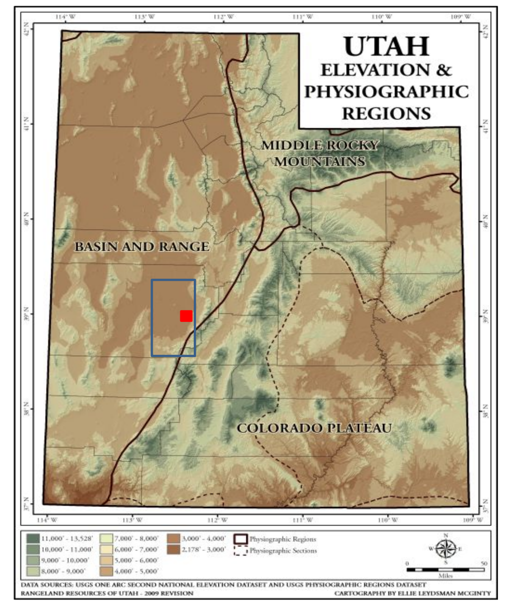


Figure 1. (Left) ISVF (red square) is one of several volcanic fields in Utah's Black Rock Desert (BRD; blue rectangle). Located in the Basin & Range Province, the BRD contains 7+ unique volcanic fields, all 1 Ma or younger (Condie and Barsky 1972).

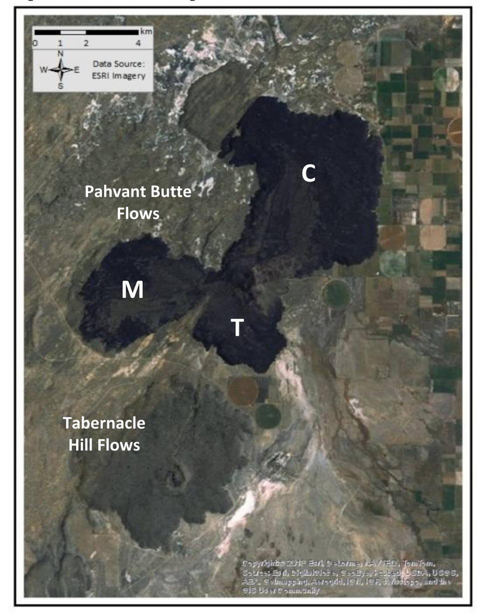


Figure 2. (Right) Aerial view of Ice Springs, which is dated at 660 ± 170 yrs ago (Valastro et al. 1972). The individual flows are labeled, using a modified map from Lynch and Nash (1980).

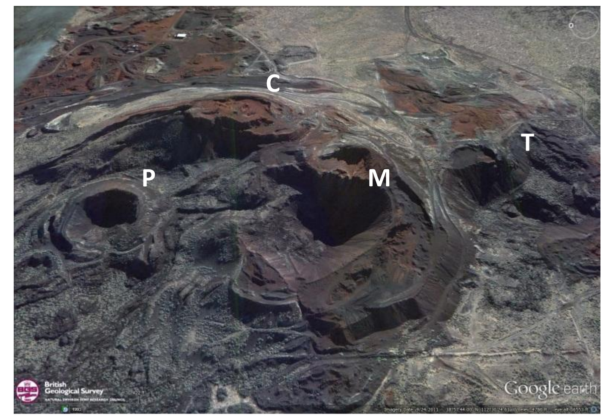


Figure 3. (Left) Relationship of Ice Springs Craters (C = Crescent; P = Pocket; M = Miter; T = Terrace). Obvious quarrying operations are present. View to the E.

Figure 4. (Right) Flow boundaries have been previously defined (Gilbert 1890; Hoover 1974). This study focuses on the Miter/Crescent and Miter/Terrace boundaries.

Methodology

Eight samples from the Miter and Crescent flows were collected for geochemical analysis. Two additional pahoehoe samples were collected from the Miter/Terrace boundary and within the Miter flow for cosmogenic ^{36}Cl dating. Whole-rock powders were prepared for major element analysis by X-ray Fluorescence (XRF) at The College of Wooster. Powders were analyzed at the Purdue PRIME lab for ^{36}Cl. The CRONUS calculator (Marrero et al. 2015) was used to find minimum and maximum ages for the lava flows. Varnish Microlamination (VML) ultra-thin thin sections (Goldsmith 2011; Liu and Broecker 2013) were made from samples of the Miter/Terrace flows to independently estimate the age.

Figure 5. Example of Pahoehoe cosmogenic sample.

Results

Varnish Microlamination

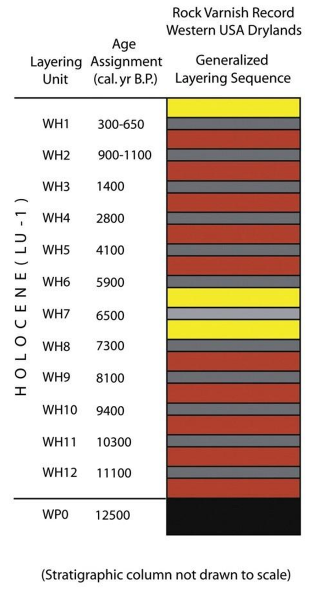


Figure 6. Stratigraphic scale from Liu and Broecker (2013) showing correlation between rock varnish record in western U.S. and assigned ages. The color scheme represents the layer's concentration of Mn and Ba.

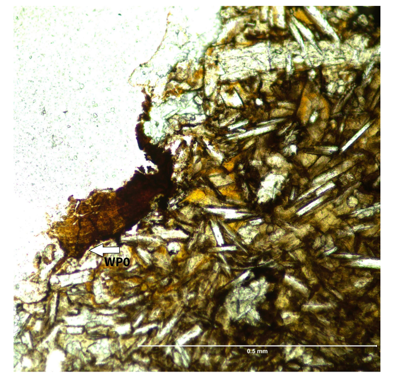


Figure 7. VML sample Keck-IS-17-12 gives the oldest date of ~12,500 years, because of the distinct layering and representation of WP0 a the base.

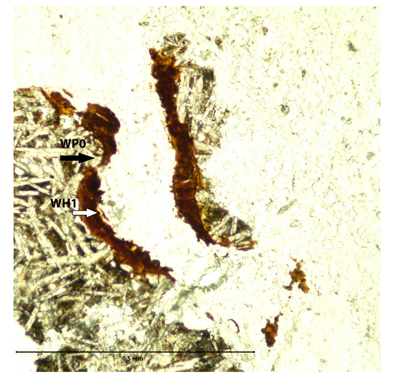


Figure 8. VML sample KS-15-VML-09 shows varnish layers WH1 to WP0 making the varnish date ~12,500 years.

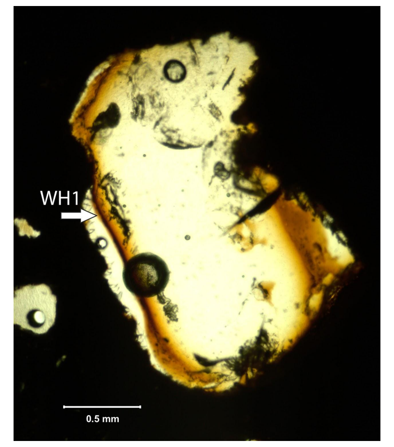


Figure 9. VML sample KS-15-VML-04B has a vesicle with varnish that shows the layer WH1 that has an age of 300-450 years.

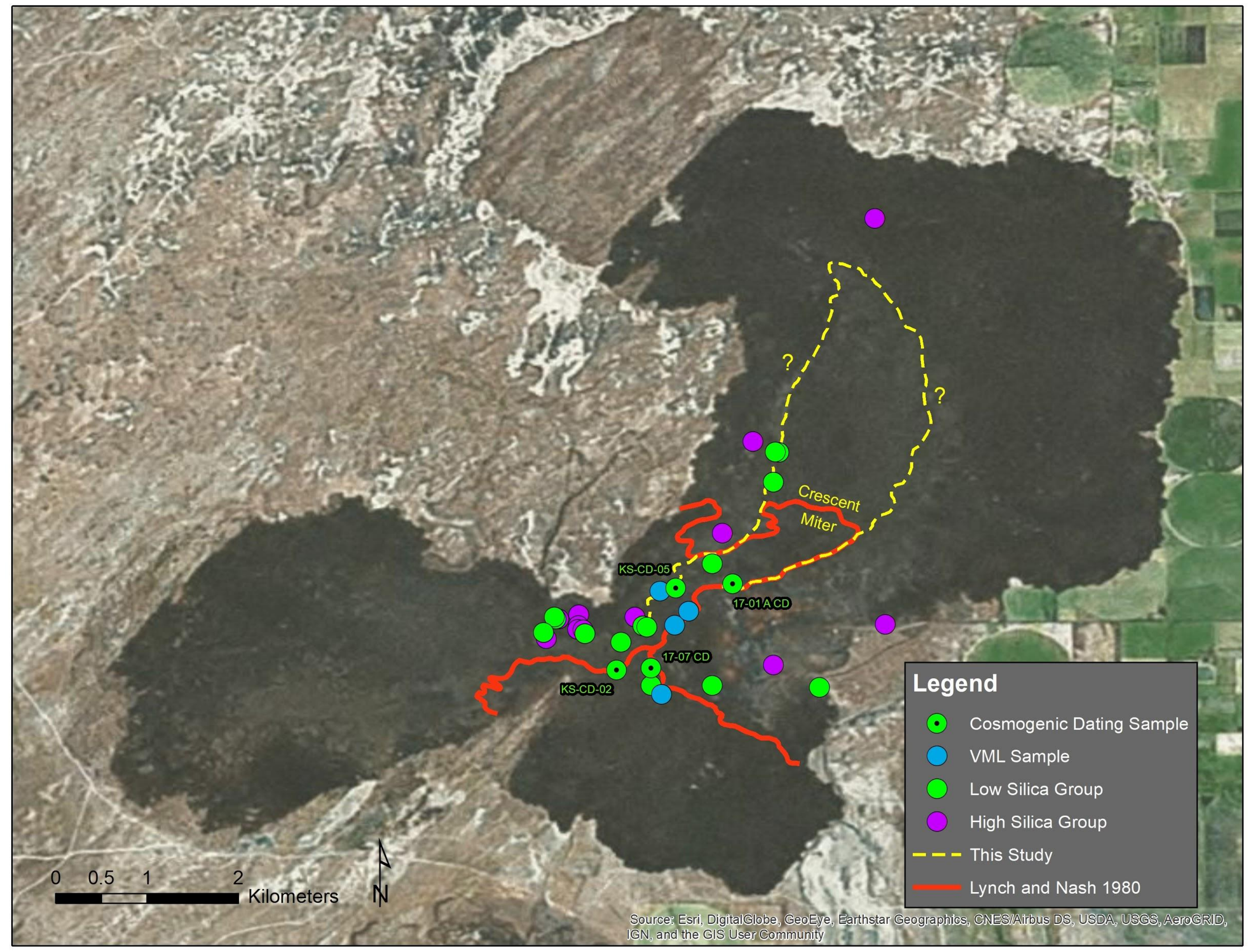
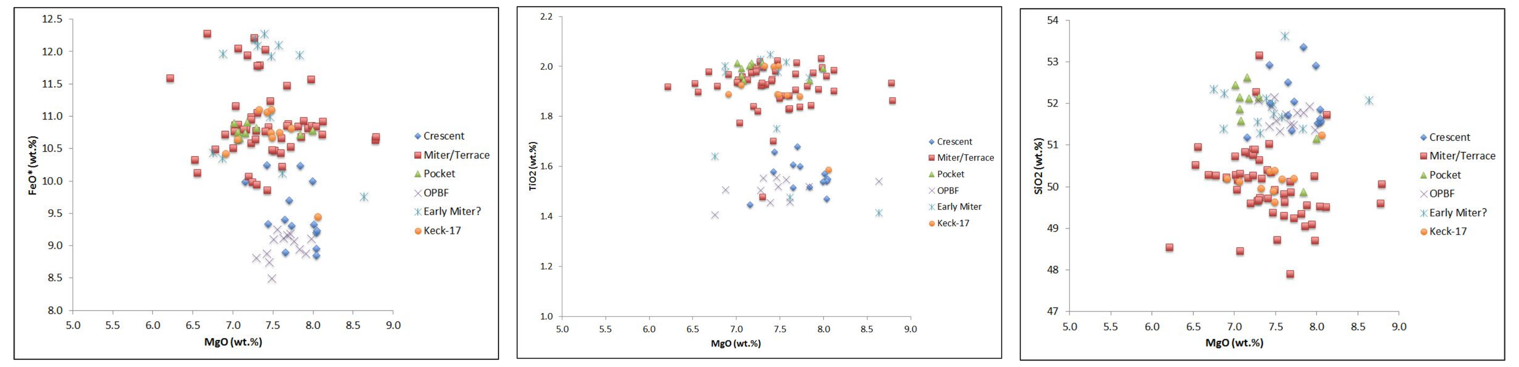


Figure 10. ISVF showing locations of low silica (green) and high silica (purple) samples. VML (blue) and cosmogenic dating (dot) samples are located in the area west of the cones. Boundaries of Lynch and Nash (1980) are in red. Proposed boundaries based on geochemistry are in yellow.

Geochemistry



Figures 12-14. FeO*, TiO_2, and SiO_2 variations with MgO (all in wt.%) for ISVF. Crescent flows show high SiO2 and low FeO* & TiO2 compared to Miter and Terrace. Samples from this study that are currently mapped at Miter (OPBF and one Keck-17) overlap with Crescent flows; those that are currently mapped as Crescent (Keck-17) overlap with Miter and Terrace flows. Previous geochemistry from (Lynch & Nash 1980; Nelson & Tingey, 1997; Thompson 2009; Matesich, 2014).

Cosmogenic Dating

Erosion rate	Sample	SF High density	SF Avg density	SF Low density	SA High density	SA Avg density	SA Low density
5 mm/kyr	CD-02 A	10.3±1.6	10.4±1.6	10.5±1.5	10.4±1.6	10.5±1.5	10.5±1.6
5 mm/kyr	CD-02 B	**9.4±1.3**	9.5±1.3	9.6±1.3	9.5±1.3	9.6±1.3	9.6±1.3
5 mm/kyr	CD-05 A	**10.9±1.6**	11±1.5	11±1.4	11±1.6	11.1±1.4	11.1±1.4
5 mm/kyr	CD-05 B	10.9±1.5	10.9±1.5	11.15	11±1.4	11±1.4	11±1.3
3 mm/kyr	CD-02 A	10.4±1.7	10.5±1.7	10.6±1.7	10.5±1.6	10.6±1.7	10.7±1.7
3 mm/kyr	CD-02 B	9.5±1.3	9.6±1.3	9.7±1.3	9.6±1.3	9.7±1.3	9.7±1.4
3 mm/kyr	CD-05 A	11±1.5	11.1±1.4	11.1±1.4	11.1±1.4	11.1±1.3	11.2±1.4
3 mm/kyr	CD-05 B	10.9±1.4	11±1.4	11.1±1.4	11±1.5	11.1±1.4	11.1±1.3
1 mm/kyr	CD-02 A	10.5±1.6	10.7±1.7	10.8±1.7	10.6±1.7	10.8±1.6	**10.9±1.6**
1 mm/kyr	CD-02 B	9.6±1.3	9.7±1.3	9.8±1.4	9.7±1.4	9.8±1.3	9.9±1.3
1 mm/kyr	CD-05 A	11.1±1.5	11.2±1.4	11.3±1.4	11.2±1.4	**11.3±1.5**	11.3±1.4
1 mm/kyr	CD-05 B	11±1.3	11.1±1.3	11.2±1.3	11.1±1.4	11.2±1.4	11.2±1.4

Table 1. Ages of ISVF from the CRONUS calculator (Marrero et al., 2015) using a selection of erosion rates from previous studies, a range of densities due to variation between samples, and the most recently developed Lifton-Sato-Dunai scaling framework (SF) and nuclide-dependent scaling framework (SA) from Lifton et al. (2015). New ages of 9.4 (±1.3) - 10.9 (±1.6) kyr for the Miter/Terrace boundary (CD-02) and 10.9 (±1.6) - 11.3 (±1.5) kyr the Miter flow (CD-05) were found.

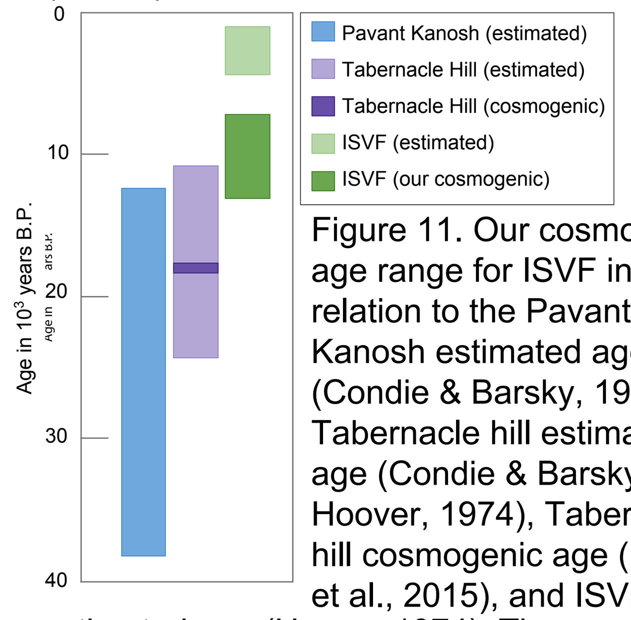


Figure 11. Our cosmogenic age range for ISVF in relation to the Pavant Kanosh estimated age (Condie & Barsky, 1972), Tabernacle hill estimated age (Condie & Barsky; Hoover, 1974), Tabernacle hill cosmogenic age (Lifton et al., 2015), and ISVF estimated age (Hoover 1974). These new ISVF ages are significantly older than those previously found by Valastro et al. (1972; 660 ±170 years) and Hoover (1974; 1 - 4 kyr), but are still viable as they would have been post Lake Bonneville at an elevation of ~1,400m (Lifton et al., 2015).

Discussion

Figure 15. A'a in the previously mapped Miter flow with a geochemical fingerprint that matches the Crescent flow, which supports a new boundary between these flows.

Figure 16. Slabby lava in the Crescent flow west of the newly mapped Miter/Crescent boundary.

Cosmogenic dates for the Miter flow range from 10.9 (±1.6) - 11.3(±1.5) kyr. Varnish from the surface of a Miter flow sample agrees with these ages with an approximate age of 12,500 years. The accumulation of varnish in a vesicle of another sample shows an age of 300-450 years, which is most likely younger since it is not at the surface. The VML sample from the Terrace flow shows an age of up to 12,500 years, which also agrees with the cosmogenic ages of 9.4 (±1.3) - 10.9 (±1.6) kyr found for the Terrace/Miter boundary. These ages would still put ISVF post Lake Bonneville at an elevation of ~1,400m (Lifton et al., 2015).

New geochemistry data also suggests that the previous boundary between the Miter and Crescent flows is either not in the correct location or that the chemistry of the Crescent flow is much more complex than previously thought. We propose a new Miter/Crescent boundary based on geochemistry.

Finally, the new information about the ages of ISVF flows and its multiple eruptions supports the hypothesis that it is a compound polygenetic volcano according to the Nemeth and Kereszturi (2015) classification.

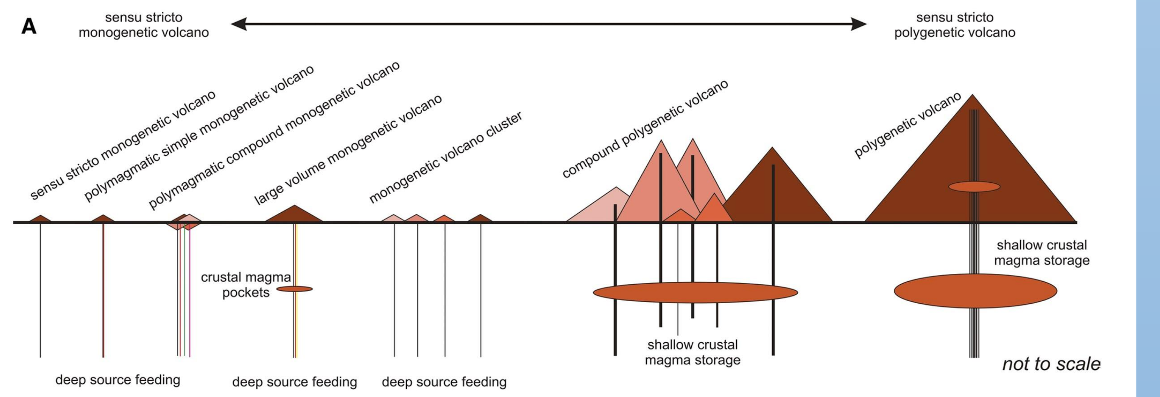


Figure 17. Volcano classification chart from Németh and Kereszturi, 2015 showing the compound polygenic volcano that ISVF is classified as.

Conclusion

- New cosmogenic dates for the ISVF range from 9.4 (±1.3) - 11.3(±1.5) kyr, similar to VML ages of ~12.5 kyr. These ages are much older than previous estimates, but still consistent with the geologic history of the BRD and Lake Bonneville.
- Additional geochemical data fill gaps in previous sampling and suggest newly mapped boundaries between the Crescent and Miter lava flows.
- The ages of ISVF flows and its multiple eruptions support its classification as a compound polygenetic volcano. Additional ages and geochemical sampling can clarify details of the eruption history.

Acknowledgements/References Cited

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