

**INVESTIGATION OF OXIDATION CONDITIONS WITHIN LAVA TUBES: ANALOGUE FOR VENUS SURFACE GEOLOGY.** D. A. Childs<sup>1</sup>, J. Acosta<sup>1</sup>, and L. J. McHenry<sup>1</sup>, <sup>1</sup>University of Wisconsin- Milwaukee Department of Geosciences, Milwaukee, WI 53211 (childsda@uwm.edu)

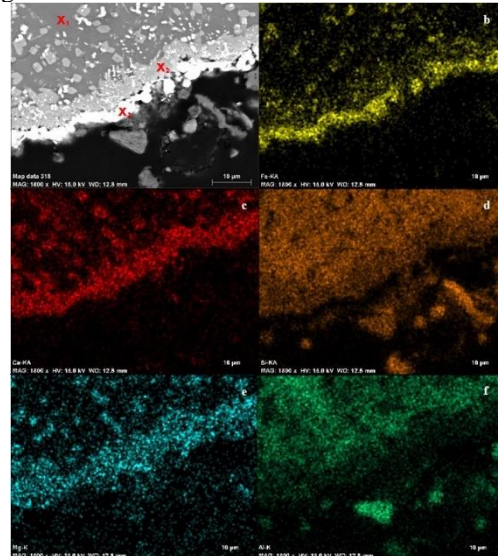
**Introduction:** Research of the surface geology of Venus through remote imagery and in situ analysis is limited by obstructing atmospheric conditions and temperatures. Emissivity measurements from Venus Express (2006-2014) were limited to  $\sim 1 \mu\text{m}$  wavelength in the Near Infrared spectrum, inhibited by the dense carbon dioxide atmosphere. The last lander sent to Venus, VEGA-2 in 1986, operated for only 56 minutes. Despite their limitations both landers and remote spectroscopy suggest a surface composition predominantly composed of subalkaline basalt. An exception to this may be Venus' tesserae which emit lower emissivity, interpreted to be from a more silicic composition. However, emissivity can also be affected by grain size, surface roughness, surface deposits, and surface weathering [1,2]. This study aims to investigate how the high temperature and atmospheric conditions of Venus could weather basalts at its surface and alter their mineralogy.

Filiberto et al. (2020) [2] and other studies [e.g. 3] show how basaltic surfaces oxidize and alter under high temperature conditions. High-temperature oxidation forms new minerals like hematite over the surface, which can lower emissivity. In artificial environments that simulate Venus-like conditions, surface weathering and the production of hematite occurs on a scale of weeks to months. These results suggest that lower emissivity measurements may be a product of surface oxidation, and that higher emissivity measurements may indicate very recent to active lava flows that have not yet been altered.

**Why lava caves:** Lava caves may serve as an appropriate Venus analogue to test the effects of high-temperature oxidation conditions. Lava caves or pyroducts are a common landform created by effusive lava flows. These roofed conduits form when the outer layer of a lava flow, exposed to the cooler air, solidifies and covers the still-flowing interior. Thermal erosion and changing pulses in lava flows permit superheated volcanic gas to fill in the upper void of the pyroduct. The solidified exterior provides a well-insulated environment for the lava flows [4]. Temperatures can initially exceed  $1,100 \text{ }^\circ\text{C}$  and remain hot for months to years after the last flow event before reaching an equilibrium with the outside environment. The formation and cooling stages of a lava cave create a distinct minerogenic environment [5].

Samples analyzed by Ruffini (2011) [6] from lava caves within Craters of the Moon National Park revealed a hematite veneer over their surface that exhibited a metallic sheen. SEM analysis (figure 1) from the

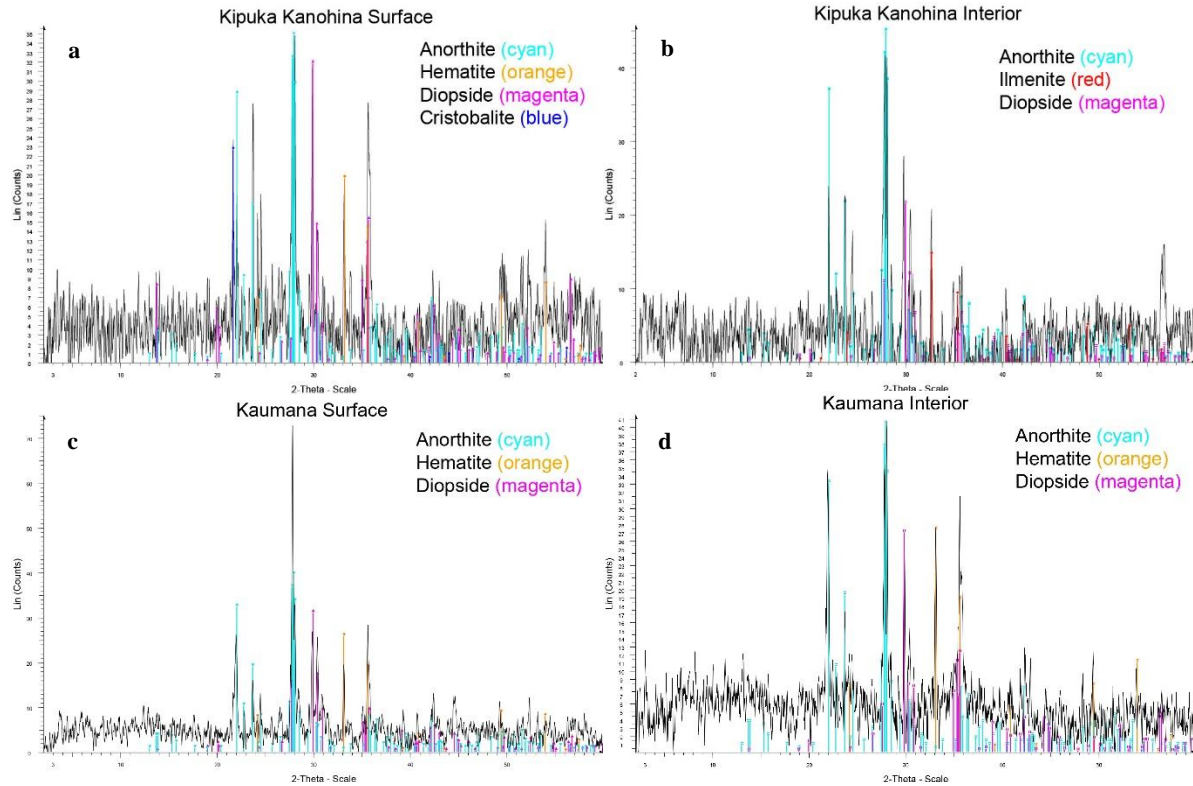
study shows evidence of cation migration produced by high-temperature oxidation [3], which would have likely occurred during the formation and/or cooling stages of the lava cave.



**Figure 1 a:** Backscattered Electron (BSE) image of a lava cave sample cross section from Craters of the Moon National Park, Idaho. b-f: Element maps show Fe (yellow), Ca (red), Si (orange), Mg (blue), and Al (green). The bright layer (X3) in map a and the high Fe concentration in map b represent the hematite veneer. Image from Ruffini, 2011.

**Mauna Loa Samples:** Hematite can also form through precipitation or low-temperature oxidation [3]. One potential complication for this analogue is that hematite could be produced through interaction with groundwater. To try to distinguish between hematite formed via high and low-temperature weathering conditions, basaltic rock samples were collected from lava caves sourced from Mauna Loa, Hawai'i flows. Samples were collected from the 1881 Kaumana flow and the most recent Kipuka Kanohina flow of 1907 [7,8]. Since these flows are from the same volcano and erupted in a relatively close time interval, they are assumed to have similar bulk and starting compositions. The major difference between the two flows is the amount of precipitation each receives. Kaumana receives approximately five times the annual rainfall as Kipuka Kanohina [9]. Increased rainfall is associated with higher rates of water infiltration which in turn affects the length of the lava tube cooling stage and how fast low-temperature weathering occurs [5].

**Methods:** Samples were collected from Kaumana and Kipuka Kanohina caves, selected from fallen ceiling and wall fragments. The surface of each sample



**Figure 2** Image of mineral spectroscopy peaks overlaying the measured two-theta wavelengths of each sample. (a) Graph of mineral spectroscopy collected from the surface of a Kipuka Kanohina sample and (b) its interior. (c) Graph of mineral spectroscopy collected from the surface of a Kaumana sample and (d) its interior.

was isolated and powdered using a power drill. A rock hammer was used to collect bits from the interiors of samples. Mortar and pestle were used to powder both surface and interior samples for X-Ray diffraction (XRD) analysis using a Bruker D8 Focus.

**Results:** XRD analysis revealed minerals present on the interior and surface of each cave sample. Minerals in the surface layer of a Kipuka Kanohina sample are anorthite, hematite, diopside, and cristobalite (Figure 2.a.). Minerals identified in the interior of the Kipuka Kanohina are anorthite, ilmenite, and diopside (Figure 2.b.). Minerals identified on the surface of Kaumana are anorthite, hematite, and diopside (Figure 2.c.). Minerals observed in the interior of the sample include anorthite, hematite and diopside (Figure 2.d.).

**Discussion:** The main mineral component of the basaltic rocks is anorthite and diopside, which are present throughout each sample. Cristobalite and hematite are found in the surface coating of Kipuka Kanohina, but not in the interior. These minerals may be products of chemical alteration from the oxidation of ilmenite, which is found in the interior of Kipuka Kanohina but not the surface. The mineral assemblage of Kaumana is consistent throughout the rock. Since hematite is a product of chemical alteration from a source iron mineral, this indicates that the sample of Kaumana has been weathered throughout the surface and interior.

Kaumana's altered composition suggests that weathering was not just limited to high-temperature oxidation. It is likely that the high abundance of precipitation at the locality of Kaumana led to increased water infiltration into the lava cave, oxidizing the rock throughout. Kipuka Kanohina's mineralogy suggests weathering was limited to just the surface. This alteration pattern better aligns with that of high-temperature oxidation, although it is still possible that other processes influenced its formation. Further experimentation can better constrain these influences.

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**References:** [1] Gilmore, M. S. et al. (2015) *Icarus*, 254, 350-361. [2] Filiberto, J. et al. (2020) *Science Advances*, 6(1), eaax7445. [3] Miniti, M. E. et al. (2005) *Meteoritics & Planetary Science*, 40(1), 55-69. [4] Sawłowicz, Z. (2020) *Annales Societatis Geologorum Poloniae* (Vol. 90, No. 4). [5] Forti, P. (2005) *Journal of cave and Karst Studies*, 67(1), 3-13. [6] Ruffini, J.J., (2011) MS thesis, University of Wisconsin--Milwaukee. [7] Cave Conservancy of Hawai'i (2003) at: [hawaii.caves.org/kanohina.htm](http://hawaii.caves.org/kanohina.htm). [8] Kempe, S., & Ketz-Kempe, C (2016). [9] Giambelluca, T.W. et al. (2013) *Bull. Amer. Meteor. Soc.* 94, 313-316.