Kilauea 2020 eruption RAPID pre-proposal **2-22-2021**

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Collaborators: Tobias Fischer – University of New Mexico

We propose to conduct investigations on the 2020 eruption at the Kilauea summit with the goal of capturing and correlating changes in the crystal content of the lava, gas geochemistry, and infrasound signals. We propose to use two tried-and-tested methods and one experimental method to build a dynamic picture of the early stages of this eruption through 1) gas collection, and 2) hyperspectral imaging. With these techniques we will constrain the carbon isotope ratio of the gas (an indicator of young, fresh magma), the crystal content (an indicator of stagnated, older magma), and the eruption vigor (quantified by infrasound recordings).

Timeliness: Gas collections to date (collected by HVO) have shown that undegassed magma is at depth, but that the current eruption location is not releasing that gas. Instead, the fresh hot undegassed magma is possibly trapped below a stagnated magma chamber. We can test this hypothesis given the current state of the eruption and may even catch the transition to fresh undegassed magma reaching the surface in the isotopic ratio of the gas samples, a decrease in crystallinity, and renewed vigor of eruption.

Science questions: Is the magma feeding this eruption young and fresh, indicative of an open system, and thus sustained activity at the current level? Or is the magma old and stagnant, suggesting a deeper reservoir that has yet to reach the surface? Do stagnant/old/degassed/crystal-rich magma correlate with decreased vigor of activity at the vent?

Broader Impacts:

A major goal of the Hawaii Volcano Observatory is to monitor and forecast the activity of all eruptions to ensure the safety of people living on the Island and to minimize property damage by providing enough time for people to evacuate animals, possessions, etc. The success of the forecasts that HVO produces depend on the quality and type of data input into the models. Synchronized data is more powerful than individual datasets and in this case, the correlation of a change in the magmatic system from gas data that is also backed up by infrasound and petrologic observations would allow HVO to confidently say that the activity we are seeing right now is just the start of a new sustained eruption. Alternatively, if no changes is detected and the eruption ends, our dataset will provide justification for calling the end of the eruption (a notoriously challenging call to make). Furthermore, our research will potentially provide a new powerful tool for "remote petrologic analysis" which would make future eruption responses safer and faster to adapt to a changing dynamic magmatic system.

Gas geochemistry: The UNM team proposes use gas samples from the Kīlauea volcanic system to assess the extent of magma degassing, assess the potential input of new magma into the system and establish the connectivity between several degassing sites inside the crater and just outside of the caldera using carbon isotopes. Samples would be collected at three locations: 1) from the crater rim of the main Halema'uma'u crater that currently contains the 2020 lava lake; 2) from the 'parking-lot' CO_2 plume. This location is the former parking lot just to the south of Halema'uma'u that 'fell into the crater' in 2018 but has a distinct CO_2 plume that originates from the cliffs there; and 3) from Sulphur Banks, the long lived hydrothermal system just to the north of the caldera. All samples would be collected on the ground utilizing our well-established foil bag-sampling techniques (Fischer and Lopez, 2016; Ilanko et al., 2019). At the Crater rim, the CO_2 parking lot and Sulphur Banks, samples would be collected from the plume and diffuse sites using foil bags at Sulphur Banks they would be collected using evacuated Giggenbach sampling flasks. Samples would be collected by HVO staff with sampling systems provided by UNM. After sampling, foil bags and glass flasks would be mailed to the University of New Mexico and analyzed by Delta Ray spectrometer (Fischer and Lopez, 2016; Ilanko et al., 2019). Ideally 10 gas and two air background samples would be collected at the crater and parking lot site per campaign to enable extrapolation to the pure CO_2 endmember composition (Fischer and Lopez, 2016). $d^{13}C$ analyses are rapid and can be performed in one day. All sampling equipment is available. We expect the sampling program to continue for about 3 months with samples collected from each site about once every two weeks. This schedule depends on HVO capabilities which we have discussed with HVO Staff (Dr. Tricia Nadeau) but also on weather and wind conditions.

The science question that we will be able to answer **is whether there is deeper, undegassed magma in the Kīlauea system that could potentially trigger an increase in volcanic activity following the current lull.** At Kīlauea undegassed magma has a $d^{13}C$ signature of around -4 (Gerlach and Taylor, 1990). Gas data from Sulphur Banks have been around -3 ‰ over the past three years (Peek et al., 2020), indicating that this site samples relatively undegassed magma, i.e. has some connection to the deep part of the system. The current (or previous for that matter) $d^{13}C$ signature of the Halema'uma'u gas plume is not known, neither is the composition of the parking-lot plume. Knowledge of the $d^{13}C$ values of these gases will enable us to assess whether deeper, undegassed magma is 'lurking' beneath the 'cap' formed by the crystallizing lava lake. Values that are heavy, i.e. about -3 ‰ would provide evidence that undegassed magma is still under the current crater floor while lighter values, perhaps around – 8 ‰ would suggest that the magma that is supplying this CO_2 is quite degassed. We would combine our findings with ongoing CO_2 flux and C/S ratio analyses being performed by HVO to assess the state of degassing at Kīlauea. In order to capture the signature of fresh, undegassed magma in the system, samples need to be obtained as quickly as possible and inf fact, sample bags and syringe to sample have already been shipped on February 2 to HVO to initiate collection. The RAPID would enable us to continue this process by supporting a student to run the samples at UNM, pay for shipping of sample foil bags and to allow us to travel to Kīlauea to help with sampling when COVID restrictions permit.

<u>Hyperspectral Imaging Science Question:</u> The inability to sample the current erupting material speaks to the need for remote techniques to make petrologic estimates on crystal content. Can we calibrate hyperspectral images of molten lava to provide crystallinity estimates during an eruption in real-time? Hyperspectral cameras are commonly used to identify the mineralogy of solidified volcanic products (e.g. Spinetti et al. 2009, Aufaristama et al. 2019, Rader et al. 2020). Total crystal proportion can be estimated from spectrums of solidified basalt but has **never been tested on flowing lava** (Ackiss et al. 2020, Rader et al. 2019, Reeder et al. 2019). This information, provided from a safe distance, in near real-time, and with a wide-view of an erupting vent **would allow for more accurate viscosity estimates to assist in real-time lava flow modeling.** Hyperspectral technology has the potential to assist in active eruption response

but testing this new method on the Kilauea eruption is critical because of the unknown influence the extreme heat produced by molten lava may have on the portion of the spectrum used to calculate crystallinity.

When coupled with gas and infrasound measurements, hyperspectral crystallinity estimates could provide a petrologic constraint on the likelihood of fresh magma instead of old stagnant magma. As these measurements are near instantaneous and can be taken from a great distance, the development of this technique could drastically improve the speed and safety of detecting fresh undegassed magma from

<u>Hyperspectral Methods:</u> I propose to rent and ship a spectral camera to Matt Patrick at HVO. He will place the camera overlooking the lava lake for a minimum of one hour. The equipment will be shipped back and a graduate student will spend three months during the summer to develop an algorithm to process the data cube. In the event that the eruption lasts into April, I have budgeted a trip to collect more targeted analyses after examining the preliminary data.

<u>Hyperspectral Urgency:</u> These data must be collected during an active eruption to provide a realistic control for experiments which will be done later to calibrate the method. The eruption at Kilauea may end at anytime and thus, this measurement is time-sensitive and thus making the RAPID the most appropriate avenue for funding.

<u>Budget Justification:</u>
Rader – The cost of renting the hyperspectral camera is $4848/month. Two months is requested to include practice/training with the instrument, shipping to and from Hawaii, and data download time ($4848 x 2 - $9696). Three months summer salary for a graduate student to process the data ($2040 + 2.1% fringe/month for 3 months = $6248.52). Shipping for the instrument to and from Hawaii is estimated at $1000 with tracking and insurance. A 10-day trip to Hilo (airfare $1000, $960 for lodging [$96/day], $550 for food [$55/day], parking ($10/day), and baggage fees ($190) for a total of $4000.

<u>Travel Conditions:</u>
With the current state of travel restrictions due to the pandemic, all funds requested for travel are only in the event that the eruption lasts long enough that restrictions are lifted, and researchers are allowed to help with data and sample collection. This travel is also conditional on additional HVO collaboration and communication as the COVID and eruption situation continues to develop. If sampling conditions end before travel restrictions are lifted or further travel approval is not granted by HVO, the requested funds will be returned.

<u>HVO Contributions:</u>
For hyperspectral imaging, HVO employee Dr. Matt Patrick will transport equipment (which will be shipped to him) to the rim during a regular monitoring visit. He will set up the camera and tripod and follow the written instructions to collect ~30 minutes of imagery. After image acquisition, he will dismantle the camera and pack it out. This process should take ~1 hour from set up to take down. Matt will then download the data and send an image to PI Rader to check if another trip is needed. Further visits will only occur if collaborator Patrick sees value in further data collection.

For the C-isotope work, HVO science staff Dr. Patricia Nadeau will collect plume samples on the caldera rim at various locations and intervals as she sees fitting into their schedule. She will also collect extra gas samples from the Sulphur Springs hydrothermal system as time and their sampling plans allow. Samples will be sent to UNM for analyses. This work would start immediately and extend into March, April, May.

Data Sharing: All data generated from this RAPID proposal will be shared via the CONVERSE network and the Volcano Listserv. Requests can be made to access this data through the CONVERSE Slack channel and progress updates will be made regularly to the broad group of scientists involved in CONVERSE.

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