CONVERSE: the Petrology, Geochemistry, Experimental, Communication and Sampling Communities Workshop

September 20-21, 2019
Pre-GSA Workshop Report

Mt. Shasta, the 5th highest threat volcano in the US as ranked by the USGS (Photo: C. Till)

Executive Summary

The Community Network for Volcanic Eruption Response (CONVERSE) Research Coordination Network (RCN) brings together volcano scientists from academia and US federal agencies. The goal of the project is to organize and prepare the volcano science community to maximize scientific returns for future volcanic eruptions within the US.

Workshop-based planning amongst key disciplinary communities is an important part of CONVERSE. To this end, a workshop was held September 20-21, 2019, where scientists from academic and federal and state agency backgrounds came together to share perspectives from the petrology/geochemistry, experimental, sample curation, and communication communities. Discussions were aimed at developing protocols to maximize scientific benefits from future volcanic eruptions, and to improve responses and communication around these events.

The workshop was based around plausible eruption scenarios at Mount Spurr, Alaska, Mauna Loa, Hawaii, and Mount Hood, Oregon. These represent different geographic locations and volcano and eruption types that could reasonably occur within the US in the near future. The scenarios were used to help recognize and refine science priorities and to discuss the complexities of conducting scientific sampling and research during and after a volcanic crisis.

There is broad consensus that the petrology/geochemistry/experimental petrology communities have much to offer in terms of efforts to understand eruption hazards, forecasting and response. These contributions may occur in the short term, as an aid to the ongoing eruption response, and over longer time frames where greater understanding of volcanic and magmatic processes will lead to improved models for forecasting, monitoring, and hazards. Important contributions include:

- Constraining the pressure, temperature and other conditions of magma storage, and how these change before, during, and after eruptions.
- Identifying underlying magmatic processes that produce changes in monitored seismicity, gas emissions, deformation and other remotely detected signals that typically herald and accompany eruptive activity.
- Identifying the magmatic (and other) processes that lead to initiation of eruptions
- Developing realistic conceptual models for magma storage regions and eruptive activity across the broad range of volcanic systems and eruption types, as well individual models for specific volcanoes.
- Characterizing the physical properties of magmatic samples during eruptions so that rheological and other information can be used in predictive models.

Workshop participants developed a number of specific recommendations for achieving these goals and improving future outcomes. In particular, participants recommend that the volcano science community undertake the following actions:

- Develop a lasting structure beyond the current CONVERSE RCN. CONVERSE would become a standalone entity charged with organization and coordination of academic activities related to science at active volcanoes in the U.S., both during non-eruptive "blue skies" times as well as during unrest, eruption, and post-eruption timeframes.

- Create Science Advisory Boards (SAB) as soon as possible. Participants, both academic and USGS, strongly advocated for the formation of Science Advisory Boards. These boards would be organized along geographic and/or disciplinary lines (perhaps both), and would serve as the interface between academic scientists and the USGS. The SAB would have important roles during both eruption response and "blue skies" phases, when they would assist the Scientists-in-Charge (SICs) of USGS volcano observatories with interactions with academic communities, help determine science priorities, have key roles in sample distribution and archiving, and serve as a conduit for communications between the government and academic communities.
- Develop recommended protocols and priorities for collecting, archiving and sharing samples and metadata. Samples drive our science before, during, and after eruptions. For short-term and long-term science outcomes, some samples must be collected *and distributed* in near real-time. Other science outcomes may be achievable with existing collections, or with samples collected after an eruption, if the samples are FAIR (**F**indable, **A**ccessible, **I**nteroperable, and **R**eusable). Archival splits should be distributed as broadly as possible to stable, curated repositories with FAIR policies. These policies would focus on the periods during and immediately after a volcanic eruption to ensure maximum scientific return and, when feasible, to provide and share key petrologic/geochemical/experimental information during an eruption that is relevant to monitoring and hazard mitigation. One priority is collection of a set of samples for higher threat volcanoes that are representative of key eruptive periods or phases. These should be collected in sufficiently large volumes that material can be provided to multiple investigators for different types of analyses.
- Improve sample archives for high threat volcanoes. It was also recognized that the number of available samples for reliable scientific access from US volcanoes rated as high threat are highly variable, and a significant number of volcanoes have insufficient publicly archived samples available through the Smithsonian Institution or other such repositories. Given that volcanic eruptions often destroy or bury material from older eruptions, improving sample archives is a priority when eruptions are not occurring.
- Improve training for Early Career Scientists. It was recognized that one way to leverage the broader community, to maintain a high level of readiness in the academic community, and to prepare the next generation of volcano scientists was through improved training of early career scientists in analytical, experimental and other tasks deemed critical to eruption responses within academic communities.
- Develop and curate lists of academic scientists and facilities who can help during eruption response. These lists would consist of people from the academic community who volunteer to assist in eruption response in a variety of ways, for example cycling in as volunteers to assist with sample and data collection, or perform rapid turnaround geochemical analyses or experimental work, or other roles that might be useful to the USGS during an eruption response. The intention would be that in the event that USGS SICs for volcano observatories have a need for additional personnel or resources beyond what is available from USGS response teams, these would serve as a mechanism for USGS SICs to quickly identify and contact individuals or groups who are willing and able to provide assistance.

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Workshop Overview

Workshop Organization & Participants

Approximately thirty people met in a 1.5 day workshop September 20-21 preceding the Geological Society of America meeting in Phoenix, Arizona (Figure 1), facilitated by a group of six organizers (Kari Cooper, Christy Till, Paul Wallace, Adam Kent, Tom Shea and Liz Cottrell). Two additional organizers (Ben Andrews and Leslie Hale) participated in the planning and participated remotely but were not able to attend the workshop in person. The conveners invited key participants encompassing different perspectives across the petrology/geochemistry, experimental, communication and sampling communities, as well as advertised the workshop widely through listervers. The participant list can be found here and in Appendix 1.

The workshop was based around plausible eruption scenarios at three different US volcanoes: Mount Spurr, Alaska, Mauna Loa, Hawaii and Mount Hood, Oregon. These three volcanoes and scenarios represent a range of geographic locations and volcano types, as well as representing a spectrum of eruption types that could reasonably occur within the US in the near future. The scenarios were developed by modifying a set of longer scenarios developed by the USGS and others for training emergency managers, and provided by Bruce Houghton (University of Hawaii). The scenarios as presented are given in Appendix 2-4. All scenarios were delivered in three parts: pre-eruption build up/unrest, eruption onset and continuing eruption, and post eruption (or in the case of Mount Hood an extended period of eruption). Each group was also provided an information sheet on the scenario volcano (Appendix 2-4), and breakouts were led by convenors with knowledge of each individual system. After each of these sessions the group participants summarized their results and reported back.

Each group participating in individual scenarios was selected to include people with relevant experience, to provide a spectrum of expertise and career stage, and to provide a mixture of academic, USGS and other affiliations. Some changes to group personnel were also made between each phase to provide different opinions and to provide participants more opportunity to interact with other participants. In addition, for the third breakout, the Mauna Loa and Mount Spurr scenarios were combined, and a separate early career group was formed to provide broader feedback from that important perspective.

For each breakout and phase of the eruption, the groups were provided the following questions to stimulate discussion:

- *What are the key science goals and opportunities right now?*
- *What are the key actions at this time?*
- *What are the key relationships at this time?*
- *What should be communicated to potential science response participants, and how?*
- *What should be communicated to monitoring agencies at this time?*

- *Can monitoring activities address science goals, and will this be disruptive?*
- *How can we minimize conflict between monitoring and science goals?*
- *What science can we do that contributes to monitoring?*
- *What are the important samples at this stage?*
- *What is required to implement sampling and sample distribution?*
- *What are the potential pitfalls at this time?*
- *Are there any other issues to consider at this stage?*

We have not recorded here in-depth discussions within each group for each phase, but we have used the many commonalities that emerged from these discussions as the basis for the ideas, issues and themes discussed below. Overall the scenario-based approach was very successful in terms of stimulating conversation and identifying critical issues, consistent with the widespread use of scenario based approaches for strategic business planning and emergency management (e.g., Bradfield et al., 2005; Zhang et al., 2018).

Figure 1. (Top) Groups work through three different eruption scenarios. (Bottom) Early career participants discuss what they can contribute to volcanic eruption response.

Recommendations Arising from the Workshop

Recommendation 1: Further Identify and Refine Science Drivers

A key point highlighted by the workshop was the tremendous value that the petrology/ geochemistry/experimental petrology community has to offer to efforts in eruption hazards, forecasting and response. In some cases exciting recent developments in the field have facilitated these opportunities. This includes the rapid recent growth in the study of kinetics in igneous minerals and magmas for determining the rates of magmatic processes (Rosen, 2016) including magma decompression rates, trigger to eruption timescales, magma thermal histories, rates of magma mixing and more over the last ~10 years (e.g., Costa et al., 2008; Cooper and Kent, 2014; Lloyd et al., 2014; Shea et al., 2015; Shamloo & Till, 2019).

In particular, the disciplines of petrology, geochemistry and experimental petrology have the ability to:

A. Place constraints on the architecture and dynamics of magma storage and plumbing system at specific volcanoes (P-T-X-volatiles-t) upon which hazard models, dynamic models, deformation models and hazards and forecasting tools can be built or refined (e.g., Box 1 & 2).

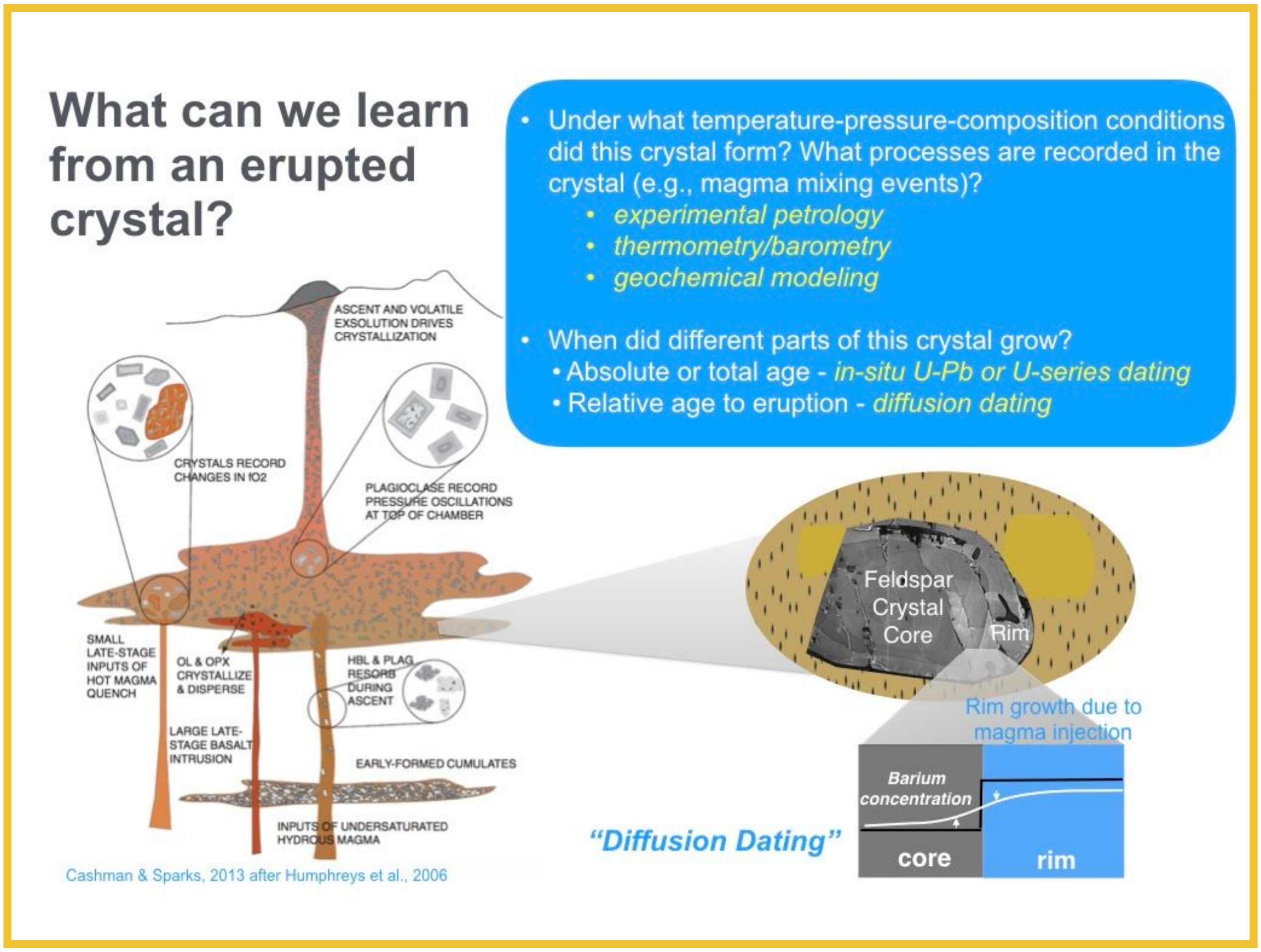
B. Identify the underlying processes that produce the monitored signals of unrest (seismicity, gas emissions, deformation etc.). Hindcasting of historic eruptions with monitoring data allows us to identify the causes of these signals, such that they can be better understood in monitoring for future hazards (e.g., Albright et al., 2019). For example, recent studies of chemical zonation in minerals have developed connections between magmatic behavior and monitoring signals of unrest at volcanoes (e.g., Saunders et al., 2012; Kahl et al., 2013; Rasmussen et al., 2018; Ruth et al., 2018).

C. Identify the processes that initiate eruptions both in general and at specific systems and for specific types of eruptions. This includes building a larger understanding of the probability of particular events, as well as conceptual models for specific volcanic systems. One example of this includes the identification of the eruption-initiating events beneath volcanoes, ranging from magma mixing or second boiling beneath stratovolcanoes (e.g., Costa and Chakraborty, 2004; Kent et al., 2007) to rejuvenation of more primitive magma driving supereruptions at large silicic volcanic systems (Shamloo & Till, 2019).

D. Characterize physical properties of magmatic samples during eruptions in near real time so that rheological information can be used in predictive models of lava flow development and hazard mitigation.

Recommendation 2: Further Refine and Identify Long-Term Science Goals

As described above, there is much that can be gained from rapid geochemical and petrological study during an eruption crisis. However it is also clear that significant long term scientific benefits can be gained from applying the full breadth of available geochemical and petrological techniques to an eruption outside of the immediate time-critical eruption response phase. Thus, there are many long term science goals that can be addressed by sets of well collected and curated samples that arise from CONVERSE efforts. The availability of a high resolution time series of samples is viewed as particularly important here, as results can emerge from these that are not available from study of samples without such temporal context (e.g. Nakamura, 1995; Venezky and Rutherford, 1999; Berlo et al., 2004; Kent et al., 2007). In addition, application of analytical and experimental approaches that take considerable time, such as high precision radiogenic isotope and uranium series geochemistry, detailed 2D and 3D textural studies, diffusion and other types of kinetic modelling, and many experimental approaches, also provide important insight into magmatic and volcanic phenomena. Even approaches that can be applied rapidly during a crisis can be also re-evaluated and supplemented once the crisis is over to provide a more complete and mature data set.



Box 1. What can we learn from erupted crystals?

Although these longer term data may not be available during a response, they do provide important information for understanding how volcanoes behave, and this in turn provides a basis for understanding future volcanic activity. Thus, over the longer term, sample archives and the data that derive from them will provide unmatched opportunities to address some of the most important goals of the petrological, geochemical and volcano science communities. These include developing and refining conceptual models to relate deeper magmatic and conduit processes to eruptive phenomena and to geophysical monitoring signals, which is a critical community goal. Long term benefits also include important opportunities to understand how conditions within the deeper magmatic system and conduit change during an ongoing eruption, and how these might affect eruptive timing and hazards.

One of the eruption scenarios involved a long-lived (3+ year) dome eruption of Mount Hood (Appendix 3). This is a realistic scenario for Mount Hood and many other arc volcanoes, and in this case it was recognized that there could be tremendous scientific benefit from researchers having access to a long lived and reasonably accessible “laboratory volcano” of this type. As with similar eruptions at Mount St Helens in the 1980’s and 2000’s, and Mount Unzen and Soufriére Hills in the 1990’s, this scenario could allow development of longer term activities and infrastructure to maximize science benefits. In this example the relative predictability of events such as dome collapse, ash generation, pyroclastic flows, and lahars provide unparalleled opportunity for high resolution observations, that in turn would promote efforts to develop more predictive models of these phenomena.

Recommendation 3: CONVERSE in Perpetuity - The role of this organization and what it facilitates

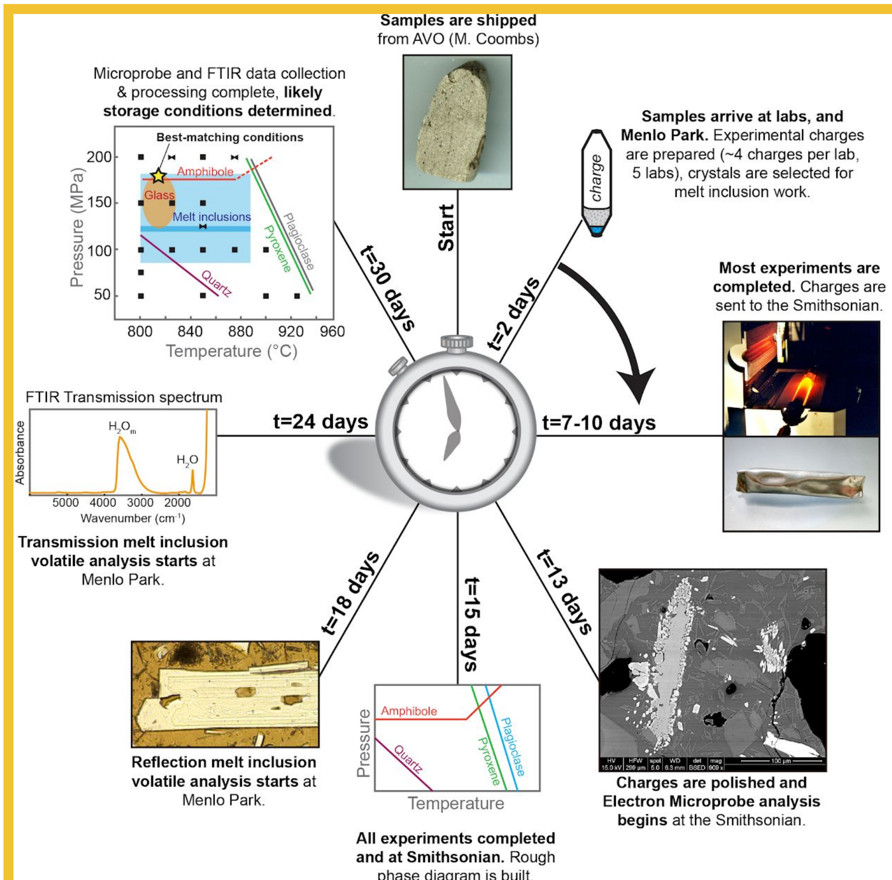
While the existing CONVERSE RCN is capable of accomplishing a significant amount in terms of developing the protocols, methodologies and communication networks for responding to a US volcanic eruption, this organizational entity and funding will come to a close with the conclusion of the RCN in Fall 2020. If there are to be organizations or bodies that exist in perpetuity to facilitate the science and communication of the US academic community during a US volcanic eruption, another entity built on the foundation laid by CONVERSE is needed to continue this work (e.g. Figure 2). The consensus of the workshop participants was that there is a continuing need for a standalone facility to organize and coordinate academic activities related to science at active volcanoes in the U.S., both during “blue skies” times as well as during unrest, eruption and post-eruption timeframes.

This is envisioned as an organizing body that would:

- Work with the USGS to populate the advisory boards (discussed below) to ensure appropriate scientific depth and regular rotation of members, as well as fairness and openness.
- Oversee communication between USGS/advisory boards and the broad academic community.
- Maintain a list of scientists in the broader community available to conduct certain types of activities during unrest and eruption (e.g., Box 2).
- Organize and potentially fund science activities during different stages (blue skies, unrest, and eruption).
- Oversee a student network and training program.
- Develop working relationships with relevant IAVCEI working groups and facilitate the integration of these with the CONVERSE community.

A number of much-needed activities identified during the workshop do not have existing organization or funding models. For example, it would be advantageous to organize a campaign to determine experimental phase diagrams and strategic mineral thermobarometry for representative units from past eruptions to produce conceptual models of the magma storage and plumbing systems beneath high threat volcanoes that presently lack them. Such conceptual models are key to eruption hazards and forecasting, and are even more critical in periods of unrest and eruption. Currently, such activities only happen on an *ad hoc* basis by PI-driven proposals to NSF Petrology and Geochemistry and similar programs and may not be a priority for funding agency peer review boards. However, a systematic approach to providing this fundamental data for very high and high threat volcanoes is a priority for the volcano science community and would be relatively inexpensive. Thus a governing body that could organize and fund a strategic campaign to do this where key gaps exist at high threat volcanoes, likely by a small grant scheme, would provide tremendous improvements in our ability to coordinate and facilitate eruption-related science. This is well within the NSF mission of the fundamental science behind hazards, and is an activity that often lies beyond the resources and time demands of USGS personnel.

One potential model for a CONVERSE organization is the highly successful Southern California Earthquake Center (SCEC), a consortium of fifteen research institutions with a mission to gather new information about earthquakes in Southern California, integrate such information into a comprehensive and predictive understanding of earthquake phenomena, and communicate this understanding to end-users in the earthquake engineering profession and the general public.



Box 2: Five experimental laboratories (UAF, Baylor, Hawaii, UT Austin, and Smithsonian) and USGS Volcano Hazards Program scientists collaborated to determine how fast an experimental phase diagram could be completed so as to develop protocols for responding to future volcanic unrest. The trial began with preparation and shipment of an Augustine dacite from Anchorage to the different laboratories. Each lab ran a suite of 96-hour experiments at pre-assigned P-T conditions. In addition, an 8-day experiment and 3 pairs of reversal experiments were run at Smithsonian to assess how closely the experiments approached equilibrium. Upon completion, experiments were shipped to Smithsonian for analysis using electron microprobe and SEM. Melt inclusion analyses were conducted concurrently at Menlo Park. Processing and synthesis of all data was complete within 32 days of the initial sample shipment; in the event of a real "crisis," instrument time and data processing could be prioritized enabling completion of a similar phase diagram within ~16 days.

Box 2. Summary of Rapid Response Experimental test to illustrate the experimental capacity to determine P-T-H2O conditions of magma storage within 2 weeks to a month.

Recommendation 4: Defining the "CONVERSE Community" - Who is in it and how do we engage them?

One of the goals of the CONVERSE RCN is to help develop and engage a broad community of volcano scientists. As envisioned in this workshop, the CONVERSE community is a network of people interested in volcano science who share the CONVERSE goal "to advance our ability to adequately monitor the unrest and run-up to volcanic eruptions and once an eruption occurs, to adequately collect critical data and samples to develop next-generation physical/chemical models of volcanoes and through these understand processes of magma generation, transfer and eruption." In the broadest sense, CONVERSE should be open to all who self-identify as part of this community, at all career stages, of any nationality, and across all disciplines related to volcano science and response for US volcanoes. We envision that if CONVERSE continues as a facility or continuing organization in the future, individuals will become part of the CONVERSE community simply by subscribing to an email list and/or by participating in CONVERSE activities.

Within this broad scope of the community, smaller disciplinary or working groups can be organized. Some examples of this would be:

- A leadership group, with representation from academia and the USGS and representing different disciplines within volcano science.
- A curated list (or lists) of scientists who agree in advance to take on specified roles during an eruption response. Some examples of possible roles would be: people who volunteer to conduct time-sensitive analyses during an eruption, or people who could volunteer time in the field to help with sampling and collecting data during an eruption.
- A list of people who would be willing to serve on advisory boards.

Critically, in order to accomplish the CONVERSE goals, membership of the broader community and of any sub-groups must include representatives from both the USGS and from academia, because facilitating coordination and communication between these groups is a key part of the CONVERSE mission. In addition, although CONVERSE is focused on volcanoes located within the US, volcano science is inherently international, and having representation from the international volcano science community will be critical to maximizing the science goals of the group. Along those lines, we envision that CONVERSE will engage with and share information and membership with other groups such as IAVCEI that have a broader mission. Where possible, CONVERSE will integrate with these existing structures and will both contribute to and draw on resources (such as sampling and communications guidelines) that are key for multiple communities.

Recommendation 5: Institute CONVERSE Science Advisory Boards

One very strong theme throughout the workshop was the importance of developing one or more advisory boards which would serve as the interface between academic scientists and the USGS. This was supported by both academic and USGS scientists present and could be both geographic and disciplinary in scope. There was much discussion about the scope, roles, membership, and maintenance of such advisory boards, which would likely differ between times of non-activity and during eruptions. Possible functions that were suggested for such a board/boards included:

- Reviewing proposals from the academic community for access/samples/data during an eruption to ensure fair and open access to samples, while also maintaining a balance between necessary replication of results and redundancy
- Compiling and maintaining a list of academic scientists who would be available to participate in an eruption response (in the event that the USGS scientists would find that useful), and assisting USGS scientists in identifying volunteers if needed
- Disseminating up-to-date information to the broader CONVERSE community during an eruption in order to assist with providing a clear and consistent message when communicating to the public during an eruption
- During "blue-sky" times (i.e., non-eruptive, non-unrest periods), coordinate workshops and other activities that build community and trust between USGS and academic scientists
- During unrest, facilitate high-priority analyses and other data collection that will be useful for eruption response, and form a sort of communications "hourglass" to facilitate consistent and timely information exchange between academic and USGS communities (Figure 2).

Although the need for such a body emerged as a consensus among the workshop participants, some open questions and challenges were also identified. For example, the membership of such a body would have to be developed with full participation by the USGS observatory scientists, in order to best serve the needs of the USGS during an eruption response. The demands on the time of the members of the boards could vary widely depending on the activity of the volcano(es) served by the board, and there would need to be a structure whereby additional members could be rapidly added to increase the size of a board if needed during a response. More broadly, there would need to be a structure in place for rotation of members through the boards, both during periods of non-activity and unrest/eruption, which would maintain institutional memory throughout the process.

Given the many functions and goals of this type of group, a model was proposed where there would be more than one advisory board at any given time. Each USGS volcano observatory would have a small (5-10 person) advisory board associated with it, composed of a diverse group of scientists from different disciplinary groups who have some interest and expertise with the region's volcanoes. These boards would be tasked with being the primary avenue of (two-way) communication between USGS observatory scientists and academic scientists (e.g. Figure 2). For example, they would review proposals for sampling and/or access during a response (according to criteria agreed upon in advance by academic and USGS communities), and would also transmit requests from USGS observatory scientists for personnel and/or analyses from the academic community that would help with a response. There would also be more specialist advisory committees run through a continuing CONVERSE structure, which would develop specific protocols and policies appropriate to the disciplinary group, maintain lists of academic scientists who are willing and able to participate in eruption response or to provide analyses on a short turnaround, facilitate training such volunteers, etc.

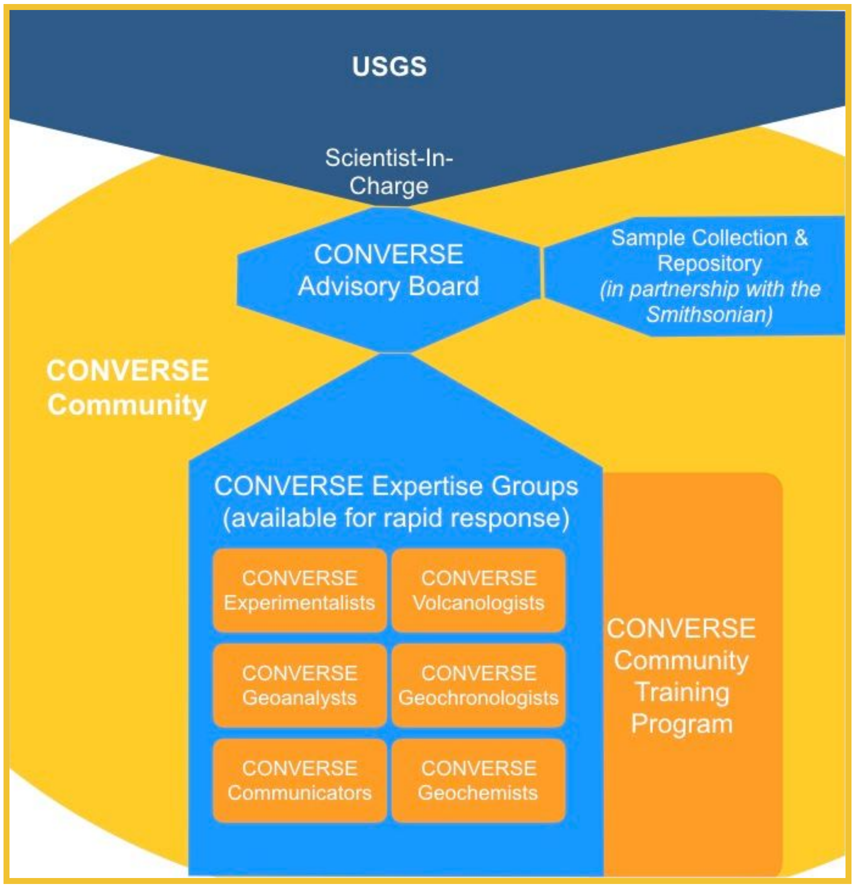


Figure 2. Possible organizational structure for the CONVERSE community, advisory boards etc.

Recommendation 6: Develop and refine sampling and archiving protocols and identify sample archives.

Workshop participants recognized that samples drive much of petrological, geochemical and experimental petrology-related science that our community can do before, during and after eruptions (Figure 3). Thus there are a number of critical issues related to collecting, documenting and archiving samples and their metadata. Many of these issues are covered elsewhere in this report, but are worth restating here.

Almost all of the stated science goals rely heavily on the availability of well-archived samples. Thus sampling collection and archiving policies and protocols are of the utmost importance to CONVERSE's community's efforts. Sampling requirements vary with different techniques and for some short-term and long-term science outcomes, some samples must be collected *and distributed* in near real-time. Examples of such short term outcomes are science results that would be useful for an eruption response, such as estimates to depth of an activating magma reservoir. Examples of long term goals that need rapid access to samples are the use of short lived radionuclides to study volcanic degassing, or samples that might degrade with continued exposure such as ash or sensitive minerals such as anhydrite. In addition the possibility that continued or subsequent eruptions might destroy or obscure eruptive products is also of critical importance.

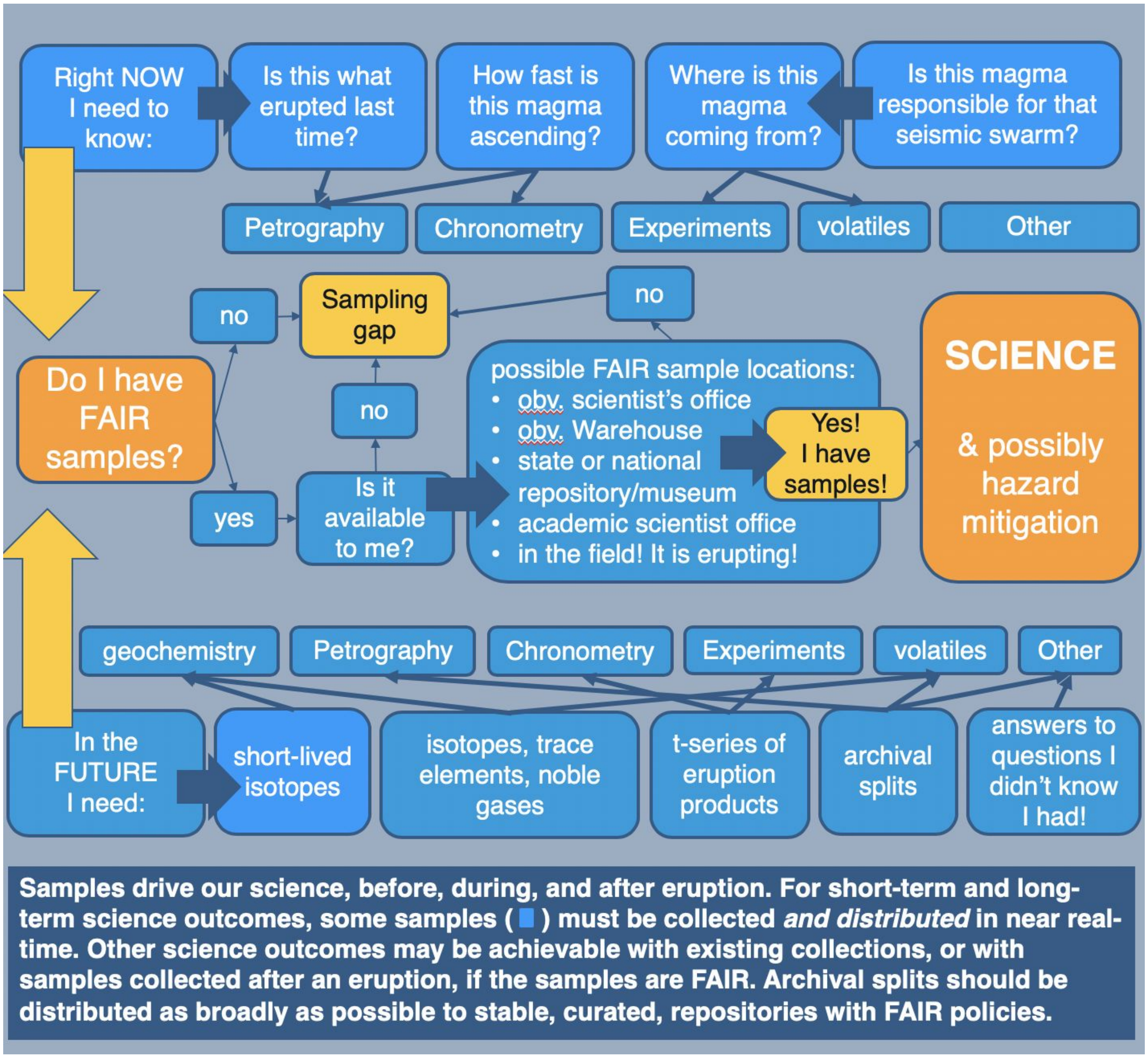


Figure 3. Science drives our need for FAIR samples.

It is also critical that sample archives are maintained at publically available institutions such as the Smithsonian or other curated repositories, and that they are available to researchers. Sampling protocols and sample archives should be designed to follow the FAIR principles: **F**indable, **A**ccessible, **I**nteroperable, and **R**eusable (Figure 3). Development of future sampling protocols can build on existing efforts from other organizations (e.g. USGS, IAVCEI), but also requires consultation with scientists familiar with the different analytical and experimental approaches to make sure that correct sample material is obtained and that archived amounts are sufficient. Previously archived samples need to be audited for suitability.

Table 1. Summary of archived samples for very high threat volcanoes.

USGS Threat Ranking[1]	Volcano Name & State	Global Volcanism Project Volcano Number[2]	Volcanic Samples NMNH[3]	Volcanic Samples ADGGS[4]	Samples in SESAR[5]
1	Kilauea (HI)	332010	3224	0	17
2	Mount St. Helens (WA)	321050	622	0	149
3	Mount Rainier (WA)	321030	41	0	0
4	Redoubt (AK)	313030	0	1718	0
5	Mount Shasta (CA)	323010	16	0	0
6	Mount Hood (OR)	322010	2	0	0
7	Three Sisters (OR)	322070	10	0	100
8	Akutan (AK)	311320	0	514	56
9	Makushin (AK)	311310	0	1340	149
10	Mount Spurr (AK)	313040	3	1090	0
11	Mount Lassen (AK)	323080	58	0	0
12	Augustine (AK)	313010	8	946	0
13	Newberry (OR)	322110	30	0	43
14	Mount Baker (WA)	321010	2	0	0
15	Glacier Peak (WA)	321020	0	0	0
16	Mauna Loa (HI)	332020	580	0	17
17	Crater Lake (OR)	322160	195	0	0
18	Long Valley (CA)	323822	59	0	N/A

1. Source: https://pubs.er.usgs.gov/publication/sir20185140, 2. https://volcano.si.edu/, 3. NMNH - National Museum of Natural History, 4. ADGGS - Alaska Division of Geological & Geophysical Surveys, 5. Samples located near volcano lat-long & not at NMNH or ADGGS) http://www.geosamples.org/.

Workshop participants identified many barriers to sample collection and distribution during an eruption. These included lack of human resources to document, process, and ship samples; lack of previously agreed upon FAIR distribution policies; lack of a standing committee to oversee sample requests and sample distribution during an eruption; loss of sample distribution channels (e.g., closed roads and airports); lack of written permission to trespass and approved permits to collect; and lack of written policies to govern sample recovery and distribution.

It was also recognized that the community can do a significant amount during non-eruptive periods. One primary goal should be to ensure that adequate sample archives are in place for all US very high threat volcanoes. Our initial assessment (Table 1) of the extant samples available at the Smithsonian shows that the numbers of stored samples are highly variable, ranging from 10,000+ to 0. In some cases additional archives of high threat volcanoes are available elsewhere but other archives – typically university or private collections – often do not conform to FAIR principles, are not suitably abundant, or have insufficient metadata available.

It is critical to note that as yet, **our community does not know if these existing samples are suitable to answer key science questions.** To answer this question, we would require an audit of existing VHTV samples to determine their type (e.g. pumice, lava, ash) and quantities, and what types of analyses could be achieved without additional sampling campaigns. A sample campaign could also involve outreach (and ideally, resources in the form of personnel and/or funding to help improve sample metadata and access) to owners of existing high priority samples, to make their samples FAIR.

Recommendation 7: Early Career Recommendations

During one of the breakout groups on the second day of the workshop, all of the graduate student and postdoc participants were asked to give us their perspective on what had been discussed thus far and what we missed. The following section outlines their feedback. In particular we would like to highlight their first suggestion of establishing a community training program for undergraduate and graduate students distinct from the other networks of individuals in the broader CONVERSE community identified by the workshop at large.

a. **The role of students & early career scientists and a community training program.**
Graduate students and other early career scientists often provide vital support for rapid experimental/analytical response efforts; therefore, financial support must be provided for work performed outside the scope of current research/dissertation progress. CONVERSE can contribute to equity via inclusion of minority populations in STEM fields, those not enrolled in research-oriented universities (e.g., undergraduates and graduates from smaller colleges, community college students, high school students), as well as at institutions that are not local to the volcano. Such students can become part of a network of individuals who are involved in conducting science related to the eruption response either prior to or during a volcanic eruption, in addition to the PI-driven list of individuals in the broader CONVERSE community who can provide a variety of expertise and services to the advisory boards. Students can be trained remotely in some cases, and in a variety of different possible skill sets (Sample Collection, Experiments and Analysis: Figure 4) depending on the local expertise. Giving this kind of opportunity and preparation such a training program will establish a broad network of trained students, engaging local communities in hazard response and expanding access to the field. These students will go on to be the future scientists and leaders of the CONVERSE community in perpetuity.

b. **Data sharing/communication**
During an eruption, there needs to be a secure and accessible platform (e.g. Slack or similar platform) for sharing pertinent information. To minimize unwanted chatter, this platform should include tiered information channels and posting ability. Moderators should be ready to vet interested participants and facilitate effective communication. After the eruption, data will be archived, potential improvements implemented, and non-essential participants will be removed from the communication platform. The general communication platform structure will be maintained and kept ready for population in the event of future eruption responses.

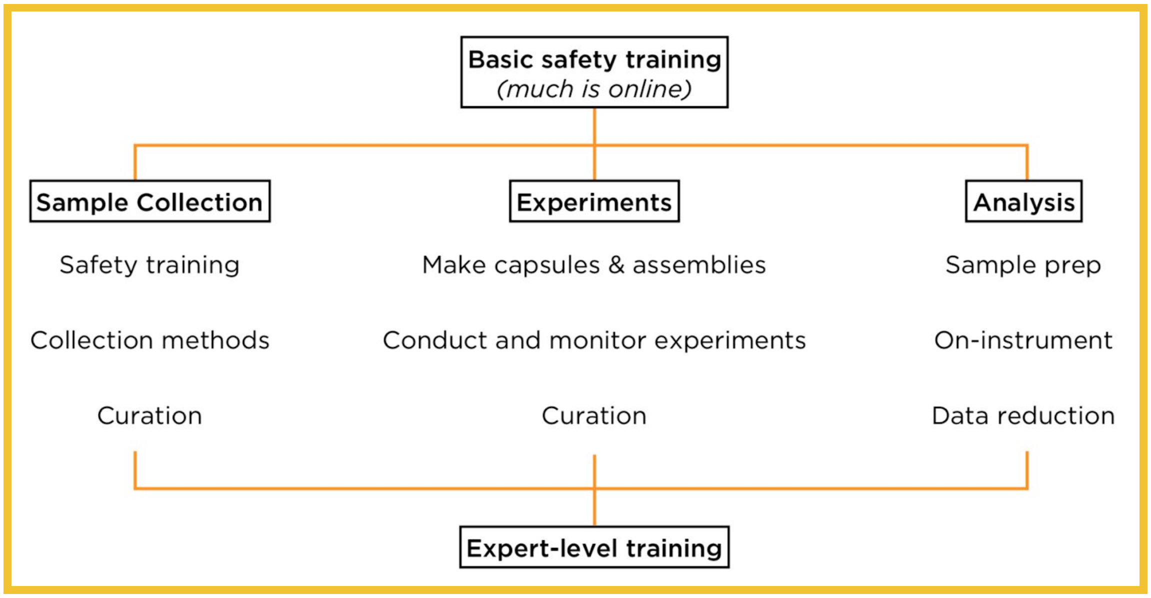


Figure 4. Potential structure for an early career community training program.

c. Advisory board decision-making criteria

Science goals are a top priority, but this does not need to limit inclusion and future research opportunities. To reinforce sample curation and community science, proposals and individual investigators involved with CONVERSE should be required to register their samples via IGSN/SESAR within a year of collection, although there could be a longer moratorium on requiring sample sharing. A potential model to encourage this effort would be that, if researchers do not comply with the policies on registering and sharing samples obtained during eruption response, they could be prevented from obtaining future CONVERSE support until compliance.

Recommendation 8: Action items - What is doable in the existing CONVERSE timeline?

The organizing committee separated action items into three categories: (a) ***Short-term*** tasks that will be completed by the next CONVERSE Workshop in March 2020, (b) ***Medium-term*** tasks that should be accomplished prior to the end of the CONVERSE RCN funding (currently end of 2020), and (c) ***Longer-term*** actions that will likely require additional time beyond the current duration of CONVERSE (See Figure 5 and corresponding numbers).

(a) Short term action items (to be completed by March 2020)

- (1) Compile the list of High and Very High Threat volcanoes to focus on and the samples available for each. These should be volcanoes that will be investigated during blue skies periods for eruptive history. The recently revised USGS list (2018) can be found at this link.
- (2) Write the report from the Phoenix 2019 workshop (i.e., this report).

- (3) Update list of participants and available skill sets and identify gaps. This will be a living document (see link here). Provides basic information on participants, specialization, their potential role(s), tools utilized and field/sample collection/processing/analytical capacities, career stage, experience working with high threat volcanoes).

- (4) Establish the list of available facilities and identify possible gaps. These facilities (see table here) should be open to outside users, with a clear understanding of the potential time-sensitivity of the analytical work requested. This includes all facilities that can/will be used to:
  - Process samples (e.g. sample cataloging, curation, and distribution)
  - Prepare samples (sorting, crushing, polishing labs, petrographic thin section companies)
  - Analyze sample characteristics (size, componentry, hand sample observations, etc.)
  - Microanalysis
    - Electron Microprobe
    - LA-ICP-MS
    - Ion probe, including large geometry SIMS, and nanoSIMS
    - FTIR and microRaman labs
    - Microtomography
  - Multicollector/solution ICP-MS
  - Experimental Petrology
  - WD- and ED-XRF
  - Alpha and gamma detectors
  - LIBS
  - XRD
  - Active eruption field equipment (e.g., IR and high speed cameras, UAVs, gas sampling equipment, geophysical instruments)

- (5) Compile a table of sample needs for different geochemical/petrological techniques (e.g., sample type, mass, and purpose). The document in progress can be found here.

(b) Medium-term action items (to be completed end of 2020)

- (6) Define rules of external communication during an eruption response. Communication to people external to CONVERSE. (Twitter/Facebook, volcano listserv, newsletters, geological organizations such as AGU , media, publishers).

- (7) Establish ethics and values statements. The CONVERSE community should set up policies for professional, ethical and scientific integrity. This document should be explicit about expected professional behavior during field, lab, and meeting interactions, and will emphasize the responsibility of each participant to uphold fairness and integrity in a safe research environment. Sensitivity to cultural, racial and gender diversity, power imbalance, and inequality in the level of experience should be incorporated. Mechanisms to address discrimination, harassment, conflicts of interest, plagiarism and other types of misbehaviors should be laid out.

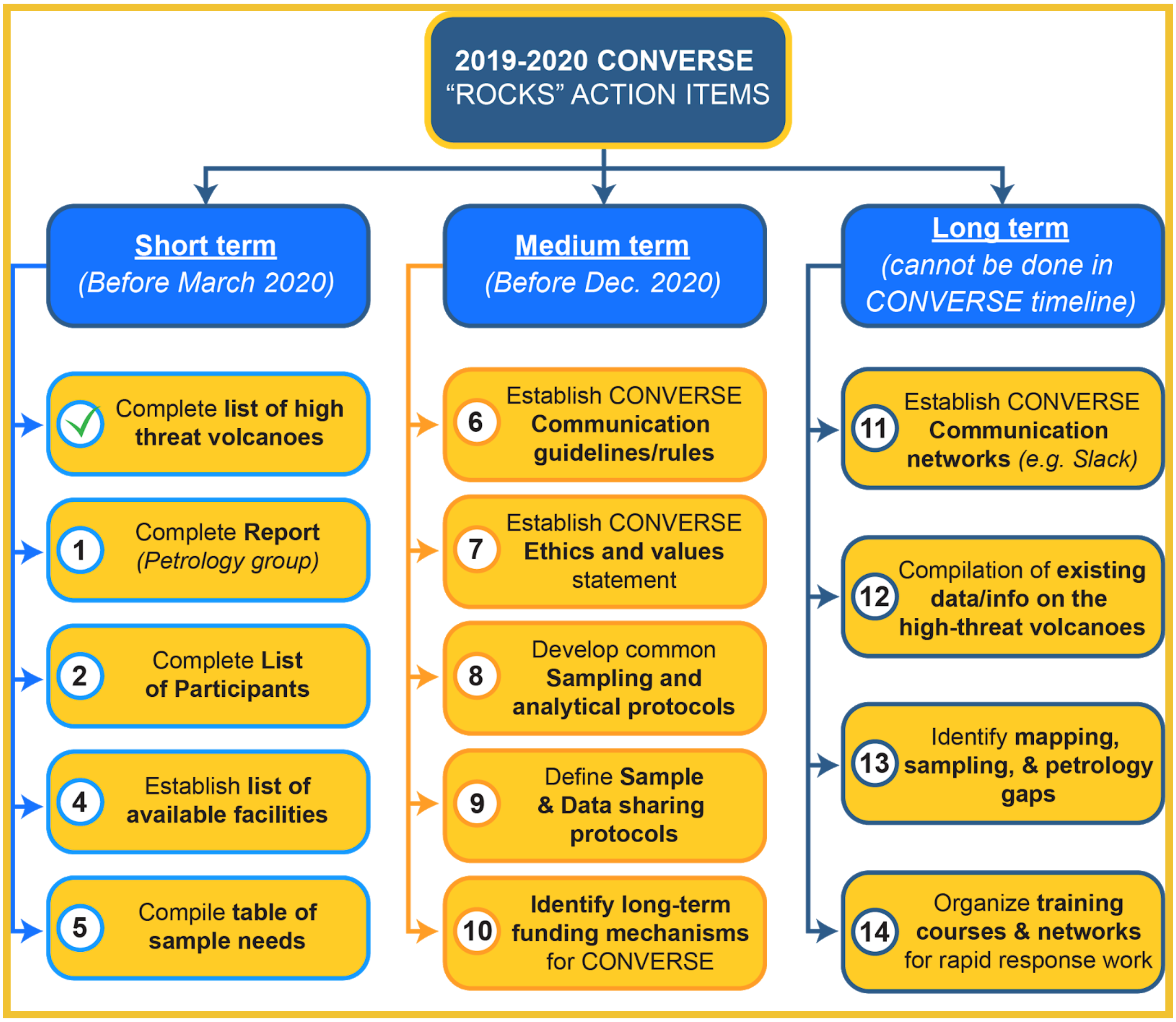


Figure 5. Action items in the short, medium and long term for this CONVERSE community. The current CONVERSE funding cycle continues until the end of 2020. For details on each item see the corresponding section numbers in the text (numbers do not correspond to activity urgency).

- (8) Develop a common sampling, analytical and metadata protocol guide. The goal of this document will be to (1) provide detailed guidelines for various stages of sample collection, labeling, registering with IGSN/SESAR, submission of voucher sub-sample to the Smithsonian (or other) Institution, and basic characterization prior to (2) describing agreed upon analytical strategies for textural, petrographic, chemical, and isotopic analysis. This document will require input from all members of CONVERSE, as well as the international community. Link to Community sampling and analytical protocol guide.

- (9) Define sample and data sharing protocols. Providing explicit guidelines and rules for sharing samples and utilizing data collected by the CONVERSE community will be a key facet of successful scientific response during and after an eruption crisis. Past experiences of USGS-academic collaborative response work (Mt. St. Helens 2004, Kilauea 2018) have highlighted the need for well-defined sample sharing protocols, with good faith efforts from all sides to favor advancing community science over 'personal' professional success. During this workshop, there was a consensus among breakout groups that establishing an advisory committee comprised of USGS and academic researchers would be a critical step towards establishing clear sample distribution guidelines. This committee would be responsible for considering and approving applications to work on samples collected during the eruption. The sample sharing guidelines document can be found here. Similarly, as petrological/geochemical data is being collected and reduced/processed by the various participating CONVERSE groups, data sharing needs to follow clear protocols. This helps (1) reduce the amount of duplicative efforts (although it was agreed at the workshop that some duplication is perhaps desired), and (2) prevent issues of data being 'scooped' for publication before those that have done the bulk of the work can get a chance to examine/interpret their data. It was suggested that certain types of basic routine monitoring analyses (e.g. XRF/bulk analyses) could form part of a data stream that is continuously shared to the community with no moratorium or rules attached.

- (10) Identify long term funding mechanisms for CONVERSE. See details in section 'CONVERSE in Perpetuity' above.

(c) Longer-term action items (started, unlikely to be completed by end of 2020)

- (11) Establishing reliable and safe CONVERSE communication and sharing platforms will be essential to prepare for and respond to a volcanic eruption. Documents and data can be shared via regular means (email, Google Docs). In the recent past, digital tools such as Mattermost or Slack have garnered success as a means of communication and data sharing by observatories. Private and open channels may be created for the various groups and task forces (e.g., General CONVERSE topics/channels as well as more petrology/geochemistry-focused channels). Rules for internal communication between the CONVERSE participants (including USGS, Smithsonian) need to be clearly defined to avoid spread of mis-information. A listserv that includes all CONVERSE Rock group participants will be created to facilitate information exchange.

- (12) Compile existing information about High or Very High Threat volcanoes. In some cases such compilations may already exist at Volcano observatories, in which case the priority may be making this information more broadly accessible. For example:
  - Geological maps and essential shapefiles
  - Satellite, aerial, LIDAR and other imagery
  - Current sample collection and availability (Smithsonian, USGS, Universities)
  - Geochemical data (whole-rock, glass, mineral, MIs, trace elements)
  - Geophysical data (seismicity, geodesy, infrasound)
  - Experimental data (phase equilibria, kinetic experiments)
  - Published works (not limited to petrologic studies)
  - Existing conceptual models

- (13) Identify mapping, sample and data gaps

- (14) Training and training networks. The need for technique-specific training of the CONVERSE community prior to a volcanic crisis was a salient topic of the Phoenix workshop. Sampling, processing, experimental and analytical routines can be extremely time-consuming, and streamlining these procedures through networks of trained scientists (students, postdocs, senior researchers, lab managers, federal scientists etc.) may be key to a successful, efficient response. Training workshops with dedicated topical working groups (e.g., sampling, textural/petrological characterization, experimental petrology, glass/mineral/bulk rock analysis, isotope geochemistry etc.) would be organized at a given location. Funding mechanisms need to be identified.

Recommendation 9: Define Activities during an Eruption Cycle

A. Pre-Eruption/"Blue Skies" Activities

CONVERSE leadership is:

a. In collaboration with USGS SICs, populating the regional Advisory Boards, and providing training and identifying new scientists to rotate onto the advisory boards, while others rotate off.
b. Establishing lines and communication platforms amongst the various regional advisory boards and USGS for both blue skies and during crisis times.
c. Overseeing a small grant program to conduct the highest priority blue skies science identified as necessary by the regional advisory boards.
d. Working with the Regional Advisory Boards to create and curate lists of scientists with relevant expertise and their desire and capability to be involved in activities, before, during and after future eruptions at the volcanoes they are responsible for (i.e., which experimental labs could drop everything to create a phase diagram for newly erupted material during an eruption).
e. Some disciplines may have their own across CONVERSE or regional advisory boards and synthesizing/organizing this activity is the responsibility of the CONVERSE leadership.

Regional Science Advisory Boards are:

f. Coordinating collection of representative samples for all Very High Threat US volcanoes and inclusion of these samples in the Smithsonian collection.
g. Coordinating along with CONVERSE leadership to conduct experimental, thermobarometric and diffusion chronometry studies, for example to create conceptual models of magma storage conditions prior to past eruptions, identify their eruption triggers and the trigger-eruption timescales to the extent possible for the volcanic centers in that region.
h. Working with the CONVERSE leadership to create and curate lists of scientists with relevant expertise and that indicate those scientists' desire and capability to be involved in activities, before, during and after future eruptions at the volcanoes

they are responsible for (i.e., which experimental labs could drop everything to create a phase diagram for newly erupted material during an eruption).

i. Overseeing and working on permitting issues and safety training necessary for scientists during times of unrest and eruption.

The broader CONVERSE community is:

j. Identifying their interest and expertise for participating in eruption-related activities now and in the future, as well as by proposing to the small grant program.
k. Training a network of students (see Early Career Perspective training program proposal) and scientists with the capabilities of assisting in eruption-related volcano science activities (including activities for during unrest and eruption).

B. Unrest Activities

CONVERSE leadership is:

a. Making sure regional advisory board has what is needed prior to a potential eruption in terms of communication, organization, infrastructure, etc.

Regional Advisory Boards are:

b. Finalizing collection of representative samples to be accessioned into the Smithsonian collection for posterity for the volcano in unrest
c. Coordinating any rapid experimental, thermobarometric and diffusion chronometry studies or other studies to assist with conceptual models of magma storage conditions prior to past eruptions that may be critical
d. Working with the UGSS to identify scientists that are trained and prepared to assist in person, as well as remotely, during unrest and potential eruption.
e. Overseeing and reviewing proposals from scientific community to sample and conduct science during unrest and/or eruption.

C. Syn-Eruption Activities

CONVERSE leadership is:

a. Coordinating media communication with USGS and providing broader community talking points and utilizing IAVCEI best practices for outreach and communication.
b. Coordinating and synthesizing/organizing any activities by disciplinary or cross-disciplinary CONVERSE or regional advisory boards.

Regional Advisory Boards are:

c. Calling upon previously designated scientists to participate in eruption response (number and type to vary depending on the eruption).

d. Overseeing the collection of “community samples” that will be large-volume reference samples available to a large number of scientists following the eruption.
e. Overseeing sampling for petrology, geochemistry & experimental purposes (see details under “Samples” below as well as for individual eruption scenarios*).*
f. Setting up a sample sharing program, which may begin during the eruption depending on its duration. Identifying a sample czar who will oversee the distribution. Potentially working with the Smithsonian for this activity. See details in “Samples” below.
g. Overseeing and reviewing proposals from scientific community to sample and conduct science during unrest and/or eruption.
h. Coordinating any rapid experimental, thermobarometric, and diffusion chronometry studies deemed critical for development of conceptual or quantitative models of magma storage or ascent.

D. Post-Eruption Activities

CONVERSE leadership is:

i. Working with Regional Advisory board to synthesize lessons learned and disseminate to other Regional Advisory boards and broader CONVERSE community.

Regional Advisory Boards are:

j. Overseeing the collection of large volume 'community samples' that will be available to a large number of scientists.

Recommendation 10. Identifying and Avoiding Pitfalls

Although the ideas of an extended role for CONVERSE and the institution of Science Advisory Boards generated widespread enthusiasm, the groups also identified several pitfalls which should be considered with this structure:

1. **Failure to plan adequately during the non eruptive “blue skies” phase.** Organizing responses to a future eruption and realizing science opportunities depends on careful planning when eruptions are not occuring. This is the reasoning behind the CONVERSE network as a whole, and it is imperative that such organization be done at a time when infrastructure and resources are not under pressure from an eruption response.
2. **Breakdown of relationships, communication and trust.** It was recognized that successful operation of a structure involving volcano observatories, science advisory boards, the wider science communities and CONVERSE will function best where there are good relationships and trust between the individuals involved and the entities they represent. This is critical for interaction between academia and USGS, but is also crucial between individual academic scientists. Relationship building and communication plans will thus be important from the very start, as are processes and exercises that will

demonstrate mutual benefits. The “blue skies” periods – when no eruptions are occurring – offer the possibility for relationship building through positive interactions, participation in exercises and workshops.

3. **Poor sample distribution protocols.** A key point where relationships could suffer, and where scientific benefits remain unrealized would be through poorly designed sample distribution practices and procedures. This is crucial in the early “crisis” phase of an eruption, where demand for samples may be high, and where resources to collect and distribute might be stretched. In this case the lack of a fair, rational, transparent and rapid system for distributing samples could substantially reduce cooperation and data sharing, and reduce immediate and long term science benefits.
4. **Burnout**. For long lived eruptions there is a high chance of burnout from long periods of activity and involvement - particularly for those on high intensity positions such as science advisory boards. For this reason the organization of any advisory board should include plans for rotation of members, for retention of institutional memory, and for mentoring of new members prior to rotating onto the board.
5. **Inadequate sample curation and loss of metadata**. The petrology and geochemistry activities during and after the response will rely heavily on access to samples. Realizing the long term benefits of such unique sample collections will require adequate curation and preservation of key metadata and a voucher sub-sample. Failure to do this, and to maintain the balance between using material for science goals related to eruption response versus preserving an archival split for longer term science benefits will reduce the science benefits that result from any eruption. Clear sample archiving, metadata and distribution protocols developed in advance of an eruption will decrease this risk.

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Venezky and Rutherford, 1999;

Zhang et al., 2018

Appendix 1. Participant List

Name	Affiliation
Beth Bartel	UNAVCO
Jessica Bersson	Arizona State University
Dawnika Blatter	USGS - CalVO
Karalee Brugman[†]	Arizona State University
Benjamin Andrews	Smithsonian Institution
Cheryl Cameron	ADGGS - AVO
Amanda Clarke	Arizona State University
Michelle Coombs	USGS - AVO
Kari Cooper	University of California at Davis
Elizabeth Cottrell	Smithsonian Institution
Holli Frey	Union College
Dennis Geist	National Science Foundation
Julia Hammer	University of Hawaii
Rachel Holsteen-Bruyere[†]	Arizona State University
Bruce Houghton*	University of Hawaii
Mary Humphreys[†]	Missouri State University
Felix Ishimwe	Arizona State University
Adam Kent	Oregon State University
Jisoo Kim[†]	Arizona State University
Jessica Larsen	University of Alaska/AVO
Mitchell Phillips[†]	Arizona State University
Terry Plank	Columbia University
Erika Rader	University of Idaho
Sarah Ramdeen	Columbia University
Kurt Roggensack	Arizona State University
Hannah Shamloo[†]	Arizona State University
Tom Shea	University of Hawaii
Ken Sims*	University of Wyoming
Wendy Stovall	USGS - VHP
Christy Till	Arizona State University
Jennifer Wade	National Science Foundation

Paul Wallace	University of Oregon
Heather Wright*	USGS - VDAP

†Student attendee   * Registered, unable to attend

Appendix 2. Scenario and information sheet for Mount Spurr

This scenario involves an eruption of Mount Spurr involving eruption columns up to 40,000’ and production of pyroclastic flows. This is based on a scenario developed by Bruce Houghton, University of Hawaii for FEMA for emergency management purposes, and is available on request.

Mount Spurr Information Sheet

No road access to Spurr

Samples at: AVO & ADGGS (analyses of ~200 samples available on AVO Spurr page), Smithsonian (3)

Seismic network (~17 stations in AVO network)

Geodetic network (~4 stations)

Background info (from GVP http://volcano.si.edu/volcano.cfm?vn=313040)
The summit of Mount Spurr, the highest volcano of the Aleutian arc, is a large lava dome constructed at the center of a roughly 5-km-wide horseshoe-shaped caldera open to the south. The volcano lies 130 km W of Anchorage and NE of Chakachamna Lake. The caldera was formed by a late-Pleistocene or early Holocene debris avalanche and associated pyroclastic flows that destroyed an ancestral edifice. The debris avalanche traveled more than 25 km SE, and the resulting deposit contains blocks as large as 100 m in diameter. Several ice-carved post-caldera cones or lava domes lie in the center of the caldera. The youngest vent, Crater Peak, formed at the breached southern end of the caldera and has been the source of about 40 identified Holocene tephra layers. Spurr's two historical eruptions, from Crater Peak in 1953 and 1992, deposited ash on the city of Anchorage.

Background Petrology for Spurr
Previous eruptions from Spurr produced porphyritic hornblende-bearing andesite with brown, microlite-rich andesitic groundmass glass. Subordinate light grey-green andesite scoria has clear rhyolitic glass. Rare light-colored pumice composed of nearly microlite-free rhyolitic glass with a few percent of plagioclase phenocrysts and rare quartz grains also occurs. Much of the distal tephra appears to be the same as the proximal bomb material. Despite large variations in groundmass glass composition, the andesite is uniform in major and trace element composition throughout the eruptions. The 1992 andesite differs from 1953 andesite in having similar or lower concentrations of highly incompatible elements at higher SiO_2. 1992 andesite is therefore not a simple fractionate of magma that fed the previous eruption, but represents a new batch of magma. Prehistoric Crater Peak lava flows record the rise of small, chemically unrelated, batches of magma which fed only a few eruptions. *(copied from the AVO's 1992 EOS description of the eruption)*

Eruption History (GVP)

1992 Jun 27	1992 Sep 17	Confirmed	4	Hist. Observations	South flank (Crater Peak)
[~~1954 Jul 2 ± 182 days~~]	[~~Unknown~~]	*Discredited*			
1953 Jul 9	1953 Jul 16	Confirmed	4	Hist.Observations	South flank (Crater Peak)
1650 ± 50 years	Unknown	Confirmed		Tephrochronology	South flank (Crater Peak)
3250 BCE (?)	Unknown	Confirmed		Radiocarbon (uncorrected)	Mt. Spurr central lava/cone complex
4050 BCE (?)	Unknown	Confirmed		Tephrochronology	South flank (Crater Peak)
5110 BCE ± 100 years	Unknown	Confirmed		Radiocarbon (uncorrected)	Mt. Spurr central dome/cone complex
6050 BCE (?)	Unknown	Confirmed		Radiocarbon (uncorrected)	Mt. Spurr central dome/cone complex

Petrology, geochemistry, and age of the Spurr volcanic complex, eastern Aleutian arc

Nye and Turner; Bulletin of Volcanology, January 1990, Volume 52, Issue 3, pp 205–226

The Spurr volcanic complex (SVC) is a calc-alkaline, medium-K, sequence of andesites erupted over the last 250,000 years by the eastern-most currently active volcanic center in the Aleutian arc. The ancestral Mt. Spurr was built mostly of andesites of uniform composition (58%–60% SiO_2), although andesite production was episodically interrupted by the introduction of new batches of more mafic magma. Near the end of the Pleistocene the ancestral Mt. Spurr underwent avalanche caldera formation, resulting in the production of a volcanic debris avalanche with overlying ashflows. Immediately afterward, a large dome (the present Mt. Spurr) formed in the caldera. Both the ash flows and dome are made of acid andesite more silicic (60%–63% SiO_2) than any analyzed lavas from the ancestral Mt. Spurr, yet contain olivine and amphibole xenocrysts derived from more mafic magma. The mafic magma (53%–57% SiO_2) erupted during and after dome emplacement from a separate vent only 3 km away. Hybrid block-and-ash flows and lavas were also produced. The vents for the silicic and mafic lavas are in the center and in the breach of the 5-by-6-km horseshoe-shaped caldera, respectively, and are less than 4 km apart. Late Holocene eruptive activity is restricted to Crater Peak, and magmas continue to be relatively mafic. SVC lavas are plag ±ol+cpx±opx+mt bearing. All post-caldera units contain small amounts of high-Al_2O_3, high-alkali amphibole, and proto-Crater

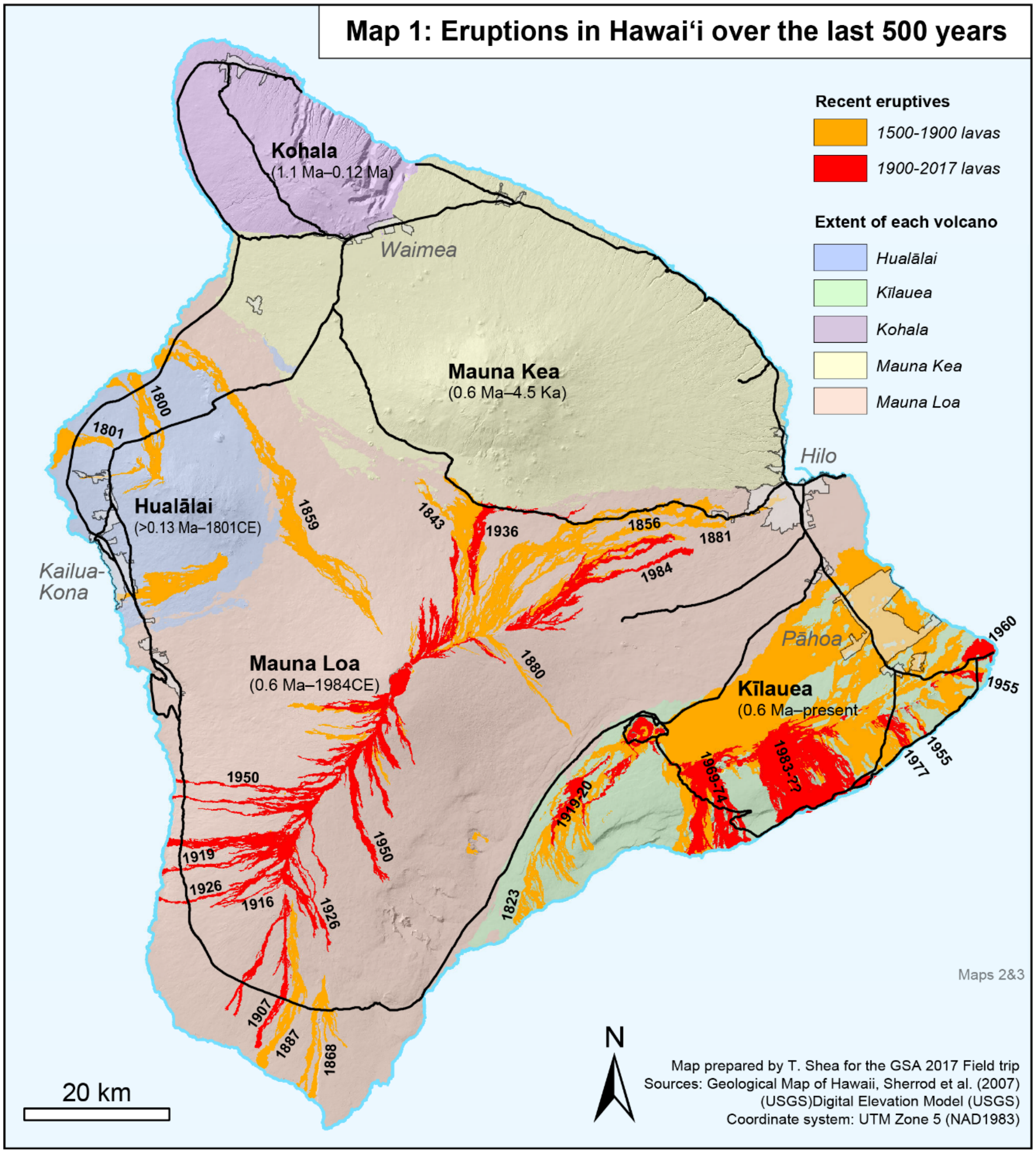
Peak and Crater Peak lavas contain abundant pyroxenite and anorthosite clots presumably derived from an immediately preexisting magma chamber. Ranges of mineral chemistries within individual samples are often nearly as large as ranges of mineral chemistries throughout the SVC suite, suggesting that magma mixing is common. Elevated Sr, Pb, and O isotope ratios and trace-element systematics incompatible with fractional crystallization suggest that a significant amount of continental crust from the upper plate has been assimilated by SVC magmas during their evolution.

Appendix 3. Scenario and information sheet for Mauna Loa

This scenario involved an eruption of Mauna Loa that starts on the summit and moves to the south west rift zone, following extended seismic unrest. This is based on a scenario developed by Bruce Houghton, University of Hawaii for FEMA for emergency management purposes, and is available on request.

Mauna Loa Information Sheet

Overview of the recent volcanic activity on the Island of Hawaii

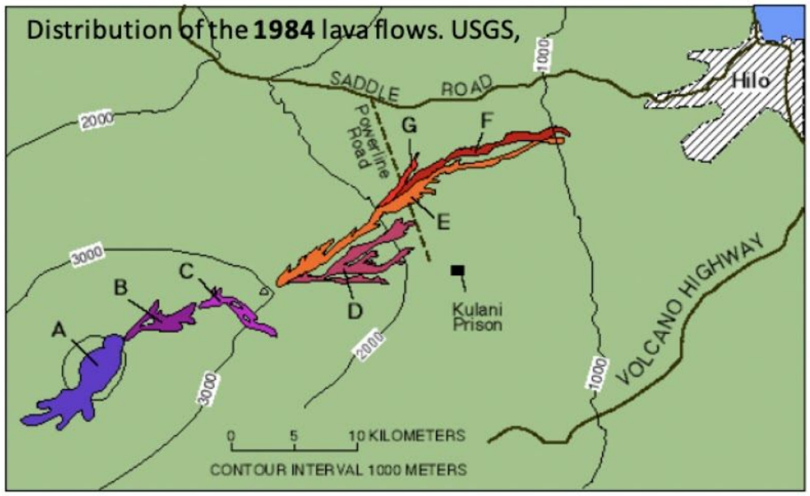


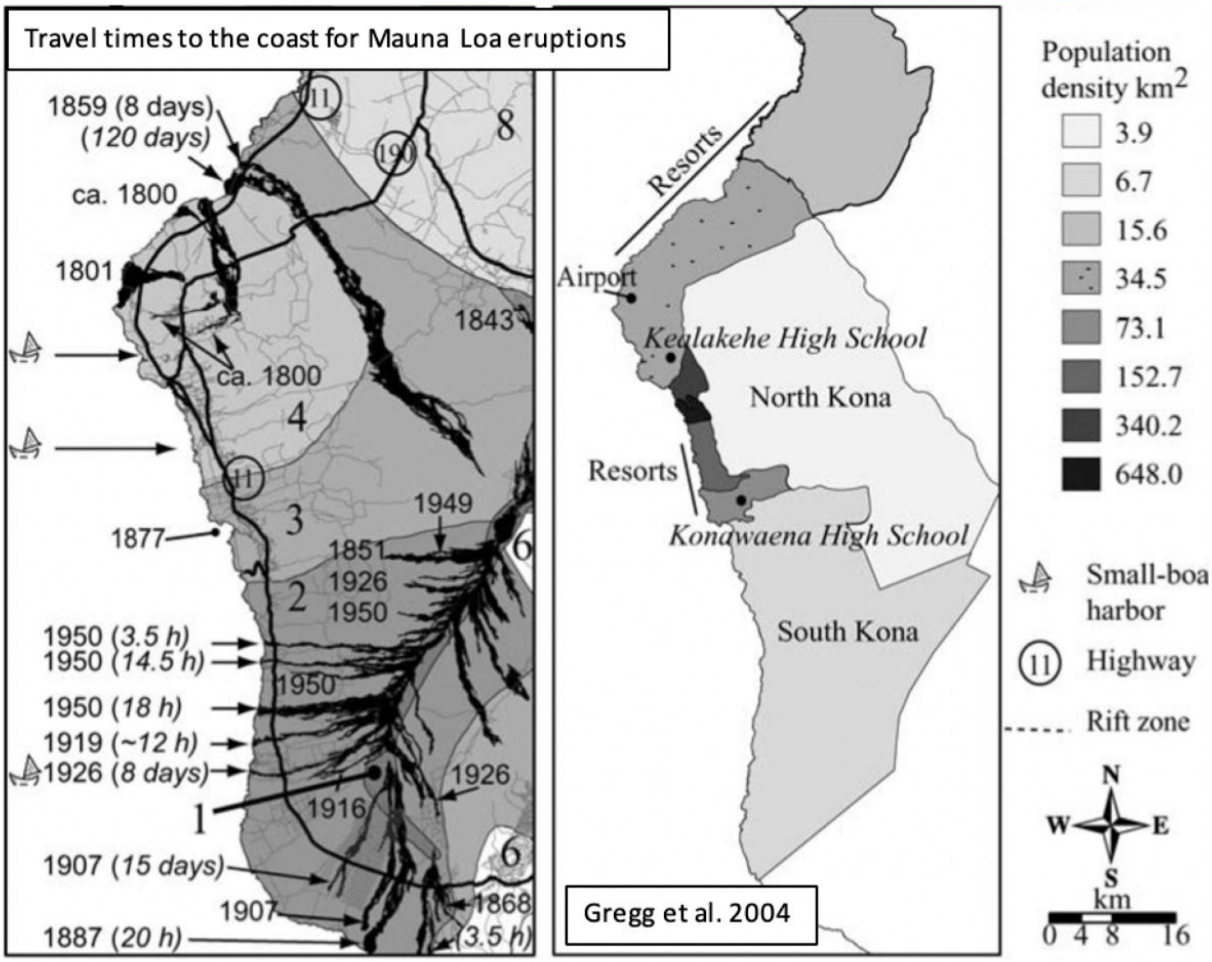
- Southwest side of Hawai`i, erupted 39 times since 1832
- Typical eruption: starts at summit and then can propagate down northeast rift zone, southwest rift zone, or radial vents
- Time for lava to reach the coast:
  - NE rift zone: weeks to months
  - Radial vents: hours to weeks

Two 20th century Mauna Loa eruptions (1950, 1984)

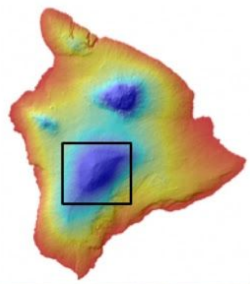
1984: Began at summit caldera, extended into the upper SW rift zone, then to NE rift zone. Lava reached 6.5 km (4 mi) from the outskirts of Hilo

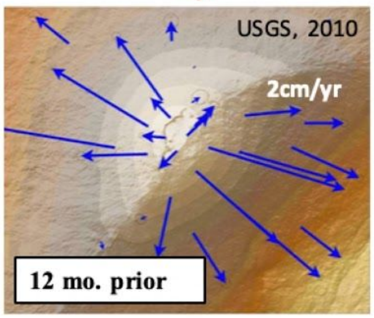
1950: Traveled to the coast in less than 4 hours

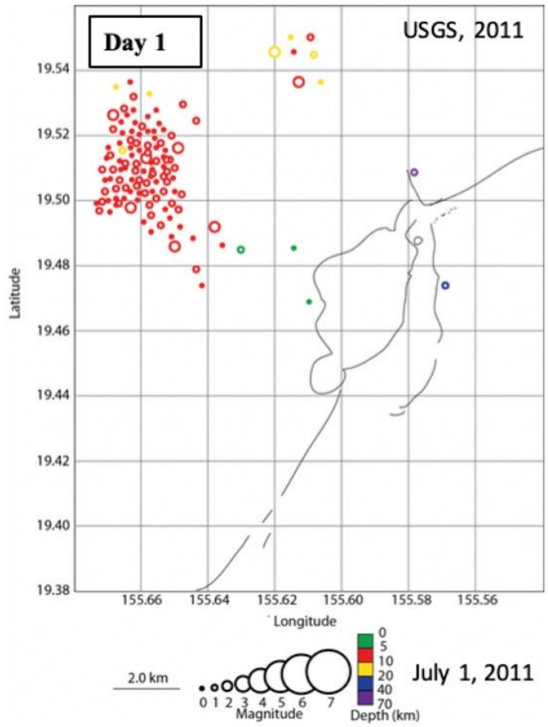


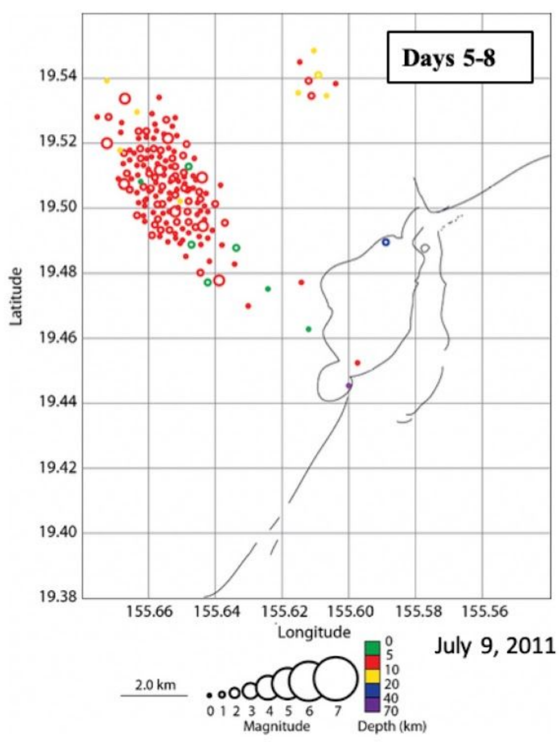


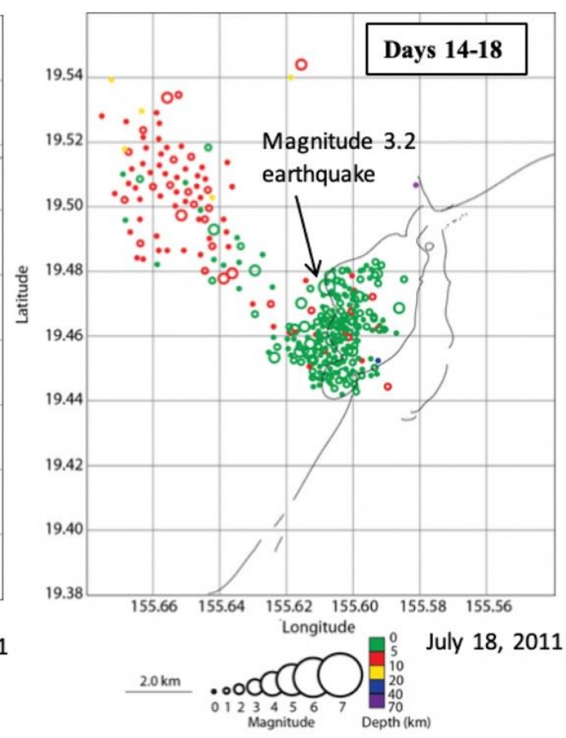
Part 1: Pre-eruption

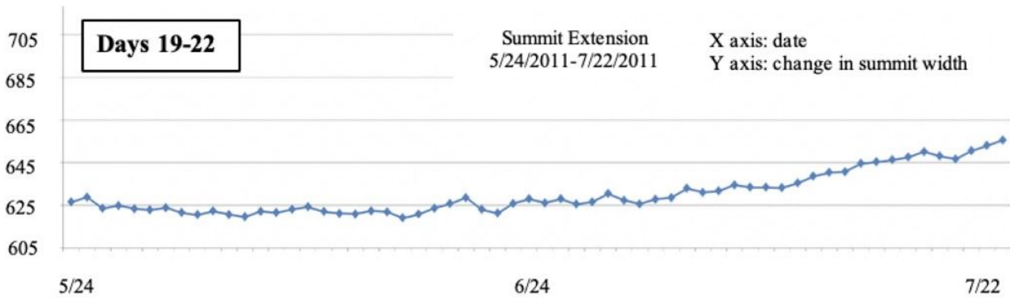


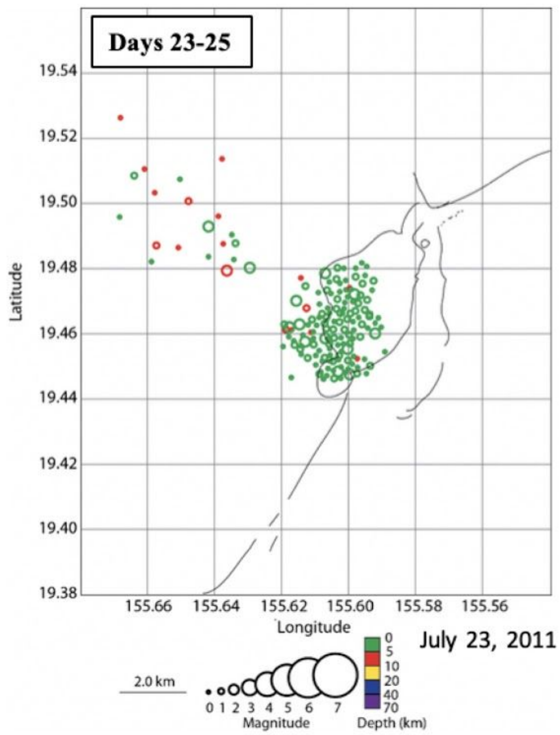


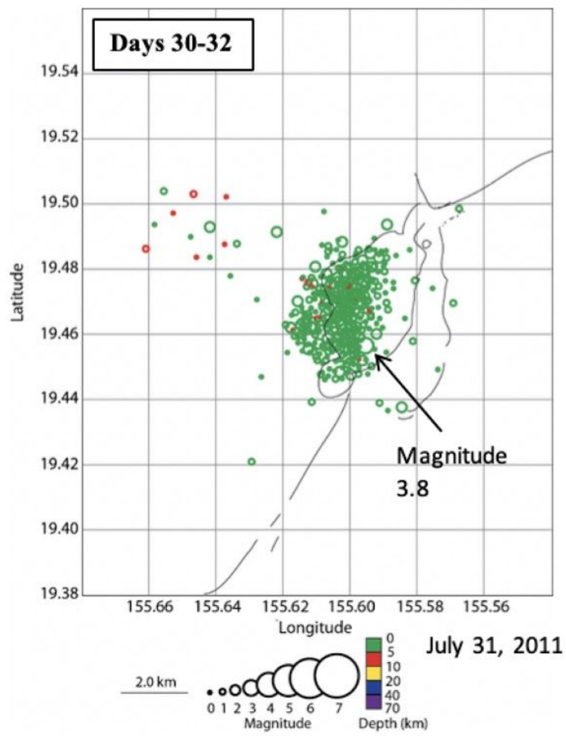


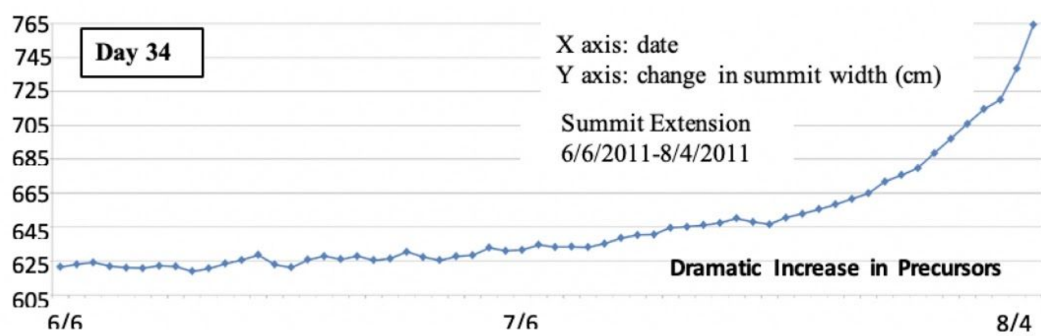




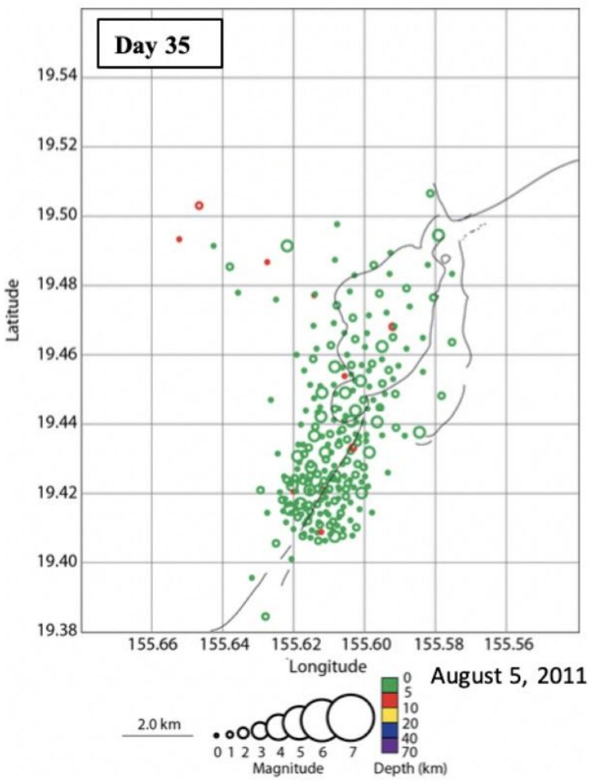

Days 19-22
Summit Extension
5/24/2011-7/22/2011
X axis: date
Y axis: change in summit width
705
685
665
645
625
605
5/24
6/24
7/22

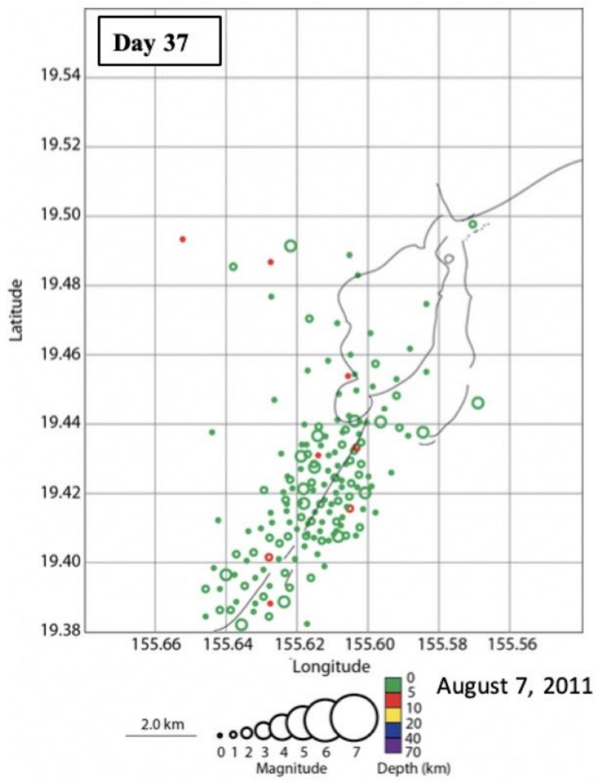

Days 23-25
Latitude
Longitude
July 23, 2011
2.0 km
Magnitude
Depth (km)

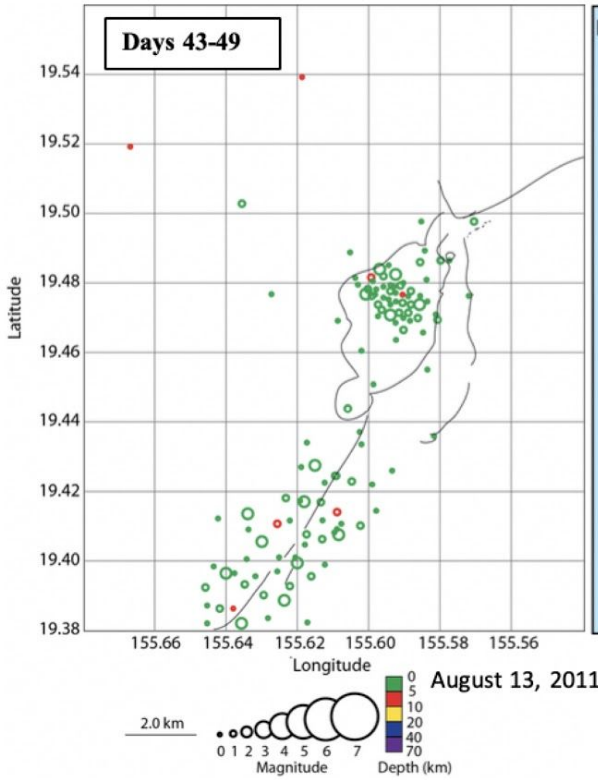

Days 30-32
Magnitude
3.8
Latitude
Longitude
July 31, 2011
2.0 km
Magnitude
Depth (km)

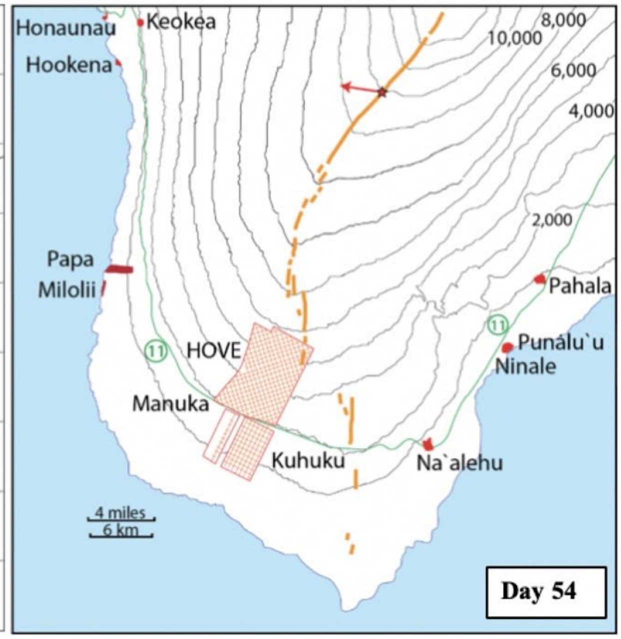

Day 34
X axis: date
Y axis: change in summit width (cm)
Summit Extension
6/6/2011-8/4/2011
Dramatic Increase in Precursors
765
745
725
705
685
665
645
625
605
6/6
7/6
8/4

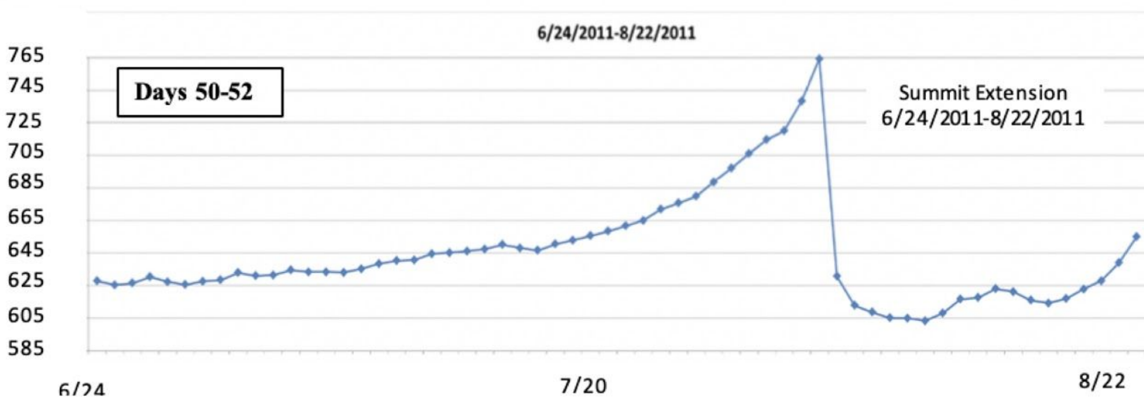
Part 2. Summit Eruption and Transition to a Flank Eruption

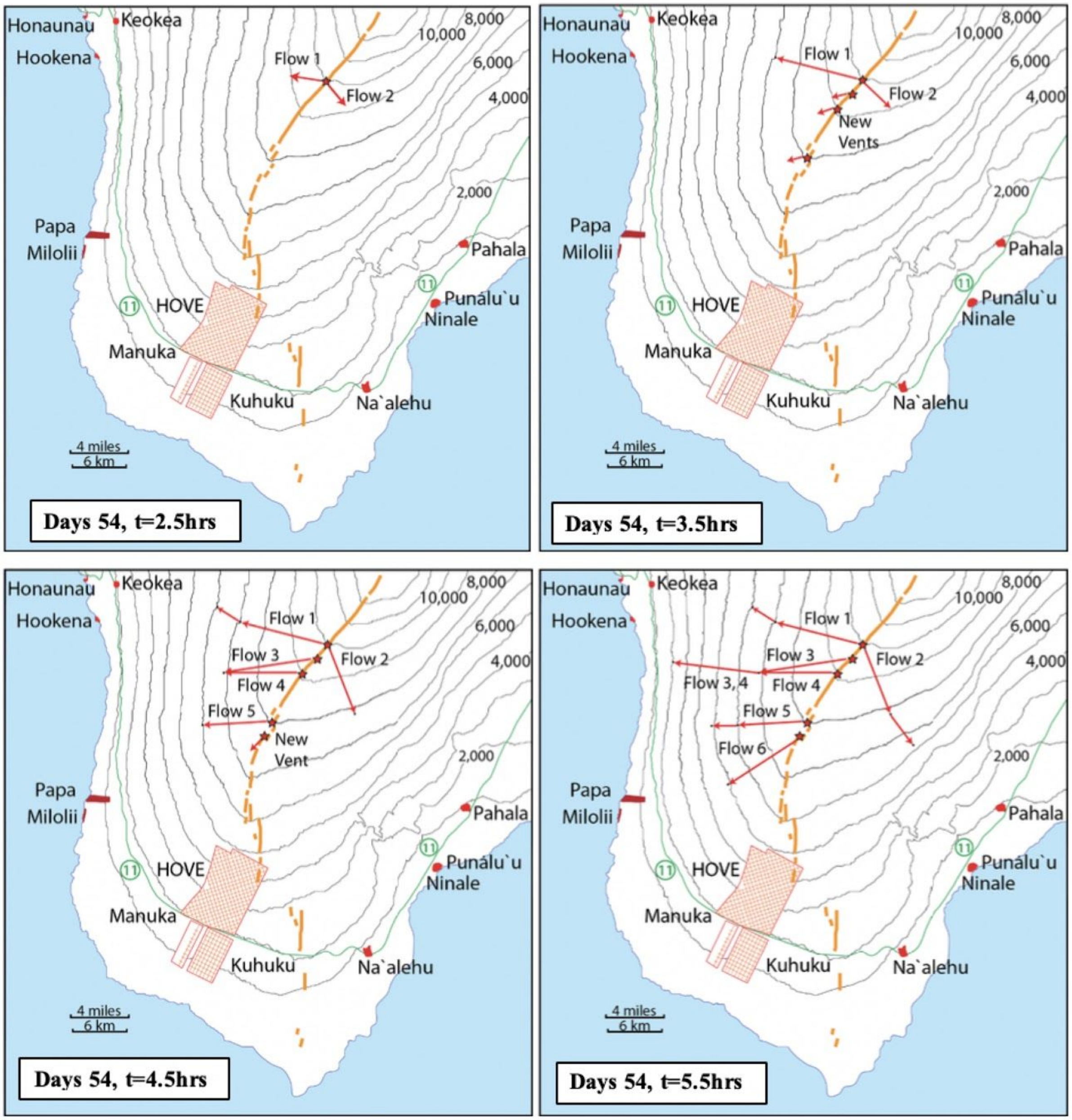


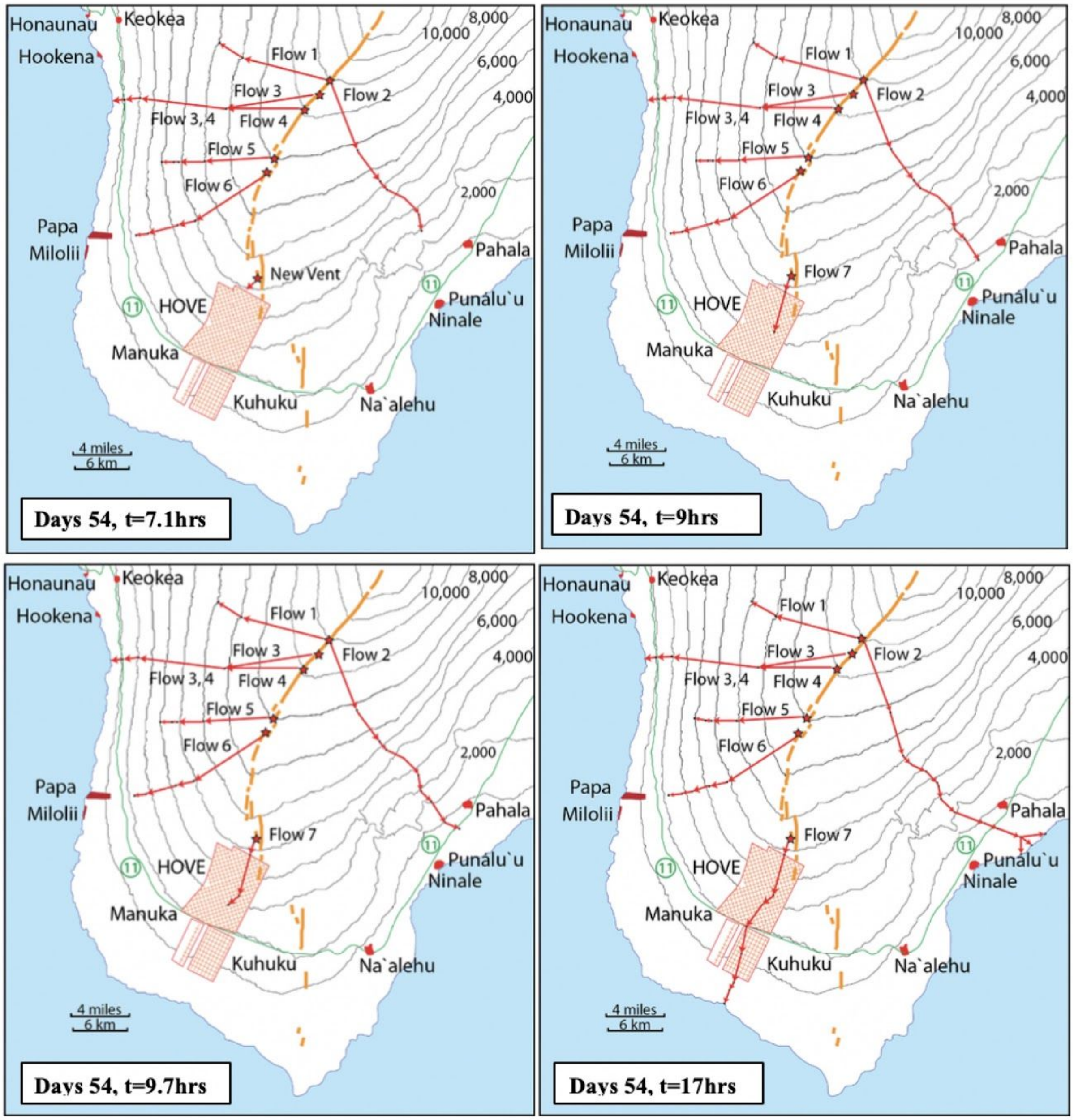



Days 43-49
19.54
19.52
19.50
19.48
19.46
19.44
19.42
19.40
19.38
Latitude
155.66
155.64
155.62
155.60
155.58
155.56
Longitude
2.0 km
0 1 2 3 4 5 6 7
Magnitude
0
5
10
20
40
70
Depth (km)
August 13, 2011


Honaunau
Keokea
Hookena
10,000
8,000
6,000
4,000
2,000
Papa
Milolii
HOVE
Manuka
Kuhuku
Na`alehu
Pahala
Punálu`u
Ninale
11
4 miles
6 km
Day 54


6/24/2011-8/22/2011
Days 50-52
Summit Extension
6/24/2011-8/22/2011
765
745
725
705
685
665
645
625
605
585
6/24
7/20
8/22


Honaunau
Keokea
Hookena
Flow 1
Flow 2
10,000
8,000
6,000
4,000
2,000
Papa
Milolii
Pahala
HOVE
Punálu`u
Ninale
Manuka
Kuhuku
Na`alehu
4 miles
6 km
Days 54, t=2.5hrs
Honaunau
Keokea
Hookena
Flow 1
Flow 2
New
Vents
10,000
8,000
6,000
4,000
2,000
Papa
Milolii
Pahala
HOVE
Punálu`u
Ninale
Manuka
Kuhuku
Na`alehu
4 miles
6 km
Days 54, t=3.5hrs
Honaunau
Keokea
Hookena
Flow 1
Flow 3
Flow 2
Flow 4
Flow 5
New
Vent
10,000
8,000
6,000
4,000
2,000
Papa
Milolii
Pahala
HOVE
Punálu`u
Ninale
Manuka
Kuhuku
Na`alehu
4 miles
6 km
Days 54, t=4.5hrs
Honaunau
Keokea
Hookena
Flow 1
Flow 3
Flow 2
Flow 3, 4
Flow 4
Flow 5
Flow 6
10,000
8,000
6,000
4,000
2,000
Papa
Milolii
Pahala
HOVE
Punálu`u
Ninale
Manuka
Kuhuku
Na`alehu
4 miles
6 km
Days 54, t=5.5hrs

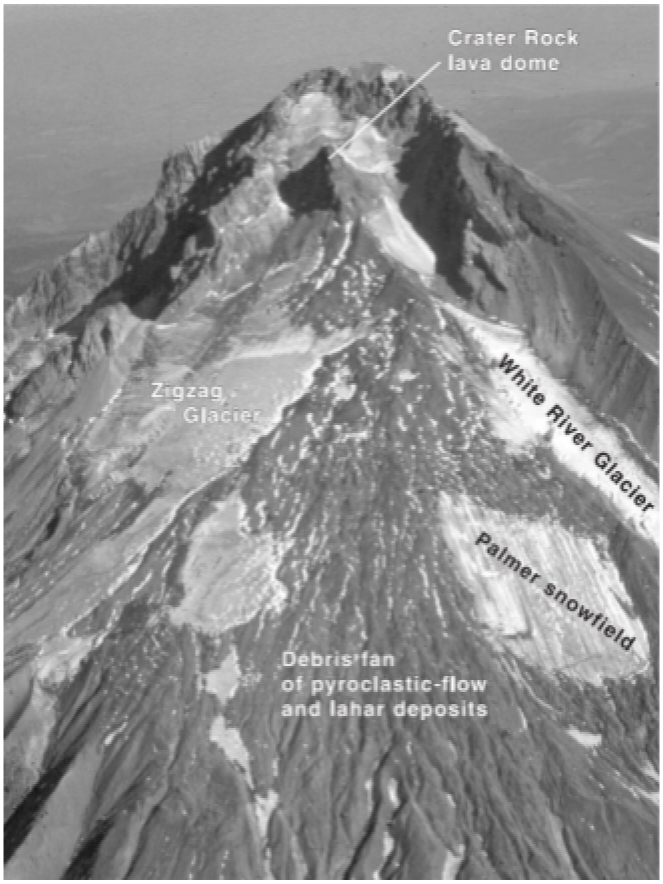

Honaunau
Keokea
Hookena
8,000
10,000
6,000
4,000
2,000
Flow 1
Flow 2
Flow 3
Flow 3, 4
Flow 4
Flow 5
Flow 6
New Vent
Papa
Milolii
Pahala
Punálu`u
Ninale
11
HOVE
Manuka
Kuhuku
Na`alehu
4 miles
6 km
Days 54, t=7.1hrs
Honaunau
Keokea
Hookena
8,000
10,000
6,000
4,000
2,000
Flow 1
Flow 2
Flow 3
Flow 3, 4
Flow 4
Flow 5
Flow 6
Flow 7
Papa
Milolii
Pahala
Punálu`u
Ninale
11
HOVE
Manuka
Kuhuku
Na`alehu
4 miles
6 km
Days 54, t=9hrs
Honaunau
Keokea
Hookena
8,000
10,000
6,000
4,000
2,000
Flow 1
Flow 2
Flow 3
Flow 3, 4
Flow 4
Flow 5
Flow 6
Flow 7
Papa
Milolii
Pahala
Punálu`u
Ninale
11
HOVE
Manuka
Kuhuku
Na`alehu
4 miles
6 km
Days 54, t=9.7hrs
Honaunau
Keokea
Hookena
8,000
10,000
6,000
4,000
2,000
Flow 1
Flow 2
Flow 3
Flow 3, 4
Flow 4
Flow 5
Flow 6
Flow 7
Papa
Milolii
Pahala
Punálu`u
Ninale
11
HOVE
Manuka
Kuhuku
Na`alehu
4 miles
6 km
Days 54, t=17hrs

Appendix 4. Scenario and information sheet for Mount Hood

This scenario is based on an extended dome eruption of Mount Hood. The eruption lasts for over a decade and includes dome extrusion, minor phreatomagmatic explozions, ash production and numerous block and ash flows. This is based on a scenario developed by Bruce Houghton, University of Hawaii for FEMA for emergency management purposes, and is available on request.

Mount Hood Information Sheet

Mount Hood is located ~70 km east of Portland, and 30 km south of the Columbia River. Mount Hood is a stratovolcano that has grown over the last ~500 ka. and consistently erupts crystal-rich andesitic magma, with occasional quenched mafic inclusions and gabbroic inclusions. No known Plinian or sub Plinian eruptions have occurred.



View of Mount Hood from the South, showing Crater Rock - the location of the most recent eruptions, and the broad Timberline surface produced by sector collapse and subsequent dome eruptions.

Recent eruptions include:

1865. Contemporary newspaper reports of summit explosions and night time glow – no known tephra or other geological record.

Old Maid dome eruption (1781 – 1790's). This was centered at Crater Rock on the upper South side of the volcano, starting in 1781 and lasting 10-15 years. The eruption resulted in block and ash flows in the upper portions of the White River and Sandy River watersheds, modest amounts of tephra, and lahars that extended to the Columbia and Deschutes Rivers. Over 50 m of aggradation occurred in the lower Sandy River.

Timberline eruption (~1.5 ka). This major eruptive phase lasted several decades (< 100 years) involved lava dome extrusion at Crater Rock, which triggered a sector collapse and landslide, and lahars down most tributaries, forming the smooth Timberline surface on the south side of the volcano. Continued dome collapse occurred for several decades, with some quiescent periods. This produced numerous block and ask flows, debris flows and lahars, and ~1 m of tephra total near summit.

Parkdale flow (~7000 ka). A small (<< 1km^3) lava flow on the lower north flank. Opinion is divided if it relates to Mount Hood or to regional volcanism.

Polallie phase (15-30 ka). Major period of dome eruptions with associated tephra, debris flows, block and ash flows, and lahars.

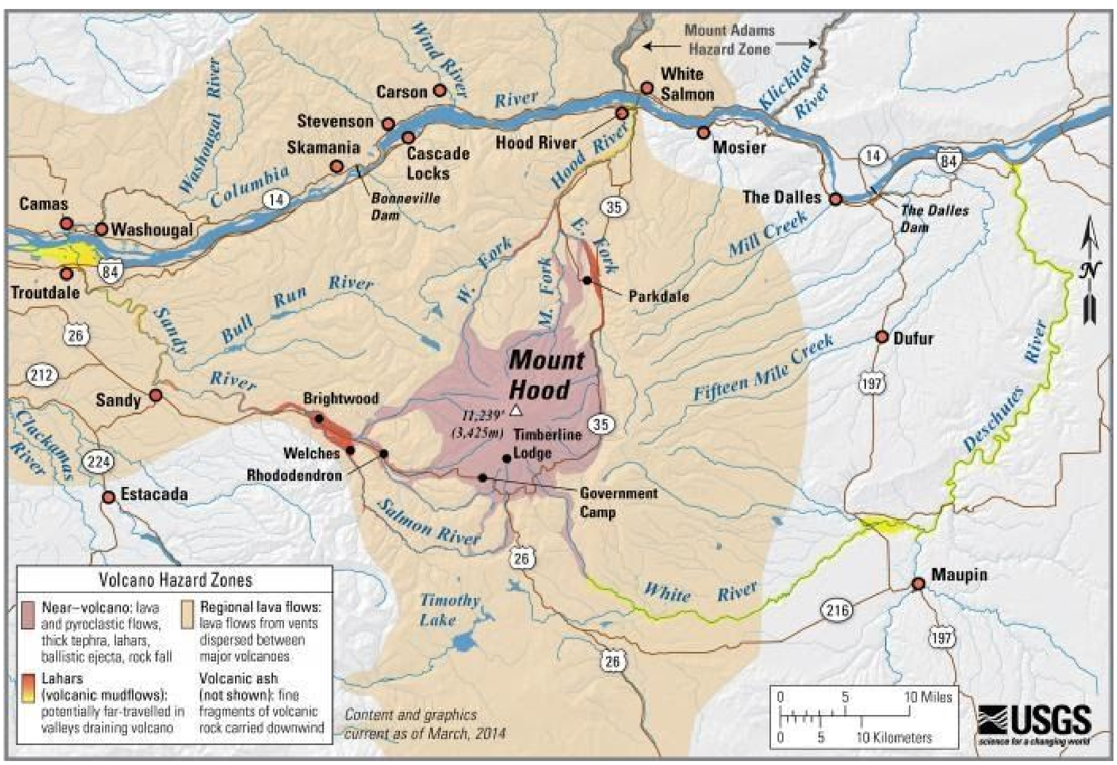
Petrology Summary (Abstract from Kent and Koleszar, 2017, USGS IAVCEI guidebook)

Mount Hood, Oregon, an archetypal subduction zone stratovolcano, is dominated by extrusive eruptions of lava flows and domes, coupled with a high degree of homogeneity in erupted lava compositions. Over the last ~500,000 years— the age of the current edifice—the volcano has repeatedly erupted crystal-rich andesites and low SiO2 dacites, with SiO2 contents largely between 55 and 65 weight percent. Lavas also show similar phenocryst mineralogy, compositions, and textures, and are dominated by plagioclase together with pyroxene, amphibole, and occasional olivine.

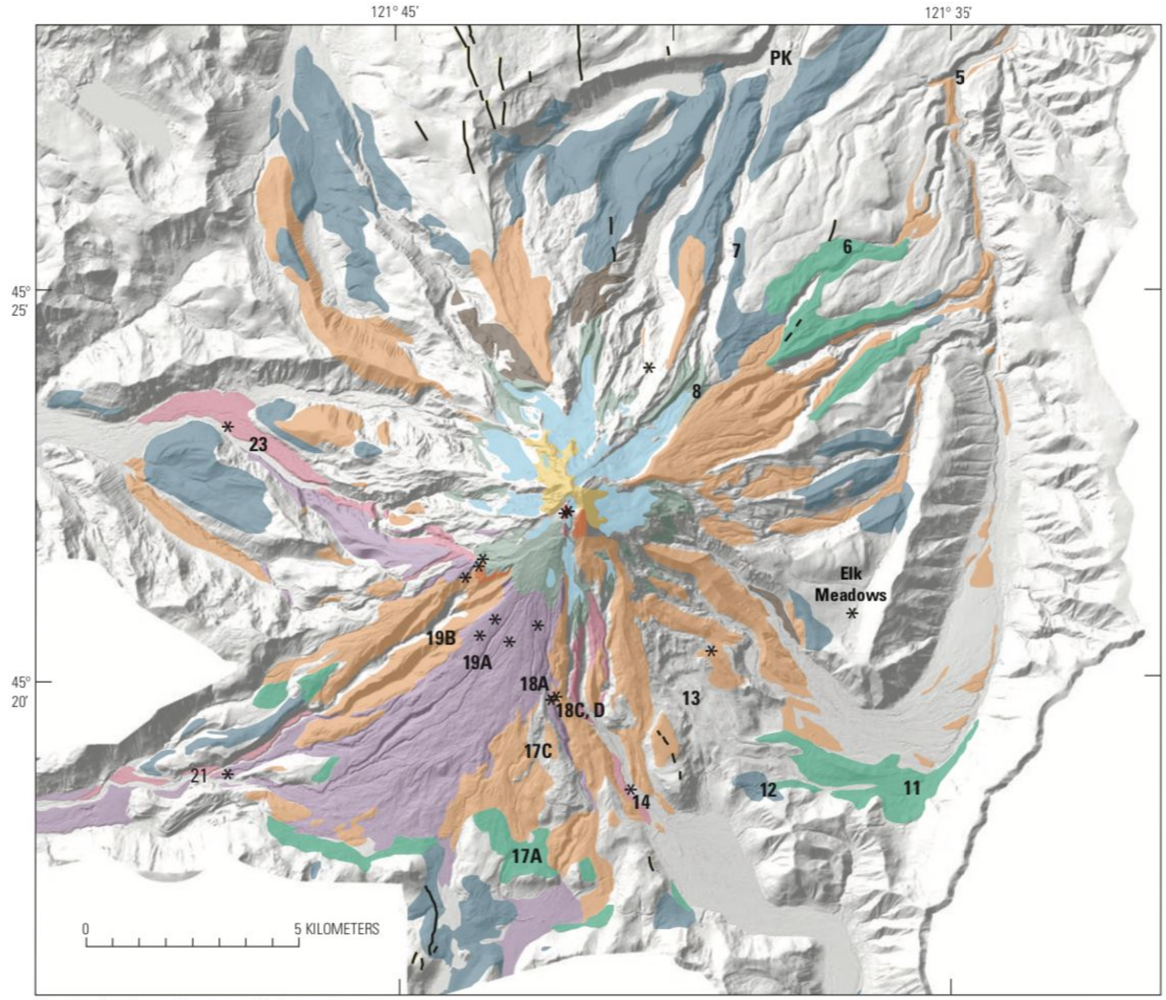
The presence of quenched mafic inclusions, bimodal populations of plagioclase and amphibole, mineral zoning, and a range of other evidence also shows that Mount Hood magmas are produced by quasi-binary mixing between relatively mafic (basaltic) and silicic (rhyodacitic-rhyolitic) parental magmas. Mineral zoning shows that magma mixing occurred very late in the petrogenetic history, within weeks to months of eruption. Mount Hood is a volcanic system driven by mafic recharge, where hot mafic magmas ascending from the mantle or lower crust interact with silicic magmas to produce mixed intermediate compositions. Evidence suggests that the silicic parental magma is stored within the shallow crust (3–6 kilometers) beneath the volcano as cool, crystal- rich mush for long periods (>>10 ka) prior to eruptions. Mafic recharge provides both the impetus to erupt and produces the intermediate compositions, resulting in the long-term eruptive output of a homogeneous series of intermediate magmas.

Hazard Summary

- Near volcano hazards include small explosions and ejecta, ballistics, rock fall, lava flows, debris flows, block and ash flows, outburst floods.
- Distal hazards include debris flows, lahars and ash. Lahars have reached the Columbia and Deschutes River.
- Mount Hood is currently monitored by a relatively minimal 6 seismometer network, with no telemetered GPS or gas. Permits recently issued by the Forest Service will upgrade this significantly.



USGS Mount Hood hazard map, https://volcanoes.usgs.gov/volcanoes/mount_hood/.



Base from 2010 Oregon Department of Geology and Mineral Industries, Oregon Lidar Consortium, Mount Hood lidar data quadrangle series, hillslope-shaded, bare-earth elevation model, 3 ft interval; Badger Lake, Bull Run Lake, Dog River, Government Camp, Mount Hood North, and Mount Hood South quadrangles

EXPLANATION

- **Fragmental deposits and lava dome (dark) of Old Maid age**
- **Fragmental deposits of Timberline age**
- **Debris avalanche and related lahar deposits of Timberline age**
- **Lava dome of Steel Cliff (dark) and fragmental deposits of Polallie age**
- **Lava domes/fragmental deposits of summit; Polallie and pre-Polallie age**
- **Glacial deposits**
  - Till of moraine belts at and near last glacial maximum consists primarily of clasts of lava-flow lithologies
  - Till on south and east flanks rich in andesite and dacite derived from summit lava domes
  - Moraines of late Neoglacial age
  - Present glaciers and perennial snowfields
- **Fault scarp**
- * **Paleomagnetic data**
- **21 Field-trip stop**

Figure 7. Shaded-relief lidar image of Mount Hood volcano showing eruptive products and glacial deposits younger than ~30 ka. Summit units shown in gold color are poorly dated and some could pre-date 30 ka. PK marks vent for 7.7-ka Parkdale lava flow.

Mount Hood Geology map. From Scott and Gardiner, 2017 USGS IAVCEI Guidebook, Scientific Investigations Report 2017-5022- G,
https://doi.org/10.3133/sir20175022G

Appendix 5. Useful LInks and information Sources

From Tephra 2017 workshop: Best practices in tephra collection, analysis, and reporting: Leading toward better tephra databases
https://vhub.org/groups/tephra2017workshop

Info from USGS on ash sampling protocols, ash samping devices & various types of analyses:
https://volcanoes.usgs.gov/volcanic_ash/for_scientists.html

AVO website on sampling of ash
https://volcanoes.usgs.gov/volcanic_ash/collecting_samples.html

List of USGS High Threat Volcanoes (https://doi.org/10.3133/sir20185140)

IAVCEI guidelines on the roles and responsibilities of scientists involved in volcanic hazard evaluation, risk mitigation, and crisis response

https://www.iavceivolcano.org/iavcei-products/iavcei-guidelines/12-iavcei-guidelines-on-the-roles-and-responsibilities-of-scientists-involved-in-volcanic-hazard-evaluation-risk-mitigation-and-crisis-response.html

IAVCEI guidelines for professional interaction during volcanic crises
https://www.iavceivolcano.org/documents/guidelines/newhall3.pdf

Geist & Garcia (2000) The role of science and independent research during volcanic eruptions
https://www.iavceivolcano.org/documents/guidelines/newhall2.pdf

Reply by the IAVCEI subcommittee for crisis protocols
https://www.iavceivolcano.org/documents/guidelines/newhall3.pdf

Bradfield et al. (2005) Review about using scenarios for business strategic planning
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.322.703&rep=rep1&type=pdf

Zhang et al. (2018) Review about scenario based planning for earthquake response
https://ideas.repec.org/a/eee/tefoso/v128y2018icp197-207.html