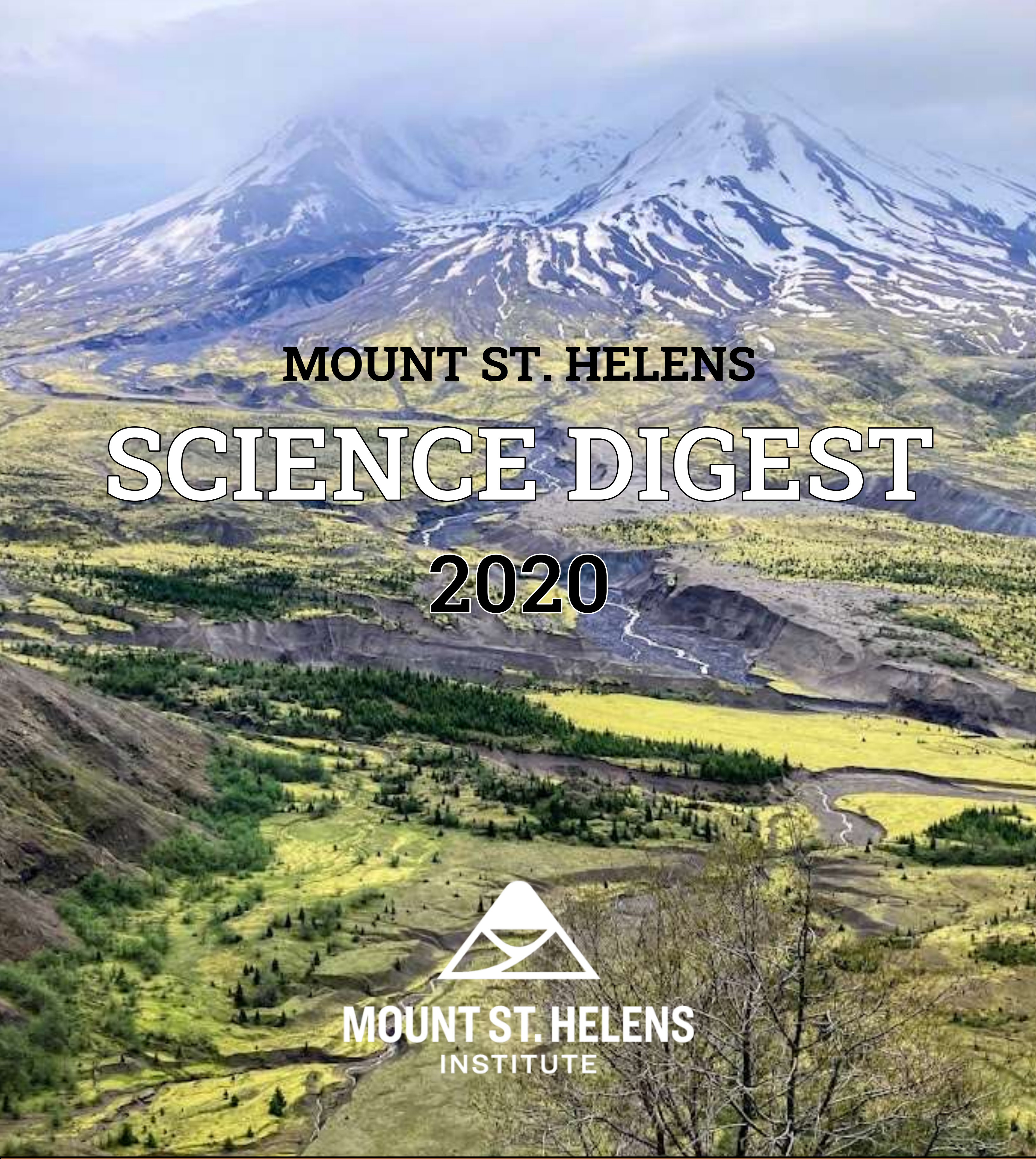
MOUNT ST. HELENS

SCIENCE DIGEST

2020



MOUNT ST. HELENS INSTITUTE

Sharing current and recent scientific and educational activity at Mount St Helens.

Contents

RECENTLY PUBLISHED RESEARCH

Recently Published:

Geochemical and petrological diversity of mafic magmas from Mount St. Helens

Maren Wanke, Michael A. Clynne, Albrecht von Quadt, Torsten, W. Vennemann, Olivier Bachmann

Contributions to Mineralogy and Petrology (2019) 174:10
https://doi.org/10.1007/s00410-018-1544-4

ABSTRACT

Quaternary eruptive products in the Cascade arc include a variety of different basalt types. At Mount St. Helens (MSH), the most active volcano in the Cascades throughout the last 35 ka, three different mafic endmembers erupted at the end of the Castle Creek period (1900–1700 years B.P.): (1) high-field strength element (HFSE)-rich basalt enriched in K, Ti, P, and incompatible trace elements; (2) low-K olivine tholeiite (LKOT) with lower amounts of incompatible trace elements; and (3) calc-alkaline (arc-type) basaltic andesite with a typical subduction signature,

i.e., enrichment in fluid-mobile large ion lithophile elements (LILE) relative to immobile high-field strength elements (HFSE). Each type has compositions projecting backwards to more primitive endmembers in the Cascades. Single units encompassing basaltic-to-basaltic andesitic compositions with intermediate trace-element abundances form two almost continuous trends towards basaltic andesite. These trends are interpreted to result from assimilation of pre-existing, more evolved, calc-alkaline material (and in one case mixing of different mafic magma types) during migration of the magmas through the crust. Most of the erupted basalts are porphyritic (10–30%) with an assemblage dominated by olivine and plagioclase and show disequilibrium textures preventing detailed reconstruction of mantle melting processes. Although typical hydrous arc basalt produced by flux melting in the mantle is absent in the eruptive products of MSH, arc-type basaltic andesite suggests its presence at depth. LKOT magmas are interpreted as decompression melts from the upper mantle, whereas HFSE-rich basalts are likely derived from the water-poor periphery of the main flux melting regime, potentially tapping a trace-element-enriched source. Primitive spinel compositions and whole-rock trace-element variations indicate at least two distinct, relatively fertile lherzolite sources for these two basalt types. Weak crustal zones associated with an old fracture system beneath MSH likely provide conduits for fast and isolated ascent of distinct batches of magma, bypassing the lower crustal mush zone. The eruption of the basalts through the upper crustal magma system and main edifice is consistent with an offset plumbing system suggested by geophysical data.

CONTACT: Maren Wanke, Prof. Olivier Bachmann
Institute of Geochemistry and Petrology, Department of Earth Sciences, ETH Zurich
Clausiusstrasse 25, NW E 83.3, 8092 Zurich, Switzerland
baolivie@ethz.ch, Tel: +41446327816

Recently Published:

The genesis of arc dacites: the case of Mount St. Helens, WA
Maren Wanke, Ozge Karakas, Olivier Bachmann
Contributions to Mineralogy and Petrology (2019) 174:7
Available online: https://doi.org/10.1007/s00410-018-1542-6

ABSTRACT

Throughout the last 35 ka, Mount St. Helens has been the most active volcano in the Cascade arc, but the origin of its voluminous dacites remains controversial. These dacites were traditionally interpreted as a result of melting metabasaltic lower crust. Yet, recent studies have challenged this view and suggested an origin dominated by differentiation of mafic magmas through assimilation-fractional crystallization (AFC) processes. To address this discrepancy on the origin of dacites at Mount St. Helens, we conduct an interdisciplinary study using a combination of thermal and geochemical modeling. Our results show that ~ 45% crystallization of a basaltic andesite parent reproduces the compositions of the dacites with a maximum of ~ 20–30% assimilation of lower crustal lithologies. Amphibole textures and compositions support such a differentiation trend in a polybaric mush system. Combined with recent geophysical imaging and experimental data, we suggest that Mount St. Helens dacites are generated by (1) mantle-derived arc magma evolving by AFC to intermediate compositions in a lower crustal magma reservoir and (2) ascent of these magmas to a mid to upper crustal reservoir, where they reach high crystallinity without significant further chemical differentiation, and are subject to frequent recharge that leave a clear mixing/ mingling overprint.

CONTACT: Maren Wanke, Prof. Olivier Bachmann
Institute of Geochemistry and Petrology, Department of Earth Sciences, ETH Zurich
Clausiusstrasse 25, NW E 83.3, 8092 Zurich, Switzerland
baolivie@ethz.ch, Tel: +41446327816

Recently Published:

Vegetation changes in blown-down and scorched forests 10–26 years after the eruption of Mount St. Helens, Washington, USA

James E. Cook & Charles B. Halpern
Plant Ecology, An International Journal, ISSN 1385-0237, Volume 219, Number 8
Plant Ecol (2018) 219:957-972. DOI 10.1007/s11258-018-0849-8
Available online: https://andrewsforest.oregonstate.edu/publications/5042

ABSTRACT

We examine patterns of vegetative change in blown-down and scorched forests in the blast zone of Mount St. Helens (USA), 10-26 years after the eruption. We compare trends in community attributes in four post-eruption environments, or site types, defined by severity of disturbance, presence/absence of a protective snowpack at the time of eruption, and seral state (previously clearcut vs. mature/old forests). Permanent plots established in 1980 at 16 sites were sampled at 5- to 6-year intervals between 1989 and 2005. Data on species presence and abundance were used to characterize changes in total plant cover, life-form spectra, species diversity, species turnover, and community composition. Due to the magnitude and heterogeneity of disturbance, vegetation re-establishment was gradual and highly variable among sites. Total plant cover averaged 36-70% after 26 years. Early-seral forbs were dominant except in snow-protected sites, where surviving shrubs were most common. Tree regeneration remained sparse after 26 years (<6% cover in all but two sites). Species richness increased in all site types, reflecting greater species gain than loss, although rates of gain declined with time. Species heterogeneity, integrating the number and abundance of taxa, did not increase. Successional trajectories were distinct, but parallel among sites, reflecting legacies of pre-eruption composition, variation in disturbance severity, and differences in composition of early-seral colonists. Slow re-colonization by forest herbs and trees likely reflect seed limitations and abiotic stress rather than competition from early-seral species. Succession following this major eruption is both slow and contingent on pre-conditions, nuances of the disturbance, and species' life histories.

CONTACTS:
jcook@uwsp.edu
chalpern@uw.edu Research Professor Emeritus, School of Environmental and Forest Sciences

Recently Published:

Local source Vp and Vs tomography in the Mount St Helens region with the iMUSH broadband array

Ulberg, C.W., K.C. Creager, S.C. Moran, G.A. Abers, A. Levander, E. Kiser, B. Schmandt, S. Hansen and R. Crosson (2020)
Geochem. Geophys. Geosys., 21, e2019GC00888
Available online: https://doi.org/10.1029/2019GC008888

ABSTRACT

We present new 3-D P wave and S wave velocity models of the upper 20 km of the Mount St. Helens (MSH) region. These were obtained using local-source arrival time tomography from earthquakes and explosions recorded at 70 broadband stations deployed as part of the imaging Magma Under St. Helens (iMUSH) project and augmented by several data sets. Principal features of our models include (1) low P wave and S wave velocities along the St. Helens seismic zone to depths of at least 20 km corresponding to high conductivity imaged by iMUSH magnetotelluric studies. This delineates a zone of weakness that magma can exploit at the location of MSH; (2) a 5- to 7-km diameter, 6–15 km deep, 3–6% negative P wave and S wave velocity anomaly beneath MSH, consistent with previous estimates of the source region for recent eruptions. We interpret this as a magma storage region containing up to 15–20 km3 of partial melt, which is about 5 times more than the largest documented eruption at MSH; (3) a broad region of low P wave velocity below 10-km depth extending between Mount Adams and Mount Rainier along and to the east of the main Cascade arc, which is likely due to high-temperature arc crust and possible presence of fluids or melt; (4) several anomalies associated with surface-mapped features, including high-velocity igneous units such as the Spud Mountain and Spirit Lake plutons and low velocities in the Chehalis sedimentary basin and the Indian Heaven volcanic field. Our results place further constraints on the geometry of these features at depth.

Plain Language Summary

We deployed 70 seismometers around Mount St. Helens volcano from 2014 to 2016, which measured the surface ground motion from hundreds of small earthquakes, as well as from 23 explosions that were set off in 2014. We recorded the onset time of shaking from these sources and used a specialized computer code to model how quickly seismic waves travel through the subsurface. Seismic wave speed can be influenced by several factors, including rock type, presence of magma/fluids, temperature, pressure, and how fractured the rock is. Based on the seismic wave speeds in our model, we make several geological interpretations, including (1) increased fluids or fractures, or presence of sedimentary rocks corresponding to

elevated earthquake activity to the NNW of Mount St. Helens; (2) a magma storage region beneath the volcano similar to results from previous studies. Our model places further constraints on the orientation and size of the region; (3) a large zone of high temperatures and possible fluids or magma related to regional volcanism between and to the east of Mount Adams and Mount Rainier; (4) more detailed size and depth constraints on geological features seen at the surface, including sedimentary basins and rock units related to previous regional volcanism.

CONTACT: C. W. Ulberg: ulbergc@uw.edu
Department of Earth and Space Sciences, University of Washington, Seattle, WA

Recently Published:

SKS Splitting beneath Mount St. Helens: Constraints on Sub-Slab Mantle Entrainment

Eakin, C.M., E.A. Wirth, A. Wallace, C.W. Ulberg, K.C. Creager and G.A. Abers
Geochem. Geophys. Geosys., 20, 4203-4217
https://doi.org/10.1029/2019GC008433

ABSTRACT

Observations of seismic anisotropy can provide direct constraints on the character of mantle flow in subduction zones, critical for our broader understanding of subduction dynamics. Here we present over 750 new SKS splitting measurements in the vicinity of Mount St. Helens in the Cascadia subduction zone using a combination of stations from the iMUSH broadband array and Cascades Volcano Observatory network. This provides the highest density of splitting measurements yet available in Cascadia, acting as a focused “telescope” for seismic anisotropy in the subduction zone. We retrieve spatially consistent splitting parameters (mean fast direction Φ: 74°, mean delay time ∂t: 1.0 s) with the azimuthal occurrence of nulls in agreement with the fast direction of splitting. When averaged across the array, a 90° periodicity in splitting parameters as a function of back azimuth is revealed, which has not been recovered previously with single-station observations. The periodicity is characterized by a sawtooth pattern in Φ with a clearly defined 45° trend. We present new equations that reproduce this behavior based upon known systematic errors when calculating shear wave splitting from data with realistic seismic noise. The corrected results suggest a single layer of anisotropy with an ENE-WSW fast axis parallel to the motion of the subducting Juan de Fuca plate; in agreement with predictions for entrained subslab mantle flow. The splitting pattern is consistent with that seen throughout Cascadia,

suggesting that entrainment of the underlying asthenosphere with the subducting slab is coherent and widespread.

CONTACT: C. M. Eakin, **caroline.eakin@anu.edu.au**
Research School of Earth Sciences, The Australian National University, Canberra, ACT, Australia

Recently Published:

Shear Velocity Structure From Ambient Noise and Teleseismic Surface Wave Tomography in the Cascades Around Mount St. Helens

Crosbie, K.J., G.A. Abers, M.E. Mann, H.A. Janiszewski, K.C. Creager, C. Ulberg, and S. Moran

J. Geophys. Res. – Solid Earth, 124, 8358-8375
https://doi.org/10.1029/2019JB017836

ABSTRACT

Mount St. Helens (MSH) lies in the forearc of the Cascades where conditions should be too cold for volcanism. To better understand thermal conditions and magma pathways beneath MSH, data from a dense broadband array are used to produce high-resolution tomographic images of the crust and upper mantle. Rayleigh-wave phase-velocity maps and three-dimensional images of shear velocity (Vs), generated from ambient noise and earthquake surface waves, show that west of MSH the middle-lower crust is anomalously fast (3.95 ± 0.1 km/s), overlying an anomalously slow uppermost mantle (4.0–4.2 km/s). This combination renders the forearc Moho weak to invisible, with crustal velocity variations being a primary cause; fast crust is necessary to explain the absent Moho. Comparison with predicted rock velocities indicates that the fast crust likely consists of gabbros and basalts of the Siletzia terrane, an accreted oceanic plateau. East of MSH where magmatism is abundant, middle-lower crust Vs is low (3.45–3.6 km/s), consistent with hot and potentially partly molten crust of more intermediate to felsic composition. This crust overlies mantle with more typical wave speeds, producing a strong Moho. The sharp boundary in crust and mantle Vs within a few kilometers of the MSH edifice correlates with a sharp boundary from low heat flow in the forearc to high arc heat flow and demonstrates that the crustal terrane boundary here couples with thermal structure to focus lateral melt transport from the lower crust westward to arc volcanoes.

CONTACTS: Kayla J. Crosbie, Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY, USA
G. A. Abers, Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY, abers@cornell.edu

Recently Published

Imaging subduction beneath Mount St. Helens: implications for slab dehydration and magma transport

Mann, M.E., G.A. Abers K.J. Crosbie, K. Creager, C. Ulberg, S. Moran and S. Rondenay

Geophys. Res. Lett., 46, 3163-3171
https://doi.org/10.1029/2018GL081471

ABSTRACT

Mount St. Helens (MSH) is anomalously 35–50 km trenchward of the main Cascade arc. To elucidate the source of this anomalous forearc volcanism, the teleseismic-scattered wavefield is used to image beneath MSH with a dense broadband seismic array. Two-dimensional migration shows the subducting Juan de Fuca crust to at least 80-km depth, with its surface only 68 ± 2 km deep beneath MSH. Migration and three-dimensional stacking reveal a clear upper-plate Moho east of MSH that disappears west of it. This disappearance is a result of both hydration of the mantle wedge and a westward change in overlying crust. Migration images also show that the subducting plate continues without break along strike. Combined with low temperatures inferred for the mantle wedge, this geometry greatly limits possible source regions for mantle melts that contribute to MSH magmas and requires lateral migration over large distances.

Plain Language Summary

Subducting oceanic plates are heated as they descend into the Earth and release fluids, generating magma that feeds overlying arc volcanoes. As a result, volcanic arcs occur along lines above where the subducting plates reach a characteristic depth, typically 100 km beneath them. The location of Mount St. Helens (MSH) volcano 35–50 km in front of the main arc of volcanoes in Cascadia is puzzling and an anomaly globally. We provide the first clear image of the subducting oceanic plate beneath MSH and find it to be 68 ± 2 km deep, making this the shallowest directly imaged subducting plate beneath an arc volcano anywhere. This suggests an unusual magma pathway. The base of the North American crust, or Moho, disappears immediately to the west of MSH, indicating a close relationship between volcano location and geological processes. The geometry creates a problem in that mantle temperatures should be too low to generate magma in the mantle beneath MSH, yet the volcano occasionally erupts magmas generated in the mantle. These observations provide some of the best evidence anywhere for lateral as well as vertical transport of magma from the mantle to volcanic arcs.

CONTACT: M. E. Mann
Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY
mem533@cornell.edu

Recently Published:

Magma reservoirs from the upper crust to the Moho inferred from high-resolution Vp and Vs models beneath Mount St. Helens, Washington State, USA

Kiser, E., I Palomeras, A. Levander, C. Zelt, S. Harder, B. Schmandt, S. Hansen, K. C. Creager, C. Ulberg, 2016

Geology, 44, 411-414. https://doi.org/10.1130/G37591.1

ABSTRACT

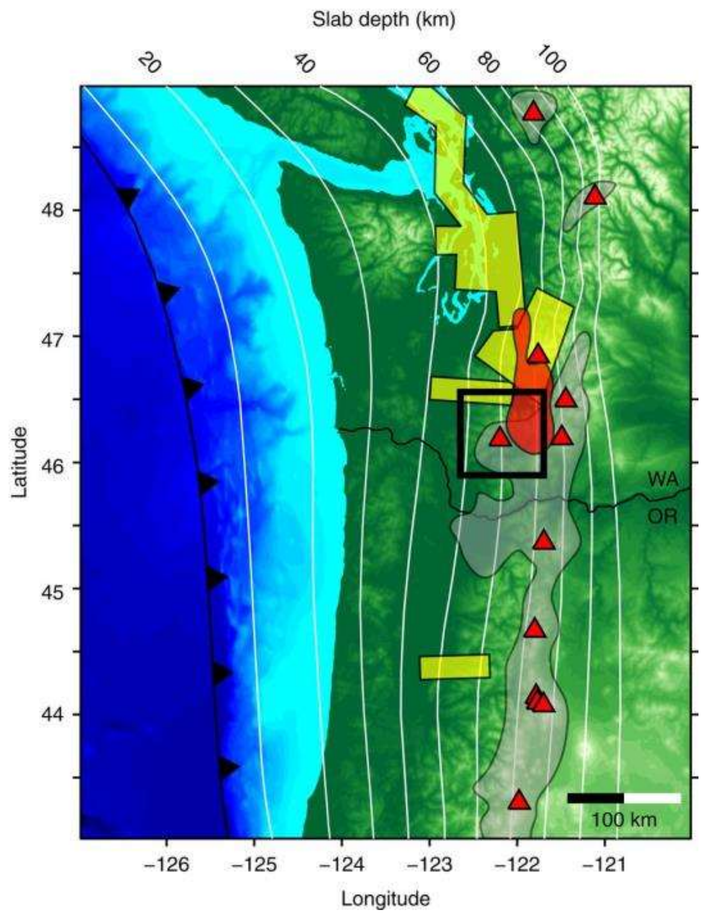
The size, frequency, and intensity of volcanic eruptions are strongly controlled by the volume and connectivity of magma within the crust. Several geophysical and geochemical studies have produced a comprehensive model of the magmatic system to depths near 7 km beneath Mount St. Helens (Washington State, USA), currently the most active volcano in the Cascade Range. Data limitations have precluded imaging below this depth to observe the entire primary shallow magma reservoir, as well as its connection to deeper zones of magma accumulation in the crust. The inversion of P and S wave traveltime data collected during the active-source component of the iMUSH (Imaging Magma Under St. Helens) project reveals a high P-wave (Vp)/S-wave (Vs) velocity anomaly beneath Mount St. Helens between depths of 4 and 13 km, which we interpret as the primary upper–middle crustal magma reservoir. Beneath and southeast of this shallow reservoir, a low Vp velocity column extends from 15 km depth to the Moho. Deep long-period events near the boundary of this column indicate that this anomaly is associated with the injection of magmatic fluids. Southeast of Mount St. Helens, an upper–middle crustal high Vp/Vs body beneath the Indian Heaven Volcanic Field may also have a magmatic origin. Both of these high Vp/Vs bodies are at the boundaries of the low Vp middle–lower crustal column and both are directly above high Vp middle–lower crustal regions that may represent cumulates associated with recent Quaternary or Paleogene–Neogene Cascade magmatism. Seismicity immediately following the 18 May 1980 eruption terminates near the top of the inferred middle–lower crustal cumulates and directly adjacent to the inferred middle–lower crustal magma reservoir. These spatial relationships suggest that the boundaries of these high-density cumulates play an important role in both vertical and lateral transport of magma through the crust.

CONTACT: Eric Kiser, Department of Earth Science, Rice University, 6100 Main Street, MS-126, Houston, Texas 77005, USA

Recently Published

Seismic evidence for a cold serpentinized mantle wedge beneath Mount St Helens
Hansen, S.M., B. Schmandt, A. Levander, E. Kiser, J. E. Vidale, G.A. Abers, K. C. Creager
2016, Nature Communications, 7, 13242 doi: 2016, 10.1038/ncomms13242.
https://www.nature.com/articles/ncomms13242

ABSTRACT



Mount St Helens is the most active volcano within the Cascade arc; however, its location is unusual because it lies 50 km west of the main axis of arc volcanism. Subduction zone thermal models indicate that the down-going slab is decoupled from the overriding mantle wedge beneath the forearc, resulting in a cold mantle wedge that is unlikely to generate melt. Consequently, the forearc location of Mount St Helens raises questions regarding the extent of the cold mantle wedge and the source region of melts that are responsible for volcanism. Here using, high-resolution active-source seismic data, we show that Mount St Helens sits atop a sharp lateral boundary in Moho reflectivity. Weak-to-absent PmP reflections to the west are attributed to serpentinite in the mantle-wedge, which requires a cold hydrated mantle wedge beneath Mount St Helens (<~700 °C). These results suggest that the melt source region lies east towards Mount Adams.

CONTACT: S. M. Hansen, Department of Earth and Planetary Sciences, MSCO3-2040, 1 University of New Mexico, Albuquerque, 87131-0001, New Mexico

Recently Published

Crustal inheritance and a top-down control on arc magmatism at Mount St Helens

Bedrosian, P. A., J. R. Peacock, E. Bowles-Martinez, A. Schultz and G. J. Hill, 2018, Nature GeoScience, 11, doi: 10.1038/s41561-018-0217-2, 865-870.
https://www.nature.com/articles/s41561-018-0217-2

ABSTRACT

In a subduction zone, the volcanic arc marks the location where magma, generated via flux melting in the mantle wedge, migrates through the crust and erupts. While the location of deep magma broadly defines the arc position, here we argue that crustal structures, identified in geophysical data from the Washington Cascades magmatic arc, are equally important in controlling magma ascent and defining the spatial distribution and compositional variability of erupted material. As imaged by a three-dimensional resistivity model, a broad lower-crustal mush zone containing 3–10% interconnected melt underlies this segment of the arc, interpreted to episodically feed upper-crustal magmatic systems and drive eruptions. Mount St Helens is fed by melt channelled around a mid-Tertiary batholith also imaged in the resistivity model and supported by potential–field data. Regionally, volcanism and seismicity are almost exclusive of the batholith, while at Mount St Helens, along its margin, the ascent of viscous felsic melt is enabled by deep-seated metasedimentary rocks. Both the anomalous forearc location and composition of St Helens magmas are products of this zone of localized extension along the batholith margin. This work is a compelling example of inherited structural control on local stress state and magmatism.

CONTACT: Paul A. Bedrosian, United States Geological Survey, Denver, pbedrosian@usgs.gov

Recently Published

Mount St. Helens at 40

Jon J. Major

Science 15 May 2020: Vol. 368, Issue 6492, pp. 704-705

https://science.sciencemag.org/content/368/6492/704

DOI: 10.1126/science.abb4120

SUMMARY

American baseball legend Yogi Berra famously quipped “It ain't over till it's over.” That tautological phrase is apt for volcanology, especially with respect to

eruptions that pummel landscapes with fragmental debris. Indeed, after such eruptions end, some of society's stiffest challenges may have only just begun. This year marks the 40th anniversary of the renowned eruption of Mount St. Helens on 18 May 1980. Its observation accentuates awareness that science and society still confront the costly and potentially lethal sediment and hydrologic hazards that linger from cataclysmic events that transpired within minutes on a sunny Sunday morning. Two key hydrologic and geomorphic (hydrogeomorphic) issues, the lingering hazard posed by a volcanically dammed lake and relentless sediment delivery to distant communities, remain as problematic legacies of the eruption.

CONTACT: Jon J. Major, U.S. Geological Survey, Volcano Hazards Program, jjmajor@usgs.gov

Recently Published:

Lessons from a Post-Eruption Landscape
By Jon J. Major, Charles M. Crisafulli, and Frederick J. Swanson
Eos 24 April 2020
https://eos.org/features/lessons-from-a-post-eruption-landscape

Four decades of research into biophysical responses to the 1980 eruption of Mount St. Helens have vastly improved our understanding of how landscapes react to cataclysmic disturbances.

CONCLUSIONS: As populations living near volcanoes increase, more can be done to impart lessons learned from biophysical research at MSH. We propose five steps for the volcano science community to take that would extend the reach of these lessons:

1. Improve public awareness in communities vulnerable to volcanic hazards of the biophysical responses to eruptions. Scientists can fold discussions of these responses into other volcano hazard awareness efforts, such as workshops and public presentations.
2. Include instruction about biophysical impacts and responses to eruptions in academic courses focused on natural hazards to pass on the knowledge gained to future generations of students and scientists.
3. Include post-eruption sedimentation hazards in volcano hazards assessments to more accurately portray the full range and duration of hazards associated with volcanism.

4. Develop an international volcano ecology and hydrology network—either informally or formally through scientific societies—to connect ecologists, hydrologists, and geomorphologists; facilitate information sharing; and identify key issues that arise in post-eruption landscapes.
5. Foster collaborations among hydrologists, geomorphologists, and ecologists who can consult with local volcano observatories and provide training for local science agencies, civil authorities, and emergency managers. Training could address what to anticipate in the immediate and long-term aftermath of future eruptions, appropriate hazard assessment methods, possible options and approaches to mitigating posteruptive hydrogeomorphic hazards, and advice for restoring ecosystems to desired states. The U.S. Geological Survey's Volcano Disaster Assistance Program [*Lowenstern and Ramsey,* 2017], which is funded by the U.S. Agency for International Development, is one example of such a team; international scientific societies could facilitate others.

Following these steps can further advance the rich scientific understanding of the myriad and dynamic processes that occur in post-eruption landscapes, which studies at Mount St. Helens since 1980 have sharpened, and could help reveal how this understanding can best be applied for the benefit of public safety and the environment.

CONTACT: Jon J. Major, U.S. Geological Survey, Volcano Hazards Program, jjmajor@usgs.gov

Recently Published

Disentangling herbivore impacts in primary succession by refocusing the plant stress and vigor hypotheses on phenology

Christian Che-Castaldo, Charlie M. Crisafulli John G. Bishop Elise F. Zipkin William F. Fagan

First published:24 July 2019 https://doi.org/10.1002/ecm.1389

ABSTRACT

The plant stress and plant vigor hypotheses are widely used to explain the distribution and abundance of insect herbivores across their host plants. These hypotheses are the subject of contentious debate within the plant herbivore research community, with several studies finding simultaneous support for both hypotheses for the same plant–herbivore interaction. We address the question of how such support is possible using dynamic site-occupancy models to quantify

the attack dynamics of Cryptorhynchus lapathi (poplar-willow weevil) on Salix sitchensis (Sitka willow), a dioecious shrub colonizing Mount St. Helens, Washington, USA after the 1980 eruption, in relation to host plant stress, vigor, and sex. We also introduce several scaling criteria as a rigorous test of the plant vigor hypothesis and demonstrate why modeling insect detection is important in plant–insect studies. Weevils responded positively to water stress associated with seasonal dry-downs, and this response was phenologically compartmentalized by larval feeding mode. Weevils preferentially attacked large and/or flowering stems, imposing an ecological cost on willow reproduction via increased stem mortality and susceptibility to future attack. We propose that the dual response to host plant stress and vigor is due to the synchronization between young weevil larval feeding and willow nutrient pulses that are mediated by environmental stress. In turn, this process drives successional dynamics, causing the juvenilization of upland willow plants and possibly delaying establishment of a willow-dominated upland sere. These results highlight the common, but often overlooked, phenological basis of the plant stress and plant vigor hypotheses, which both focus on how stress changes the quality of plant resources available to immature insects.

CONTACT: Christian Che-Castaldo, Department of Biology, University of Maryland, College Park, Maryland, chrischecastaldo@icloud.com

Recently Published:

A Multidecade Analysis of Fluvial Geomorphic Evolution of the Spirit Lake Blockage, Mount St. Helens, Washington
Major, J.J., Grant, G.E., Sweeney, K.R., Mosbrucker, A.R., 2020,
U.S. Geological Survey Scientific Investigations Report 2020-5027.
https://pubs.er.usgs.gov/publication/sir20205027

Volcanic eruptions can affect landscapes in many ways and consequently alter erosion and the fluxes of water and sediment. Hydrologic and geomorphic responses to volcanic disturbances are varied in both space and time, and, in some instances, can persist for decades to centuries. Understanding the broad context of how landscapes respond to eruptions can help inform how they may evolve, and therefore provides context for managing and mitigating hazards associated with future volcanic and hydrologic events. Here, we assess the geomorphic evolution of the upper North Fork Toutle River valley, the valley most heavily affected by the Mount St. Helens May 18 and later 1980s eruptions. By doing so, we provide context for the landscape changes caused by the eruptions as they relate to potential hydrological hazards associated with Spirit Lake, an iconic landform at the northern foot of the volcano. The Spirit Lake basin was transformed by the cataclysmic 1980 eruption and had its outlet blocked. The analyses presented provide context for considerations of potential outlets for Spirit Lake, a landform which might be viewed as a "sleeping giant" on this landscape: a giant capable of causing catastrophic downstream consequences if water is released uncontrollably from the lake.

Contact: Jon J. Major, U.S. Geological Survey, Volcano Hazards Program, jjmajor@usgs.gov

Recently Published:

Recovering Analog-Tape Seismograms from the 1980 Mount St. Helens Pre-Eruption Period
Malone, S. D. (2020).
Seismol. Res. Lett. XX, 1–11, doi: 10.1785/ 0220190327) in Seismological Research Letters

ABSTRACT

Mount St. Helens in Washington State erupted violently (Volcano Explosivity Index = 5) on 18 May 1980. During the previous two months, intense seismic activity at the volcano was recorded by a combination of continuous analog-tape recordings, paper drum recordings, and a recently installed triggered digital event computer system. Because of the technological constraints of the time, the digital data available cover only a little more than 1% of the two-month period. The paper drum records only exist for a few of the seismic stations and are also quite incomplete. However, the analog-tape data from some stations is near complete for almost the whole two months. During the period 2005–2014, these old analog tapes were recovered from storage and digitized to generate standard digital data for archiving at the Incorporated Research Institutions for Seismology Data Management Center. This recovery process was long and complicated but, for the most part, was fairly successful. Although the quality of these recovered data is nowhere near as good as modern digital seismograms, this dataset does provide a near-continuous record of the significant seismic sequence that led up to the major volcanic eruption. It includes the large variety of seismic signals from different types of volcanic earthquakes and harmonic tremor and should be a valuable resource for those studying volcanic seismicity.

CONTACT: Steve Malone, Professor Emeritus, Department of Earth & Space Sciences, University of Washington, smalone@uw.edu

Recently Published:

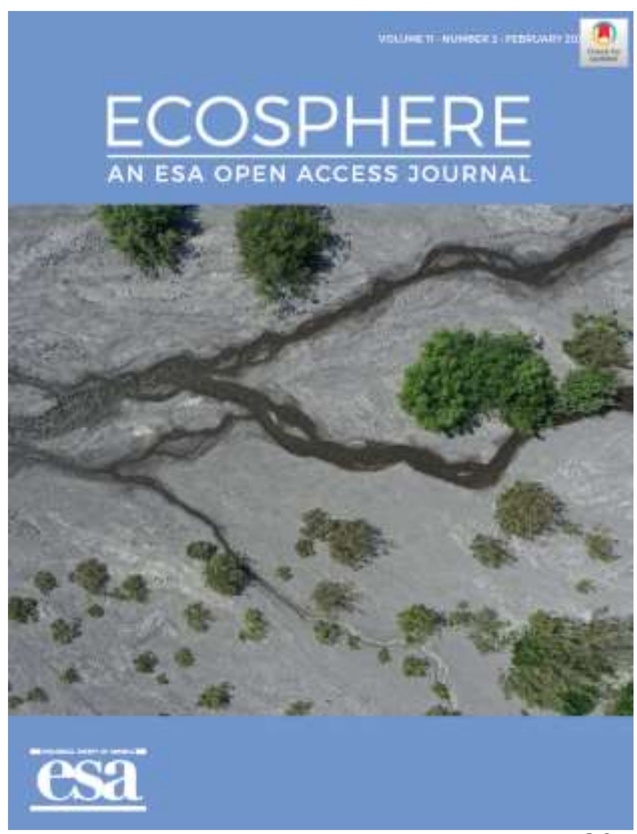
Plant Sex Influences Aquatic-Terrestrial Interactions

Carri J. LeRoy, Joy M. Ramstack Hobbs ,Shannon M. Claeson, Jordan Moffett, Iris Garthwaite Nichole Criss, Lauren Walker

Ecosphere (January 7, 2020):
https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecs2.2994

ABSTRACT

A growing body of research shows that plant genetic factors can influence ecosystem processes and structure communities, but one aspect that has received little study is sex differentiation in dioecious plants. Since headwater streams are reliant on riparian leaf litterfall, plant sex differences in leaf traits may influence in-stream processes. Sitka willow (Salix sitchensis) at Mount St. Helens is dioecious and heavily infested with the stem-boring weevil (Cryptorhynchus lapathi), which causes branch dieback and summer litterfall. We found that female willow shrubs tend to grow closer to the stream bank, are more likely to be infected by the weevil, and have 42% higher litter C:N than male willows. These factors may lead to increased litter inputs and slower litter mass loss for female willows. The combination of colonization location, herbivore attack, altered litter quality, and slower mass loss results in female shrubs providing more sustained carbon and nutrient resources to microbes and invertebrates in the early successional streams at Mount St. Helens. In addition, since dioecy is a relatively common trait in riparian habitats, it is possible that plant sex plays a far more interesting role in structuring linked terrestrial–aquatic communities and ecosystem processes than previously understood.



COVER PHOTO: The Pumice Plain of Mount St. Helens (Washington, USA) was created in the 1980 eruption and

massive lateral landslide. After the deposition of tens of meters of pumice, tephra, and ash, new watersheds have begun to form. LeRoy et al. show that in populations of Sitka willow (*Salix sitchensis*), an early riparian colonist, female willows are colonizing closer to stream edges than males. This influences organic matter inputs and the authors found that plant sex influences litter processing rates and alters in-stream early successional communities. Photo Credit: Carri J. LeRoy (Hasselblad L1D-20c camera on Mavic 2 Pro drone).
Associated news articles,

1) Longview Daily News (May 14, 2020): https://tdn.com/news/local/sex-and-the-volcano-researcher-learns-nature-favors-females-in-new-creeks/article_58b3a359-b75b-575d-aa92-7410c969e9ec.html;
2) A photo diary: https://tdn.com/mount_st_helens/photos-a-day-near-the-water-with-ecologist-carri-leroy/collection_e0a387a8-d938-5e8a-8fa9-03f670f3266d.html#1
3) ThurstonTalk: https://www.thurstontalk.com/2020/05/22/evergreen-students-contribute-to-groundbreaking-mount-st-helens-stream-research/

CONTACT: Carri J. LeRoy LeRoyC@evergreen.edu The Evergreen State College
2700 Evergreen Parkway NW, Olympia, WA 98505

Recently Published:

Geologic field-trip guide of volcaniclastic sediments from snow- and ice-capped volcanoes—Mount St. Helens, Washington, and Mount Hood, Oregon
Pierson, T.C., Siebert, L., Harpel, C.J., and Scott, K.M., 2018
U.S. Geological Survey Scientific Investigations Report 2017–5022–F
https://doi.org/10.3133/sir20175022F.

This field guide for the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) Scientific Assembly 2017 focuses on volcaniclastic sediments from Mount St. Helens in Washington and Mount Hood in Oregon. The trip spends four days in the field and includes nine stops at each volcano. For completeness, this guidebook also includes sixteen optional stops in the Mount St. Helens area and three in the Mount Hood area. These two volcanoes provide excellent depositional records of the broad spectrum of volcanic hazards that involve the flow or fall of volcaniclastic particles. At the field-trip stops we will contrast and compare the different types of deposits—sediments that can be frustratingly difficult to distinguish from one another. Correct identification of deposit origin leads to a better understanding of hazards that can impact vulnerable communities at particular volcanoes.

During this four-day field trip, we will spend two days in the Mount St. Helens area and two days near Mount Hood. On the first day, we will visit debris-avalanche and lahar deposits in the Toutle River valley in Washington. The second day will focus on pyroclastic density current, pyroclastic-fall, lahar, and volcano-fluvial deposits in the Lewis River drainage system near Mount St. Helens. On the third day, we will visit hyaloclastites, glacial tills, and other diamicts in the Hood River and Sandy River basins near Mount Hood. The fourth and final day will focus on distal lahar and volcano-fluvial deposits downstream of Mount Hood.

What follows is an in-depth introduction to the deposits studied on this field trip. We provide criteria that are observable in the field to aid in differentiating between pyroclastic density current, pyroclastic-fall, debris-avalanche, lahar, water-flood, and glacial deposits. We also introduce the Holocene eruptive histories of Mount St. Helens and Mount Hood and discuss the processes responsible for deposit emplacement. Field-trip stops and features of interest along the route are described in detail in a road log that provides daily cumulative mileage.

CONTACT: David A. Johnston Cascades Volcano Observatory, U.S. Geological Survey
1300 SE Cardinal Court, Building 10, Suite 100, Vancouver, Washington, 98683-9589

Recently Published:

A re-examination of the three most prominent Holocene tephra deposits in western Canada: Bridge River, Mount St. Helens Yn and Mazama

Britta J. L. Jensen, Alwynne B. Beaudoin, Michael A. Clynne, Jordan Harvey, James W. Vallance

Quaternary International, Volume 500, January 2019, Pages 83-95
https://doi.org/10.1016/j.quaint.2019.03.017

ABSTRACT

Volcanic ash deposits (tephra) in western Canada are instrumental in providing independent chronologic control for many archaeological and paleoenvironmental sites. In Alberta, tephra are a key chronologic tool in a region where radiocarbon dates are often unreliable because of the prevalence of carbonate-rich bedrock and other “old carbon” sources, such as coal. However, many studies using tephra for age control, particularly archaeological projects,

identify tephra simply through field characteristics or light microscopy. In both Alberta and British Columbia, many radiocarbon dates that were used to date key tephra deposits were bulk conventional ages on peat and lake sediments, which are not always reliable. These factors have led to uncertainty in the age and number of Bridge River and Mount St. Helens (MSH) set Y tephra present in the region and incomplete distribution maps. New major-element geochemical analyses from archaeological and sedimentary sites across south-central Alberta, complemented by new analyses of tephra from British Columbia and Saskatchewan, refine the distribution of the Bridge River, MSH Yn and Mazama tephra. New geochemical data, radiocarbon dates, and a detailed overview of proximal MSH set Y stratigraphy and geochemistry show that only one MSH layer, Yn, is present in this region, rather than two MSH set Y tephra as previously suggested. Additionally, re-assessment of age data combined with new geochemical analyses confirm that there is also only one Bridge River tephra. A Bayesian modelled age estimate is determined for MSH Yn based on new AMS dates on the tephra and vetted existing conventional ages, providing a revised age estimate for MSH Yn of 3805–3535 cal BP (mean of 3660 cal BP).

CONTACT: Britta J. L. Jensen, University of Albert, Edmonton, Canada, 3-02 Earth Sciences Building, 11223 Saskatchewan Drive NW, Edmonton AB, T6G 2E3

RECENTLY PRESENTED RESEARCH

Recently Presented:

Preliminary Geothermal Resource Assessment of the St. Helens Seismic Zone Using the Results from the Geothermal Play-Fairway Analysis of Washington State Prospects

Michael W. Swyer, Matthew E. Uddenberg, Trenton T. Cladouhos, Alexander N. Steely, Corina Forson and Nicholas C. Davatzes

https://www.researchgate.net/publication/325793471_Preliminary_Geothermal_Resource_Assessment_of_the_St_Helens_Seismic_Zone_Using_the_Results_from_the_Geothermal_Play-Fairway_Analysis_of_Washington_State_Prospects

ABSTRACT

The northern St. Helens Seismic Zone was one of the areas of interest during Phase 2 of the Washington State Play-Fairway analysis. The area is assessed for geothermal resource potential using the volumetric reserve estimation method developed by the US Geological Survey. Multiple hypotheses for reservoir volume are proposed and analyzed based on interpretation of data gathered during Phase

2 within a geothermal lease. The data utilized in the analysis includes new geologic mapping, ground-based gravity survey, magnetotelluric survey, and passive seismic survey. The hypotheses will be tested, and the resource model will be updated after temperature gradient holes are drilled in the area during Phase 3 at sites selected from Phase 2. The analysis also makes use of the prior geologic knowledge of the area, including the increased seismic and geodetic monitoring following the eruption of Mount St. Helens on May 18th , 1980, existing geologic mapping and models developed from seismic and geodetic data, and past geothermal prospecting efforts by the Washington Division of Geology and Earth Resources. The analysis uses reservoir temperature from geochemistry and a single temperature gradient hole for a low value, and a temperature required for steam flash as a high value. Subsurface temperatures, and heat flows are expected to be better constrained after Phase 3 drilling. The preliminary results suggest power generation potential ranging from 65 MWe to 1.5 GWe within the lease area.

CONTACT: Michael Swyer: michael.swyer@cyrqenergy.com

***Recently Presented*:**

Geothermal Exploration North of Mount St. Helens, Washington State Play-Fairway Project

Drew Spake, Alexander Steely, Trenton Cladouhos, Michael Swyer, Corina Forson, Matt Uddenberg, Nicholas Davatzes

Paper presented at Stanford Geothermal Workshop 2019
https://pangea.stanford.edu/ERE/db/IGAstandard/record_detail.php?id=29094

ABSTRACT

Despite active volcanism, geothermal energy remains an under-utilized resource in the Cascades region of the Pacific Northwest. The lack of development partly reflects the difficulty in locating potential reservoirs. The geothermal Play-Fairway Analysis (PFA) for Washington state developed and implemented an exploration method (Swyer, et al., 2018a,b, Forson et al., 2017) to improve the search for blind geothermal systems by assessing the likelihood of key elements of a complete geothermal system, including: (a) a heat source, (b) a permeable conduit connecting the heat source to a (c) shallow porous and permeable reservoir that is (d) saturated. One of the sites identified with a high potential for these characteristics, as well as necessary infrastructure and development potential, is approximately 15 km north of Mount St. Helens within the NNW-SSE trending St. Helens seismic zone. In the summer of 2018, we began two studies to test this prediction. First, the potential for fault-related porosityâ€"to support a

reservoirâ€"is assessed through combined analysis of image and petrophysical logs in the Plate Boundary Observatory borehole B201 and outcrop and petrographic mapping of faults and fracture systems. These studies characterize the geometry, kinematics, and associated healing or alteration of the fracture and fault population. The goal is to determine if faults and fractures in basalt flows or indurated volcaniclastic deposits at reservoir depths are likely to provide connected porosity sufficient to host commercially viable geothermal reservoirs. In addition, borehole wall failure in image logs of B201 and slickenlines on the mapped faults provide new constraints on the regional geomechanical model. Second, the presence of heat is being assessed with a temperature-gradient hole drilled in the summer of 2018. In this paper, we: 1) review fault-associated porosity in the Mount St. Helens study area, and 2) present preliminary drilling results.

CONTACT: Drew Spake pspake@ORMAT.COM
Staff Geologist, ORMAT, 6140 Plumas St. Reno, NV 89519

Recently Presented:

Geothermal Exploration North of Mount St. Helens

Spake, Phillip

2019 MS Thesis presented to Temple University for MS in Geology
https://digital.library.temple.edu/digital/collection/p245801coll10/id/585698/rec/5

ABSTRACT

Active seismicity and volcanism north of Washington state's Mount St. Helens provide key ingredients for hydrothermal circulation at depth. This broad zone of seismicity defines the St. Helens Seismic Zone, which extends well north of the volcanic edifice below where several faults and associated fractures in outcrop record repeated slip, dilation, and alteration indicative of localized fluid flow. Candidate reservoir rocks for a geothermal system include marine metasediments overlain by extrusive volcanics. The colocation of elements comprising a geothermal system at this location is tested here by analysis of the structures potentially hosting a reservoir, their relationship to the modern stress state, and temperature logs to a depth of 250 m. Outcrop mapping and borehole image log analysis down to 244 m document highly fractured volcaniclastic deposits and basalt flows. Intervening ash layers truncate the vertical extent of most structures. However, large strike slip faults with well-developed fault cores and associated high fracture density cross ash layers; vein filling and alternation of the adjacent host rock in these faults suggest they act as vertically extensive flow paths. These faults and associated fractures record repeated slip, dilation, and healing by

various dolomite, quartz, and hematite, as well as clay alteration, indicative of long-lived, localized fluid flow. In addition, where these rocks are altered by igneous intrusion, they host high fracture density that facilitated heat transfer evidenced by associated hydrothermal alteration. Breakouts in image logs indicate the azimuth of SHmax in the shear zone is broadly consistent with both the GPS plate convergence velocity field as well as seismically active strike slip faults and strike-slip faults mapped in outcrop and borehole image logs. However, the local orientation of SHmax varies by position relative to the edifice and in some cases with depth along the borehole making a simple regional average SHmax azimuth misleading. Boreholes within the seismic zone display a wider variety of fracture attitudes than those outside the shear zone, potentially promoting permeability. Temperature profiles in these wells all indicate isothermal conditions at average groundwater temperatures, consistent with rapidly flowing water localized within fractures. Together, these results indicate that the area north of Mount Saint Helens generates and maintains porosity and permeability suggesting that conditions necessary for a geothermal system are present, although as yet no modern heat source or hydrothermal circulation was detected at shallow depth.

CONTACT: Drew Spake, pspake@ORMAT.COM
Staff Geologist, ORMAT, 6140 Plumas St. Reno, NV 89519

Recently Presented:

Simulating Local Sources of Crustal Deformation for Washington State Geothermal Prospects Using Geomechanical Models

M. W. Swyer, T. T. Cladouhos, C. Forson, A. N. Steely, N. C. Davatzes.
American Rock Mechanics Association ARMA-2018-464; 52nd U.S. Rock Mechanics/Geomechanics Symposium, 17-20 June, Seattle, Washington 2018

ABSTRACT

Three geothermal prospect areas in Washington State were modeled using Poly3D, a boundary element code that simulates fault slip and volcanic magma chamber deflation which causes local stress perturbation within an elastic half-space. This work was done as a part of Play-Fairway Analysis for Washington State by the Washington Geological Survey, AltaRock Energy Inc., and Temple University. The region has complex tectonics which causes areal and 3D complexity in the crustal stress-strain field. Geodetic strain rate tensors from GPS velocities that represent surface block rotation as opposed to deep subduction were used to constrain the remote stress. 3D fault geometries were created for seismogenic faults using the earthquake catalog from the Pacific Northwest Seismic Network for the faults

located at Mount St. Helens and the Wind River Valley. A magma chamber deflation model was used for Mount Baker that was best fit to a campaign geodetic survey on the volcano. The results of the modeling give insight into natural processes that cause dilational stress favorable for geothermal resources and are also used for siting temperature gradient holes.

CONTACT: Michael Swyer michael.swyer@cyrqenergy.com

REPORTS ON STUDIES IN-PROGRESS

Report on study in-progress:
Mt. St. Helens Glacier Cave Project: 2019 Expedition Reports

- **Continued studies of a new system of Glaciovolcanic caves in the Crater of Mt. St. Helens.** Christian Stenner, Alberta Speleological Society, Linda Sobolewski
- **Continued studies of climatology inside the glacier caves in the Crater of Mt. St. Helens.** Andreas Pflitsch, Ruhr-University Bochum, Germany
- **Extreme Microbial Communities from Ice Caves in the Mt. St. Helens crater.** Dr. Roberto Anitori and Richard Davis

Mount. St. Helens Glacier Cave Project Report Overview

The 4th expedition to the glacier caves of Mt. St. Helens took place from June 19 to June 25 2019. Organization and managed by: Eduardo Cartaya and Barb Williams, Glacier Cave Explorers, Redmond, OR

The expedition team comprised a total of 21 people, including: Expedition leader: (2),Medical: (2), Rescue: (5), Survey: (5), Climatology: (3), Biology: (2), Nasa: (2), Photography: (1).

GENERAL OBJECTIVES FOR THE STUDY

1. Continue survey of each glacier cave located using compass, GPS, and laser disto. This includes both an interior, 3-D cave survey, and a surface survey of the ice over the cave in order to establish ice thickness at any given point.
2. Conduct continuing microbial community screening vicinity in-cave fumaroles, to include mineral scrapes, and placement of temperature / humidity data loggers. To be followed up with 3 annual readings.
3. Conduct wind flow study of caves to determine distributive patterns of geothermal heat and outside air. Uses ultrasonic anemometers placed in cave during study and removed at end of week. Conduct thermal imaging scans.
4. Conduct volume flow measurements and chemical consistency of key fumaroles using gas monitors and flow meters.
5. Perform mobility testing for the JPL Ice Worm rover in a variety of slopes and ice mediums.
6. Conduct extensive photo documentation of the current condition of the caves for subsequent comparison and archiving. It is also to record the execution of the above experiments and surveys for subsequent review.

Continued studies of a new system of Glaciovolcanic caves in the Crater of Mt. St. Helens

Christian Stenner, Alberta Speleological Society

ABSTRACT

The exploration and mapping of glaciovolcanic cave systems in the crater has revealed a number of new caves in addition to those located and explored by this project team from 2014-2018. A total of ten distinct caves have been located and surveyed surrounding the 2004-2008 lava dome. Exploration of the caves has facilitated climatology and microbiology studies which are also ongoing. Additionally, testing has occurred for precursor technologies for exploration of icy bodies and void spaces in the solar system which include NASA Jet Propulsion Labs' IceWorm, the worlds' first ice climbing robot. Dark, oligotrophic volcanic environments such as the Mt. St. Helens glaciovolcanic caves are thought to mimic environments that may exist elsewhere in the solar system and as such the study of them has far reaching implications in addition to revealing more about how volcanoes and glaciers interact.

Survey

The documentation of cave characteristics via photography and repeated survey methods allow comparisons of passage extent and volume to be made. This gave us a unique opportunity to observe their genesis over time. The caves comprise a combined length of 2,232.3 m, the three most significant ones reaching more than 400 m each. Surveyed lengths ranged from 33 to 539 m. Depths varied between 7 and 65 m (fig. 1).

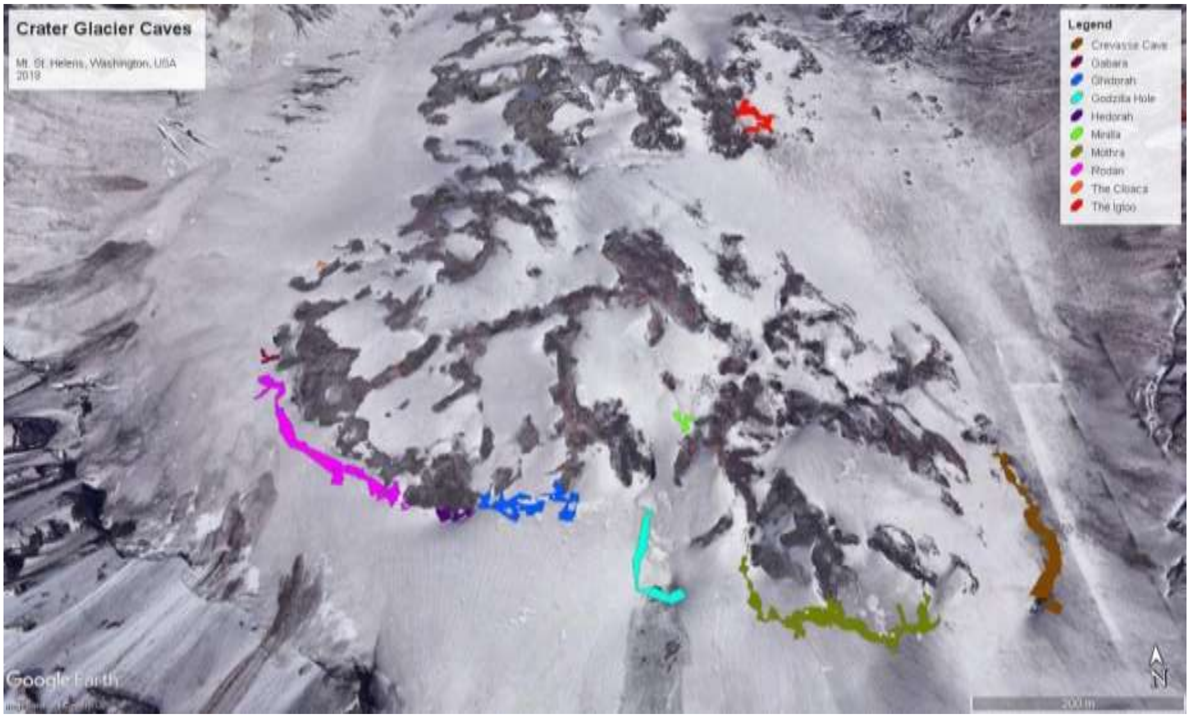


Figure 1: Georeferenced cave locations surrounding the 2004-2008 lava dome, 2014-2019. (C Stenner)

Resurveys of cave passages over multiple years has revealed the dynamic nature of the systems, which are not necessarily in balance with the geothermal heat release. Two caves in particular demonstrated significant growth. The largest cave demonstrated an estimated increase of approximately 243 % in length and 530 % in volume in nearly 7 years, or per annum growth rates of 35 %, and 77 % respectively. In another example, from 2014 to 2018 a new cave passage with a length of ~ 139 m and a volume of ~ 5060 m³ had formed. This represents cave growth of 102 % in length and 251 % in volume during the study. Another cave which was one of the first new caves in the crater to be studied has become inaccessible due to snow accumulation filling in the entrance shaft.

Changes in the output of individual fumaroles which have melted the passages have also contributed to the appearance and disappearance of subglacial rooms and marginal dendritic passages which typically orient to entrances along the rock/ice interface. Caves located on the east and west arm of the glacier are additionally influenced by glacier movement and a fast flow rate which contribute much to morphology changes.

Figure 2: Passage in a newly discovered Glaciovolcanic cave, June 2019. (C Stenner photo)

We expect that the overall growth of the cave systems will continue as long as snow accumulation and glacier building persist. These highly dynamic caves are trending to expand until an equilibrium of snow accumulation and ablation is reached or changes in volcanic activity occur that will affect the systems. First results from the cave surveys done between 2014 and 2019 as well as climatologic studies performed between 2017 and 2019 are being prepared for publication.

Continued studies of climatology inside the glacier caves in the Crater of Mt. St. Helens

Andreas Pflitsch, Ruhr-University Bochum, Germany

Some theoretical basics:

Glacier caves and ice caves have been universally recognized as climatology indicators. Organizations such as the UIS Glacier, Firn, and Ice Cave Commission, The National Cave and Karst Research Institute (NCKRI), and specific study events, such as the International Workshop on Ice Caves (IWIC), coordinate studies and present findings on the data collected for this purpose. The dark, high altitude / lower oxygen, and cold climate of the caves, coupled with geothermal gases from the numerous vents housed under the ice, creates a unique laboratory and time capsule in which to study climatology trends. Tracking / monitoring air temperature as well as wind flow speed and direction throughout the system over a period of a several years will provide valuable data and modeling as to how the local climate in the PNW is affecting our ice packs, and how the geothermal influences of the crater affect the morphology of the caves, possibly serving as an early warning indicator for volcanic activity.

Our study is focused on present climate conditions for basic climatologic research in alpine glacial caves in general. Here inside the crater of Mt. St. Helens especially, we will investigate the climatic condition of the glacial caves above an active volcano with active fumaroles and the correlation between microclimatic conditions with microbial communities. This study will attempt to identify the primary drivers of the energy balance in the caves and the glacier on Mt. St. Helens

The **scientific program** of the climatology group was like followed:

1. Finding the temperature sensor in Mothra Caves and downloading the data.
2. Placing of additional temperature sensors in Mothra Cave and surrounding caves.
3. Temperature measurements using a sensor chain with 20 sensors within the fumaroles and their input for comparative long-term recording of fumarole temperatures and soil surface temperatures.
4. Air flow measurements with ultrasonic anemometers at 3 different locations.
5. Measurement of the volume flow of different fumaroles.
6. Detection of the different fumaroles and fumarole fields inside Mothra Cave using a thermal camera.

Altogether we have located 6 temperature sensors with data loggers in the glacial caves of Mt. St. Helens.

First results:
The measurement results of the first two years show that the climate system within the glacier caves is strongly determined by the fumaroles inside the caves and the external weather. The yearly average temperature inside the caves is well above the freezing point, even most of the winter month and especially deeper inside the cave. Close to the openings to the outside we do have some short cold waves moving in.
The temperature of fumarole exhalations is not stable. As you can see in figure 3 the temperature changes can be very rapid. A clear cycle could not be identified yet. Even a seasonal cycle is not visible. During the summer (July) it has been as cold as during the winter (December). The warmest periods have been in January/February as well as in May.

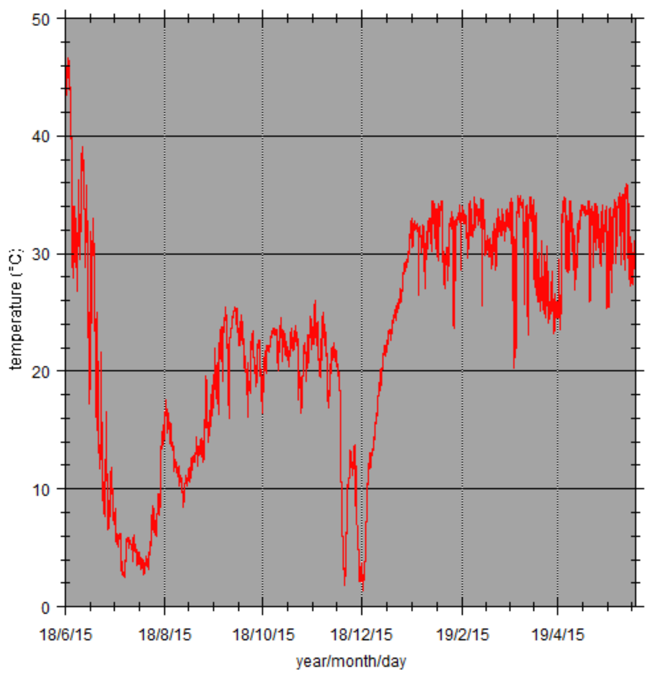


Figure 3: Temperature (°C) of the exhalation of a fumarole in the connection conduit between the lower level of Mothra Cave from June 15, 2018 to June 22, 2019 (Pflitsch).

Further results will be prepared for publication.

Extreme Microbial Communities from Ice Caves in the Mt. St. Helens crater

Dr. Roberto Anitori and Richard Davis

The Mt. St. Helens extremophile ice cave project is a multi-year study aimed at understanding microbial communities that live in volcanic systems. The discovery and description of several firn, and glacier caves within the crater of Mt. St. Helens offers a unique and exciting opportunity to study how organisms first colonize volcanic environments and how the communities and habitats change over time. We hope to understand which microbes are able to colonize these inhospitable ecosystems, how they are able to obtain the nutrients and energy to grow, and how these communities change as the ecosystems mature. Understanding these mechanisms will give us insight into what drives the progression of ecosystems in volcanic systems and potentially discover new metabolic strategies and products utilized by these unique microbes that could be adapted for use in the industrial and healthcare fields.

Over the course of three annual field trips (2017 - 2019) we have collected almost 30 samples from within six glacier and firn caves of the Mt. St. Helens crater, the majority being sediments co-located with fumaroles. Sample temperatures ranged from about 1 - 75°C, with the majority being between 10 - 45°C. Upon collection, sediments were subsampled for geochemical analysis, microbial culturing, and preserved for DNA analysis. We have also collected temperature and light readings via data loggers at sampling sites (Figures 1 and 2).

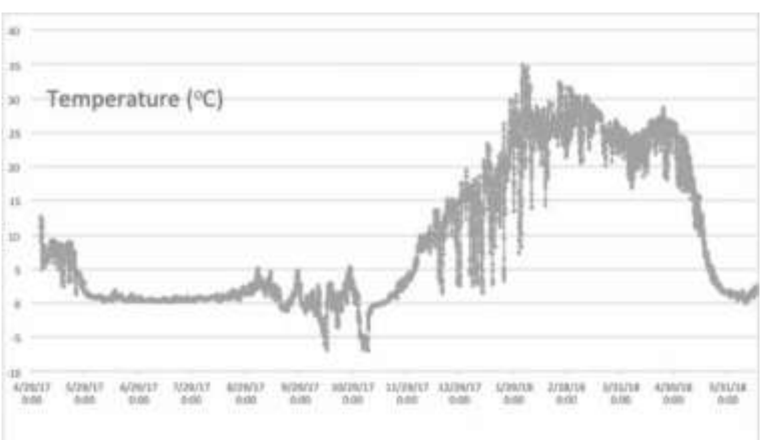
Sediments contained large concentrations of Fe and P, unmeasurable N and very low levels of organic C. The latter result indicates that the caves are highly oligotrophic (nutrient poor) environments, just like similar cave systems we have studied in Antarctica.

We have successfully demonstrated the presence of previously undescribed microbial communities in the caves, both by culture- and DNA-based methods. A variety of different microbes have been cultured from the samples (Figure 3) – for example, members of the genera *Streptomyces*, *Pseudomonas*, *Bacillus, Burkholderia, Variovorax* and *Arthrobacter*. Furthermore, as part of an undergraduate class at Clark College in which students search for novel antibiotics (BIOL105), we have also screened several cave bacterial isolates for the production of bioactive compounds. A number of isolates do produce antibiotics, and students have successfully determined the complete genome sequences of some of these bacteria (e.g. a *Streptomyces* isolate), and identified several potential genes involved in antibiotic production.

Extraction of DNA from the sediment samples followed by DNA sequencing to determine the entire resident microbial community (metagenomics) has been conducted on five selected samples. Analysis of this data has led to a number of important findings: 1) communities found in these ice caves are taxonomically unique. Each of the caves has a unique microbial composition indicating diverse populations are able to colonize these habitats; 2) low temperature fumarole communities contain similar metabolic make-up, despite unique taxonomy; and 3) high temperature samples from firn and glacial caves have unique community and metabolic communities suggesting there are significant differences between high temperature fumaroles found in these caves.

Future work involves further analyses and more sample collections. Analysis of these new cave samples, along with environmental data, will be used to achieve a comprehensive temporal and spatial analysis of the ice cave microbial communities of the Mt. St. Helens crater.

Figure 1. Sample MSH01, showing temperature/light data logger at fumarole entrance.



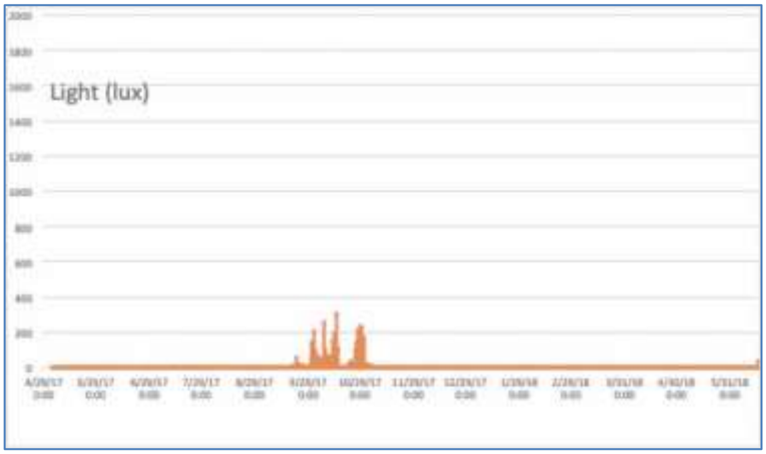


Figure 2. Temperature and light intensity data for sample location MSH16 for a 1-year period. The temperature of the sampling area was cold in the first 6 months, followed by a warming period (upper graph). The cave was dark except for a short period in late summer/early Fall when faint illumination was present (lower graph).

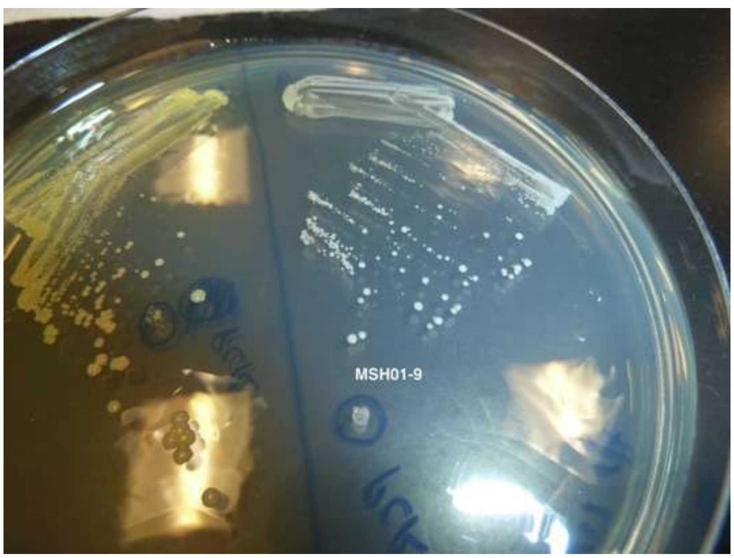


Figure 3. Bacteria cultured on agar plates from sample MSH01 by Clark College undergraduate student Kawther Elolaimi.

Funding was received from the Mazamas mountaineering organization (OR) and equipment from FLIR Systems (OR).

CONTACT: Dr. Roberto Anitori, Clark College, Vancouver, WA, ranitori@clark.edu;
Dr. Richard Davis, NASA Johnson Space Center, Houston, TX, Richard.e.davis-1@nasa.gov

Report on study in-progress:

Assessing the Potential Effects of Treponeme Associated Hoof Disease (TAHD) on Elk Population Dynamics in Southwest Washington

Report submitted by Kyle Garrison, Washington Department of Fish and Wildlife

OVERVIEW

The primary research goals are to quantify how TAHD may affect the survival, pregnancy rates, productivity, and nutritional condition of adult female elk. Specific study objectives include:

1. Estimate the effects of TAHD on survival of adult (≥ 2 years old) female elk.
2. Determine cause-specific mortality rates for adult female elk that have TAHD.
3. Estimate the effects of TAHD on the pregnancy rates of adult female elk.
4. Estimate the effects of TAHD on elk productivity (i.e., survivorship of calves).
5. Estimate the effects of TAHD on the level of condition adult female elk are able to achieve in autumn.
6. Increase our understanding of how TAHD progresses in individual elk, and whether affected elk may recover from the disease.

Our study area consists of 5 Game Management Units that, collectively, represent the core range of the MSH herd (Figure 1). This area is within the TAHD endemic area and allows us to compare to previous research on elk. In total, we captured 180 individual elk across 258 capture events. Preliminary results indicate that elk infected with TAHD enter winter months in poorer condition and have lower survival rates than uninfected elk. We were unable to directly estimate survivorship of calves. Preliminary analysis of lactation rates indicates that TAHD-infected animals likely exhibited calf survival rates similar to uninfected animals. Importantly, however, we documented lower pregnancy rates for TAHD-infected animals and therefore lower overall per-animal productivity. From repeat captures of the same individuals, we documented rapid progression of this disease in individual elk and only limited instances of recovery from TAHD. The primary cause of mortality for elk with TAHD is general debilitation – the combined effects of disease and malnutrition. For uninfected elk, the primary cause of mortality was human-related (i.e., harvest). Field work associated with this study concluded

in mid-2019. Final analyses and report preparation are in progress. To learn more about TAHD and the Department's efforts, please visit the Washington Department of Fish and Wildlife's website:
https://wdfw.wa.gov/conservation/health/hoof_disease/

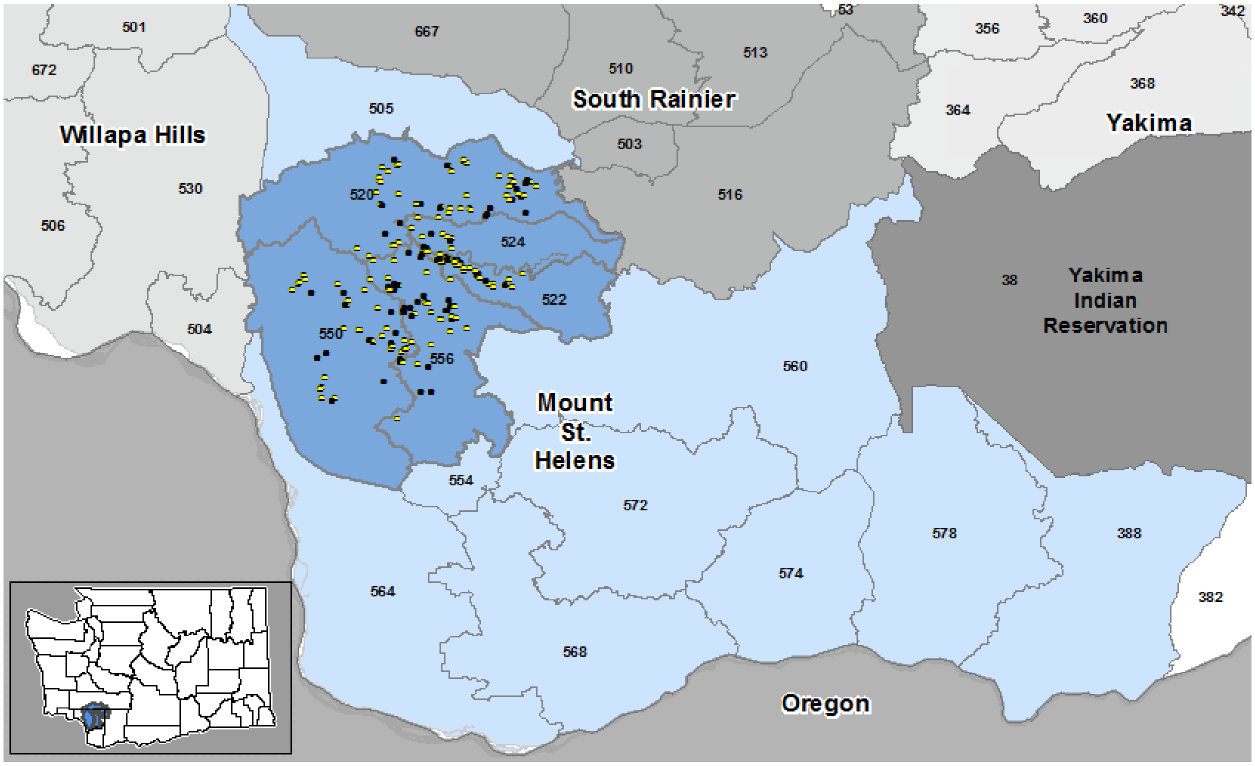


Figure 1. Map depicting the Game Management Units (GMUs) that comprise the Mount St. Helens elk herd area (light blue), the 5 GMUs that represent the core range of the herd and our study area (dark blue), and the locations where we have captured elk affected (yellow) or seemingly unaffected (black) by treponeme-associated hoof disease, February 2015–December 2017. Also included for spatial reference are GMUs associated with the Willapa Hills, South Rainier, and Yakima elk herds.

CONTACT: Kyle Garrison, Washington Department of Fish and Wildlife, Kyle.Garrison@dfw.wa.gov

Report on annual study:

2020 Mount St. Helens Mountain Goat Survey
Washington Department of Fish and Wildlife, Cowlitz Indian Tribe, Mount St Helens Institute. August 2020

Mountain goats returned to the blast zone in the early 2000's, and since 2014 Mount St Helens Institute (MSHI) has partnered with the Cowlitz Tribe and the Washington Department of Fish and Wildlife to take an annual pulse of their population. Ten teams of volunteers hiked out to sites all around Mount St. Helens and the Mount Margaret Backcountry with binoculars, maps, compasses, and data sheets, documenting all the mountain goats they found. The results of the 2020 survey are being finalized, and should be released soon.

Mountain goats hold cultural significance for the Cowlitz Tribe, and are an awe-inspiring sight for all visitors to Mount St. Helens today. Though the 1980 eruption killed the few resident mountain goats, it also blew down trees, leaving an exposed, rocky landscape. 40 years later, those hillsides are full of shrubs and wildflowers, creating the perfect mountain goat habitat, and the population appears to be thriving. We'll be watching to see how mountain goats fare as the blast zone returns to forest in the decades to come within the living laboratory that is the Mount St. Helens National Volcanic Monument.

To learn more about mountain goats and the annual survey, watch our recent Views & Brews with Nathan Reynolds.
https://www.youtube.com/watch?v=aFb3lTIYZmg&feature=youtu.be

Photo credit: Gary Stewart (goat photo), Doug Briedwell, Gina Roberti, Jordan Koppelman, Sarah Philips

ARTICLES & STUDIES IN PREPARATION

Long-term monitoring of Mount St. Helens micrometeorology conditions.

Che-Castaldo, C., and Crisafulli, CM. Target Journal Ecological Archives.

Post-eruption Insect Succession on the Mount St. Helens Volcano, 1980-2015: "Boom-and-Bust" Population Dynamics of a Non-Native Species, the European Earwig

(Dermaptera: Forficulidae).
Parmenter, RR, Crisafulli, CM, Culhane, K., Crawford RL., Myers, OB., Parmenter, CA., and MacMahon, JA. (in prep) Target Journal: Ecological Entomology.

Warmer Conditions Favor Conifer Tree Establishment at the Muddy River Lahar in Mt. St. Helens, Washington.

Ignacio Falcon, Thesis to be presented to Department of Geography, Portland State University. CONTACTS: Ignacio Falcón-Dvorsky ifdvorsky@gmail.com , Andrés Holz, Department of Geography, Portland State University, andres.holz@pdx.edu; phone: (503) 725-3158

MEDIA

New road at Mount St. Helens? Scientists see another disaster.

Wagner, E. Columbia INSIGHT. 6/18/2020. https://columbiainsight.org/new-road-at-mount-st-helens-scientists-see-another-disaster/

Audio Interview with C. Crisafulli:

B. Bernstein KBOO-FM 90.7, Portland, OR, Locus
Focus, https://kboo.fm/media/80667-mt-st-helens-eruption-40th-anniversary.

The threat below Mount St. Helens.

Wagner, E, High Country News.. 2020.
5/1/2020. https://www.hcn.org/issues/52.5/north-scientific-research-the-threat-below-mount-st-helens

40 years ago, Mount St. Helens blew its top.
Here's how it got green again, interview with Charlie Crisafulli CBC Radio · Podcast, 5/30/2020 May 29, 2020 https://www.cbc.ca/radio/quirks/may-30-swearing-makes-pain-more-tolerable-mt-st-helens-40-years-later-and-more-1.5589125/40-years-ago-mount-st-helens-blew-its-top-here-s-how-it-got-green-again-1.5589135

Mount St. Helens' mysteries still astound scientists, 40 years after eruption. Mapes, L. V. 2020. Seattle Times, 5/18/2020. https://www.seattletimes.com/seattle-news/environment/mount-st-helens-mysteries-still-astound-scientists-40-years-after-eruption/

Mount St. Helens 40 years later: What we've learned, and still don't know.
Cornwall, W. 2020. Science Magazine: 5/18/2020. doi:10.1126/science.abc8655. https://www.sciencemag.org/news/2020/05/ecologist-has-been-studying-mount-st-helens-it-erupted-40-years-ago "Charlie Crisafulli first visited Mount St. Helens 2 months after the 18 May 1980 eruption that ripped the top off the volcano, obliterated 600 square kilometers of forests, killed 57 people, and coated much of the Pacific Northwest in ash. He was a 22-year-old with an undergraduate degree in ecology, accompanying a Utah State University professor as scientists descended on the mountain. Since then, Crisafulli—now an ecologist at the U.S. Forest Service's Pacific Northwest Research Station—has spent much of each summer taking the mountain's pulse as life returns. He recently spoke with Science Insider about the 40th anniversary of the eruption that has defined his scientific career, and shaped people's understanding of how ecosystems respond to such devastation."

Witness to a landscape's recovery.
Cornwall, W. Science. 22 May 2020, pg. 806, Issue 6493 (not available online without subscription)

Video presentation by Portland Art Museum
Portland Art Museum and Mount St. Helens Institute reflect on the art, culture, and science of the mountain's ever-changing landscapes. Special Guests include Barbara Noah (Seattle Artist), Sonja Melander (Science Education Manager, Mount St. Helens Institute), Nathan Reynolds (Ecologist and Interim Director of Cultural Resources, Cowlitz Indian Tribe), and Ray Yurkewycz (Director, Mount St. Helens Institute).

https://www.facebook.com/portlandartmuseum/videos/2547282415586295/?v=2547282415586295

Mount St. Helens Rocked Our World: What We've Learned Since 1980.
Heather Wright, FB Live, (program begins with pre-show and trivia)
https://www.facebook.com/omsi.museum/videos/2274152552893308/?t=1872

- OMSI YouTube Channel https://www.youtube.com/watch?v=md4UrBKRjI8

Mount St. Helens: 40 Years Later.
Seth Moran, Podcast. https://thirdpodfromthesun.com/2020/05/18/mt-st-helens-40-years-later/

Magma, Monitoring and Mount St. Helens: The Scientific Story of the 1980 Eruption.
Seth Moran, Recorded Presentation, Fort Vancouver National Historic Site.
https://www.facebook.com/FortVancouver/videos/270346050766834/?t=1

Mount St. Helens and the Cascade Range Volcanoes: The 40th Anniversary.
Seth Moran, YouTube, FB. https://youtu.be/2naM6Kun9J0

Mount St. Helens 40th Anniversary Story Hour.
Carolyn Driedger, Washington State History Museum, FB Live.
https://www.facebook.com/watch/live/?v=710430639806444&ref=watch_permalink

OTHER REFERENCES/MATERIALS

Ten ways Mount St. Helens changed our world—The enduring legacy of the 1980 eruption: U.S. Geological Survey Fact Sheet 2020-3031

Driedger, C.L., Major, J.J., Pallister, J.S., Clynne, M.A., Moran, S.C., Westby, E.G., and Ewert, J.W., 2020, , 6 p., https://doi.org/10.3133/fs20203031

After the Blast: The Ecological Recovery of Mount St. Helens

By Eric Wagner, Published: April 2020
ISBN: 9780295746937
On May 18, 1980, people all over the world watched with awe and horror as Mount St. Helens erupted. Fifty-seven people were killed and hundreds of square miles of what had been lush forests and wild rivers were to all appearances destroyed. Ecologists thought they would have to wait years, or even decades, for life to return to the mountain, but when forest scientist Jerry Franklin helicoptered into the blast area a couple of weeks after the eruption, he found small plants bursting through the ash and animals skittering over the ground. Stunned, he realized he and his colleagues had been thinking of the volcano in completely the wrong way. Rather than being a dead zone, the mountain was very much alive.
Mount St. Helens has been surprising ecologists ever since, and in *After the Blast* Eric Wagner takes readers on a fascinating journey through the blast area and beyond. From fireweed to elk, the plants and animals Franklin saw would not just change how ecologists approached the eruption and its landscape, but also prompt them to think in new ways about how life responds in the face of seemingly total devastation.
https://uwapress.uw.edu/book/9780295746937/after-the-blast/
CONTACT: erlwagne@gmail.com

Mount St. Helens: A Living Laboratory for Ecological Research

PNW Research Station website: https://www.fs.usda.gov/pnw/projects/mount-st-helens.

Online Bibliography

A bibliography of more books about Mount St. Helens compiled by Mount St Helens Institute can be found at: https://www.mshinstitute.org/science-arts/arts-humanities/books-about-mount-st-helens.html

US FOREST SERVICE UPDATE

Research and Management of Spirit Lake Update 2020

BACKGROUND

A massive debris flow during the 1980 eruption of Mount St. Helens created Castle and Coldwater lakes, and blocked the natural outflow from Spirit Lake. To maintain a safe water level in Spirit Lake, in 1985 the U.S. Army Corps of Engineers (USACE) constructed a tunnel, completed a 1.6 mile, 11-ft diameter shaft bored horizontally through rock on the Mount St. Helens National Volcanic Monument.

CURRENT SITUATION

As the tunnel ages its components require repair and replacement, and total deferred maintenance is in the tens of millions of dollars. The 2017 National Academies of Science, Engineering, & Medicine report (NASEM) provides recommendations for improved understanding of long-term management options of Spirit Lake's outflow.

The Gifford Pinchot National Forest continues to invest in operations and maintenance, mid-range outflow planning, and long-term community and partnership development. To support current and future management decisions, the Forest Service has directed studies and research to occur around the tunnel and pumice plain.

COMPLETED STUDIES:

- A Decision Framework for Managing the Spirit Lake and Toutle River System at Mount St. Helens was published by the NASEM.
- The Geologic, Geomorphic, and Hydrologic Context Underlying Options for Long-Term Management of the Spirit Lake Outlet- USFS Pacific Northwest Research Station Gordon Grant, U.S. Geological Survey Jon Major, Oregon State University Sara Lewis
- Tunnel and lake velocity flow telemetry- U.S. Geological Survey Cascade Volcano Observatory
- Lidar mapping of Mount St. Helens, Spirit Lake, Pumice Plain and Toutle River sediment.

- Following a recommendation by NASEM, a situation assessment conducted by the William D. Ruckelshaus Center assessed Toutle basin interest in a consortium or working group made up of land managers and decision makers in the system.
- Multi-Decade Analysis of Fluvial Geomorphic Evolution of the Spirit Lake Blockage- U.S. Geological Survey Jon Major, USFS Pacific Northwest Research Station Gordon Grant, University of Portland Kristin Sweeney and Adam R. Mosbrucker 2020.

USFS boat operations on Spirit Lake.

ONGOING STUDIES

- Ground Penetrating Radar and Seismic Refraction on the debris blockage- Colorado School of Mines. Geophysical exploration (using ground penetrating radar and seismic reflection equipment) of Spirit Lake debris blockage through agreement with Colorado School of Mines. Colorado School of Mines team completed 10-day debris blockage field sessions August 2018 and again in July/August 2019.
- Seismic Hazard Mapping – The USGS Earthquake Science Center is updating seismic hazard mapping for the Spirit Lake area to include the Pumice Plain and outflow tunnel.
- The USGS Cascade Volcano Observatory is modeling inundation maps from a hypothetical Spirit Lake breakout flood.
- The Forest Service commissioned a 3D survey for the 1.6 mile Spirit Lake tunnel.
- In response to the 2017 NASEM findings, the USFS, in cooperation with USACE, initiated a project to characterize the debris blockage which will include a subsurface exploration program, engineering analyses to evaluate risks related to seismic events and internal erosion. The safe lake level will be reevaluated considering the new data from the blockage material.

Spirit Lake Project website:
https://www.fs.usda.gov/detail/giffordpinchot/landmanagement/?cid=FSEPRD488792

Mount St Helens Eruption; Spirit Lake and Toutle River Watershed video (https://youtu.be/UoSyHMAXpI0)

Contact:
Michele Palmer, Project Manager, michele.palmer@usda.gov, 360-891-5052

MOUNT ST. HELENS INSTITUTE UPDATE

Mount St. Helens Institute (MSHI) is devoted to advancing understanding and stewardship of the Earth through science, education, and exploration of volcanic landscapes. MSHI conducts youth and adult education and volunteer programs on-site at Mount St. Helens, in local communities and virtually via technology. MSHI regularly collaborates with federal, state, and nonprofit partners throughout Washington and Oregon to promote inclusive outdoor science education, stewardship, and recreation opportunities, prioritizing equity in access. In partnership with the US Forest Service, we provide unique experiences for visitors, promote understanding of volcanic hazards, protect and steward the Monument, deliver exceptional educational and interpretive programming, invest in sustainable recreation, and elevate scientific research.

At Mount St. Helens Institute (MSHI) high quality education and experiential learning programs continue to be our hallmark. In 2019, over 3,700 youth joined the Mount St. Helens Institute in the field and classroom to explore science concepts, practices, and careers. Foundation, government and donor funding ensured that all student have access to learning at Mount St. Helens; over 50% of students who participated in Volcano Outdoor School come from low-income families and had never visited Mount St. Helens before. The Mount St. Helens research community enhances students' learning.

In 2020 to adjust to the COVID pandemic, Mount St. Helens Institute shifted strategies to continue providing science education and awareness both on the mountain and in homes throughout the Northwest. Our education team hosted an online spring series called Volcano Tuesdays and we had over 4000 views. They are now developing more virtual learning programs such as student-driven interdisciplinary curriculum storylines to support teachers and students for either at home or in the classroom learning.

Big thanks to the following scientists and educators as well as their institutions for supporting education work at Mount St Helens:

- Amy Boyd (Portland of Longview)
- Charlie Crisafulli (PNWRS)
- Jim Gawel (UW-Tacoma)
- Brooke Henwood (Arcadis)
- Amanda Keasberry (Cascade Forest Conservancy)
- Alisa Kotash (OSU)
- Allison Kubo (U of O)
- Carri LeRoy (The Evergreen State College)
- Olivia Marshall (Arcadis)
- Janet Prevey (PNWRS)
- Cat Samson (WA-DNR)

- Emily Shirron (WSU-Vancouver)
- Valerie Strasser (Central Washington University)
- Kathy Trafton (U of O)
- Emily Wolfe (PSU)
- and so many women from USGS

CONTACT: Abigail Groskopf, Programs Director, Mount St. Helens Institute, (360) 891-5067, abi@mshinstitute.org

A major new initiative in the planning stages is the transformation of the Coldwater Visitor Center to a world-class, energy-efficient, educational, and multi-day experience for youth and adults alike. Rich opportunities abound in close proximity to the blast zone of the most inspiring volcano in the continental United States. What has been primarily a day-use site will be reborn as a venue where visitors can relax and stay for a few days, more fully engaging in the learning opportunities that the volcano landscape has to offer. Expanded programming being considered includes:

- outdoor school (multi-day programs)
- youth & family camps
- conferences, workshops, events, trainings, reunions & retreats
- community events
- overnight visitor accommodations

CONTACT: Ray Yurkewycz, Executive Director, Mount St. Helens Institute, (360) 449-7883, ray@mshinstitute.org

Mount St. Helens Institute is proud to operate under a Special-Use permit from the U.S. Forest Service and is an equal opportunity education provider.
www.mshinstitute.org