SYMPOSIUM PROGRAM

A Virtual International Symposium on Research and Advancements In Identifying and Evaluating Potential Volcanic Hazards

Convened by AEG's Geologic and Seismic Hazards Technical Working Group (GASH TWG)
(All sessions will be recorded for paid attendees to view anytime. 15 PDHs available.)

Volcanoes are dominant geologic features that shape the landscape and pose risks to ever-expanding critical infrastructure and population centers. Government agencies around the globe operate volcano observatories to monitor active volcanoes, issue activity warnings and eruption updates, and develop hazard models and maps to help prepare members of the public in the event of an eruption. It is crucial to understand the range of complex processes associated with volcanic hazards. However, each volcano poses unique challenges related to gathering data, developing eruption models, interpreting precursors of an eruption, and quantifying the potential hazards that might occur. These challenges make it difficult to standardize the identification and evaluation of volcanic hazards. Additionally, the methods of how to best estimate volcanic hazards remain an open area of research, which can lead to disparate outcomes depending on methodology. This symposium brings together volcanologists from universities, volcano observatories, and consulting firms to discuss their work with the goal of furthering the scientific understanding of volcanic hazards and the methods applied for evaluation of those hazards.

GASH TWG Symposium Planning Committee

Michael Cline, RIZZO International, Inc.
Mitchell Hastings, RIZZO International, Inc.
Courtney Johnson, Slate Geotechnical Consultants
Kelley Shaw, Slate Geotechnical Consultants
Gerry Stirewalt, U.S. Nuclear Regulatory Commission

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On the Cover

Zoomed in aerial view of Fissure 3 erupting on the Northeast Rift Zone of Mauna Loa. Its lava fountains consistently throw molten lava bombs up to 30 m (98 ft) in the air with some bursts to 40 m (131 ft) high. Over time as these bombs cool, around the base of the fissure, they built up a spatter cone. Since Fissure 3 became the dominant source of lava effusion, it has built up a significant spatter cone around its lava fountains. USGS image by D. Downs.

Research and Advancements in Identifying and Evaluating Potential Volcanic Hazards!

The members of AEG's Geologic and Seismic Hazards Technical Working group (GASH TWG) who planned and are convening the virtual symposium on Volcanic Hazards are very pleased to welcome all speakers and participants to this symposium! It brings together volcanologists from universities, volcano observatories, and consulting firms, as well as independent consultants, to discuss work done to increase the scientific understanding of volcanic hazards and the methods applied to identify and evaluate those hazards. The symposium provides the unique opportunity for attendees to hear from national and international experts directly and interact with them in facilitated discussion sessions at the end of each day.

The following information summarizes the technical topics to be presented during each day of the symposium.

Day One – Sponsored by DMI, LLC
(1) A Keynote address on how volcanoes work. (2) Building and curating a comprehensive dataset for hazard analysis in a distributed volcanic field. (3) Volcanic, seismic, and hydrothermal hazards in the Yellowstone region. (4) Precursors of and hazards from volcanic earthquakes. (5) Approach to screening volcanic phenomena in a volcanic terrain. (6) Application of the SSHAC Level 3 process for the Idaho National Laboratory (INL) Probabilistic Volcanic Hazard Assessment (PVHA). (7) The volcanic hazards question to SSHAC or not to SSHAC. (8) Lessons learned from the first use of the U.S. Nuclear Regulatory Commission's Regulatory Guide 4.26 for assessment of volcanic hazards at a proposed nuclear power reactor site.

Day Two – Sponsored by RIZZO International, Inc.
(1) A Keynote address on new methods developed for PVHA at INL using a SSHAC Level 3 approach. (2) Modeling pre-historic recurrence rate in volcanic systems with a volcanic event age model. (3) Comparing lava flow inundation hazard from numerical and borehole methods in the Eastern Snake River Plain of Idaho. (4) Three-dimensional analysis of silicic volcanism using Aerogravity and AeroLiDAR. (5) Real-time graben formation in Grindavik, Iceland, and associated hazards in the volcanic-tectonic system. (6) Constraining deformation in volcanic systems using deep learning to mitigate atmospheric effects in InSAR displacement maps. (7) The scale of volcanic ground deformation.

Day Three
(1) A Keynote address on volcanic tsunamis from physics to hazard assessment. (2) Potential far-field hazards from volcanically generated tsunamis in Alaska. (3) Developing a volcanogenic tsunami potential index for Alaska volcanoes. (4) Improving volcanic hazard assessment at Makushin Volcano for the Community of Unalaska in Alaska. (5) Pryoclastic currents and their effects. (6) Re-tooling an observatory to monitor deadly volcanic hazards in real time for Montserrat, 2000-2003. (7) VICTOR - A new cyber infrastructure for volcanologists.

AEG and the GASH TWG wish to thank all speakers who participated and greatly appreciate the sponsors of the sessions recognized above. The speakers and sponsors helped make the symposium a success! The GASH TWG hopes that speakers and attendees alike enjoy the symposium and benefit from the facilitated discussions to be held at the end of each daily session.

<u>GASH TWG Symposium Planners and Convenors</u>
Michael Cline – RIZZO International, Inc.
Mitchell Hastings – RIZZO International, Inc.
Courtney Johnson – Slate Geotechnical Consultants, AEG GASH TWG Co-Chair
Kelley Shaw – Slate Geotechnical Consultants
Gerry Stirewalt – U.S. Nuclear Regulatory Commission, AEG GASH TWG Co-Chair

BAGNELL DAM | Missouri | Anchor Replacement, Tainter Gate Replacement Design, PMF Updates, FERC Part 12 Safety Inspection

KRŠKO NUCLEAR POWER PLANT SEISMIC HAZARD ANALYSIS | Slovenia | PSHA, Site Response Analysis, Fault Displacement Analysis

TODD SPRINGS DAM | Pennsylvania | Field Geotechnical Investigation, H&H Analyses, Rehabilitation Design

CARBON FREE POWER PROJECT | Idaho | New Nuclear Power Plant Site Characterization, PVHA Support License Application Section 2.5, Multiple ER Sections

PANTEX | Texas | Site Characterization and PSHA in Support of US DOE Order 1020

TURKEY POINT NUCLEAR POWER PLANT | Florida | Supplemental Field Investigation, Update FSAR Subsection 2.5

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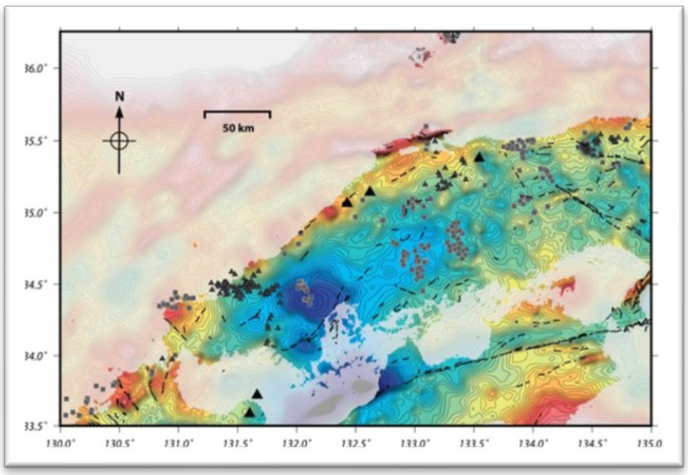

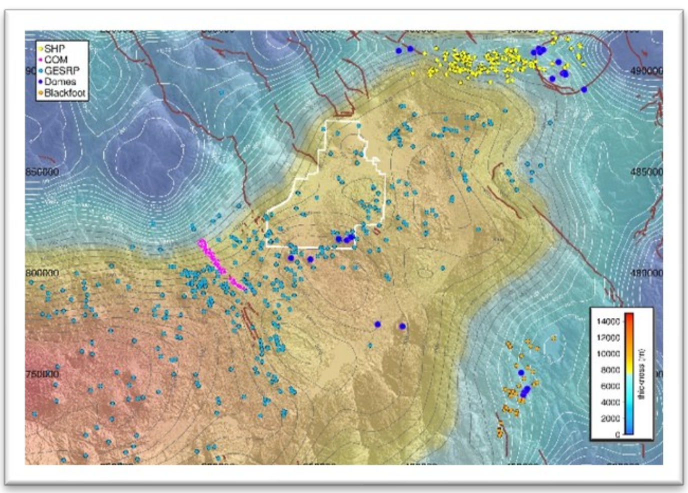

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SYMPOSIUM SCHEDULE
(All Times are Eastern Time)

APRIL 28 – Sponsored by DMI, LLC
Moderated by Mitchell Hastings and Michael Cline

Time	Title	Speaker
11:00am	Introduction to the Symposium Session	Kelley Shaw and Gerry Stirewalt
11:15am	Keynote Speaker: How Volcanoes Work	Bill Hackett, WRH Associates
12:15pm	Building and Curating a Comprehensive Dataset for Hazard Analysis in a Distributed Volcanic Field	Shannon Kobs Nawotniak, Idaho State University
12:45pm	Volcanic, Seismic, and Hydrothermal Hazards in the Yellowstone Region	Michael Poland, USGS (YVO)
1:15pm	Volcanic Earthquakes: Precursors and Hazards	Suzette Payne, SMJP Consulting
1:45pm	BREAK	
2:00pm	Approach to Screening Volcanic Phenomena in a Volcanic Terrain	Michael Cline, Rizzo
2:30pm	The Successful Application of the SSHAC Level 3 Process in the Integrated Multisite INL PVHA: Regulatory Compliance and Future Use	Kevin Coppersmith, Coppersmith Consulting, Inc.
3:00pm	To SSHAC, or Not To SSHAC: The Volcanic Hazards Question	Brittain Hill, Independent Consultant
3:30pm	Lessons-Learned from the First Use of Regulatory Guide 4.26 in the Assessment of Volcanic Hazards at a Proposed Nuclear Power Reactor Site	Jenise Thompson, US NRC
4:00pm	Questions/Discussion	

APRIL 29– Sponsored by RIZZO International
Moderated by Mitchell Hastings and Michael Cline

Time	Title	Speaker
11:00am	Introduction to the Symposium Session	Kelley Shaw and Gerry Stirewalt
11:15am	Keynote Speaker: New Methods Developed for the Probabilistic Volcanic Hazard Assessment of the Idaho National Lab: A SSHAC Level 3	Chuck Connor, University of South Florida
12:15pm	Modeling Pre-Historic Recurrence Rate in Volcanic Systems with a Volcanic Event Age Model	James Wilson, RIZZO
12:45pm	Comparing Lava Flow Inundation Hazard from Borehole and Numerical Methods: A Case Study from the Eastern Snake River Plain	Mitchell Hastings, RIZZO
1:15pm	3D Analysis of Silicic Volcanism in Basaltic Flow Fields Using Aerogravity and AeroLiDAR	Troy Berkey, University of South Florida
1:45pm	BREAK	
2:00pm	Real Time Graben Formation in Grindavík Iceland and Associated Hazards in the Volcanic-Tectonic System	Greg de Pascale, University of Iceland
2:30pm	Constraining Deformation at Volcanic Systems; Using Deep Learning to Mitigate Atmospheric Effects in InSAR Displacement Maps	Rebecca Brussard, Pennsylvania State University
3:00pm	The Scale of Volcanic Ground Deformation	Emily Montgomery-Brown, USGS
3:30pm	Questions/Discussion	

APRIL 30

Moderated by Mitchell Hastings and Michael Cline

Time	Title	Speaker
11:00am	Introduction to the Symposium Session	Kelley Shaw and Gerry Stirewalt
11:15am	Keynote Speaker: Volcanic Tsunamis: From Physics to Hazard Assessment	Raphaël Paris, University of Clermont
12:15pm	Potential Far-Field Hazards from Volcanically Generated Tsunamis in Alaska	Chris Waythomas, Alaska Volcano Observatory
12:45pm	Developing a Volcanogenic Tsunami Potential Index of Alaskan Volcanoes	Charlie Mandeville, Alaska Volcano Observatory
1:15pm	Improving Volcanic Hazard Assessment at Makushin Volcano and for the Community of Unalaska, AK	Hannah Dietterich, Alaska Volcano Observatory
1:45pm	BREAK	
2:00pm	Pyroclastic Currents and Their Effects	Greg Valentine, University of Buffalo
2:30pm	Re-Tooling an Observatory to Monitor Deadly Volcanic Hazards in Real-Time: Montserrat, 2000-2003	Glenn Thompson, University of South Florida
3:00pm	VICTOR - A New Cyber Infrastructure for Volcanologists	Einat Lev, Lamont-Doherty Earth Observatory - Columbia Climate School
3:30pm	Questions/Discussion	

Mauna Loa Fissure Eruption, Hawai’i Volcanoes National Park. USGS photo by L. Gallant

Michael Cline, RIZZO International, Inc.

Mr. Michael Cline, registered professional geologist, is a principal geologist with RIZZO International, Inc. (RIZZO). He has more than 50 years of professional experience participating in and managing seismic, fault displacement, and volcanic hazard analyses for nuclear facilities, dam projects, and major population centers. This work has included probabilistic hazard analyses. He has also performed independent technical reviews of geologic hazard investigations. He has technical expertise in remote sensing imagery interpretation, paleoseismology, geomorphology, structural geology, geologic mapping, economic geology, and high-resolution seismic surveys. His management experience includes field offices, large-scale projects, major programs, and corporate operations. His geographical experience includes conducting investigations in North America, Central America, and South America; the Middle East; Europe; and northern Asia. Notable projects include a probabilistic volcanic hazard analysis for a nuclear power site on the Eastern Snake River Plain (Idaho), Pantex Probabilistic Seismic Hazard Analysis (Texas), Probabilistic Seismic Hazard Analysis for the Krsko Nuclear Power Plant (Slovenia), Yucca Mountain Probabilistic Volcanic Hazard Analysis and Consequence Analyses (Nevada), Tsruga Nuclear Power Plant fault hazard study (Japan), Earthquake and Volcanic Hazard study for the Valle Central (Costa Rica), and the Managua Metropolitan Fault Hazard Study (Nicaragua).

Mitchell Hastings, PhD, RIZZO International, Inc.

Dr. Mitchell Hastings is the Director of Computational Geophysics at RIZZO International Incorporated. He joined RIZZO in 2022 after completing his doctorate on modeling volcanic and tectonic systems in the western United States (Idaho) and in Central America (Costa Rica and Nicaragua) and has since been involved on probabilistic volcanic and seismic hazard assessments. His technical expertise ranges from conducting geophysical field surveys, such as gravity and magnetic surveys, terrestrial radar interferometry, and geologic mapping, to numerical and statistical analysis of complex volcanotectonic systems. Projects of note include identifying and characterizing large silicic intrusions and their emplacement-related surface deformation in southeastern Idaho, quantifying slow-slip events and earthquake interactions in Costa Rica, probabilistic volcanic hazard assessment for a proposed nuclear facility on the Eastern Snake River Plain, and probabilistic seismic hazard assessment for the Krško Nuclear Power Plant in Slovenia.

Kelley Shaw, PG, CEG, Slate Geotechnical Consultants

Mrs. Kelley Shaw is a registered professional geologist and engineering geologist, with extensive experience in seismic hazard studies, geotechnical investigations, geologic mapping, and geophysical studies. Over the last 13 years, she has contributed to a wide array of projects across the United States and internationally. Her expertise includes the characterization of seismic sources, conducting probabilistic and deterministic ground motion analyses, and evaluating fault rupture hazards. Kelley is skilled in geologic field mapping, geotechnical drilling, with a strong background in soil logging. Kelley has successfully managed large-scale, multi-year subsurface investigations, leading diverse teams of subcontractors and subconsultants, collecting valuable data in challenging conditions. Notable projects include SSHAC 3 Probabilistic Volcanic Hazard Analysis for Idaho National Lab, SSHAC EL2 Probabilistic Seismic Hazard Analysis for NPP in western South Africa, and Probabilistic Seismic Hazard Analysis for the Point Lepreau NPP.

Gerry L. Stirewalt, PhD, PG, CEG, Senior Geologist and Environmental Technical Reviewer, U.S. Nuclear Regulatory Commission

Dr. Gerry Stirewalt, a Structural Geologist and member of AEG for more than 48 years who formed and co-chairs AEG's GASH TWG, is a Registered Professional Geologist (PG) in North Carolina and Oregon and a Certified Engineering Geologist (CEG) in Oregon. He conducted post-doctoral research at Lamont-Doherty Earth Observatory in New York (1969 - 1971) and taught undergraduate geoscience classes at the University of British Columbia in Canada, Furman University in South Carolina, and his PhD alma mater, the University of North Carolina at Chapel Hill (1971 - 1975). Gerry worked for various contractors and as an independent consultant between 1973 and 2005 on projects in Southeast Asia and the United States (U.S.) involving geologic characterization of sites for proposed new nuclear power facilities; the U.S. Department of Energy's (DOE) salt and crystalline rock repository site exploration programs for disposal of high-level radioactive waste (HLW), including public outreach meetings in states being considered for a HLW repository; the Canadian Underground Research Laboratory crystalline rock HLW disposal program in Manitoba; and DOE's geologic repository HLW disposal program in volcanic rock at Yucca Mountain (YM), Nevada. He was the lead technical expert on 3D geospatial modeling of DOE's proposed HLW disposal site at YM, as well as sites for non-HLW facilities, for the U.S. Nuclear Regulatory Commission (NRC). At the NRC from 2005 to 2024, Gerry worked to protect public health and safety and the environment by ensuring nuclear power reactor applicants adequately characterized geologic features at proposed nuclear facility sites in accordance with regulatory safety requirements in Title 10 of the Code of Federal Regulations (10 CFR). This effort involving accomplishing the following: [1] Conducting outreach efforts to address public concerns about the geologic characterization of DOE's proposed YM HLW disposal site; [2] writing the geologic sections for six Safety Evaluation Reports for proposed nuclear power reactor sites in the southeastern U.S.; [3] participating in briefings and mandatory public hearings for those six sites, one of which was a contested hearing; [4] functioning as a member of the Technical Integration Team for characterization of seismic sources in the central and eastern U.S. using the Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 process, the results of which were published by the NRC in NUREG-2115; [5] assessment of geologic and seismic data collected by the Columbia Generating Station licensee in Washington State, as required by the NRC for seismic hazard re-evaluation of that nuclear power plant after the incident at the Fukushima nuclear facility in Japan in March 2011, which was due to a M9 earthquake and tsunami generated by displacement along an offshore thrust fault; [6] development and implementation of the NRC's Geologic Mapping License Condition to ensure licensees adequately characterized geologic features found in excavations for safety-related engineered structures at proposed new nuclear power reactor sites; [7] functioning as a member of the initial NRC team that developed Regulatory Guide 4.26 addressing characterization of volcanic hazards at proposed new nuclear power facility sites; [8] addressing natural hazards associated with faulting and volcanism site characterization issues at potential new reactor sites in meetings with external stakeholders; [9] observing SSHAC assessment of volcanic hazards at Idaho National Laboratory workshops conducted by the DOE to ensure that the SSHAC process was followed; and [10] contract management to ensure technical work performed by NRC contractors was timely, of high quality, and within budget. From 2024 to the present at the NRC, Gerry worked to expand his regulatory knowledge and experience beyond geologic site safety concerns to include National Environmental Policy Act (NEPA) reviews under NRC environmental protection regulations in 10 CFR Part 51 for renewal of operating nuclear power plant licenses and licensing of new and advanced reactors. He currently reviews Environmental Reports prepared by applicants and the technical information acquired during discussions with the applicants and observations made during environmental site audits related to geologic environment and groundwater resources at and adjacent to the existing or proposed new power plants. Using that site-specific information, he prepares parts of the Environmental Assessments (EAs) and Environmental Impact Statements (EISs) for renewal of operating nuclear power plant licenses and licensing of new and advanced reactors. The EAs and EISs address the potential environmental effects from construction and operation of the respective nuclear power facilities on the geologic environment and groundwater resources to ensure those two facets of the natural environment are not detrimentally affected.

3D Analysis of Silicic Volcanism in Basaltic Flow Fields Using Aerogravity and AeroLiDAR

Berkey, Troy, University of South Florida, troyberkey@usf.edu; Connor, Charles, University of South Florida, cbconnor@usf.edu; Wetmore, Paul, wetmore@usf.edu; Bakowski, Rachel, University of South Florida bakowskir@usf.edu; Bockholt, Blaine, Idaho National Laboratory, blaine.bockholt@inl.gov

The Eastern Snake River Plain (ESRP) in Idaho, USA, hosts extensive silicic volcanism, yet its subsurface structure and eruption history remain poorly constrained. Estimating silicic magma volumes is essential for improving hazard and forecasting models, which rely on volume assessments and eruption rates to predict future activity. This study represents an initial step in quantifying silicic volcanic volumes in the ESRP by integrating aerogravity and aeroLiDAR data from the Idaho National Laboratory (INL) to estimate the 3D subsurface structure and volume of silicic volcanic features. We applied 3D inversions of gravity data, with surface volumes derived from high-resolution LiDAR data (< 1m) subtracted to isolate subsurface mass distributions. Results indicate these silicic features have relatively shallow bases, ranging from ~100 to 350 m, with East Butte (EB, ~600 ka) and Middle Butte (MB, <1 Ma) extending to 100–200 m and Big Southern Butte (BSB, ~300 ka) reaching 100–350 m. Estimated volumes range from 10^8 m^3 (MB) to 10^9 m^3 (EB and BSB), varying with depth and density contrasts used in the models. Eruption volumes associated with these features increased over time, suggesting progressive silicic magma accumulation within the ESRP and changes in eruption dynamics. These estimates provide critical input for hazard models by refining volume constraints, assessing magma supply rates, and improving recurrence interval calculations. The results highlight the effectiveness of aerogravity and aeroLiDAR in resolving subsurface silicic volcanic structures, improving volume estimates, and enhancing hazard forecasting. Future work will focus on refining these techniques to better constrain buried caldera volumes across the ESRP, further improving estimates of silicic magma storage and recurrence rates. These methods are also applicable to other bimodal volcanic fields where silicic magmatism is difficult to quantify due to overlying basaltic eruptions, offering a valuable framework for assessing volcanic hazards in similarly complex volcanic systems.

Bio:

Troy Berkey is a geophysicist specializing in gravity and magnetic modeling to aid volcanic hazard forecasting, with expertise in geophysical survey design, numerical inversion techniques, and geologic mapping. He is a Ph.D. student at the University of South Florida, where he develops computational methods in Python and C to enhance potential field modeling, improve the characterization of subsurface volcanic structures, and advance the interpretation of volcanic systems. His research integrates gravity, magnetic, and LiDAR data to model fissure-fed dike systems, silicic intrusions, and lava tubes, contributing to both terrestrial hazard assessments and planetary exploration. He has conducted fieldwork across volcanic terrains in the western U.S., including Idaho, California, Utah, Arizona, and Oregon, applying geophysical techniques to investigate subsurface magmatic systems. He earned a B.S. in Geology from Indiana University of Pennsylvania and an M.S. in Geology (Geophysics/Volcanology) from the University of South Florida.

Constraining Deformation at Volcanic Systems; Using Deep Learning to Mitigate Atmospheric Effects in InSAR Displacement Maps

Bussard, Rebecca, Pennsylvania State University, rqb5400@psu.edu; Wauthier, Christelle, Pennsylvania State University, cuw25@psu.edu

Atmospheric artifacts are a common cause of noise in InSAR data that can mask deformation signals related to volcanic activity. While several techniques have been developed over the past few decades to mitigate atmospheric noise, the success of these techniques is highly variable depending on the regional setting, and in some cases can even introduce more noise. We introduce a Convolutional Neural Network (CNN) trained to predict deformation from input consecutively unwrapped InSAR displacement maps. The CNN framework consists of a U-net structure that runs the input data through a series of convolution and deconvolution layers to handle the dimensionality of such a large image dataset, as well as to improve the model's generalization capacity. For model training, we simulate ground deformation from a magma storage region using a point source at depth undergoing various volume changes (linear, step-wise, sinusoidal) through time. The resulting input data consists of 5000 unique time series of 20 unwrapped deformation maps each that are read into the CNN. We also test whether adding simulated atmospheric noise or downloaded atmospheric phase maps from Generic Atmospheric Correction Online Service for InSAR (GACOS) to these deformation time series trains the CNN to produce better deformation predictions from Cosmo-SkyMed unwrapped interferograms over Masaya volcano. Understanding how to train the CNN to improve prediction accuracy will allow us to apply the model more generally at a variety of other volcanic systems to better constrain ground deformation during their eruptive cycles.

Bio:

Dr. Rebecca Bussard is currently a post-doctoral scholar at Penn State University, where she is combining geodetic techniques including InSAR with deep learning to better extract deformation signal from her areas of interest. During her PhD in Earth Sciences at the University of Oregon, she studied both distributed and focused magmatic systems from the Cascades Volcanic Arc to the southwest US to New Zealand. Her work involves ranges from optical and microwave remote sensing of composite volcanoes to statistical analysis of distributed volcanic fields.

Approach to Screening Volcanic Phenomena in Volcanic Terrain

Cline, K. Michael, RIZZO International, Michael.cline@rizzointl.com; Hackett, William, WRH Associates, wrhackett@comcast.net; Hastings, Mitchell, RIZZO International, Mitchell.hastings@rizzointl.com, Connor, Charles, University of South Florida, cbconnor@usf.edu; Kimball, Jeffrey, RIZZO International, Jeffrey.kimball@rizzointl.com

The myriad of volcanic features (sources) and associated phenomena (products of volcanic sources) present in volcanic fields pose organizational challenges when assessing volcanic hazards. This is particularly the case when evaluating volcanic hazards for critical facilities or population centers that lie within or near volcanic fields. In accordance with the U.S. Nuclear Regulatory Commission's Regulatory Guide 4.26, we develop a screening process to comprehensively and systematically evaluate near and far field volcanic features and their associated phenomena to assess the volcanic hazards relevant to a given site. The first step involves developing a tectono-magmatic conceptual model (TMCM) of Quaternary volcanism, which serves as the basis for identifying magma types and volcanic features that may be present within the region of interest. This process may result in an overwhelming number of features and phenomena to evaluate; therefore, a screening matrix is used to systematically identify those phenomena common to different volcanic features. The matrix plots observed features, including distant sources, against possible phenomena. If a phenomenon listed in the matrix is not identified within the geologic record nor associated with a magma-type or volcanic feature present in the region of interest, it is screened out requiring no further evaluation. Those phenomena screened in (i.e., present within the region of interest) are then evaluated using a grading scheme to determine the level of analysis required to characterize the hazard based on their presence, frequency, and potential impact. The grading scheme ranges from simply documenting the potential hazard based on the available data to requiring statistical and numerical modeling to quantify the hazard. This approach was successfully implemented for the investigation of a proposed nuclear facility site on the Eastern Snake River Plain (ESRP), Idaho. Eight (8) features within the region of interest, four (4) distal sources, and 18 phenomena were identified. This amounted to 180 possible phenomena related to the volcanic sources. Of the 180 possible phenomena identified, 85 were screened out because they were not present, 39 were screened out by technical justification or simple calculation, 30 required a bounding calculation, and 26 were deemed significant requiring numerical modeling to quantify the potential hazard. We conclude that this is a logical, organized, and systematic approach to assessing volcanic hazards.

Bio:

Mr. Michael Cline, registered professional geologist, is a principal geologist with RIZZO International, Inc. (RIZZO). He has more than 50 years of professional experience participating in and managing seismic, fault displacement, and volcanic hazard analyses for nuclear facilities, dam projects, and major population centers. This work has included probabilistic hazard analyses. He has also performed independent technical reviews of geologic hazard investigations. He has technical expertise in remote sensing imagery interpretation, paleoseismology, geomorphology, structural geology, geologic mapping, economic geology, and high-resolution seismic surveys. His management experience includes field offices, large-scale projects, major programs, and corporate operations. His geographical experience includes conducting investigations in North America, Central America, and South America; the Middle East; Europe; and northern Asia. Notable projects include a probabilistic volcanic hazard analysis for a nuclear power site on the Eastern Snake River Plain (Idaho), Pantex Probabilistic Seismic Hazard Analysis (Texas), Probabilistic Seismic Hazard Analysis for the Krsko Nuclear Power Plant (Slovenia), Yucca Mountain Probabilistic Volcanic Hazard Analysis and Consequence Analyses (Nevada), Tsruga Nuclear Power Plant fault hazard study (Japan), Earthquake and Volcanic Hazard study for the Valle Central (Costa Rica), and the Managua Metropolitan Fault Hazard Study (Nicaragua).

On March 11, 2025, HVO geologists observed episode 13 of the ongoing Kīlauea summit eruption from the western caldera rim. Lava fountains from the north vent (left) and south vent (right) were feeding channelized flows across the floor of Halemaʻumaʻu crater. USGS photo by M. Patrick.

New Methods Developed for the Probabilistic Volcanic Hazard Assessment of the Idaho National Lab: A SSHAC Level 3 Investigation

Connor, Charles, University of South Florida, cbconnor@usf.edu

Several new methods in probabilistic hazard assessment were invented for the recent SSHAC Level 3 investigation of volcanic hazards at the Idaho National Lab (INL). These include development of a new approach to spatial density estimation of events that is generally applicable to point processes in hazard assessment, such as locations of future volcanic vents, earthquakes, landslide, and other hazardous phenomena. By developing machine learning methods to improve spatial density estimation, we have been able to make these probabilistic estimates more sensitive to tectonic models. Specifically, we employ a Random Forest machine learning algorithm that objectively combines multiple statistical models of spatial density with multiple geophysical models across a common area within a distributed volcanic field (DVF). This approach uses a variance weighting scheme to create composite spatial density estimates that directly incorporate relevant geophysical observations with statistical models for the probability of the opening of new vents. The approach is applied and tested in the eastern Snake River Plain (ESRP), Idaho, where 617 Quaternary vents are mapped along the path of the Yellowstone hotspot track. Six spatial density models are applied to this dataset: three kernel density estimators and three adaptive estimators. Four geophysical models and measurements are included as predictor variables: (1) long-wavelength topography, (2) a strain model for a block representing the ESRP lithosphere, (3) an ESRP gravity model, and (4) an ESRP aeromagnetic model. Composite Random Forest spatial density estimates are created using the multiple spatial density and geophysical data grids. A composite spatial density estimate for the opening of new vents is then applied to a tephra fallout hazard assessment for various facilities located within the INL on the ESRP. This approach could be used as an alternative to expert judgment when weighting alternative spatial density models for probabilistic volcanic hazard assessments.

Bio:

Dr. Conner is a Professor in the School of Geosciences in USF's College of Arts and Sciences and Partner in DMI, LLC. Over the course of his career, Dr. Connor has made significant breakthroughs in the fields of volcanology and natural hazards assessment which have contributed to national and international policies on preventing and mitigating natural disasters and advancing understanding and prediction of volcanoes and their effects. His work has had substantial impact on government policy worldwide on volcanic hazard assessment for nuclear facilities, especially nuclear power plants and high-level radioactive waste facilities. He developed one of the first algorithms for modeling volcanic ash fallout which is still in wide use across the field. He and colleagues also developed a highly efficient lava flow inundation code that can be used to make probabilistic hazard maps, and which has been successfully implemented worldwide for modeling lava flow hazards, in countries including New Zealand, Mexico, Colombia, the western U.S., Jordan, and Nicaragua, among others. He revealed the clustered nature of volcanism in volcanic arcs and how to quantify these patterns of volcanic activity. He and his research team also developed a new method for constraining the ages of the youngest volcanoes on Mars — a method helping to clarify the ages of volcanic features around our solar system. His extensive leadership includes serving on panels of the International Atomic Energy Agency which developed guidelines for evaluating potential volcanic hazards at nuclear energy sites worldwide; serving on an expert panel for the U.S. Department of Energy; and member of two National Academies' committees. He holds B.A. and B.S. degrees from the University of Illinois (Urbana-Champaign), and earned his M.S. and Ph.D. from Dartmouth College.

Craters of the Moon National Monument and Preserve, Idaho. Photo Credit: https://www.discoverlostrivervalley.com/contact-us/

The Successful Application of the SSHAC Level 3 Process in the Integrated Multisite INL PVHA: Regulatory Compliance and Future Use

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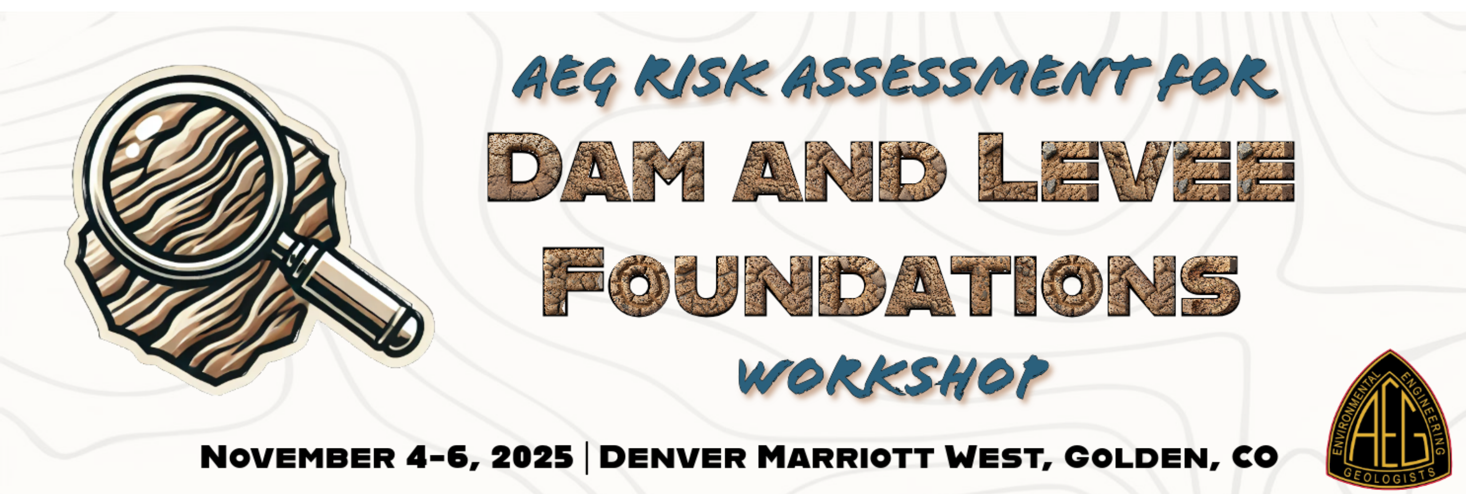
The Idaho National Laboratory Probabilistic Volcanic Hazard Assessment (INL PVHA) was conducted using a SSHAC Level 3 (SL3) process, which has seen considerable application for nuclear and critical facilities throughout the US and internationally. Typically, the experience gained from these projects has been for probabilistic seismic hazard assessments (PSHA), but the SL3 approach is applicable to any natural hazards assessments where the hazards are uncertain and quantifiable. SSHAC implementation guidance, such as NUREG-2213 (NRC 2018), states the procedures are adaptable to accommodate a wide range of Natural Phenomena Hazards (NPH) assessments and the INL PVHA is a notable example. The INL PVHA includes all of the essential aspects of the SL3 process, including: the fundamental goal of capturing the center, body, and range of technically defensible interpretations; detailed project planning to define the project organization; expert selection criteria; roles and responsibilities for all participants; project activities that occur during the evaluation, integration, and documentation phases; database compilation, dissemination, and new data collection; and clear definition of the site-specific hazard products for each facility. The INL PVHA workflow was designed to follow the guidance in NRC Regulatory Guide 4.26 regarding the basic steps and development of conditional and integrated hazard probabilities. The screening activity was extensive, given the potential for both proximal and distal volcanic hazards, and the evidence of diverse Quaternary basaltic and silicic volcanic processes in the INL region. Database development was a critically important activity and tapped the long history of geologic and geophysical studies and monitoring at INL. The PVHA model was built by the Technical Integration (TI) team with due consideration of the available data, and uncertainties were quantified using well-known tools such as logic trees and probability distributions. The INL PVHA anticipated the use of the results at multiple existing sites of interest for design safety assessments with future definition of characteristics of each hazard (e.g., lava flow, tephra fall), as needed. The comprehensive multisite PVHA provides a basis for future applications at other sites as well as a basis for periodic NPH updates at INL, as required by DOE regulations. With the recent completion of the SL3 PSHA and PVHA, subsequent updates at various INL sites can be conducted using lower SSHAC levels. The use of SSHAC Level 1 and 2 studies to update previous Level 3 studies has become quite common throughout the US and demonstrates the flexibility of the SSHAC process to incorporate previous information in a cost- and time-efficient manner. Work planning for such follow-on studies is underway.

Bio:

Kevin J Coppersmith, Ph.D., of Coppersmith Consulting, Inc., has more than 45 years of consulting experience, with primary emphasis in probabilistic hazard analyses (seismic, volcanic, tsunami, fault displacement, and related geohazards) for design and safety review of critical facilities within regulated environments. He has pioneered approaches to characterizing earth sciences data and their associated uncertainties for probabilistic seismic hazard analysis(es) (PSHAs) for a range of critical facility sites, including nuclear power plant sites, high-level waste repositories, dams, offshore platforms, pipelines, and bridges. Dr. Coppersmith was a member of the Senior Seismic Hazard Analysis Committee (SSHAC), which provided expert judgment methodology guidance to the U.S. Nuclear Regulatory Commission (NRC), U.S. Department of Energy (DOE), and Electric Power Research Institute (EPRI). As a coprincipal investigator (PI), he has worked with NRC research staff reviewing lessons learned from the application of SSHAC Level 3 and 4 methodologies resulting in NUREG-2117 and was a coauthor of the SSHAC guidance in NUREG-2213 providing detailed implementation guidance for SSHAC studies of all Study Levels. Dr. Coppersmith was the Technical Facilitator/Integrator for the SSHAC Level 4 probabilistic volcanic hazard analysis (PVHA) conducted in 1996 for Yucca Mountain, as well as for the update to that study completed in 2008. He recently served as the Project Technical Integrator for the INL PVHA, which is the integrated multi-site volcanic hazard analysis to be used for safety assessments of several nuclear facilities. Dr. Coppersmith has participated in ~35 SSHAC hazard studies worldwide ranging from SSHAC Levels 1 through 4.



Real Time Graben Formation in Grindavík Iceland and Associated Hazards in the Volcanic-Tectonic System

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How do we or can we constrain the rift and graben extension with partitioning between tectonics (i.e., non-magmatic faulting) and igneous intrusions (i.e.. diking)? Is rifting continuous or is diking and periodic opening of rifts the main process at play here? Extensional plate boundaries present certain challenges for Southwest Iceland (i.e., Reykjanes) today with 2023 to present Grindavík and Svartsengi related tectonic (i.e., fault ruptures destroying infrastructure) and lava protection barriers costing over $1.5 Billion USD. However, this unrest allows opportunities and provides new observations related to extensional seismic-tectonic-volcanic systems. A review of graben forming and extensional events from around the world, in addition to those from 2023-present in Grindavík (e.g., De Pascale et al., 2024), gives us firsthand insight into graben formation and transtensional extensive systems and implications for tectonic and diking controls of both geological structures and subsequent control of volcanism. Dike intrusions certainly play a role (e.g., Sigmundsson et al., 2024), but can we decouple graben forming mechanisms? In Grindavík, we documented graben formation in real-time through satellite mapping (InSAR), seismicity, GNSS data, repeated lidar surveys, and field mapping. Five normal faults, some with strike slip components, and several fissures ruptured the surface delineating two grabens (~ 5 km wide at surface) separated by a horst, a context not present in other contemporary case studies. The graben normal faults slipped rapidly (i.e., over hours) and maximum surface motions coincided with the occurrence of turbulent seismic swarms in both space and time. Although 3 eruptions took place nearby (<15 km away) from 2021 to 2023 attributed to dikes, none of these also formed grabens, thus Grindavík gives us a rare 4D insight into extensional systems to explore the questions posed above which remain major challenges in our understanding of how plate boundaries operate.

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Bio:

Dr. Gregory P. De Pascale is currently an Associate Professor (Docent) of Structural Geology and Tectonics in the School of Engineering and Natural Sciences and member of the Science Institute at the University of Iceland. He was formerly an Assistant Professor of Geology at the University of Chile. He has a PhD in Geology from the University of Canterbury in New Zealand where he worked on New Zealand's plate boundary. Between academic postings, Dr. De Pascale has extensive experience in the private sector working on geological hazards including fault ruptures and seismic source characterisation and analysis of faults and fault systems globally. Although he has worked in the field on all 7 Continents, he is currently focusing on the Patagonian Andes of Chile and Argentina and Iceland's currently very active plate boundary. His students and he use classic field structural geology techniques mixed with modern and ever-improving tech including lidar and structure from motion (SfM) drone models in addition to subsurface and submarine geophysics, and Quaternary dating to explore, characterise, and model active faults and neotectonics and associated geohazards including earthquakes and seismic hazard, fault rupture, and the interaction between active tectonic structures and volcanism.

Improving Volcanic Hazard Assessment at Makushin Volcano and for the Community of Unalaska, Alaska

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Most efforts to assess hazards at active volcanoes lead to detailed reports and hazard maps that may not be readily usable by those who live, work, and play in the areas at risk. We discuss a new hazard assessment of Makushin Volcano, Alaska, that incorporates user needs, revised eruptive history, and physics-based modeling to develop a "next-generation" of volcano hazard products. Makushin is a stratovolcano located near the remote city of Unalaska and the large port of Dutch Harbor in the eastern Aleutian Islands (population ~4,200 with up to 5,000–10,000 seasonal workers). While historical eruptions of Makushin have been small with limited impacts, it has a highly explosive past. Recent eruptions from Makushin and regional volcanoes, as well as larger events like those of the past, can impact the community, infrastructure, air and marine transportation, and major fishing industry owing to airborne ash and ash fall. We met with government, tribal, industry, and community organizations to learn how the previous long-term hazard products and short-term unrest-and-eruption products are used. We investigated unmet needs for hazard information and received feedback on product content and design virtually and in-person. The results reveal not only a need for an up-to-date, complete, detailed hazard map and report but also integrated information on hazards from regional volcanism and a short-format pamphlet and public signage to provide accessible and distributable information. Users also requested QR codes to link these to online real-time hazard information. Our results show that the integration of physical and online products helps meet many diverse needs of this volcanically active and remote region and may inform user engagement and hazard assessment elsewhere.

Bio:
Hannah Dietterich is a Research Geophysicist at the U.S. Geological Survey Alaska Volcano Observatory. Her work focuses on the physics of volcanic processes, remote sensing of volcanic activity, numerical modeling of volcanic hazards, and probabilistic volcanic hazard assessment. She integrates geologic mapping, physical volcanology, remote sensing, and numerical modeling with observations of ongoing eruptions to advance our understanding of volcanic hazards.

How Volcanoes Work

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This presentation is a qualitative overview to illustrate terrestrial volcanic processes and phenomena. It provides a foundation for subsequent presentations on hazard assessment, numerical and analytical modeling, specific eruptive phenomena, and regulatory considerations. There is no accurate count of the world's volcanoes but about 70 erupt each year, more than 1,000 have erupted during the Holocene (i.e., the last 10,000 years), there are at least 1,000 identified magma systems on land and many thousands more submarine volcanoes. These occur worldwide near facilities and population centers as central volcanoes formed by multiple eruptions over millions of years (e.g., the polygenetic composite cones of the Pacific rim and the basaltic caldera systems of oceanic island chains). Other volcanoes form during a single geologically brief event, commonly clustered as monogenetic pyroclastic cones, and lava fields of distributed volcanic fields. Magma generation, rise and storage are key processes of global tectonics, reflecting deep thermal and stress regimes along plate boundaries and within tectonically extending plate interiors. Magma composition is controlled by the protolith, the degree of partial melting and the P-T conditions of melting. Chemical composition and temperature control the physical properties of magma, viscosity and volatile content being the fundamental controls on eruptive phenomena. These range from low-energy effusive volcanism (e.g., fluid basaltic lava flows, minor magma fragmentation) to high-energy explosive volcanism including major fragmentation and tephra eruption of silicic magma. Interaction with the hydrosphere and atmosphere further affects explosivity and dispersal. Potentially hazardous volcanic phenomena have diverse characteristics and dispersal patterns: opening of new vents, ground deformation, ballistic ejecta, tephra fallout, atmospheric phenomena (lightning, shock waves), hydrothermal activity, volcanic gases, lava flows and domes, pyroclastic density currents, lahars, debris avalanches and sector collapse, volcanic tsunami, volcanic earthquakes. Each of these will be described and illustrated. Not all phenomena leave a record, so multiple methods are employed for identification and interpretation: forensic observation and interpretation of prehistoric deposits; observations of actual eruptions at analog volcanoes; and theoretical, numerical, and analytical models of physical-volcanic processes.

Bio:
Bill earned his BA in Geology at Franklin & Marshall College, his MS in Earth Science from Case Western Reserve University and his PhD from Victoria University of Wellington New Zealand, where he studied Mt Ruapehu, a large composite volcano of central North Island, and authored publications on its volcanic stratigraphy, petrology and hazards. At Idaho State University (ISU) he taught a slate of graduate and undergraduate courses including introductory geology, mineralogy, igneous & metamorphic petrology, regional geology, scientific photography and physical volcanology. In Idaho he pursued student-collaborative research on the Eastern Snake River Plain and the Challis volcanics of central Idaho, and co-authored publications from research in those areas. He edited Guidebook to the Geology of Central and Southern Idaho (Idaho Geological Survey Press) and co-authored Paleoseismology of Volcanic Environments, Chapter 4 of the monograph Paleoseismology, focusing on dike-propagation processes with illustrations from the eastern Snake River Plain. Bill served as a staff scientist at the Idaho National Laboratory, which offered many opportunities for applied research in volcanology, seismology, hydrology and safety analysis of nuclear facilities. Bill is Idaho Registered Professional Geologist #704. His consulting practice also includes research for commercial clients, including exploration models for volcanic-hosted ore deposits and bulk-commodity mining operations. He served on two SSHAC Level 4 volcanic hazard expert panels for the Yucca Mountain Project in Nevada, the proposed U.S. high-level nuclear waste repository. He consulted for the Carbon Free Power Project, a proposed SMR at the INL, and co-authored its volcanic hazards assessment. Since the 1990s he has served on INL teams for a number of seismic- and volcanic hazards assessments. He designed and worked on a volcanic-hazard assessment of Taiwan. Most recently he was Lead of the Technical Integration Team of the SSHAC Level 3 PVHA for the INL. When he's not engaged in geoscience, Bill enjoys woodworking, fly fishing, hiking and photography.

Comparing Lava Flow Inundation Hazard from Borehole and Numerical Methods: A Case Study from the Eastern Snake River Plain, Idaho, USA

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Lava flows are critical hazards to communities and infrastructure located near volcanoes. Evaluation of lava flow hazard depends on factors such as physical and chemical properties of the lava, eruptive style, local topography, and frequency of eruptions. In distributed volcanic fields, where renewed volcanism typically results in the formation of a new vent/edifice, future eruptions can occur anywhere within the field making the evaluation more difficult. As part of a recent project to assess the volcanic hazards for a proposed nuclear facility on the Eastern Snake River Plain (ESRP) in southcentral Idaho, two methods were used to quantify lava flow hazards at the site. The first method used data from a borehole nearly 1,600 ft deep, paleomagnetic data, and radiometric age dating to correlate buried lava flows to their sources and constrain their ages. The borehole data help quantify the evolution of lava flows reaching the site location over the last ~780ka. The second method used numerical methods to estimate the annual probability of a lava flow erupting on the ESRP and reaching the site. This included spatial density and volcanic event age models to quantify the probabilities of where and how often a future eruption could occur, as well as a lava flow model to estimate the areas on the ESRP that generate lava flows that reach the site, termed the lava catchment. The results from the borehole method suggest that lava flows occur on the ESRP and reach the site location every ~55-98 kyr, while the numerical methods suggest that the return interval is significantly longer (1.5 Myr to 970 kyr). We interpret the borehole results to be biased against the constructional topography associated with the local lava flows over time that have reduced the size and morphology of the lava catchment. Meanwhile, the numerical methods consider the current topography as well as the spatio-temporal patterns of volcanic eruptions on the ESRP as a whole, rather than the borehole data which considers only the eruptions that intercept the location of the borehole.

Bio:
Dr. Mitchell Hastings is the Director of Computational Geophysics at RIZZO International Incorporated. He joined RIZZO in 2022 after completing his doctorate on modeling volcanic and tectonic systems in the western United States (Idaho) and in Central America (Costa Rica and Nicaragua) and has since been involved on probabilistic volcanic and seismic hazard assessments. His technical expertise ranges from conducting geophysical field surveys, such as gravity and magnetic surveys, terrestrial radar interferometry, and geologic mapping, to numerical and statistical analysis of complex volcanotectonic systems. Projects of note include identifying and characterizing large silicic intrusions and their emplacement-related surface deformation in southeastern Idaho, quantifying slow-slip events and earthquake interactions in Costa Rica, probabilistic volcanic hazard assessment for a proposed nuclear facility on the Eastern Snake River Plain, and probabilistic seismic hazard assessment for the Krško Nuclear Power Plant in Slovenia.

To SSHAC, or Not To SSHAC: The Volcanic Hazards Question

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Some sites might not require a SSHAC study to develop a technically defensible probabilistic volcanic hazards assessment (PVHA). The low likelihoods of volcanic hazards in many areas represent beyond design-basis external events. Predominantly aleatory uncertainties in mean hazard also adequately capture a defensible range of uncertainty for probabilistic risk assessments and other licensing analyses. The PVHA technical investigation for the proposed TerraPower site near Kemmerer, WY (NRC ADAMS ML23115A387), followed a stepwise approach from NRC Regulatory Guide 4.26: 1) Published information identified ≈600 volcanoes <2.6 Ma within 100–320 km of the proposed site; 2) Deterministic criteria allowed screening-out of all hazards except tephra fallout; 3) Characteristics of past tephra eruptions were developed using straightforward analyses; 4) Mean and 95th percentile tephra-thickness exceedance curves were calculated using an NRC-accepted tephra dispersal model (ASHPLUME); 5) Peak-flood events in ephemeral drainages would not remobilize sufficient tephra to form overbank debris flows that might reach the proposed site. The likelihood of any measurable tephra fallout at the proposed site is $<10^{-5}$/yr. NRC accepted the TerraPower PVHA report for licensing in 9/2024 (NRC ADAMS ML24198A092). Based on lessons learned from this investigation, a SSHAC study might not be needed to conduct a defensible PVHA if: i) a precise evaluation of hazards isn't needed to support design basis; ii) hazard uncertainties can be evaluated using available information and analyses with straightforward technical bases; iii) large aleatory uncertainties are more significant than epistemic uncertainties from alternative models; iv) potential caldera eruptions can be bounded by analyses of past events; v) site characteristics inhibit formation of post-eruption debris flow hazards; and vi) the final report undergoes a rigorous, independent technical review. The technical investigation also can shift to a SSHAC-level process if data or model uncertainties become intractable, or if input and review from multiple experts appears warranted.

Bio:

Brittain's 40-year-career has focused on applying scientific research to solve real-world hazard and risk problems, and on developing fundamental insights on how hazardous phenomena work. In addition to having extensive experience in technical, public, and policy communication, he has conducted many field investigations at quiet and grumpy volcanoes around the world. For the last seven years of pseudo-retirement, he has continued to consult on variety of interesting volcanic hazard issues at nuclear installations around the world. Before retirement, he served as the U.S. Nuclear Regulatory Commission's Senior Advisor for Repository Science. In that role, he helped the NRC make risk-informed technical, regulatory, and policy decisions on geoscience safety issues at all U.S. nuclear facilities, including the proposed Yucca Mountain nuclear waste repository. He also collaborated with the International Atomic Energy Agency to develop and apply regulatory and technical guidance for conducting volcanic hazard assessments, and other nuclear safety issues. Prior to joining the NRC, he was a Principal Scientist at the Southwest Research Institute, where he directed scientific research and detailed risk assessments for engineered facilities. Early on, he worked extensively in the geothermal industry, including a stint with the Oregon Department of Geology and Mineral Industries, and was a consultant for various natural resource companies while working on his degrees. He has earned M.S. (1984) and Ph.D. (1991) degrees in geology from Oregon State University.

Building and Curating a Comprehensive Dataset for Hazard Analysis in a Distributed Volcanic Field

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Volcanic hazard assessments rely on the successful integration of reliable inputs, models, and probabilities. In a distributed volcanic field, models need field-based data including single and multi-vent event locations, timing, styles, geochemistry, and approximate volumes of past eruptions. Depending on the size of the distributed field, it may not be reasonable to acquire these data for each eruptive event. The distributed volcanic field of the eastern Snake River Plain (ESRP) in Idaho is a basalt-dominated system that has been active for millions of years, covering more than 30,000 km^2 and locally exceeding 1.5 km thick. The majority of the vents in the ESRP are presumed to be buried by subsequent events. Lacking comprehensive subsurface vent data, the vents dataset used to conduct hazard analyses must be limited to those currently exposed at the surface. These vents are subdivided into groups on the basis of geochemistry and/or regional structural control, both of which may have a primary influence on subsequent eruptions. These data come from a variety of published and unpublished sources, including new field work and analysis of existing maps, digital elevation models (DEMs), and aerial imagery. This presentation will discuss the requirements and steps in building an input database for evaluation of a distributed volcanic field using the ESRP as a case study.

Bio:

Dr. Shannon Kobs Nawotniak (BS Geology Michigan Technological University, PhD Geology University at Buffalo) is a professor of volcanology at Idaho State University. Her work focuses on physical volcanology with emphasis areas in planetary analogs and science operations for exploration. She served as a member of the Idaho National Laboratory's Probabilistic Volcanic Hazard Assessment (PVHA) Technical Integration team.

VICTOR — A New Cyber-infrastructure for Volcanology

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Numerical models are essential for forecasting volcanic hazards for both short-term responses and long-term hazard assessment. While many models of volcanic processes already exist, challenges in finding, installing, and evaluating these models, coupled with limited computational resources, hinder their widespread use. To address this, we introduce VICTOR, the Volcanology Infrastructure for Computational Tools and Resources. VICTOR is a cutting-edge, cyber-infrastructure platform offering an open-source, cloud-based environment tailored for the volcanology community. It features Jupyter notebooks that integrate existing volcano models, such as the lava flow codes MOLASSES and IMEX_lava, the tephra dispersal codes Tephra2 and HYSPLIT, and the mass flow code TITAN2D. The backend of VICTOR is managed as a JupyterHub, operated by the non-profit 2i2c under the Code for Science and Society. VICTOR not only provides access to individual modeling tools, but also hosts workflows that use them in data inversion, model benchmarking, and uncertainty quantification. For example, we developed a workflow to validate mass flow models using multiple metrics and Bayesian statistics. VICTOR provides built-in access to external databases such as OpenTopography, Copernicus, and NASA's remote sensing products to streamline obtaining and using data in workflows. VICTOR also serves as an educational resource. In Spring 2023 and 2024 we taught graduate level, multi-institutional courses in Computational Volcanology using VICTOR, and we are creating multilingual tutorials for the workflows. We are developing teaching modules on topics such as lava flows and remote sensing to be shared with instructors. Lastly, VICTOR collaborates with national efforts including CONVERSE and SZ4D. In summary, VICTOR addresses the critical need for accessible, effective volcanic hazard modeling tools and resources, fostering advancements in both research and education within the volcanology community.

Bio:

Einat Lev is a volcanologist at Columbia University's Lamont-Doherty Earth Observatory. Dr. Lev got her PhD in Geophysics from MIT in 2009. Dr. Lev leads the Physical Volcanology group at LDEO which strives to improve our understanding of volcanic eruptions. Her team uses numerical modeling, analog lab experiments, and field observations at active volcanoes and eruptions to better understand how lava and magma move inside and outside volcanoes.

Shishaldin Volcano, or Mount Shishaldin, is one of six active volcanoes on Unimak Island in the eastern Aleutian Islands of Alaska. Photo Credit: USGS

Developing a Volcanogenic Tsunami Potential Index for Alaska Volcanoes

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Recent volcanogenic tsunamis generated during the December 2018 eruption of Anak Krakatau in Indonesia and the January 2022 eruption of Hunga Tonga-Hunga Ha' apai in the Kingdom of Tonga have resulted in fatalities and prompted the USGS to assess the potential of active volcanoes in Alaska to generate volcanogenic tsunamis. In this assessment of tsunami potential, we have developed several subaerial and submarine criteria that identify volcanoes with evidence of likely tsunami generation during eruptions in the last 12,000 years. These criteria were established taking into account all known tsunami generation mechanisms at volcanoes following a literature review and documented cases of tsunami generation during historical eruptions. Causes of volcanogenic tsunamis include edifice failure during or between eruptions, pyroclastic flow discharge into the sea, submarine slope failure, submarine explosions, and caldera formation (rapid subsidence). Adding complexity to these generation mechanisms is the fact that multiple mechanisms may be occurring simultaneously on the volcano during an eruption. In our assessment of the volcanogenic tsunami potential of 67 Alaska volcanoes we have used IFSAR-derived DEMS, published geologic maps, and surrounding bathymetric data to identify evidence of past flank failures, pyroclastic flows and debris avalanches reaching the shoreline, and caldera formation. Pertinent features include horseshoe-shaped collapse scars, evidence of lava bench collapse, hummocky and blocky subaerial topography and/or submarine bathymetry, bright sonar backscatter areas, and the presence of submarine calderas and vents. We also identify slopes steeper than 33 degrees, which may indicate potential for future collapse. We have identified and semi-quantitatively ranked the volcanoes in their volcanogenic tsunami potential based on the occurrence and number of these features, their known geologic deposits, eruptive histories, and historical accounts of tsunami activity. Our preliminary ranking has identified 9 high, 28 moderate, and 17 low potential volcanoes. Thirteen volcanoes were designated as too far from the ocean to have any tsunami potential. The high and moderate potential volcanoes are dominated by island volcanoes with steep slopes where flank collapse would result in near instantaneous displacement of seawater. Volcanoes where caldera-forming eruptions have occurred are represented in the high and moderate potential rankings, but their tsunami potential is more dependent on the probability of another large volume caldera-forming eruption more than any current subaerial or submarine morphologic features.

Bio:
Dr. Charles W. Mandeville is currently a research geologist for the Alaska Volcano Observatory of the U.S. Geological Survey (USGS) where he is now working on a volcano caused tsunamis hazard assessment for active Alaskan volcanoes. Dr. Mandeville served as the Program Coordinator (head) of the USGS Volcano Hazards Program for over ten years and as the deputy program head for 2.5 years. Prior to his service at USGS, he was a senior research scientist at the American Museum of Natural History for more than 13 years. He is a trained physical volcanologist and geochemist, and has conducted volcano research for the National Science Foundation at numerous sites throughout his career, including Krakatau and Galunggung volcanoes in Indonesia, Mount St. Helens in Washington, Crater Lake in Oregon, and Augustine Volcano in Alaska. He earned a bachelor's degree in geology from the University of Rhode Island (URI), a master's degree in geology from Virginia Tech, and a Ph.D. in oceanography from the URI Graduate School of Oceanography. In his years as Program Coordinator for the USGS, he was directly involved with efforts to establish a National Volcano Early Warning System for all active volcanoes in the United States and assisted in the management of the Volcano Disaster Assistance Program (a partnership between the USGS and USAID Bureau of Humanitarian Assistance) which assists developing countries during times of volcanic crises.

January 2022 eruption of Hunga Tonga-Hunga Ha' apai in the Kingdom of Tonga. Courtesy of Tonga Geological Services.

The Scale of Volcanic Ground Deformation

Montgomery-Brown, Emily, U.S. Geological Survey Cascades Volcano Observatory (emontgomery-brown@usgs.gov)

Ground deformation can originate from many processes, including tectonic and volcanic sources, with consequences ranging from inconsequential to hazardous. Subsidence events have been documented at volcanoes across the globe, some of which have caused damage to buildings and infrastructure, while others have been subsiding slowly for decades without any significant impacts. For example, the massive 2018 eruption of Kīlauea volcano, Hawaii, resulted in nearly a cubic kilometer of magma being withdrawn from the summit reservoir over the course of the 3-month eruption. The episodic collapse of the summit deepened the existing caldera by nearly 400 m and seismic shaking irrecoverably damaged the nearby Hawaiian Volcano Observatory. On the other hand, Lassen Volcanic Complex has been subsiding for decades, as the magma reservoir from the 1914-1917 eruption continues to cool and contract, resulting in about 1 cm/yr of subsidence. Other global examples of volcanic subsidence include Mt. Etna, Campi Flegrei, Medicine Lake, and Yellowstone.

Bio:

Emily Montgomery-Brown is a research geophysicist at the U.S. Geological Survey (USGS) Cascades Volcano Observatory specializing in volcano geodesy. She analyzes ground- and satellite-based data to understand how magma moves underground and how volcanoes change their shape before, during and after eruptions. She holds a BSc in Geology from New Mexico Tech with a minor in Math, and MS and PhD degrees in Geophysics from Stanford University. Her research involves exploring volcanic deformation using time-series analysis and numerical models that integrate multidisciplinary data including geodetic (GNSS, tiltmeters, strainmeters, InSAR), seismic, hydrological, and geological information. She has continued to extensively study eruptions, intrusions, and flank deformation at Kīlauea Volcano, Hawaii. Additional research projects include: finite element models of caldera deformation at Long Valley, shallow vent eruptions at Mt. Erebus, dike intrusion probabilities derived from exhumed volcanic centers, dynamics of coinciding flank deformation and eruptions at Mt. Etna, ongoing long-term deformation of the Three Sisters volcanic complex, and deformation processes at other Cascade volcanoes including Mt. St. Helens and Lassen. She was a visiting researcher at the Earthquake Research Institute at the University of Tokyo, and former co-chair of the joint IUGG IAVCEI/IAG Volcano Geodesy Commission. Her work directly contributes to the USGS's mission to enhance public safety through monitoring and assessing volcanic hazards, and delivering forecasts, warnings and information about volcanic hazards.

Volcanic Tsunamis: From Physics to Hazard Assessment.

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The tsunamis generated by the Anak Krakatau volcano landslide in 2018 and the Hunta-Tonga eruption in 2022 have served as a reminder that volcanic tsunami hazard must not be neglected and requires even greater concern from the scientific community. During this lecture, we will review the source mechanisms of volcanic tsunamis and their characteristics in terms of dynamics, geometry, and physical processes, with reference to relevant case studies. We will try to understand the links between the different types of volcanoes and the different types of eruptions on the one hand, and the different mechanisms that generate volcanic tsunamis on the other. The complexity of the physical processes at work during the generation of a volcanic tsunami makes their numerical modelling a challenge and that is why laboratory experiments are often needed to understand physical phenomena and improve numerical models. The presentation will also look at the existing monitoring strategies (e.g., Stromboli, Krakatau), and the uncertainties involved in predicting volcanic tsunamis, before concluding with a discussion of different approaches to hazard assessment.

Bio:

Raphaël Paris is a geologist working at Laboratoire Magmas & Volcans (CNRS-UCA, Clermont-Ferrand, France), with a 25-years' experience of research on tsunami deposits, volcanic tsunamis, and landslide tsunamis. Raphaël has developed an integrated approach to the volcanic tsunami hazard, combining information from tsunami deposits with laboratory experiments and numerical modelling. This approach was applied to natural cases studies of tsunamigenic eruptions in the Canary Islands, the Mediterranean (Santorini, Kolumbo) and Indonesia (Krakatau, Tambora).

Volcanic Earthquakes: Precursors and Hazards

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Ascending magma in the Earth's crust deforms host rocks, evolves compositionally, exsolves fluids and gas, and may erupt, generating a range of seismic signals referred to as volcanic earthquakes. Seismograms from local broadband seismic stations on and around volcanoes provide waveforms for determining source mechanisms, classifying volcanic earthquakes as volcanic-tectonic (VT), long period (or low frequency), very long period, volcanic tremor, and explosion events. Of these categories, VT earthquakes are the most hazardous because their moderate to large sizes can exceed magnitude 5.0, generating ground motions that threaten life and infrastructure. Several characteristics distinguish VT from tectonic earthquakes. VT earthquakes occur in short-duration swarms near volcanoes with multiple, same-size maximum magnitudes. Tectonic events exhibit mainshock-aftershock sequences with lower-magnitude, time-decaying aftershocks proximal to crustal faults. As precursors, VT earthquakes accompany vertical and lateral propagation of magma signaling a potential eruption. They can induce other volcanic hazards such as triggering collapse of a volcano edifice that initiates an eruption or generates a tsunami in a proximal waterbody. Low-frequency earthquakes (typically M<3) are of mixed type, involving volumetric changes and shear failure associated with fluid movement, reflecting ongoing long-term processes within and near a magma body such as fractional crystallization, gas exsolution and geothermal-fluid migration. Low-frequency earthquakes in combination with very long period, volcanic tremor, and explosion earthquakes reveal processes in the volcanic edifice or magma conduit during eruptions. Worldwide examples of volcanic earthquake characteristics include maximum magnitudes of VT earthquakes associated with dike intrusion, central volcanoes and calderas, and tectonic earthquakes triggered by magmatic processes. Examples are drawn from the recently completed Idaho National Laboratory probabilistic seismic hazards analysis, which supports seismic safety of nuclear facilities in the extensional setting of the distributed volcanic field, eastern Snake River Plain (Idaho, USA).

Volcanic, Seismic, and Hydrothermal Hazards in the Yellowstone Region

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The Yellowstone region is subject to numerous geological hazards, including volcanic eruptions, earthquakes, and hydrothermal explosions. Volcanic eruptions capture public attention due to media portrayals, but they are the least likely hazards to impact the area. Large caldera-forming eruptions take place about once or twice per million years. Rhyolite and basaltic lava flows are more frequent but occur in episodes that are separated by tens to hundreds of thousands of years. The last volcanic eruption in the region was a rhyolite lava flow about 70,000 years ago. Seismic and magnetotelluric imaging indicate that magma storage areas beneath Yellowstone caldera are mostly solid and probably incapable of feeding a significant eruption. Any remobilization due to new magmatic input into the system might require centuries to millennia to culminate in a volcanic eruption. More likely on human timescales are hydrothermal explosions and strong earthquakes. The Yellowstone region is on the northeastern margin of the Basin and Range province, and large faults are common. Major historical earthquakes include a M6 in 1975 within Yellowstone National Park and a M7.3 just west of the park in 1959. The latter caused a landslide that swept through a campground, causing over 2 dozen fatalities, and dammed a river. Hydrothermal explosions of varying sizes occur almost annually within Yellowstone National Park. The largest hydrothermal explosion crater known in the world (~1.5 miles across) is Mary Bay, on the north side of Yellowstone Lake. Smaller explosions that are more frequent pose hazards to park visitors, especially during the summer in well-visited thermal basins. The July 23, 2024, hydrothermal explosion at Biscuit Basin is a poignant example. Communicating the nature and frequency of these hazards is an important mission of the Yellowstone Volcano Observatory consortium.

Bio:

Mike Poland is a research geophysicist with the U.S. Geological Survey specializing in volcano geodesy, particularly using interferometric synthetic aperture radar (InSAR) and microgravity. He completed his BS at the University of California at Davis in 1997 and his PhD at Arizona State University in 2001. From 2002 to 2005, he worked at the Cascades Volcano Observatory to implement InSAR for monitoring volcanoes in the USA. During 2005-2015, he was the research geodesist at the Hawaiian Volcano Observatory, where he studied magma supply and storage at Kīlauea and Mauna Loa volcanoes. In 2015 he returned to the Cascades Volcano Observatory to conduct InSAR and microgravity studies, and in 2017 he became the Scientist-in-Charge of the Yellowstone Volcano Observatory. While continuing to conduct volcano geodesy research in the Cascades, Hawaii, and Yellowstone, Mike also devotes significant energy to public communication, particularly about the Yellowstone magmatic system.

Re-tooling an Observatory to Monitor Deadly Volcanic Hazards in Near-real-time: Montserrat, 2000-2003

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On July 18th, 1995, the Soufriere Hills Volcano on Montserrat awoke from a 400-year slumber with a phreatic explosion. Within 9 days, the University of the West Indies Seismic Research Centre (UWI SRC) assisted by the U.S. Geologic Survey's Volcano Disaster Assistance Program (USGS VDAP) had installed seismic/tiltmeter network and set up the Montserrat Volcano Observatory (MVO). The MVO Operations Room was staffed 24/7, watching the helicorders, and alerting scientists/authorities to rapid escalations in seismicity. By September 1995, a lava dome building eruption had begun, and as the dome complex grew over the next 2.5 years, pyroclastic flow and lahar hazards escalated, leading to permanent evacuation of the southern part of the island. However, the eruption stopped in March 1998, and subsequently, funding and staffing levels for the observatory fell. A 24/7 Operations Room was no longer possible, and monitoring equipment and computer systems deteriorated. Furthermore, systems were not compliant with the contemporary standards at the time. Thus, when the eruption recommenced in November 1999, it was a race against time to re-establish seismic monitoring and automate it due to the lack of funding and resources. At the time, volcano-seismologists were stuck in a paradigm where the focus was to create a catalog of detecting and locating volcano-tectonic earthquake signals, which are short and impulsive. However, these were only one type of volcanic earthquake and escalations in eruptive activity were marked by swarm and tremor signals comprising overlapping earthquakes. The potential for pyroclastic flows and lahars had increased with the growth of the dome complex, however, the types of signals associated with these events were not being cataloged at any observatory at the time, let alone MVO. To restore and improve on the operational monitoring, systems were developed to detect, classify, locate, and quantify all these types of volcanic seismicity in near-real-time as well as send alarms. The result was an early warning system for pyroclastic flows which led to more recent efforts to extend into early warning for lahars.

Bio:

Glenn Thompson is a volcano seismologist specializing in real-time monitoring techniques. He first worked at the Montserrat Volcano Observatory (MVO) in 1996 during the height of the volcanic crisis, where he realized that enhanced volcano-seismic monitoring could better inform real-time hazard assessments and improve public safety. This experience fueled his commitment to developing cutting-edge monitoring tools to mitigate volcanic hazards. While completing his PhD, he worked in the IT industry, which led to a postdoc at the Alaska Volcano Observatory (AVO), where he developed core web-based seismic monitoring tools still in use today. From 2000 to 2003, he returned to Montserrat as Seismic Network Manager, working with the MVO team to rebuild the seismic monitoring program, upgrade data acquisition, analysis, and alarm systems, and pioneer seismic amplitude-source location (ASL) techniques for pyroclastic flows. He also recovered data from 500+ orphaned media, helping to create one of the most comprehensive eruption datasets in the world. From 2006 to 2013, he worked at AVO again, contributing to several volcano crises. Since 2013, he has been based at the University of South Florida, mentoring the next generation of observatory specialists. In 2020, he led a comprehensive review of the monitoring of Whakaari volcano on behalf of the New Zealand government, following the fatal eruption on December 9, 2019. More recently, he has been working with the USGS VDAP to restore legacy seismic data from volcanic crises at Pinatubo, Nevado del Ruiz, and Popocatépetl, ensuring these invaluable datasets can be analyzed with modern techniques and yield new discoveries.

Soufrière Hills volcano in Montserrat. Photo Credit: USGS

Lessons-Learned from First Use of Regulatory Guide 4.26 in the Assessment of Volcanic Hazards at a Proposed Nuclear Power Reactor Site

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In June 2021, NRC staff issued Regulatory Guide (RG) 4.26, "Volcanic Hazards Assessments for Proposed Nuclear Power Plant Sites," which was revised in August 2023 (ADAMS Accession No. ML23167A078) as part of an administrative change. By letter dated April 25, 2023, TerraPower, LLC (TerraPower) submitted topical report (TR) TPLIC-LET-0070 Revision 0A, "An Analysis of Potential Volcanic Hazards at the Proposed Natrium Site Near Kemmerer, Wyoming" (ML23115A387) to the U.S. Nuclear Regulatory Commission (NRC) staff. This topical report was the first volcanic hazards assessment for a proposed reactor that followed the guidance in RG 4.26. The NRC staff completed its review of the topical report and issued the safety evaluation report on September 6, 2024 (ML24198A093). The TerraPower TR was not based on a senior seismic hazard analysis committee (SSHAC) study and, while the TR followed the initial steps in Figure 1 to RG 4.26, TerraPower invoked the engineering analysis option and deferred later steps in the volcanic hazards assessment process to a future review. Specifically, the TerraPower TR characterized the applicable volcanic hazards and determined their magnitudes and probabilities of occurrence but deferred the consideration of the effect of these hazards on the nuclear structures, systems, and components (SSCs) to the construction permit or operating license application review. The NRC staff identified several lessons-learned from the review of the topical report, including providing greater clarity on the use of the SSHAC process to assess volcanic hazards and providing further explanation on the flexibility of the stepwise approach to defer certain actions to later stages of an application review. The NRC staff is considering how to incorporate these lessons-learned into a future revision to RG 4.26. The NRC staff is also closely following the development of ANS 2.34 for incorporation into a future revision to RG 4.26.

Bio:
Jenise Thompson is a Geologist in the External Hazards Center of Expertise within the Office of Nuclear Reactor Regulation at the United States Nuclear Regulatory Commission. In this capacity, she is responsible for the siting reviews of geologic and volcanic hazard for numerous NRC-regulated facilities, including new reactor applications and consolidated interim storage facilities. Ms. Thompson is also actively involved in revising existing guidance for siting reviews and developing new guidance based on emergent needs. Ms. Thompson is the technical lead for the development and revision of Regulatory Guide 4.26, "Volcanic Hazards Assessment for Proposed Nuclear Power Reactor Sites" and is the staff lead for the consideration of new guidance on a graded approach to site characterization for new reactor applications. She is also the NRC representative and chair of the American Nuclear Society (ANS) working group developing ANS 2.34, "Characterization and Probabilistic Analysis of Volcanic Hazards."

Pyroclastic Currents – Dynamics, Effects, and Modeling Approaches

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Pyroclastic currents, also known as pyroclastic density currents, are mixtures of volcanic gases and particles and entrained air wherein the mixture density is greater than the ambient atmosphere and the currents flow along the ground. Two end-member types are: (1) mixtures with low particle concentrations (~0.1-5 vol.%) where particles are transported by turbulent suspension and deposited through bed load processes known as pyroclastic surges. (2) High particle concentration mixtures (~20-50 vol%), called *pyroclastic flows*, that are more akin to hot, dry debris flows where elevated pore gas pressure reduces friction between particles. Pyroclastic flows are accompanied by surges, but the opposite is not always true. Origins of the currents include collapse of vertical eruption columns (sustained or from a discrete explosion), lava dome collapse, and lateral blast. These currents can be related to eruptions driven purely by magmatic gases as well as those caused by explosive magma-water interaction. Flow speeds range from a few m/s to more than 100 m/s. Runouts range from hundreds of meters for very small explosions to 150 km or more for large caldera-forming eruptions. Effects of pyroclastic currents are related to high dynamic pressure, temperature, projectiles in the flows, asphyxiation, and burial. Even relatively cool (i.e., ~100 °C) and slow dilute currents can cause severe burns and asphyxiation for humans and animals. A range of modeling approaches have been developed to advance our fundamental understanding of pyroclastic currents and to estimate hazards and risks for future eruptions. The most complex models solve time-dependent conservation equations for air, volcanic gas, and a range of particles (sizes and densities) and are relatively computationally expensive. Models used in hazard assessments tend to be depth averaged (e.g., velocity, concentration, temperature) and use either turbulent transport or granular rheology for constitutive models. The simplest models use an energy cone or topography filling approach.

Bio:
Mr. Valentine is Distinguished Professor of Earth Sciences at the University at Buffalo, where for the past sixteen years he has conducted research on: (1) Basaltic volcanic fields in the American Southwest and in France; (2) Phreatomagmatic processes based on field-scale experiments, geologic studies, and numerical modeling; and (3) General explosive volcanic processes such as eruption columns, pyroclastic currents, and their deposits in the United States and Italy. These themes continue with his current projects on deposits of large-volume caldera-related pyroclastic flows, basaltic volcanism in Utah, and multiphase numerical modeling of pyroclastic currents. Valentine was a technical staff member and group leader at Los Alamos National Laboratory for twenty years prior to his appointment at Buffalo. There he focused on a range of geoscience problems including subsurface flow and contaminant transport, urban systems, nuclear weapons effects, volcanic eruption modeling, and volcanic risk for the proposed Yucca Mountain radioactive waste repository. He earned his B.S. at New Mexico Institute of Mining & Technology, and Ph.D. at University of California-Santa Barbara.

Potential Far-Field Hazards from Volcanically Generated Tsunamis in Alaska

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Volcanic mass flows are a well-known source of tsunamis. Particularly hazardous are mass flows that originate at volcanic islands surrounded by open oceans where far-field hazards can be significant (Abadie et al., 2012; Grilli et al., 2019). In this presentation, hypothetical mass-flows from sources in the Aleutian Islands are described based on a 2009 study (Waythomas et al, 2009) that sought an improved understanding of the relationship between mass flow volume and potential far-field tsunami inundation. We wanted to know the approximate mass flow size capable of initiating tsunamis around the Pacific Rim. As a result of our modeling studies, we concluded that mass flows entering the North Pacific Ocean from volcanic sources in the Aleutian Islands would need to be on the order of 500 km^3 to produce waves that could reach the west coast of the United States. Although evidence in the form of past tsunami deposits has not been found and specific volcanic mass flow sources are currently being evaluated, as discussed by Mandeville and others in this symposium (Mandeville et al, this symposium), the 2009 study shows that it is plausible for tsunamis from Aleutian volcanic sources to reach populated areas along the West Coast. The results of Waythomas et al (2009) have been incorporated into tsunami hazard assessments, such as the study completed by the Canadian Geological Survey (Leonard et al., 2014). Future modeling efforts will make use of volcano tsunami sources identified by the author and his associates and discussed in this symposium (Waythomas et al, 2009; Mandeville et al., this symposium) as part of ongoing efforts to evaluate volcanically initiated tsunamis in Alaska and their far-field effects.

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Bio:

Dr. Waythomas is a geologist with the USGS Alaska Volcano Observatory in Anchorage Alaska. He primarily works on volcano hazard assessments, geologic mapping of volcanoes and the radiocarbon chronology of eruptive events. He has a background in Quaternary geology, geomorphology, and hydrology. He received his Ph.D. from the University of Colorado-Boulder in 1990 and then was a post-doctoral fellow on a National Research Council-USGS project in Denver Colorado. In 1992 he moved to Anchorage and soon after joined the Alaska Volcano Observatory as a staff geologist. An ongoing subject of study are the hazards associated with volcanically initiated tsunamis.

A gas plume arising from Augustine Volcano, Alaska, during its eruptive phase 2005-06. Photo Credit: USGS – Cyrus Whitney Read

Modeling Pre-Historic Recurrence Rate in Volcanic Systems with a Volcanic Event Age Model

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Volcanic hazard analysis requires knowledge of styles, intensity, magnitude, location, and recurrence of past volcanic events to characterize the impact and how often a future event may occur in a region of interest. For pre-historic events, recurrence rate must be estimated from a dating technique such as isotopic age dating which is costly and often incomplete for volcanic fields. As a result, recurrence rate estimates may have substantial variance and interpretations of temporal stationarity may be subjective. The Wilson Volcanic Event Age Model (VEAM) provides an objective means to reduce variance in recurrence rate by including stratigraphic relationships and the geomagnetic timescale. The model utilizes Monte Carlo simulations to generate sets of volcanic event ages conforming to stratigraphic relationships. Event ages are sampled from isotopic dates represented by a Gaussian distribution, C-14 calendar dates, or uniform probability distribution for undated events. Paleomagnetic data is incorporated as a Boolean mask to probability density functions. Stratigraphic relationships are used to truncate probability density functions. The model employs a variance reduction technique consisting of a precision-based event group hierarchy that allows the model to converge more quickly. The output is used to compute recurrence rate for each simulated set of ages. The recurrence rates are used to calculate epistemic uncertainty in recurrence rate using a multi-point estimate to capture center, body, and range for volcanic hazard analysis. Additionally, the resulting age model is useful for identifying stratigraphic and dating inconsistencies in a dataset. The model has been applied to characterizing volcanic hazard for a site on the Eastern Snake River Plain, USA, correlating Icelandic eruptions to European tephra deposits, volume flux history at Medicine Lake Volcano, and recurrence rate of volcanism within Arsia Mons, Mars.

On the Halemaʻumaʻu crater floor, the front of a fast-moving channelized lava flow from the north vent fountain was composed of slabby pāhoehoe. USGS photo taken on March 11, 2025, by M. Patrick.