The Response of Continental Hydrothermal Systems to Tectonic, Magmatic, and Climatic Forcing

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Overview: Continental hydrothermal systems have immense scientific and practical significance and are critically important to the Earth's thermal budget and geochemical cycles. Continental hydrothermal systems are a primary source of economically important metal deposits, provide geothermal resources, support exotic ecosystems that are just beginning to be explored, and in some settings pose a significant geologic hazard via hydrothermal explosions. The subsurface conditions and processes that control these systems are poorly understood because they entail the flow of multi-phase and multi-component fluids through rocks with heterogeneous permeability fields that are perturbed by a multitude of geological and environmental processes. Carefully designed multidisciplinary field experiments and modeling efforts are required to understand the coupled processes that drive these dynamic systems and control their response to geological and environmental forcing.

Our research is focused on quantifying the response of continental hydrothermal systems to tectonic, magmatic, and climatic processes operating on time-scales from seconds to thousands of years. We address important and timely scientific questions, such as: How do multi-phase fluids and dissolved constituents flux through hydrothermal systems? How do these systems redistribute elements to produce mineral deposits and microbial habitats? How do earthquakes and magmatic activity perturb hydrothermal systems? What triggers hydrothermal explosions? How do environmental processes and climate affect continental hydrothermal systems?

Intellectual Merit: We propose to achieve our scientific objectives through a combination of fieldwork, data analysis, and modeling. Our field program uses a combination of innovative instrument networks and sediment coring activities that will be integrated through modeling activities to study the response of the Yellowstone Lake hydrothermal system to tectonic, magmatic, and climatic forcing. Yellowstone Lake is an ideal site for this research because it hosts an active hydrothermal system located in a region with high levels of tectonic and magmatic activity that has been influenced by a broad range of climate conditions in postglacial times. Our research activities include components of geochemistry, seismology, geology, geodesy, heat flow, micropaleontology, limnology, paleoclimatology, statistics, analytical modeling, and numerical modeling, all of which are essential for unraveling the coupled processes that drive system behavior. Working on a lake-floor system provides an exceptional opportunity to study forcing-response relationships on an expanded range of time-scales spanning more than 11 orders of magnitude.

Broader Impacts: Our research activities will generate data and modeling products that will inform research across the global set of hydrothermal fields, ranging from the deep seafloor to subaerial calderas. Working in Yellowstone National Park (YNP) expands the impact of our research by providing superb outreach opportunities and by contributing to YNP's mission to understand the Yellowstone Lake ecosystem and the hazards posed by hydrothermal explosions. Our outreach activities include the generation of innovative multimedia products for: the Fishing Bridge Visitor Center (in YNP), a traveling museum exhibit, *Smithsonian Magazine*, and websites hosted by YNP, the US Geological Survey (USGS), and our home institutions. Our education activities include training for graduate students and interns from under-represented groups in STEM research.

Our project features collaborations with key personnel at the USGS and ISTerre (France), allowing us to bring leading expertise to the project at no cost to NSF. As described in the support letter from Yellowstone Volcano Observatory scientist-in-charge Jacob Lowenstern, the USGS has agreed to commit salary and logistical support for Hurwitz, Shelly, Shanks, Morgan, and Taron to participate in the project. J. Vandemeulebrouck and P. Roux at ISTerre have also agreed to commit ~2 months/year to the project and provide novel instrumentation for monitoring volatile flux on the lake floor. These collaborations expand the scientific scope of our research, improve our ability to integrate our results into system-scale models, and provide a direct link for incorporating our results into hazard assessments for YNP.