Collaborative Research: Magnetotelluric and Seismic Investigation of Arc Melt Generation, Delivery, and Storage beneath Okmok Volcano

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Project Summary

Alaska accounts for nearly 99% of the seismic moment release within the US. Much of this is associated with the Aleutian volcanic arc, the most tectonically active region in North America, and an ideal location for studying arc magmatism. The arc contains numerous small- to moderate-sized calderas; such calderas suggest low mantle magma production rates and associated small volumes of melt ascending from the mantle and accumulating within the crust. Future caldera forming eruptions would likely be small and locally focused in such a volcanic setting. In contrast, geochronologic and volumetric estimates of mantle magma production are high and argue in favor of large volumes of magma generated in the mantle and ubiquitous magma storage within a thermally and mechanically weakened crust. Such crustal magma reservoirs could host large future caldera forming eruptions. Gaining a greater understanding of Aleutian arc melt generation, migration, and storage beneath an active caldera should help resolve these two disparate views of the arc's magmatic system.

Okmok is an active volcano located in the central Aleutian arc, which hosts a 10 km diameter caldera. The subdued topography of Okmok, relative to other Aleutian volcanoes, improves access and permits dense sampling of the volcanic edifice. We have selected Okmok as the site of study for this project due to frequent volcanic activity and the presence of a crustal magma reservoir as inferred from previous seismic studies. At least two caldera forming eruptions are recognized, and Okmok is believed to be representative of volcanos both within the Aleutian arc and worldwide, where long periods of effusive eruptions are punctuated by much larger explosive caldera forming eruptions. As one of the most active volcanos in the Aleutian arc, Okmok also poses a major hazard to trans-Pacific air travel, hence understanding crustal magma storage and transport is a critical component in assessing future volcanic hazards at the volcano.

This project uses geophysical techniques to characterize the magmatic system beneath Okmok. During the summer of 2015 we collected onshore and offshore magnetotelluric data and installed a temporary year long seismic deployment. These new geophysical data will be used to test hypotheses regarding the role of slab fluids in arc melt generation, melt migration within the crust, and the crustal magmatic plumbing and storage system beneath Okmok caldera. Analysis of these data will include a suite of seismic and magnetotelluric modeling efforts (ambient noise and earthquake tomography, surface wave anisotropy, 3D onshore and 2D amphibious magnetotelluric inversion, joint ambient noise/body-wave and seismic/magnetotelluric tomography), as well as petrologic modeling using SIGMELTS. These analyses will result in geophysical models of seismic velocity and electrical conductivity that in turn will constrain the distribution of temperature, fluids and melts from the top of the slab through the shallow crust.

Field Work

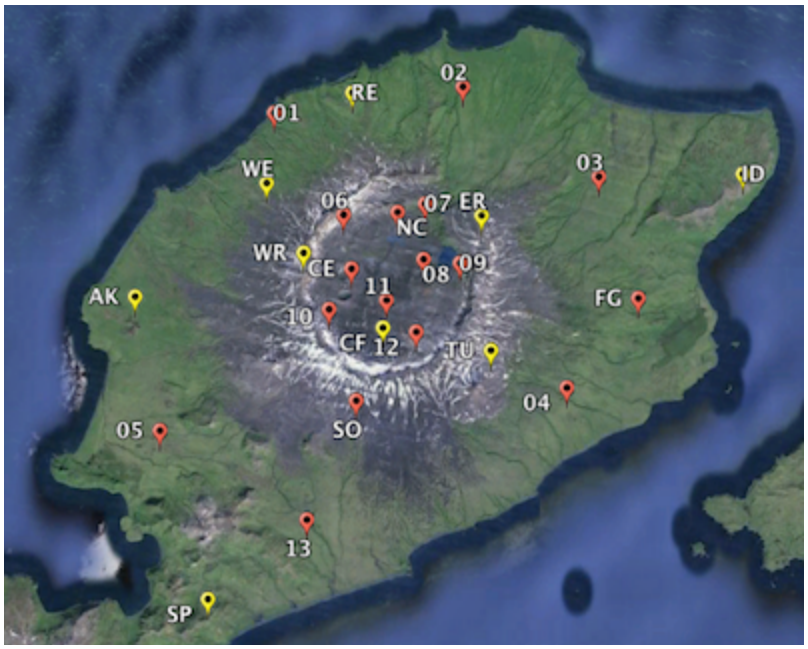
In June-July 2015 we carried out the amphibious field deployment. The onshore work was based out of Bering Pacific Ranch at Fort Glenn, an abandoned WWII military base,

with a helicopter transporting the seismic and MT teams and equipment during the 19 days of field operations. Offshore MT deployments were made during a four day cruise on the RV Thompson, with the instruments being recovered three weeks later during a six day cruise on the new RV Sikuliaq.

We installed 13 temporary broadband seismometers both in and around the Okmok caldera (Figure 1a). In tandem with the Alaska Volcano Observatory's 12 permanent seismic stations, there are now 12 seismic instruments within/at the rim of the caldera and 14 seismic instruments outside the caldera. The temporary array will record seismic data until its retrieval in summer 2016.

Onshore magnetotelluric data were collected in a 3D array using a combination of long-period and wide-band MT systems, with 19 stations within the caldera and 10 stations outside (Figure 1b). Offshore magnetotelluric stations were deployed along a 2D tectonic profile spanning the trench, volcanic arc and backarc in order to constrain melt formation and migration to the crust and the hydration state of the forearc mantle (Figure 2). A ring of offshore stations surrounding the eastern portion of Umnak island supplements the onshore 3D MT data and will be used to constrain the distribution and migration of melt within the crust. Of the 54 offshore deployments, 53 instruments were successfully recovered while one instrument was lost in Umnak pass due to strong tidal currents in the shallow water. Initial analysis of the data shows strong MT signals, especially from data collected during a geomagnetic storm in late June.

(a)



(b)

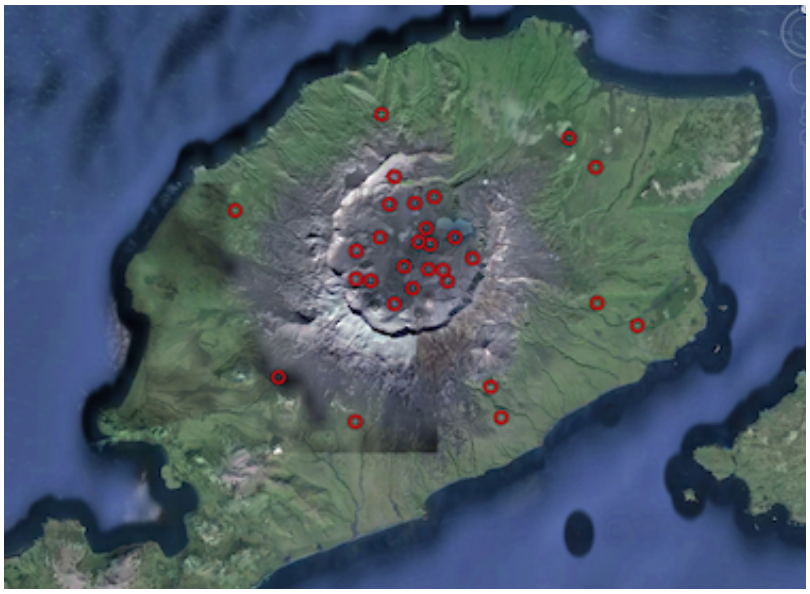


Figure 1. (a) Distribution of seismic instruments at Okmok volcano where broadband and short period instruments are indicated as orange and yellow flags, respectively. Lettered station labels designate the Alaska Volcano Observatory seismic instruments and temporary, year-long seismic installation is indicated via two-number designation. **(b)** Distribution of the 29 onshore magnetotelluric stations.

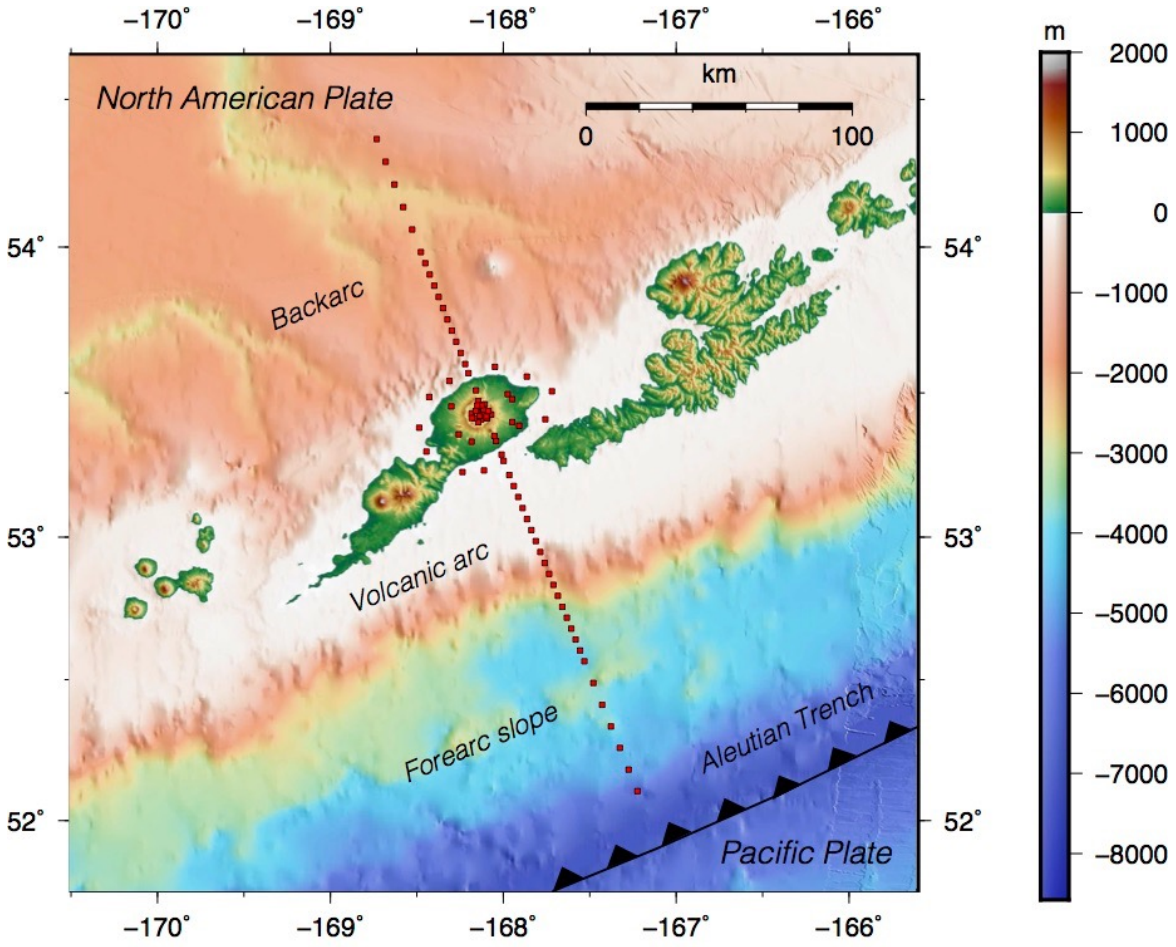
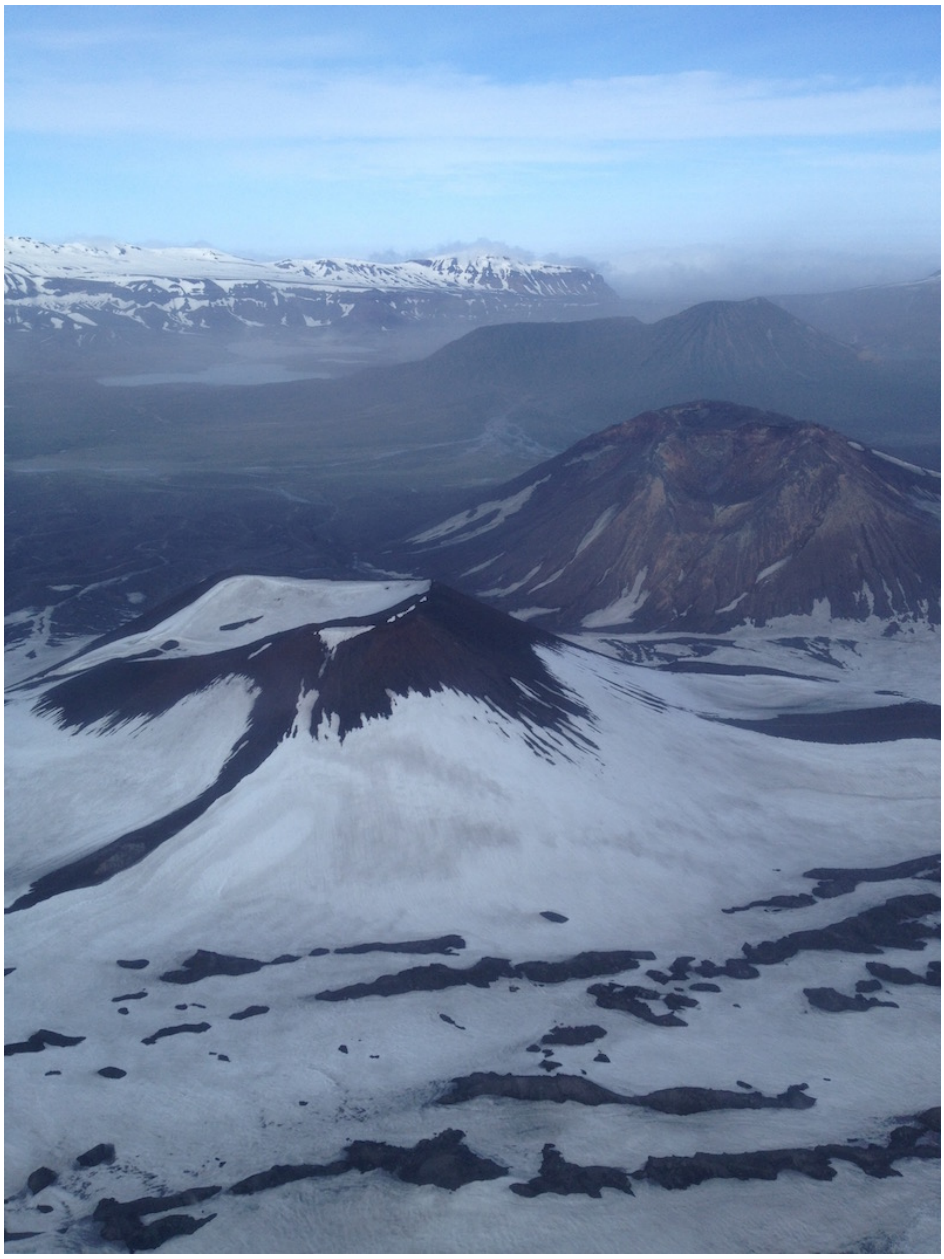


Figure 2. Distribution of the 53 offshore and 29 onshore magnetotelluric stations shown along with the regional tectonic framework.

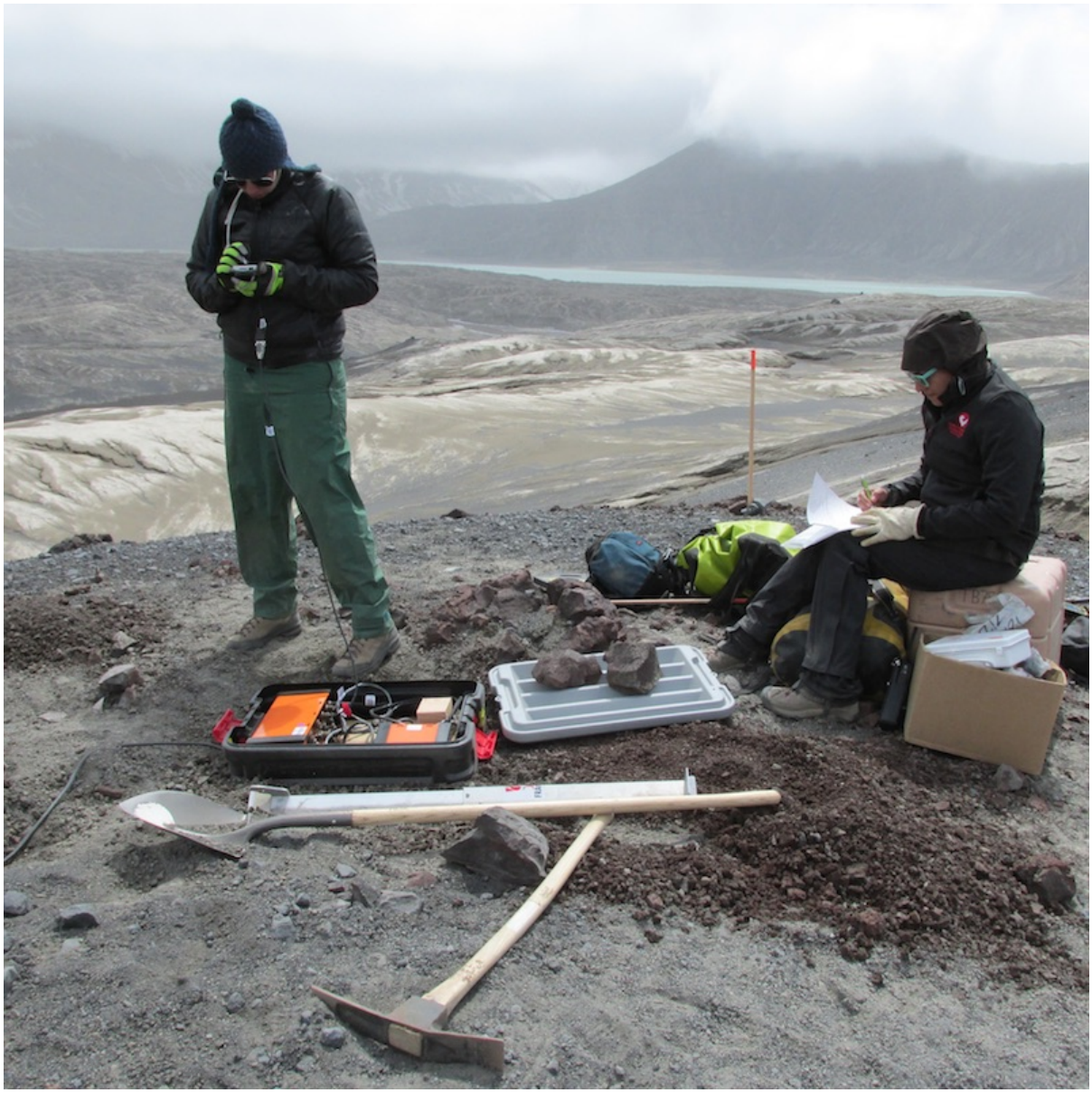
Highlight pictures from fieldwork

Okmok caldera (cone F in the foreground, cone C in mid-ground, and cone D and new cone from the 2008 eruption in the background):



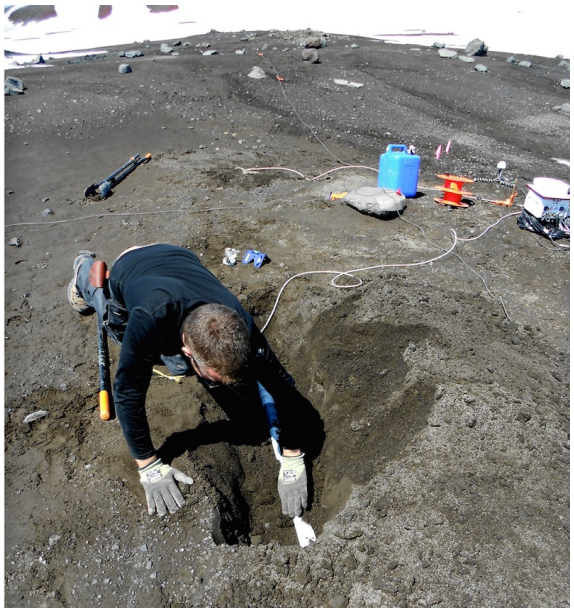
Seismic fieldwork

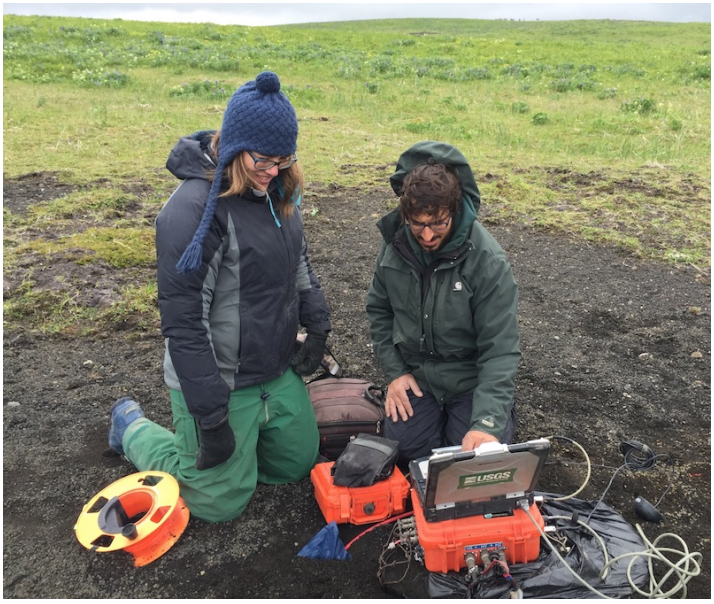
Seismic station being installed inside Okmok caldera:



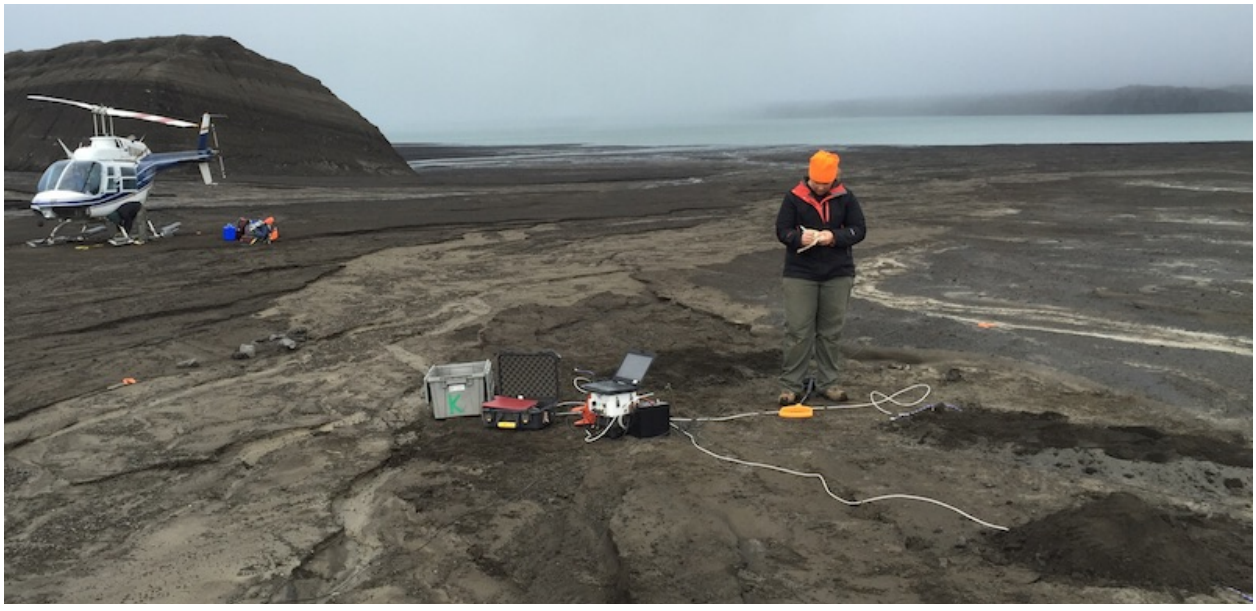
Onshore magnetotelluric fieldwork

MT magnetometer being buried inside the caldera floor (left) and an MT station outside the caldera (right):





MT station in the caldera:



Offshore magnetotelluric fieldwork

Scripps broadband MT receiver being prepared for deployment on the RV Thompson:

Image from a drone video of an MT receiver being recovered on the RV Sikuliaq with Umnak Island in the background (video available at http://okmok.ucsd.edu):