GEOPHYSICAL CHARACTERIZATION OF A VOLCANIC CINDER CONE FIELD, AN ANALOG TO LUNAR EXPLORATION.

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Introduction: Terrestrial volcanic fields are excellent analogs for the geophysical examination of features that will be studied on the Moon. Field sites such as the San Francisco Volcanic Field (SFVF), AZ can be used for the refinement of field techniques, data analysis methods, and interpretation of results for extrapolation to the future exploration of similar locations on the lunar surface. These sites also provide for the examination of potential difficulty accessing model field locations for obtaining idealized data, which can be applied to future lunar surface science operations.

Expectations of the geophysical characteristics of the near surface, as well as understanding field accessibility will be key points to successfully executing lunar surface science operations and subsequent data analysis. These issues can be addressed via the work we are performing on the seismic and magnetic characterization of the SFVF region surrounding the SP Crater cinder cone.

The results discussed here stem from our second field season at this site. This research is a direct follow-on to the NASA Desert Research and Technology Studies (RATS) 2010 simulated lunar mission [1,2,3], and is designed to understand the impact of including geophysical studies in a human planetary traverse. [4] Our goals are to acquire and compare two geophysical datasets, while simultaneously examining relevant geologic problems. The first dataset is from a planetary "mission-based" scenario, and was acquired during our 2016 field season. The second dataset, using standard "terrestrial-based" deployment methodology, was designed to explore the possible correlation between the alignment of cinder cone vents and the local fault system providing magmatic propagation pathways. The results of this analysis provide for initial seismic and magnetic characterization of the field site.

Study Region: Our field site is a portion of the SFVF that is an approximately 50 km^2 area that is centered on the SP Crater cinder cone, and is part of the San Francisco Mountain stratovolcano complex, Figure 1. It is characterized by numerous cinder cone volcanoes, lava flows, rilles, and faults. [5] During the 2010 NASA Desert RATS campaign, this area constituted a significant portion of the rover traverses, and the majority of the science stations. [6]

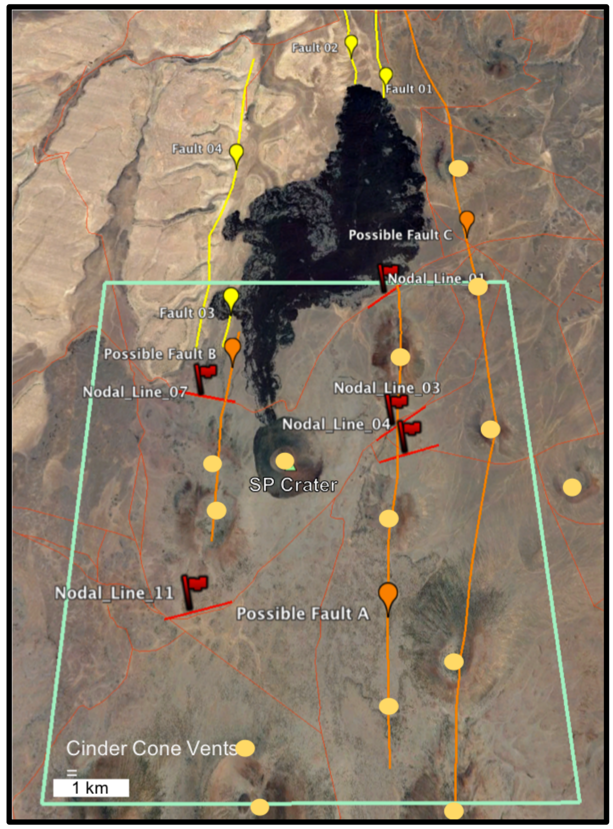

Figure 1: Perspective view of the SFVF field site. Yellow and orange lines denote known and possible faults, respectively. Beige dots indicate volcanic vents. Red lines show locations of 1-km long active seismic receiver lines.

Approach: For this study, we employed the use of both active seismic tools as well as an absolute magnetic field magnetometer. With the scientific goal being to explore the possibility of magma propagation along local fault lines, we set 1-km long active seismic lines oriented perpendicular to the suspected faults, as can be seen by the red lines in Figure 1. These lines consisted of 51 individual seismometers spaced every 20 meters. The energy source for this study was a Propelled Energy Generator (PEG), on loan from the Incorporated Research Institutions for Seismology (IRIS) Instrument Center. The PEG source was shot at 40 meter intervals beginning from 130 meters prior to the first seismic node and continuing to 110 meters after the final seismic node. There were 10 shots performed at each of these 32 source locations. Additionally, centered on each of these seismic lines, we collected eight parallel paths of magnetic data at 20 meter intervals. The magnetometer collected absolute magnetic intensity data continuously at 5 Hz as it was carried along each of these paths surrounding the nodal seismic lines. [7]

Analysis: Analysis of the seismic data consists of using a 2-D seismic Bayesian inversion method for a refraction analysis that has resulted in discerning several stratigraphic layers and possible fault locations. [8] For example in Figure 2, the initial results of this analysis for Nodal Line 7 (see Figure 1 for location), a subsurface graben feature propagating in a north-south direction is revealed. Additionally, the seismic data will be used to create probabilistic power spectrum plots of the background seismicity. These will be useful for characterizing the seismic environment of this field site.

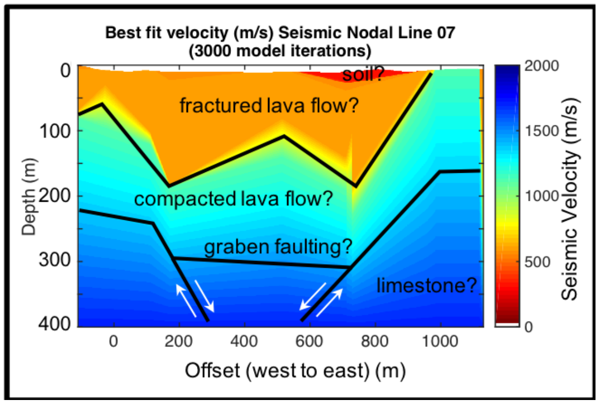

Figure 2: 2-D Bayesian seismic refraction analysis results of Nodal Line 07, revealing possible subsurface graben feature.

The characterization of the seismic environment of this analog field site is also applicable to future lunar fieldwork. In this regard, the characterization will include a comparison to the Apollo 17 Lunar Seismic Profiling Experiment (LSPE) methodology and subsequent results. [9, 10] For this, we plan to process the LSPE seismic P-wave arrival times in the same manner used to analyze the SFVF data. This will provide a baseline comparison in field operations and data analysis between the SFVF and LSPE studies.

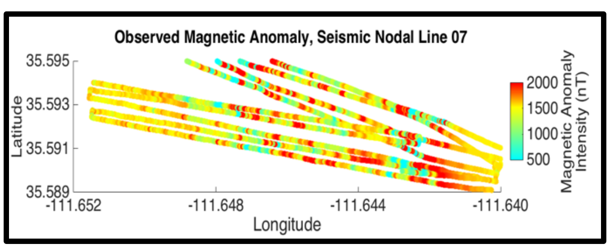

Figure 3: Plot of magnetic anomaly intensity of the surface surrounding the cross-section beneath Seismic Nodal Line 07 seen in Figure 2. Earth magnetic field strength of 47,236 nT subtracted from observed data. Plot covers approximately 1000 m west-to-east and 250 m north-to-south. Nodal line is roughly centered within the magnetic lines.

The magnetic data has been initially adjusted by removing the terrestrial dynamo background magnetic field to reveal any positive or negative magnetic anomalies recorded around the seismic lines, as seen in Figure 3. It is expected that if a significant magmatic intrusion was injected along a fault plane and propagated sufficiently towards the surface, it will be revealed as a positive magnetic anomaly at the surface. In Figure 3, continued analysis is required to interpret if the higher magnetic readings seen grouped north-to-south in the center and right sides of the plot are related to magmatic intrusions or to the overlying lava flows.

Conclusion: We have collected seismic and magnetic data sets to address the question of magma propagation along local fault planes within a volcanic field. Both the seismic and magnetic data analysis results can help to envelope necessary geophysical instrument specifications for future field studies, both terrestrial and lunar. The seismic data specifically can also be compared to the methods and results from the Apollo 17 LSPE.

In addition, this data will be used as the results of a standard terrestrial field research study in the comparison of planetary "mission-based" fieldwork versus traditional "terrestrial-based" field studies. These results will help inform the operational aspects for future geophysical field campaigns to the lunar surface.

References: [1] Abercromby, A. et al. (2012), *Acta Astronautica*, doi: 10.1016/j.actaastro.2012.02.022. [2] Bell E. et al. (2012), *Acta Astronautica*, doi.org/10.1016/j.actaastro.2012.11.020. [3] Ross, A. et al. (2013) *Acta Astronautica*, doi:10.1016/j.actaastro.2012.02.003. [4] Bell, E. et al. (2017) LPSC 48, Abstract #1716. [5] Tanaka, K. et al. (1986) GSA Bulletin v. 97. [6] Horz, F., et al. (2012), *Acta Astronautica*, 90(2), 254-267. [7] Bell, E. et al. (2018) AGU 100, Abstract #460945. [8] Montgomery, L. et al. (2017) *Frontiers in Earth Science*, 5, 10. [9] Kovach, R. et al. (1973), *Apollo 17: Preliminary Science Report*, Vol. 330. [10] Nakamura, Y., et al. (1982), Journal Geophysical Research: Solid Earth, 87, S01.