PLANETARY ANALOG STUDIES OF GEOPHYSICAL FIELD TECHNIQUES

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Introduction: Beginning in 1997, NASA performed an evolution of analog field studies in preparation for exploration of other planetary surfaces, called Desert Research and Technology Studies (RATS). Initially these were engineering based studies on the operability of performing geologic field activities while wearing a planetary spacesuit. They evolved to full-scale multi-week simulated lunar excursions with realistic geologic objectives. [1]. The most elaborate of these, in 2010, included prototype habitable rovers, habitats, and representative communication restrictions that resulted in detailed and realistic human piloted rover traverse paths around the lava fields and cinder cones of the San Francisco Volcanic Field (SFVF), north of Flagstaff Arizona, specifically around the SP Crater area [2]. The results studied the impacts of operational constraints on the efficiency of the geologic work performed [3] [4].

This research is a direct follow-on to the NASA Desert RATS 2010 simulated lunar mission, and designed to understand the impact of including geophysical studies in a human planetary traverse. Our goals are to acquire and compare geophysical datasets from both a planetary "mission-based" scenario, as well as a standard "terrestrial-based" deployment, and to address several fundamental geologic problems of the volcanic and sedimentary structures in the San Francisco Volcanic Field. Our ongoing work will guide future geophysical surveys of planetary bodies.

Study Region: Our 7 km x 7 km study region is located within the SFVF and contains numerous cinder cone volcanoes with crisscrossing lava flows. The study region is roughly centered on SP Crater, a cinder cone exhibiting 250 meters of relief **(Fig. 1).** During the 2010 NASA Desert RATS campaign, this area constituted a significant portion of the rover traverses, and the majority of the science stations where the crews stopped to perform simulated extravehicular activity to acquire geologic samples, and perform other visual observations. This study region has been further reduced into eight areas that correspond to the Desert RATS 2010 traverse science station locations.

Approach: This study will use a comparison of two datasets to determine measures to increase the

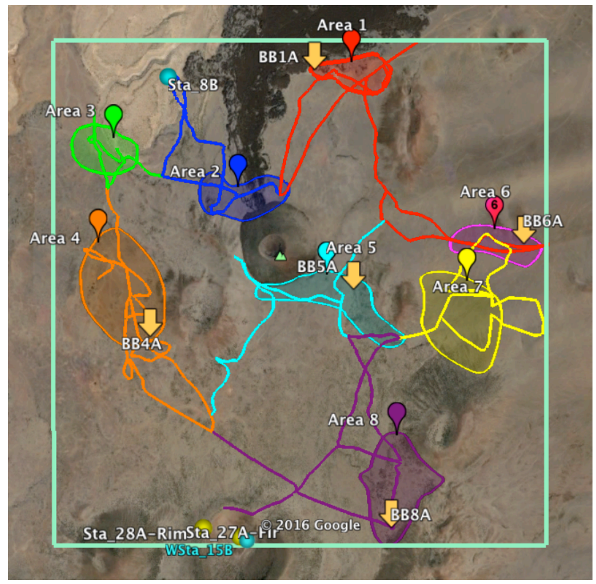

Figure 1: San Francisco Volcanic Field Planetary Analogs Studies Field Site. Turquoise box indicates 7 km x 7 km study region. Individual colored 'Areas' envelope Desert RATS 2010 science stations. Colored paths denote 2010 rover traverse paths. Beige arrows indicate broadband seismometer array install locations.

efficiency of conducting geophysical surveys on planetary bodies in conjunction with geologic field mapping and sample collection. The first dataset, collected during the 2016 field season, is a "mission-based" deployment of geophysical instrumentation; including seismic (both active source geophone lines and a passive broadband array), magnetic, and ground penetrating radar (GPR). These measurements were made in proximity to science stations from the Desert RATS 2010 traverses to test the fidelity of geophysical field techniques on simulated planetary traverses. The second dataset, to be collected during an upcoming 2017 field season, will be from a standard "terrestrial" field deployment of geophysical instrumentation, placed in a geometry that is idealized for the detection of detailed subsurface volcanic and sedimentary structures.

The guidelines used in this first year of the study for selection of geophone line locations, broadband seismometer placement, and magnetometer and ground penetrating radar (GPR) tracks assumed that any geophysical objectives were secondary to those of the

DRATS 2010 traverse planning. These basic ground rules for the traverse based studies were:

- Field season planning that was based on DRATS 2010 precursor data (primarily USGS geologic map of the SFVF, SP Crater region).
- Geophone lines and broadband installation locations were less than 100m from DRATS 2010 traverse EVA science stations.
- Magnetometry and GPR surveys were performed along the route of the Desert RATS 2010 rover traverse paths. This assumed that these geophysical instruments would have been mounted on the rovers, but that they did not dictate the route taken.

Analysis: From the data acquired from this first field season, we begin by undertaking a systematic approach to analyzing the 21 active source geophone seismic refraction lines that were acquired. For each of these lines, 1-D velocity models are created from P-wave travel time plots and used to resolve the subsurface layers to distinguish between the various overlying lava flows (**Fig. 2** & **Fig. 3**) [5] [6]. The passive broadband array data will use receiver function analysis to establish crustal thickness, search for both low and high velocity zones, and determine locations of regional faulting/seismicity. These results will provide a data set that includes: 1) seismological interpretation of lava flow thicknesses; 2) stratigraphic interpretations of the structure of the lava flows and subsurface, potentially including depths to ground water and bedrock; and 3) a catalog of local seismicity.

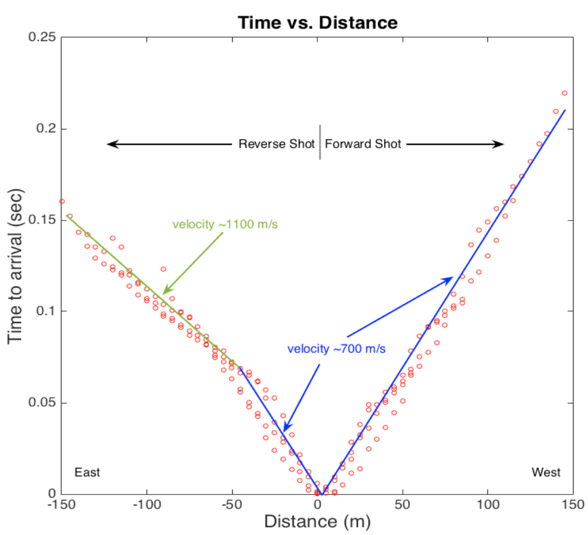

Figure 2: Example travel time plot. Geophone line G3C (Area 3, from west side of Kaibab limestone running east to west across adjacent lava flow).

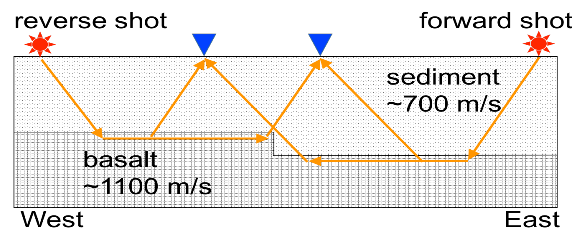

Figure 3: Possible subsurface structure at geophone line G3C. (Blue triangles = geophones; Red stars = seismic sources; Orange lines = seismic rays)

Our products will simulate the geophysical objectives from a planetary traverse based mission perspective. It is expected that the lava field stratigraphy will confirm multiple lava flows of varying temporal and geographic origins. The catalog of seismicity will help to determine the associated faults in the area. However, we expect the resolution and/or completeness of these products will be lacking due to the planetary mission traverse based constraints (ground rules) that have been levied for this initial field season.

The upcoming 2017 field season will not be constrained to the traverse based ground rules. Therefore, the ensuing data set is expected to provide higher resolution results of the geophysical problems. These will include a more complete analysis of the stratification, quantities and origins of the lava flows, and possibly a tomographic map of the SP volcanic plumbing system.

Conclusion: In conclusion, our initial seismic analysis provides a planetary traverse based understanding of the characteristics of local volcanic features (flows, vents) and their relationship with the underlying sediments, water table, bedrock, and crustal structure. This includes estimates on the flow thicknesses, as well as depths to ground water and bedrock. Additionally, the broadband seismometer data is expected to reveal the deep crust/upper mantle seismic velocity anomalies (either low or high velocity structures) that lie beneath the SFVF surface. The GPR and magnetic data will also be analyzed and used to augment the findings from the seismic data.

References:

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