PLANETARY ANALOG STUDIES OF GEOPHYSICAL FIELD TECHNIQUES

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LUNAR EXPLORATION ON EARTH

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1. MOTIVATION & GOALS

- NASA Desert Research and Technology Studies (RATS)
  - Engineering based studies on the operability of performing geologic field activities that evolved to full-scale multi-week simulated lunar excursions with realistic geologic objectives
  - 2010: realistic human piloted rover traverse around the San Francisco Volcanic Field (SFVF) with prototype habitable rovers, habitats, & communication restrictions
  - Geophysical tools and exploration were not included
- ***Goal of study***: *compare geophysical datasets from a planetary "mission-based" scenario & "terrestrial-based" deployment to determine measures to increase the efficiency of conducting geophysical surveys on planetary bodies while using the collected data to analyze real-world volcanic field geologic problems*

Above: optimization of geophysical fieldwork, such as Lunar seismic station deployment (*left*) (Image credit NASA, Apollo 12), through use of Terrestrial analogs (*right*) (Image credit D. Pettit, SFVF 2016).

2. STUDY REGION & APPROACH

Study Region:

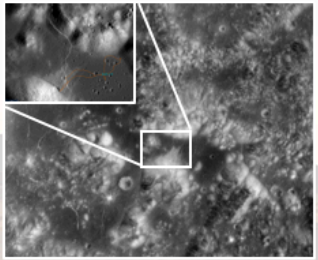
- 7 km x 7 km region, analogues to Taurus-Littrow lunar region, located within the SFVF
- Roughly centered on SP Crater (cinder cone with 250 m of relief)
- Contains cinder cone volcanoes & lava flows
- Includes significant portion of RATS 2010 rover traverses
- Eight areas encompass science stations used for simulated crew extravehicular activities

Left: SFVF Study Region. Colored Study Areas encompass RATS science stations. Colored lines indicate rover traverse paths. Arrows indicate broadband array seismometer locations.

Traverse Mission Based Approach:

1. Assume that geophysical objectives were secondary in relation to RATS 2010 geologic traverse planning.
2. Field season planning based on RATS 2010 precursor data (primarily USGS geologic map of the SFVF, SP Crater region).
3. Geophone lines and broadband installation locations were less than 100m from RATS 2010 traverse EVA science stations.
4. Magnetometry and GPR surveys were performed along the route of the RATS 2010 rover traverse paths. Assumed these geophysical instruments were mounted on the rovers, but did not dictate the route.

Left: Study Area #3, with geologic units (approximately 1 km x 0.8 km). Blue & yellow dots indicate RATS science stations. 'Flagged' lines represent planned 115 m geophone lines. Red lines indicate locations of executed geophone lines (three in series).

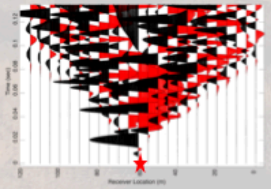


Right: Lunar analog to SFVF, Taurus-Littrow region of moon, containing multiple cinder cone vents (approximately 125 km x 100 km).

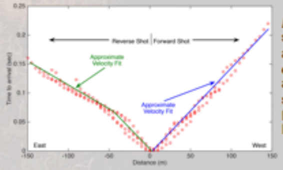
Inset: Apollo 17 mission area showing traverse paths (approximately 20 km x 15 km).

(Images credit NASA/GSFC/LROC)

5. ANALYSIS: example



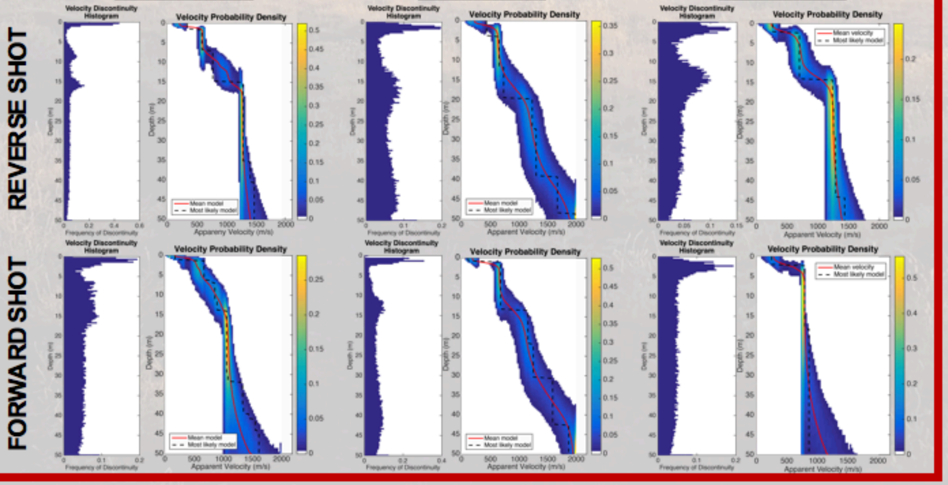
Left: example geophone line seismic wave propagation from Central Profile location (red star on x-axis indicates source location)



Left: example seismic wave arrival time plot of all forward and reverse shots for Eastern Profile location

Left: diagram depicting forward and reverse shot seismic ray propagation

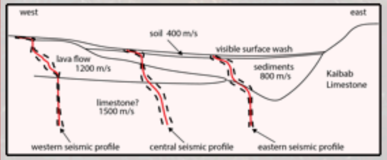
Resulting apparent subsurface seismic velocity profiles for Area 3 forward and reverse shot profiles.



4. CONCLUSIONS

Geologic:

- Seismologic interpretations are limited, providing 'snapshots' of subsurface layering and structure to a depth of ~40 m at specific science station locations, verses overall regional structure.
- Initial interpretation, of Area 3 apparent seismic velocity profiles, results in:



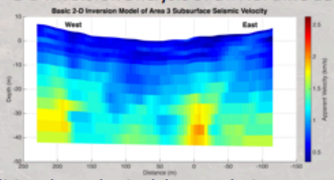
Planetary Traverse Operations:

- Inclusion of seismologic measurements on a planetary traverse require pre-coordination with geologic hypotheses for proper seismic array design to provide appropriate connection between interpretation of subsurface layering and structure, with visible surface features.

5. NEXT STEPS

Updates for likely 2-D subsurface variations:

1. Modify analysis to resolve for dipping layers
2. 2-D inversion analysis of arrival time data



Additional geophysical data analysis:

1. Traverse paths:
   A. Magnetometry results
   B. Ground penetrating radar results
2. Broadband seismometer (1st data set)

Next field season:

1. Select terrestrial based geologic problem within SFVF for detailed analysis. Options:
   1) tomographic analysis of SP Crater
   2) geophysical mapping of select lava flow

[1] Ross, A., et al. (2013), *Acta Astronautica*, doi:10.1016/j.actaastro.2012.02.003. [2] Horz, F., et al. (2012), *Acta Astronautica*, 90(2), 254-267. [3] Abercromby, A., et al. (2012), *Acta Astronautica*, doi: 10.1016/j.actaastro.2012.02.022. [4] Bell, E., et al. (2012), *Acta Astronautica*, doi.org/10.1016/j.actaastro.2012.11.020. [5] Shearer, P. (2009), Introductino to Seismology, Second Edition. [6] Burger, H., et al. (2006), Introduction to Applied Geophysics, Exploring the Shallow Subsurface. [7] McGetchin, T., Head, J. (1973), *Science*, Stable URL: http://www.jstor.org/stable/1735306. [8] Montgomery, L., Schmerr, N., et al. (2017) *Frontiers*.