APPLYING NEAR-SURFACE GEOPHYSICICAL TECHNOLOGY TO DETERMINE ENGINEERING PROPERTIES OF THE UPPER 30M OF THE LUNAR SURFACE. G. S. Baker and L. A. Taylor, Dept of Earth & Planetary Sciences, University of Tennessee, 1412 Circle Drive, Knoxville Tn 37996-1410, (gbaker@utk.edu, lataylor@utk.edu).

Introduction: Several experiments performed by the astronauts on the Moon (e.g., the Apollo Lunar Surface Experiments Package, ASLEP), and proposed experiments as ground-prep for the return of humans to the Moon (RPLP-2/LPRP-2) involve the use of seismic (acoustic) energy for exploration. These seismic signals can be used for a wide array of purposes, from imaging the Lunar interior to detecting evidence of strange quark matter. However, one important—but often overlooked—use of seismic signals is in determining engineering properties (e.g., Poisson's Ratio) of the shallowest layers of the Lunar subsurface. Understanding the physical properties within the upper 100m of the Lunar surface will be critical as Lunar exploration advances and the deployment of large structures becomes necessary. *A priori* knowledge of the load-bearing capacities of the surface layers will be critical.

Methods: There have been tremendous advances in near-surface geophysical technology, since the Apollo missions, which have greatly improved our ability to quickly and easily resolve subsurface variations in physical properties that relate to Young's Modulus, Bulk- or Shear-Modulus, and Poisson's Raito [1]. These active-source seismic techniques include the analysis of seismic surface waves and P- & S-wave refraction tomography. A large volume of literature exists demonstrating the usefulness of these techniques in determining engineering parameters prior to large-structure construction, tunneling or trenching, deployment of heavy vehicles (e.g., heavily armored vehicles in deserts), etc. [2].

Seismic surface-wave methods involve the deployment of either single seismometers or multiple seismometers (Fig. 1). When multiple seismometers are used, acquisition and real-time data processing rates are greatly increased. Results include cross-sectional maps of seismic shear-wave velocity that can be correlated to various engineering properties (Fig. 2, top).Seismic refraction tomography is a form of travel-time inversion that yields velocity maps similar to those generated from surface wave analysis (Fig. 2, right). By combining the two techniques, a much improved and better constrained determination of subsurface properties can be generated.

Current research is underway to develop more portible and reliable sensors for use in Lunar exploration [4,5]. This includes the Swept-Frequency Acoustic Seismic Source (SASS) and the integration of piezoelectric vibration sensors into the Multi-channel Acoustic Portable Profiler (MAPPer). Testing and development of these new tools on Earth yield results comparible to traditional tools and provide a significant decrease in weight and labor requirements for data acquisition.

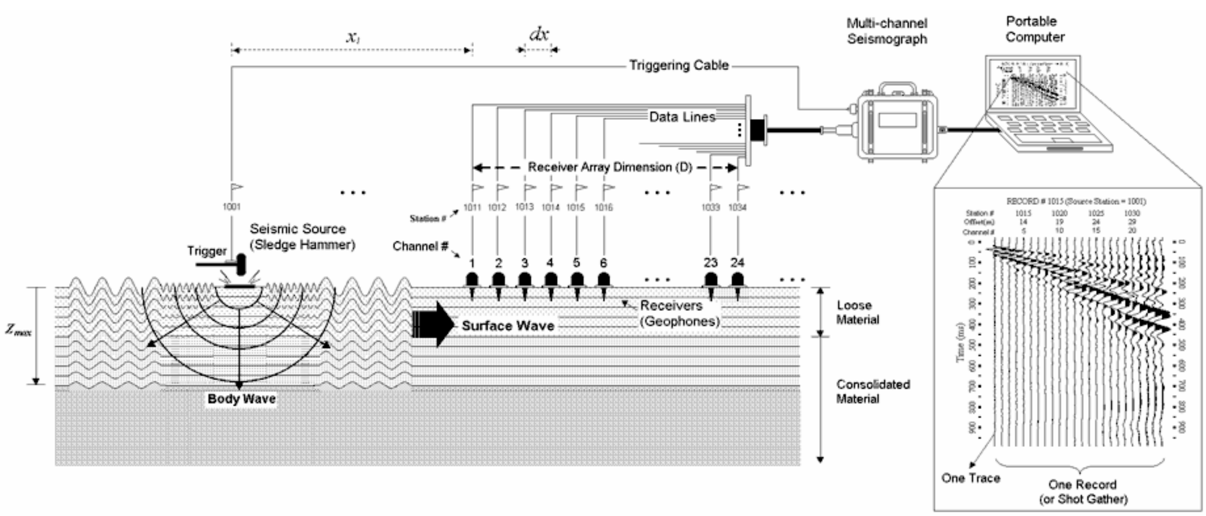
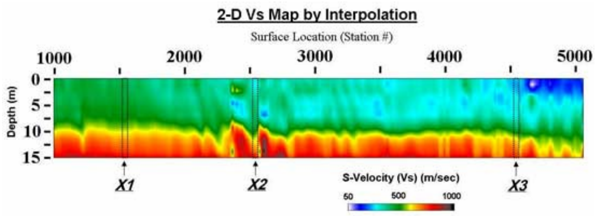


Fig. 1. Typical multichannel seismic surface-wave experiment as deployed on Earth. Modified from [3].



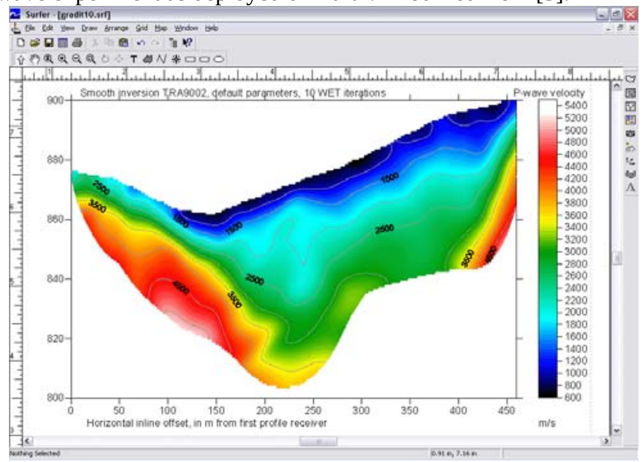


Fig. 2. Typical shear-wave velocity map of the shallow subsurface obtained from multichannel seismic surface-wave methods (above) and example output from a shallow seismic refraction-tomography experiment (right). Modified from [3].

Discussion: The technological advances of the last decade have yielded significantly improved data-acquisition, data-processing, and data-visualization tools for determining engineering (physical) properties of the shallow subsurface, i.e., upper 30m. This information has proven critical on Earth for various engineering projects including building, bridge, and roadway construction, as well as in mining/excavation, for identifying regions having laterally-varying properties (Fig. 3). Based on the anticipated engineering needs of Lunar exploration, the application of these near-surface geophysical methods on the Moon should prove to be a critical component of data gathering prior to—and during—upcoming projects. Imagine the detection and mapping of a subsurface lava tube – a possible ready-made habitat, complete with radiation shielding!

References: [1] G.S. Baker, D.W. Steeples, and C. Schmeissner (1999) In situ, high-resolution P-wave velocity measurements within 1 m of the Earth's surface: *Geophysics*, 64, no 2, 323-325. [2] G.S. Baker (1999) Processing near-surface seismic-reflection data: A Primer: *Society of Exploration Geophysicists Publications* [ISBN 1-56080-090-9] [3] C.B. Park, R.D. Miller, and J. Xia (1999) Multichannel analysis of surface waves (MASW); *Geophysics*, 64, 800-808. [4] M. Malinowski, G.S. Baker (2003) Experimental results of energy and soil-moisture effects on nonlinear deformation associated with near-surface seismic reflection sources: *Journal of Environmental and Engineering Geophysics*, *8*, no 4, 221-226. [5] G.S. Baker, D.W. Steeples, C. Schmeissner, and K.T. Spikes (2000) Source-dependent frequency content of ultrashallow seismic reflection data: *Bull. Seis. Soc. Amer.*, *90*, 2, 494-499. [6] K.A. Sturtevant, G.S. Baker, M. Lord, J. Miller, D. Jewitt, D., Germanoski, J. Chambers (2006) Utilizing multiple geophysical techniques to analyze bedrock geometry and sedimentological controls on riparian meadow complexes in the Central Great Basin, NV: *Geological Society of America Abstracts with Programs*, Vol. 38, No.3.

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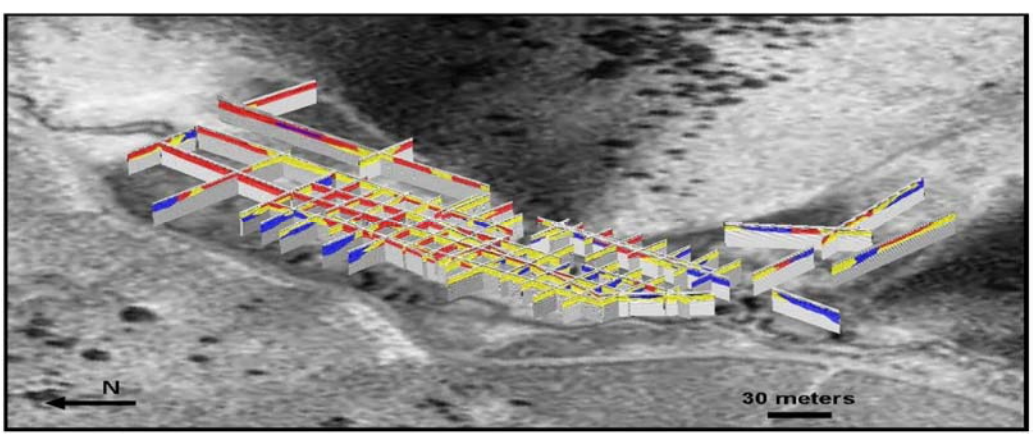

Fig. 3. Pseudo-3D perspective view of physical properties (correlated with available borehole information) at a test site in central Nevada. These types of data allow for differentiation among subsurface regions having similar physical properties, and would allow for improved selection of construction/landing/mining sites. Modified from [6].