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Comment on "Subsurface water detection on Mars by astronauts using a seismic refraction method: Tests during a manned Mars simulation," by V. Pletser et al.

Robert E. Grimm*, David E. Stillman

Department of Space Studies, Southwest Research Institute, Boulder, CO 80302, USA

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Abstract

Pletser et al. performed a seismic-refraction survey on Devon Island with the goal of assessing the feasibility of astronauts carrying out such operations on Mars to detect subsurface water. We demonstrate that the seismic analysis is fundamentally flawed. The survey performed in this test will likely bear little resemblance to future crewed geophysical surface operations, and better methods exist to detect subsurface water.

Keywords: Mars; Interior; Geophysics; Experimental techniques

The analysis by pletser and coworkers failed to recognize the presence or absence of the principal waveforms of exploration seismology, which can be easily done from their photograph of the seismograph screen (their Fig. 4). Software on the seismograph was used to identify the direct wave and its 2600 m/s velocity. However, a refracted wave is evident as the first arrival on traces 4–18. This wave has a velocity of approximately 5200 m/s. Because "a trigger geophone [was] installed close to the source seismic event," we infer that the first geophone is near zero offset and so the crossover of the direct to refracted wave as the first arrival occurs at a distance of 12 m. Given this distance and these two velocities, an interface lies at 3.4 m depth (e.g., [1,2]). These results are consistent with a thin cover of compacted and/or saturated alluvium overlying carbonate bedrock [3, 5]. A faster first arrival on traces 19–24 may indicate a second interface at 10–20 m depth.

The claim of investigation depth up to several hundred meters is particularly egregious. The seismic refraction method senses subhorizontal interfaces at a fraction of the total length of the geophone line used. This is because the direct and refracted ray paths are primarily horizontal, and it physically restricts the maximum depth of investigation to several tens of meters in this survey. The characteristic signature of more vertically traveling reflected waves from subhorizontal contacts—hyperbolae with apices nearly below the shotpoint—are absent in these records. The claimed depth of 550 m appears to have been derived by multiplying the record length (0.2048 s) by the derived P-wave velocity (2600 m/s). This is erroneous because (1) it neglects the factor of 2 for two-way traveltime, (2) it uses surficial and not bedrock velocity, and (3) there is no evidence of reflections late in the records, only noise. Just because a long time interval are recorded does not mean there is any useful data.

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* Corresponding author.
E-mail address: grimm@boulder.swri.edu (R.E. Grimm).

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There was no demonstration or even capability for true three-dimensional imaging. If the subsurface is composed of gently dipping beds then the two orthogonal survey lines would have been sufficient to determine overall bed strike, dip, and thickness variations; otherwise a denser configuration of both geophones and shots is necessary for tomographic imaging.

The Apollo 14 and 17 crews already demonstrated that near-surface active-seismic profiling is tractable. Current state-of-the-art seismic instrumentation uses wireless technology, so astronaut implementation on Mars (or the Moon) will likely not be constrained by extensive cable deployment and recovery (wires are still necessary in some kinds of electromagnetic exploration). Alternatively, "land streamers" towed behind moving vehicles now allow seismic data to be acquired on-the-go. Sledgehammers are inefficient and dangerous for spaceflight: mini-vibrators exist that provide controllable, high-quality signals. Difficulties relating to keyboard and other instrument use while wearing bulky gloves are not unique to geophysics. Other obstacles to crew activities cataloged by Pletser et al. are largely related to the decidedly non-martian environment (rain and mud) and implementation (low-fidelity "spacesuits").

In spite of the controversy that has surrounded the existence and depth of water on Mars, Pletser and colleagues have correctly stated that any liquid H_2O must exist within a few hundred meters of the surface to be accessible for exploration or as a resource. Ground-penetrating radar is more portable and has higher efficiency in this regime. Saline water is better identified from its high conductivity rather than its elastic impedance or even dielectric properties. Low-frequency, diffusive, electromagnetic methods are then favored. Using a 10 m diameter transmitter loop, the time-domain electromagnetic method (TDEM) can detect groundwater on Mars to depths of $\sim$ 1 km [4].

In summary, active seismology—particularly the refraction method—is not optimally suited to detecting groundwater in the upper several hundred meters of Mars. The results presented in this paper do not follow the first principles of seismic analysis and do not support exploration to depths of several hundred meters using the specified geophone array. Astronaut-deployed geophysical experiments will likely use distributed networks and be less labor-intensive than classical terrestrial counterparts.

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