SUBSURFACE WATER DETECTION ON MARS BY ACTIVE SEISMOLOGY: SIMULATION AT THE MARS SOCIETY ARCTIC RESEARCH STATION

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The Mars Society has established a Mars Arctic Research Station (M.A.R.S.) on Devon Island, North of Canada, in the middle of the Haughton crater [1] formed by the impact of a large meteorite several hundred million years ago. The site was selected for its similarities with the surface of the Mars planet.

One of the conducted experiments in Summer 2001 was to conduct an active seismology experiment to detect the potential presence of subsurface water. Crewmans wearing a Martian EVA suit have installed a set of 30 seismometer sensors on the surface of the Haughton crater to record signals generated by a hammer source, somehow similar to experiments conducted on the Moon [2]. The instrumentation was provided by the Institute of Physics of the Earth, (IPGP), Paris, France. Recorded signals will be analyzed later on to extend the characterization of the Haughton crater structure by supporting scientists from the IPGP and the Royal Observatory of Belgium.

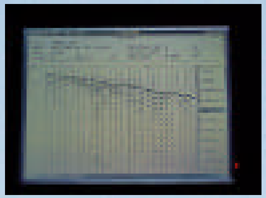


Figure 2: Signal recorded during Test #2

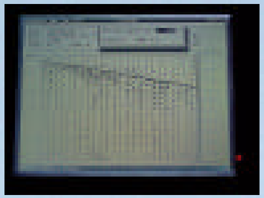


Figure 3: Velocity analysis on signal of Test #2

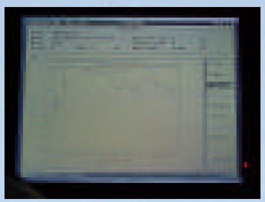
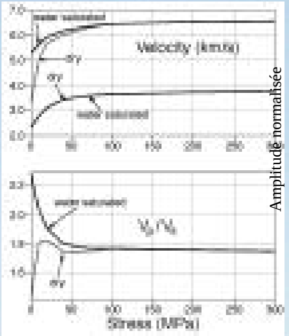
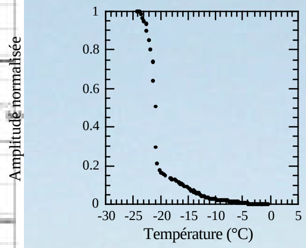


Figure 4: Spectrum analysis of one channel.

Signature of Water on Seismic parameters



Effect on velocities: Velocity data for Casco granite. Data on dry rock from Nur and Simmons (1969). Data on saturated rock calculated from dry rock data using Biot–Gassmann low–frequency limit. Increase of stress on Mars is 10 MPa per km.

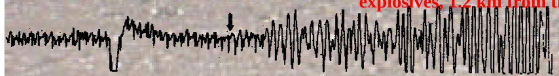


Effect on Attenuation: Amplitude data for Fontainebleau Sandstones with respect to temperature for saturated rocks. FromGuichet et al., 2001

Figure 1: Three person EVA conducting the seismic experiment with hammer seismic source

Transmitter noise

S/N on the Moon: Apollo 17, 454 g of explosives, 1.2 km from the geophone



Moon seismic source: Mortar, Apollo 16

Active Seismology on the Moon: summary of results. The subsurface of the Moon has been reviewed by Cooper et al. [1974] and was studied by an active experiment with the deployment of several lines of geophones and with active seismic sources deployed by a Mortar. Explosive charges up to about 1 kg of explosive were used. Advanced seismic sources with increased safety could be now envisaged, with binary storage and electrical detonators . We will only briefly present the main results here. The subsurface of the Moon, typically up to 1 km deep, is composed of very low seismic velocity materials [Kovach & Watkins, 1973a, 1973b,, Watkins & Kovach, 1973; Cooper et al., 1974]. A first layer with a typical P velocity of 105 ± 5 m/s, constitutes a moonwide layer of young regolith done with porous, highly fracturated and brecciated rocks. Depending on the Apollo site, this layer was between 2 and 12 meters thick. Below this layer, a second layer was observed, characterized with higher seismic velocities, around 300 $\pm$ 50 m/s and a thickness between 0 and 100 m, which may a mixture of ejecta material and older, more consolidated regolith. These two regolith layers have important station frequency dependent amplification effect on the seismic signal: signals arriving at Apollo 15 site were amplified by a factor of 1.5 relative to the Apollo 12 site. For the Apollo 14 and 16 sites, the amplification factor was even higher: 3.5 [Nakamura et al., 1975, Horvarth et al., 1980]. These sites were indeed characterized by an increasing thick upper regolith layer, respectively of 2-4, 5 , 8.5 and 12 meters. Below these layers and up to 1-1.5 km a layer with velocities around 1 km/s was found. It has been interpreted as a fractured and broken zone extending to the lower crust discontinuity, where P velocity rises respectively up to 4.7-4.9 km/s [Cooper et al., 1974; Nakamura, 1983].

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- A three member EVA crew (Robert Zubrin, Katy Quinn, Vladimir Pletser) conducted a seismic experiment during a four hour EVA in poor weather conditions (rain and wind); see Figure 1.
- A line of 24 seismic sensors (geophones), delivered by IPGP and CRG-Garchy for this experiment were deployed in the Haynes Ridge plain, in front of the Flashline MARS Habitat. The line (geophone flute) was laid in a South-South-East direction, approximately parallel to the Haughton crater rim. This direction was chosen as being perpendicular to the direction of the flute laid in a previous dry run trial.
- The geophones were spaced every 4 m. Three tests were conducted with a trigger geophone triggered by quakes created by sledge hammer shots. The trigger geophone and the hammer shots were respectively located at the middle of the flute (Test # 1) and at both ends of the flute (Tests # 2 and 3).
- Locations were measured using a hand-held GPS receiver as follows (within GPS precision and related to the WGAS4 ellipsoid):
  - 4 m mark at N 75 deg 25.871, W 89 deg. 50.067, 240 m elevation
  - 96 m mark at N 75 deg 25.847, W 89 deg 49.894, 242 m elevation
  - Shot (Test #1) at N 75 deg 25.859, W 89 deg 49.976, 253 m elevation
  - Shot (Test #2) at N 75 deg 25.872, W 89 deg 50.075, 260 m elevation
  - Shot (Test #3) at N 75 deg 25.846, W 89 deg 49.881, 256 m elevation
- In order to improve the signal to noise ratio, tests were conducted in a stacking mode with ten hammer shots for each test. Sampling interval was 100 microsec, with 2048 samples and no filters.
- The geophones were tested individually and automatically prior to conducting the first Test and were found in functioning conditions.
- A first glance analysis of data back in the Hab showed the following:
  - For the three test configurations, the average underground velocity of the signal was approximately 2600 m/s. (See Figures 2 and 3)
  - The spectrum analysis for each geophone signal for the three tests showed the following ranges of maximum frequency peaks :
  - Test 1: 135 Hz (channel 18) to 405 Hz (Channel 17)
  - Test 2: 121 Hz (channel 22) to 443 Hz (Channel 7)
  - Test 3: 67 Hz (channel 3) to 409 Hz (Channel 17) (see Figure 4).
  - Sounding extended to vertical depths in excess of 550 m.
  - The first refracted signal recorded in Test 1 is returned after 70 milliseconds, consistent with an approximate position of an interphase at a depth of 90 m.

In conclusion, no water is detected under the ground of Haynes Ridge, Average velocities of wave transmission for water are catalogued between 1450 and 1500 m/s for liquid water and between 3300 and 3800 m/s for ice. The average velocity deduced from test results is consistent with Calcium Carbonate and Dolomite (catalogued range: 12000 to 7000 m/s), which is commonly found in this area. More detailed analysis will be conducted after the campaign to further characterize the underground structure.