Thermal Modeling of Fine Gravel, Coarse Sand and Fine Sand Sediments with Varying Amounts of Saturated Layers A. Jowell[1] and A. Jowell[1], K. Pokuri[2], [1]Durham Academy Upper School, Durham NC, [2]Green Hope High School, Cary NC

Introduction: The question of whether or not life exists on other planets has dominated the scientific community for hundreds of years. The quest to find water and ultimately life on Mars is challenging, especially since most of the planet is covered with layers of sands and gravels; however, there is the possibility that water is buried beneath the Martian surface [1].

An important characteristic of these layers of sediments is their adhesive and cohesive properties, which determine the strength of sediments' interparticle forces. A smaller grain size results in stronger capillary action and greater interparticle forces between grains. These stronger interparticle forces allow water more effectively to rise towards the surface [2].

Due to limitations such as expense and technologies, it is difficult to send rovers to Mars and dig beneath the surface to look for water. However, we believe that the presence of water below the surface can be found by analyzing the heating and cooling curves created from data collected by infrared thermometers orbiting Mars. These curves depict the thermal inertia of sediments. Thermal inertia is "a measure of the subsurface's ability to store heat during the day and reradiate it during the night" [3]. Thus, the purpose of this experiment was to model the thermal inertia of different grain sizes with varying amounts of saturated sediments beneath the surface.

Analytical Approach: The sediments used in this experiment were found in a sample from the North Carolina Eno Riverbed. The sample was first sifted into three different grain sizes: fine gravel, coarse sand and fine sand. In preparation for each trial, the sediments were dehydrated in an oven and then placed in a bucket filled from the base with 2cm, 4cm, 6cm, 8cm or 10cm of saturated fine sand, coarse sand or fine gravel. The rest of the bucket was filled with the corresponding dry sediments. We defined saturation as mixing the sediment with enough water indicated by small pools of water on the surface. A dry run was used as a control.

In order to standardize the experiment, the sands and gravels containing various amounts of saturated sediments were placed in buckets 10cm deep and 20cm wide in correlation with NASA's thermal study guidelines. Each bucket was heated using a standard 100 watt bulb. The heat lamp was located 40cm above the bucket and an infrared thermometer was placed on a tripod 30cm away from the base of the bucket and 40cm above the bucket. The thermometer measured the center of the sediment.

Each bucket with varying amounts of saturated sediments was placed below the heat lamp. After taking the initial temperature, the heat lamp was turned on and the temperature of the sediments was measured in 30-second increments until the sample stabilized. We defined the sample as stable when its temperature fluctuated within 1°C over a 10 minute period. Once stabilized, the heat lamp was turned off and the cooling temperatures were measured using the same parameters. Each trial was repeated at least twice. Additionally, a FLIR infared camera was used to authenticate our results. Overall, we found that the camera was within +/- 1 degree Celcius of the temperature readers.

After data collection, the curves were modeled mathematically to compare and analyze. The data were entered using the program Logger Pro and regressions were found and then averaged together using the mathematical, web-based tool Wolfram Alpha. These final regressions were then entered into the graphing program Grapher and the models were obtained.

Results: After compiling the data on Logger Pro, we determined that the heating curves were best modeled with the natural logarithm function while the cooling curves were best modeled with the natural exponent function with time (minutes) as the independent variable and temperature (degrees Celsius) as the dependent variable. Graphs of the data are shown below.

Figure 1: *Thermal behavior of fine gravel at different levels of saturation: dry (red), saturated within 8 cm below the surface (orange), 6cm below the surface (yellow), 4cm below the surface (green), 2 cm below the surface (blue), and completely saturated (violet).*

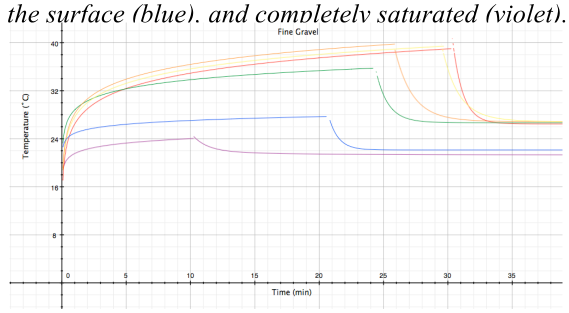


Figure 2: *Thermal behavior of coarse sand at different levels of saturation: dry (red), saturated within 8 cm below the surface (orange), 6cm below the surface (yellow), 4cm below the surface (green), 2 cm below the surface (blue), and completely saturated (violet).*

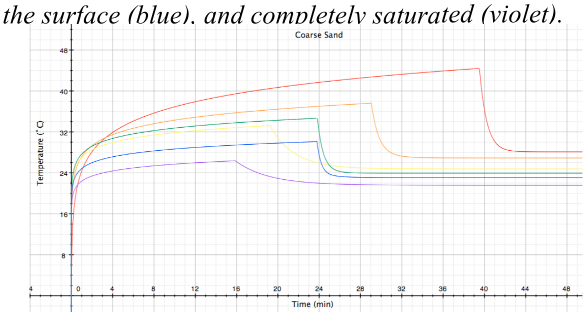
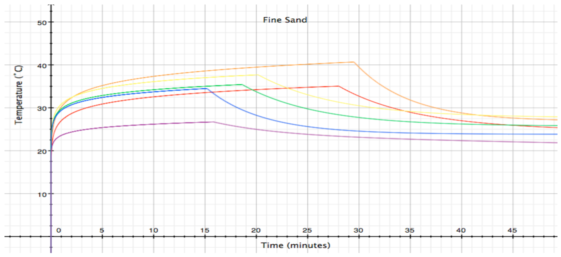


Figure 3: *Thermal behavior of fine sand at different levels of saturation: dry (red), saturated within 8 cm below the surface (orange), 6cm below the surface (yellow), 4cm below the surface (green), 2 cm below the surface (blue), and completely saturated (violet).*



Discussion: Analysis of results showed two general trends. The first was that the time required for sediments to stabilize decreases with increasing moisture content. The second was that as the moisture content increases, the sediments reach lower temperatures. One possible explanation for these trends is that the heat capacity of water is greater than that of sediments [4]; consequently, the samples containing more water do not reach as high a temperature and stabilize more quickly. Furthermore, since evaporation is a cooling process, more water present results in greater evaporation and thus lower temperatures.

By comparing the fine gravel, coarse sand and fine sand models, we found that some sediments deviated from the general trends more than others. For instance, the fine gravel curves (Figure 1) deviated the most, particularly with the dry sediments and sediments saturated within 8 and 6 cm from the surface. This observation can be explained by the cohesive properties of fine gravel sediments. Since these properties are less prominent with increasing grain size [2], small amounts of saturated sediments did not have a noticeable effect on the thermal signatures of fine gravel samples since water did not rise close to the surface. Therefore, with fine gravel and coarser sediments, it is difficult to use thermal signatures to detect water deep below the Martian surface.

On the other hand, the smaller grained sediments, namely the coarse and fine sands, more accurately followed the general trends presented at the beginning of the discussion. This is because wicking of water is more noticeable with smaller grain sizes [2], allowing the water to be drawn effectively towards the surface. Water closer to the surface results in the heating and cooling curves following the general trends more precisely for these curves are heavily reliant on water content. Thus, even small amounts of saturated fine sediments have an effect on these curves, unlike with fine gravel, where small amounts of saturated sediments had little effect. One discrepancy was the fine sand dry run (colored red Figure 3), whose difference can be accounted for by experimental error.

When analyzing the data, one must take into consideration possible sources of error. First, we collected the data in two labs using slightly different set ups. These different testing sites could have led to uncontrolled variables and inconsistency in collected data. Furthermore, the air conditioning often turned on and off during data collection. Finally, the amount of water used to saturate each sample was qualitatively determined and not standardized between each trial; therefore, imprecise water amounts were used to saturate the samples, which affected the accuracy of the results.

In conclusion, we found that generally the time required for sediments to stabilize and the maximum temperature reached decrease with increasing moisture content. These trends are followed most precisely by sediments with smaller grain sizes. Thus, thermal signatures would be most effectively used with smaller sized sediments to determine the presence of water on the Martian subsurface.

Future Work: We would like to continue our studies of thermal properties of these sediments with different saturation levels in the hopes of developing models to use on Mars. We would also like to draw some conclusions about how fast each grain size relatively heated and cooled as well as the maximum temperature each grain size reached comparatively. However, with our data we could not determine a pattern due to error. Thus, we would like to perform additional runs in more controlled environments with standardized amounts of water used in saturation.

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References:[1]Evidence for Recent Groundwater Seepage and Surface Runoff on Mars, Michael C. Malin and Kenneth S. Edgett, *Science* 30 June 2000: 288 (5475),23302335,[DOI:10.1126/science.288.5475.2330] [2] Huang, J., Hilldale, R., & Griemann, B. (n.d.). Erosion and Sedimentation Manual. *Bureau of Reclamation Homepage*. Retrieved Dec 29, 2012, from http://www.usbr.gov/pmts/sediment/kb/Eros [3] Thermal Inertia at CU. (2007, May 26). *Laboratory for Atmospheric and Space Physics*. Retrieved Dec 29, 2012, from http://lasp.colorado.edu/inertia/ [4] Coastal Versus Inland Temperatures. (n.d.). *Space Educators Handbook*. Retrieved Dec 31, 2011,from http://er.jsc.nasa.gov/seh/Ocean_Planet/activities/ts1ssac3.pdf