Thermal Modeling of Fine Gravel at Different Saturation Levels.
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Introduction: The scientific community is headed in a direction of space exploration where finding life outside of planet Earth is a desired intention. Due to its proximity and sediments, Mars is an optimal site of interest that shows prospective signs of life. As water is an essential substance for life on Earth, we can presume it is also an indicator of life on Mars. The Phoenix lander confirmed the existence of water on Mars [1]. Scientists suspect there might be significant amounts of groundwater underneath the Martian surface [2]. Therefore, by identifying thermal inertias of sediments (at different saturations) typically found on Mars, we can potentially identify areas where there may be moisture on or below the surface of Mars. One common sediment size on Mars is fine gravel, which is characterized by a grain size between 2mm and 4mm [3]. The focus of our investigation is to determine the effect of different levels of saturated fine gravel have on its thermal inertia.

Thermal inertia in this study is defined by the ability of fine gravel to absorb and conduct heat throughout the day and retain it at night [4]. By simulating this diurnal and nocturnal occurrence in a controlled setting, we were able to collect the thermal inertia data of fine gravel. This data was instrumental in constructing a thermal model.

The thermal model provides a visual aid showing the heating and cooling curves of fine gravel at different levels of saturation. By comparing our data and thermal models with infrared data of Mars taken by orbiting satellites [5], we hope to identify potential places where water lies on or below the surface of the planet.

Analytical Approach: To emulate conditions and sediments on Mars, we designed a heavily controlled experiment.

After obtaining a large amount of sand and gravel from the Eno River in Durham NC, we sifted the sediments until we had a significant amount of fine gravel. In compliance to NASA guidelines, we sifted enough sediment to fill a bucket 10cm tall and 20cm wide with fine gravel. During the setup, we positioned a 100-watt heat lamp 40cm directly above the center of the bucket and was not changed in order to ensure consistency. An infrared thermometer was mounted to a ring-stand 30cm away and 40cm above the center of the bucket of fine gravel.

During the experiment, all temperatures were taken in 30-second increments. First we took three initial measurements without the heat lamp turned on in order to get a baseline, which was close to the ambient temperature. Then we turned on the heat lamp and proceeded to record the temperature shown on the infrared thermometer every 30 seconds. We continued to record temperatures until the sediment started to stabilize which was defined as a change of +/- 1°C for ten minutes. After stabilization occurred, the heat lamp was turned off and measurements were once again taken every 30 seconds until the sediment stabilized.

The objective of our experiment was to measure and model the thermal inertias of fine gravel that was dry, saturated within 8 cm below the surface, 6cm below the surface, 4cm below the surface, 2 cm below the surface, and completely saturated. In order to perform the saturated tests, the pre-determined fine gravel was placed in the bucket and was then saturated with water. The dry fine gravel was then placed on the saturated sediment until a height of 10cm was achieved. At the end of each data cycle, the wet sediments were placed in an oven to dry.

These procedures were repeated many times for each saturation level and were averaged out in order to obtain the most accurate results possible. At the end of the entire data collection process, a thermal model was made to compare the thermal curves of the different saturation levels.

Results: Graphing of thermal inertias was achieved using natural logarithmic functions for the heating curves and natural exponental functions for the cooling curves. The independent variable was time and the dependent variable was temperature. Analysis of the data and thermal models shows that there is a significant difference in temperature of sediments that was saturated within 2 cm below the surface in to sediments that were saturated within 4 cm below the surface or more. Also, the thermal curves depict a trend where the more saturated sediment, the lower its maximum temperature and stabilization time. The heating and cooling curves for the six different saturation levels are shown in Figure 1.

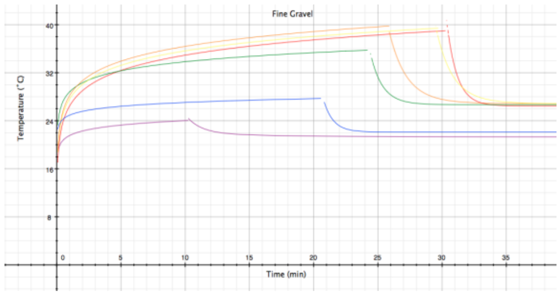

Figure 1: *Thermal behavior of fine gravel at different levels of saturation: dry (red), saturated within 8 cm below the surface (orange), 6cm below the surface (yellow), 4cm below the surface (green), 2 cm below the surface (blue), and completely saturated (violet).*

Discussion: As of the data we have now, we cannot positively distinguish the dry sediments and sediments saturated within 8cm, 6cm, and 4cm below the surface with data taken of Martian sediments. This is because for these saturation levels, the water table is too deep to show any significant difference in thermal curves from the dry fine gravel. However for a water table of within 2cm of the surface, there is discernible difference to where the data can be considered reliable. By comparing these results with data obtained from infrared satellites orbiting Mars, we hope to identify locations of water on or below the surface of the planet.

Throughout the course of our study, there were many precautions taken to make this experiment as controlled as possible. Possible sources of error include that the air conditioning periodically switched on and off, and even though we directed the air away from our experiment, the ambient temperature still changed. Furthermore, the thermometers that we used had not been recently calibrated and could have skewed the results. Also, when sifting the sediments from the Eno River, we used two different types of sifters to acquire our fine gravel. The two different sifters had slightly different fine gravel filters, which gave us a minimal difference from the 2mm to 4mm grain size that we desired. However, even with these errors, we think the trends in our data are valid due to the multiple repetitions of each trial.

Future Work: We would like to expand our experiment to more specific saturation levels. As of now, we have six saturation levels but by testing a wider variety of saturation levels, we could achieve a more thorough thermal model. Having more saturation levels would be useful in correlating our data with that taken of Martian sediments. Therefore, it would be easier to pinpoint potential depth of water on Mars if we in fact find ideal data. One of our main points of focus would be the interval between sediments saturated within 6-4cm from the surface. Currently we know that there is a significant difference in the thermal curves of 6cm and 4cm saturated fine gravel but by testing more specific saturation measurements within this interval, it will be possible to find a pivotal point where data is different enough from the dry sediment so that it can be considered reliable.

Additionally, fluctuating moisture levels and below surface temperatures could potentially be subjects for future study. Subsurface moisture probes would be an ideal tool for this task.

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