THE EFFECT OF POROSITY ON THE THERMAL INERTIA OF LIGHT AND DARK GRAVEL.

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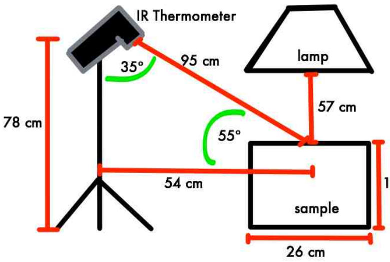
Introduction: The team of students associated with the Mars Outreach for North Carolina Students (MONS) conducted experiments that will ultimately help in the research of Mars and its potential for life. This past year, we experimented with sediments to provide geological knowledge for future study on Mars. What is the difference between the heating patterns of low albedo sediments and high albedo sediments before and after being compressed? If we learn as much as we can about the properties of Earth's sediments, we can eventually compile all data to better understand thermal effects on Mars. Additionally, if we know these heating patterns, we can determine which areas potentially carry groundwater, which is one of the most important factors to life.

THEMIS has been an important tool to further the studies of Mars over the past years. It is the instrument orbiting Mars that images the surface in visible and infrared light to determine the thermal properties of the surface. Since it has the ability to view these areas on the surface, studying the albedo of sediments will help in the interpretation of the data. Our goal was to be able to understand the pattern between compressed and uncompressed gravel in different albedos, which can ultimately tell us more information about the areas underneath the surface of Mars.

Analytical Approach: This experiment required the team to use three 360-watt/m^2 heat lamps, 3 buckets at least 20 cm in diameter and 12-16 cm deep, sieves to wash clay from the sediments, 3 infrared thermometers, 3 tripods for the thermometers, meter sticks to adequately measure the distance between the materials, water to measure the porosity, graduated cylinders to measure the porosity, and light and dark gravel from the Eno River, in North Carolina. The layout of the materials used during the experiment is shown in the diagram below.

First the IR thermometers were calibrated for precision. The temperature of the same spot on a blackboard with all 3 thermometers the same distance from the point was measured to ensure consistency in their readings. All three heat-lamps were calibrated as well; with the calibrated thermometers measuring they heated three different points at the same rate. Each sediment type was washed to remove clay by spreading the sediments on the sieves and running water over them.



Pouring set amounts of water into the gravel and filling the pores completely determined the porosity of the gravels. These sets were then added up to see the amount of space in milliliters there was between the rocks, and this space was divided by the total space of the graduated cylinder to get a percentage. The sediment was then dried by baking it in metal oven pans. It was cooled to room temperature, and the process was enhanced by using refrigerators to cool the sediments.

The experiment was set up according to the diagram. The sediment should be poured in the buckets so that it is 12 cm deep, which allows it to abide by NASA's 10 cm rule after it is compressed (which means that any soil tested must be greater than 10 cm deep). When it was poured, the bucket was not moved or compressed for the initial experiment.

Three initial temperature readings were taken in Celsius with the IR thermometers to determine the starting temperature. The temperature of the very center of the surface was measured and all readings were recorded.

The heat lamp was turned on and readings were recorded every 30 seconds for 1 hour. It was originally thought that we should wait for the readings to plateau, however upon testing when they stabilized it was shown that the sediments heated up indefinitely so long as the heat lamp was on. The lamp was then turned off, while readings continued to be recorded.

Results: Our data is in four sets: Dark Uncompressed, Dark Compressed, Light Uncompressed, and Light Compressed. To create trendlines, they were separated further between when the lamp was on and off, shown in the following:

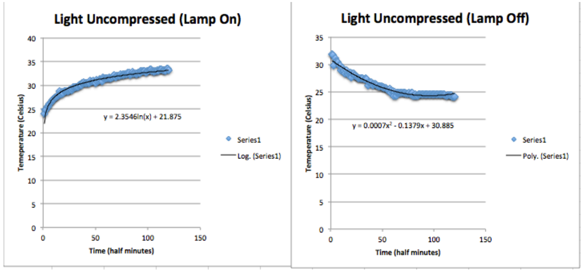
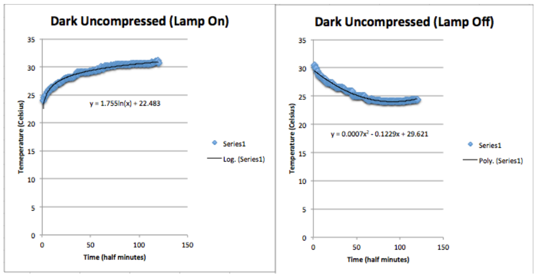


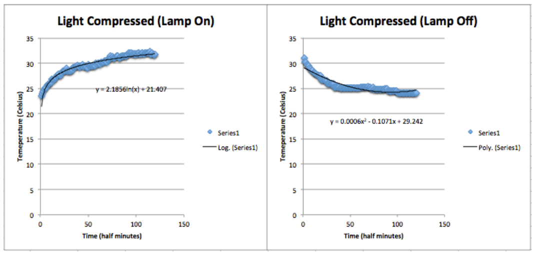
Figure 1



Dark Uncompressed (Lamp On)

Dark Uncompressed (Lamp Off)

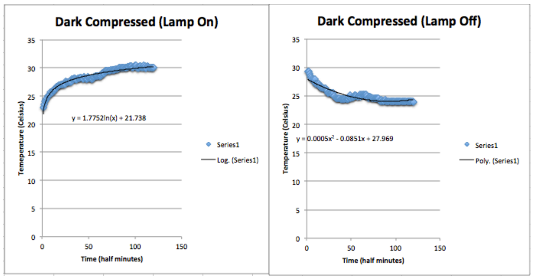
Figure 2



Light Compressed (Lamp On)

Light Compressed (Lamp Off)

Figure 3



Dark Compressed (Lamp On)

Dark Compressed (Lamp Off)

Figure 4

Uncompressed and compressed of both light and dark gravel had data that showed a trendline. These equations show that over time, the temperatures rise as concave down logarithmic curves and fall as concave up polynomial curves. For example, for dark uncompressed gravel, as time t increases between 0 and 60, the temperature will be 22.483 plus 1.755 multiplied by $\ln t$. After 60 minutes has passed however, when the light is turned off, as time t increases, the temperature will be .0007 multiplied by t^2 plus.1229t plus 29.621.

Figure 1 shows that the dark uncompressed gravel has the piecewise equation that follows:

$$f(x) = \begin{cases} 1.755\ln x + 22.483\ if\ 0 < x \leq 60 \\ 0.0007x^2 - 0.1229x + 29.621 \end{cases}$$

Figure 2 shows that the dark compressed gravel has the piecewise equation that follows:

$$f(x) = \begin{cases} 1.7752\ln x + 21.738\ if\ 0 < x \leq 60 \\ 0.0005x^2 - 0.0851x + 27.969 \end{cases}$$

Figure 3 shows that the light uncompressed gravel has the piecewise equation that follows:

$$f(x) = \begin{cases} 2.3546\ln x + 21.875\ if\ 0 < x \leq 60 \\ 0.0007x^2 - 0.1379x + 30.885 \end{cases}$$

Figure 4 shows that the light compressed gravel has the piecewise equation that follows:

$$f(x) = \begin{cases} 2.1856\ln x + 21.407\ if\ 0 < x \leq 60 \\ 0.0006x^2 - 0.1071x + 29.242 \end{cases}$$

It was assumed that the porosity of both the light and dark gravel was the same. When the porosity was tested, uncompressed gravel was at 43% while compressed gravel was at 41%.

Therefore, dark gravel, whether compressed or uncompressed, heated more quickly than light gravel. The difference between compressed and uncompressed gravel was minimal, but there was a slight increase in temperature when the gravel was compressed.

Discussion: This experiment showed that compressing gravel increases the overall temperature. Due to the slight increase in temperature of both light and dark gravel after being compressed, areas with the same sediments that heat up on the surface of Mars could be compressed, and areas that show less of an increase over time could be uncompressed. Additionally, the dark gravel, or gravel with a lower albedo, heats and cools more quickly than high albedo gravel.

Potential error in this experiment was exhibited in our inability to determine the precise horizontal asymptote of the gravel, or the stabilization point.

Future Study: Future study could involve using Dr. Moersch's activity surrounding THEMIS, which would apply our findings to the thermal imaging of Mars. Additionally, future study connecting sediment albedo with water could prove useful in the search for water-based life forms.

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