WATER PRESENCE DETECTION THROUGH THERMAL INERTIA ANALYSIS IN COARSE SEDIMENT. J. Katz[1] C. Peterson[1] A. Viswanathan[1] R. E. Tedder[2] A. Jowell[1] [1]Durham Academy Upper School, Durham, NC, [2]St. Andrew's School, Middletown, DE

Introduction: In recent years, scientific research concerning Mars has been focused on determining the existence of life on the planet. Since a high presence of water in an area may indicate that life is or was once present, it is essential to locate the places on Mars in which water is prevalent. Due to limitations, namely the high cost of rovers and other surface technologies, such efforts to discover the presence of water are impractical. Thus, the scientific community needs to develop a method of remotely determining the relative amount of water in a certain area of Mars in an easy and accurate way.

Water tables have the unique property of adhesion. Since the cohesive attraction of water is weaker than its attraction to the sediment, water rises up from the water table towards the surface. This is an important factor in determining the thermal properties of water, and thus is an essential component in this experiment. [1]

Remote sensing instruments can easily determine the temperature of a given area on the planet. The presence of a water table perceivably alters the rate of heating and cooling of the sediment, or the thermal inertia ("the ability of the subsurface to conduct and store heat energy away from the surface during the day and to return that heat energy to the surface through the night." [2]). Therefore, dichotomies in the thermal inertias of sedimentary similar areas on Mars could perhaps indicate the absence or presence of a water table. Such analysis has been proven possible using THEMIS [3]. Consequently, this experiment aims to investigate the relationship between the depth of a water table in sediment and the sediment's thermal inertia, aiming to derive a mathematical relationship to describe this phenomenon.

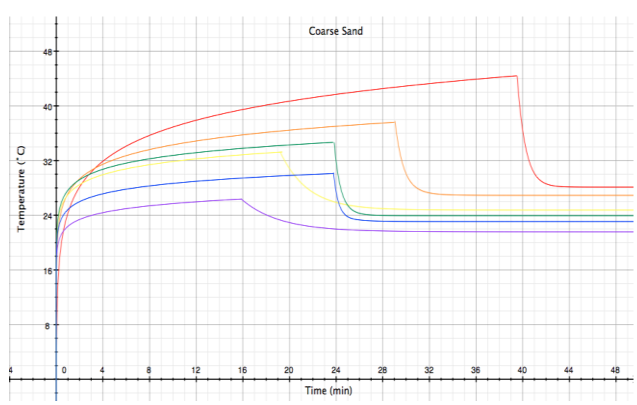
Methods: There are two variables besides the presence or absence of water that alter the thermal inertia of sediment: the composition of the sediment and the grain size. While the latter is relatively easy to control, the former presents a more challenging problem. To eliminate this variable, we had to conduct three separate experiments—one for fine grained sand, one for a coarse sand, and one for a fine grained gravel. This report only addresses coarse sand.

The sediment was collected from the banks of the Eno River in Durham, NC and was sifted into the aforementioned categories of grain size. In accordance with NASA's 10 cm rule, which states that all geological experiments must use a sample of sediment at least 10 cm deep and 10 cm in diameter, we created containers to meet these specifications. The sediment was placed on a stand that held it fixed 40 cm from a 100-Watt heat lamp. We secured an infrared thermometer 30 cm laterally from the center of the sample and 40 cm vertically and aimed it at the center. In an attempt to eliminate the affects of the climate control system in our building, we diverted the fans from the air conditioning system away from the setups. To obtain an initial temperature reading for the sample, we took three measurements, 30 seconds apart, with the infrared thermometer. We then turned on the heat lamp and proceeded to take measurements every 30 seconds until the temperature readings stabilized, defined as only fluctuating within one degree for 10 minutes. The lamp was then turned off, at which point measurements were again taken until the temperature stabilized. After the run was complete, the sediment was taken out of the bucket and put in an oven to dry overnight.

To control for moisture, we first ran a dry run before filling the bucket with an artificial water table 8 cm below the surface. This was created by saturating the sediment, which we defined as the point when pools of water began to form on the sand. After the 8 cm run, we conducted runs with water tables 6 cm, 4 cm, and 2 cm below the surface before conducting a run with fully saturated sediment. Using the heating and cooling curves of the sediments, we could determine their relative thermal inertias. We conducted two runs for each level of moisture.

Results: The mathematical model for the data was a piecewise function, with the first piece representing the heating section of the curve, and the second piece representing the cooling segment. To model the first piece, we used a natural logarithmic regression; to model the second piece, we used a natural exponential regression. Regressions were calculated using Logger Pro, while the functions were averaged using Wolfram Alfa. The average calculated models are shown in Figure 1.

Figure 1*: Thermal behavior of dry (red), 2cm saturated (orange), 4cm saturated (yellow), 6cm saturated (green), 8cm saturated (blue) and 10cm-fully*



saturated (violet) coarse sand sediments.

Discussion: As seen in Figure 1, there is a clear and distinct correlation between rate of heating and cooling of the sample and the depth of the water table. The dry sample reaches the highest temperature, and, for the most part, as the water table is raised, the sample's maximum temperature decreases. The only anomaly in the data set is the 6 cm water table: it seems to reach a slightly lower temperature than the sample with the 4 cm water table. This can be explained by some of the sources of error in our experiment. Our resources make it so that we cannot completely control the temperature of the room where the experiment is being held. Because of that fact, it is possible that, on the days that the 6 cm runs were being conducted, the room was simply cooler than the other days. Perhaps one of the erroneous first runs was not completely negated by the second run (As we collected more data, we became more refined and exact in our collection process). But this run seems to ask us to, instead of analyzing the data in the context of which run reached the greatest temperature, to analyze it by looking at the *rate* of heating and cooling.

To simplify the analysis, it makes the most sense to examine the cooling curves. This is because, while the amount of energy applied by the heat lamp may vary over the course of one run, or the lamp may not distribute heat evenly throughout the sample while the sediment is heating up, in the cooling curve the entire sample is subject to the same room temperature at any given time. Put simply, the rate of cooling will be more constant across the entire sample. Therefore, the conclusions drawn from this part of the models will be most accurate.

Looking at the equations that model the cooling piece of the data, the clearest disparity in rate of cooling exists between the dry sample and the fully saturated sample. In that instance, it is clear that the dry sample had a lesser thermal inertia, since it loses the heat from the lamp more quickly (cools down faster). Once we examine the other runs, however, the results become less clear. While the 2 cm and 6 cm runs fit the trend that we expect by cooling down at a rate that nicely fits between the dry run and the 10 cm run, the other runs do not show as clear of a pattern.

Clearly, then, in the two forms of analysis of the data, there are some runs that do not fit the pattern of thermal inertia increasing as the depth of the water table decreases. The reason for this is threefold. First, due to the adhesive forces between the water and the sediment, water rose to the surface. This inevideably affected the results. For example, on the 4 cm runs, water spots became visible on the top portion of the sample. With a water table 2 cm below the surface, the entire top was covered in water. This means that our classification of the depth of our water table was misleading. Second, due to the fact that we could not turn off the air conditioning in the space in which we conducted the experiments, the temperature that the samples were being heated in was fluctuating. Third, we only conducted two runs for each level of saturation. Because, in some cases the data for the two runs were quite disparate, the averages were likely not incorrect. To conduct this experiment again, then, it would be preferable to have more than just two runs: a more comprehensive average might eclipse the other sources of error in this experiment.

Implications: The fact that clearer patterns emerged at the extremes of the data (i.e. the dry run and the 10 cm saturation) means that there is a distinct pattern between the amount of water in a sample and its thermal inertia. Since the pattern does not perfectly hold for the other levels of saturation, it is likely that interpretation of thermal inertia data can only detect presence or absence of a water table, not the amount.

Future Study: We plan to continue our exploration of thermal inertia and how water affects it. We would like to try the experiment again, but use a brine solution, similar to what was discovered on Mars. Future experiments will hopefully obtain more accurate thermal models which could hopefully be used to help analyze the surface of Mars through the thermal data coming back from orbital instruments such as THEMIS.

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