**Thermal Modeling of Fluvial Sediments.** Mary Tobias [1], Michael Jones[1], Sophia Tsang[2], Andrew Annex[2], Caroline Bodager[2], Faridah Bori[1], Asa Eckert-Erdheim[1], Sinclair Guthrie[1], Max Spencer[1], Jon Sweitzer-Lamme[1], Lise Williams[2], Joel Nackman[2], [1]Durham Public Schools, Durham, NC, [2]Durham Academy Upper School, Durham, NC.

**Introduction:** On Earth, many types of landforms are recognized and classified by their sorting of grain sizes. Fluvial systems, for example, have the largest grain sizes in the middle, and smaller ones lying outwards on both sides from the middle. Sometimes, in infrared images, we can see this and similar patterns. However, this is only a comparative scale. The use of thermal modeling and profiling may allow us to find exact grain sizes on Mars, and thus see thermal patterns characteristic of processes that create them.

Thermal modeling of sediments is the process of modeling and recording the way sediments heat up and cool down, that is, their *thermal inertia*. Larger-sized sediments heat and cool at a much slower rate than smaller-sized sediments. Graphing these records yields a characteristically exponentially-shaped curve for each sediment. While different curves peak and fall at different times, they all share this general shape. Thermal modeling has been used to determine rock abundance on Mars [1].

Fluvial systems have characteristic sediment size distributions [2]. During the MONS program, we have been involved with an experiment to create thermal profiles for certain grain sizes. By doing this, we seek to be able to recognize certain grain sizes by their characteristic thermal properties, and compare them to sediments on Mars in order to determine how water moved across the landscape.

**Analytical Approach:** To collect materials related to sedimentary or alluvial features, we went to the Eno River, in Durham North Carolina, at a location that once held a dam. Here, fluvial sediments were readily available. We sieved the materials into 5 different grain sizes: Coarse Gravel (larger than or equal to 4mm), Fine Gravel (between 2 and 4 mm), Coarse Sand (between .25 and 2 mm), Fine Sand (between .25 and .063 mm), and Silt and Clay (smaller than .063 mm). Also, in order to model the heating of sediments in general, we added a mixture of all the different measured grain sizes, as well as one large rock.

Our models of the materials were then created by filling five different hemispheres of 30 cm globes each with a different type of sediment up to 3 cm below the top. This amount prevented the thermal properties of the globe from affecting the thermal sampling point, which was placed at a point where the sediment was at least 10 cm thick in all directions.

Another requirement for the procedure was supplying 1000 watts per square meter of material. We calculated that a 70 watt flood light bulb would provide enough energy to meet this requirement. However, after another revision of our procedure, we decided to use a 90 watt bulb, so as to allow for some leeway, if some bulbs were faulty in their wattage output. We also set the heat lamp distance from the sediment at 40 cm, so that the heat provided to the material would be standardized throughout the different experiments.

The next decision made was how to accurately and consistently measure the temperature of the sediment. This issue was solved by using a handheld infrared thermometer mounted on a tripod and set to continuously take measurements. By doing this, we could receive accurate readings of the temperature without interfering with the materials. Also, the placing of the thermometer on a stable tripod regulated its distance and accuracy in relation to the materials.

After setting up the heat lamp and thermometer, the process of receiving data began. We took measurements every 30 seconds to see how the materials heated up. The temperature was judged to be stable when it changed less than 0.5 degrees Celsius in 20 minutes. When the heated soil reached this degree of stability, we turned off the lamp, and continued with the measurements to monitor how the sediments cooled down.

Our hypothesis was that the sediments' temperature profiles would present a very organized pattern, with the coarser materials heating up and cooling down the slowest, and the smaller materials both taking on and letting off heat quickly. However, many of the sediment models were different than expected. Figure 1.1 shows our original graphs of some of our first tests. The silt and clay model, for example, instead of being the quickest to heat up and have the highest temperature, had the lowest peak temperature of all the sediments. Also, within the measurements, there was a large amount of noise, caused by several factors: doors were opened, air conditioning systems came on, and the temperature of the room heated up significantly by the end of the heating segment, as all the experiments were held in the same room. Because of this, we decided to split up the sediments between separate groups, and take several more measurements in order to get a good idea of the data trends.

**Results:** At first, we approached the analysis of the data very simply. Separate graphs of the cooling temperatures for each grain size were prepared, and overlaid with a "line of best fit" by using Microsoft Excel®. As the graphs of the dropping temperatures were very similar to regular exponentially decaying lines, these fits were typically quite good.

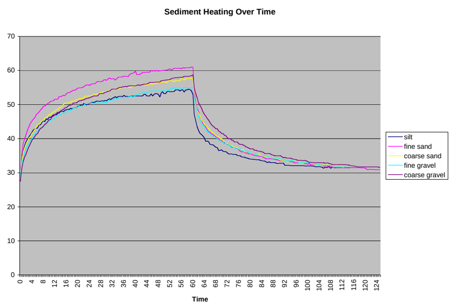


**Fig 1**- The resultant graph from one of our experiments shows the characteristic thermal pattern of the sediments.

With time, however, we realized that this was not the best analysis for this data. After learning some basic information pertaining to Newton's law of cooling (and heating), we began to graph the data. Ideally, we could use Newton's law more exactly, finding the value of the ratios of each sediment, and relating it to measurements of sediment on Mars. However, we first wanted to become more acclimated to simpler modeling first, before starting a much more challenging task. And so, using Microsoft Excel, we entered the experimental data into a spreadsheet, making it all easy to access, add formulas to, and "fiddle with".

**Discussion:** The first step in fitting a more complex, but accurate model to this data was to find a "target temperature" for both the heating and cooling sides of the graph. As Newton's law says, the temperature rises in relation to the ambient (current air) temperature and the starting temperature. In order to find the difference, we first estimated a temperature that was slightly higher than the highest measurement in each data set, and then subtracted the actual heating temperatures from it. We then repeated this procedure with the cooling measurements, but with a temperature slightly lower than the lowest temperature at the end of the experiment, and subtracting this from the actual numbers so as to keep all the numbers positive. There is a warming line and a cooling line because the equation to derive the log difference for the cooling is different. By looking at the warming lines, we can confirm that smaller sediment sizes tend to heat up faster than large sediments such as a rock. The cooling lines also show that smaller sized sediments tend to cool off faster than larger sized sediments. This can be clearly seen with the slopes of the sand, mixed, gravel, and rock sediments. There is a clear trend there that shows the slope decreasing as the sediment size increases.

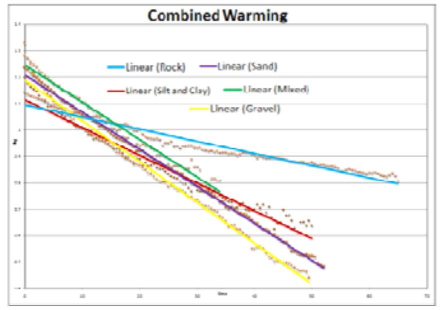


**Fig 2**- Logarithmic regression of sediment heating trends.

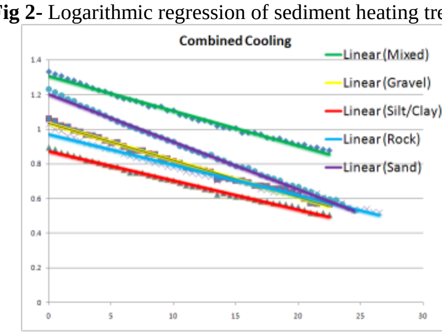


**Fig 3**- Logarithmic regression of sediment cooling trends.

This successfully gave us linear models that stayed quite similar within the same grain size. Figure 1.2 displays the transformed data and the line of best fit for one temperature profile. This is not the last step of our experiment, but our work on soil temperature profiles through the past year has gotten us a few steps closer to decoding the soil and sediment patterns of Mars.

**Future Work:** We plan to continue with this experiment through MONS and to discover more about the thermal properties of sediments. We hope to come to an understanding that will allow us to accurately identify the grain sizes on Mars from infrared pictures, as well as from experiments and measurements taken from Martian soil.

**Acknowledgements:** I would like to thank the entire MONS team of students and teachers for their dedication and hard work towards this experiment. Also, thanks to the University of Tennessee for providing us with this excellent learning experience. This is truly a rare and very special opportunity to discover more about the planet that is so mysterious and enticing to us.

**References:** [1] Mellon, M.T. (2002) *Thermal Inertia and Rock Abundance*, University of Colorado at Boulder. [2] Ortiz, R.M. (2004) *A River in Transition: Geomorphic and Bed Sediment Response to Cochiti Dam on the Middle Rio Grande, Bernalillo to Albuquerque, New Mexico*, University of New Mexico at Albuquerque.