2020-2

The Geologic Times, Vol. 6

Sara Mana

The Geologic Times

Earth Science Association

ESA Newsletter Feb 2020

Edited by Sara Mana

What makes Mercury so dark?

By Kathleen E. Vander Kaaden, SSU Alumna '10

The terrestrial planets that comprise our inner solar system, including the Moon, are all rocky bodies that have differentiated into a crust, mantle, and core. Furthermore, all of these bodies have undergone various igneous processes since their time of primary crust formation. These processes have resurfaced each of these bodies, at least in part, resulting in the production of a secondary crust. Mercury, however, has been shown to have an exotic surface, unlike any of the other terrestrial planets. It also has a much darker albedo than what we see on other planetary surfaces, especially when compared with the Moon. Since its first flyby encounter with Mercury on January 14, 2008, the MErcury Surface, Space ENvironment, GEochemistry and Ranging (MESSENGER) spacecraft collected data on the structure, chemical makeup, and density of the planet among other important characteristics [Solomon et al., 2019]. MESSENGER-based observations suggested that Mercury is made up of a crust, mantle, and core similar to the structure of the other terrestrial planets, albeit diverse in its composition, including a low reflectance material (LRM) mainly found in and around craters causing an overall darkening on the surface of the planet (dark blue regions in Figure 1).

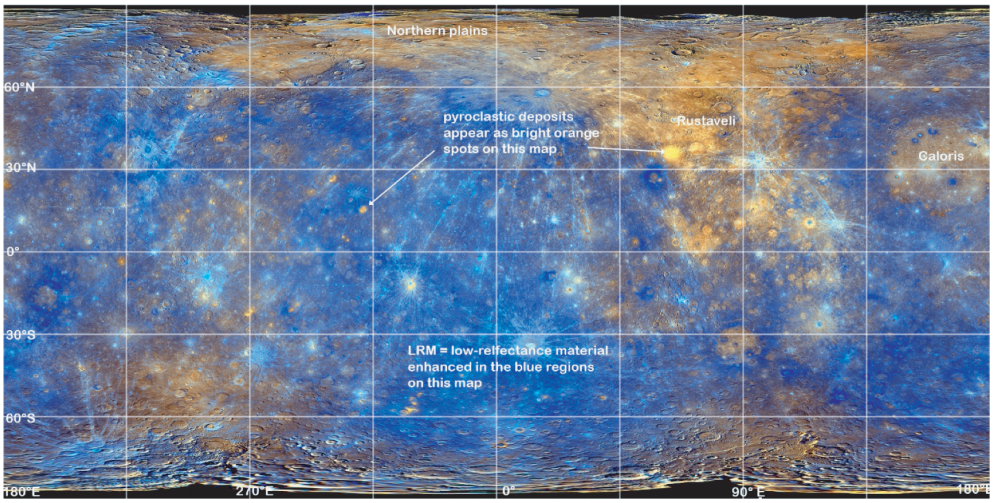

Figure 1. Enhanced color map of Mercury, showing the variety and diversity of materials on the planet's surface. Image from Vander Kaaden et al. (2019).

On Earth, the mantle extends to about ~3480 km depth (~135 GPa) and the metal-silicate ratio of the Earth is similar to the other terrestrial planets. However, on Mercury, the boundary between the silicate portion of the planet and this metal portion beneath it has been estimated to be as shallow as ~420 km (4–7 GPa). This shallow mantle depth places restrictions on the depth of origin of magmatic materials, as well as the mantle mineralogy. Another interesting feature discovered with data from the MESSENGER spacecraft is the low iron (<2 wt%) and high sulfur and carbon (up to 4 wt%) on the surface of Mercury. Given the exotic conditions under which Mercury formed, likely with limited oxygen available, this resulted in a relatively large core, shallow mantle, and low iron surface. Much like forsterite and fayalite are considered end-member minerals of olivine, Mercury is considered a geochemical end-member among the terrestrial planets, making it crucial to understand is

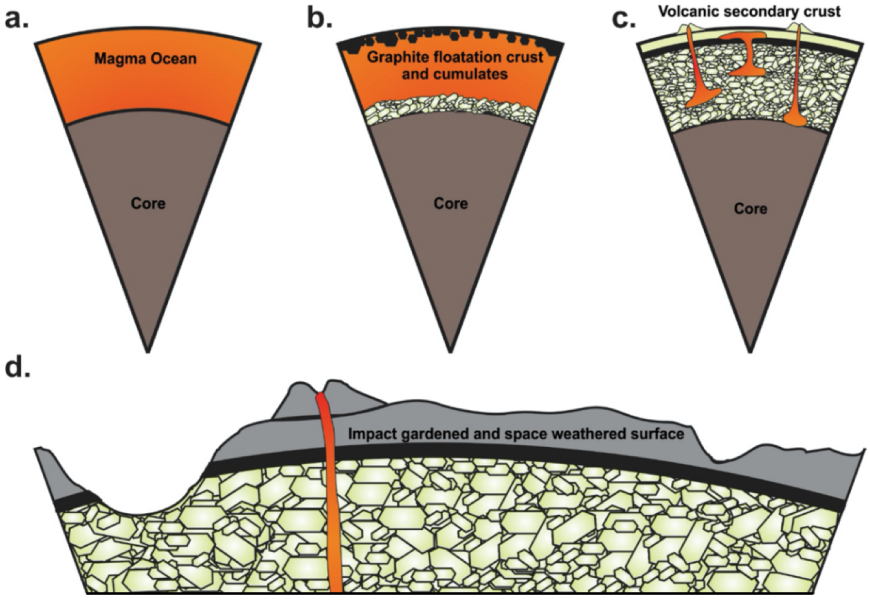

Figure 2. Cartoon illustrating the stages of a Mercurian magma ocean and subsequent primary and secondary crust formation. (a) Molten mantle and formation of the core; (b) Crystallization of the magma ocean continues with low-FeO cumulates sinking to the base of the mantle and the formation of a primary graphite flotation crust; (c) Continued crystallization followed by subsequent partial melting and volcanism produce a secondary crust; (d) Impacts to the planet have exposed portions of the mantle, the primary, and secondary crusts. Image modified from Vander Kaaden et al. (2019).

composition, structure, and thermochemical evolution.

Since we do not have physical samples from Mercury, we must rely on laboratory experiments and analyses to make discoveries about the planets thermochemical evolution. We ran high pressure and high temperature experiments on a melt composition representing Borealis Planitia, the largest volcanic field on the surface of Mercury. Using the sink-float density method, we were able to bracket the density of this melt and determine which minerals would sink or float in a mercurian magma ocean (see Vander Kaaden and McCubbin 2015 for full details). From this experimental data, it was discovered that graphite is the only mineral able to float in a mercurian magma ocean (Figure 2b), and therefore is the candidate material to form a primary flotation crust on the planet. In comparison, when we look up at the Moon, we see the bright white regions and dark black regions. These white regions are composed of anorthositic plagioclase and believed to represent the primary flotation crust in a lunar magma ocean whereas the black regions are the products of volcanism. This exotic primary flotation crust composed of graphite determined from experimental data has been supported by measurements on the surface of Mercury, mainly within the LRM excavated from depth, which suggests that the measured carbon is likely endogenic.

Following planetary differentiation and the formation of a primary graphite crust on Mercury, partial melting in the mantle along with subsequent volcanism has resurfaced the majority of the planet (Figure 2C). The primary crust, secondary crust, and upper mantle have since been excavated and mixed by impact processes, as evidenced by the large number of craters observed on Mercury's surface, leading to the complex, chemically enigmatic, darkened surface that is observed today (Figure 2d). So the answer to the burning question "what makes Mercury so dark?" is nothing more than what you write with when you use a pencil, graphite!

Sources: (1) Solomon, Nittler, and Anderson (2019) "Mercury: The View After MESSENGER" Cambridge Planetary Science.

(2) Vander Kaaden and McCubbin (2015) "Exotic Crust Formation on Mercury: Consequences of a Shallow, FeO-poor mantle" JGR-Planets.

(3) Vander Kaaden et al., (2019) "Revolutionizing our understanding of the solar system via sample return from Mercury" Space Science Reviews.

What are you going to do after graduation?

By Hannah Newcombe, SSU Alumna '19

Everyone hates the dreaded question: "So what are you going to do after you graduate?" Being in a bachelor of science program it feels like the two options are to start working or pursue a higher education degree. In Spring of 2019 I asked myself the dreaded question and I honestly did not know what I wanted but I knew it could not be nothing. With my desire to apply my geology degree to working with the National Park Service, I wanted to take some time before stepping into the 'real world'. So I applied for a program called Americorps NCCC knowing this would be a great opportunity to travel, gain experience and give myself sometime before I needed to answer the question for myself. Americorps NCCC - the National Civilian Community Corps; is a volunteer based program for people from ages 18 to 24 that strives to strengthen communities and build leaders through team-based direct and national service. The program puts its focus on five main areas: environmental stewardship, education, disaster relief, economic opportunity and healthy futures. There are three main campuses for the programs - Pacific, Southwest and Southern regions. This past October I started in Aurora, Colorado as a member of the Southwest region. After three weeks of training in Colorado, I was deployed to Austin, Texas. The first project was at McKinney Falls State Park, which is a popular state park within the city limits of Austin. It has incredible geology features as it was once a part of the intercontinental sea. My project was to clear cut a half mile trail reroute for the parks most popular trail. While there I got chainsaw certified and we got to work with other heavy machinery and tools. The park staff was very helpful and gave me a lot of information and resources on how I can pursue a career in rangering. This program has helped advance my leadership skills and help me obtain other technical skills that aren't necessarily learned in everyday life. In 11 days my team was able to clear cut 0.62 miles of trail. We also were able to replace a barbed wire fence around the parks historic horse trainer cabin where I found some artifacts. It honestly reminded me of field camp in Montana dealing with all the barbed wire. I had a lot of fun at McKinney Falls. The next project is to take place in Kansas City, Missouri helping low income families prepare and file their taxes. My team is going to get advanced tax certified which is a really valuable life skill to learn. Americorps has allowed me to meet some amazing people from all over, travel to places I would never expect and skills applicable to life. I recommend considering the program if you are looking for some real life experience after college.

Figure 3. Hannah Newcombe and her team at McKinney Falls.

AmeriCorps NCCC (N-triple-C) is a full-time, residential, national service program in which about 1,700 young adults serve nationwide annually. During their 10-month term, Corps Members – all 18 to 24 years old – work on teams of eight to twelve on projects that address critical needs. Traditional NCCC members travel to a variety of different six- to 12-week-long projects related to education, healthy futures, environmental stewardship, economic opportunity, and disaster response and recovery. Members of FEMA Corps, a branch of NCCC, focus their projects exclusively on emergency management work in partnership with the Federal Emergency Management Agency. The Southwest Region campus in Denver is one of four regional hubs in the nation and serves nine states in the central and southwest parts of the country. Approximately 300-400 members come through the Southwest Region campus each year to train for and transition between service projects. The other campuses are located in Vinton, Iowa, Vicksburg, Miss., and Sacramento, Calif. In exchange for their service, Corps Members receive $6,195 to help pay for college, or to pay back existing student loans. Other benefits include a small living stipend, room and board, travel, leadership development, increased self-confidence, and the knowledge that, through active citizenship, people can indeed make a difference. AmeriCorps NCCC is administered by the Corporation for National and Community Service. The Corporation improves lives, strengthens communities, and fosters civic engagement through service and volunteering. For more information about AmeriCorps NCCC, visit the website at *www.americorps.gov/nccc*.

Seismic refraction applications at SSU

By Kyle McCaffery

In Applied Environmental Geophysics, offered by the Geological Sciences Department at Salem State, we recently went out in the field to investigate subsurface profiles (Figure 4). These are used to map different layers of sediment on the surface of the Earth. The method that we used is seismic refraction. This method sends a seismic wave down into the ground from a source, in this case to produce the signal we used a sledge hammer hitting a thick aluminum plate. The waves travel through the surrounding rocks and subsequently are recorded by a series of geophones when they return back to the surface through refraction.

Figure 4. GLS 380 Environmental Geophysics Students in the field working on data collection.

This method is able to identify if different layers are present below the surface that have a higher seismic velocity than the surface layer. When the signal is created, direct waves travel towards each geophone at a certain velocity. If beneath the surface a “faster” layer is present the deep waves will reach the geophones located further down the line before the direct wave gets to them which travels along the surface and is not refracted. The waves that are refracted by the lower layers are called head waves (Figure 5).

The field area that we are studying is the forest river conservation area located near South Campus. Thanks to some previous studies done by Dr. Hubeny and GLS alumni for their senior research, we know that this area is a salt marsh that has at least two layers. In fact, as part of this study, they took core samples of the area to see what different depositional layers are present and

found that there is a layer of peat at the surface that the marsh grass is rooted in and a deeper glacial clay layer.

This seismic survey allows us to see whether any additional layers are present below the glacial till. Our results will expand our understanding about how salt marshes form and how they have changed over time. We expect that the underlying layers could be bedrock, sand or any other layer that might be present in the coastal marine environment.

In our investigation we identified three layers but the velocity difference between the bottom two units is too close to be a change from the glacial marine clay to bedrock. The newly identified layer is thought to be a denser form of the glacial marine clay because it has a very similar velocity to the known layer of marine clay. Therefore, we must conclude that the bedrock is deeper than our survey can detect and other methods would have to be used to find it. The new layer does give some further insight adding a third layer to the know stratigraphy of this area.

This field work was a great display of how the seismic refraction method can help us to identify the different layers below the Earth based on their seismic velocities. This method can have many other applications as well. Some of these applications include, urban planning, stratigraphy mapping and environmental protection. This is a very applicable skill for the job market. I am glad that I took Environmental Geophysics and was able to get firsthand experience with this method and many other methods of subsurface surveying. Some of the other methods that we will be learning about include seismic reflection, ground penetrating radar and magnetic susceptibility. These methods have different viability and purposes that can be used throughout the geophysics field. This class teaches very applicable skills for many field of work not just geology.

Sources: (1) Flora Garofalo, 2014. Physically constrained joint inversion of seismic and electrical data for near-surface application. Thesis

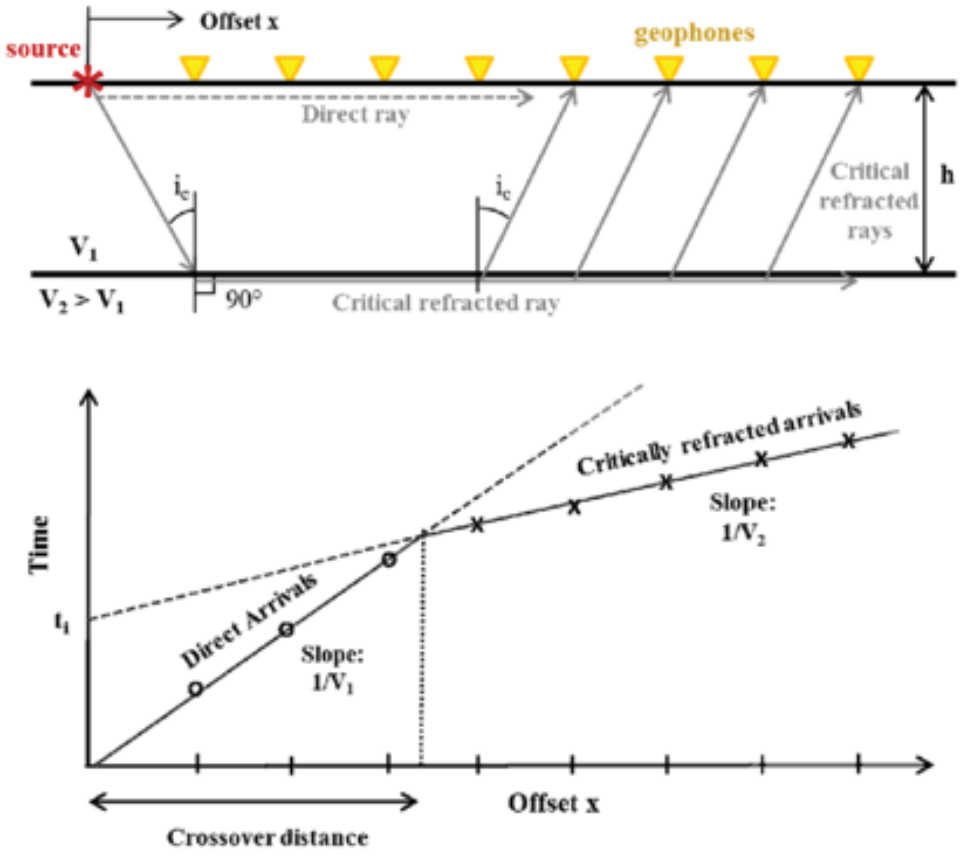

Figure 5. Conceptual sketch of the experimental setup used. Image from Garofalo (2014).

SHERLOCK AND WATSON ON THE HUNT FOR AN OUTCROP OF WELDED TUFF

Comic By Adam Surette

What is new in the ESA community?!

• In conjunction with SSU Earth Days, which this year focus on the "**There is NO planet B**" theme (*www.dgl.salemstate.edu/earthdays/*) ESA is hosting a textile drive and a river cleanup. The **Textile Drive** will run during the week of April 13-17 and it will be advertised during the Student Climate Festival on April 15 (12-1:30PM, Ellison Plaza). The **River Cleanup** will be on April 15 3-5PM meet us in MH 340. Pizza will be served after the event. Please join us!

• ESA is going to benefit from the funds obtained by the Wrestling event organized on March 28 at O'Keefe, 7PM. Join us, student can enter free of charge.

• Are you interested in having a more active role? Apply for the new ESA position for social-media liaison by emailing *esa.salemstate@gmail.com*

• Check ESA Google calendar using the link below:
https://calendar.google.com/calendar?cid=dGplbmVoYTZ1bmQzZ-jRqMWNlYW03bmJ0ZDhAZ3JvdXAuY2FsZW5kYXIuZ29vZ2xlLmNvbQ

• Follow us on Facebook "*Viking Geology*" and the ESA "*Earth Science Association at Salem State University*"

• ESA is looking for volunteers to write short summary articles for future newsletters. To participate please contact us at *esa.salemstate@gmail.com*