MSIP Final Report, May 2013:
"Searching for Gullies on Mars"
Accelerated Learner Program, Washington Academy

I. Introduction

As young explorers, we are anxious to look at Mars as a future place for humans to live and explore. We've spent a lot of our class time discussing the basic survival needs of humans and how those needs could be met on Mars when its environment is so different from Earth. We've developed a criteria list that we feel any area being evaluated as a living site should meet to make sure human survival is possible. Meeting this criteria would mean that an area has a temperature range that space suited astronauts could tolerate, a terrain that allows for safe landings and rover travel, and possesses a cratered terrain with young gullies and evidence of snow that could indicate a potential water source. As part of our MSIP participation, we chose the border area between the Hellas Planitia and Eridania regions and the cratered terrain there as our focus.

During our early discussions, we thought it would be important to choose a site near the equator because of temperature needs. Our interest in crater gullies began after reading Dr. Christensen's research proposing that in mid-latitudes, gullies were formed because of snow melt on pole facing slopes (Christensen, 2003). We knew that if we were going to base our investigation on his ideas, picking an area near the equator would not be where we should look. The equator band would not have areas of slow-melting snow and ice. Using the information from his research of these specific craters being found more often in the mid-latitudes, we narrowed our focus to this band in the southern hemisphere. This hemisphere has a larger presence of craters and gives us more craters to look at (MOLA Colorized Elevation Map, JMARS). While exploring the different layers in JMARS we came across the HEND map and were curious about how this map might change our thoughts about this latitude band. We noticed that the area on the border of the Hellas Planitia and Eridania regions fell in the mid levels for epithermal neutrons (JMARS HEND map layer, retrieved 1/17/13). This tells us that this area is thought to have a valuable presence of H_20 (Important Maps in JMARS, http://msip.asu.edu/curriculum.html, retrieved 12/13/12). Using the MOLA colorized elevation layer, we also saw that this area has an elevation and terrain that meet our criteria. We know from researching the temperature on Mars that it is colder at higher elevations, and that at the mid-latitudes, the average temperature is -50 degrees Celsius (-58 degrees F) with a range from -60 degrees C to 0 degrees C (-76 degrees F to 32 degrees F) depending on the time of day and season (NASA Quest Website, http://quest.nasa.gov/aero/planetary/mars.html, retrieved 1/17/13). This is not as warm as a position near the equator would be, but we believe that these temperatures could be acceptable with how we currently outfit astronauts for space. For these reasons, we felt strongly about this area being targeted for more investigation.

To see if this area met our gully criteria, we focused on a specific research question about this region's craters. We wanted to answer the question of whether gullies were present in the craters we would observe. This would allow us to confirm and support our criteria for choosing this location.

> Is there evidence of gullies in craters found at the border between the Hellas Planitia and Eridania regions?

We believed that this question was both interesting and important. Gullies provide possible evidence of the recent presence of liquid water or snow covered areas (Feature ID Chart, pg. 2). We know that water is vital to human existence and necessary for not only our own human bodies to work but also for the growth of food. It isn't realistic to bring all of the water we would need to live on Mars with us, and having a source on the planet that could be utilized would help us to be successful. Gullies can be used as an indicator of where we should look further for water. Dr. Philip Christensen's research discussed below made this interesting because we had always thought that features that were associated with flowing water only indicated a past presence. It was exciting to us to think that water in the form of melting snow and ice could be utilized now.

We had the following hypotheses:

- If this region is south of the 30 degree latitude line and in an area that contains craters and similar steep sloped terrain, then we will observe evidence of gully formation.

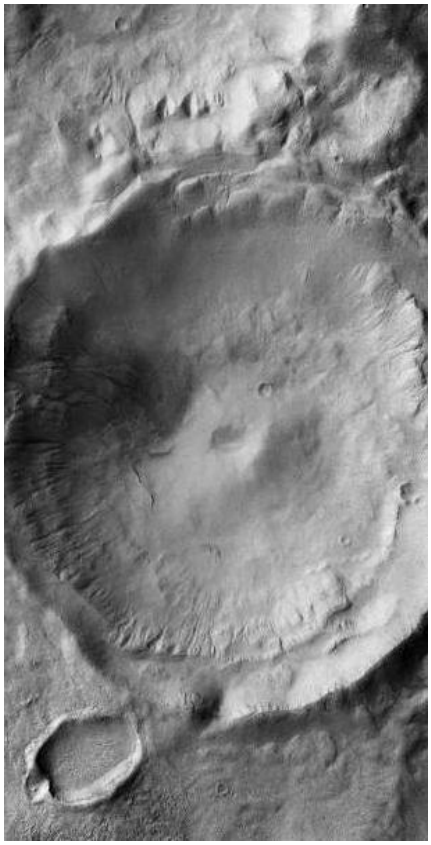
- If we do not observe the presence of gullied craters, then this may indicate that the craters and landforms in this region do not have enough depth to develop gullies or that snow melt is not occurring.

If the second hypothesis was found to be true then we would know that we needed to reevaluate our choice of region and look for a different location that met our criteria.

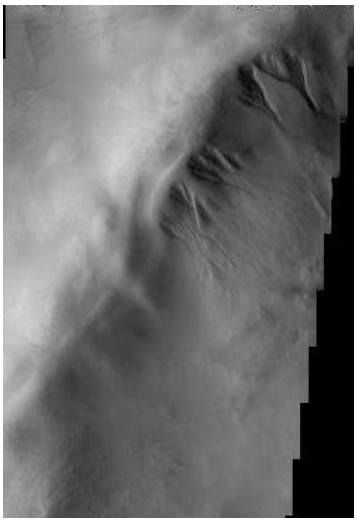
II. Background

Craters happen when meteorites hit the surface and leave a circular indentation. A crater can be identified by its shape and its features: a rim, floor and walls. Sometimes at the center there remains a mountain peak. The age of a crater can be determined based on the preserved or changed shape of the rim as well as its depth (Feature Identification Chart, pg. 2). Gullies are also present on Mars where they are most often found inside craters near the rim or along sloped landforms. They are believed to be a sign of past liquid water or that an area was once snow-covered (Feature Identification Chart, pg. 2). To answer our research question, we looked at craters to determine if gullies were present.

The following are examples of what these features look like on Mars:



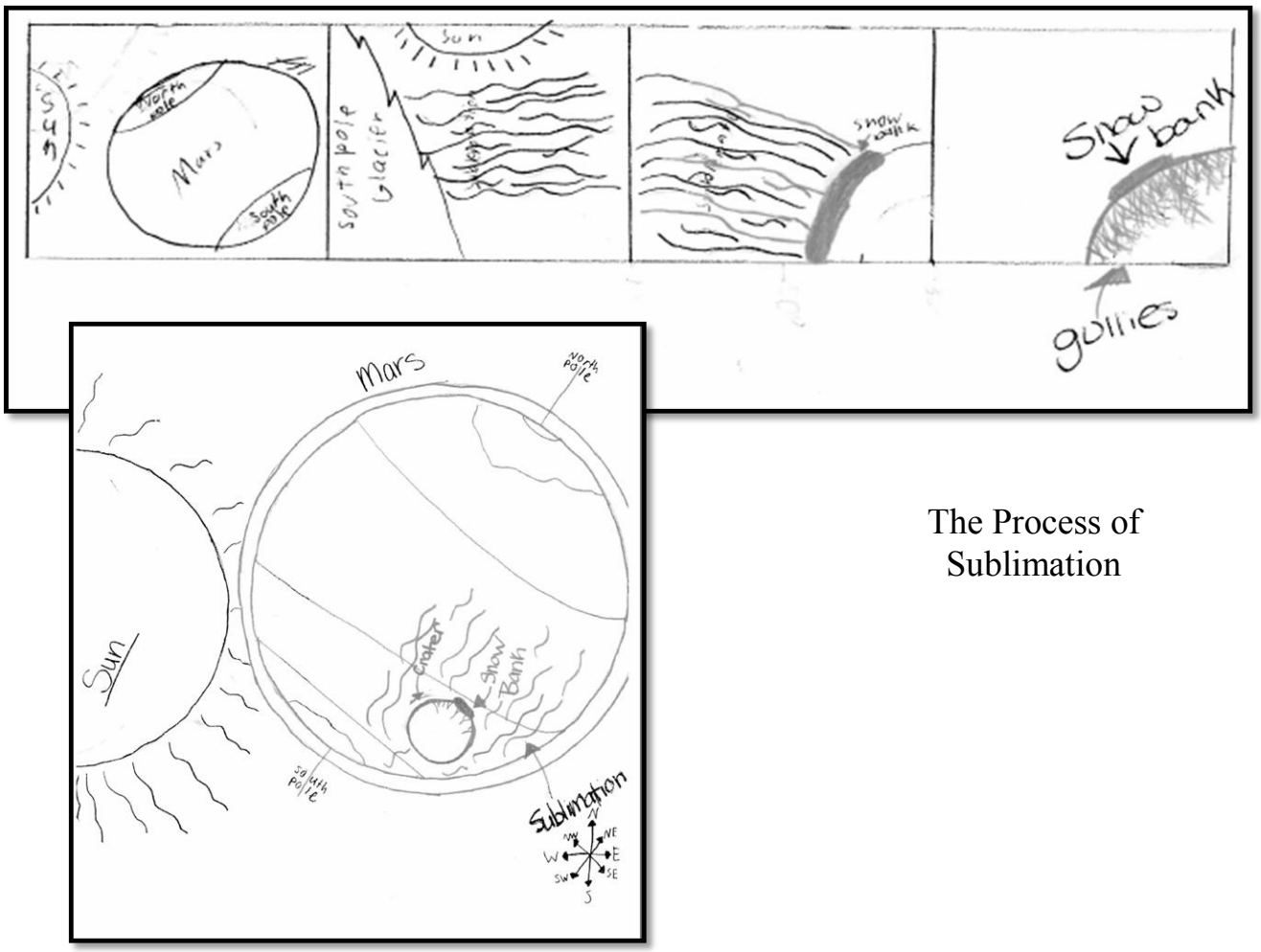
THEMIS Website: http://themis.asu.edu
Image ID # V01131003
Latitude: -41.2517, Longitude: 161.115



THEMIS Website: http://themis.asu.edu
Image ID # V16503003
Latitude: -52.3557, Longitude: 304.535

There are other features on Mars that without careful observation could be labeled as gullies by mistake. Canyon walls and layers appeared similar to us as we studied the feature identification charts. We used these pictures above as a reference when evaluating whether what we were seeing could accurately be labeled as a gully. These pictures gave us an example of how a gully begins near the rim and lengthens down the crater or slope wall in a funnel-shape. As we looked for gullies, we specifically looked for gully heads near the rim of the crater.

There are two groups of theories about how gullies are created on Mars. The first group is based on the idea that water or some other fluid like liquid carbon dioxide created the gullies much like flowing water does here on Earth. The second group is based on the idea that dry materials of some kind cause the erosion of gullies like you would see in an avalanche. We took a particular interest in a research paper written by Dr. Philip Christensen on how snow and ice deposits in the mid-latitudes create gullies as they melt. In his research, he determined that because of a fine dust cover, snow and ice at these latitudes was less affected by sublimation. Sublimation is a process where solid material transfers directly to a gas state without passing through a liquid state first. Sublimation is responsible for moving moisture from the poles to the mid latitudes that then deposited to become the snow and ice in these mid-latitudes. There is a lot of dust deposit here which covers the snow and helps it to not sublimate to another location. What was really interesting about his research was the discussion of how this snow and ice is still present and melting slower on the pole-facing side of a crater because this area is in the shadow (Christensen, 2003).



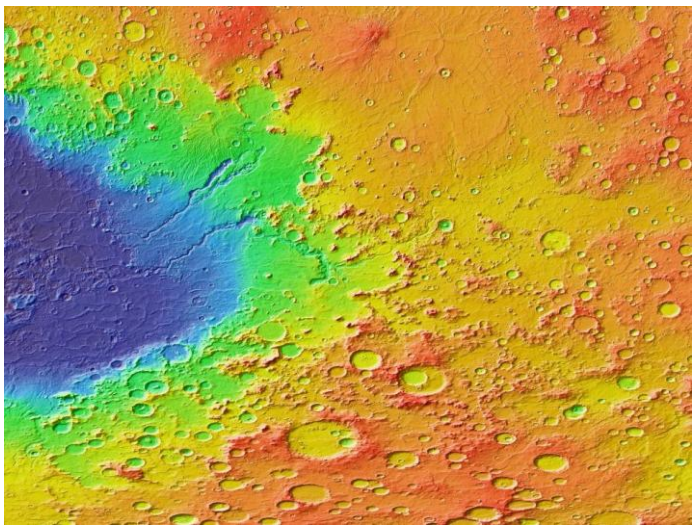
The Process of Sublimation

Both gullies and craters can be found on Earth. Gullies on Earth are formed when the movement of flowing water, sand or dust erodes the side of a steep hillside. As this material is worn away, cuts are made forming a network of channels leading down the hillside. Gullies are not seen where the ground is not steep. When first formed, they are narrow with vertical sidewalls. These gullies continue to form as the soil is less able to stand up to the erosion. Once the gully is fully formed, it begins to get wider and longer as water continues to flow along these channeled paths (Iowa Geological & Water Survey by the Iowa Dept. of Natural Resources, http://www.igsb.uiowa.edu/browse/gullyero/gullyero.htm, retrieved on 1/29/13).

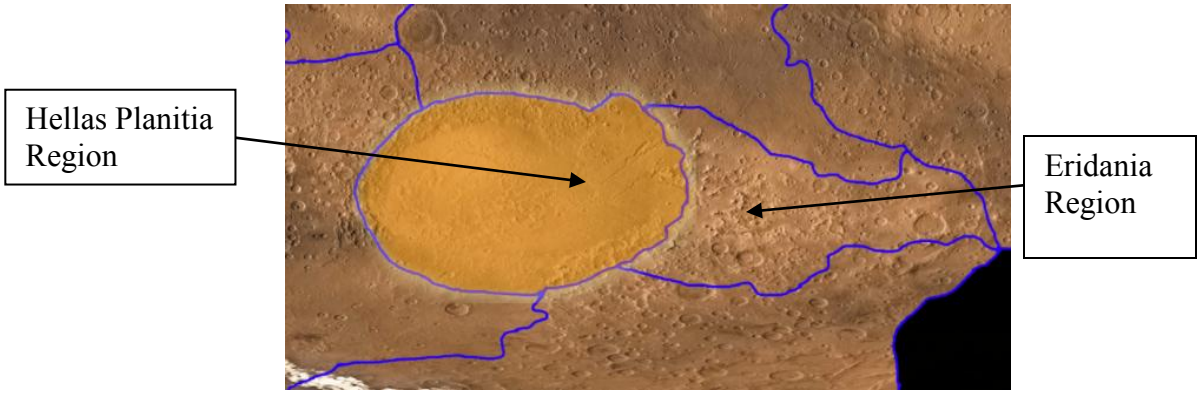
Craters can also be found on the Earth's surface. Craters can be formed when objects from space connect with the Earth. There are also craters formed by volcanic explosions from our own surface. Intact craters can be hard to find because they are old, and our Earth is constantly changing. The movement of tectonic plates often buries existing craters making them hard to study (NASA Lunar Science Institute, http://lunarscience.nasa.gov/articles/how-are craters-formed/, retrieved 1/31/13).

III. Methods

To complete our research we used the Mars Odyssey satellite and its onboard THEMIS camera to collect data needed to answer our research question. To answer our question of whether gullies are present in the area we selected as having potential for landing, living and exploring, we documented information about the craters found in this area. Gullies are known to form inside craters on the walls and rim. We looked here for evidence of features that point to a history of water. We chose to focus on a region in the southern hemisphere south of thirty degrees latitude. Specifically, we looked at the bordering area between the Hellas Planitia and Eridania regions as indicated on this section of the MOLA colorized elevation map in green and yellow.



Approximate Latitude Range: -20 degrees to -60 degrees
Approximate Longitude Range: 75 degrees to 115 degrees



http://beamartian.jpl.nasa.gov/visitorcenter/orientationmap

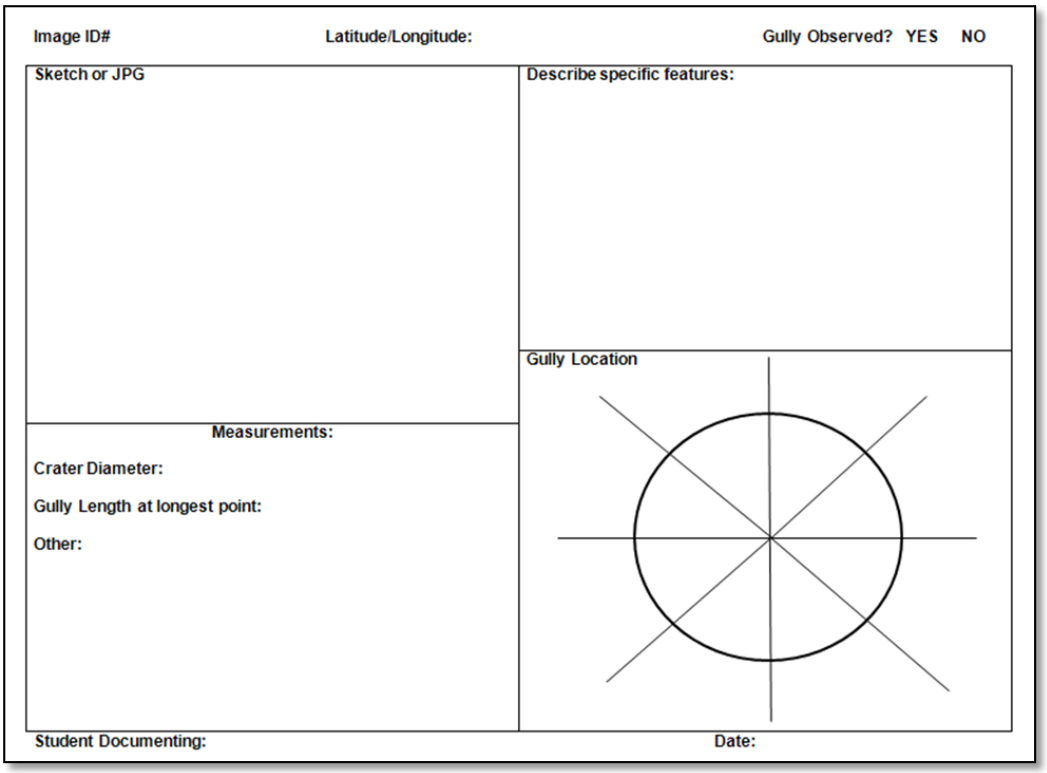
To gather our data we used several websites:

Website	Specific Use
THEMIS Website http://themis.asu.edu	As we looked at THEMIS images in JMARS, we also used this site to read descriptions about some of these images. We also used this site to reference other examples of gullies in craters either from this region or from others on Mars.
JMARS	We used this GIS tool to access THEMIS images from this area as well as to document and measure specific features such as crater diameter, gully length, latitude and longitude and elevation.
MSIP Website http://msip.asu.edu/msip	We used this site to access specific resources needed to complete our assessment of this region: Feature ID Charts, MOLA map, and an outline for reporting our findings.

To answer our research question, we aimed to gather at least 80 images. As part of our experiment design, we recorded the following information from each image onto a data collection tool:

- **Student Names and Date:** This allowed us to track who collected the data and when.
- **Image identification # (V#):** This allowed us and other scientists to reexamine the images we observed to check our data.
- **Latitude and longitude:** This allowed us to map where each crater we examine is located.
- **Specific feature(s) (*Craters and Gullies)*:** We looked for craters and gullies as those directly relate to our science question.
- **Gully Present:** Answering yes or no helped us to assess the percentage of all craters observed that showed a gully presence.
- **Gully Location:** Noting if the gully was forming on the pole-facing side helped us to understand and compare our findings to what Dr. Christensen has written about.
- **Measurements:** Here we listed crater diameter and gully length measurements. Knowing these pieces of information allowed us to look for patterns later and draw conclusions about whether gullies were found more commonly in one type of setting.

The team-created data sheet was designed in a way to easily document needed information and to be able to discuss the data later. We chose to organize the data by crater instead of by stamp because we wanted to also collect information about the location of any gullies within the crater for a rose diagram.



Our team used the JMARS program and began with the latitude/longitude and MOLA colorized elevation layers. We then zoomed into our designated region in the southern hemisphere south of thirty degrees latitude. Specifically, we looked at the bordering area between the Hellas Planitia and Eridania regions as indicated on this section of the MOLA colorized elevation map in green and yellow. Using the latitude/longitude line square grid as a guide, we divided up the region for survey.
Within our assigned square, students zoomed in on each crater and pulled up the THEMIS stamps for that crater to observe its features & measurements. Students then used the JMARS measurement tool to measure the diameter of each crater at its widest point and the length of any gullies found. We also used the location measurements within JMARS to note the latitude & longitude at the center of each crater.

Agreeing to specific controls helped us to collect accurate and uniform data. These specific controls were:

- Observed gullies will be double checked by another student.
- Each suspected gully will be compared with the Feature ID Chart.
- The label of "gully" will mean having a triangular shape, wider at the head, located near the rim of the crater.

IV. Data

Our research process included collecting eighty THEMIS images that represented fifty diverse craters. Within our region we did observe the presence of craters with and without gullies. The following pictures show THEMIS stamp examples of each from our data set.

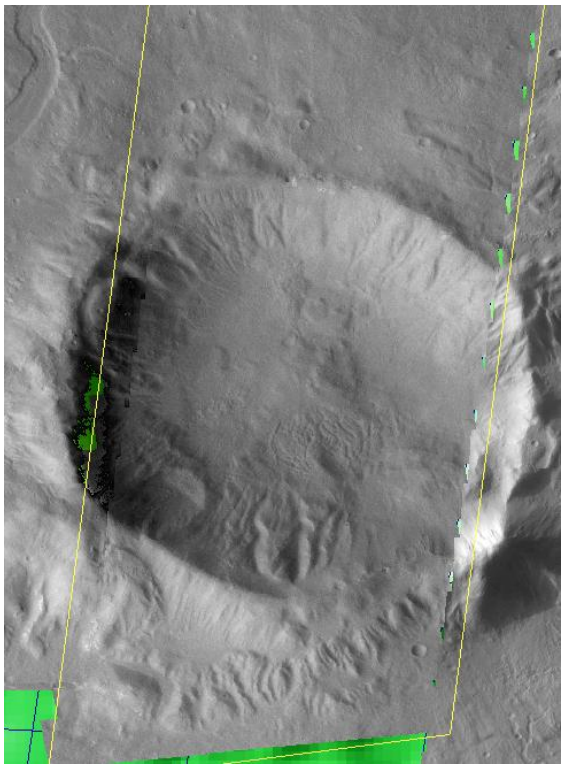


Image ID# V16311003
Modified crater with gullies

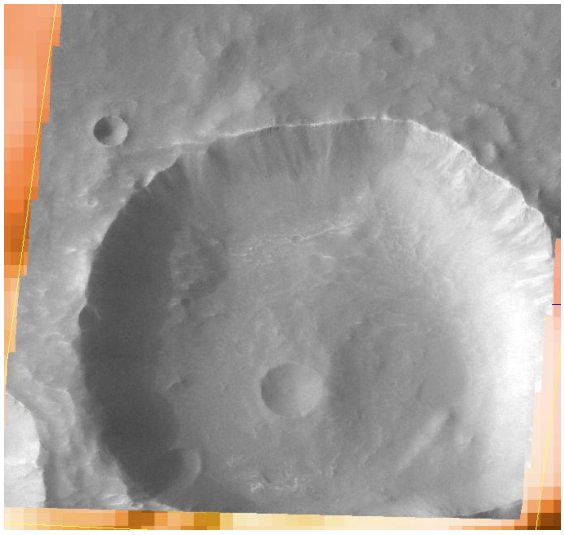


Image ID# V39608002
Modified crater with no observed gullies

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The following THEMIS image was the specific image that our team captured using the THEMIS camera. It allowed us to observe features directly north of an interesting crater within our region.

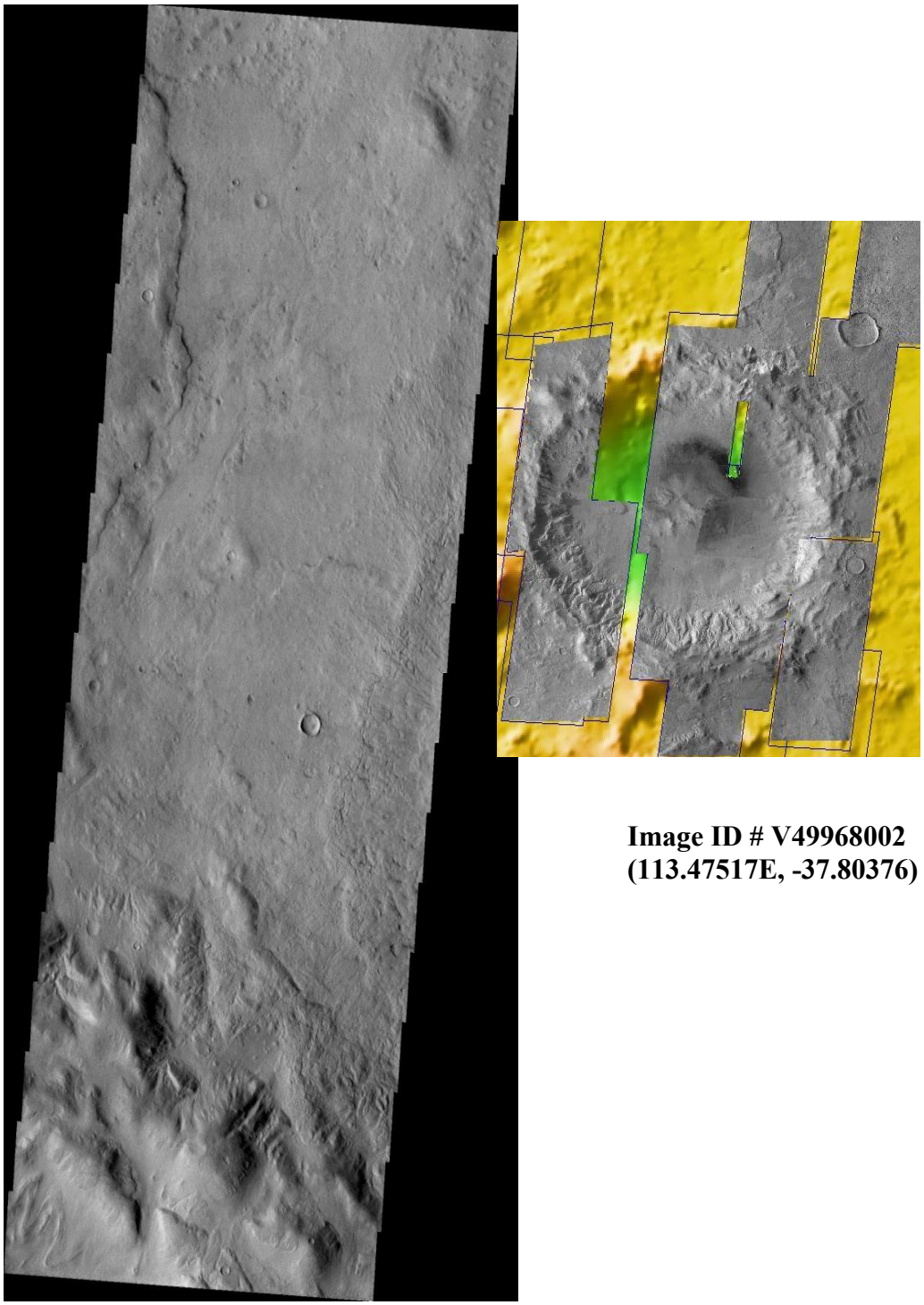


Image ID # V49968002
(113.47517E, -37.80376)

All information from individual Crater Data Sheets was compiled into **Data Table A** to allow for easier viewing and manipulation of the data. Again, we chose to organize the data by crater instead of by stamp because we wanted to also collect information about the location of any gullies within the crater for a rose diagram.

Data Table A

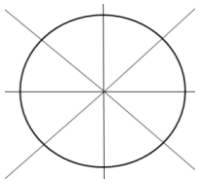
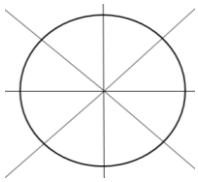
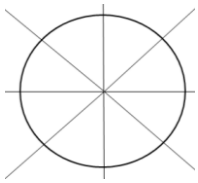
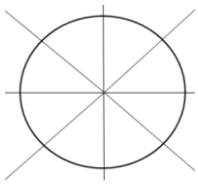
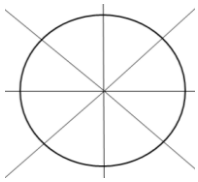
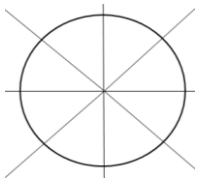
Image ID#	Lat/Long	Specific Features (Craters & Gullies)	Gully observed? (Y/N)	Gully Location (pole facing/ equator facing)	Measurements: Crater Diameter, Gully Length
V17683011	105.652E, -50.561	Modified Ejecta Oval Shaped Simple Crater Layers (ATH)	No		Crater:19.0km
V18070005 V26344010	102.924E, -43.602	Appearance of canyons Modified Crater Cross-Cutting relationships Complex Crater (ATH)	No		Crater:38.2km
V25982009	105.2695E, -46.4258	Football Shaped 6 or so tiny craters inside big crater Destroyed crater Simple crater Lip (ATH)	No		Crater:12.61km
V14850005	109.7021E, -46.0146	Destroyed Crater Complex Crater Lots of sand dunes inside the crater (ATH)	No		Crater:12.60km
V31609004	109.291E, -45.869	Fuzzy picture Destroyed Crater (ATH)	No		Crater:27.9km
V18045008 (smaller crater B)	104.1499E, -44.2058	Destroyed crater Complex crater Things inside of it Layers (ATH)	No		Crater:3.27km

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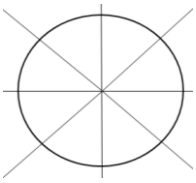
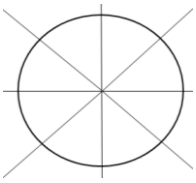
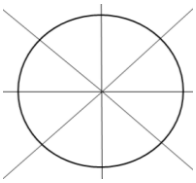
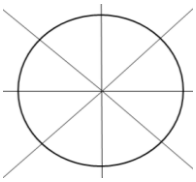
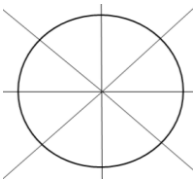
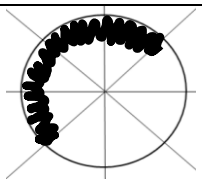
Image ID#	Lat/Long	Specific Features (Craters & Gullies)	Gully observed? (Y/N)	Gully Location (pole facing/ equator facing)	Measurements: Crater Diameter, Gully Length
V06563004	106.2651E, -50.5176	Layers Oval Shaped Destroyed crater Simple crater Can't see the left side (ATH)	No		Crater:6.37km
V18045008 (larger crater A)	103.9688E, -43.4824	Small ejecta 1 picture. (ATH)	No		Crater: 24.42km
V33842001 V34728003	109.637E, -35.965	This crater has two modified craters and also has one small crater layered on top of the larger one. The smaller crater is newer than the other one. On the right, there are canyon walls. (A.M.H.)	No		
V17084005	108.070E, -31.219	This crater is very destroyed and old, having several layers of old craters. These craters are flattened. It is fairly large and has no gullies on it. This crater is a complex crater. (A.M.H)	No		Crater Diameter: 70 kilometers
V40344002	101.7637E, -33.4600	Only half of this crater had a THEMIS stamp. It is a medium sized crater and has some glacial movement. This crater is complex and modified. This crater is gully-less and has one smaller crater on its rim. (A.M.H.)	No		Crater Diameter: 23.46 kilometers
V24547005 V10133002 V26656009	103.074E, -32.461	This is a small crater that has gullies. It is a modified crater which also overlapped a destroyed crater. It has a small preserved crater inside of it. The gullies are large and the crater has sand dunes inside it. A.M.H.)	Yes		Crater Diameter: 30.1 kilometers Gully Length (At longest point): 9.2 kilometers

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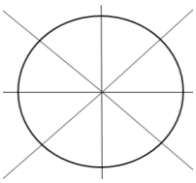
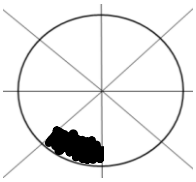
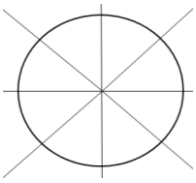
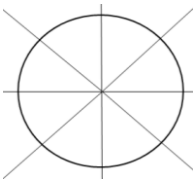
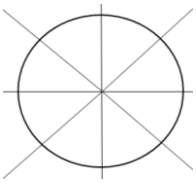
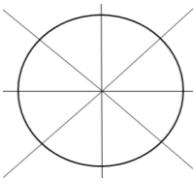
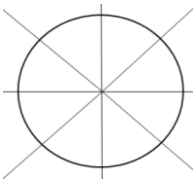
Image ID#	Lat/Long	Specific Features (Craters & Gullies)	Gully observed? (Y/N)	Gully Location (pole facing/ equator facing)	Measurements: Crater Diameter, Gully Length
V10295004	108.7983E - 38.1523	This crater is complex and modified. On its rim, it has canyon walls. It has no gullies and has small craters inside of this crater. The canyon walls looked like gullies, but they were not gullies. (A.M.H.)	No		Crater Diameter: 58.8 kilometers
V23723006 V24347006 V15449004	111.08989E, -43.4561	There Are Modified/Destroyed Craters, Gullies, Simple Craters (MM)	Yes		Crater:33.38km Gully:2.59km
V26593012 V09446004 V16497002 V08535001	118.552E, -42.73	There Are Canyon Walls, Modified Craters, Complex Craters (MM)	No		Crater:49.1km
V16597008 V43426005 V23960006 V34915003	114.283E, -43.863	There Are Modified Craters Complex Craters (MM)	No		Crater:44.8km
V17508007 V15349008	115.371E, -42.926	There Is Pasted On Terrain Modified Craters (MM)	No		Crater:37.1km
V47634006	90.062E, -23.727	Image shows one larger modified crater and a smaller preserved crater. Larger crater has a raised center. (KS)	No		Crater: 7km
V26481009	110.6343E, -40.2720	There Is Pasted On Terrain And Canyon Walls Not Gullies (MM)	No		Crater:15.13km

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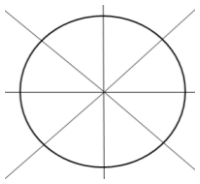
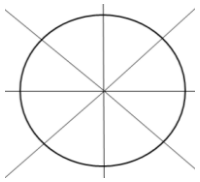
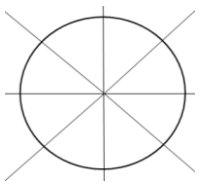
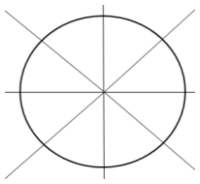
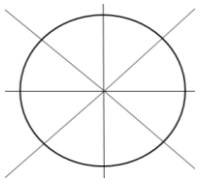
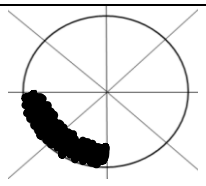
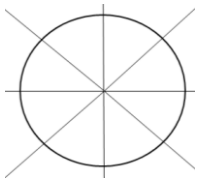
Image ID#	Lat/Long	Specific Features (Craters & Gullies)	Gully observed? (Y/N)	Gully Location (pole facing/ equator facing)	Measurements: Crater Diameter, Gully Length
V15112008	112.799E, -42.014	There Are Complex Craters (MM)	No		Crater:43.8km
V15474005	110.578E, -41.937	There Are Simple And Modified Craters (MM)	No		Crater:22.2km
V16497002 V26593012 V08535001 V09496004 V25994010	119.152E, -42.59	There Are Preserved And Simple Craters (MM)	No		Crater 47.7km
V17546007 V14788005 V23973009	98.781E, -44.705	Simple crater Preserved crater (SK)	No		Crater Diameter: 26.7 km
V26731012 V17883006	98.332E, -38.7471	Modified crater Complex crater Ejecta present (SK)	No		Crater Diameter: 14.26 km
V18557008 V08748003 V23449004	96.020E, -35.775	Modified crater Complex crater Well defined gullies (SK)	Yes		Crater Diameter: 37.2 km Gully Length: 4.1 km
V16485003	107.8179E,-29.5830	Canyon walls Modified crater Complex Crater (VC)	No		Crater Diameter: 27.6 Km. Crater Radius: 13.8 Km.

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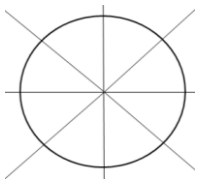
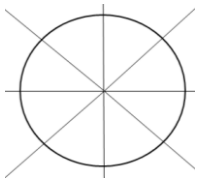
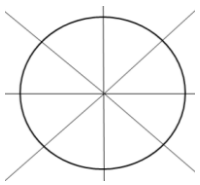
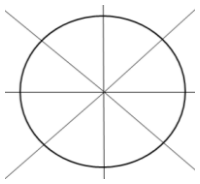
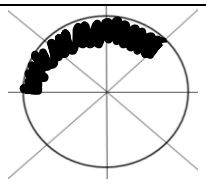
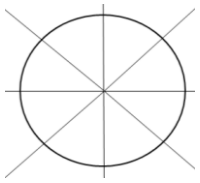
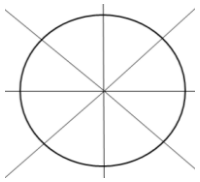
Image ID#	Lat/Long	Specific Features (Craters & Gullies)	Gully observed? (Y/N)	Gully Location (pole facing/ equator facing)	Measurements: Crater Diameter, Gully Length
V07849002	102.740E,-34.238	Many new mini preserved craters outside of larger crater (VC)	No		Crater Diameter: 54 Km. Crater Radius: 27 Km.
V17521004	102.1956E,-30.7378	Preserved Small Crisp Border Almost Perfect Circle (VC)	No		Crater Diameter: 7.83 km. Crater Radius:3.915
V23586003	105.1962E, -31.7048	1 Small Persevered Crater 3 Smaller Modified Craters 1 Medium Sized Preserved Crater (VC)	No		Crater Diameter: 5.07 km. Crater Radius:2.535
V17658008	109.7500E, -33.1274	Almost Destroyed (VC)	No		Crater Diameter; 23.26 km. Crater Radius: 11.63km
V18008006	93.6865E, -31.6284	-Gullies(Old) -Canyon Walls -Preserved/Complex Crater ZR	Yes		Crater Diam:14.88km Gully:2.45km
V17097006 V26282004 V18008009 V23524003	90.77E, -45.488	-Mini Crater -Modified/Complex Crater ZR	No		Crater Diam:42.9km Mini Crater Diam:3.km
V16947010	97.3E, -48.1	-Destroyed/Simple Crater ZR	No		Crater Diam: 104.1km

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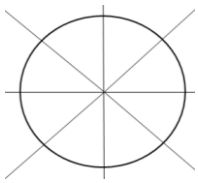
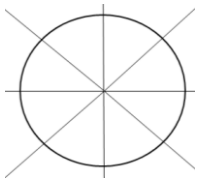
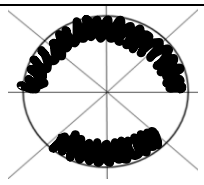
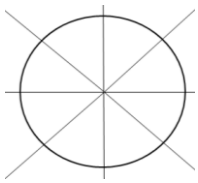
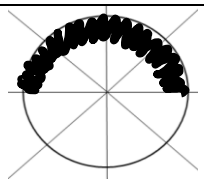
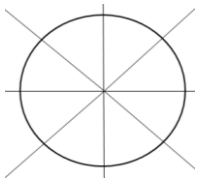
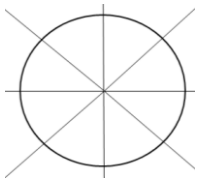
Image ID#	Lat/Long	Specific Features (Craters & Gullies)	Gully observed? (Y/N)	Gully Location (pole facing/ equator facing)	Measurements: Crater Diameter, Gully Length
V081488008 V17745010	119.078E, -41.578	-modified crater -simple in nature	No		Crater Diam: 24.17 km
V08535001	119.152E, -42.59	Modified Crater Complex Crater	No		Crater Diameter: 47.7 Km. Crater Radius: 23.85 Km.
V17846008	86.6113E, -33.2749	Ejecta Blanket Has Gullies ET	Yes		Crater Diameter: 12.88 Km
V34292001	86.629E, -36.309	Destroyed crater Simple channels	No		Crater 30.1km
V16311003 V16623005 V31535002	87.0703E, -30.7266	Gullies are oresent inside this crater; modified crater	Yes		Crater 20.27km Gully 2.61km
V18557005	98.0469 E, -21.5896	In the image there is 2 craters and a smaller younger crater is overlapping a bigger older crater. Both caters are modified and have canyon wall. There is also lots of preserved craters on the side.	No		Crater Diameter: 33.8 km
V42703004	91E, -22.6973	There are lots of preserved craters that are simple and there are 2 modified complex craters.	No		Crater Diameter: 28.1 km

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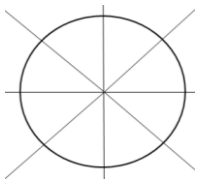
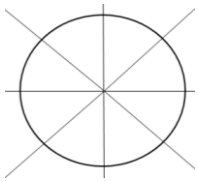
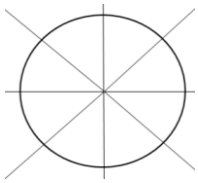
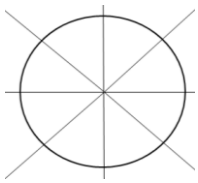
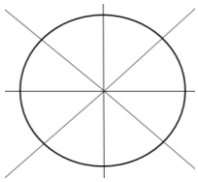
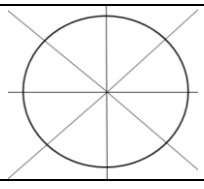
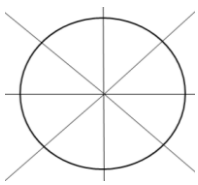
Image ID#	Lat/Long	Specific Features (Craters & Gullies)	Gully observed? (Y/N)	Gully Location (pole facing/ equator facing)	Measurements: Crater Diameter, Gully Length
V39608002	95.9980 E -23.5195	There are canyon walls in a big modified crater.	No		Crater Diameter: 14.53 km
V07612002	99.969E, -20.461	This crater is a much modified crater with a younger crater overlapping it.	No		Crater Diameter: 53.8 km
V25845004	94.289 E, -59.012	This crater has no gullies. It is modified and complex. This crater has layers and is fairly large. TB	No		Crater Diameter: 43.6 km Gully Length at longest point: No gullies observed
V10258007	92.352 E, -56.668	This crater has no gullies. It is a modified crater with a smaller crater on the inside which is smaller. The smaller crater is a destroyed crater that is younger. The crater has an ejecta blanket. TB	No		Crater Diameter: 53.5 km Gully Length at longest Point: No gullies Smaller Crater Diameter: 2.132 km
V14414002 V15038001 V15949001 V18395003	91.051E, -20.674	Canyon walls are present. Small destroyed craters inside this larger modified crater. (KS)	No		Crater: 40.3 km
V17696003	94.5117E, -26.7368	Canyon walls are there. Modified, complex crater. (KS)	No		Crater: 32.9 km
V26594006	93.7002E, -20.5049	Complex, modified crater. Puffy edges with smaller craters or impacts inside. (KS)	No		Crater: 36.9 km

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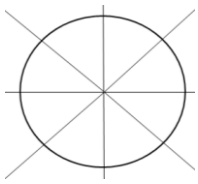
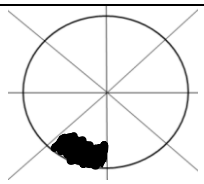
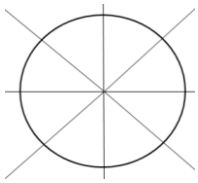
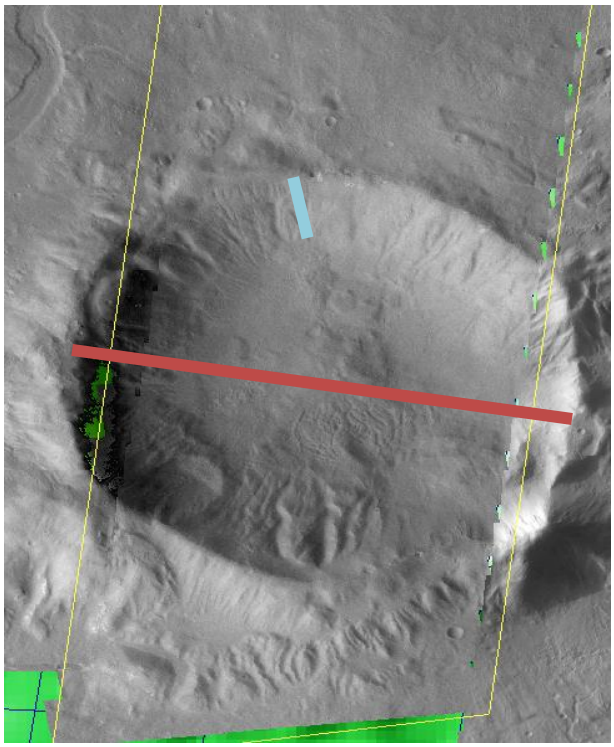
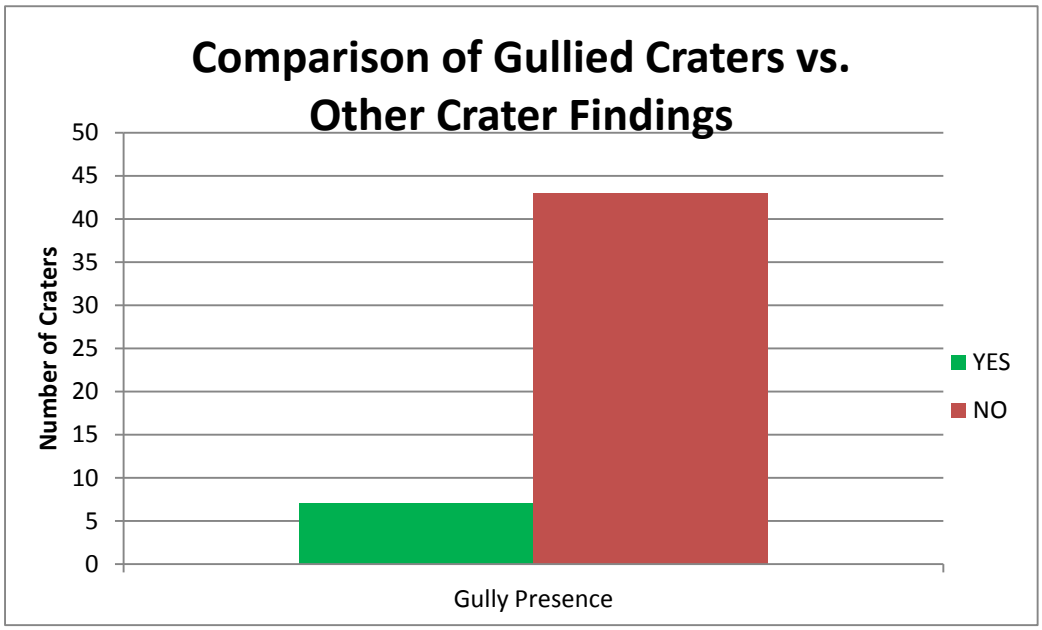
Image ID#	Lat/Long	Specific Features (Craters & Gullies)	Gully observed? (Y/N)	Gully Location (pole facing/ equator facing)	Measurements: Crater Diameter, Gully Length
V08024006	97.0576E, -26.0361	Canyon walls, chaotic terrain, modified complex crater (KS)	No		Crater: 25.31 km
V31822003	83.0420E, -36.6123	Modified crater with gullies seen (ET)	Yes		Crater D: 23.63 km Gully Length: 1.76 km
V26794009	81.328E, -36.729	Destroyed crater; chaotic terrain	No		Crater: 45.7 km

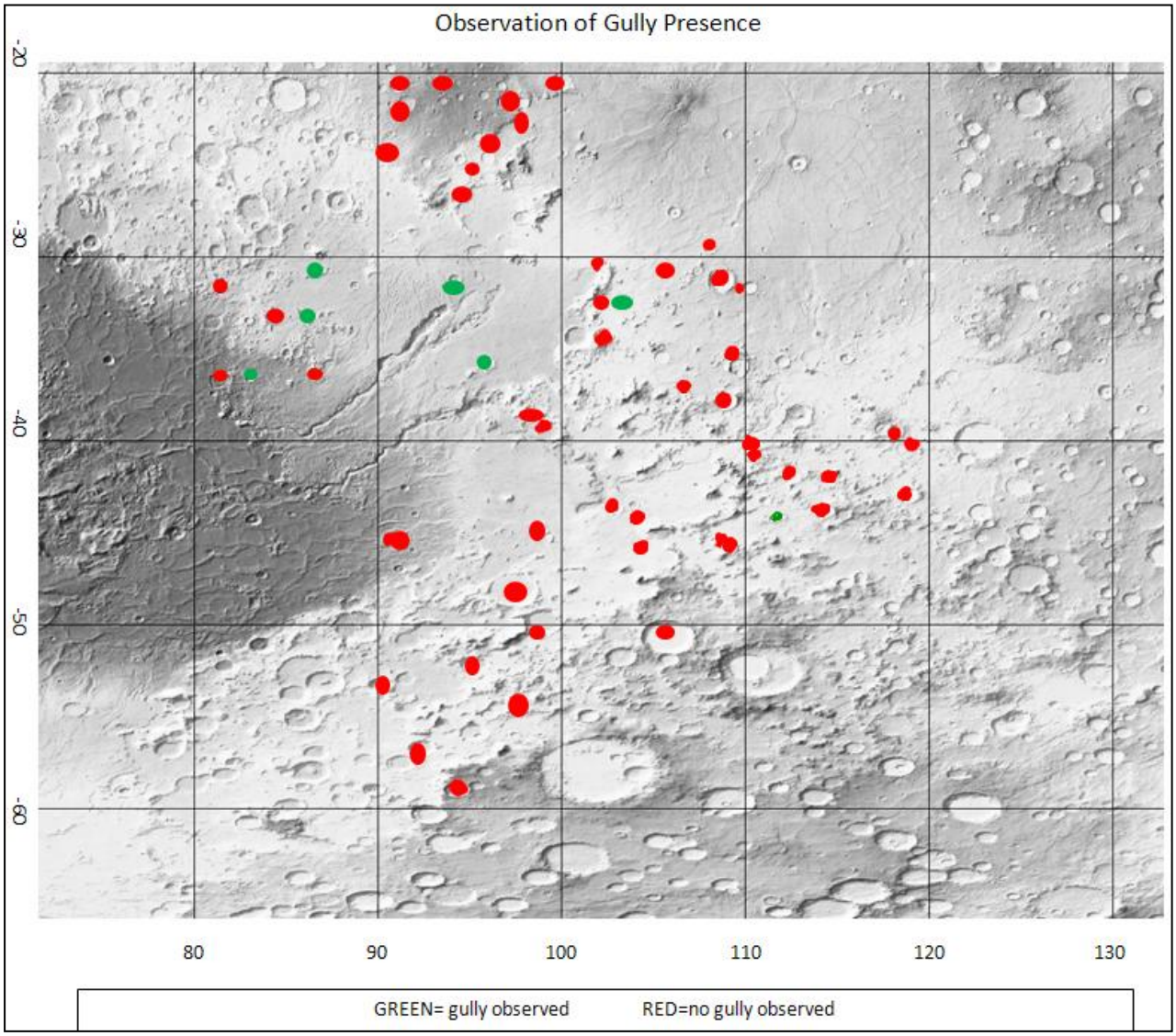


The screen shot of Image ID #V16311003 shown at the left provides an example of the location of the measurements contained within the data chart. The colored lines indicate the distance that was measured. The red line shows the location of the diameter measurement for this crater. The blue line indicates how an observed gully was measured for length. We chose not to graph the data on gully length only because it does not answer our specific research question, and we did not feel that we had a big enough gully length data set to draw conclusions about these measurements.

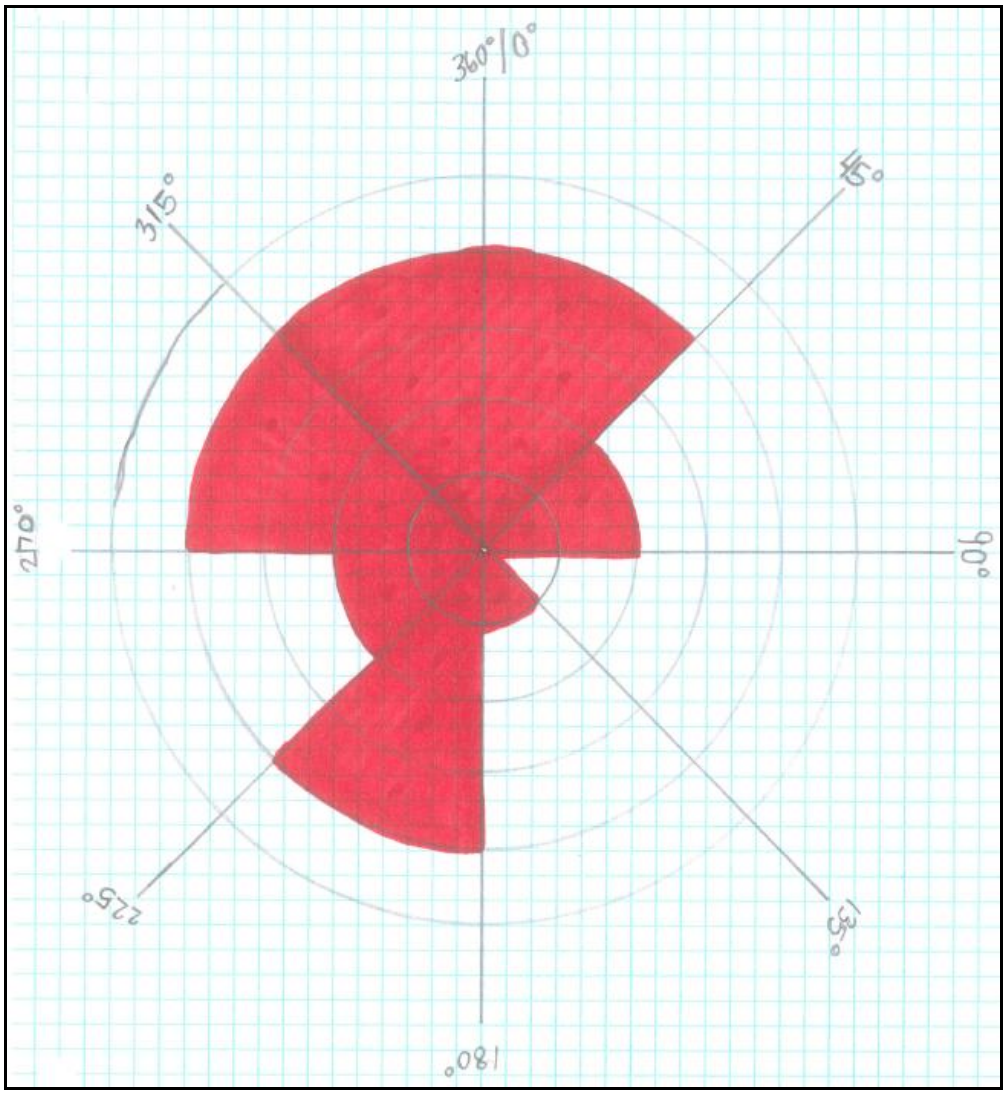
Data was also represented within a bar graph to compare side by side the amount of craters observed to have gullies and those to not have gullies.



The location of all surveyed craters within our selected region was also documented on a map. Red was used to indicate that the crater did not have gullies. Green indicated that gullies were observed.

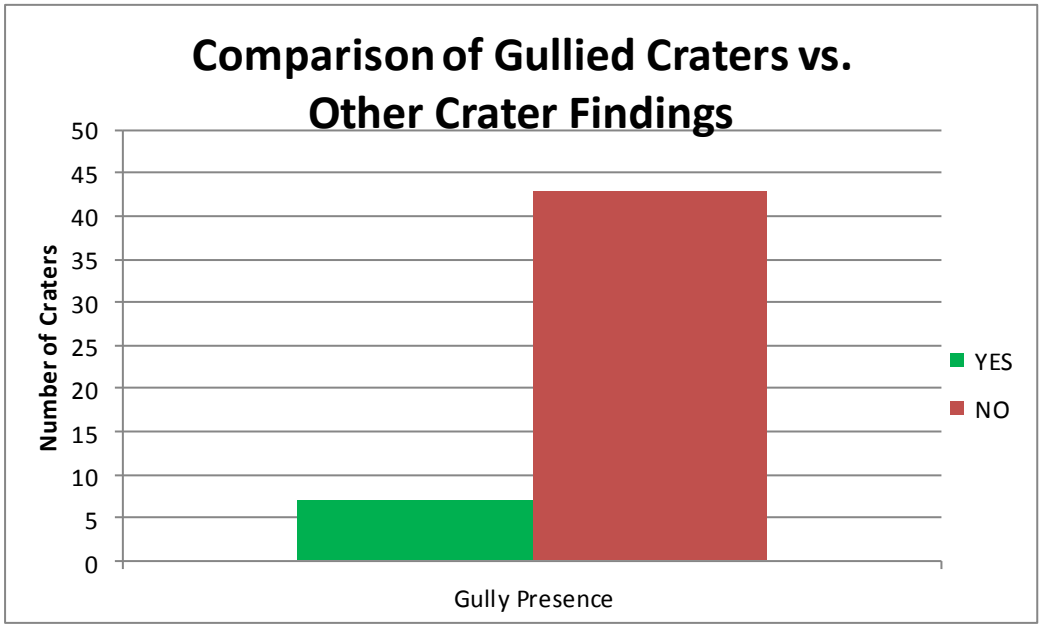


A rose diagram was developed to display the overall trend in gully location for the seven craters that were observed to have gullies.

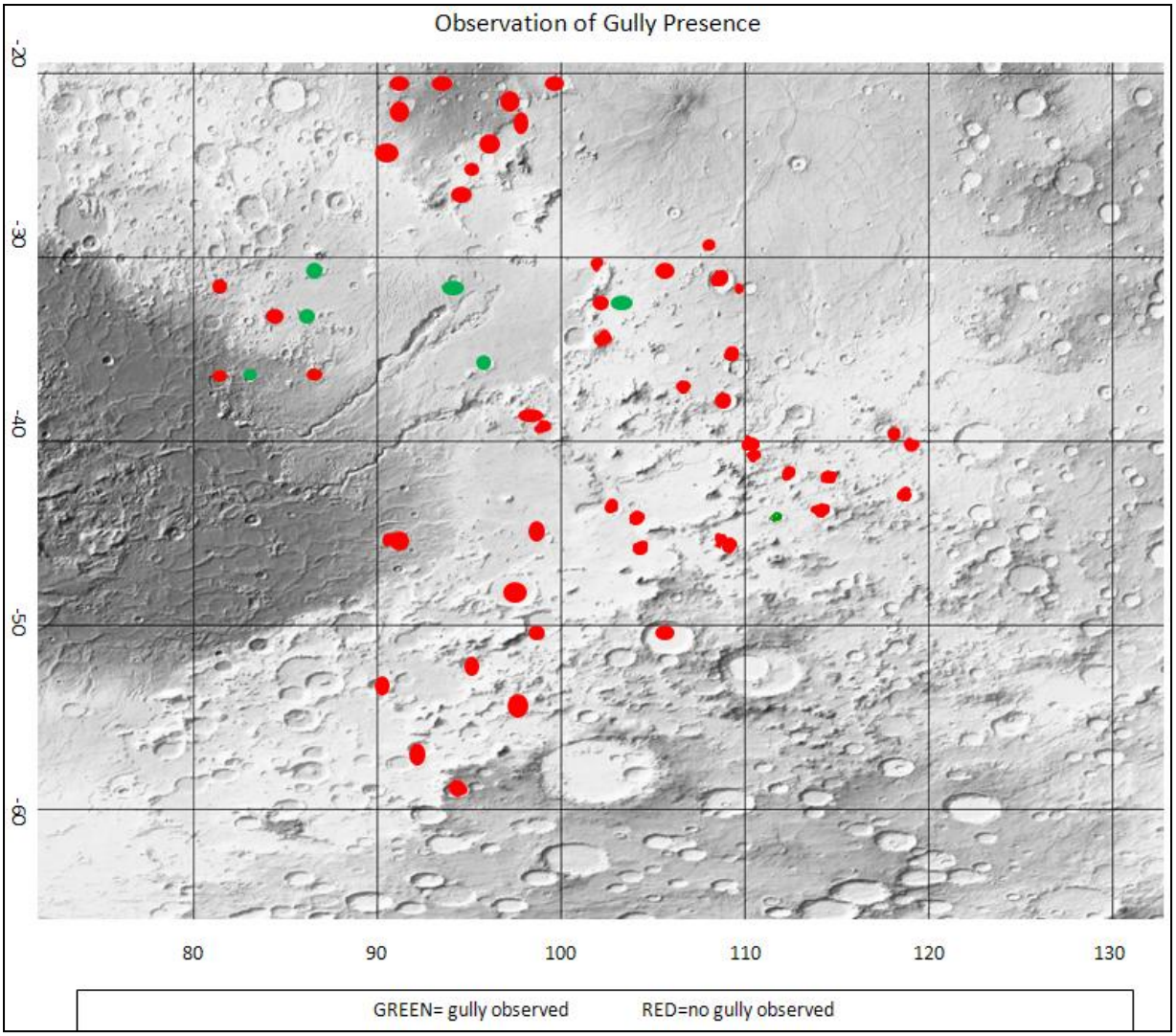


V. Discussion

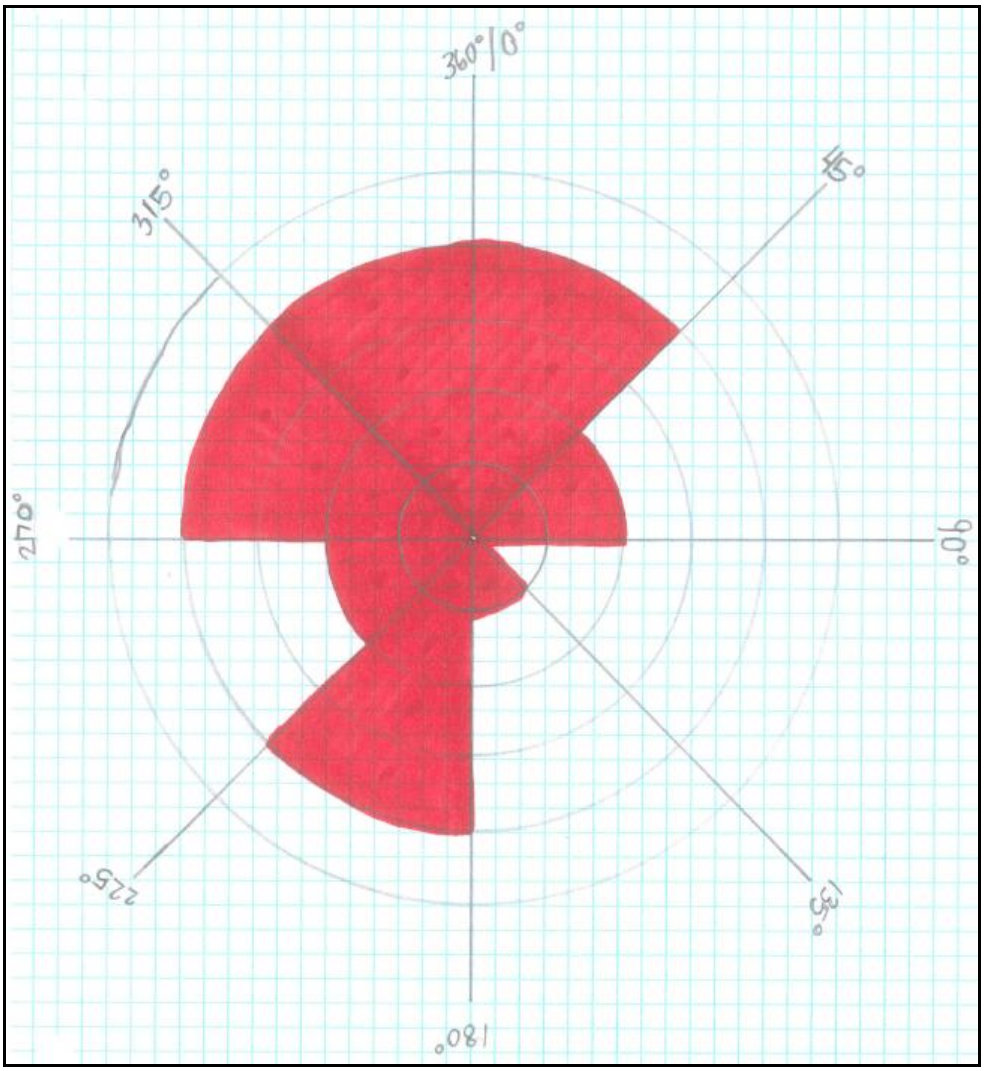
Data Table A (shown above) was used to create our bar graph, crater map, and rose diagram. We feel that we've collected a good sized data set and organized this table in a way that allowed us to begin having discussions about the area and to develop our other data result representations. Looking at the data table we were able to observe that out of fifty craters, only seven were observed to have gully formations. While only fourteen percent of our survey set of craters possessed gullies, this amount was enough to confirm that our targeted area met our criteria.



The bar graph allowed us to quickly see that craters without gullies greatly out-numbered craters with gullies for this region. It showed that gullies were present, even in small number, which also confirmed our hypothesis and positively answered our research question. This result tells us that some process on Mars is creating these gully formations. If we use Dr. Christensen's hypothesis it could be assumed that because of the latitude band, these gullies are the result of slowly melting snow banks that have formed as a part of the sublimation process happening on Mars. What is not able to be learned from our research is if this is true. Further research would be needed on the surface to know if these gullies came from a liquid or dry material source.

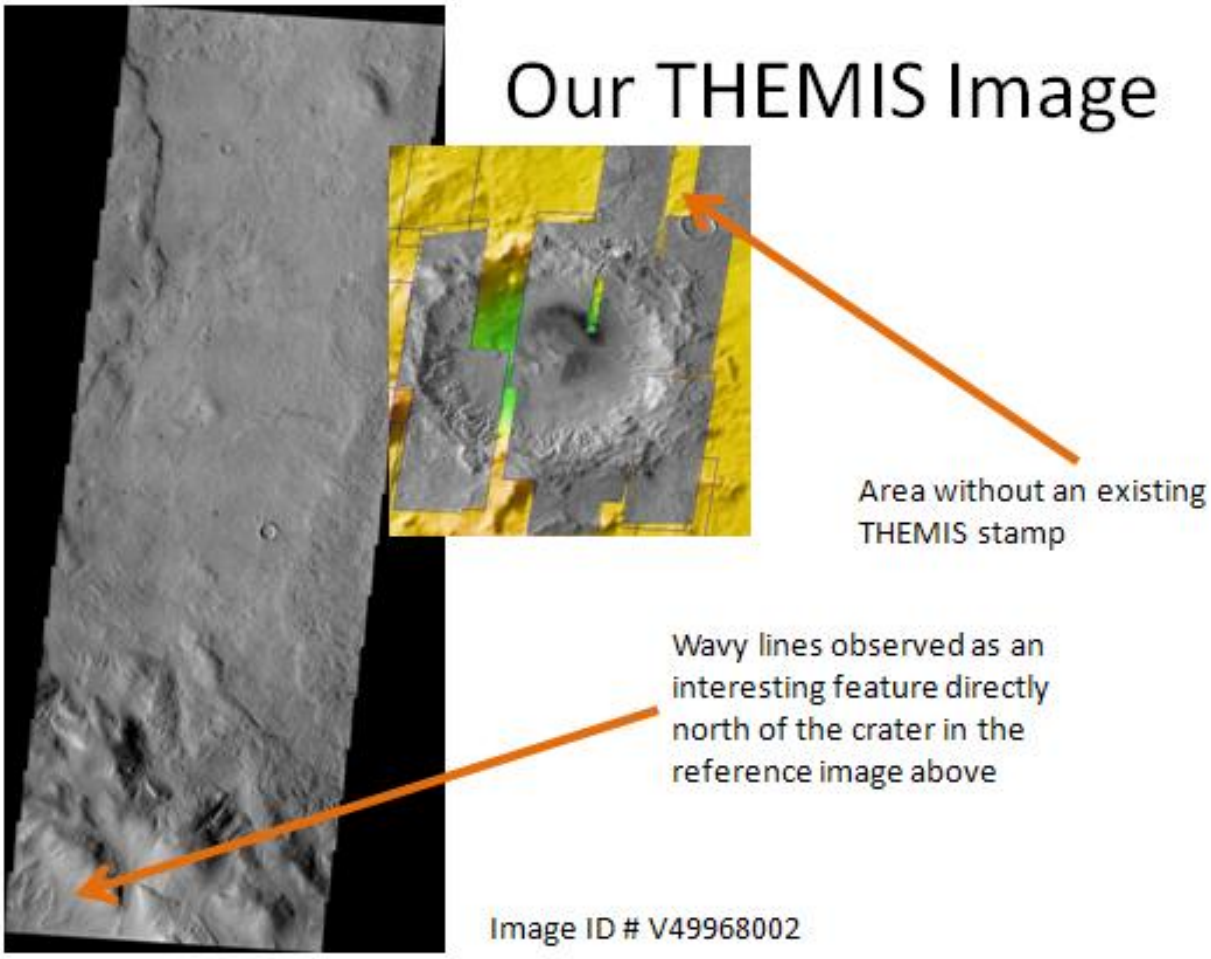


Looking at each colored data point within our crater map, we observed again that the number of craters without gullies out-numbered the craters with gullies. We also observed a pattern that the majority of the observed gullies were found between -30 and -40 degrees latitude. This helps us to narrow the region to a smaller latitude band that meets our criteria for possible human survival and that encourages further research.



Looking at the completed Rose Diagram, we observed that the area with the most prevalence for gullies was on the pole facing side overall, however, there is one equatorial facing area that matched in number of occurrences. We were surprised by this as this is not in agreement with the theories we read about in Dr. Christensen's research paper.

Our research question asked about the big picture when it comes to gullies, and the presence of any color on this diagram confirms that yes, gullies are present in this region. Therefore, our selected region also meets our criteria for possible human exploration and habitation.



Looking again at the specific image that our team captured using the THEMIS camera, we were able to see the area directly north of a crater that we found interesting while using JMARS. We were pleased to see that the stamp partially covers an area that did not have a previous THEMIS image.

We were very interested in the wavy lines seen in the bottom of the image. We believe these lines represent the movement of ice as you see in glaciers. We think it is significant to see this because it could indicate that the gullies in this area are formed by a liquid source rather than a dry material source.

There is potential for error within our research data. Inaccuracies are possible in our measurements. Even with our controls in place, we must question whether student researchers always measured crater diameter at the widest point and whether a second student would measure in the same location. It is also possible that we were inaccurate in our feature identification. At first, we found it difficult to tell gullies from canyon wall and layer features. It was suggested to us during our proposal that we establish a clear criteria to avoid this confusion. We cannot say with certainty that all of our identified gullies were named accurately, however, our best efforts were made. Misinterpretation is also possible. We are still learning about data and how to see its trends and patterns. We may have picked out the wrong patterns when

interpreting the data. Bias is also a possibility. We really wanted to find gullies, and it is possible that we mislabeled at some point because of the excitement over this finding.

VI. Conclusions

We selected a specific area of the border between the Hellas Planitia and Eridania regions to evaluate against our criteria for human survival. To test our final criteria, we evaluated if this region had a gully presence at the time of research.

To see if this area met our gully criteria, we focused on a specific research question about this region's craters. We wanted to answer the question of whether gullies were present in the craters we observed. This would allow us to confirm and support our criteria for choosing this location.

> Is there evidence of gullies in craters found at the border between the Hellas Planitia and Eridania regions?

We hypothesized that:

- If this region is south of the 30 degree latitude line and in an area that contains craters and similar steep sloped terrain, then we will observe evidence of gully formation.

- If we do not observe the presence of gullied craters, then this may indicate that the craters and landforms in this region do not have enough depth to develop gullies or that snow melt is not occurring.

In responding to our research question, we can confirm that there is positive evidence of gullies in the craters found between the Hellas Planitia and Eridania regions. This makes our first hypothesis true. This also means that this region meets all 3 of our criteria for possible human survival: it has a temperature range that is tolerable with proper space suits, a terrain that would allow for landing and rover travel, and the potential for a water source given that we consider Dr. Christensen's research. Our true hypothesis was developed based on the theories of Dr. Christensen that these gullies were formed as a result of slow-melting snow banks formed in this region as part of the sublimation process and preserved by a fine layer of dust.

Future research should now be considered. We believe that human beings should have the goal of trying to go to Mars to live and explore. We need to make sure it will be safe before sending humans that far from home. If un-melted snow and ice found near gullied craters can help us to supply astronauts with an accessible water source, then it is important that we find these areas.

It is our feeling that our findings tell us that this area should be studied more. We had difficulty identifying the "pasted on terrain" that signifies snow banks due to our own inexperience but think that a rover mission could tell us more about what is happening on the surface. We also believe that our results help to narrow down where to look, with the -30 to -40 degree latitude band having the majority of the

gullies we were able to identify. During our peer review and final MSIP presentation, we engaged in discussion about the current limitations in exploration of this area. With this area being identified as a special region possessing the possibility of holding past or current life, it is currently off limits for rover exploration due to the possibility of introducing germs from Earth. The process for sterilizing a rover is extensive and expensive, and the risk to contaminating this region is too great at this time. While this is the reality, we feel that a need for exploration still exists and hope that future developments will allow a rover destination in the area to be possible.

Our work on this project was memorable and provided us with incredible learning opportunities. We would like to say thank you to Jessica Swann, our MSIP/ASU liaison for giving us a lot of guidance and support. We also wish to thank Dr. Steve Ruff for joining us during our final presentation and providing a lot of new information for us to consider. We want to thank Mrs. Bauman, our teacher and MSIP facilitator, for giving us this experience, sharing her love of space exploration, and for helping us complete our research. We also want to acknowledge Mrs. Johnson and Ms. Murdock, our building administrators, and Mrs. Brahmstedt, Mrs. Graff, & Mr. Bojda, our homeroom teachers, for being flexible with our scheduled class time and allowing us to spend extra time in Mrs. Bauman's classroom.

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