Volcanic and Tectonic Martian Fissures

How are They Similar?

by The Team at Cyber Village Academy

Science Question

Based on process(es) of formation, how does the overall size and features of a Martian fissure differ?

Importance and Interest

This question is important and interesting because it will help scientists classify characteristics, like size, of differently formed fissures, which will assist in determining how Martian fissures were formed, and will help scientists learn more about them. This understanding may be generalized to other planets under research and perhaps could even be applied to undiscovered planets.

Hypothesis

We hypothesize that the different formation processes of fissures will create similar but not identical overall characteristics, such as length, width, depth, and presence of lava fields.

Background Information

Tectonic Fissures

Tectonic plates are large, raft-like pieces of the crust sitting on a sea of fiery magma. Interactions between these plates can cause tectonic fissures. Plate boundaries can either be divergent (pull apart), convergent (push together/under), transform (slide against each other), and micro-plates (complex geological features). (Understanding plate motions, 2012)

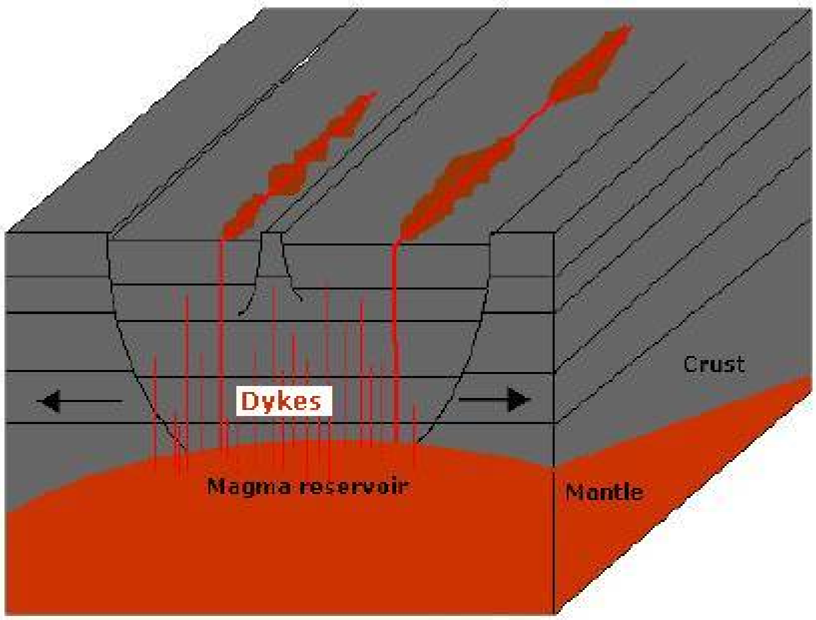
There is strong evidence of plate tectonics on Mars. By examining images of geological examples on Earth and comparing them to Mars, UCLA scientist An Yin has shown that Earth isn't the only planet in the solar system with plate tectonics. Major tectonic shifts do not occur often, but are expected to happen around every million years. The slower plate movement on Mars could be accounted for by less thermal energy than Earth, fewer main plates than Earth, or a more primitive stage of plate tectonics. (Dvorsky, 2012), (Villard, 2012), (Wolpert, 2012)

Stretching of the crust also creates tectonic fissures, a process called regional tectonic stretching. Scientists have found that Cerberus Fossae was created through this process, which can be found in Iceland on Earth. This stretching was caused by the same magmatic movement that created the Elysium Volcanic field. Incredible tectonic stress must have been needed for fissures in Cerberus Fossae to slice through hills and highlands like a hot knife through butter. (Mars Odyssey THEMIS, 2005), (Okubo, 2010)

Volcanic Fissures

Many cracks in the Earth's crust are formed volcanically, much like the Memnonia Fossae region, where our image was taken. In many areas on Earth where volcanoes are present, such as Hawai'i, large pieces create fissure volcanoes. (What on Earth, 2013)

Volcanic fissures form when magma is injected through the ground along long vertical fractures called dykes. These dykes can be parallel, which may indicate a tectonic role in their formation. The magma explosively forces the dykes open. Through geologic analysis, scientists have determined that the fissures in the Memnonia Fossae region were formed through magmatic dykes. (Okubo, 2007)



Ice Fissures

Ice fissures, which are polygon-shaped depressions with raised rims on Mars and Earth's polar surfaces, are formed through the gradual freeze-thaw process, where the gradual cycle of freezing and thawing causes ice to expand between the rocks themselves, creating large, polygonal depressions.

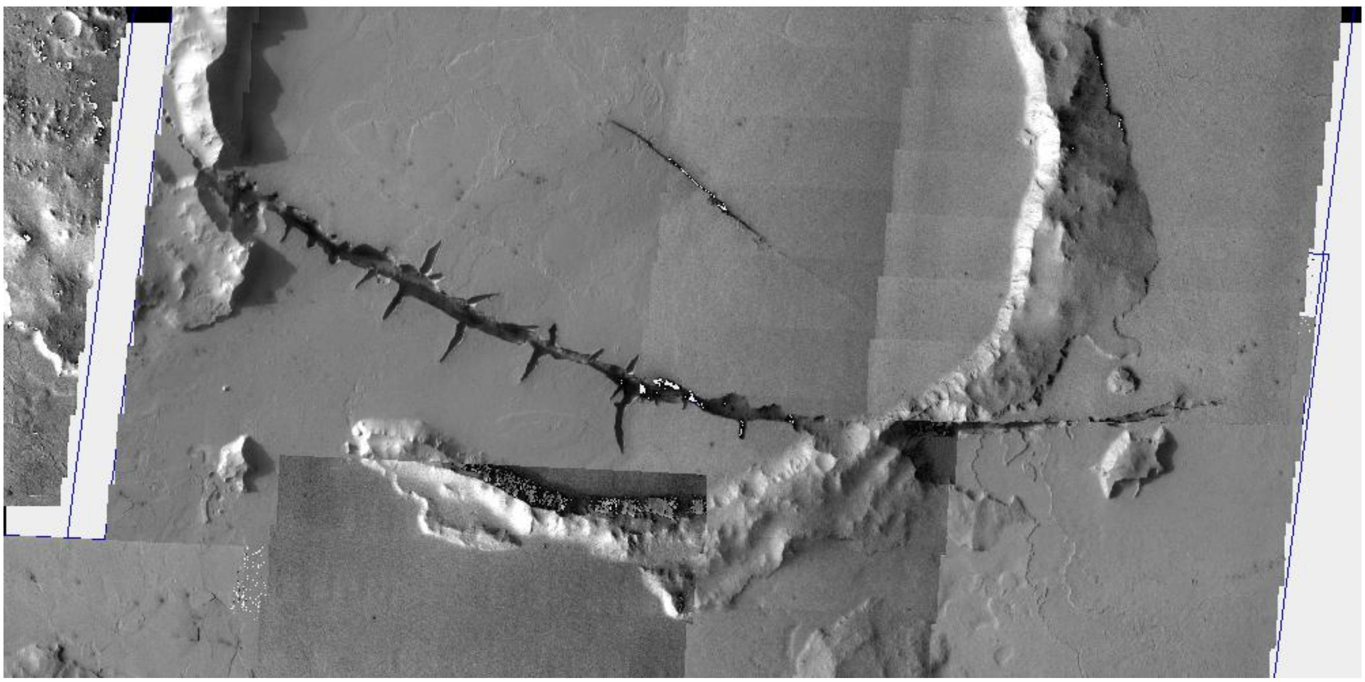
These unique and special fissures, unlike any other sort of geological feature yet to be described, inhabit the icy coldness of Earth's and Mars' frigid polar regions. The seasonal warming and cooling of the ice causes the expansion of ice and the freeze-thaw cycle. (Mangold, et. al.)

Water Formed Fissures (Canyons)

Canyons on Earth and elsewhere form when fast-flowing water from a channel such as a river slowly erodes rock faces, leaving a deep depression in its wake. Over millions of years, sediment from the rock faces are washed away and carried off by the river, exposing the substrate’s striated secrets.

The Grand Canyon is a very well-known example of a geological formation created by the erosion of water over millions of years. The widening of the rock faces is slow and stable. (“Geologic Features”)

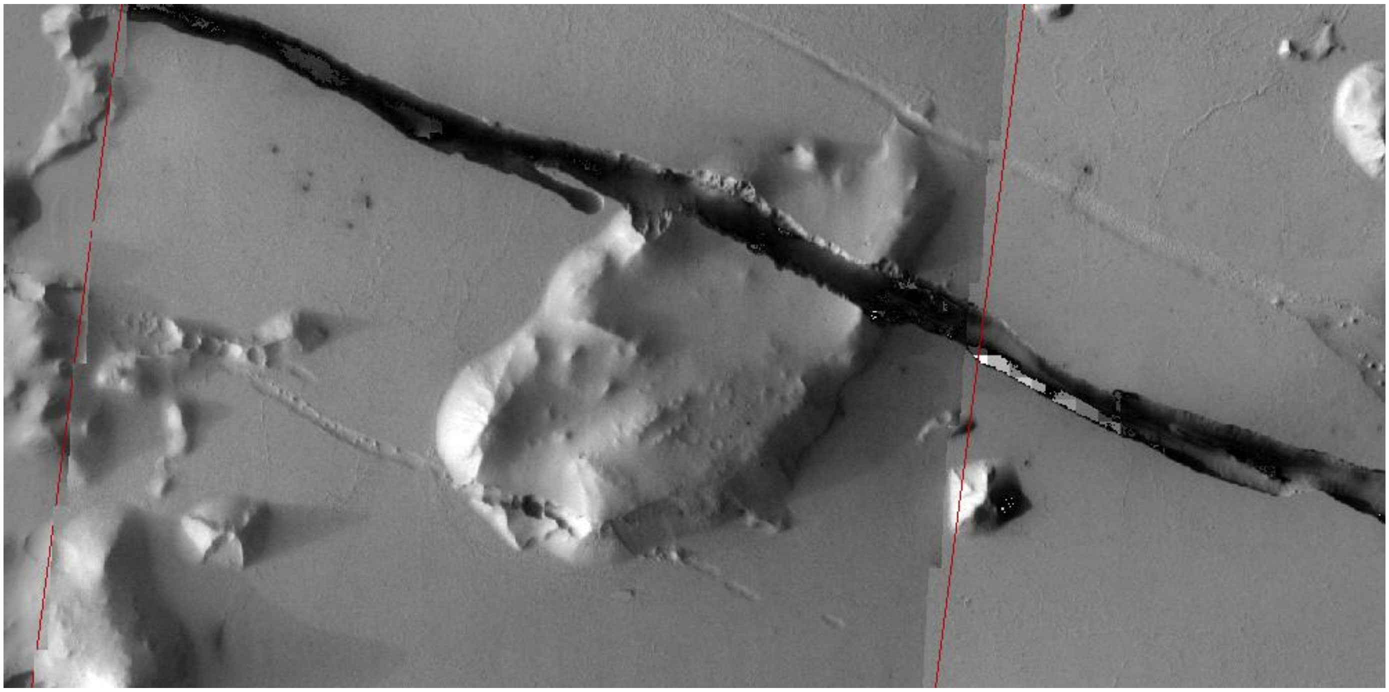
Areas Being Studied



Pictured above is a zipper-shaped fracture in the Cerberus Fossae region. This fracture is unique and mysterious in that there are perpendicular channels cutting across the main channel. Many scientists believe that the fracture was formed tectonically.

Nearby, to the north, there is a much smaller fracture, as well as lava fields. The fact there are no lava fields elsewhere around fractures we are studying, this suggests the lava field was formed independently from the fissure, though lava has been known to explode from fissures.

Here, in another part of Cerberus Fossae, there is a fissure that breaks through a hill, which indicates incredible tectonic stresses.



MARS STUDENT IMAGING PROJECT

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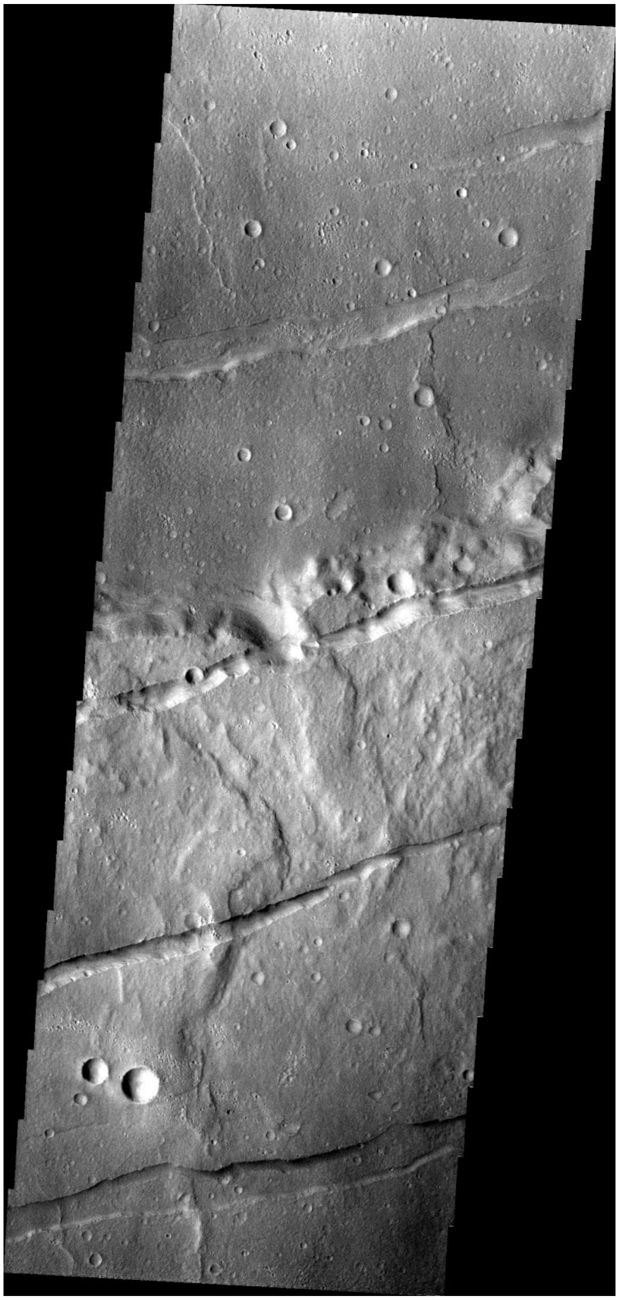

“Our” image (V50040002) comes from an area known as Memnonia Fossae. There are five fractures in our image.

The fractures in our image look older and more eroded (the fact that they are cold in Night IR and there are craters inside also suggests their age), and also have some craters inside of them. The northern half of our image is more smooth, while the southern half is much higher and more rugged.

MARS STUDENT IMAGING PROJECT

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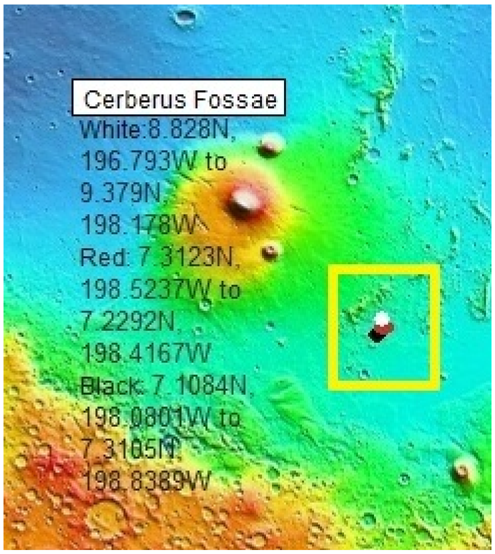
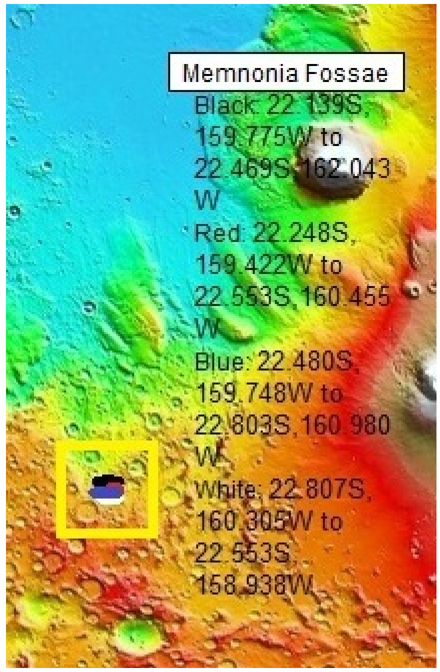
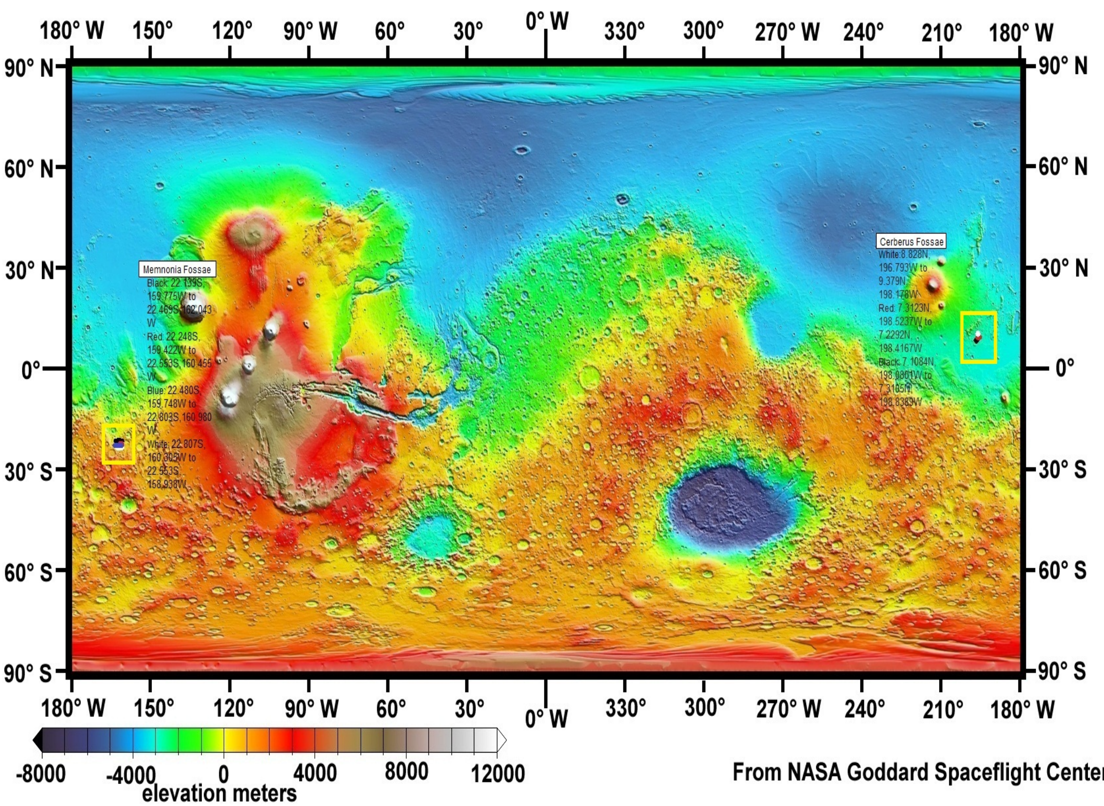
<u>Location of Areas Studied (on the MOLA Map)</u>





Color-coded Elevations on Mars, MOLA Altimeter, MGS Mission



(Recovered from: http://www.lpi.usra.edu/science/treiman/greatdesert/workshop/marsmaps1/marsmaps1_imgs/mola_color_4.jpg)

Methods

Spacecraft

We used the THEMIS camera on the Mars Odyssey spacecraft to conduct analysis of the fractures in the nearby regions and used THEMIS Night IR to determine the temperature of the fractures, so we can analyze the type of rock.

Geological Features

Our research subjects are the fractures that were most likely formed by volcanic or tectonic processes. We compared and contrasted the different types of fracture formation with these test subjects. Our experiment utilized Cereberus Fossae, hypothesized to be a group of tectonic fractures, and Memnonia Fossae, which are assumed to be volcanic in origin. Our image was taken from Memnonia, and our experiment worked with both hemispheres simultaneously.

Geographic Regions

The main regions we studyed are Cerberus Fossae, located in the Elysium Planitia in the northern hemisphere, and Memnonia Fossae, located in the southern hemisphere. These regions were chosen because of their statistically large amount of fractures. We took our image in the Memnonia Fossae Region because of the relatively low coverage of the southern hemisphere.

Websites

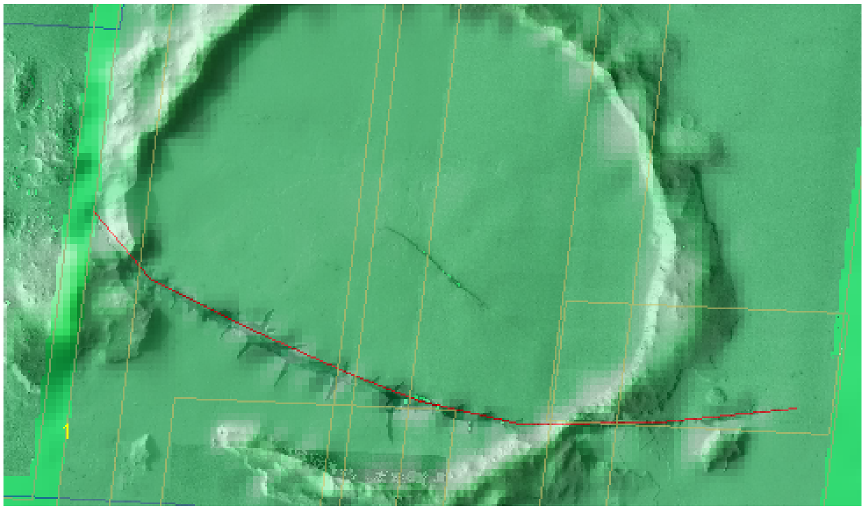
For backgrounds on volcanic and tectonic terms, we used the USGS website and NASA's pages on Mars and Mars' geological features. The hi-rise site (http://hirise.lpl.arizona.edu/) would be good to use in addition to the THEMIS site for us to look at pictures of fractures. We also used the ASU website.

Information We Recorded

We measured the length, width, and depth of fissures in the Cerberus and Memnonia regions. We did this to look for similarities in different fissures. We also looked for the presence of lava fields around the fissures, because the original image we looked at (in Cerberus Fossae) had a lava field around it. Though lava is known to spew from fissures, we could not find any lava fields along the other fissures that we studied.

Methods of Measurement

To standardize the measurement of depth and width of fissures. We first used JMARS to find the depth along a center of the of the fissure. We recorded the coordinates for what appeared to be the lowest elevation, and the highest elevation, as well as the two endpoints for the fissure, the center of the fissure, and ¼ of the distance along the fissure, and ¾ of the length of the fissure. These coordinates were then used to use for the width and depth analysis at each of these points and then were used for the averages.



Screen Capture of JMARS image to determine length of the Cerberus Zipper.

Using the Chart and the Coordinate from JMARS, determination of where important points to record width and depth are used to determine where to do cross-cutting of a fissure.

Chart showing the determination of the where to determine depth and width of a fissure, example from the Cerberus Zipper.

We then cut across the fissure at each of these points, and recorded the depth and width of the fissure at these points. The width was determined by finding the edges where the depth began to decrease as we cross-cut the fissure, and the depth was determined by averaging the elevation at each side and then subtracting the deepest point along the line. The width and depth were then an average of 7 points along each fissure.

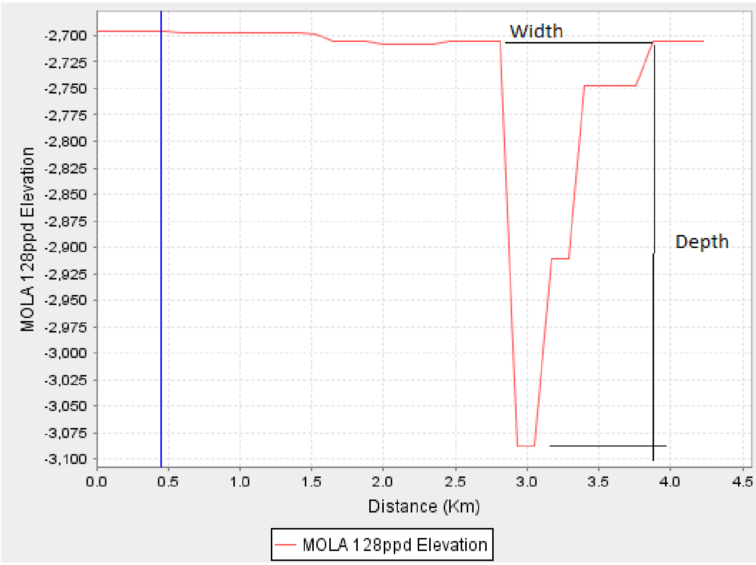


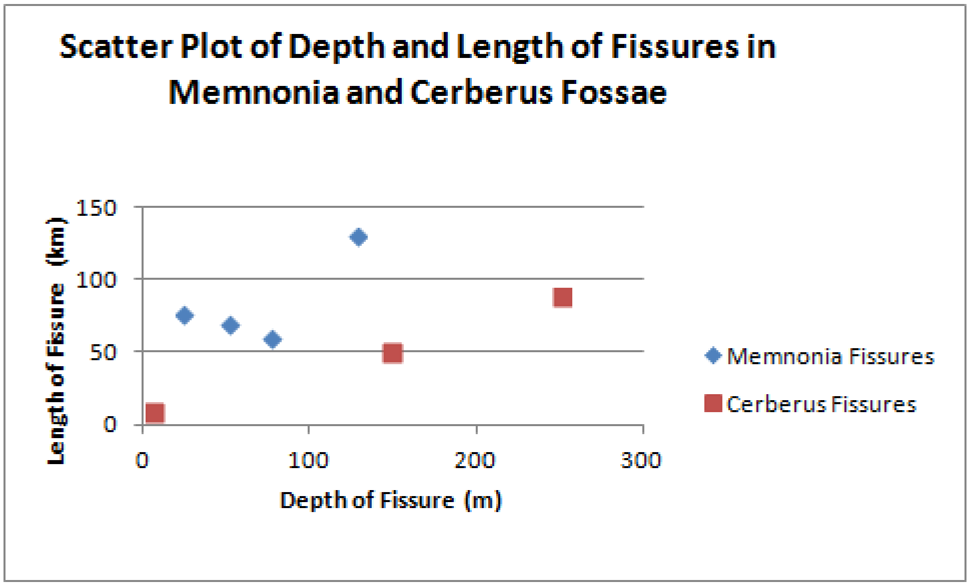
Chart showing how depth and width are determined from JMARS analysis of a cross-cut of a fissure.

Data Collected

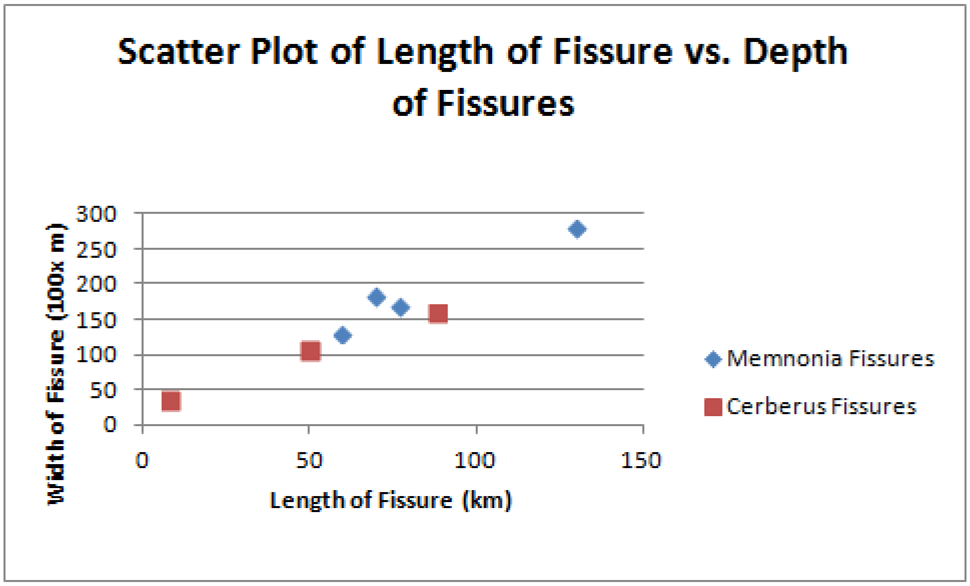
Table of Information Recorded

Nickname	"The Zipper"	"The Teeny Fissure"	"Time"	"Flynn Fracture"	"Rooze's Rent"	"Gardner Graben"	"Taylor Trench"
Location	7.1084N, 161.9199E to 7.3105N, 161.1611E (Cerb.)	7.3123N, 161.4763E to 7.2292N, 161.5833E (Cerb.)	8.828N, 163.207E to 9.379N, 161.822E (Cerb.)	-22.139N, 200.225E to -22.469N, 197.957E (Mem.)	-22.248N, 200.578E to -22.553N, 199.545E (Mem.)	-22.480N, 200.252E to -22.803N, 199.020E (Mem.)	-22.807N, 199.695E to -22.553N, 201.062E (Mem.)
Avg. Width	~1064.3m (or 1.0643km)	~342.5m (or 0.3425km)	~1585.7m (or 1.5857km)	~2785.7m (or 2.7857km)	~1291.3m (or 1.2913km)	~1833.3m (or 1.8333km)	~1683.3m (or 1.6833km)
Avg. Depth	~149.7m	~7m	~251.5m	~128.3m	~76.5m	~51.75m	~24.7m
Avg. Length	~50km	8km	~88km	~130km	~60km	~70km	~77km
Lava fields	Yes - could have been formed separately	Yes - could have been formed separately	No	No	No	No	No

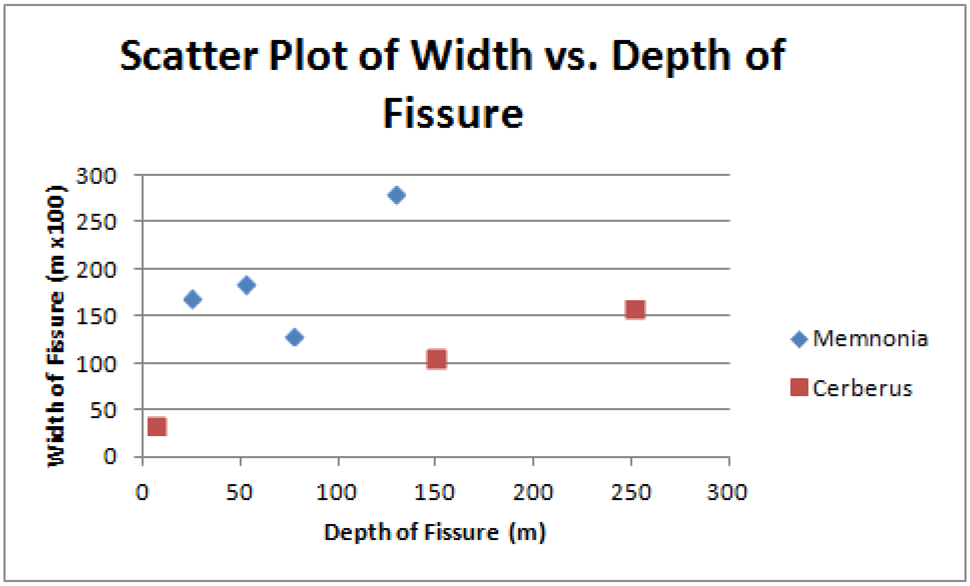
Graphs of Information Recorded



Scatter Plot of the Length of the Fissures vs. the Depth of the Fissures



Scatter Plot of Width vs. Length of Fissures



Scatter Plot of Width vs. Depth of Fissure

V. Discussion & Conclusion

Discussion

The data shown above shows some clear trends with the Cerberus Fissures. The three plots appear points appear to lie on a line, implying that the variables for these fissures are correlated. In addition, the width and depth plots and the length and depth plots, appear to segregate the two sets of fissures into different non-overlapping sets. This may indicate that one might be able to use scatter plots to segregate fissures according to their features. The volcanic fissures in Memnonia Fossae are heavily eroded and their depths, widths and lengths vary greatly. Using crater counting, we have deduced that Memnonia is a relatively old formation of Mars, which likely allowed for more erosion. The different ages of the two areas is an uncontrolled variable, which likely leads to that the plots above show little correlation, as erosion will affect the depth and the width of fissures greatly.

There are some very interesting unanswered questions involving these fissures that we have uncovered during our research. We would look into further into these if we were to do more research in this area. If the Memnonia fissures in our image were formed by explosive eruptions, then why do we not see lava fields around them? Have the fields eroded away? Also, can we find mineral evidence to show the issue of lava formation? If we probe other fossae, will we find similar clustering into types on scatter plots. Are there other fissure sets which might show the linear behavior we see with the Cerberus Fissures?

Conclusion

We conclude that, that the two sets of fissures show distinct differences in correlation, and can be preliminarily sorted according using scatter plots. We believe that further work looking at erosion, and mineral data, as well as probing other fissure sets may lead in the ability to classify fissures, in terms of age, and formation mechanisms.

Acknowledgments

We would like to acknowledge the following people and agencies who have helped us in our research. We would like to thank NASA and the Mars Student Imaging Program through Arizona State University for providing us the opportunity to do this project. We would like to thank Dr. Leon Manfredi for providing feedback from our final presentation, and Jessica Swann for providing important feedback during the proposal process. We would like to thank Ms. Kate Doan for her guidance through our research, and we would like to thank the rest of the Cyber Village Academy staff, for their patience as we worked together.

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