Analysis of Wrinkle Ridges to Determine Distribution and Depth of Blind Thrust Faults in Mare Imbrium

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Introduction

Purpose:

We chose to study wrinkle ridges to expand the limited amount of research available on them and also to determine information about structures in the basalt infill. We used wrinkle ridges to determine if any relationships between their characteristics and the basalt thickness in Mare Imbrium are present.

Mare Imbrium:

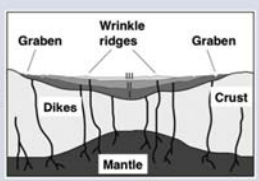
http://www.nasa.gov/images/content/346589main_moonimg_02_full.jpg

Mare Imbrium is located in Imbrium Basin, which is an impact basin located on the near side of the moon centered at approx 33° N, 16° W. The impact basin is about 3.5-4 billion years old, 1,100 km in diameter, and the mare contained within the basin are estimated to be about 2 km in depth, based on analysis of thickness measurements from impact craters that penetrate through the mare. It also is part of the Procellarum KREEP Terrane, which includes most mare basalts on the moon.

Structure:

Wrinkle ridges are low sinuous ridges found in volcanic materials that filled the giant impact basins on the Moon. Some can be hundreds of kilometers long.

Hundreds of millions of years after an impact basin is formed, volcanic eruptions fill the basin with basalt. Over time, the basalt is bombarded by meteoroids and a layer of regolith forms. This process repeats itself and eventually there are multiple layers of basalt and regolith.



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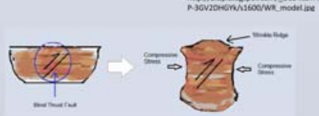
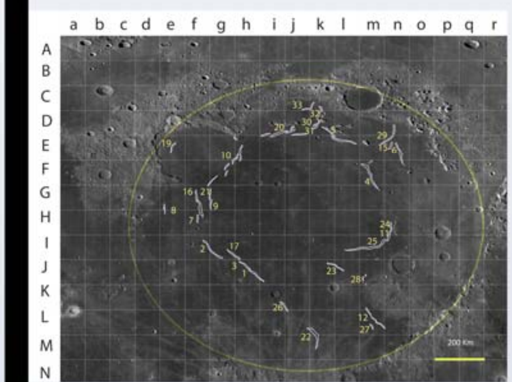


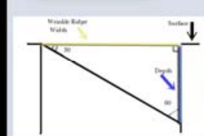
Wrinkle ridges are formed by the loading of the basin floor. The weight of the basalt layers causes the center of the basin to sag; as it sags, the sides of the basin push inward, causing compression that results in the folding and faulting of the basalt.

Collecting Data

The image of Mare Imbrium we used is a mosaic of images compiled from the Lunar Reconnaissance Orbiter Camera. Our first task after acquiring the image was to find a way to navigate the image. The high resolution and large size of the image made it difficult to go back to exact locations. As a solution we created a grid coordinate plane over the image. This made it easier to identify exact locations. We then assigned a number to each wrinkle ridge and wrote down it's location. We then proceeded to collect other data. We extensively utilized Photoshop for the entire process.



To calculate the depth of wrinkle ridges, we measured their widths. The ruler tool in Photoshop was used to measure the widths every 50 pixels along strike. On the original image, 1 pixel is equal to 100 meters so the measurements were 5 km apart. Lines were drawn across the width of the wrinkle ridge to keep track of progress. The measured lengths were converted from pixels to kilometers and entered into an Excel document for analysis.



We calculated the depth of the faults at every 50 pixel mark. With the width we measured, we used the formula Depth = Width x tan(30°) to calculate the depth. In this right triangle, the hypotenuse represents the fault. On Earth, thrust faults typically have a dip of 30°, so this value was assumed for the identified thrust faults. The calculated depth of faulting would increase with a steeper fault dip and decrease with a shallower dip.

After working on the image for some time, we started to notice a trend. The wrinkle ridges were formed in a circular pattern, concentric to the Imbrium Basin. This led us to measure the distance of each wrinkle ridge from the rim of Mare Imbrium and compare this information to the depth of the faults to see if there is any correlation. The rim of Imbrium was hard to identify however. We created an artificial ellipse as an estimate for the rim. We initially created a circle but it did not seem to fit so we made an oval. We then measured the distance of each wrinkle ridge from the artificial rim we drew. In map view, the rim appears as an oval as opposed to the typical circular shape of most craters due to the projection of the image. The image captures the lunar surface on a flat panel. The area is circular when viewed from a 3d form.

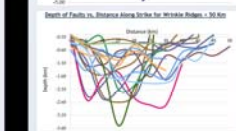
Statistics

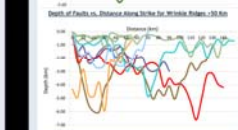
Total Number of Wrinkle Ridges	30
Total Number of Measurements	341
Wrinkle Ridges Length Range	15 to 150 Km
Maximum Depth of the Faults Range	0.35 to 6.61 Km
Wrinkle Ridges Concentric to the Outer Rim of Mare Imbrium.	14

Since we collected a multitude of data, our data is displayed graphically. We wanted to explore as many relationships as possible between wrinkle ridges and the faults below them, so we looked for various correlations between the depth of the fault, the length of the wrinkle ridge, and the distance from the rim of Imbrium.

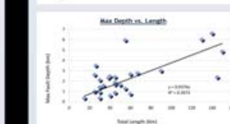
Data Analysis:

Through this graph one can say that the deepest point of the fault in the wrinkle ridge is found in the middle. This relationship is typical of terrestrial faults, thus confirming our interpretations and assumptions. This graph was made inversely in order to make a better visual as if you are seeing it sliced out of the moon.

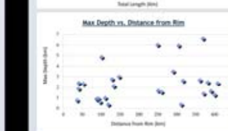




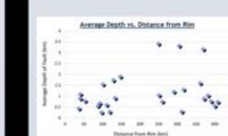
This is a graph like the previous one that relates the depth and the distance along strike for all of the wrinkle ridges less than 50km long. As you can see, the faults are deepest close to the center. This is consistent with faults on the Earth. Some of the faults, such as the fault depicted by the pink line, appear to have two separate maximum depths. We think this may be caused by the joining together of two separate faults. The next graph also shows the depth vs. distance along strike, but for wrinkle ridges greater than 50km long. We split data into two graphs to prevent one from being crowded. The deepest point measured, as shown on the red curve, is approximately 6.5km.



This graph displays the relationship between the maximum depth of the fault and the total length of the wrinkle ridge. There is some correlation between depth and length. Generally, it appears that the deeper the fault is, the longer the wrinkle ridge is and therefore the longer the fault is.



We expected that the depth of the faults would increase as we got closer to the center of the basin, because the basin is bowl shaped, thus reflecting the depth of the mare. We plotted the maximum depth as it relates to the distance from the rim but as you can see there is no correlation. However, we did notice that there are no wrinkle ridges between 150 and 250 km, possibly identifying a ring on the basin floor.



This graph shows the average depth verses the distance from the rim. There is no direct correlation. The three highest points are toward the right of the graph, representing the wrinkle ridges close to the center of the basin with average fault depths between 3.0 and 3.5km. There are, however, five points still farther to the right and thus closer to the center, representing shallow faults averaging between 0.5 and 1km, possibly due to a central uplift or interior ring structures.

Conclusion:

We had hoped that our data would show some relationships. We thought that length might be proportional to the depth of faults, and there does seem to be a very weak relationship. We had also thought that there might be a relationship between the depth of fault and its distance from the rim of Mare Imbrium, but there appears to be no correlation, though there is a possible indication of a ring structure. Also, previous work has concluded that the basalt in Mare Imbrium is thought to be about two kilometers deep. However, our data shows that there are faults that are over six kilometers deep. This could mean either that the faults extend through the basalt layer to the pre-impact surface beneath, or that the basalt layer is deeper that previously thought.

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http://lunar.gsfc.nasa.gov/lroc.html
http://www.lroc.asu.edu/EPO/LROC/lroc.php?pg=objectives
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