MODELING VOLCANIC THERMAL DEMAGNETIZATION OF THE MOON'S REINER GAMMA MAGNETIC ANOMALY. M. R. Kelley[1], I. Garrick-Bethell[1,2]. [1]University of California Santa Cruz, Santa Cruz, CA, USA. [2]School of Space Research, Kyung Hee University, Korea.

Introduction: The Moon no longer possesses a global magnetic field [1,2]. However, localized magnetic anomalies are present at many locations in its crust. The magnetic fields of these localized anomalies have been measured with orbital magnetometers. In spite of these measurements there is no consensus on the formation mechanism for the magnetic source bodies or what these crustal anomalies mean for the history and evolution of the ancient lunar dynamo. Investigating lunar crustal magnetic anomalies may provide insights into the Moon's thermal evolution [3,4] and possibly unusual dynamo generation mechanisms [5,6]. To further these goals, we expand on previously presented work on one of the Moon's strongest magnetic anomalies, Reiner Gamma [7]. Here we seek to test the hypothesis that a portion of Reiner Gamma was demagnetized by the heat of nearby volcanoes. If true, we may be able to constrain the depth, thickness, and Curie temperature of the magnetized material.

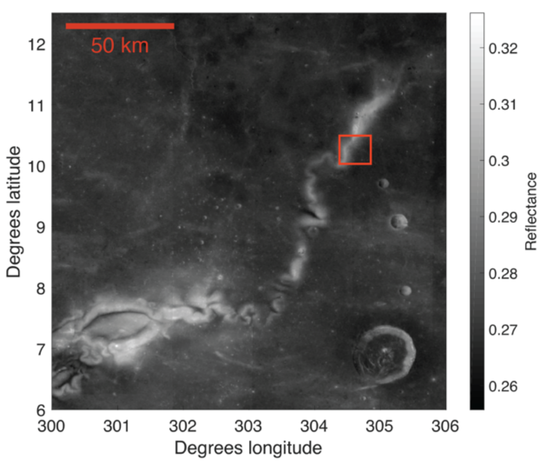

Fig. 1: A 750nm Clementine reflectance image of Reiner Gamma swirl, located at 7.5°N, 59.0°W. The red box indicates the area shown in Figs. 2, 3, and 4.

Reiner Gamma: Reiner Gamma (Fig. 1) is a lunar swirl where the albedo patterns at the surface are likely correlated with the structure of the magnetic field [8]. Reiner Gamma is found on the volcanic plains of Oceanus Procellarum [9]. The northeastern portion of the swirl, herein called the 'tail', extends northeast towards the Marius Hills. The Marius Hills are a topographically distinct volcanic region with the highest density of volcanic domes on the Moon [10]. Previous work has suggested that because the lunar swirl does not overprint the centers of nearby volcanic domes (Fig. 2), the heat from the emplacement of the domes is responsible for the thermal demagnetization of the swirl source body and the subsequent loss of swirl pattern in the location of the volcanic domes [7]. Changes in swirl albedo likely occur on a timescale of millions of years [11], while lunar volcanism ceased on a timescale of billions of years ago. The difference between these two timescales implies that it is not volcanic material simply covering up a preexisting swirl pattern, but rather that the swirl morphology reflects the distribution of the buried remaining magnetic source bodies. To test this hypothesis, we present a model of heat flow around a Marius Hills volcano with implications for the history of magnetic material near the volcano.

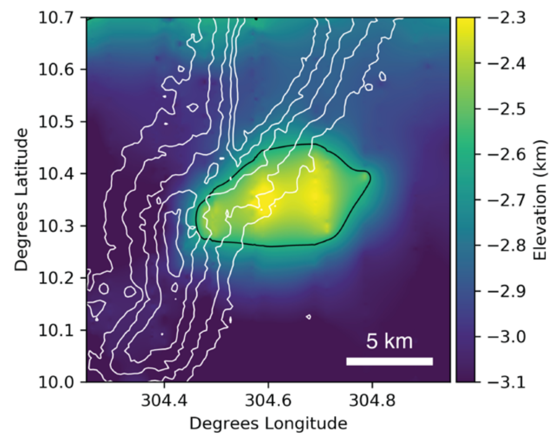

Fig. 2: A map of LOLA topographic data for the red subset box shown in Fig. 1. The black contour indicates the boundary for high/low temperature in Figs. 3 and 4, and the white contours indicate the location of the lunar swirl near the volcano.

Thermal Model: The goal of our thermal model is to determine (1) where demagnetization of magnetic materials occurs around the emplaced and then cooling volcanic products, and (2) the timescales over which this demagnetization, if any, occurs. Our model is a two-dimensional grid of temperature values that are stepped through time using the heat diffusion equation. This first model considers only conduction laterally through the crust, and neglects radiation of the volcano's heat upwards into space. This assumption of only two dimensional heat flow implies that the extent of the demagnetization boundary around the volcano will represent an upper bound.

The initial condition of the temperature grid consists of a high temperature (T_{hot} = 1127°C, basalt liquidus = 1200°C) in the shape of a particular Marius Hills volcano that is near Reiner Gamma (Fig. 2), and a low temperature (T_{cool} = -23°C), representative of the mean near-surface temperature, that makes up the background around the volcano (Fig. 3). The value of T_{hot} and the total area over which it is expressed, are chosen to be high to produce an upper bound on the extent of demagnetization. This grid of temperatures is then stepped through time until the simulation has reached approximately 250,000 years. This timescale has proved sufficiently long enough for each cell outside the volcano to pass its maximum temperature and begin cooling. For each cell, the maximum temperature reached over the course of the simulation is recorded (Fig. 4). We calculate the remaining demagnetization in each location using the assumption that any magnetic material around the volcano retains 100% of its initial magnetization if the temperature stays below its Curie temperature, and is immediately reduced to 0% magnetization if the temperature reaches its Curie temperature. Three possible Curie temperatures are that of iron (770°C), hematite (730°C), or magnetite (585°C). The latter two materials would likely be present on the Moon as exogenous materials (e.g. [12]).

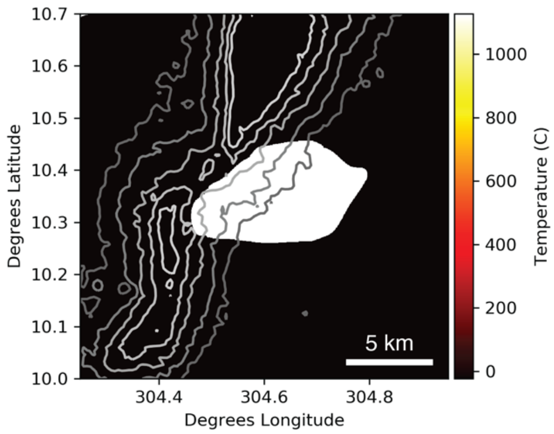

Fig. 3: The initial temperature distribution of the heat flow model. The shape of the volcano (white) is from Fig. 2. The grayscale contours indicate the location of the lunar swirl near the volcano.

Results: Using these assumptions, we find that the spatial pattern of thermal demagnetization follows almost the exact shape of the volcano, i.e. the demagnetization boundary does not propagate very far beyond the edges of the volcano. This result is partially due to the simplicity of our initial model. In future treatments of this problem, we will consider the full time-temperature history of each cell.

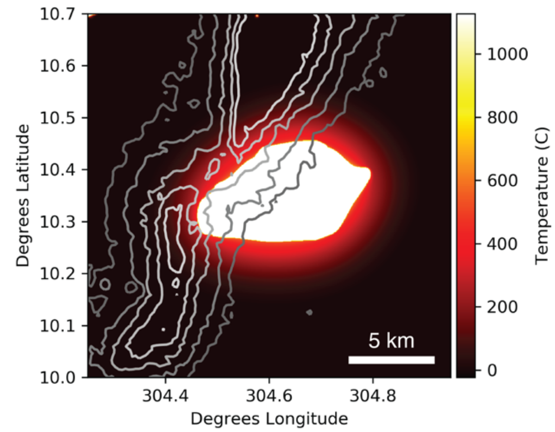

Fig. 4: Map showing the maximum temperature reached at each point during the heat flow evolution. The initial shape of the volcano temperature distribution (black contour at the edge of the white region) was determined from one contour of LOLA topographic data. The red contours indicate the location of the lunar swirl near the volcano.

The maximum temperature reached by a particular region of magnetized material is not the only important factor in its demagnetization history; holding a source body at a lower temperature for a long time will produce partial demagnetization (quantified for iron in [13]). Hence, in order to produce more useful results about the demagnetization behavior around a volcano, we must consider the entire temperature history of each cell, rather than just the maximum temperature reached. Additionally, we plan to implement a 3D thermal diffusion model that permits intrusive bodies with more complex geometries. Previous work has successfully used a 3D volcanic intrusion model to explain the demagnetization of martian magnetic anomalies [14].

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