

Structural Mapping of the Thaumasia Graben, Implications for Formation. G. L. Studer-Ellis¹ and D. A. Williams¹, ¹Arizona State University School of Earth and Space Exploration, PO Box 876004 Tempe, AZ 85287-600, gstudere@asu.edu

Introduction: The region of Thaumasia, Mars is a geomorphologically diverse area containing highland and lowland terrains (planum, terra, and fossae), modified by varying degrees of cratering that indicate different ages [1-3]. The Thaumasia region extends across a large portion of the Martian surface, from just southeast of the Tharsis Volcanic province, to the edge of Vallis Marineris in the east, and south to Aonia Terra. The ages for regions inside Thaumasia range from the early Noachian (4.1 Ga to 3.7 Ga) through the Hesperian (3.7 Ga to 3 Ga) and Amazonian (3 Ga to present) [2]. Major regions in Thaumasia include (but are not limited to) the Thaumasia Planum, Thaumasia Highlands, Solis Planum, and Icaria Planum.

Understanding the region's formation and evolution is essential to discerning the history of Mars itself. Because terrain within Thaumasia spans the entirety of the Martian timeline and has varied geomorphologic features, this region is of prime interest for further study. Regional formation mechanisms include a mega-landslide originating from the Tharsis volcanic complex [4], crustal flexure from intrusion of magma at depth and gravitational relaxation resulting in the Thaumasia plateau [1,2,5], orogenic belt production through crustal mobility or plate tectonics [6,7], and domal uplift from salt diapir intrusion [8].

Chemical provenances have been examined to support and further understand the aforementioned regional formation mechanisms. The greater Thaumasia region has chemical signatures from volcanic episodes consistent with a magmatic evolution of basalt in three distinct provinces [9]. These provinces were found to be inconsistent with a proposed mega-landslide origin for

the region, but to be consistent with distinct magmatic emplacements of differing compositions [9].

The Thaumasia graben has been previously studied by [10] where it was compared to the Kenyan Rift system on Earth. The study finds the graben inconsistent with the Earth analog. Our study will use newer higher resolution data and compare the Thaumasia graben to the Afar rift system on Earth which we present as an alternative analog.

New higher resolution data from the Context Imager (CTX) and the High Resolution Stereo Camera (HRSC) data aboard the Mars Reconnaissance Orbiter (MRO) and Mars Express orbiter, respectively, enable analysis on a much finer scale than has been previously available. Using data from the aforementioned missions this project analyzes the Thaumasia graben extensional regime through mapping and structural analysis.

Regional Geology: The Thaumasia Highlands are a mountain range which extends across the Thaumasia region from 250° to 300° E, and -15° to -45° S (Figure 1). The Thaumasia Highlands were interpreted by [1,11] as an early Noachian tectonic mountain building site and as a source for channel systems including Warego Vallis. The production of the volcanic material in the highlands is thought to have occurred via repeated volcanic episodes with modification by tectonism after volcanic emplacement [9]. In [2,12] possible structural and tectonic formation methods for the highlands are discussed. These methods suggest that the region formed as volcanic emplacement and was later deformed extensional processes. [6] discuss possible structural and tectonic formation methods for the Thaumasia Highlands, and suggest that the region

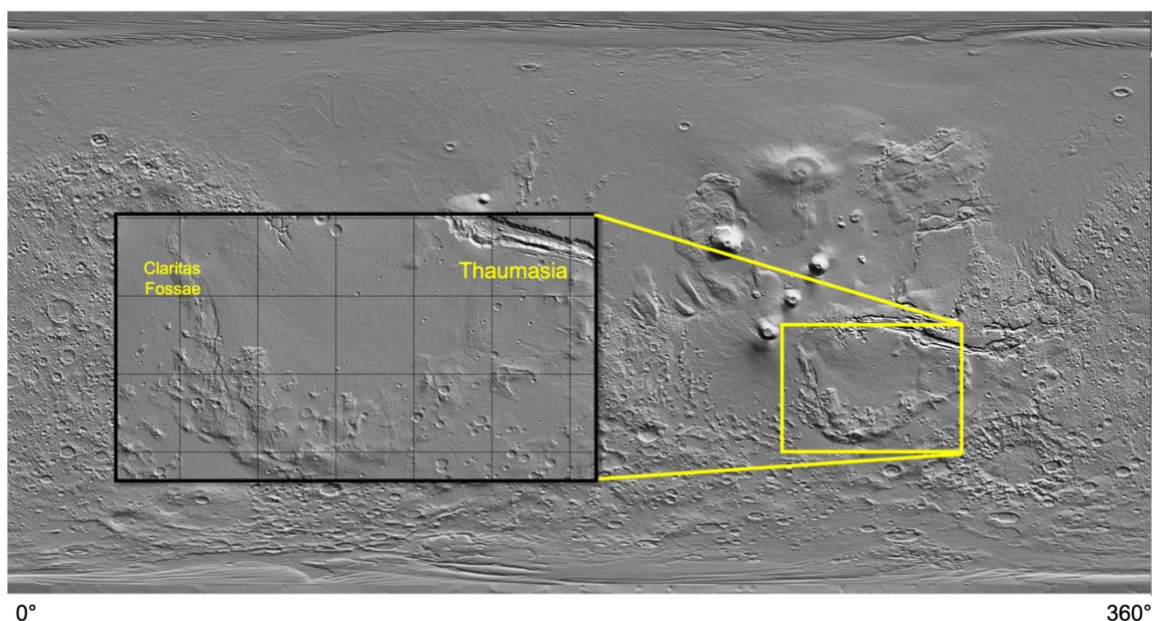


Figure 1. Location map of study area in Thaumasia. Claritas Fossae is the approximate location of the graben under study. Basemap shown is the MOLA shaded relief. Map generated with the use of JMARS.

formed because of lithospheric flexure during volcanic emplacement. Other studies give alternative hypotheses for the formation of the highlands, including uplift through early plate tectonics [13-15], large-scale salt structure buoyancy uplifting overlying rocks [8], crustal flexure caused by volcanic loading [5], and tectonic movement downslope caused by the formation of Tharsus [7].

The west section of the Thaumasia Highlands is referred to as Claritas Fossae. Claritas Fossae is covered in lineations (predominately NS-trending), including a long NS-trending graben. The Thaumasia graben and the Kenya Rift system are compared using regional extension analysis and geomorphological studies in (Hauber and Kronberg). The Thaumasia graben is concluded to be consistent with some characteristics of the Kenya Rift system but lacking in four key areas. No alternative formation mechanisms for the extensional regime were investigated at the time.

Methods: This project will create a geomorphological map of the Claritas Fossae region of interest (ROI) using ArcGIS software and an ISIS3 mosaic [16]. The mosaic will be compiled from images taken by the CTX and HRSC instrument, HiRISE images will not be utilized because they do not encompass a continuous area in the ROI and are too fine scale for use over the extended study region. 325 CTX images which cover the Thaumasia graben region from 250 to 260°E and -20 to -40°N are used in this study additionally 4 HRSC DTMs are utilized as well. USGS ISIS3 was used to calibrate and project the CTX images over the ROI, the HRSC DTMs were publicly available through the PDS already calibrated and projected. The DTMs utilized in this study are calibrated to the areoid reference and not the spherical reference. ArcGIS will then be used to produce a map of the region which focuses on structural elements and unit terrains. Structural analysis will include an estimation of extension in the region comparing large and small scale rates. Surface extension will be determined by using $e = \frac{l_f - l_0}{l_0}$. Where l_f is final length and l_0 is initial length. Extension will be measured across regional and local profiles. Measurements of this variety will allow us to determine if extension was consistent across the region or of local pockets experienced differing stress regimes. Additionally, the extension measurements will be compared to the Afar triple junction region on Earth and measurements by [17].

Expected Results

Preliminary examination of CTX images through the web and a GIS software JMARS [18] of calibrated/non-mosaiced images shows an area riddled with lineations and scarps indicating a complex structural history. We will be presenting a preliminary

map of the study area as well as initial structural analyses.

Formation Mechanism*	Key Features	Reference
Mega-landslide	Lobate edge to flow, scarp detachments at origin flowing west, faults parallel to flow front	Andrews-Hanna
Early Rift System	Regional and locally uniform extension, faults forming in triple junction morphology	Hauber and Kronberg, and Manighetti
Salt Diapir	Detachment faults flowing east, lobate edges to flow, surface slumping	Montgomery

Table 1 summarizes the formation methods to be tested and their key identifying features (not all formation mechanisms for the region will be tested only those which we estimate can be informed by this study).

References: [1] Dohm, J.M., Tanaka, K.L., (1999) *Planetary and Space Science* 47, 411–431. [2] Dohm, J.M. et al. (2001) *Journal of Geophysical Research: Planets* 106, 32943–32958. [3] Tanaka, K.L. et al. (2014) *USGS Publication*. [4] Andrews-Hanna, J. C. (2009) *Nature Geoscience*, 2, 248–249. [5] Williams, J.P. et al (2008) *Journal of Geophysical Research*, 113, E10011. [6] Nahm, A. L., & Schultz, R. A. (2010) *Journal of Geophysical Research*, 115(E4). [7] Webb, B. M. and J. W. Head (2002) *33rd LPSC, Abstract #1358*. [8] Montgomery, D. R., et al. (2009) *Geol. Soc. Am. Bull.*, 121, 117–133. [9] Hood, D.R., et al. (2016) *Journal of Geophysical Research: Planets* 121, 1753–1769. [10] Hauber, E., and P. Kronberg (2005) *J. Geophys. Res.*, 110, E07003. [11] Dohm, J.M., Tanaka, K.L., (1994) *25th LPSC, 331-332 Abstract*. [12] Grott, M., et al. (2007) *Icarus*, 186, 517–526. [13] Courtillot, V. E., et al. (1975) *Earth Planet. Sci. Lett.*, 25, 279–285. [14] Anguita, F., et al. (2001) *J. Geophys. Res.*, 106, 7577–7589. [15] Anguita, F., et al. (2006) *Icarus*, 185, 331–357. [16] Anderson, J.A et al. (2004), *35th LPSC, Abstract #2039* [17] Manighetti, I. et al (2001) *J. Geophys. Res: Solid Earth*, 206, 13667-13696. [18] Christensen, P.R. et al. (2009) AGU Fall Meeting, Abstract id.IN22A-06.