FORMATION OF PATERAE ON IO: GEOLOGIC MAPPING AND EXPERIMENTAL MODELS. M.C. Decker[1], J. H. Smith[1], J. Radebaugh[1], E. H Christiansen[1] and D. A. Williams[2] [1]Department of Geological Sciences, Brigham Young University, Provo UT 84602; meganccdecker@gmail.com, smithjohnh@gmail.com. [2]School of Earth and Space Exploration, Arizona State University, Tempe, AZ.

Introduction: Jupiter's moon, Io, is the most volcanically active object in the Solar System, and it has several unique volcanic features called paterae. There are over 400 paterae, or volcanic-tectonic depressions, on Io, covering approximately 2% of the surface [1-4]. Although several models have been suggested to explain the formation and evolution of these features [3, 5, 6], no experimental models have been constructed specificially for paterae on Io. We are attempting to understand the formation of paterae on Io using experimental models and comparing the results to the geomorphology of Tupan Patera.

Geomorphological Map: We are constructing a geomorphological map in ArcGIS of Tupan Patera (Figure 1). We utilize ArcGIS because of its strong spatial analysis capabilities, and because other geologic mapping of Io has been done in Arc. The mapping approach is similar to that employed by Williams et al. [7,8,9]. Because Tupan Patera covers a much smaller area we have been able to map and analyze small features in more detail - in particular, of patera floor units and structures.

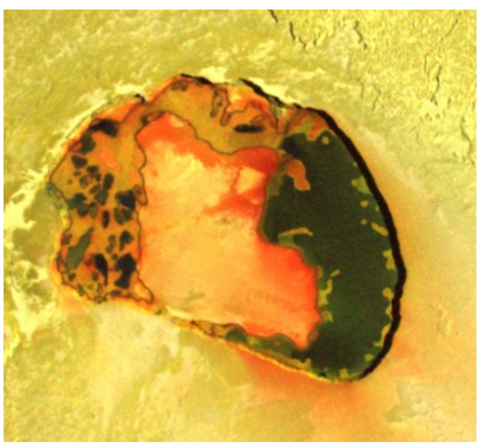

Figure 1 - *Tupan patera is 80 km in diameter as seen in this full-color, 150 m resolution image illuminated from the southwest. Dark materials are interpreted to be recent, mafic lava flows or the surface of a lava lake, the bright "island" is cool and elevated. Tongues of orange material can be seen atop the solidified lava lake and are interpreted to be sulfurous flows that may have emerged from the walls as sulfur melted. Red materials are short-lived S_2 deposits indicating recent activity. Galileo image obtained October 2001.*

Tupan Patera was selected because it is large, recently active, and its qualitites are representative of the range of patera morphologies.The wall of the depression at Tupan is composed of arcuate and straight segments; this is characteristic of several paterae. Also, there is a central "island" that is bright and contrasts with the surrounding patera floor. This feature is seen in other paterae. Tupan Patera also has several unique features, including a complex mottled area on the floor of the depression that may be informative in regard to patera formation.

Preliminary Geomorphological Map: Our current draft of the geomorphological map of Tupan Patera (Figure 2) includes eleven different units: bright flow [maroon], bright patera floor [orange], dark patera floor [blue], green patera floor [green], red patera floor [purple], patera "island" [yellow], patera scarp [black], mottled plains [grey], plains [pink], thick red diffuse deposits [red], and thin red diffuse deposits [salmon] (Figure 2). We are currently working on mapping the distribution of lineaments, ridges, grooves, scarps, depressions, and any other structural features.

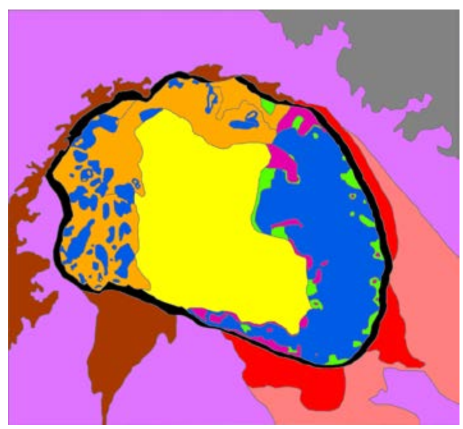

Figure 2 – *Geomorphic map of Tupan Patera. This map includes eleven different units, some unique to Tupan, which were delineated using the mapping methods of [7,8,9] The color key is in the text.*

The straight segments of the bounding scarp may indicate either ongoing tectonism and the development of faults oriented by the principal stresses, preexisting fractures in the crust, or the failure of a brittle crust during patera collapse.The central "island" is thought to be a relatively cooler region composed of material that did not collapse and is elevated above the hotter floor materials. The mottled plains are thought to be intermingled older crust covered by sulfurous volatiles.

Overall, most of the features are consistent with the development of the patera by collapse associated with the rise of hot mafic magma through a volatile-rich crust as outlined by Keszthelyi [12] and Radebaugh [5]. No eruptive emptying of a magma chamber is necessary.

Experimental Model: To test these ideas for patera formation and evolution, we have constructed an experimental apparatus similar to analog models for caldera formation utilized over the past several decades [10, 11]. We are attempting to account for the unique circumstances related to Io paterae volcanism such as: a crust composed of dense, high melting-temperature silicates interlayered with less-dense, mafic pyroclastic layers, and volatile frosts [12], an association with hot mafic or ultramafic magma, the absence of obvious outflow deposits that would have accompanied eruptive emptying of a magma chamber and collapse, the appearance of volatile frosts on the rim and floor, and the strong role of tectonism in patera formation [2].

Our apparatus is a metal box approximately 0.5 meters on its edge placed on an electric hot plate, with inlets for use of a bladder to simulate a magma chamber or for drainage of the melt produced. One side of the box is a movable paddle that can be used to simulate tectonic compression or extension. Our experiments utilize methods similar to [8] in terms of monitoring and attempting to create a scaled analog. We monitor each experiment with a thermal infrared camera and also acquire images at specific stages in the experiment with a digital camera. We are also experimenting with using a 3D laser scanner to map the topography of each experiment.

Our initial experiments are intended to examine the features produced by the “melt through” model of Keszthelyi [12]. Therefore, we constructed a stratified “crust” analog with a 5 cm layer of wet sand on the bottom, overlain by a layer of dry sand, followed by 0.5 cm thick layer of dry ice, a 2.5cm layer of dry sand, a 0.5 cm layer of crushed ice, and finally 1 cm thick layer of dry sand. This complex interlayering is meant to simulate the layers of dense, strong, silicates (sand) and weak, less dense, volatile ices thought to form Io’s crust. The dry ice is used to simulate a volatile that vaporizes when heated and water ice to simulate those that form liquids when heated. The layer thicknesses were chosen in order to help emphasize any potential depressions caused by the evacuation of the dry ice. The hot plate simulates a hot subsurface magma chamber.

Experimental Results: We have performed several runs with our experimental apparatus; each has yielded interesting results. During the heating runs, the first things to appear are multiple vents releasing steam, and probably invisible carbon dioxide gas, as the subterranean volatiles vaporize during heating. Gas venting is followed by development of a thin frost of water ice as steam is cooled by the dry ice in the crust. Eventually, a multitude of oblong depressions form, approximately 0.5 cm deep and 2-3 cm across. These reflect the loss of volatiles in the subsurface which allows overlying layers of sand to collapse. The depressions are about the same depth as the thickness of the layer of sublimating dry ice. This results in a frosty depression at the surface dotted by frost-free pockets where the hot steam is venting. Short linear fractures form along the margins of the small depressions during volatile escape. Finally, the frost is eliminated as hot volatiles continue to rise through the permeable crust,

Discussion:. Thus far, both the geomorphic mapping and the simple analog experiments are consistent with the development of paterae by collapse, following removal of volatiles from the crust overlying a hot magma chamber. Future experiments will use varying proportions of sand and volatiles, varying thicknesses of the volatile layers, as well as experiments using the paddle to simulate the tectonic influence.

Summary: We have constructed a geomorphic map of the Tupan Patera region on Io to better understand its geology and sequential develoment. The interpretation of the map is guided by experimental analogs .

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