RELATIONSHIPS BETWEEN PATERAE, MOUNTAINS, AND HOTSPOTS ON IO FROM A GLOBAL DATABASE. J. Radebaugh[1], W. L. Jaeger[1], L. P. Keszthelyi[2], E. P. Turtle[1], M. P. Milazzo[1], J. Perry[1], A. S. McEwen[1], R. Lopes[3], A. G. Davies[3], and P. Geissler[2], [1]Lunar and Planetary Laboratory, University of Arizona, Tucson AZ 85721 (jani@LPL.arizona.edu), [2]United States Geological Survey, Astrogeology Team, Flagstaff, AZ., [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109

Introduction: Now that the Galileo spacecraft's tour of the Jupiter system is over, we seek to integrate all available datasets in the hopes of understanding Io as completely as possible. We have compiled information about the morphologies and locations of paterae (volcano-tectonic depressions), mountains, and hotspots on Io in a single database. It is our hope that an analysis of the spatial and temporal relationships between these features will provide more indications of the nature of the crust of Io and the mechanisms leading to these features' formation. Since Io's tidal heat escapes through its crust, more knowledge about the crust will lead to an understanding of internal processes, such as magma generation and delivery to the surface, and magnitude and orientation of internal stresses.

Io Database: We have compiled data on the distributions, and where appropriate, morphologies, sizes, date of activity, and other attributes for over 400 paterae, 150 mountains and 160 hotspots on Io's surface. Relational tables were created for each feature, so that we can determine if a given hotspot is the result of an eruption within a patera, or if and how the paterae and mountains are linked. The area of Io's surface analyzed was limited by image resolution; for example, the paterae were measured from Galileo and Voyager spacecraft images with resolutions better than 2 km/pixel, covering about 70% of Io's surface. The area analyzed for mountains was slightly better, perhaps 80-85%, since some mountains could be measured on the terminator in lower resolution images. The same is true for hotspots since the most important criterion was positive identification and was not as dependent on resolution. However, higher spatial resolution data leads to an increase in hotspot detections.

Analysis has already been performed on many of the individual aspects of the features, and continues in other work. See, for example, analyses of the sizes, distributions, and morphologies of the paterae [1] and of the mountains [2], and a look at the patterns in hotspot distribution and activity [3-5, Lopes et al., this volume]. In the current study we focus more specifically on the interrelationships between all of the features, in addition to refining the details of each subset.

Paterae adjacent to mountains: A previous study by Jaeger et al. [2] showed that 41% of the mountains on Io have one or more paterae adjacent to them. This is in contrast to the 12% of paterae that have mountains adjacent to them [1], and therefore indicates that there may be a genetic link between mountains and paterae. A plot of the distribution of all mountains and all paterae that are adjacent to mountains on Io's surface (Fig. 1) reveals some interesting aspects of their relationship.

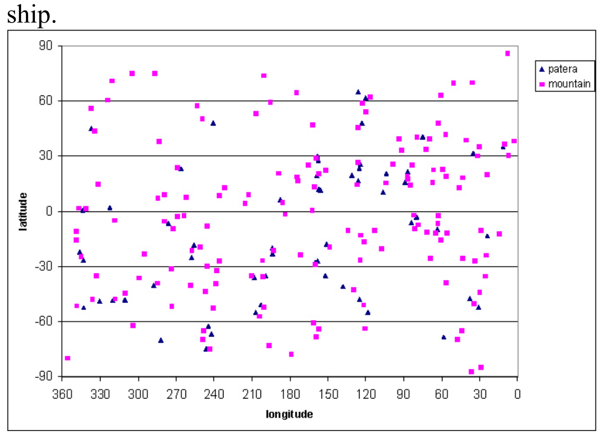

Figure 1. Plot of distribution of all mountains (pink squares) and paterae adjacent to mountains (blue triangles). Some lineations and clusters can be seen in the paterae.

First, many mountains (15) have not only one, but two or even three paterae next to them, as can be seen in Fig. 1. Most of these paterae are arranged at opposite ends of the mountains, and may represent fractures due to mountain formation that magma has exploited, leading eventually to patera formation. Second, some of the paterae that are adjacent to mountains appear to form patterns, such as broad lineations that cover several tens of degrees of latitude. It is necessary to do detailed analyses to see if these patterns are statistically significant. If these patterns are real, then the paterae may be the surface expressions of large scale tectonic features related to mountain formation. It is typically challenging to see global or even regional tectonic features on Io, since cold regions are buried by SO_2 frost and plume deposits quickly [6].

Hotspot locations and activity: The database enables us to keep track of the many observations of hotspot activity, and their locations within paterae or lava flow fields. It also helps us determine which hotspots are long-lived or persistent, in contrast to those that erupt briefly and fade away. Since Voyager, just over 160 separate hotspots have been observed on Io's surface [3-5], many of which have been seen to be active by Galileo, Voyager, Cassini, and groundbased observations. At least 45 hotspots have been observed to be active more than four times. Hotspots that are highly persistent, with 15-30 observations of activity, are found both inside paterae (Loki and Pele), indicating a likely lava lake or ponded lava-syle eruption [7-10,3], and outside paterae (Pillan, Marduk, and Prometheus), revealing exposed lava in large flow fields [7]. Complementary work on the distribution of hot spots is presented in this volume by Lopes et al.

Irregular patera margins: In determining the mechanism of formation of ionian paterae, we consider the highly irregular nature of the margins of many of the features. This aspect of ionian paterae sets them apart from calderas elsewhere in the solar system, and almost certainly indicates a strong tectonic control on their formation, in addition to unique crustal properties [1]. Although nearly every feature is in some way unique, it is useful to quantify the irregularity of patera margins in order to compare them with solar system caldera margins. One way to do this is to take the ratio of the perimeter of the feature to the perimeter of a circle having the same area as the feature. This is essentially a measure of the "deviation from circularity". Numbers greater than one can indicate both an elongate feature as well as a feature with sharp and angular departures from curvature. Of 169 paterae for which this measurement was made, 38, or 22% of them had ratio values greater than 1.3. Fig. 2 shows two features with this ratio value of approximately 1.3. It is an example of the value of this measurement, in that it shows that the feature is not round, and the drawback, in that it does not discriminate in what way it is not round.

Figure 2. Both features have a "deviation from circularity" of close to 1.3. Feature on left has a long axis of 40 km, on right has long axis of 112 km. Both from Galileo.

Preliminary comparisons with calderas on Earth, in the New Mexico Mogollon-Datil volcanic field [11], reveal that of ten ash flow calderas measured, only two have a "deviation from circularity" value of greater than 1.17. One of these is almost certainly a result of overlap of multiple calderas, so it should be measured separately. It is not obvious in the cases of ionian paterae whether some irregular shapes are the result of compound collapses, because the floors and possibly old margins become covered by lava flows [1]. The margins themselves in most cases do not look the same as compound caldera margins elsewhere in the solar system, so the formation process that leads to these unusual shapes is still a mystery.

Further work: We are continuing to search the database for connections between the paterae, mountains, and hotspots on Io in order to address some global issues. For example, we can run a distribution analysis on materials (dark and light flows and diffuse materials) that are associated with paterae and hotspots, and then link this information to hotspot activity. We can ask questions such as how many paterae with persistent hotspots are adjacent to mountains? Do these mountains look young in our current understanding of their age progression? If so, this correlation would strengthen the connection between volcanism and mountain building processes. Is there a pattern in the size of paterae that are adjacent to mountains, or, that exhibit hotspots? What does this say about the ages and sizes of paterae? Are paterae adjacent to mountains typically more irregular? Answering these questions will help us develop and test hypotheses for the formation and evolution of the major features on the surface of Io.

References:

[1] Radebaugh J. et al. (2001) *JGR, 106,* 33,005-33,020. [2] Jaeger W. L. et al. (2003) *JGR, 108,* doi:10.1029/2002JE001946. [3] Lopes, R., et al. (2004), *Icarus*, in press. [4] Rathbun, J., et al. (2004), *Icarus*, in press. [5] Lopes-Gautier, R. et al. (1999), *Icarus, 140,* 243-264. [6] Geissler P. et al. (1999) *Icarus, 140,* 265-282. [7] Davies A. G. et al. (2001) *JGR, 106,* 33,079-33,104. [8] Davies, A. G. (2003) *GRL, 30,* 2133-2136. [9] Rathbun, J. A., et al. (2002) *GRL, 29,* 84-88. [10] Radebaugh J. et al. (2004), *Icarus*, in press. [11] McIntosh W. C. et al. (1991) *N. M. Bur. Mines Min. Res. Bull., 135,* 79 pp.