VOLCANIC ACTIVITY AT TVASHTAR CATENA, IO. M.P. Milazzo[1], L.P. Keszthelyi[2], J. Radebaugh[1], A.G. Davies[3], A.S. McEwen[1], [1]Planetary Image Research Laboratory, LPL, University of Arizona, Tucson, AZ. (mmilazzo@pirlmail.lpl.arizona.edu), [2]United States Geological Survey, Astrogeology Team, Flagstaff, AZ., [3]Jet Propulsion Laboratory-California Institute of Technology, Pasadena, CA.

Introduction: Tvashtar Catena (63 N, 120 W) is one of the most interesting features on Io. This chain of large paterae (caldera-like depressions) has exhibited highly variable volcanic activity in a series of observations. Tvashtar is the type example of a style of volcanism seen only at high latitudes, with short-lived Pele-type plumes and short-lived by intense thermal events.

Evidence for a hot spot at Tvashtar was first detected in an eclipse observation in April 1997 (orbit G7) by the Solid State Imager (SSI) on the Galileo Spacecraft [1]. Tvashtar was originally targeted for observation at higher resolution in the close flyby in November 1999 (I25) because of its interesting large-scale topography. There are relatively few but generally larger paterae at high latitudes on Io [2]. I25 images revealed a 25 km long, 1-2 km high lava curtain via a pattern of saturation and bleeding in the CCD image, which requires very high temperatures [3]

Three months later, in February of 2000 (I27), Galileo returned to observe Tvashtar in multiple wavelengths. The lava curtain from I25 had shut down, but 50 km to the west there was a ~500 km^2 area hot enough to glow in the daytime observations, again saturating many of the pixels. The activity was, again, so intense that it saturated many of the detector's pixels. To the north of this new active area were two small incandescent spots that were intense enough to saturate the detector in the clear and 756 nm bandpass filters.

In December of 2000 (G29), Galileo had the opportunity to perform joint observations with the Cassini spacecraft as it flew by the Jovian system on its way to Saturn. No thermal emission was detected in the low-resolution images, but, surprisingly, an ~900 km diameter red plume deposit was observed by SSI [4], and Cassini observations showed a 385 ± 30 km high Pele-like plume centered at Tvashtar Catena [5].

Finally, in October, 2001 (I32), Galileo took its last look at the Tvashtar region. From the observation, which consisted of two frames in just the clear filter, it appears as though Tvashtar had quieted down. Comparison with the I25 images indicates that there were no obvious changes to the lateral extent of the pre-I27 dark area. This argues strongly for topographic confinement of the I27 active lavas. We discuss each of these observations of Tvashtar in detail below.

Orbit I25: Tvashtar's activity was first observed by Galileo's Solid State Imager (SSI) on orbit I25 using the clear filter. The eruption turned out most likely to be a 25-km-long fissure eruption with a 1-2 km high curtain of lava [6]. The brightness temperature is ~1150K (assuming emissivity=1). Of course, the brightness temperature is almost certainly an underestimate of the actual lava temperature which is expected to be a few hundred Kelvins hotter. Using a lava cooling model developed by Keszthelyi and McEwen [7], we estimate that the lava in the fire fountain, during its ~31 second flight time (for a 1 km height), cooled from an initial temperature of ~1500 K to produce the pixel-integrated brightness temperature of 1150 K. However, there are many, poorly constrained, sources of error in this estimate.

Orbit I27: On orbit I27, a very different style of eruption was observed, with a large, ~500 km^2 region of active lava west of the I25 lava curtain with two small incandescent points approximately 50 km north of the main activity.

The active region in I27 was low in albedo in the I25 observation. Low albedo regions have invariably been associated with enhanced thermal emission [8] that either drives off sulfur and sulfur dioxide frosts or prevents these frosts from forming. The low albedo observed during I25 in the region of Tvashtar that was active during I27 suggests that the surface was still cooling from the result of an older eruption. It is also possible that new surface activity was taking place, albeit on a smaller scale than the lava curtain to the east.

There appears to be a strong topographic confinement of the I27 eruption, because the active areas did not extend beyond the boundaries of the dark material seen in the I25 observation.

The I27 incandescent points: The most puzzling aspect of the I27 eruption is the existence of two small hot spots about 50 km north and north west of the large active region. These small, northern spots are, because of their detection in the clear and 756-nm filters (and the non-detection of the large southern region in the clear and 756-nm filters), much hotter or more vigorously erupting than the southern 500 km^2 active region. The minimum temperature derived from these data is between 1300 and 1450 K based on a pixel-integrated brightness temperature estimated using the minimum flux of electrons required to saturate the

756-nm filter (giving ~1300 K) and the flux of electrons detected in the clear filter (giving ~1450 K).

The I27 "glowing patera floor": The glow from the 500 km^2 active region was seen through the 968-nm and 889-nm filters [fig. 1] during the I27 observation. Most of the pixels in these images were saturated (none are obviously bleeding), but there were a fair number of pixels useful in deriving color temperatures. The color temperatures and the measured thermal emission in the two infrared filters were used to compute the area needed to match the observations. The total power output for the eruption was calculated using the areas of hot material calculated for each pixel. Saturated pixels were included by assuming that the pixels were just barely saturated (providing a lower limit on power output). The total power output from the I27 large eruption is 8.3×10^{10}-2.4×10^{11} W (with the low value including only valid, unsaturated pixels in the calculation). The temperature distribution of the I27 active region has an average of 1347 K with a standard deviation of 390 K. The highest believable temperature will be reported once error analysis is completed. A map of the surface age distribution of the lavas based on a cooling model [7], which will provide better understanding of the eruption style, will also be presented.

Orbit I32: The SSI I32 observation[fig.2] showed no incandescent activity in the Tvashtar region. The camera settings were the same as in the I25 observations and the clear filter of the I27 observation, so any comparable activity should have been detected. Clear filter comparisons show that no detectable change of the extent or area of in the floor of the western patera requires that these lavas be topographically confined. The maximum height of this topographic confinement cannot significantly exceed more than 50-100 m or it would be visible in the 300 m/pixel images. Such topographic confinement is easily explained if Tvashtar is a patera with an active lava lake confined within a secondary depression. However, it is possible that the activity is a result of lava flows being erupted into the depression, rather than the overturning of an active lava lake.

Lava Emplacement: One possible interpretation of the emplacement of lava seen in I27 is that lava is flowing through tubes either from north to south or from south to north. There is no obvious north-south trending slope, though it could be shallow enough not to be detectable in our medium spatial resolution images and still steep enough to allow the lava to travel 50 km with little loss of heat.

Another interpretation of the activity is that this is an episodically active lava lake. The separation of active regions in the I27 images is consistent with, though not diagnostic of, a currently overturning lava lake. The northern spots may be small, active fountains near the edge of the lake, while the large southern region may be an over-turning lid or a sheet flow onto the surface. Multiple small active fountains in the north and a larger, less violent eruption to the south are consistent with the northern spots' increased power per unit area relative to the large southern region.

A third interpretation is that the I27 activity is due to flows on the floor of the patera. These should flow across the floor of the patera and possibly cover the entire floor. If enough material was erupted, it would produce topographically confined flows, resulting in a stagnant lava pond.

References: [1] McEwen, A.S. et al. (1998) *Icarus,* 135, 181-219. [2] Radebaugh, J. et al. (2001) *JGR,* 106, 33,005–33,020. [3] McEwen, A.S. et al. (2000) *Science*, 288, 1193-1198 [4] McEwen et al. (2003) in *Jupiter: Planet, Satellites and Magnetosphere*, Cambridge Univ. Press. [5] Porco, C.C. et al. (2003) *Science*, 299, 1541-1547. [6] Keszthelyi, L. et al (2001) *JGR*, 106, 33025-33052. [7] Keszthelyi, L. and McEwen, A.S. (1997) *GRL*, 24, 2463-2466. [8] McEwen, A.S. (1997) *GRL*, 24, 2443-2446.

Figure 1: I27 889-nm filter image of volcanic activity at Tvashtar. The projection in this image is different from that in figure 2. The dark floored patera right of center at the bottom is the dark floored patera in the lower right corner of figure 2.

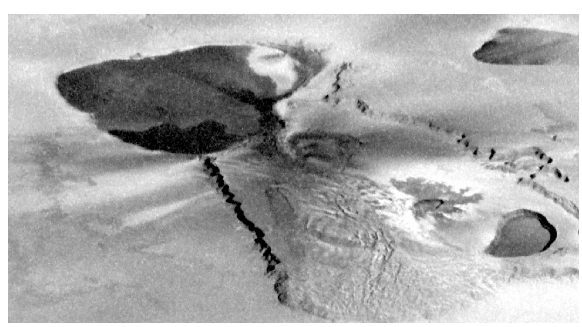

Figure 2: I32 image of Tvashtar Catena. The darkest lavas were active in I27, as seen in Fig. 1