GISH BAR PATERA, IO: GEOLOGY AND VOLCANIC ACTIVITY, 1996-2001. Jason Perry[1], Jani Radebaugh[1], Rosaly Lopes[2], Alfred McEwen[1], Laszlo Keszthelyi[3]. [1]Planetary Image Research Lab., Lunar and Planetary Lab., Univ. Of Arizona, Tucson, AZ 85716; perry@jupiter.lpl.arizona.edu. [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109. [3]U.S. Geological Survey, Flagstaff, AZ 86001

Introduction: Since the two Voyagers passed by Jupiter in 1979, it has been known that volcanic activity is ubiquitous on the surface of Io. With over 400 volcanic centers, Io is even more volcanically active than the earth with massive flood basalt-style eruptions and komatitite lavas a common occurrence. Additionally, some volcanoes appear to be giant lava lakes, with violent activity churning the crust of the lake for periods of 20 years or more. Finally, sulfur is believed to play a large role in Io's volcanism, be it as a primary lava or as a secondary product of large, high-temperature eruptions. By studying one volcano in particular, Gish Bar Patera, one can observe many of these characteristics in one volcanic center.

Geology of Gish Bar Patera: Gish Bar Patera is one of the many large volcanoes on Io. It lies at the base of an eleven-kilometer tall mountain at 15.6° N, 89.1° W. The patera itself is quite large at 106.3 km by 115.0 km with an area of 9600 km^2. The irregular shape of the caldera shows signs of multiple collapses [1]. Recent collapses appear to have eroded the southern portion of the mountain; however, no recent flows can be seen at this portion of the mountain's base.

Galileo SSI imaging from orbit C21 (July 1, 1999) provided our first good look at Gish Bar (Figure 1A). The images reveal two main active areas at Gish Bar. The active region to the northwest has a mottled floor from several eruptions. The smaller subpatera to the southeast is covered in green material with darker material along the edges. The rest of the patera is covered in orange to yellow material, indistinguishable in lower resolution images from the surrounding terrain. A 500-meter tall wall surrounds the entire patera.

According to Williams et al., albedo variations within paterae floors represent various ages of lava [2]. As lavas cool, they accumulate brighter frost. Thus, the surface becomes brighter as the lava ages. This principle can be used to determine the relative ages of lavas seen in the C21 imagery of Gish Bar. In the middle area there are dark lava flows mixed with bright orange flows and green channels/ridges. These perhaps correspond to activity that took place in late 1996 to early 1997 or later. Near the center of the patera are curious orange flows. The albedo of these flows would seem consistent with flows older than its surroundings. However, the flows appear to cover darker, seemingly younger flows. This would mean that these bright flows are younger than the dark flows. Either these flows age at a different rate from it surroundings due to rapid cooling or these flows have a different composition from its underlying material. One candidate composition might be sulfur, suspected in other bright flows on Io.

The western portion is mostly green with a few bright islands (as confirmed in I32 imaging), this perhaps corresponds to an eruption before late 1996, or if the middle section was later, during that period. Filler areas between lava flows in the middle section are the same shade of green suggesting that whatever flow covered the western section covered the rest of the patera at that time with the exception of that far eastern portion. The eastern section is orange, suggestive of even earlier activity, similar in age to Ababinili Patera, west of Camaxtli Patera.

The smaller sub-patera to the southeast is also green, suggesting a similar age to the far western area. Sharp contacts at the edges of the subpatera indicate topographic (perhaps tectonic) control of the subpatera's flows.

Activity at Gish Bar: During the Galileo Nominal Mission, NIMS observed a low to moderate hotspot at Gish Bar during orbits G1 (June 26, 1996), C3 (November 6, 1996), and C10 (September 19, 1997). Gish Bar was also observed during orbit E4 (December 20, 1996) by Galileo SSI while in eclipse using its clear filter. Eclipse images were taken to observe the hottest of Io's hotspots and auroral activity on Io. Assuming that an entire pixel in the hotspot was radiating at the same temperature, a minimum temperature of 825 K with an area of 310 km^2 was obtained [4]. If the hotspot were assumed to be a blackbody at 1000 K, the area would be greater than 5.5 km^2 [5]. The radiance and 1000 K area recorded by SSI from E4 are similar to or even greater than Kanehekili from the same observation. Kanehekili has been shown to be a site of ultramafic volcanism making it seem likely that the lavas at Gish Bar from E4 were ultramafic but without multiple filters to better constrain temperature, this cannot be confirmed.

Outburst in August 1999. On August 2, 1999, during an observation campaign by Howell et al. coinciding with the Io flybys by Galileo later that year, a very bright outburst eruption was observed on the leading hemisphere of Io [6]. Howell et al. reports that the eruption was relatively short-lived, even for outbursts and that the eruption was one of the brightest observed from earth in fourteen years. One temperature fits for 2.28 um and 3.39 μm indicate a temperature of 1247 K and an area of 200 km^2 [6]. The initial location reported for the outburst was 14° N, 74° W, well east of Gish Bar. However, according to Keszthelyi et al. (2001), the outburst is attributed to Gish Bar [7].

Aftermath of the outburst. Galileo flew by Io three times in late 1999 and early 2000. During the first pass, I24 (October 11, 1999), Galileo observed a large area at 500 m/pixel which included Amirani, Skythia Mons, Monan Patera, and Gish Bar Patera (Figure 1B). However, the images were garbled and the fix reduced the effective resolution [7]. Much of patera remained unchanged in appearance between July and October 1999. However, the southeastern sub-patera was considerably darker in I24 imagery than in C21.

Gish Bar was observed in a strip by NIMS during orbit I25 (November 25, 1999) at 6.6 km/pixel. Two areas of thermal emission were observed at Gish Bar [8].

Mid- to late-2001. Galileo returned to Io three more times in late 2001 and early 2002, and again Gish Bar was a target for observation. Gish Bar was viewed at 4.5 km/pixel by NIMS on orbit I31 (August 6, 2001) [9]. This observation shows several areas of low to moderate activity within the main patera. A large area of moderate activity is seen in the smaller section to the southeast. Most of that activity is seen in the northern part of the subpatera. Like the new lava flows in I24, the warm area appears to cover the entire subpatera. The NIMS also indicates decreased activity in the main portion of the patera compared to NIMS data from I25. This repeated and complete covering by lava with activity confined to the margins during inactive periods is similar to other lava lakes on Io.

In the next orbit, I32 (October 14, 2001), Gish Bar was viewed at 250 m/pixel by SSI (Figure 1C). A new 30 km long lava flow was observed in the northwestern portion of the patera shading seems to indicate that the eruption began in the central area of the patera. This area corresponds to a moderately bright area in the I31 NIMS data. Several branches of the lava flow seem to be following topographic constraints. In addition, the subpatera remained dark, in line with I31 NIMS data. Total amount of new flow in the I32 SSI image is around 1500 km^2.

A NIMS global observation at 15.36 km/pixel on orbit I32 showed increased activity at Gish Bar, indicating that the eruption that produced the western lava flows is on going. The eruption continued until at least December 2001, as shown in data from the AO-system at Keck by Marchis et al. [10].

Conclusions: Galileo SSI and NIMS data show that Gish Bar Patera has punctuated, vigorous eruptions followed by longer periods of low to moderate activity. Eruptions appear to be caused by a large lava lake in the western portion of the patera. The eruption observed by Galileo in October may represent a particularly vigorous eruption during which the lava lake overflowed onto the surrounding patera floor. Some evidence for sulfur volcanism can also be seen at Gish Bar, represented by a 15-km long, bright flow in the center of the patera. Finally, Gish Bar has a secondary caldera consisting of a large lava lake that may have produced an outburst eruption in August 1999. This high-level activity at Gish Bar along with other lava lakes near mountains like Pele and Radigast Patera may imply large reservoirs of lava near mountains

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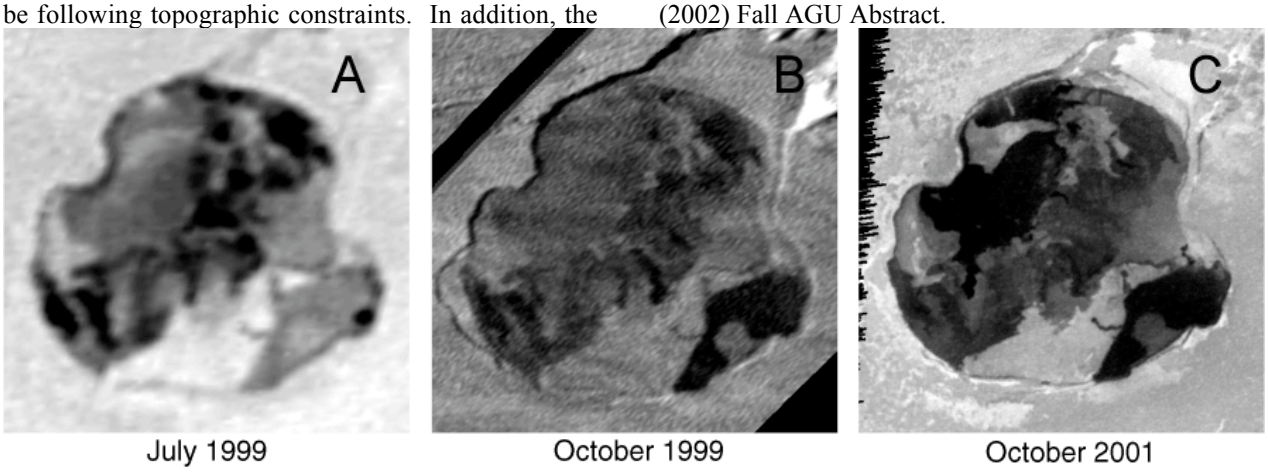

Figure 1: Gish Bar as seen by Galileo SSI: A, C21 (July 1999); B, I24 (October 1999); C, I32 (October 2001)