GEOLOGIC MAPPING OF THE ZAL, HI'IAKA, AND SHAMSHU REGIONS OF IO. M. K. Bunte, D. A. Williams, and R. Greeley. School of Earth and Space Exploration, Arizona State University, Box 871404, Tempe, Arizona 85287, (Melissa.Bunte@asu.edu).

Introduction: We have produced regional geologic maps of the Zal, Hi'iaka, and Shamshu regions of Io's antijovian hemisphere based on *Galileo* mission data. Here we discuss the geologic features, summarize the map units and structures that are present, discuss the nature of volcanic activity, and give an analysis of the volcanic, tectonic, and gradational processes that affect the regions in order to better understand Io's geologic evolution.

Zal Region: The Zal region (25-45˚N, 65-85˚W) consists of Zal Patera (120 km wide x 197 km long), two major mountains (north and south Zal Montes) which border Zal Patera to the west and south [1], and an unnamed patera ("Patera A") west of south Zal Montes. The Zal region includes at least two hotspots detected by *Galileo*: one along the western scarp of the Zal Patera volcano and one at the "Patera A" volcano. The floor of Zal Patera has been partly resurfaced by dark lava flows since *Voyager* imaging; portions of the patera floor appear unchanged during the *Galileo* mission. Mountains exhibit stages of degradation. The western bounding scarp of Zal Patera appears to be a fissure source vent for multiple silicate lava flows. The Zal Montes and Patera complex appears to be an example of volcano-tectonic interactions [1, 2]. Several of the flow units emanate from the fissure at the western scarp [2].

Hi'iaka Region: The Hi'iaka region (~12˚S-5˚N, 75-87˚W) consists of Hi'iaka Patera, a large (60 km wide x 95 km long) patera, north and south Hi'iaka Montes which border Hi'iaka Patera to the west and south and are L-shaped mirror-images of each other, west Hi'iaka Montes, a small isolated peak, and an unnamed patera ("Patera B") located south of north Hi'iaka Montes. The region includes one hotspot at Hi'iaka Patera. The floor of the patera exhibits flow deposits of differing ages. The eastern scarp of Hi'iaka Patera may be a fissure source vent for the patera floor materials. The Hi'iaka Montes and Patera complex appears to be an example of volcano-tectonic interactions [1, 2].

Shamshu Region: The Shamshu region (~15˚S-5˚S, 55-77˚W) consists of Shamshu Patera, three mountain units (west, north, and south Shamshu Mons), and a small unnamed patera ("Patera C") southwest of Shamshu Mons.

Map Units: Material units and structural features in regions are consistent with SSI-and *Voyager*-based maps of other regions [3, 4, 5, 6, 7, 8]. We have identified 19 units derived from five types of materials: plains, mountains, patera floors, flows, and diffuse deposits. *Plains* are thought to consist of silicate crust mantled by dark silicate and bright sulfurous explosive and effusive deposits [9, 10]. The plains are formed by combinations of over-lapping effusive flows, mass wasting of flow materials, SO_2 sapping scarps and pits, deposits from volcanic plumes containing SO_2 and sulfur frosts, and pyroclastic flows [11, 12, 13]. Based on color, we subdivide the plains into yellow (sulfur-dominated), white (SO_2-dominated), and red-brown (radiation-altered) subunits. *Mountain* materials are often visible only in low-sun images where shadows highlight scarps, ridges, grooves, and mountain peaks [2, 13, 14]. We characterize three types of mountain materials: lineated (containing well-defined ridges and grooves, interpreted to be tectonically-uplifted crustal blocks), mottled (containing lobes and hills, interpreted to be materials displaced by mass movement that is likely the result of SO_2 sapping [2, 12]), and undivided (mountain material that is characterized by aspects of both the mottled and lineated units, but is dominated by neither). Plateaus can exhibit characteristics of any type of mountain materials. *Patera floor materials* are compositionally similar to flow materials but are emplaced within the bounding scarps of paterae. We characterize two subunits: bright and dark (sulfuric and silicate lavas coated by sulfurous deposits; e.g., [3, 4, 15]). *Flow* materials are typified by their generally linear morphology (lengths >> widths) and sharp contacts [3, 4, 5, 6]. Like patera floors, lava flow materials are characterized using morphology, color and albedo as undivided, bright (sulfur-dominated), or dark (silicate-dominated and associated with active hotspots [15, 16, 17]). Albedo variations in the dark flows are thought to indicate surface exposure: the freshest flows are generally darkest. Color tint of flows is due to mantling by diffuse material. Flows with intermediate albedos and ill-defined contacts make up undivided flow materials. *Diffuse deposits* thinly mantle underlying topography and typically occur near active volcanoes. Colors are interpreted to be indicative of the dominant chemical constituent: sulfur, sulfur dioxide, silicate, either short-chain sulfur and/or sulfur chlorides, and products of silicate-sulfur alteration, respectively [18, 19]. Dark, white, bright, and red diffuse deposits are present.

Structural Features: These regions contain a variety of structural features, including scarps, ridges, grooves, pits, graben, and lineaments. Scarps delineate both mountains and plains. Most grooves, lineaments, and ridges are found in the mountain units. The plains contain several scarps and depressions indicative of tectonic activity. None of these features are found within the flow fields. No positive relief volcanic constructs such as domes, cones, or shields are resolvable; however, flow morphologies suggest the presence of a shield in the Zal region. As in all previous Io images, no impact craters were detected, supporting the contention that the surface of Io is perhaps only a few million to a few tens of millions of years old [20].

Discussion: Our mapping provides insight into the geologic processes that are active in these regions of Io. Each region exhibits various forms of volcanic activity, including hotspots, Promethean style flows, fissure vents, and pyroclastic and diffuse deposits. Both silicate and sulfur-rich lava flows are present; individual flows appear to be of different ages, i.e., in different stages of alteration inferred from their differing albedo and color. The paterae appear to be active compound flow fields but not flooding lava lakes. The detection of a plume by LORRI on *New Horizons* [21, 22] confirms that Zal is currently active, producing small-scale Pele-type plumes.

Strike-slip faulting and subsequent rifting likely separated the mountain units, opening vents for lava flow and creating pull-apart basins that became the paterae. The formation of the paterae may be related to the locations of the mountain units in that the crust at the location of the paterae is more susceptible to foundering due to the weakness near the scarps. We show possible reconstructions of the original mountain configurations and possible sequences for the progression of events that formed the current complex appearances.

The mountain units appear to be tectonically related by rifting, although they each exhibit different degradation features suggestive of SO_2 sapping and mass wasting. Morphologies and cross-cutting relationships of several flows suggest that mountain structures were uplifted and modified. We speculate that degradational effects are progressive and that the level of degradation of each of the mountain and plateau units is influenced greatly by the proximity to active vents [12]. Lineated mountain material is the least degraded of the mountain units. Degradation causes the destruction of the lineated texture; perhaps this destruction is aided by mantling deposits infilling the grooves. Further degradation by mass wasting or by SO_2 sapping creates depressions, debris aprons, or lobes [12]. Mottled materials are still more degraded and may degrade into layered plains.

The bounding scarps of Zal, Hi'iaka, and Shamshu Paterae are aligned with the scarps of their mountain counterparts. A similar alignment between "Patera B" and Hi'iaka Montes also exists. These alignments suggest a tectonic control for the formation of the paterae. Multiple episodes of deposition likely occurred to cover the patera floors.

A trend in the progression of volcanic activity has become apparent due to the mapping results. Areal extent of flows is measurable and can be used to infer volume and viscosity of material. The oldest flows (plains), as indicated by superposition, cover large areas. The youngest flows (dark flows) cover smaller areas. Large areal extent indicates high volume and/or low viscosity whereas small areal extent indicates low volume and/or high viscosity. This difference in areal extent indicates that, as time passed, flows may have progressed from high to low volume and from low to high viscosity. A reduction in areal extent may also indicate a decrease in volume flow rate. As indicated by areal extent, the volume decrease between patera floor and flow materials may be directly related to the tectonic activity of the region. As the faulting and rifting process began, high volumes of material were erupted from the fissure vent that was created. As the rifting process continued, lower volumes of lavas were erupted from the fissure.

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