GLOBAL GEOLOGIC MAPPING OF IO: FIRST STEPS. David A. Williams, Department of Geological Sciences, Arizona State University, Box 871404, Tempe, Arizona, 85287 (David.Williams@asu.edu); Laszlo Keszthelyi, Paul Geissler, Windy Jaeger, and Tammy Becker, Astrogeology Team, U.S. Geological Survey, Flagstaff, Arizona; David Crown, Planetary Science Institute, Tucson, Arizona.

Introduction: The objective of this work is to discuss mapping methodology for producing a new global geologic map of Io using the new global Io mosaics. These mosaics, produced by the USGS at a nominal resolution of 1 km/pixel, combine the best images from the *Galileo* and *Voyager* missions. To develop a mapping methodology we have studied the preliminary mosaics, all previous *Voyager*- and *Galileo*-based geologic maps of Io, and new maps of the Amirani-Gish Bar region that we recently produced from a ~500 m/pxl regional mosaic. In this abstract we present an overview of the classes of geologic material units and structures that can be identified from existing images, and we discuss our conclusions about the best mapping approach to produce a new global map of Io.

Background: Io, the innermost Galilean satellite of Jupiter, is the most volcanically active body in the Solar System. Tidal heating within Io produces magma that feeds ~300 active volcanic centers [1-3]. The 1979 *Voyager* flybys observed ~25% of the moon at resolutions of <2 km/pixel (the rest at 2-20 km/pixel: [4]), covering mostly the subjovian hemisphere. The recently completed *Galileo* mission (1996-2003) included five close flybys of Io, focused mostly on the antijovian hemisphere [5-7], with resolutions between ~10 m/pixel to 20 km/pixel. This complementary coverage of Io has enabled the production of a series of high quality grayscale (high-sun and low-sun) and color global mosaics (1 km/pixel nominal resolution). These recently-completed mosaics, produced by the USGS, are now the definitive global compilation of image products for Io.

Our goal is to complement the new mosaics with a corresponding global compilation of geologic understanding at the end of the *Galileo* era. Geologic mapping is a tool that enables the definition and characterization of surface features into process-related material units and structures and places them within their stratigraphic context, allowing recognition of the geologic evolution of an area, region, or planet (depending upon the scale of the mapping). Before global mapping begins on the new Io mosaics, it is prudent to identify the optimal mapping methodology. Such an activity was done prior to global mapping of Europa [8].

Overview of Ionian Materials & Structures: Io displays five primary types of material units: plains, patera floors, flows, mountains, and diffuse deposits. Plains cover >70% of Io's surface [9], and appear as yellow (S-dominated), gray-white (SO_2-dominated), and red to red-brown (radiation-altered, short-chain sulfur-dominated) color units in *Galileo* images. Plains are thought to consist of the silicate crust of Io, mantled by dark silicate and bright sulfurous volcanic deposits [10-11]. Eroded plateaus, or layered plains, have also been detected in low-sun images and are mappable at global scales.

Patera floors have a range of albedos and colors, and these materials sometimes extend outside these volcano-tectonic depressions. Patera floors range from bright white to yellow-orange to dark black in *Galileo* images, in which the colors suggest various compositions, including mixes of silicates, sulfurous compounds, and relatively pure sulfur dioxide in some cases [3, 11]. Three broad subunits of patera floor materials are characterized for mapping: Bright (presumably sulfur-dominated), Dark (presumably silicate-dominated), and Undivided.

Lava flow units are also characterized by their albedo and color: Bright flows (sulfur-dominated), Dark flows (silicate-dominated), and Undivided Flows (units with intermediate albedos and colors). Two subunits are used for both bright and dark flows based on their inferred "freshness"; i.e., the youngest bright flows are very bright (high albedo), the youngest dark flows are very dark (low albedo). Flow materials are typified by their sharp contacts with the other units and generally elongated morphology (lengths >> widths: [10-12]). Correlation between *Galileo* Near Infrared Mapping Spectrometer and Solid State Imager data also shows that the darkest flow materials are associated with active hot spots [3, 13]. Lithologically, patera floor materials and lava flow units are probably identical. However, their distinctive geologic settings justifies separating them in the global map.

We recognize three types of mountain materials in regional images: Lineated, Mottled [12], and Undivided [13], although for the global mapping we map only massifs and layered plains. Lineated materials are associated with topographically-distinct ridges, grooves, graben, scarps, and lineaments on positive-relief edifices. This unit is interpreted as tectonically-disrupted sections of crust containing planar structural features, possibly faults involved in uplift and/or collapse during mountain formation. Mottled materials contain lobes or domical mounds that are lacking in lineations. This unit is interpreted as sections of mountains that show evidence of mass wasting processes, most likely involving flow with or without rotational sliding [2, 12, 16]. Mountain material whose morphology does not fall within either of these two units is classified as Undivided. Volcanic mountains on Io are rare; the few edifices that have been found are mapped as Tholus materials.

Diffuse deposits are diverse on Io's surface, which was recognized because of the higher resolution color imaging of the *Galileo* camera. White Diffuse deposits are thought to be dominated by SO_2-rich frosts. Yellow Diffuse deposits are likely composed of some combination of sulfur-rich materials and SO_2, albeit less SO_2, than white deposits. Red Diffuse deposits occur as ephemeral mantles around active vents. They have been interpreted as pyroclastic deposits rich in metastable, S_3 and S_4 allotropes, which are red when quenched from magmatic S_2 gas [6, 14], possibly also containing Cl-bearing materials at some vents [15]. Dark Diffuse deposits are interpreted as pyroclastic deposits derived from silicate lavas; *Geissler et al*. [9] performed a spectral analysis on the dark diffuse deposits from Babbar and Pillan Paterae, and found a spectral signature consistent with Mg-rich silicates. Finally, Green Diffuse deposits occur around active vents and underneath or near active plumes, where dark, fresh silicate flows also underlie the green material. This observation led to the suggestion that the green color results from alteration of cold sulfurous gases interacting with still warm silicate flows.

A wide range of structural features can be identified on Io, including scarps, ridges, graben, lineaments, faults, and circular depressions (pits and patera rims). The additional low-sun observations and higher resolution of the *Galileo* camera has enabled recognition of these and other structural features over a wider part of Io's surface than was previously possible.

Strategies for Global Mapping: After analysis of our new regional maps of the Amirani-Gish Bar region, analysis of previous geologic maps, and study of early versions of the new global Io mosaics, we have developed the following strategy for global mapping on the new mosaics with ArcGIS by ESRI.

1) *Map diffuse deposits using Galileo global color data:* The first mapping step will be to map diffuse deposits as a separate layer using the color mosaics. Typically various hachure patterns are used to delineate different types of diffuse deposits, and this approach will be used here. The wide variety of diffuse deposits on Io (black, yellow, white, red, green), which are thought to represent distinct compositions (silicates, sulfurous materials, SO_2-dominated materials, short-chain sulfur allotropes, products of silicate/sulfur interaction, respectively), cannot always be discerned in grayscale images. The color images are required to map their diversity. Based on analysis of the preliminary global color mosaic, all five types of diffuse deposits are resolvable (1 km/pixel) and mappable.

2) *Map mountains, surrounding plateaus, and structural features using the low-sun mosaic:* The second mapping step will be to map mountains, layered plateaus, and other materials delineated by scarps and other structural features using the low-sun mosaic. Because mountains and plateaus have nearly the same color and texture as background plains, it is difficult to reliably identify them except from images taken during low solar incidence angles, resulting in shadows that delineate the rugged topography of ridges, grooves, and scarps. We anticipate having one unit, Mountain Material, for the global (paper) map, with the potential of defining additional subunits (e.g., Lineated vs. Mottled, massifs, mesa/plateaus, volcanic edifices) depending on their resolvability in the final mosaics. One option might be to create a separate structural map showing identified and inferred structural features (e.g., thrust faults).

3) *Map vents and paterae:* The third mapping step will be to map vents and paterae using the grayscale and high-sun color mosaics. These image products provide the greatest albedo and color (respectively) contrasts available to identify these features. Active vents are usually visible as dark spots in the bright plains or within the floors of larger paterae. We anticipate having one unit, Patera Floor Material, for the global (paper) map, with the potential of defining additional subunits (e.g., bright, dark, undivided and/or intermediate) depending on their detectability and scale in the final mosaics.

4) *Map lava flow fields:* The fourth mapping step will be to map flow fields using the grayscale and high-sun color mosaics. We will first map the outermost boundaries of each flow field around a vent, followed by the addition of more detail (lobate flow margins or fresher interior flows) as the available resolution permits. Active or recently active flows are identified by the following criteria: 1) observed surface changes in images obtained at different times; 2) thermal anomalies detected in NIMS data; and/or 3) an observed plume source at or near the flow margins. Based on analysis of the preliminary global color mosaic, we anticipate having three primary Lava Flow Material units (bright, dark, undivided) that are resolvable (1 km/pixel) and mappable.

5) *Map plains:* The final mapping step will be to map the bright plains. This should include everything not mapped in the previous categories. The primary Interpatera Plains Material has three subunits based on color (Yellow, White, and Red-Brown), as well as a Layered Plains unit composed of plateaus separated from surrounding plains by scarps and thought to be produced by degradational processes [16].

References: [1] *Radebaugh et al.*, 2001, *JGR 106*, 33,005-33,020; [2] *Schenk et al*., 2001, *JGR 106*, 33,201-33,222; [3] *Lopes et al*., 2004, *Icarus 169/1*, 140-174; [4] *Smith et al*., 1979a,b, *Science 204*, 951-972, & *Science 206*, 927-950; [5] *McEwen et al*., 2000, *Science 288*, 1193-1198; [6] *Keszthelyi et al.*, 2001, *JGR 106*, 33,025-33,052; [7] *Turtle et al*., 2004, *Icarus, 169/1*, 3-28; [8] *Greeley et al*., 2000, *JGR 105*, 22,559-22,578; [9] *Geissler et al*., 1999, *Icarus 140*, 265-282; [10] *Williams et al*, 2002, *JGR 107*, 5068, doi:10.1029/2001JE001821; [11] *Williams et al*., 2004, *Icarus, 169/1*, 80-97; [12] *Williams et al.*, 2005, *Icarus, 177*, 69-88; [13] *Lopes et al*., 2001, *JGR 106*, 33,053-33,078; [14] *Spencer et al.*, 2000, *Science 288*, 1208-1210; [15] *Schmidt and Rodriguez*, 2003, *JGR 108*, 5104, doi: 10.1029/2002JE001988; [16] *Moore et al.*, 2001, *JGR 106(E12)*, 33,223-33,240.