GLOBAL GEOLOGIC MAPPING OF IO: DATA AND TECHNIQUES. David A. Williams[1], Laszlo P. Keszthelyi[2], Paul E. Geissler[2], Windy L. Jaeger[2], Tammy L. Becker[2], David A. Crown[3], Paul M. Schenk[4], and Julie A. Rathbun[5]; [1]School of Earth and Space Exploration, Arizona State University, Box 871404, Tempe, Arizona, 85287 (David.Williams@asu.edu); [2]Astrogeology Team, U.S. Geological Survey, Flagstaff, Arizona; [3]Planetary Science Institute, Tucson, Arizona; [4]Lunar and Planetary Institute, Houston, Texas; [5]University of Redlands, Redlands, California.

Introduction: Jupiter's volcanic moon Io is a challenging place to study using typical planetary mapping techniques, because of 1) rapid (in geologic terms) resurfacing from volcanic activity and 2) non-uniform coverage from multiple spacecraft flybys, resulting in a wide range of image resolutions and photometric properties. Nevertheless, because Io's level of volcanic activity makes it unique in our Solar System, it is desirable to map its surface in order to complete a global reconnaissance of its surface features and material units and to understand better its geologic evolution. In this abstract we discuss our approach to producing a global geologic map of Io. For production of our map, we are using a set of combined *Galileo-Voyager* global mosaics and ArcGIS software. We are also creating a GIS database to contain all compatible *Galileo*, *Voyager*, and other Io data sets to show surface changes and aid in geologic interpretations.

Background: Io, the innermost Galilean satellite of Jupiter, is the most volcanically active body in the Solar System. Tidal heating produces magma that feeds ~300 active volcanic centers [1-3]. The 1979 *Voyager* flybys observed ~25% of Io's surface at resolutions of <2 km/pixel (the rest at 2-20 km/pixel: [4]), covering mostly the subjovian hemisphere. The *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. Previous geologic mapping of Io includes a series of four regional *Voyager*-based maps [8], a *Voyager*-based global map [9], and four *Galileo*-based regional maps [10].

The complementary coverage of Io by *Voyager* and *Galileo* has enabled the production of a series of high quality grayscale and color global mosaics. 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.

Global Io Mosaics: The USGS Io global mosaics (1 km/pixel nominal resolution) are now the definitive global compilation of image products for Io. They consist of four distinct products: 1) a global mosaic of *Galileo* color images (756nm-green-violet as R-G-B, 4° phase angle); 2) a global mosaic of the best resolution *Galileo* monochrome images; 3) a global mosaic of the best resolution *Voyager* and *Galileo* monochrome images; and 4) a merged product combining *Galileo* color information with the higher resolution monochrome images. Each of these four products is available as an ISIS cube in Sinusoidal, Mercator and Polar Stereographic projections (both north and south pole). An extensive set of ancillary data was developed for all of these mosaics to help users understand the various combinations of data from different sensors, filters, dates, and illumination and viewing geometries. These include footprint plots showing the identity of each of the component images and diagrams that show the incidence, emission, and phase angles, along with the spatial resolutions of the individual frames used.

Strategies for Global Mapping: After analysis of all previous geologic maps and study of the new global mosaics, we developed the following strategy for global mapping. All mapping is done using ArcMap software, part of the ArcGIS package by ESRI:

1) *Map diffuse deposits using Galileo global color data.* This is done because of 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).

2) *Map mountains, surrounding plateaus, and structural features using various mosaics.* Various image products are used to identify mountains, layered plateaus, and other materials delineated by scarps and other structural features, because they have nearly the same color and texture as background plains and cannot be identified except in images taken during low solar incidence angles.

3) *Map vents and paterae using various mosaics.*

4) *Map lava flow fields using various mosaics.* We first map the outermost boundaries of each flow field around a vent, followed by the addition of more detail (individual lobate flow margins, 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.

5) *Map plains.* The bright plains include everything not mapped in the previous categories, and are thought to consist of silicate crust mantled by various S-bearing materials [10]. The primary interpatera Plains Material has three subunits based on color (Yellow, White, and Red-Brown); Layered Plains are composed of plateaus separated from surrounding plains by

scarps and are thought to be produced by degradational processes [11].

Mapping Progress: We have mapped the polar regions of Io (±57.5˚-90˚) as of January 2007. The following summarizes our results:

In general, Io displays five primary types of morphological units: plains, patera floors, flows, mountains, and diffuse deposits. Plains materials cover ~86% of Io's surface in the polar regions. The greatest percentage (79%) consists of radiation-altered Red-Brown Plains, with lesser amounts of White Plains (SO_2-dominated, 3%) and Bright (yellow) Plains (sulfur-dominated, 2%). Eroded plateaus, or Layered Plains, make up ~3% of the polar regions.

Patera floors have a range of albedos and colors in the polar regions, and are mapped as Bright (presumably sulfur-covered, 0.3%), Dark (presumably silicate-covered, 0.3%), and Undivided (0.8%). There are suggestions of additional paterae in the polar regions, based on albedo and color differences in the mosaics, but confirmation must await more high-resolution coverage. 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 [12]. Heno Patera (57.1˚S, 311.5˚W), a 71.1 km diameter patera, has dark floor and dark flows that surround a circular feature approximately centered on the patera floor. We speculate that this may be a site of an impact that is experiencing modification by volcanism.

There are significant expanses of Bright Lava Flow materials in the polar regions (3% of all mapped polar units), thought to be indicative of sulfur volcanism. The area of the Bright Flows is twice that of the Dark Flows (silicate-dominated, ~1%), although Undivided Flows (units with intermediate albedos and colors) make up another 6% of polar materials. These mapping results suggest that lava flows outside paterae may have a greater role in resurfacing Io than previously thought. Many polar bright flow fields are not directly adjacent to dark flows, perhaps indicative of a significant component of primary sulfur volcanism. Lithologically, Patera Floor materials and Lava Flow materials are probably identical in composition. However, their distinctive geologic settings justifies separating them on the global map.

In the polar regions, Lineated Mountain materials make up about ~2% of the surface. By number there are more mountains identified in the south polar region, due to the better *Voyager* imaging {i.e., need right illumination & resolution}. Mottled and Undivided Mountain materials each make up <1% of the polar areas. Lineated Mountain materials are topographically-distinct massifs (relative to layered plains) containing ridges, grooves, 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 [2]. Massifs with no visible patterns are classified as Undivided. Mottled Mountain materials have smoother surfaces lacking lineations and indicative of mass wasting processes. No volcanic mountains (Tholus, Cone, or Shield materials) were recognized in the polar regions.

The polar regions contain extensive diffuse deposits, which cover 16.5% of the surfaces of other units. White Diffuse deposits are thought to be dominated by SO_2-rich frosts, and make up 64% of all diffuse deposits at the poles. They usually occur at the margins of lava flows or around paterae, but also make up extensive halos around some mountains. Yellow Diffuse deposits are likely composed of some combination of sulfur-rich materials and SO_2, albeit less SO_2 than White deposits. Only 10% of diffuse deposits at the poles are yellow, and these are less extensive than in equatorial regions. Red Diffuse deposits occur as ephemeral mantles around active vents, and make up ~10% of polar diffuse deposits. There are the remnants of two faint red rings in the north polar region, one surrounding Dazhbog Patera (which erupted during the *Galileo* I31 flyby) and one around an unnamed patera at 70˚N, 55˚W. 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 [13], possibly also containing Cl-bearing materials at some vents [14]. Dark Diffuse deposits are interpreted as pyroclastic deposits derived from silicate lavas [15], and cover ~16% of the area of polar units.

A wide range of structural features can be identified in the polar regions of Io, including scarps, ridges, lineaments, 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.

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] *Moore, H.J.*, 1987, *USGS Map* I-1851, 1:1,003,000; *Greeley, R., et al.*, 1988, *USGS Map* I-1949, 1:2,000,000; *Schaber, G.G., et al.*, 1989, *USGS Map* I-1980, 1:5,000,000; *Whitford-Stark, J.L., et al.*, 1991, *USGS Map* I-2055, 1:5,000,000; [9] *Crown, D.A., et al.*, 1992, *USGS Map* I-2209, 1:15,000,000; [10] *Williams, D.A., et al.*, 2002, *JGR* 107, 5068, doi:10.1029/2001JE001821; *Williams, D.A., et al.*, 2004, *Icarus* 169, 80-97; *Williams, D.A., et al.*, 2005, *Icarus* 177, 69-88; *Williams, D.A., et al.*, 2007, *Icarus*, *186*, 204-217; [11] *Moore et al.*, 2001, *JGR 106*, 33,223-33,240; [12] *Carlson, R.W., et al.*, 1997, *GRL 24*, 2479-2482; [13] *Spencer et al.*, 2000, *Science 288*, 1208-1210; [14] *Schmidt & Rodriguez*, 2003, *JGR 108*, 5104, doi: 10.1029/2002JE001988; [15] *Geissler et al.*, 1999, *Icarus 140*, 265-282.