GEOLOGIC MAPPING OF THE POLAR REGIONS OF IO. David A. Williams[1], Laszlo Keszthelyi[2], Paul Geissler[2], Windy Jaeger[2], Tammy Becker[2], David Crown[3], and Paul Schenk[4]; [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.

Introduction: The objective of this work is to determine the geology of Io's polar regions through geologic mapping. Specifically, we applied a global mapping methodology established last year for Io [1] to 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. The mapping methodology was developed from studies of the preliminary mosaics, all previous *Voyager*- [2] and *Galileo*-based geologic maps of Io [3], and a new map of the Amirani-Gish Bar region that we produced from a ~500 m/pxl regional mosaic [4]. In this abstract we present the results of mapping on the north and south polar stereographic mosaics and provide a discussion of the types of geologic material units and structures found in the polar regions of Io.

Background: The polar regions of Io (±57.5˚-90˚) are the least studied part of the satellite. During the 1979 *Voyager* flybys, good coverage was obtained of slightly less than one half of the subjovian south polar region at <2 km/pixel. During multiple flybys in 1999-2001, the *Galileo* spacecraft imaged part of the antijovian north polar region covering Tvashtar Catena, an active volcanic chain of craters, at up to 185 m/pixel [5], as well as the whole antijovian hemisphere at 1.4 km/pixel [6]. Most of the rest of the polar regions are covered at ≤20 km/pixel.

Our goal is to complement the new USGS 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. We have tested our mapping methodology on the most challenging part of Io, the poorly-imaged polar regions.

Materials Units in Io's Polar Regions: 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%). Plains are thought to consist of the silicate crust of Io, mantled by dark silicate and bright sulfurous volcanic deposits [3]. Eroded plateaus, or Layered Plains, can also be detected using low-sun images that reveal scarps, and these 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 [7]. 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 in 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 {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 [8]. Massifs with no visible patterns are classified as Undivided. Mottled Mountain materials have smoother, unlineated surfaces 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 [9], possibly also containing Cl-bearing materials at some vents [10]. Dark Diffuse deposits are interpreted as pyroclastic deposits derived from silicate lavas [11], 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.

Evaluation of Strategy for Global Mapping: Using our mapping of the Io polar mosaics, we have tested our strategy for global mapping of Io with ArcGIS [1]:

Step 1) *Map diffuse deposits using Galileo global color data:* The SSI color data are useful to identify and map diffuse deposits. In some cases, the context of the diffuse deposits is not clear, and it is beneficial to switch from views of the SSI color-only mosaic to the SSI color + best *Galileo-Voyager* monochrome mosaic to see the underlying morphology. This is especially true around positive or negative-relief topographic features.

Step 2) *Map mountains, surrounding plateaus, and structural features using the low-sun mosaic:* These features are easily visible in the monochrome and color + monochrome mosaics, in which the initial images were obtained at low sun. Additional filtering is required to maximize viewing of the monochrome mosaic. The SSI color + best *Galileo-Voyager* monochrome mosaic is also useful to map mountains, layered plateaus, scarps, and other structural features. Lineated, Mottled, and Undivided Mountain materials can all be mapped on the mosaics.

Step 3) *Map vents and paterae:* Bright, Dark, and Undivided Flow materials can all be mapped on the mosaics. The combined SSI color + best *Galileo-Voyager* monochrome mosaic is the best tool to identify these features.

Step 4) *Map lava flow fields:* Bright, Dark, and Undivided Patera Floor materials can all be mapped on the mosaics. The combined SSI color + best *Galileo-Voyager* monochrome mosaic is the ideal product to identify these features (in terms of color and context), although switching views to other mosaics is useful for robust mapping.

Step 5) *Map plains:* Plains are mapped as everything that does not fit in the previous categories. The primary interpatera Plains materials have four subunits based on color or morphology (Yellow, White, Red-Brown, and Layered). Lower resolution coverage and color variations in the polar mosaics make some identifications difficult, although all subunits are present.

Summary: The global mapping strategy for Io [1] has been employed to produce maps of the geology of Io's polar regions. Use of the various different global mosaics facilitates compilation of these maps. Our results for the polar regions suggest that lava flows outside paterae make up a significant fraction of polar terrains (10.5%), and that these flows may make a greater contribution to Io's plains development than previously thought. Unusual color and morphology patterns on the patera floor of Heno Patera might be the scar of an impact event. Diffuse deposits cover 16.5% of polar terrains, 64% of which are White Diffuse deposits associated with warm volcanic regions. The next step is to complete global mapping on the equatorial mosaic.

References: [1] *Williams et al.*, 2006, In *Lun. Planet. Sci. XXXVII*, Abst. #1143, Lunar & Planetary Inst., Houston (CD-ROM); [2] *Moore, H.J.*, 1987, *USGS Misc. Invest. Series Map* I-1851, 1:1,003,000; *Greeley, R., et al.*, 1988, *USGS Misc. Invest. Series Map* I-1949, 1:2,000,000; *Schaber, G.G., et al.*, 1989, *USGS Geol. Invest. Series Map* I-1980, 1:5,000,000; *Whitford-Stark, J.L., et al.*, 1991, *USGS Misc. Invest. Series Map* I-2055, 1:5,000,000; *Crown, D.A., et al.*, 1992, *USGS Misc. Invest. Series Map* I-2209, 1:15,000,000; [3] *Williams, D.A., et al.*, 2002, *J. Geophys. Res.* 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; [4] *Williams, D.A., et al.*, 2007, *Icarus*, *186*, 204-217; [5] *Milazzo, M.P., et al.*, 2005, *Icarus*, 179, 235-251; [6] *Keszthelyi et al.*, 2001, *JGR 106*, 33,025-33,052; [7] *Carlson, R.W., et al.*, 1997, *Geophys. Res. Lett.*, 24, 2479-2482; [8] *Schenk et al.*, 2001, *JGR 106*, 33,201-33,222; [9] *Spencer et al.*, 2000, *Science 288*, 1208-1210; [10] *Schmidt and Rodriguez*, 2003, *JGR 108*, 5104, doi: 10.1029/2002JE001988; [11] *Geissler et al.*, 1999, *Icarus* 140, 265-282.