THE EUROPA GLOBAL GEOLOGIC MAP. D. A. Senske[1], E. J. Leonard[2], D. A. Patthoff[3], and G.C Collins[4] [1]Jet Propulsion Laboratory, California Institute of Technology (David.a.senske@jpl.nasa.gov), [2]University of California, Los Angeles, (erinleonard@ucla.edu) [3]Planetary Science Institute (apatthoff@psi.edu), [4]Wheaton College (gcollins@wheatoncollege.edu).

Introduction: First discovered by Galileo Galilei over 400 years ago and imaged in detail by Voyager 2 in 1979, Jupiter's icy moon Europa has been a source of fascination as a result of a range of scientific investigations that suggest it contains the key ingredients for habitability [e.g., 1,2]. Investigations of Europa's geology show that its surface is geologically complex and, based on the dearth of impact craters, interpreted to be as young as ~60 Ma [3-9]. Establishing the global context of the distribution and timing of Europan geologic units forms a basis to understand regional and local scale processes, serves as a tool for the planning of future missions, and most of all is essential to gaining insight into the potential habitability of this icy world.

Procedure: Our geologic map is produced following planetary mapping standards [e.g., 10-14] in order to separate observations of characteristics and interpretations thereby ensuring that the objective descriptions of each unit and feature are valid for any future Europa dataset.

Units: Because interpretations are subject to change with time, especially with future datasets from the Europa Clipper and other missions, objective unit and feature descriptions will allow this global map to still be relevant. The units defined in this map are grouped by morphologic type and named with respect to that type. This is a practice often used for mapping on Europa [e.g., 7-9, 15]. We also base all of the unit names and colors on previous maps of Europa as to preserve heritage and to make this map clearly comparable to other published maps of Europa [7, 9, 16].

Linear Features: Features that are less than ~20 km wide are too narrow to be resolvable as units on the 1:15M map, but can still be prominent because of their length (> 50 km) or albedo contrast. Instead, these structures are mapped with a line which marks the length, location, and trend of the feature. To simplify the map, not all lineaments on Europa's surface are identified. We identify those that are prominent (e.g. longer and wider than most), useful for constraining stratigraphy, or represent the density and distribution of the other lineaments of the area.

Initial Results: We have generated a global map at a scale of 1:15M of Europa (Figure 1) and established seven aerially extensive, geologic map units which we can divide into four categories: (1) crater material (c) and its subunits, continuous crater ejecta (ce) and discontinuous crater ejecta (dce)—materials associated with impact craters including the primary impact crater and its local deposits and farther ranging ejecta material; (2) Various morphological types of chaos materials identified as high albedo chaos (chh), mottled chaos (chm), low albedo chaos (chl) and knobby chaos (chk)—disrupted terrains whose textures vary and albedos range from high to low with various degrees of mottling; (3) general band forming material (b) and high albedo bands (bha)—linear to curvilinear zones with a distinct, abrupt albedo change from the surrounding region; and (4) ridged plains (pr)—the most abundant unit that is distributed across all latitudes and is characterized by subparallel to cross-cutting ridges and troughs visible at intermediate to high resolution (<100 m/pixel).

In addition to the geologic units, our map also includes a number of structural features including: depression margins (dm), troughs (t), multi-ring structures (mrs), microchaos (mch)—areas of surface disruption that are too small (10-75 km in diameter) to be mapped as a unit at the 1:15,000,000 scale, but whose presence is ubiquitous and significant enough to be identified on the map as a point—cycloids (cy), band linea (bl), ridges (r), and undifferentiated linea (ul).

Relative Ages: Relative ages of geologic units and structures on planetary bodies are determined largely by cross-cutting, or superposition and embayment, relationships. However, determining relative ages of structures or units on Europa is challenging for a variety of reasons including: (1) the overall complexity of the surface, (2) the lack of consistent image resolution at the global scale necessary to determine cross-cutting, and (3) the small number of impact craters. Despite these limitations, we can draw general conclusions about Europa's global surface history.

Chronostratigraphy: We have created a general stratigraphic column of the different units and features identified on Europa (Figure 1) despite the challenges described above. The jagged boundaries on the units and dotted lines on the linear features indicate the complexity and uncertainty of unit relationships.

There appear to be three separate periods in Europa's visible surface history, ~100 Ma [e.g., 17, 18]. The first, or oldest, of these periods is dominated by ridged plains, ridges, and undifferentiated linea indicating that this period was dominated by ridge building processes. We observe this to be the case as there are no units or structures that appear older, or cross-cut, the ridged plains unit.

The second, or middle, period is dominated by Band and High-Albedo Band formation. The Band and High-Albedo Band units always appear younger and cross-cut the Ridged Plains unit. Cycloids also appear to be formed during this period and can appear similar to ridge or band linea structures and even transform from one to the other along their length, potentially indicating a transition from a ridge-building to a band-forming mechanism (0°, 133° E).

The third, or most recent period, is dominated by chaos terrain formation including microchaos formation. Chaos terrain does not appear to have any cross-cutting units besides craters and their associated deposits, the troughs in the northern leading hemisphere, and potentially depression margins (though this is difficult to determine). Likewise, mircrochaos is observed breaking up previously formed bands, ridges, cycloids and other features, indicating that as a whole it is younger.

Though three different periods have been identified in Europa's surface history, in agreement with regional mapping by others [e.g., 7], we emphasize that they are still heavily inter-fingered with one another and are not necessarily discrete periods. The apparent interfingering could be a result of mapping complications associated with data of various resolution and illumination, though we believe that this will hold true even with increased resolution or other age dating techniques.

References: [1] Wackett et al. (2004), *A. and E. Microbio.*, *70*, 647-655. [2] Hand et al. (2009), *Europa*, U of AZ Press. [3] Lucchitta and Soderblum (1982), *Satellites of Jupiter*. U of AZ Press. [4] Pappalardo et al. (1999), *JGR*, 104, 24015–55. [5] Bierhaus et al., (2001), *Icarus*, *153*, 264-276. [6] Bierhaus et al. (2009), *Europa*, U of AZ Press. [7] Figueredo and Greeley (2004), *JGR*, *105*, 22,629-46. [8] Prockter and Schenk (2005), *Icarus*, *177*, 305-326. [9] Doggett, et al. (2009). *Europa*, U. of AZ Press, 137-159. [10] Wilhelms (1990) *Planetary Mapping*, Cambridge U. Press, 208–260. [11] Skinner and Tanaka (2003), *LPSC XXXIV*, Abstract 2100. [12] Tanaka et al., (2005), USGS Map. [13] Wilhelms (1972), *Astrogeology*, 55. [14] Tanaka et al. (2011), Planetary Geologic Mapping Handbook. [15] Prockter et al. (1999), *JGR*, *104*, 16531-40. [16] Prockter et al. (2002), *LPSC XXXIII*, Abstract #1732. [17] Zahnle et al. (1998), *Icarus*, *136*, 202-22. [18] Zahnle et al. (2003), *Icarus*, *163*, 263-289.

Figure 1: Global geologic map of Europa, legend (bottom right) and the correlation of map units (top right).