CULTIVATING DIGITAL MAPPING RESOURCES FOR THE PLANETARY SCIENCE COMMUNITY: UPDATES FOR 2023. S. R. Black, H. C. Buban, C. H. Wilber, and S. R. Bogle, U.S. Geological Survey Astrogeology Science Center, 2255 N. Gemini Drive, Flagstaff, Arizona 86001 (sblack@usgs.gov).

Introduction: Planetary geologic maps play a key role in space exploration and have done so since the creation of the first lunar geologic maps in the 1960s [*e.g.*, 1]. However, for many decades, access to these key products was limited to paper copies. The first planetary geologic map that was prepared in and distributed as GIS product was in 2001 [2]. Although maps are valuable products in mission planning, operations, and scientific research, the need for map readers to acquire paper maps or have technical GIS skills and software has ultimately limited the utility of planetary maps.

Results from the 2017 USGS-NASA Planetary Geologic Mapping (PGM) Program and USGS Planetary Geologic Map Coordination Group (PGM Group) community survey showed a significant need for greater accessibility when working with planetary geologic maps, and a need for planetary maps to be available to the broadest range of users [3 – Findings #1, 8, 10, and 14]. In response, we have worked to expand online geologic map resources, leveraging work from our decade-long effort to digitize planetary geologic maps [*e.g.*, 4]. This effort includes both ongoing map digitization efforts and the creation of interactive versions of published USGS planetary geologic maps.

Map digitization: Making planetary geologic maps more accessible begins with digitizing the physical paper map in a desktop GIS application. This allows the digital map to be spatially referenced and analyzed by anyone who has access to GIS. Additionally, the digitized map can then be used to create a public-facing, web-based, interactive map – a more accessible option for those needing to view and use planetary maps without access to hard copies or GIS software.

During digitization, the paper map sheet is first scanned using a large-format scanner, and imported into ArcGIS Pro. It is then georeferenced to the most recent appropriate basemap (**Figure 1A**) (this may be a different basemap than was originally used for mapping) to ensure the map is placed according to the current generation of orbital imagery. All map features (*e.g.,* geologic contacts) are then traced and saved as feature classes (**Figure 1B**). During digitization, map features are traced exactly as they appear on the map and are not modified. Modification of linework is instead reserved for map renovation projects [*e.g.,* 4, 6]. Final feature symbologies are formatted to match the original map (**Figure 1C**). This ensures that the scientific integrity of the map is preserved, and the information is conveyed as the original map author intended. Once all map features are digitized, the GIS and its metadata are released through the corresponding map page on the USGS Publications Warehouse website.

To date, 249 planetary geologic maps have been published by the USGS. Of these, 22 were submitted with a GIS package. Of the remaining 227 that did not have a GIS package, 150 have been digitized since this effort began over 10 years ago. To make as many maps available as quickly possible, the initial digitization effort focused exclusively on converting geologic

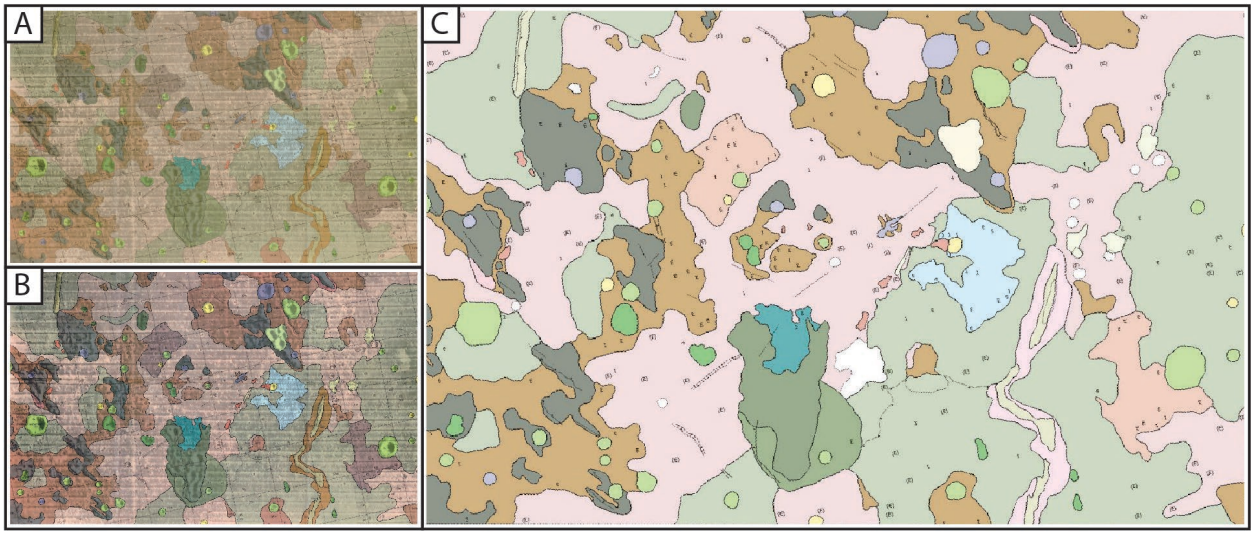

Figure 1. An in-progress digitization project of the USGS IMAP 616: Maskelyne DA Region of the Moon [5]. A) The scanned map sheet available on the USGS Publication Warehouse website before any work in GIS. B) The map sheet once georeferencing is complete and all geologic contacts are traced. C) The map once all other features are traced and geologic units are created.

Table 1: All currently available interactive planetary maps

USGS MAP #	SHORT TITLE	AUTHORS	LINK
	VENUS		
SIM 3250	Geologic Map of the Agnesi Quadrangle (V-45), Venus	Hansen and Tharalson (2014)	View
SIM 3249	Geologic Map of the Lada Terra Quadrangle (V-56), Venus	Kumar and Head (2013)	View
SIM 3163	Geologic Map of the Hecate Chasma Quadrangle (V-28) of Venus	Stofan, Guest, and Brian (2012)	View
SIM 3178	Geologic Map of the Snegurochka Planitia Quadrangle (V-1), Venus	Hurwitz and Head (2012)	View
SIM 3121	Geologic Map of the Ganiki Planitia Quadrangle (V-14) of Venus	Grosfils et al. (2011)	View
SIM 3158	Geologic Map of the Metis Mons Quadrangle (V-6) of Venus	Dohm, Tanaka, and Skinner (2011)	View
SIM 3099	Geologic Map of the Artemis Chasma Quadrangle (V-48), Venus	Bannister and Hansen (2010)	View
	MOON		
TBD	Unified Map of the Moon	Fortezzo et al. (2020)	View
	MARS		
SIM 3489	Geologic Map of Morava Valles and Margaritifer Basin, Mars	Wilson et al. (2022)	View
SIM 3470	Geologic Map of Olympus Mons Caldera, Mars	Mouginis-Mark (2021)	View
SIM 3477	Geologic Map of the Athabasca Valles Region, Mars	Keszthelyi et al. (2021)	View
SIM 3480	Geologic Map of the Aeolis Dorsa Region, Mars	Burr et al. (2021)	View
SIM 3464	Geologic Map of Jezero Crater and the Nili Planum Region, Mars	Sun and Stack (2020)	View
SIM 3389	Geologic Map of the Nepenthes Planum Region, Mars	Skinner and Tanaka (2018)	View
SIM 3356	Geologic Map of Meridiani Planum	Hynek and Di Achille (2017)	View
SIM 3297	Geologic Map of Tooting Crater, Amazonis Planitia Region of Mars	Mouginis-Mark (2015)	View
SIM 3245	Geologic Map of the Reull Vallis Region of Mars	Mest and Crown (2014)	View
SIM 3292	Geologic Map of Mars	Tanaka et al. (2014)	View
SIM 3309	Bedrock Geologic and Structural Map of Western Candor Colles Region of Mars	Okubo (2014)	View
SIM 3177	Geologic Map of the North Polar Region of Mars	Tanaka and Fortezzo (2012)	View
SIM 3197	Geologic Map of the Olympia Rupēs Region of Mars	Skinner and Herkenhoff (2012)	View
SIM 3096	Geologic Map of East Hellas Planitia, Mars	Bleamaster and Crown (2010)	View
	IO		
SIM 3168	Geologic Map of Io	Williams et al. (2011)	View
	GANYMEDE		
SIM 3237	Global Geologic Map of Ganymede	Collins et al. (2013)	View

contacts and units. All additional map features, including linear features and nomenclature, will be digitized and added to the GIS download package on the USGS Publications Warehouse website in upcoming digitization efforts. The 77 remaining maps will be digitized in their entirety and will include all geologic contacts, units, features, and symbols.

Interactive map production: We are working to make all planetary maps that have been published through the USGS available as web-based, interactive products. Interactive map production began in 2020 with the release of the Geologic Map of Jezero Crater and Nili Planum [7] prior to the landing of the Perseverance rover. Since then, an additional 23 interactive maps have been created and released (**Table 1**) following the methods described in [8]. The available interactive maps span several bodies: Venus, the Moon, Mars, Io, and Ganymede. Twelve additional interactive maps are completed and will be available in the upcoming months. Since the first interactive map release in December 2020, the interactive maps produced by the PGM Group have received nearly 10,000 views and continue to serve the planetary science community on a daily basis. All available interactive maps are now accessible through the PGM website, with additional maps in progress.

Next steps: Digitization and interactive map efforts are ongoing. The addition of members to the PGM Group allows for more time to be spent creating these community resources. With the Artemis missions underway, we will prioritize making lunar maps available to the public and planetary science community as both downloadable GIS packages and web-based interactive maps. However, maps of other planetary bodies may also be digitized and made interactive during this time. As soon as archived maps are digitized, they will also be made interactive, making these resources available to the community as quickly as possible. All new map publications will be released alongside their corresponding interactive map. Existing interactive maps will continue to be updated with additional tools and capabilities as they develop – for example, adding the ability to change between equatorial and polar projections in global maps.

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References: [1] Mason and Hackman, 1961, *USGS IMAP 351*; [2] Dohm et al., 2001, *USGS IMAP 2650*; [3] Skinner et al., 2019, *USGS OFR 2019-1012*; [4] Huff et al., 2016, *LPSC #2501*; [5] Carr, 1970, *USGS IMAP 616;* [6] Skinner, 2006, *LPSC #2331*; [7] Sun and Stack, 2020, *USGS SIM 3464;* [8] Black and Skinner, 2021, *PGM Meeting Abstract #7037*