
Introduction: Geoscience maps present scientific information that is inherently cross-disciplinary. These products bridge knowledge from geomorphology, geophysics, geochemistry, and geochronology to establish comprehensive geologic context for planetary studies. Common aesthetic components like grids, north arrows, and scales, and content such as map unit descriptions and correlations are well-known, fundamental aspects of maps. Standards that guide cartographic components and content facilitate cross-comparison of maps by theme, scale, and body, creating products with a common look and feel for users to universally comprehend.

Planetary geologic maps have challenges inherent to the study of remotely-sensed data that can be mitigated by standardization. Data coverage, resolution, and type influence the level of map detail, which limits planetary mappers from solely employing traditional, terrestrial-based mapping methods and standards. As a solution, planetary mappers have developed non-traditional (i.e., non-terrestrial) methods to create an innovative suite of products for planetary community use. However, through time, this practice has introduced variability in maps across bodies, scales, and themes which can be lessened by further development and use of standards. Our role as the USGS Planetary Geologic Map Coordination Group is to actively assess map components and methods that would benefit from additional standardization to lessen this variability. Based on community feedback, we identified prioritization of both mapping impact-related terrains and documenting standards for planetary geologic maps in the Planetary Geologic Mapping–Program Status and Future Needs document [1]. Therefore, we are reviewing, documenting, and standardizing the representation of impact crater-related units in planetary geologic maps.

Purpose: Impact craters are present on all solid surface bodies in the Solar System and have been extensively studied and documented through observations, numerical models, experiments, and Earth-based analog investigations. Thus, basic impact crater processes are well understood and impact-related terrains are prevalent on planetary geologic maps. Despite this familiarity and ubiquity, craters have been classified and represented on maps in various ways over time that are not wholly consistent by body or scale. Craters range in map representation from basic line features, to one map unit, to multiple morphology-based units. Additionally, there has been no uniform approach to defining and delineating boundaries of commonly used crater units, (e.g., crater rim, Fig. 1). In response, we have drafted a standardized crater schema for planetary geologic mapping to address crater-related map variabilities. This schema will enhance comparison of crater presence, age, and morphologies across maps, evaluation of crater variation across bodies, and communication of crater information to map users who are not impact experts. Furthermore, based on literature from the crater community, we are aware there are issues in some map representations that are extensively used. For example, "crater rim" units include sections of crater walls where target rock is exposed but not distinguishable (i.e., mappable). We are building this standardized schema with an explicit purpose to leverage and incorporate existing community-specific, published expertise to address this and other known discrepancies. The resulting schema will map and represent craters to accurately reflect the current understanding of impact-generated morphologies.

Methods: Development of this crater schema is initially focused on the Moon and Mars because of the abundance of maps of these bodies, as well as the range of crater modification processes. 184 of the 308 USGS published planetary geologic maps are on the Moon or Mars. Therefore, a crater schema based on these two bodies will apply to a majority of map makers and users in the planetary science community. It also allows us to demonstrate how the crater schema is useful across multiple bodies and at a variety of scales. Additionally, being able to incorporate morphologies from different crater modification processes on the Moon and Mars (i.e., near-pristine to heavily-modified end members) helps ensure that we are working toward a crater schema that can be extended to the rest of the Solar System. When establishing this schema, we decided to use the generic term "unit" as opposed to the historical term "facies" for distinguishing crater-related morphologies. We understand the application of "facies" for morphologies derived from known impact processes. However, the level of analysis and data resolution required to reliably tie crater morphology to process is higher than typical for planetary geologic mapping. Therefore, we recommend the use of less interpretive terminology and exclusively identify genetically-related impact units.

We reviewed published classifications of craters and informed our terminology and units from those defined by the Mars Crater Morphology Consortium [2] for crater ejecta textures and Barlow and Bradley [3] for crater interior morphologies. We documented crater representations in the 184 published lunar and martian
published maps to base the framework upon mapping community expertise. Historically, impact craters have been represented as surface features (defined in the Explanation of Map Symbols), map units (defined in the Correlation of Map Units), or a combination of both. Graphical representation of surface features included points identifying crater centers, lines delineating crater rims or crater boundaries, stipple patterns for craters and (or) ejecta, one to three polygons, or some combination of these approaches. Crater morphologies represented as map units were either “lumped” into single units or “split” into multiple units that are genetically-related (e.g., [4-5]). Different temporal designators were used to represent relative ages of craters: time-distinctive craters were separated by temporal epochs whereas time-transgressive craters showed gradation from one morphology to another over time. We are in the process of determining the situational applications of surface features versus map units and their temporal representation. These will be based on discernment of morphology classes, body of study, and map scale.

Results: We have developed a draft schema that aims to standardize multiple crater units and determine when to use surface features versus units and the use of time-distinctive versus time-transgressive designators. So far, we define four foundational units for complex craters: crater ejecta is a recognizable continuous deposit surrounding a central depression, and may have hummocks, ramparts, and (or) lobate margins; crater floor is a smooth, pervasively flat deposit filling the depression, and may have local ridges, scarps, and (or) grooves; crater peak is a positive topographic feature with a sharp to rounded summit commonly in the center of the depression. The final unit outcrops between the ejecta and floor and was historically termed “crater wall” or “crater rim”. We note accuracy issues when employing one unit to map an escarpment of the ejecta, overturned flap, and impacted strata sequence. We are examining whether the term “undivided” can convey that multiple units exist but are not distinguishable.

We determine preliminary size parameters based on print map scale for the use of surface features, single units, and multiple units. We propose that craters 5 mm in diameter or less on the print map will be represented by a surface feature, whereas 5-16 mm diameter craters will be mapped as single units and craters larger than 16 mm will be split into multiple map units. For example, a 1:1,000,000-scale map would apply the standardized size parameters to craters ≤ 5 km, 5-16 km, and ≥ 16 km in diameter respectively. Lunar units will be time-distinctive; martian units will be time-transgressive.

Discussion: Moving forward, we will assess the effectiveness of this schema by applying it to comparative craters on Earth, the Moon, and Mars. We will also expand this schema by evaluating its application to other bodies and to the spectrum of crater complexity. As part of these exercises, we will document limitations and diagnose situations where this schema breaks down and must be retrofitted. This schema will also address the Description of Map Units and Correlation of Map Units because of the integrated nature of these core map components. During finalization, we will request community input and feedback for iteration as necessary.

This crater schema presents a conceptual framework to be applied by mappers and adapted as necessary. The strength of planetary geologic mapping lies in the autonomy of mappers to exercise creativity in mapping methodologies, within reason. We encourage mappers to use their diverse expertise to develop innovative ways to shape this standardized crater schema into a representation that is the most effective for enhancing the scientific purpose of the map they are generating.