THE CHALLENGES OF STANDARDIZED PLANETARY GEOLOGIC MAPPING. J. A. Skinner, Jr., Astrogeology Science Center, U.S. Geological Survey, 2255 N. Gemini Drive, Flagstaff, AZ, 86001 (jskinner@usgs.gov).

Introduction: Geologic maps provide the contextual framework for understanding the formative histories of planets. These are based on consistently documentable characteristics of rock and sediment units as well as their spatial and temporal associations with one another. The geologic mapping concept – that a planetary surface can be uniquely differentiated into three-dimensional bodies of lithic material – is relatively straightforward. However, strategies and tactics differ depending on the body of interest, the scale of the map, and the background of the mapper. The observations provided in standardized geologic maps critically outnumber the interpretations, providing an objective context wherein map users are encouraged to make their own interpretations. Moreover, this standardized context allows for researchers to rely on the mapping process and product and to "speak the same language" when discussing differing terrains.

Planetary geologic mapping – similar to most planetary science disciplines – has undergone an important positive transformation during the past ~15 years due to the exploding volume, variable type, and diverse spatial resolution of data returned from orbiting and landed spacecraft. Other significant contributors to this transformation include increased availability (and lowered cost) of various programs that support data integration and analysis, required production of geologic maps in geographic information system (GIS) format, and a gradual trend away from projects that focus almost exclusively on the production of a geologic map (i.e., "mapping for the sake of mapping"). Although the renaissance of planetary geologic mapping has resulted in more informative and unique cartographic products, it has been met with its own set of challenges. This abstract examines some of these challenges and offers recommendations to overcome them in order to ensure the continued production of benchmark, contextual geologic maps of planetary bodies.

Background: The U.S. Geological Survey's (USGS) Astrogeology Science Center has historically provided coordination and guidance for NASA's planetary geologic mapping program sponsored by NASA's Planetary Geology and Geophysics program. Under the auspices of NASA's Planetary Cartography and Geologic Mapping Working Group and its Geologic Mapping Subcommittee, USGS provides the community with (1) assistance with geologic mapping program, (2) collective coordination of all active maps, (3) generation of base maps and databases for funded researchers, (4) development of (and guidance for) achieving cartographic standards, (5) editorial support in map reviews and revisions, and (6) preparation for and final printing of maps in the USGS Scientific Investigations Map (SIM) series. It should be made clear that the USGS is not equivalent to – but a part of – the broader cartographic research community. The USGS is directed by the science community and NASA to facilitate the standardization and production of geologic maps. In short, we create and maintain the infrastructure that enables scientific investigation. The USGS survives on critical input from the scientific community and should be viewed as a resource that evolves in response to strategic needs on the 5+ year timeframe.

Challenge #1 – Map Specifications: Researchers who perform systematic geologic mapping on non-terrestrial bodies as part of a scientific investigation now have an increased responsibility (relative to past decades) to carefully select the most appropriate data sets to answer the outstanding scientific problem at hand. This poses an interesting question to be answered by proposers, review panels, and program managers: What are the "correct" approaches, rationales, and specifications for the successful completion of a standardized geologic map?

To make an effective case for competitive selection, proposers who opt to produce a USGS SIM series geologic map must summarize (and succinctly justify) critical specifics regarding the map product, including (1) scientific relevance by delineating limitations of past-published maps, (2) selected (primary) base and (secondary) supplemental data sets that are required for effective mapping, (3) latitude and longitude boundaries of the map region, and (4) map scale and projection. Map base, scale, and projection are particularly important for evaluating whether the project can be completed as proposed and whether the map can be feasibly supported by USGS and NASA. For example, mappers must be aware of incompatibilities of image resolution and map scale, as not all data sets are relevant at all map scales (*e.g.*, HiRISE images cannot feasibly support unit identification and delineation at 1:1,000,000 scale).

Challenge #2 – Community Awareness: A critical part of the NASA-supported and USGS run planetary geologic mapping program is properly conveying map information to community researchers. It is not helpful to USGS, NASA, the scientific community or

public if high-level data products are not advertised and pushed into the community for use. The challenge is ensuring that the community is continuously aware of the process and products of planetary maps. Understanding the process helps the community understand the timeframe as well as the efforts that support the work. It helps to have the community aware so that they can obtain and use the products and evaluate them on review panel. Use of geologic maps can be evaluated by various quantities, including citation statistics, web requests, and shipping details. It is the totality of these quantities that most appropriately track the health of the planetary geologic mapping community and help to ensure that NASA is getting a sufficient return on its investment.

Challenge #3 – International Collaboration: The process and product of geologic mapping is approached by institutions in multiple countries around the world. However, there are no other institutions that produce standardized geologic maps of planetary surfaces. The NASA-USGS relationship maintained over the past four decades has resulted in cartographic products, particularly planetary geologic maps, as the international benchmark standard. The challenge is that international contributors do not have direct access to USGS publication opportunities despite a high level of understanding of and commitment to the mapping process. Though community standards for planetary geologic mapping are posted on USGS websites and are available to the national and international community for adoption and use, it is the process of technical review, coordination, cartographic standard, and objectivity that is the benchmark component of USGS products. Currently, non-NASA products geologic maps are published in peer-reviewed journal articles, which is a sufficient (and encouraged) venue for publishing topical study maps where interpretations outweigh the observations. However, the scientific community is losing out on elevating these contextual products, which undercuts community education about the value of the process and product.

Challenge #4 – Timeliness: There is a perception in the science community that the production of planetary geologic maps is lengthy (perhaps too lengthy), which in turn fosters a perception that these products are behind the times. This perception has embedded accuracies and inaccuracies and a particular challenge is disentwining these two in order to make sure the broader science community understands the timeliness and responsiveness of geologic maps. Timeliness starts with proposers understanding not only the requirements of the geologic mapping process and product but also budgeting accordingly for these requirements. Proposers must ensure that they have budgeted time to accommodate response to technical reviews, which often entail significant alteration of maps components. One challenge is that maps are often submitted near the end of the funding cycle, which leaves little time (or money) for the authors to integrate the required changes. Another element of timeliness to community needs is the ability to "expedite" the review and publication process when maps are considered by the community to be high priority. It should be realized, however, that the review and production process of standardized maps is – by definition – tedious and time consuming. Proposers (and program managers) can consider the time from submission for technical review to final printing to be at least 12 months if all players (reviews, authors, USGS coordinators, editors and cartographers) are responsive. Assistive measures for ensuring timely work flows include tutorials and workshops, map component templates, author and reviewer checklists, and active liaising between authors and USGS Publication Services Center (PSC). However, the best assistive measure is a clear understanding of (and dedication to) the mapping process, which includes technical review and production. Authors must remain engaged throughout.

Challenge #5 – Next Generation Mappers: Geologic mapping is an inherently integrative scientific endeavor, which makes it appealing to students. Though project management and the flurry of details related to map review and production should necessarily be handled by the author, the planetary mapping community needs to grasp that part of our responsibility in maintaining the health of the mapping program long term is seeding the community with young researchers who have an understanding of (and "knack" for) the geologic mapping process. Equivalent to other disciplines, standardized geologic mapping is a learned and skilled endeavor which must be developed and honed. The perception that "anyone can do geologic mapping" is not correct. A challenge is ensuring that geological mapping skills are maintained, if not enhanced, over the coming years so that the science community does not lose the personnel or product resource.

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