Planetary Geologic Mapping Handbook – 2011

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WHAT'S NEW: This addition includes instructions on formatting maps for official USGS submission, including required map components, file structures and formats, and digital templates (tables, correlation of map units). Because information and guidelines provided herein may be refined, readers are encouraged to check for and use the most recent version of this mapping handbook.

1. INTRODUCTION

Geologic maps present, in an historical context, fundamental syntheses of interpretations of the materials, landforms, structures, and processes that characterize planetary surfaces and shallow subsurfaces (e.g., Varnes, 1974). Such maps also provide a contextual framework for summarizing and evaluating thematic research for a given region or body. In planetary exploration, for example, geologic maps are used for specialized investigations such as targeting regions of interest for data collection and for characterizing sites for landed missions. Whereas most modern terrestrial geologic maps are constructed from regional views provided by remote sensing data and supplemented in detail by field-based observations and measurements, planetary maps have been largely based on analyses of orbital photography. For planetary bodies in particular, geologic maps commonly represent a snapshot of a surface, because they are based on available information at a time when new data are still being acquired. Thus the field of planetary geologic mapping has been evolving rapidly to embrace the use of new data and modern technology and to accommodate the growing needs of planetary exploration.

Planetary geologic maps have been published by the U.S. Geological Survey (USGS) since 1962 (Hackman, 1962). Over this time, numerous maps of several planetary bodies have been prepared at a variety of scales and projections using the best available image and topographic bases. Early geologic map bases commonly consisted of hand-mosaicked photographs or airbrushed shaded-relief views and geologic linework was manually drafted using mylar bases and ink drafting pens. Map publishing required a tedious process of scribing, color peel-coat preparation, typesetting, and photo-laboratory work. Beginning in the 1990s, inexpensive computing, display capability and user-friendly illustration software allowed maps to be drawn using digital tools rather than pen and ink, and mylar bases became obsolete.

Terrestrial geologic maps published by the USGS now are primarily digital products using geographic information system (GIS) software and file formats. GIS mapping tools permit easy spatial comparison, generation, importation, manipulation, and analysis of multiple raster image, gridded, and vector data sets. GIS software has also permitted the development of project-specific tools and the sharing of geospatial products among researchers. GIS approaches are now being used in planetary geologic mapping as well (e.g., Hare and others, 2009).

Guidelines or handbooks on techniques in planetary geologic mapping have been developed periodically (e.g., Wilhelms, 1972, 1990; Tanaka and others, 1994). As records of the heritage of mapping methods and data, these remain extremely useful guides. However, many of the fundamental aspects of earlier mapping handbooks have evolved significantly, and a comprehensive review of currently accepted mapping methodologies is now warranted. As documented in this handbook, such a review incorporates additional guidelines developed in recent years for planetary geologic mapping by the NASA Planetary Geology and Geophysics (PGG) Program's Planetary Cartography and Geologic Mapping Working Group's (PCGMWG) Geologic Mapping Subcommittee (GEMS) on the selection and use of map bases as well as map preparation, review, publication, and distribution. In light of the current boom in planetary

exploration and the ongoing rapid evolution of available data for planetary mapping, this handbook is especially timely.

2. PURPOSE OF THIS HANDBOOK

The production of high-quality geologic maps is a complex process involving a wide range of data, software tools, technical procedures, mapping support specialists, review steps, and publication requirements. This handbook provides a comprehensive 'how to' mapping guide that covers each of these topics to clarify the process for map authors. This guide emphasizes the production of planetary geologic maps in a digital, GIS format, because this format is required by NASA PGG for maps beginning in (1) 2011 that are submitted for technical review and (2) 2013 that are finalized for publication. Because of continual changes in data availability and mapping techniques, it is understood that the geologic mapping process must remain flexible and adaptable within time and budgetary constraints. Users are advised to seek the latest edition of this handbook, which will be updated periodically as an appendix to the annual abstracts of the Planetary Geologic Mappers' (PGM) meeting (downloadable at the PGM web page; see below for a complete list of web links). Other updates, including recently published maps, will be posted on the USGS Astrogeology Science Center's (ASC) PGM web page.

First, we describe the steps and methods of map proposal, creation, review, and production as illustrated in a series of flow charts (Figs. 1-4). Second, we include basic formatting guidelines for each map component. Third, we provide a list of web sites for useful information and download.

3. MAP PROCESSING

Planetary geologic maps as supported by NASA and published by USGS are currently released under the 'USGS Scientific Investigations Maps' (SIM) series. In this section, we summarize the process of completing USGS SIM series planetary geologic maps from proposal submission to publication (Figs. 1-4; note that the SIM series was formerly named Geologic Investigations Series and Miscellaneous Investigations Series and both used "I" for the series abbreviation for published maps; all I and SIM series share a common, progressive numbering scheme). These processing steps are subject to change as they are dictated in many cases by higher-level organizational policies, budget constraints, and other circumstances. Planetary geologic mapping support personnel are listed in Section 7; these are subject to change on an annual basis.

a. Proposals. Planetary geologic maps published by USGS have been sponsored largely by the NASA PGG program. Thus, maps submitted to USGS for publication must have been accepted under a NASA PGG grant (see the NASA research opportunities web page) and/or have the approval of the NASA PGG Discipline Scientist. Map publication and printing costs are covered by separate PGG funding and thus are not included in PGG research proposals. The proposal submission deadline is generally during the spring, and selections are usually announced by the following winter (depending on when funds can be released from NASA). Those considering proposing for a grant to perform planetary geologic mapping should visit the USGS Planetary Geologic Mapping web page, where information on current mapping programs and projects, map preparation guidelines, and links to published maps can be found. While a variety of map areas,

scales, and projections are potentially feasible for publication, some issues may make a conceived map untenable for publication (e.g., NASA PGG has a limited budget and multiple and oversized map sheets may be prohibitive in cost). Mappers are highly encouraged to contact the USGS Map Coordinator (MC) regarding the maps to be proposed for prior to proposal submission to ensure that preparation of the desire map base and publication of the final product are feasible. (See table in Section 7 listing PGM personnel names and email addresses). Generally, proposals should address:

1) Digital production: Will the map be generated in GIS software compatible with ESRI's ArcGIS® software (the USGS standard)?
2) Map base: The proposal should include a description and justification of the desired map base that addresses the following questions. What data set is desired for the map base (which forms the map background) and are all the needed data released? Does USGS have the capability to generate the map base with available capability and resources? (Consult with the USGS Map base Specialist to find out.) What other data sets are desired and can they also be imported into the GIS geodatabase? Does the work plan allow for adequate time for USGS to construct the base (usually within 6 months after the USGS is notified by the PGG Discipline Scientist of the proposal's award), depending on complexity?
3) Map printing: At the proposed scale and projection, will the map be oversized (i.e., >40x56 inches)? Will multiple sheets be required for a given map area? (Consult with the USGS Map Coordinator for estimates of potential extra costs.) Proposer should be aware that increased complexity adds considerable time for preparation, review, and publication.
4) Map reviews: Proposers should be prepared to review two other planetary geologic maps for each intended map publication. It is appropriate to budget your time to review maps in each new mapping proposal that you submit.
5) Supplemental digital products: Digital map supplements may be proposed. These can include helpful figures and ancillary GIS raster and vector layers that can greatly enhance the map product but may not fit on the printed map.
6) Additional analyses and products: Detailed and interpretative analyses outside of the scope of the map product may be desired (for example, to test existing and construct new hypotheses, model observations, etc.), but these should be expressed as tasks independent of map generation (best suited for publication in science journals). Maps will no longer contain such material.
7) Attendance at mappers meetings: Proposal budgets must include funding for attendance at the annual Planetary Geologic Mappers' meetings and possible GIS workshops.

b. Map base package *(Fig. 1).* The map base forms the background image (usually in reduced contrast form) upon which the drafted geologic map units, symbols, and nomenclature are superposed. It is a geometrically controlled product that is the fundamental data set upon which map drafting is performed. In some cases, there are adequate data available from a particular data set, but the map base itself does not yet exist when the mapping proposal is submitted. Thus USGS must generate the map base. (In special cases, the proposer may construct the base, with advance permission from the USGS Map Coordinator). Sometimes, data gores can be filled in with other lower-quality yet useful data. Even if a desirable data set is released, there may be as-yet unresolved issues in radiometric and geometric processing and/or in data volume that prevent

USGS from producing a map base with that particular data set. For example, the number and volume of images may be too large to generate a map base with available resources. Alternatively, such data may be readily viewable as individual frames by using image-location footprints as GIS shapefiles having web links to data repositories. Other ancillary data in various forms may be provided at the request of the author if there is a demonstrated need for the data and if they can be readily integrated into a GIS geodatabase. The USGS Map base Specialist is tasked by PGG to produce the digital map base and ancillary data products and to satisfy reasonable and tractable mapping requests by map authors.

Typically, the USGS must generate several map base packages in a given year; these are generally compiled in order of increasing complexity and/or areal extent. Map bases for Venus quadrangles are usually the simplest and are thus generated first during each funding cycle. Map bases for Mars quadrangles may require mosaicking of many individual image frames that must be compared visually and stacked in order of quality and then collectively processed for tone balance. More complex maps may require several months to complete after USGS is notified to produce them.

For GIS mapping projects, the USGS GIS Project Specialist generates a GIS map template after quality-checking and collating GIS data layers. The template includes map bases and a map-ready geodatabase with pre-populated symbols. These products are compiled and delivered using ESRI's ArcGIS® software. (USGS can import shapefiles produced from other software in some cases, but authors should consult with USGS GIS specialists *prior* to mapping to ensure that their map files will be usable.) In addition, a variety of GIS thematic maps can be downloaded and imported into the project, as well as other GIS tools, as administered by the USGS GIS PIGWAD Specialist (see PIGWAD web site). For Mars, Moon, and Venus maps, the mapping projects will include a stand-alone DVD volume (or equivalent compressed, digital file) of global datasets that can be incorporated into the project-specific GIS template.

c. Digital mapping. Mappers presently are mapping mostly in Adobe Illustrator or ArcGIS. For proper building of polygons in Illustrator layers, see the help web site. For ArcGIS, contact and structure mapping is generally done first as polyline shapefiles. Vertex snapping is important for later generation of polygons. Point shapefiles can be used to indicate unit identification for each outcrop. At an advanced stage in mapping, the contacts can be cleaned, smoothed, and converted to polygons. We recommend that the final GIS linework have a vertex spacing of ~0.3 mm at map scale (equivalent to 300 m for a 1:1,000,000-scale map). We also recommend that a consistent scale is used to digitize linework, usually a factor of 2 to 5 larger than the published map to ensure adequate precision but not overkill (e.g., map at 1:200,000 to 1:500,000 for a 1: 1,000,000 map). GIS tools can be applied to generalize and smooth linework to achieve the desired result, such as rounded corners. Also, outcrops should generally be at least 2 mm wide at map scale. Reasonably sized cutoffs should also be defined for line feature lengths (for example, 1 or 2 cm long at map scale). Point features can be used to show the distribution of important features such as craters and shields that are too small to map (their size ranges should be indicated). For clarity and completeness, we encourage the compilation and summary of digital mapping approaches and settings for inclusion in the map text.

d. Mappers' meetings and GIS workshops. These meetings are announced by the GEMS Chair and are also posted on the NASA Mars Exploration Program Analysis Group (MEPAG) calendar web page and the Planetary Exploration Newsletter (PEN) calendar of events. While under

active NASA mapping grants, mappers are expected to submit and present abstracts for the Annual Meeting of Planetary Geologic Mappers typically held in late June each year. Others are encouraged to attend as a means to benefit from various aspects of the program. At these meetings, mappers demonstrate their progress and discuss mapping issues and results. Preliminary map compilations are also displayed and informally reviewed by other attendees during poster sessions. In addition, programmatic issues, mapping standards and guidelines, and related scientific issues are presented and discussed. Expert-led GIS workshops and/or geologic field trips to nearby localities of interest are commonly attached to the mappers' meeting. When possible, associated GIS workshops are held prior to or immediately following mappers' or other appropriate workshops (and occasionally as stand-alone meetings) throughout the year. These GIS workshops are customized to assist planetary geologic mappers in developing proficiency in GIS software and tools as applied toward planetary geologic maps published in the USGS SIM series. Abstracts and related reports are published in an abstract volume in either a USGS or NASA publication series, and they can be downloaded from the USGS Planetary Geologic Mappers web page.

e. Submission and technical review *(Fig. 2).* Mappers are expected to prepare maps in accordance with guidelines herein (see Map Contents section below) as well as with those posted on the USGS Planetary Geologic Mappers web page. Once the map is produced according to required guidelines, it is submitted in digital form to the USGS Map Coordinator (MC). The MC reviews the map submission for completeness. If the map is incomplete, the MC returns the map to the corresponding author for revision. If the map is complete, the MC assigns two reviewers, with the approval of the GEMS Chair. The MC fills out an Information Product Review and Approval Sheet (IPRAS; Figure 5) in which all reviewers are listed. Both reviewers must approve (in rare cases, a third reviewer may be assigned to help resolve reviewer conflicts). Maps are returned to authors one or more times until review comments are adequately addressed as determined by the MC. The MC may adjudicate some issues that arise (for more challenging cases and in cases of potential conflict of interest, the MC consults with the GEMS Chair). Normally, initial map reviews are expected to be returned within 1 to 2 months and any additional reviews within 2 weeks.

f. Map Coordinator review *(Fig. 3).* Once the technical reviews are complete, the MC, with assistance from other USGS specialists as needed, performs a review that ensures that (1) the map conforms to the proper scale and projection, (2) final technical reviewer comments were adequately addressed, (3) map materials follow PSC author submission checklist guidelines, (4) map information conforms to established USGS and GEMS conventions, (5) nomenclature is sufficient, given what the map text discusses, and (6) stratigraphic inferences are properly conveyed and supported by observations. Map authors respond to the MC review comments and resubmit the map package. Name requests for mapped or referenced features are made by the author as needed using the online form; these can be made anytime during the mapping process. New name proposals may take 4 to 8 weeks or longer for approval. Proposed names *may not be used* in publications until they have been approved by the International Astronomical Union.

g. Nomenclature review *(Fig. 3).* The USGS Nomenclature Specialist then reviews the map to assess whether the use of nomenclature accurately reflects the current terminology in the IAU Gazetteer of Planetary Nomenclature. The map itself should have a nomenclature layer that

presents all available formal names. Note that some exceptions to this naming requirement may apply in special situations; for example, overly small named features may exist only for a sub-region of the map. (For a brief review of how IAU nomenclature is being managed and developed in the case of the Moon, see Shevchenko and others (2009)).

h. USGS metadata preparation *(GIS maps only; Fig. 3).* Metadata is the necessary ancillary documentation that describes each GIS layer in a geologic map, including rationale, authorship, attribute descriptions, spatial reference, and other pertinent information as required by the metadata standard. This information is archived with and becomes part of the map layer. The USGS GIS specialists will oversee metadata preparation and will tap authors for information when needed. Metadata for a map is comparable to the documentation required by NASA's Planetary Data System for digital planetary data, but it is created specifically for geospatial data sets. USGS GIS specialists will oversee incorporation of metadata for the mapped layers according to USGS publication standards and Federal Geographic Data Standards (FGDC). Metadata and readme files are required when the manuscript is submitted to PSC for publication. The PSC Digital Map Editor reviews general information (such as correct USGS contact information, information in appropriate fields, etc.).

i. ***USGS Publications Services Center (PSC) editing and production*** *(Fig. 3).* The PGM Administrative Specialist works with other USGS staff to ensure that the product is complete for PSC processing, and sends the product and review materials on CD or DVD and hardcopy form according to PSC guidelines (see PSC author submission and Astrogeology submission checklist web pages). PSC contacts the Map Coordinator and estimates costs for PSC editing and production and printing through a contractor selected by the Government Printing Office (GPO). Based on available funds for these costs, maps are put into the editing and production queue for the current or next fiscal year. A USGS PSC Map Editor then is assigned to the map and works with the author to produce the edited copy. Next, the map goes to the PSC Production Cartographer to produce a printable version in Adobe Illustrator®. The author has an opportunity to proof the map before it is finalized for publication; however, no significant content changes are allowed (authors will be responsible for proofing non-standard items such as special characters (small caps, diacriticals, etc.)). Also, if there is room on the map, the author may be notified by PSC that appropriately sized tables and/or figures can be shifted from the pamphlet and/or digital supplement to the map.

j. ***Map printing and web posting*** *(Fig. 3).* The PSC Production Cartographer submits the completed map to GPO for bid and printing. Generally, 100 copies of the map are sent to authors, and 300 copies are received by the USGS Regional Planetary Image Facility (RPIF) in Flagstaff, Arizona, for distribution to other RPIFs and PGG investigators on a mailing list provided by the PGG Discipline Scientist. Extra copies are kept by the USGS RPIF and can be requested by investigators through the Map Coordinator. Digital files of map materials are posted by the PSC Web Master on a USGS server for downloading, including: (a) PDFs of all printed materials produced by PSC, (b) author-provided Adobe Illustrator® files, and (c) GIS database, metadata, readme, and additional data files provided by PSC (a copy of these final files is provided to the author). Minor corrections and cosmetic improvements of the digital map product can be generated by authors as a new digital version of the map and submitted to the Map Coordinator for review, editing, and posting (however, consult first with the MC before

initiating such a product, as authors have to pay for this service). Minor, non-science changes are shown by a decimal number, for example, correcting spelling of a name throughout the publication or correcting a number in a table would generate a version upgrade from 1 to 1.1. Changing science on the map or adding data would generate a version upgrade from 1 to 2.

4. MAP CONTENTS

Planetary geologic maps in the past have varied widely in content and arrangement, largely at the preference of map authors. Though some flexibility is desirable to convey the geologic data and interpretation in ways that are suitable for each particular geologic map, unnecessary divergences and details come at a cost. Highly complex and uniquely assembled maps require more effort from mappers, reviewers, cartographers, and editors to prepare the map for publication. This handbook, under the direction of GEMS, defines a basic content template for planetary geologic maps, so that they become more uniform in format and thus simpler for users to assimilate and use as well as easier and cheaper to produce. In addition, following established USGS style guidelines in initial text preparation will result in less editing and revision. Mappers should refer to recently published geologic maps for examples of proper style in terms of spelling, word usage, grammar, and formatting, as well as the USGS Tips web page that addresses common formatting and editing issues. *Doing so will save time and effort!*

a. Map sheet components. To keep the printed map sheet as small as possible, authors are requested to keep map components to a minimum.

1) Map: Of course, the map itself is the fundamental product. It should be complete with map base at correct scale and projection, outcrops clearly colored and labeled, and structures consistently mapped. (The PSC Production Cartographer will cosmetically fine tune these elements, as well as add the map scale and grid and any notes on base, but cannot be expected to complete or decipher any aspects prepared incompletely or unclearly.) To avoid clutter, highly detailed information may be included in the digital product as a layer (see the digital data products section below). Printed maps normally must be contained within a single sheet having a maximum size of 40 x 56 inches (larger or additional sheets result in significant additional printing costs; authors desiring multiple or oversized sheets may choose to pay for the extra costs, with prior approval via the Map Coordinator).
2) CMU/SMU: Each map will include a Correlation or Sequence of Map Units (CMU/SMU) chart. The chart is organized horizontally left to right showing the following elements:
   a) *Stratigraphic column*: Formal or informal stratigraphic divisions (where available).
   b) *Map units*: Units can be arranged in groups according to location or unit type. Units that form groups closely related in provenance and/or definitive characteristics may have similar unit names and symbols (e.g., Utopia Planitia 1 unit, Utopia Planitia 2 unit) and should be juxtaposed horizontally and/or aligned vertically in the CMU/SMU. Also, younger units and unit groups divided by region or morphologic type generally are placed toward the left, and older and diverse (e.g., ‘undivided highland materials’) and widespread (e.g., ‘crater material’) units are placed to the right. If more complex relations are portrayed, such as unconformities, time transgressive contacts, and other juxtaposition relations, they may be explained using

a key (e.g., Young and Hansen, 2003; see also GEMS guidelines for Venus SMUs and Appendix D in Tanaka and others, 1994).

c) *Major geologic events (optional)*: Juxtaposed chart to the right of the CMU/SMU showing inferred episodes of geologic activity (such as deposition, erosion, deformation, etc.; e.g., Tanaka and others, 2005).

d) *Crater density scale (where data are available)*: Cumulative density of craters larger than specified diameter(s) (e.g., Tanaka and others, 2005). Supporting text should be provided in the 'age determinations' text section (see below).

3) Nomenclature: Published USGS maps are expected to display nomenclature completely (with minor exceptions, such as features that are spatially insignificant at map scale) and accurately according to the International Astronomical Union (IAU) Gazetteer of Planetary Nomenclature. For adding nomenclature labels in ArcGIS, see tutorial on Annotation & Nomenclature. Whenever named features are mentioned anywhere in the map, including the text, they should be properly capitalized and spelled (including the Latin plural forms for descriptor terms). In this regard, the IAU recommends that the initial letters of the names of *individual* astronomical objects be capitalized (e.g., "Earth is a planet in the Solar System"). Also, 'crater' is not capitalized: "Mie crater occurs in northeastern Utopia Planitia, north of Elysium Mons and Albor and Hecates Tholi." Informal terrain terms (e.g., 'Utopia basin' and 'dark lava plains') should not be capitalized and non-IAU-approved proper names should not be introduced. If a feature needs a name or name redefinition, the USGS Nomenclature Specialist can assist with a name proposal. Nomenclature needs can be addressed at any time over the course of mapping, but keep in mind that it generally takes one to two months for a name to be approved. Informal names should be identified clearly as such (e.g., 'the feature dubbed Home Plate…'). Formal names proposed to the IAU should not be used in maps or publications until the approval process is complete. Name proposals should be based on the need to single out for identification as-yet unnamed features in the map area (a need for names for use in journal articles may also qualify). Consult with the USGS Map Coordinator and Nomenclature Specialist when nomenclature issues arise.

4) Geologic sections: A limited number of geologic sections can be shown on the map. These must be drafted in ArcGIS® or Illustrator®. Unit colors and symbols and other symbology and nomenclature should be identical to those on the map. The sections should be at the same horizontal scale as the map, and the amount of vertical exaggeration should be indicated and minimized.

5) Map symbol legend: The legend is a chart on the map sheet that includes all line, point, and stipple symbols, with a feature type name and brief explanation (see recently published maps for examples). Where possible, the features should follow official, published USGS cartographic symbols (see FGDC web page as well as examples recently published in planetary geologic maps). The Production Cartographer will assist with converting symbols into final forms when necessary (e.g., when converting from GIS format to Illustrator®). See Tanaka and others (in press) for a discussion of types of tectonic structures found on particular planetary bodies.

6) Unit legend: The unit legend is a list of map units organized by the unit groupings as illustrated graphically in the CMU/SMU. The units include a box showing the unit color (perhaps overlying the base) and are ordered from youngest to oldest exactly as in the Description of Map Units (DMU; see Tanaka and others, 2005). The only text shown is

the unit name (this is a new policy); all unit information is included in the DMU table. However, if the DMU can be included on the map sheet, the unit legend will not be necessary, and colored unit boxes will be added to the DMU.

7) Selected figures, tables, and text: During the map sheet layout construction phase, the USGS Production Cartographer may determine that there is room for additional material on the map sheet, and he/she will notify the author. The author then selects appropriate figures and tables from already submitted material that will fit. For smaller maps with brief text, all the material may fit on the map sheet (e.g., Price, 1998).
8) Map envelope: The map sheet (sometimes accompanied by a pamphlet with descriptive text) is contained within an envelope. In addition to standard publication citation information, the envelope may include an index map showing the map region typically on a hemispherical view of the planet. Digital data generally will be provided on-line only, as inclusion of a DVD in the map envelope is cost prohibitive.

b. Text components. Text will appear in a pamphlet or, when room is available, on the map sheet. Note that unit and feature descriptions are to be put into tables (i.e., delimited text files or other GIS compatible formats), which will encourage concise presentation and easier conversion to metadata for GIS maps.

1) Introduction and background: This section of the map text introduces the map area, including its geography and general geologic setting. It also acknowledges previous work for the map area, particularly any published geologic maps. However, it should not expound on existing scientific controversies. The rationale and purpose of the map are also described here. If the description of geography is extensive, a separate section devoted to it may be provided.
2) Data: Data sets should be described that were used to construct the map base and that were needed to identify and discriminate elements of map units and features critical to the mapping. Additional data sets that were consulted should also be mentioned, along with how they benefitted the mapping (or not). Relevant parameters and descriptions that affect mapping-related understandings should be stated, including what particular subsets of data were particularly useful for mapping; examples of such include pixel or other spatial resolution, solar incidence angle, solar longitude, wavelength bands, night vs. day time acquisition of thermal data, look-direction for synthetic aperture radar data, etc. Many of the most useful data sets for planetary mapping are available from the USGS PIGWAD and Map-a-Planet web sites. Where appropriate, key data sets may be shown in supplemental figures or as GIS layers as digital products. Also, data measurements applicable to the mapping might be shown in tables (e.g., morphometric measurements of landforms, radar properties of map units, etc.).
3) Mapping methods: A variety of techniques can be employed in showing unit names, groupings, symbols, colors, and contact and feature types. The actual methods used should be clearly described and consistently applied.
   a) *Unit names:* Popular approaches to unit naming include morphologic type (e.g., 'corona material,' 'crater material'), geographic names ('Utopia Planitia material'), relative age/stratigraphic position ('lower/older crater material') and combinations thereof. Closely-related units (e.g., units in a sequence or morphologic variations of otherwise similar units) may be mapped as members (e.g., 'lower member of the

Utopia Planitia material') or units having names showing their close association with other units ('Utopia Planitia 1 unit, Utopia Planitia 2 unit…').

b) *Unit groups*: Units commonly are grouped by their geographic occurrence (e.g., 'highland materials') or morphologic type (e.g., 'lobate materials'). Capitalize only proper nouns in unit and group names (e.g., 'Alba Patera Formation,' 'Utopia basin unit,' 'western volcanic assemblage').

c) *Unit symbols:* These can indicate chronostratigraphic age (e.g., 'A' for 'Amazonian'), unit group (e.g., 'p' for 'plains materials'), specific unit designations (including morphology, albedo/reflectivity, and associated geographic feature name), and unit member (commonly as subscripts; may include numbered sequences, as in 'member 1,' 'member 2'…). Small capital letters have been used for unit groupings (e.g., 'E' for 'Elysium province'). Also, capital letters have been used for geographic names on Venus (e.g., 'fG' for 'Gula flow material'). On the geologic map, some symbols may be queried to show that the unit assignment is highly uncertain. For adding unit symbols in ArcGIS, see tutorial on Annotation & Nomenclature.

d) *Unit colors:* Unit color hues may be applied according to suitable precedents, or they may reflect the group they are in (e.g., warm colors for volcanic materials, cool colors for sedimentary rocks, yellows for crater materials, browns for ancient highland materials), or their relative age using a color spectrum for scale (e.g., Tanaka and others, 2005). Also, color saturation can reflect general areal extent of unit outcrops (low saturation for extensive units and high saturation for small units), which assists in finding smaller units. Colors must follow USGS publication guidelines, which ensure that they will print well. Generally, colors should not be changed after submission to PSC.

e) *Contact types:* The quality of contacts varies considerably on most maps. Definitions for contact types are not precisely expressed in most geologic maps, including terrestrial ones. Thus, contact types should be used as consistently as possible for a given map and they should also be defined (e.g., Tanaka and others, 2005). For example, (1) a 'certain' contact may indicate that the contact is confidently located; (2) an 'approximate' contact indicates that the confidence is not well defined (perhaps due to data quality or the surface expression of the juxtaposed units being unclear); (3) a 'buried' contact indicates that surficial material buries the contact but morphologically the contact is still traceable, although subdued; (4) a 'gradational' contact means that the contact is broadly transitional at map scale (which may reflect a gradually thinning, overlapping unit or a unit margin expressed by gradually thinning out of numerous outcrops too small to map, as in the margin of a dune field or of a field of relict knobs); and (5) an in 'inferred' contact, which may be used to delineate map units where the validity of the map unit or distinction between the units is hypothetical (e.g., the contact between the Vastitas Borealis interior and marginal units in Tanaka and others (2005) was drawn as inferred, because the marginal unit may be or may not be the same material as the interior unit).

f) *Feature types:* Mapped geologic features involving line and point symbols and stipple patterns are listed in the map symbol legend. Also, the feature table (see below) provides a format to systematically describe the features and their geologic relationships and interpretations.

g) *Drafting parameters:* Note minimum sizes of outcrops and linear features mapped, as well as the size range of features mapped with point symbols. For GIS maps, note the vertex spacing, digitizing scale, line smoothing methods, and any other important digital controls and processing applied.

4) Age determinations: Techniques and reliability of relative and absolute-age determinations for map units should be discussed, as they vary widely according to data quality and preservation and exposure state of key features. These include superposition and cross-cutting relations and crater densities. For quantitative approaches, error analysis should be included. As absolute-age models are based both on cratering theory, lunar sample dating, and empirical data on bolide populations, they are subject to high uncertainty. Appropriate references should be used throughout. Where possible, crater statistics can be summarized in the unit stratigraphic relations table described below.

5) Geologic history: A summary of the geologic history of a map region serves to provide a context for the entire geologic map and is encouraged. The synthesis is intended to be a brief yet informative review of unit development, tectonic deformation, and erosional and other modifications of the surface and shallow subsurface, with first-order interpretations on geologic and climate process histories as appropriate. However, lengthy considerations of previous and new hypotheses and other interpretive discussions that go beyond immediate mapping results and implications are to be left out.

6) References: The list of references and reference citations in the text follows USGS style guidelines; see published maps and this handbook for examples. Note that for more than 5 authors in a reference, only the first 3 are listed and "and x others" substitutes the number of unlisted authors for their names (see reference for Tanaka and others, 1994). Also, note formats for commonly used conference publications in the reference list below, as follows: *American Geophysical Union meeting abstract*: Banerdt, 2000; *Lunar and Planetary Science Conference abstract*: Skinner and Tanaka, 2003; *NASA Technical Memorandum abstract*: Grant, 1987; *edited NASA Special Publication*: Howard and others, 1988; *book chapter*: Wilhelms, 1990; *web-posted geologic map*: Young and Hansen, 2003.

7) DMU table: To simplify map texts, the Description of Map Units (DMU) table now forms a concise description of the map units, their stratigraphic relations, interpretation, and other pertinent information (previously, most planetary geologic maps provided a separate, stratigraphic narrative resulting in redundant information in the two sections). The DMU table will consist of four columns of information for each unit:
   a) *Unit symbol and name*
   b) *Definition:* Defining, primary characteristics essential to identifying and delineating each map unit from all others. In most cases, 2 to 5 characteristics define a unit, including aspects such as morphology/texture, albedo/reflectivity/spectral character, stratigraphic position or relative age, relative elevation, regional occurrence, and source feature. Where not obvious, mention the critical data sets. Type localities are optional and should be placed at the end of the definition.
   c) *Additional characteristics:* Brief discussion of additional aspects such as relation to units in previous and adjacent maps, local anomalies in unit character, and prominent secondary features (that may obscure or be partly controlled by primary features).
   d) *Interpretation:* Interpreted unit origin focusing mainly on origin of primary features and stratigraphic relationships; secondary features may also be discussed as they

relate to the unit (i.e., fracture systems related to contraction, compositional information relating to surface alteration, etc.); and model crater absolute age (optional). As maps are meant to be enduring products, the interpretations should be inclusive of all reasonably possible alternatives, and wording should reflect the degree of uncertainty (e.g., 'lava flows' vs. 'possible lava flows' vs. 'uncertain; may be lava flows, pyroclastic or impact-related deposits, or tabular sedimentary deposits').

8) Unit stratigraphic relations table: For each unit, show total areal extent in map area and relative-age relations (younger, older, similar in age, or younger and older) for every adjacent unit. Where crater density data are available, show helpful crater density values, including standard deviations. Additional columns can be used for assigned chronologic units and model crater absolute ages. Use footnotes to explain abbreviations used and other important details.
9) Feature table(s): Additional tables can be added as needed to describe the characteristics, relationships, and interpretation of other mapped features, such as tectonic structures, volcanic features, erosional and modificational features, surficial materials, and impact craters.
10) Additional tables: Other useful map information can often be summarized in a table for easier reference and comparisons, such as quantitative aspects of map units, their appearance in specific image data sets, etc.
11) Figures: Figures typically will not be included in the pamphlet. See digital data and map sheet components sections for formatting and possible placement.
12) Digital supplement table: All materials appearing in a digital supplement should be listed in a summarized fashion, such as data and mapping layers, measurements and statistics, and figures.

c. Digital data products. Authors are encouraged to make use of digital repositories for useful ancillary data products and figures. When in GIS form, the products are more accessible to researchers via digital tools and methods. Map authors should follow all guidelines, so that modifications using the original digital files by the USGS Production Cartographer and perhaps other specialists will be minimal in order to meet publication standards.

1) Supplemental figures: These may include, for example, a few reduced-scale images of the map region showing key data sets, distributions of key features, contact relationships, and geologic cross sections. However, additional, digital-only figures can be used generously to show unit characteristics, superposition relations, crater size-frequency distributions, and secondary features as desired. Images, image mosaics, and thematic maps should include in the caption or on the figure as appropriate the data source, type, and resolution (e.g., 'THEMIS daytime infrared mosaic at 100 m/pixel'), solar/incoming energy incidence angle and azimuth, north direction, scale bar (or image width), and latitude/longitude grid. Figures should be prepared at intended publication size with consistent label font types and sizes.
2) GIS layers: For GIS maps, authors can construct raster and vector data layers that are georegistered to map bases as digital-only supplements. These can be used to effectively show ancillary data sets and detailed feature mapping.

3) GIS maps: USGS GIS specialists will convert map files and supplemental figures and GIS layers as needed to conform to USGS geodatabase and FGDC metadata standards. GIS data supplements will be served via the web.
4) On-line map: The map, text, and supplemental figures will be converted to pdf format and made available for download via a USGS server and web page by the USGS PSC. GIS products, if available, will also be included for download.

5. REFERENCES

Banerdt, W.B., 2000, Surface drainage patterns on Mars from MOLA topography: Eos, Transactions of the American Geophysical Union, fall meeting supplement, v. 81, no. 48, Abstract #P52C–04.

Grant, J.A., 1987, The geomorphic evolution of eastern Margaritifer Sinus, Mars, *in* Advances in planetary geology: Washington, D.C., National Aeronautics and Space Administration Technical Memorandum 89871, p. 1–268.

Hackman, R.J., 1962, Geologic map and sections of the Kepler region of the Moon: U.S. Geological Survey Miscellaneous Geologic Investigations I-355 (LAC-57), scale 1:1,000,000.

Hansen, V.L., 2000, Geologic mapping of tectonic planets: Earth and Planetary Science Letters, v. 176, p. 527-542.

Hare, T.M., Kirk, R.L., Skinner, J.A., Jr., and Tanaka, K.L., 2009, Chapter 60: Extraterrestrial GIS, *in* Madden, Marguerite, ed., Manual of Geographic Information Systems: Bethesda, The American Society for Photogrammetry and Remote Sensing, p. 1199-1219.

Howard, A.D., Kochel, R.C., and Holt, H.E., eds., 1988, Sapping features of the Colorado Plateau—A comparative planetary geology field guide: Washington, D.C., National Aeronautics and Space Administration Special Publication, NASA SP-491, 108 p.

Price, K.H., 1998, Geologic map of the Dao, Harmakhis, and Reull Valles region of Mars: U.S. Geological Survey Geologic Investigations Map I-2557, scale 1:1,000,000.

Shevchenko, V., El-Baz, F., Gaddis, L., and 5 others, 2009, The IAU/WGSPN Lunar Task Group and the status of lunar nomenclature [abs.], *in* Lunar and Planetary Science Conference XV: Houston, Tex., Lunar and Planetary Science Institute, Abstract #2016, [CD-ROM].

Skinner, J.A., Jr., and Tanaka, K.L., 2003, How should planetary map units be defined? [abs.], *in* Lunar and Planetary Science Conference XXXIV: Houston, Tex., Lunar and Planetary Science Institute, Abstract #2100, [CD-ROM].

Tanaka, K.L., Moore, H.J., Schaber, G.G., and 9 others, 1994, The Venus geologic mappers' handbook: U.S. Geological Survey Open-File Report 94-438, 66 pp.

Tanaka, K.L., Skinner, J.A., Jr., and Hare, T.M., 2005, Geologic map of the northern plains of Mars: U.S. Geological Survey Science Investigations Map 2888, scale 1:15,000,000.

Tanaka, K.L., Anderson, R., Dohm, J.M., and 5 others, in press, Planetary structural mapping, *in* Watters, T., and Schultz, R., eds., Planetary Tectonics: New York, Cambridge University Press.

Varnes, D.J., 1974, The logic of geological maps, with reference to their interpretation and use for engineering purposes: U.S. Geological Survey Professional Paper 837, 48 pp.

Young, D.A., and Hansen, V.L., 2003, Geologic map of the Rusalka Planitia quadrangle (V–25), Venus: U.S. Geological Survey Geologic Investigations Series, I–2783, scale 1:5,000,000 [http://pubs.usgs.gov/imap/i2783/].

Wilhelms, D.E., 1972, Geologic mapping of the second planet: U.S. Geological Survey Interagency Report, Astrogeology, v. 55, 36 pp.

Wilhelms, D.E., 1990, Geologic mapping, *in* Greeley, R, and Batson, R.M., eds., Planetary Mapping: New York, Cambridge University Press, p. 208-260.

6. USEFUL WEB PAGES

FGDC (Federal Geographic Data Committee) Digital Cartographic Standard for Geologic Map Symbolization: http://ngmdb.usgs.gov/fgdc_gds/geolsymstd.php

IAU Gazetteer of Planetary Nomenclature home page: http://planetarynames.wr.usgs.gov/

IAU Gazetteer of Planetary Nomenclature descriptor terms: http://planetarynames.wr.usgs.gov/jsp/append5.jsp

IAU Gazetteer of Planetary Nomenclature feature name request form: http://planetarynames.wr.usgs.gov/jsp/request.jsp

NASA MEPAG calendar: http://mepag.jpl.nasa.gov/calendar/index.html

NASA research opportunities: http://nspires.nasaprs.com

USGS Planetary Geologic Mapping: http://astrogeology.usgs.gov/Projects/PlanetaryMapping/

USGS Planetary Interactive GIS on-the-Web Analyzable Database (PIGWAD): http://webgis.wr.usgs.gov/

USGS Map-a-Planet: http://www.mapaplanet.org/

USGS PSC author submission checklist for planetary maps: http://astrogeology.usgs.gov/Projects/PlanetaryMapping/guidelines/PSC_author_checklist_7-20-09.pdf

USGS Astrogeology manuscripts to PSC submission process: http://astrogeology.usgs.gov/Projects/PlanetaryMapping/guidelines/AstroSubmitProcess_june2009.pdf

USGS tips and information for preparation of astrogeology maps: http://astrogeology.usgs.gov/Projects/PlanetaryMapping/guidelines/preparationTips.pdf

USGS instructions on building polygons in Illustrator: http://astrogeology.usgs.gov/Projects/PlanetaryMapping/guidelines/layersexample_small.pdf

7. PLANETARY GEOLOGIC MAPPING SUPPORT PERSONNEL

Position/Function	Name	Email	Institution
Map Coordinator	Ken Tanaka	ktanaka@usgs.gov	USGS ASC
GIS Data Specialist	Trent Hare	thare@usgs.gov	USGS ASC
GIS Project Specialist	Jim Skinner	jskinner@usgs.gov	USGS ASC
Map base Specialist	Bob Sucharski	bsucharski@usgs.gov	USGS ASC
Nomenclature Specialist	Jen Blue	jblue@usgs.gov	USGS ASC
PGM Administrative Specialist	Jen Blue	jblue@usgs.gov	USGS ASC
Regional Planetary Image Facility Director	Justin Hagerty	jhagerty@usgs.gov	USGS ASC
Regional Planetary Image Facility Manager	David Portree	dportree@usgs.gov	USGS ASC
Digital Map Editor	Jan Zigler	jzigler@usgs.gov	USGS PSC
Production Cartographer	Darlene Ryan	dryan@usgs.gov	USGS PSC
Map Submission Editor	Carolyn Donlin	cdonlin@usgs.gov	USGS PSC
GEMS Chair	Leslie Bleamaster	lbleamas@psi.edu	NASA PGG
Discipline Scientist	Michael Kelley	Michael.S.Kelley@nasa.gov	NASA PGG

8. ABBREVIATIONS

ASC	Astrogeology Science Center (part of USGS)
CMU	Correlation of Map Units
DMU	Description of Map Units
FGDC	Federal Geographic Data Committee
GEMS	Geologic Mapping Subcommittee (of PCGMWG)
GIS	geographic information system
GPO	Government Printing Office
IAU	International Astronomical Union
MC	Map Coordinator
NASA	National Aeronautics and Space Administration
PCGMWG	Planetary Cartography and Geologic Mapping Working Group (part of PGG)
PEN	Planetary Exploration Newsletter
PGG	Planetary Geology and Geophysics Program
PGM	planetary geologic mapping
PIGWAD	Planetary Interactive GIS on-the-Web Analytical Database
PSC	Publications Services Center
SMU	Sequence of Map Units
USGS	U.S. Geological Survey

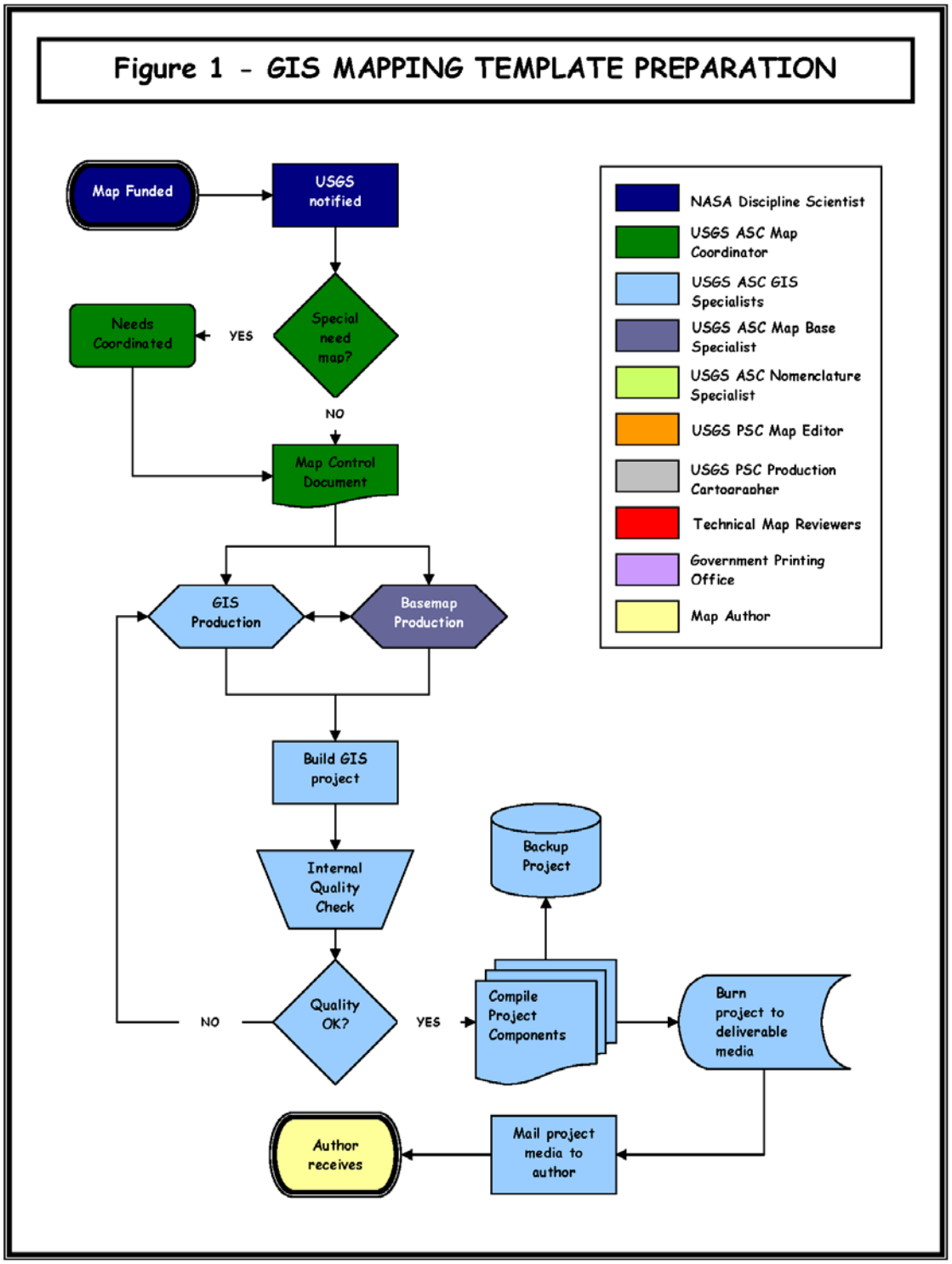
Figure 1 - GIS MAPPING TEMPLATE PREPARATION
Map Funded
USGS notified
Special need map?
YES
Needs Coordinated
NO
Map Control Document
GIS Production
Basemap Production
Build GIS project
Internal Quality Check
Quality OK?
NO
YES
Backup Project
Compile Project Components
Burn project to deliverable media
Mail project media to author
Author receives
NASA Discipline Scientist
USGS ASC Map Coordinator
USGS ASC GIS Specialists
USGS ASC Map Base Specialist
USGS ASC Nomenclature Specialist
USGS PSC Map Editor
USGS PSC Production Cartographer
Technical Map Reviewers
Government Printing Office
Map Author

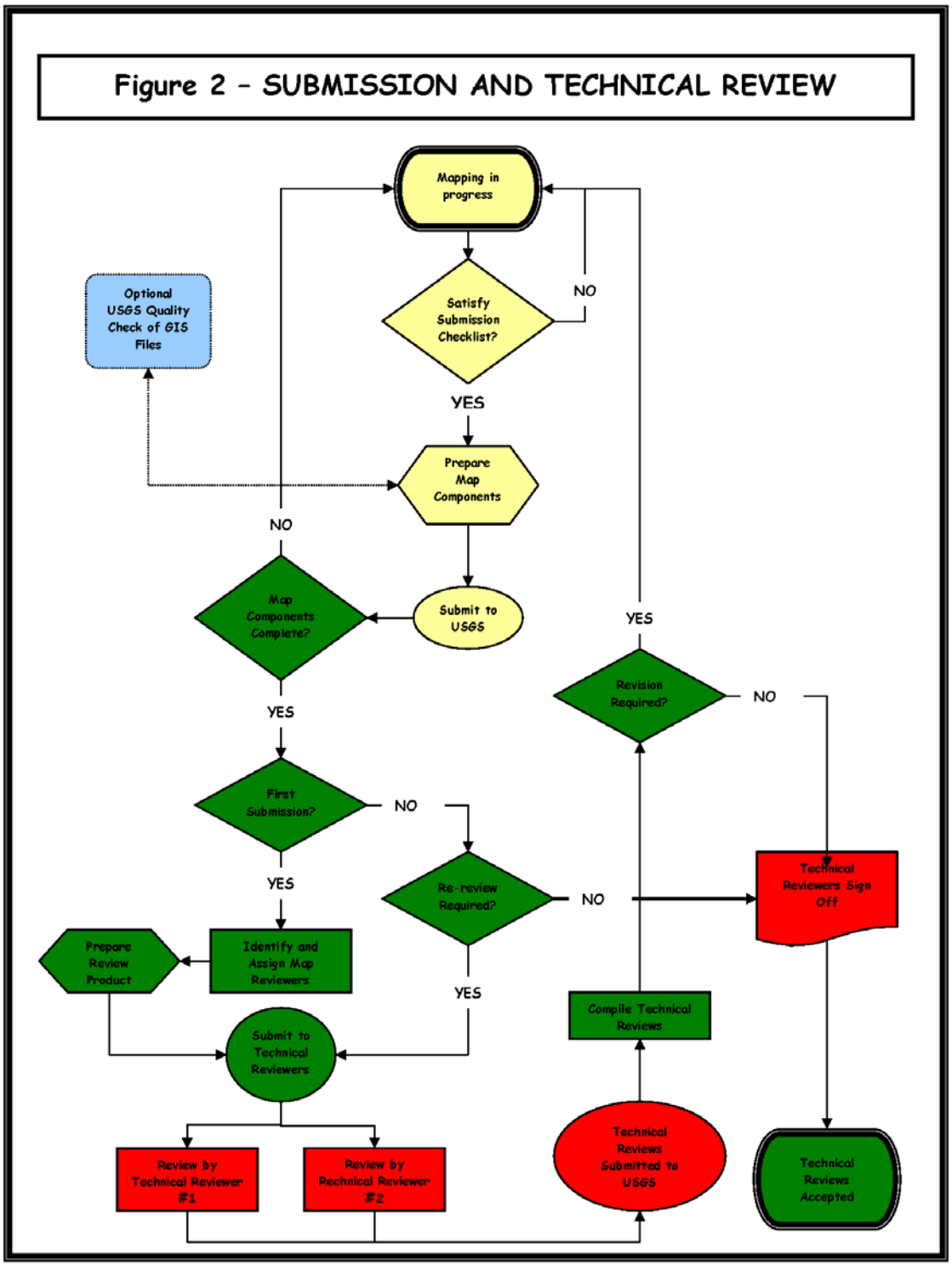
Figure 2 – SUBMISSION AND TECHNICAL REVIEW
Mapping in progress
Satisfy Submission Checklist?
NO
YES
Optional USGS Quality Check of GIS Files
Prepare Map Components
NO
Map Components Complete?
Submit to USGS
YES
Revision Required?
NO
YES
First Submission?
NO
YES
Re-review Required?
NO
Technical Reviewers Sign Off
Prepare Review Product
Identify and Assign Map Reviewers
YES
Compile Technical Reviews
Submit to Technical Reviewers
Technical Reviews Submitted to USGS
Review by Technical Reviewer #1
Review by Rechnical Reviewer #2
Technical Reviews Accepted

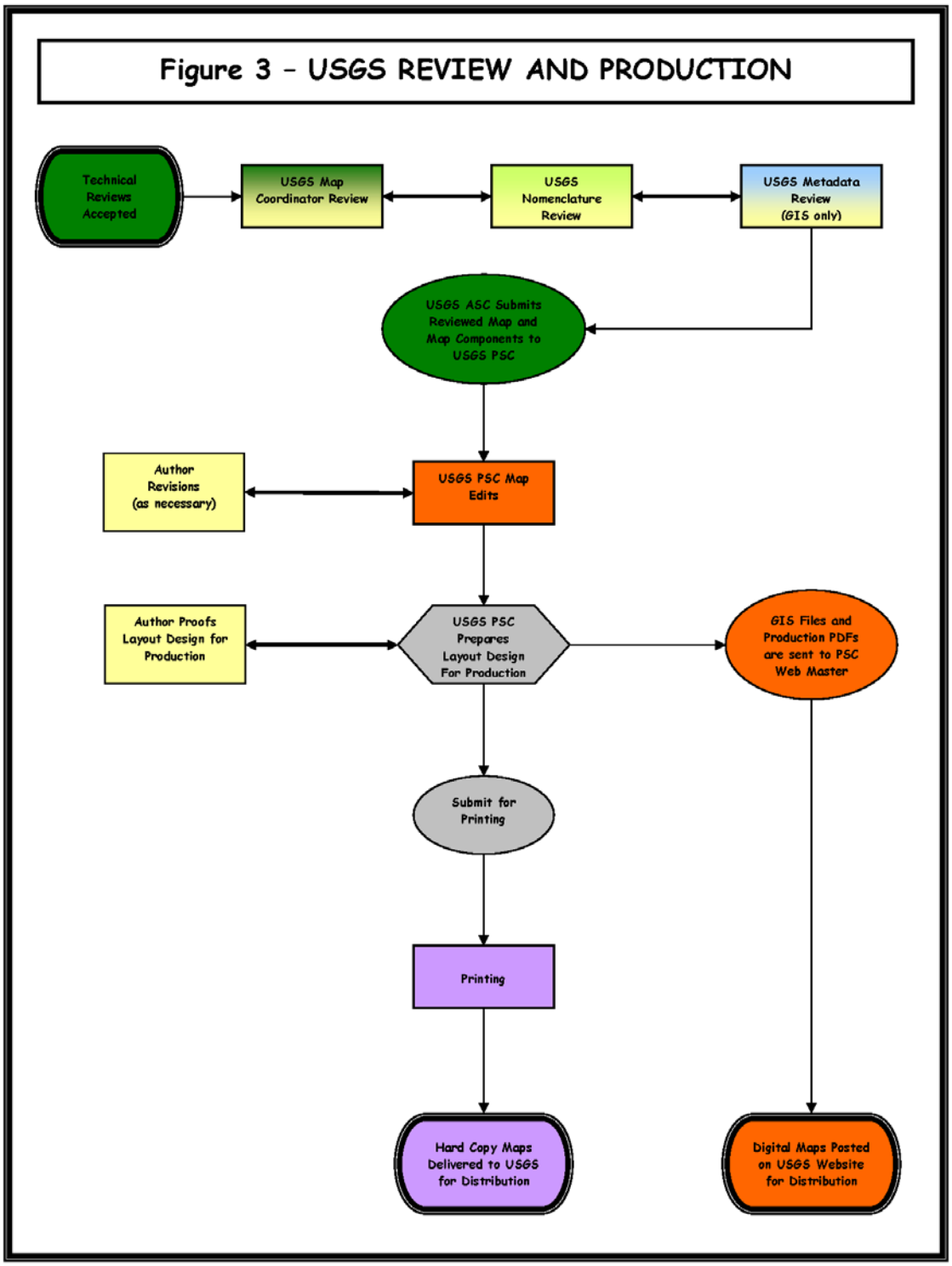
Figure 3 – USGS REVIEW AND PRODUCTION
Technical Reviews Accepted
USGS Map Coordinator Review
USGS Nomenclature Review
USGS Metadata Review (GIS only)
USGS ASC Submits Reviewed Map and Map Components to USGS PSC
Author Revisions (as necessary)
USGS PSC Map Edits
Author Proofs Layout Design for Production
USGS PSC Prepares Layout Design For Production
GIS Files and Production PDFs are sent to PSC Web Master
Submit for Printing
Printing
Hard Copy Maps Delivered to USGS for Distribution
Digital Maps Posted on USGS Website for Distribution

Figure 4 – FLOWCHART SYMBOL DEFINITIONS

Symbol	Symbol Name	Symbol Description and Example Activity
	Terminator	Terminators show the start and stop points in a process flow. *A proposed map is accepted for funding.*
	Process	A process or action step, perhaps comprised of multiple segmented actions. *Layout and proofing of final map.*
	Alternate Process	A process or action step that is an alternate (or option) to normal process flow. *Preparation of non-standard map base.*
	Decision	Indicates a critical question or branch in the process flow. *Does the submitted map adhere to submission requirements?*
	Preparation	Any step that is substantially comprised of preparation and/or collation of digital and/or hard copy product. *Creation of map base.*
	Manual Operation	Any step that is substantially comprised of manual (non-automated) input. *Map reviews.*
	Document	Any process flow step that results in the creation of a critical document. *Map Control Document.*
	Multi-document	Any process flow step that results in the creation of a critical package of documents. *Prepare Review Package.*
	Copy to digital media	Any process flow step that results in the creation of (transitory) digital copy. *Copy to DVD for review.*
	Back-up	Any process flow step that results in the creation of permanent digital copy. *Copy to map base to USGS hard-drive.*
	Shipping/Delivery	Denotes process step comprised of packaging, shipping, or delivery. *Submit map project to USGS.*

Form 9-1325
(revised, August 2006)
USGS

INFORMATION PRODUCT REVIEW AND APPROVAL SHEET

SCIENCE CENTER
Yucca Mountain Project Branch

INFORMATION PRODUCT TRACKING NO.
IP-

AUTHOR(S): (last name first; show first name and(or) initials as shown in manuscript)

TEMPLATE! SAVE AS: your document filename_RAS
in X: Publications/From Authors folder (write access granted)

SCIENCE CENTER CONTACT:
(name, address, telephone, fax, email)
Pamela B. Daddow
U.S. Geological Survey
Box 25046 MS 421 DFC Building 53
Denver, Colorado 80225
303-236-5050, ext. 249 Fax 303-236-5047
pbdaddow@usgs.gov

TITLE:

FORM OF PUBLICATION

USGS series

- [ ] Administrative Report
- [ ] Circular
- [ ] Data Series
- [ ] Fact Sheet
- [ ] General Information Product
- [ ] Open-File Report
- [ ] Professional Paper
- [ ] Scientific Investigations Map
- [ ] Scientific Investigations Report
- [ ] Techniques and Methods

- [ ] Outside information product
  - [ ] Edit requested
  - [ ] No edit requested
- [ ] Abstract

PUBLISHER, JOURNAL, OR MEETING:

Format

- [ ] Print
- [ ] CD-ROM
- [ ] WWW
- [ ] Video
- [ ] Print on Demand
- [ ] Other

Check all of above that apply

TOTAL PAGES (including title page and all page-size figures and tables) _____

_____ **TABLES COVERING** _____ **PAGES**

NUMBER OF ILLUSTRATIONS:

Color	*B&W*	
_____	_____	Line drawings
_____	_____	Photographs
_____	_____	Plates

IF PART OF A MULTICHAPTER USGS PUBLICATION:

Total number of chapters [ ] To be published [ ] Together [ ] Separately

DEADLINE:

ARE GEOLOGIC NAMES USED? IF YES, REVIEW REQUIRED. Yes [ ] No [ ]

SUPERSEDES OPEN-FILE REPORT? No [ ] Yes, number: _____

REMARKS: (with initials, add additional pages if needed)

PUBLICATION CONTENTS

- [ ] New interpretive
- [ ] Previously approved interpretive
- [ ] Noninterpretive

NAME, TITLE, AFFILIATION	DATE IN	DATE OUT (indicate hours spent)	CHECK PROCESSING STEP WITH "X"									SIGNATURE (or attach e-mail)
			Author Submission	Supervisor Approval	Peer Review	Technical Specialist Review	Office of Communications Review	Science Center Approval	Editorial Review	PSC Approval	Bureau Approval	

CONTINUE ON ADDITIONAL FORMS IF NECESSARY

Figure 5: USGS Information Product Review and Approval Sheet.

INSTRUCTIONS FOR AUTHORS

- Map Submission -

In an effort to continue refining and streamlining the geologic map review and publication process, the NASA Planetary Geology and Geophysics (PGG) Program's Geologic Mapping Subcommittee (GEMS), in conjunction with the USGS Astrogeology Science Center, provides guidelines and checklists for formal map submission. For detailed explanations of the following map components, please see the most recent version of the GEMS-endorsed Planetary Geologic Mapping Handbook:
http://astrogeology.usgs.gov/Projects/PlanetaryMapping/guidelines/

COVER LETTER – A signed and dated cover letter should be included addressed to USGS Map Coordinator Ken Tanaka to serve as the indicator of formal map submission. The map title, author, and scale should be indicated therein.

COVER INFORMATION – A cover page should be included with the map text that denotes map title, authors, USGS SIM series, scale, contact, and lineage (*e.g.*, date submitted, date re-submitted). Below is an example of the cover information.

Geologic Map of the Willy Nilly Region (MTM 12345), Mars

By John A. Smith and Jane B. Jones

U.S. Geological Survey Scientific Investigations Map SIM xxxx (TBD)

Scale 1:1,000,000

Contact:
John A. Smith
Planetary Research Institute
1234 Elm Street
Sunny, CA 12345

EXAMPLE

LIST OF COMPONENTS – The cover page should be followed by a page listing text and map components that are being submitted. Below is an example of the component list, which should be used as a guide for compiling the text and map.

Geologic Map Text
- Introduction
- Physiographic Setting
- Map Base and Data
- Methodology
- Geologic Summary
- References
- Description of Map Units

Table(s)
Figure Captions

Map Sheet
Colored and annotated geologic map
Correlation of Map Units (COMU)
Explanation of Map Symbols (EOMS)
Pamphlet Cover/Geologic map context [optional]
Figure(s)
Cross-sections [optional]

EXAMPLE

NOMENCLATURE – Map author is encouraged to include IAU-approved nomenclature as a GIS layer to the geologic map prior to map submission. Please contact USGS for assistance (Jen Blue, jblue@usgs.gov).

FILE FORMATS – Text components should be submitted for external and editorial review as Word documents (*.doc or *.docx preferred) or some other editable digital format. Map components should be submitted as Adobe PDF documents (*.pdf) and ArcGIS files (see example below). Please contact USGS for assistance.

FILE NAMES – Consistent file names assist with organization, review, and lineage tracking. Each text and map component file should be identified by (1) **component**, (2) **author initials**, and (3) **date**. For example, for a Correlation of Map Unit submitted by John A. Smith on May 15, 2011, the file should be in Microsoft Word format (*.doc or *.docx) and named "COMU_JAS_5-15-11". Below is an example list of file structures and naming conventions.

FILE STRUCTURE – Files should be organized into an intuitive directory tree for delivery to USGS for external and editorial review. These should include not only the text and map components but also the complete set of GIS files. An example structure is located below (folders are shown in **bold**).

MTM12345_500K_GEOMAP <top level folder>
- **Geologic_Map_Text** <second level folder>
  - DOMU_JAS_5-15-11.docx <file>
  - MapText_JAS_5-15-11.docx <file>
  - Table1_JAS_5-15-11.docx <file>
  - Table2_JAS_5-15-11.docx <file>
  - FigureCaptions_JAS_5-15-11.docx <file>
- **Map_Sheet** <second level folder>
  - **COMU** <third level folder>
    - COMU_JAS_5-15-11.pdf <file>
  - **EOMS** <third level folder>
    - EOMS_JAS_5-15-11.pdf <file>
  - **Figures** <third level folder>
    - Figure1_JAS_5-15-11.pdf <file>
    - Figure2_JAS_5-15-11.pdf <file>

Figure3_JAS_5-15-11.pdf <file>
GeoMap <third level folder>
MTM85200_500K_JAS_5-15-11.pdf <file>
GIS_Files <third level folder>
BaseMaps <fourth level folder>
LayerFiles <fourth level folder>
MTM12345_1M.gdb <ArcGIS geodatabase>
MTM12345_1M.mxd <ArcGIS project>

EXAMPLE

SUBMISSION PACKAGE – The author is responsible for compiling the full map submission package, as outlined above and in the Planetary Geologic Mapping Handbook, and conveying that package in full to the USGS Map Coordinator. Map packages can be delivered either via FTP sites or as a CD/DVD. Delivery method should be worked out in connection with the USGS Map Coordinator. No hard-copy maps are required, as these will be printed and delivered to reviewers by USGS as needed.

DIGITAL TEMPLATES – Digital templates are available as guidelines for tables and the Correlation of Map Units. These can be downloaded at the following link:

http://astrogeology.usgs.gov/Projects/PlanetaryMapping/

USGS CONTACT INFORMATION - Please contact the USGS Astrogeology Science Center using information provided below for assistance or clarification.

Map Coordinator: Ken Tanaka (ktanaka@usgs.gov)
GIS Data Specialist: Trent Hare (thare@usgs.gov)
GIS Project Specialist: Jim Skinner (jskinner@usgs.gov)
GIS Project Specialist: Corey Fortezzo (cfortezzo@usgs.gov)
Nomenclature Specialist: Jen Blue (jblue@usgs.gov)