NASA's Planetary Geologic Mapping Program: Overview

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MAPPING AND PLANETARY SPATIAL INFRASTRUCTURE TEAM

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INTRODUCTION

- Why Planetary Geologic Mapping
- Advantages of Planetary Mapping
- History of Planetary Map production (USGS)
- Current Organization: GEMS & MAPSIT
- NASA Funding: Planetary Mapping
- Current Map Production Approach & Techniques
- Summary

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WHY PLANETARY GEOLOGIC MAPPING?

"On first examining a new district [planet] nothing can appear more hopeless than the chaos of rocks [landforms]; but by recording the stratification and nature of rocks [morphology, superposition & crosscutting relations] at many points, always reasoning and predicting what will be found elsewhere, light soon begins to dawn on the district [planet], and the structure of the whole becomes more or less intelligible."

Charles Darwin, autobiography (1958)
(w/paraphrasing by J.F. McCauley & J.M. Moore)

"… a geological map is like a graph to a physicist: it allows one to understand many observations in a comprehensive form that would be more difficult without it."

John Guest, Principles of Extraterrestrial Geologic Mapping (1974)

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WHY PLANETARY GEOLOGIC MAPPING?

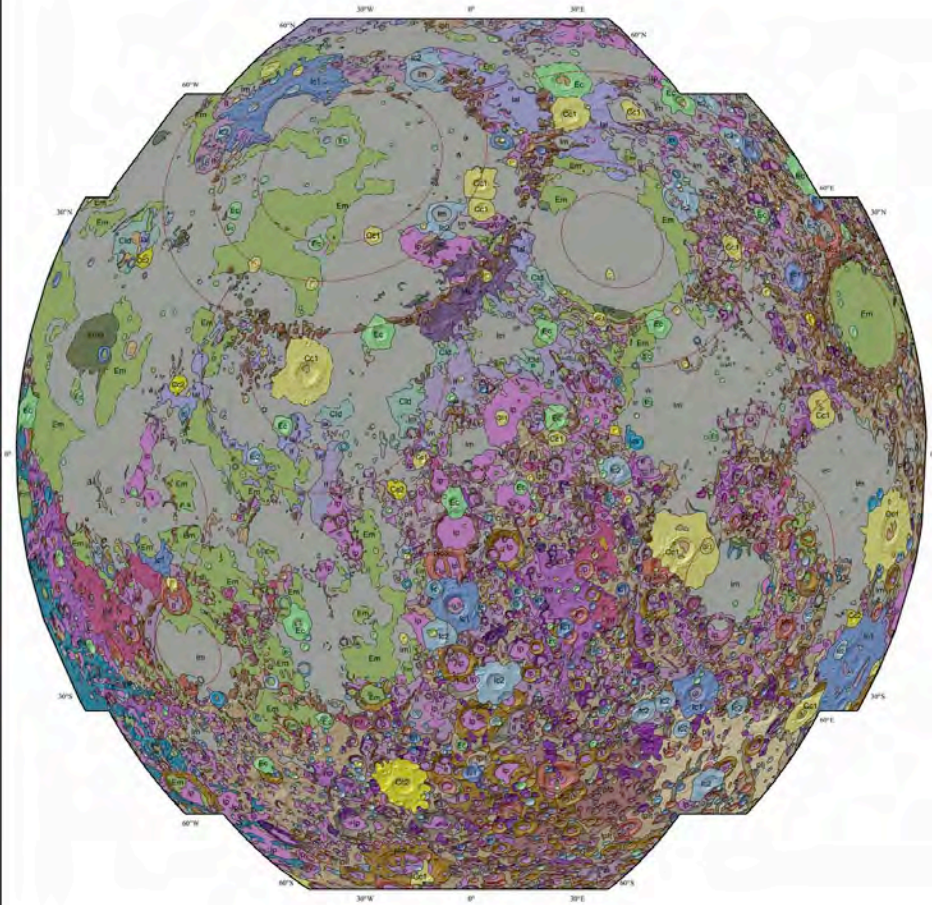
- Geologic mapping documents main geologic units and features and their relative ages and other characteristics. These form the basis for the recognition of major resurfacing events and processes operative on planetary surfaces through time

Specific accomplishments include:

- 1. Documentation of the geological evolution of Earth's Moon. This knowledge served to guide sampling and interpretation of Apollo rock sample. Radiometrically dated surfaces that were mapped and crater counted established lunar chronology and a stratigraphic system

I-703: Geologic Map of the Near-Side of the Moon
Wilhelms and McCauley, 1971

Shown at 1:10,000,000-scale

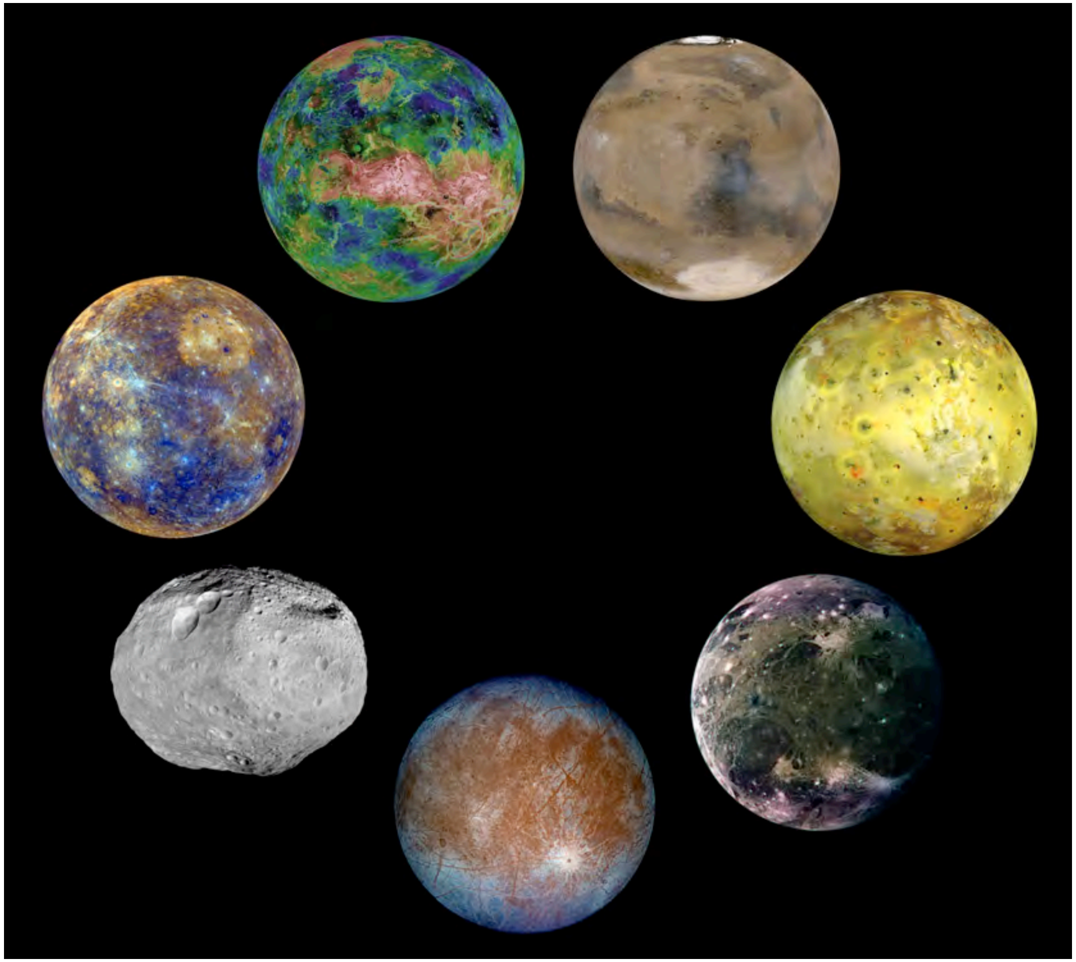


WHY PLANETARY GEOLOGIC MAPPING?

- 2. Documentation of the geological evolution of other solid surface planetary bodies imaged by spacecraft, including Mars, Venus, Mercury, the Galilean satellites, and other outer solar system bodies

  For example, documentation of the diverse geological evolution of Mars via mapping is regarded by MEPAG as no. 2 in its top 10 list of science discoveries:

  http://mepag.jpl.nasa.gov/science/2_Complex_Surface_Geology/index.html



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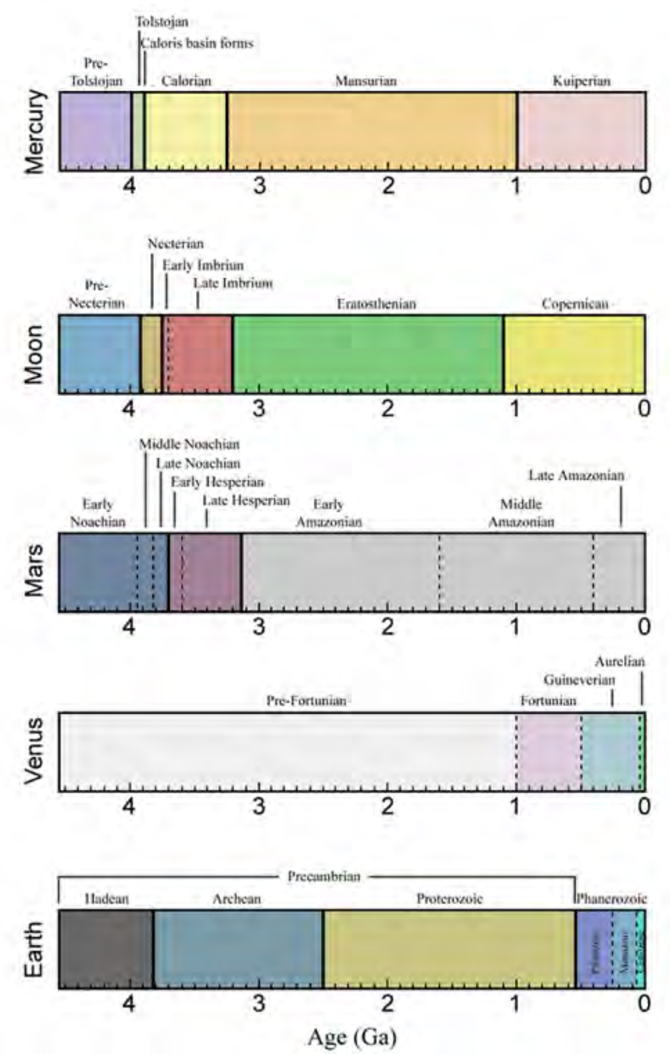
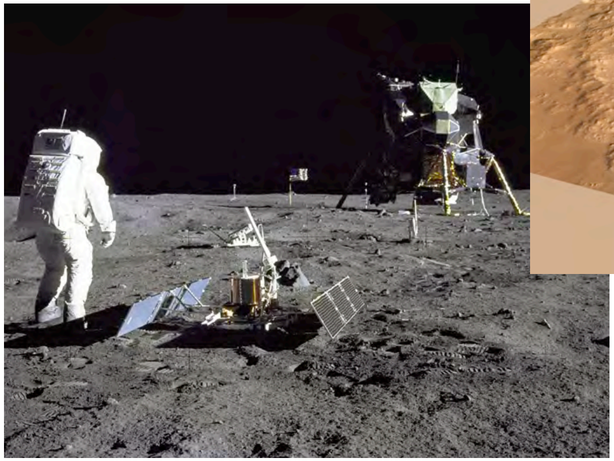
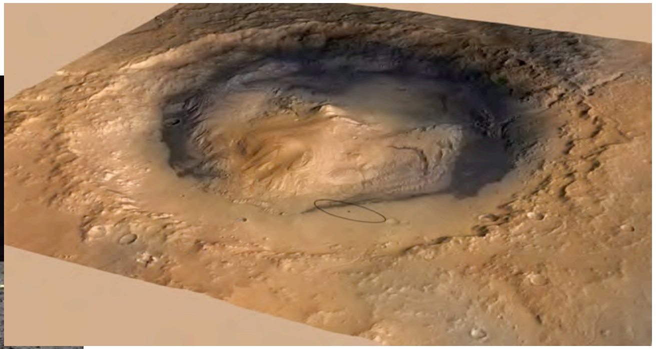
WHY PLANETARY GEOLOGIC MAPPING?

- 3. Based on estimated impact rates, terrestrial planetary surfaces can be dated with model ages. This produced the first planetary time scale, which is now published in The Geologic Time Scale 2012.

- 4. Geologic mapping has been performed for landing site selection and characterization for numerous landing sites on the Moon and Mars.







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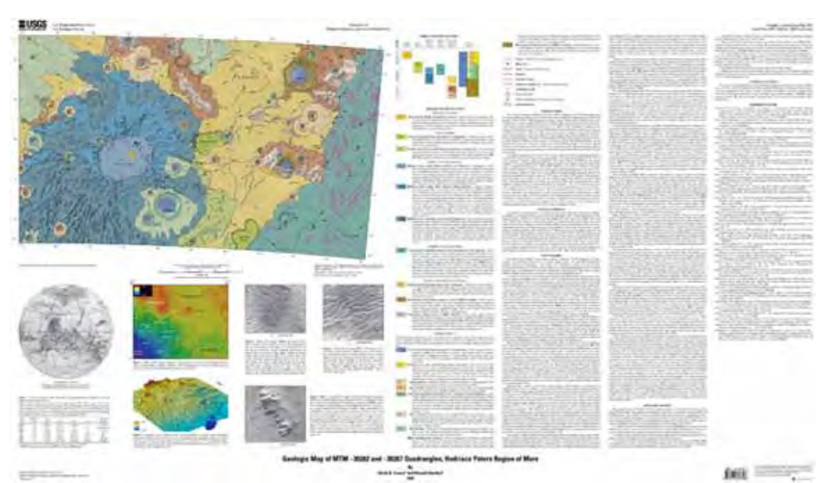
ADVANTAGES of PLANETARY MAPPING

- The advantage of geologic mapping over photogeological studies alone is that it reduces the complexity of heterogeneous planetary surfaces into comprehensible proportions through interpretation
- The distributions of these units are then mapped, along with visible structural features, in order to identify the relative roles of impact cratering, volcanic, tectonic and gradational processes in shaping their surfaces.
- Geologic mapping has aided in the understanding of the processes that produced compositionally-distinct materials observed on many planetary bodies, and generally chemical and physical analyses of a given site on a planetary body can be investigated far better if the geologic setting of the site is known first



HISTORY of PLANETARY MAP PRODUCTION

- With advent of planetary exploration by NASA in 1960s, recognized need for geologic maps of the Moon to prepare for Apollo crewed landings
- NASA collaboration with US Geological Survey geologists for map production and coordination
- Lunar quadrangle system established & LAC maps made using telescopic & Lunar Orbiter images
- Nearside map completed (Wilhelms & McCauley 1971)
- As each new planetary object has been imaged, lower resolution global maps followed by higher resolution quadrangle map series were made:
  - 1960s-70s: Moon (Lunar Orbiter), Mercury (Mariner 10), Mars (Mariner 9)
  - 1980s-90s: Mars (Viking), Venus (Magellan)
  - 1990s-2000s: Galilean satellites (Voyager, Galileo), Mars landing sites (MER)
  - 2000s-10s: Saturnian satellites (Cassini), Vesta & Ceres (Dawn), Comet 67P/C-G (Rosetta), Mercury (MESSENGER), Moon (LRO), Pluto & Charon (New Horizons)
- With time, greater desire to make maps during nominal portion of active flight missions

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CURRENT ORGANIZATION: GEMS & MAPSIT

- *Image mosaics, DTMs, geologic maps, derived regional & global data products, & associated geospatial infrastructure are integral to the success of the planetary science enterprise*
  - Science investigations and mission operations for all Solar System bodies
  - Influences all phases of the mission lifecycle

- Strategic needs must be anticipated and prioritized by the community, requiring a NASA-sanctioned analysis group

- Mapping & Planetary Spatial Infrastructure Team (MAPSIT)
  - MAPSIT succeeds PCGMWG and assumes strategic planning role

- MAPSIT's Geologic Mapping Subcommittee (GEMS) advises on NASA planetary geologic mapping program
  - GEMS collects PG Mapping community concerns, issues findings, advises NASA on mapping issues

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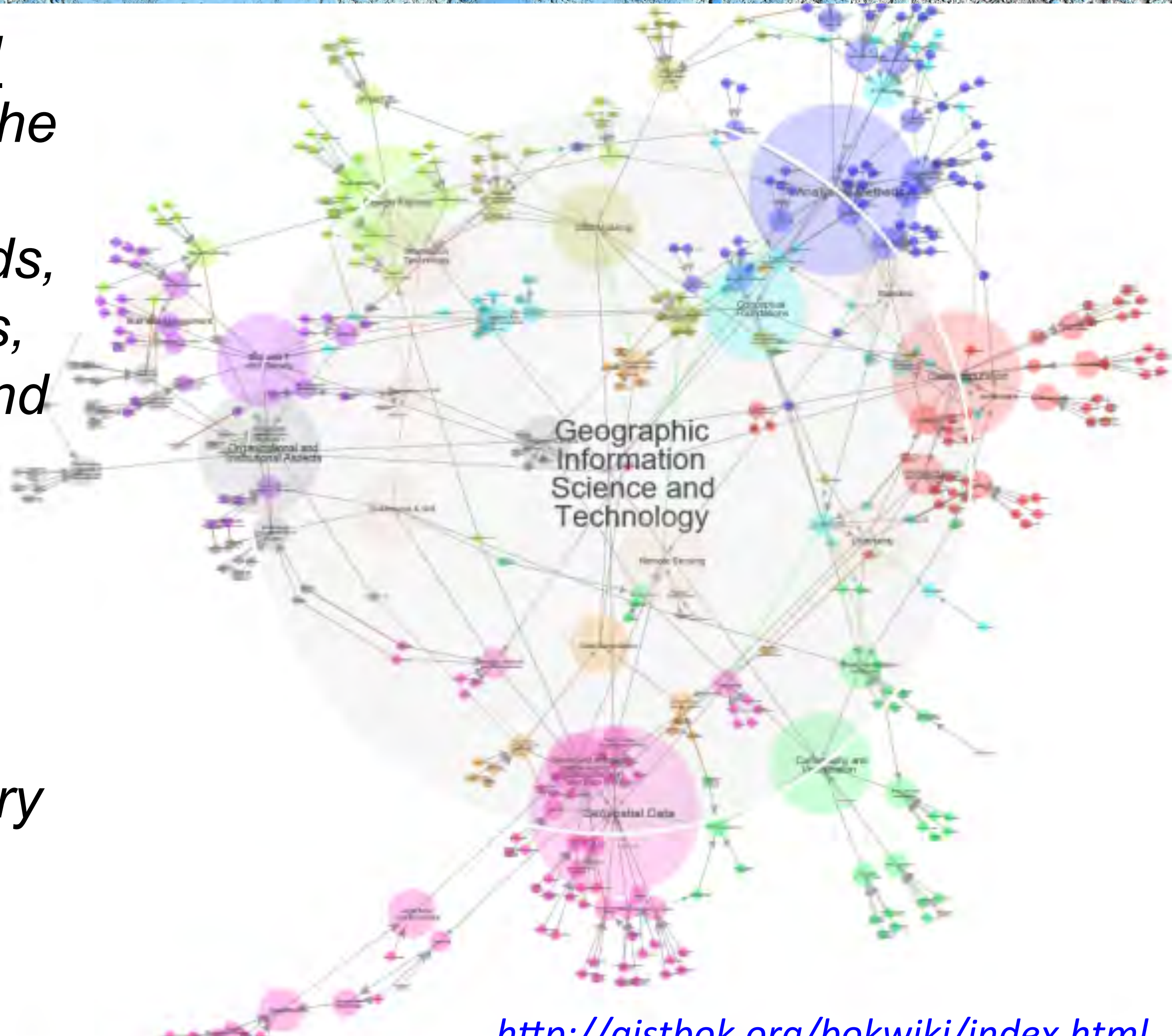
ENABLING PLANETARY SCIENCE

- *Planetary Spatial Infrastructure* is the *technology, policies, standards, human resources, software tools, and related activities necessary to acquire, process, distribute, use, maintain, and preserve planetary spatial data for science and exploration*



http://gistbok.org/bokwiki/index.html

CURRENT ORGANIZATION: GEMS & MAPSIT

- Jani Radebaugh, Brigham Young University [Chair]
- Brad Thomson, Boston University [Vice-Chair]
- Shane Byrne, University of Arizona
- Sarah Sutton, University of Arizona
- Daniella DellaGiustina, University of Arizona
- Erwan Mazarico, NASA Goddard Space Flight Center
- David Williams, Arizona State University
- James Skinner, United States Geological Survey
- Trent Hare, United States Geological Survey
- Brent Archinal, United States Geological Survey
- Robin Fergason, United States Geological Survey
- Justin Hagerty, United States Geological Survey
- Lisa Gaddis, United States Geological Survey
- Jay Laura, United States Geological Survey

- Sarah Noble, NASA Headquarters Officer

Representing a Diverse Community:

- *Domain geoscience specialists*
  - *Moon, Mercury, Small Bodies, Outer Planets, Mars…*
- *Photogrammetry and Geodesy*
  - *SOCET-SET, SOCET-GXP*
- *Geologic Mappers*
- *Mission participation*
  - *LRO, MRO, OSIRIS-Rex, MESSENGER, Cassini, Galileo*
- *Cartographic Software expertise*
  - *e.g. ISIS, ArcMAP, QGis, Lunaserv*
- *Human Exploration*
  - *SKG and ISRU expertise*

Geologic Mapping Subcommittee

David Williams [ASU] (Chair)
David Crown [PSI]
Debra Buczkowski [JHU-APL]
Corey Fortezzo [USGS]
James Skinner [USGS]

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NASA FUNDING: PLANETARY MAPPING

- NASA supports geologic map production through several funding programs
- For maps made using image data from current/recent flight missions, send proposals to appropriate Data Analysis Program (DAP):
  - Mercury, Vesta, Ceres – Discovery DAP
  - Moon – Lunar DAP
  - Mars – Mars DAP
  - Saturn's Moons – Cassini DAP
  - Pluto, Charon – New Frontiers DAP (New in 2017)

- For maps made using older data not covered in a DAP, send proposals to Solar System Workings Program (Venus maps, Galilean satellite maps, etc.)

- For map production where science has already been done, or to upgrade older maps using GIS, send proposals to Planetary Data, Archiving, & Tools Program (PDART)

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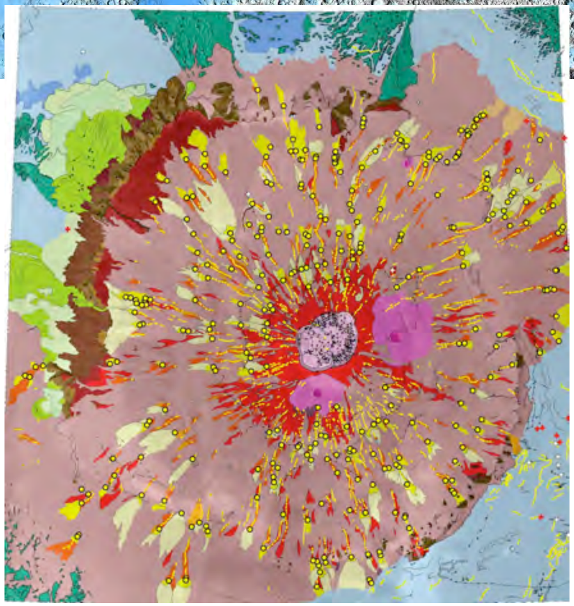
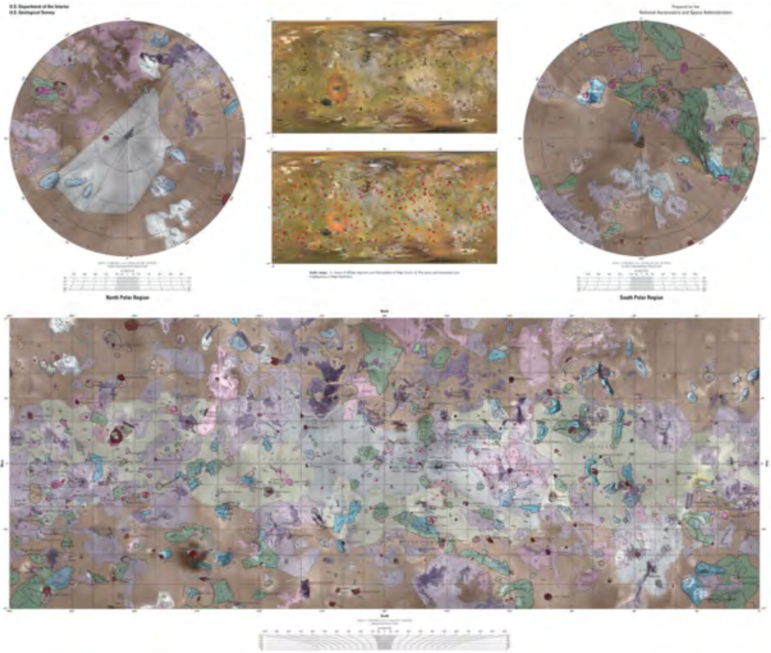
HOW PG MAPPING IS DONE I

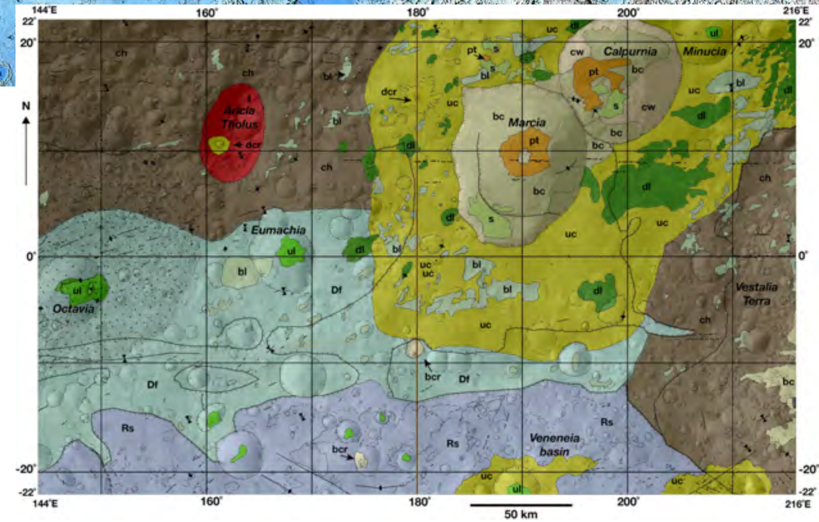
- Iterative process, using ever better imaging data
  - ✧ Most mapping is done using grayscale images and topographic data
  - ✧ Compositional and spectral data often used to aid in devising map units
- *Define* and *characterize* surface map units based on specific physical attributes related to the geologic processes that produced them
  - ✧ Brightness (albedo), texture, contact types
  - ✧ Morphology & slope, topography of surface
  - ✧ Color images if available => composition
- *Identify* & map types & extents of structural features
  - ✧ Ridges, troughs, graben, lineaments, scarps
  - ✧ Crater rims, pits, etc.

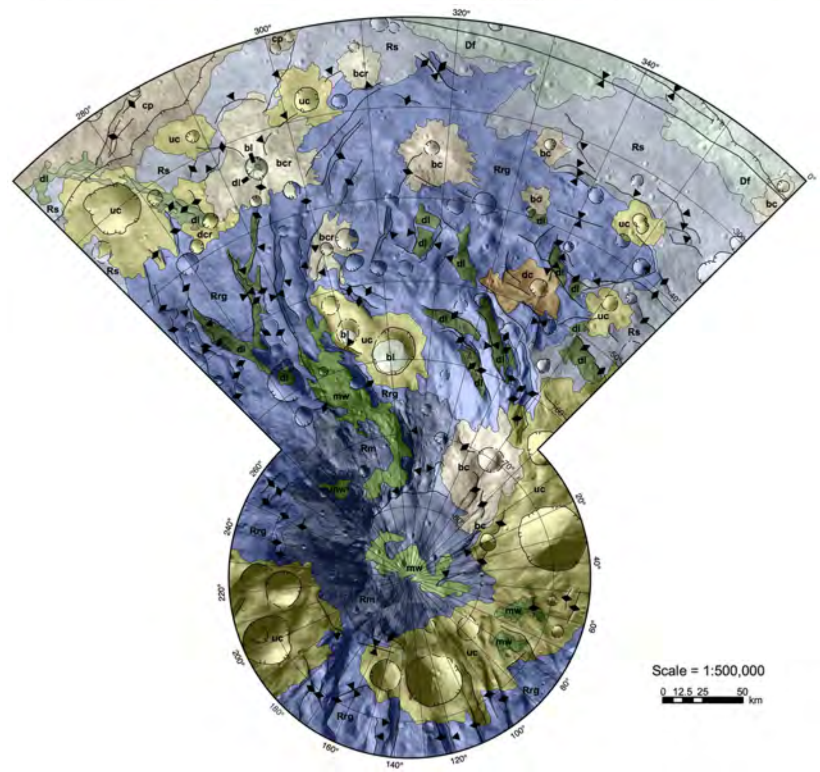




HOW PG MAPPING IS DONE II

- *Determine stratigraphic history* through contact relations among units and features
  - ✧ Superposition, cross-cutting, embayment, intrusion leads to determining *relative* stratigraphy
  - ✧ Crater counting of homogeneous map units & application of crater chronology systems can provide *cratering model age dates* in Ma to Ga, providing "*absolute*" stratigraphy
- *Derived cross sections* can aid determining 3D nature of rock units, where topographic information is available
- *All planetary mapping done using GIS software*





HOW PG MAPPING IS DONE III

- Guidelines for making geologic maps given in *Planetary Mappers Handbook* (Tanaka et al., 2010): http://astrogeology.usgs.gov/Projects/PlanetaryMapping/
- *ArcGIS™ software* by ESRI is preferred by USGS, which supports funded mappers through their GIS laboratory and technical support
- PI's should have *their own mapping computers* & access to ArcGIS™ software at their home institutions prior to start of the project
- Recommended that mappers *obtain basic ArcMap™ training* through ESRI online classes or other means before the start of the project
- Once funded, *USGS provides PI w/digital ArcGIS™ project* including preferred basemap, possibly some supplementary data sets, and layers for mapping linear features (lines), point features (points), geologic contacts (lines), surface features (polygons), and map units (polygons)
- Mappers produce digital map in GIS + map text, reporting results or problems at annual Planetary Mappers Meeting

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HOW PG MAPPING IS DONE IV

- Once draft map & text is completed, *submitted to USGS* for review
- USGS Map Coordinator checks for accuracy w/*Handbook* guidelines
- Map then undergoes *peer review by two mappers*, as well as science review by map coordinator
- *After revision* for any reviewer comments, *map is again checked* by MC and *once approved, sent to USGS Publications* for production
- In the past, this process from start to finish *typically lasted 5 years*
- However, with advent of digital map production and refinement of procedures, it is hoped this timeline can be *reduced to 3-4 years total*

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SUMMARY

- NASA has supported geological mapping of planetary surfaces since the 1960s, working in conjunction with the U.S. Geological Survey
- Since 1960s NASA and the USGS have overseen geological mapping campaigns for the Moon, Mars, Venus, and Mercury, and has supported mapping of Jovian & Saturnian satellites, asteroid Vesta, and the dwarf planet Ceres
- >170 planetary geologic maps have been produced, and ~60 more are in various states of production
- MAPSIT and GEMS are currently working with NASA to streamline procedures for planetary geological mapping in the digital age
- Goal: Produce robust infrastructure and resources for planetary mapping community to continue geologic mapping of planetary objects in shortest time possible (3-4 years)

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Recommendations: Geologic Mapping During Active Missions

Table 3b. Recommendations for future missions on conducting a geologic mapping program during the nominal mission.

Recommendation
(1) Complete draft global geologic map before beginning regional mapping
(2) Identify science drivers from global mapping: Regions, features, terrains that would benefit from larger scale geologic/stratigraphic mapping
(3) Devise a regional/quadrangle-scheme to match science drivers. Match map areas to researchers with requisite science interest and mapping skills. Minimize the number of mappers
(4) Retain generic descriptors for units and features for as long as possible to allow for flexibility in unit delineation and interpretation as well as more consistent coordination between global and regional maps
(5) Develop mapping templates early in Nominal Mission; adapt as necessary as more data becomes available. This includes the GIS package for mapping, conference posters, publication formats, etc.
(6) Use the USGS for guidance on creation of geologic mapping program, including projections, scales, symbols, etc. They can advise on different mapping approaches
(7) Use conference abstracts to document the evolving knowledge of global-regional geology based on geologic mapping during mission timeline
(8) Do not automatically link geologic mapping to peer review manuscript publications
(9) Regional and/or quad-based geologic mapping is a good way to involve graduate students and younger team members
(10) After Nominal Mission ends, consider asking USGS to formally format, review, and publish geologic maps as Special Investigations Map (SIM) series