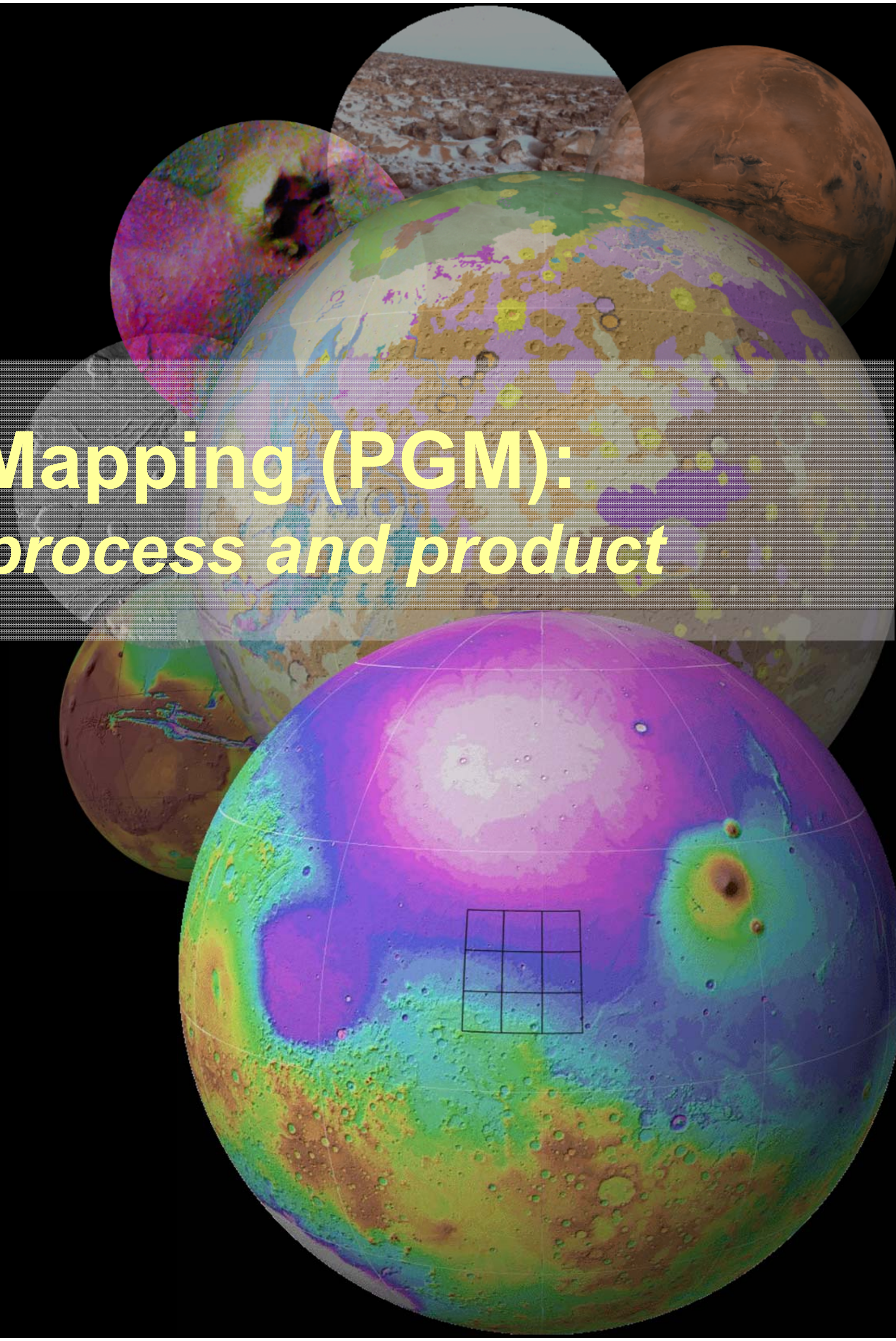
USGS
science for a changing world

Planetary Geologic Mapping (PGM):
An introduction to the process and product



J. A. Skinner, Jr.
Astrogeology Science Center
U. S. Geological Survey
Flagstaff, AZ

Objectives

- This presentation <u>IS</u> intended to be:
  - Faces to names and "lay of the land"
  - <u>Process and product</u> of geologic mapping
  - Participants and dependencies
  - Tasks funded by NASA
  - Re-enforcing relationships
  - Broadening understanding toward common goal
  - <u>*Ensuring best value*</u>

Objectives

- This IS NOT intended to be:
  - Exhaustive description
  - Specifically about USGS Astrogeology
  - NASA R&A re-organization
  - Creating a monopoly in map production
  - Requesting more (or less) funding
  - The last discussion

Outline

Planetary cartography
Basic concepts
History
*Topic vs. Context
*Map components
*Work flow
*Funding
*Management
*Concerns
Conclusions

Outline

Planetary cartography

Basic concepts

History

Topic vs. Context

Map components

Work flow

Funding

Management

Concerns

Conclusions

Planetary Cartography

- Process and products of creating maps for solid objects beyond the Earth
  - Geodesy and control
  - Image processing
  - Precision co-registration and geo-registration
  - Tool development
  - Visual representation
  - Community standards
- Critical infrastructure for dissemination, scientific analysis, and public consumption of mission data

Planetary Cartography

- Short- and long-range planning maintains health of infrastructure
  - Technology (hardware and software)
  - Human capital and knowledge base
- Fundamental reliance on “standardized” mission information
  - Allows community to speak the same language
- Requires collaboration, cooperation, and community oversight
  - Development
  - Adherence

Planetary Cartography

- Planetary geologic mapping is a component of planetary cartographic infrastructure
  - Geodetic control at various scales
  - Processing, mosaicking, and co-registration
  - Driven by community needs
  - Standardized <u>process and product</u>

Planetary Cartography

- Dispense with some myths
  - USGS = Planetary Geologic Mapping?
  - USGS geologic maps are “absolute”?
  - USGS geologic maps = Journal articles?
  - USGS geologic maps take a long time?
  - Geological mapping is not a scientific endeavor?

Outline

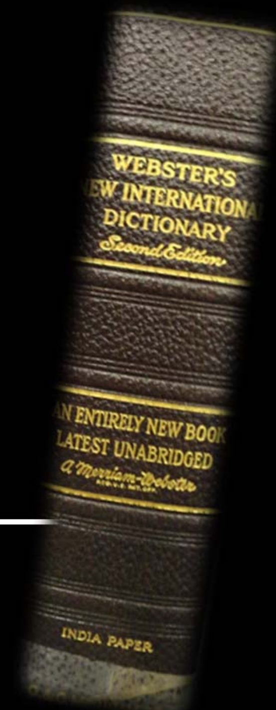
Planetary cartography
Basic concepts
History
Topic vs. Context
Map components
Work flow
Funding
Management
Concerns
Conclusions

Concepts of geological mapping

geo•log•ic map ***noun*** (\ jē-ə-lä-jik \ map \)

: a chart that shows the distribution of discrete rock and sediments bodies and associated landforms of a particular area, emphasizing their spatial and temporal associations relative to one another, in order to inform about the formational history of a region and/or planet

: a contextual framework for displaying bulk <u>observations</u>, intended to visually convey the formative history of a particular area



Concepts of geological mapping

- **Consistently recognizable and traceable across landscape**
- **Described thoroughly and objectively so that others can recognize and verify presence and identity**
- **Must be repeatable**
- **Minimally consists of**
  - **Map**
  - **Symbol key**
  - **Description of map units**

Concepts of geological mapping

- Types (or subsets) of geologic maps
  - Thematic
    - Groundwater
  - Geomorphic
    - Glacial landforms
  - Stratigraphic
    - Age of sand bodies
  - Compositional
    - Hydrated minerals
  - Facies
    - Textures on volcanic flows

Concepts of geological mapping *(cont'd)*

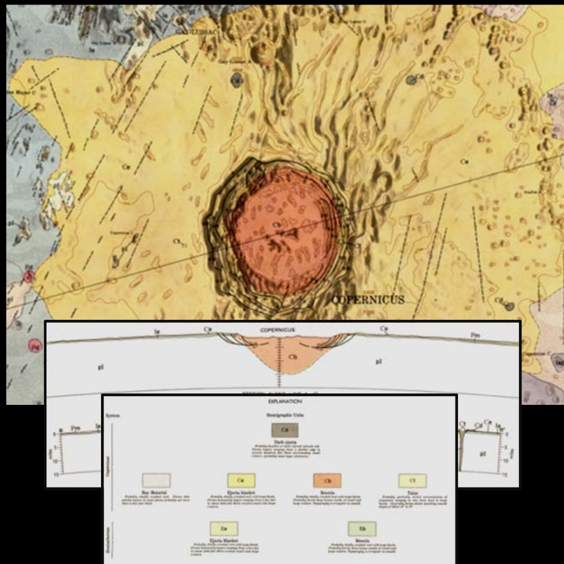
- Basic process of terrestrial mapping
  - Field-based: Traversing, outcrop examination, existence and nature of a contact, unconformities
  - Outcrop … erosion … 3-D exposure
  - Lines (contacts, structures) identified on mylar over topographic base
  - Notes compiled in notebook, correlated with field map → represent "hard" documentation
  - Inked and colored
  - Unit descriptions, cross-section, geologic history
- How do these apply to other bodies?

Outline

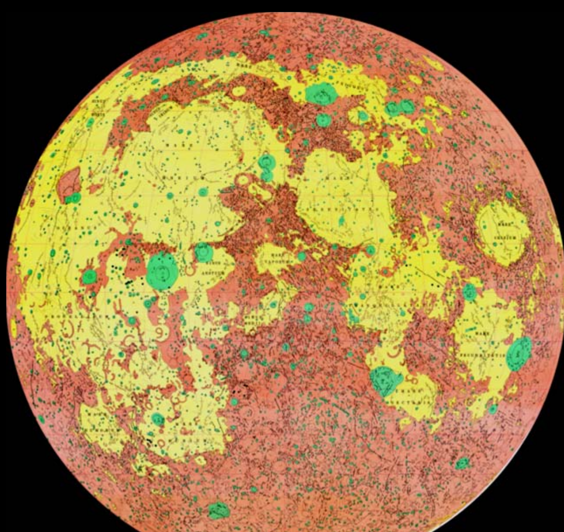
- Planetary cartography
- Basic concepts
- History
- Topic vs. Context
- Map components
- Work flow
- Funding
- Management
- Concerns
- Conclusions

History of Planetary Geological Mapping

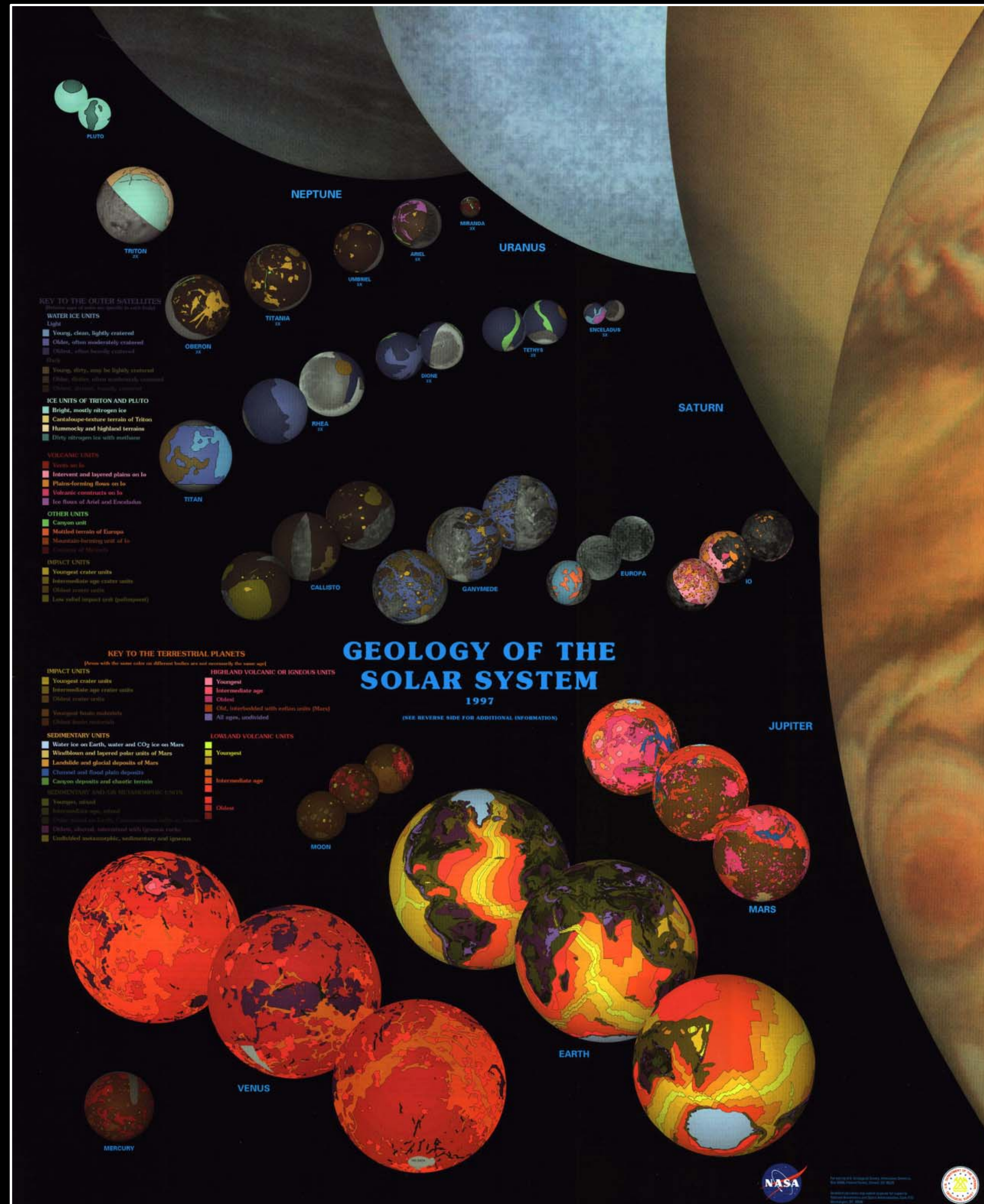
- **Application of terrestrial geological mapping concepts to other bodies**
  - **Remote observations**
  - **Limited datasets (topography)**
  - **What to describe? In what detail?**
  - **How infer 3-D architecture?**
    - **Terrestrial outcrop formed by tectonism and erosion**
  - **How similar are the geological processes?**
- **Shoemaker et al. addressed these questions**
  - **Concept works because it is focused primarily on <u>observation</u>**



Shoemaker, 1960
1:1,000,000 scale (LPC-58)
ACIC



Mason and Hackman, 1961
1:3,800,000 scale
USGS

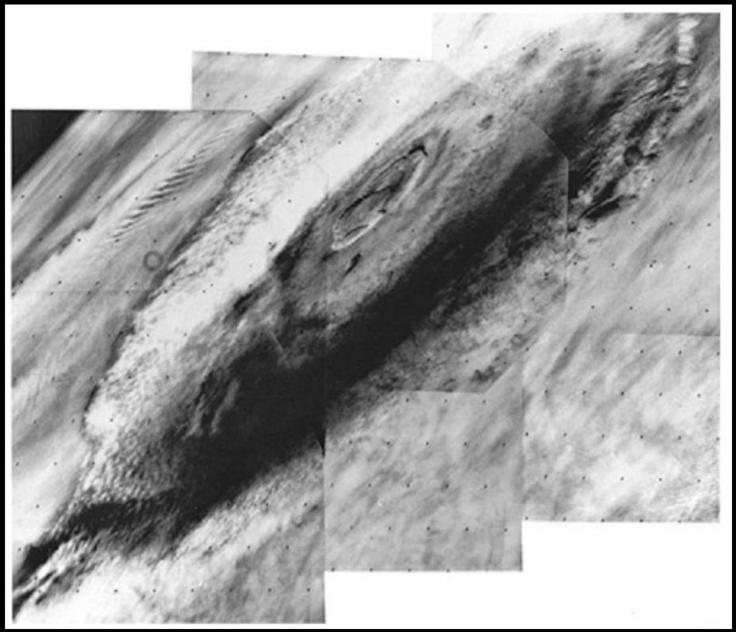


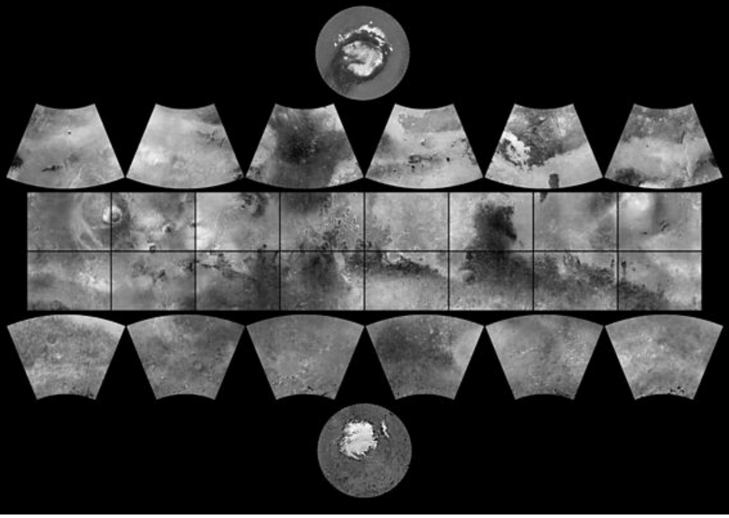
History of Planetary Geological Mapping

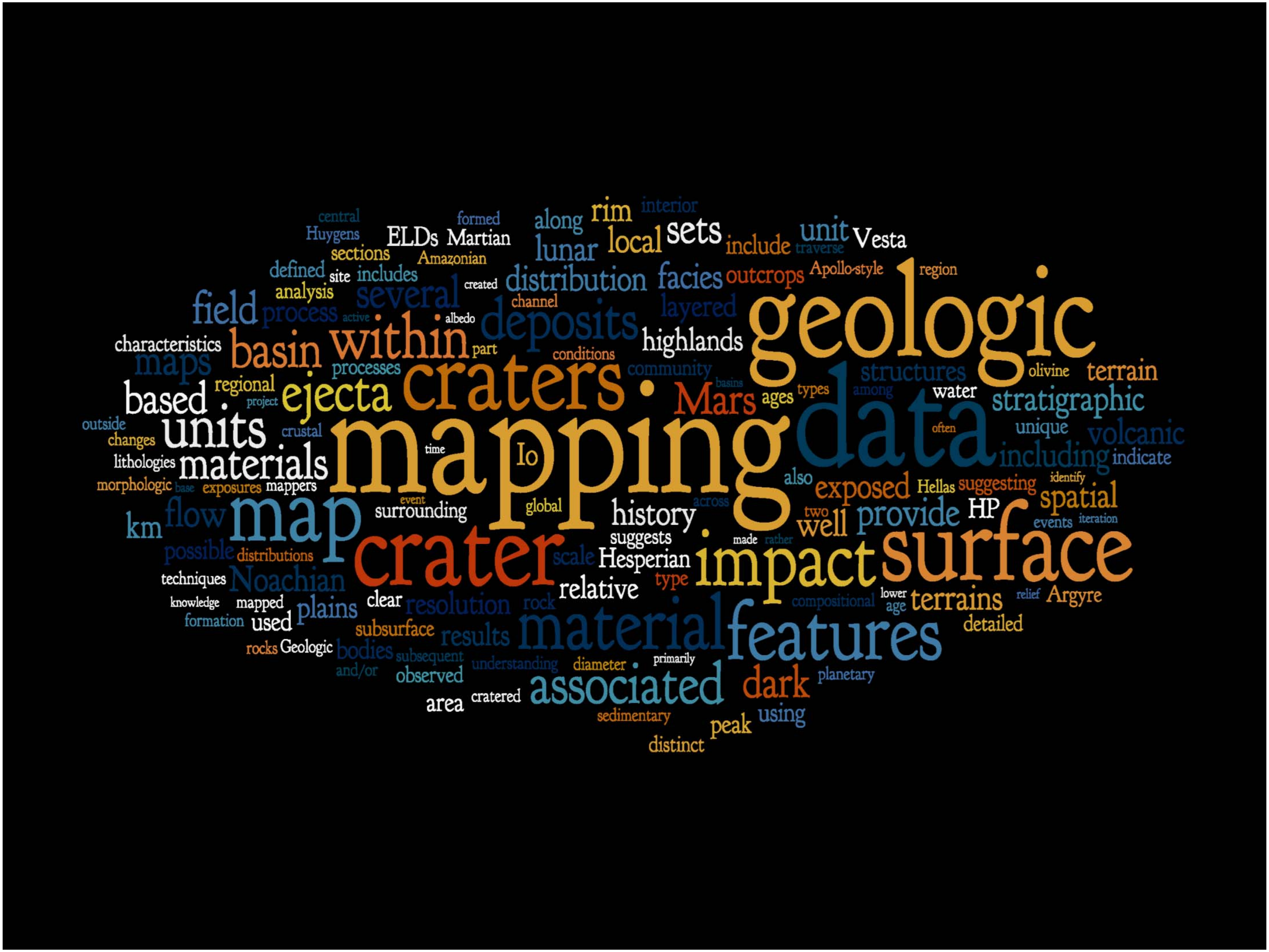
- Relationship with NASA and USGS
  - Planetary cartography
  - Geologic mapping
  - Technology development
  - Mission support (astronaut training, landing sites)
- On behalf of NASA, USGS has published:
  - >150 of planetary geologic maps
  - Multiple bodies, scales, bases
- Standardized <u>process and products</u>

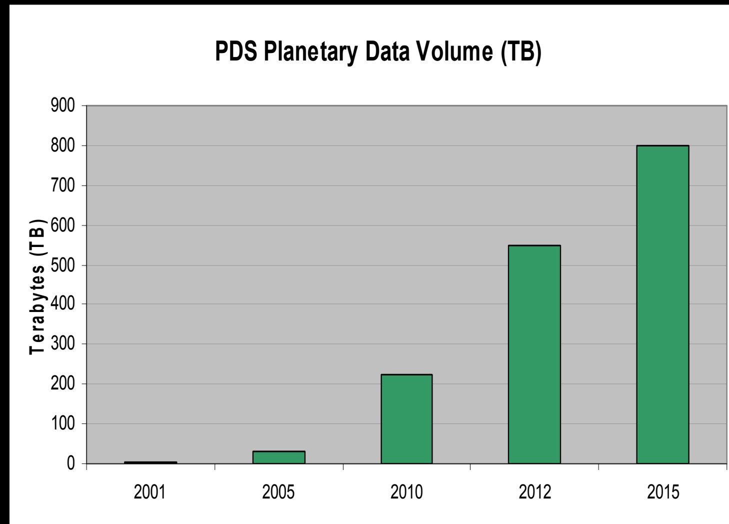
History of Planetary Geological Mapping

- Historical process
  - Brown-line, vellum, and photo-bases
  - Sticky colors
  - Scribing
  - Quadrangle schemes (mapping campaigns)
  - Mapping at production scale
- Historical product
  - Hard copy maps
  - Limited distribution
  - Utility and archive






central
formed
along
rim
interior
Huygens
ELDs
Martian
sets
unit
Vesta
sections
lunar
local
include
traverse
Amazonian
defined
site
includes
distribution
facies
outcrops
Apollo-style
region
analysis
created
several
channel
layered
geologic
field
process
active
albedo
deposits
characteristics
within
highlands
basin
part
conditions
maps
processes
community
structures
olivine
terrain
regional
craters
basins
types
among
water
based
project
ejecta
Mars
ages
stratigraphic
outside
crustal
data
often
unique
volcanic
changes
units
mapping
lithologies
time
Io
including
indicate
materials
morphologic
base
exposures
mappers
also
exposed
Hellas
suggesting
identify
spatial
flow
event
global
across
map
surrounding
history
two
HP
events
iteration
km
well
provide
suggests
made
rather
possible
crater
distributions
scale
Hesperian
impact
surface
type
techniques
Noachian
relative
compositional
lower
relief
Argyre
knowledge
mapped
clear
resolution
rock
age
terrains
formation
used
plains
material
features
detailed
subsurface
results
rocks
Geologic
bodies
subsequent
understanding
diameter
primarily
and/or
observed
planetary
associated
dark
area
cratered
sedimentary
using
peak
distinct



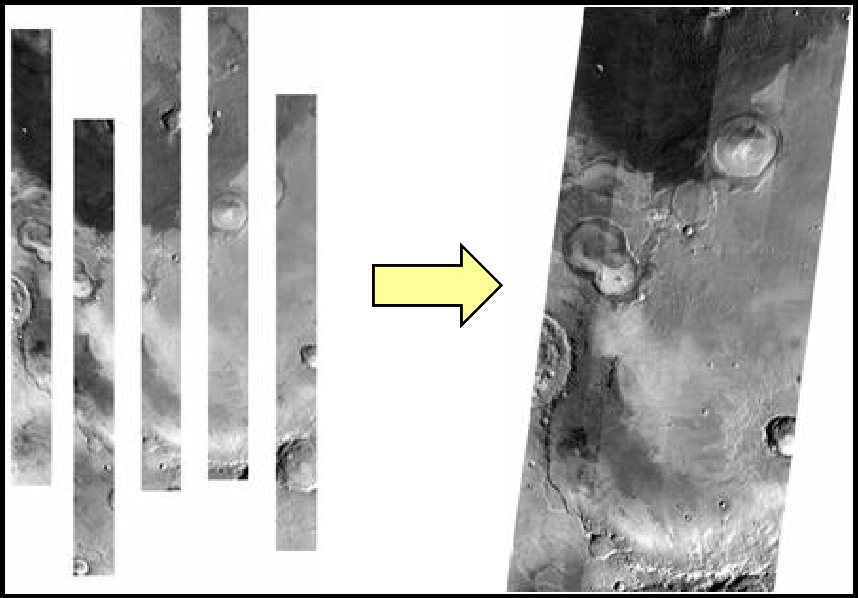
- Data volumes
- Data types
- Spatial scale
- Formats
- Digital environments (GIS)

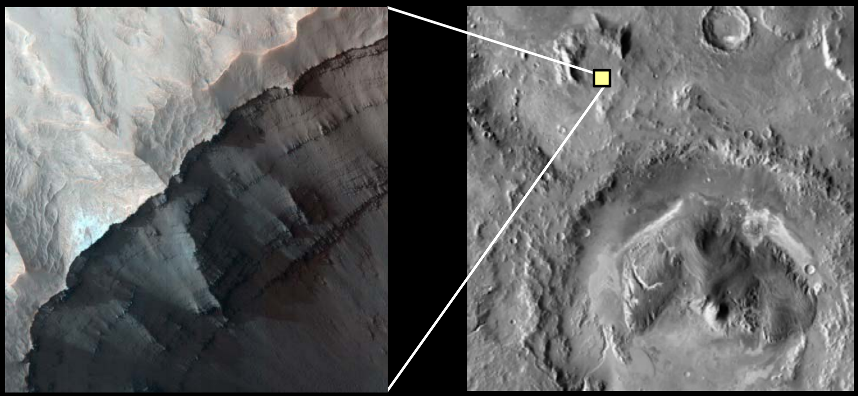
PDS Data Portals

Mission Portals

History of Planetary Geological Mapping

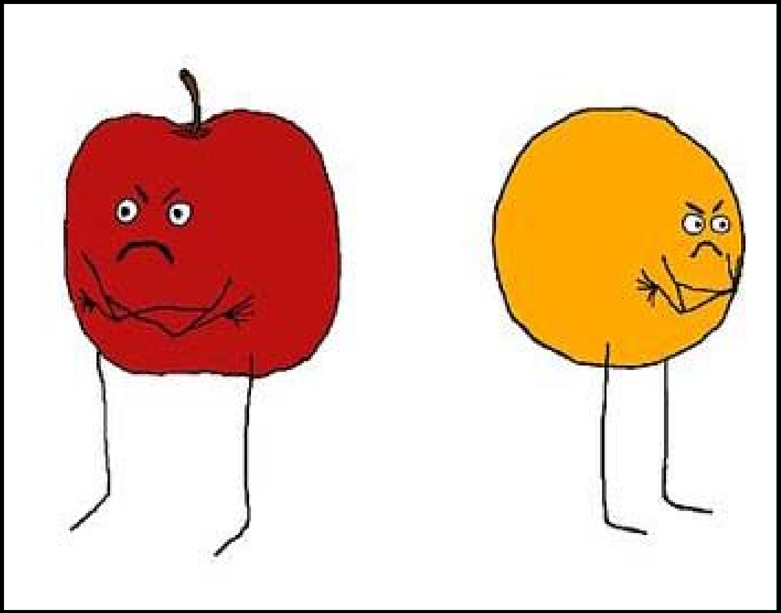
- Modern process
  - Controlled digital mosaics
  - GIS and tablets
  - Quad or non-quad
  - Mapping ≠ production scale
- Modern product
  - Hard copy and digital maps
  - Unlimited and immediate distribution
  - Utility





Outline

Planetary cartography
Basic concepts
History
Topic vs. Context
Map components
Work flow
Funding
Management
Concerns
Conclusions



Topical vs. Contextual Maps

- Data volumes and digital environments means cartographic concepts are common
  - Pipeline production (*e.g.*, DTM, mosaics)
  - Geodetic control (mission-specific)
  - Nomenclature (your name here!)
  - Journal-based geologic maps
- They all fulfill purpose, but they are not automatically equivalent
  - Lack review using community-adopted criteria
  - Lack accuracy and precision
  - Not standardized
  - Easy to say, hard to do

Topical vs. Contextual Maps

- Topical Science Geological Mapping
  - Flexibility in approach (base, scale, symbols, projections, intent)
  - Executed on a tactical timeline (generally responsive to the data curve)
  - Reviewed for scientific (not cartographic or technical) integrity
- Contextual Science Geological Mapping
  - Rigid in approach (set scale, primary vs. secondary data, approved symbols, objective)
  - Executed on a strategic timeline (generally not responsive to data curve)
  - Reviewed specifically for scientific, cartographic, and technical integrity

Topical vs. Contextual Maps

Contextual Maps

- *Review and publish **via geological survey***
- *Consistent, controlled base, scale, symbol, style*
- *Low response to data curve*
- ***Observations > Interpretations***

Topical Maps

- *Review and publish via **scientific journals***
- *Variable base and intent (thematic)*
- *High response to data curve*
- ***Observations ≤ Interpretations***

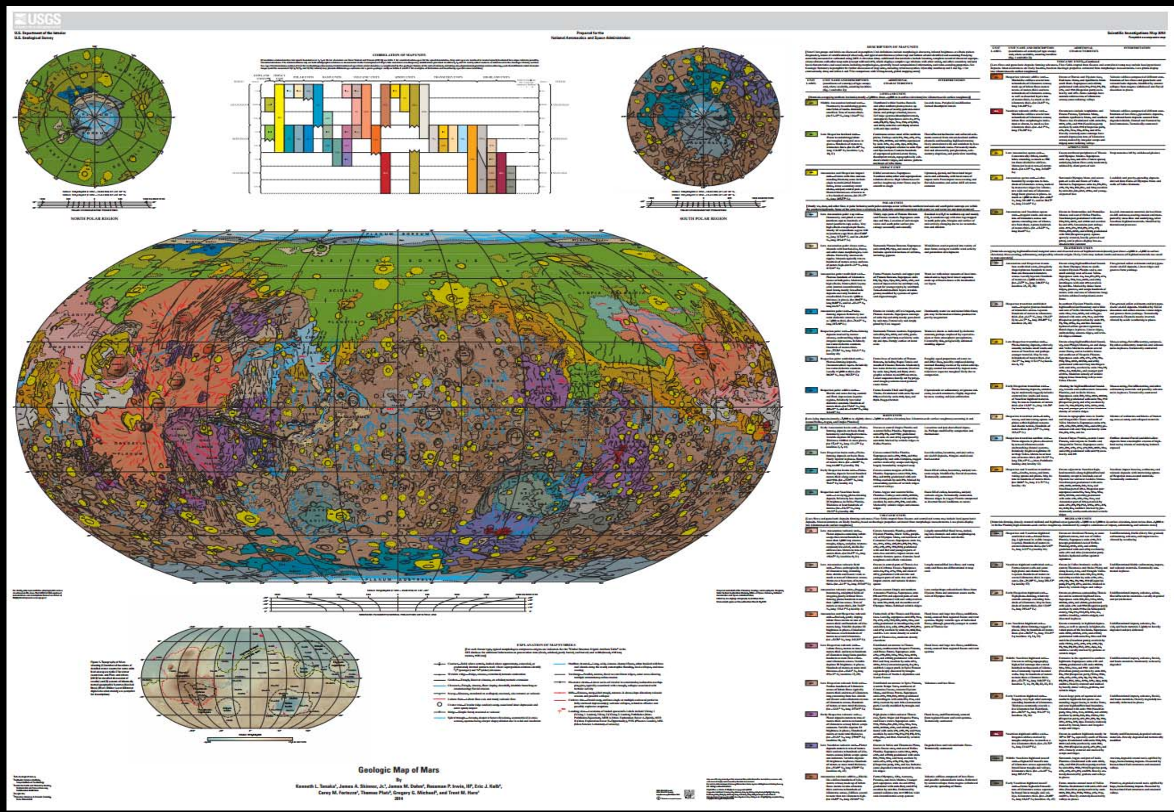
Outline

Planetary cartography
Basic concepts
History
Topic vs. Context
Map components
Work flow
Funding
Management
Concerns
Conclusions

Map Components

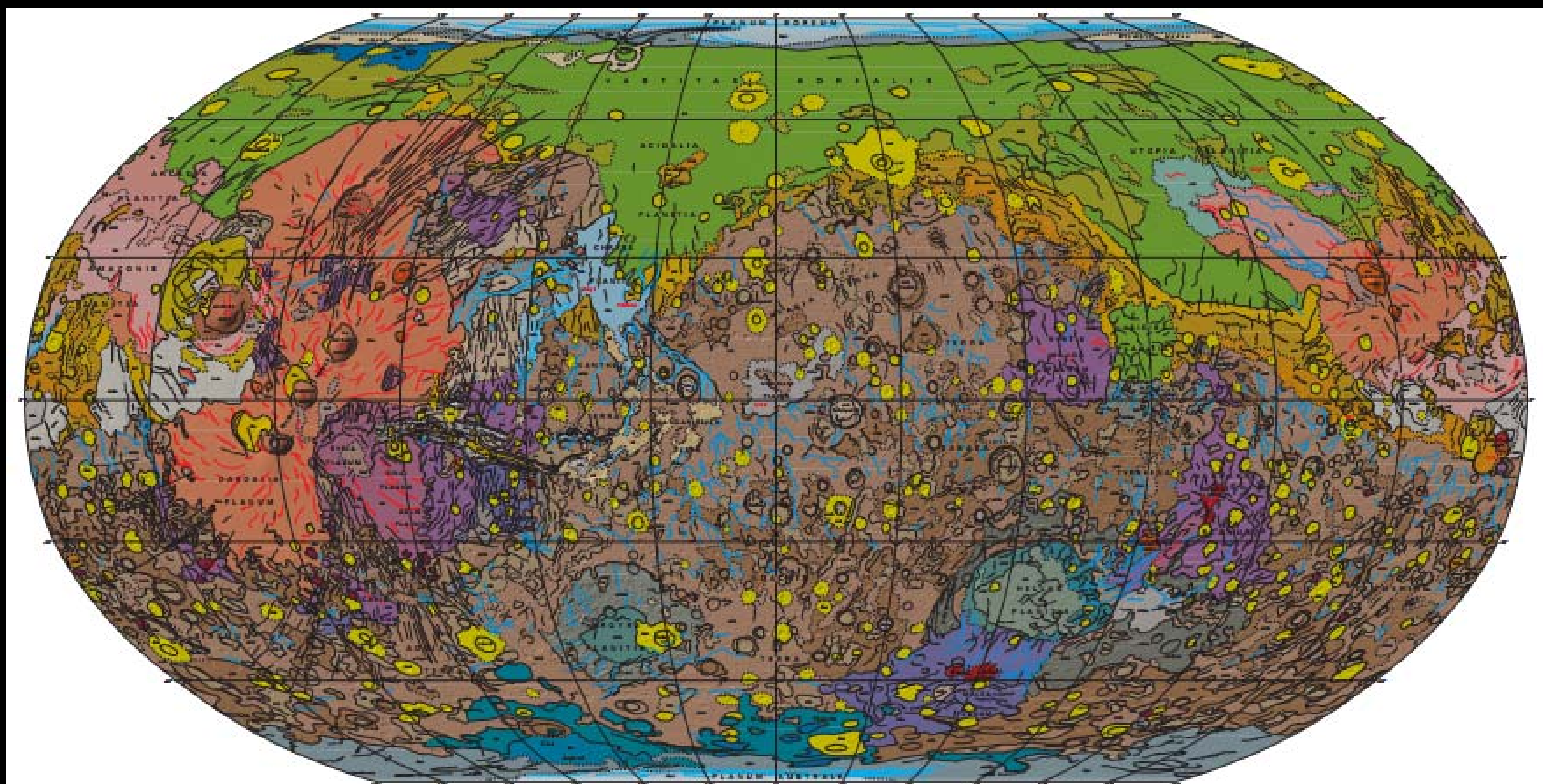
- Map
- Nomenclature
- COMU
- DOMU
- EOMS
- Text

56 inches

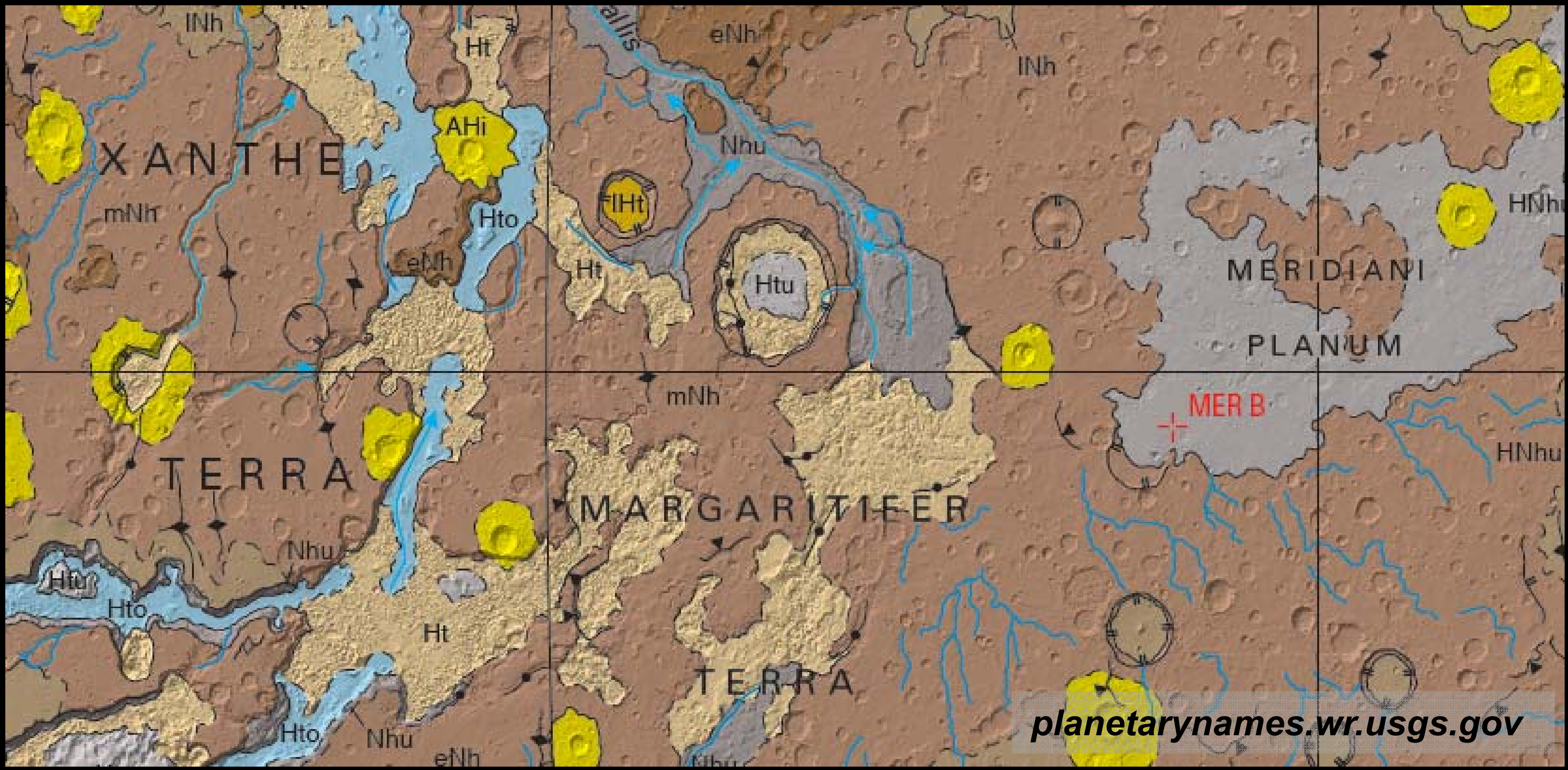


42inches

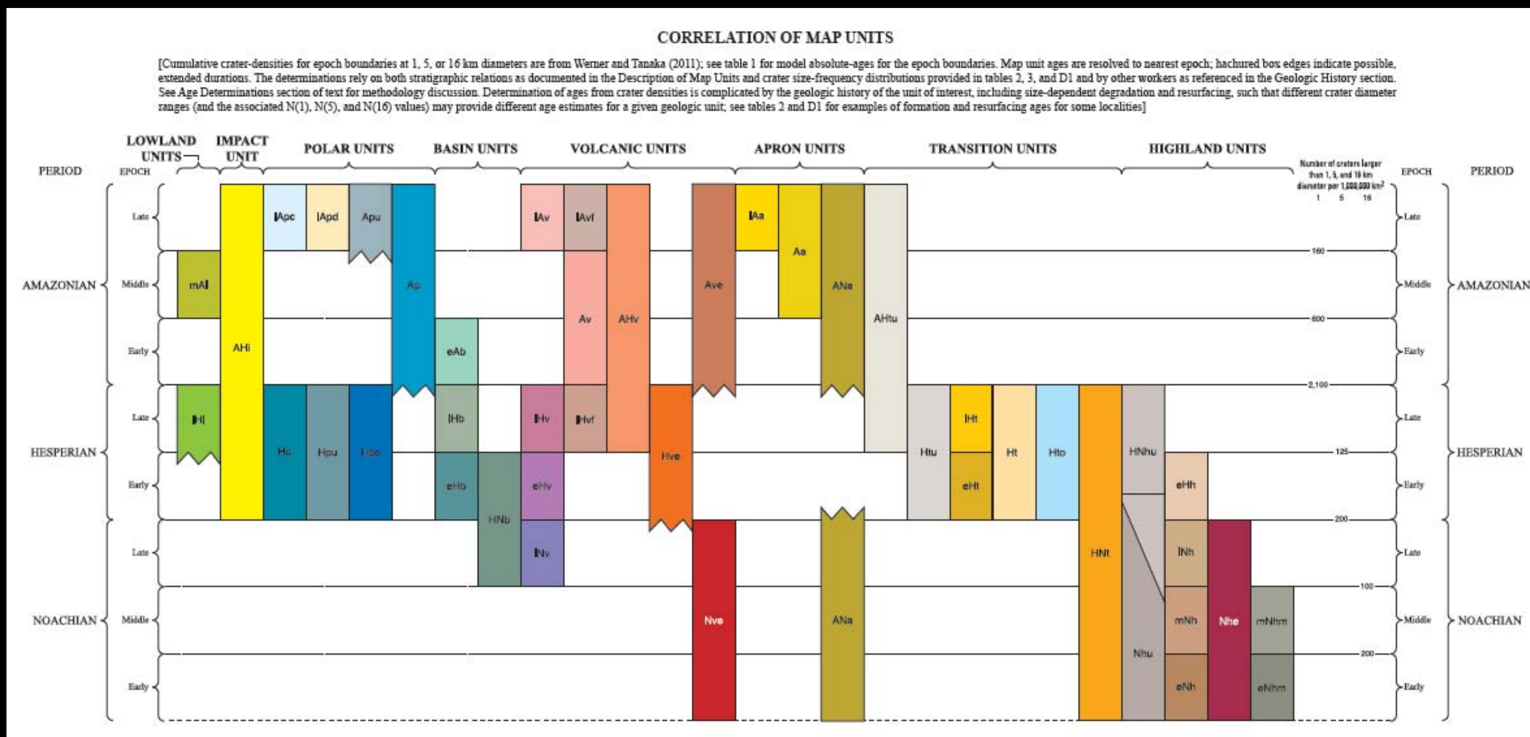
Map Components: *Geologic Map*



Map Components: *Nomenclature*



Map Components: *COMU*



Map Components: *DOMU*

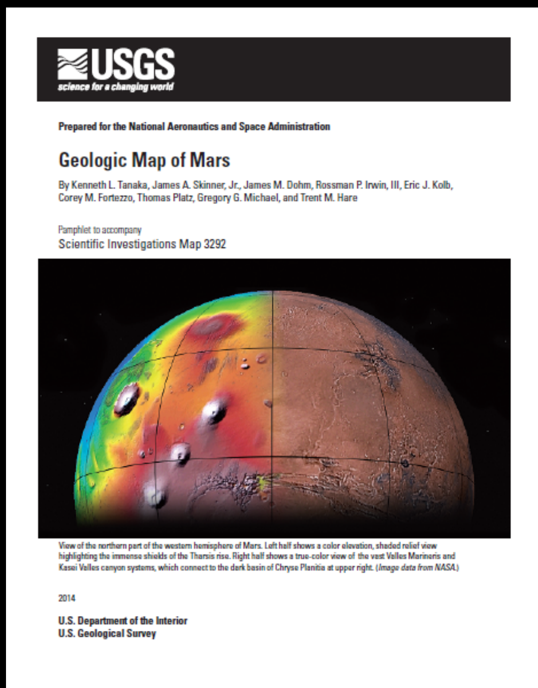
DESCRIPTION OF MAP UNITS

[Note: Unit groups and labels are discussed in pamphlet. Unit definitions include morphologic character, infrared brightness or albedo (where diagnostic), nature of stratification (if observed), and typical unit thickness (where top and bottom of unit identified and assuming flat-lying materials; measured or estimated using MOLA elevation data). Additional characteristics include location, complete record of observed superposition relations with other map units (except with unit AHl, which displays complex age relations with other units), and other secondary and (or) local characteristics and associations including morphologies, spectrally based compositional information, and radar-sounding properties. See Geologic Summary in pamphlet for further discussion of map units, including references; tables 2 (locality numbers) and 3 and fig. 1 for crater-density data; and tables 6 and 7 for comparison with Viking-based, global mapping units]

UNIT LABEL	UNIT NAME AND DESCRIPTION (coordinates of center(s) of type area(s) and, where available, counting localities (fig. 1 and table 2))	ADDITIONAL CHARACTERISTICS	INTERPRETATION
LOWLAND UNITS [Materials occupying northern lowlands (mostly –5,000 to about –4,000 m in surface elevation; low kilometer-scale surface roughness)]			
mAl	**Middle Amazonian lowland unit**—Hummocky to undulating; grades into fields of knobs. Internally stratified. Tens of meters thick. (lat 51.43° N., long 118.45° E.)	Distributed within Vastitas Borealis and other northern plains; makes up the platforms of nearby pedestal-crater forms and perhaps whorled, low-relief ridge systems (thumbprint terrain, unmapped). Superposes units Av, AHv, eAb, lHl, lHt, Hpe, Hve, HNt, eHt, lNh, and mNh; underlies unit lApd; relation with unit Apu unclear	Ice-rich loess. Periglacial modification formed thumbprint terrain

- Single base that provides definition
- Production scale – 1:1,000,000
- Digital mapping scale – 1:250,000
- Vertex spacing – 250 meters

Map Components: *Text, etc.*



USGS
science for a changing world

Prepared for the National Aeronautics and Space Administration

Geologic Map of Mars

By Kenneth L. Tanaka, James A. Skinner, Jr., James M. Dohm, Rossman P. Irwin, III, Eric J. Kolb, Corey M. Fortezzo, Thomas Platz, Gregory G. Michael, and Trent M. Hare

Pamphlet to accompany
Scientific Investigations Map 3292

View of the northern part of the western hemisphere of Mars. Left half shows a color elevation, shaded relief view highlighting the immense shields of the Tharsis rise. Right half shows a true-color view of the vast Valles Marineris and Kasei Valles canyon systems, which connect to the dark basin of Chryse Planitia at upper right. (*Image data from NASA.*)

2014

U.S. Department of the Interior
U.S. Geological Survey

materials than are compositional signatures and other data sets. The latter primarily reveal surficial information or very low resolution geophysical data that pertain to buried materials and structures (though all existing information informs on aspects of the geology of Mars). Geomorphic characteristics that are most useful to geologic mapping include stratigraphic relations (for example, layers, layer truncations, and unit embayments and (or) burial), lithologic properties (for example, impact, mass-wasting, and volcanic morphologies), and modificational features (for example, tectonic, fluvial, and periglacial landforms). In addition, terrestrial photogeologic mapping studies based on simulated planetary data sets have applied ground truth to test the reliability of planetary photogeologic mapping approaches (*, Tanaka and others, 2009; Skinner and Fortezzo, 2013), leading to a conservative and defensible methodology that we employ here. With some minor refinement to defining crater-density boundaries (Werner and Tanaka, 2011; Michael, 2013), the eight-epoch chronology system of Tanaka (1986) is employed in the current map.

Map Development and Author Roles

The methods described in the following subsections chiefly result from (1) our collective experience mapping Mars (*, Scott and Tanaka, 1986; Tanaka and Scott, 1987; Dohm and others, 2001a; Tanaka and others, 2005; Skinner and Herkenhoff, 2012; Tanaka and Fortezzo, 2012; Irwin and Grant, 2013); (2) the state of the art in handling global mapping data sets using digital mapping technologies (see below); (3) methods used in recent terrestrial geologic maps at global (*, Bouysee, 2009) and continental (*, Reed and others, 2005) scales; (4) guidance provided by the Geologic Mapping Subcommittee of NASA's Planetary Geology and Geophysics Program and its Planetary Geologic Mapping Handbook (Tanaka and others, 2010); and (5) the application of the interrelated, guiding principles of consistency, simplicity, clarity, utility, and communicability as chosen by our mapping team.

The production of a global map necessitates spatial and categorical generalization of geologic units and features that would otherwise be mapped in more detail at larger scales (*, Varnes, 1974). These generalizations can be accommodated at the selected map scale by carefully balancing cartographic symbols and geologic descriptions. However, unlike many terrestrial examples of small-scale geologic maps (*, Bouysee, 2009), the map presented herein represents original mapping work, augmented with a variety of published topical science investigations, rather than the compilation and generalization of multiple larger-scale geologic map products.

The initial mapping of units and features by region was the responsibility of four of the authors: Tharsis region and Argyre basin (Dohm), northern lowlands and Arabia Terra (Skinner), southern highlands (Irwin), and south polar region and Hellas basin (Kolb). To establish consistency, the global-line-feature mapping and contact attributing were later given to a single mapper (Fortezzo). The entire map was edited and compiled under the direction of the lead author (Tanaka) through iterative reviews with primary mappers as well as mapping team discussions, when the schemes for unit naming, grouping, and coloring, as well as for contact and line-feature attributing were developed. Outcrop unit assignments were based partly on age, which required determination of high-accuracy, local crater-density ages of type localities (Platz and Michael). To assist in global unit and outcrop age assignments, we compiled cumulative crater densities for all unit occurrences through a global crater database (Robbins and Hynek, 2012) (see Age Determinations section below). Data management and validation and GIS software oversight (Hare) ensured spatial accuracy and efficiency in mapping.

Unit Delineation

Map units identify temporally unique geologic materials of substantial thickness and extent for portrayal at map scale. Identifying characteristics that establish geologic uniqueness include primary (formational) morphology, IR brightness (daytime or nighttime), and (or) albedo characteristics from visual-range-image data, stratification, relative age, and spatial geologic associations, which are described in the Description of Map Units. Primary characteristics and landforms in this map include lobate scarps (identifying flow boundaries within or at the margin of a unit), layering (presence and thickness of layers), dunes, plains, and shields and cones (indicative of volcanic vents). The primary versus secondary (modificational) nature of some morphologic features is uncertain, and defining units using secondary features was avoided (although they were commonly helpful in establishing time gaps between adjacent units, as well as typical modification history; they are noted in the additional characteristics column in the Description of Map Units). Our unit delineation approach thus differs from the previous global geologic maps of Mars, which included secondary morphologic and albedo features among the principal attributes of map units. For the Noachian units, we did not delineate Noachian crater ejecta within them, as shown in many other Mars geologic maps (*, Scott and Carr, 1978; Scott and Tanaka, 1986), because of the difficulty in many cases of identifying the limit of the ejecta plus the fact that most Noachian materials are interpreted to include impact ejecta.

Units are delineated by relative age as borne out by stratigraphic overlap and embayment relations, and their chronostratigraphic ages were determined by the densities of impact crater populations. Units were assigned ages according to the three periods previously defined by Scott and Carr (1978) and the eight epochs that the periods were later divided into by Tanaka (1986). Many units are likely to consist of complexly intermixed materials of contrasting age and provenance. Such intercalations are neither consistently observable nor possible to represent using regional to global data sets and small map scales. We ignored surficial materials that are estimated to be meters thick (or smaller), including dust, duricrust, desert pavement, and icy soils and mantles (*, Mustard and others, 2001; Putzig and Mellon, 2007). These generally are too thin to recognize and map at global scale. An exception is the approximately meter-thick Amazonian polar cap unit that constitutes

4

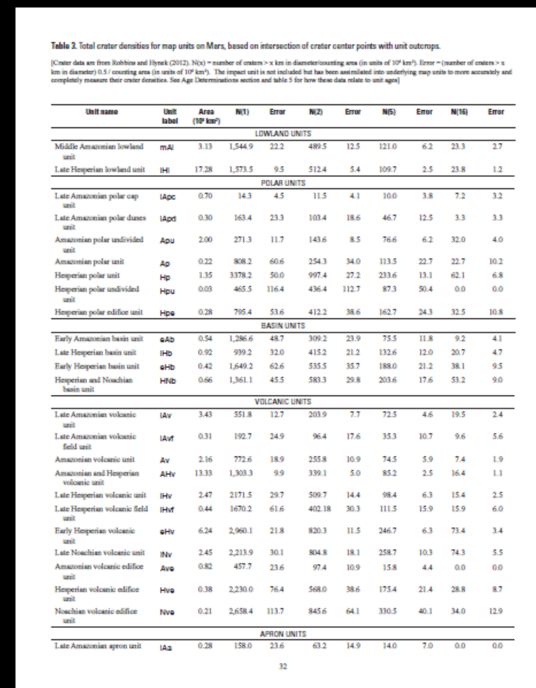


Table 3. Total crater densities for map units on Mars, based on intersection of crater center points with unit outcrops.

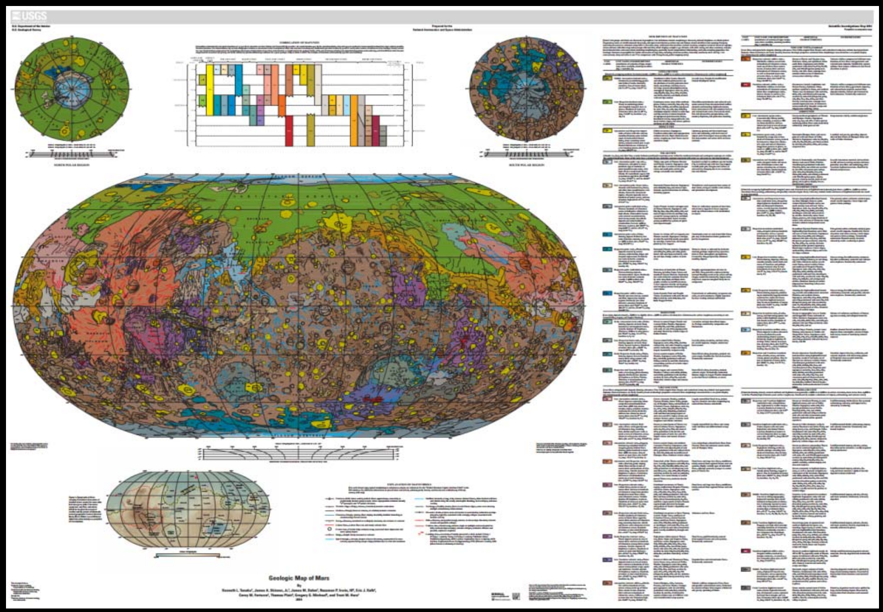
[Crater data are from Robbins and Hynek (2012). N(x) = number of craters > x km in diameter/counting area (in units of 10^6 km²). Error = (number of craters > x km in diameter) 0.5 / counting area (in units of 10^6 km²). The impact unit is not included but has been assimilated into underlying map units to more accurately and completely measure their crater densities. See Age Determinations section and table 5 for how these data relate to unit ages]

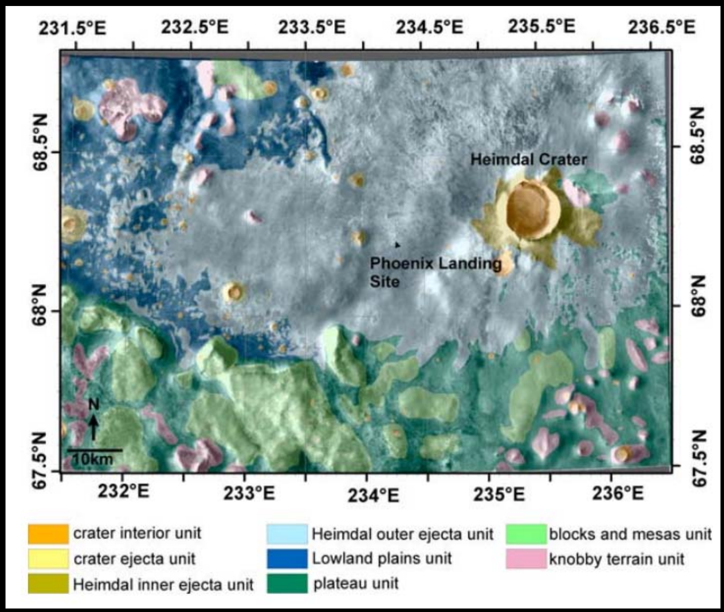
Unit name	Unit label	Area (10^6 km²)	N(1)	Error	N(2)	Error	N(5)	Error	N(16)	Error
				LOWLAND UNITS						
Middle Amazonian lowland unit	mAl	3.13	1,544.9	22.2	489.5	12.5	121.0	6.2	23.3	2.7
Late Hesperian lowland unit	lHl	17.28	1,573.5	9.5	512.4	5.4	109.7	2.5	23.8	1.2
				POLAR UNITS						
Late Amazonian polar cap unit	lApc	0.70	14.3	4.5	11.5	4.1	10.0	3.8	7.2	3.2
Late Amazonian polar dunes unit	lApd	0.30	163.4	23.3	103.4	18.6	46.7	12.5	3.3	3.3
Amazonian polar undivided unit	Apu	2.00	271.3	11.7	143.6	8.5	76.6	6.2	32.0	4.0
Amazonian polar unit	Ap	0.22	808.2	60.6	254.3	34.0	113.5	22.7	22.7	10.2
Hesperian polar unit	Hp	1.35	3378.2	50.0	997.4	27.2	233.6	13.1	62.1	6.8
Hesperian polar undivided unit	Hpu	0.03	465.5	116.4	436.4	112.7	87.3	50.4	0.0	0.0
Hesperian polar edifice unit	Hpe	0.28	795.4	53.6	412.2	38.6	162.7	24.3	32.5	10.8
				BASIN UNITS						
Early Amazonian basin unit	eAb	0.54	1,286.6	48.7	309.2	23.9	75.5	11.8	9.2	4.1
Late Hesperian basin unit	lHb	0.92	939.2	32.0	415.2	21.2	132.6	12.0	20.7	4.7
Early Hesperian basin unit	eHb	0.42	1,649.2	62.6	535.5	35.7	188.0	21.2	38.1	9.5
Hesperian and Noachian basin unit	HNb	0.66	1,361.1	45.5	583.3	29.8	203.6	17.6	53.2	9.0
				VOLCANIC UNITS						
Late Amazonian volcanic unit	lAv	3.43	551.8	12.7	203.9	7.7	72.5	4.6	19.5	2.4
Late Amazonian volcanic field unit	lAvf	0.31	192.7	24.9	96.4	17.6	35.3	10.7	9.6	5.6
Amazonian volcanic unit	Av	2.16	772.6	18.9	255.8	10.9	74.5	5.9	7.4	1.9
Amazonian and Hesperian volcanic unit	AHv	13.33	1,303.3	9.9	339.1	5.0	85.2	2.5	16.4	1.1
Late Hesperian volcanic unit	lHv	2.47	2171.5	29.7	509.7	14.4	98.4	6.3	15.4	2.5
Late Hesperian volcanic field unit	lHvf	0.44	1670.2	61.6	402.18	30.3	111.5	15.9	15.9	6.0
Early Hesperian volcanic unit	eHv	6.24	2,960.1	21.8	820.3	11.5	246.7	6.3	73.4	3.4
Late Noachian volcanic unit	lNv	2.45	2,213.9	30.1	804.8	18.1	258.7	10.3	74.3	5.5
Amazonian volcanic edifice unit	Ave	0.82	457.7	23.6	97.4	10.9	15.8	4.4	0.0	0.0
Hesperian volcanic edifice unit	Hve	0.38	2,230.0	76.4	568.0	38.6	175.4	21.4	28.8	8.7
Noachian volcanic edifice unit	Nve	0.21	2,658.4	113.7	845.6	64.1	330.5	40.1	34.0	12.9
				APRON UNITS						
Late Amazonian apron unit	lAa	0.28	158.0	23.6	63.2	14.9	14.0	7.0	0.0	0.0

32

Map Components

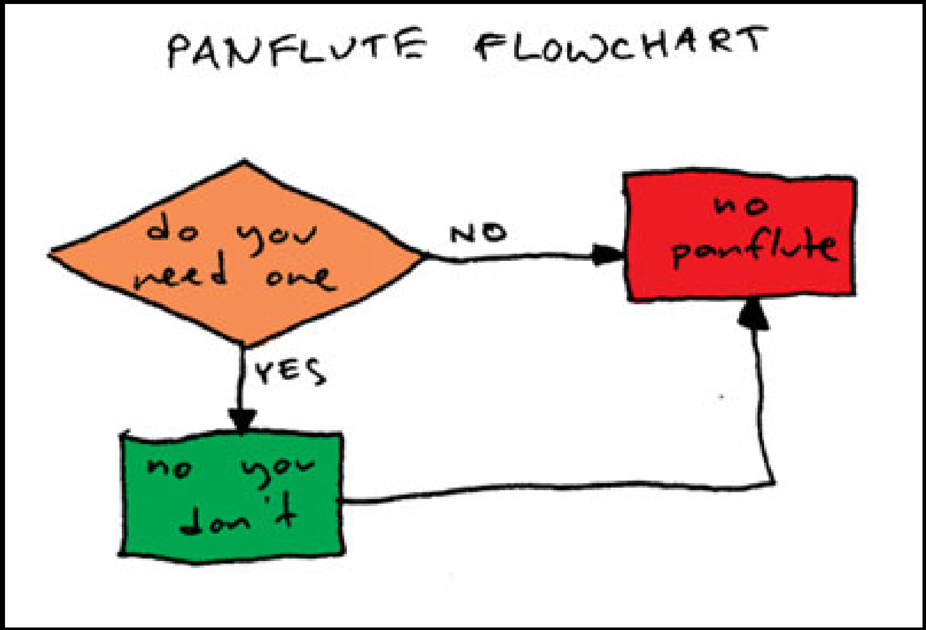
- Context maps must include components
  - Reviewed for scientific accuracy, objectivity, and internal consistency
  - Standard compilation and presentation
  - Line symbols, colors, names, format
- Topical maps have elements of process and product





Outline

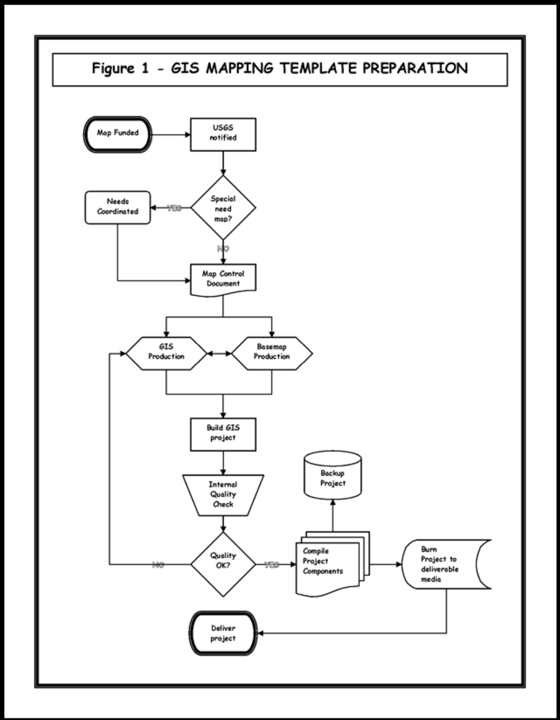
- Planetary cartography
- Basic concepts
- History
- Topic vs. Context
- Map components
- **Work flow**
- Funding
- Management
- Concerns
- Conclusions

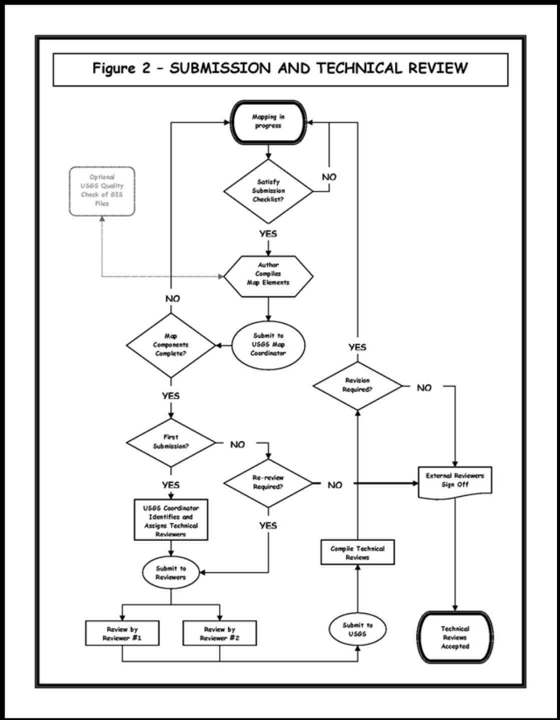


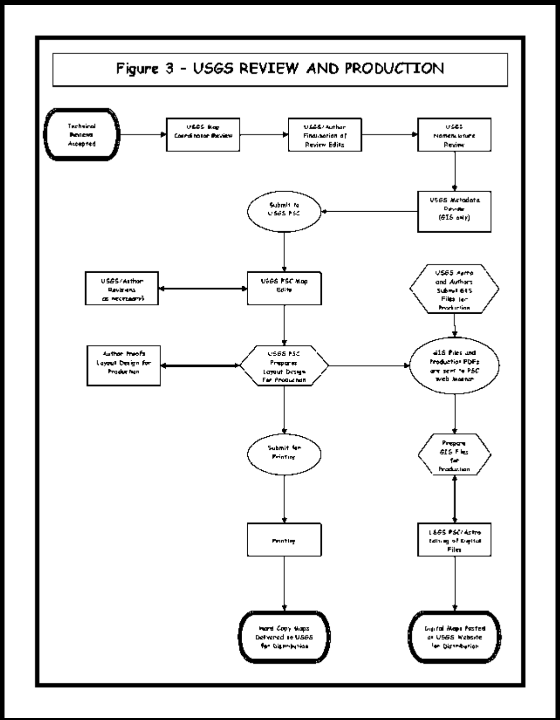
Work Flow

Proposal to pamphlet….

From Planetary Geologic Mappers Handbook







Work flow

- Pre-proposal
  - Contact USGS - boundaries, base, scale, etc.
- Review and selection
  - Boxes checked in NSPIRES (?)
- USGS notified of “new starts”
  - Allows us to schedule and start work
- Base map and GIS project created
  - Clipped, processed/mosaicked, registered, quality checked

Work flow

- GIS delivered to author
  - Opened and verified
- Mapping by author (+support as needed)
- Planetary Geologic Mappers Meeting
  - Status reports and receive guidance
- Pre-submission review
  - Checked for completeness and accuracy
- Formal submission to USGS
  - Standard components in standard format
- Submission review
  - Checked for completeness and accuracy

Work flow

- Technical reviewers assigned and delivered
  - 2, sometimes 3
- Technical reviews completed
  - 1 month
- Map Coordinator review
  - Technical reviews addressed
  - Internally consistent
- Nomenclature review
- Map accepted for publication
- GIS and map files formatted

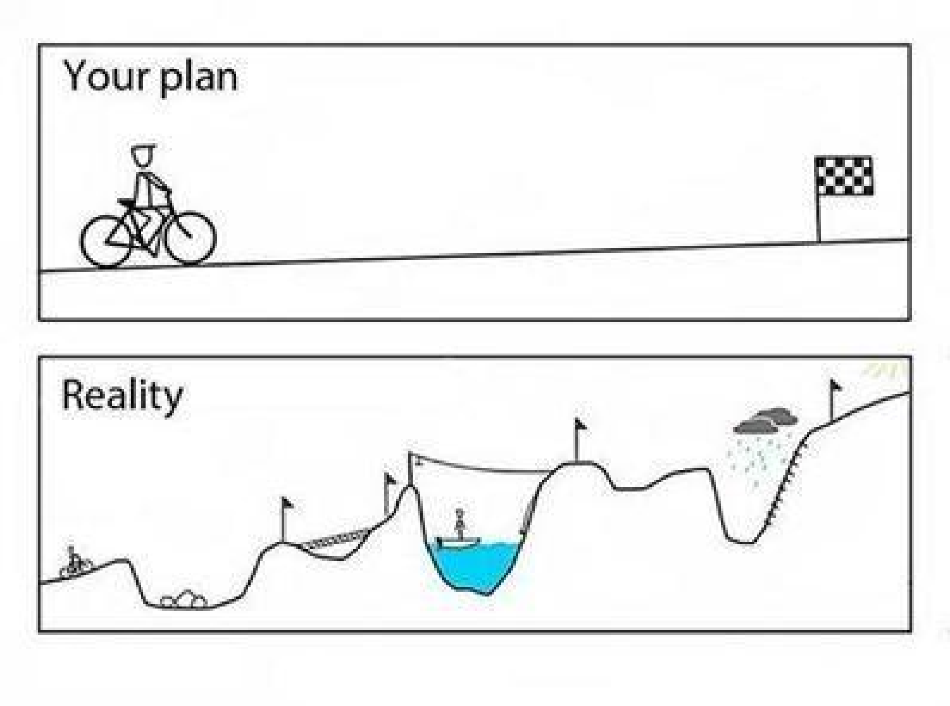
Work flow

- Submission to USGS PSC - Menlo Park
- Map editing for USGS compliance
  - Interaction with author
- Map cartography for USGS compliance
  - Interaction with author
- Galley proof and final edits
- Print bid and acceptance
- Print, post, distribution

Work flow

- Tractable timeframe
  - Base map/GIS — 3 months
  - Mapping — 24 months
  - Submission prep — 3 months
  - Review and re-submit — 6 months
  - Editing and cartography — 6 months
  - Production — 6 months

48 months


Your plan
Reality

Work flow

- Pre-proposal
  - No contact
- Base map and GIS project created
  - Not possible as proposed
- GIS delivered to author
  - Not checked
- Mapping by author (+support as needed)
  - Varying author ability in process
- Planetary Geologic Mappers Meeting
  - Not attended
- Pre-submission review
  - Not submitted
- Formal submission to USGS
  - Submission incomplete

Work flow

- Common deviations (and mitigation)
  - Multiple programs funding maps
    - Multiple notices of “new starts”
    - Multiple points of contact and follow-ups
    - Potentially over-commits USGS
    - (NASA alerts USGS of “new starts”)
  - Map not possible as proposed
    - Base, scale, projection not possible, not considered
    - (Encourage pre-proposal contact)
    - (Reviewer and program office awareness)
    - (Improve author awareness)

Work flow

- Common deviations (and mitigation)
  - Varying levels of author expertise
    - GIS and data sets unfamiliar
    - (Encourage pre-proposal contact)
    - (Reviewer and program office awareness)
    - (Improve author awareness)
  - Influx of data makes authors “wait”
    - The next image or data set is “the one”
    - (Attendance at annual PGM meeting for status report)
    - (Educate authors on role of map)

Work flow

- Common deviations (and mitigation)
  - Scales and bases necessitate adapted approach
    - (Solicit community input – PCGMWG/GEMS)
    - (Improve author awareness)
    - (Encourage USGS contact)
  - Map submitted after project funds over
    - (Improve author awareness)
    - (Attendance at annual PGM meeting for status report)
    - (Encourage USGS contact)
    - (Establish a cut-off term for delinquent maps)
    - (Propose for 4 years)

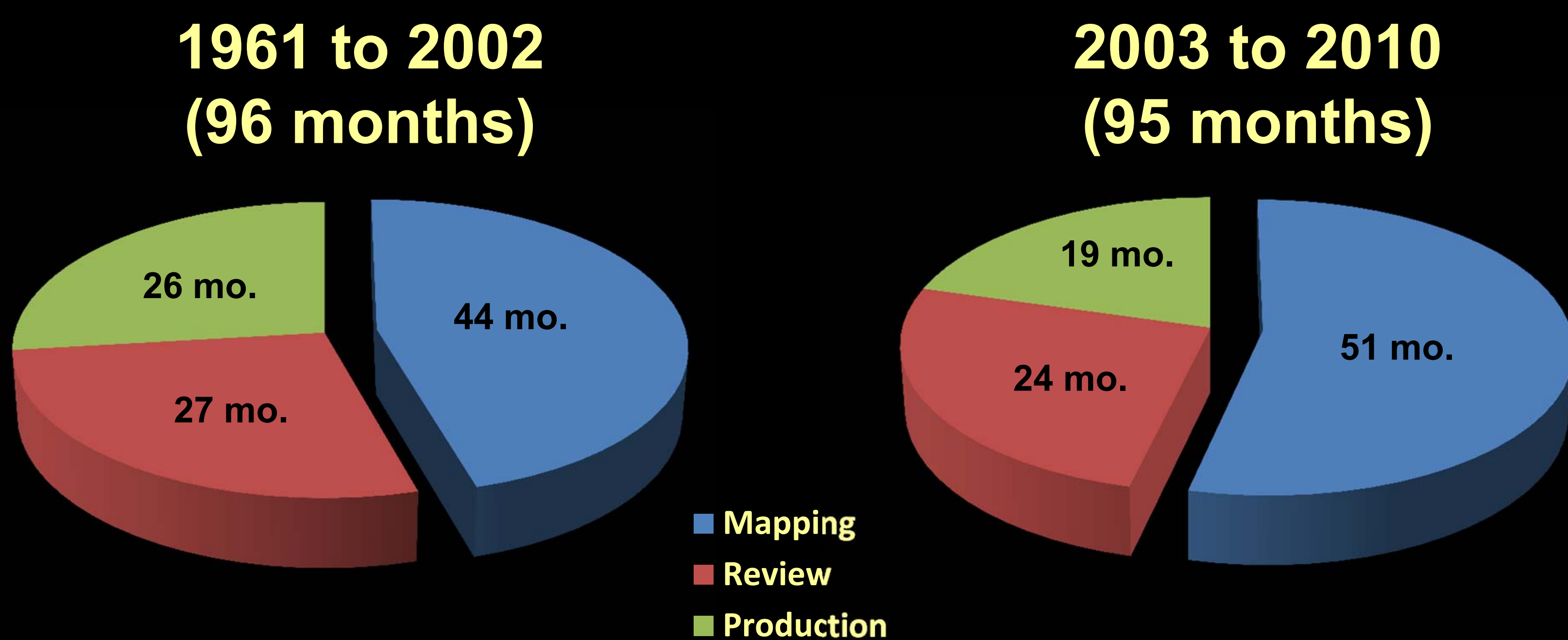
Work flow

- Common deviations (and mitigation)
  - Scales and bases necessitate adapted approach
    - (Solicit community input – PCGMWG/GEMS)
    - (Improve author awareness)
    - (Encourage USGS contact)
  - Technical reviews lengthy
    - Technical reviews are not one-off … exchange
    - Requires detailed editing
    - (USGS hard follow-up with reviewers)
    - (Encourage USGS contact)

Work flow

- Common deviations (and mitigation)
  - Components fragmented
    - (Improve author awareness)
    - (Organize by USGS)
  - USGS Menlo Park ←→ Author
    - Lack of communication/understanding
    - Decreased response time
    - (Improve author awareness)
    - (Improve USGS Menlo Park awareness)
    - (Assign point of contact at USGS Astrogeology)

What is the time for production of USGS geologic map?



Work flow

- Delinquent maps
  - Lots of reasons for delinquency
  - USGS and author want NASA to get return on investment
  - USGS wants to be able to predict our work flow
- Defined as
  - >10 years past funding date
  - >5 years since PGM meeting attendance
  - >3 years since initial review
- Contact author
  - "Relinquished" to USGS (re-posted as available)
  - Establish plan for submission
    - Scan hard copies and register, re-package GIS, create GIS, convert Illustrator to GIS, etc.
    - Plan must be enforced … NASA assistance

Outline

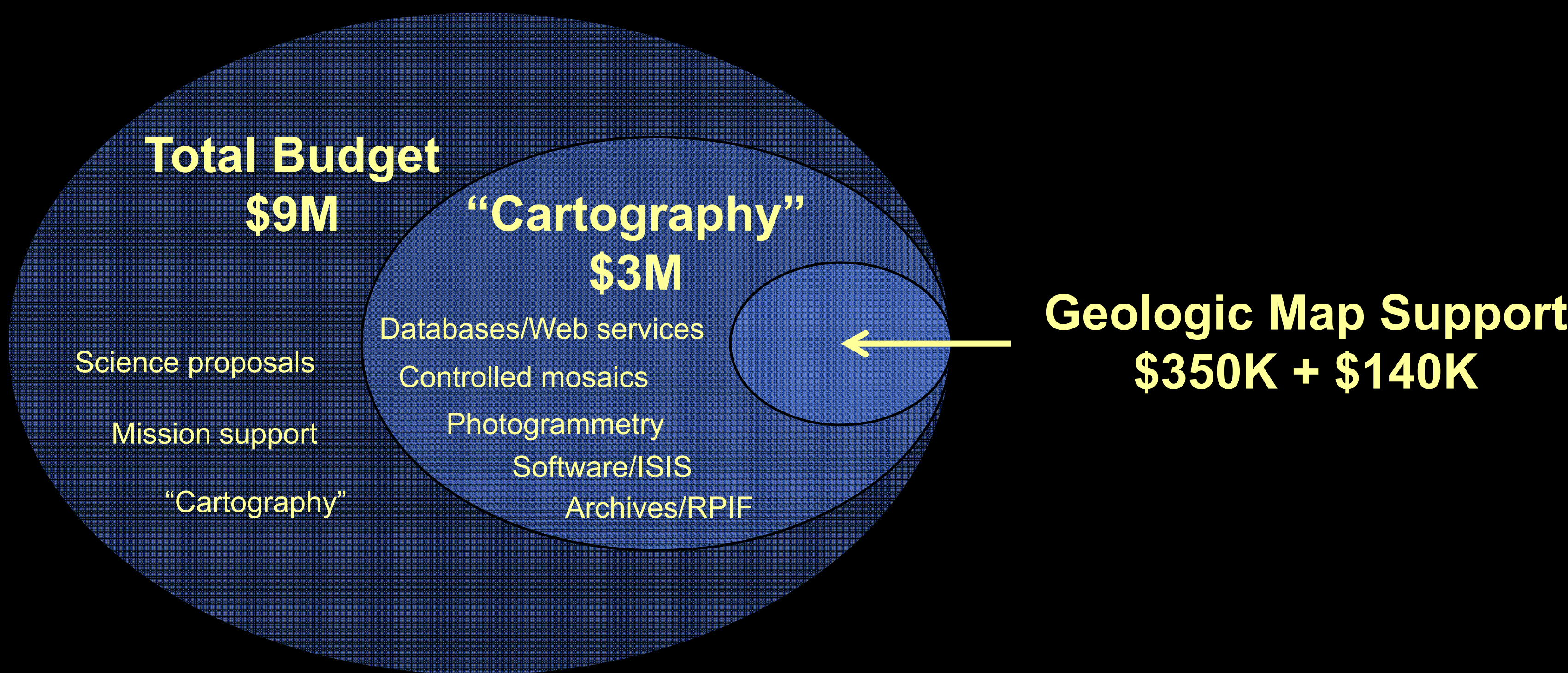
- Planetary cartography
- Basic concepts
- History
- Topic vs. Context
- Map components
- Work flow
- Funding
- Management
- Concerns
- Conclusions

Funding

- NASA ROSES (to individuals)
  - SSW
  - MDAP
  - LDAP
  - PDART
  - Others?
- "Cartography" funds to USGS
  - Program TBD

Funding - *to USGS*

USGS Astrogeology Budget Breakdown



Funding - *to USGS*

- **USGS Cartography Project**
  - **Section C: Geologic Mapping Program Support**
    - **Task C1: Geologic Map Coordination ($350K)**
      - **Image and/or topographic bases**
      - **Technical review coordination**
      - **Editing/print production of USGS SIM**
      - **Cartographic standards and "best practices"**
      - **PGM Website maintenance**
    - **Task C2: MRCTR GIS Lab (PIGWAD) ($140K)**
      - **Tools, tutorials, workshops, guest facility**
      - **Data formatting and packaging**
      - **GIS web interfaces**

Funding - *to USGS*

- Task C1: Geologic Map Coordination (Skinner)
  - Sub-task #1 – Project Management
  - Sub-tasks #2 – Map Processing
    - *Coordination – 80 hours per map*
    - *Nomenclature – 10 hours per map*
    - *PSC Guidance – 40 hours per map*
    - *PSC Editor – 125 hours per map***
    - *PSC Cartographer – 125 hours per map***
  - Sub-task #3 – Community Interaction
  - Sub-task #4 – PGM Web Maintenance
  - Sub-task #5 – Map Base Preparation
  - Sub-task #6 – Support Cartography

Funding - *to USGS*

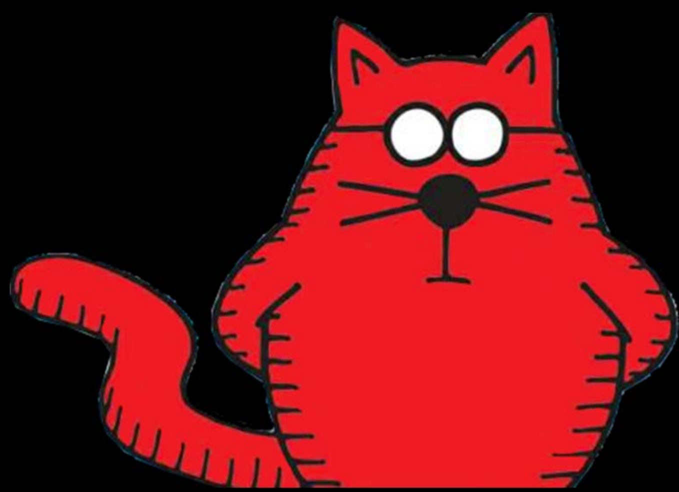
- Task C2: MRCTR GIS Lab (Hare)
  - Sub-task #1 – Project Management
  - Sub-task #2 – Digital Map Support, Guest Facility, Workshops, Tools, and Tutorials
  - Sub-task #3 – Data ingestion and web-site maintenance
  - Sub-task #4 – Standardized GIS web interfaces
  - Sub-task #5 – Promotion

Funding - *to USGS*

- Personnel
  - J. Skinner – Map Coordinator
  - T. Hare – GIS/Data sets
  - C. Fortezzo – Geology/GIS
  - R. Hayward – Nomenclature
  - S. Akins – Web
  - T. Gaither – Database/Misc.
  - *PSC Editor*
  - *PSC Cartographer*
- *Total Cost Per Map - $25,000*

Outline

- Planetary cartography
- Basic concepts
- History
- Topic vs. Context
- Map components
- Work flow
- Funding
- Management
- Concerns
- Conclusions



Management

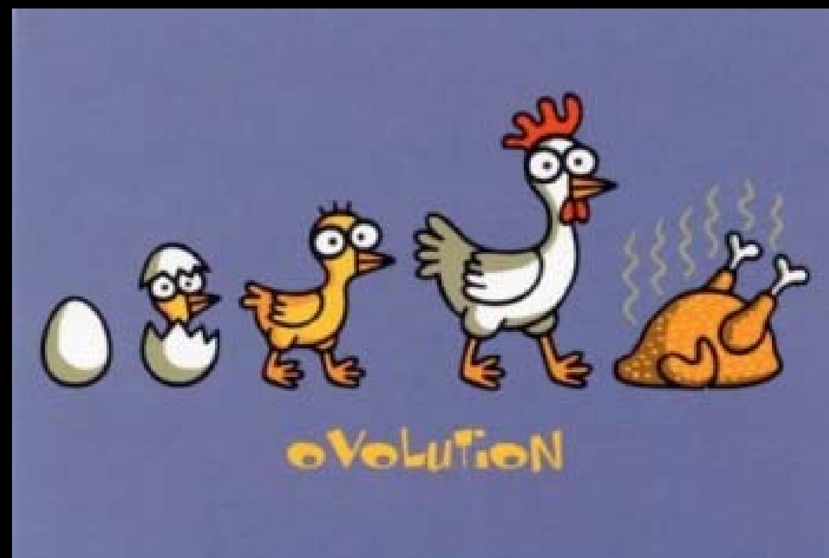
- Planetary Cartography and Geologic Mapping Working Group (PCGMWG)
  - Define and prioritize cartographic needs
  - Represent community (including NASA)
  - Review USGS Cartography proposal
- Geologic Mapping Subcommittee (GEMS)
  - Adopt new approaches
  - Represent geologic mapping community
  - Chair sits on and communicates with PCGMWG

GEMS Members

- David Williams (ASU) – Chair
- Debra Buczkowski (JHU/APL)
- David Crown (PSI)
- Corey Fortezzo (USGS)
- Jim Skinner (USGS) – Map Coordinator
- Mike Kelley (NASA)*
- - vacant -

Outline

Planetary cartography
Basic concepts
History
Topic vs. Context
Map components
Work flow
Funding
Management
Concerns
Conclusions



Community Concerns

- GEMS comments re: NASA re-organization
- November 30, 2013
  - How will the geologic mapping program be impacted
  - How will NASA maintain health of mapping program
  - Which themes (sub-themes) will provide funds
  - How will coordination, etc. (presently overseen by PCGMWG) be impact by re-organization?
- January 22, 2014
  - Recommend adding verbiage
    - Derived from PG&G
    - Acknowledges following standards and requirements, including GIS format, PGM meeting, and reviews
    - Contact USGS Map Coordinator
  - This verbiage was included (Thanks!)

Community Concerns

- July 9, 2014 – After 2014 PGM Meeting
  - Background
    - Historical funding through PG&G (some DAPs)
    - Reliance on USGS cartographic support (PG&G)
    - One “core” program facilitated communication between NASA program managers and scientists
    - PCGMWG has been intermediary between NASA and science community on technical elements of cartography
    - GEMS intermediary between PCGMWG, NASA, scientists
    - PCGMWG and GEMS ensures standards
    - Standardized cartographic products (incl. geologic maps) are foundation for scientific analyses and protection of robotic and human assets

Community Concerns

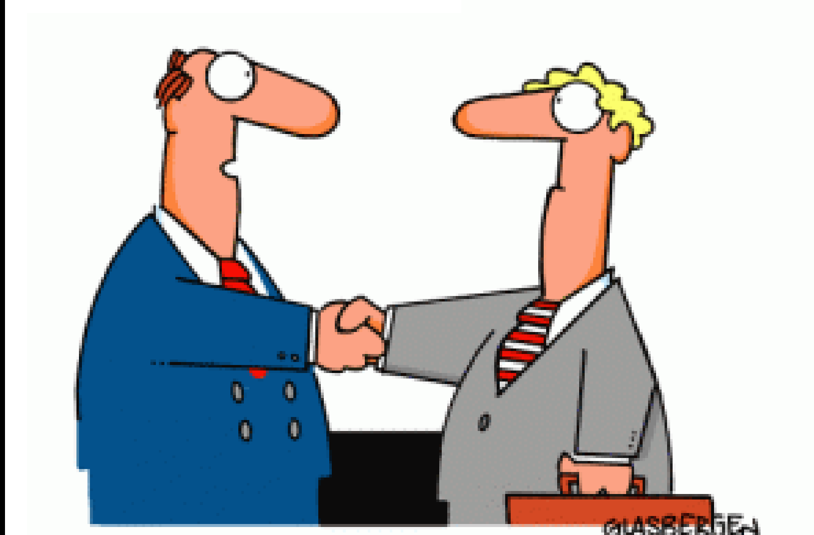
- July 9, 2014 – After 2014 PGM Meeting
  - Concerns
    - Re-structured NASA R&A programs separate geologic mapping-related proposals from the program that provides infrastructure and support
    - No single point of contact at NASA
    - Will PCGMWG and GEMS remain in existence as critical intermediary between research community and NASA
    - Where will PCGMWG be "located", who from NASA will lead representation, and how will institutional knowledge be transferred
    - How will NASA continue to be informed about critical cartographic infrastructure related to science and exploration?

Community Concerns

- July 9, 2014 – After 2014 PGM Meeting
  - Recommendations
    - Designate a NASA program manager as the lead representative to the planetary cartography and geologic mapping community
    - Notify USGS of geologic mapping “new starts”
    - Match level of “new starts” from each of the various NASA R&A programs with USGS
    - Ensure DAPs include sufficient new funds and knowledgeable panel members to accommodate selection of geologic mapping-related science
    - Create a Planetary Cartography and Geologic Mapping Analysis Group, or equivalent

Outline

Planetary cartography
Basic concepts
History
Topic vs. Context
Map components
Work flow
Funding
Management
Concerns
Conclusions



"You're a pretty good sales rep, except for the nine times you called me 'wallet' instead of 'Walter'."

Conclusions

- Planetary geologic mapping has an established history
- NASA and USGS >50 years collaboration
- Thriving sub-discipline of planetary science
- Topical science ≠ contextual science maps
- “Standardized” mapping is inherently lengthy

Conclusions

- There are more diverse maps now than ever
- Diversity requires oversight of standards
- NASA program managers need to be aware
- Geologic mapping is just one component of broader issues related to planetary cartography
- Benefit from continuity, oversight, planning, and communication between participants

Questions? Comments?