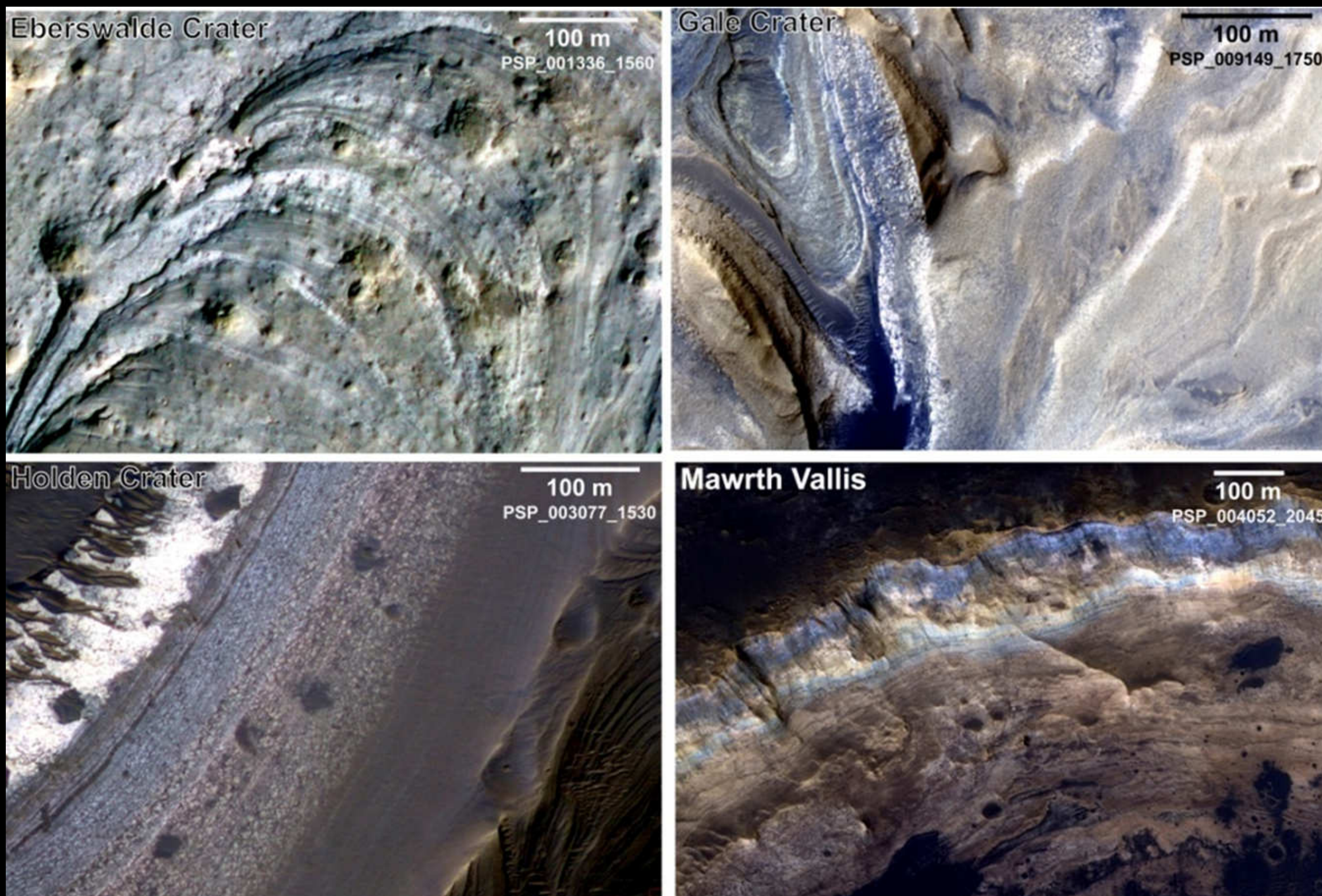
Mars Landing Site Selection Activities:

An Update on MSL and Future Missions

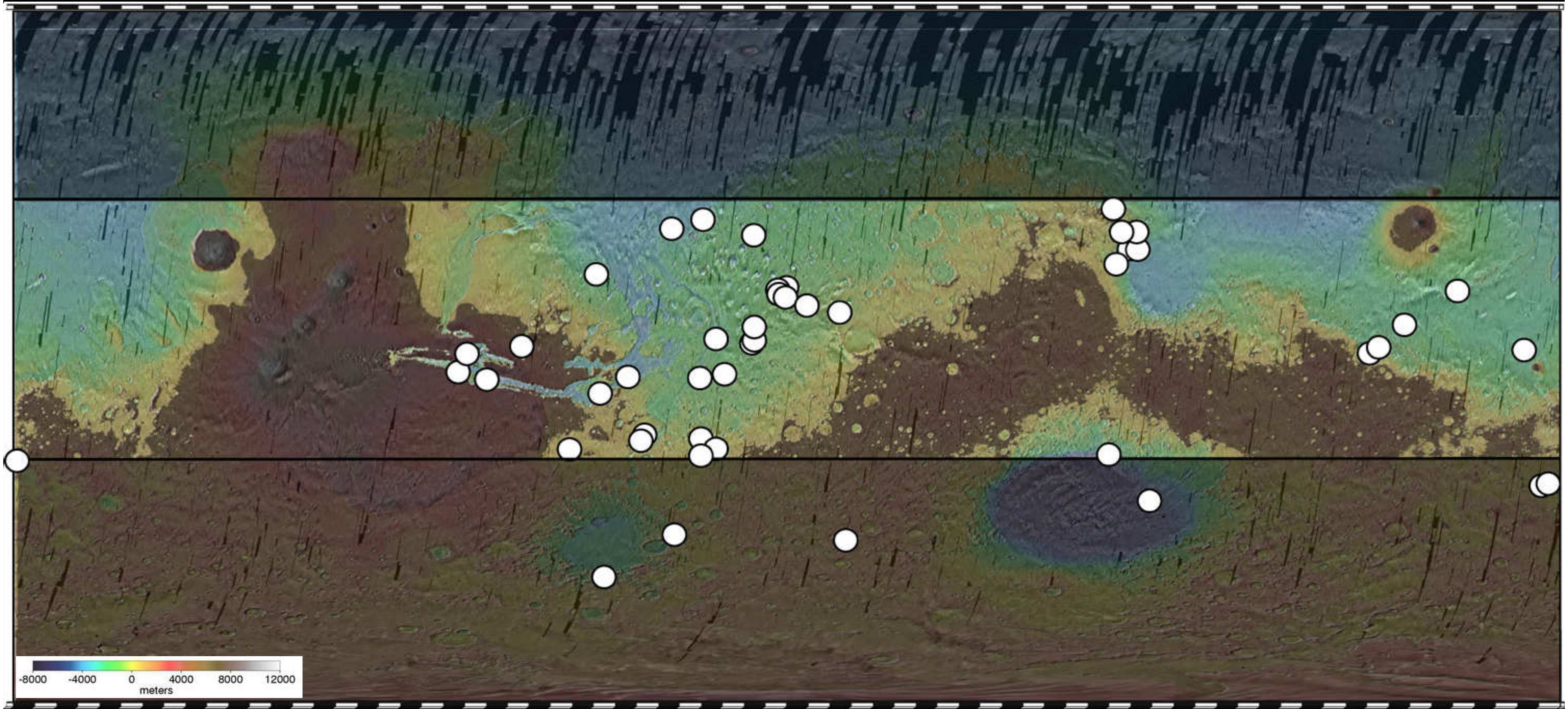


John Grant, Matt Golombek, John Grotzinger, and Many Others

(Smithsonian Institution) (Jet Propulsion Laboratory, California Institute for Technology) (All over the place)

Proposed MSL landing sites:

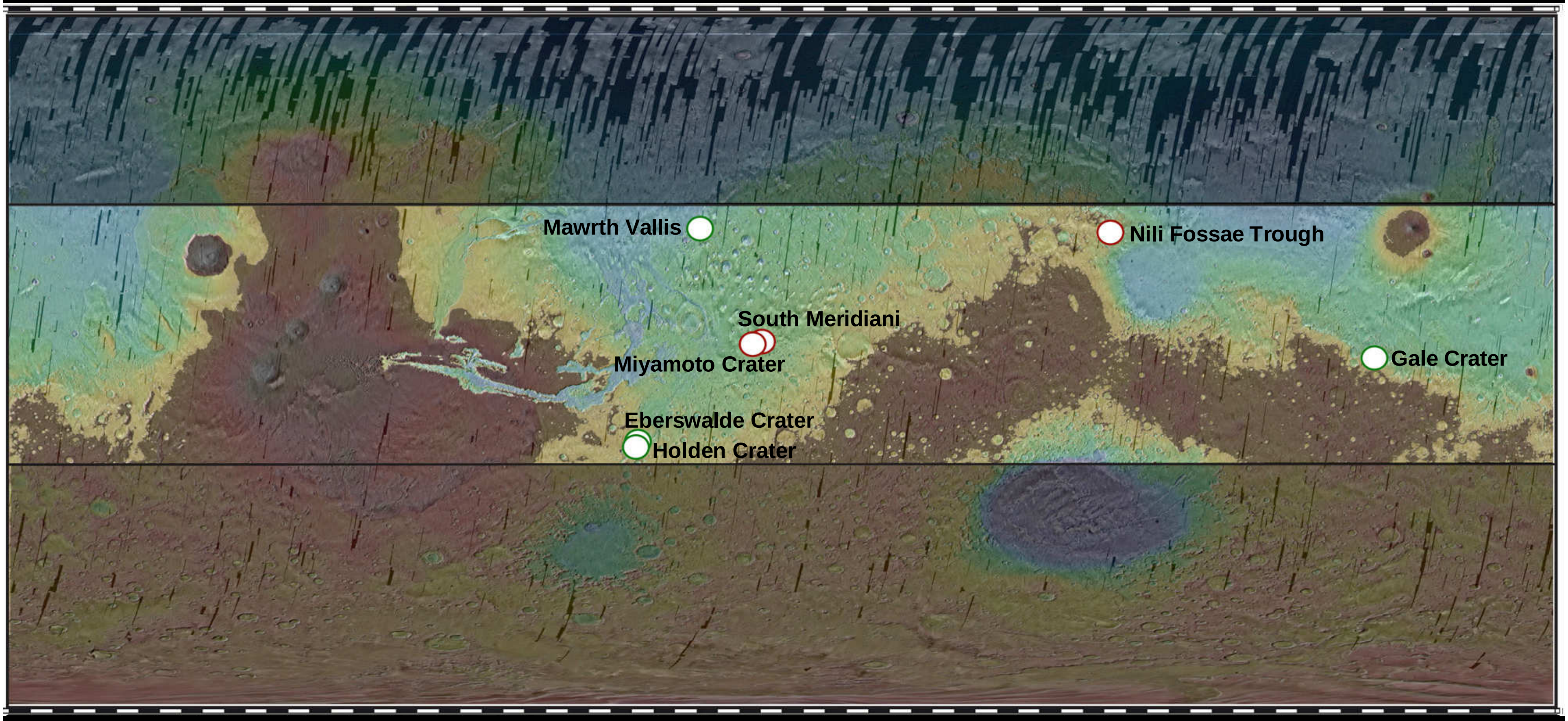
Mars Landing Site Selection Activities



Shaded areas are above +30°N, below -30°S, and above +1 km in elevation

Update on MSL Landing Site Selection Activities:

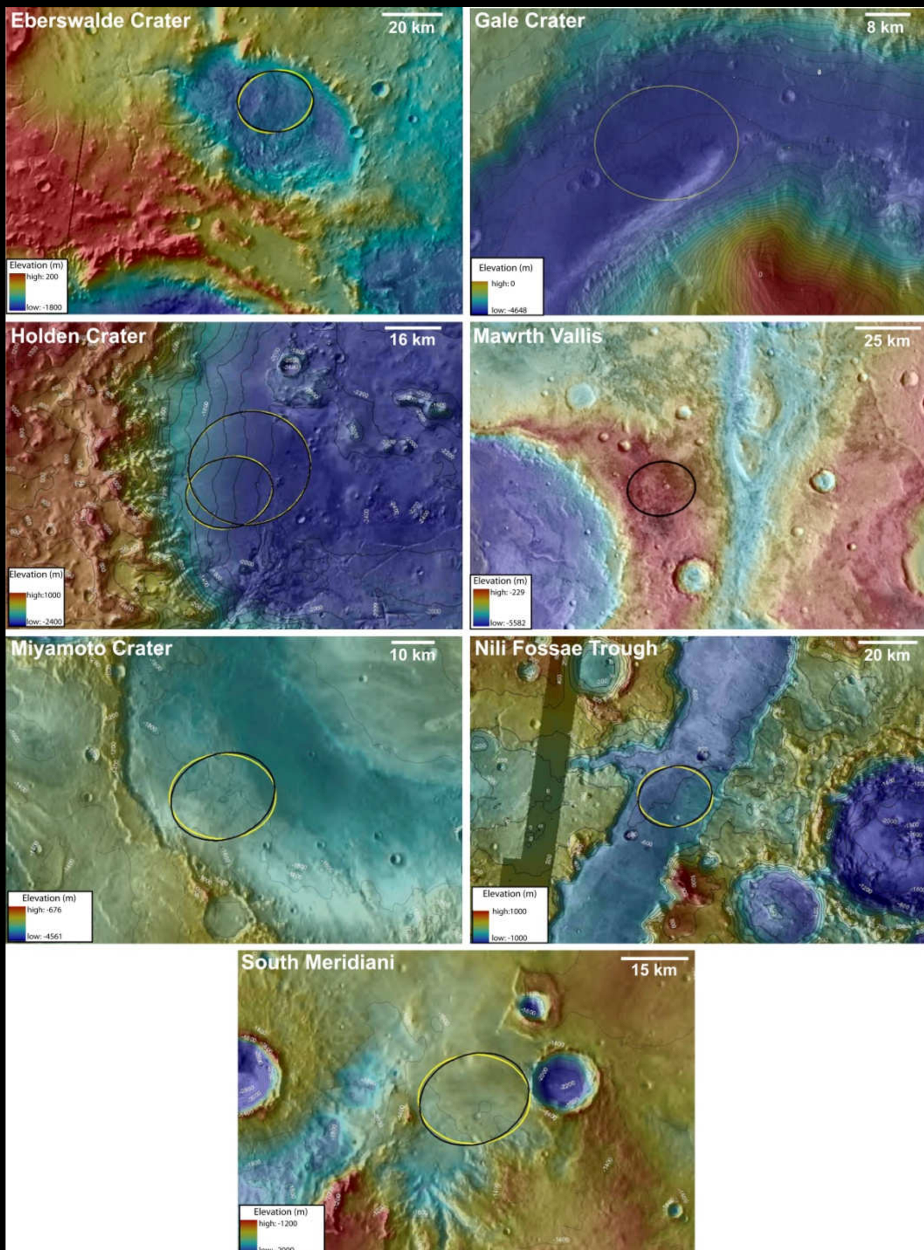
Mars Landing Site Selection Activities



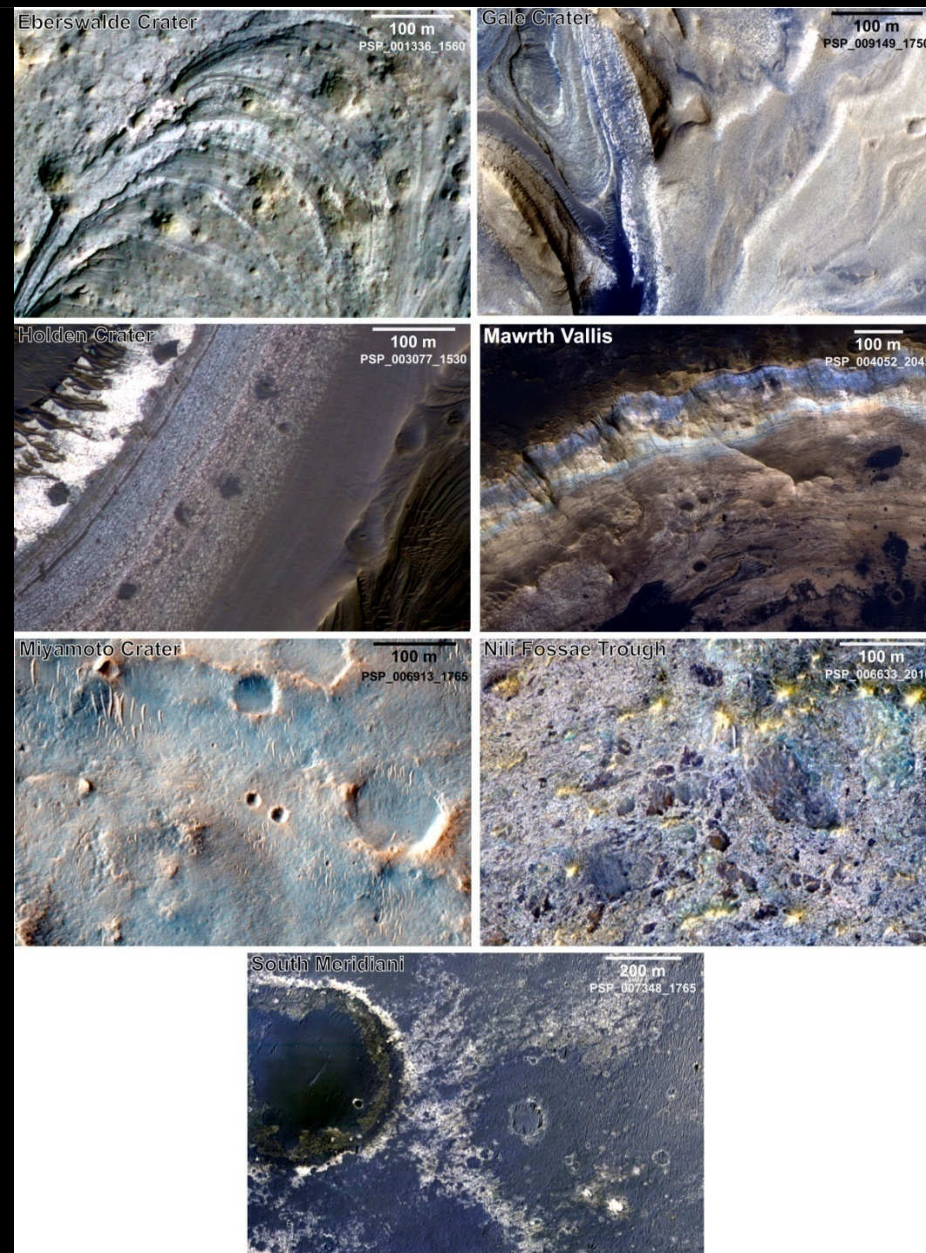
Seven Sites Receiving Highest Science Ranking:

Shaded areas above +30°N and -30°S, elevations >1 km
Green outlines denote final four sites based on science, engineering

Ellipses on MOLA and THEMIS



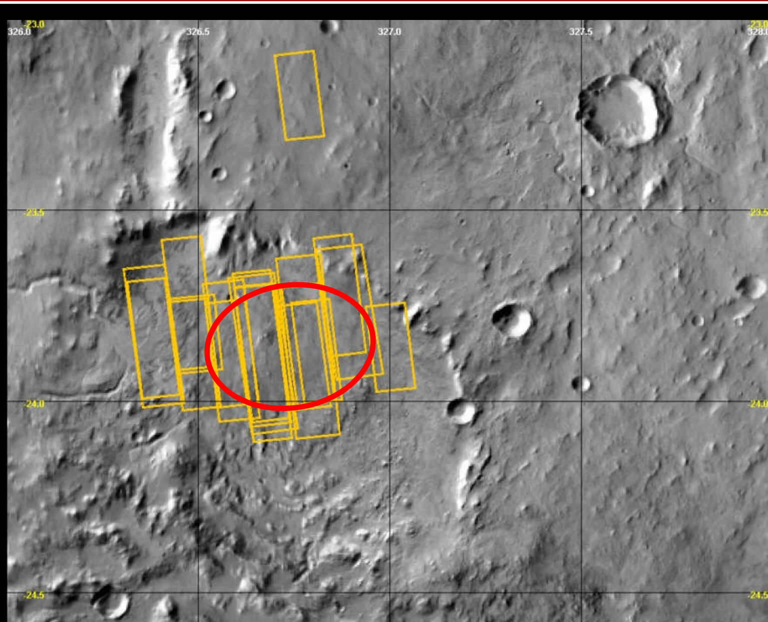
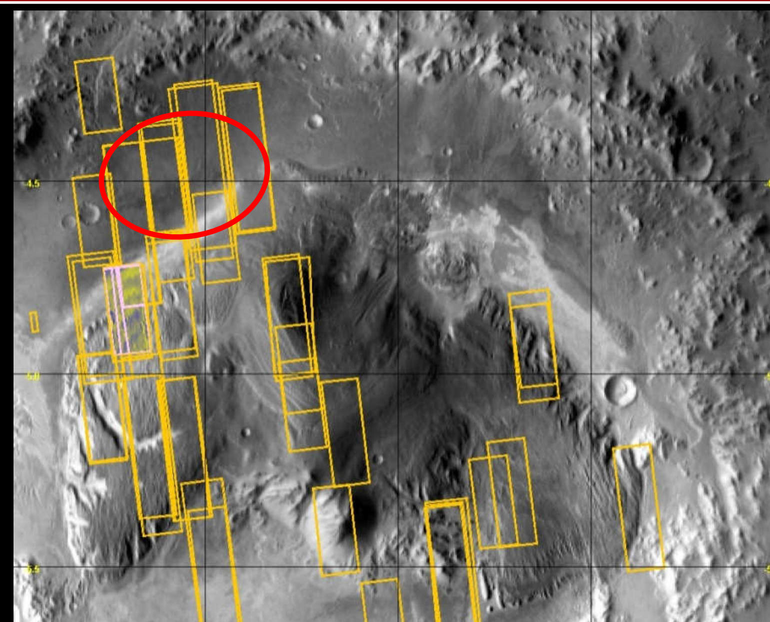
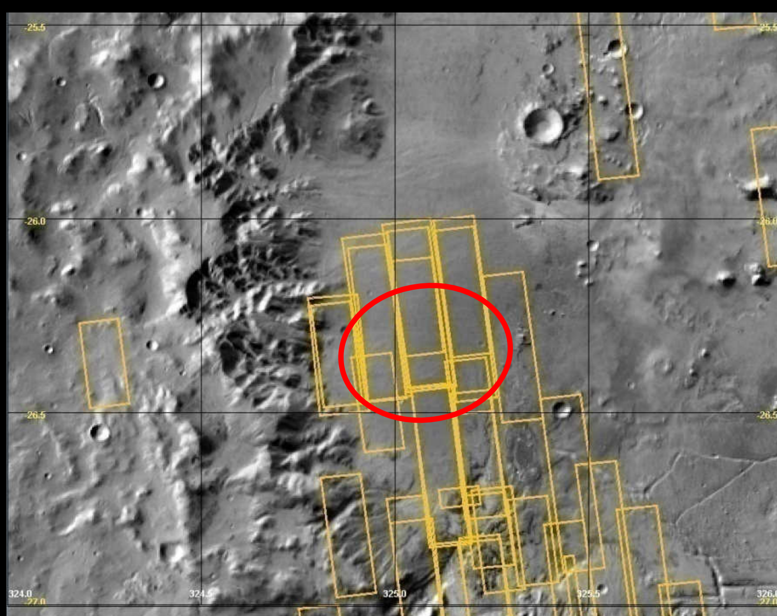
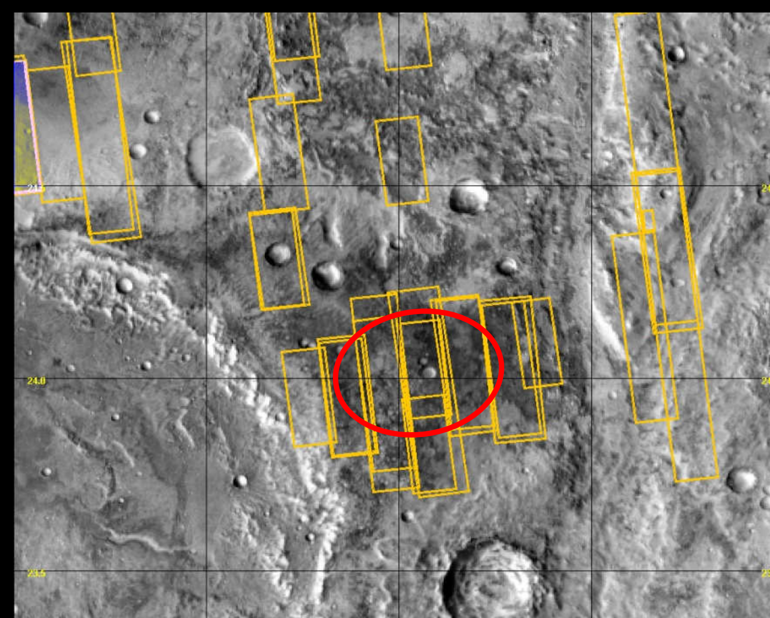
Snippets of HiRISE Color



Each of the final seven sites represents an exciting science target

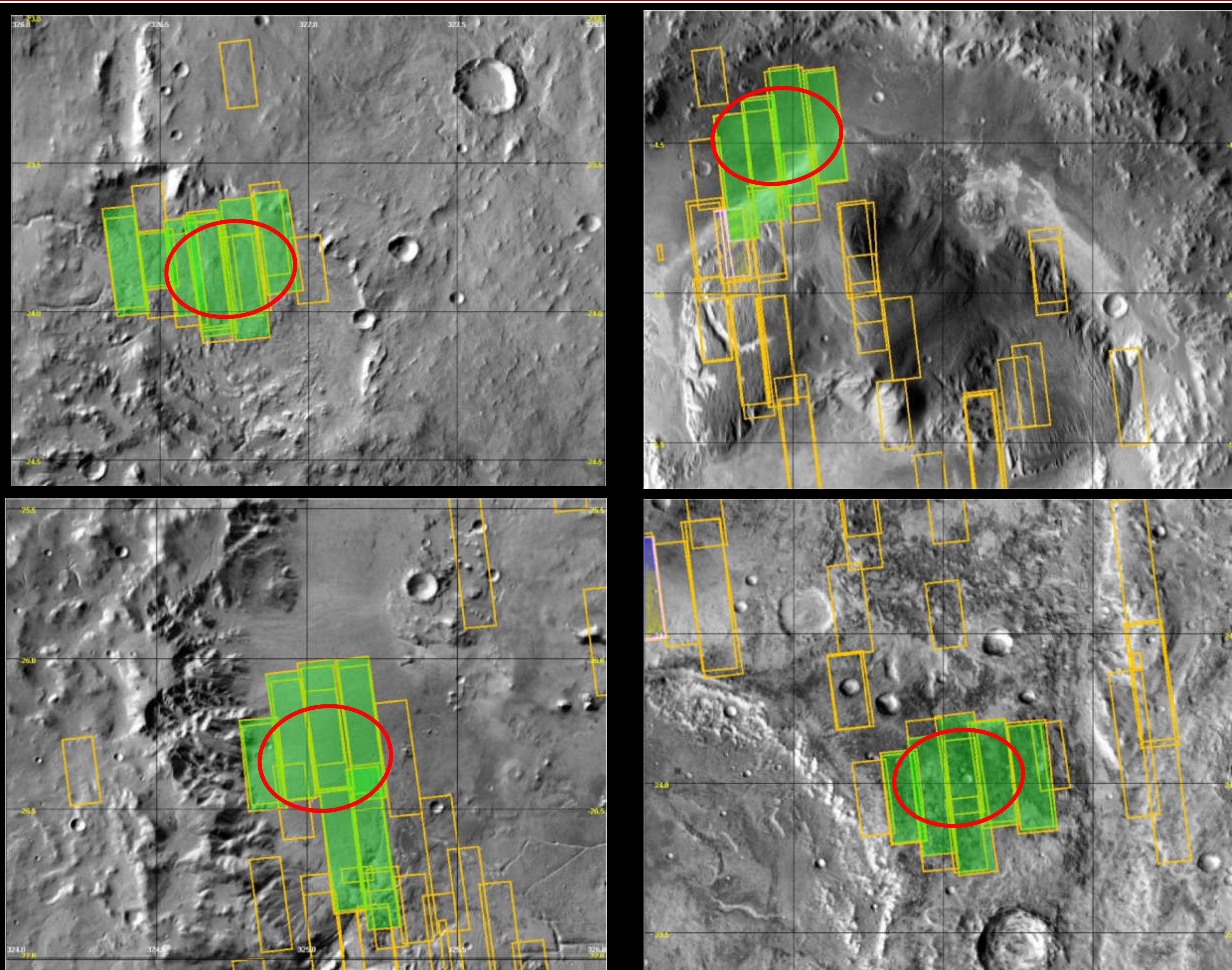
HiRISE Coverage of Four MSL Landing Sites:

Mars Landing Site Selection Activities

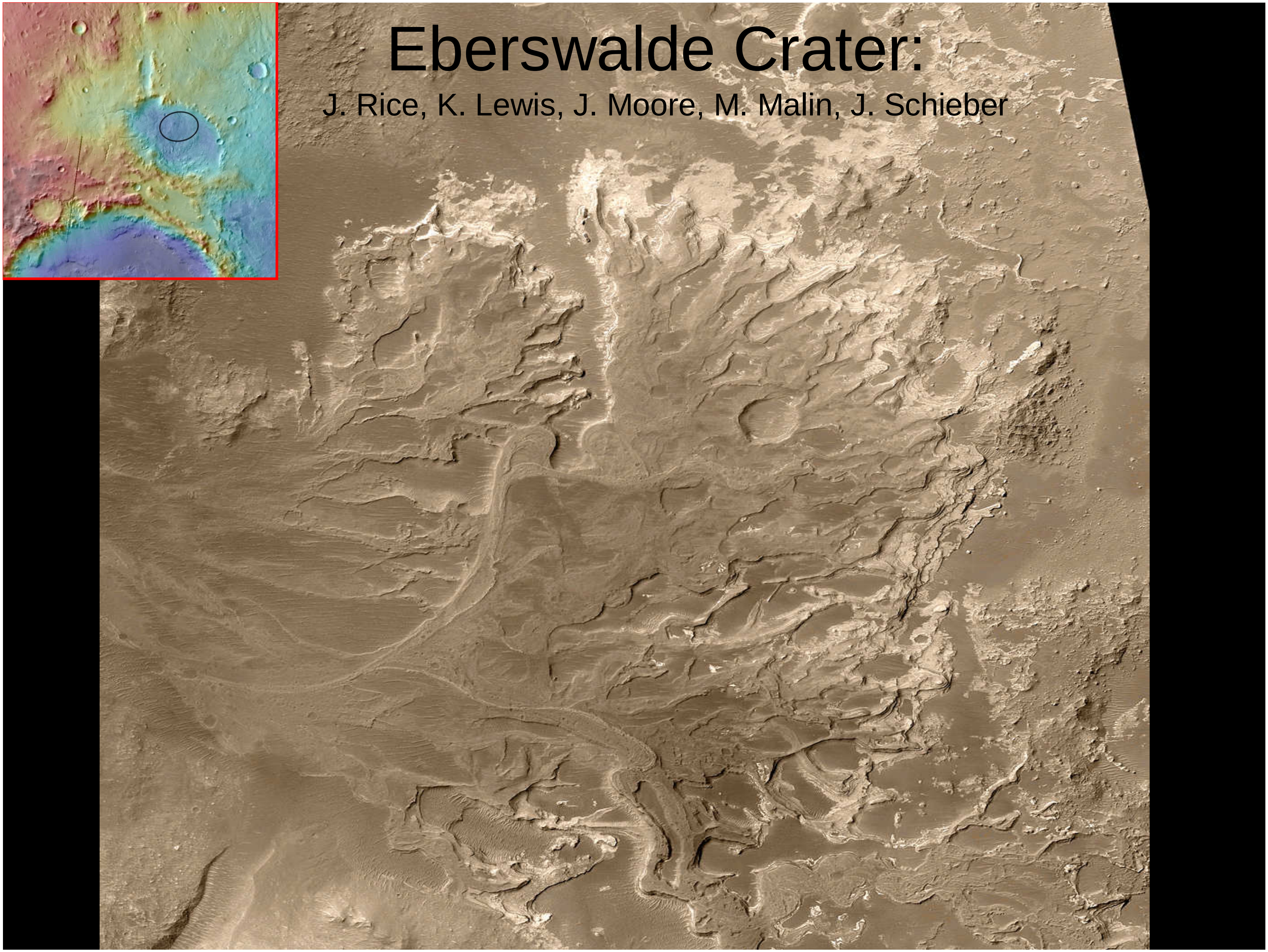
Stereo HiRISE Coverage of Four MSL Landing Sites:

Mars Landing Site Selection Activities



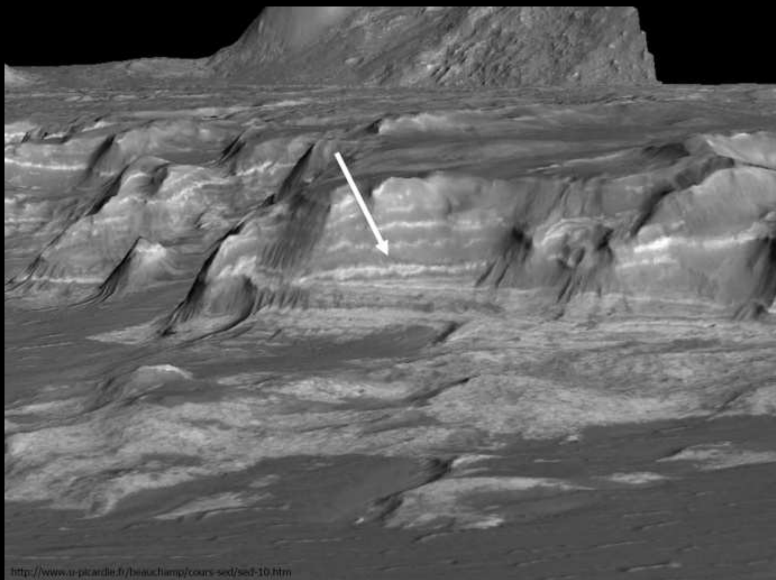
Eberswalde Crater:

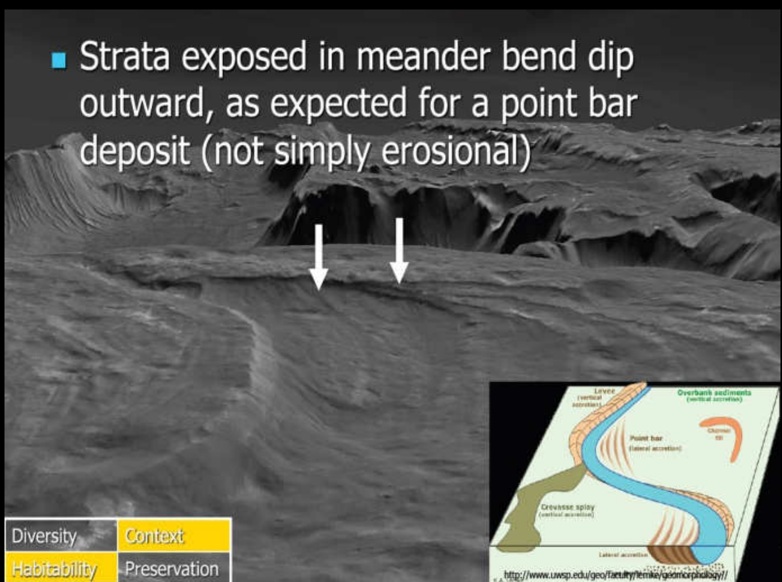
J. Rice, K. Lewis, J. Moore, M. Malin, J. Schieber

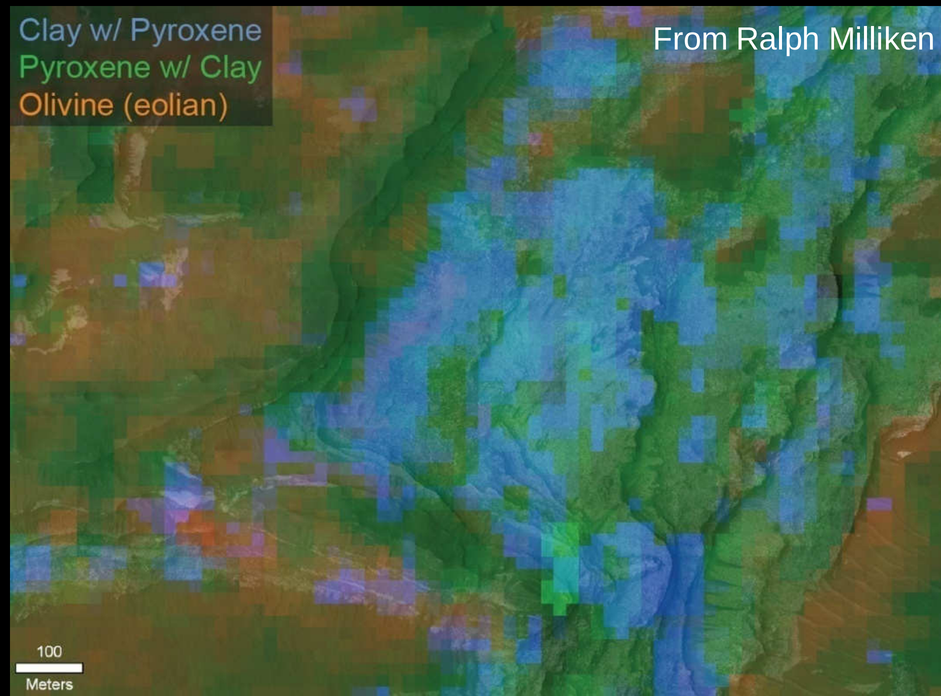


Clay-Bearing Beds in Deltaic Setting:

Mars Landing Site Selection Activities



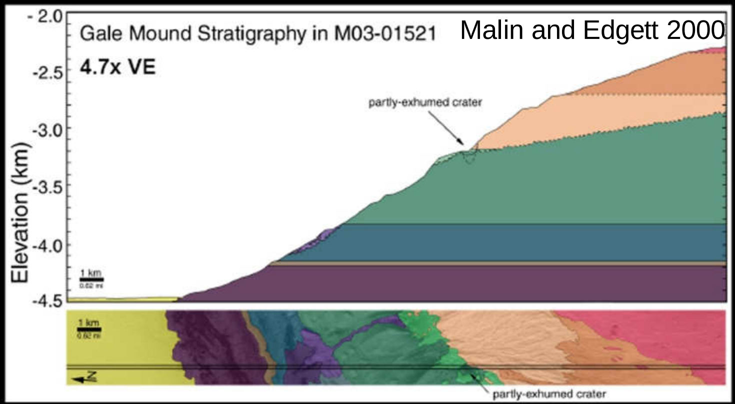


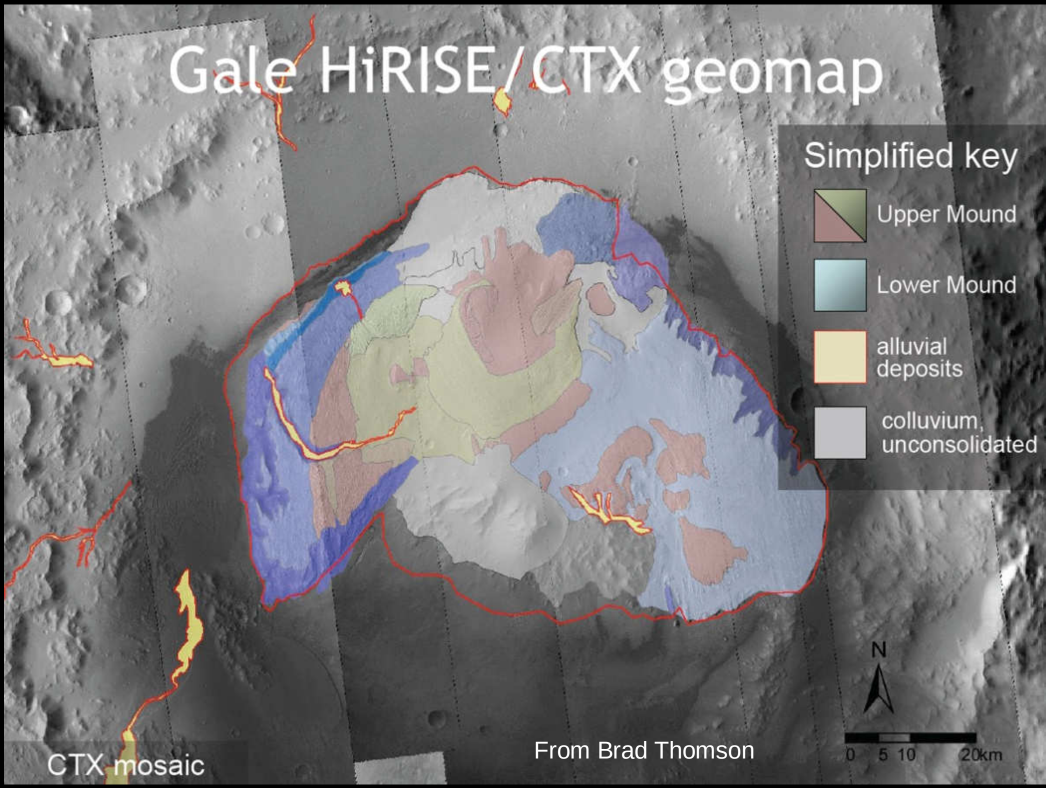


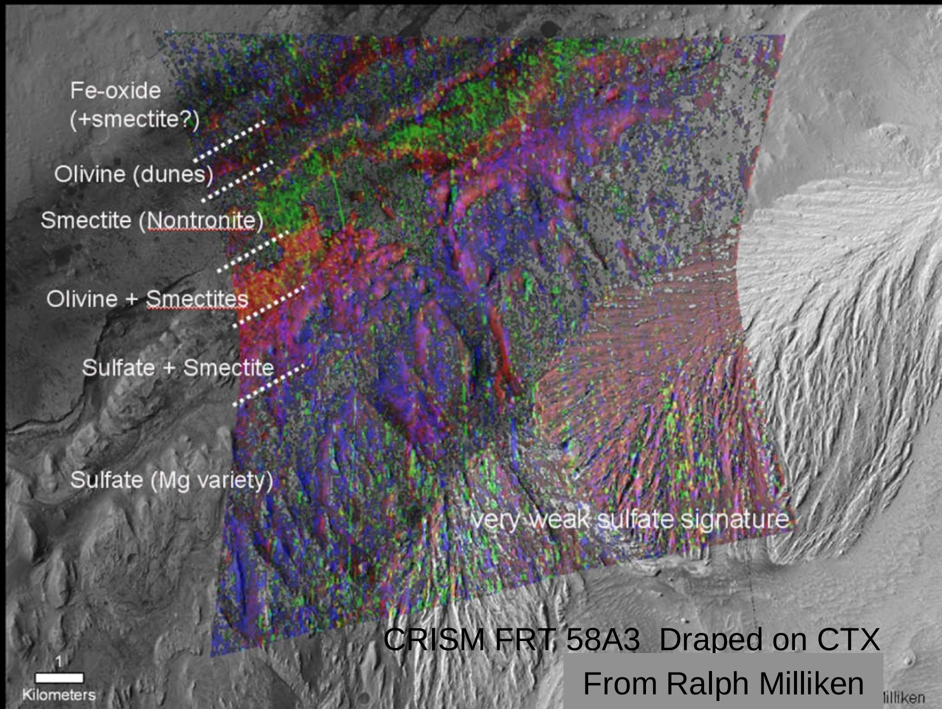
Gale Crater: K. Edgett, B. Thomson, N. Bridges, R. Milliken

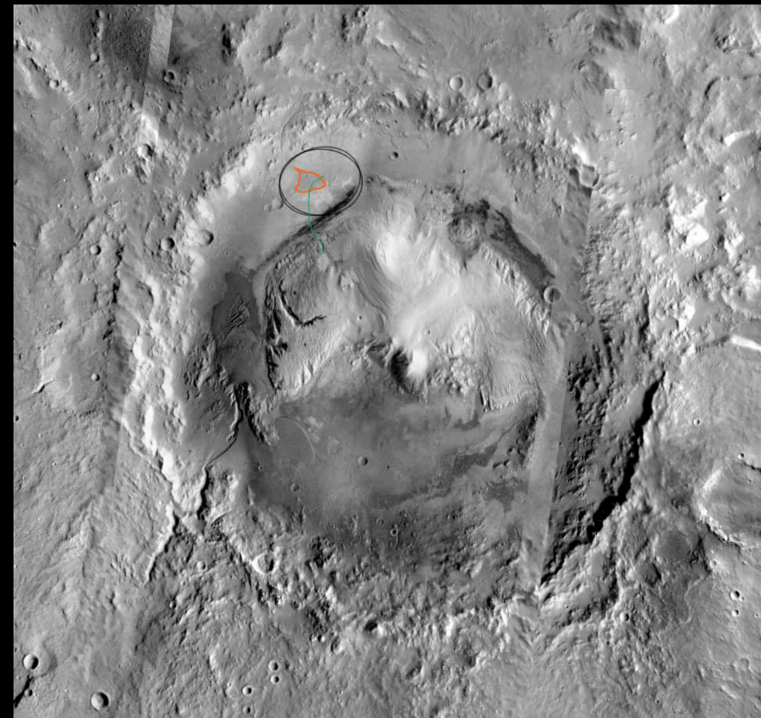
Mars Landing Site Selection Activities

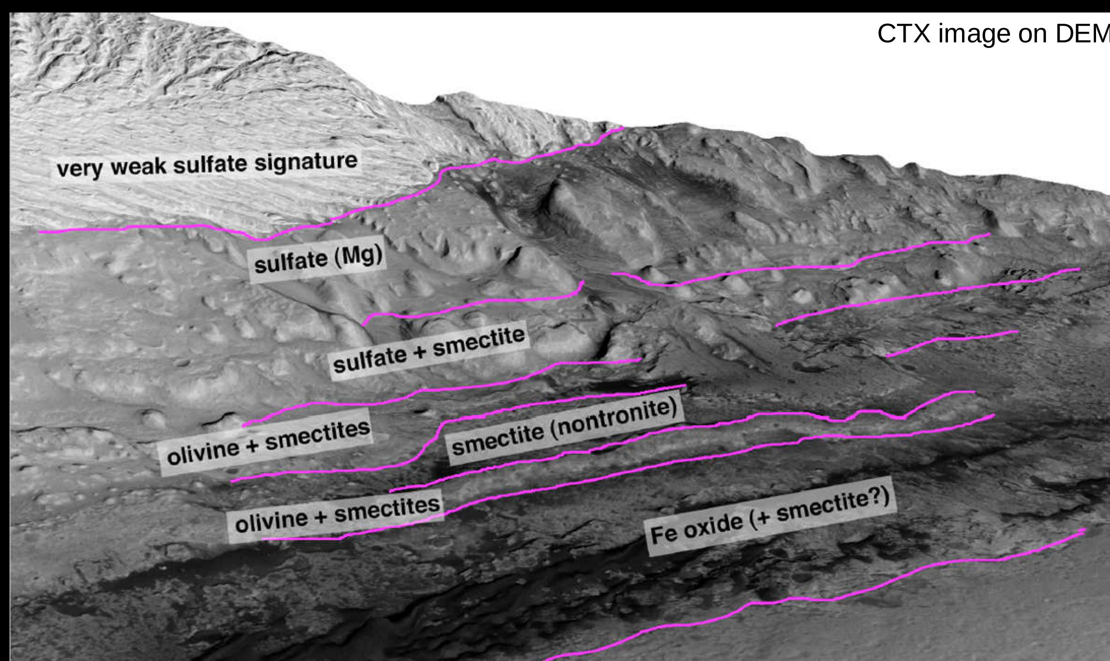
- **High diversity of geologic materials with different compositions and depositional conditions**
- **This diversity is arranged in a stratigraphic context**
- **Stratigraphy records multiple early Mars environments in sequential order**
- **Gale is characteristic of a family of craters that were filled, buried, and exhumed, providing insights into an important martian process**



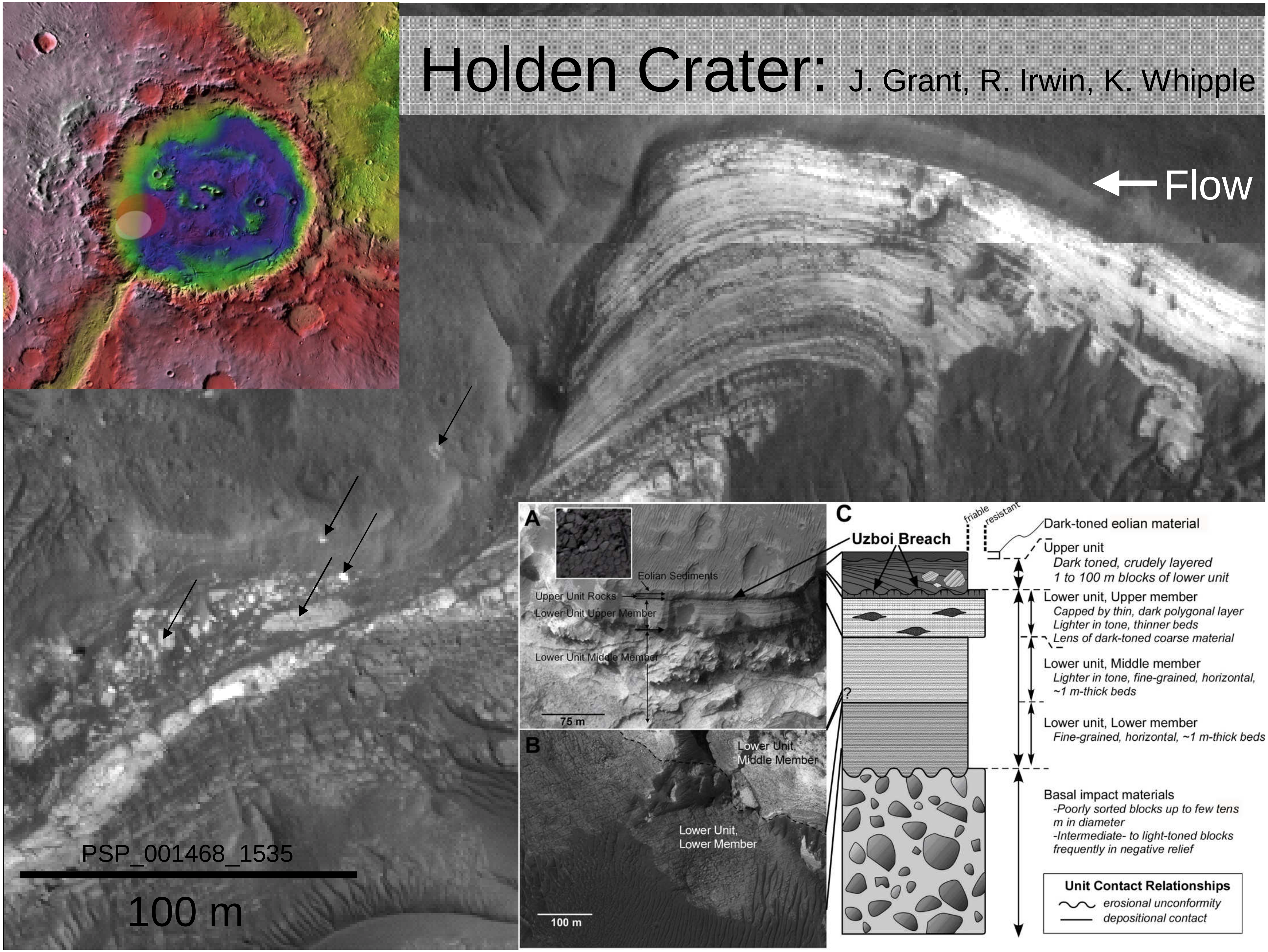


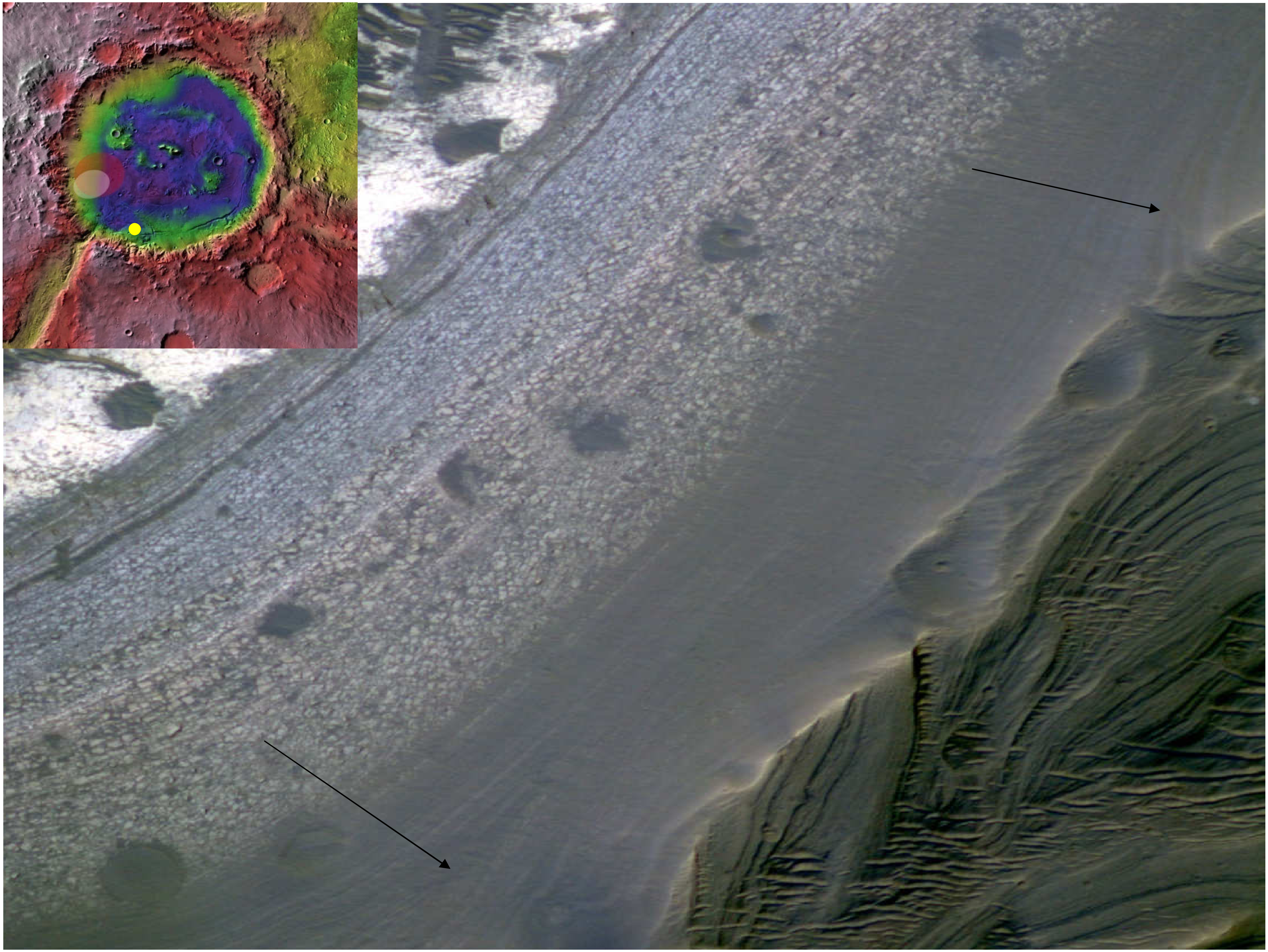

Fe-oxide
(+smectite?)
Olivine (dunes)
Smectite (Nontronite)
Olivine + Smectites
Sulfate + Smectite
Sulfate (Mg variety)
very weak sulfate signature
CRISM FRT 58A3 Draped on CTX
From Ralph Milliken
1
Kilometers

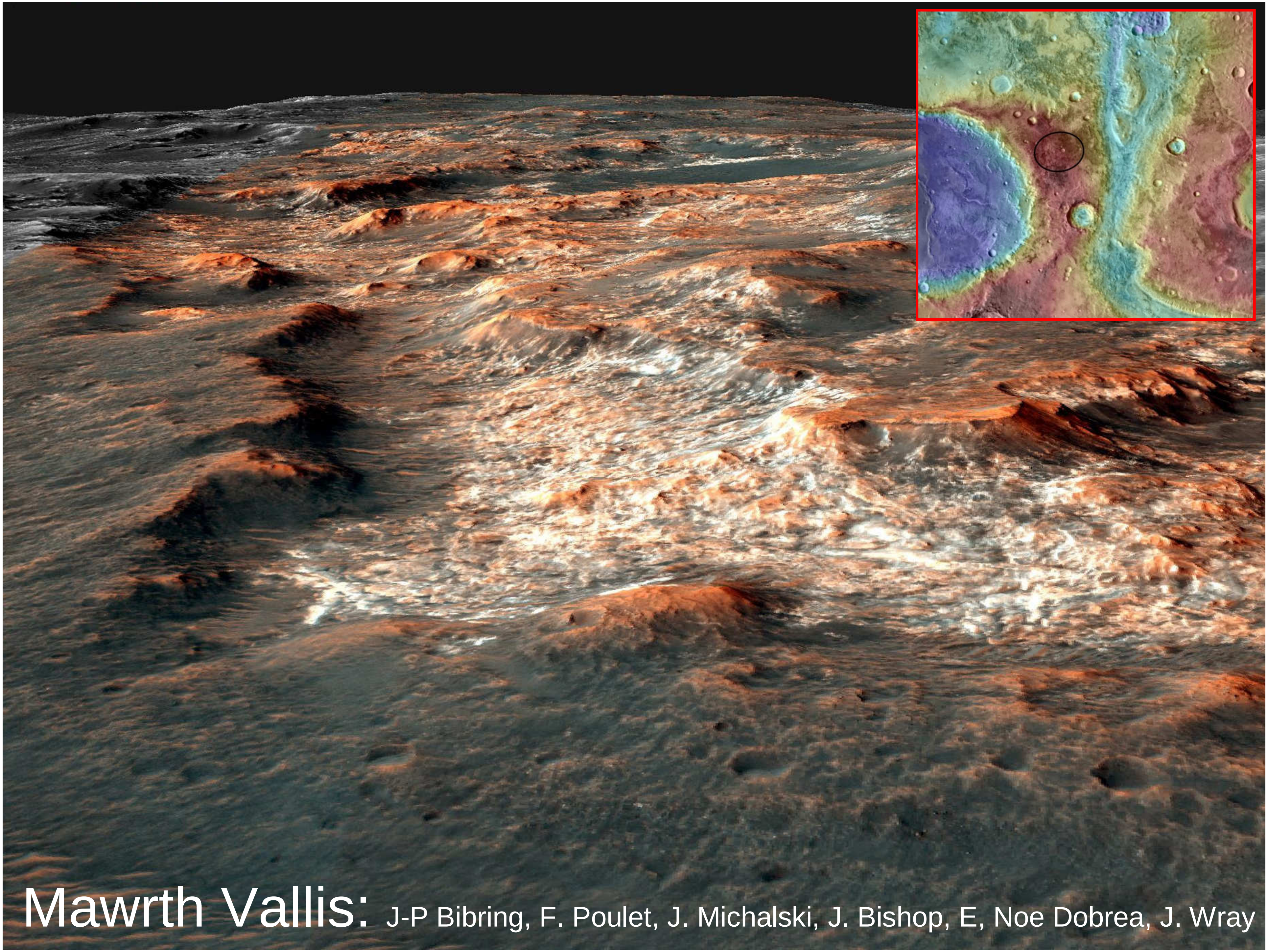



CTX image on DEM
very weak sulfate signature
sulfate (Mg)
sulfate + smectite
olivine + smectites
smectite (nontronite)
olivine + smectites
Fe oxide (+ smectite?)

Holden Crater: J. Grant, R. Irwin, K. Whipple



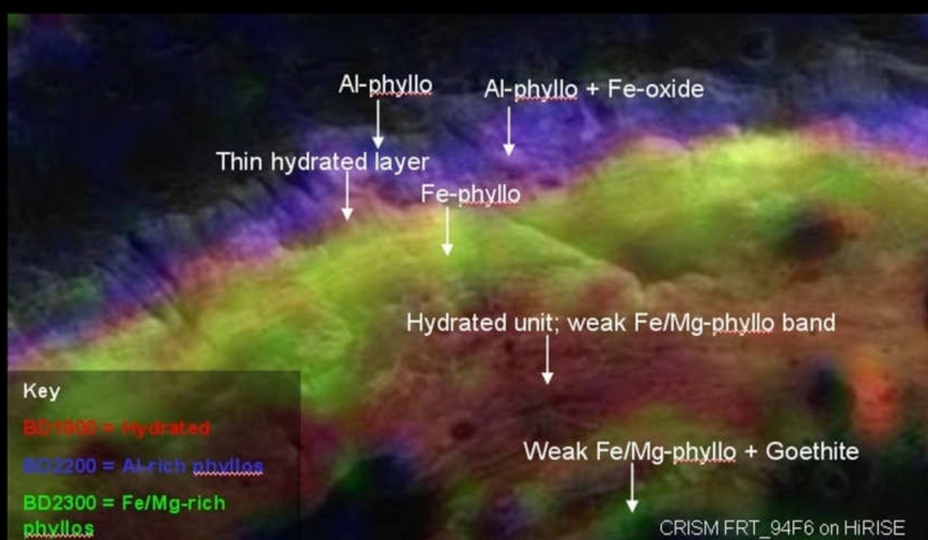




Mawrth Vallis: J-P Bibring, F. Poulet, J. Michalski, J. Bishop, E, Noe Dobrea, J. Wray

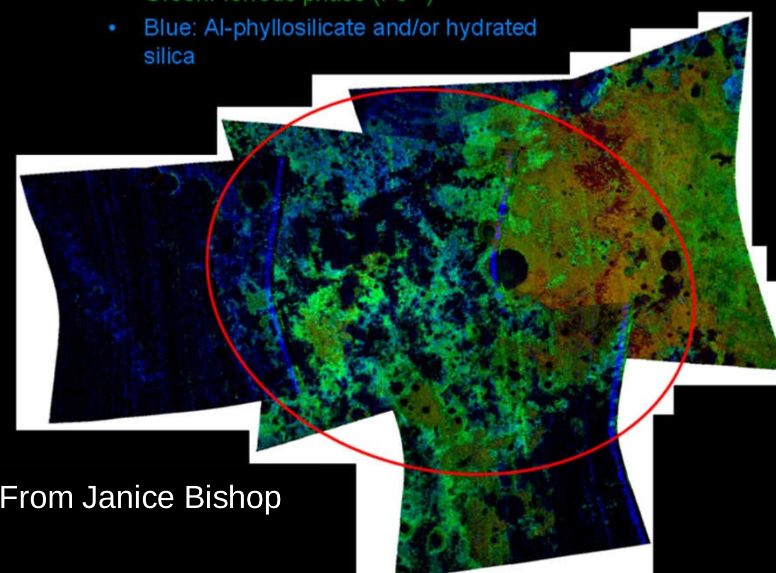
Mawrth Vallis: Phyllosilicate-Bearing Stratigraphy within the Landing Ellipse:

Mars Landing Site Selection Activities



From James Wray

- Red: Fe/Mg smectite (Fe^{3+})
- Green: ferrous phase (Fe^{2+})
- Blue: Al-phyllosilicate and/or hydrated silica



From Janice Bishop

Courtesy of Janice Bishop

History and New MSL Site Selection Milestones

Mars Landing Site Selection Activities

	Year	
Started with 35 Sites	2006	Define/Refine Constraints
1st Workshop New MRO data/50 sites	2007	Consider constraints where possible (e.g., rock abundance)
2nd Workshop 6 sites	2008	
Steering Comm. adds 7th Site 3rd Workshop	2009	Consider Engineering constraints
Call for New Site	2010	Limited Ongoing Studies
4th Workshop	2011	Engineering Studies
5th Workshop		Mature Engineering constraints (e.g., wheel actuators)

NASA HQ Selection Spring 2011

Review of New MSL Site Candidate Sites:

Mars Landing Site Selection Activities

Call for new sites in Fall, 2009 (August, reminder in October)
Use LPI e-mail, past list of workshop participants

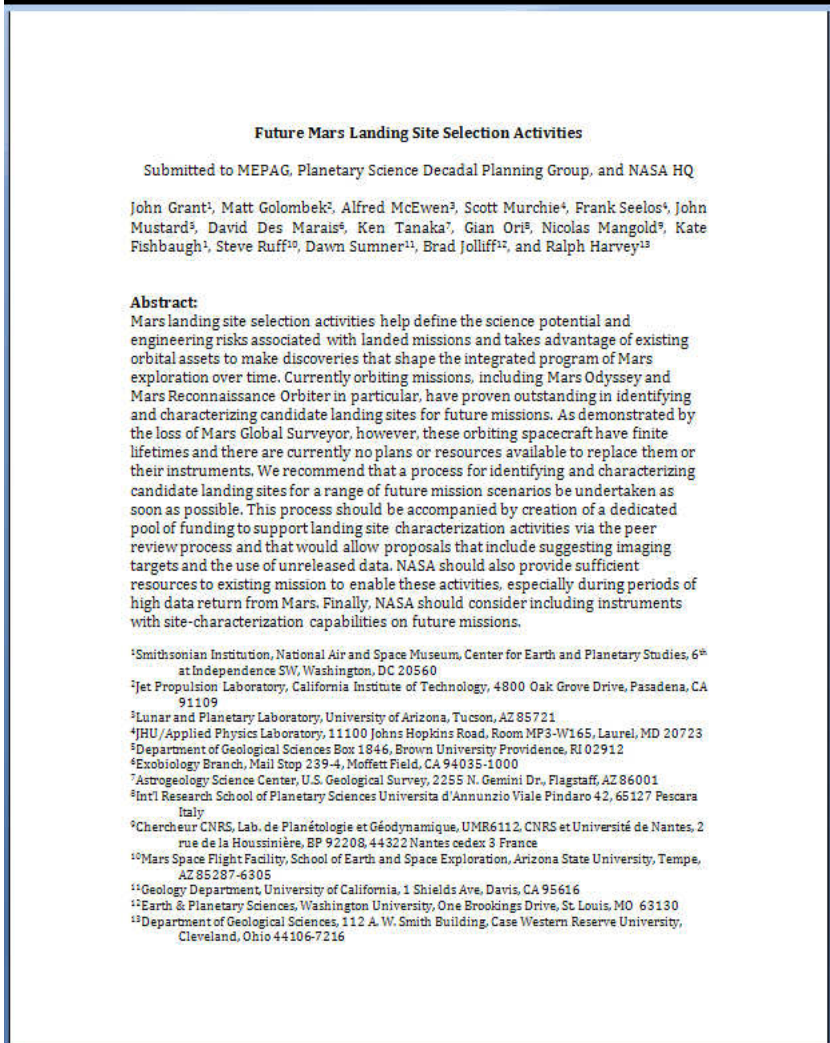
Interpretation of Setting at Candidate Sites Must be Mature
- As compelling as existing candidate sites
- Ideally peer-reviewed and published
- Submission using abstracts (need detailed information on sites)
- Anticipate ~handful of new candidate sites
- Likely some existing HiRISE, CTX, CRISM

Initial Review by Steering Committee
- Some additional MRO data would likely be acquired
- Will be provided to site proposer

Sites reviewed by Landing Site Steering Committee
- Would Include Presentations by proposers

Planning Future Site Selection Activities:

Mars Landing Site Selection Activities



Future Mars Landing Site Selection Activities

Submitted to MEPAG, Planetary Science Decadal Planning Group, and NASA HQ

John Grant[1], Matt Golombek[2], Alfred McEwen[3], Scott Murchie[4], Frank Seelos[4], John Mustard[5], David Des Marais[6], Ken Tanaka[7], Gian Ori[8], Nicolas Mangold[9], Kate Fishbaugh[1], Steve Ruff[10], Dawn Sumner[11], Brad Jolliff[12], and Ralph Harvey[13]

Abstract:
Mars landing site selection activities help define the science potential and engineering risks associated with landed missions and takes advantage of existing orbital assets to make discoveries that shape the integrated program of Mars exploration over time. Currently orbiting missions, including Mars Odyssey and Mars Reconnaissance Orbiter in particular, have proven outstanding in identifying and characterizing candidate landing sites for future missions. As demonstrated by the loss of Mars Global Surveyor, however, these orbiting spacecraft have finite lifetimes and there are currently no plans or resources available to replace them or their instruments. We recommend that a process for identifying and characterizing candidate landing sites for a range of future mission scenarios be undertaken as soon as possible. This process should be accompanied by creation of a dedicated pool of funding to support landing site characterization activities via the peer review process and that would allow proposals that include suggesting imaging targets and the use of unreleased data. NASA should also provide sufficient resources to existing mission to enable these activities, especially during periods of high data return from Mars. Finally, NASA should consider including instruments with site-characterization capabilities on future missions.

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[8]Int'l Research School of Planetary Sciences Universita d'Annunzio Viale Pindaro 42, 65127 Pescara Italy
[9]Chercheur CNRS, Lab. de Planétologie et Géodynamique, UMR6112, CNRS et Université de Nantes, 2 rue de la Houssinière, BP 92208, 44322 Nantes cedex 3 France
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[11]Geology Department, University of California, 1 Shields Ave, Davis, CA 95616
[12]Earth & Planetary Sciences, Washington University, One Brookings Drive, St. Louis, MO 63130
[13]Department of Geological Sciences, 112 A. W. Smith Building, Case Western Reserve University, Cleveland, Ohio 44106-7216

Orbital assets exist now that can provide data for a wide variety of candidate landing sites

These orbiters and instruments have finite capabilities and lifetime (MGS) and instruments with equivalent or better/unique capabilities might not fly before possible landings in 2018 and beyond

What is the best way to identify candidate landing sites for future missions that would best use, but not dominate, the capabilities of the existing assets?

Activity encouraged by NASA and MEPAG

Sent to more than 50 people for comment, more than 20 reviews received to date, all strongly positive

White paper to be given to Decadal Survey Group

Background

Mars Landing Site Selection Activities

Landing Site Selection Process

- Has Involved Community via workshops for MPF, MER and MSL
- Directed Acquisition of New Information – Made available to community
- Engineering Constraints – Surface Characterization involved Community
- Science Objectives of Mission – Actively Debated for Landing Sites

MSL Experience

- MRO Imaging Data – Superb for Landing Site Selection
  - CTX, HiRISE, CRISM – Provide Synoptic, High-resolution, Mineralogic Views
- Data from ODY and MEx are also valuable (especially for science assessment)
- MSL Ellipse Relatively Small (~20 km) So Number Images Required Modest

Mars Program Perspective

- MRO Should be Used While operating to Collect Data for Future Landing Sites
- Replacement of MRO is >500M and is not included in current program plans

Use Landing Site Selection Program to Acquire Data Needed to Select and Certify Landing Sites for Future Landers

- Could Estimate Important Engineering Constraints for Future Landers?
- How Could we Deal with Unknown Science Objectives for Future Landers?
- This has been done before (e.g., Greeley et al. catalog), but not with MRO capabilities

Broad Aspects of Landing Site Selection

Mars Landing Site Selection Activities

- Landing Site Selection
  - Engineering Constraints
    - Most Important for Imaging is Ellipse Size
    - Ellipse Size for Future landers Likely ~10 km Diameter (Mars Program Estimate)
      - 6 HiRISE Images to Certify (complete stereo)
    - Elevation and Latitude Constraints – Leave Open
    - Preliminary Guesses for 2018, Sample Return and Derive from MSL
  - Science Objectives
    - Categorize
    - Open for Sample Return – Let Proposer Specify, Forum for Best SR Science

- Open Workshops
  - Provide Focus to Activity
  - Open Exchange of Science and Characterization/Safety of Potential Sites
  - Prioritize Sites for Future Data Acquisition

- Process Chair(s) and Steering Committee
  - Steer Process
  - Report to NASA Headquarters

How are candidate sites solicited and prioritized?

- Community Conferences (AGU, LPSC, MEPAG, e-mail)
- Web based entries (USGS and Marsoweb)
  - Must require robust inputs to filter – Extended Abstracts
  - Include specifics on science, surface, ~10 km ellipse, "go to", images
  - Cast wide net, but candidates must betraceable to MEPAG, encourage multiple science objectives
- Dedicated Landing Site Workshops (1/year)
- Standard review process to prioritize candidates
  - Landing Site Steering Committee makes first cut
  - Community workshops used to decide which advance
  - Peer review of proposals to NASA decide which advance
  - Matrix: types of sites (e.g. MSR, geochronology, Polar, astrobiology, networks) vs categories within types (e.g., past life vs. present life)
- Create Lists for annual targeting
  - Provide to MRO, ODY, and MEx
  - Results in tiered process with new sites being introduced while highly ranked sites advance

Discussions with the MRO PSG:

- 3-4 targets per cycle are reasonable, similar to MSL requests & equates to ~80-100 targets/year (26 planning cycles/year)
- Would use prioritized list, but goal would be to image all targets in ~1 year (no MH in any cycle).
- Rate and amount of imaging may vary (e.g. could get stereo early) based on team interest
- Initial data includes CTX, CRISM, HiRISE (after MSL model) May include atm and radar observations
- First Observations prior to mid Feb 2010, balance with proposed ExoMars, would take advantage of peak data period

Recommendations:

Mars Landing Site Selection Activities

All agree that targeting and imaging of candidate future landing sites is essential and must begin as soon as possible.

Because orbital assets have a finite lifetime and because there is currently a lull in imaging of MSL sites and imaging of candidate landing sites for ExoMars has not yet begun, this process should begin by 2010 (peak data rate for MRO). In order to be successful, the proposed activity requires all instruments on MRO to continue to operate and to collect and process data at a high rate. It is essential that MRO and ODY receive adequate support to enable these activities to proceed.

Funds to support future landing site proposals must be set aside and should be included in NASA's 2010 ROSES omnibus NRA.

A critical aspect of the proposed process involves the participation of the broader community in landing site activities and workshops. To date, participation in these activities has been widespread and enthusiastic, but most individuals lack funding to take on related work and travel. Moreover, current funding sources for work on landing sites do not allow for proposals that include the targeting or use of unreleased data or for analysis of data that has not yet been acquired. For the proposed process to be successful, the planning, targeting and evaluation of unreleased and as yet unacquired data should be permitted. We further recommend that process chair(s) and a steering committee be appointed by NASA to help steer the process, prioritize image requests, and report on activities.

Orbital instruments are critical for defining landing sites and NASA should consider inclusion of instruments with at least comparable capabilities on future orbiter missions.

All activities geared towards identification of future landing sites would be incomplete to some degree, as ongoing evaluation of existing data will likely yield new discoveries. If these discoveries occur after the key aspects of existing orbital assets are no longer functioning (e.g., CRISM IR data or HiRISE camera), the ability to characterize related candidate landing sites would be compromised.