Phobos/Deimos
State of Knowledge in Preparation for Future Exploration

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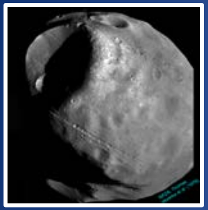
Initial Phobos/Deimos DRM Meeting for HAT

Outline

Introduction

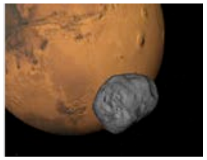


Science at Phobos

Deimos

Human Exploration Considerations

Outline



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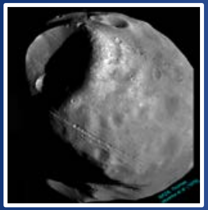

Science at Phobos

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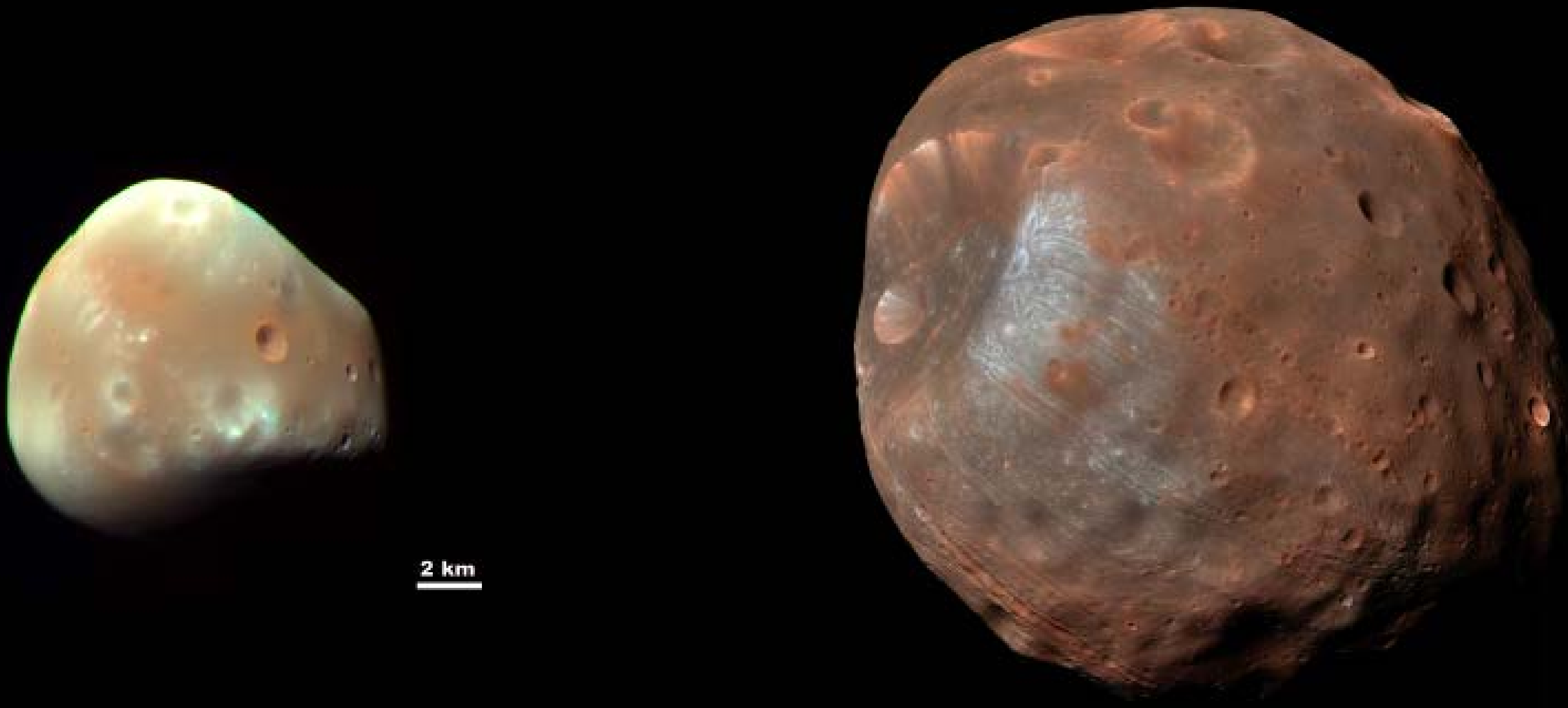
Human Exploration Considerations

Scope

- Characterize Phobos/Deimos environment
  - Soil properties – mechanical and chemical
  - Surface dynamics
  - Subsurface properties (e.g., caves, regolith thickness)
  - Hazards – Radiations, topography, dust, electrostatic charging
- Identify potential landing sites
  - Hazards – topography, surface dynamics
  - Vantage point wrt Mars
  - **Scientific interest**

Moons Properties

	Phobos	Deimos
Shape (km)	26.8 × 22.4 × 18.4	15 × 12.2 × 10.4
Density (kg/m^3)	1876	1471
Surface Gravity (Equator) μg	190-860	390
Escape Velocity (m/s)	11.3	5.6
SMA (km)	9,377	23,460
Eccentricity	0.015 1	0.000 2
Rotation Period (hr)	7h39.2	30h18
Forced Libration in Longitude (deg.)	1.24±0.15	??
Orbital Period (hr)	Synchronous	Synchronous
Equatorial Rotation Velocity (km/h) – Longest axis	11.0	1.6
Surface Temperature (K)	150-300	233



Deimos

Phobos

Outline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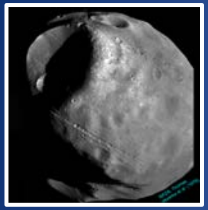

Science at Phobos


Deimos


Human Exploration Considerations

Key Science

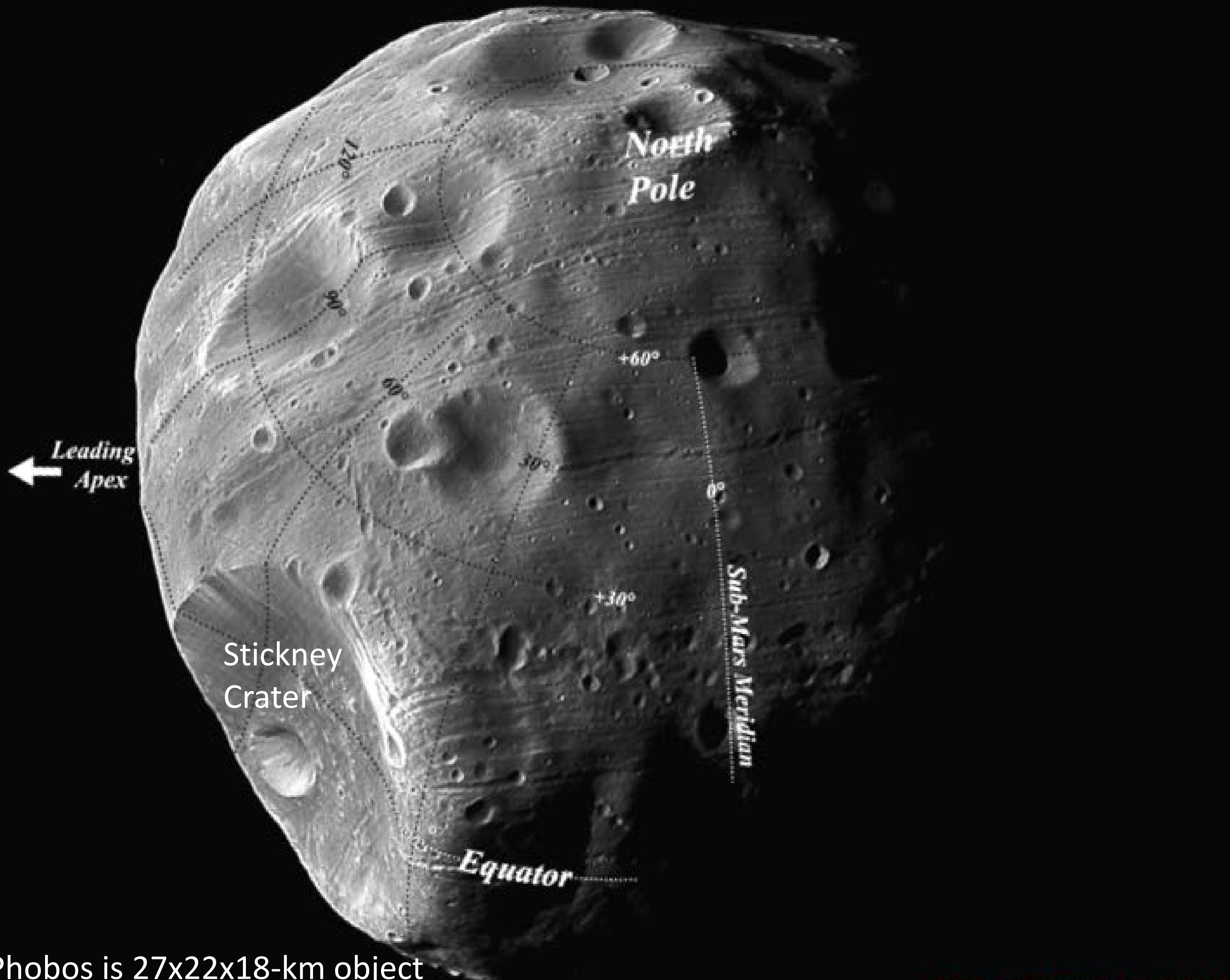
- **Mysterious origin** is endless subject of discussion
  - Remnant planetesimal vs. captured asteroid vs. Mars ejectas
  - Brings constraints on Mars’ early history and/or Solar system
- Likely to have accumulated **material from Mars**
  - Some of the material (red dust) believed to come from Mars
  - Discrete number of large blocks associated with Mars’ ejecta
  - Is Phobos itself the product of reaccretion of Martian ejectas?
- Determining the presence and location/distribution of **water** is key
  - Key to solving the origin
  - Important for Human exploration

State of Knowledge Prior to MEX

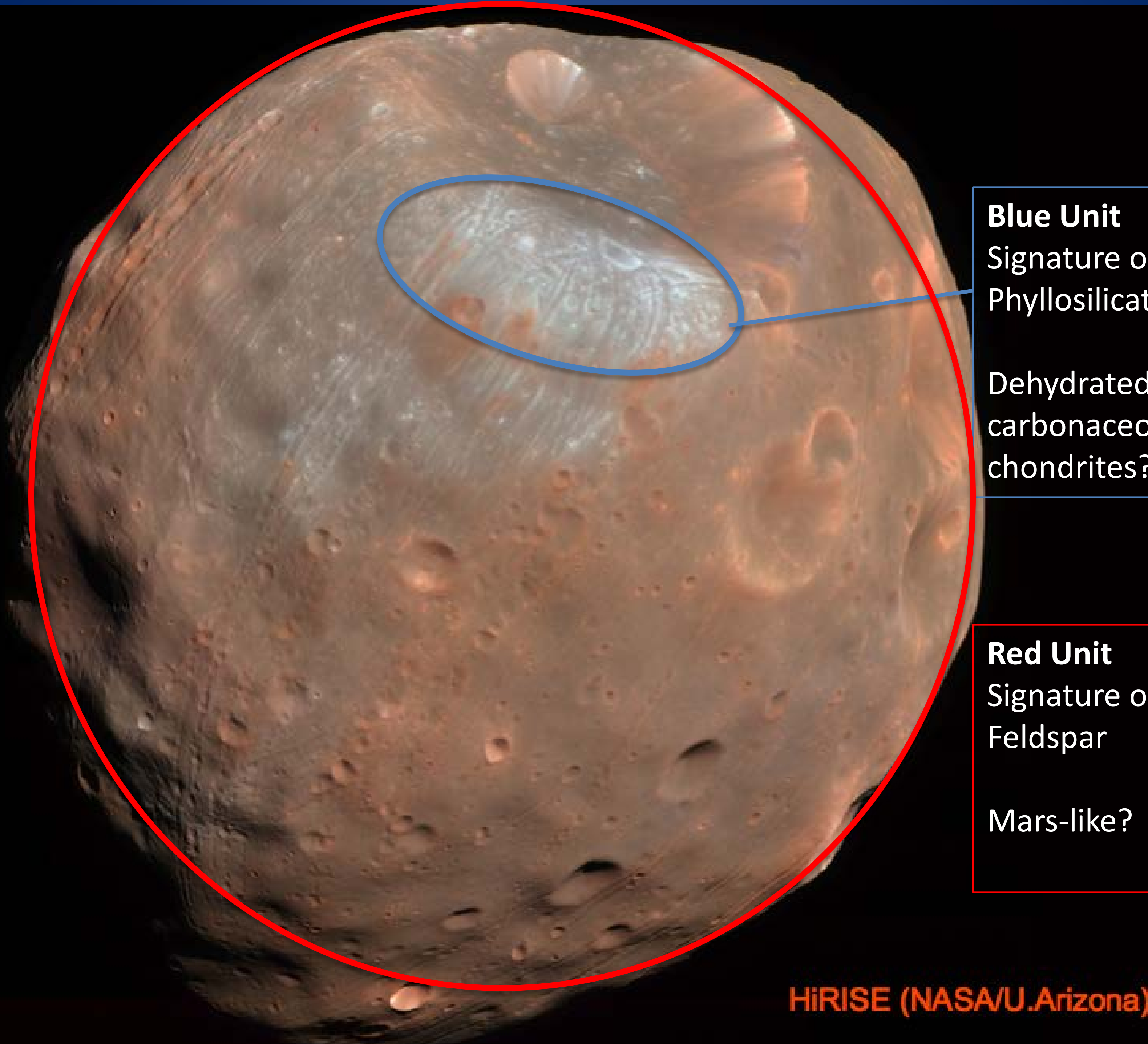
- Phobos' origin was *unknown*: captured asteroid, or remnant planetesimal
- Structure was *unknown*, rubble-pile or more coherent, water-rich object
- Origin of the grooves was *unknown*
- Composition was *unknown*, assumed ultraprimitive D-type bodies
- Two spectral units (Murchie):
  - "blue" around Stickney and crater streamers
  - "red" everywhere else
- Probably water-rich (free water)
- **Identified as a key to understanding the early history of volatiles in the Solar system**

Recent Observations of Phobos

- Mars Express
  - Several flybys by MEx < 100 km (77 km the lowest)
  - High-resolution imaging and Radioscience
  - Thermal IR spectrometer (PFS), overlapping with MGS' TES
- High-resolution imaging with HiRISE (MRO)
- Also comparison with visible and NIR spectra from Phobos 2



Phobos is 27x22x18-km object



Blue Unit
Signature of Phyllosilicates

Dehydrated carbonaceous chondrites?

Red Unit
Signature of Feldspar

Mars-like?

Key Results

- Imaging and spectral properties
  - "red" units are feldspar-rich material
  - "blue" units are phyllosilicates
  - Interior of Stickney is heterogeneous in composition
  - Stickney is associated with three different spectral units (e.g., "white" on rims; "green" in adjacent grooves)
- Mass and density
  - Density is 1.9 g/cm^3 (highly porous anhydrous objects or low-porosity water-rich body)
- Rotational properties and control network
  - Large-scale heterogeneities in the interior – origin unknown, but likely variations in porosity

State of Knowledge After MEx

- Phobos is not an ultraprimitive D-type
- MEX community believes that Phobos came from Mars, probably reaccreted in a disk of ejecta
- Red material most likely comes from Mars
- Grooves may be linked to rolling blocks that may come from Mars
- **Key science target because a possible giant sample from Mars**

Limits and Questions

- No firm compositional constraints, especially for the “red” unit
- MEx team assumed that the “blue” and “red” units have the same origin
- “Red,” unit coats the surface, but the bulk of the body seems to be composed of the “blue” material
- P. Lee (Ames) suggests that impact-ejected dust and electromagnetically entrained dust from Mars is coating Phobos’ surface
- Better spatial resolution could have helped understand the relationships of the two spectral units
  - MEX team was planning to go below 70 km but difficult maneuver was missed
- If Phobos accreted in a disk of Martian ejecta, should be rubble-pile, inconsistent with morphological features

Key Science Questions

- Does Phobos come from Mars?
  - Reaccreted in a disk of ejecta?
  - What is the size of the fragments making up Phobos?
  - Was the water content in Martian ejecta preserved?
  - Was the organic content preserved?
  - Is the “red” material the product of weathering of the “blue” material?
- If Phobos does not come from Mars
  - Does some components of Phobos come from Mars? Dust, scattered blocks possibly ejected from Lyot crater?
  - Is Stickney the product of impact with a fragment from Mars (E. Asphaug)?
  - Where is the material representative of Phobos’ bulk material? “Blue” units and blocks near impact rims?
- Are the phyllosilicates associated with organics (like in carbonaceous chondrites?)
- Is there water in Phobos? Where?

Lessons Learned from MEx

- Surface is more heterogeneous and complex than previously thought
- Spectroscopy is not the right approach for accurate constraints on composition
- MEx payload not appropriate to detect deep water ice
- Science return from MARSIS was limited

Why Spaceborne Observations are not Enough

- The interpretation of spectroscopic data is ambiguous
- Establishing the genetic link between two objects relies on certain signatures (e.g., isotopic)
  - Could be obtained with Gamma ray and Neutron detection or UV spectrometry
  - Phobos contains different units, linking the signature to surface or interior is not possible with these techniques
- Water ice may be inferred from gravimetric measurements, but requires very low-altitude orbit (<20 km)
- Sample return proposed in many occasions (e.g., *Gulliver*, *Phobos-Grunt*) as the most compelling approach to origin determination

Sample Return – Rationale

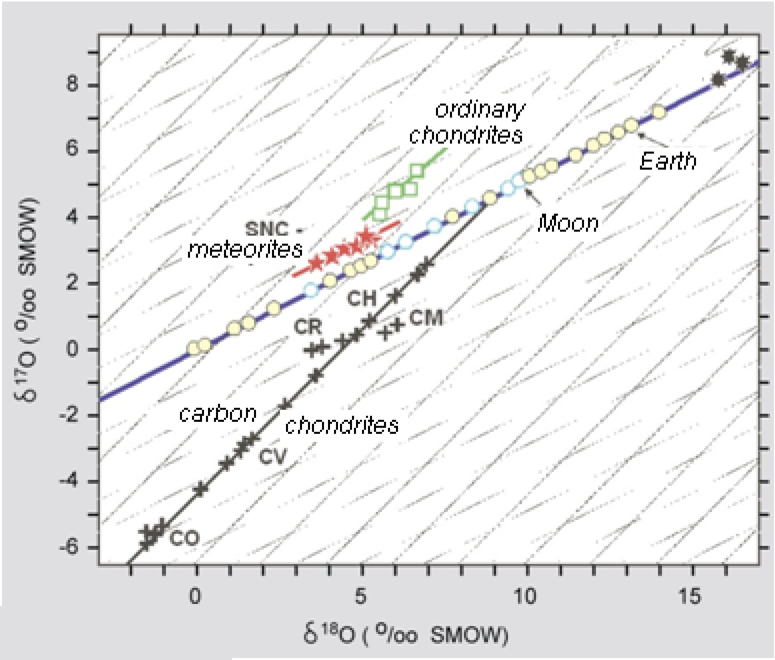
- Take advantage of ground-based lab capability for **chemical** characterization
- Selecting the sample is key
  - Trade between accessing high-risk/high-science value material vs. "easy" sample
  - Aspect where Human support would be very useful
- See also
- P. Lee (2011): *Phobos and Deimos Sample Return: Importance, Challenges, & Strategy*

http://www.lpi.usra.edu/meetings/sssr2011/presentations/lee.pdf

Sample Science

- **study** **physical and chemical characteristics of Phobos** **regolith *in situ* and under laboratory conditions** - these data can provide information on properties of primordial matter of the Solar system;

  - Does Phobos contain traces of protosolar material?
    - Isotopic ratios
  - Is Phobos matter kindered to the matter of Mars and NSC meteorites?
    - O^{16} – O^{17} – O^{18}, Kr/Ar/Ne ratio
  - Are there particles ejected from Mars on Phobos?
    - Search and analysis of such material
  - Is organic matter on Phobos?
    - Presence of amino acids, nucleine basics, etc.
  - Age of Phobos
    - 1. Sm/Nd 2. Hf/W 3. U/Pb/Rb/Sr
  - Which type of meteorites Phobos material is close to?
    - $\delta^{13}C$, δD, $\delta^{18}O$, $\delta^{17}O$, $\delta^{18}O$, H_2O

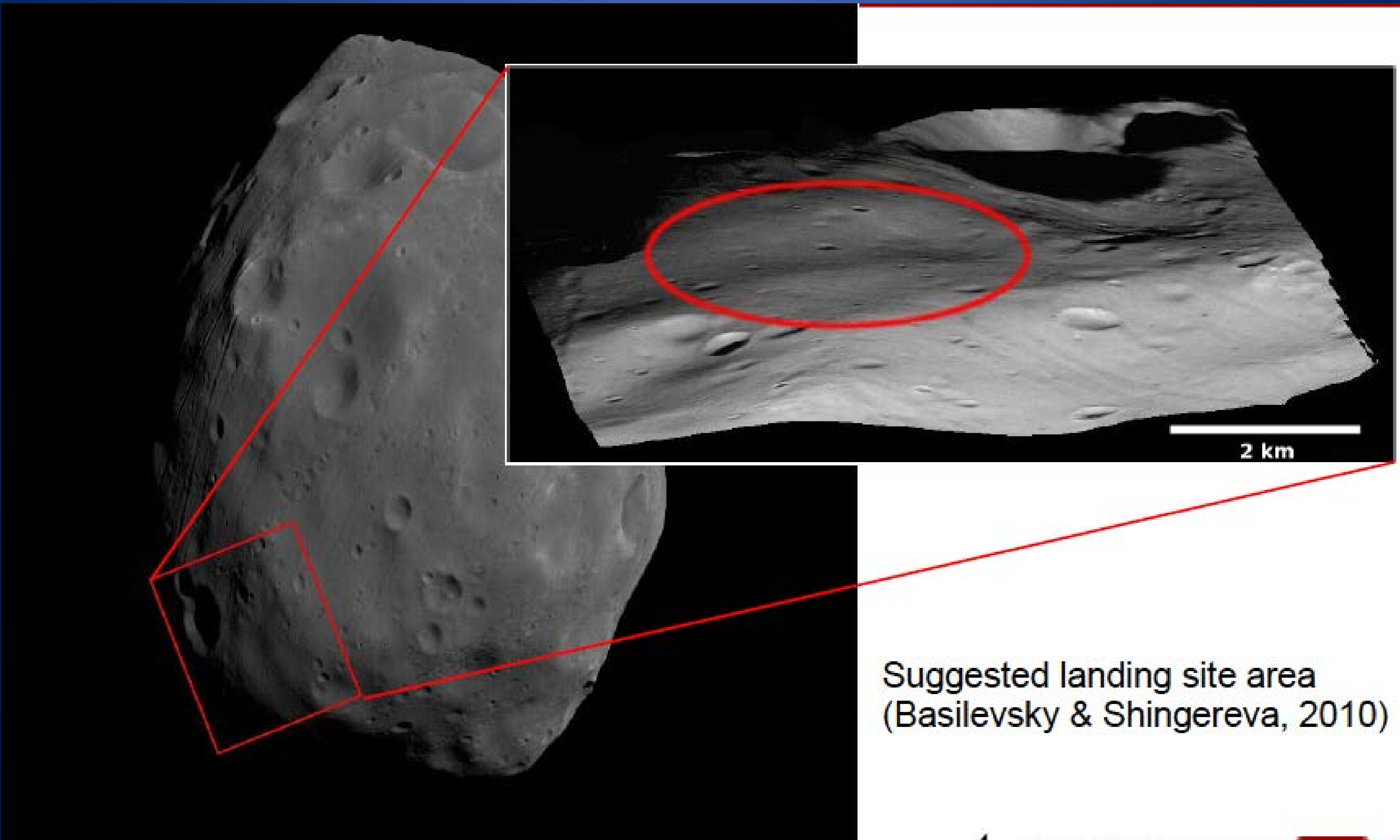


(E.Galimov courtesy)

- **study of** **peculiarities of orbital and proper motion of Phobos**, what is important for understanding their origin, internal structure, celestial mechanics applications;
- **study physical conditions of** **the Martian environment** (plasma components) what is important to study of treatment processes of small body regolith under influence of external conditions and creation of engineering model of the Martian environment for future Martian missions;
- **Monitoring of dynamic of** **the Martian atmosphere and seasons climate changing**.

From Zakharov, 2011

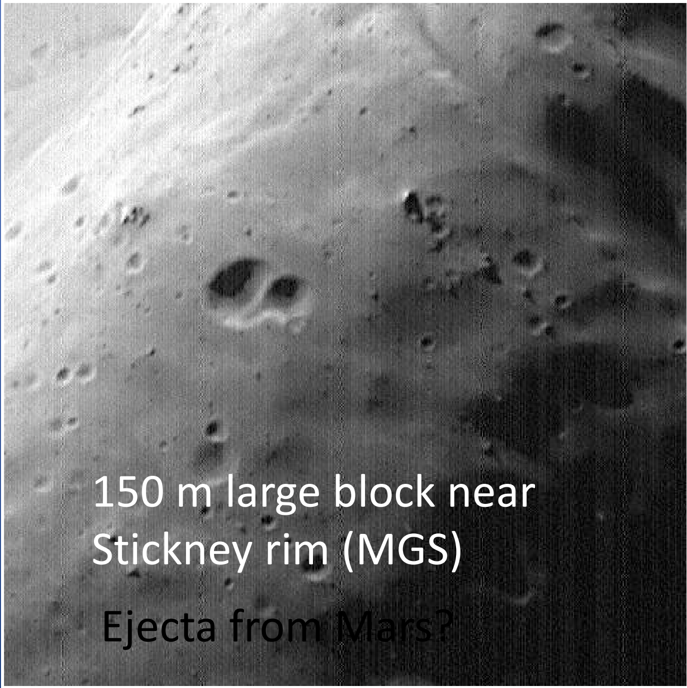
Landing Site for Phobos-Grunt



Suggested landing site area
(Basilevsky & Shingereva, 2010)

If you can just pick one…

- “Blue” spectral unit is more likely to represent Phobos’ bulk properties
- Recover Mars’ ejecta, possibly representative of Mars’ early history



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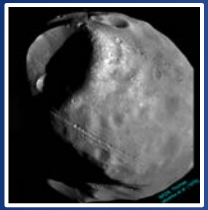

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Deimos

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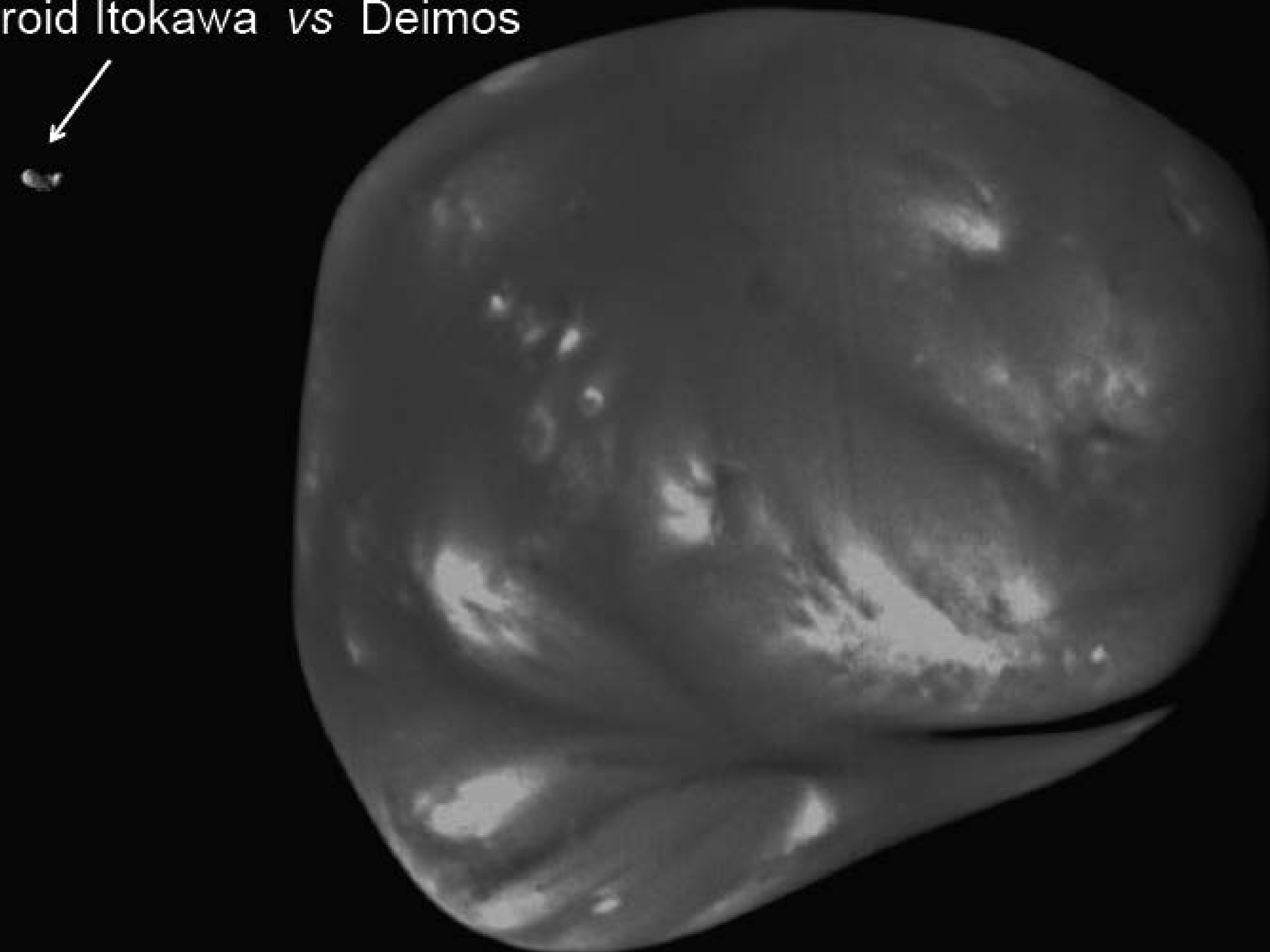
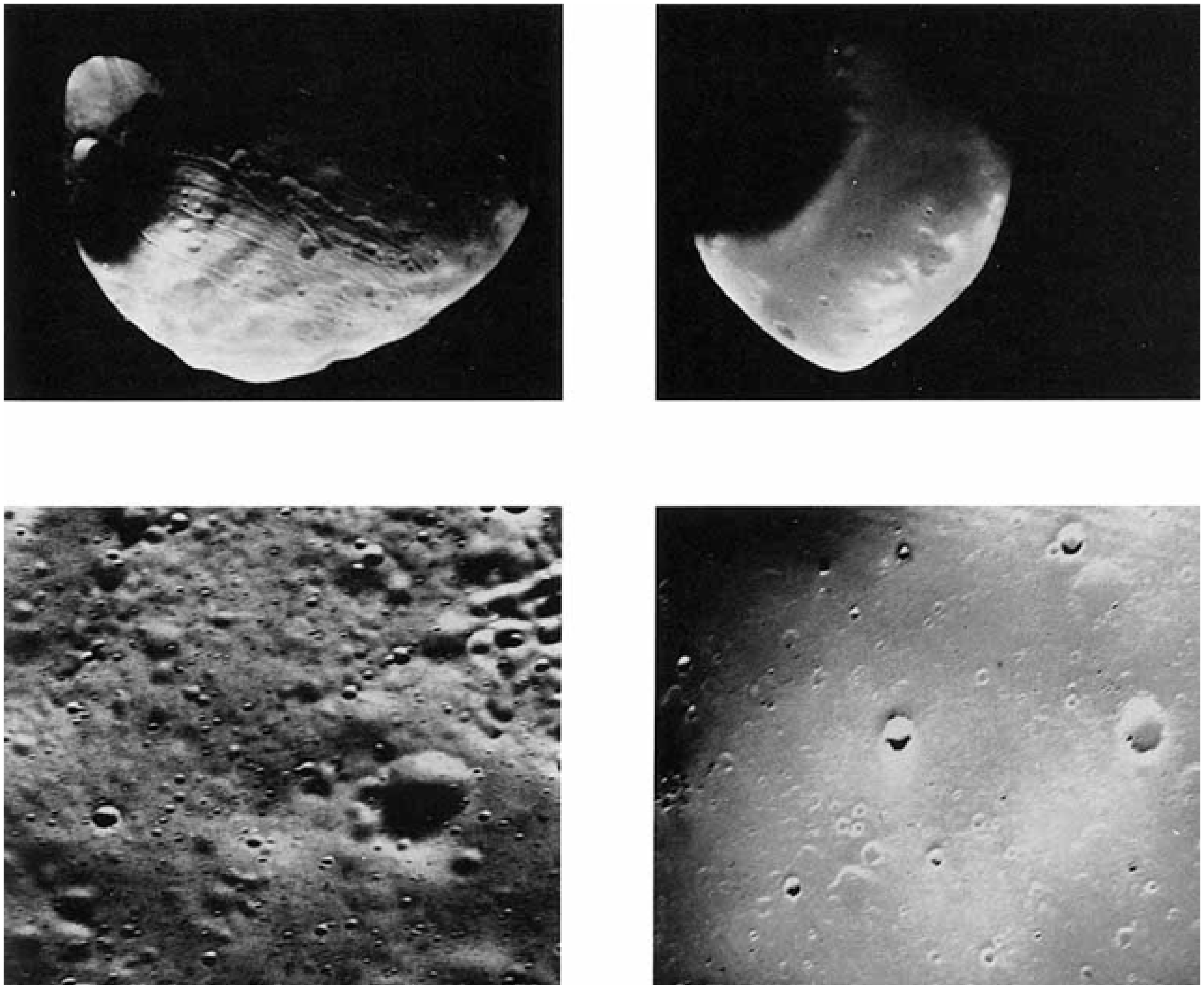
Asteroid Itokawa *vs* Deimos



Phobos and Deimos

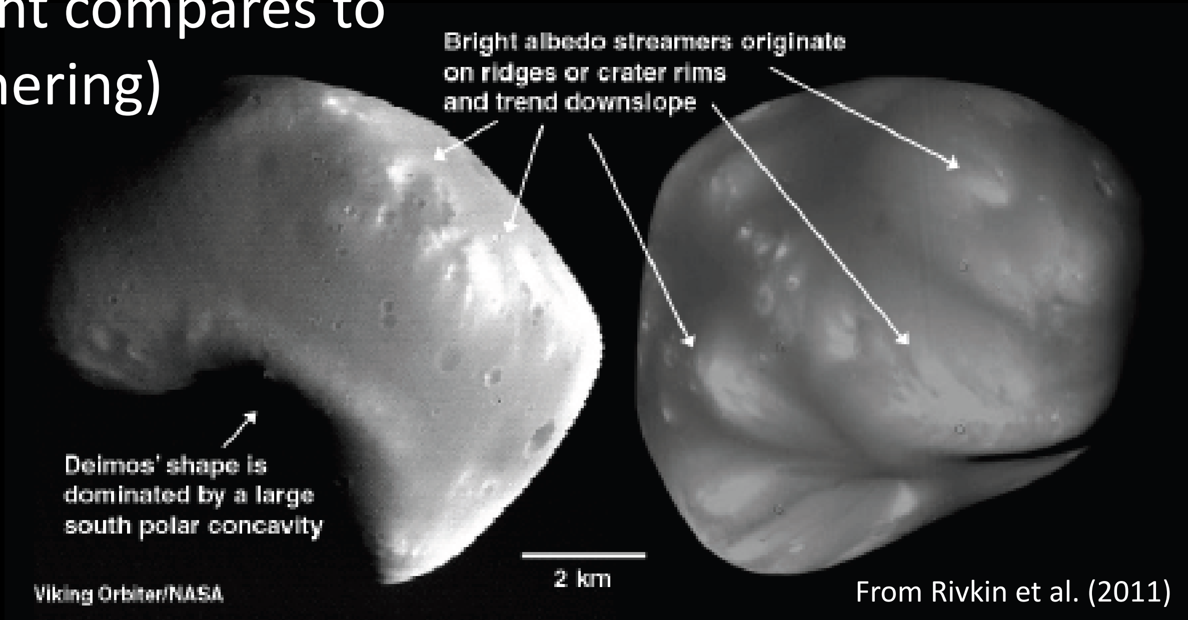
1400 km

~50 km



Science Questions at Deimos

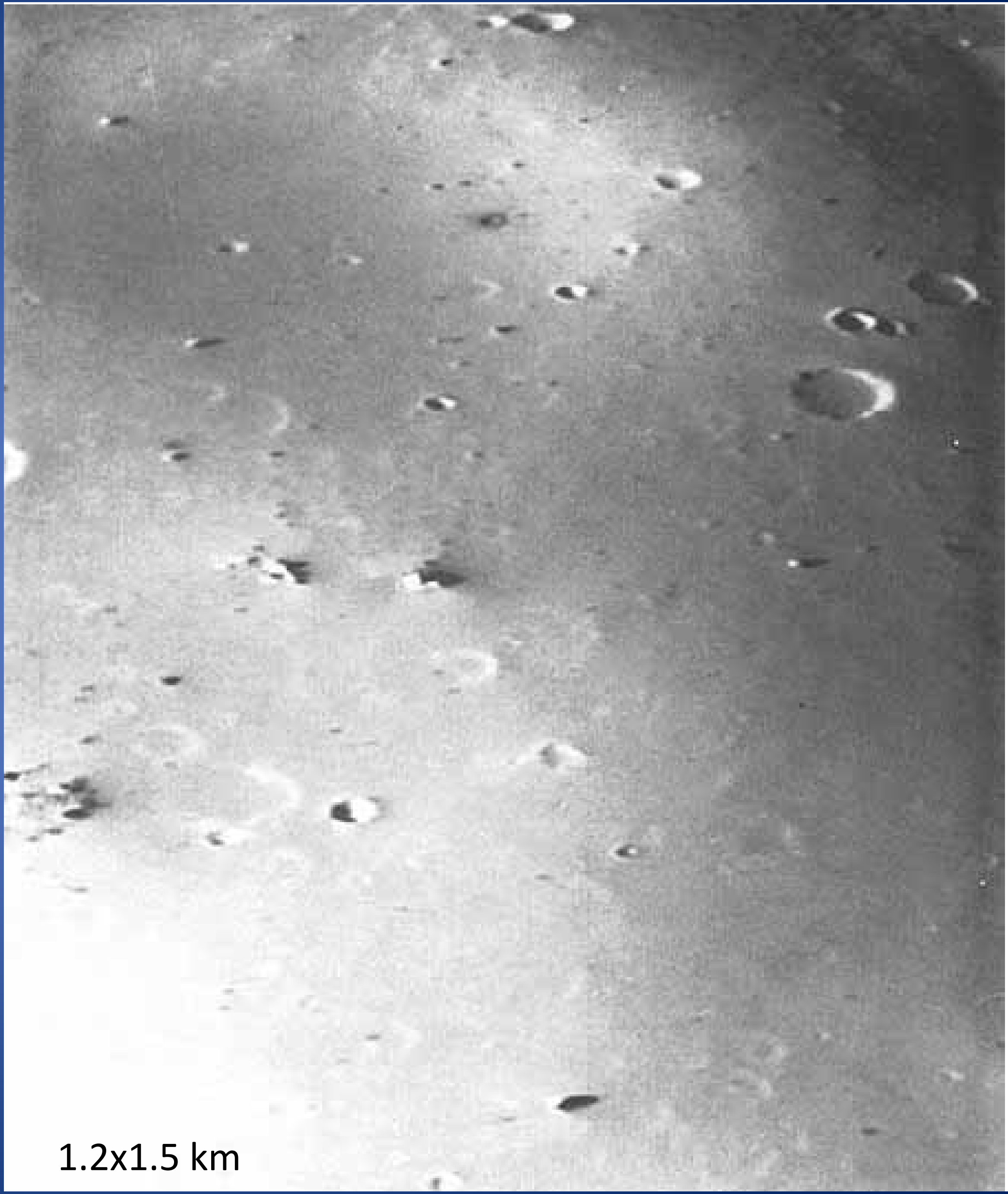
- Same as for Phobos (origin, composition)
- Origin of surface dust?
- How much exchange of material with Phobos and Mars?
- Same origin as Phobos?
- How deep is material representative of Deimos?
- How Deimos' environment compares to Phobos' (e.g., space weathering)



From Rivkin et al. (2011)

Deimos from 30 km

- Global regolith cover
- Craters infilled with regolith
- Boulder ejectas are 10-30 m across
- Very smooth surface
- No grooves



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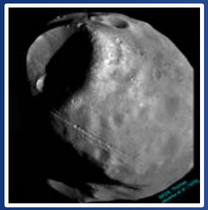

Science at Phobos

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Human Exploration Considerations

Contribution of *In situ* Mobility and Human Exploration

- Visit and characterization of different spectral units
- Obtain diagnostic information on Phobos' origin to be compared against in situ measurements acquired on Mars, and to other possible analogs
- High-resolution gravity measurements, Neutron detection to detect and locate deep water
- Reconnaissance prior to sampling
- Implementation of seismic network, sample acquisition…

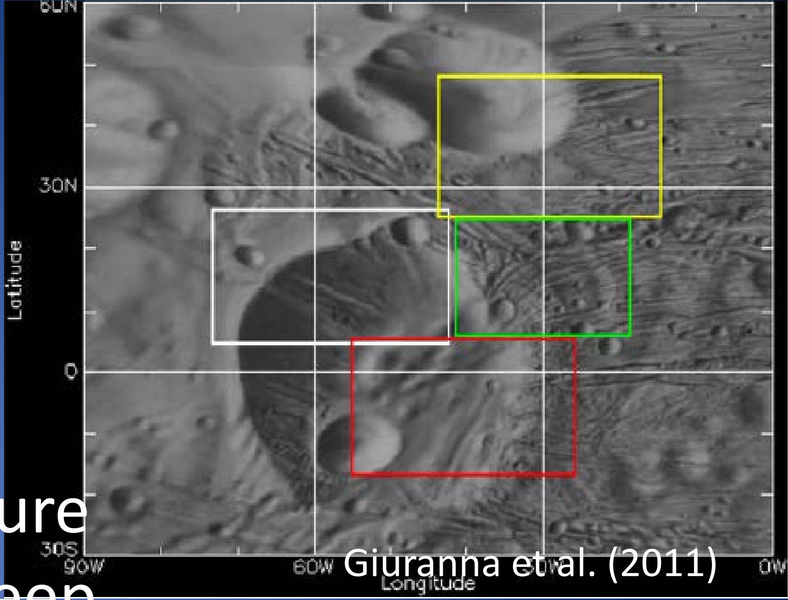
Considerations Specific to Human Exploration

- Interior properties (re: tidal stressing)
- Surface properties
- Landing site identification
- ISRU potential
- Planetary protection (P. Lee)
- *Vantage point*

Soil and Dust

- Dust layer, 20 to 120 m thick in most places < 10 meters in Stickney region
- Tecto-/Nesosilicate, similar to Mars' red soil?
- Soil properties are poorly known but upper limit on grain size is ~10-100 microns
- Images indicate dust accretion for the past 20 years (rate is TBD)
- Evidence for surface particle transport with topography and influenced by tidal pattern
- All this is poorly constrained though, particle friction and electrostatic charging are difficult to model (J. Bellerose's work)

Stickney Crater



Giuranna et al. (2011)

- ~9 km in diameter, ~1.5 km deep
- Near the crater, the grooves measure ~700 meters across and 90 meters deep.
- May contain water-rich material, or not (interpretation OMEGA and PFS in progress)
- Offers some shelter
  - Relatively less dust
  - Crater offers some protection against radiations
- Or not…
  - Tidal stressing has maximum amplitude at Stickney
  - May trigger landslides