Exploring the Moons of Mars

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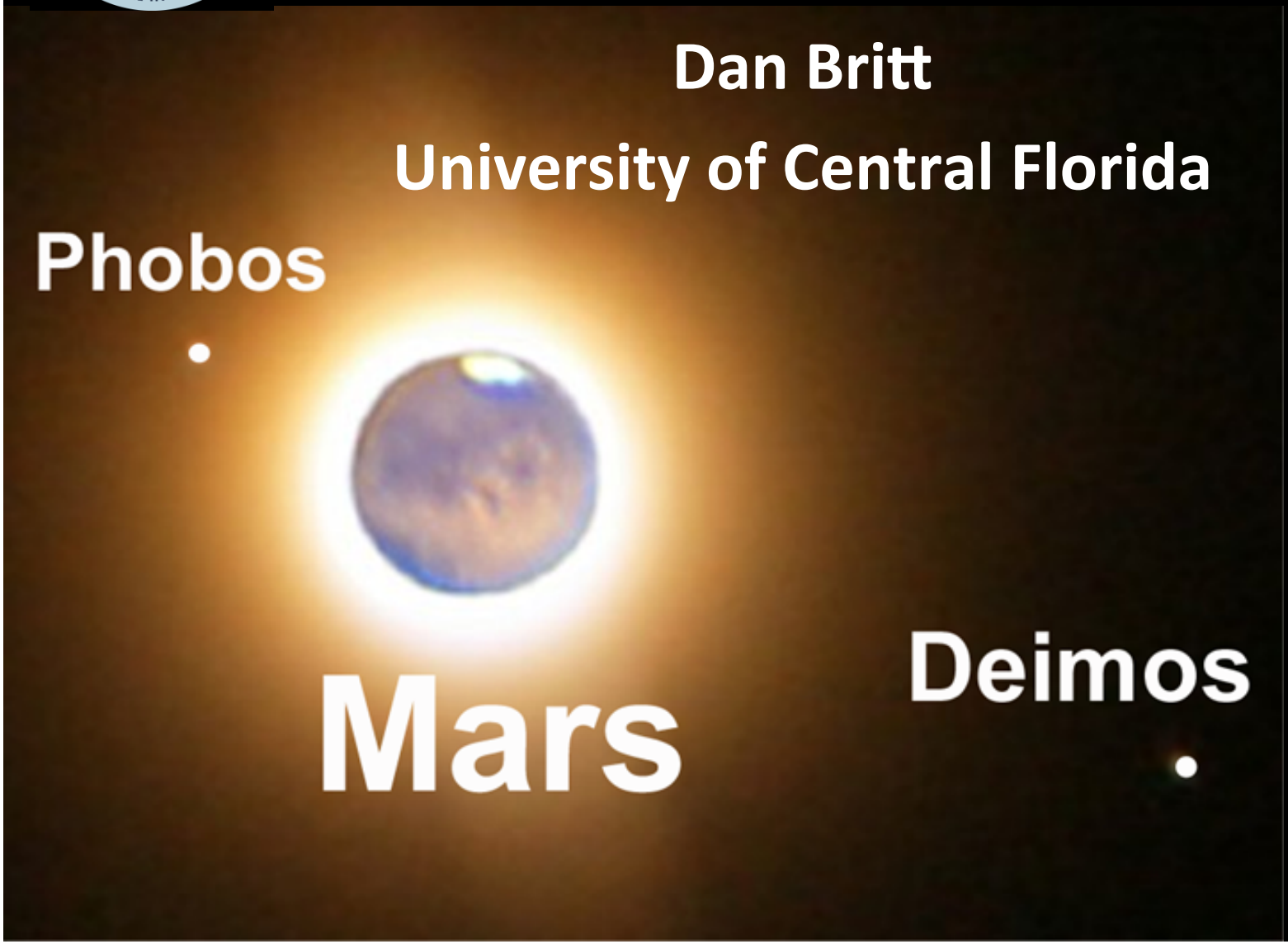
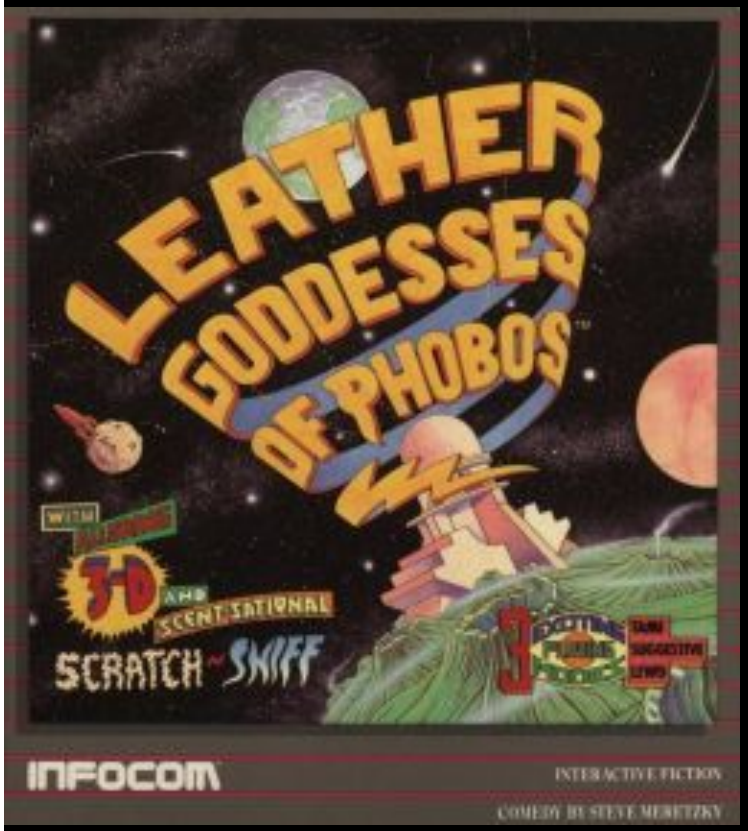
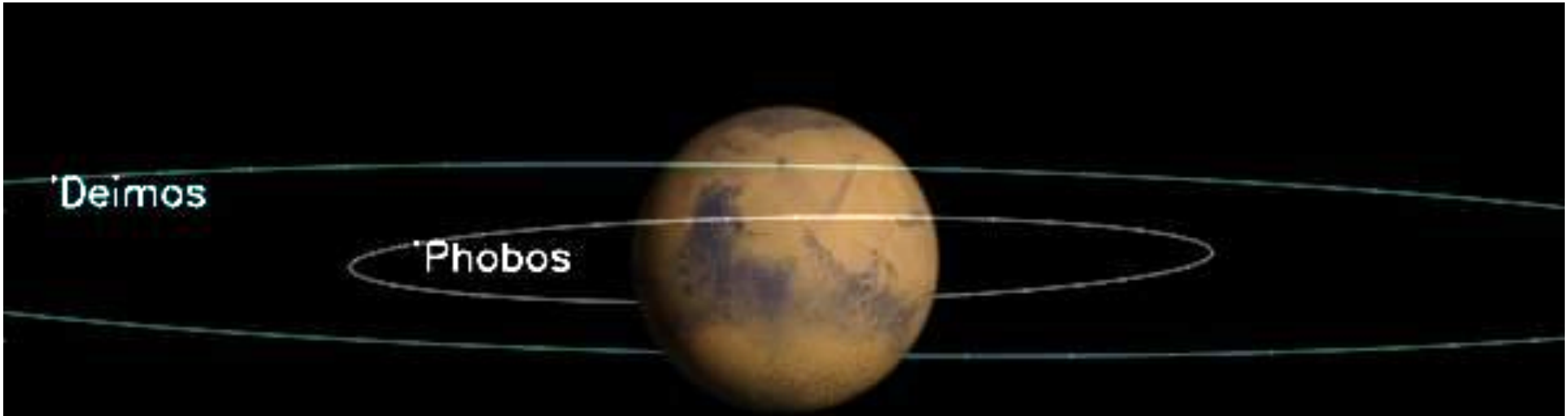




"They [Laputian astronomers] have likewise discovered two lesser stars, or satellites, which revolve about Mars, whereof the innermost is distant from the centre of the primary planet exactly three of his diameters, and the outer-most, five…"

Jonathan Swift, Gulliver's Travels (1726)

151 years prior to the moon's discovery by Asaph Hall of the US Naval Observatory



Phobos

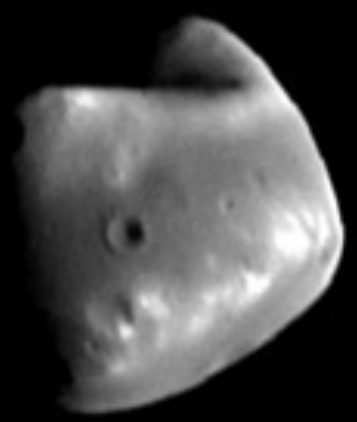
- 9,377.2 km (2.8 Mars radii)
- About 23 km in diameter
- Albedo 7.1%
- Density 1.87 g/cm3
- Surface gravity 0.0057 m/s2
- Escape velocity 11.39 m/s

Deimos

- 23,459 km (~7 Mars radii)
- About 6 km in diameter
- Albedo 6.8%
- Density 1.47 g/cm3
- Surface gravity 0.003 m/s2
- Escape velocity 5.556 m/s

For Phobos the (strengthless) Roche Limit is about 10,800 km. Adjusting for strength the limit is ~5000 km.

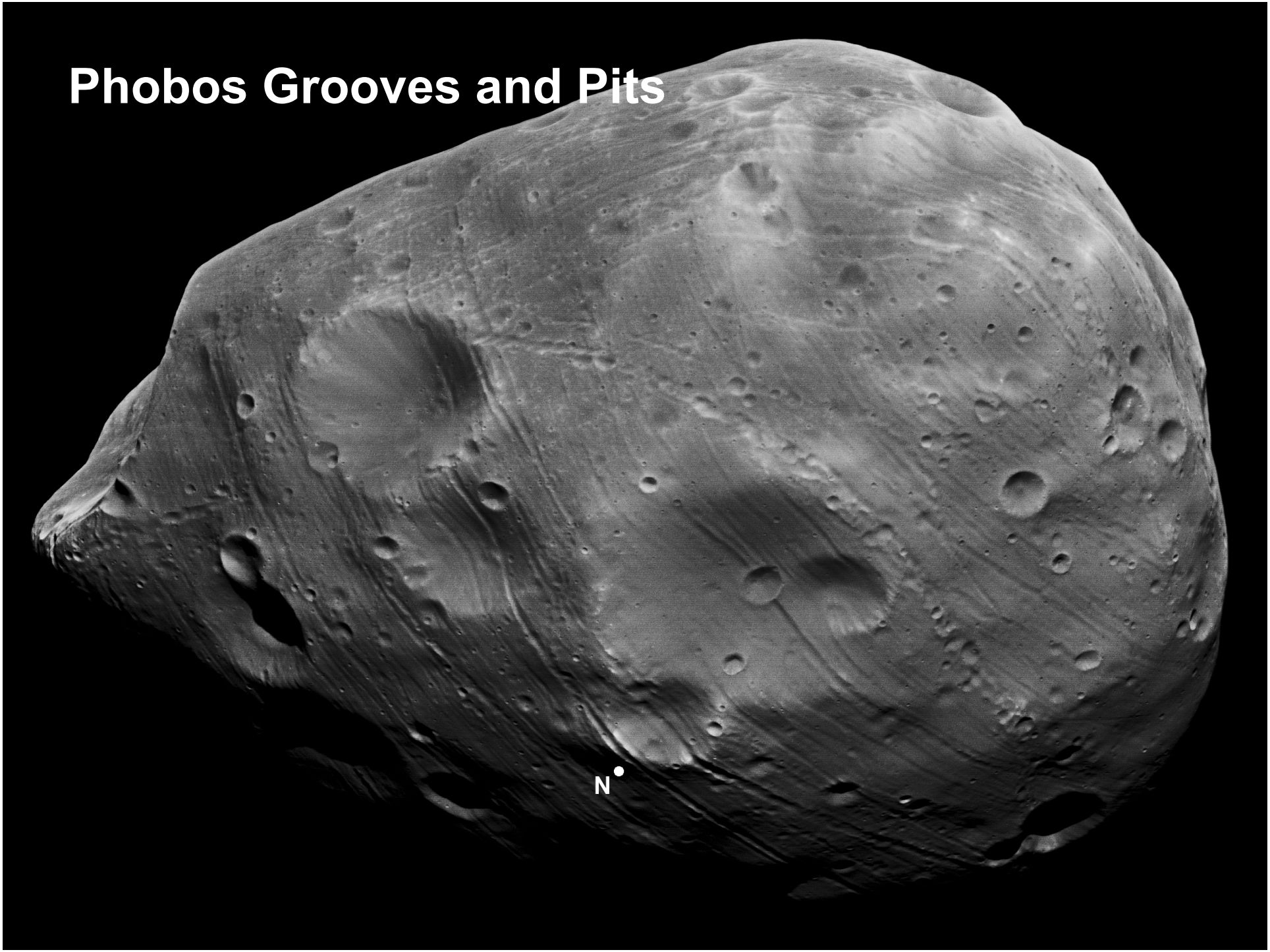
Similarities and Differences

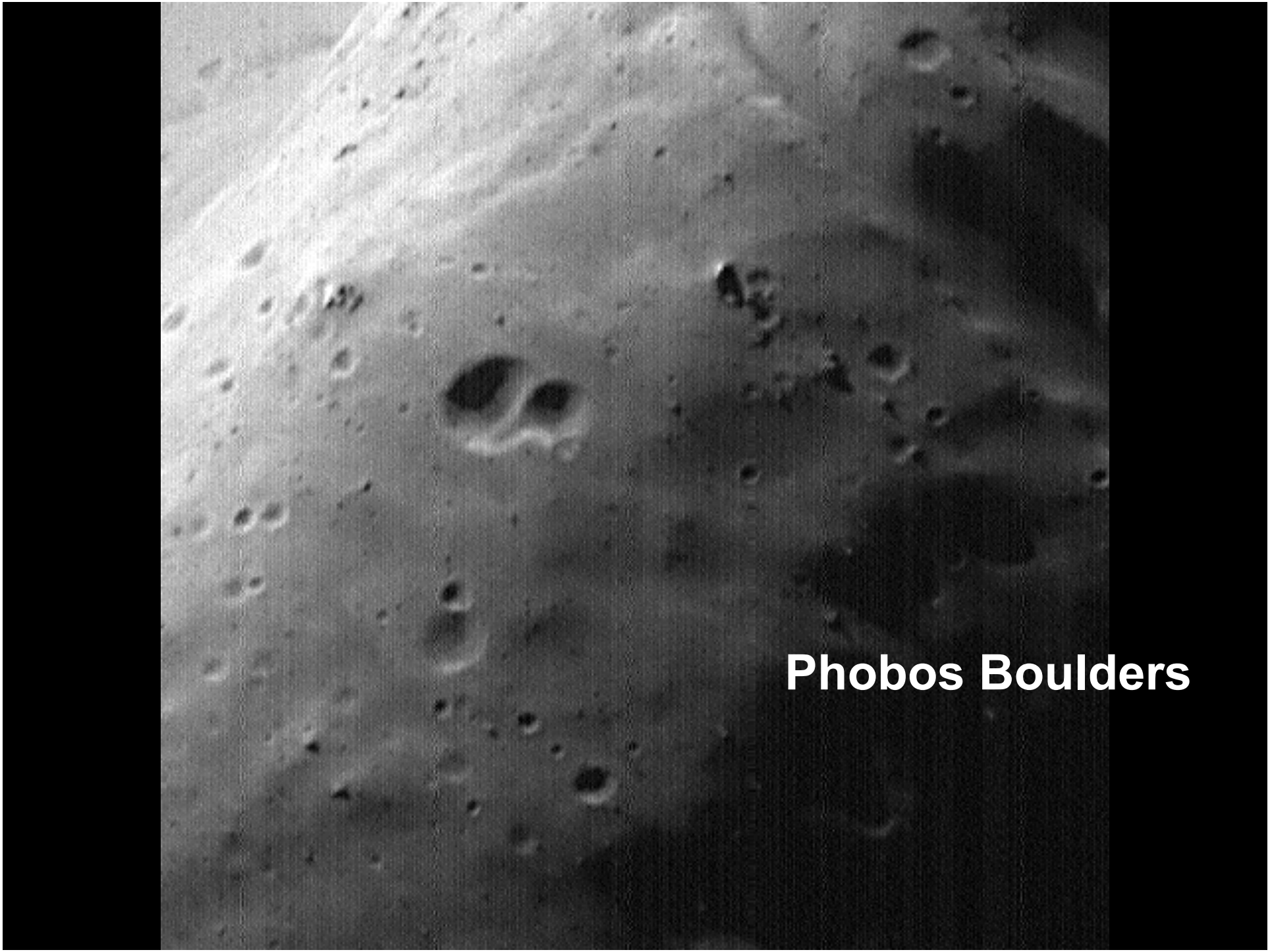


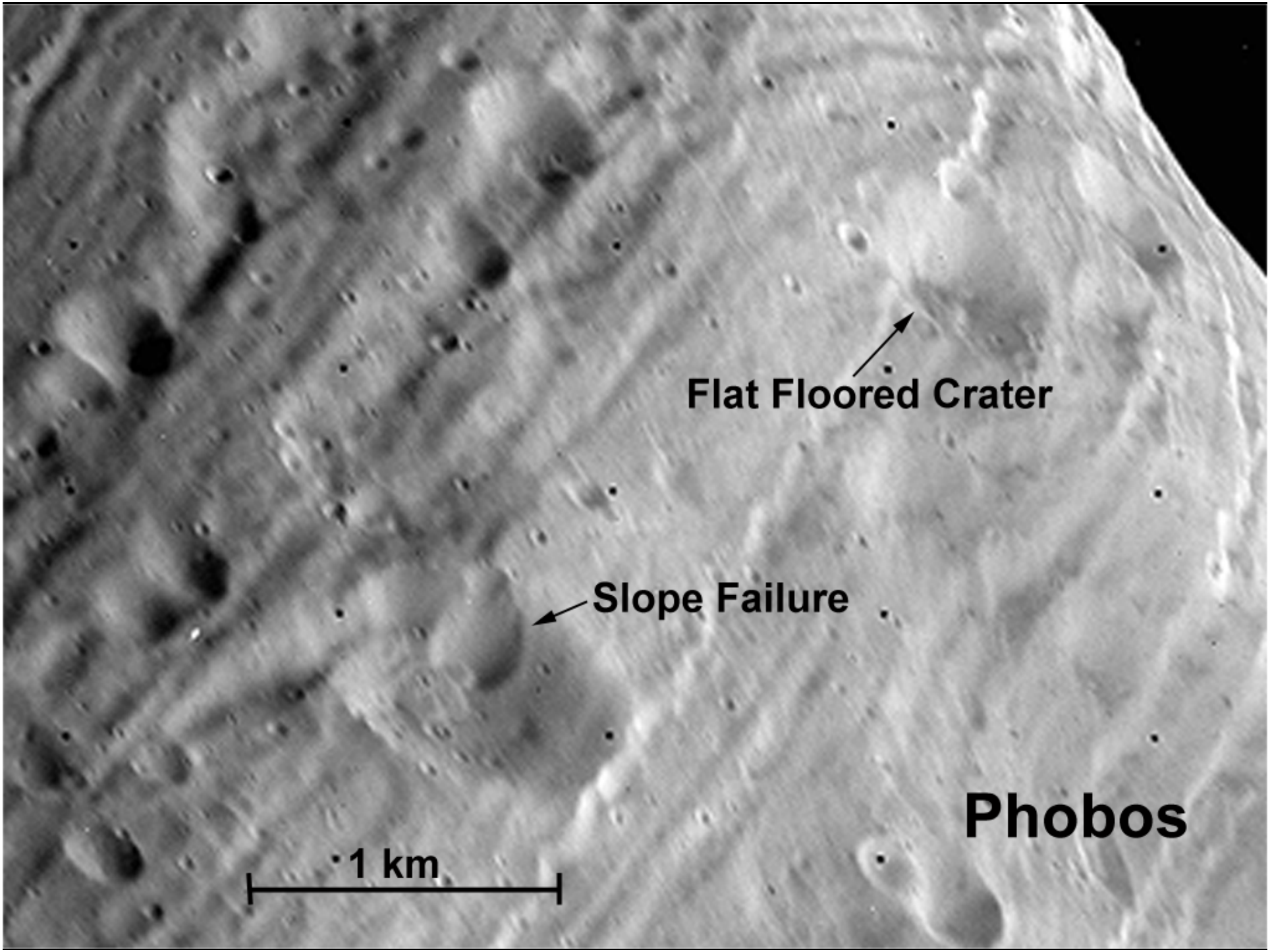
- Both small, dark, low density
  - Surface gravity is millimeters/sec^2
  - Surface material is about as black as copy machine toner
  - Density about the same as a dirt clod. Lots of empty space in both objects (i.e. ~ 30-40%)
- Both are tidally locked with Mars
  - Always present the same side to Mars
- Phobos is inside of Mars synchronous orbit, Deimos just outside
  - Tidal forces are causing Phobos orbit to decay
- Phobos is much rougher than Deimos

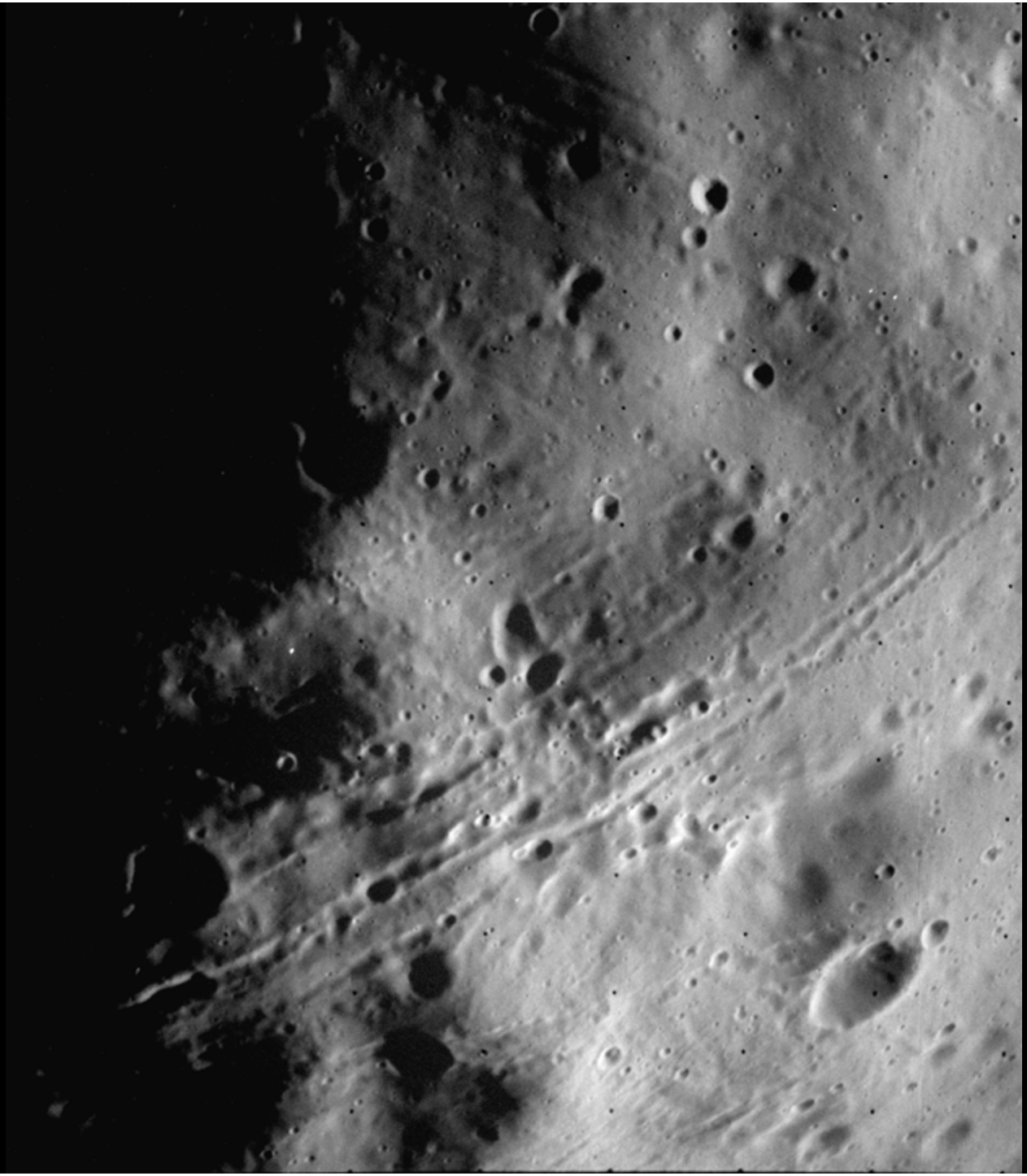
Phobos

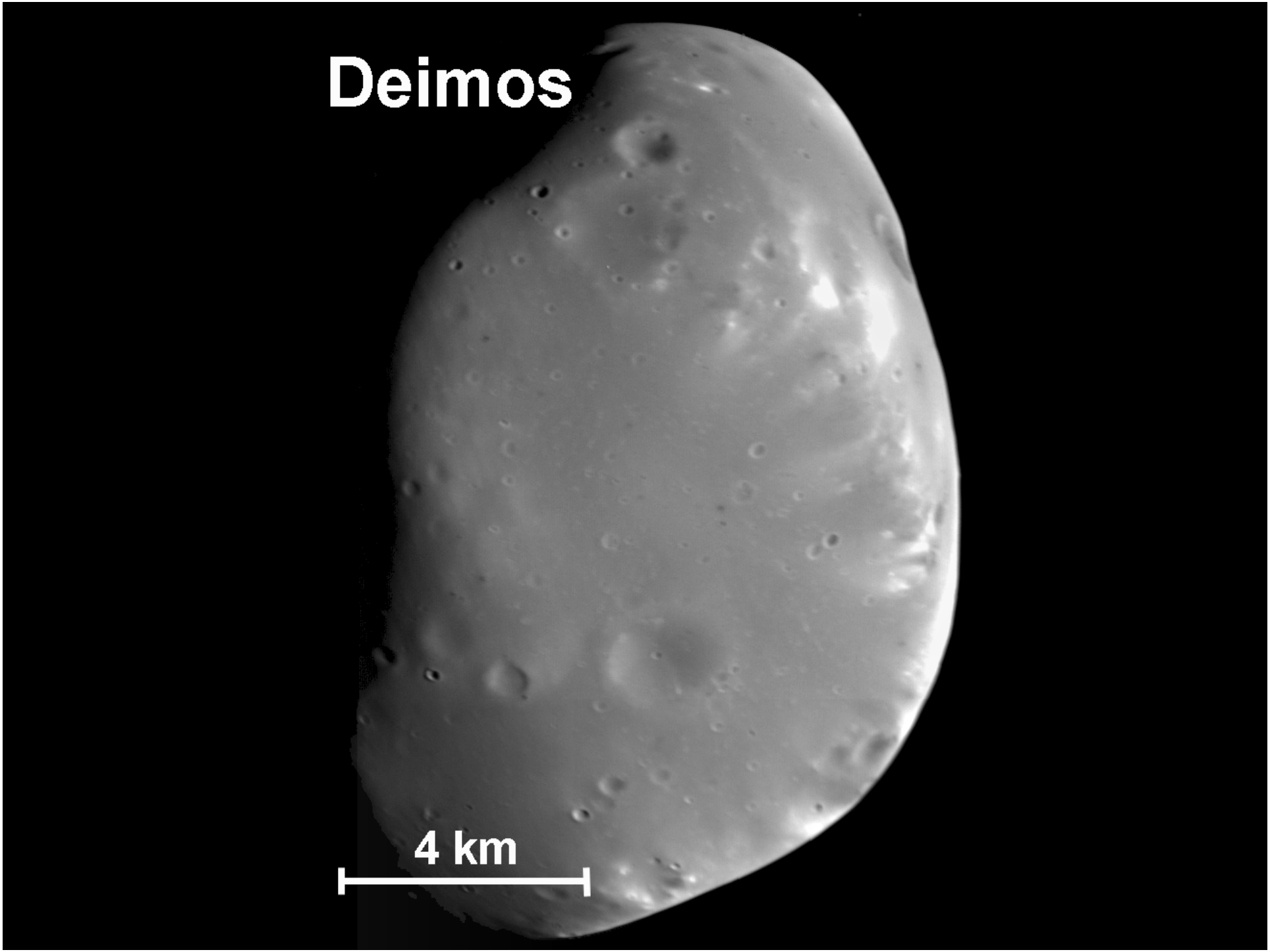
Phobos Grooves and Pits

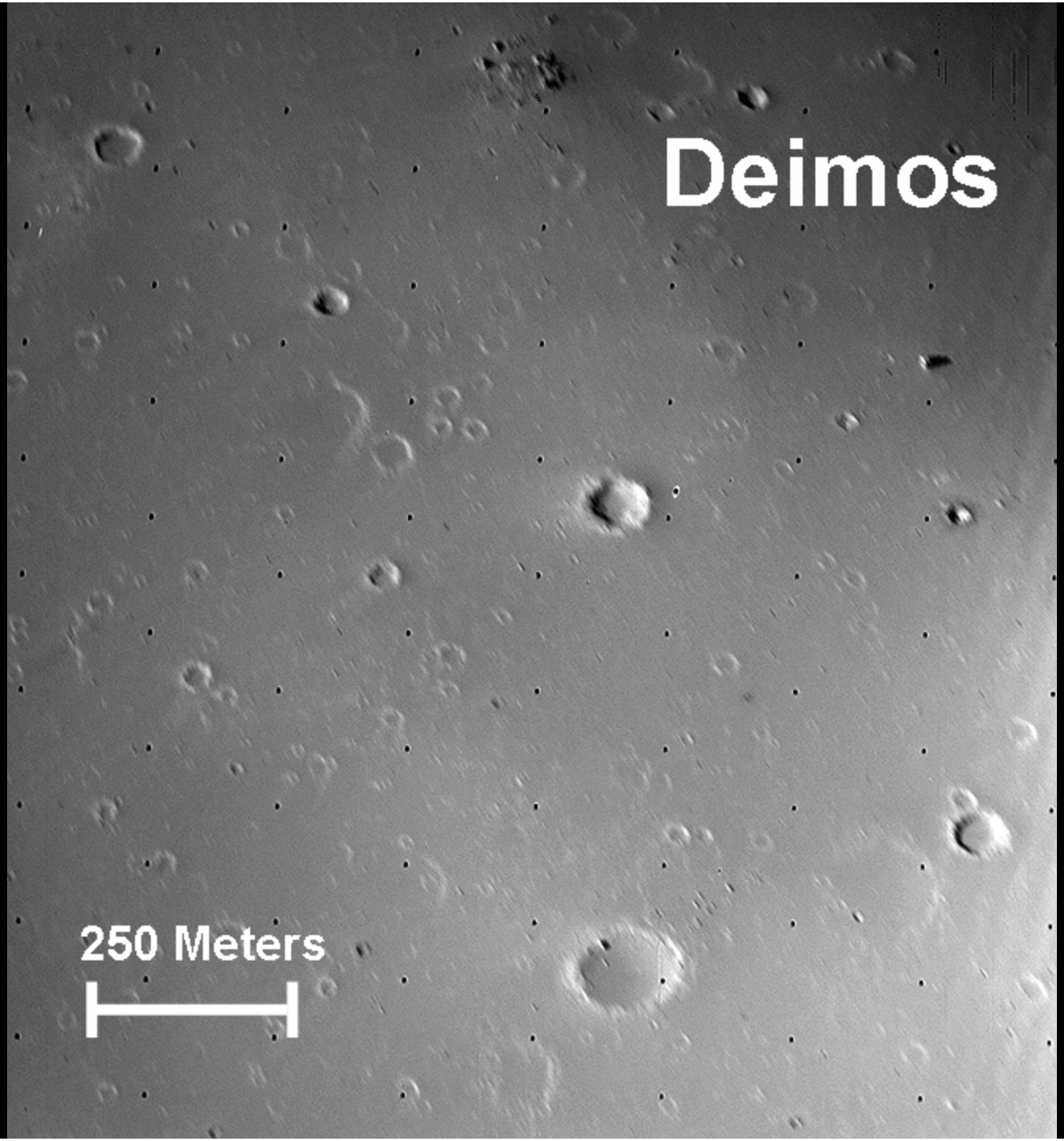


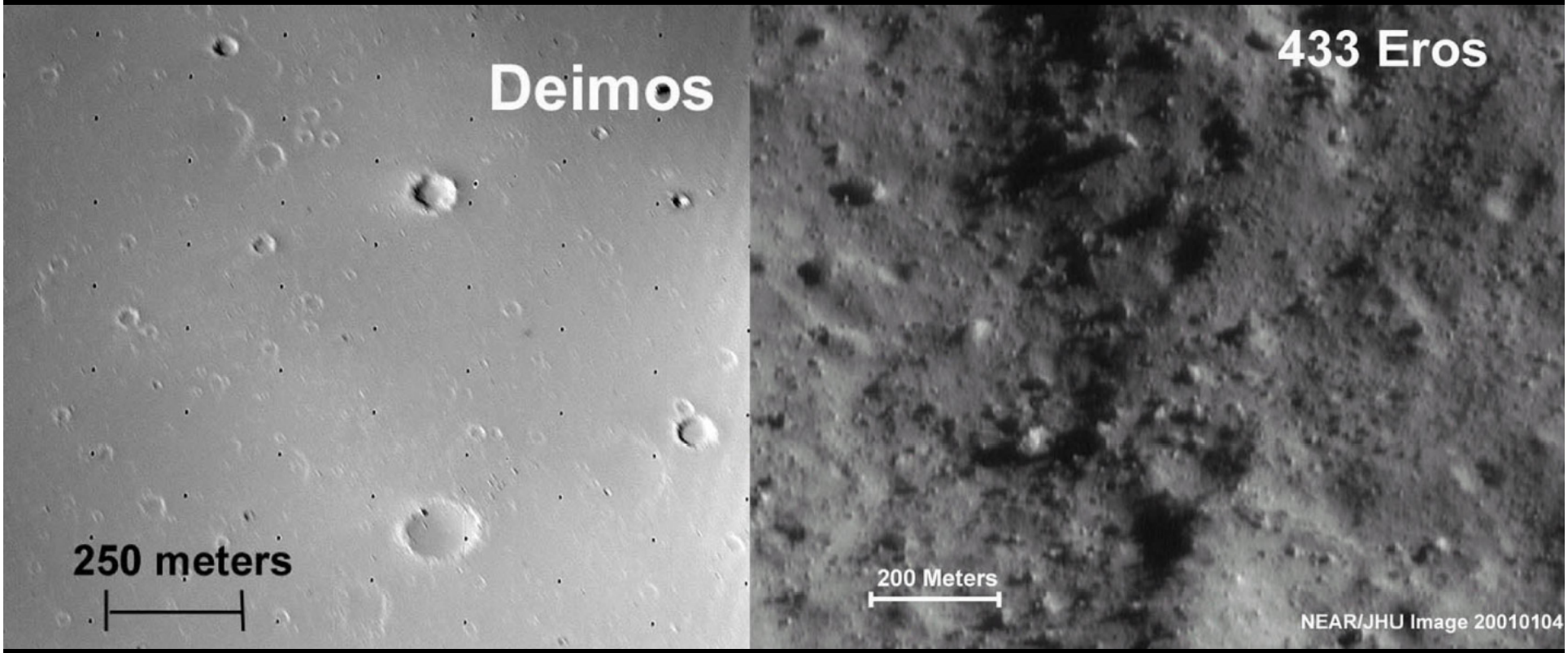

Phobos Boulders


Flat Floored Crater
Slope Failure
Phobos
1 km

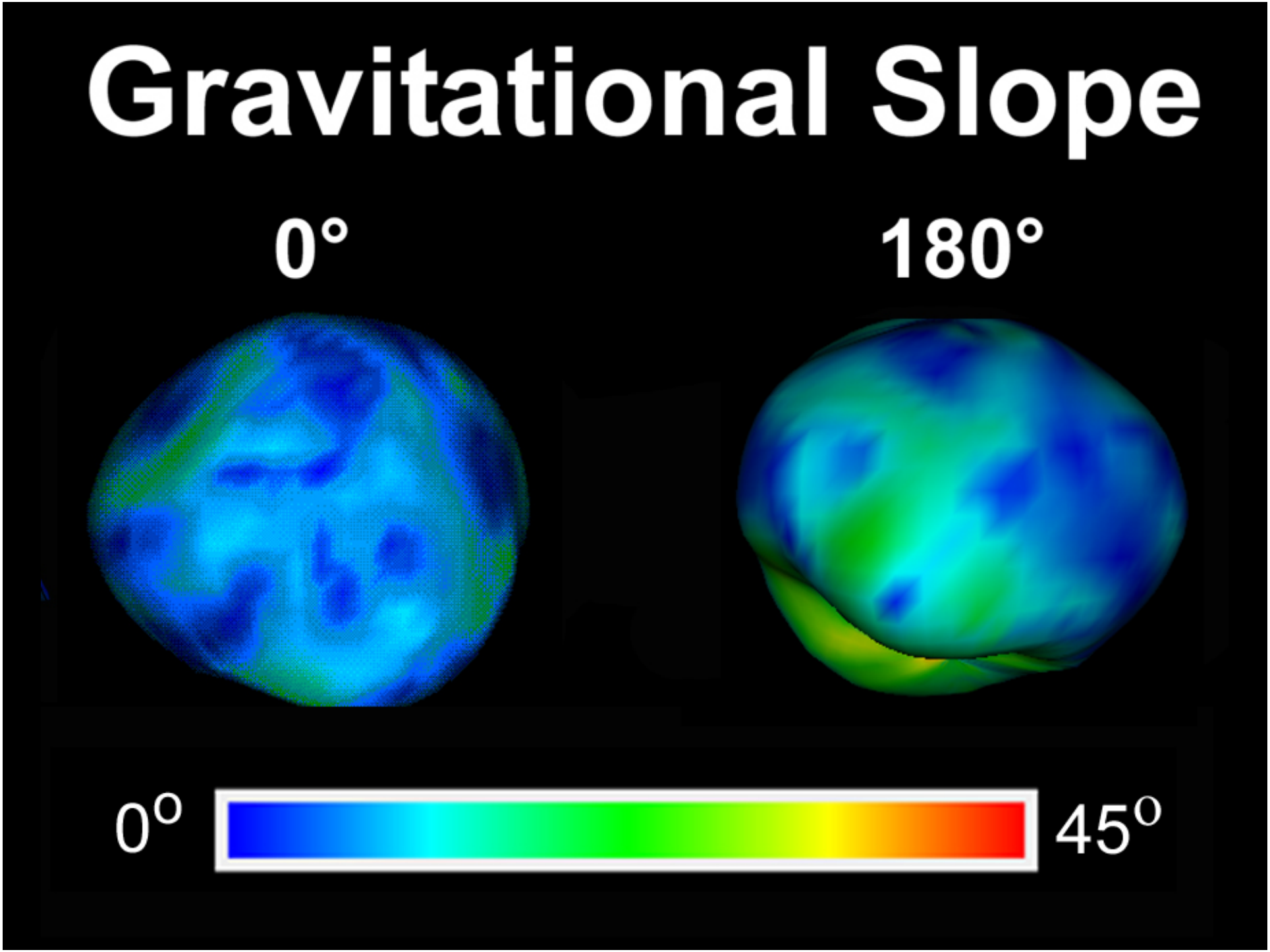



Deimos
4 km


Deimos
250 Meters

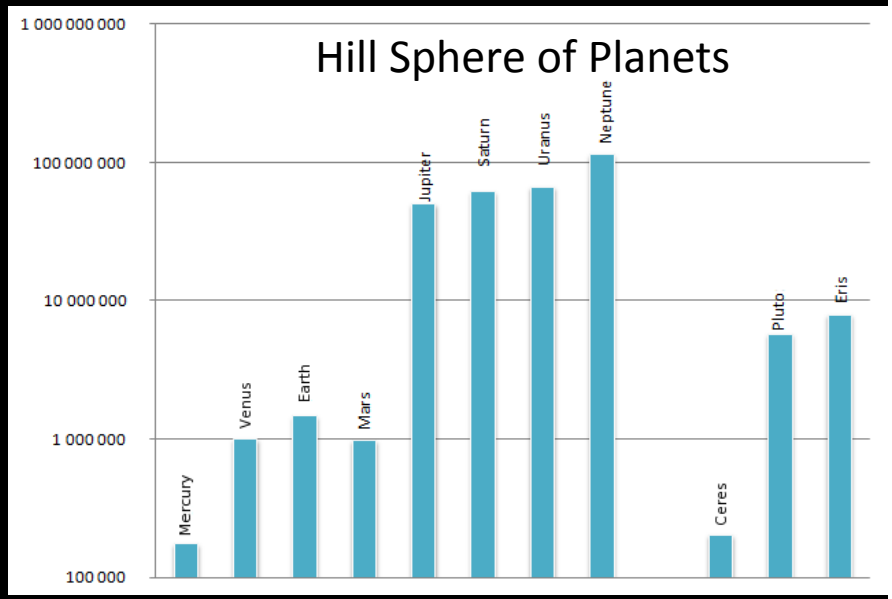

Deimos
250 meters
433 Eros
200 Meters
NEAR/JHU Image 20010104

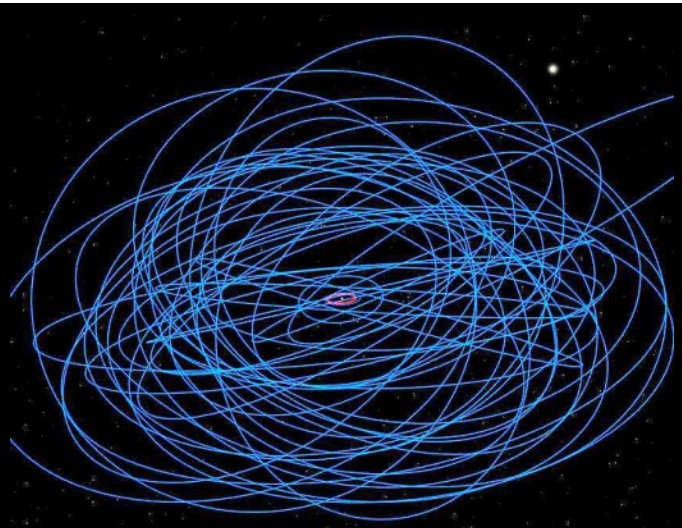
Gravitational Slope

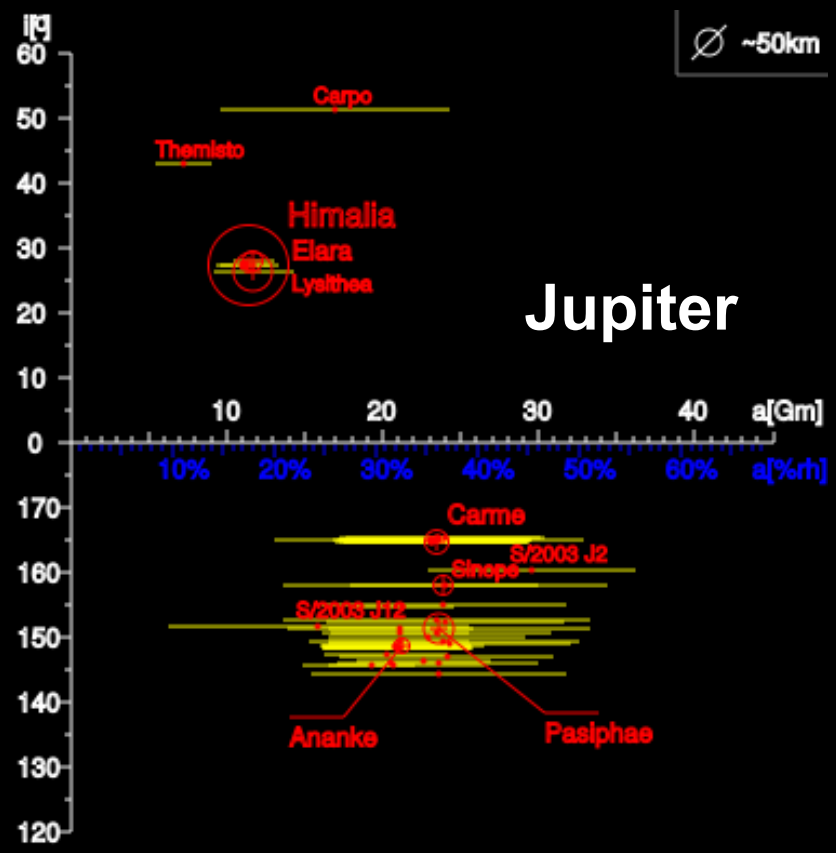


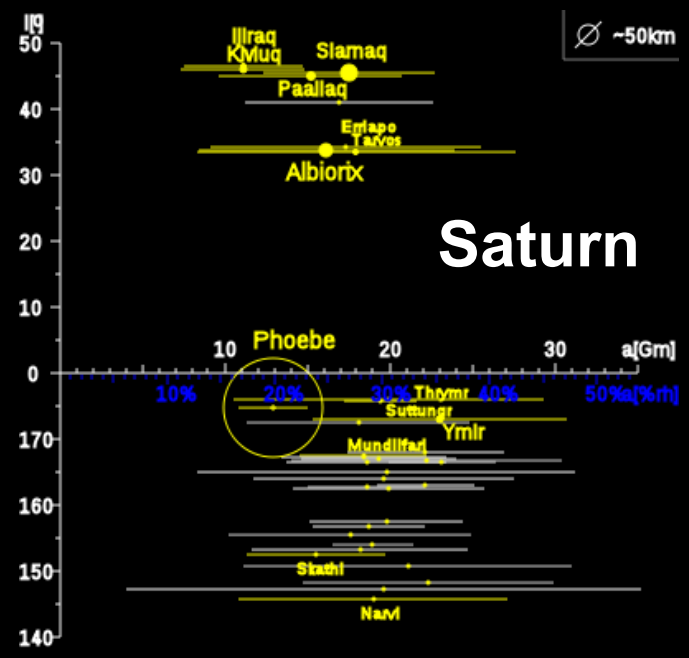
The Origin of Phobos and Deimos: Captured Asteroid

- **Evidence: Low density, low albedo (6%), Spectral D-class similar to outer asteroid belt small bodies.**
- **Source: From high flux of Jupiter-scattered planetesimals**
- **Problem: Capture requires energy loss within the Hill Sphere**
  - **There are mechanisms for this…**
  - **Gas drag from an extended early Martian atmosphere**
  - **Gravitational encounter incoming binary object and the planet, resulting in one component of the binary being captured**
  - **Impacts when the body is within the Hill Sphere**
  - **There are no shortage of captured bodies around the gas giants**

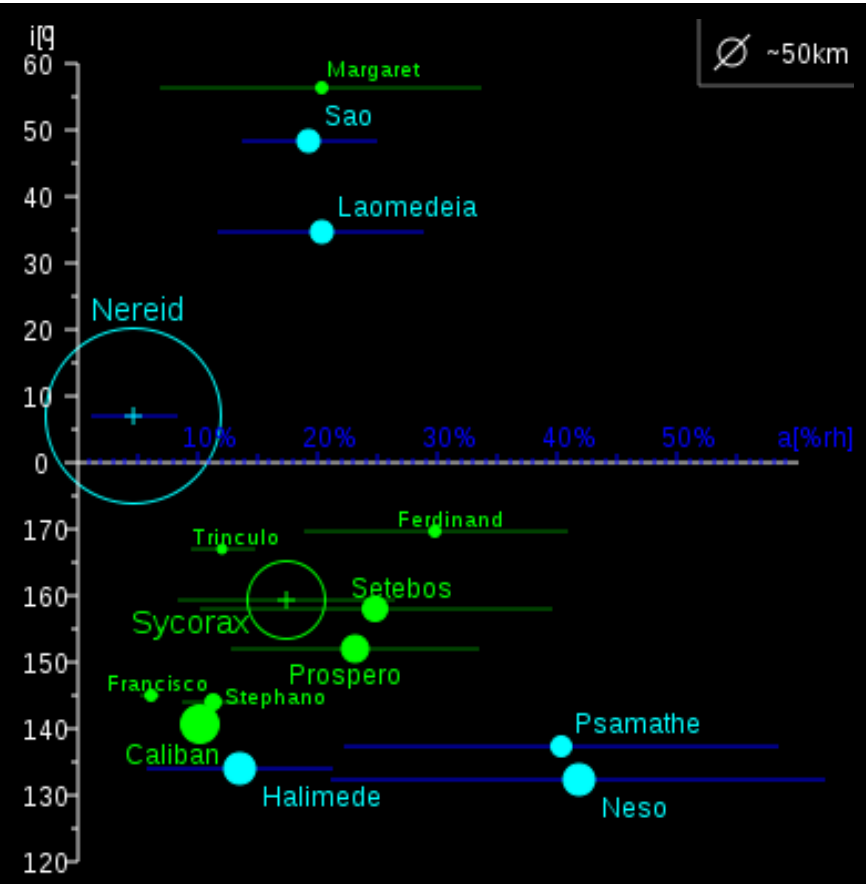








- Horizontal axis: Object's semi-major axis in Gm (xis)
- Vertical axis: Object's inclination's i (to the ecliptic) in degrees (vertical axis).
- Size of the circle illustrates the satellite's size relative to others
- The eccentricity of the orbit is shown indirectly by the line segment extending from the left (pericenter) to the apocenter to the right.
- The percentage in blue shows the fraction of the Lagrangian point at which the semi-major axes of the moon lie.
- Satellites beneath the axis (i>90) are retrograde.



Irregular satellites of Uranus (green) and Neptune (blue)

- Horizontal axis : Object's semi-major axis in Gm (xis)
- Vertical axis: Object's inclination's i (to the ecliptic) in degrees (vertical axis).
- Size of the circle illustrates the satellite's size relative to others
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The Origin of Phobos and Deimos

- **Formed from Mars Ejecta**
  - Evidence: Albedo on high end of primitive bodies, shallow absorption features
  - Source: Early Mars heavy bombardment
  - Problems: Albedo is too low, Mars-material content appears low, requires extra impulse for orbit.
    - Again, there are ways out of this problem….extended early atmosphere, ejecta interactions, gas-ejecta interactions.
- **Accreted In Place**
  - Evidence: "Consequence of planetary formation"
  - Source: Mars space nebular material
  - Problems: Expect material in Mars space to be high-albedo. Albedo too low.

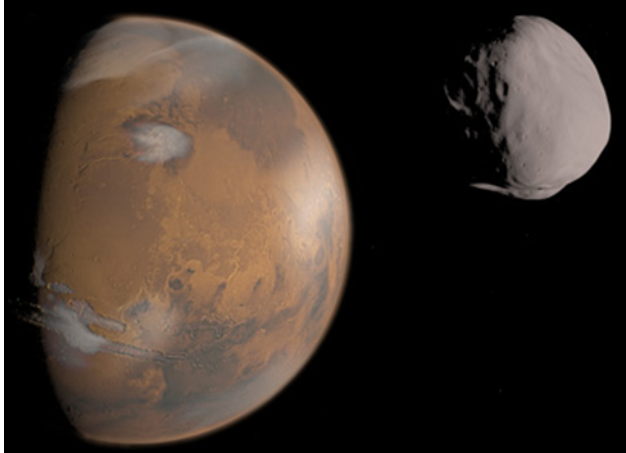
Phobos/Deimos Science: Primitive Materials

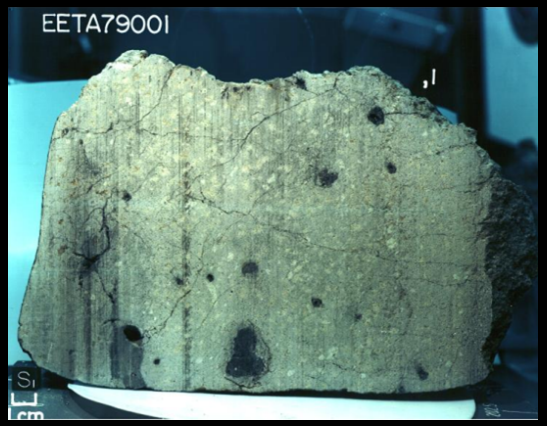
- What is the composition of primitive bodies?
  - Deimos provides "ground truth" mineralogy and remote sensing for other, less accessible primitive bodies.
- What is the geochemical reservoir that primitive bodies formed
  - How does that compare to the geochemistry of the inner solar system?
  - What does that say about early solar system condensation?
- What organic compounds are found in primitive bodies like Phobos/Deimos?
  - How did these materials evolve over the age of the solar system?
- What are the prebiotic compounds on primitive bodies?
  - How did primitive asteroids contribute to the availability of prebiotic materials?
- What are the physical properties (mass, volume, density, gravity field) of Phobos/Deimos?
  - What is the structure of a rubble pile small body?
  - How did Deimos survive impacts over the age of the solar system?

THE UPSHOT

- We observe a 6 μm water feature in Mars Global Surveyor Thermal Emission Spectrometer data
- Tantalizing suggestion of finely-mixed secondary phase (carbonate?) in regolith
- Phyllosilicates, as suggested by previous authors, may explain mid-IR spectral observations

P/D Science: Accreted from Mars Ejecta

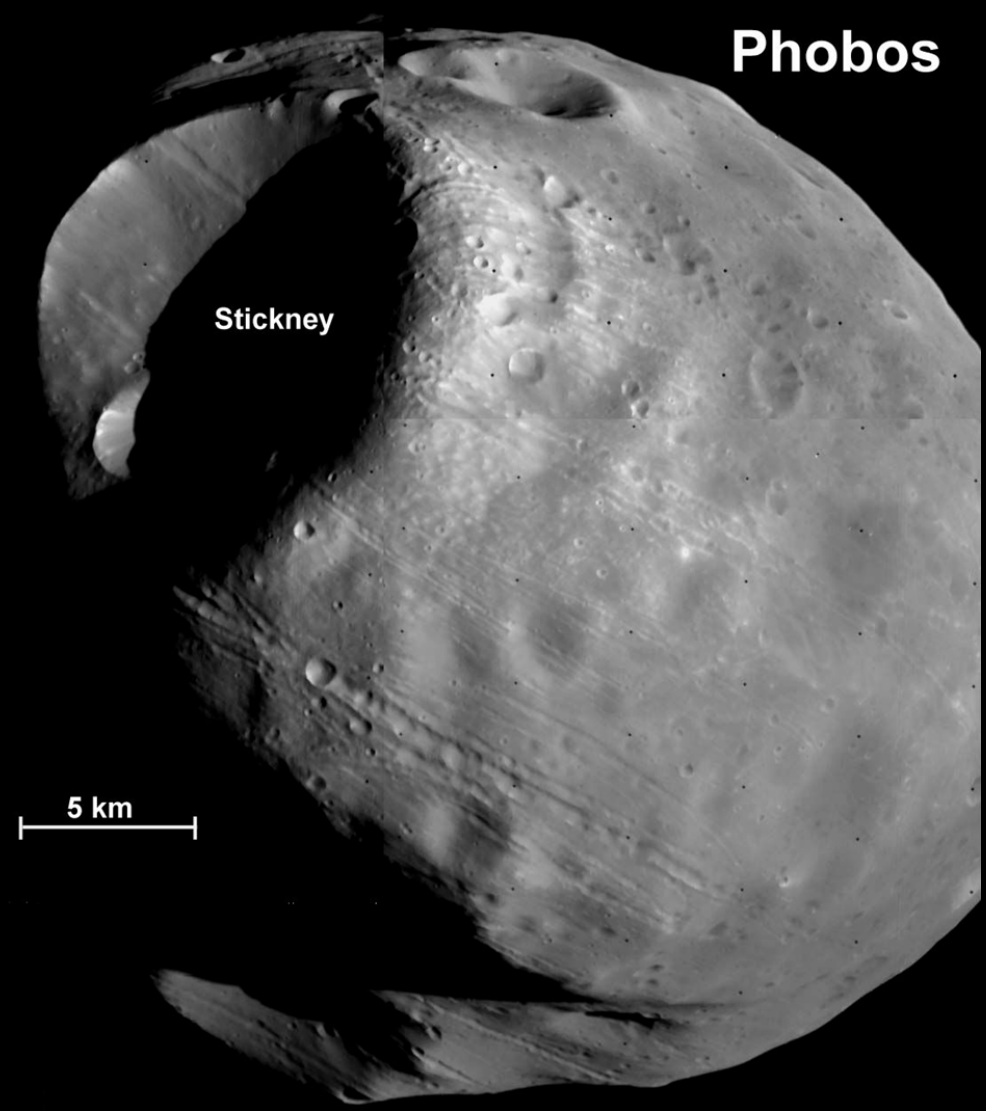




- **Samples of Early Martian Crustal Evolution**
  - There are very few ancient samples in the Mars meteorite collection,
- **A time machine to the earliest epochs on Mars.**
  - Martian crustal geochemistry and petrology
  - Isotopic fractionations in igneous and sedimentary rocks
  - Timing and sequence of crustal differentiation and Martian mantle geochemistry
- **The "storehouse" of Ancient Mars**
  - Timing of major impacts and basin-forming events
  - Direct evidence of early crustal conditions, volatile inventory, early conditions for life
- **What are the physical properties (mass, volume, density, gravity field) of Phobos/ Deimos?**
  - What is the structure of a rubble pile small body?
  - How did P/D survive impacts over the age of the solar system?

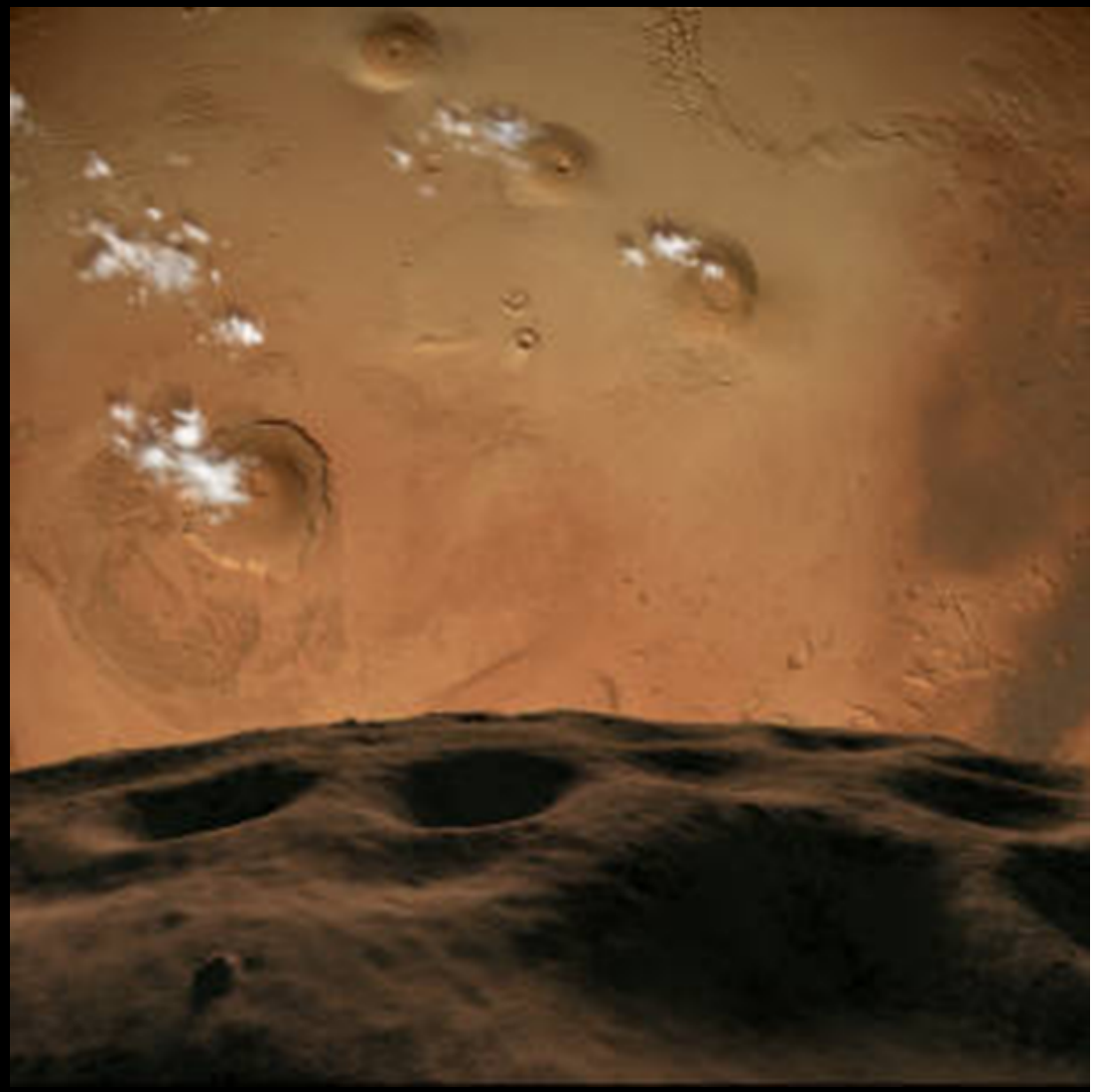
Why Go to Phobos and/or Deimos?

- **Stepping Stone to Mars**
  - Allows for Martian voyages without the major risk factor of dropping into a deep gravity well.
- **Source of Potential Resources**
  - Low albedo suggest a mineralogy that may be rich in volatiles and other potentially useful minerals.

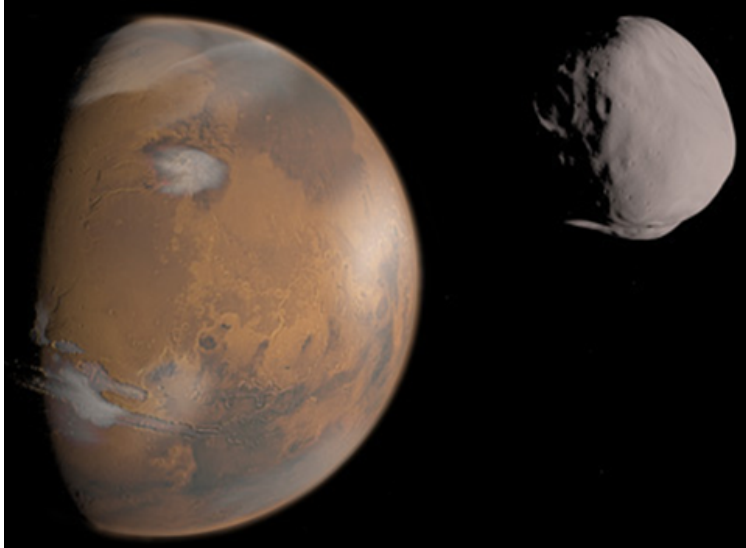


Why Go?

- **Bases for Surface Exploration**
  - **Their mass and location close to Mars can provide critical shielding from the space radiation and cosmic ray environments.**
  - **Nearby base to support telepresence and remote surface operations.**



Science Questions for Phobos/ Deimos Exploration



- **Composition**
  - Origin (captured or accreted?)
  - Potential for Resources (water, carbon compounds….or not)
- **Structure**
  - Internal structure (rubble, voids?)
  - Depth of regolith
  - Resources at depth?
- **Regolith properties**
  - Depth and particle size
  - Angle of repose and compaction
- **History**
  - Age of Phobos/Deimos
  - Impact flux and history
  - Conditions in Mars space