Landing at Cleopatra Crater: Granite Mountains and Tellurium Snow?

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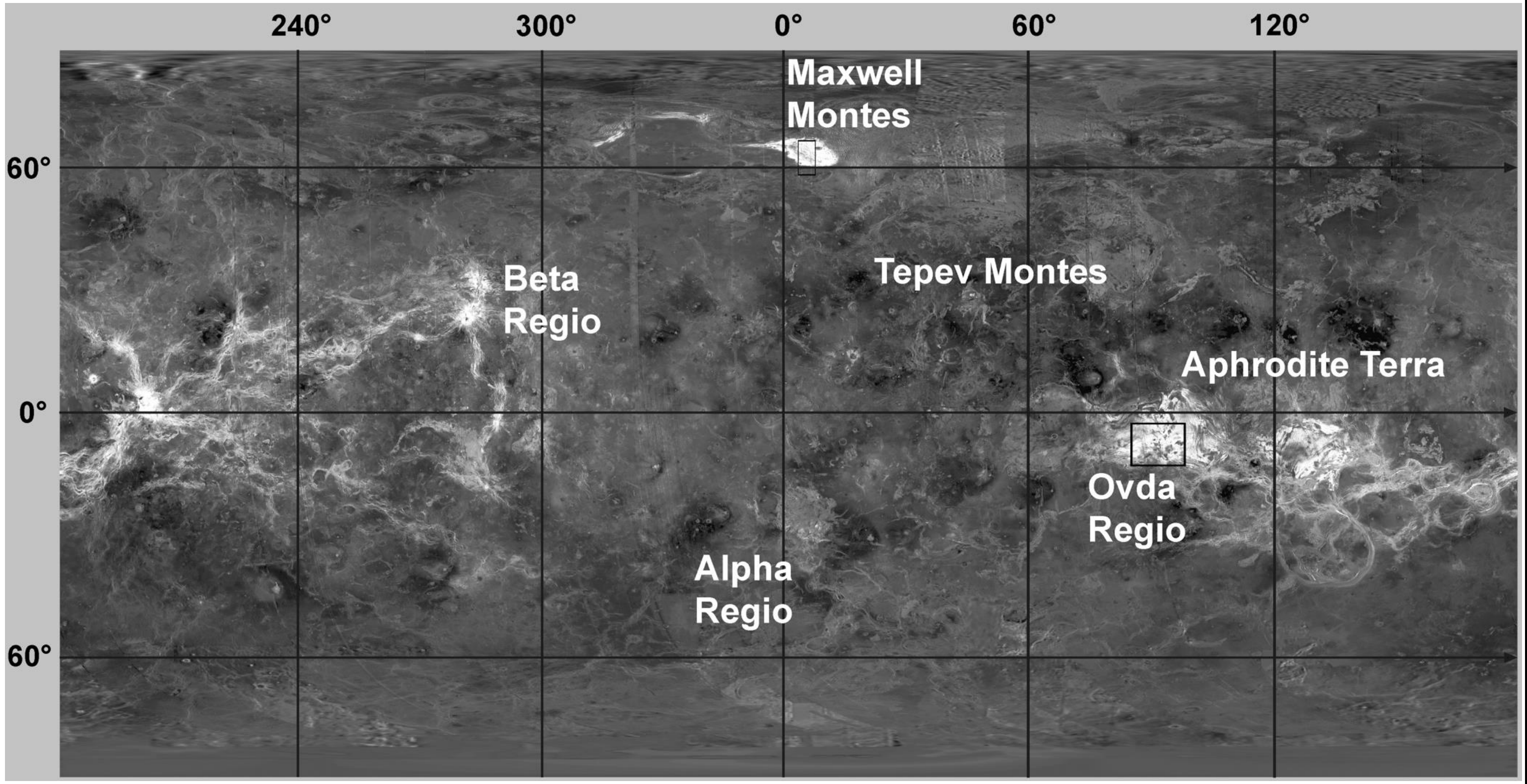
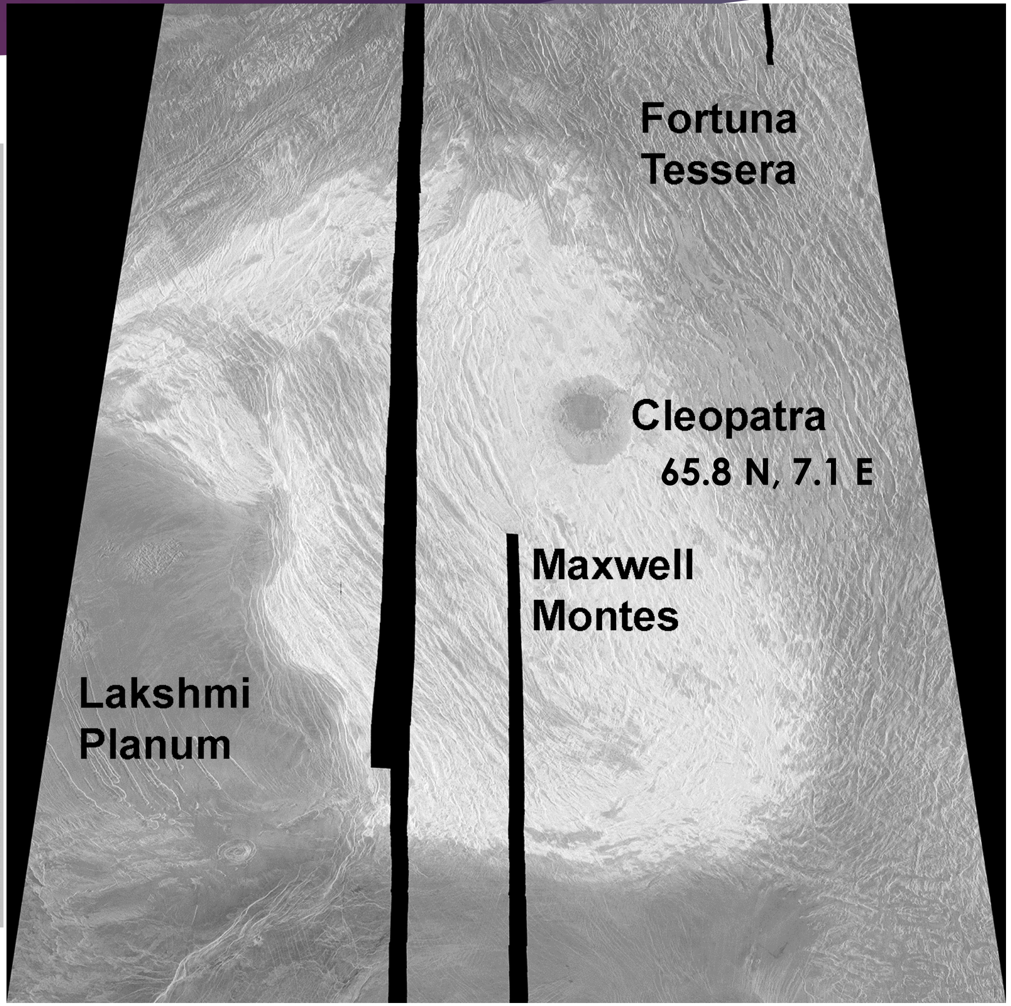
Cleopatra: Impact basin on Maxwell Montes





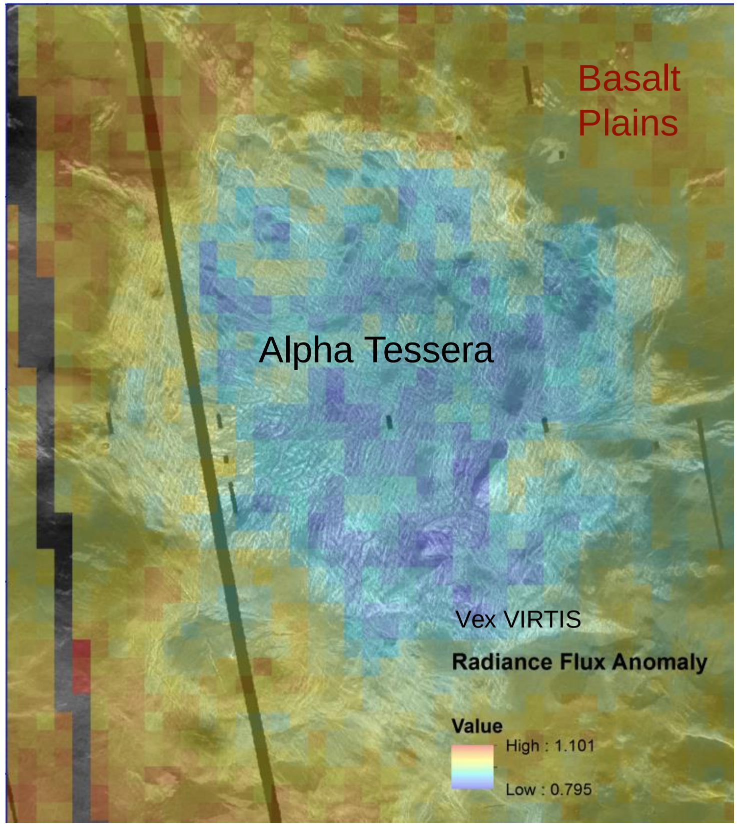
Critical Venus Questions: *VEXAG Goals, Objectives and Investigations* 2019

- "Did Venus have temperate surface conditions and liquid water at early times?" [VEXAG GOI 2019. Goal I, Objective A]
  - "Determine whether Venus shows evidence for abundant silicic igneous rocks and/or ancient sedimentary rocks." [Investigation 1: **HO. Hydrous Origins (1)].**
- "What geologic processes have shaped the surface of Venus?" [VEXAG GOI 2019. Goal III, Objective A]
  - "Determine elemental chemistry, mineralogy, and rock types at localities representative of global geologic units on Venus." **GC. Geochemistry (1).**
- "How do the atmosphere and surface of Venus interact?" [VEXAG GOI 2019. Goal III, Objective B]
  - "Evaluate the mineralogy, oxidation state, and changes in chemistry of surface-weathered rock exteriors at localities representative of global geologic units on Venus." **LW. Local Weathering (1).**

Silicic (Granitic) Igneous Rocks?

- To create abundant granitic rock on a chondritic planet **requires abundant water**.
  - Campbell, I. H., & Taylor, S. R. (1983). No water, no granites - No oceans, no continents. *Geophysical Research Letters*, *10*(11), 1061-1064.
  - Granitic highlands (continents) on Venus would imply ancient oceans ! !
- Evidence
  - Tall mountains (like Maxwell) impossible without low density rock or dynamic support. (Kaula et al. 1992)
  - Near-infrared emissivities of some highlands are low, and consistent with silicic rocks. (Hashimoto et al. 2008; Gilmore et al. 2015)
- To be certain, we need in-situ analyses of chemistry & mineralogy.

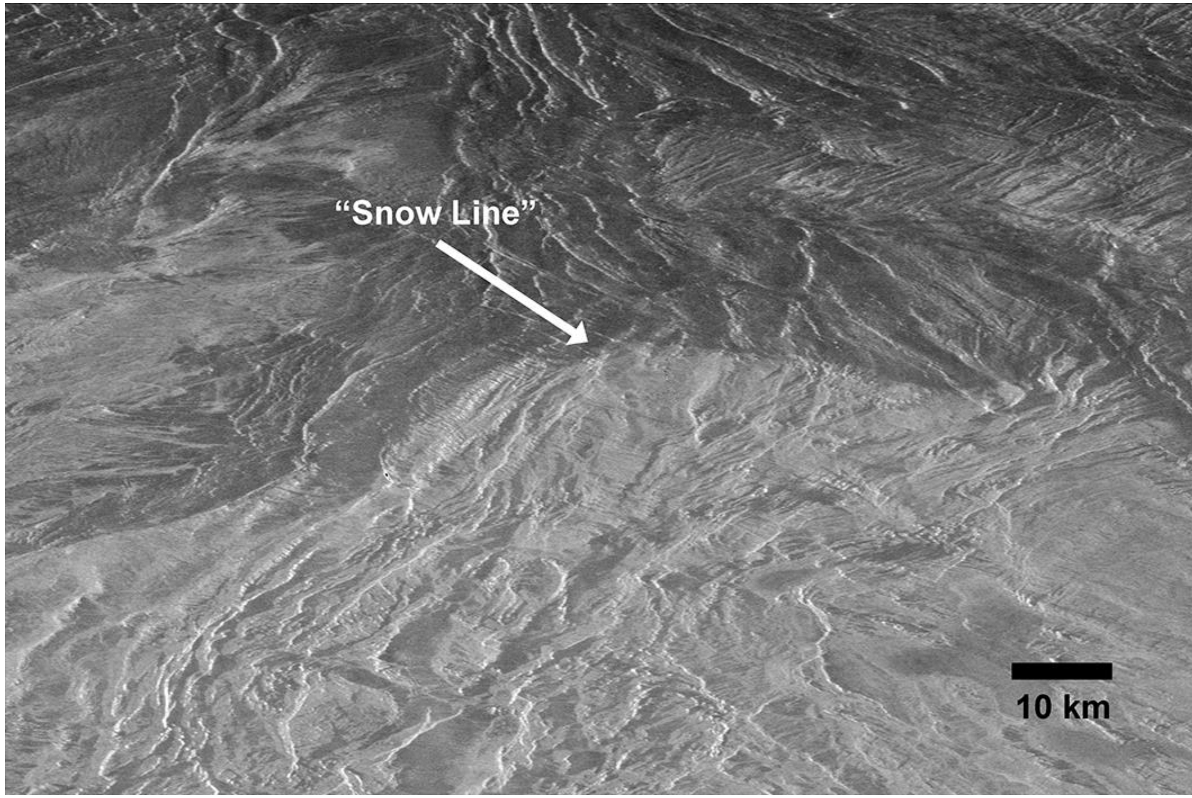
Alpha Regio -1 μm NIR Emission. Gilmore et al. 2015



Surface-atmosphere chemical interaction

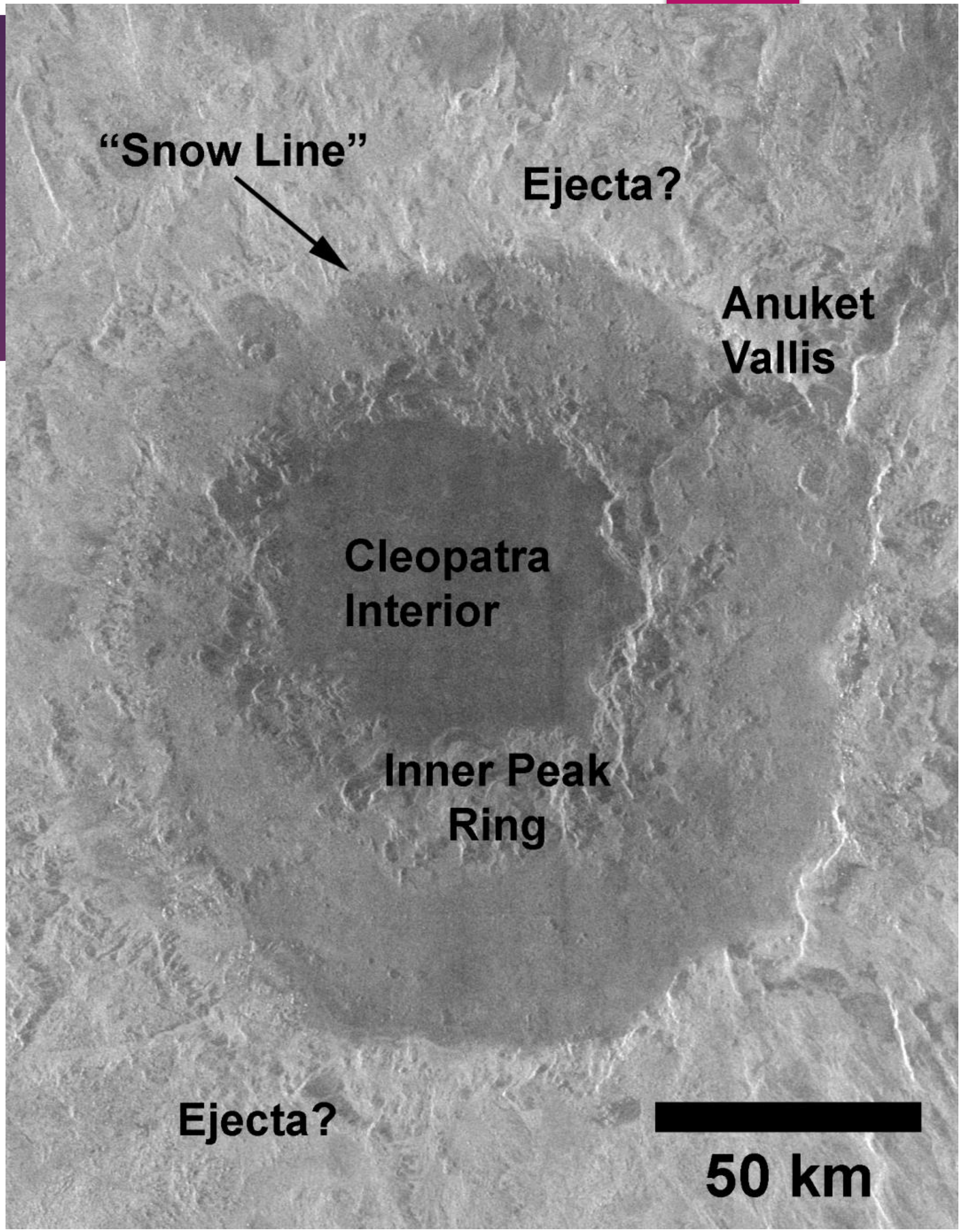
- Surface-atmosphere reactions shown by color & chemistry from Venera/VEGA
  - $CaSO_4$ formation – S abundances in rock/soil
  - Oxidation – hematite coatings (Pieters et al. 1986)
    - May provide age estimates for young flows (Smrekar et al. 2010; Filiberto et al. 2019)
- High radar backscatter at high elevations! "Snow line", especially on Maxwell. What is the "snow"?
  - Tellurium metal? (Pettengill et al. 1996)
  - Chalcogenides, e.g. Bi_2S_3, Bi_2Te_2S, PbS ? (Schaefer et al. 2004; Port et al. 2019)
  - Pyrite, FeS_2 ? (Klose et al. 1992)

North flank of Maxwell Montes; center at ~68°N 6°E

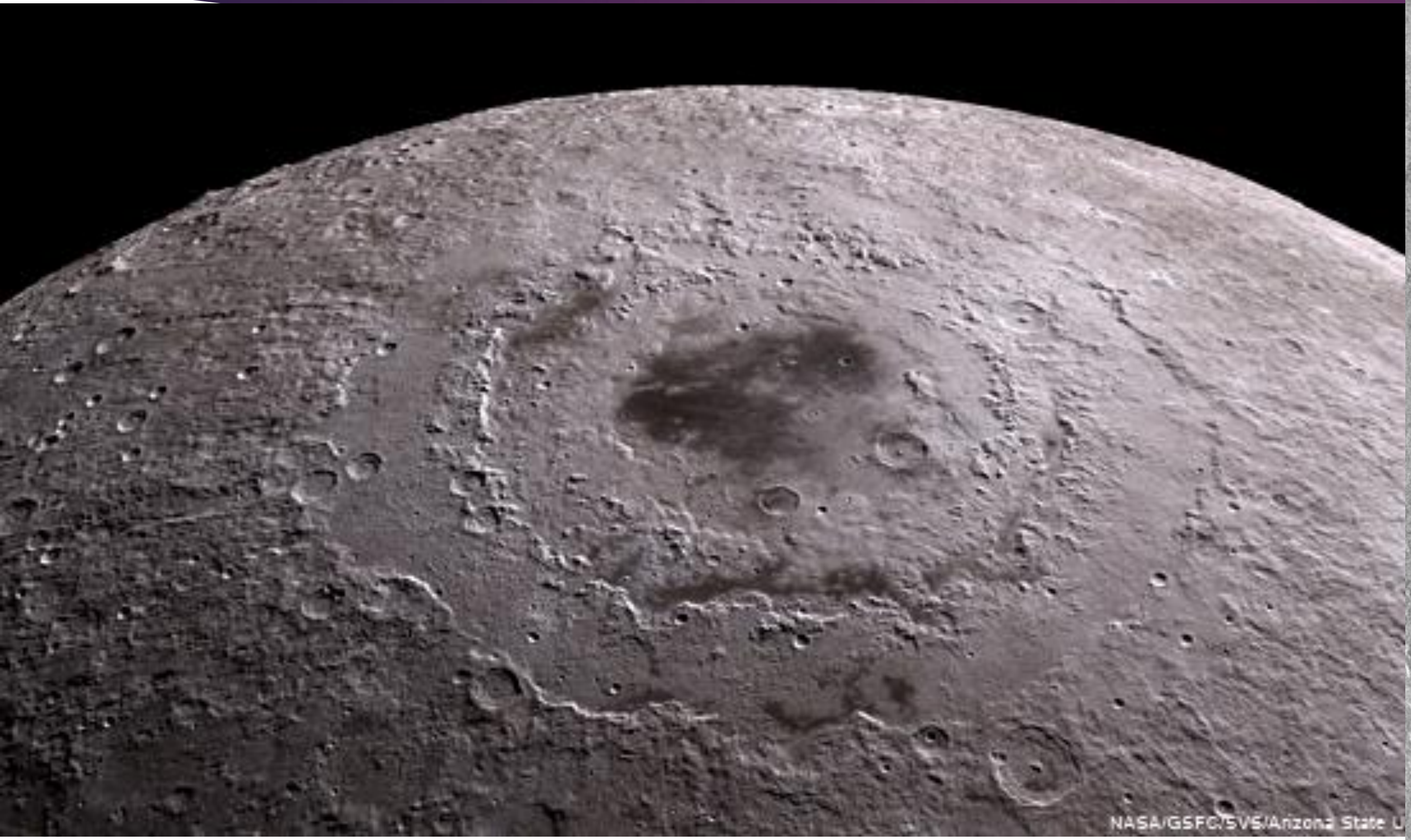


Cleopatra Geology

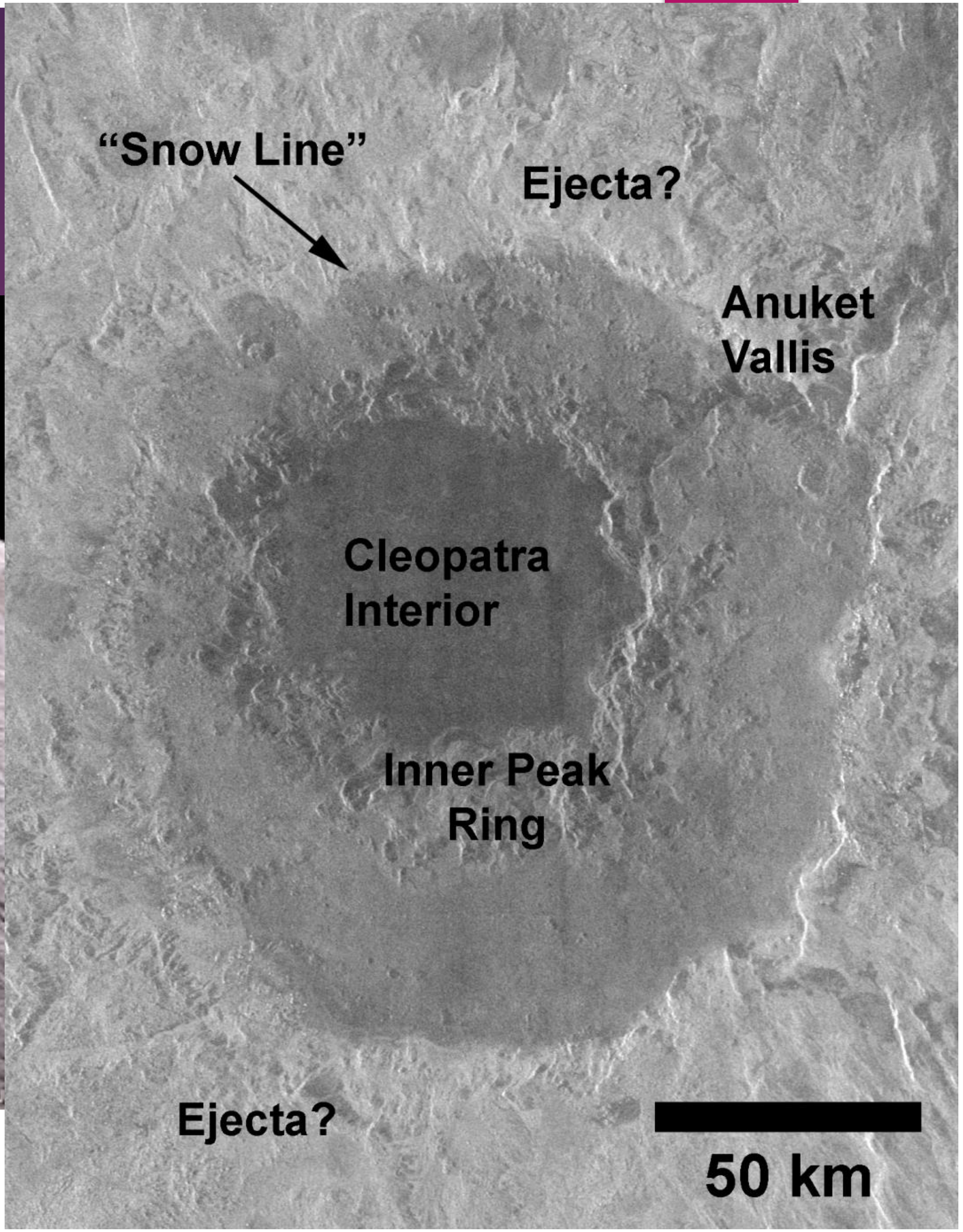
- Poorly known – mapped only as part of larger efforts
- Subdued outer ring and inner peak ring
- Flat, smooth interior, presumably lava or impact melt
  - Feeding Anuket Vallis, which drains east into Fortuna Tessera
- Relatively flat, smooth band between peak ring and outer ring – impact melt pools?
- Radial sculpture around crater – impact ejecta



Cleopatra Geology

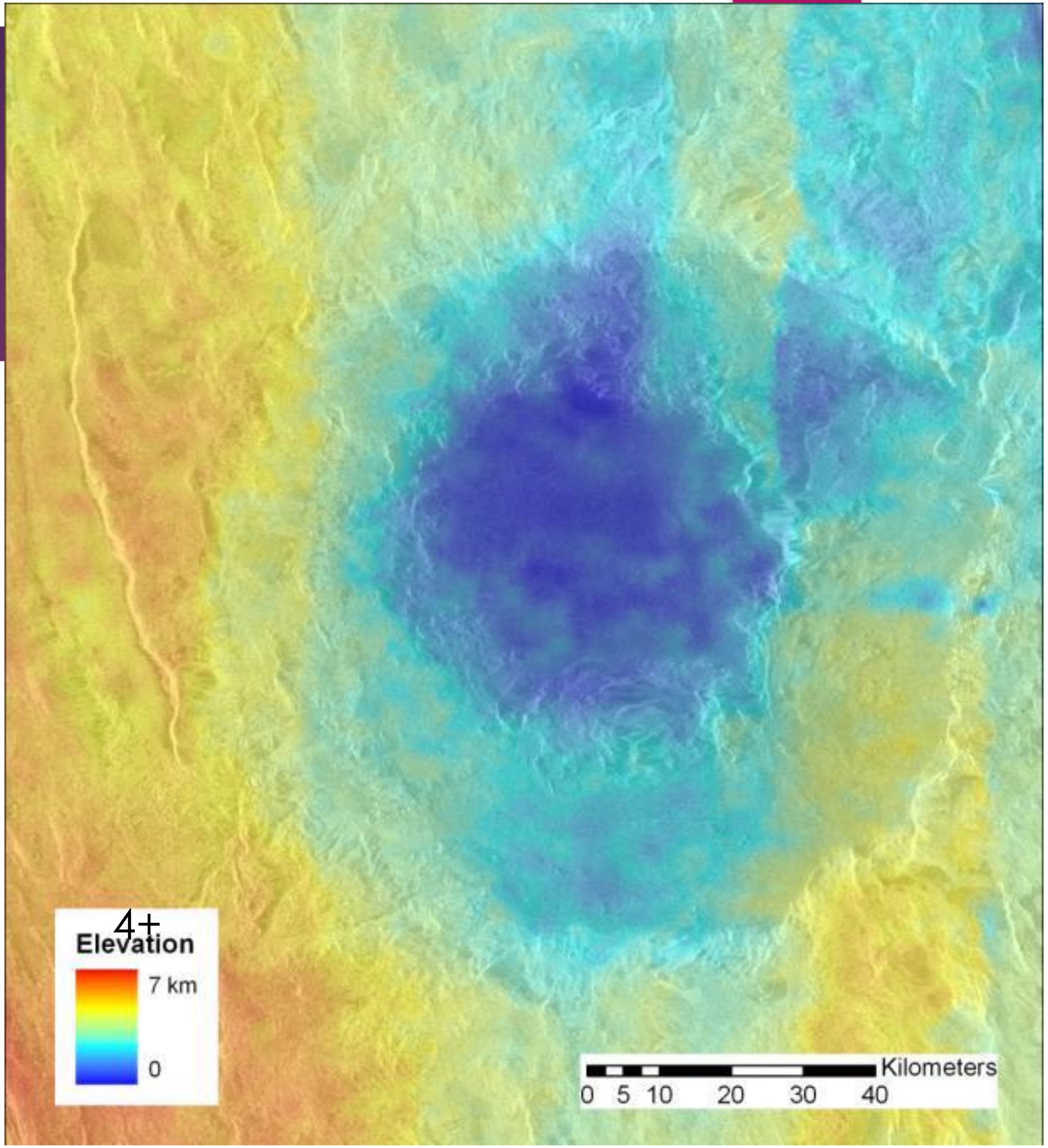


Orientale Basin, Moon (~900 km across)



Cleopatra topography

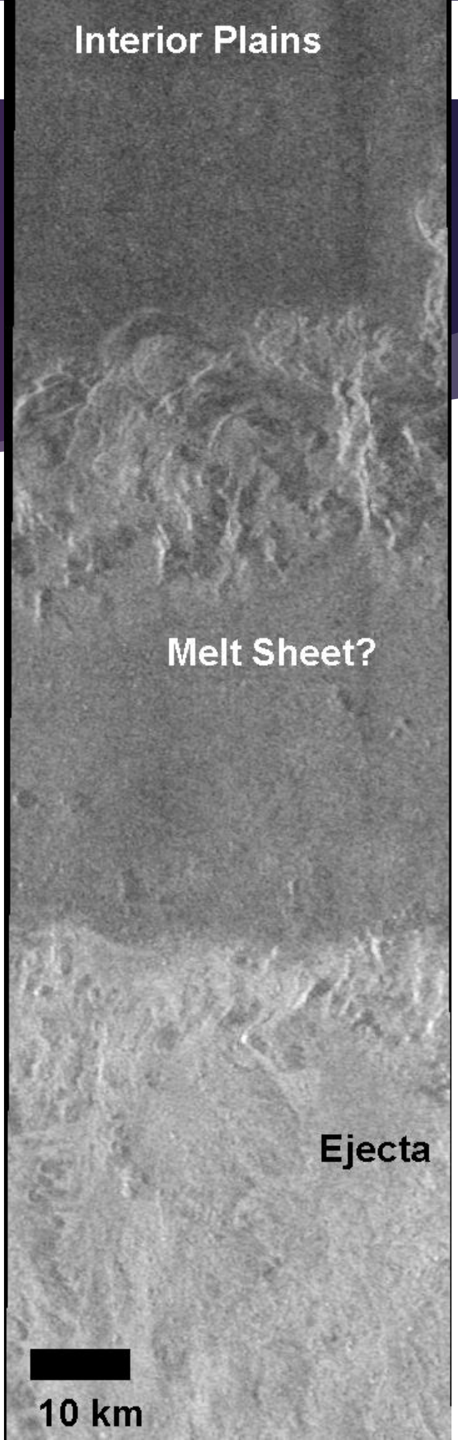
- Interior at ~ 4 km above datum
- Stereo DEM from Magellan
  - < 2 km spatial resolution
  - 50-100 m elevation resolution
- Full of artifacts!
  - Km-height 'boundary faults'
  - Inconsistent offsets on 'boundary faults'
- F-MIDRs, on which stereo is based, are
  - Incorrectly mosaiced
  - Show across-swath elevation variations suggestive of incorrect orbit parameters
- Could be improved by reprocessing!



Stereo elevation. Herrick 2014

Cleopatra potential landing targets

- Cleopatra interior plains
  - Appears smoothest, large area
  - Could be post-impact basalt fill
  - No view of high-radar-backscatter surface
- Plains between peak ring and crater rim
  - Relatively smooth, smaller area
  - Likely impact melt sheet – average highlands chemistry!
  - Possible view of high-radar-backscatter surface
- Near Exterior to Cleopatra
  - Moderately rough, large area
  - Likely impact ejecta - average highlands chemistry!
  - On high-radar-backscatter surface!



Advantages - Cleopatra - Issues

- Addresses critical questions
  - Highlands chemistry & mineralogy: granite or basalt?
  - High-elevation 'snow': tellurium, pyrite, or what?
  - Others: e.g.,
    - Atmosphere at high latitude: Treiman et al. 2016
    - Tectonics: Herrick 2014
- Uniquely smooth highland site
- High elevation means longer life
  - Less descent time (~10 -15 min)
  - Lower temperature (~40 – 60 K)

- Geology poorly known
- Topography poorly constrained
  - Surface rougher than lowlands, but risks uncalibrated.
- Relatively small landing area
- Requirements / desirements:
  - Geologic map
  - Better radar products
  - Evaluation of landing risk
  - Terrain-relative navigation
  - Autonomous hazard-avoidance landing system