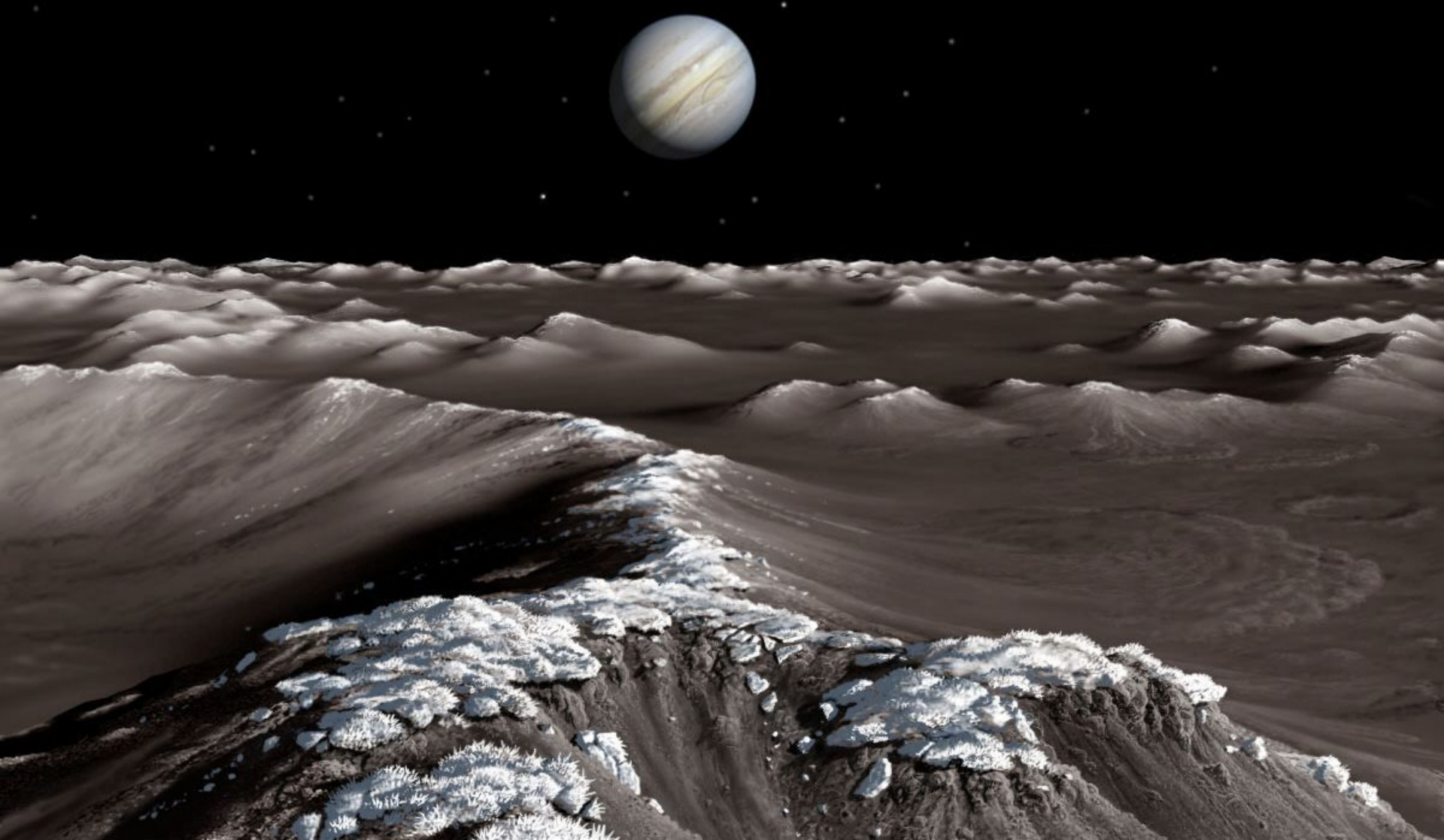
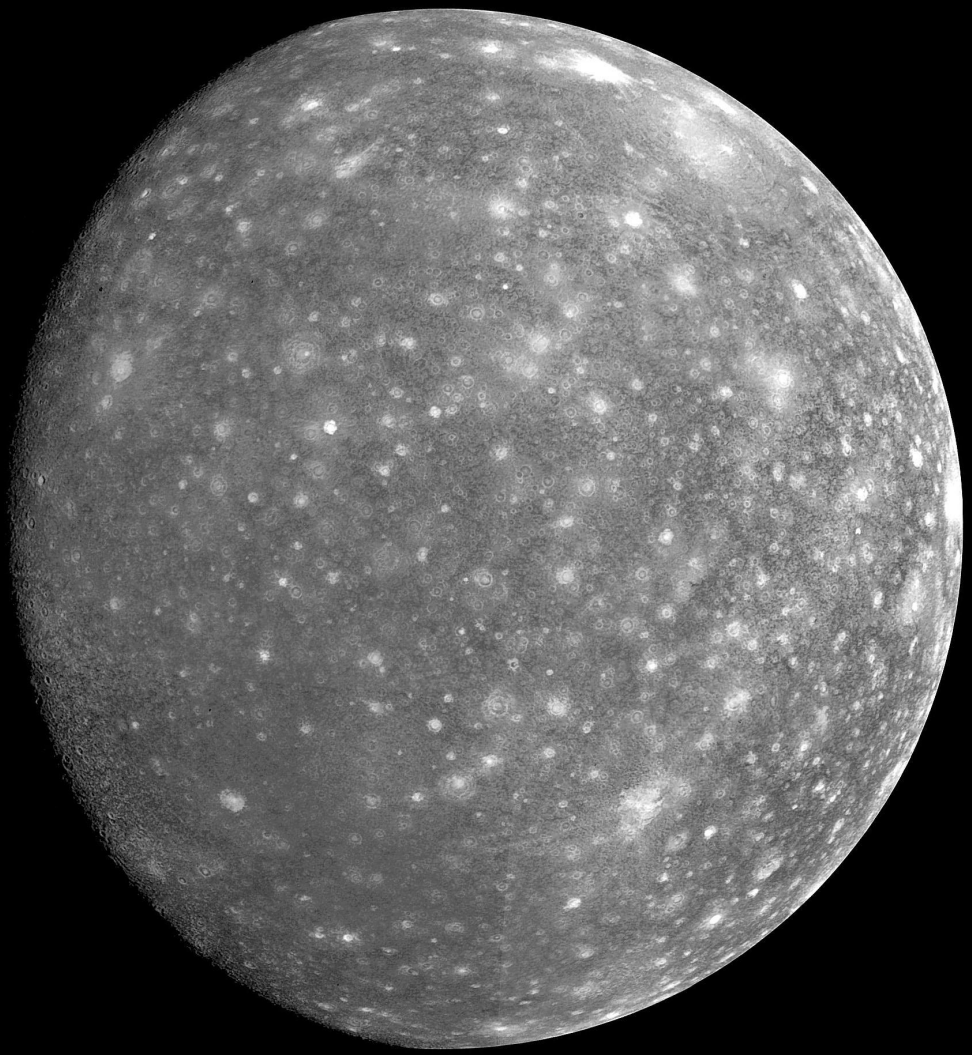
CALLISTO REVEALED BY *GALILEO*: A WORLD IN ITS OWN RIGHT

Jeff Moore (NASA Ames)

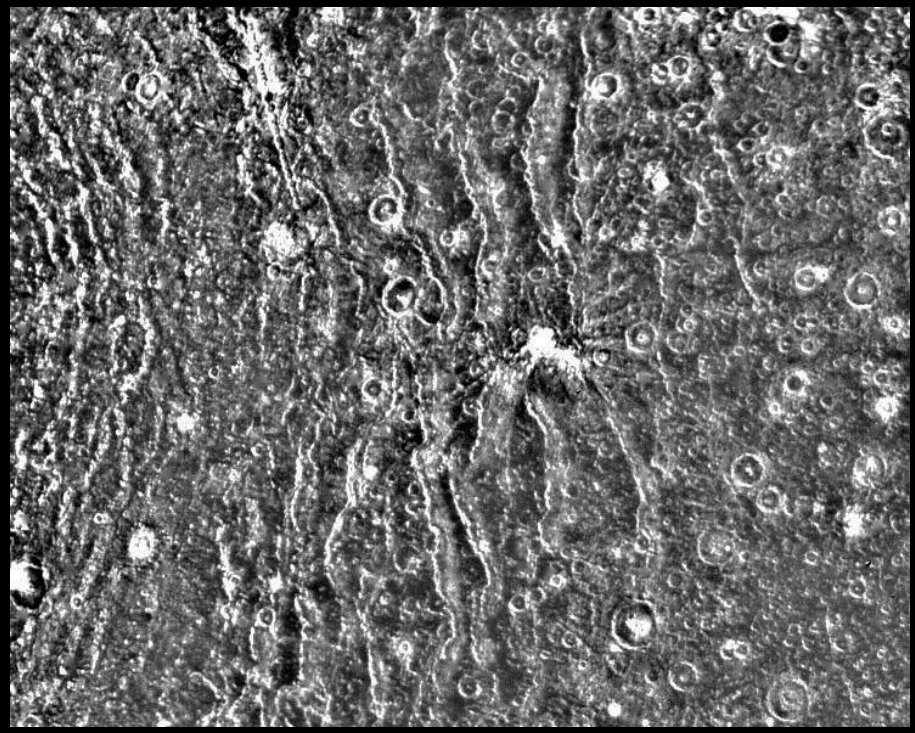


VOYAGER'S CALLISTO

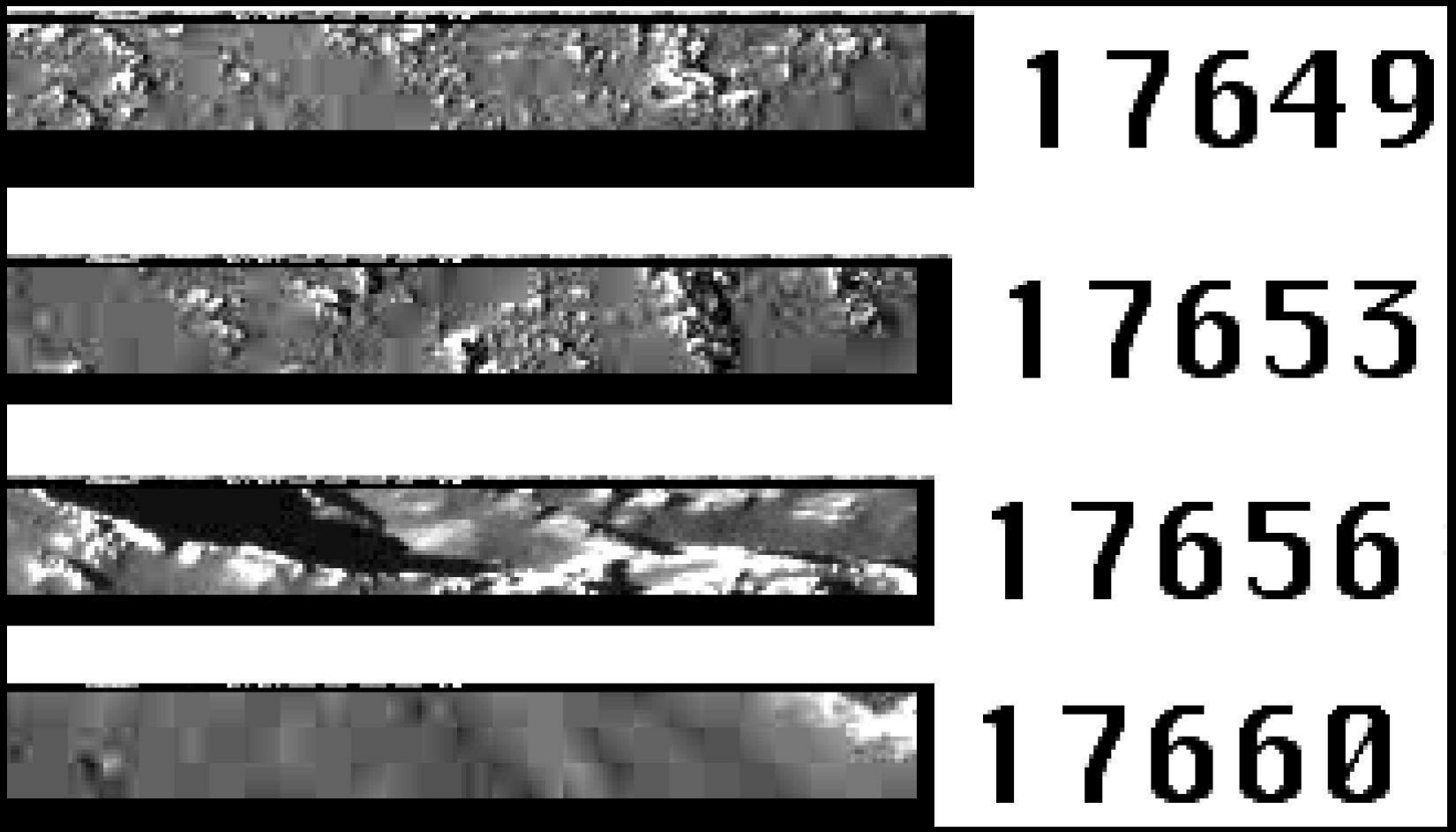
- Wall-to-Wall craters
- Several multi-ringed basins
- Frost migration
- Often described as "boring"



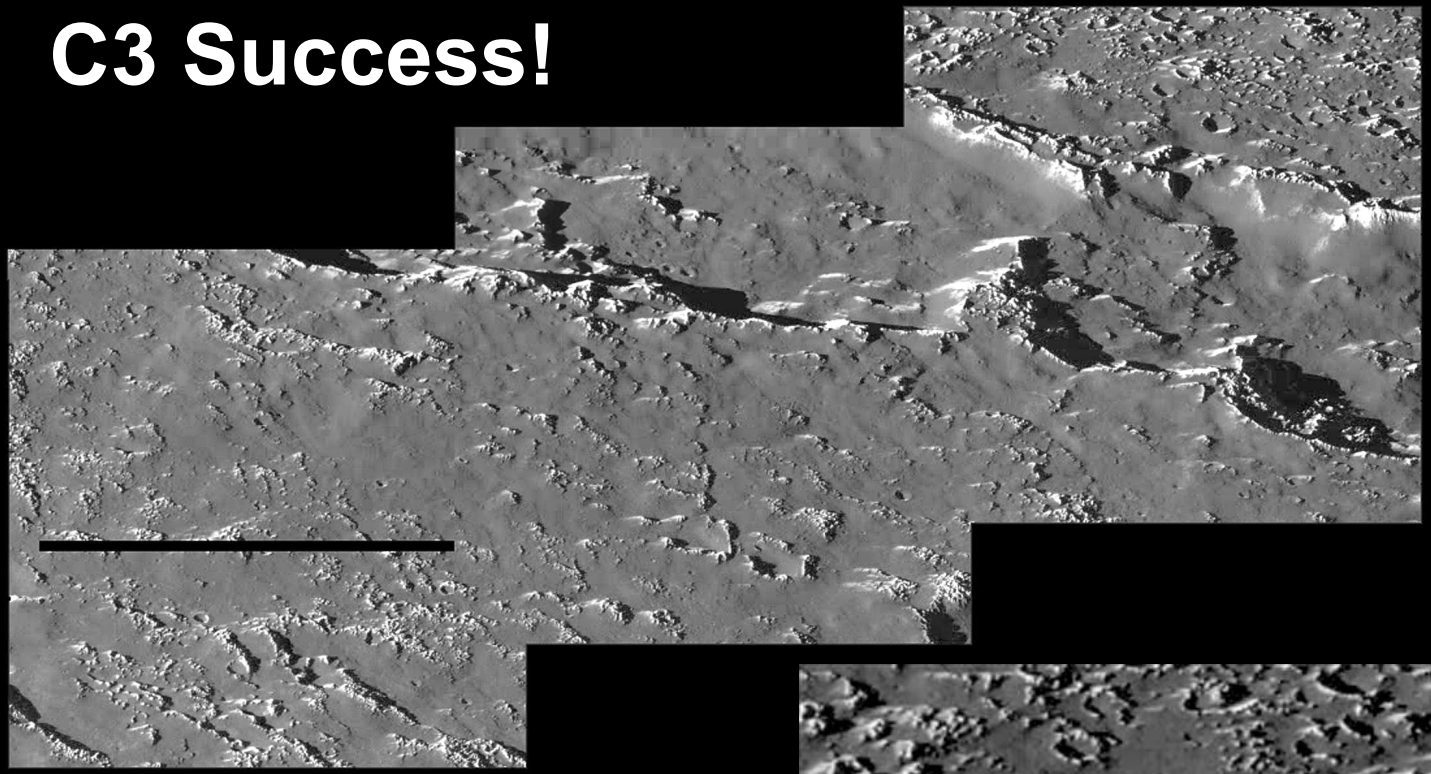
Highest resolution images ~ 2 km/line-pair



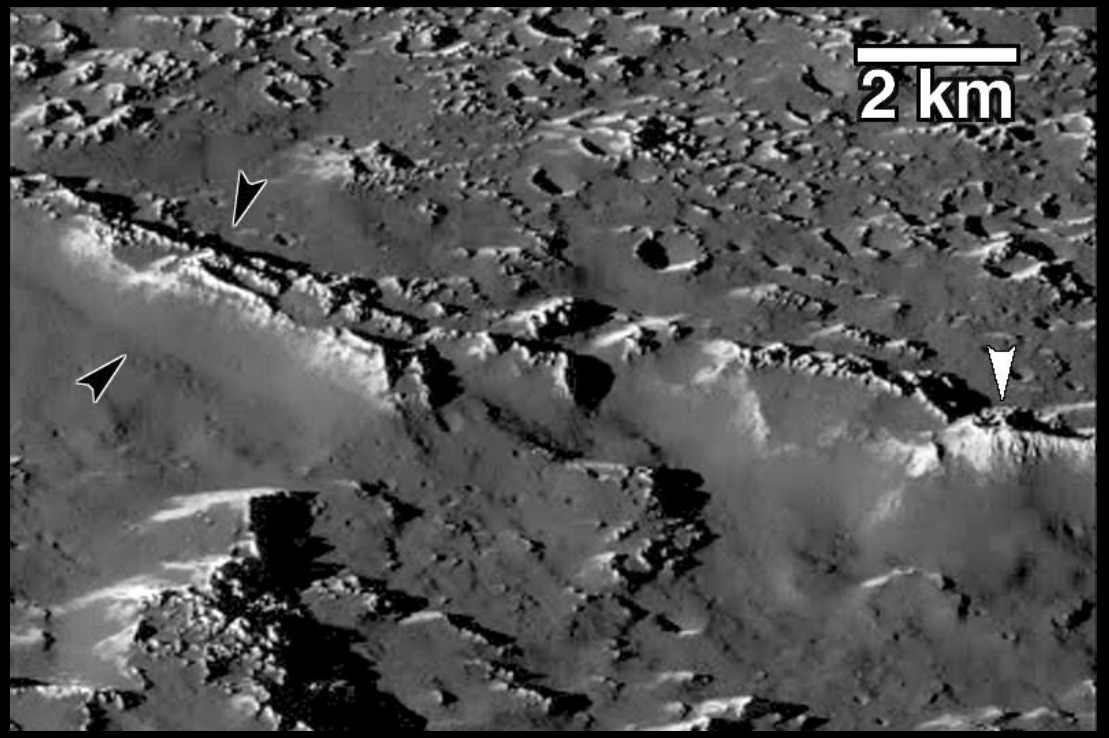
C3 initial downlink high-res strips:
Highly compressed: compression verses areal coverage decision for next downlink



C3 Success!

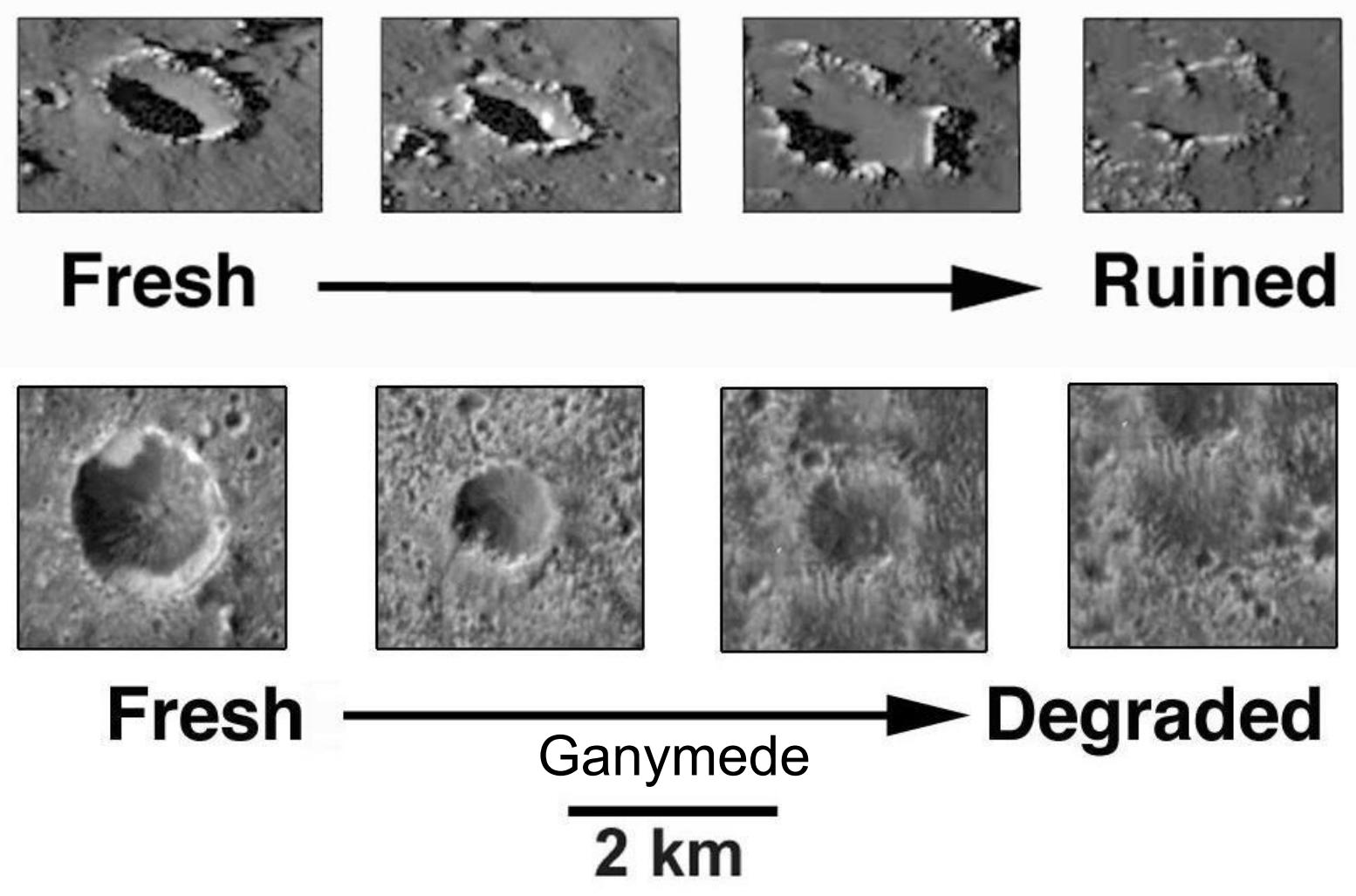


Gomul Catena seen at 40 m/pixel)



High albedo (~0.8) local topographic highs and slopes covered with smooth, nearly featureless, dark material.

Craters in various states of decomposition compared with those on Ganymede

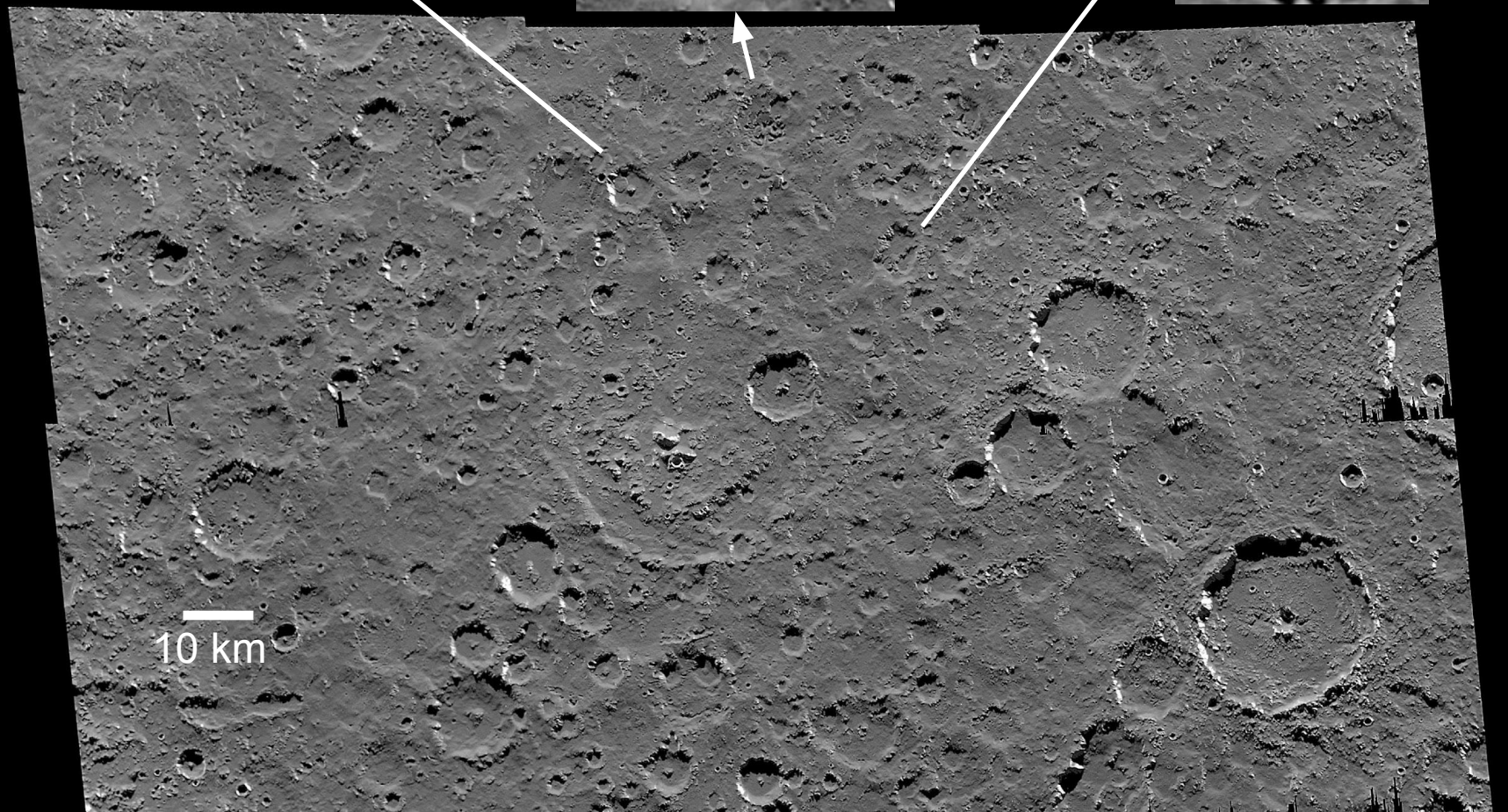


Massive Landform Erosion Driven by "Bedrock" Undermining

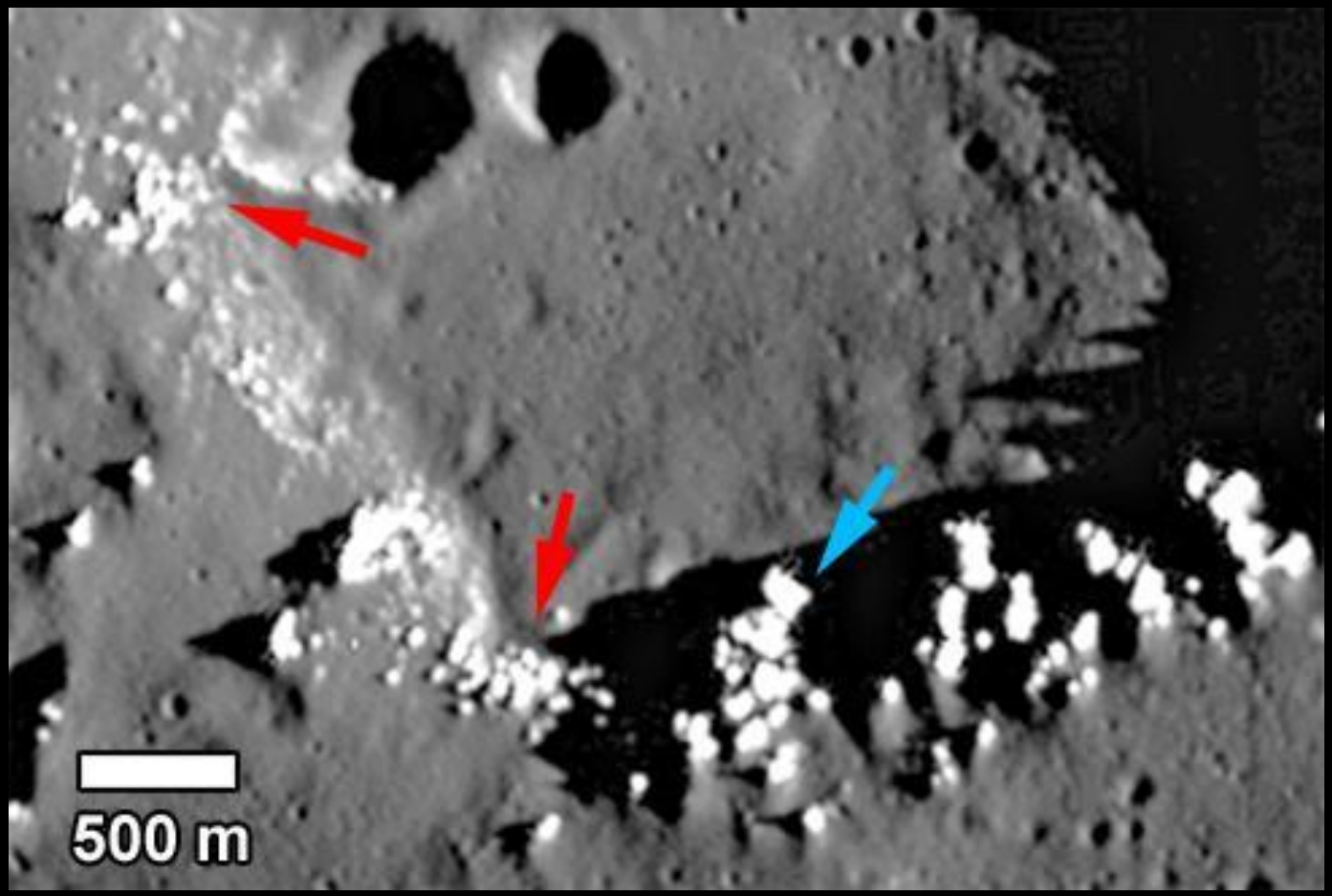
Debris Flow

Pits

Gullies

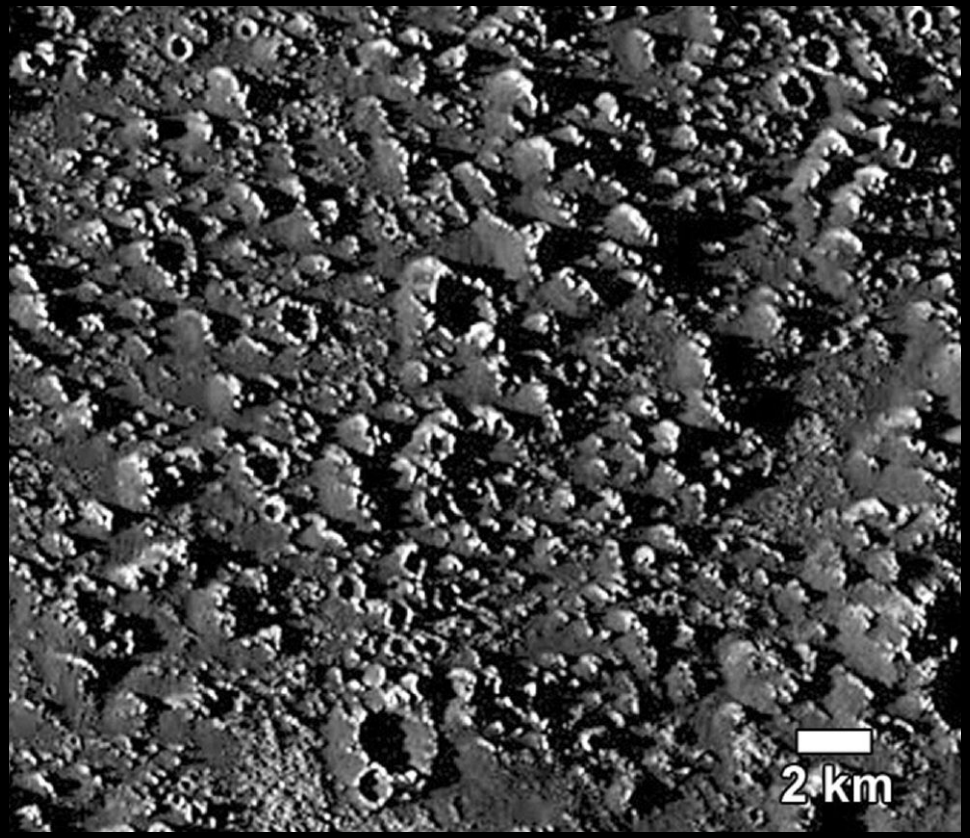


Ice Pinnacle Degradation



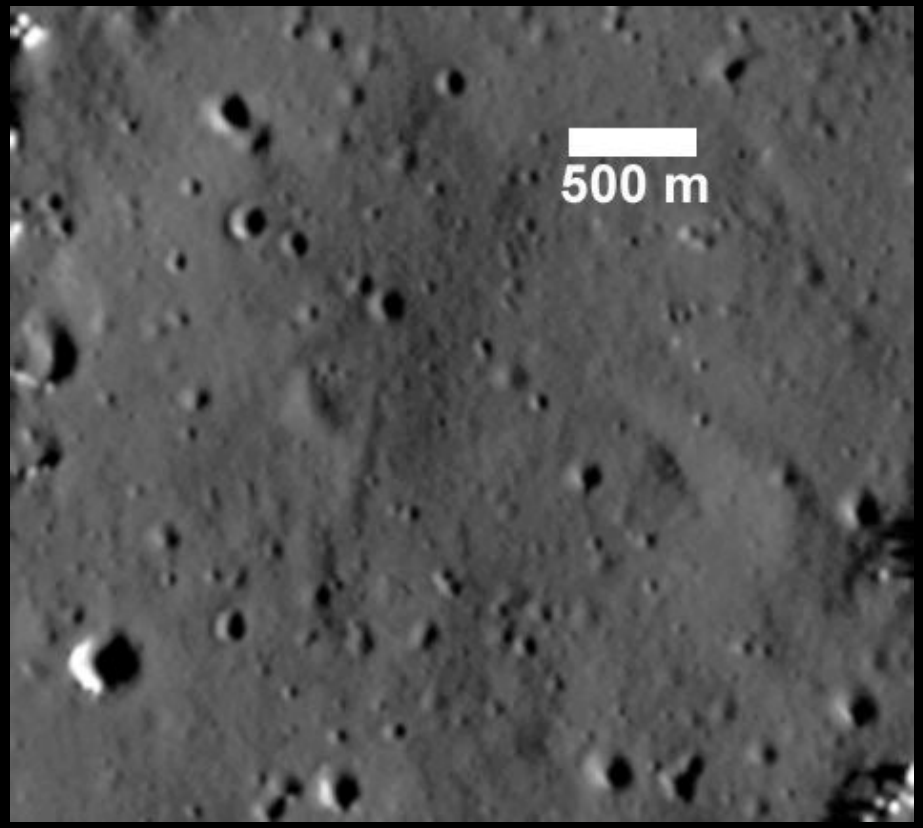
- Red arrows indicate 25-60 m blocks that may be dispersed remnants of former pinnacles undermined by mass wasting.
- Blue arrow points to one of several high pinnacle complexes on the south rim of the crater with skeletonized planforms.
- These isolated pinnacles may result from mass wasting by avalanching and/or seeding of new sites of ice deposition on debris from earlier pinnacle collapse.

Efficiency of Mass Wasting and Ice Redeposition



Some areas show almost no fresh craters with well-defined ejecta and ice-free rims.

Rapid transformation of fresh craters by sublimation, mass wasting and ice reprecipitation?

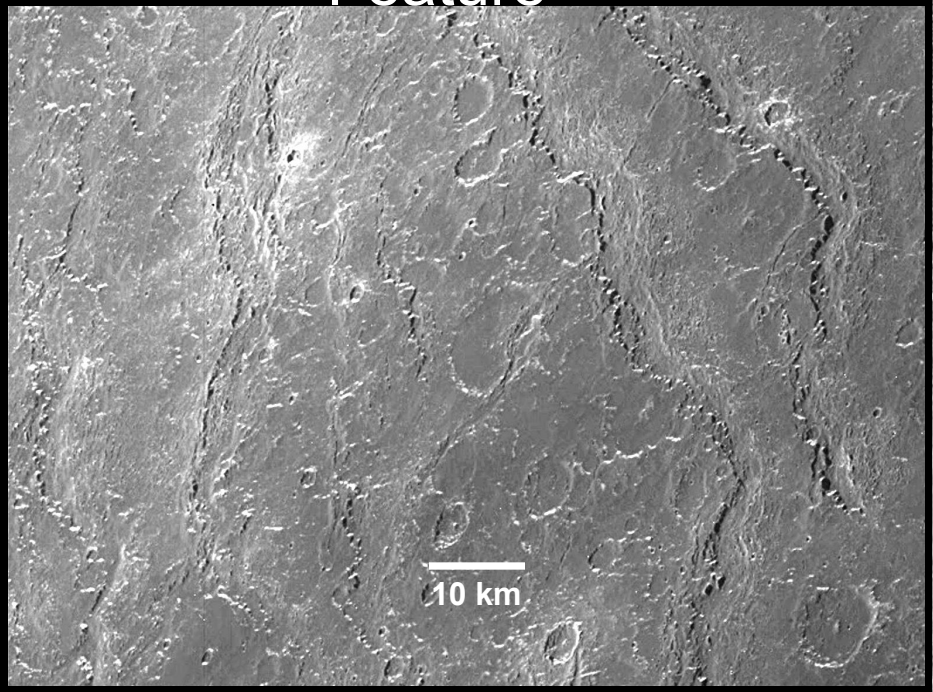


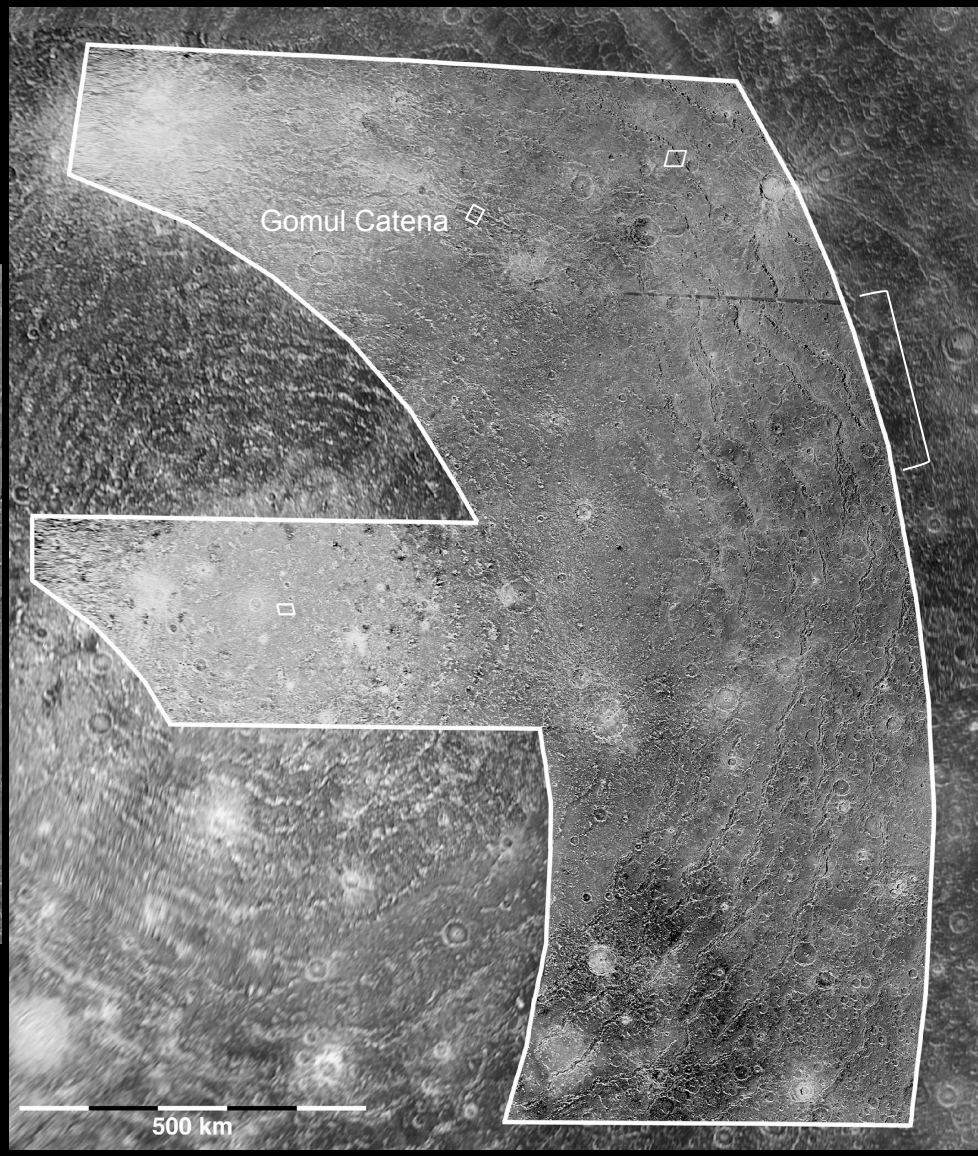
Some areas show small, sharp-rimmed craters that lack both ice pinnacles and visible ejecta sheets.

Is mass wasting very efficient on Callisto, or is the dust cover very thick and lacks competent coarse materials?

REGIONAL COVERAGE

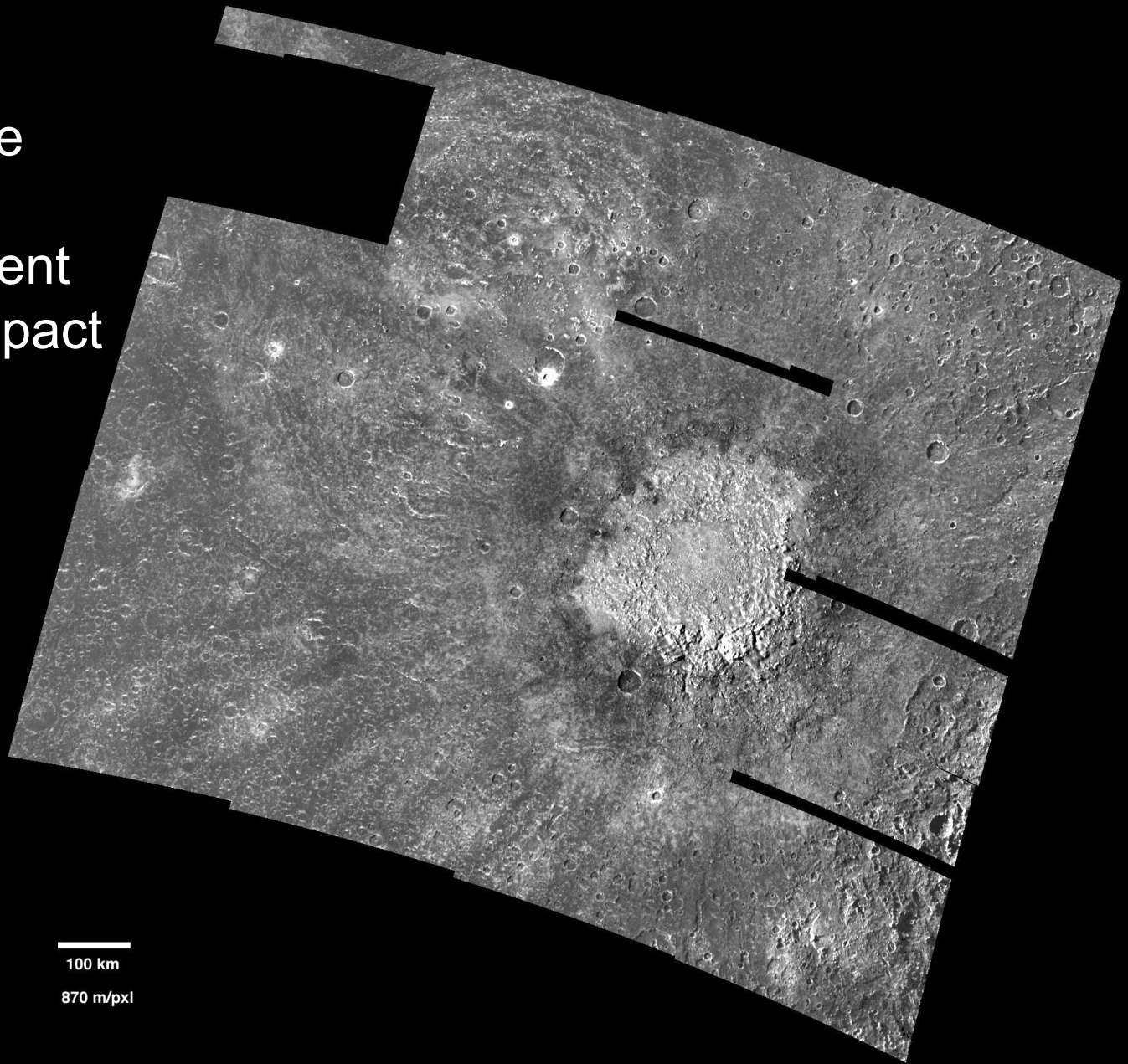
Eastern Valhalla Multi-ring Impact Feature



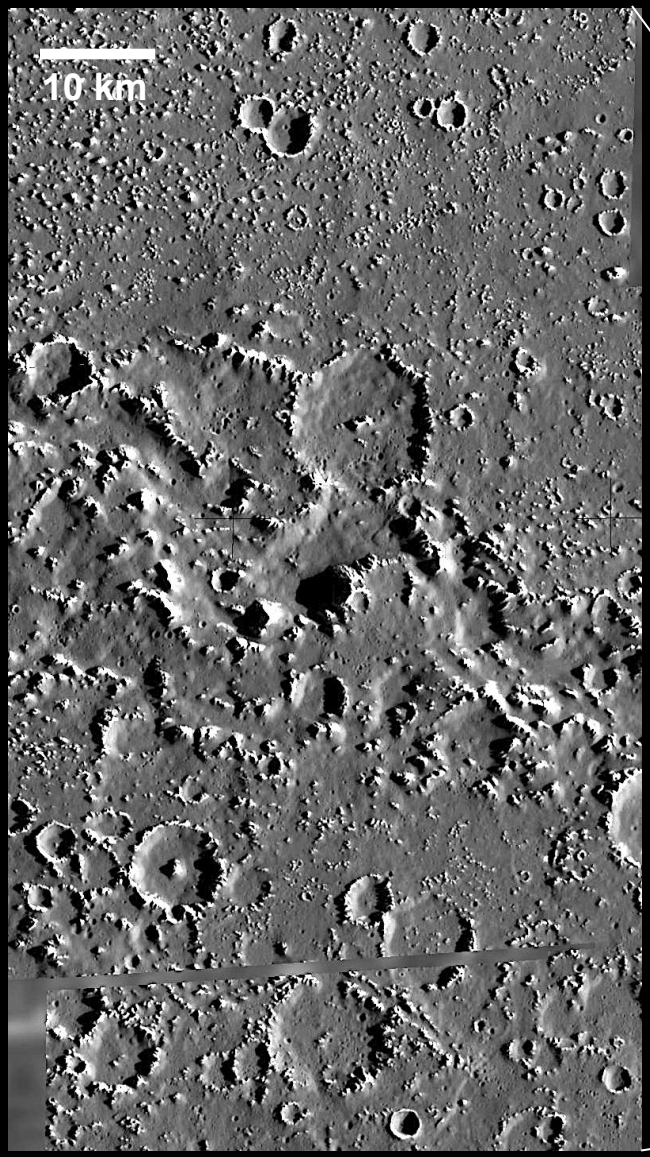


REGIONAL COVERAGE

Lofn recent large impact feature supposed on ancient Alinda Multi-ring Impact Feature



REGIONAL COVERAGE



Asgard mosaic from center to periphery

Utgard

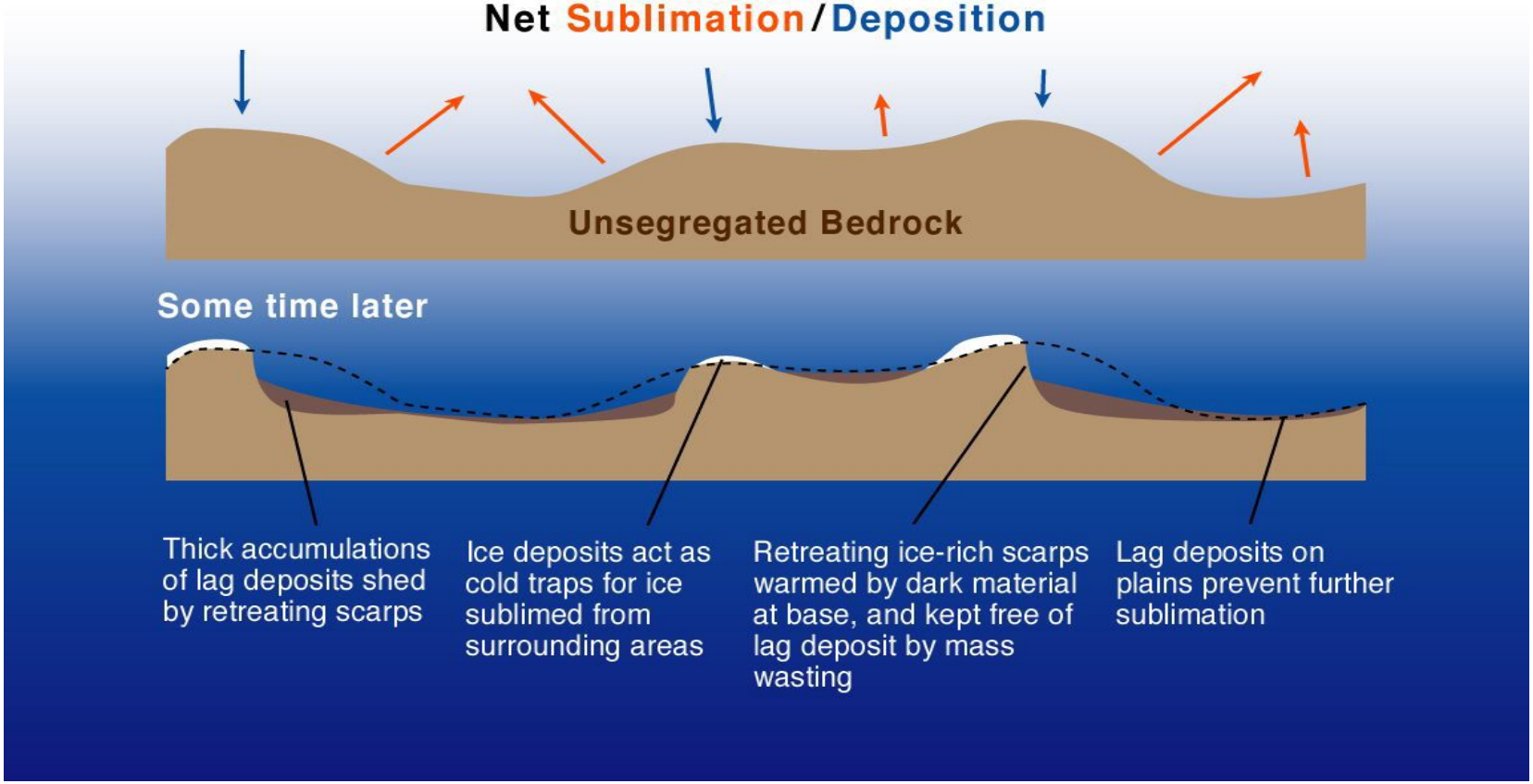
Burr

Tornasuk

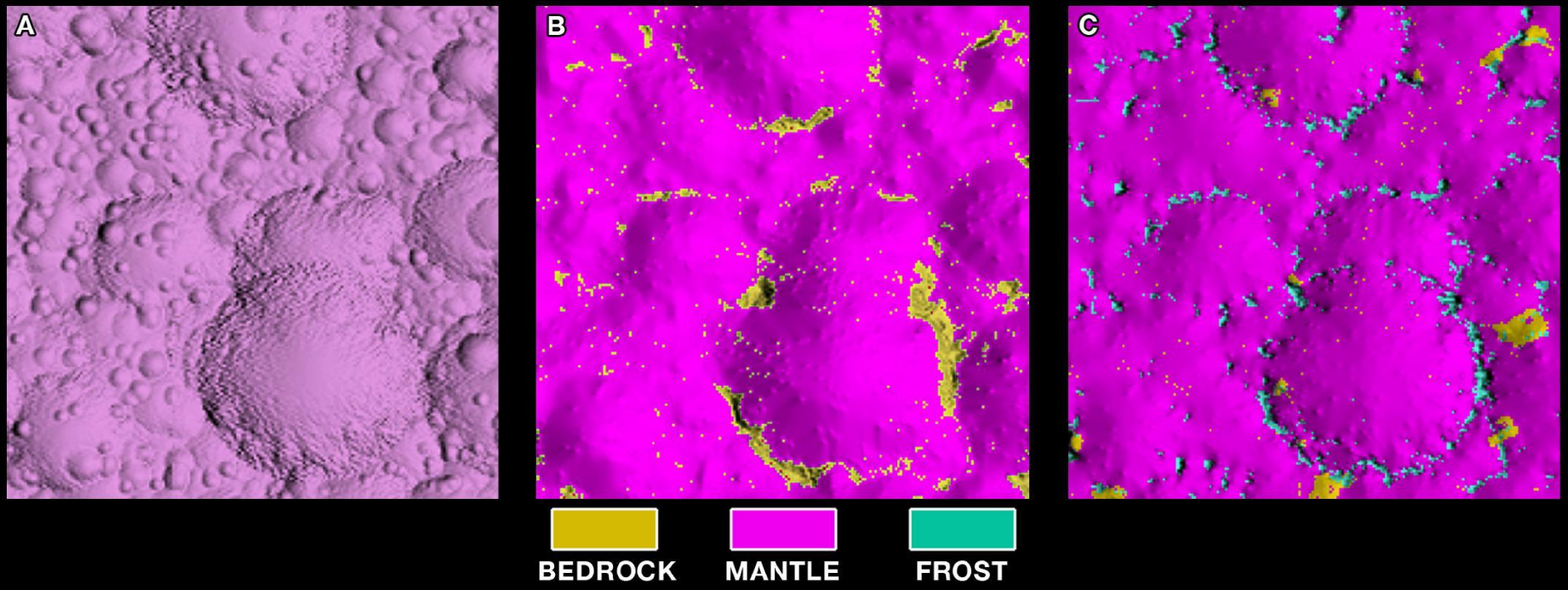
100 km

Principal Geological Discovery by *Galileo*

- **The process of sublimation degradation was recognized as *the* major surface modification process on Callisto. Its role in mass wasting and landslide initiation was elemental in creating the bizarre and astonishing scenery imaged by *Galileo*.**



MODEL TEST OF HYPOTHESIS (Howard & Moore, 2008)

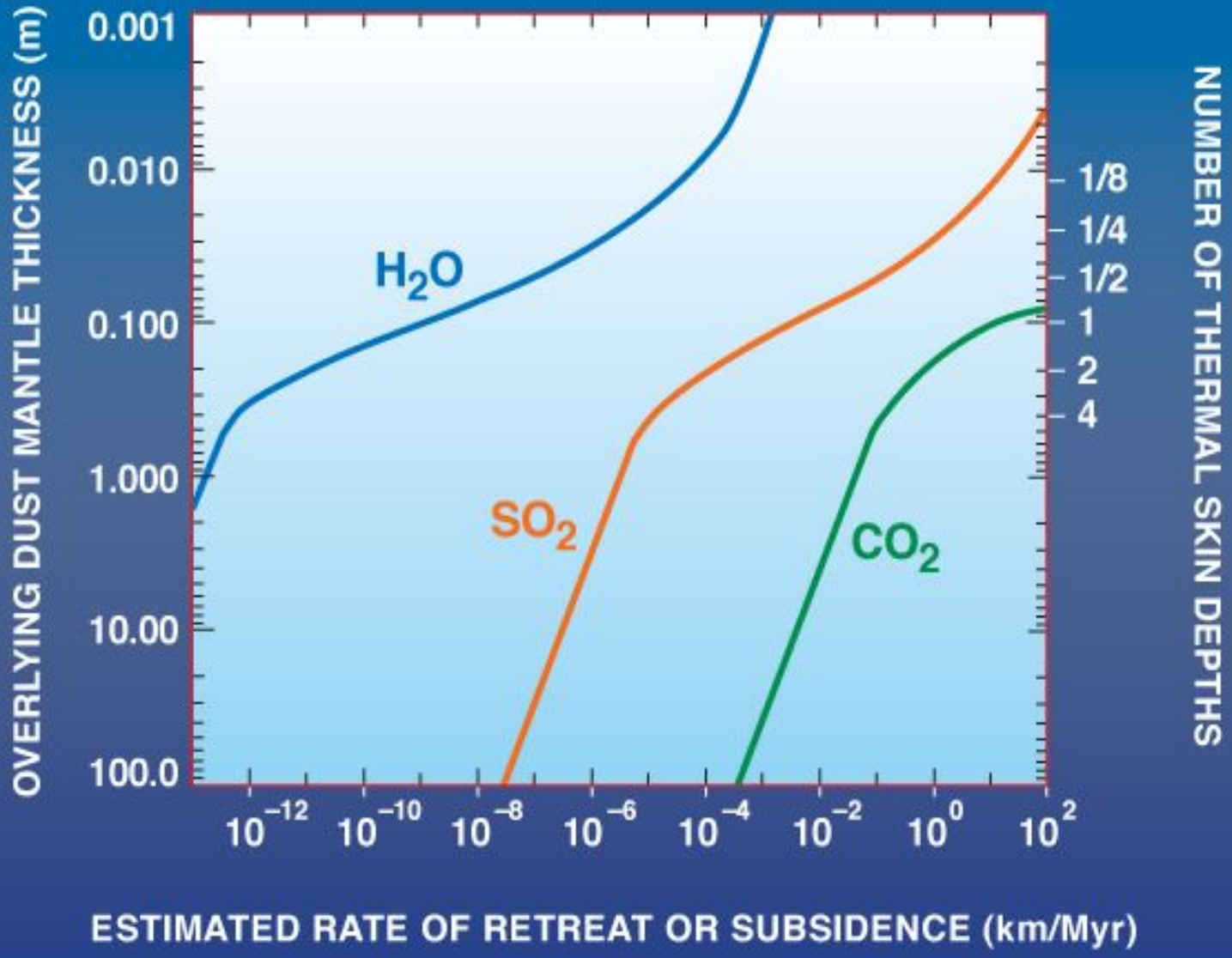


A. Initial conditions: equilibrium cratered surface with a thin uniform mantle

B. Model Surface formed by sublimation release of debris. After long-continued sublimation, isolated crescents of steep-sided crater rim crests remain as the rim crests are attacked from both sides.

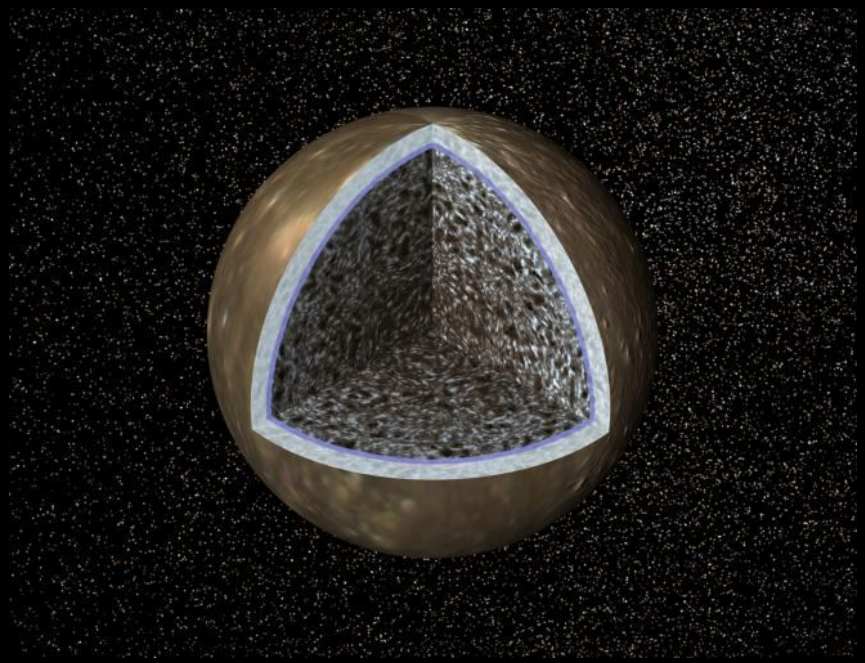
C. Same as B now with redeposition of sublimated ices as frost on nearby convex surfaces (mostly crater rims) that have low exposure to reradiated energy (local cold traps).

SUBLIMATION AS A FUNCTION OF DEPTH BENEATH DARK DUST COVER

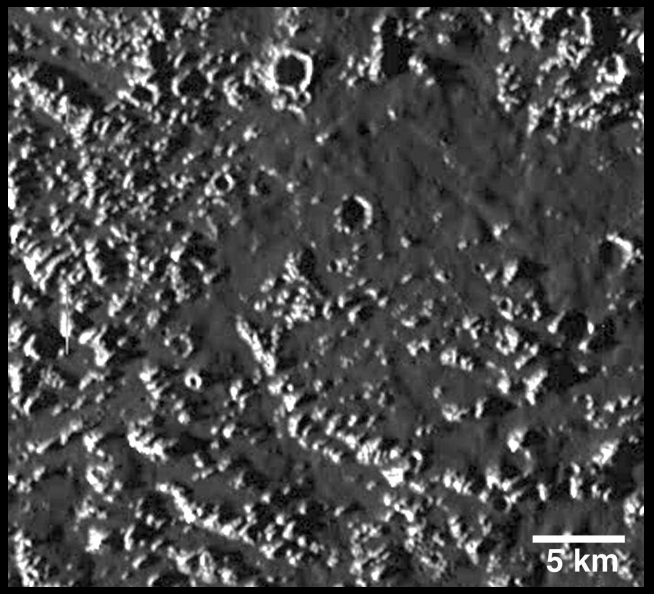


Moore *et al.*, 1996

MAJOR DISCOVERIES FROM *GALILEO*: 1



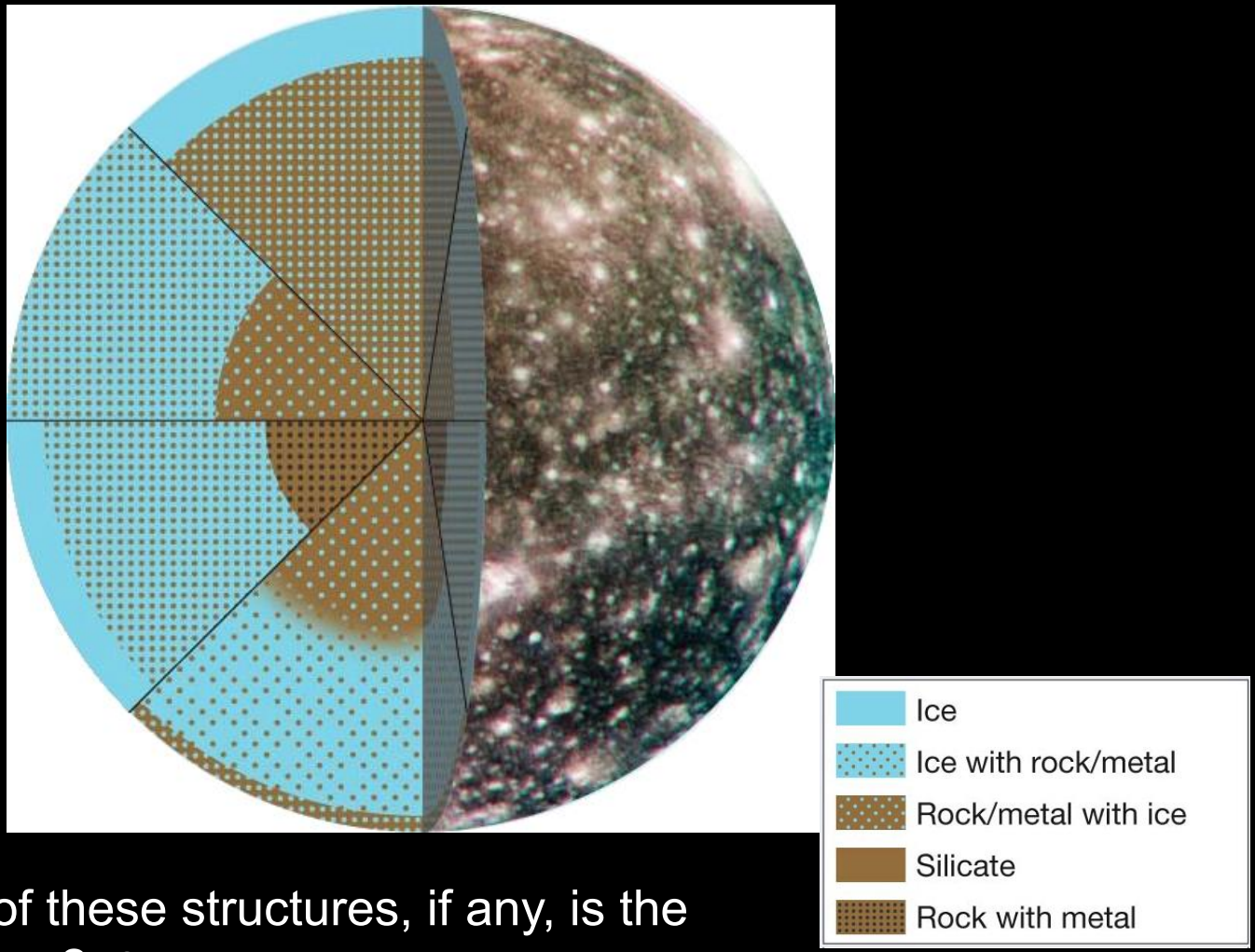
- Apparently* incompletely differentiated interior
- YET Magnetic field behavior indicating a conducting possible interior water-rich liquid layer
- Complete absence of cryo-volcanic resurfacing



* If in hydrostatic equilibrium

A hydrostatic Callisto that is only partially differentiated

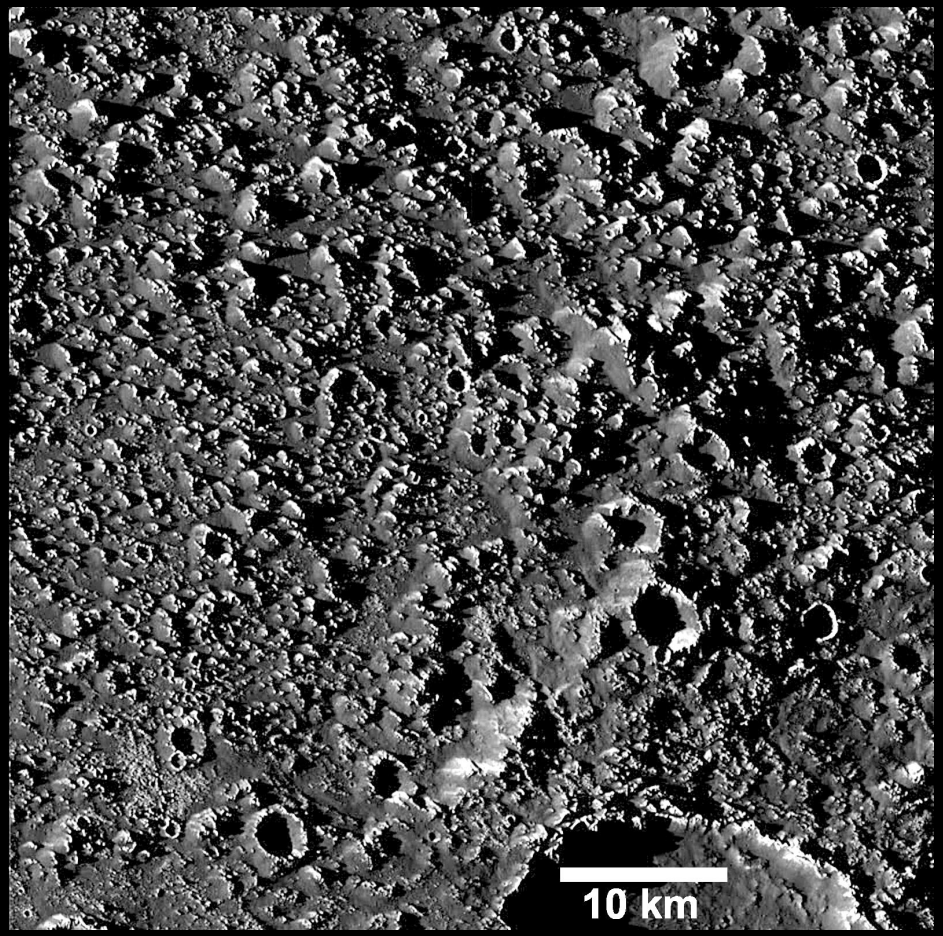
(Anderson et al. 2001, Schubert et al. 2004)

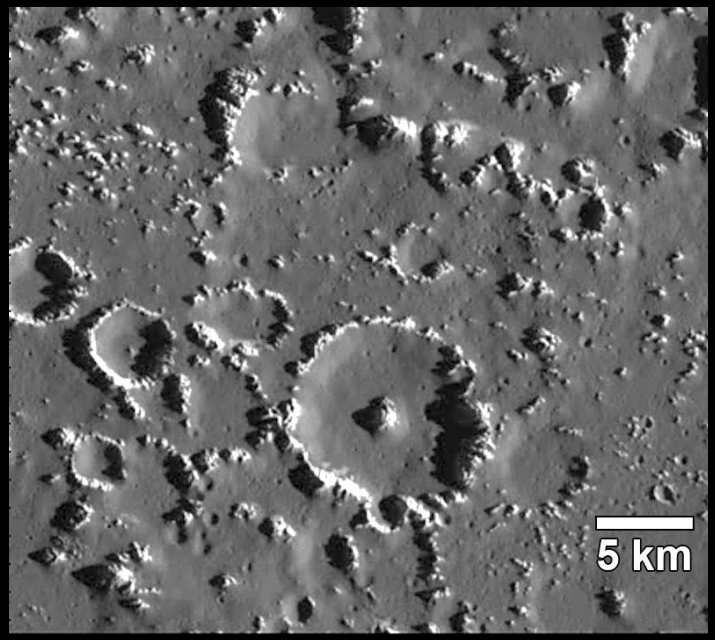


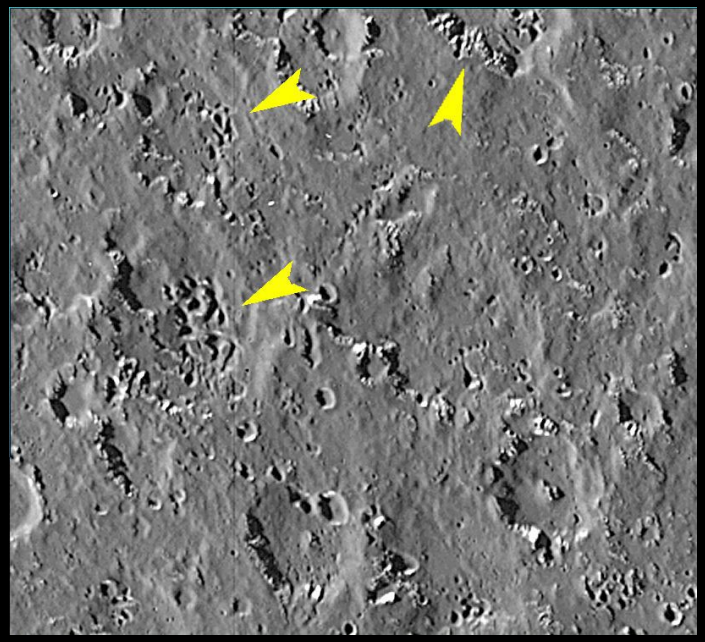
Which one of these structures, if any, is the correct one? (from Bagenal et al. 2004)

MAJOR DISCOVERIES FROM *GALILEO*: 2

- **Massive Landform Erosion.**
  Callisto's landscape at hectometer scales is unique among the Galilean Satellites, and might be most akin to that of cometary nuclei.







MAJOR DISCOVERIES FROM *GALILEO*: 3

- Callisto is surrounded by an extremely thin atmosphere composed of carbon dioxide and probably molecular oxygen. (Carlson *et al*., 1999; Liang *et al*., 2005)

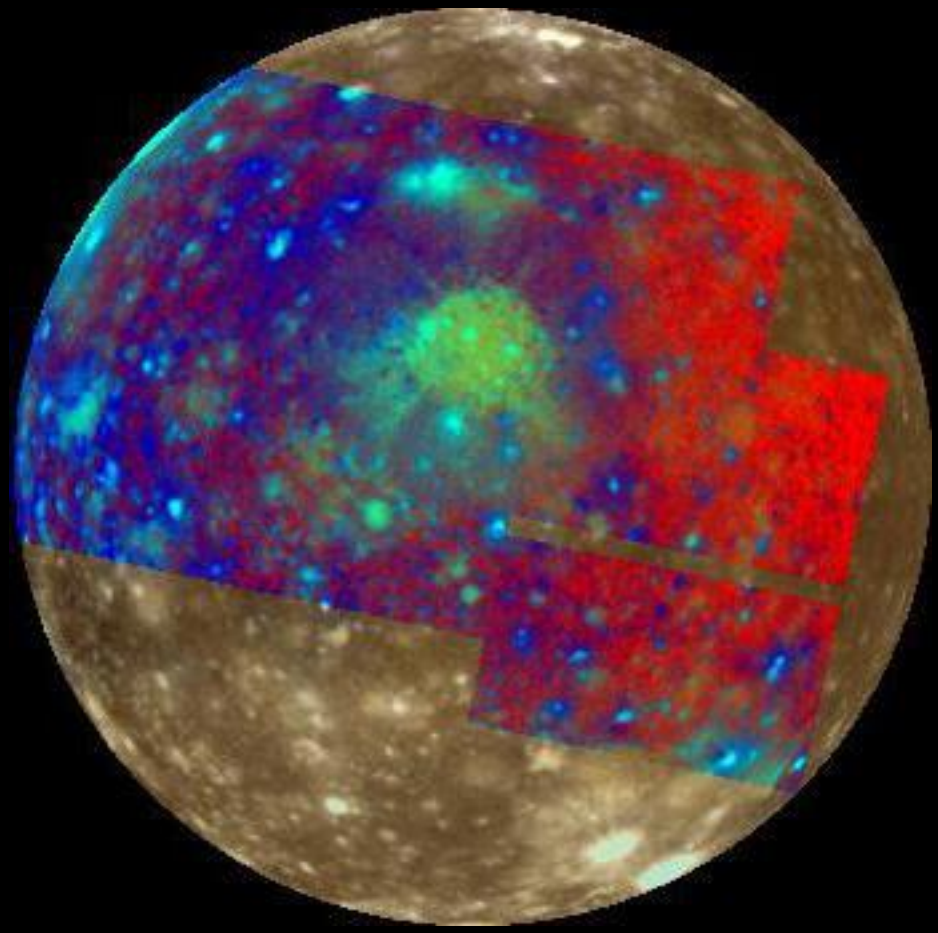
- The atmosphere is so thin that it would be lost in only a few years though atmospheric escape, it must be constantly replenished, possibly by slow sublimation of carbon dioxide ice from Callisto's crust, which is compatible with the sublimation–degradation hypothesis for the widespread surface erosion.

- It has an intense ionosphere. (Kliore *et al*., 2002)

MAJOR DISCOVERIES FROM *GALILEO*: 4

- A leading-trailing hemisphere dichotomy in photometric properties

- Spectroscopic analysis indicated that the trailing hemisphere of Callisto appears to be enriched in carbon dioxide, whereas the leading hemisphere has more sulfur dioxide (Hibbits *et al*., 1998)



OUTSTANDING QUESTIONS ABOUT CALLISTO: 1

- What is the actual configuration of its interior? Is there a rock core?
- What is the composition and thickness of the liquid layer? Does it indeed exist, and, if so, and how has it survived to the present?
- Moving toward the surface, what is the structure of the “crust?”
- Is the dark, non-icy material, so abundant on its surface, restricted to the upper several km?
- What is the composition of this non-icy material?
- Why is Callisto’s “crust” apparently so volatile-rich compared to its siblings?
- Why are there 100 km-scale heterogeneities in composition and albedo of the surface?
- Do we really understand why knobs with bright summits dominate the surface at decameter scale?
- What is the nature and origin of the leading-trailing hemisphere dichotomy in photometric properties?

OUTSTANDING QUESTIONS ABOUT CALLISTO: 2

- Why is there apparently a dearth of palimpsests relative to Ganymede?
- How do large impact ring structures vary with azimuth, radial distance, and overall scale, and what do they imply for Callisto's interior (and by extension to the smaller structures on Europa, for ice shell/ocean combinations in general)?
- How do impact crater populations vary (1) as a function of distance from the apex of motion, (2) everywhere else on Callisto?
- What are the roles of "saturation equilibrium," viscous relaxation, sublimation degradation, and nonsynchronous rotation (and other possible lithospheric shifts) in determining these populations (and high-resolution views of crater chains are important here)?
- And what *are* the retention ages represented by these crater counts?
- What is all of this telling us about Galilean satellite formation and evolution?
- **And the big question: should we assume that the reason Callisto and Ganymede had divergent histories is solely the consequence of the role of tidal heating, or are there viable alternative explanations (such as accretion dynamics)?**

“A whole new life awaits you on the off-world Colonies!”

Callisto: The Only Galilean Satellite that can be visited by Humans

Modified graphic from the *President’s Vision of Space Exploration* (2004): a human exploration base on Callisto