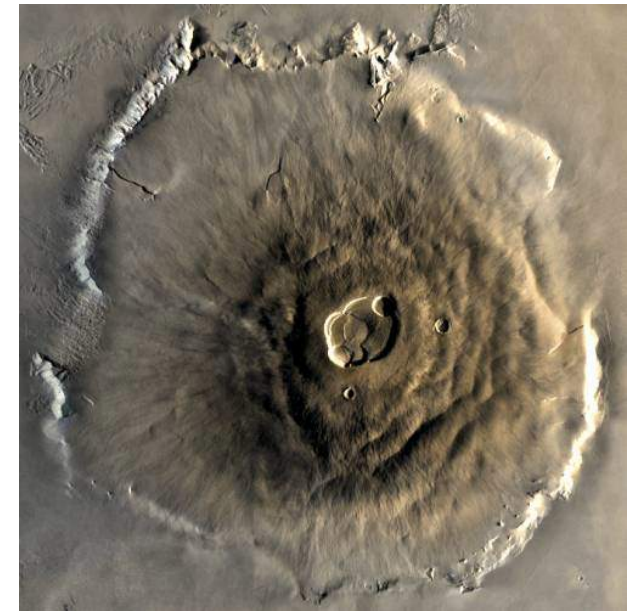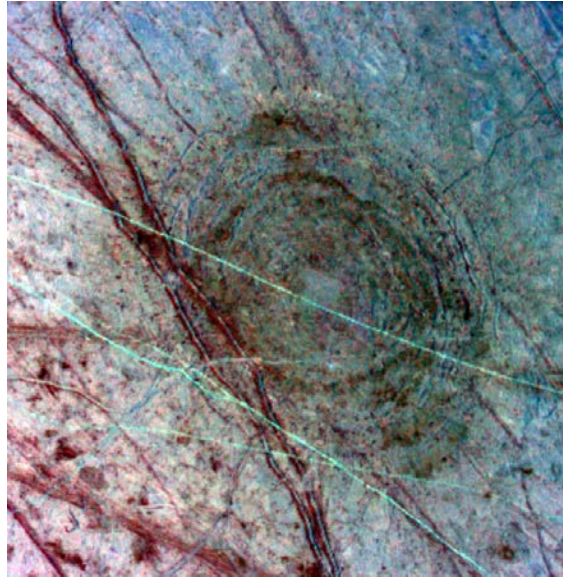# Planetary Surface Processes

Cratering
Gravity
Tectonics
Volcanism
Winds
Fluvial
Glacial
Chemical
  weathering

Simple craters

Contact and compression stage

- Most of projectile's energy, momentum transferred to target rocks

- $t_{cc} \approx 2R/v_i$

- Rankine-Hugoniot equations can be solved for pressure

- At few km/s, energy per unit mass ≈ that of TNT

Recreating the Moon on Earth
Cinder Lakes, Flagstaff, Arizona

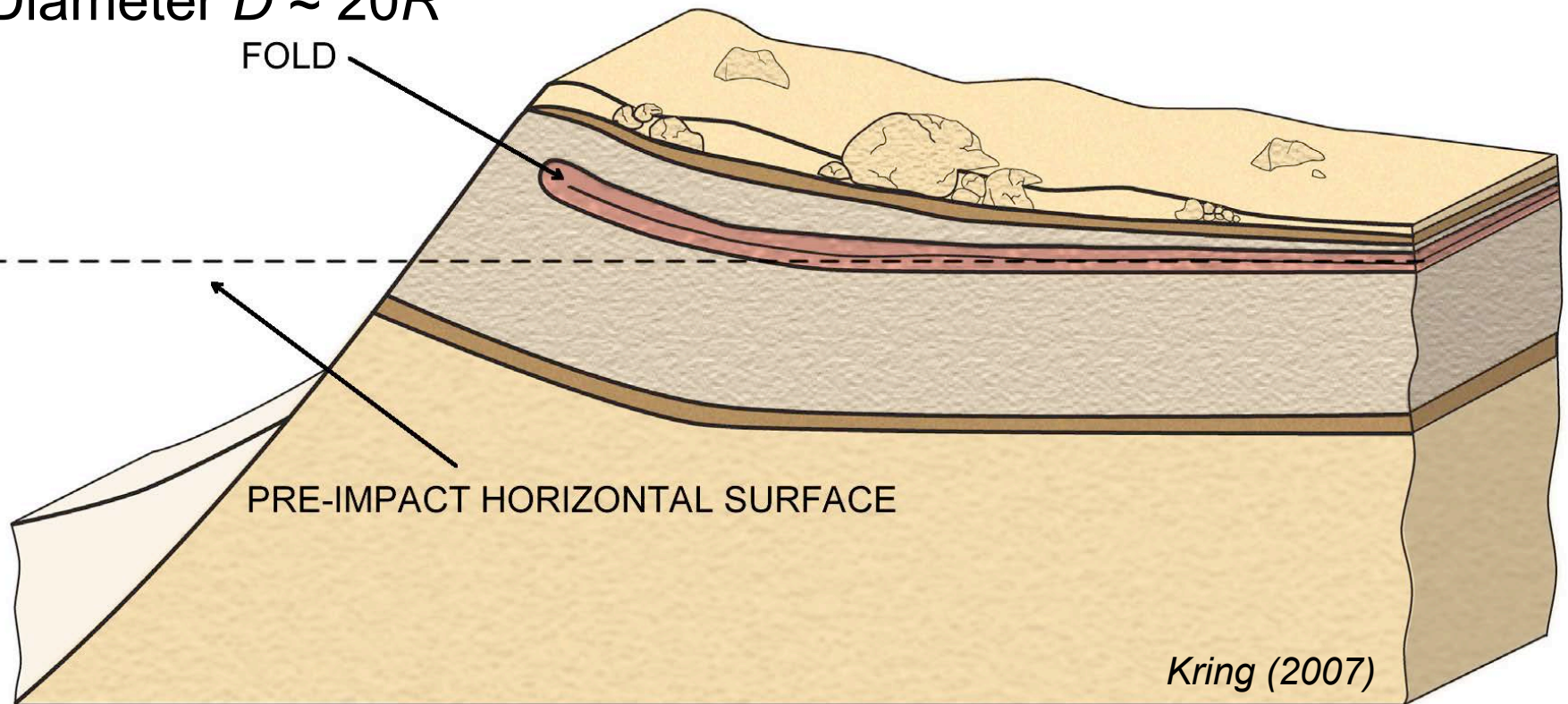≋USGS   http://astrogeology.usgs.gov

Ejection/excavation stage

- *Rarefraction wave vaporizes/melts/ fractures rocks*

- $t_{cf} \approx (D/g_p)^{1/2}$

  ~10 s for Meteor crater

  ~13 min for Mare Imbrium
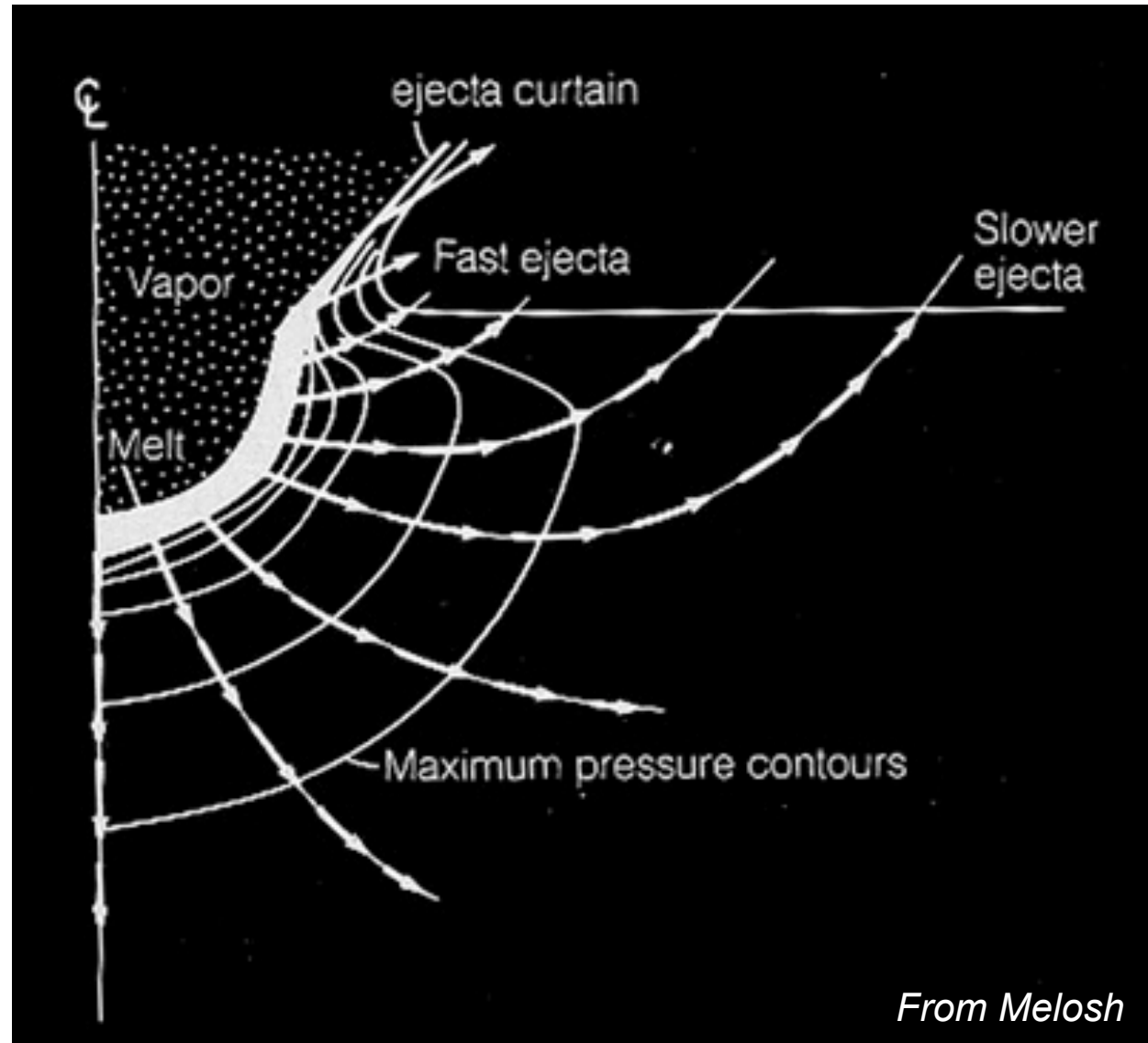
From Melosh

Collapse/modification stage

- Steep rim of *transient crater* collapses into interior
- $t \approx$ few x $(D/g_p)^{1/2}$
- Final depth $d \approx 0.2D$
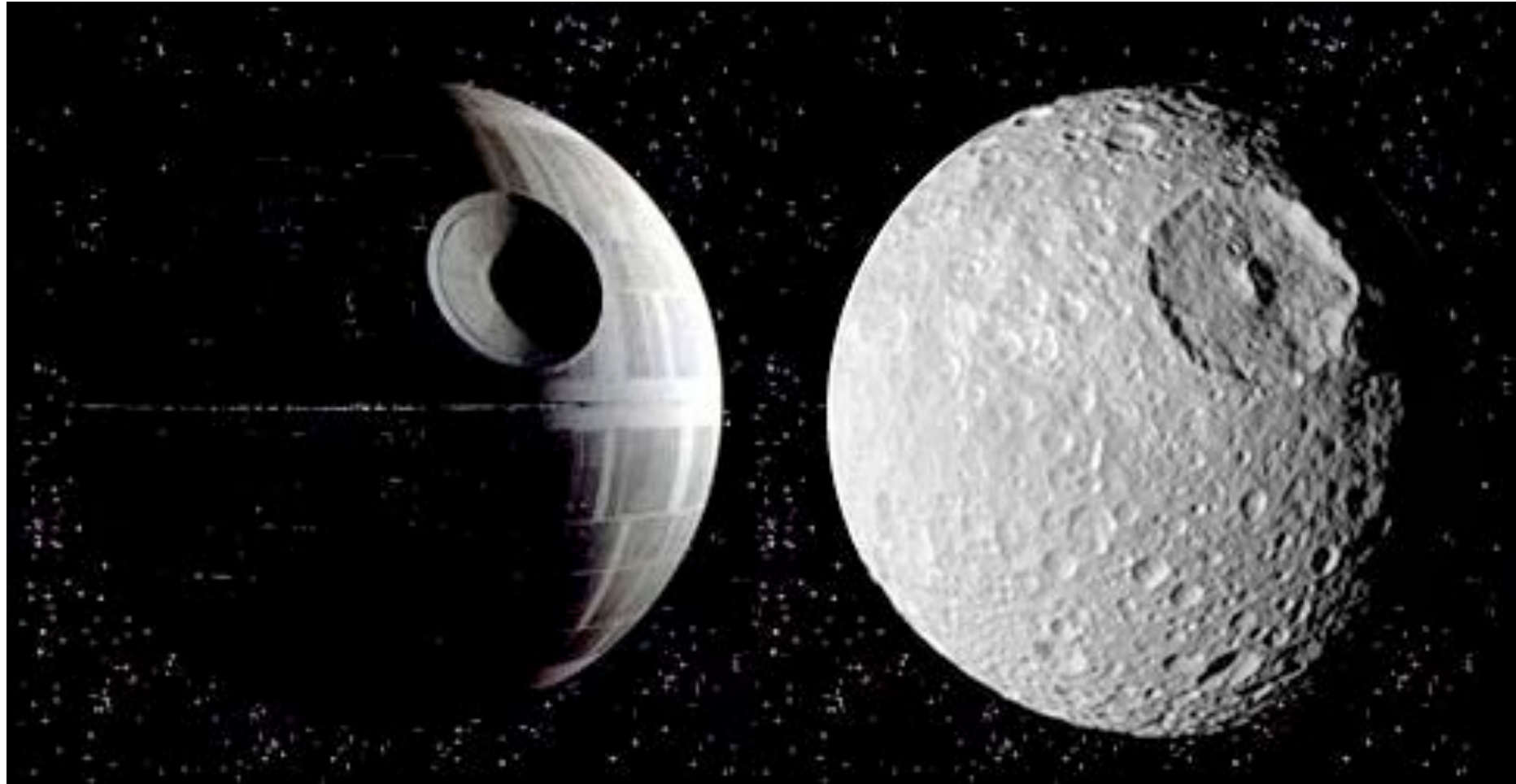- Rim height $h \approx 0.04D$
- Diameter $D \approx 20R$

FOLD

PRE-IMPACT HORIZONTAL SURFACE

Kring (2007)

Victoria Crater as viewed by Opportunity

Impact Breccia
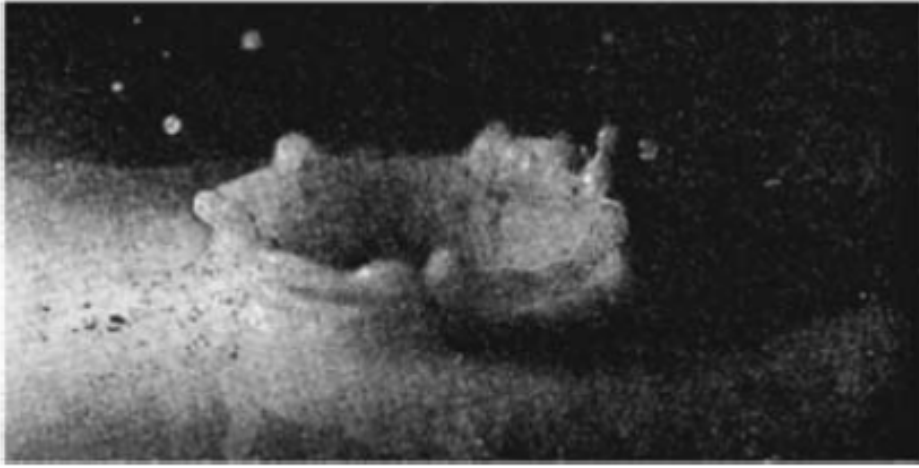
Fractured In Place

Bedrock

2.3 m

Pre-Impact Surface
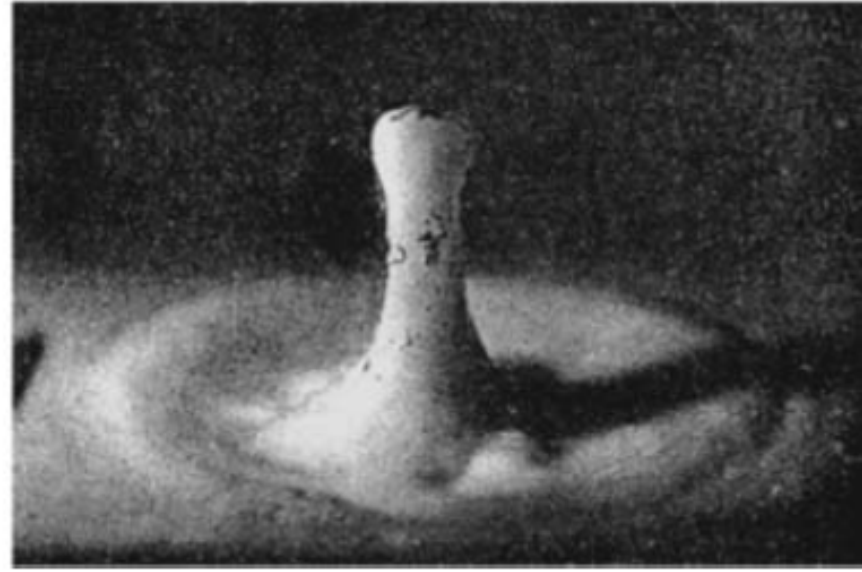
Squyres et al. (2009)

Complex craters
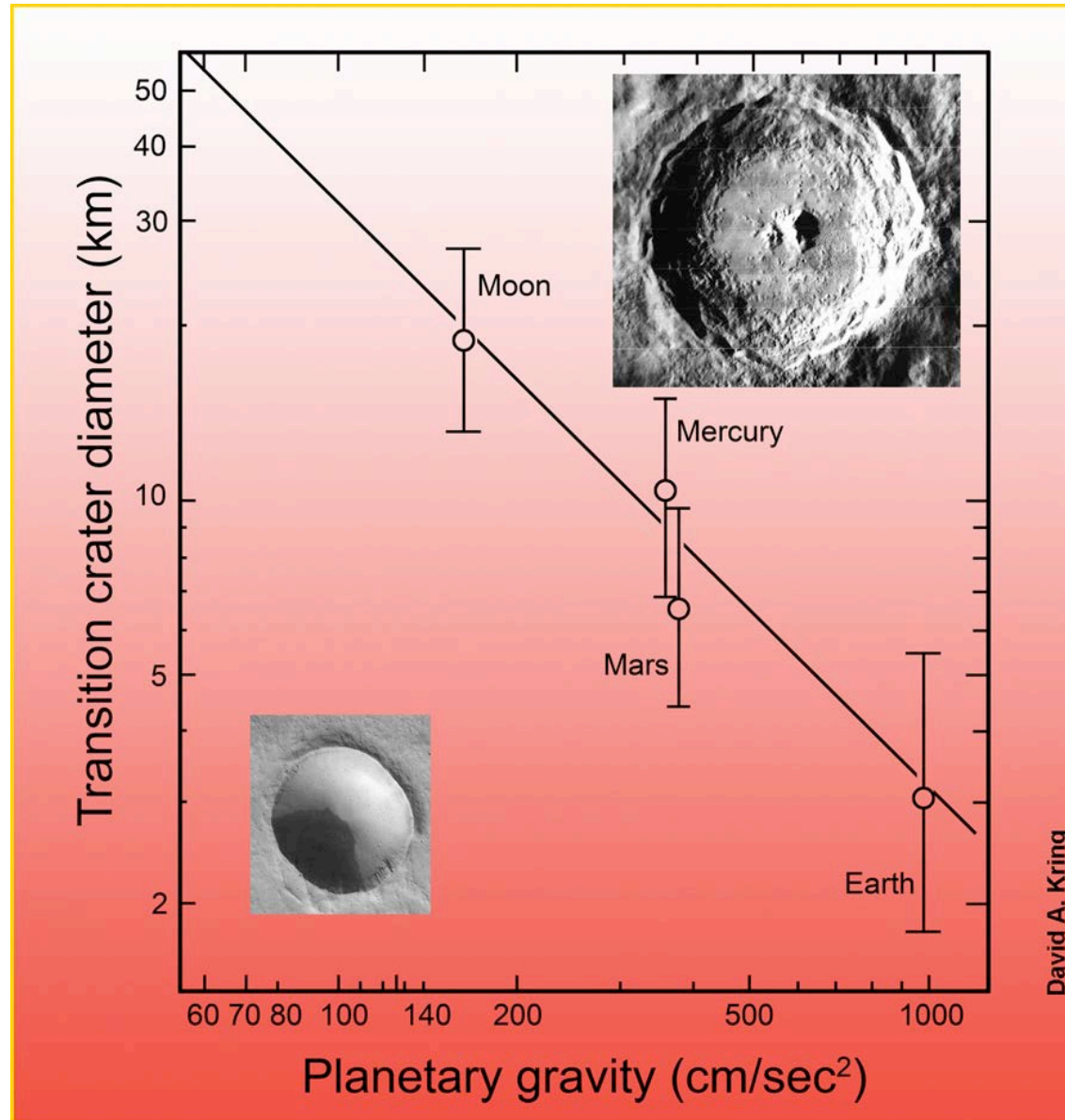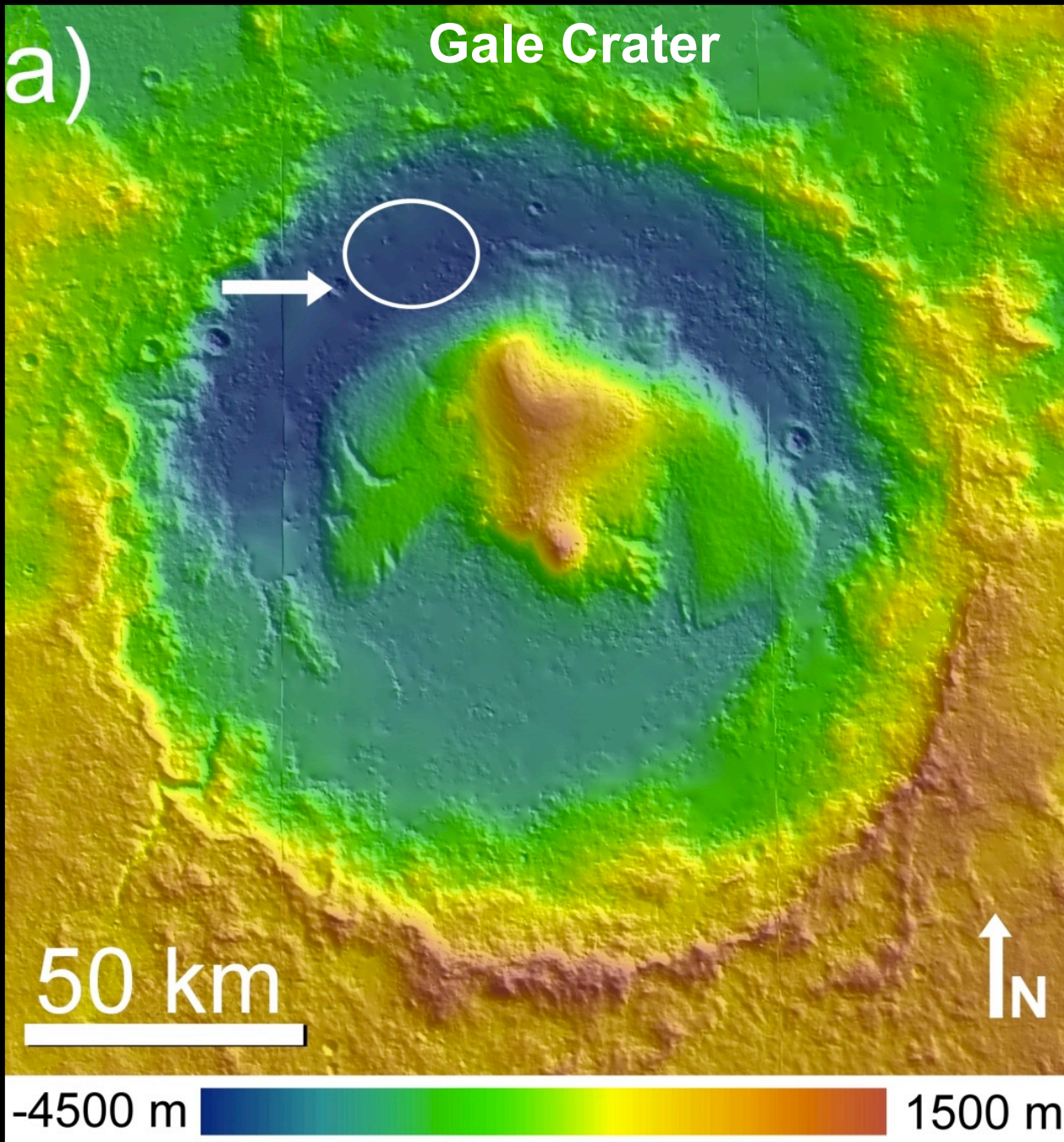
Simple vs. complex craters

Worthington (1908)

Simple vs. complex craters

$SU \approx 0.1D$

Ejecta

Crater-fill deposits (impact melt rocks and/or impact breccias)

D = Final crater (rim-to-rim) diameter
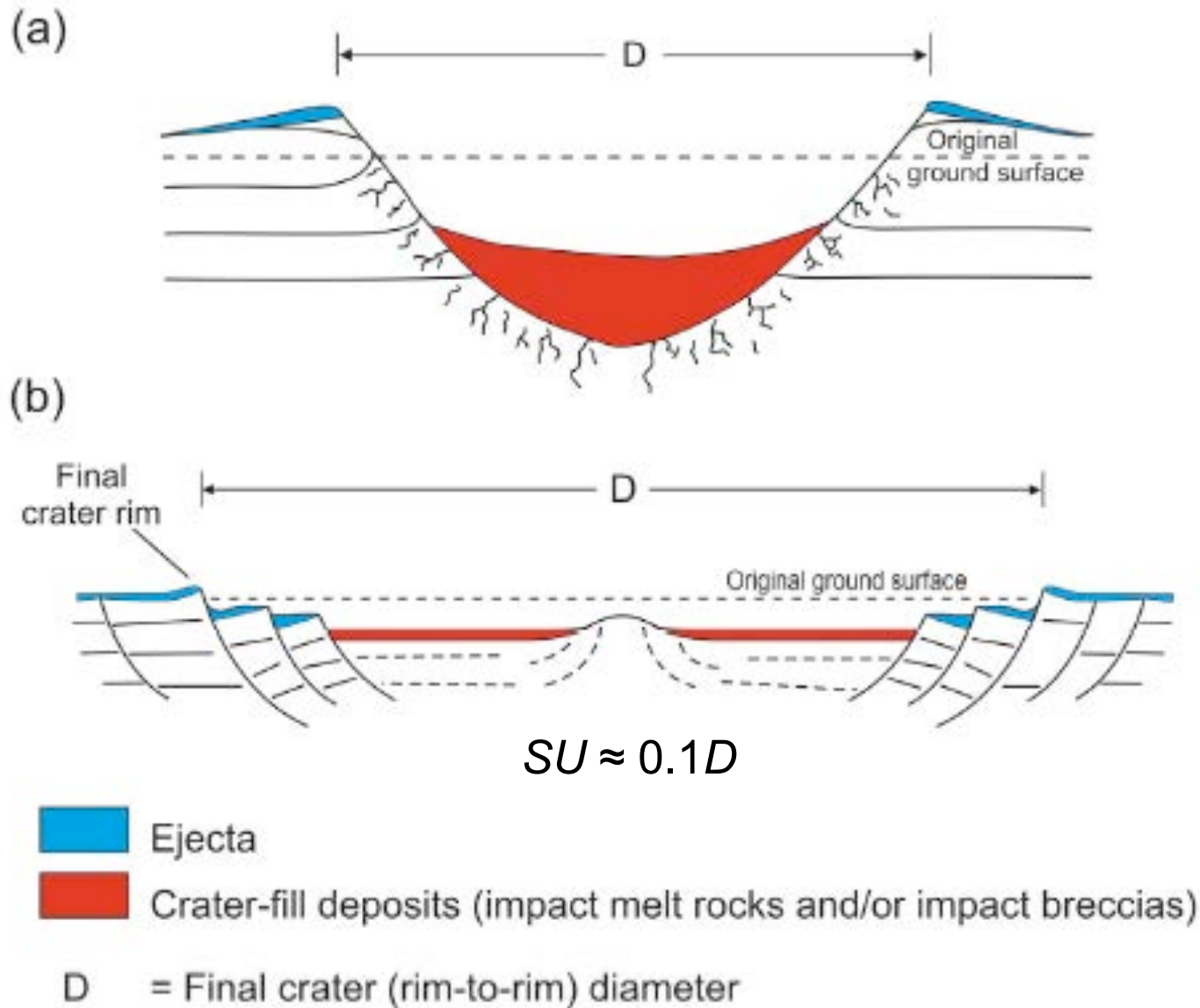
Simple vs. complex craters

Kring (2006)

a) Gale Crater

Central uplifts should be shorter than crater rims…

$h_{cp} \approx 0.1d$ (Mars)
[Garvin et al., 2003]
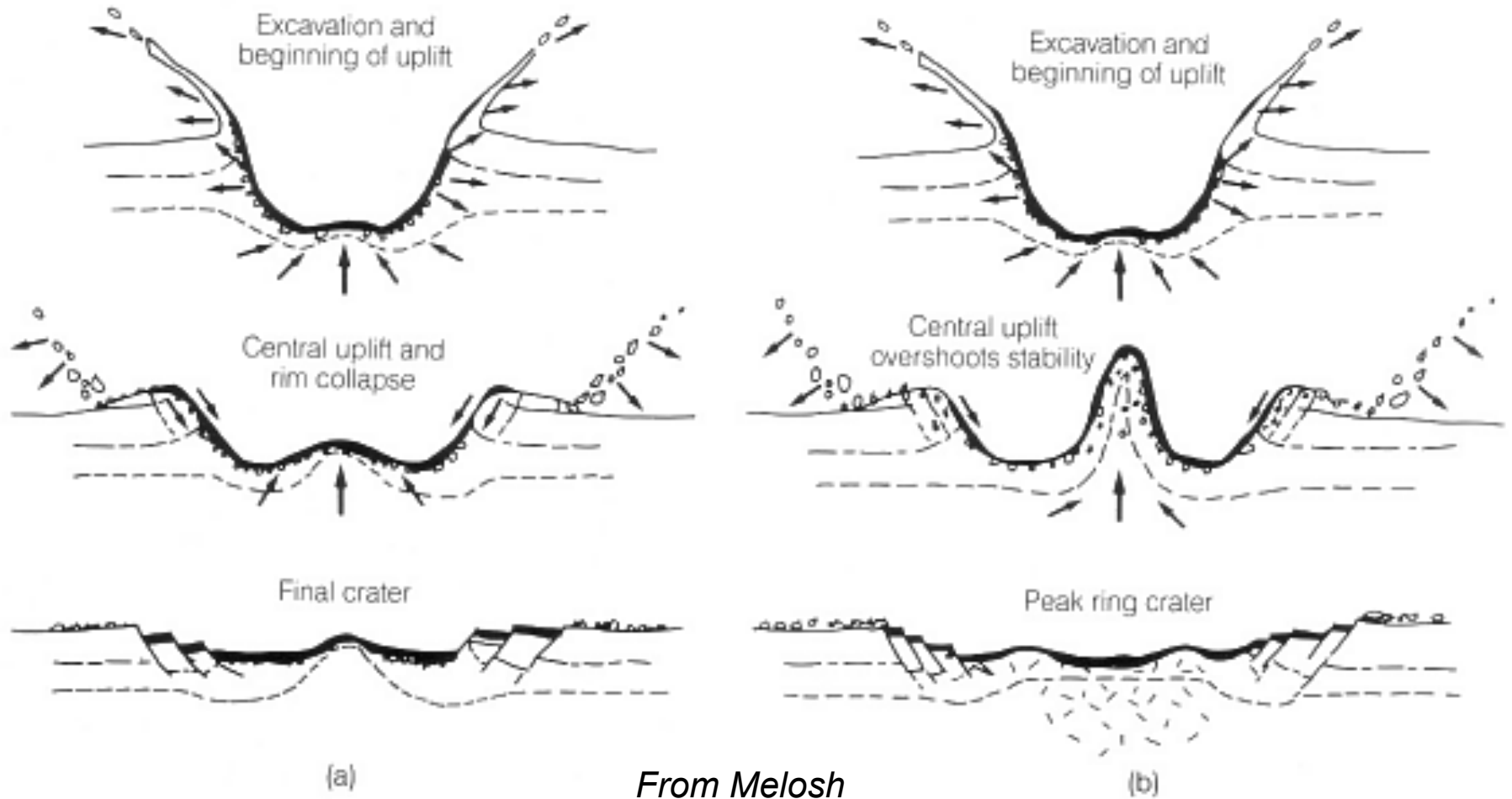
50 km

N

-4500 m ▮▮▮▮▮▮▮▮ 1500 m

Vesta
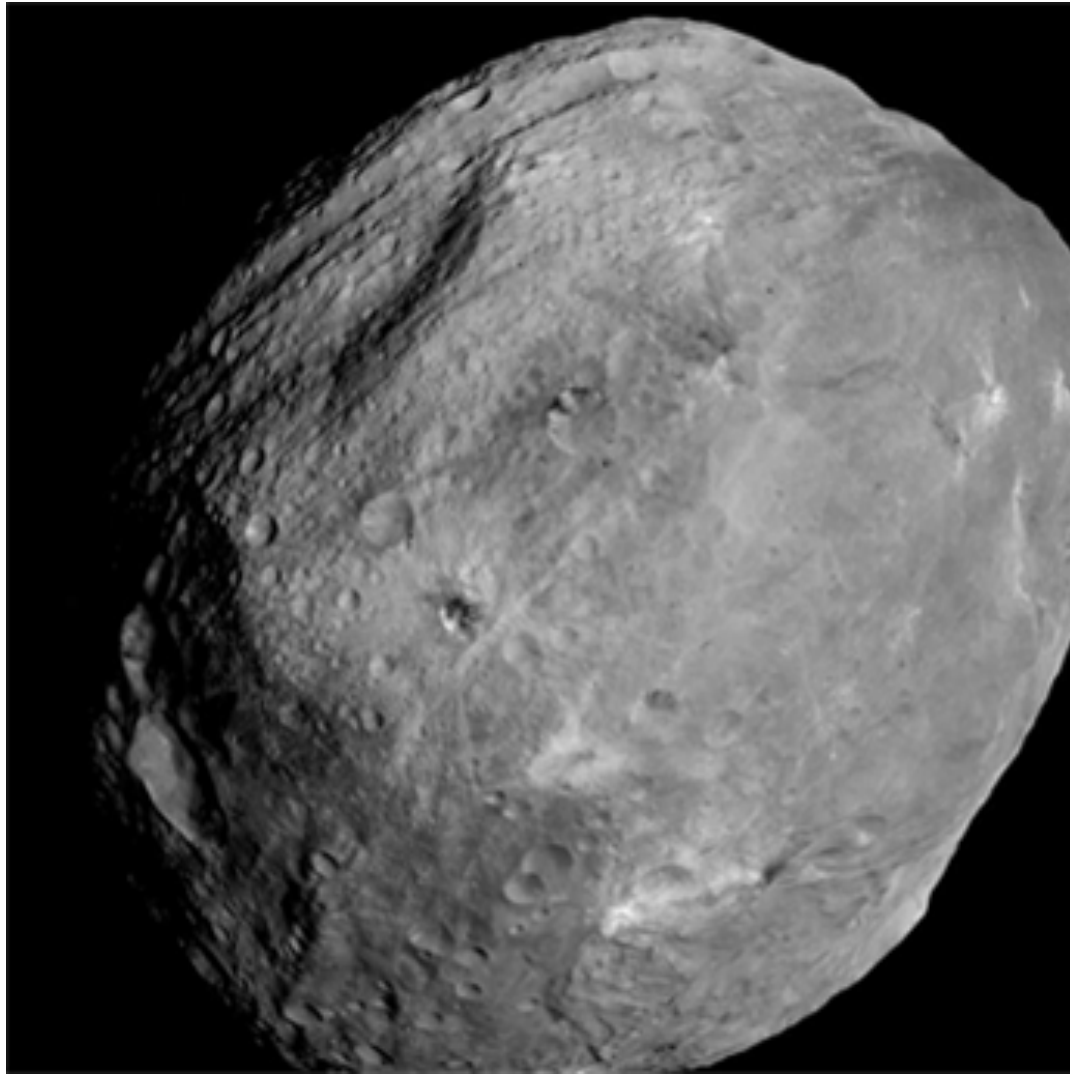
July 24, 2011

For $D \sim R_p$, normal rules do not apply…
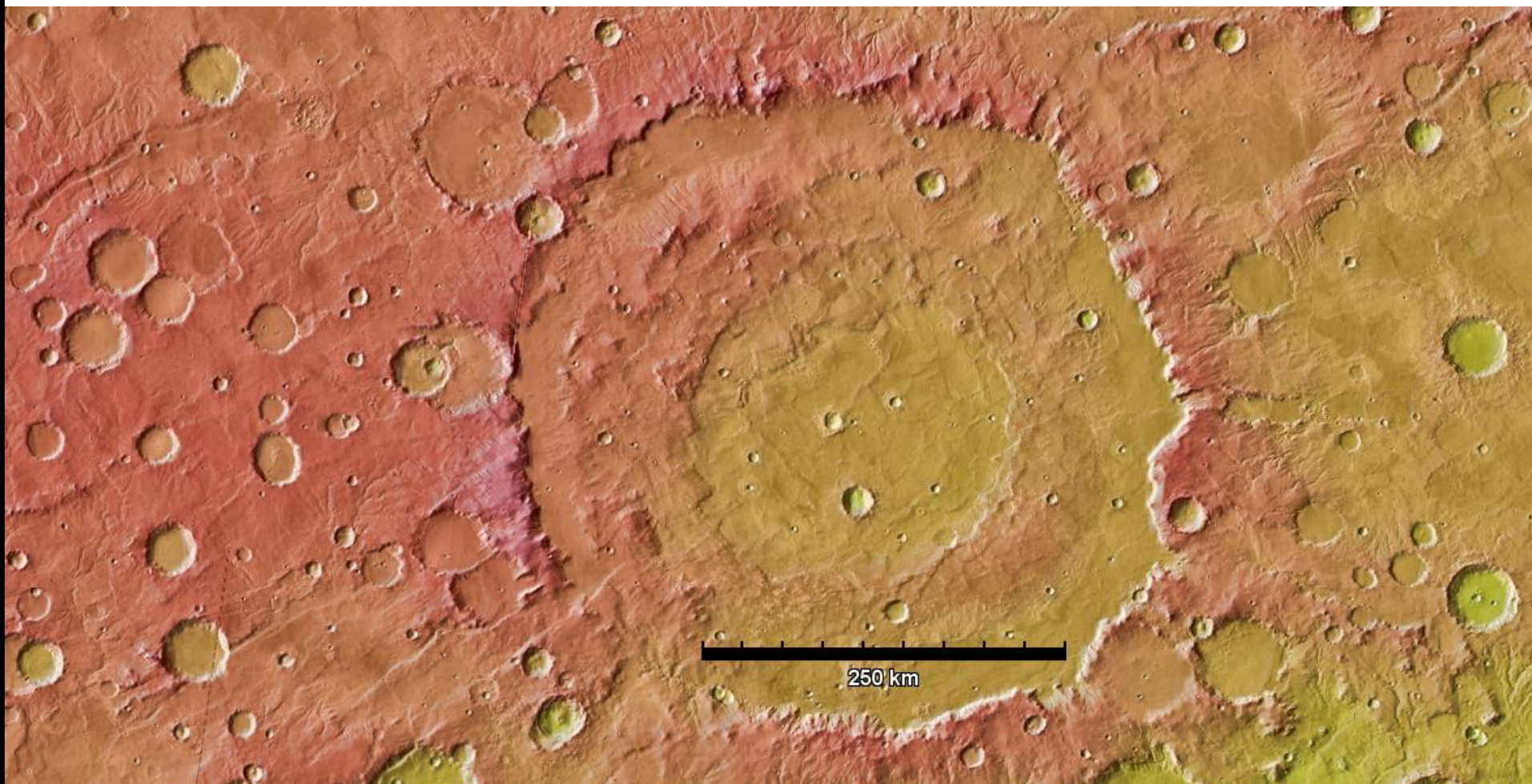
Multi-ring basins
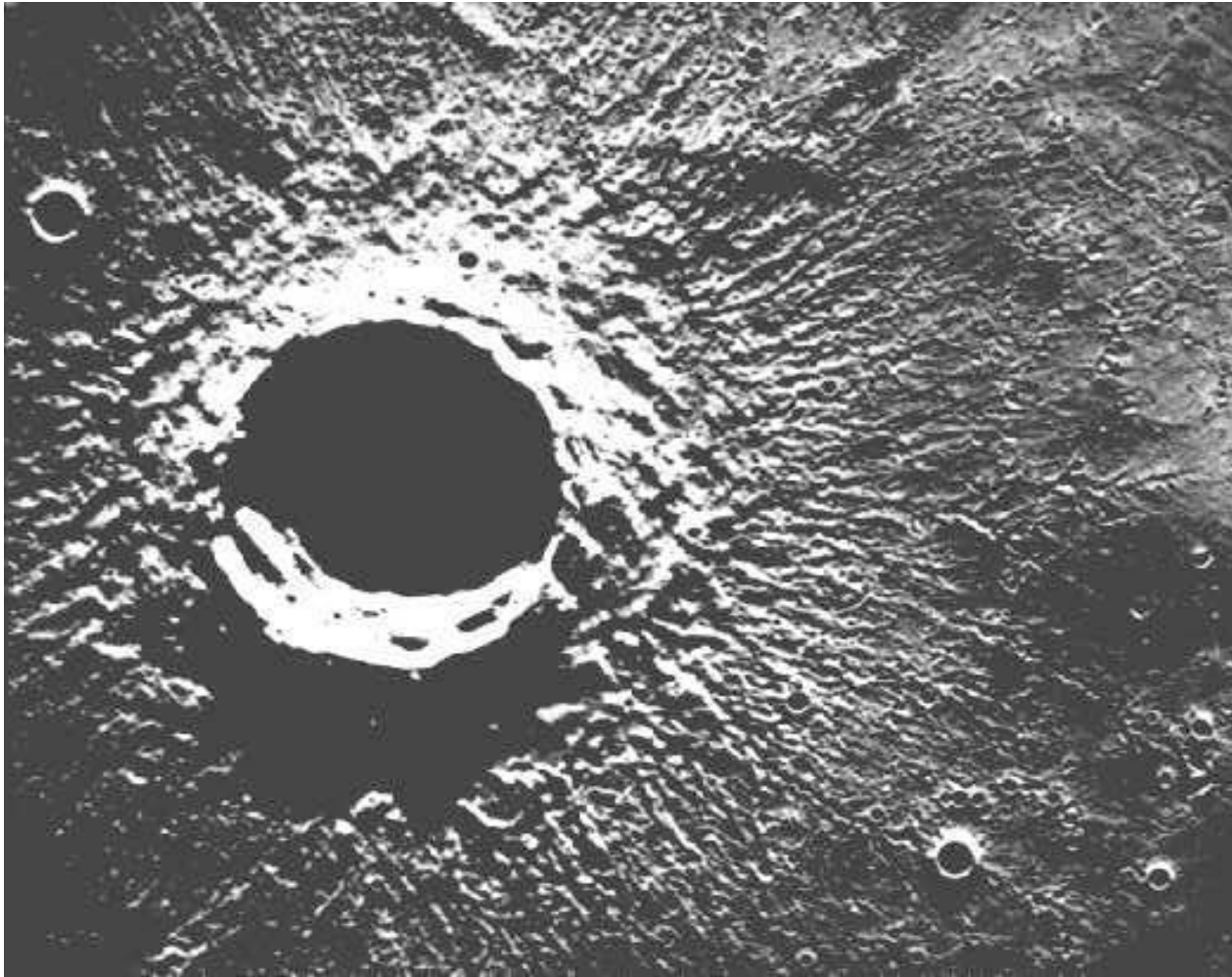

From Melosh
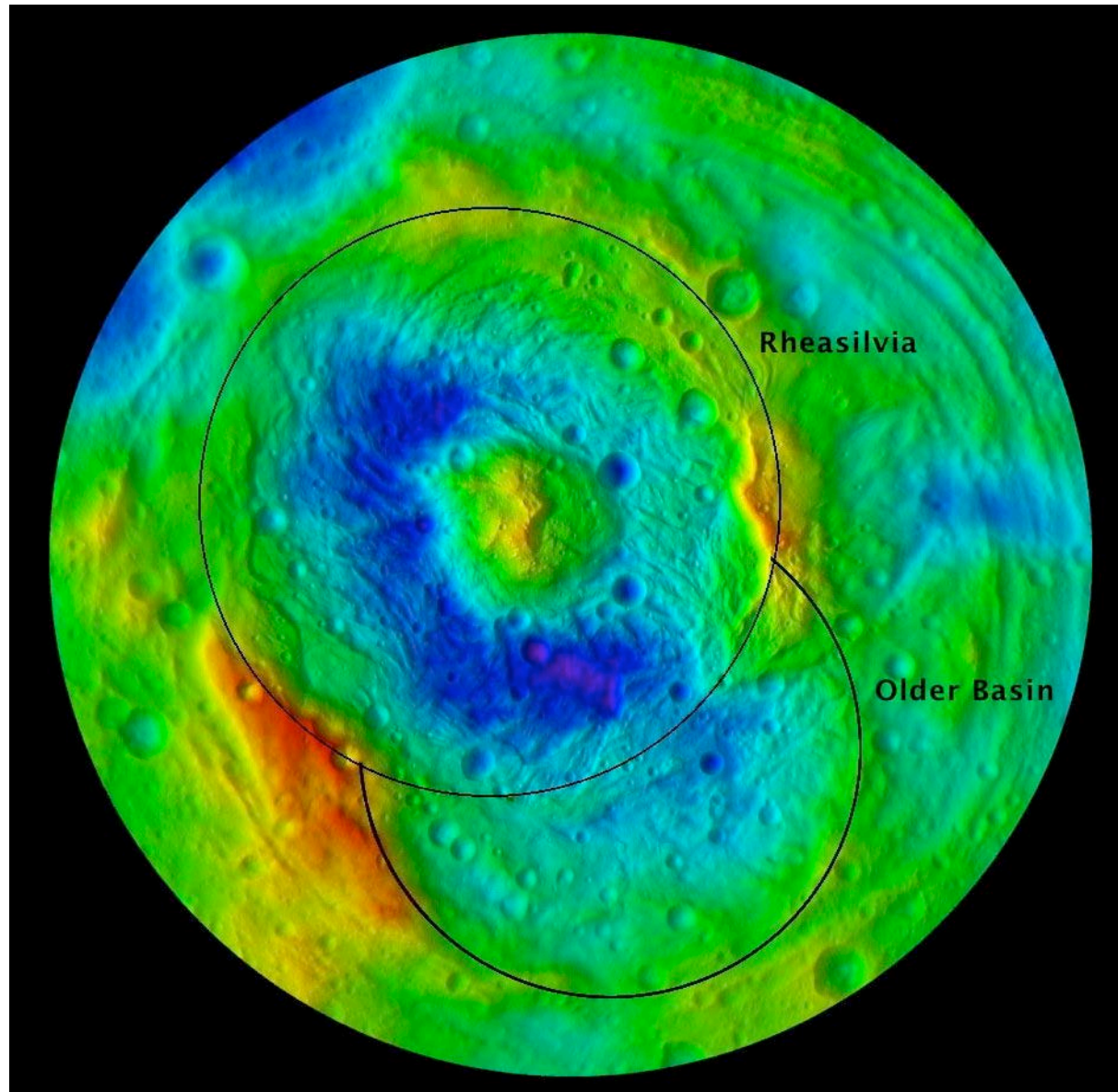
Multi-ring basins
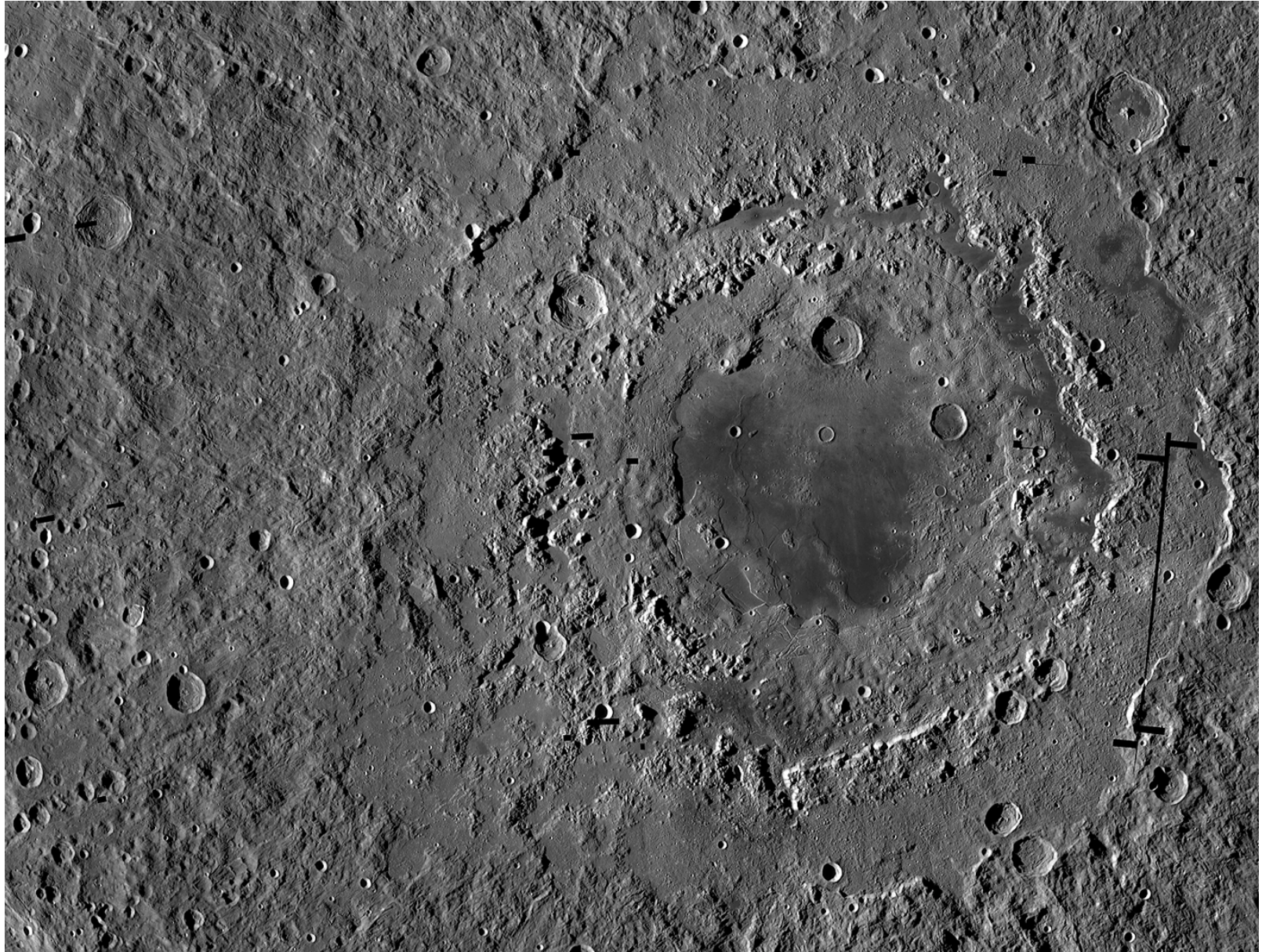
Multi-ring basins

Crater ejecta

- Continuous and discontinuous ejecta
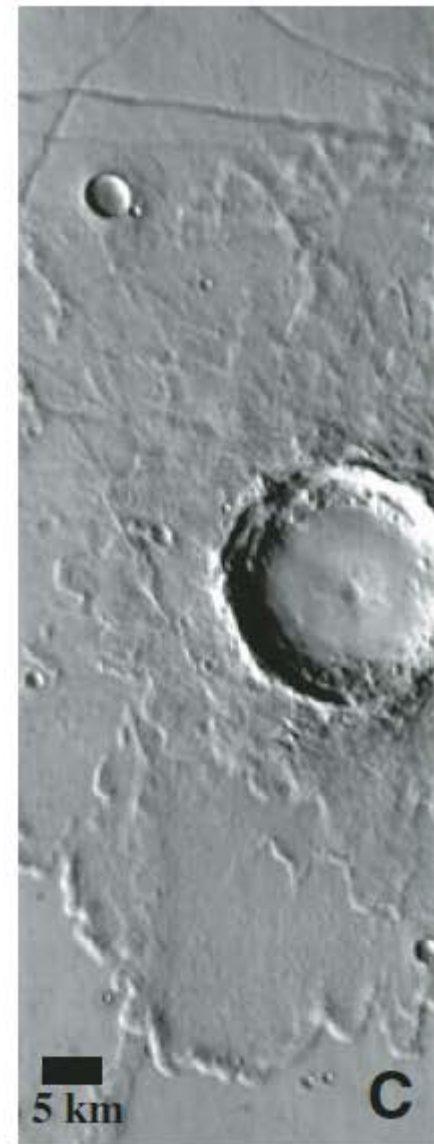- Secondary crater chains
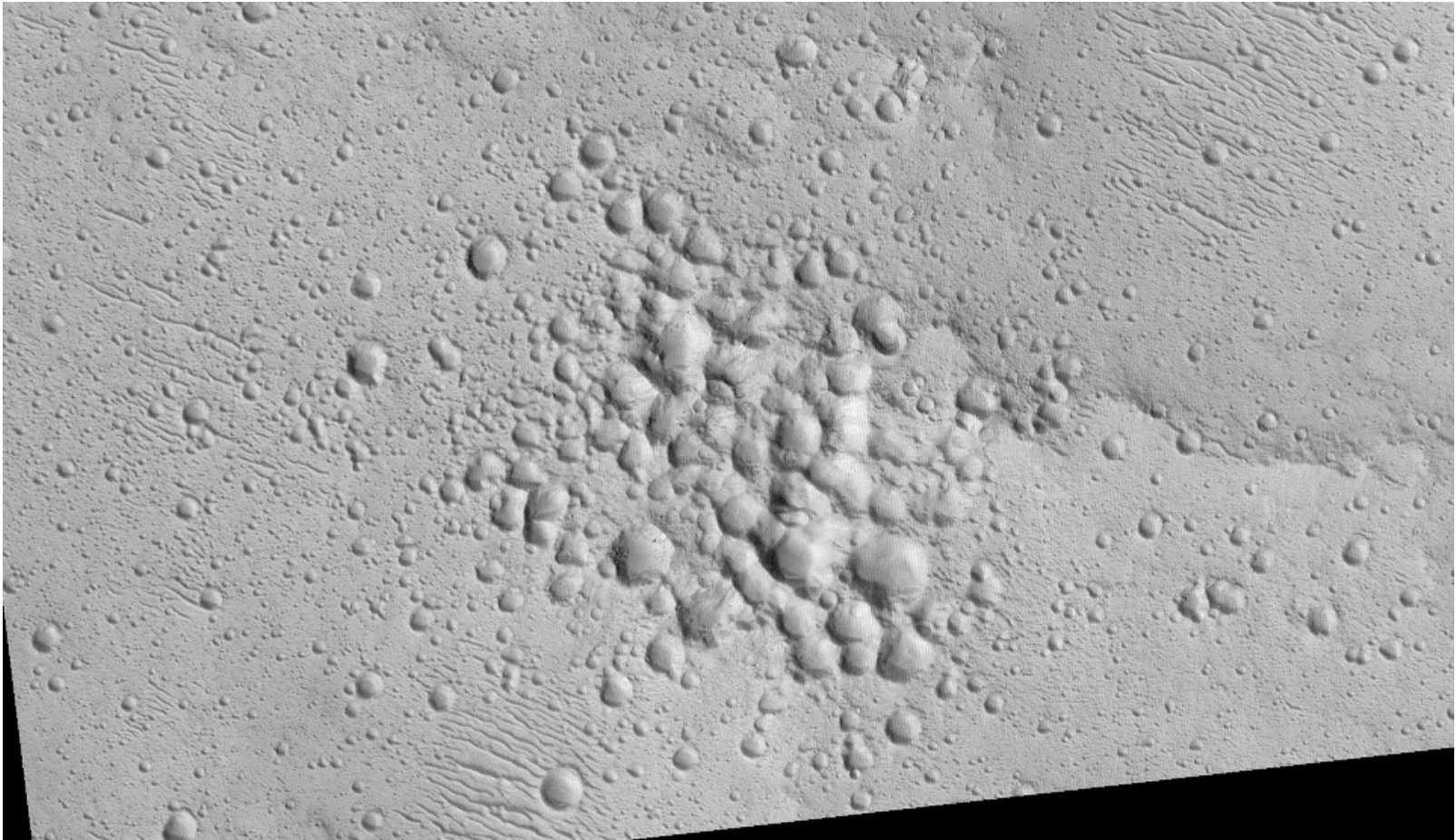
Ejecta rays

Marquette Island, Meridiani Planum

NASA/JPL/S. Atkinson

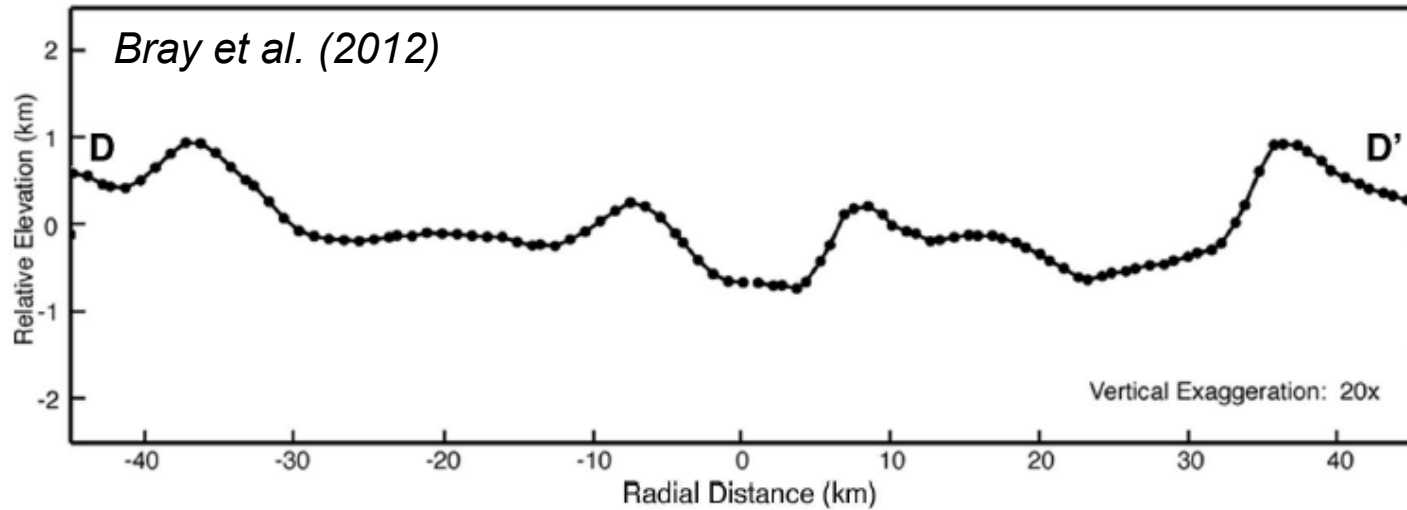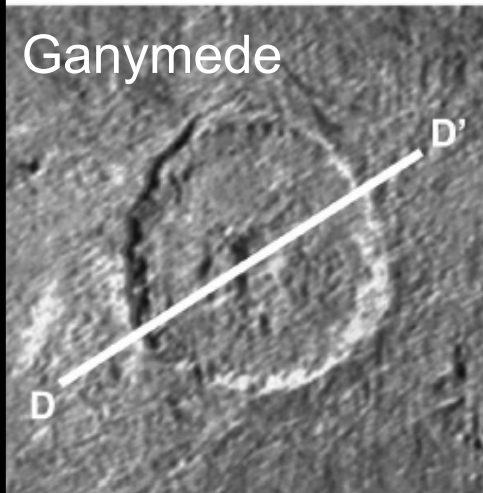# Layered / "fluidized" ejecta

5 km

A

5 km

B

5 km

C

Barlow (2010)

Atmospheric effects

- Can slow down / break up meteoroids, producing crater clusters
- Significant when displaced mass $\sigma_\rho A/\sin\theta \approx$ meteoroid's mass
  - ➔ Likelihood of breakup ~ $\sigma_\rho/R\rho\sin\theta$
- No craters smaller than ~3 km on Venus! (Few < 30 km)

Central pit craters
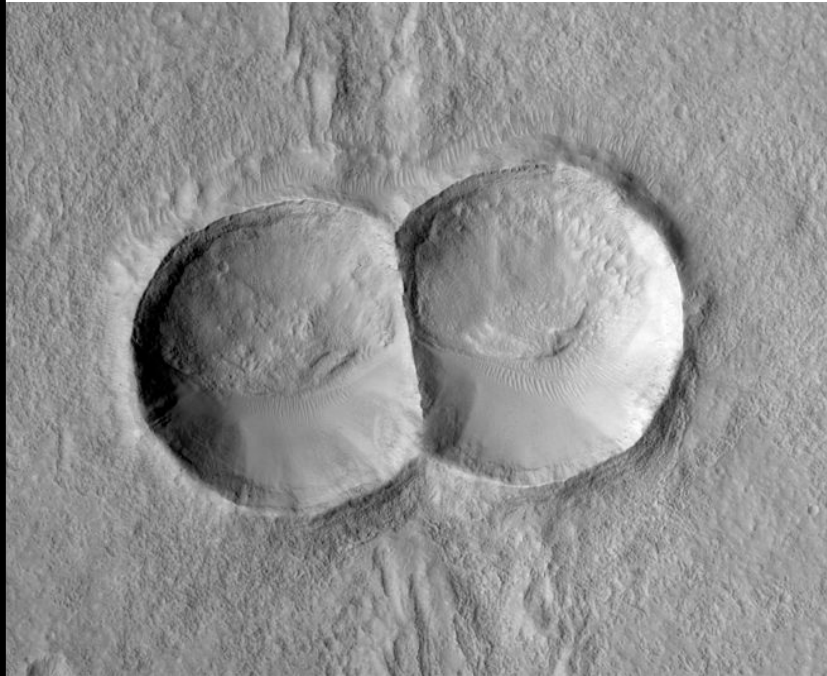

Ganymede

Bray et al. (2012)

Vertical Exaggeration: 20x

Relative Elevation (km) / Radial Distance (km)

Form on Mars, icy moons via:

1) target volatile vaporization?

2) collapse of weak icy crust?

3) excavation into liquid?

Mars

25 km
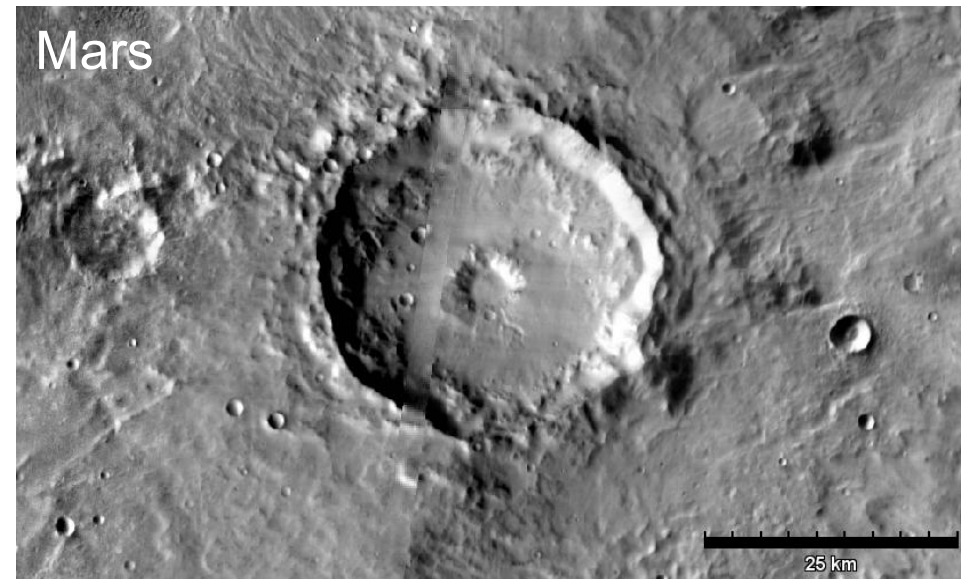
Other oddities

Very oblique impact? (<5°)

Binary asteroid?

Subsurface structure?