Morphology and geochemistry of Europa: A comparative planetology view.

Surface layer of Europa: Implications for landing

Alexander T. Basilevsky
Vernadsky Institute of Geochemistry and Analytical Chemistry
Russian Academy of Sciences

International Workshop
EUROPA LANDER:
SCIENCE GOALS AND EXPERIMENTS
9-13 February, 2009
Moscow, Russia

Characteristics of Europa and the Earth's Moon:

	Europa	The Moon
Mean distance from the Sun, a.e	5.2	1
Mean distance from the planet, km	671,000	384,000
Orbital period, Earth's days	3.55	27.3
Mean radius, km	1569	1738
Mean density, g/cm^3	3.01	3.34
Escape velocity, km/s	2.02	2.38
Surface gravity, m/s^2	1.31	1.62
Atmosphere pressure, bar	10^{-11}	10^{-15}
Surface temperature, min, K	50	100
mean	102	220
max	125	290
Surface material	H_2O ice	Silicate rocks
Mean surface age (Ma)	10^7	$4 * 10^9$

Expected surface processes
superposed on volcanic & tectonic “basement”

- Impact cratering and regardening
- Downslope movement of surface materials
- Radiation effects

Impact cratering and regardening

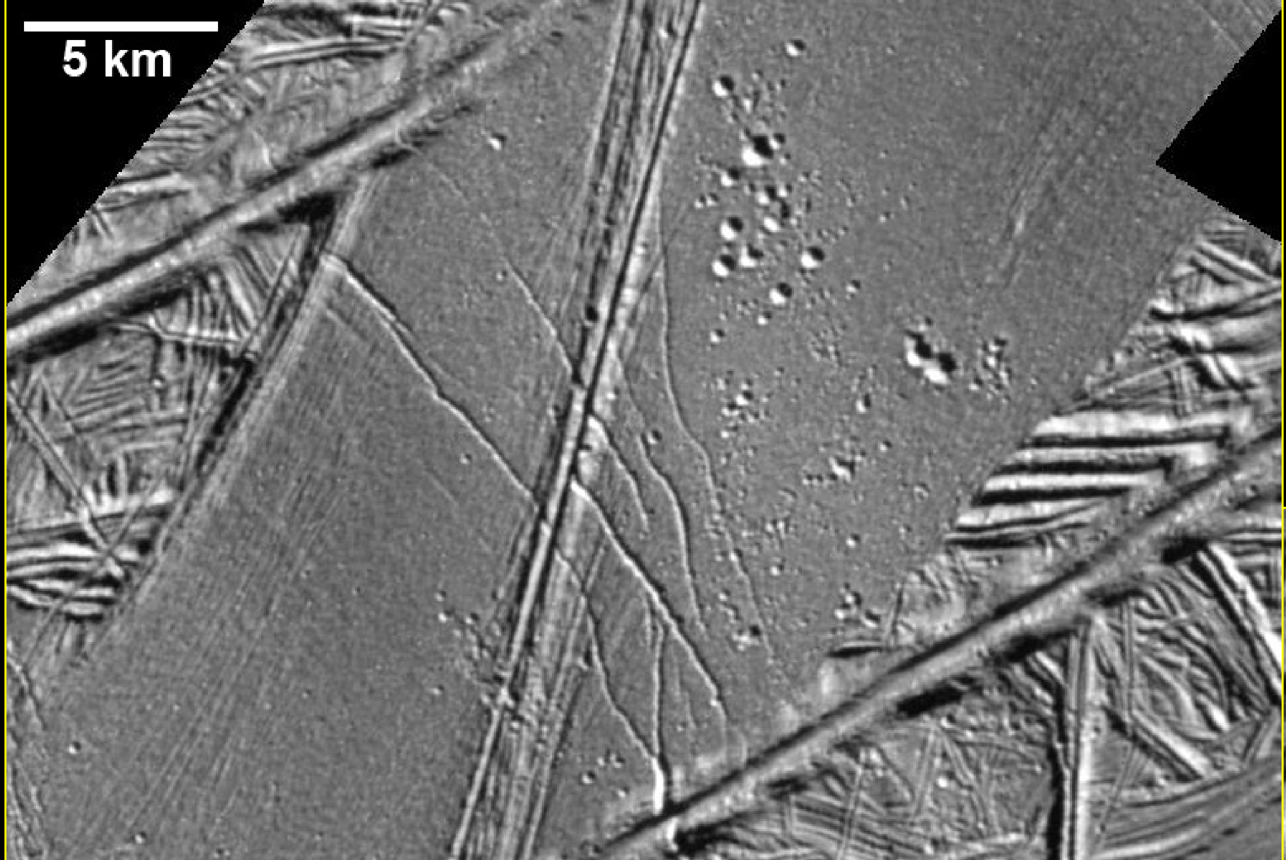
Impact fragmentation, ejection and ballistic deposition

=> Formation of fragmental regolith

Impact melting and vaporization (minor role)

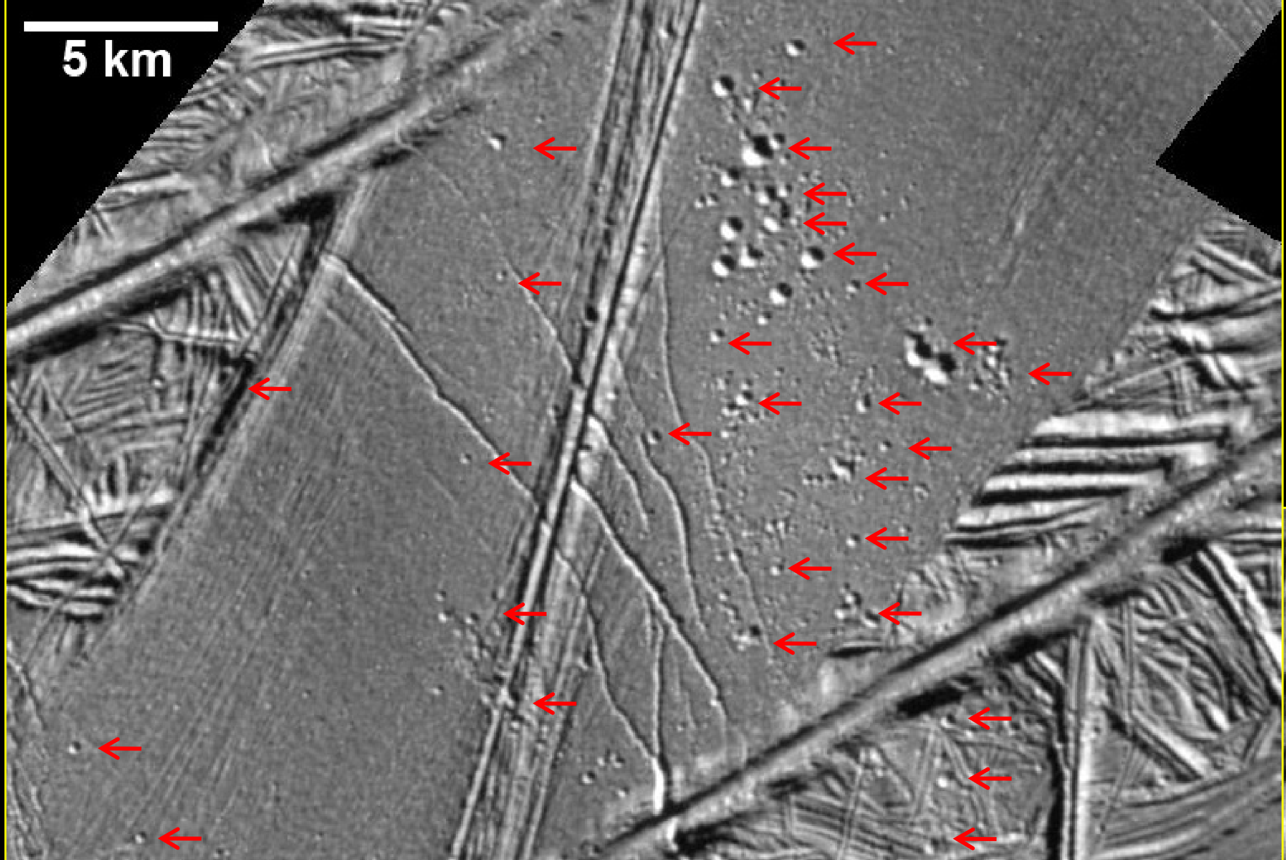
=> Glueing together of fragments

=> Frost condensation on the surface and in pores



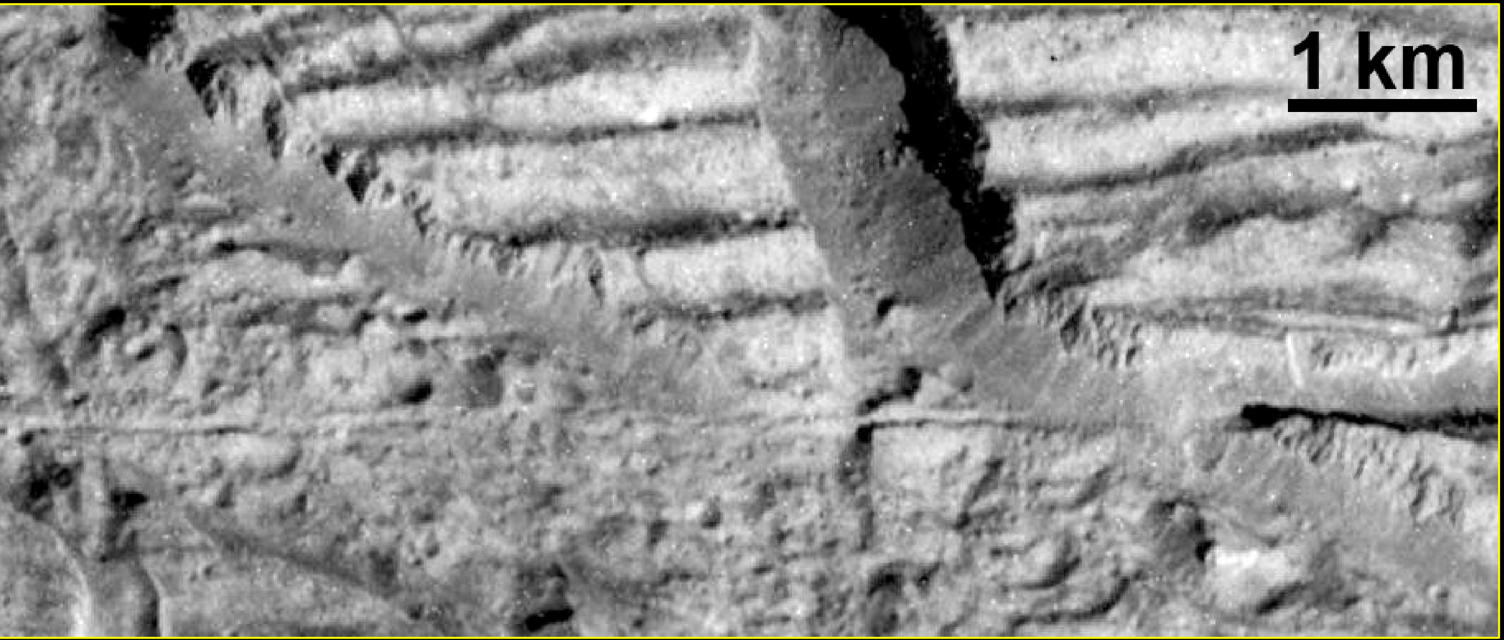
Europa,
Connamara Chaos
Galileo image
42 m per pixel
Cluster of secondary craters

The Moon,
Floor of crater Alphonsus
Ranger 9 image
50 m per pixel
Primary and secondary
craters

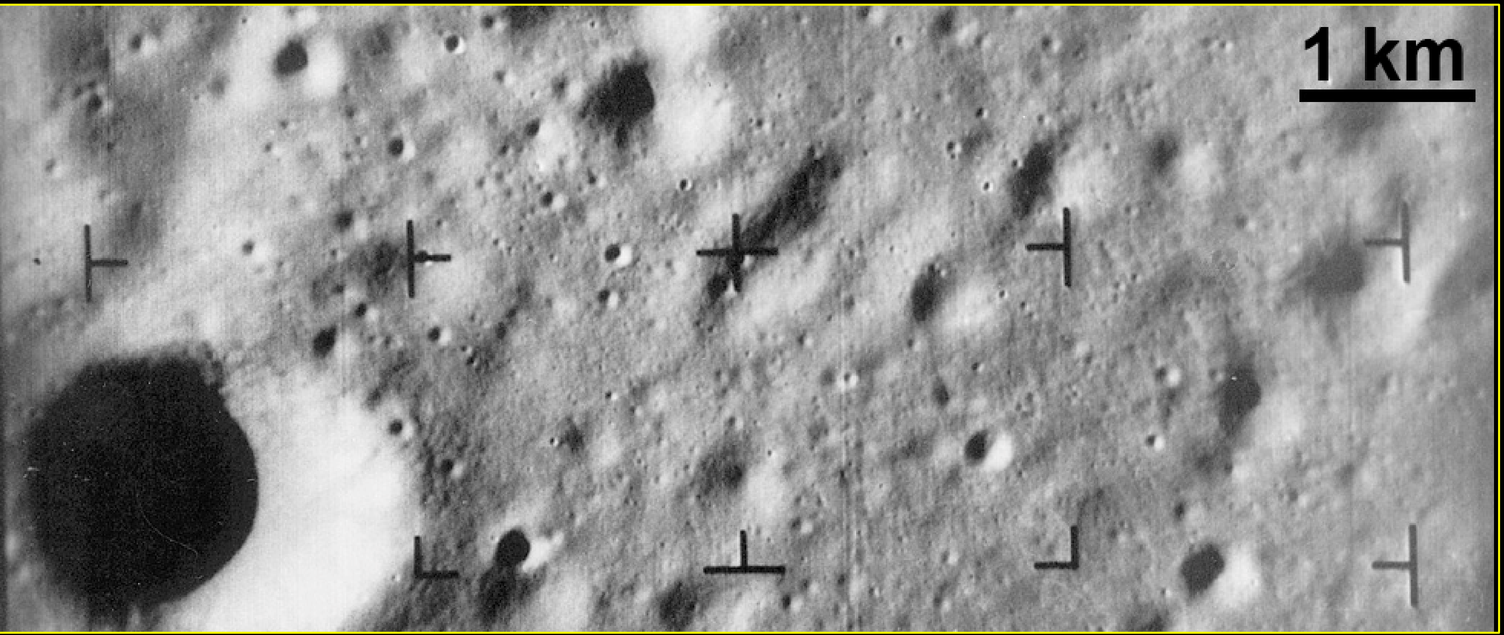


Europa,
Connamara Chaos
Galileo image
42 m per pixel
Cluster of secondary craters

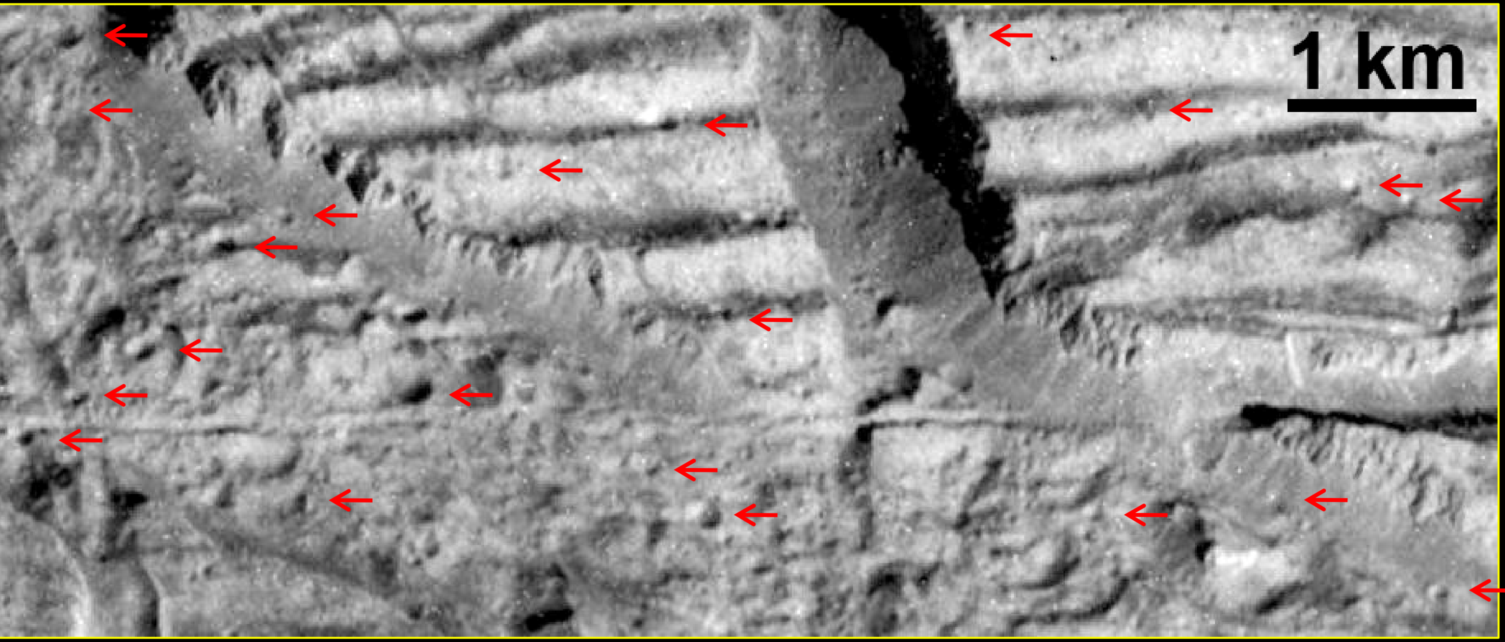
The Moon,
Floor of crater Alphonsus
Ranger 9 image
50 m per pixel
Primary and secondary craters



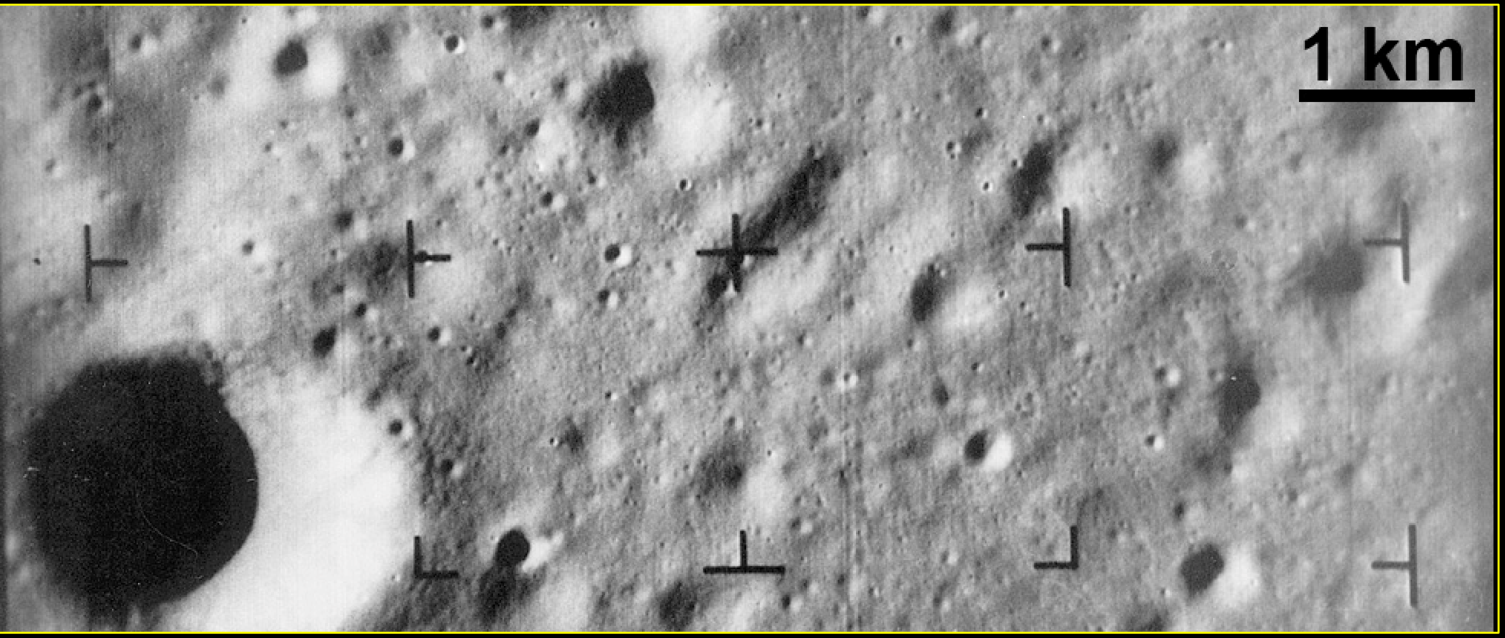
Europa,
Connamara Chaos
9 m per pixel
Unfrequent craters



The Moon,
Floor of Alphonsus
8.5 m per pixel
Numerous
craters

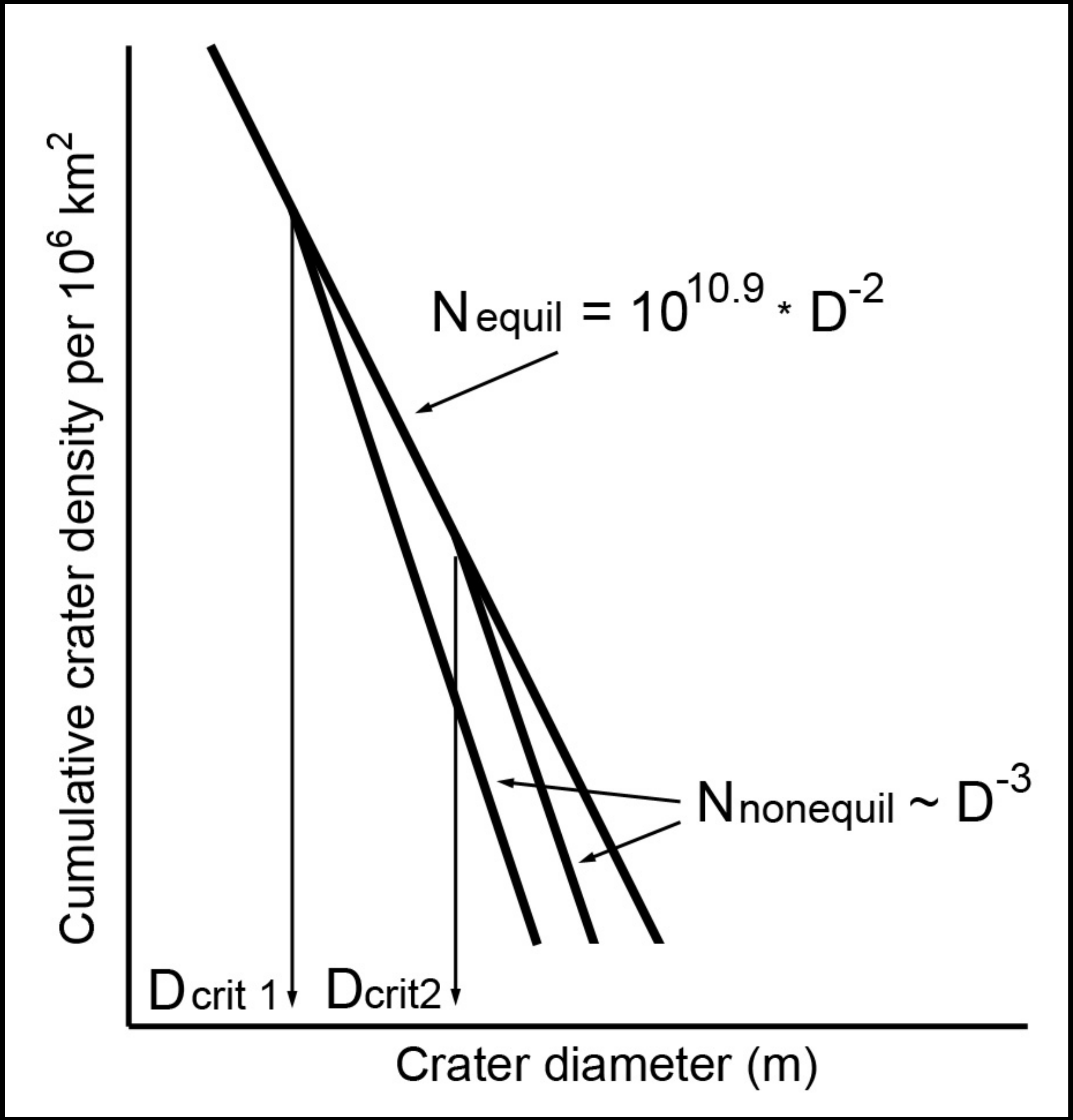


Europa,
Connamara Chaos
9 m per pixel
Unfrequent craters



The Moon,
Floor of Alphonsus
8.5 m per pixel
Numerous
craters

Equilibrium & nonequilibrium parts of impact crater population



Shoemaker, 1971; Florensky et al., 1972

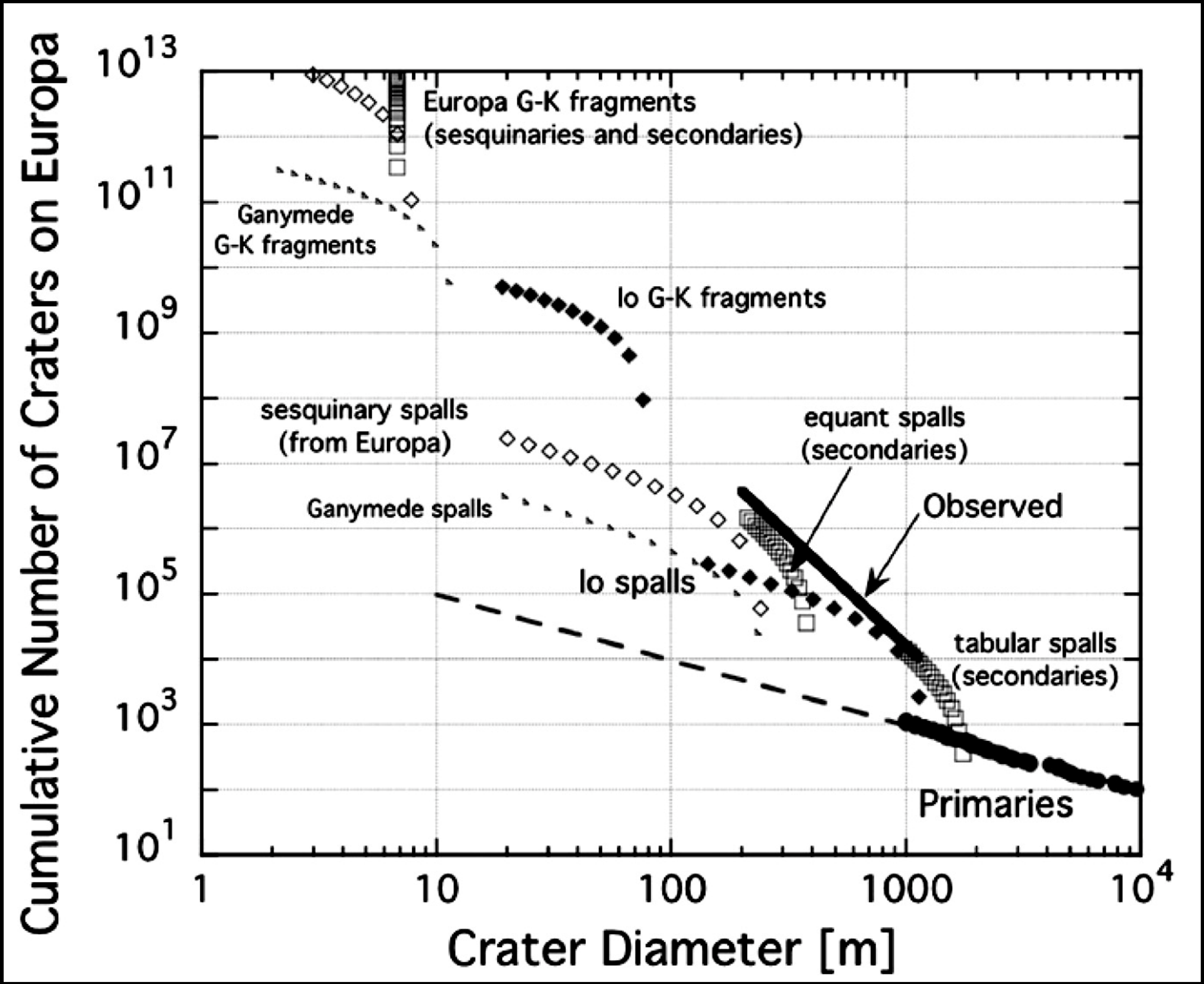
Basilevsky, 1974:

On the Moon median thickness of regolith:
$H_{med} \approx D_{crit} / 25$

This work:

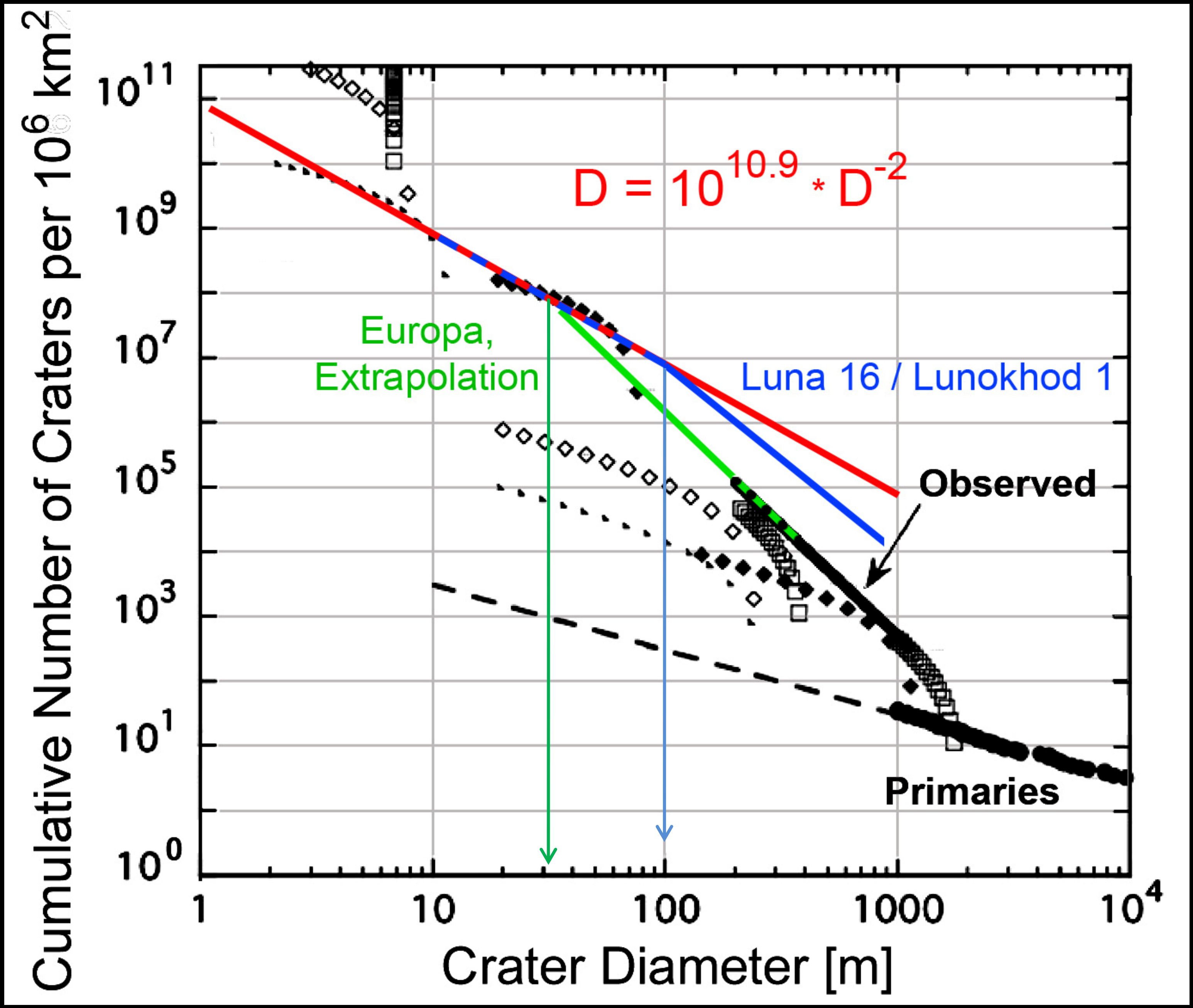
On Europa, where majority of craters seems to be secondary and thus more shallow, median thickness of regolith should be smaller
$H_{med} \approx D_{crit} / 50$

Impact crater frequencies on Europa



Zahnle et al., 2008

Impact crater densities on Europa and the Moon



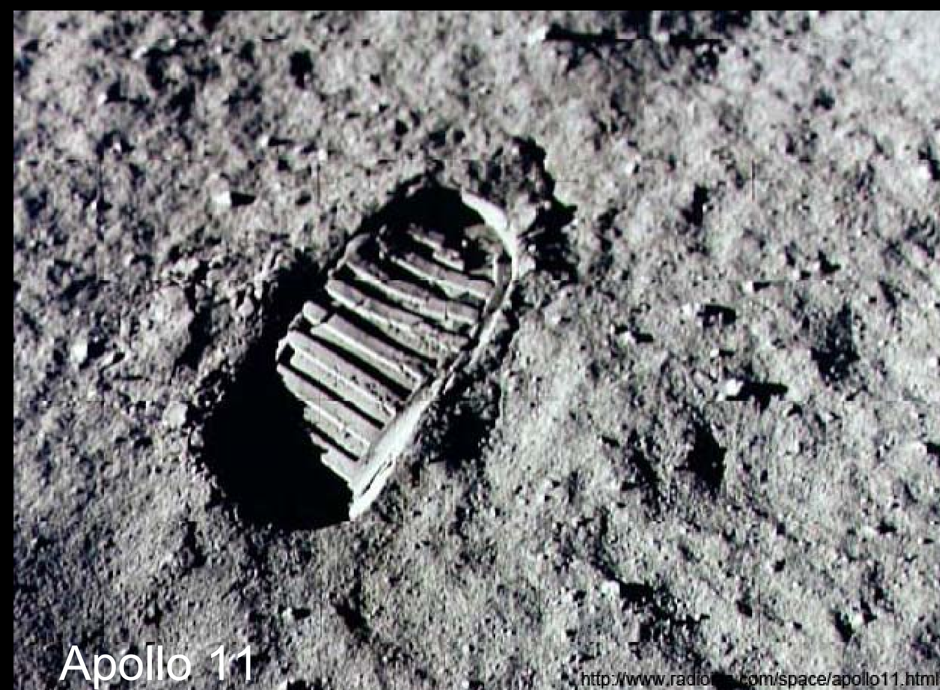
Estimates of regolith thickness:

Luna 16 / Lunokhod 1	Europa
D crit ≈ 100 m	D crit ≈ 30 m
H med ≈ D crit / 25	H med ≈ D crit / 50
=> ~ 4 m	=> ~ 0.5 m

Cooper et al. (2001) => ~ 1 m

On Europa, within the clusters of secondaries, thickness of impact-formed regolith is probably much larger than H med, while far from the clusters and in the areas of recent endogenic resurfacing such regolith should be much thinner or even absent.

On Europa: Coarse-grained fragmental ice regolith, possibly with some frost on top
and
On the Moon: Fine-grained fragments + agglutinates



Downslope movement of surface materials:

On Europa a downslope surface material movement is expected and observed in the areas with rough surface topography:

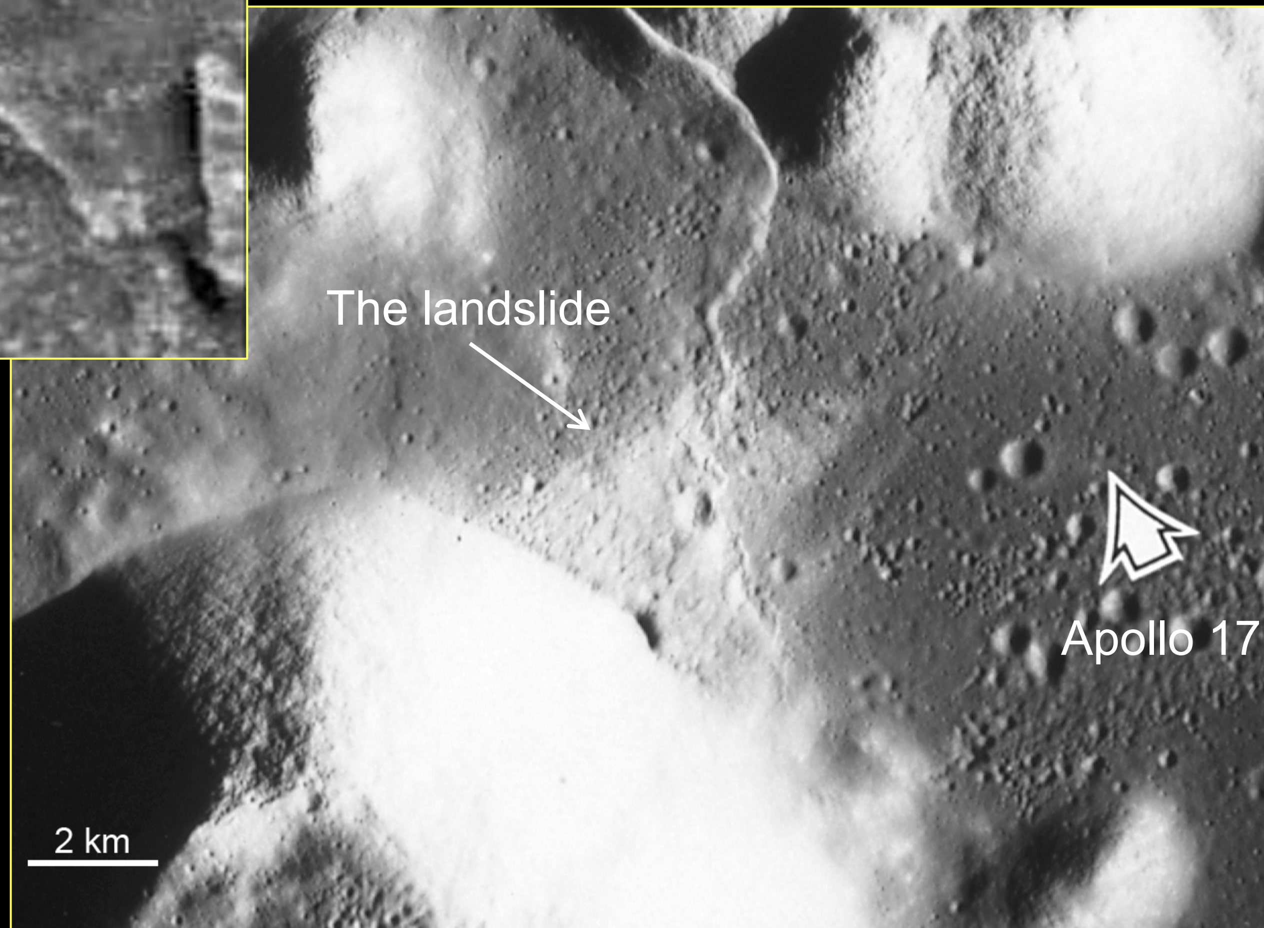
Chaoses, Rugged terrain,
Faults, Domes, Impact craters

It should be provoked by day-night temperature change and meteorite impacts

Downslope material movement on Europa and terrestrial and lunar analogs

Taluses on Europa

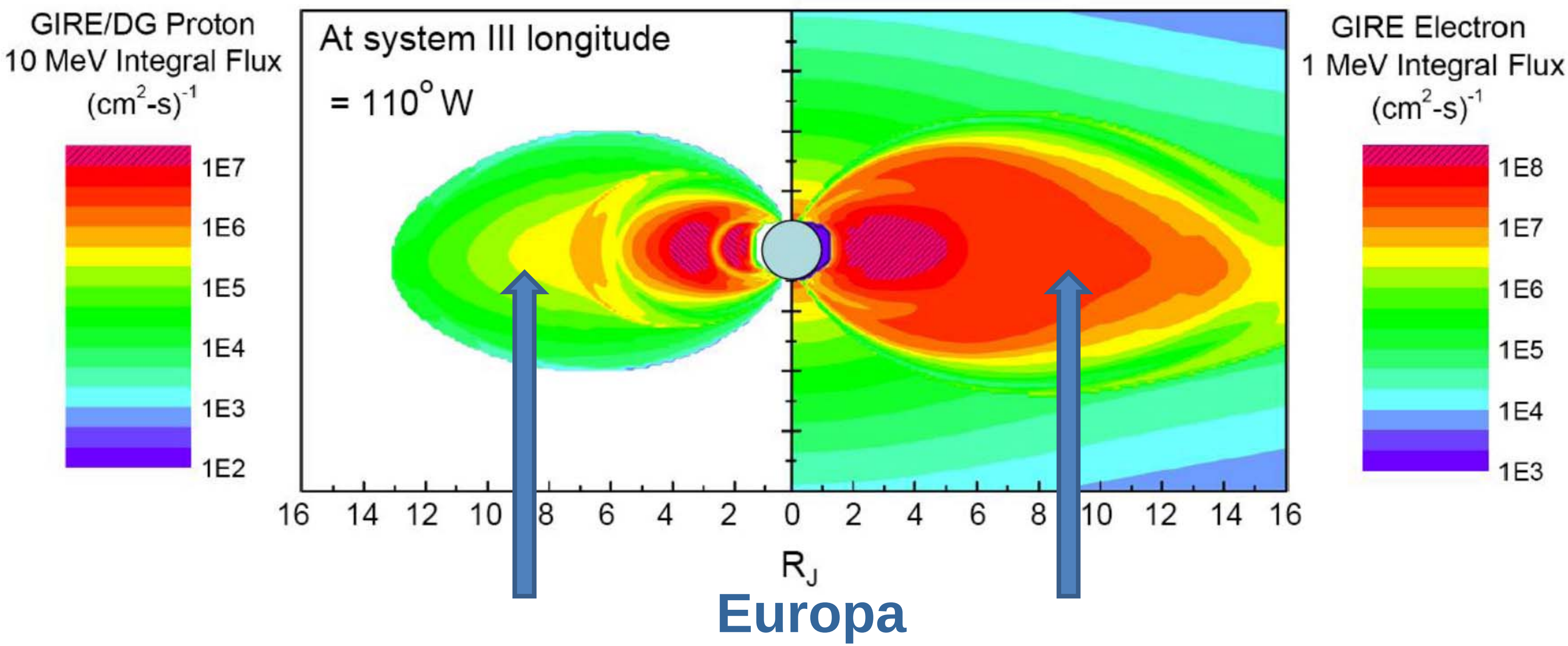
Earth, Talus cone



The Moon, Landslide at the Apollo 17 site

Radiation environment at Europa orbit

DIVINE + GIRE JOVIAN RADIATION MODELS

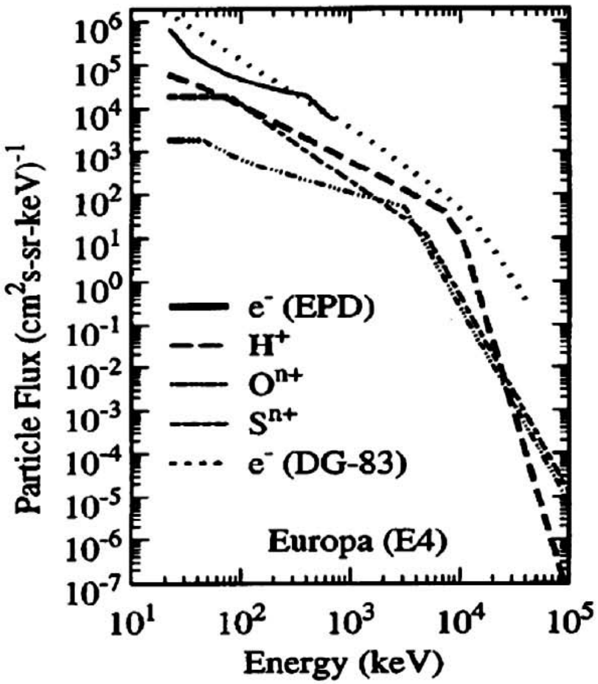


Contour plots of ≥1 MeV electron and ≥10 MeV proton integral fluxes at Jupiter. Coordinate system used is jovi-centric. Models are based on Divine/GIRE models. Meridian is for System III 110° W.

From: Henry B. Harrett, JPL / OPFM Instrument Workshop / June 3-5, 2008

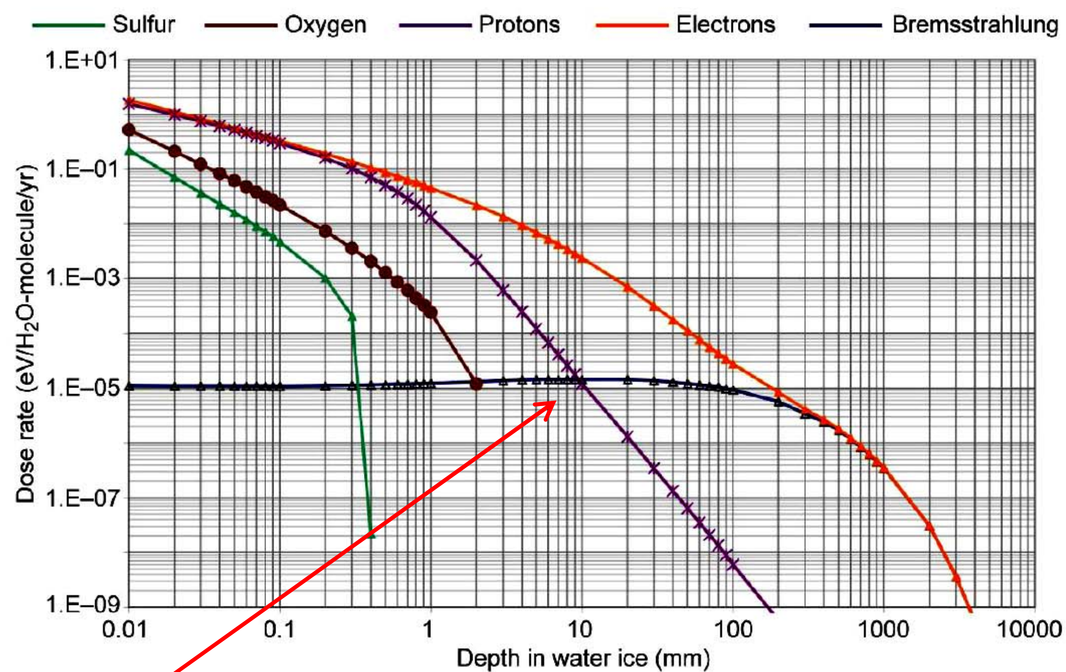
Radiation by particles on Europa is very surficial

Radiation Environment at Europa's Surface



Flux spectra from EPD measurements at Europa during E4 encounter (Cooper et al., 2001). Electron spectra from EPD at 20-700 keV and from Divine and Garrett (1983).

Dose rate (rad(H_2O)/s) vs depth curves for, electrons, protons, oxygen, and sulfur at apex of Europa's trailing hemisphere.



Paranicas et al. (2002)

Dose of protons falls by 6 orders of magnitude at 1 cm depth

Radiation effects on Europa:

Most charged particles preferentially impact trailing hemisphere, except > 25 MeV electrons, which preferentially impact the leading hemisphere.

Radiolysis:

=> Major reaction $2\ H_2O \longrightarrow H_2O_2 + H_2$
(Spinks and Wood, 1990)

Sputtering:

=> $6 * 10^4$ years to erode 1 mm of ice
Compare: Impact burial => 10^3 years per mm of ice
so impacts are much more effective than sputtering
(Cooper, 2001)

Radiation Damage:

=> Defects in ice => Thin (<1 mm) amorphous layer
(Hansen and McCord, 2004).

Conclusions:

- Surface layer of Europa is expected to be mostly an impact-produced regolith with decimeter-scale median thickness. In some areas it may be much thicker, while in others – thinner or almost absent.

- It consists probably of relatively coarse-fragmets of water ice (ice breccia) partially lithified due to contact welding and frost deposition in the pores.

- On top of fragmental regolith a water frost may present.

- Within the topographically rough areas and landforms a downslope material movement may occur.

- Radiation effects (radiolysis, sputtering, radiation damage) affect mostly the uppermost mm-cm layer.

Thanks to A.V. Ivanov, B.A. Ivanov, M.A. Ivanov, R. Kuzmin and V.I. Shematovich for help.

Thank you for your attention!

www.xtywebworks.ns.ca/week37.html