How the Median S-Band Circular Polarization Ratio (CPR) of Kilometer-Scale Craters Evolves with Time on the Lunar Maria

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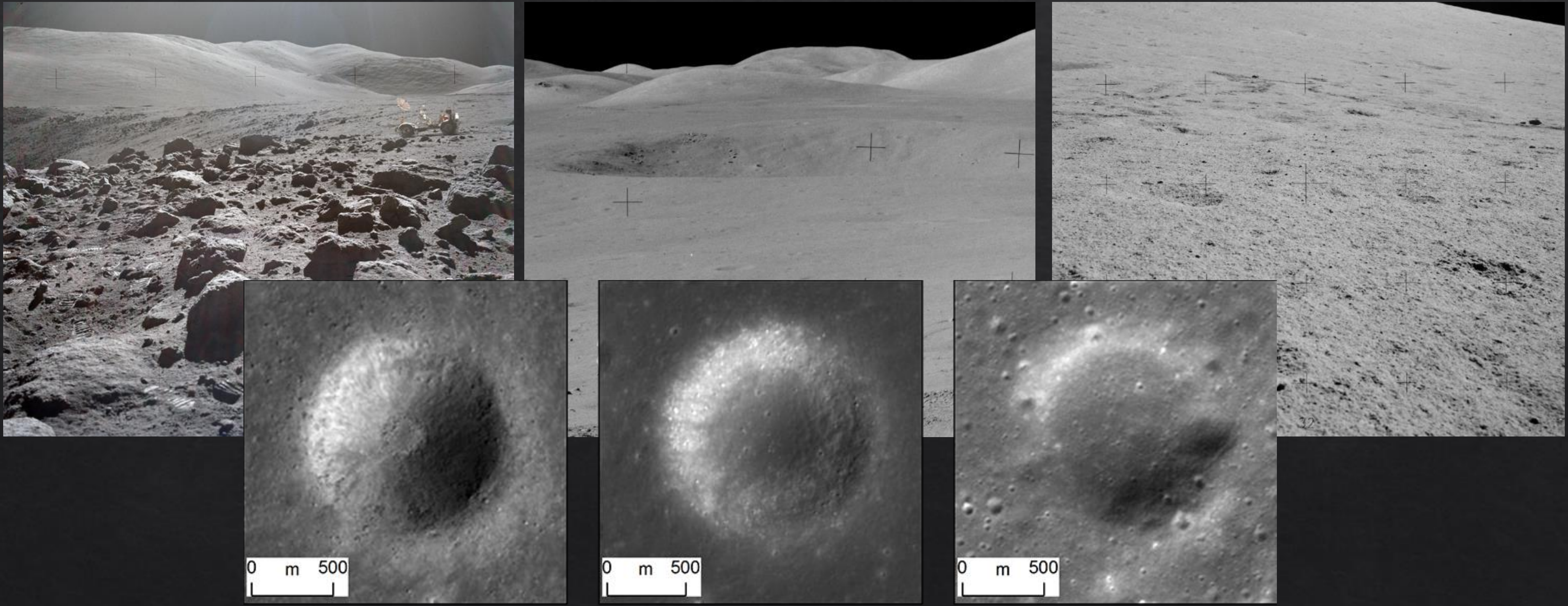
Coming Soon!
Paper on this topic is in revision at *JGR-Planets*.

Goal: Temporal evolution of craters and regolith on the Moon

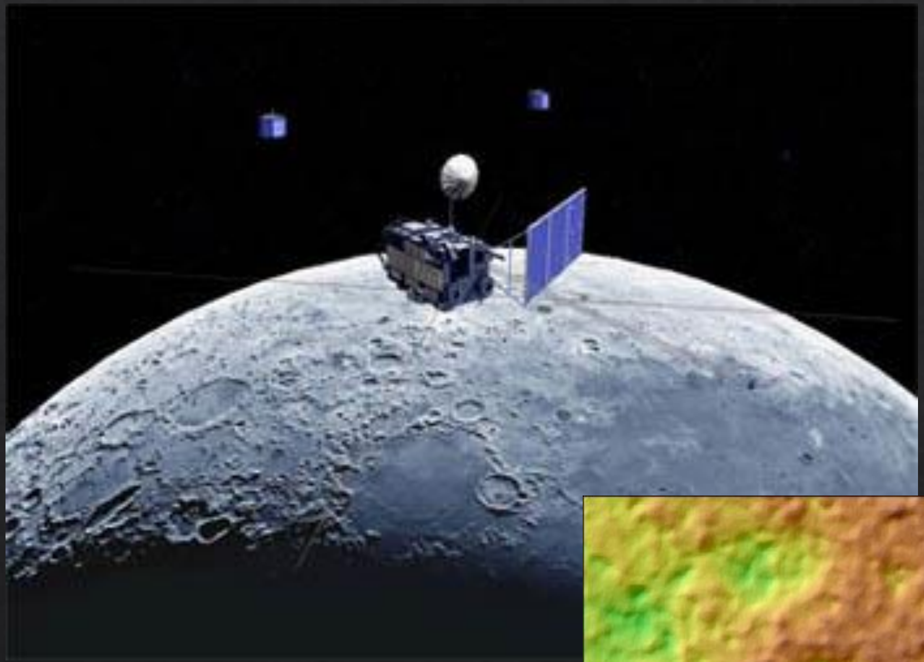


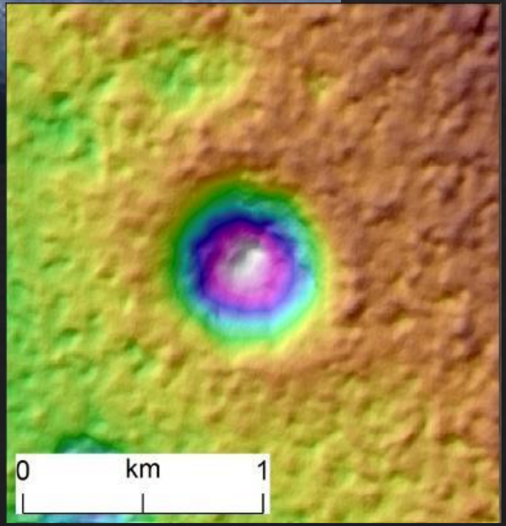
Fresh Crater
T~0.01 Ga

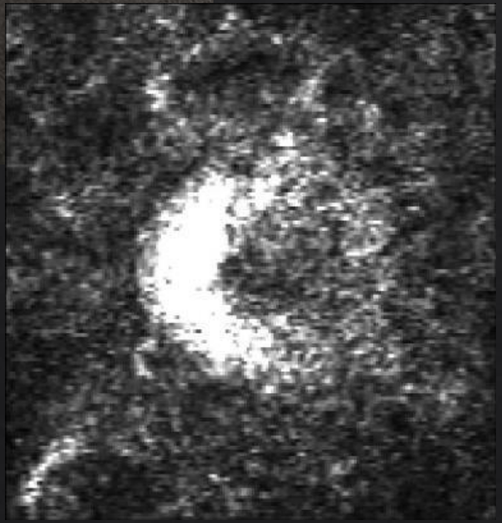
Moderately Degraded
T~3 Ga

Very Degraded
T~3.7 Ga

Approach here is to combine: (1) Age estimates from Kaguya Topography w/ (2) CPR from Mini-RF radar

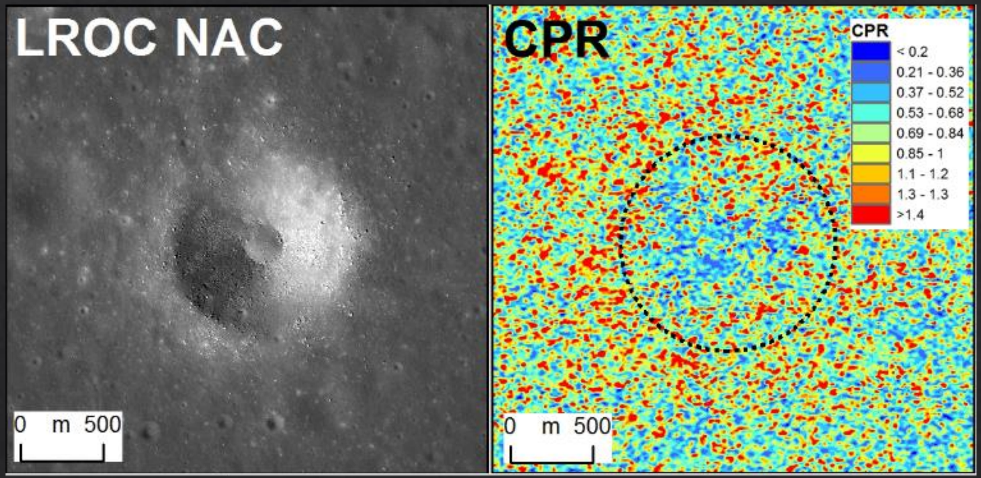


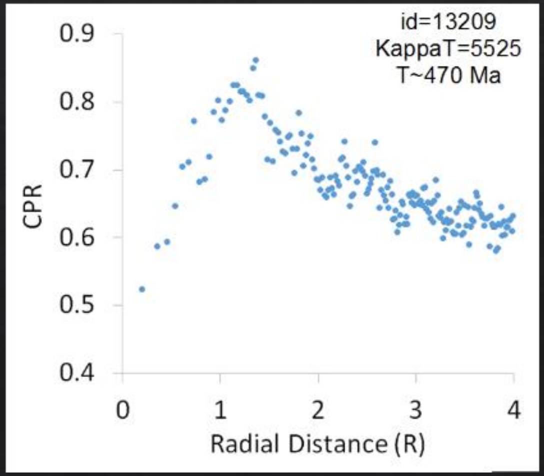




Background: Mini-RF S-band

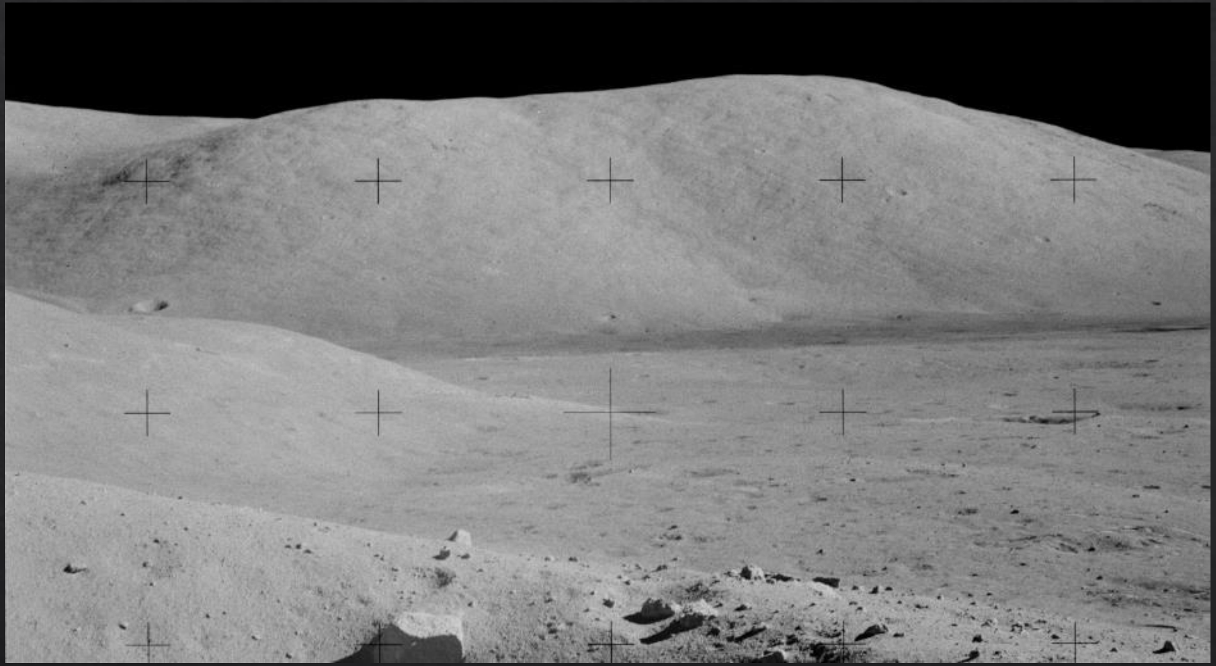
- S-band (12.6 cm) measurements are sensitive to rocks + roughness ~1 m depth.
  - Complementary to analyses of surface from images (LROC) or thermal IR rock abundance maps (DIVINER).
- Circular Polarization Ratio, CPR = SC/OC
  - CPR is mostly a function of blockiness at λ-scale…
  - Some compositional dependence (TiO_2).
- Mini-RF Zoom mode: ~15x30 m spatial resolution (but S/N is low at full resolution).





Sample references: Campbell et al., 2006, 2010; Fa et al., 2013; Ghent et al., 2016

Background: Topography on the Moon evolves diffusively*



Sample references: Soderblom, 1970; Ross, 1968; Craddock and Howard, 2000; Fassett and Thomson, 2014; Minton et al., 2018.

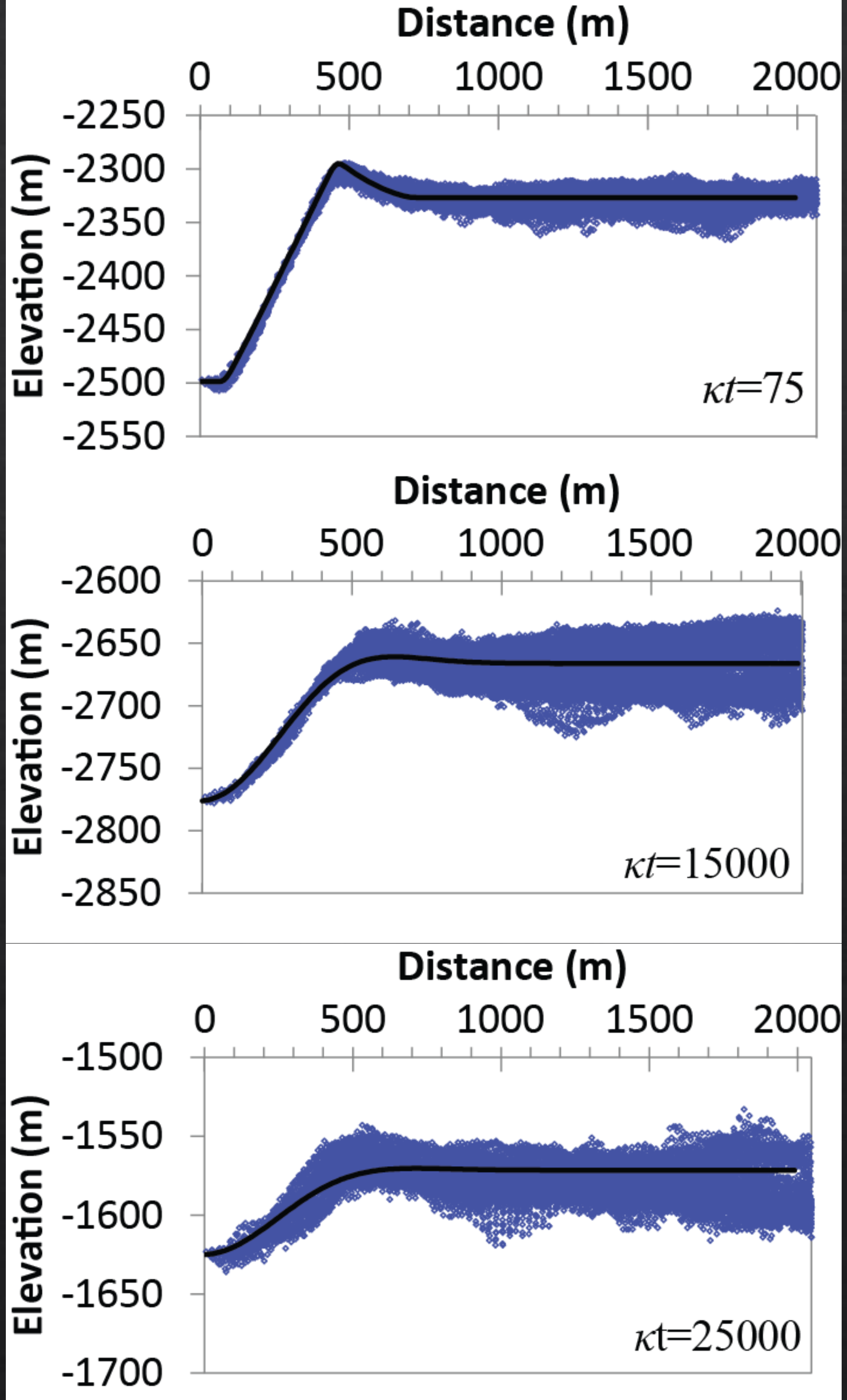
- Diffusion of topography *h*: $\frac{\partial h}{\partial t} = \kappa \nabla^2 h$
  - Can be caused by multiple processes, downslope transport q ∝ slope (at least for moderate slopes).
  - A classic model for hillslope evolution on Earth.
  - Leads to smoothed, rounded, topography.

***actually anomalous diffusion, but that is a complicated different talk**

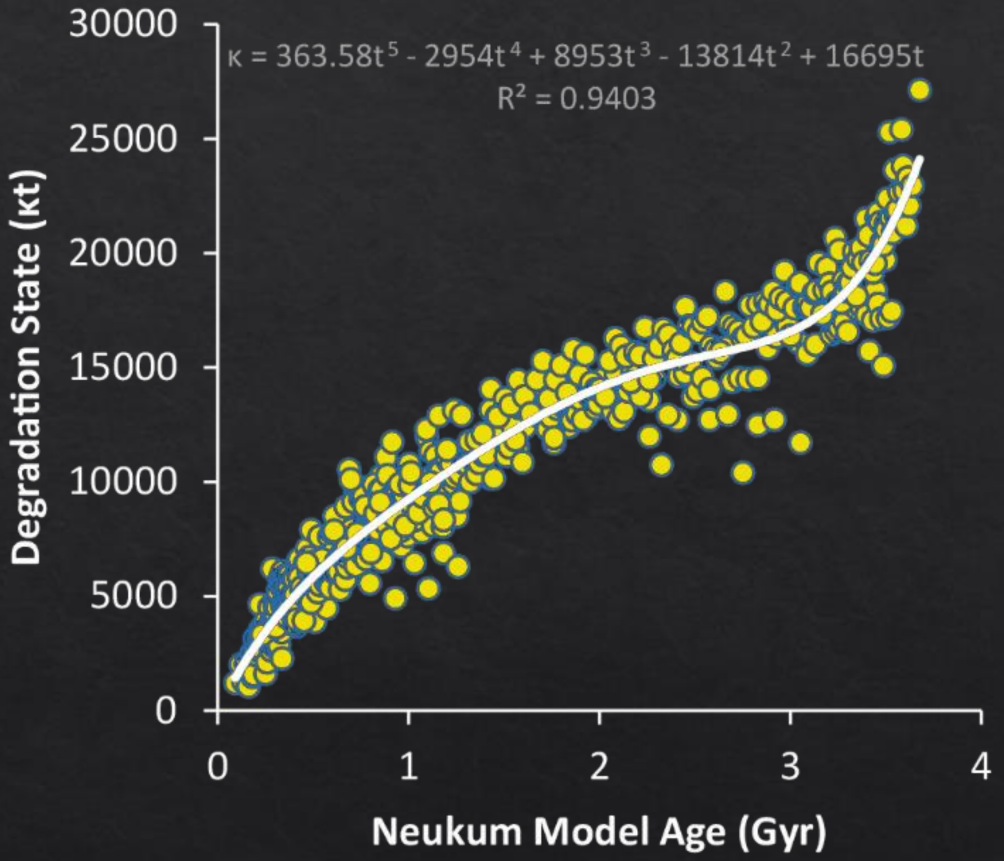
Fassett and Thomson (2014): Measuring Topographic Diffusion

- Mapped, extracted topography, and fit diffusion profiles to radial profiles of topography
  - 13000+ craters on the maria (D=800 m to 5 km)
  - 96% of craters were between 800m and 2 km (12,913).

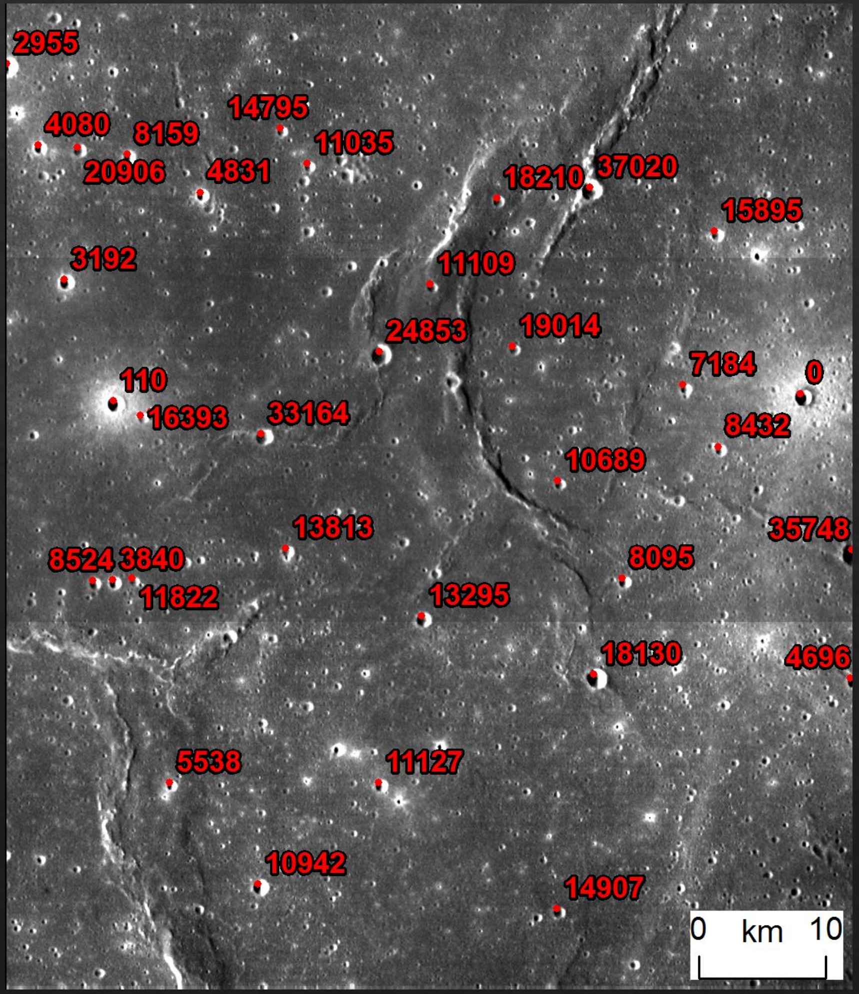
- Solve for three parameters:
  - H_0: “zero value” for surrounding elevation
  - D_0: initial diameter
  - κt: Degradation state



Fassett and Thomson (2014): Deriving (model) age estimates for individual craters

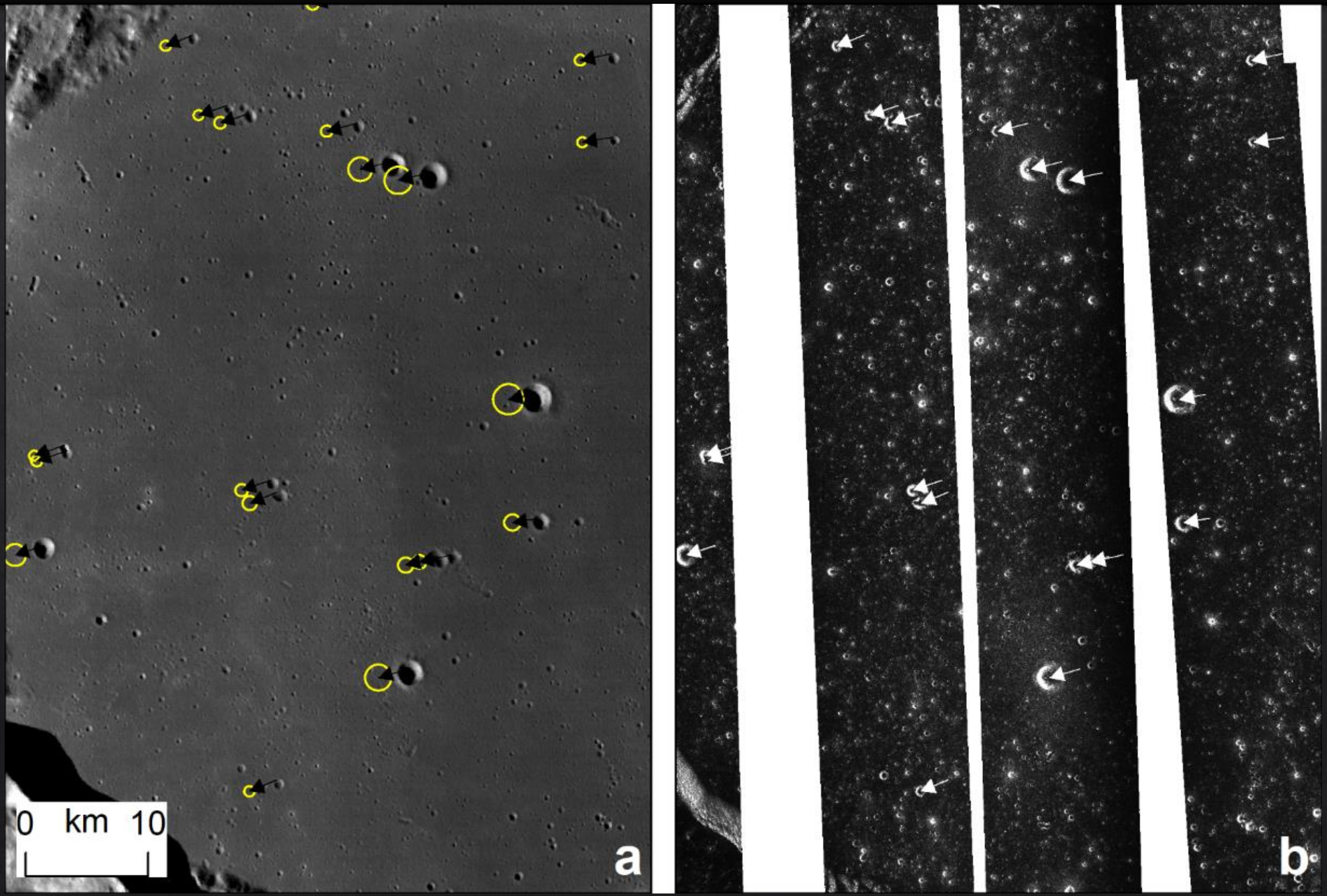


Re-analysis w/ scale-dependent κ_{eff}
(uses 0.9 power law dependence)



Degradation State, κt Age (billions of years)

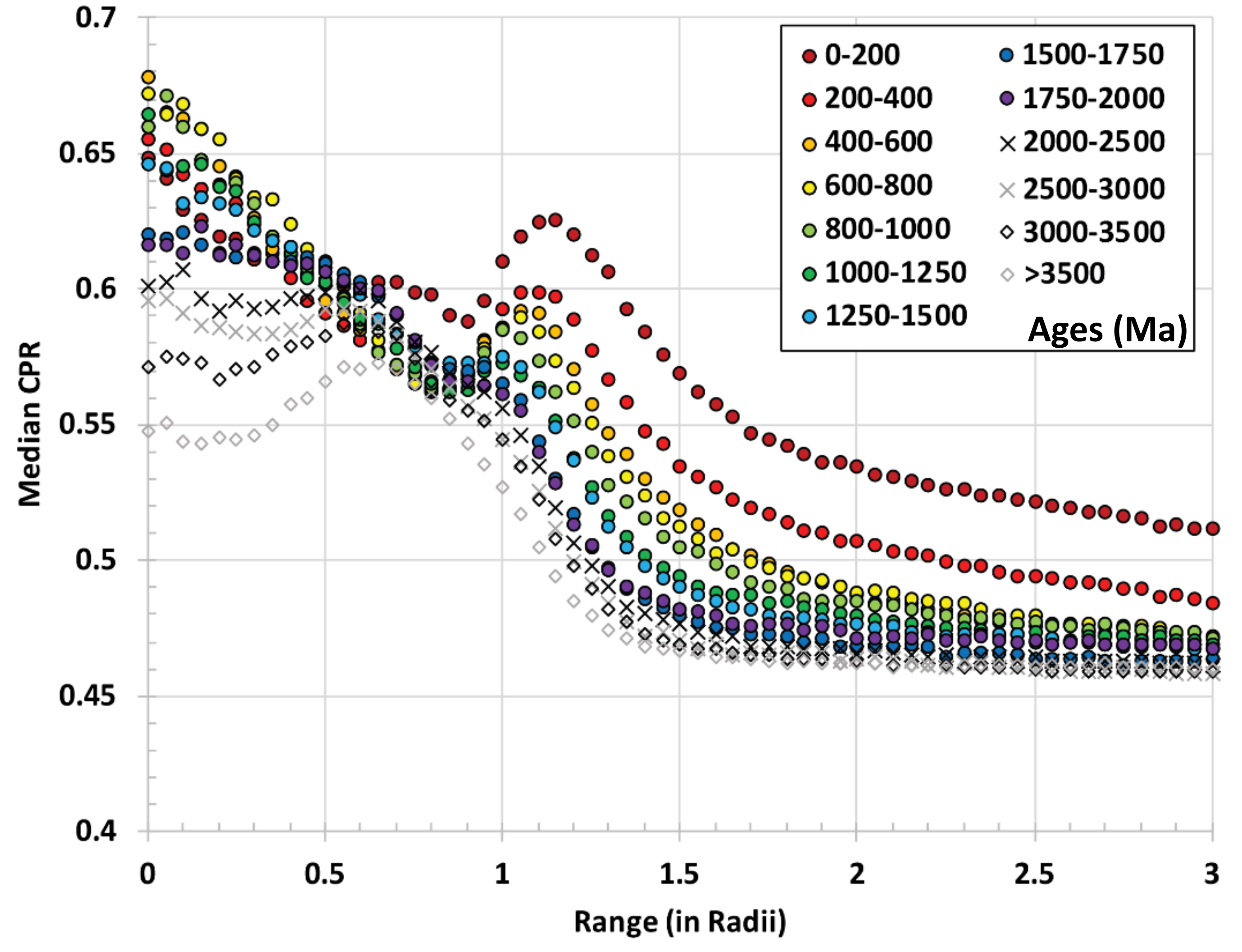
Combining (1) Degradation age estimates from *Fassett & Thomson* 2014 w/ (2) CPR from Mini-RF radar



Ugh: They don't line up

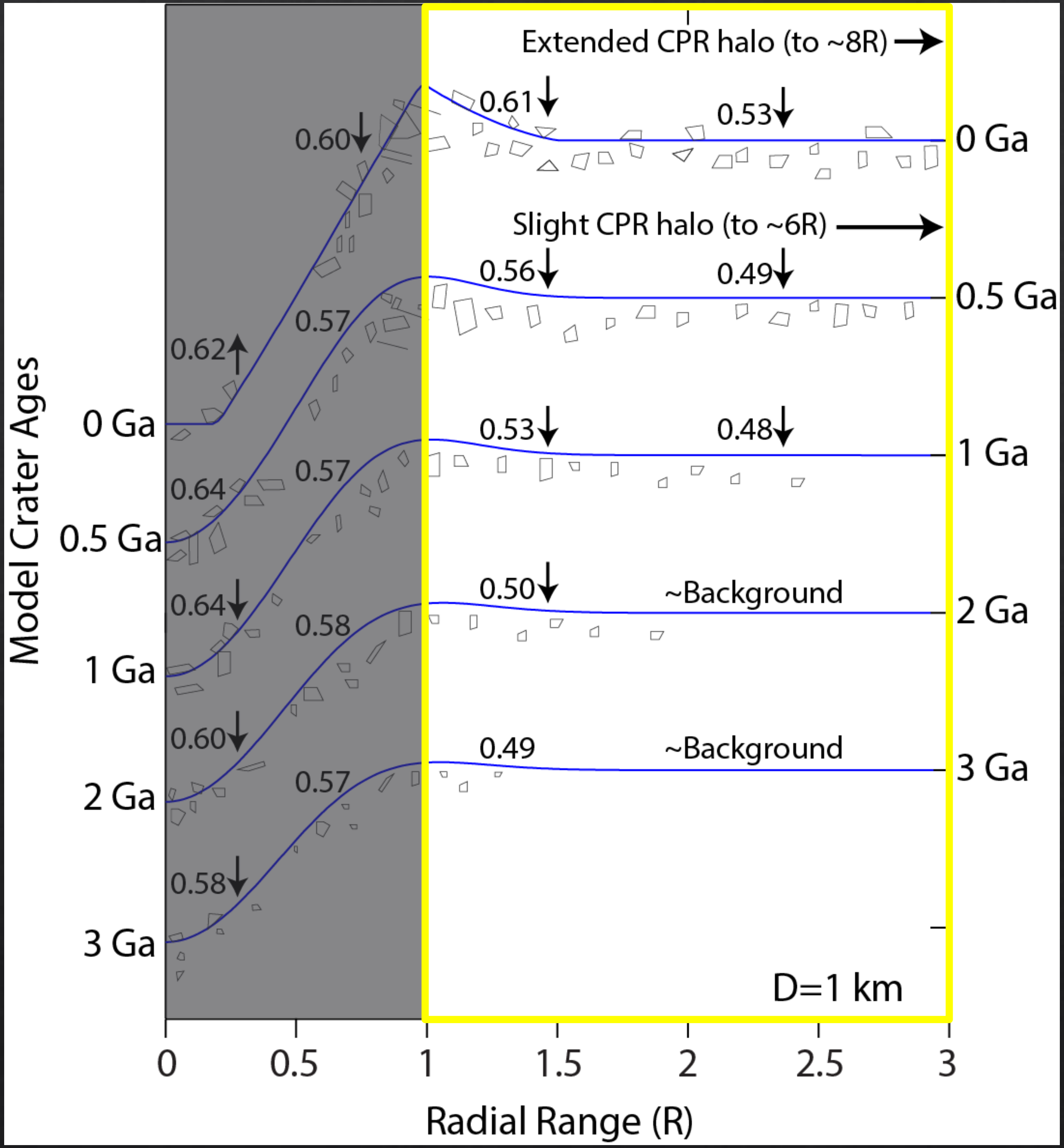
Combining (1) Degradation age estimates from *Fassett & Thomson* 2014 w/ (2) CPR from Mini-RF radar

- Ultimately co-registered 6,206 craters in 800m-2km size range.
- Extracted CPR data as a function of radial range, R (R=1 is the rim).
- Binned the CPR data by model age and 0.05R increments in range R.



Key Observations

- Exterior CPR only declines.
  - Beyond R~1.5: Reaches background in ~2 Ga.
  - From rim to R=1-1.5, enhanced CPR over ~lifetime of maria.
- Central interior CPR initially increases (~500 Ma), then declines.
  - Rock-producing, eroding upper wall slopes remain rocky over lifetime of maria.



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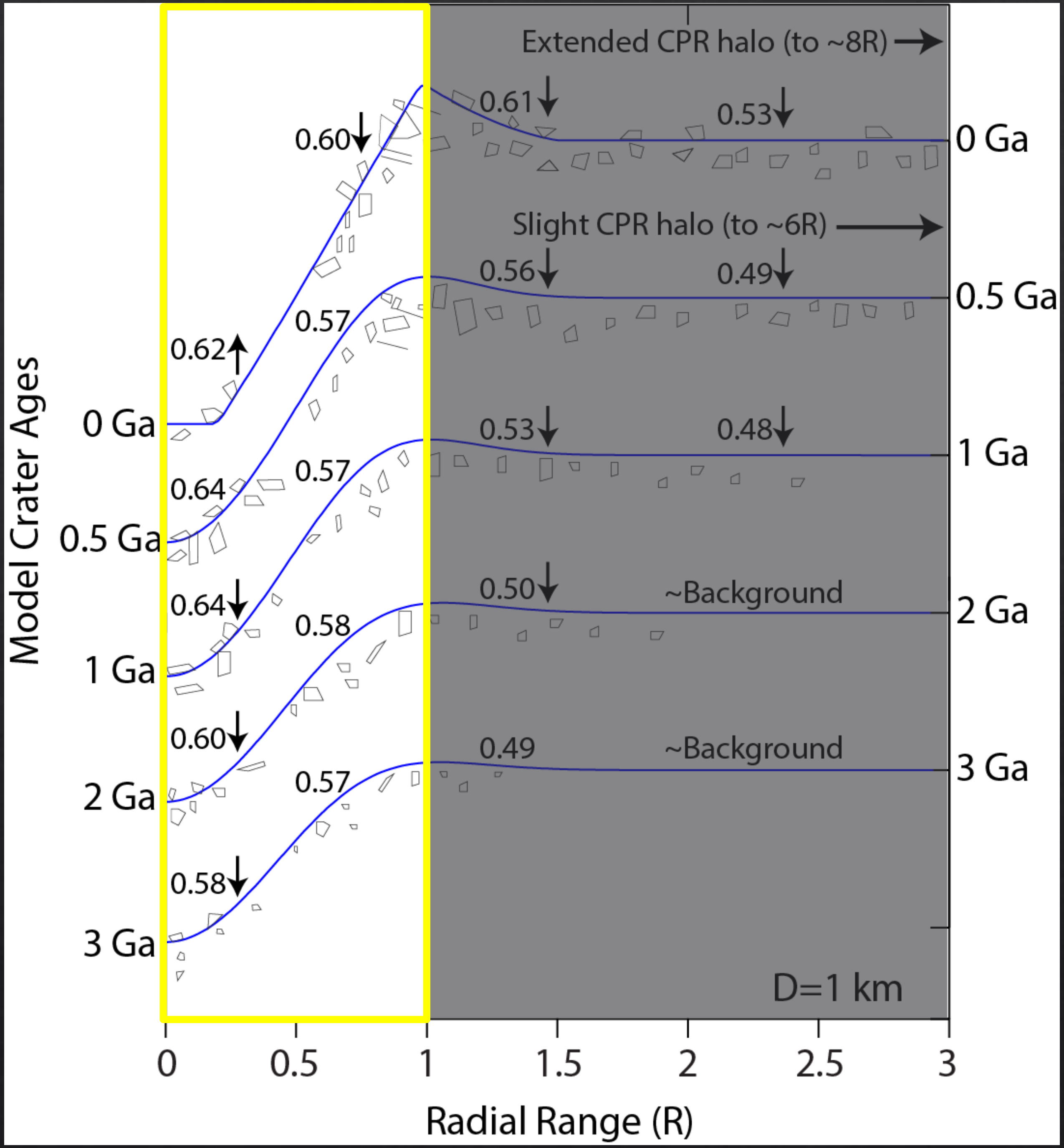
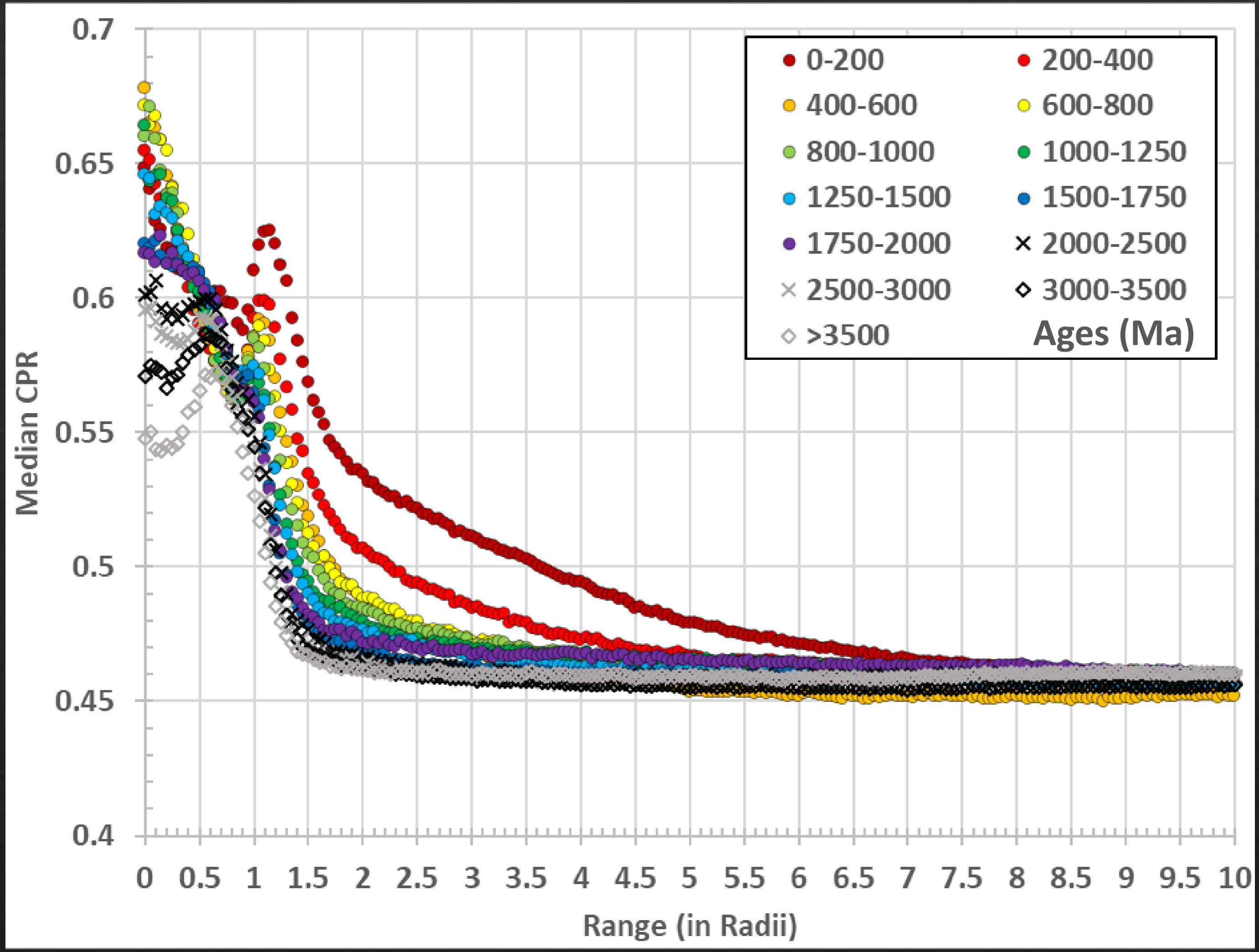


Implications / Interpretation

- Data helps constrain regolith evolution + transport:
  - Clasts in meters-thick part of ejecta can be buried and survive for billions of years.
  - In distal thinner ejecta, clasts get these are destroyed at ~surface rates.
  - *See: Basilevsky et al, 2013, 2015; Huang et al., 2018*



Implications / Interpretation

- Interior and exterior shows a decoupled evolution that forms "anomalous"-appearing craters.
  - Anomalous craters can form without requiring interior water ice.
  - *See also: Fa+ Eke, 2018*

- Note: This does not rule out the idea that some polar craters with high CPR interiors have water ice in their regolith.

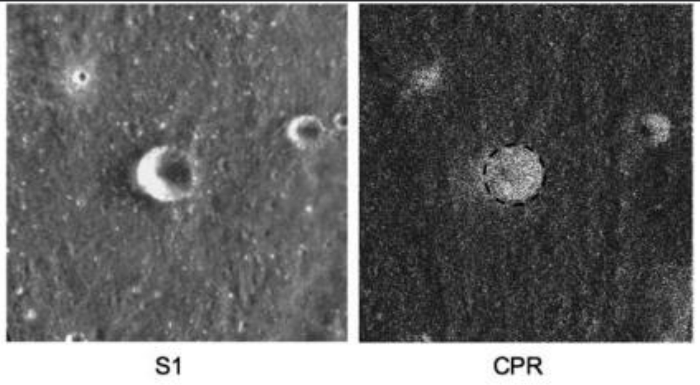
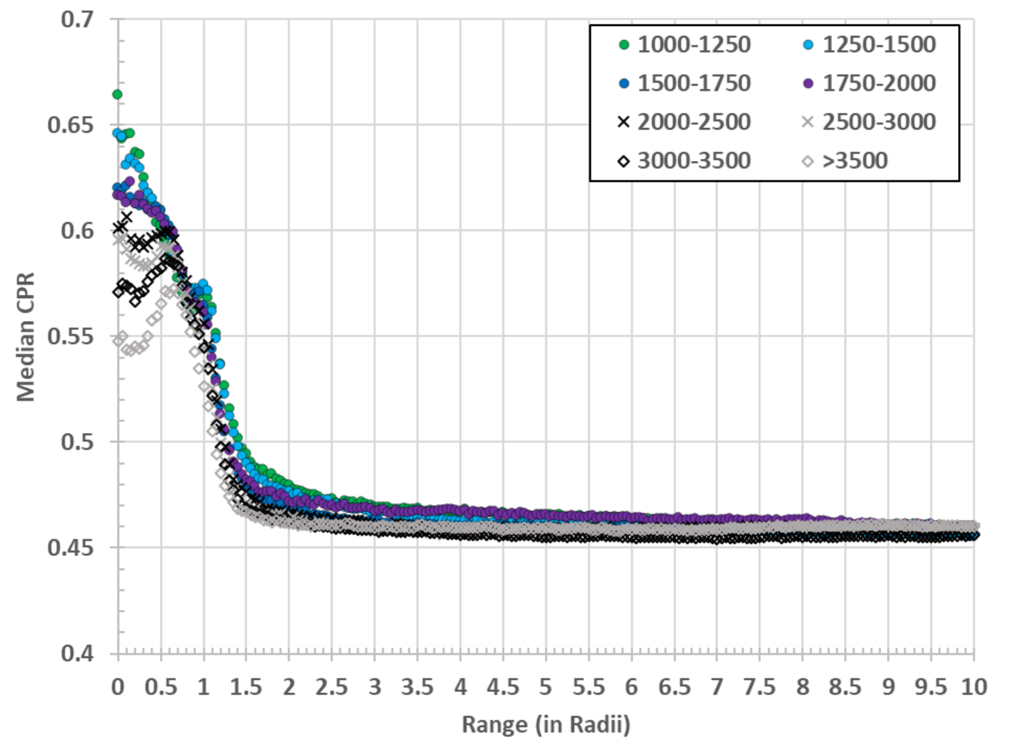


Figure 4. (top row) Main L (14 km diameter; 81.4°N, 22.6°E) is a "normal" fresh, young crater showing nearly identical high CPR both interior and exterior to its rim crest (dashed circle). (bottom row) Rozhdestvensky N (9 km diameter; 84.0°N, 202.6°E) is a polar anomalous crater showing high CPR only within its rim crest (dashed circle on CPR image).

Spudis et al., 2013



Conclusions

- Data helps constrain regolith evolution + transport.
  - Generally consistent with existing models for rates.
- Interior and exterior evolution is decoupled, forming “anomalous” craters.
  - Limits need for ice in “anomalous” polar craters’ interiors.