Evolution of Gas and Foam in Lunar Floor-Fractured Craters

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SSERVI Exploration Science Forum

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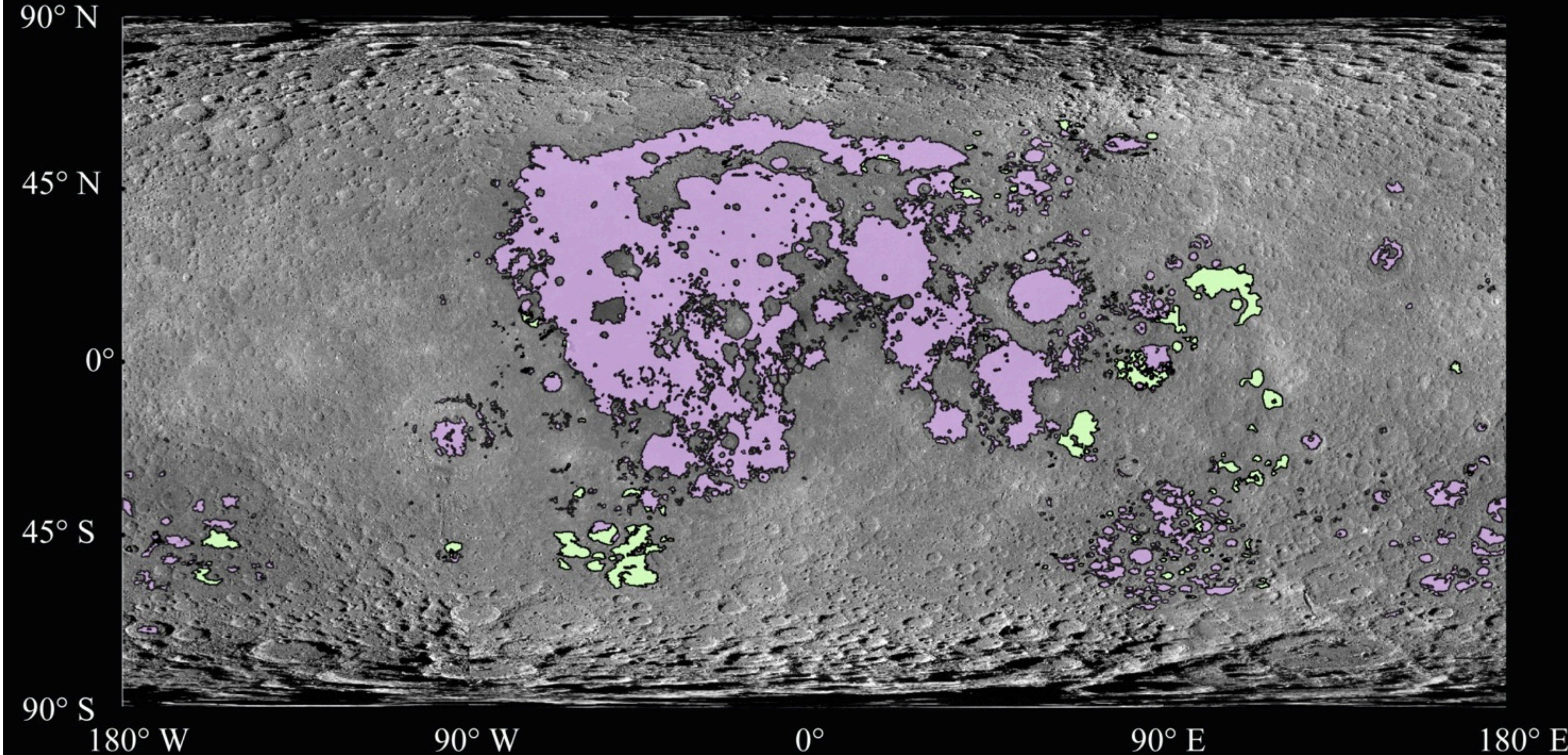
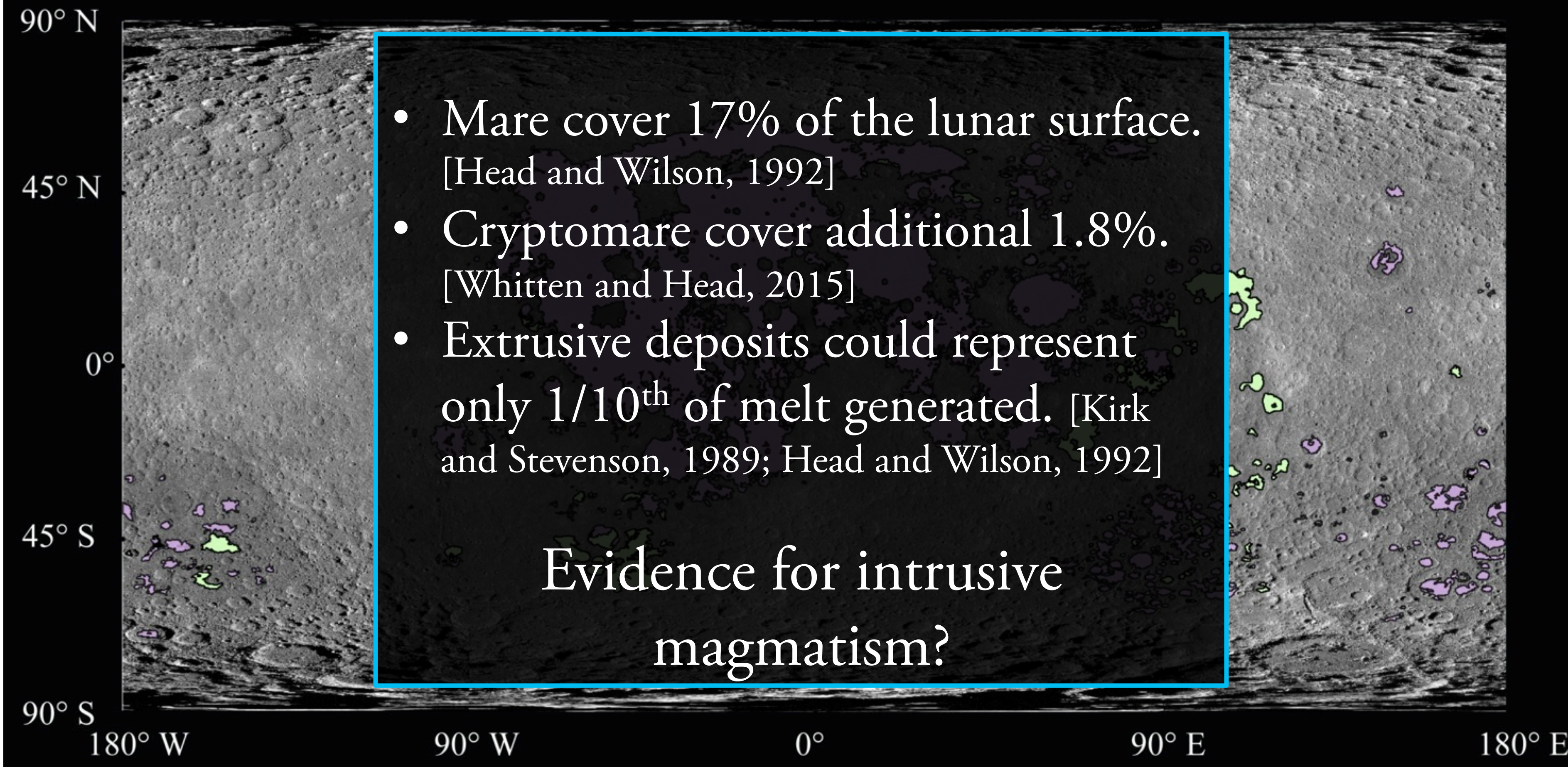
Lunar Volcanism



Mare Distribution: USGS
Cryptomare Distribution: Whitten and Head (2015)

Lunar Volcanism



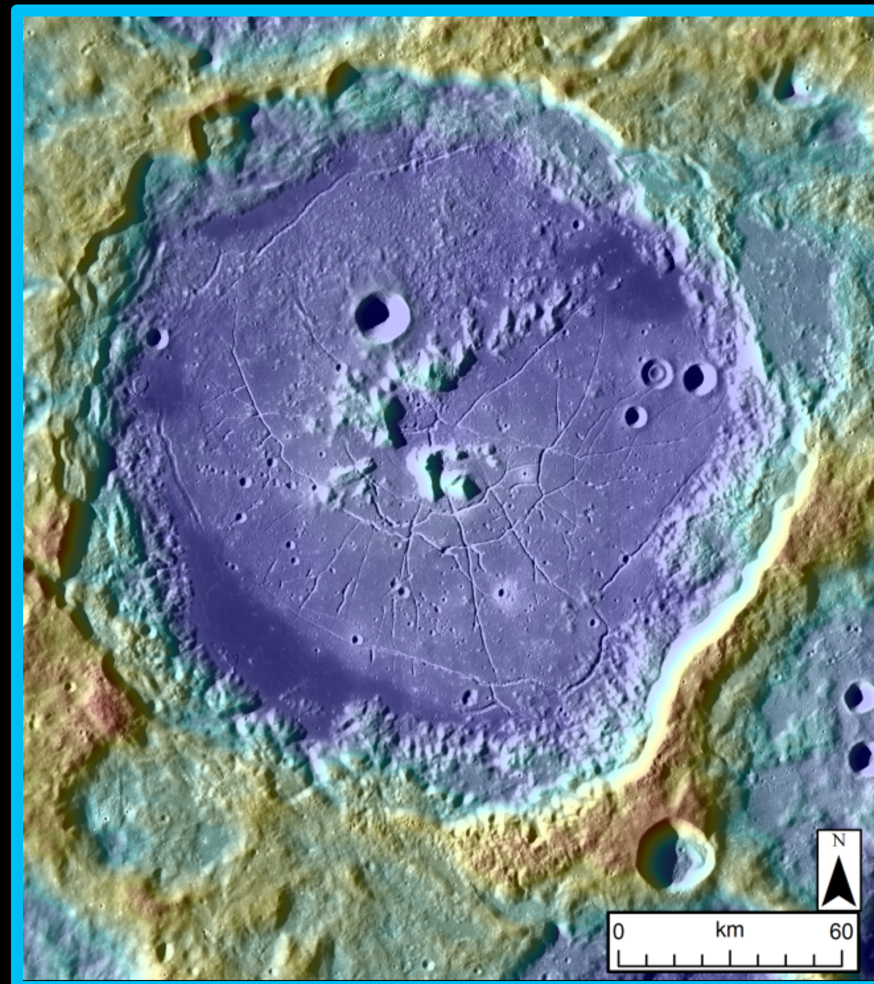
- Mare cover 17% of the lunar surface. [Head and Wilson, 1992]
- Cryptomare cover additional 1.8%. [Whitten and Head, 2015]
- Extrusive deposits could represent only 1/10th of melt generated. [Kirk and Stevenson, 1989; Head and Wilson, 1992]

Evidence for intrusive magmatism?

Mare Distribution: USGS
Cryptomare Distribution: Whitten and Head (2015)

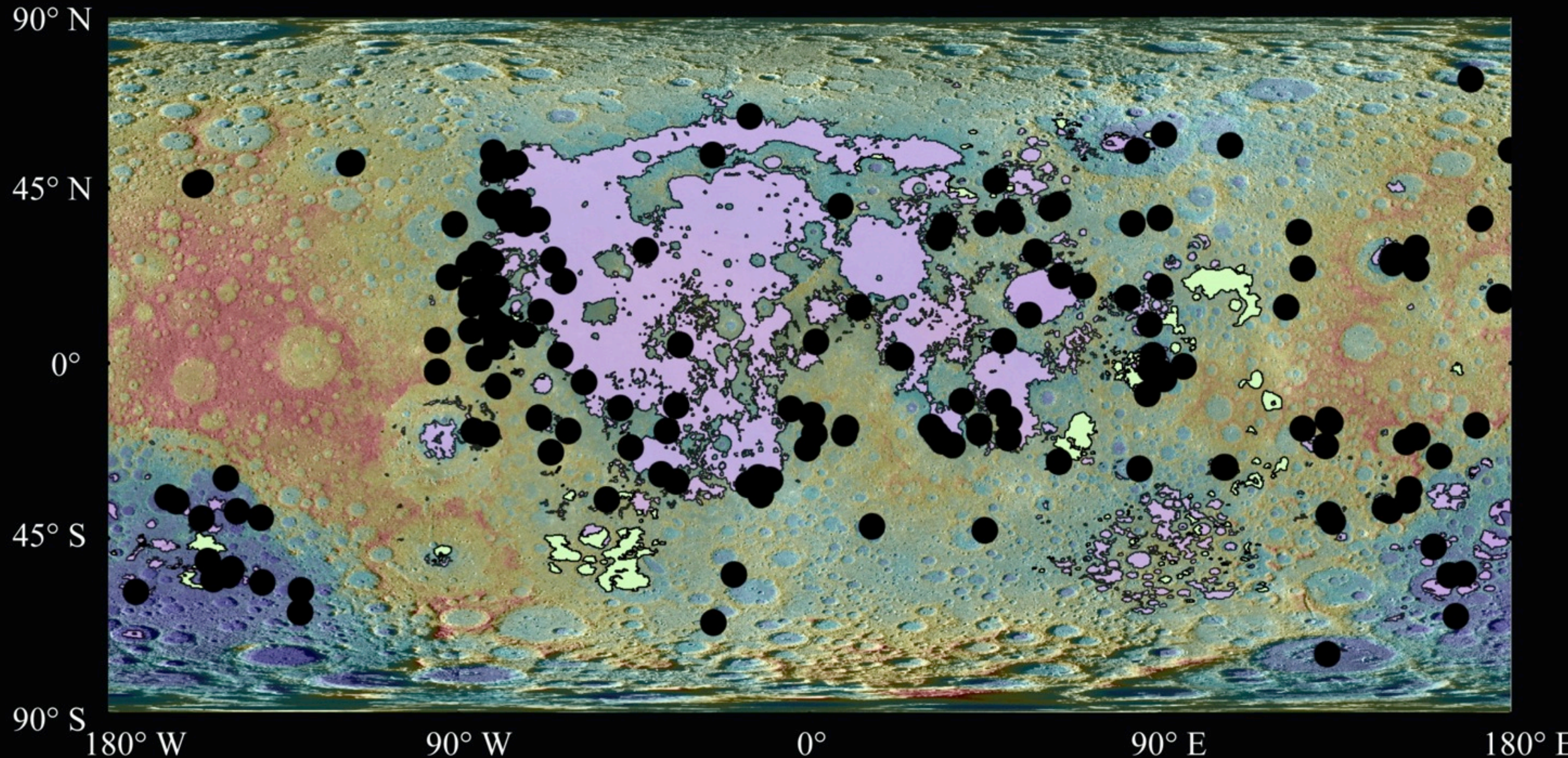
Lunar Floor-Fractured Craters

- Anomalously shallow craters with fractured floors. [Schultz, 1976]
- 170 craters. [Jozwiak et al., 2012)
- Diameter range:
  13 - 208 km. [Jozwiak et al., 2012]
- 8 morphologic subclasses.
  [Schultz, 1976; Jozwiak et al., 2012]



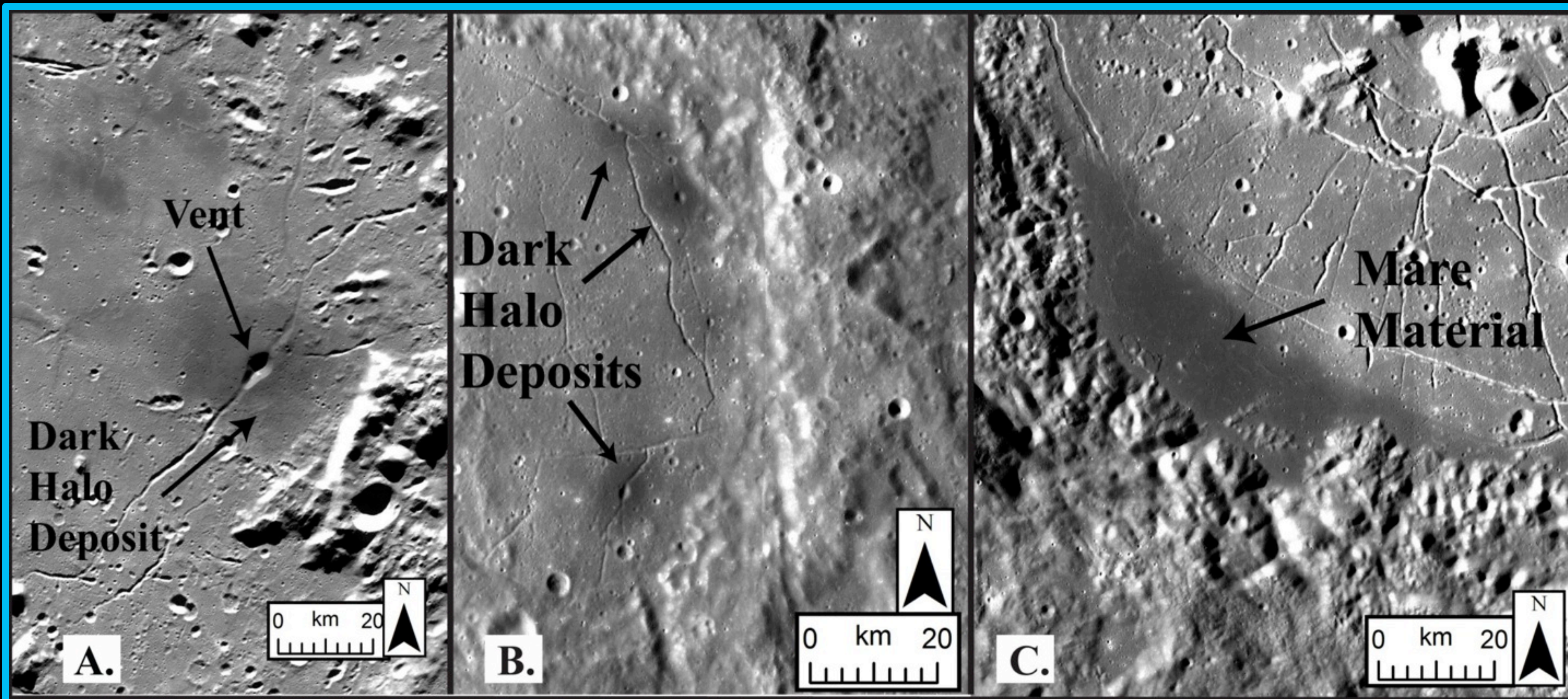
Crater Humboldt, D= 207 km
(LOLA +LROC-WAC)

Floor-Fractured Crater Distribution, N=170



Floor-Fractured Crater Distribution: Jozwiak et al. (2012)
Mare Distribution: USGS
Cryptomare Distribution: Whitten and Head (2015)

Volcanic Morphologies

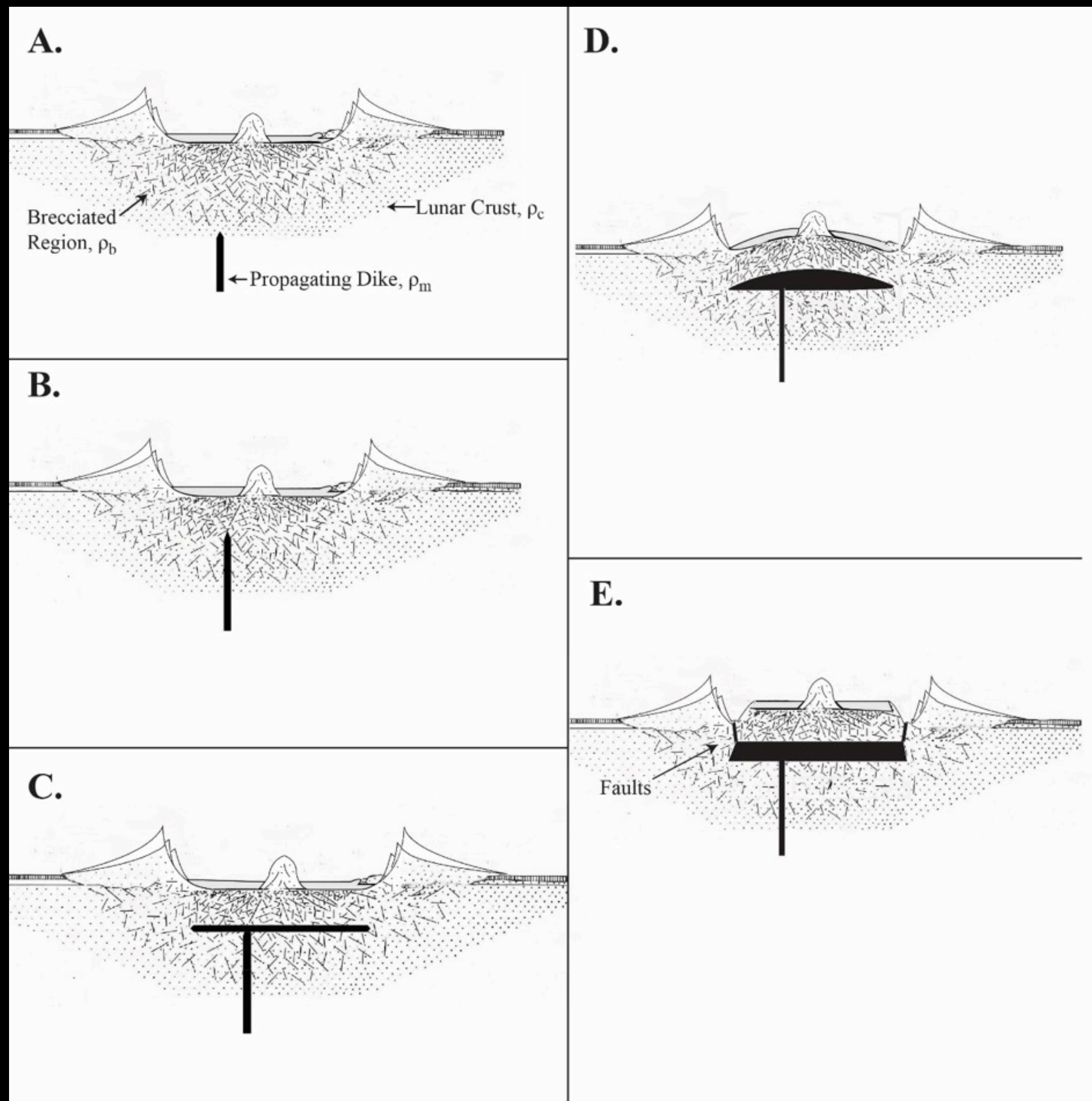


Magmatic Intrusion and Sill Formation

Dike Propagation

Dike Stalling

Sill Formation



Domed End-Member D < 40 km

Flat End-Member D > 40 km

Jozwiak et al. (2015)

Not to scale.

Intrusive Magmatic Volume

- Use floor morphology to estimate intrusion morphology—Domed vs. Tabular.
  - Supported by modeling of floor deformation [Thorey and Michaut, 2014].
- Intrusion thickness= $D_{theoretical} - D_{observed}$
  - Theoretical depth from Pike [1980].
  - Observed depth from LOLA.

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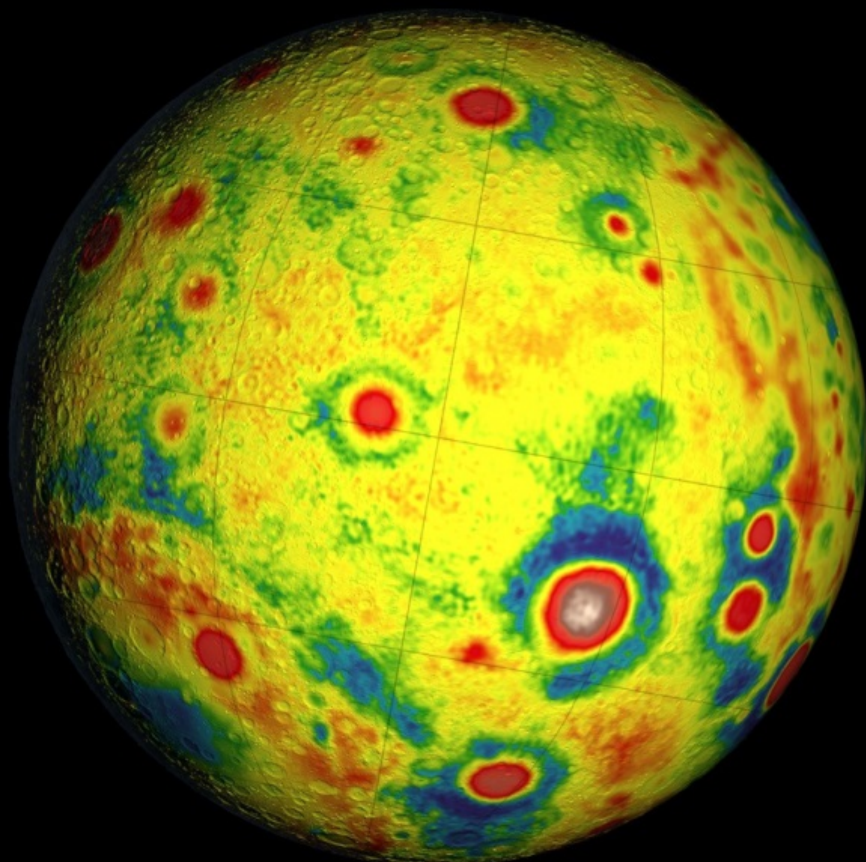
- Estimated volume $\sim 3 \cdot 10^6 \text{km}^3$

Equivalent to 30% of the mare volume!

Investigating Intrusion Structure and Evolution



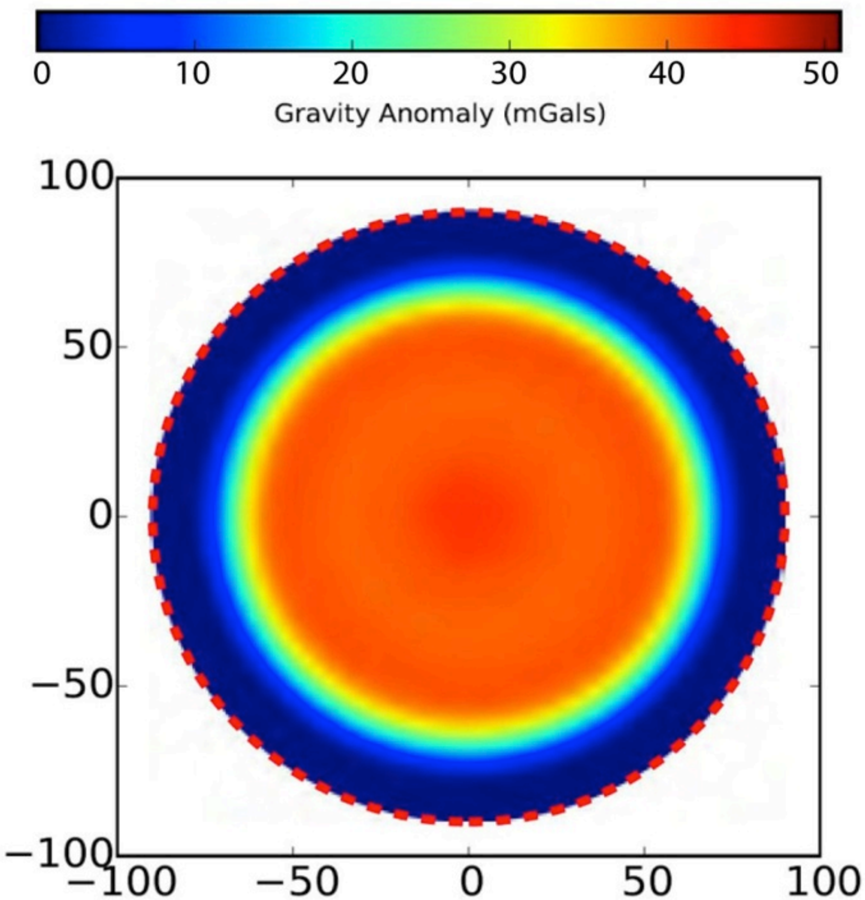
- Bouguer gravity data reveals variations in internal mass distribution.
- Mare basalt density > lunar crustal density.
- Predict intrusions to have distinct, positive anomaly.

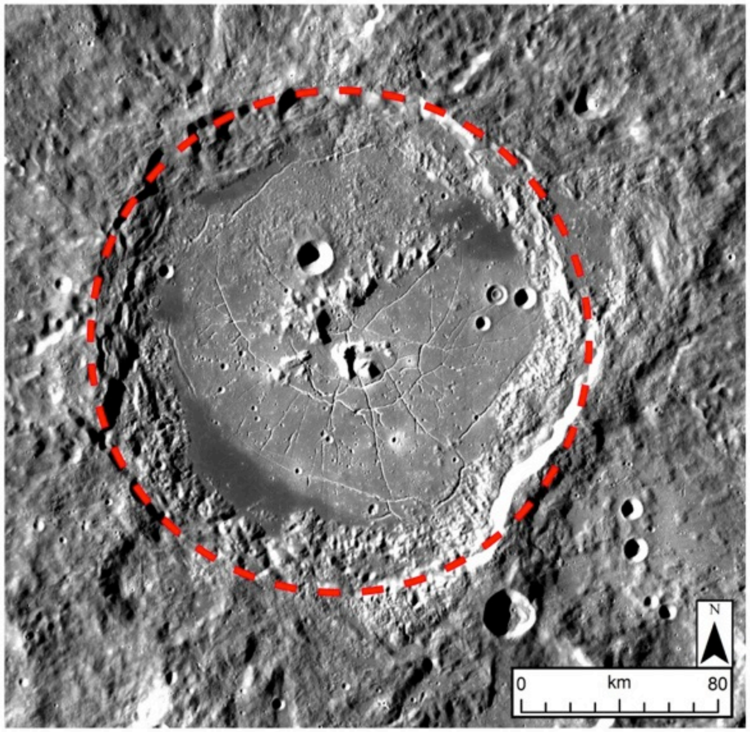
[NASA GSFC/SVS]

Predictions for Bouguer Anomaly

Humboldt

D = 207 km



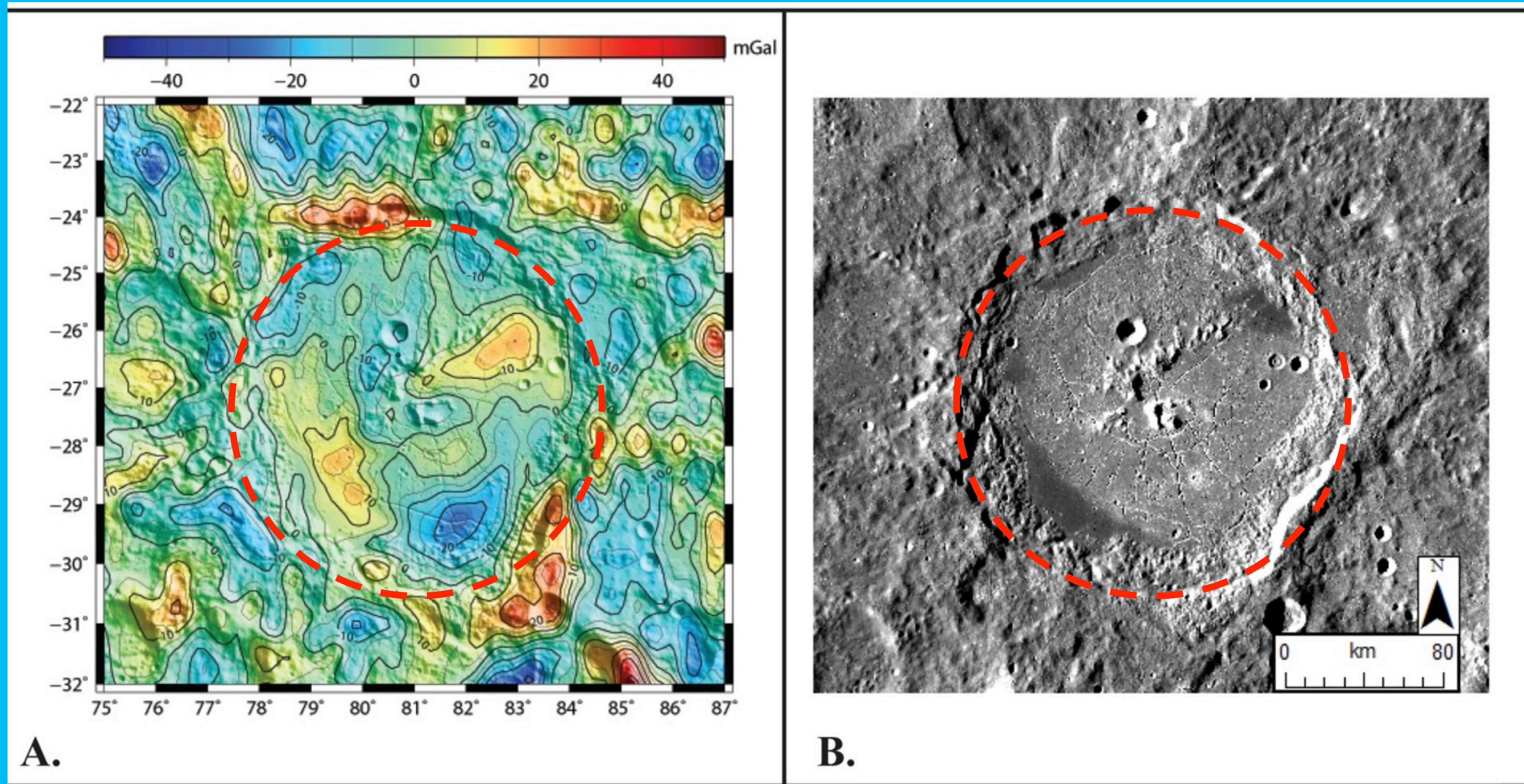


Synthetic Bouguer Gravity
Thorey et al. (2015)

Observed Bouguer Anomaly

Humboldt

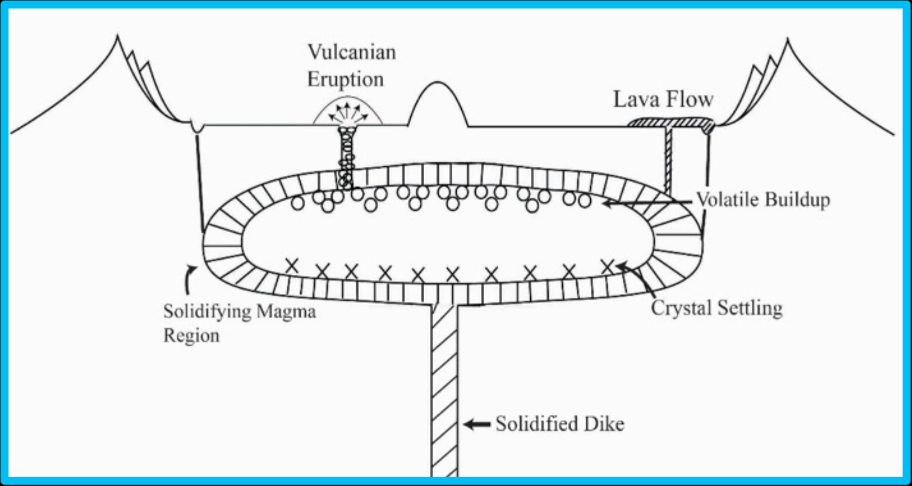
D = 207 km

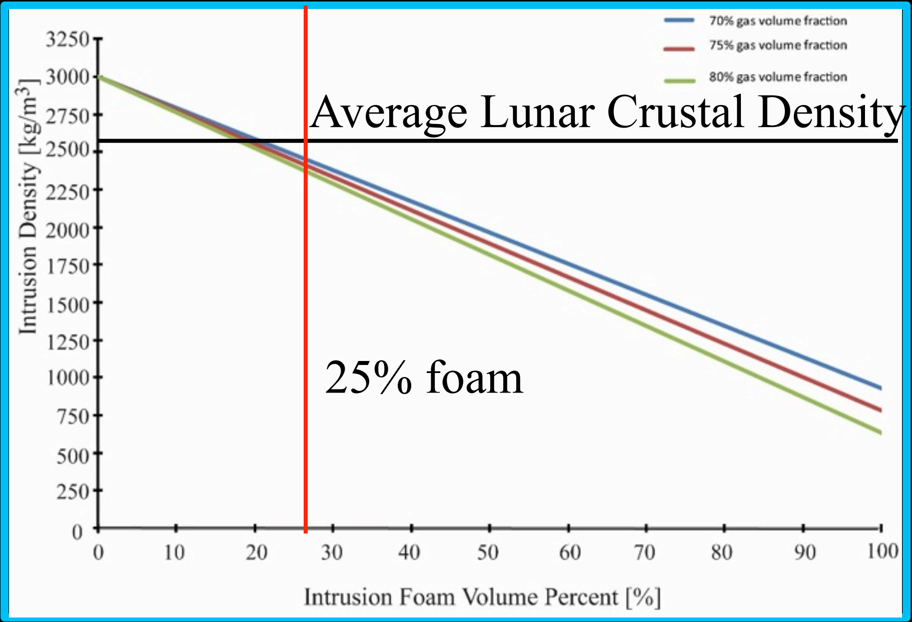


Orders 100-600

LROC-WAC

Degassing of Intrusions



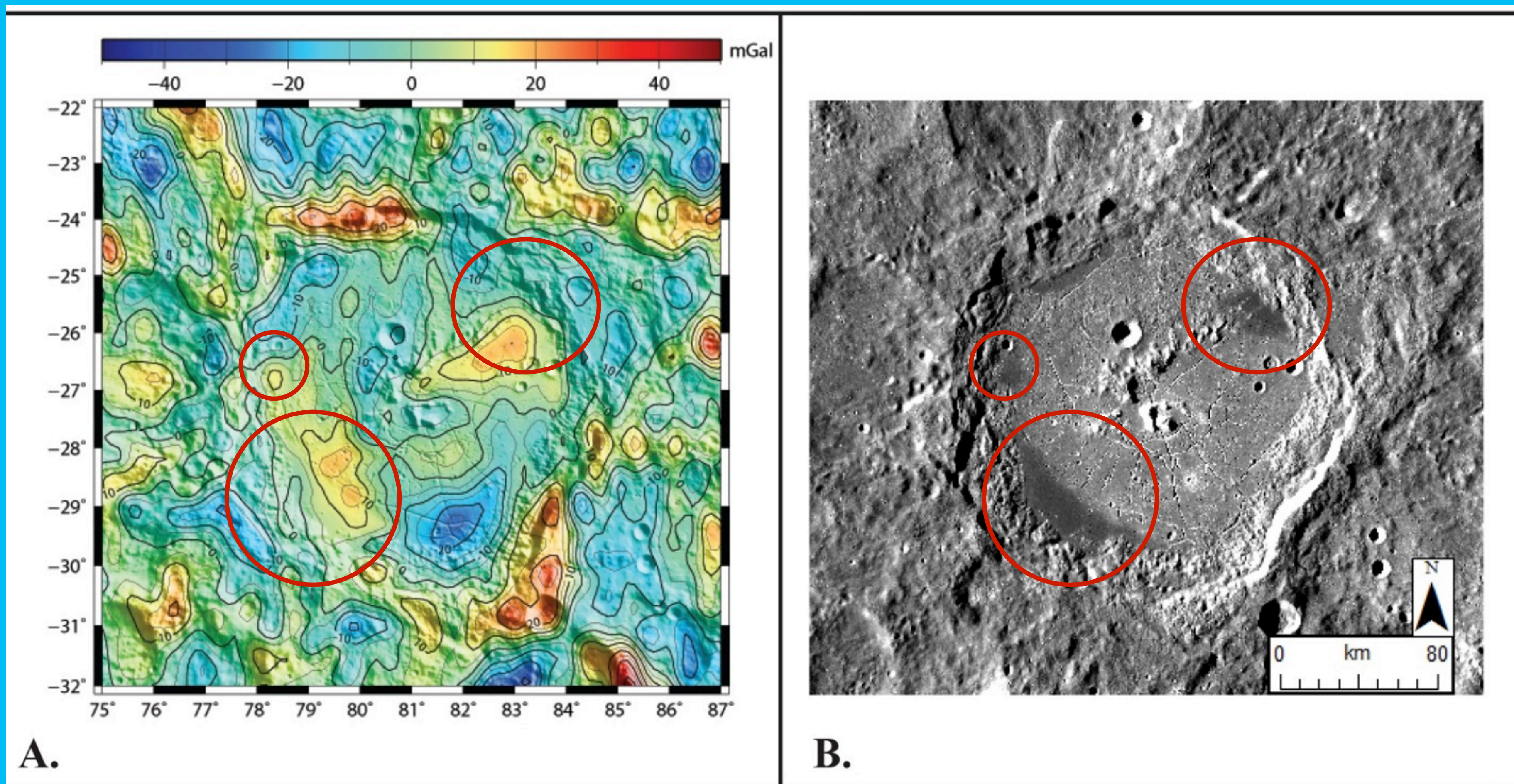


- Smelting reaction in magma between metal oxides and graphite forms CO at shallow depths, and dike propagation concentrates the bubbles in a foam at the dike tip. [Fogel and Rutherford, 1995]
- Additional volatile contributions from H_2O, Cl_2, and F_2 [Saal et al., 2008].
- Bubbles form gas-rich foam at the intrusion roof. [e.g. Jaupart and Vergniolle, 1989; Wilson and Head, 2003]

Correlation with Volcanic Features

Humboldt

D = 207 km



Orders 100-600

LROC-WAC

Implications for Lunar Magmatic Intrusions

- Volatile buildup and degassing is a natural consequence of magmatic intrusion evolution. [Wilson and Head, 2003]
- Variations in foam gas density and foam volume have significant effect on overall intrusion density.
- Process explains observation that higher BA are correlated with surficial volcanic deposits, which would have been formed during initially explosive degassing of the local intrusion region.
- Passive venting can also result in foam loss and density changes.
- The heterogeneous nature of this process and the lunar crust in general means that magmatic intrusions suspected from gravity data can be better understood and often verified when studied in combination with geological data.