China's Chang'e-5 Landing Site: An Overview

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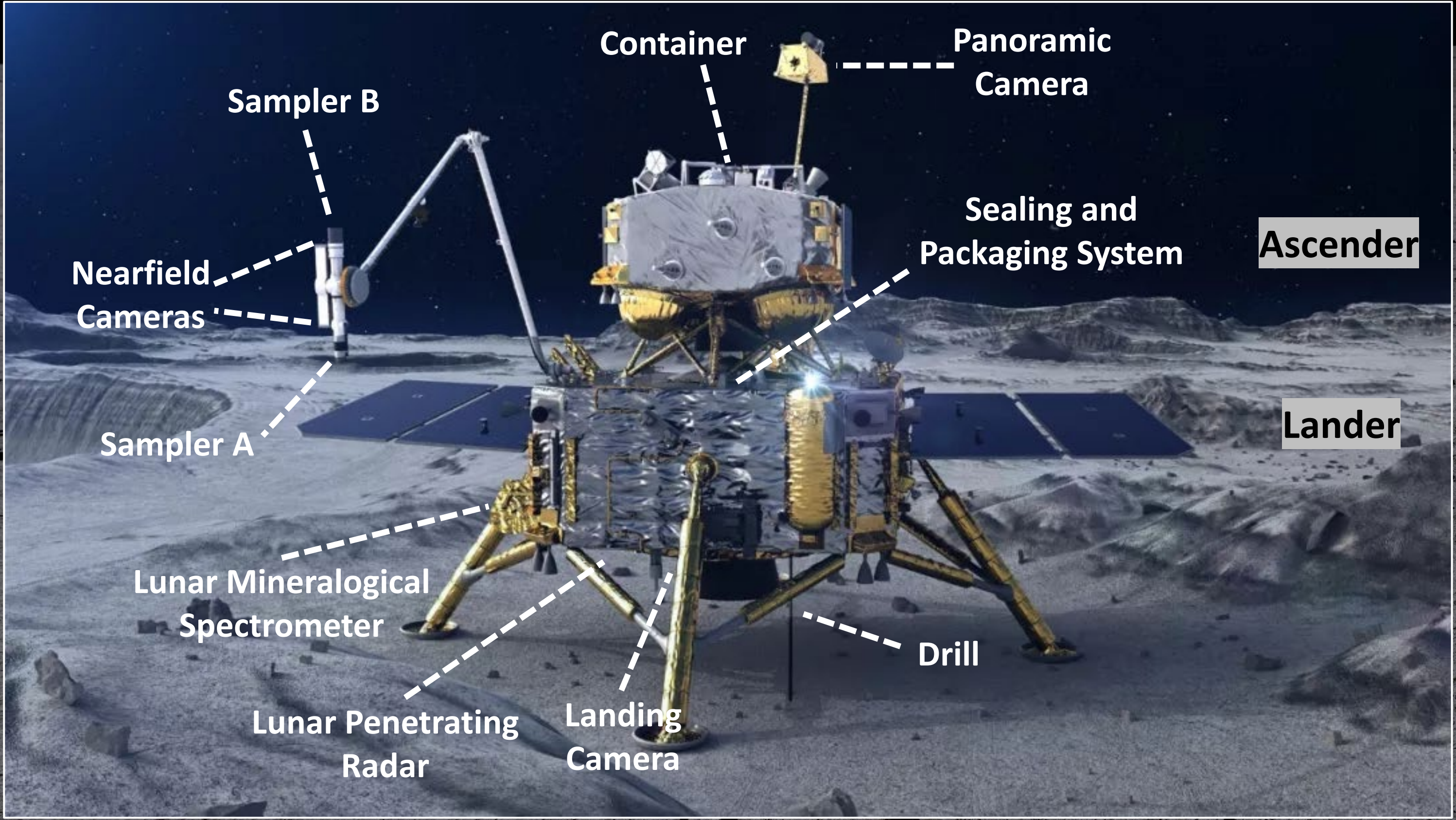
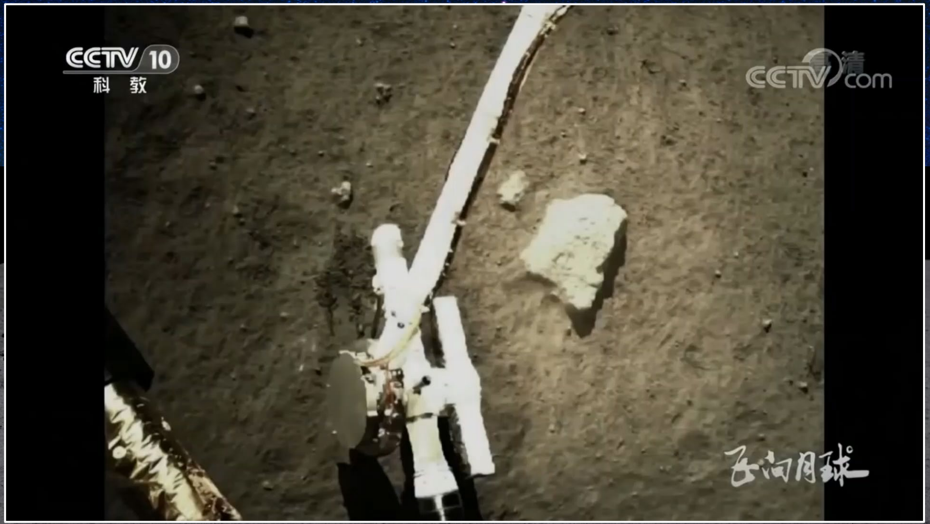
NESF & ELS 2021
July 22nd, 2021

Chang'e-5





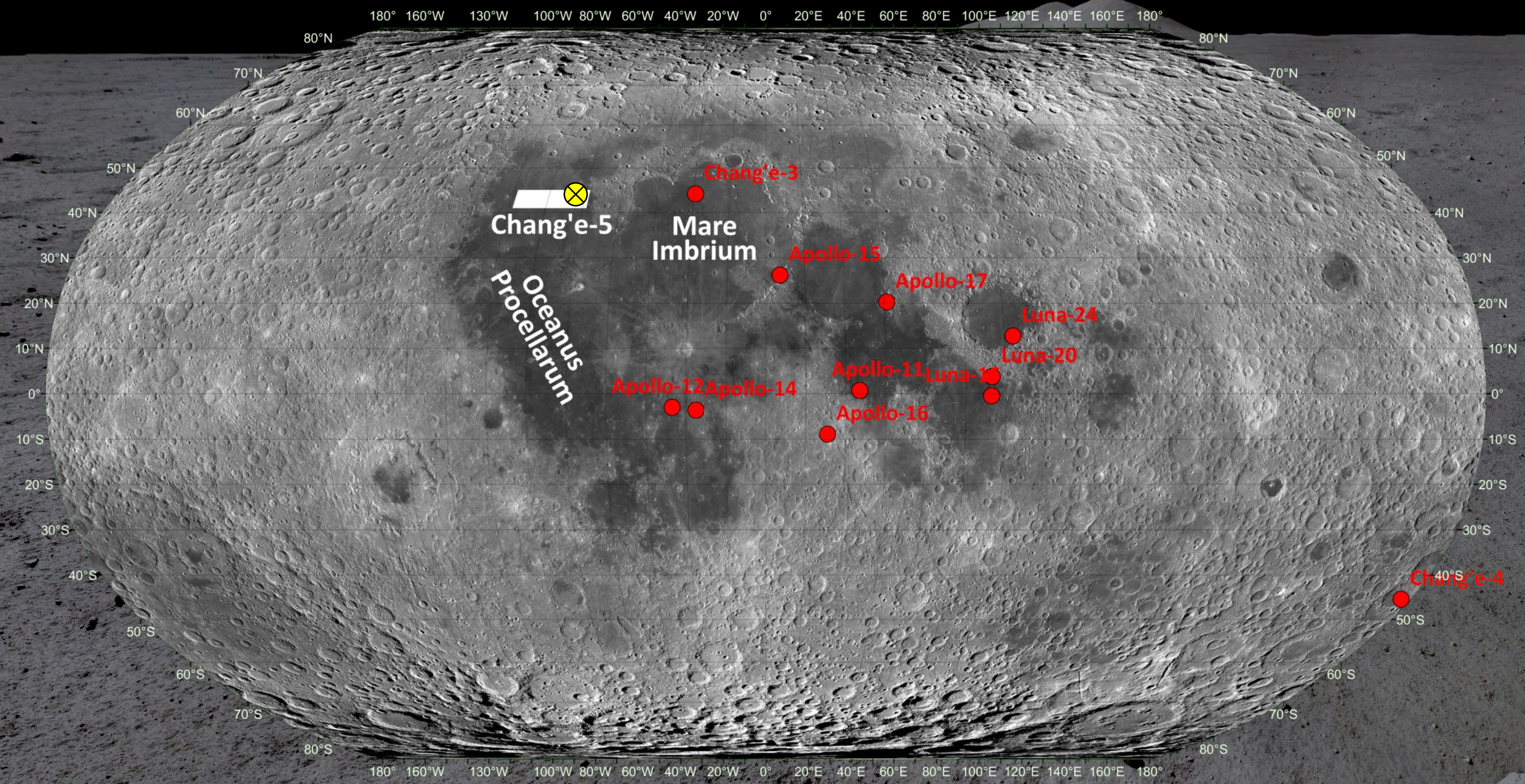

Sampler A


Sampler B

- **Sampler A**: ~35 cm in length, shovel-shaped, used to collect loose regolith
- **Sampler B**: ~30 cm in length, used to collect sticky samples by coring into the ground with teeth-like metal flaps when opened
- **Sealing and Packaging System:** 1.5 kg in weight, used to seal and store the lunar samples for returning to Earth

1,731 g of lunar samples were taken back

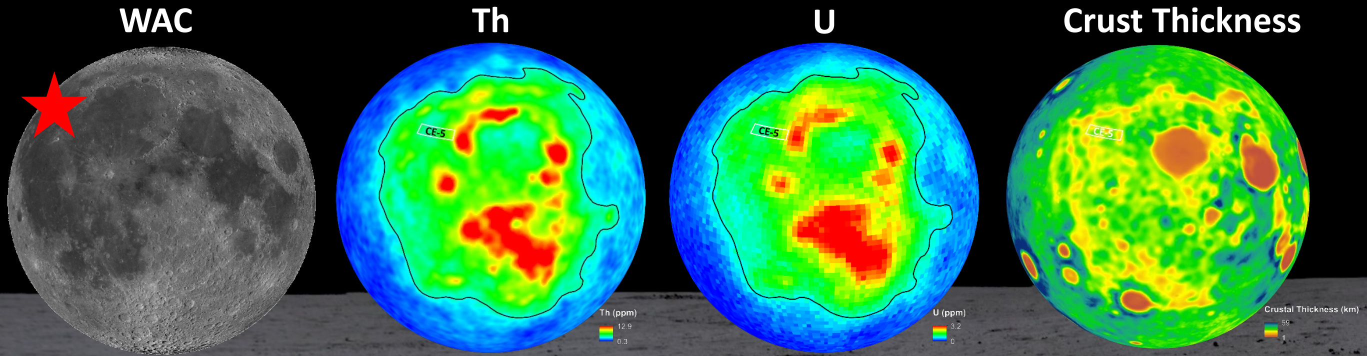
Chang’e-5 Landing Site

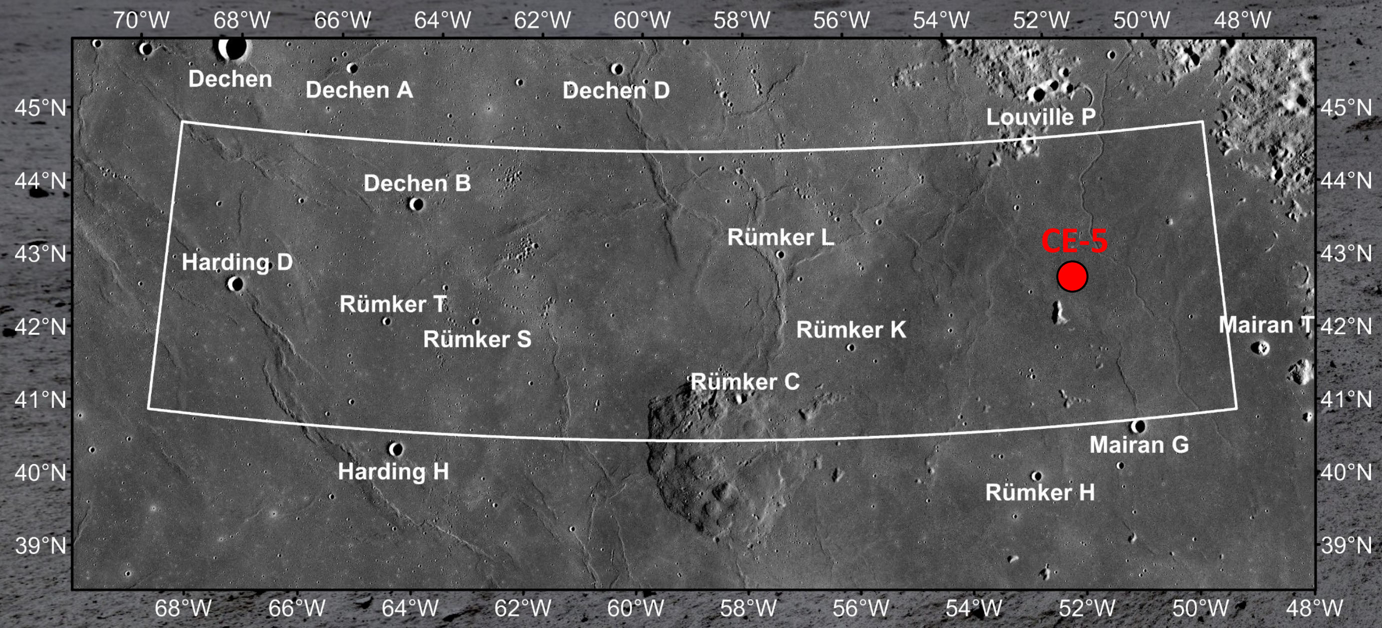


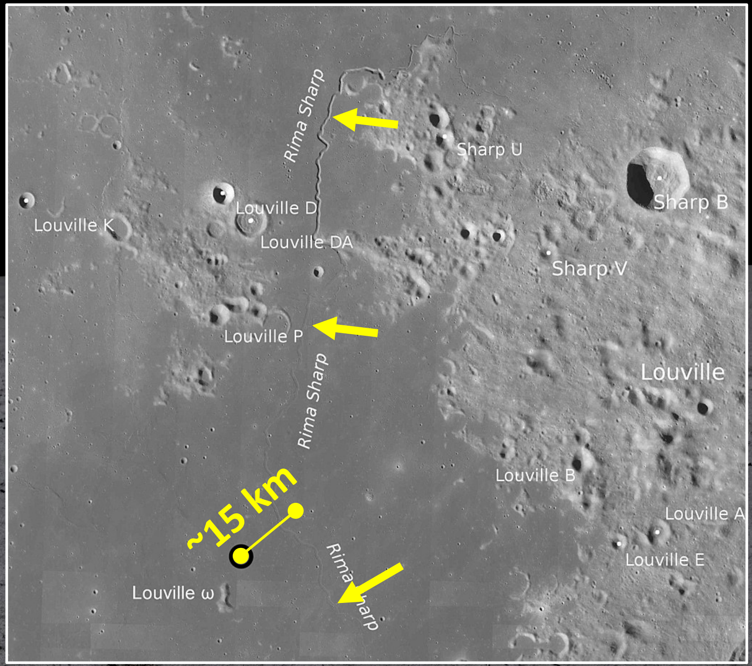
11:13 PM, Dec. 01, 2020, ~1731 g of surface and subsurface samples

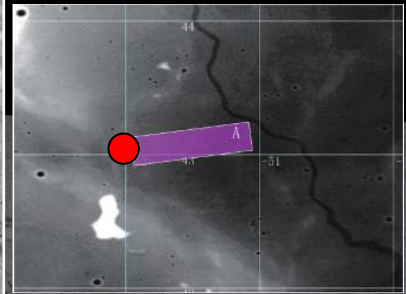
43.06 N, 51.92 W (Wang et al. 2021)

Northern Oceanus Procellarum

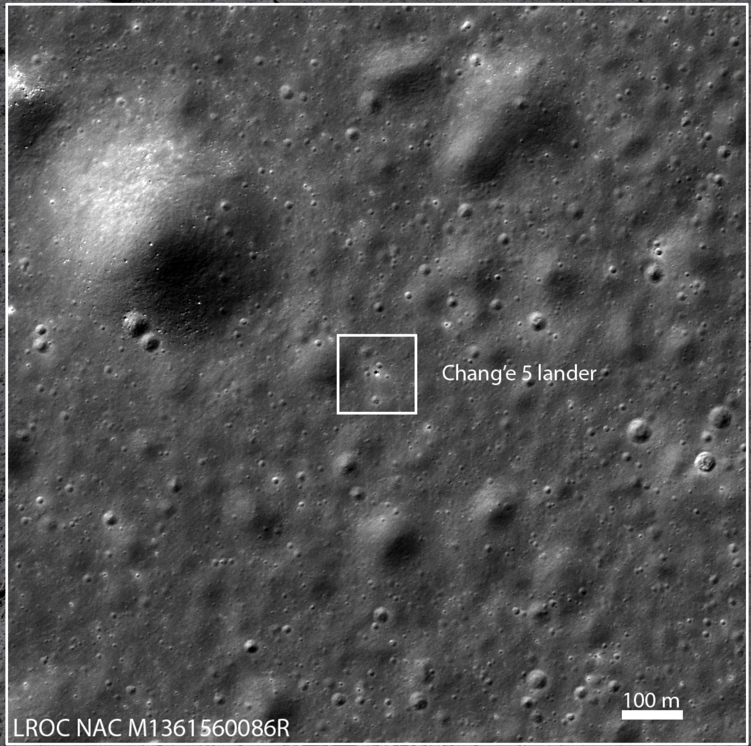


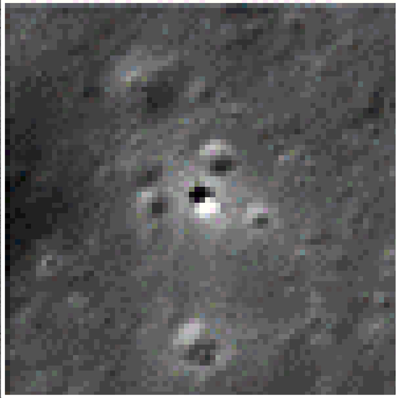






Selected landing zone (Meng et al., 2021)





CE-5 landing point
43.06 N, 51.92 W
(Wang et al., 2021)

Ideal place to study lunar volcanism

Volcanic Plains: Mare basalts, wrinkle ridges

Volcanic Complex: Mons Rümker

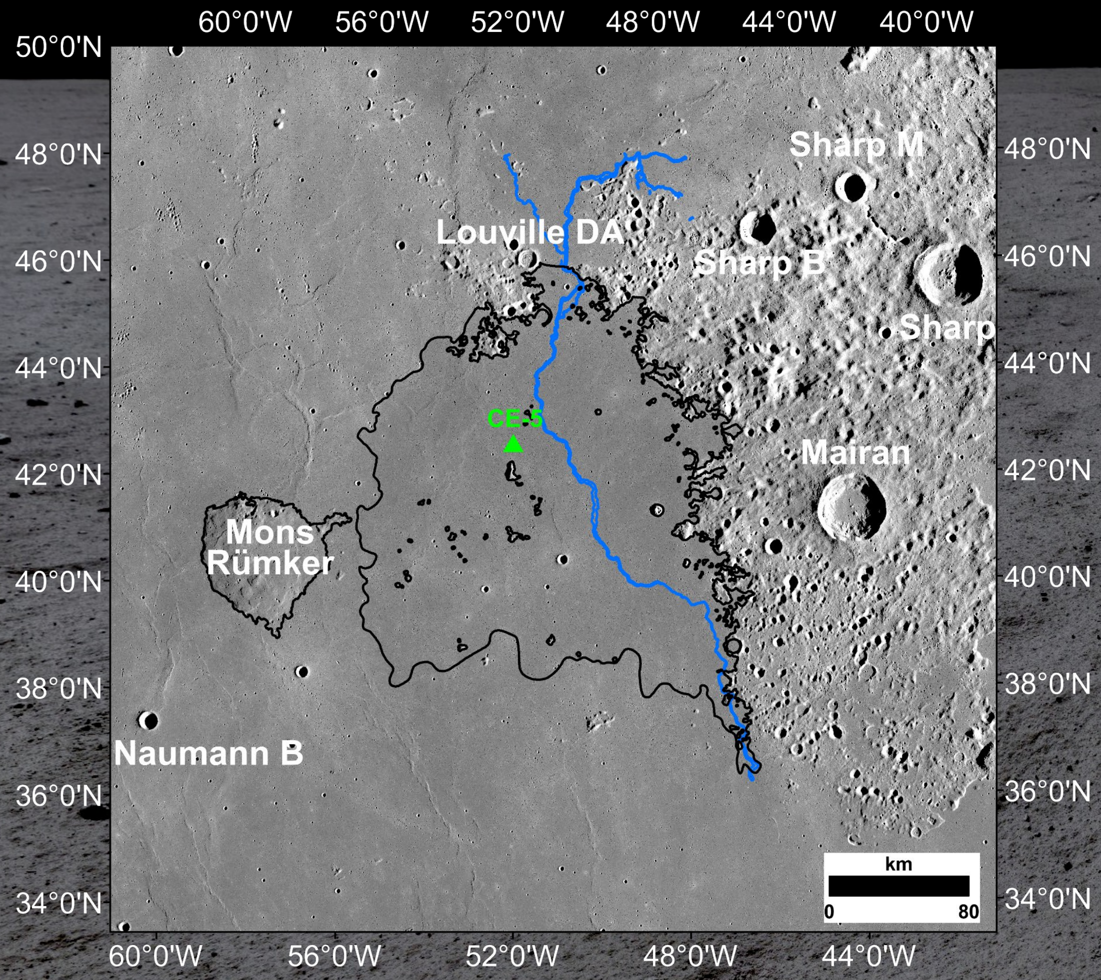
Volcanic Domes: Mairan domes, silica rich, evolved volcanism

Volcanic Channels: Sinuous rilles (Rima Sharp), ~ 566 km, longest on the Moon

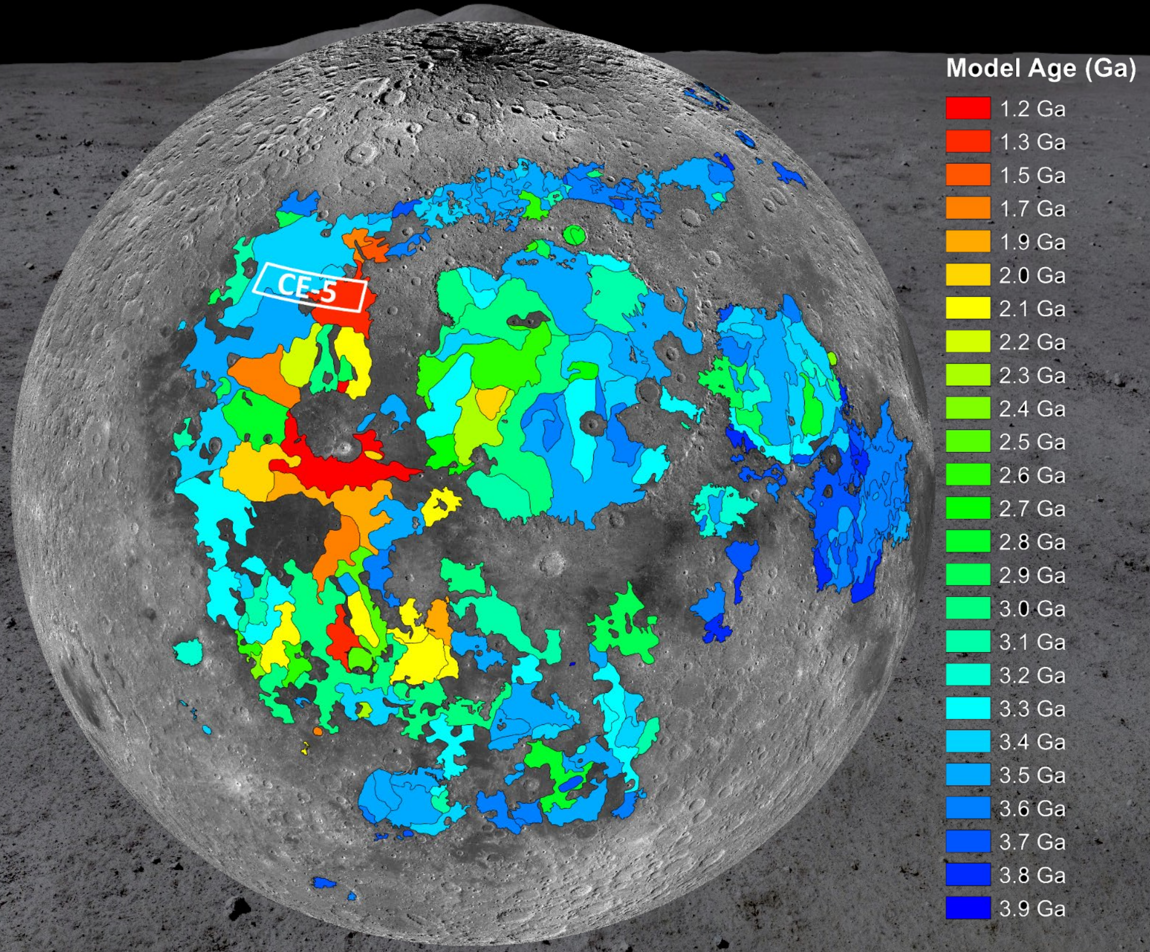
Procellarum KREEP Terrane (Jolliff et al., 2000)

- Geochemical anomaly, elevated heat-producing elements, high heat flux
- Thin crust (Wieczorek et al., 2013)
- Extended volcanism (Hiesinger et al., 2006), especially in central OP

Young Mare Basalts

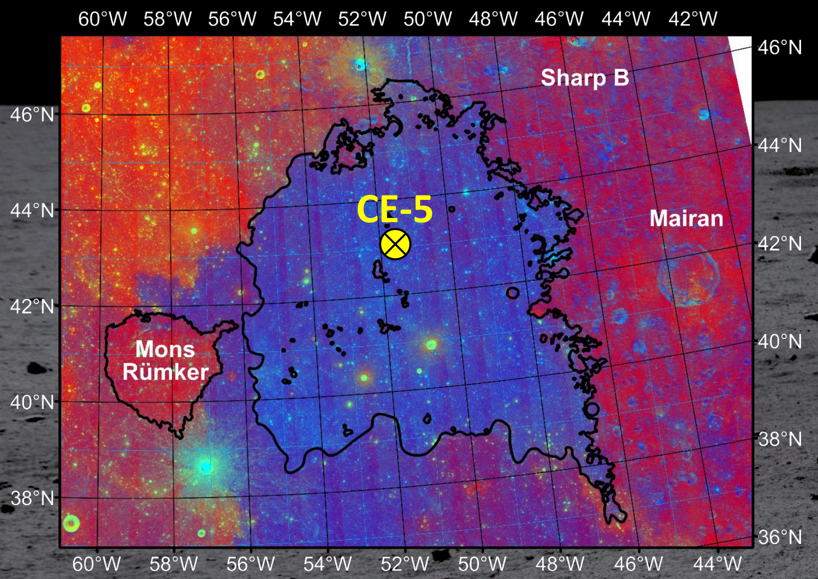


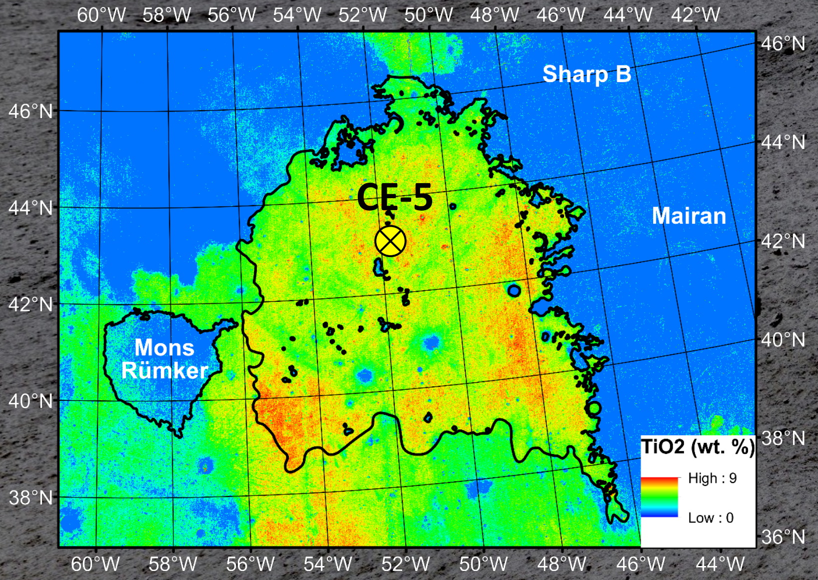
Eratosthenian-aged (~1.53 Ga) intermediate-Ti mare basalts
(Qian et al., 2021, EPSL)



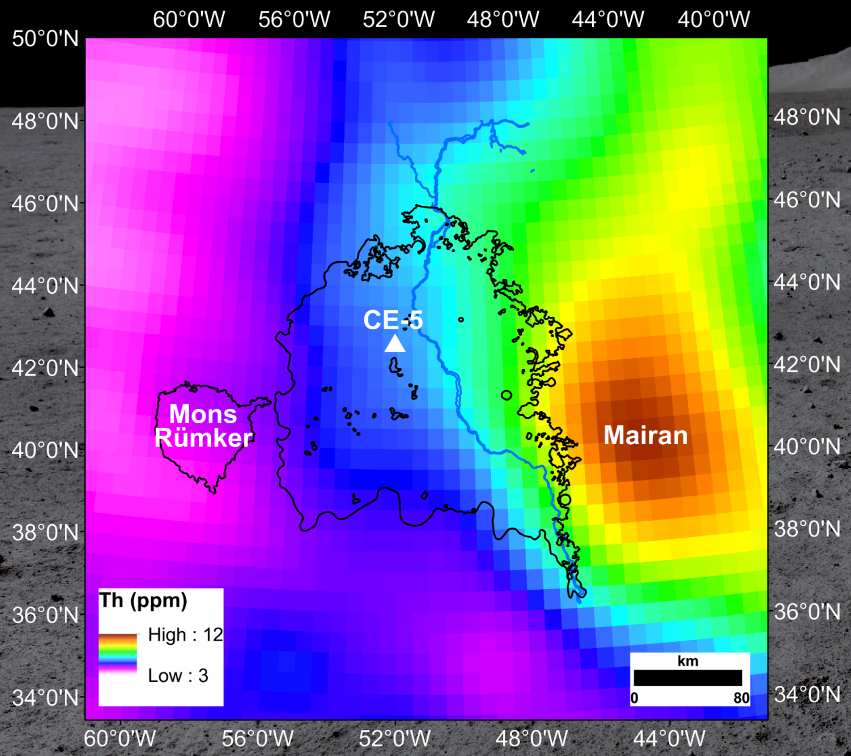
Lunar mare unit age map
(Hiesinger et al., 2011, JGR)

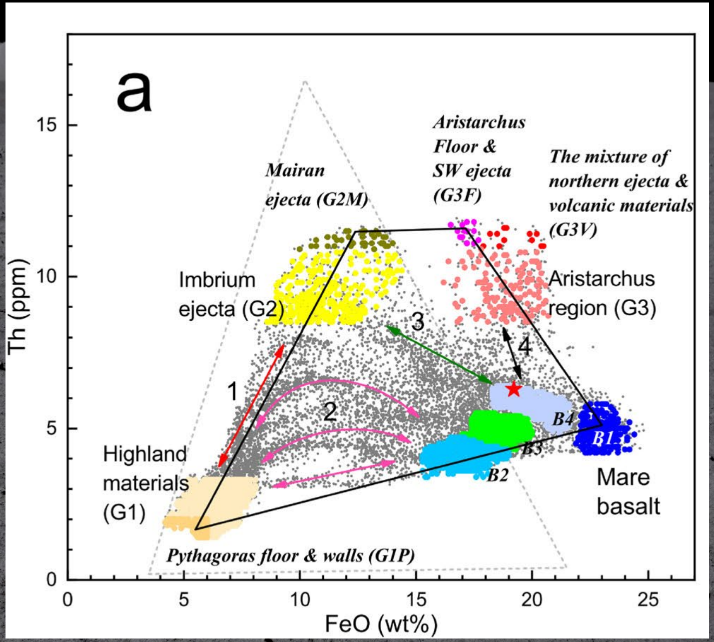
Young Mare Basalts: Composition





Intermediate-Ti mare basalts





Fu et al., 2021, JGR-Planets

Unmix 12 FeO-Th endmembers, thorium is indigenous to basalts.

Inherent Hypothesis

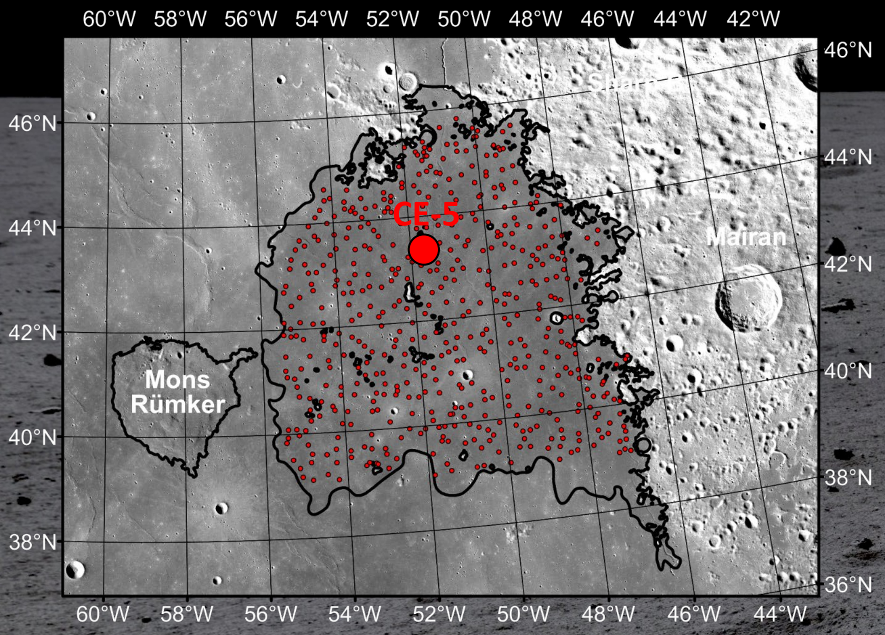
- Assimilation of high-Th materials when the magma rises
- Abnormal concentration of Th in the mantle source
- Example : Apollo 12 thorium-rich mare basaltic rock fragment (12032,366-18) can not be explained by simple mixing (Jolliff et al., 2005, LPSC; Barra et al., 2006, GCA; Stadermann et al., 2021, LPSC)

Extraneous Origin Hypothesis

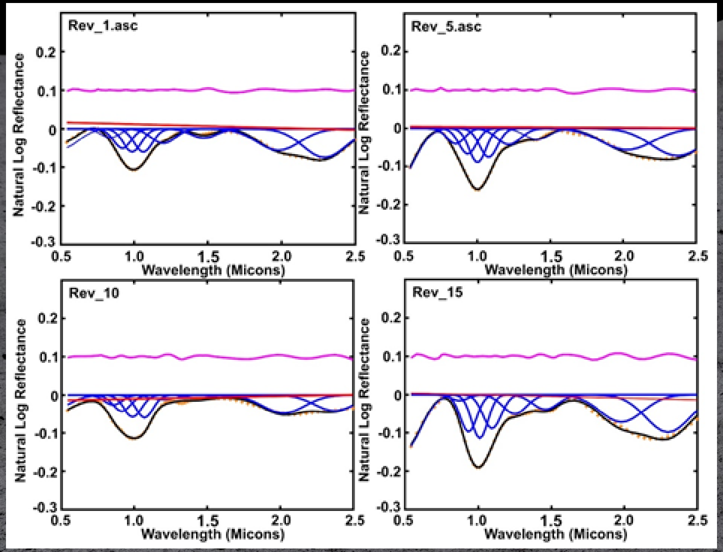
- Contamination of high-Th crustal materials by vertical and lateral mixing
- Example: Apollo 12 soils, composed of ~ 46% nonmare high-Th materials from Copernicus and Reinhold craters (Korotev et al., 2000)

If thorium is extraneous, where do they come from? What is the thermal source for the young mare basalts?

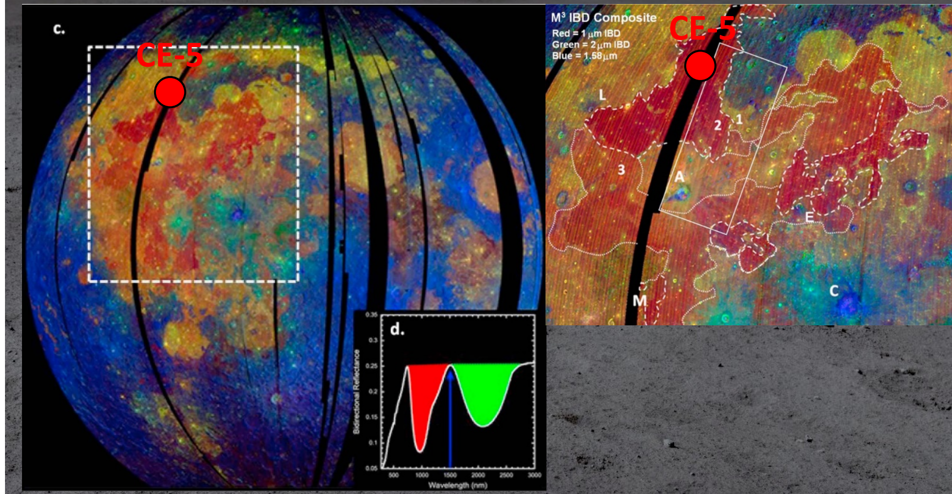
Young Mare Basalts: Mineralogy

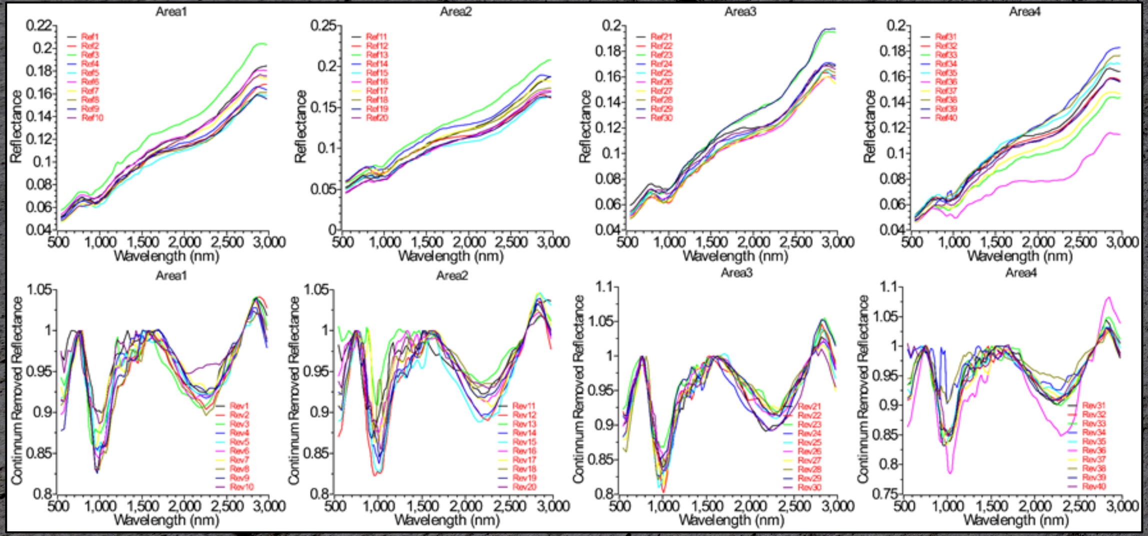


(Qian et al., 2021, EPSL)



Nearside IBD color composite
(Staid et al., 2011, JGR)





Modified Gaussian Model

- CPX: 47%
- OPX: 32%
- OLV: 21%

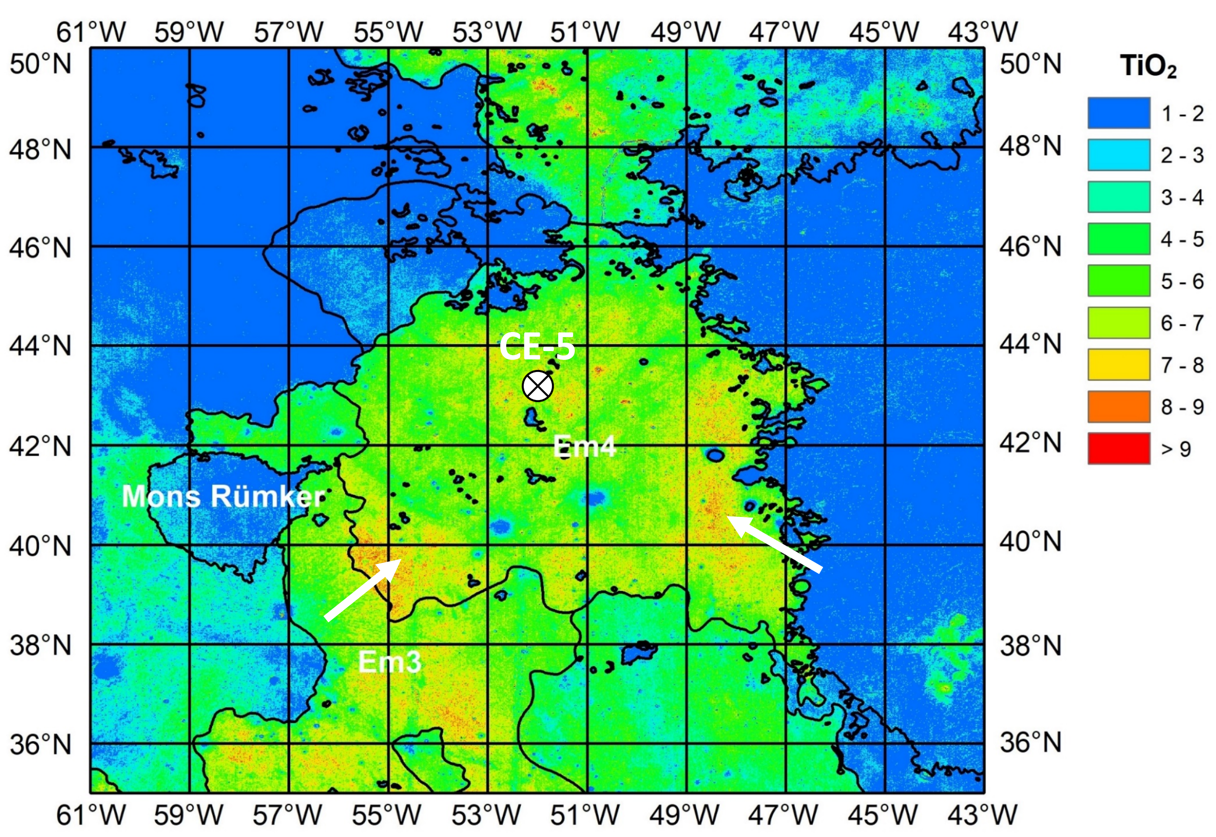
The younger the mare flow, the higher OLV abundance (Pieters et al., 1978; Staid 2001, 2011; Zhang et al., 2016)

We don't find clear evidence of olivine of the CE-5 mare basalts, although it is young and rich in Ti

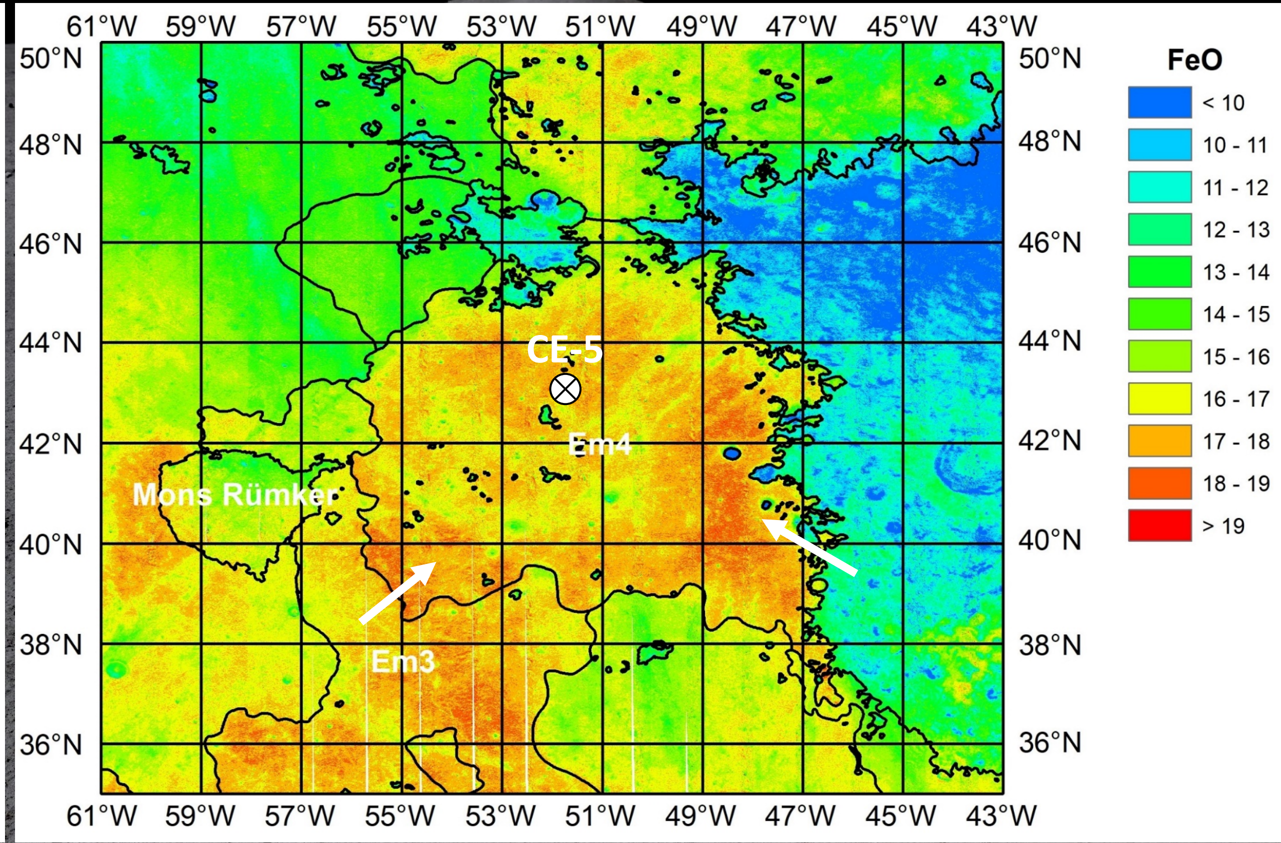
M3 Spectra

- 1 and 2.2 μm features
- Dominant mineral: CPX
- No clear OLV feature

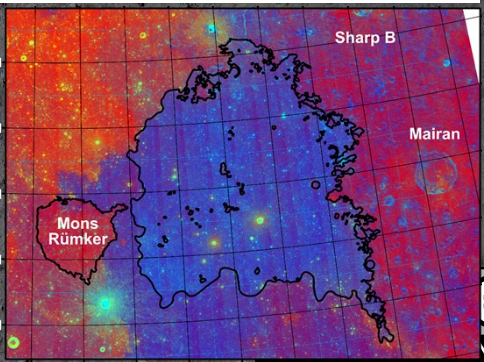
Young Mare Basalts: Chronology



LROC WAC TiO_2 Abundance Map
(Sato et al., 2017)

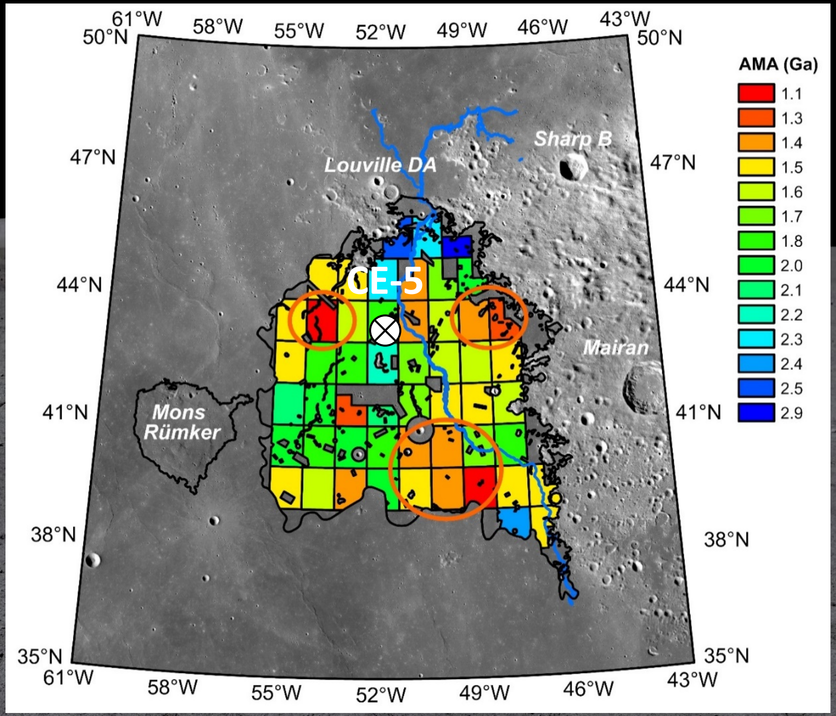


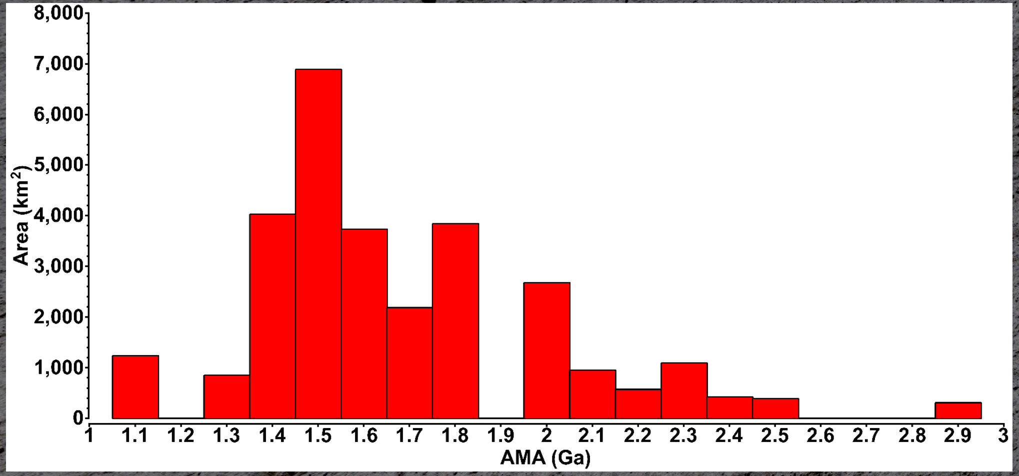
Kaguya MI FeO Abundance Map
(Lemelin et al., 2015)

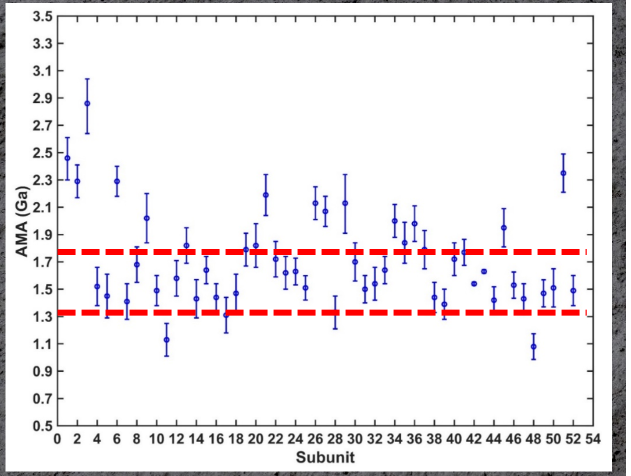


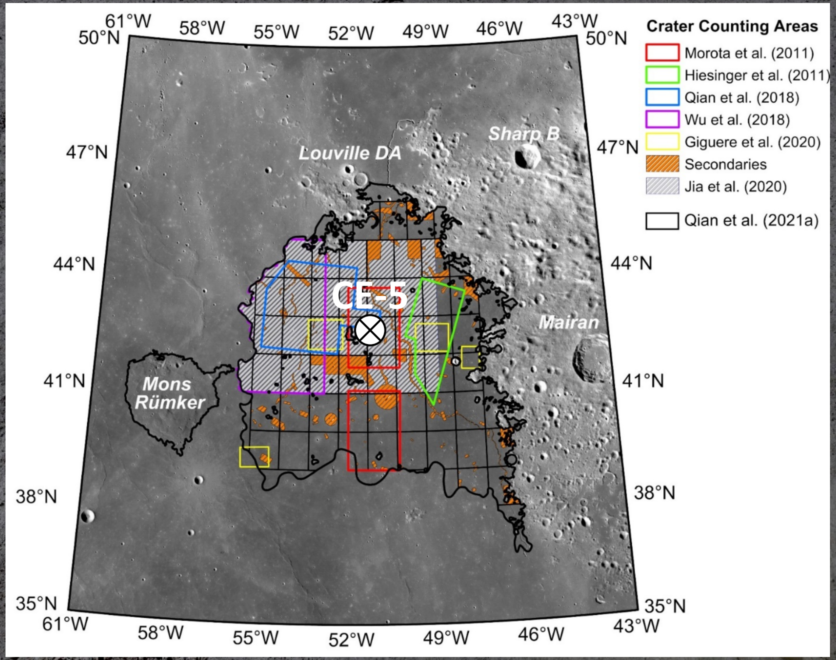
Is the young mare unit really a single unit (homogeneous in general)?
What do these composition variations mean (Impact mixing? Geochemical evolution in one flow? Separated flows?)

Geologic Units						
	Im1	**Im2**	**Im3**	**Em1**	**Em3**	**Em4**
Hiesinger et al. (2003, 2011)	3.47	3.44	3.40			1.33
Morota et al. (2011)	/	/	/	/	/	$1.91^{+0.11}_{-0.11}$ (Model A) $2.20^{+0.13}_{-0.13}$ (Model B)
Qian et al. (2018)	$3.42^{+0.02}_{-0.02}$	$3.39^{+0.02}_{-0.02}$	$3.16^{+0.06}_{-0.09}$	$2.30^{+0.10}_{-0.10}$	$1.51^{+0.07}_{-0.07}$	$1.21^{+0.03}_{-0.03}$
Wu et al. (2018)	$3.48^{+0.03}_{-0.04}$	$3.47^{+0.02}_{-0.02}$		$2.03^{+0.33}_{-0.33}$	$2.06^{+0.24}_{-0.24}$	$1.49^{+0.17}_{-0.17}$
Giguere et al. (2020, 2021)	/	/	/	/	/	3.33/3.0
Jia et al. (2020)	$3.23^{+0.035}_{-0.042}$	$3.27^{+0.022}_{-0.025}$	$3.35^{+0.053}_{-0.079}$	$2.02^{+0.16}_{-0.16}$	$2.54^{+0.41}_{-0.50}$	$2.07^{+0.026}_{-0.027}$
Qian et al. (2021a, EPSL)	/	/	/	/	/	$1.53^{+0.027}_{-0.027}$
Qian et al. (2021b, EPSL)	/	/	/	/	/	1.6-1.7
Xu et al. (2021)	/	/	/	/	/	$1.41^{+0.027}_{-0.028}$
Compare with Wu et al. (2018)						
	Subunit 10	**Subunit 11**	**Subunit 18**	**Subunit 19**	**Subunit 26**	**Subunit 27**
Wu et al. (2018)	$1.53^{+0.069}_{-0.069}$	$1.23^{+0.036}_{-0.036}$	$1.28^{+0.051}_{-0.051}$	$1.67^{+0.072}_{-0.072}$	$2.02^{+0.078}_{-0.078}$	$1.94^{+0.072}_{-0.072}$
Qian et al. (2021a)	$1.49^{+0.11}_{-0.11}$	$1.13^{+0.12}_{-0.12}$	$1.47^{+0.14}_{-0.14}$	$1.79^{+0.12}_{-0.12}$	$2.13^{+0.12}_{-0.12}$	$2.07^{+0.11}_{-0.11}$

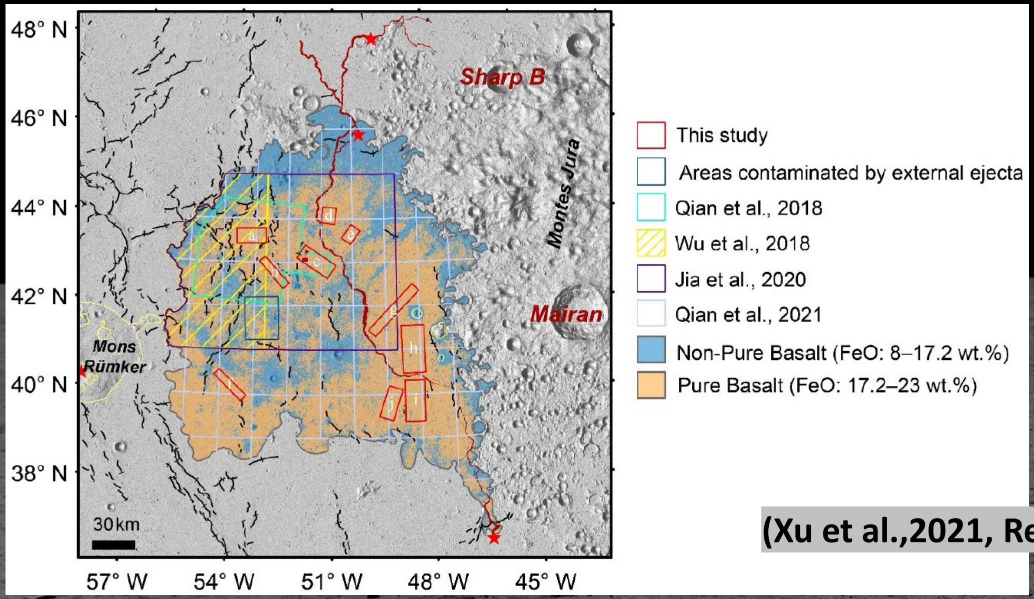


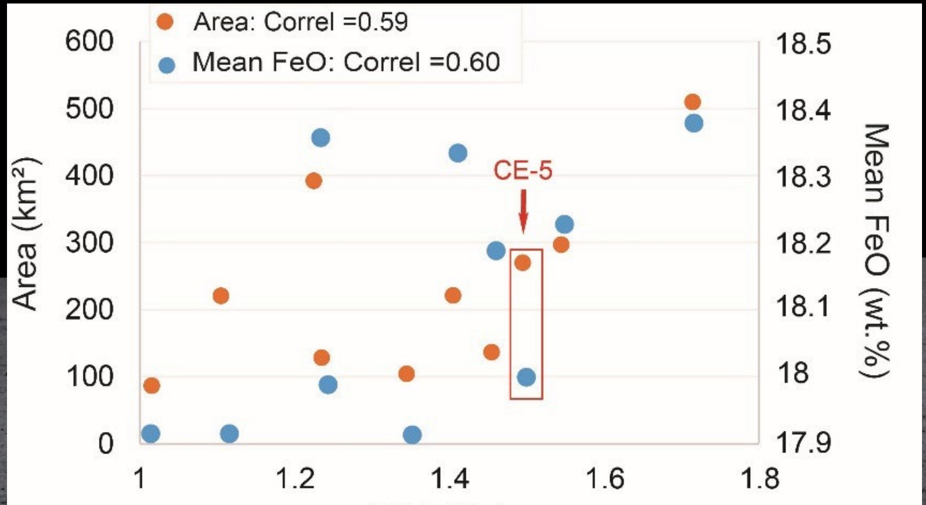




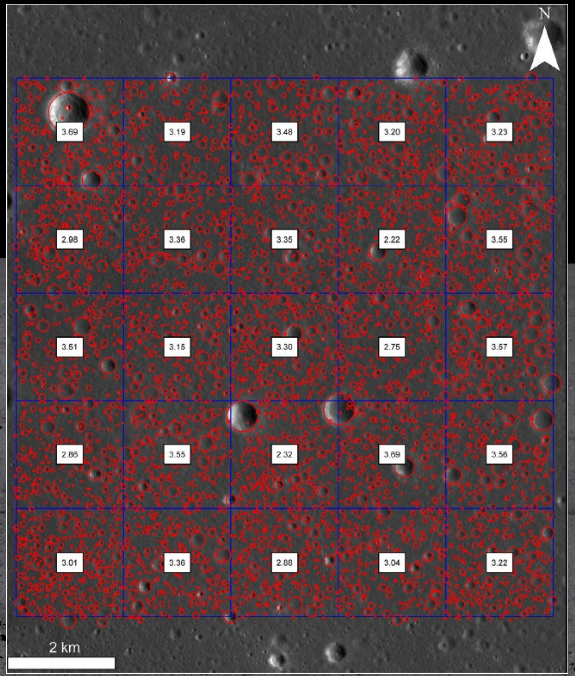


(Qian et al.,2021, EPSL)

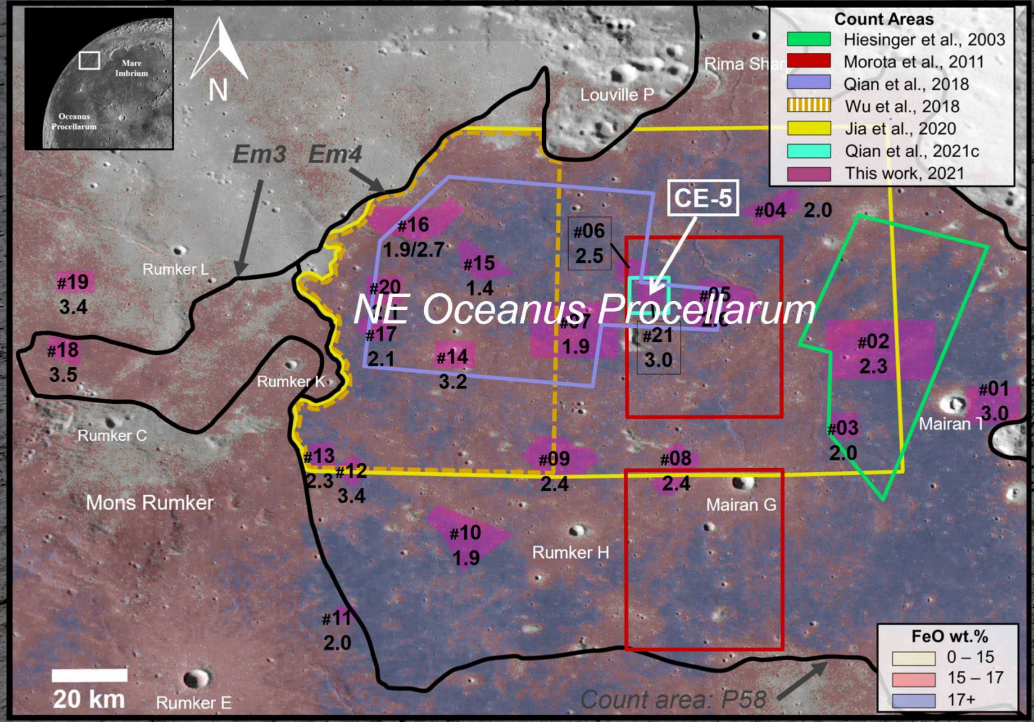




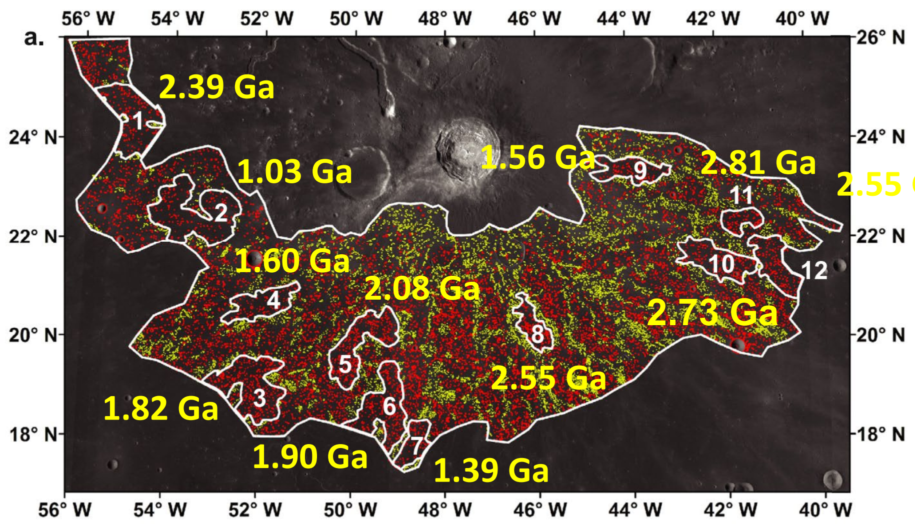
(Xu et al.,2021, Remote Sensing)



Local geology?
Farside volcanism example
(Paskert et al. 2015)



(Giguere et al., 2021, NESFELS)

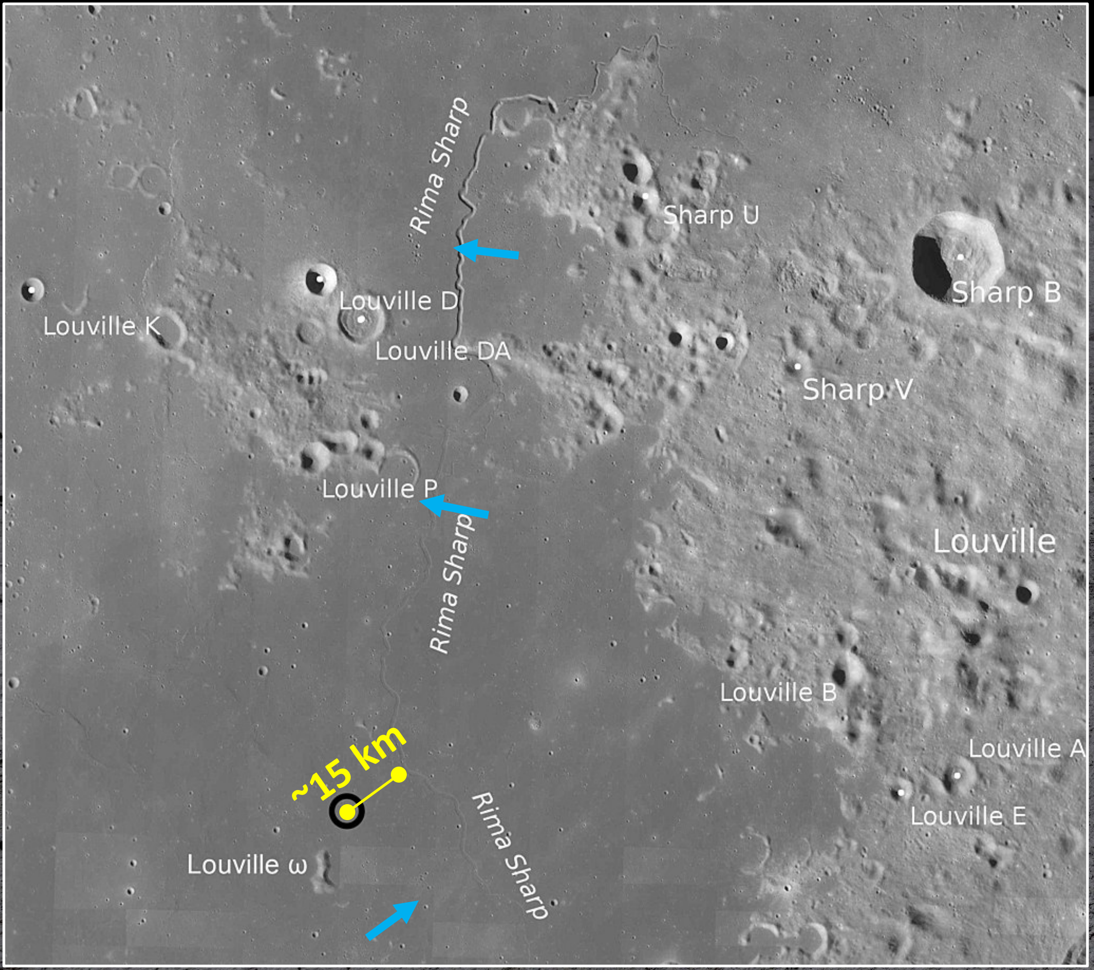


Continuous eruption?
South of Aristarchus example
(Stadermann et al., 2018)

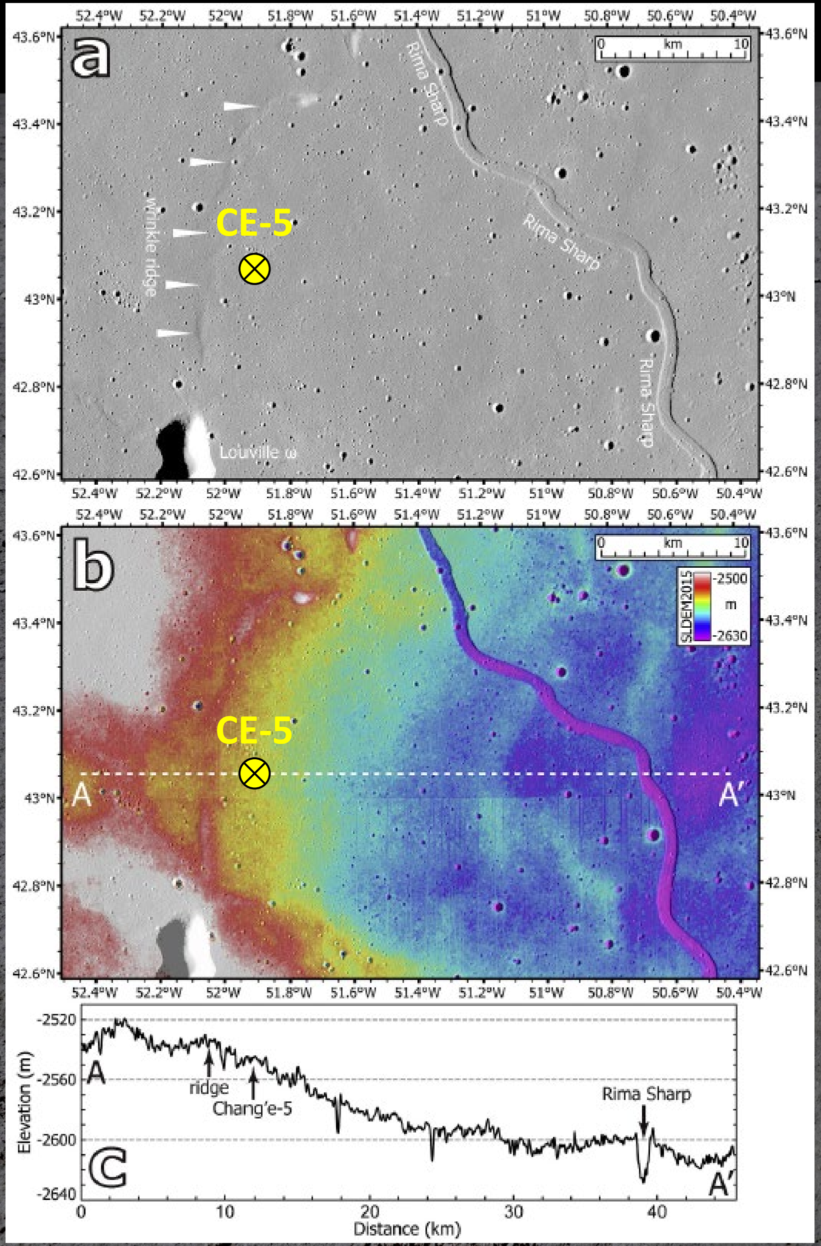
- What control the age variations (Continuous eruption? Local geology? Selection of crater areas? Method uncertainties?)
- Update lunar chronology function?
- Rethink crater counting methods?

Williams et al., 2018. Dating very young planetary surfaces from crater statistics: A review of issues and challenges. Meteorit. Planet. Sci. 53, 554–582.

Young Mare Basalts: Origin



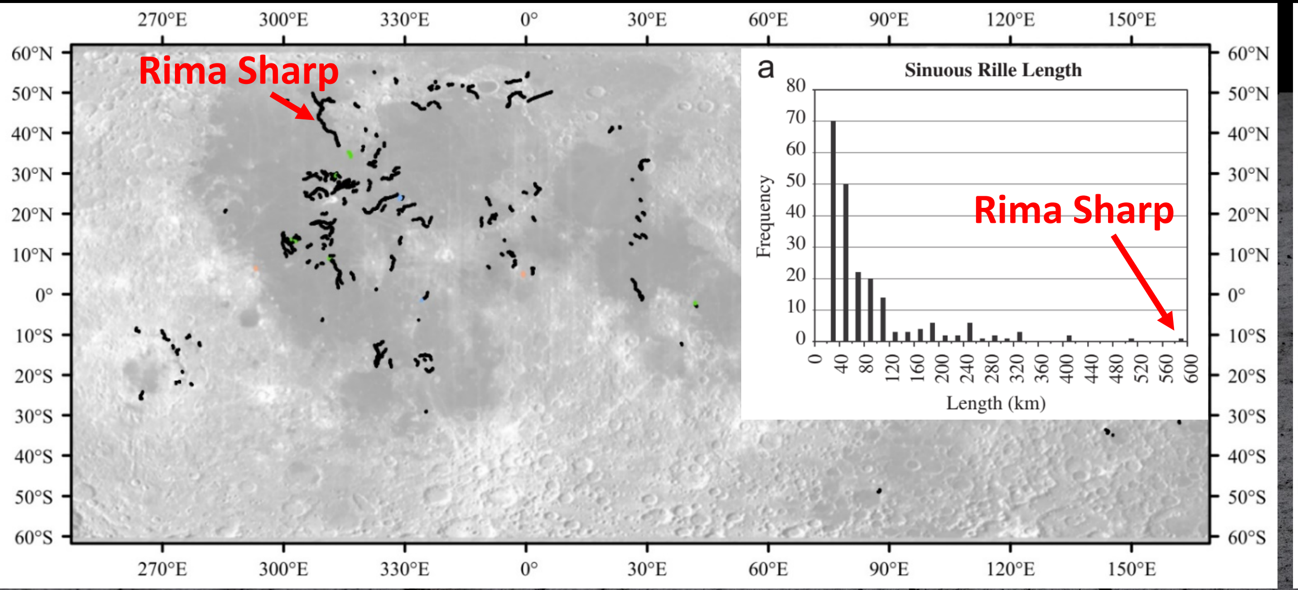
LROC WAC (NASA/ASU)

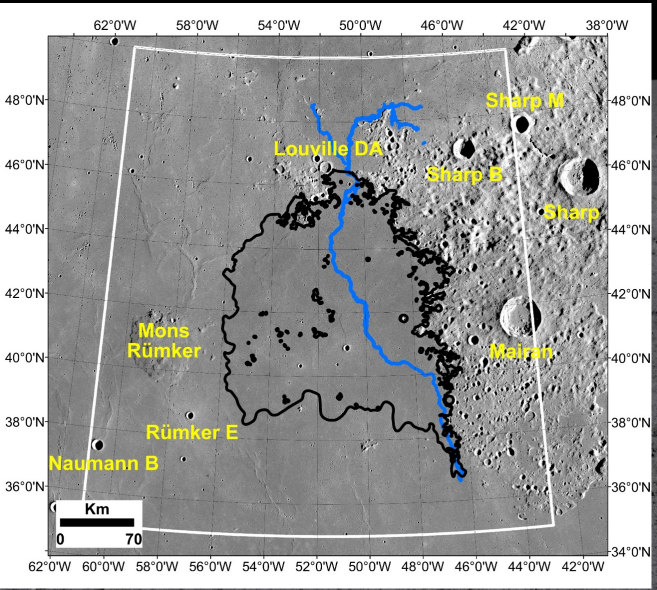


(Qiao et al., 2021, Icarus)

No observable eruption source vents (i.e., fissures, cones, domes, dikes) for Em4/P58, except for Rima Sharp

In-situ materials: Mare Basalt Origin

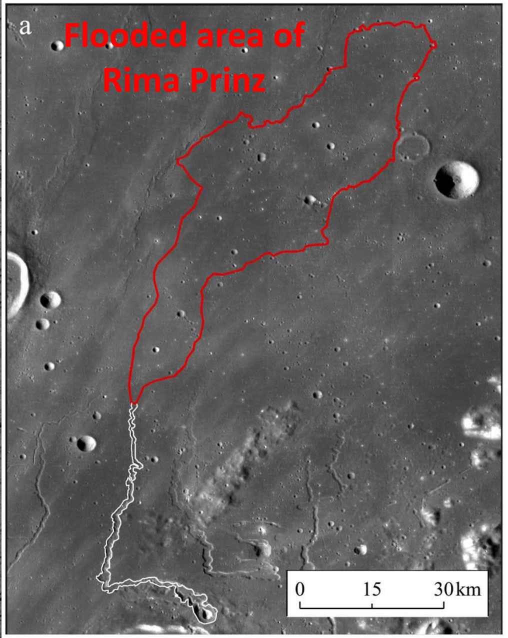


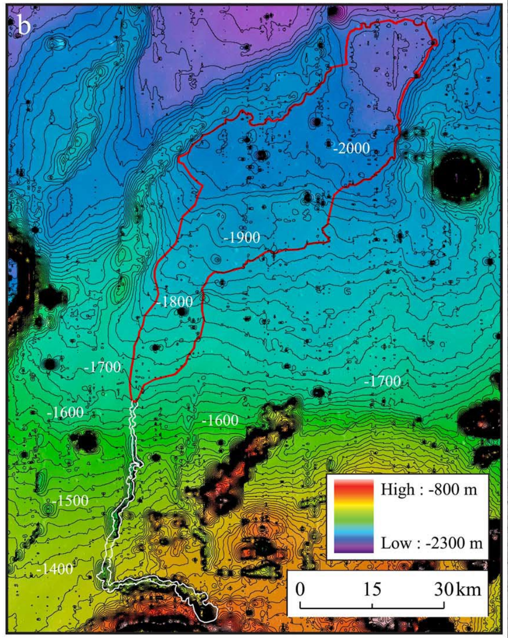


Rima Sharp

- Length: ~566 km
- Average width: ~840 m
- Average depth: ~76 m
- Regional slope: ~-0.008

Rima Sharp is the "LONGEST" sinuous rille on the Moon (Hurwitz et al., 2013)





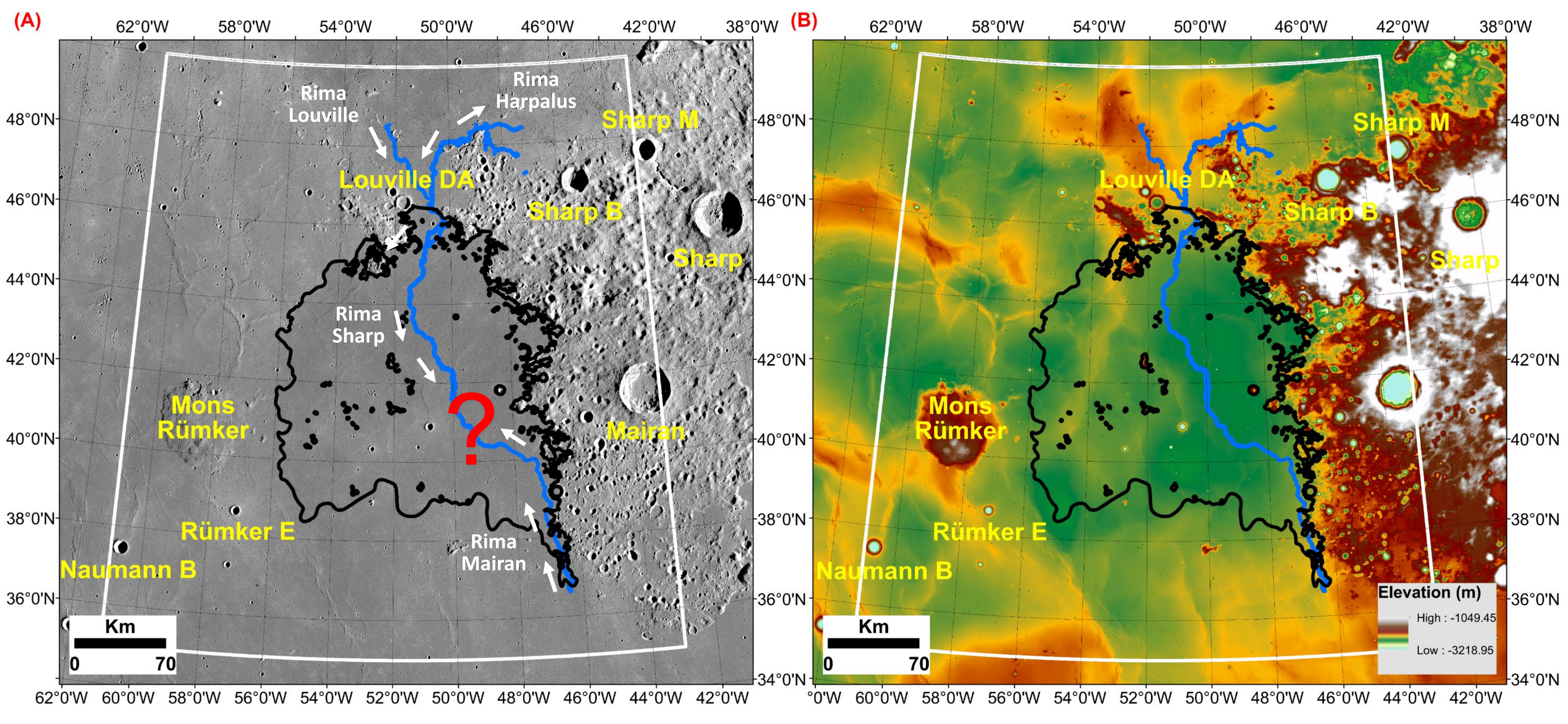
Rima Prinz
(Hurwitz et al., 2012, JGR)

- Length: ~87 km
- Average width: ~1,100 m
- Average depth: ~170 m
- Magma volume: ~50-250 km^3 (physical volcanology model)

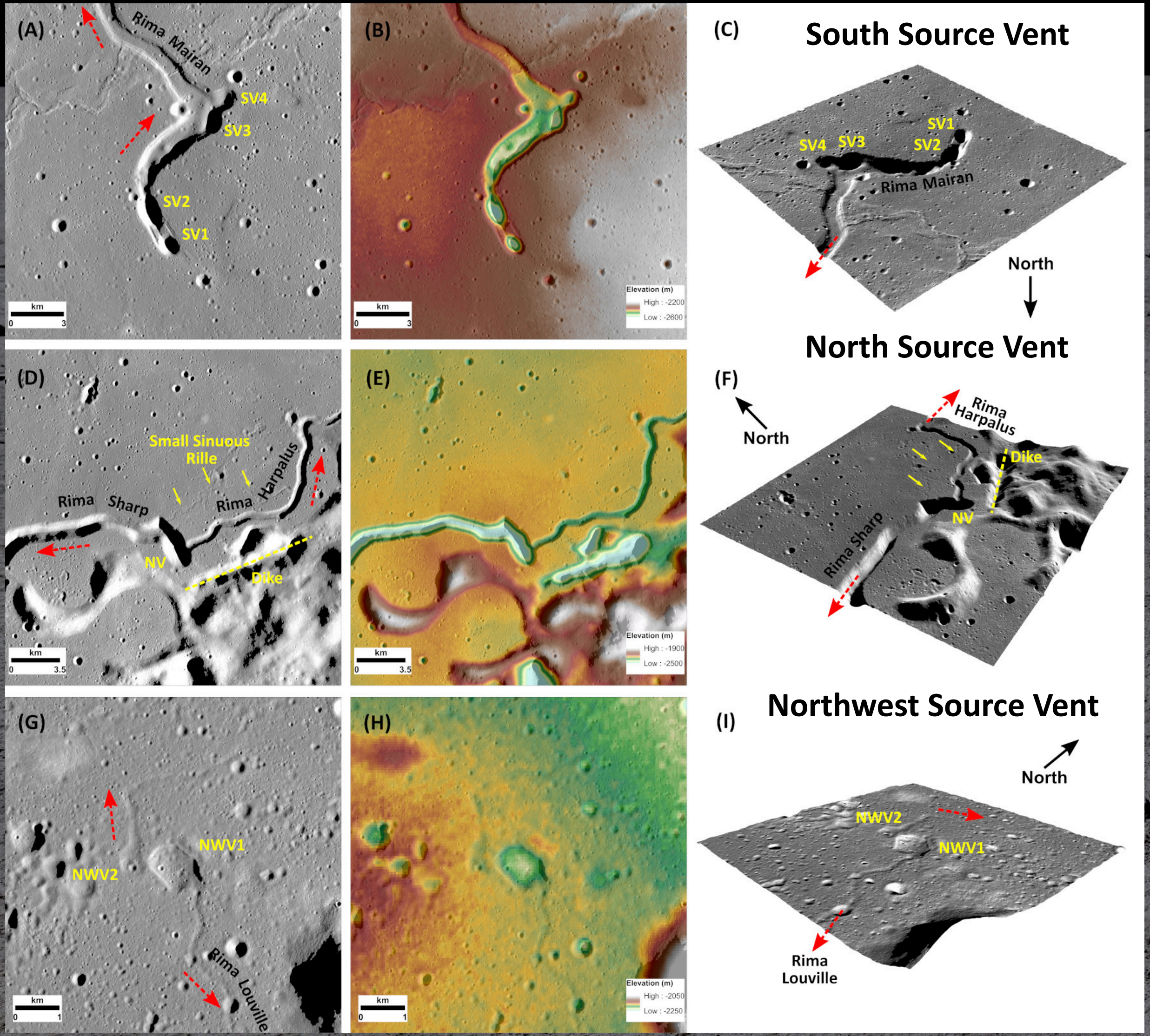
CE-5 mare basalts volume: 1,450-2,350 km^3, ~ 1900 km^3 in average (Qian et al., 2021)

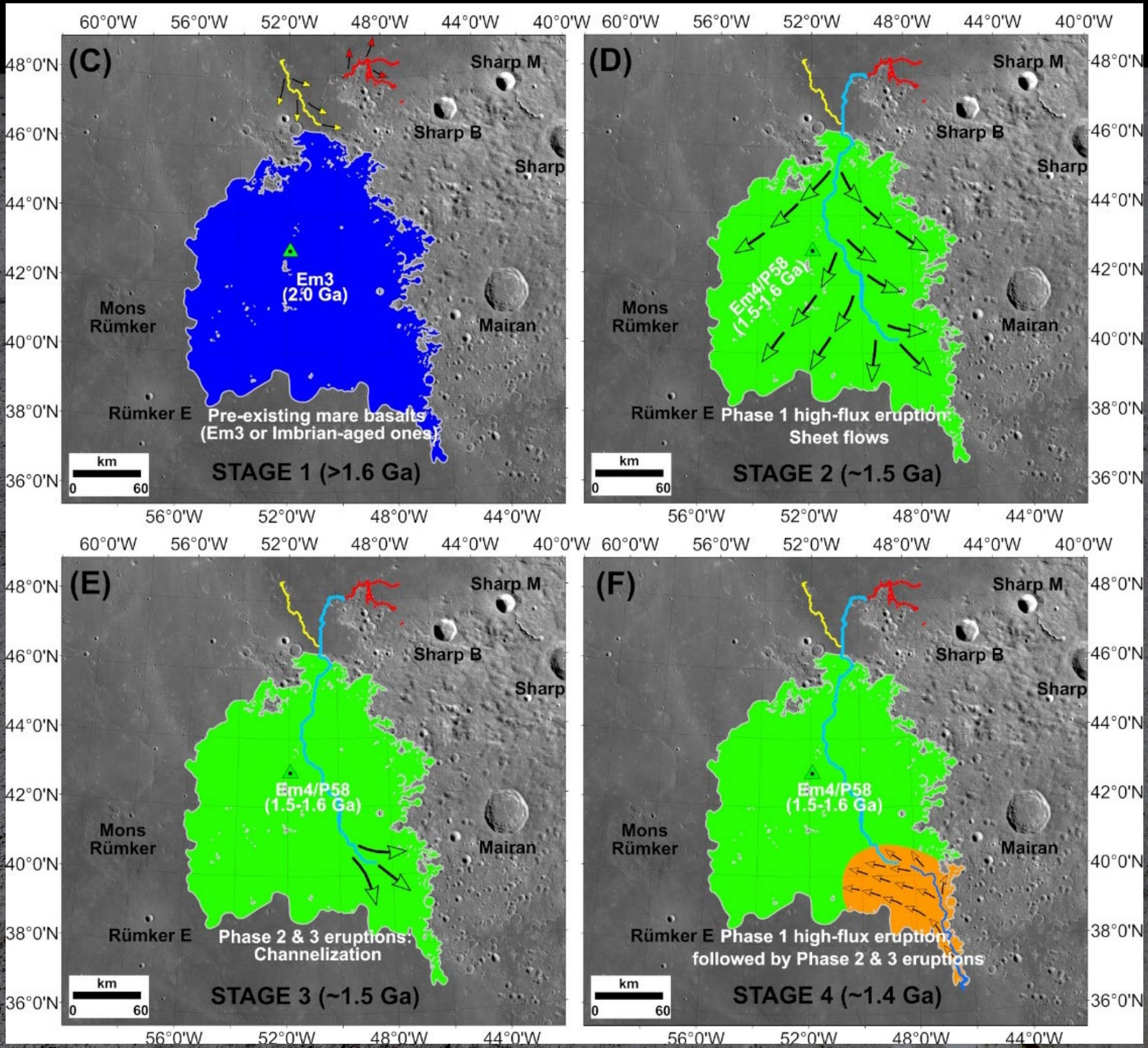
Are CE-5 mare basalts the products of Rima Sharp eruption?

In-situ materials: Mare Basalt Origin



In-situ materials: Mare Basalt Origin

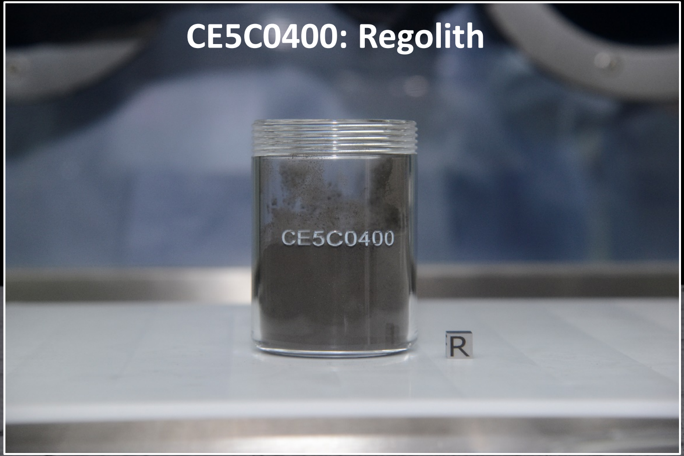


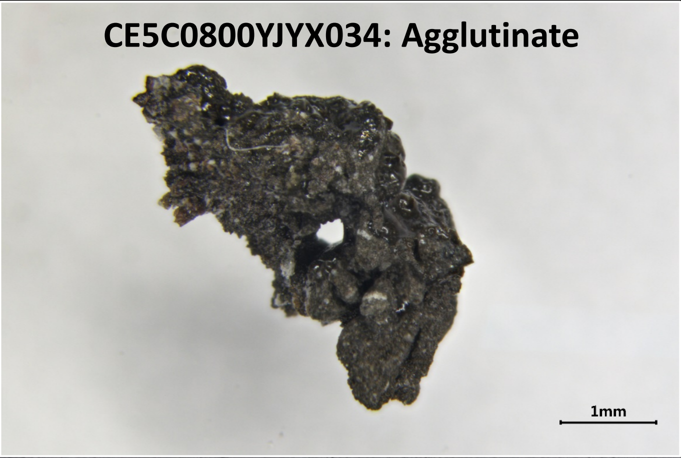


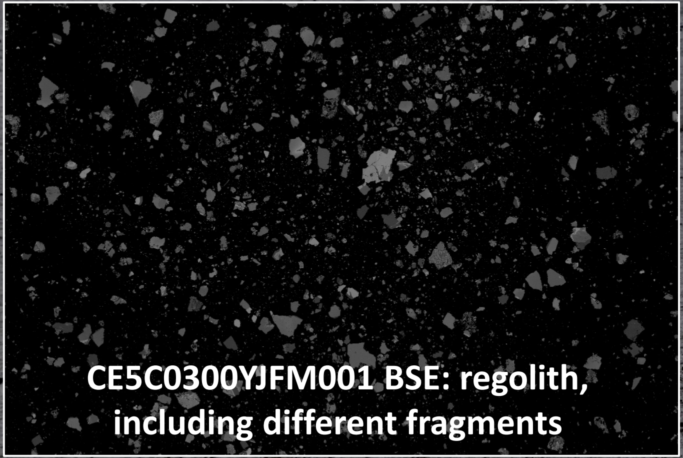
(Qian et al., 2021, GRL)

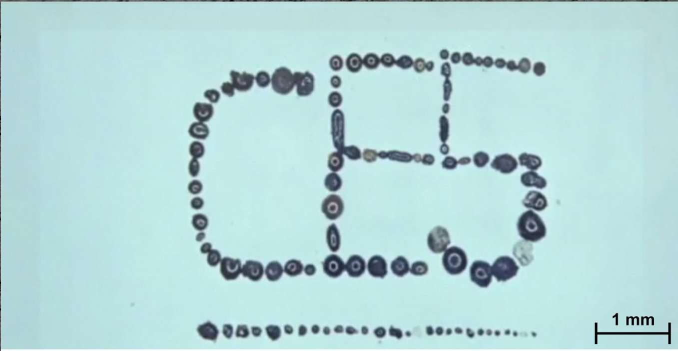
PROVENANCE OF CHANG'E-5 REGOLITH SAMPLES

- In-situ materials
- Exotic materials
  - Distal impact ejecta
  - Meteorites
  - Volcanic glass (explosive eruption)



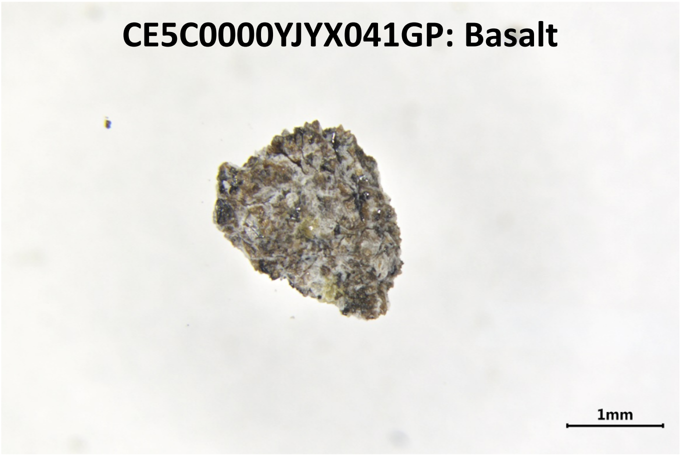


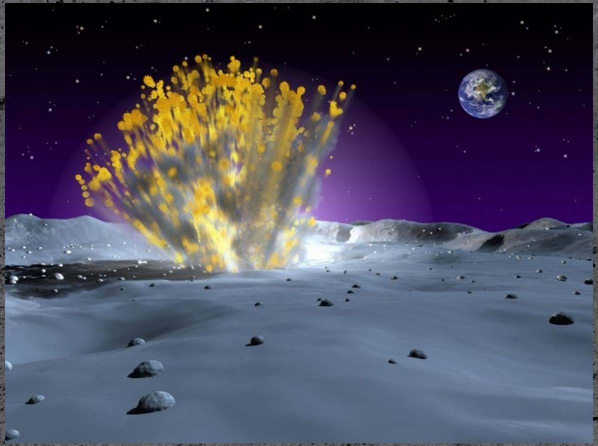




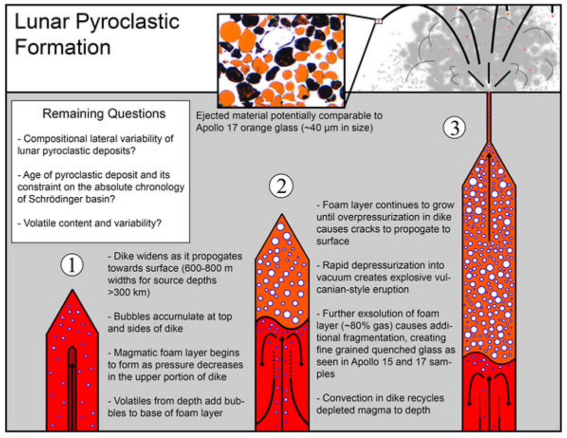
Chang'e-5 Regolith Glasses

Credit: Xinhua Net





Impact ejection
(Credit: Steve Roy)

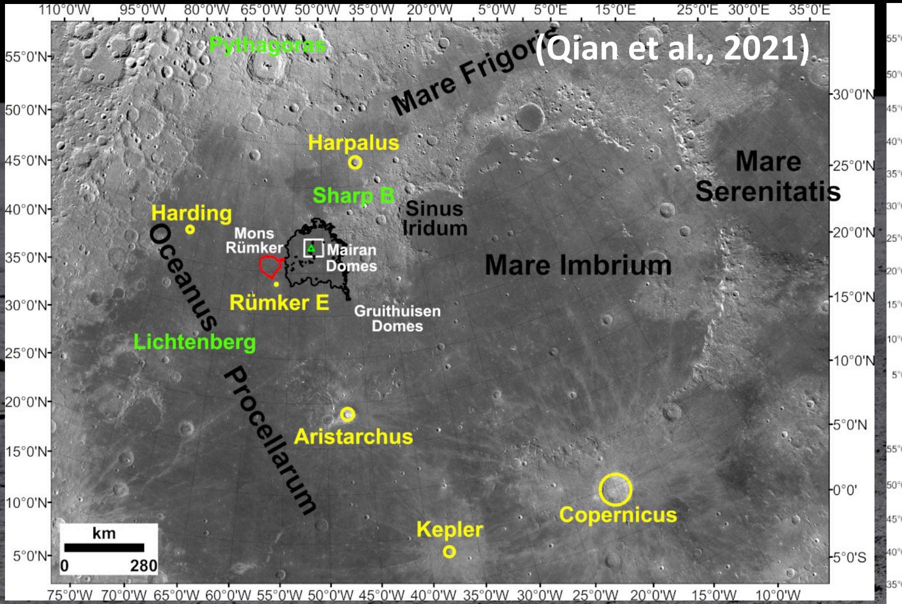


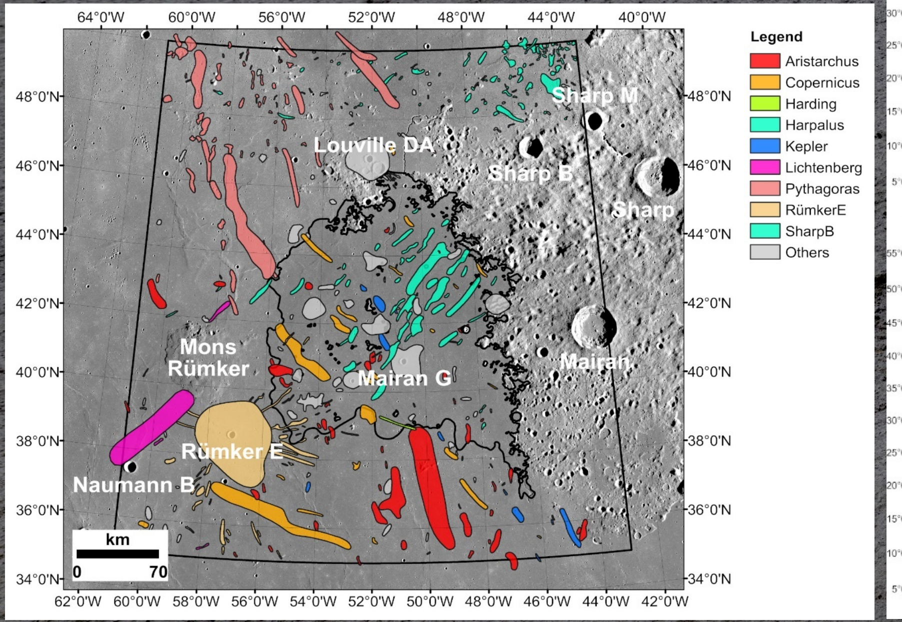
Lunar pyroclastic eruption
(Credit: LPI)

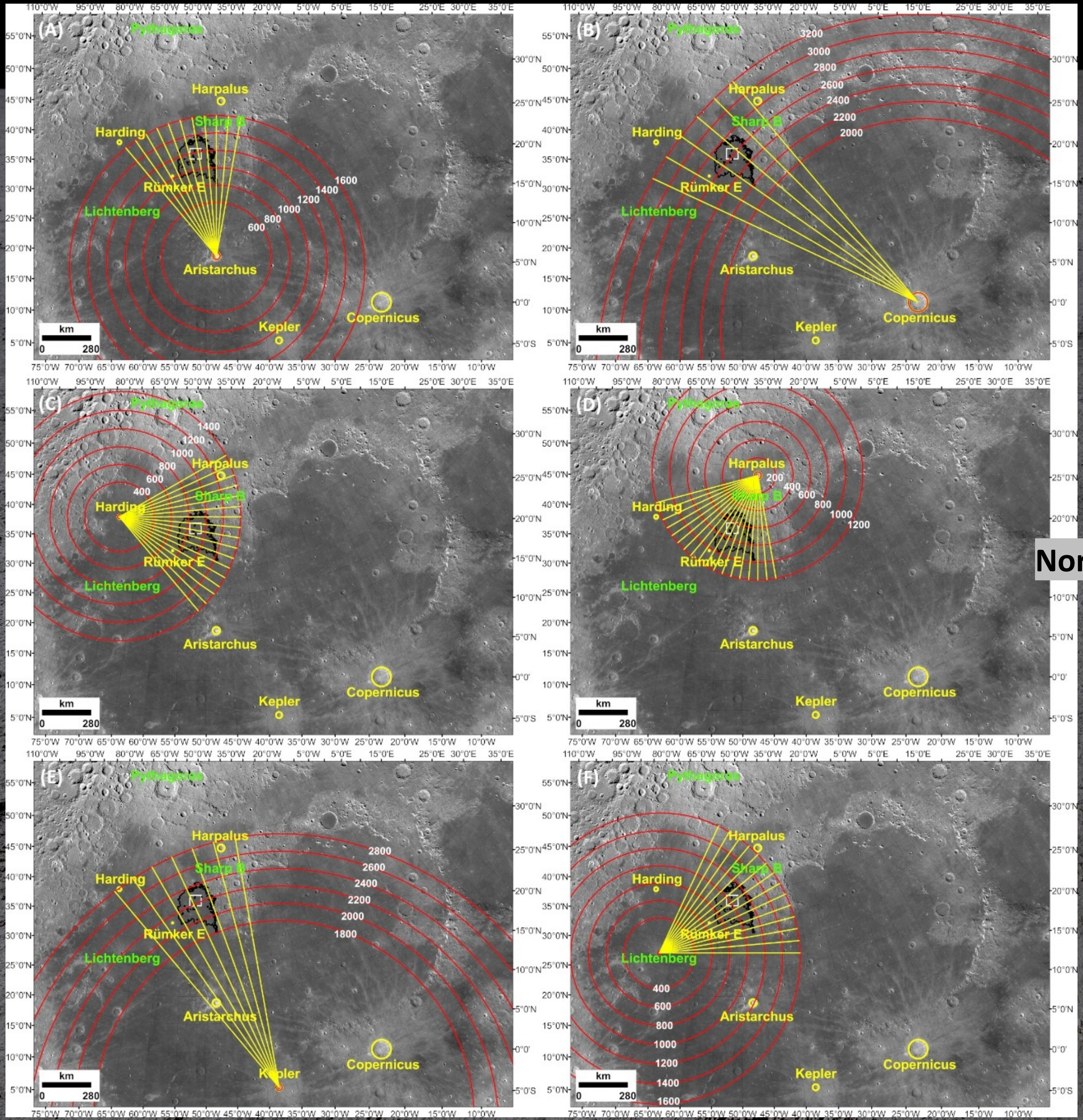
Xie et al., 2020, JGR
Qian et al., 2021, EPSL
Jia et al., 2021, JGR

Consistent conclusion
Exotic materials <10 wt.%
Local materials > 90 wt.%

Exotic materials: Impact Ejecta

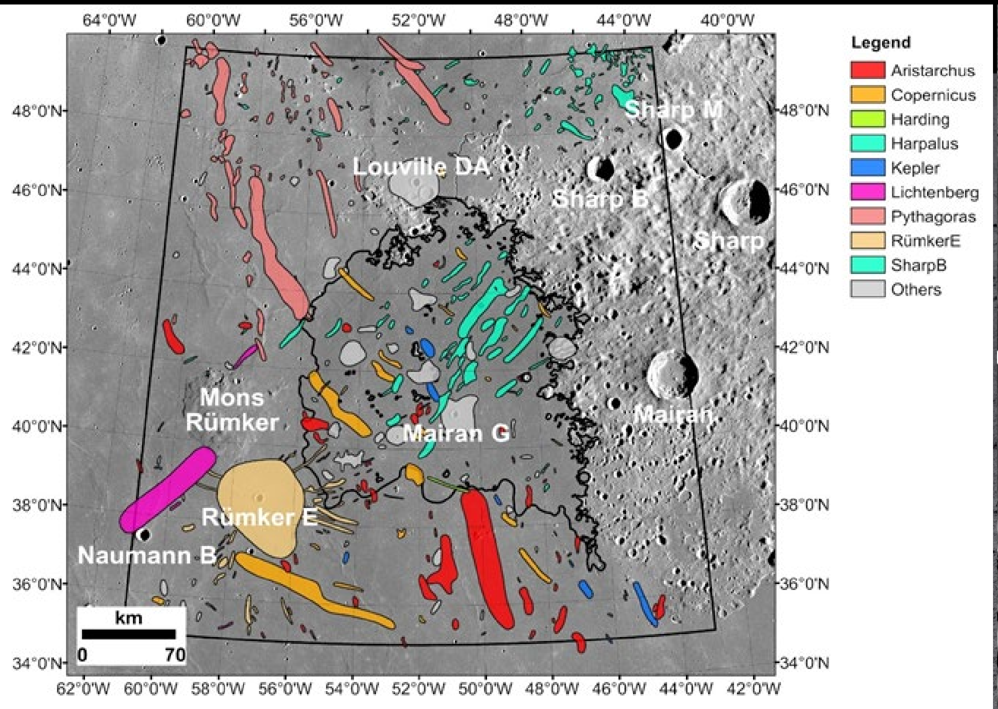


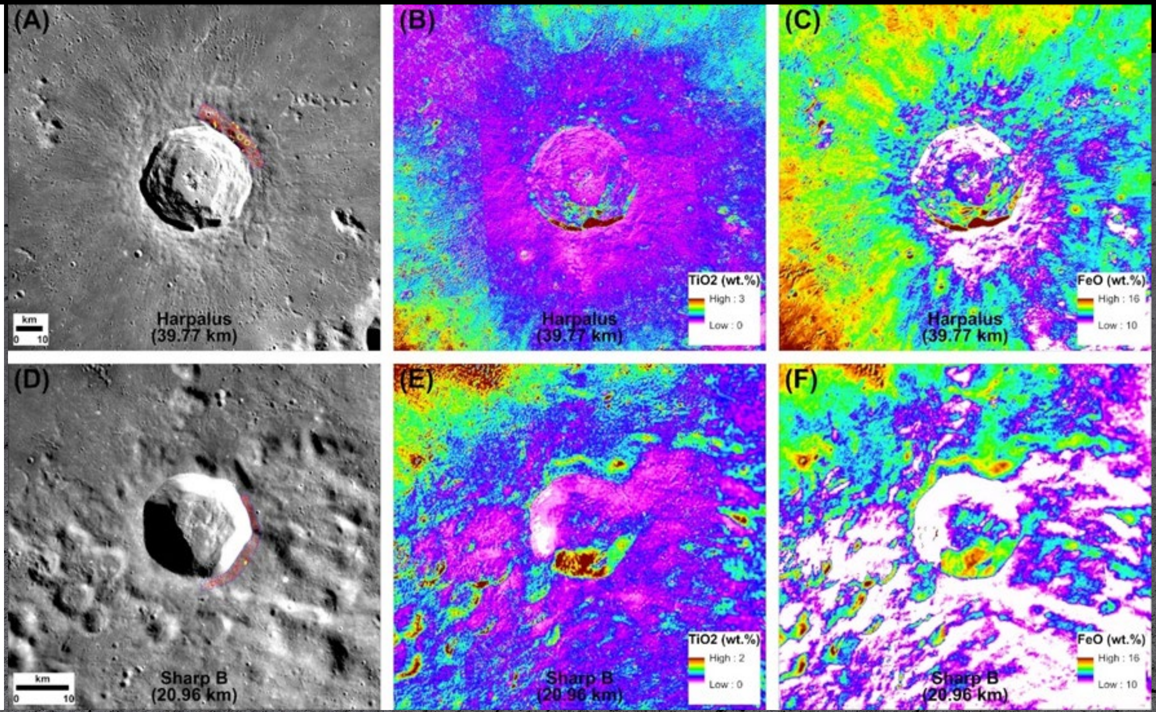


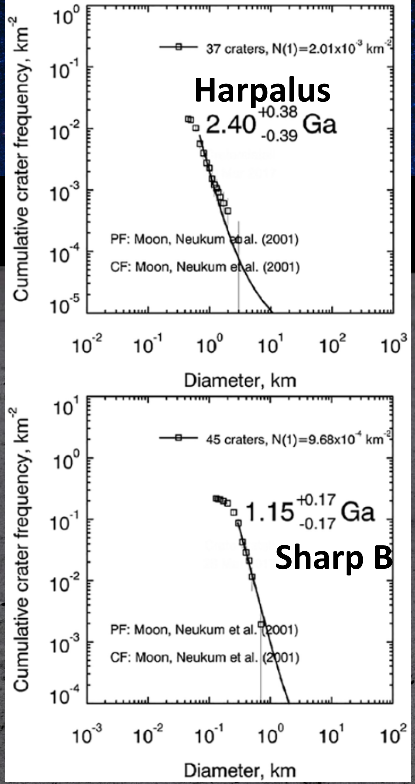


Tracing impact ejecta in Northern Oceanus Procellarum (Qian et al., 2021)

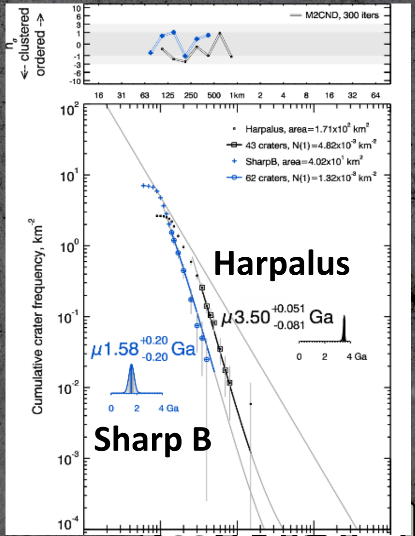
Exotic materials: Impact Ejecta







(Xie et al., 2020)



(Qian et al., 2021)

Dominated by the NE-SW ejecta, either from Harpalus or Sharp B crater or both of them

Xie et al., 2020, JGR-P; Jia et al., 2021, JGR-P: from Sharp B

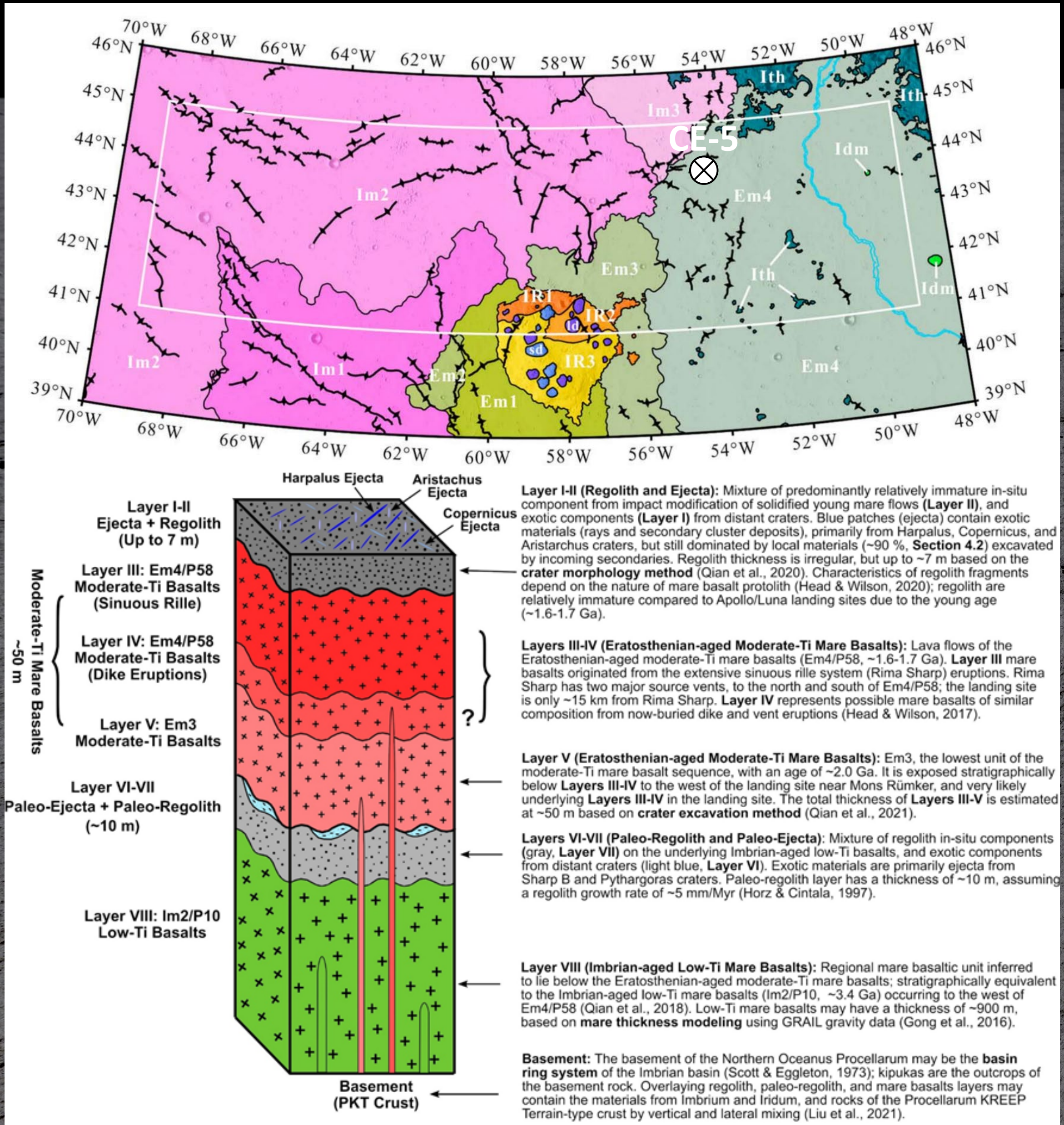
Qian et al., 2021, EPSL; Qiao et al., 2021, Icarus: from Harpalus

HOWEVER, HARPALUS IS MORPHOLOGICALLY MUCH YOUNGER THAN SHARP B CRATER, MAYBE BECAUSE DIRECTLY DATING THE CRATER EJECTA IN THIS CASE WOULD SUFFER:

Secondary craters, self-secondary craters, partially buried craters, abnormal degradation on a rough surface

THEREFORE, NOT RELIABLE. CRATER DATING ON THESE TWO CRATERS SHOULD BE DEALED WITH MORE CAUTIONS

Conclusion



- Chang'e-5 Em4/P58 mare basalt is one of the youngest mare units on the Moon, with ages between 1.2-2.0 Ga dated by different authors, and internal age variations
- Chang'e-5 Em4/P58 mare basalts are a type of intermediate-Ti basalt with elevated heat-producing elements. Clinopyroxene is the dominant mafic mineral.
- Chang'e-5 Em4/P58 mare basalts may be the products of Rima Sharp eruptions.
- Rima Mairan is younger than Rima Sharp, whose lava buries the southeast portion of Rima Sharp, and enters Rima Sharp, producing inner features and lava ponds within Rima Sharp.
- Exotic materials mainly from Harpalus, Aristarchus, Copernicus craters. Volcanic glass may come from the source vents of Rima Sharp and Rima Mairan.
- Chang'e-5 samples would provide opportunities to calibrate lunar chronology function, with at least two points: 1) local mare basalts, and 2) Harpalus crater.