The Long Sinuous Rille System in Northern Oceanus Procellarum and its Relation to the Chang'e-5 Returned Samples

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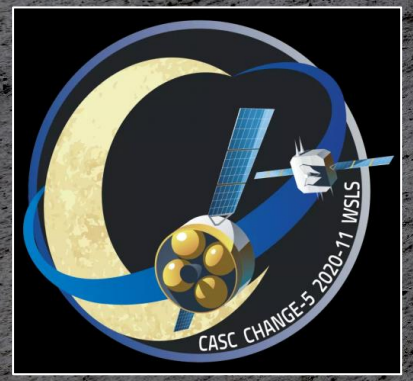
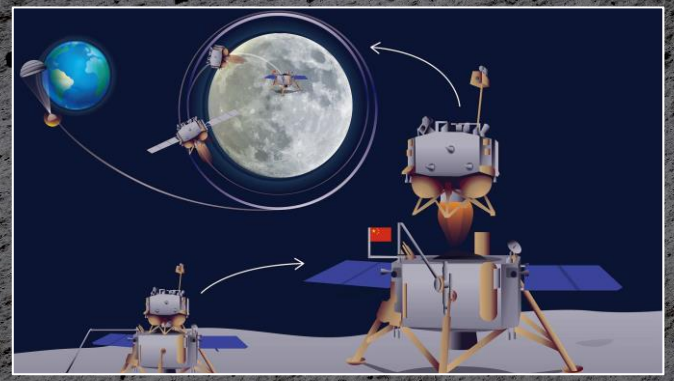
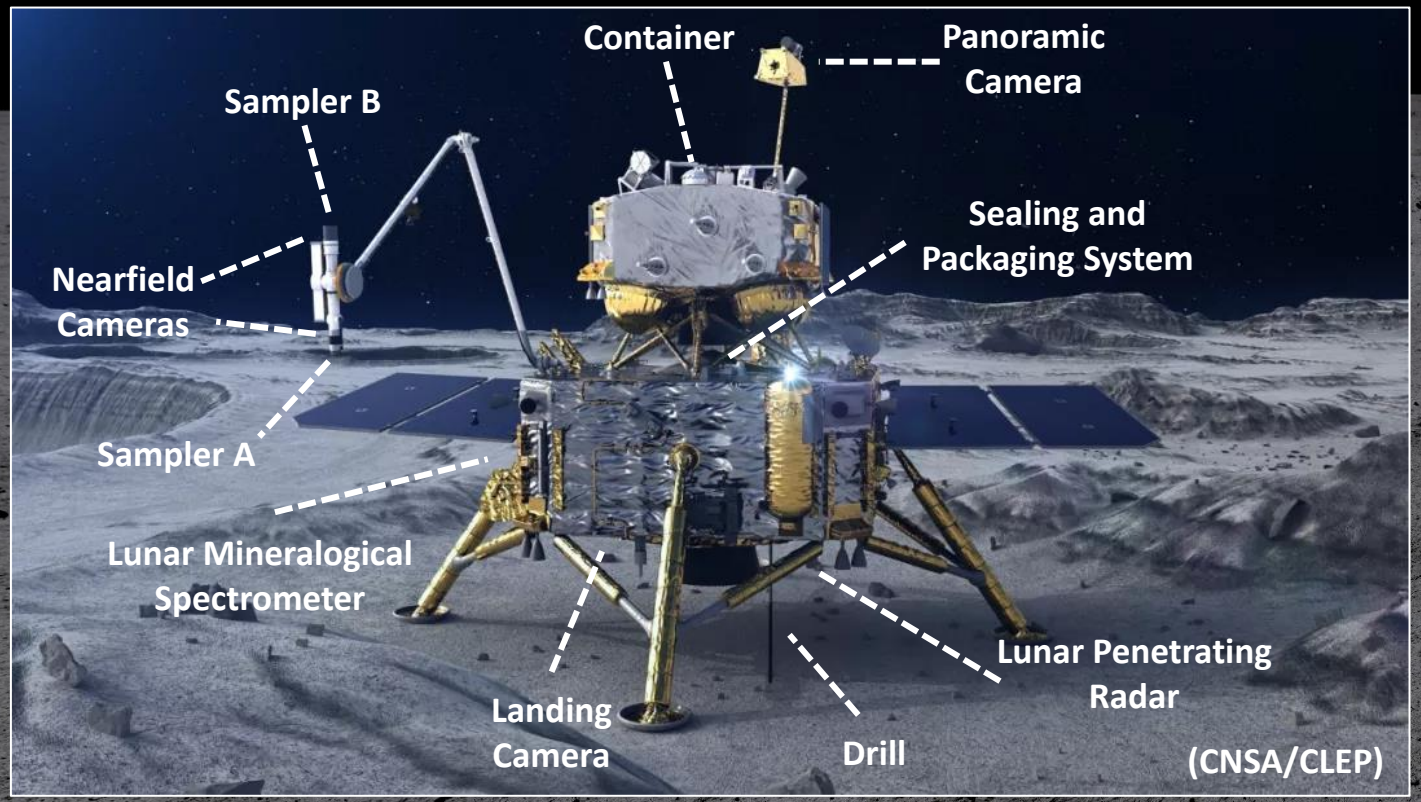
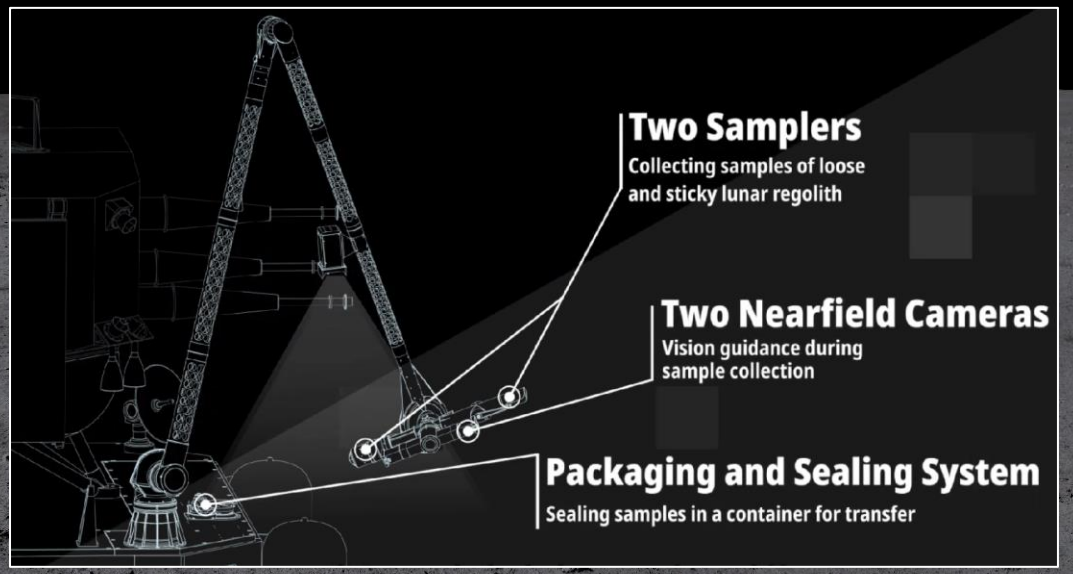




New Orleans
Dec 13-17, 2021

Chang'e-5, ~1731 g of lunar samples

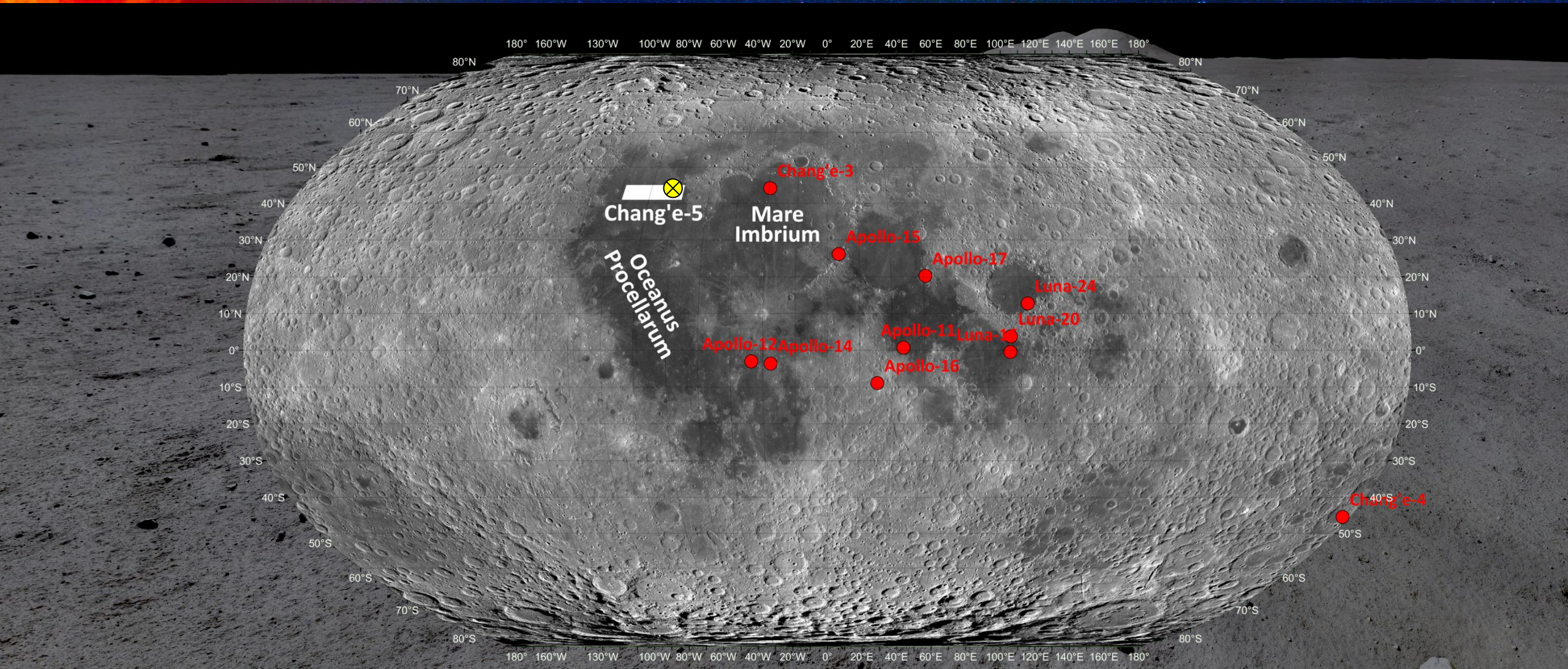




~1480 g scoop sample

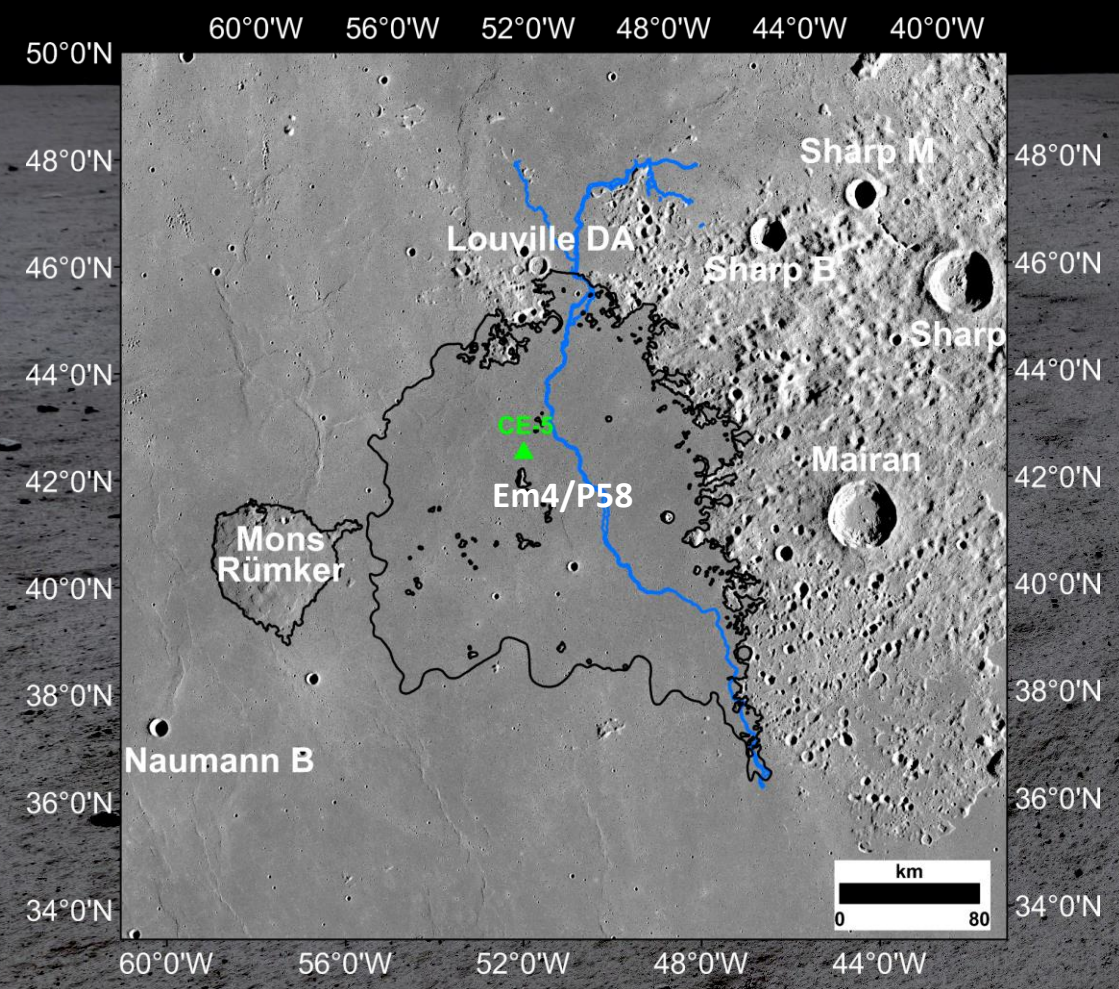
~251 g drill sample

Chang’e-5 Landing Site

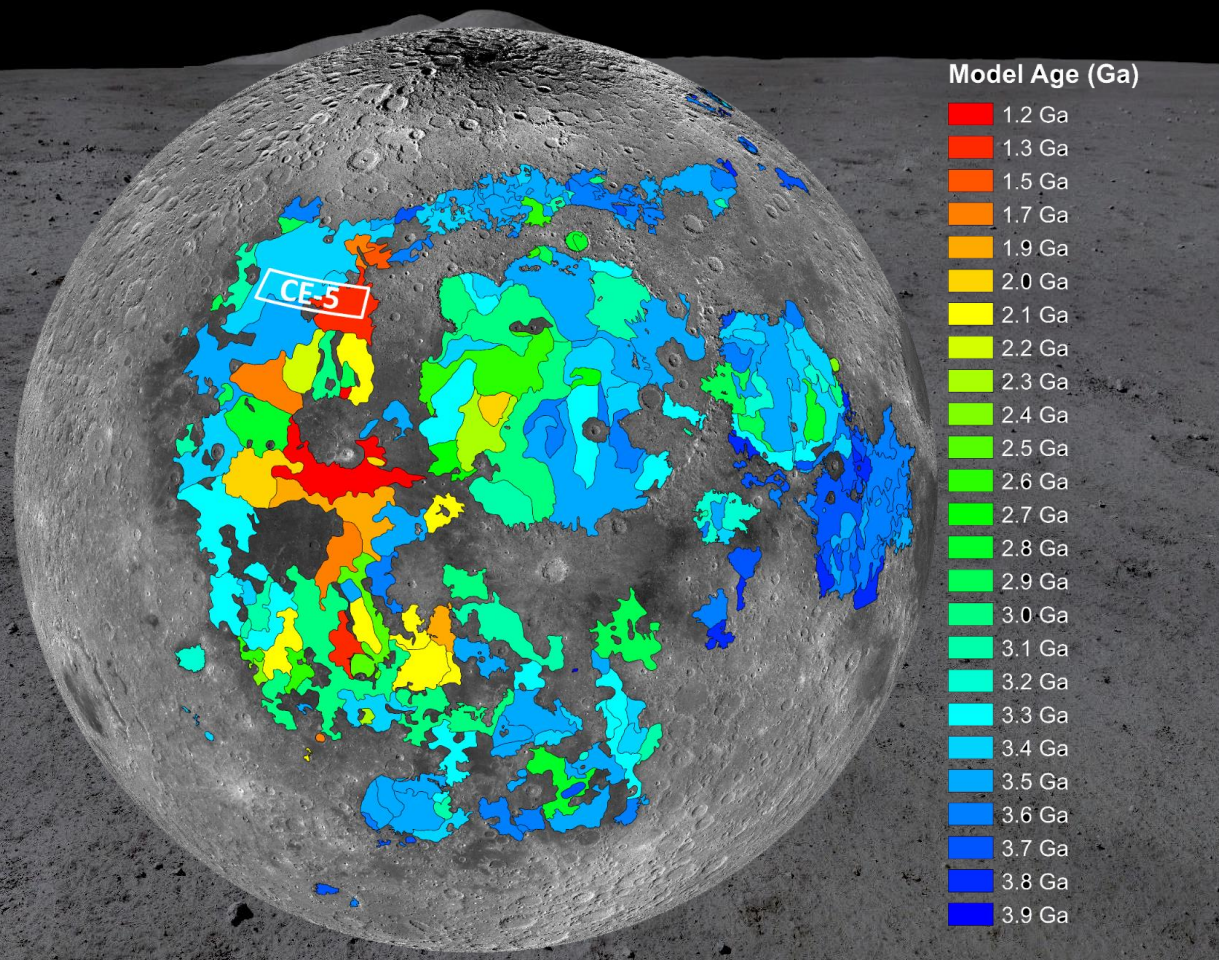


11:13 PM, Dec. 01, 2020, ~1731 g of surface and subsurface samples
43.06 N, 51.92 W (Wang et al. 2021)
Northern Oceanus Procellarum

Young Mare Basalt



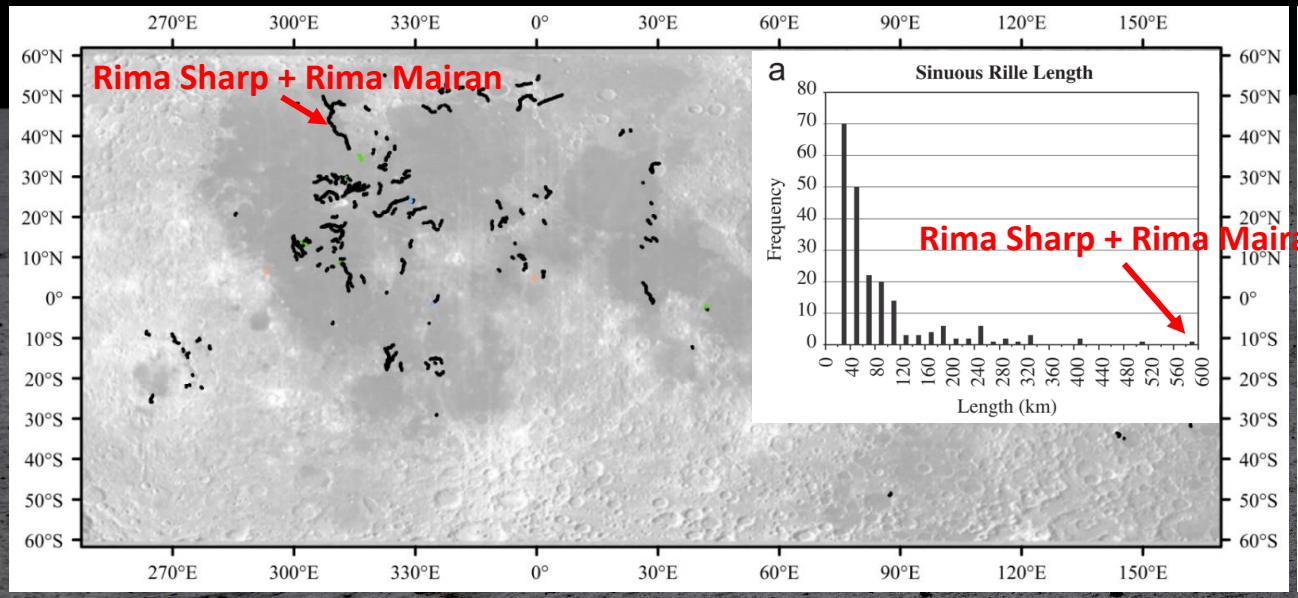
Intermediate-Ti mare basalts
(Qian et al., 2021, EPSL)

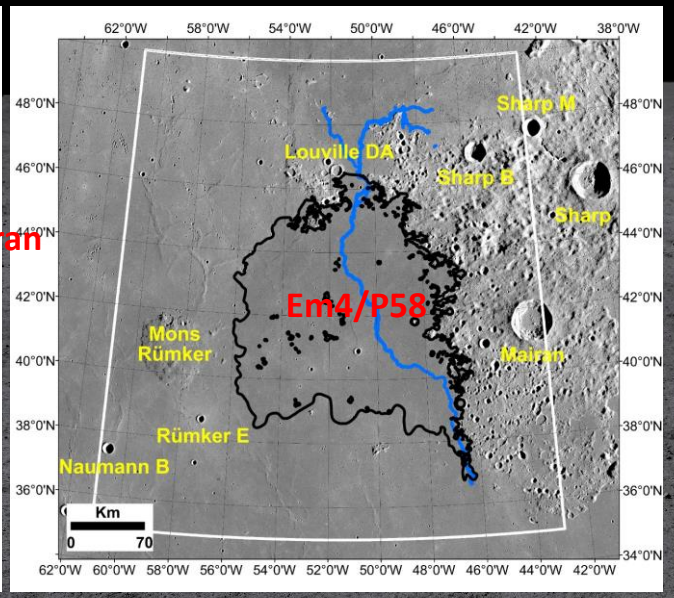


Lunar mare unit age map
(Hiesinger et al., 2011, JGR)

Youngest dated (~2.0 Ga) lunar mare basalts
(Che et al., 2021, Science; Li Q. L., et al., 2021, Nature)

Origin

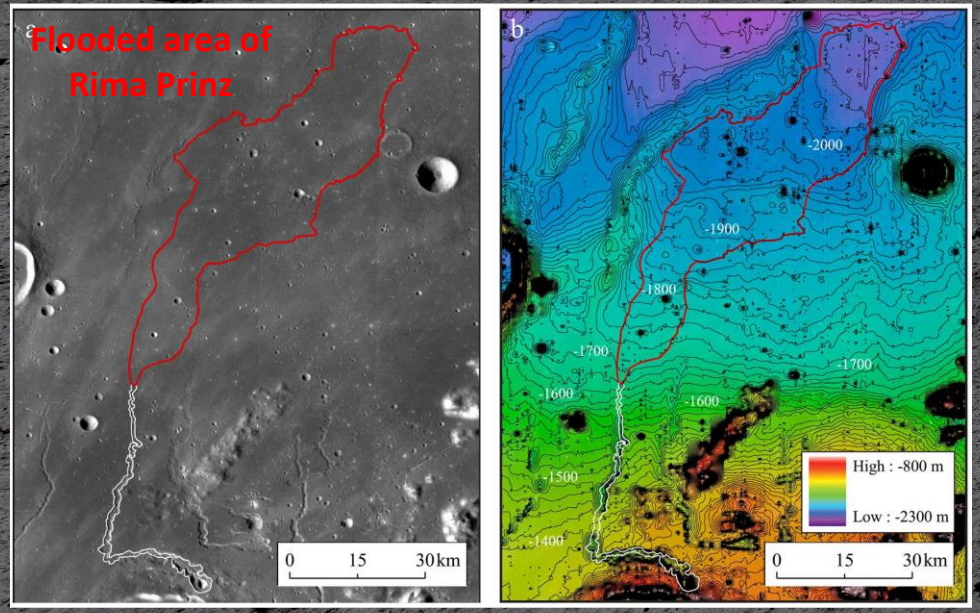




Rima Sharp

- 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 Sharp = Rima Sharp + Rima Mairan



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

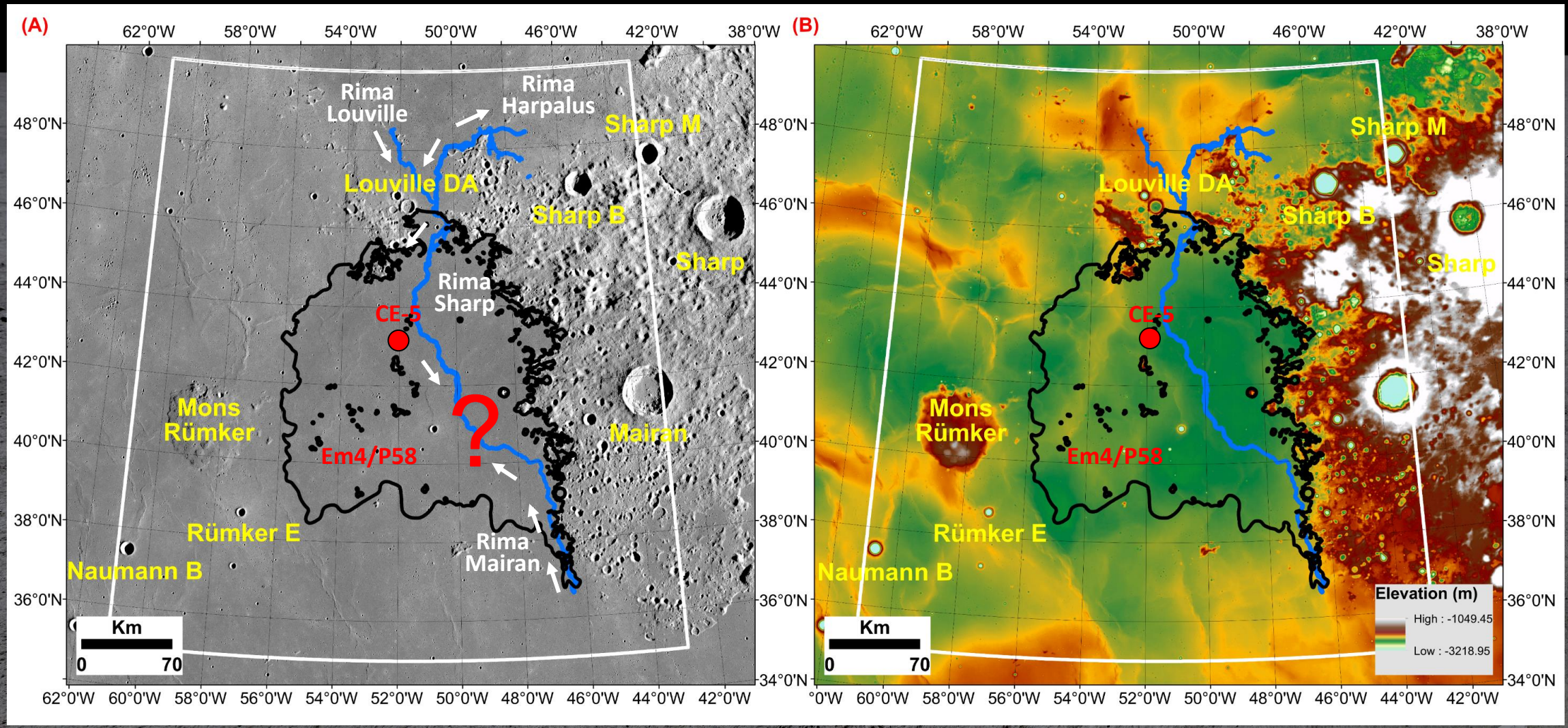
- Length: ~87 km
- Average width: ~1,100 m
- Average depth: ~170 m
- Magma volume: ~50-250 km³ (physical volcanology model)

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

CE-5 mare basalts volume:
1,450-2,350 km³, ~ 1900 km³ in average
(Qian et al., 2021, EPSL)

Are the lava forming CE-5 mare basalts coming from Rima Sharp + Rima Mairan eruption?

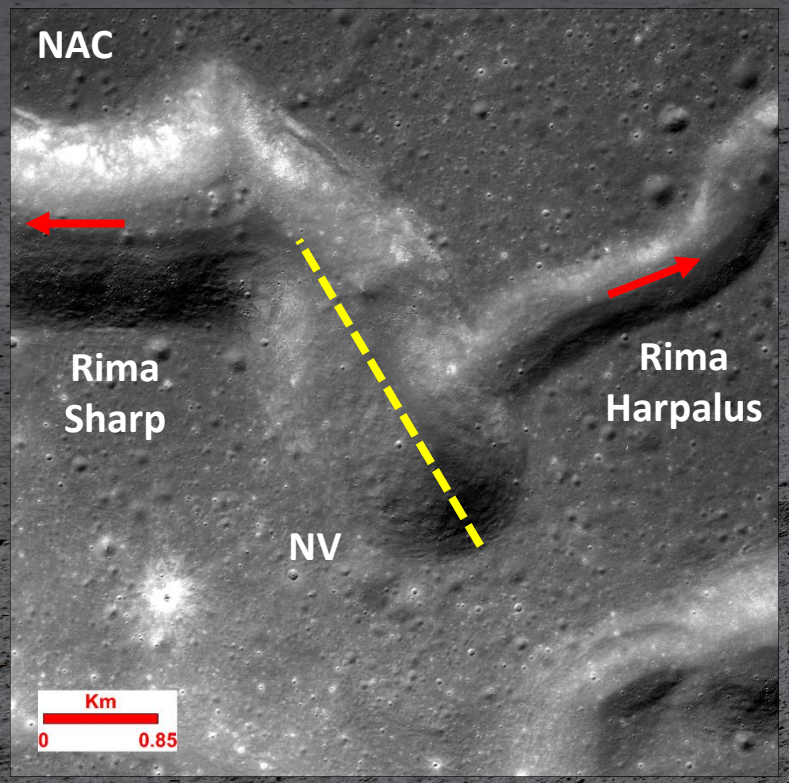
Complex Sinuous Rille System

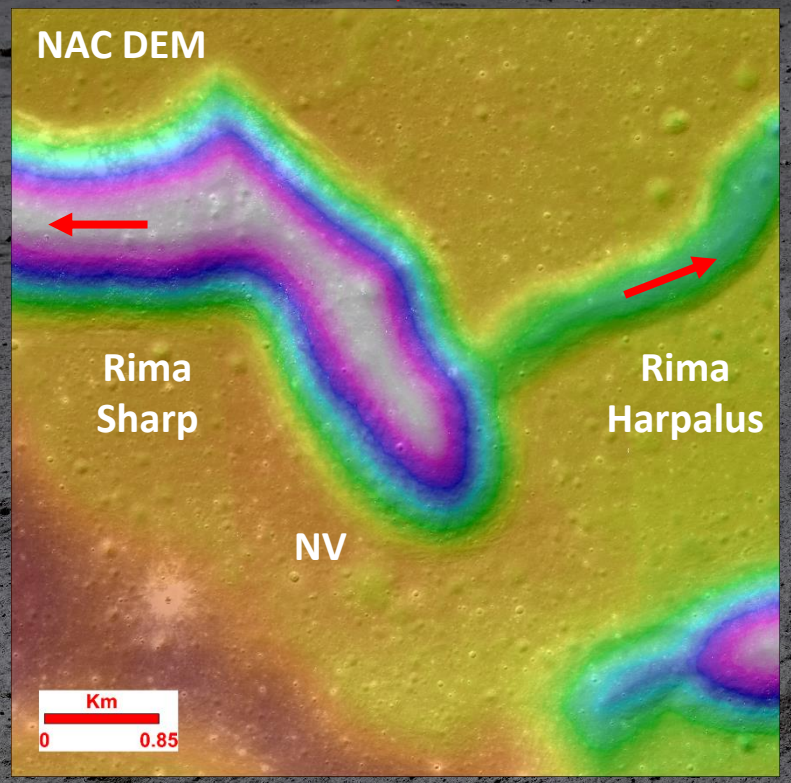


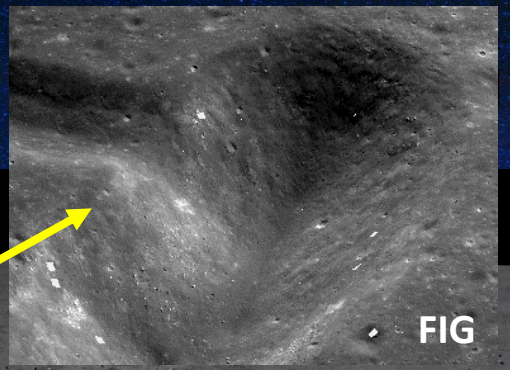
Complex Sinuous Rille System = Rima Sharp + Rima Mairan + Rima Louville + Rima Harpalus

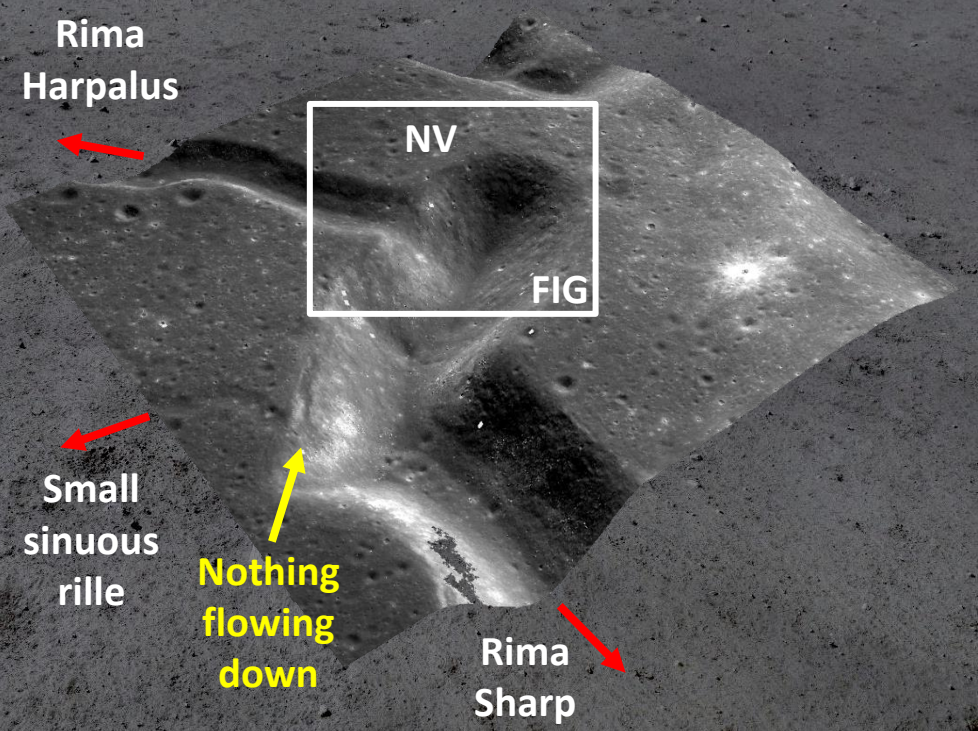
(Qian et al., 2021, GRL)

Rima Sharp





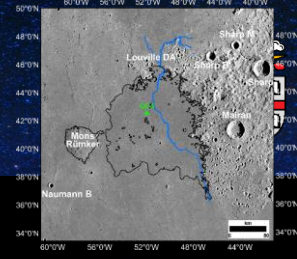


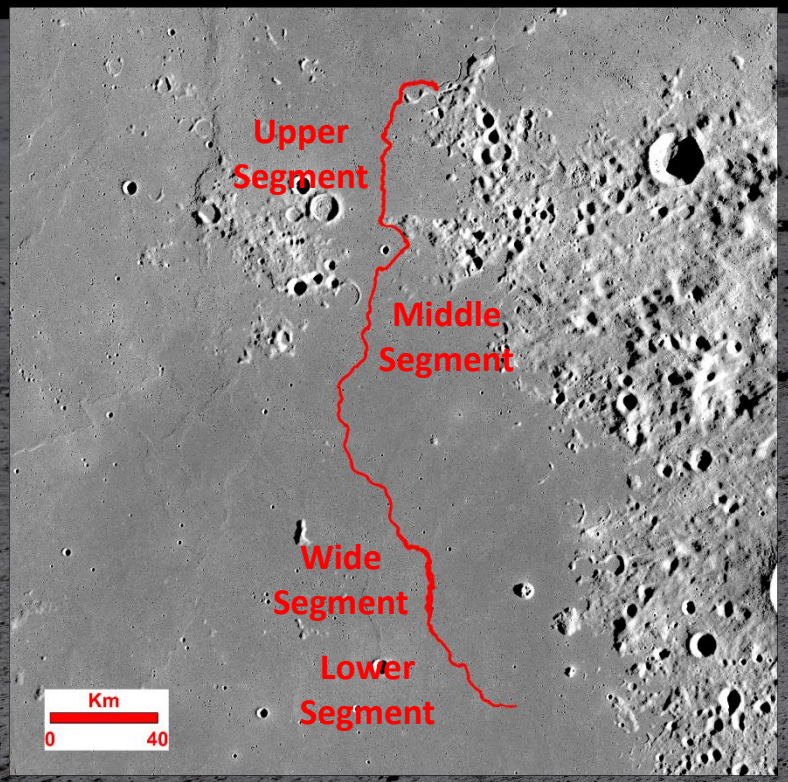


- One elongated source vent (NV)
- Rima Harpalus formed earlier than Rima Sharp
- Small sinuous rille formed earlier than Rima Sharp

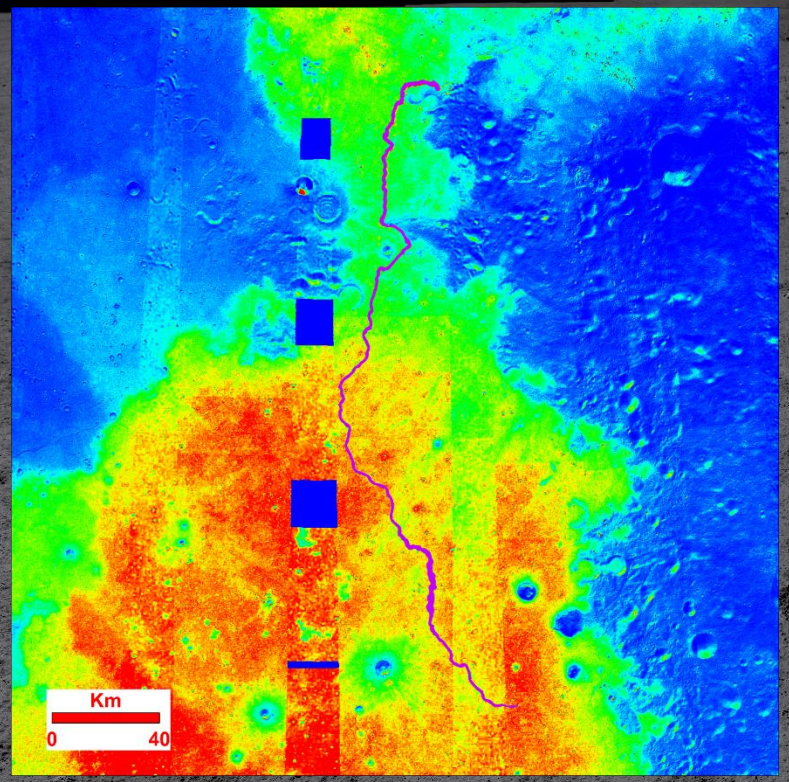
(Qian et al., 2021, GRL)

Rima Sharp

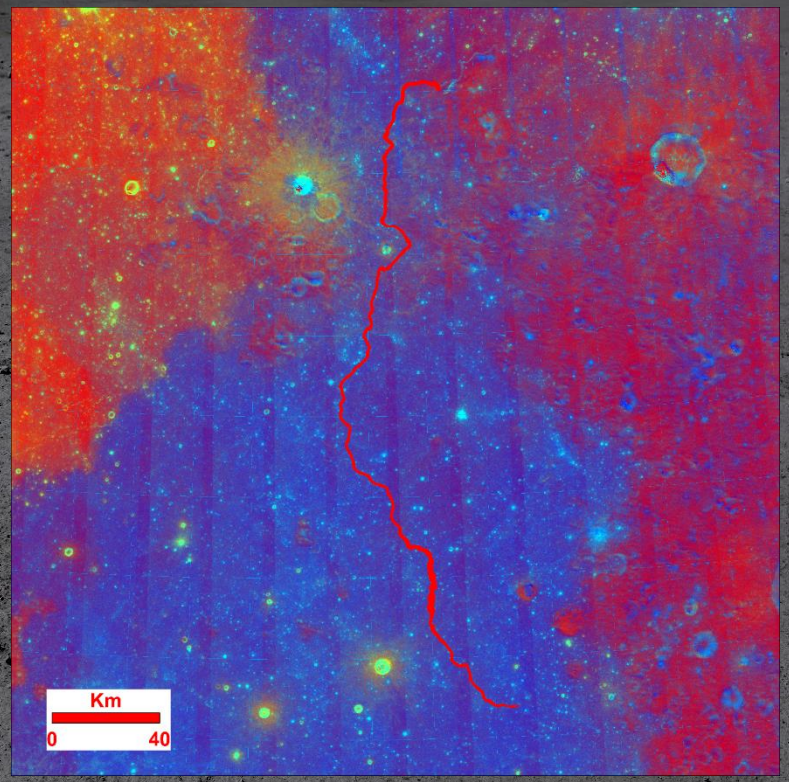




TC Morning Map



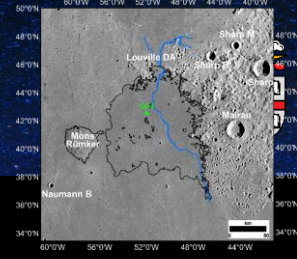
Clementine TiO2

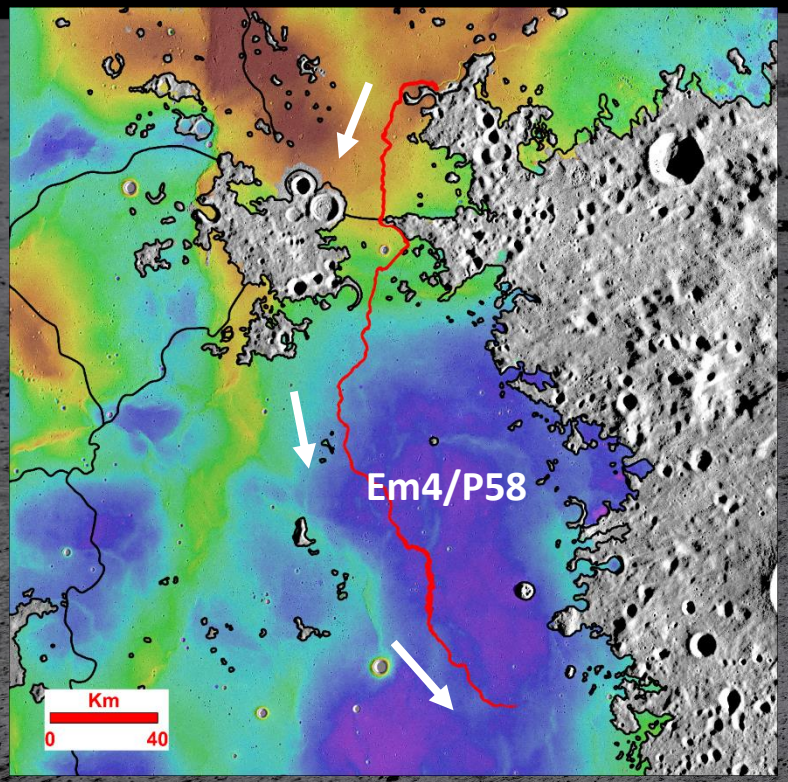


MI False Color Ratio Map

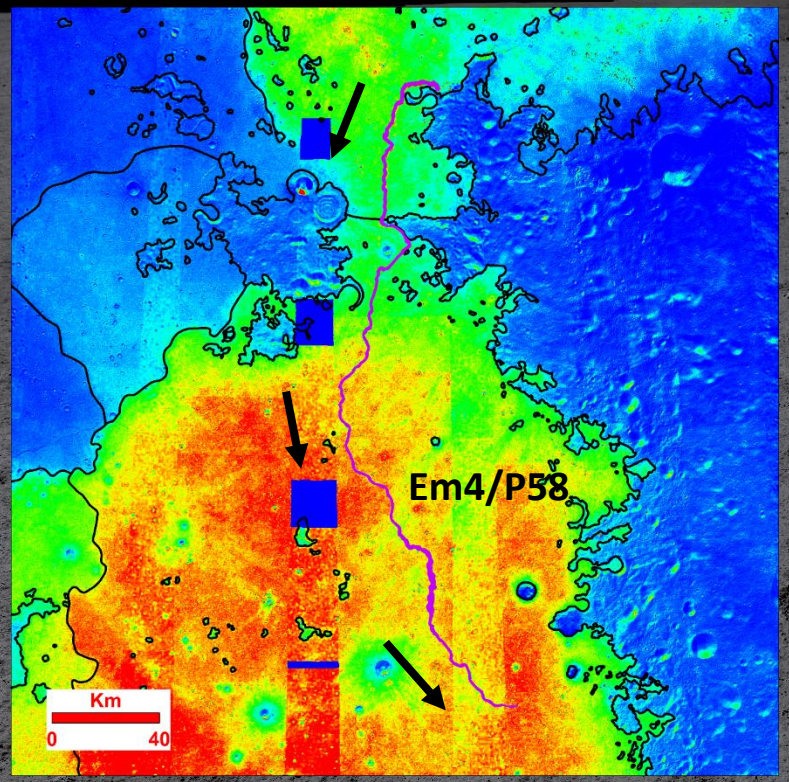
(Qian et al., 2021, GRL)

Rima Sharp

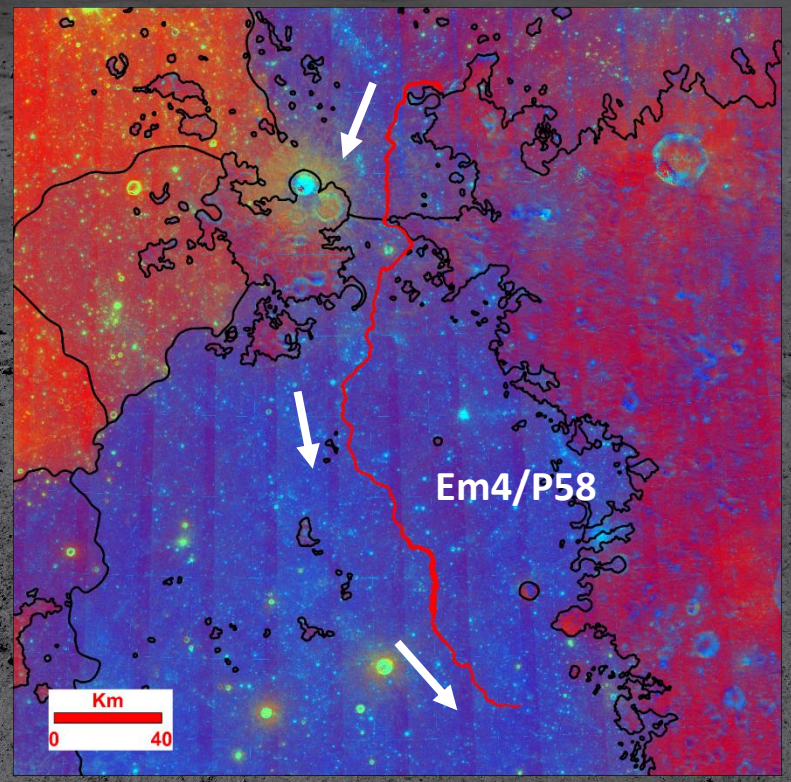




SLDEM2015



Clementine TiO2

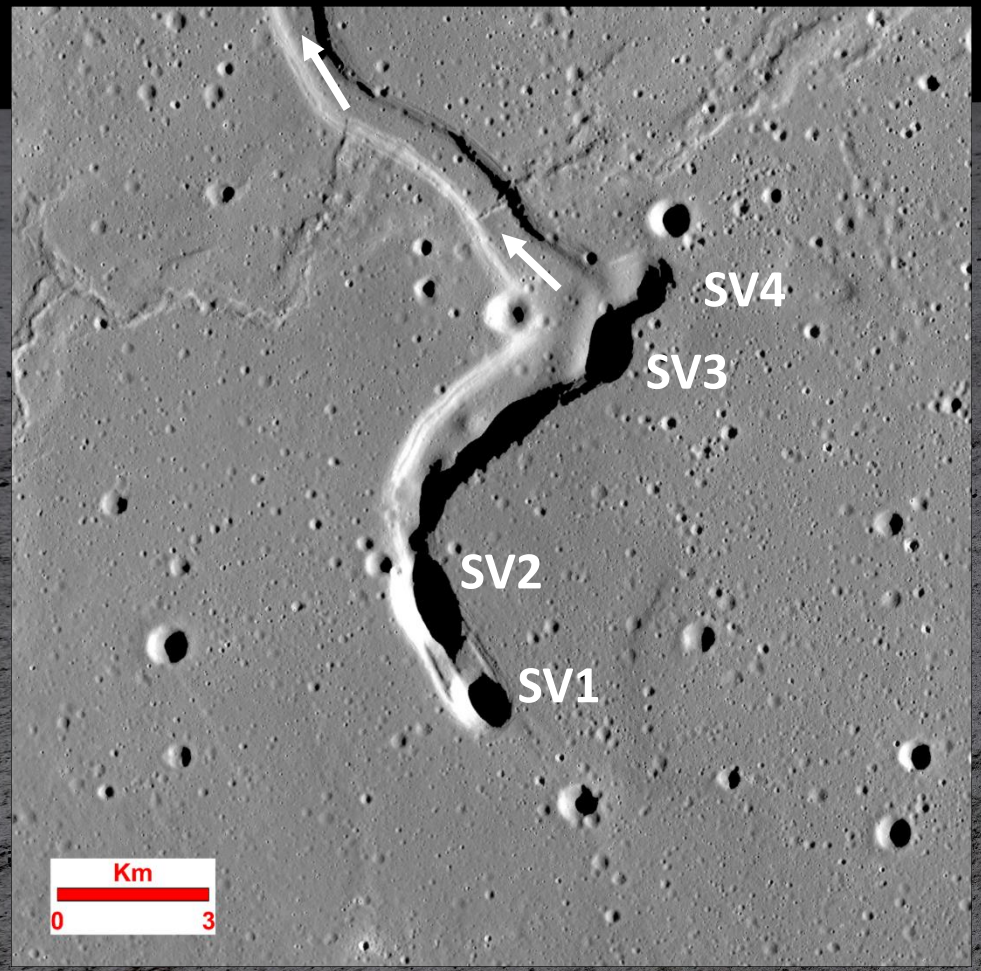


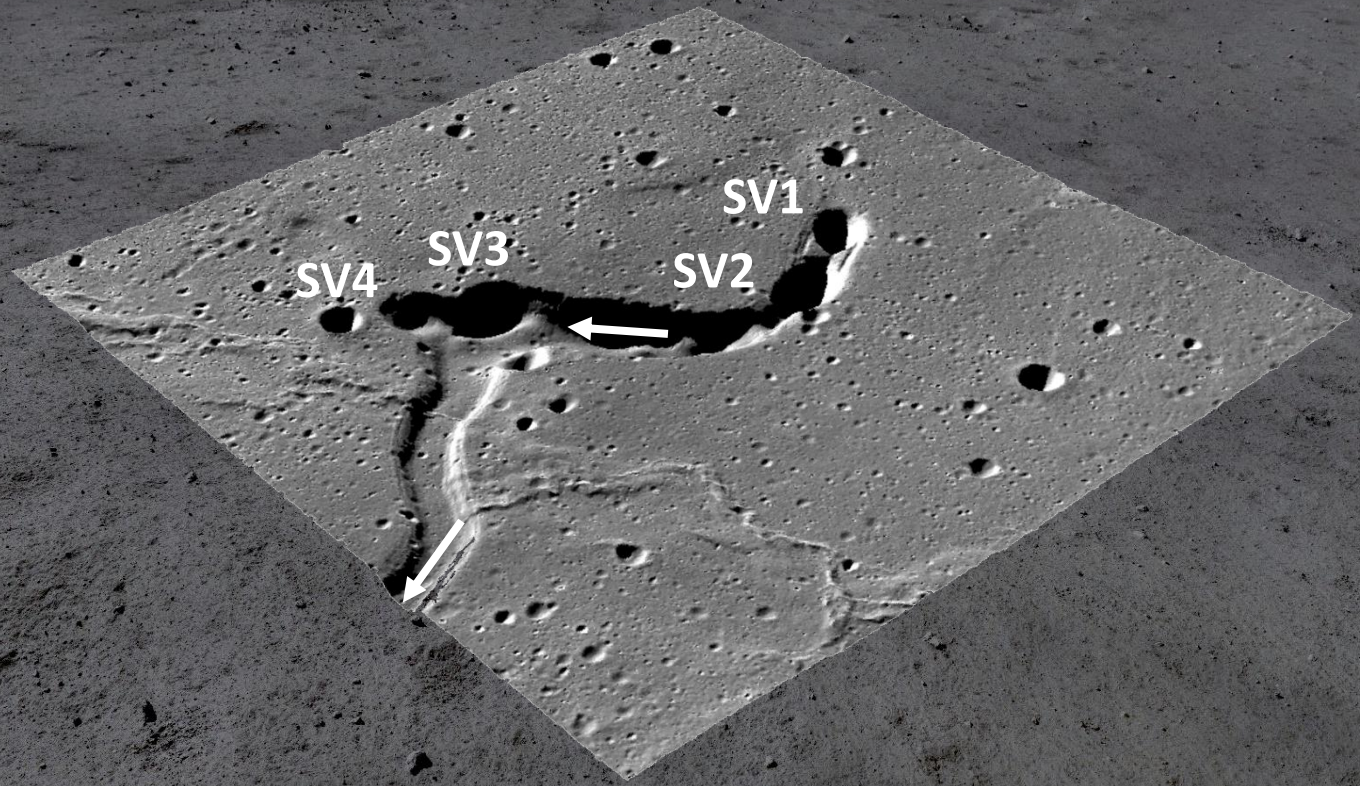
MI False Color Ratio Map

- Rima Sharp originates outside Em4/P58
- No clear evidence of materials from Rima Sharp (No overflow? The overflowed lavas have the same composition with the surrounding mare basalts? If so, 1) Rima Sharp doesn't provide mare basalt materials, but their compositions are identical by coincidence; or 2) Rima Sharp does provide all the mare basalt materials, therefore their compositions are the same naturally)

(Qian et al., 2021, GRL)

Rima Mairan

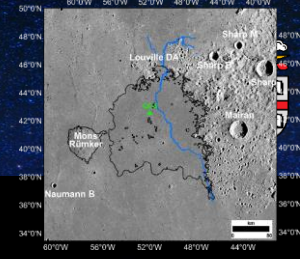


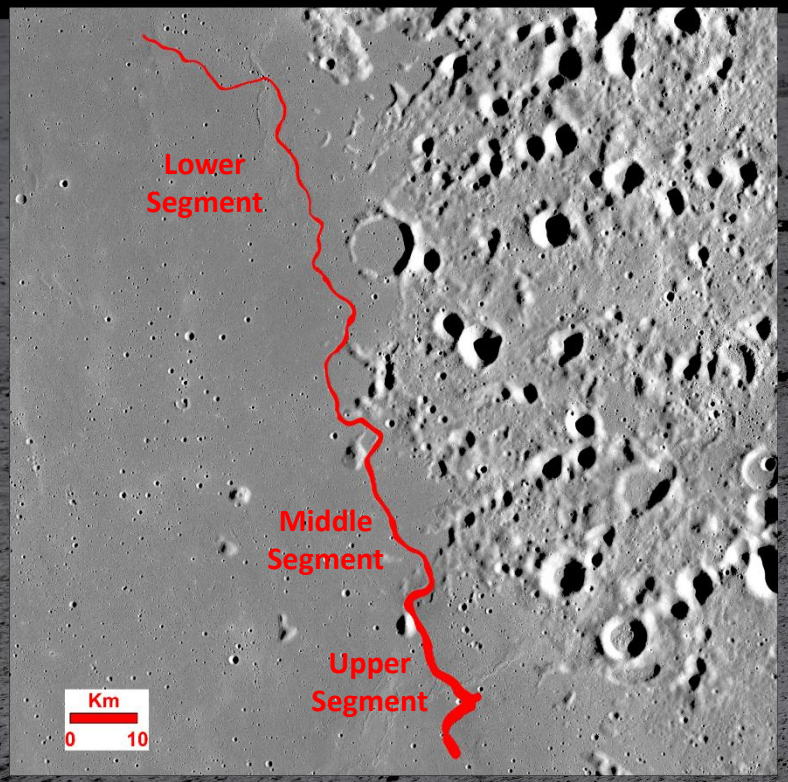


- Two elongated source vents, SV1 and SV2
- SV3 and SV4 don't have rims, which is more likely to be depressions not impact craters
- SV3 and SV4 are ponds of lavas controlled by wrinkle ridges

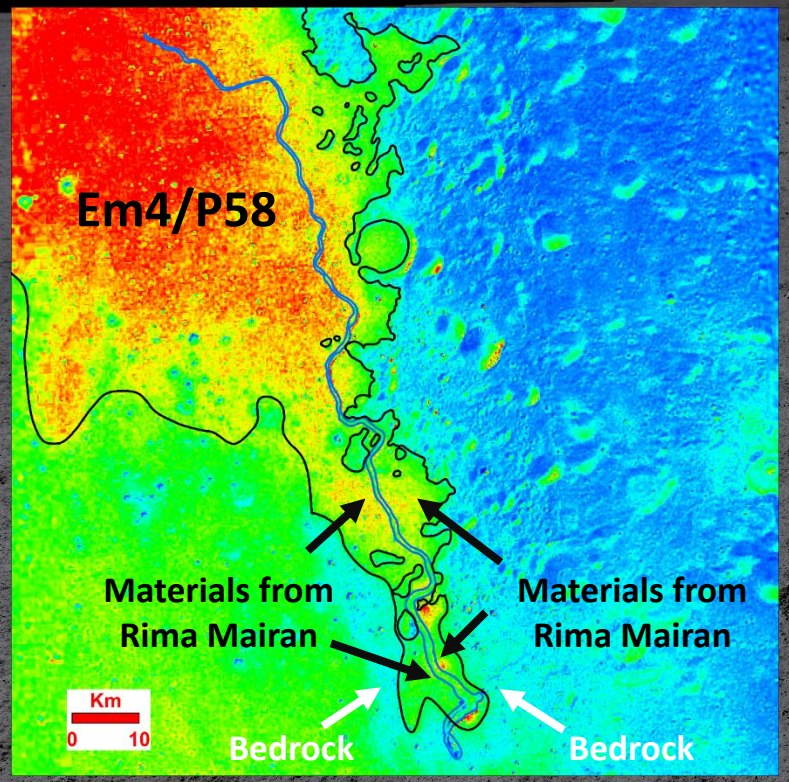
(Qian et al., 2021, GRL)

Rima Mairan

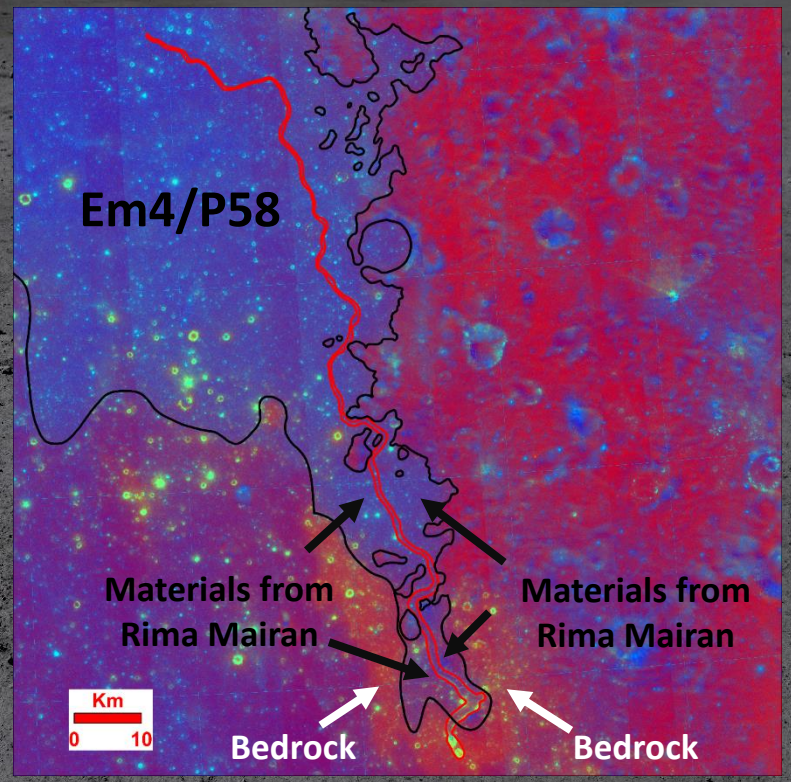




Kaguya TC Morning Map



Clementine TiO2

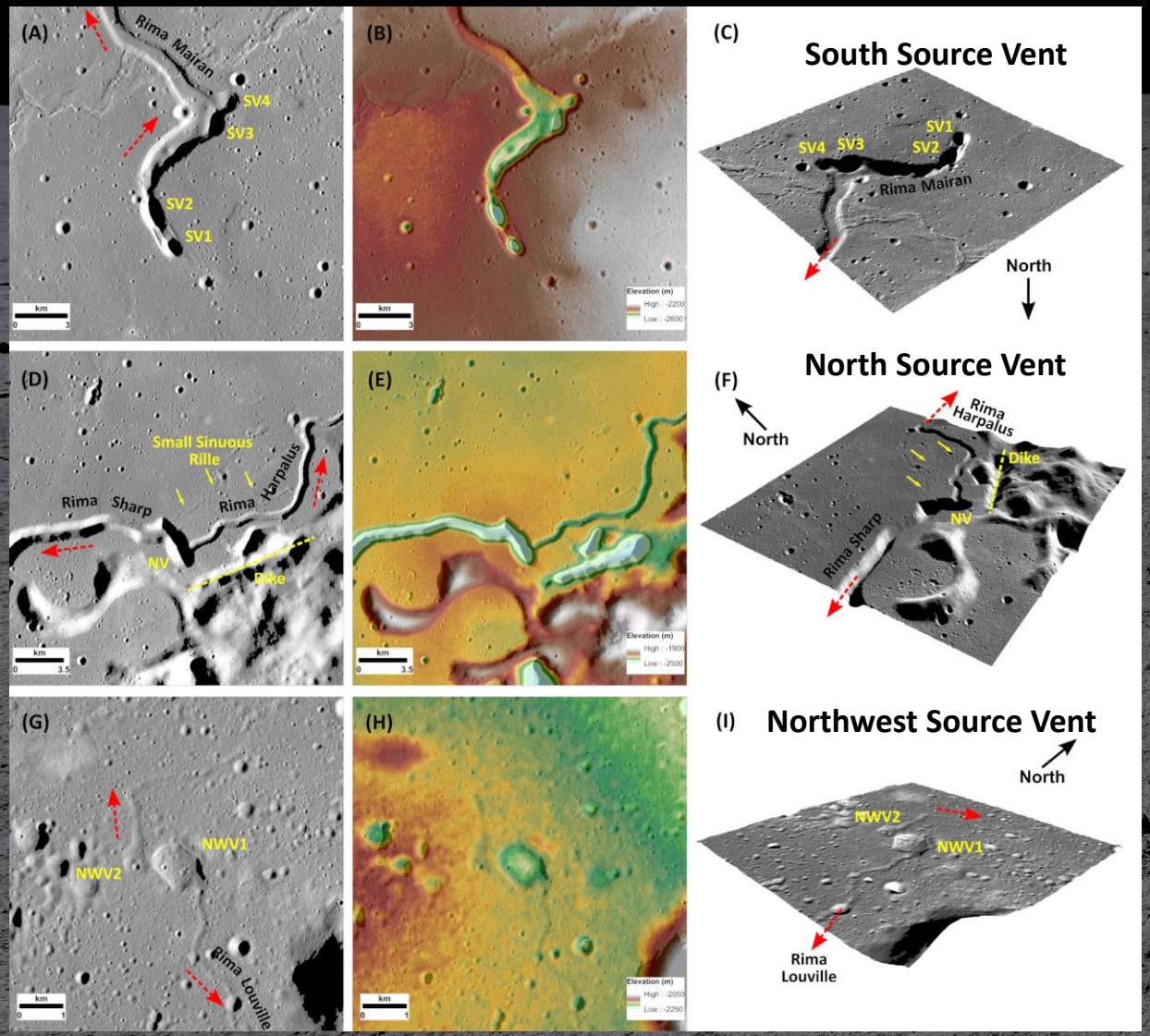


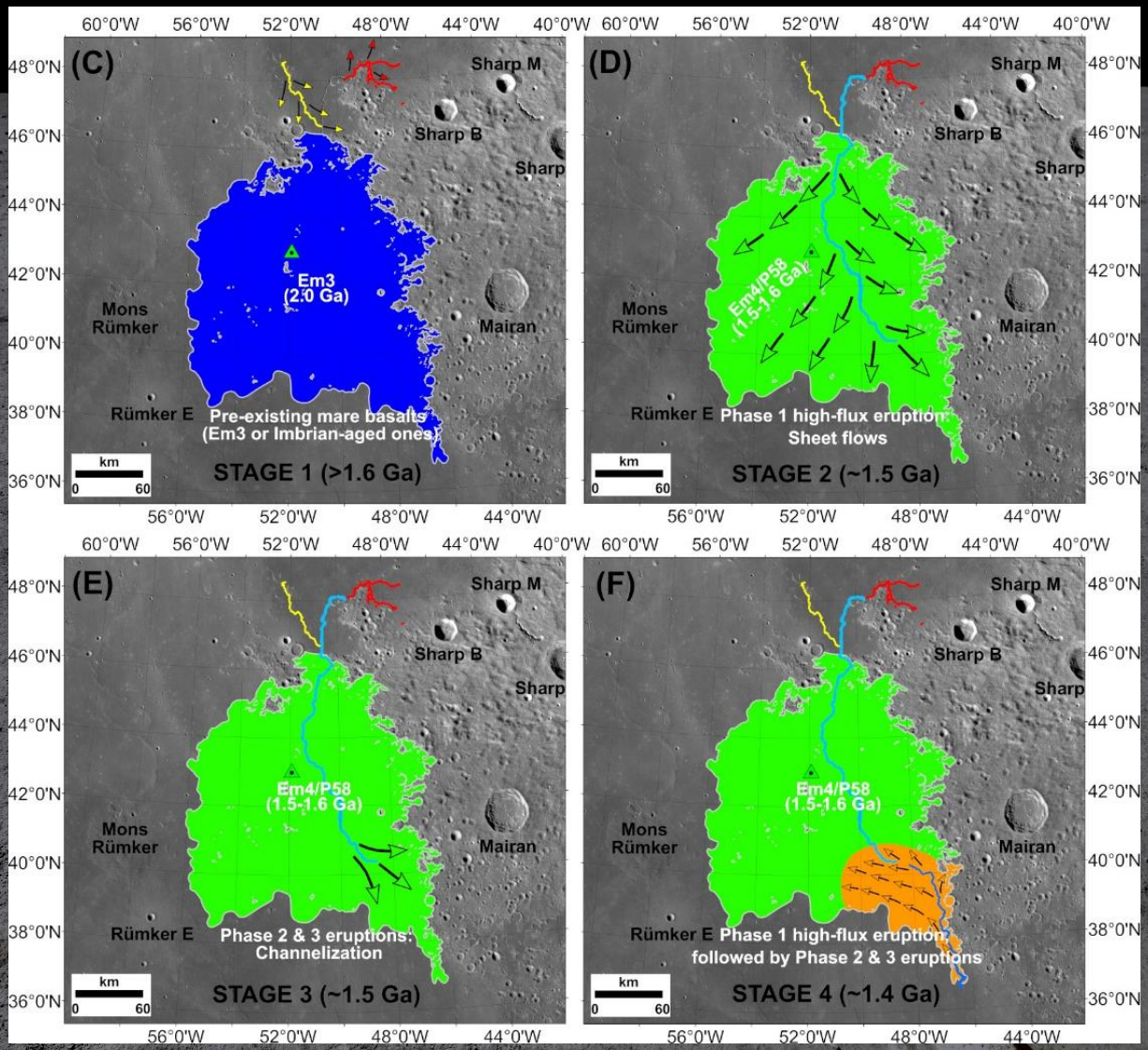
Kaguya False Color Ratio Map

- Intermediate-Ti materials surround Rima Mairan in the upper and middle segment (black arrows), may overflowed from Rima Mairan
- The bedrock before the formation of Em4/P58 has low-Ti abundance (white arrow), extending to the Gruithuisen region

(Qian et al., 2021, GRL)

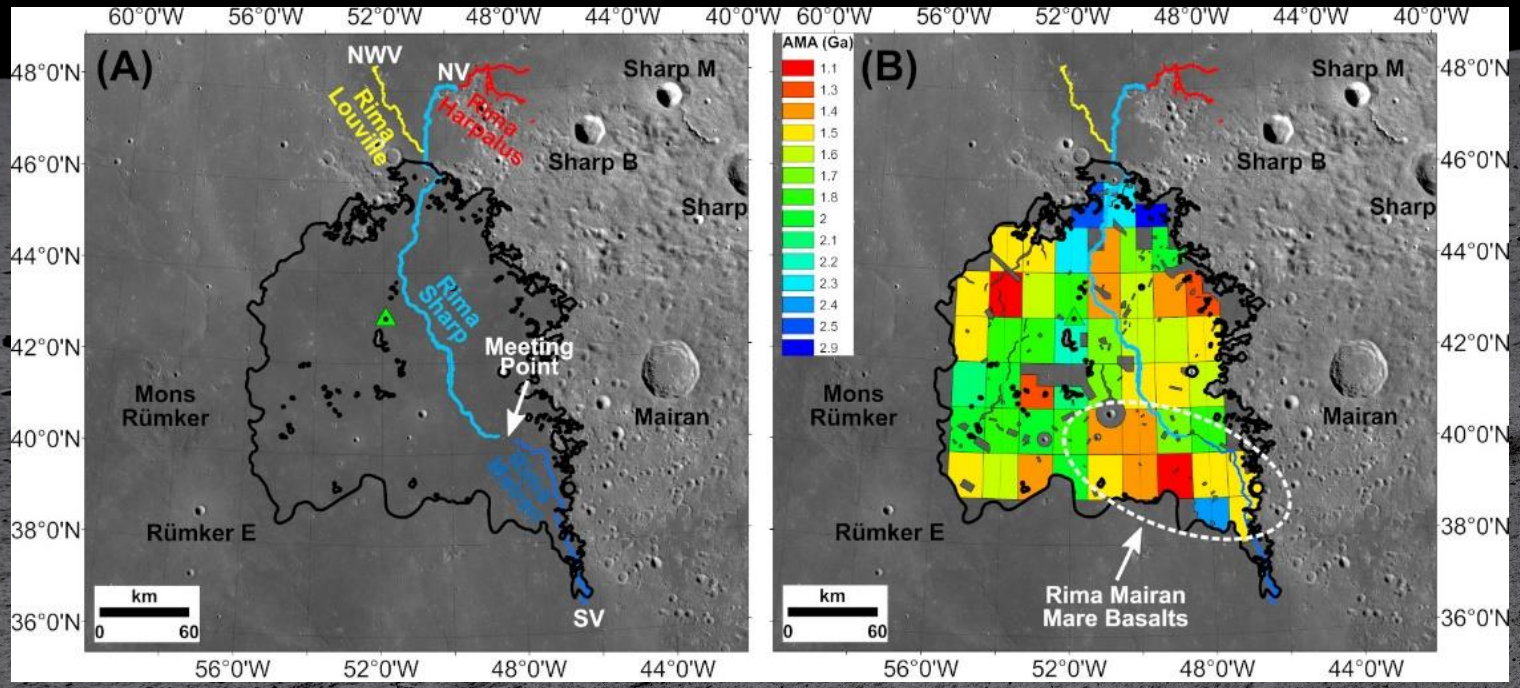
Formation Sequence

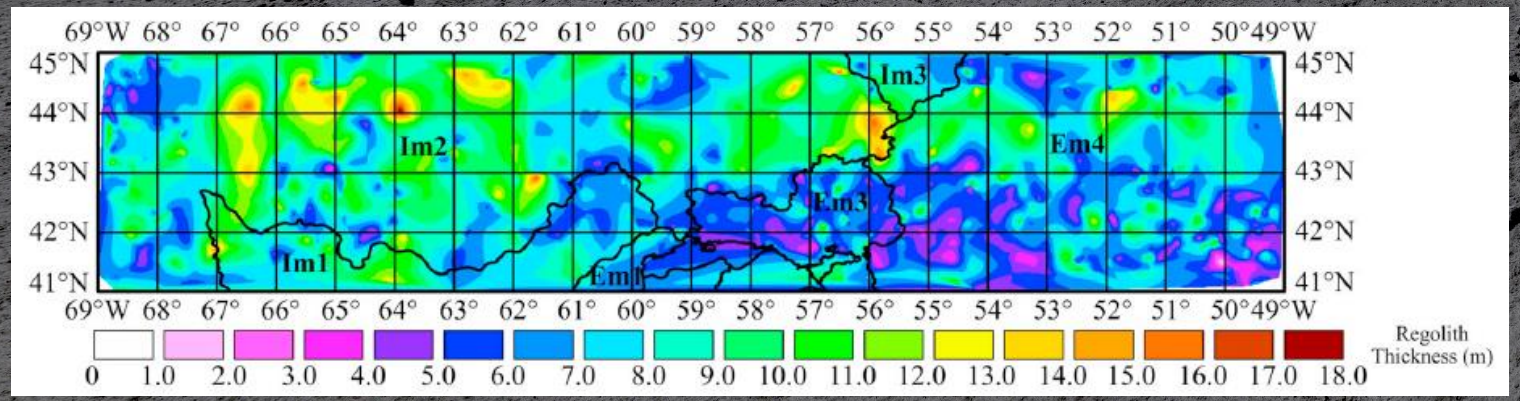




(Qian et al., 2021, GRL)

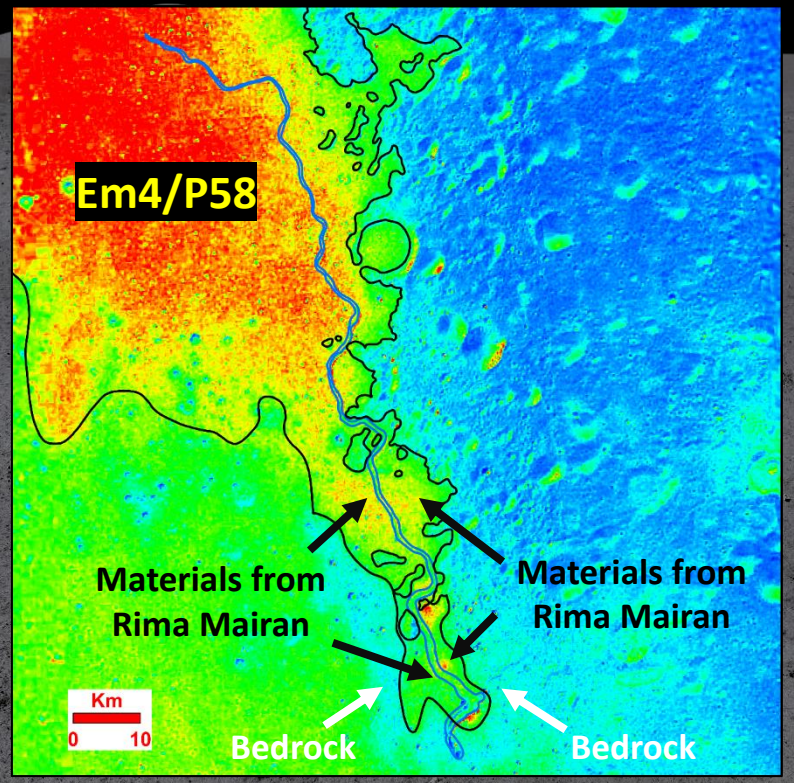
Evidence





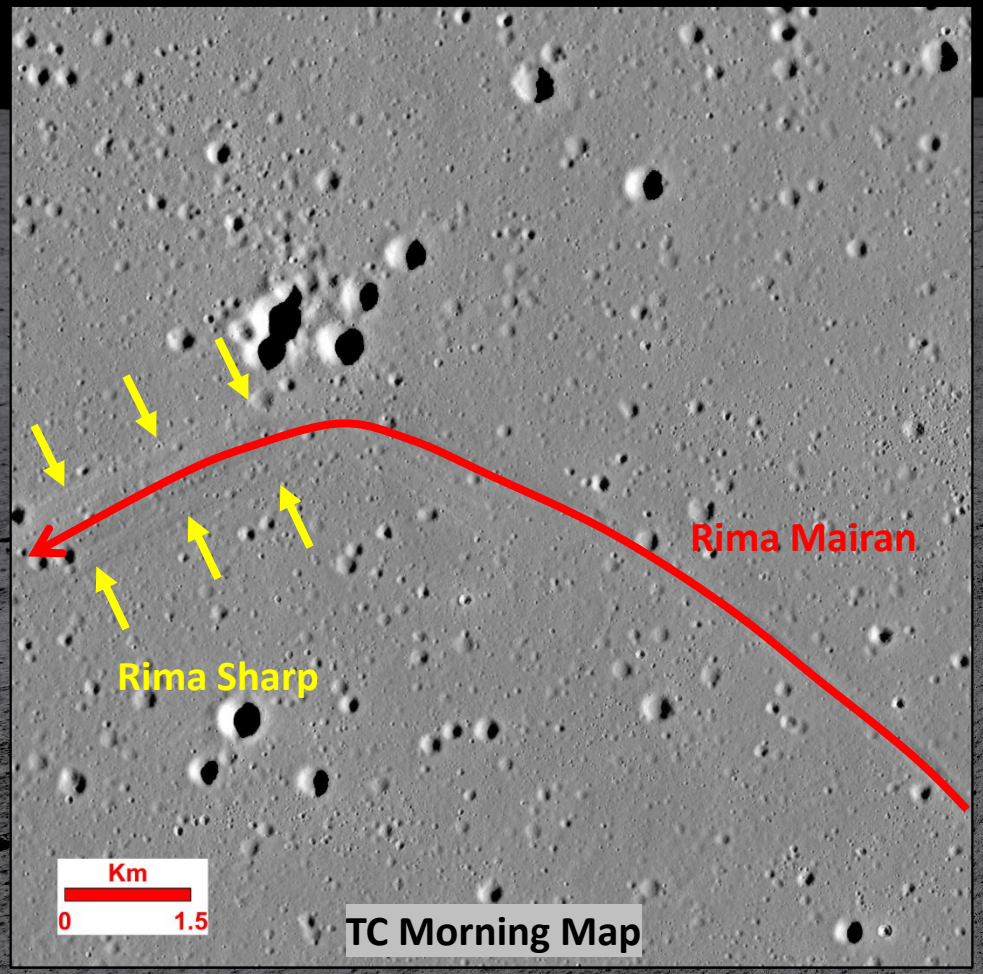
(Qian et al., 2020, Icarus)

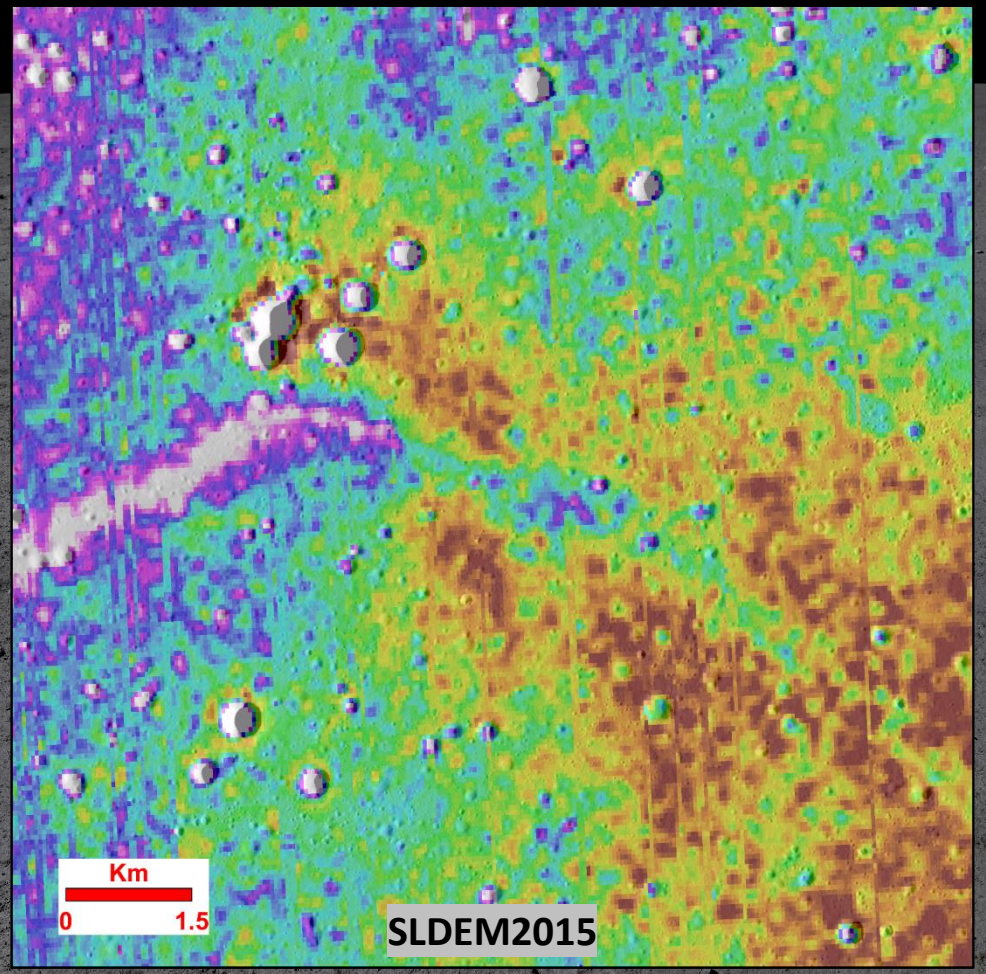
(Qian et al., 2021, GRL)



(Clementine TiO2)

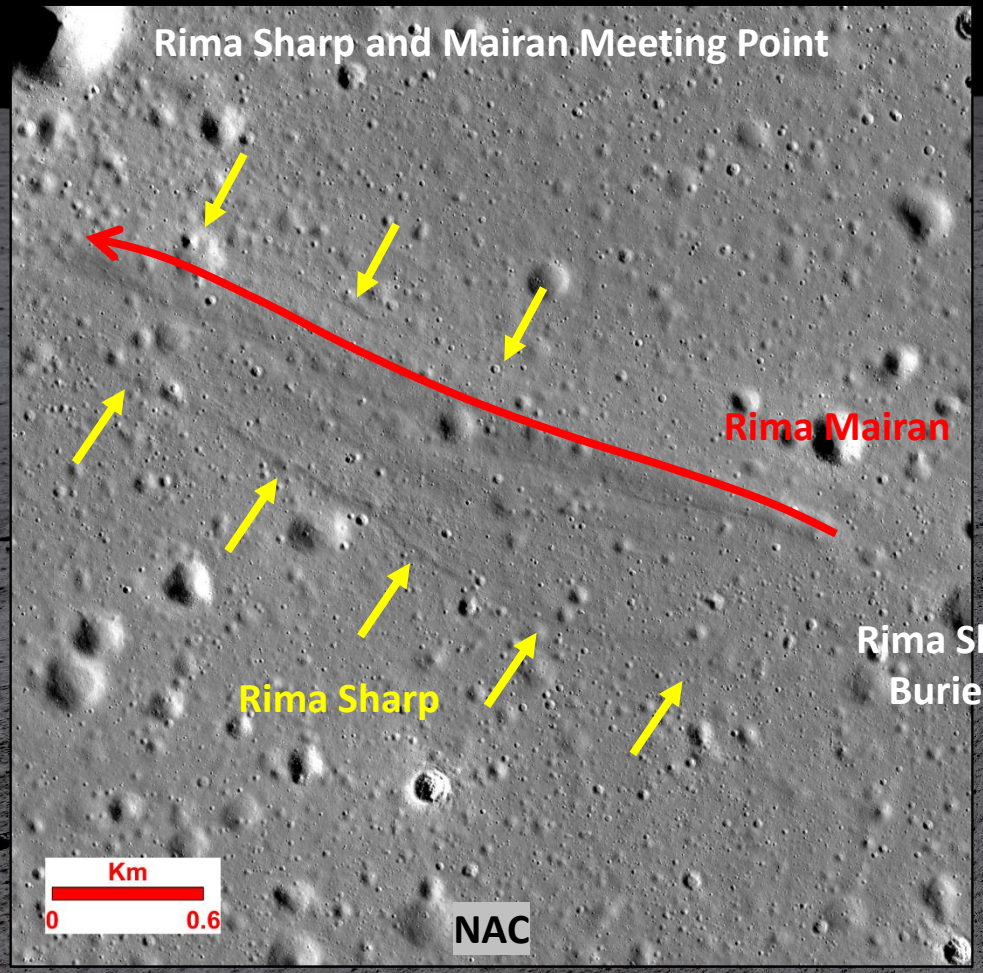
Evidence: Rima Mairan enters Rima Sharp

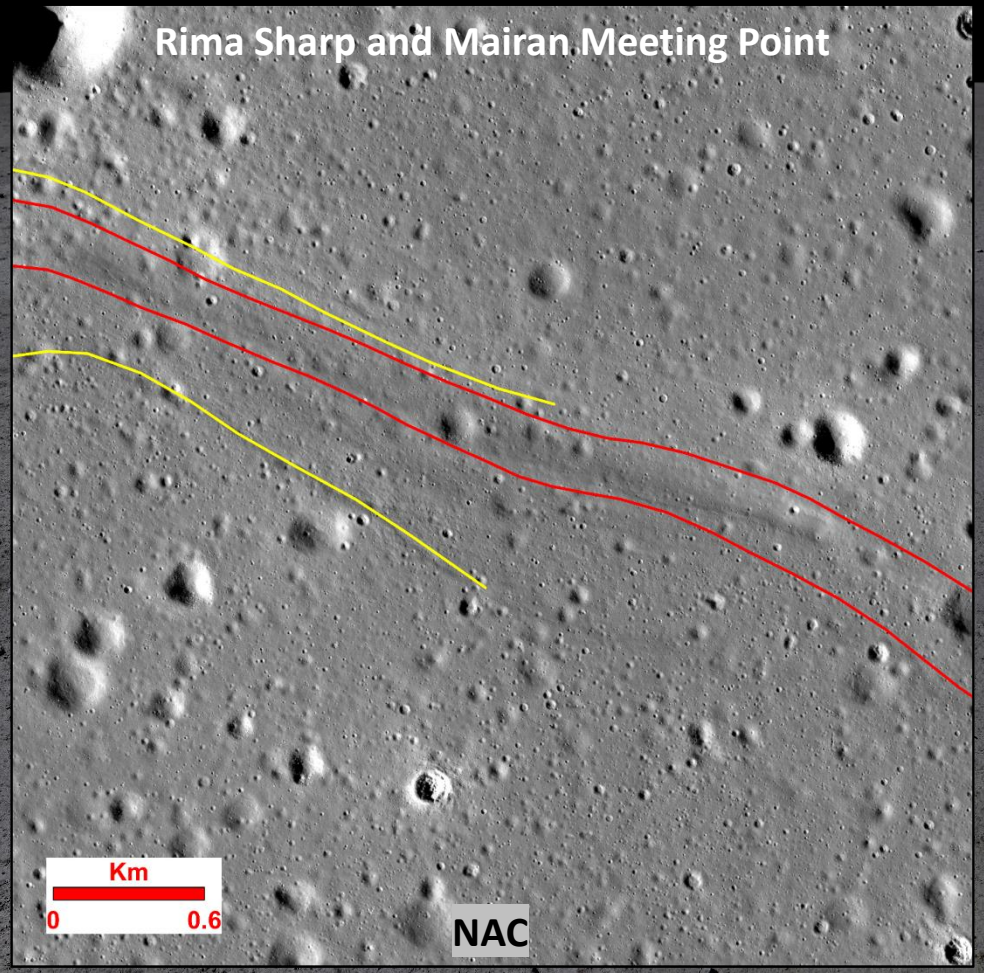




(Qian et al., 2021, GRL)

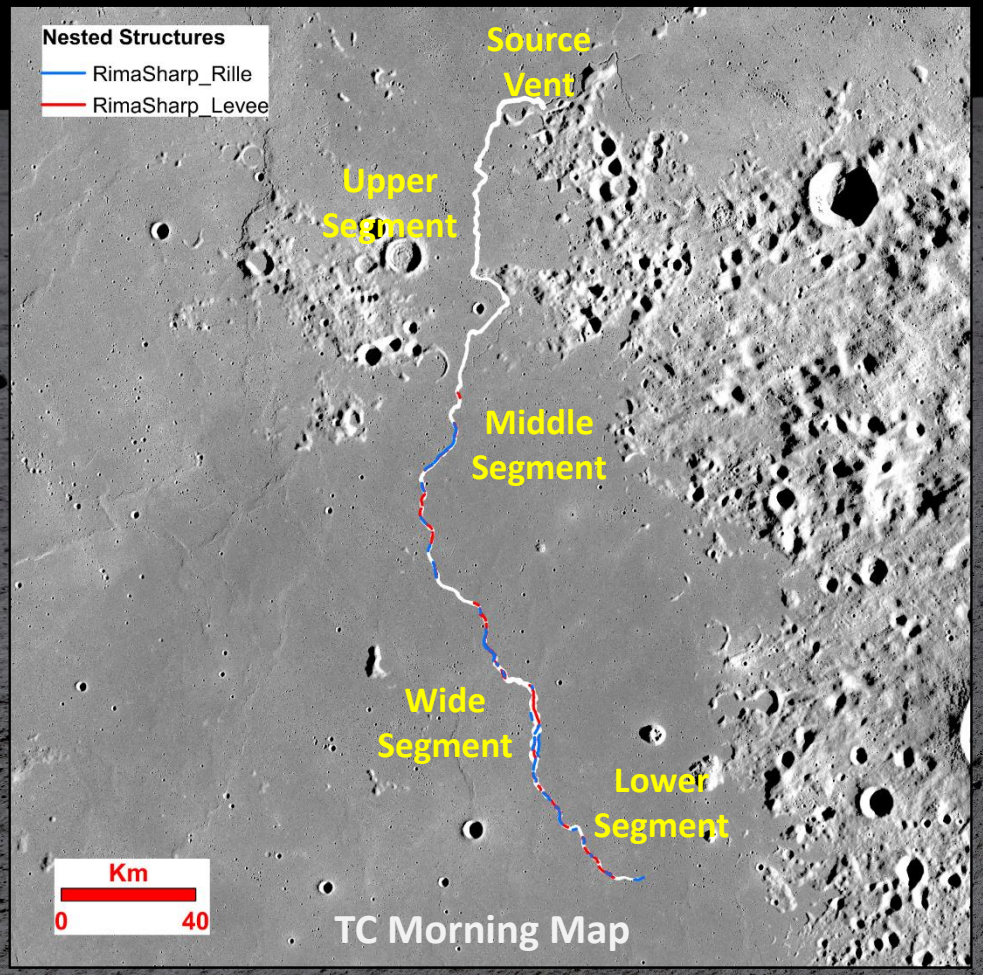
Evidence: Rima Mairan enters Rima Sharp

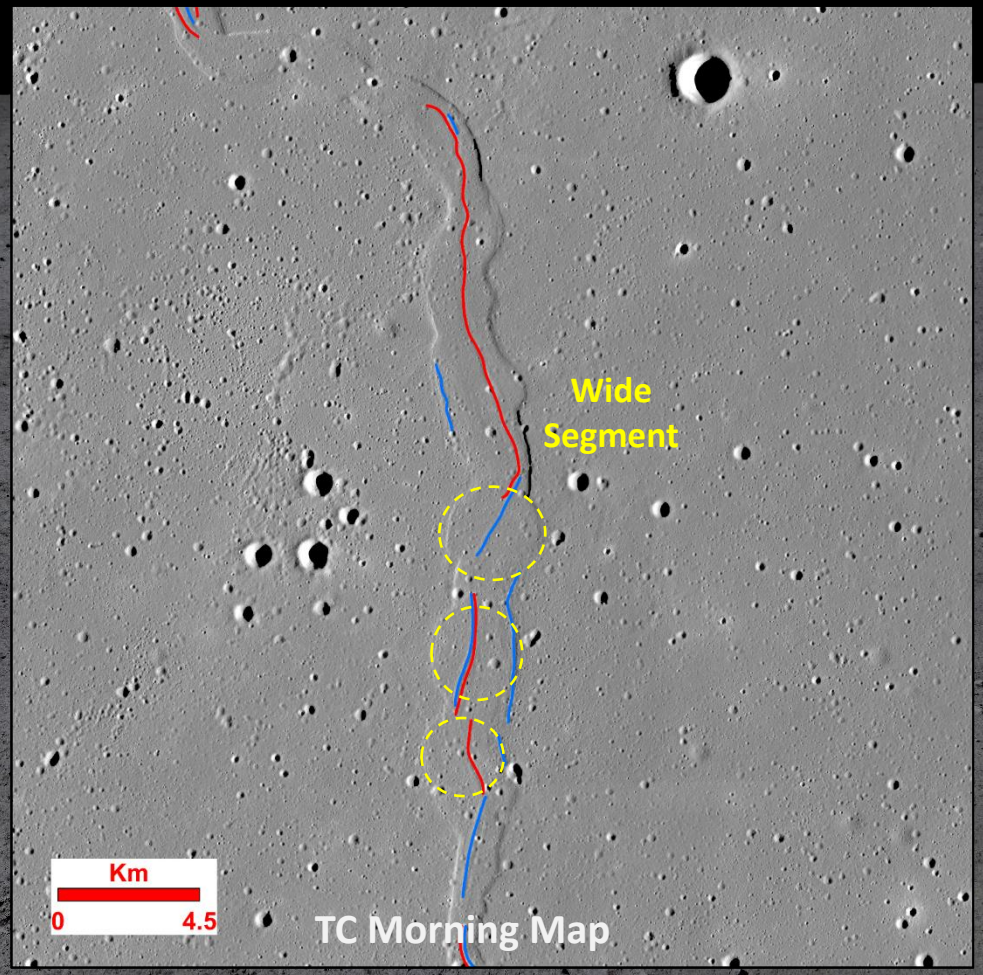




(Qian et al., 2021, GRL)

Evidence: Lava pond & inner features

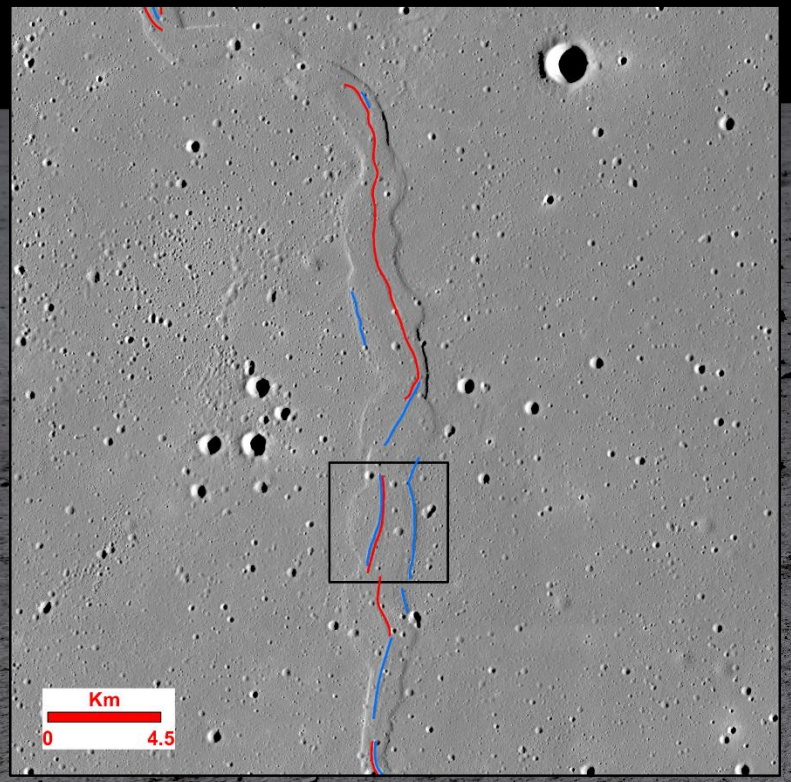




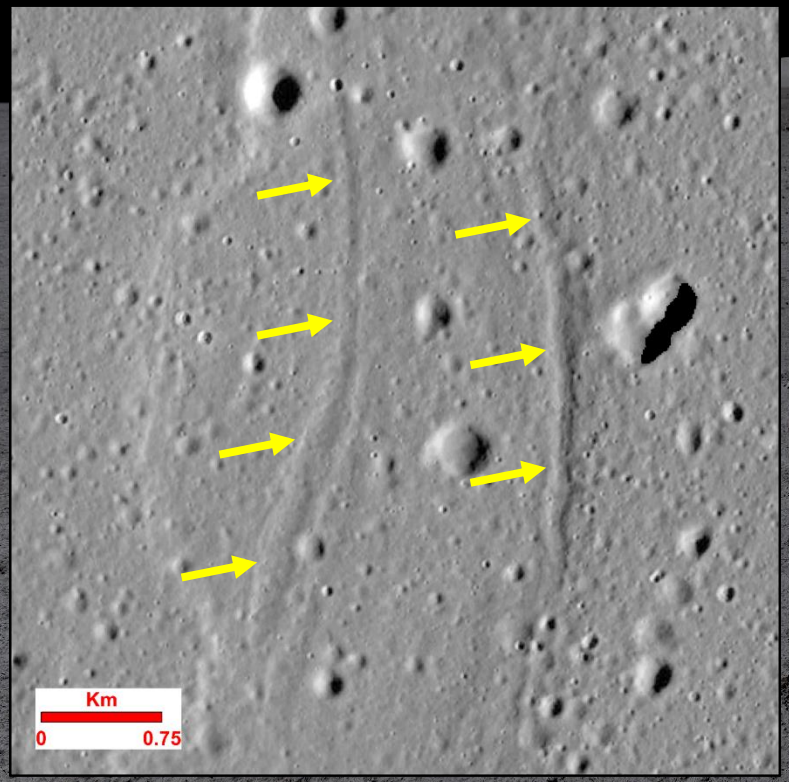
Lava pond & inner features within Rima Sharp were produced by Rima Mairan entering Rima Sharp

(Qian et al., 2021, GRL)

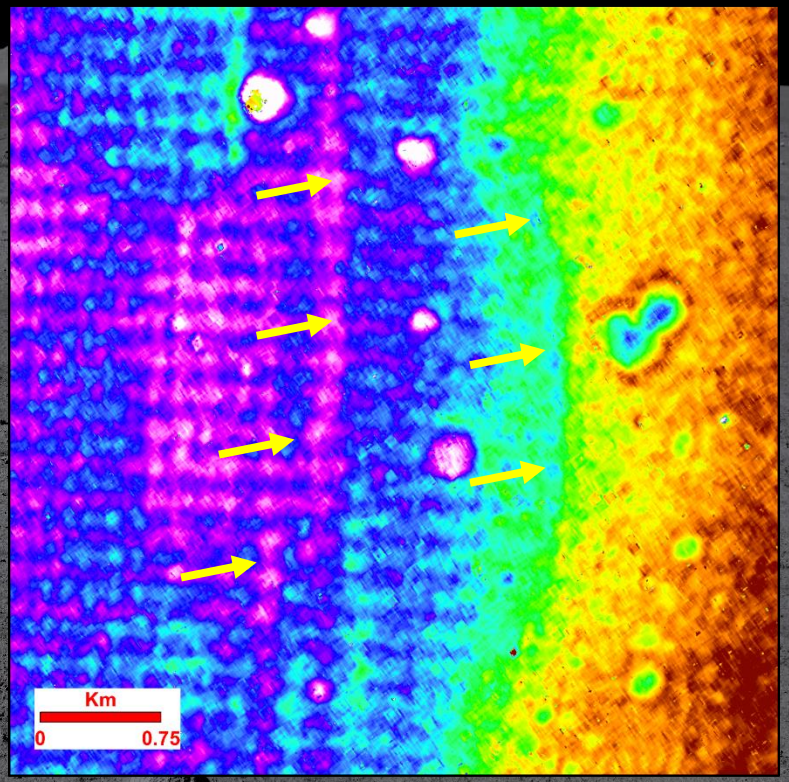
Evidence: Lava pond & inner features



TC Morning Map
Figure Location (black box)



TC Morning Map

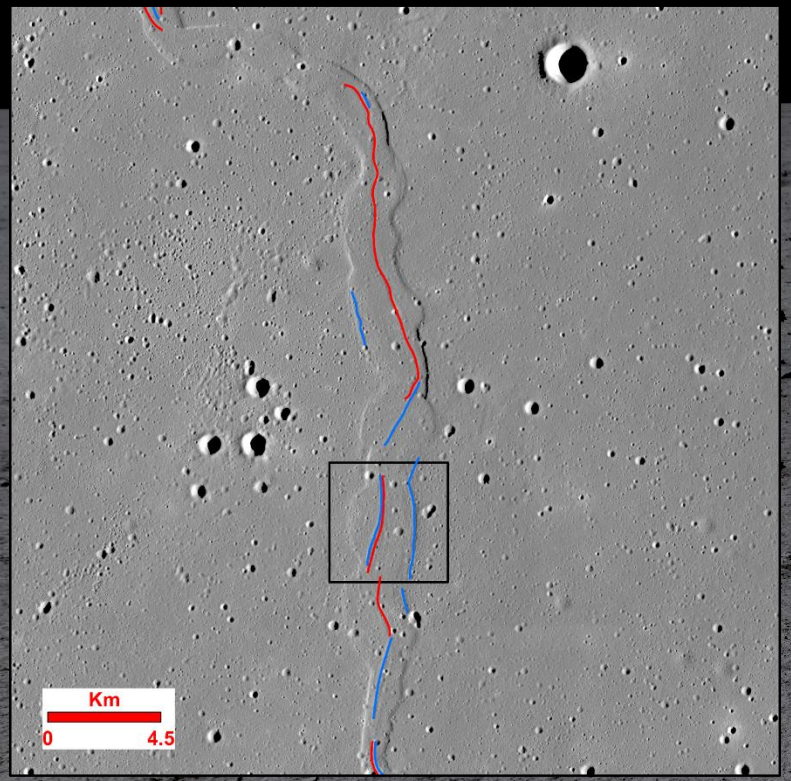


NAC DEM
(high resolution data not available)

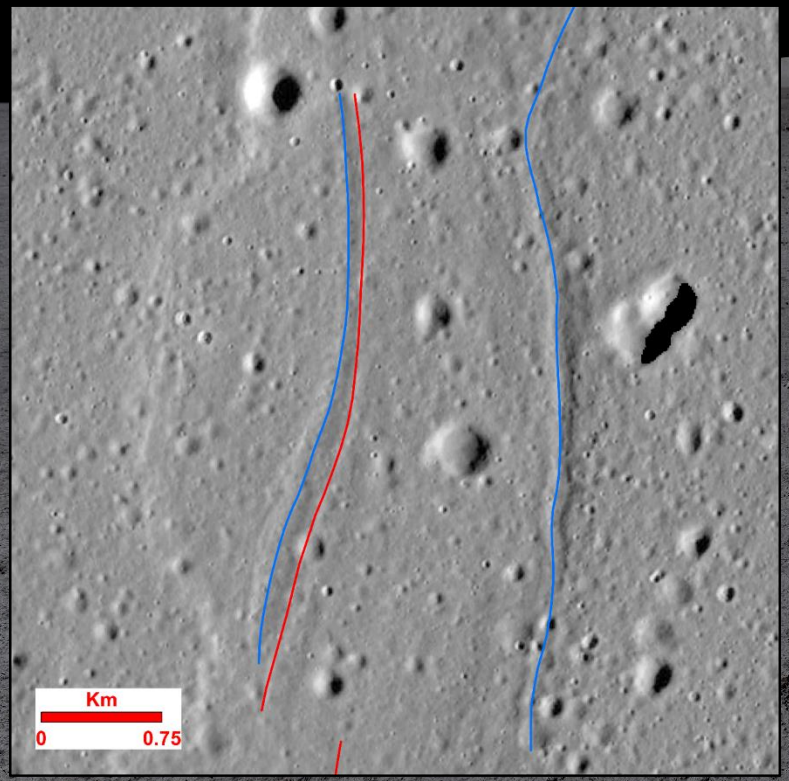
Lava pond & inner features within Rima Sharp were produced by Rima Mairan entering Rima Sharp

(Qian et al., 2021, GRL)

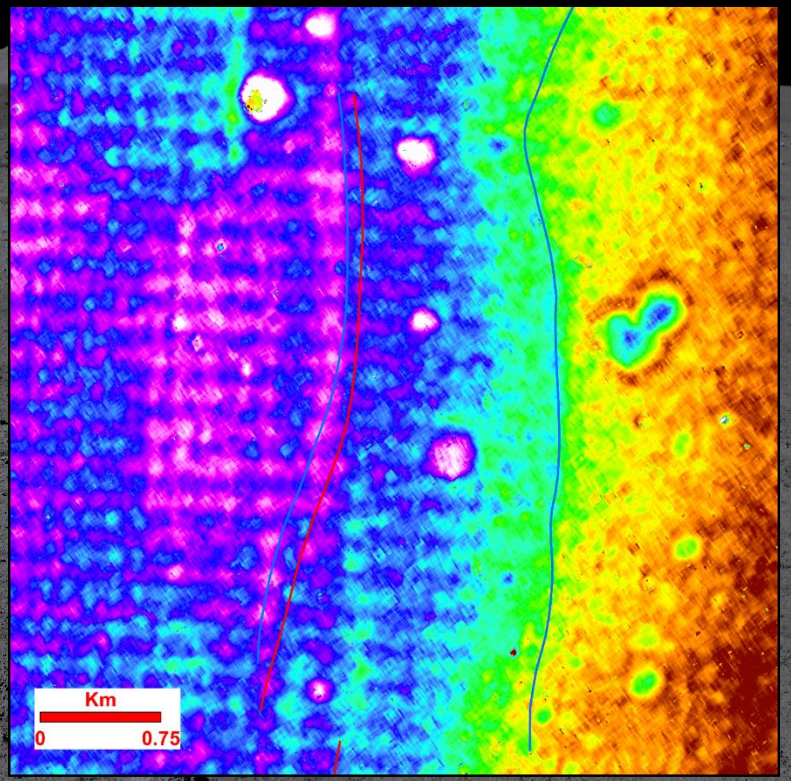
Evidence: Lava pond & inner features



TC Morning Map
Figure Location (black box)



TC Morning Map

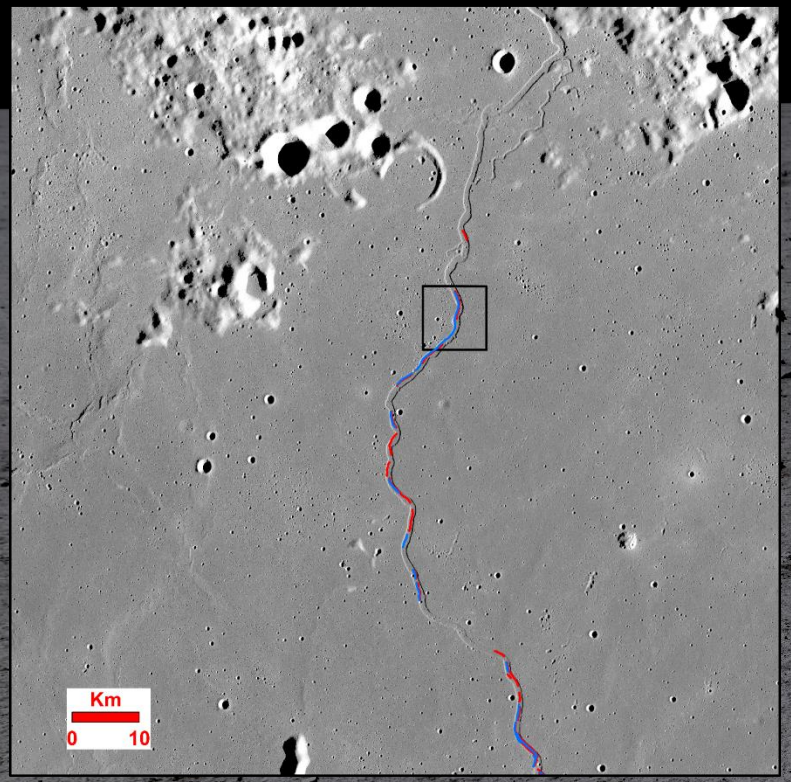


NAC DEM
(high resolution data not available)

Lava pond & inner features within Rima Sharp were produced by Rima Mairan entering Rima Sharp

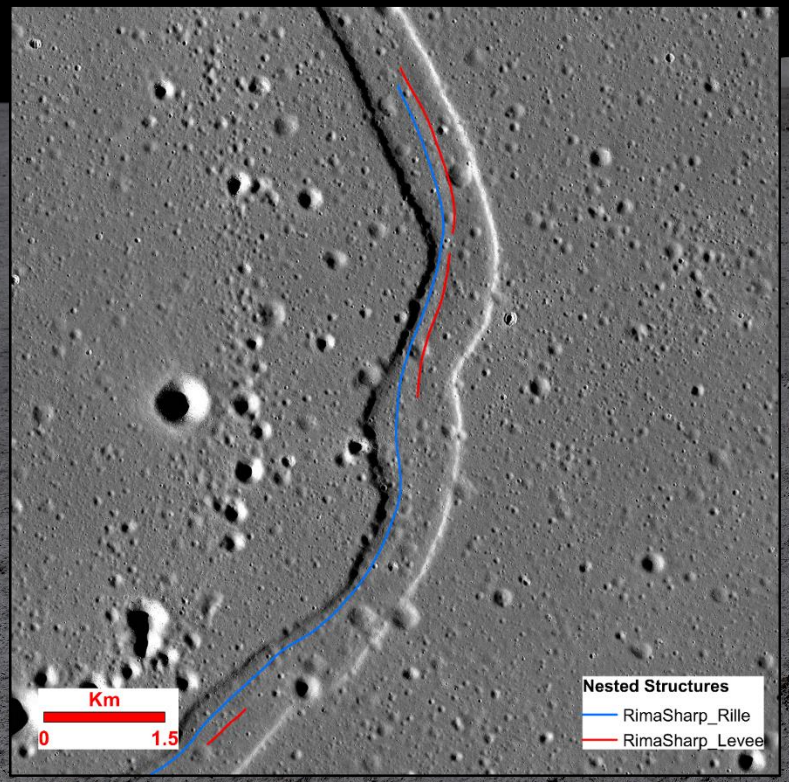
(Qian et al., 2021, GRL)

Evidence: Inner features



TC Morning Map

Figure Location



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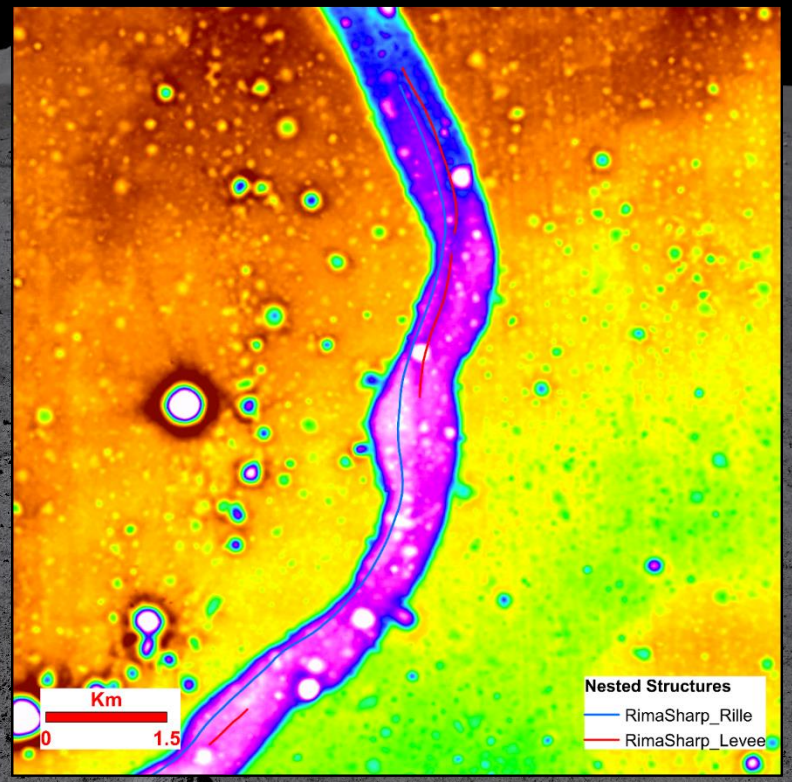
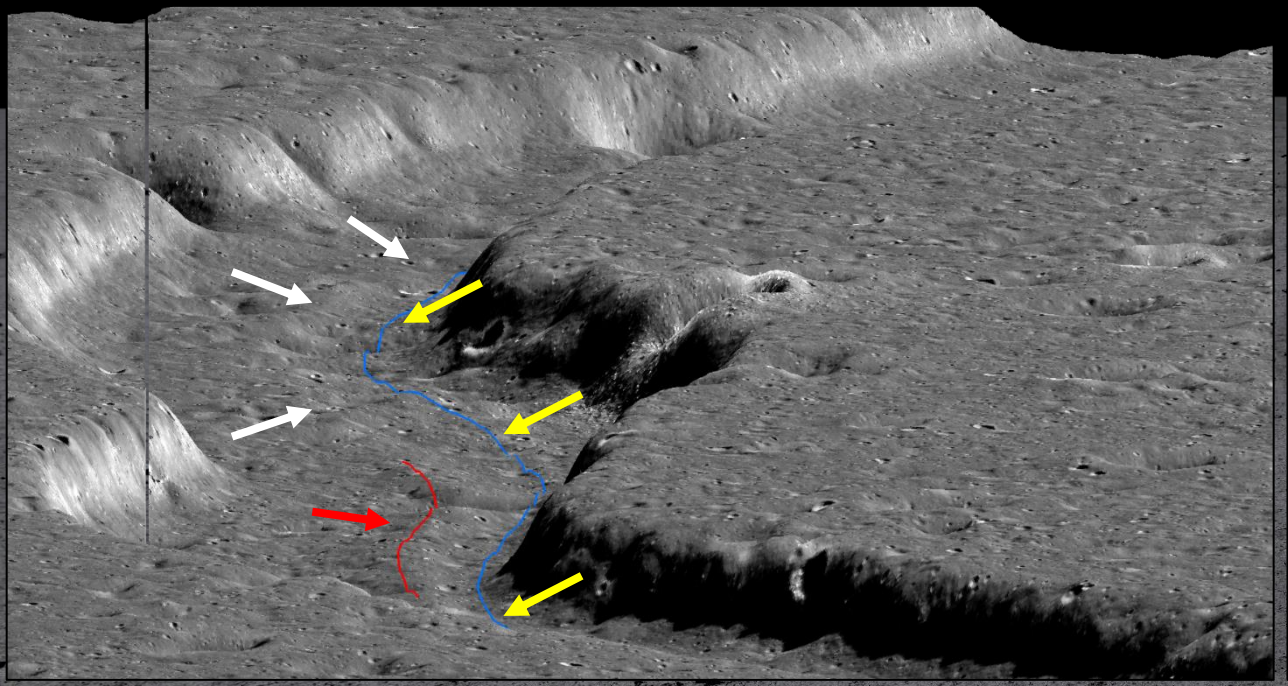


NAC DEM

Lava pond & inner features within Rima Sharp were produced by Rima Mairan entering Rima Sharp

(Qian et al., 2021, GRL)

Evidence: Inner features



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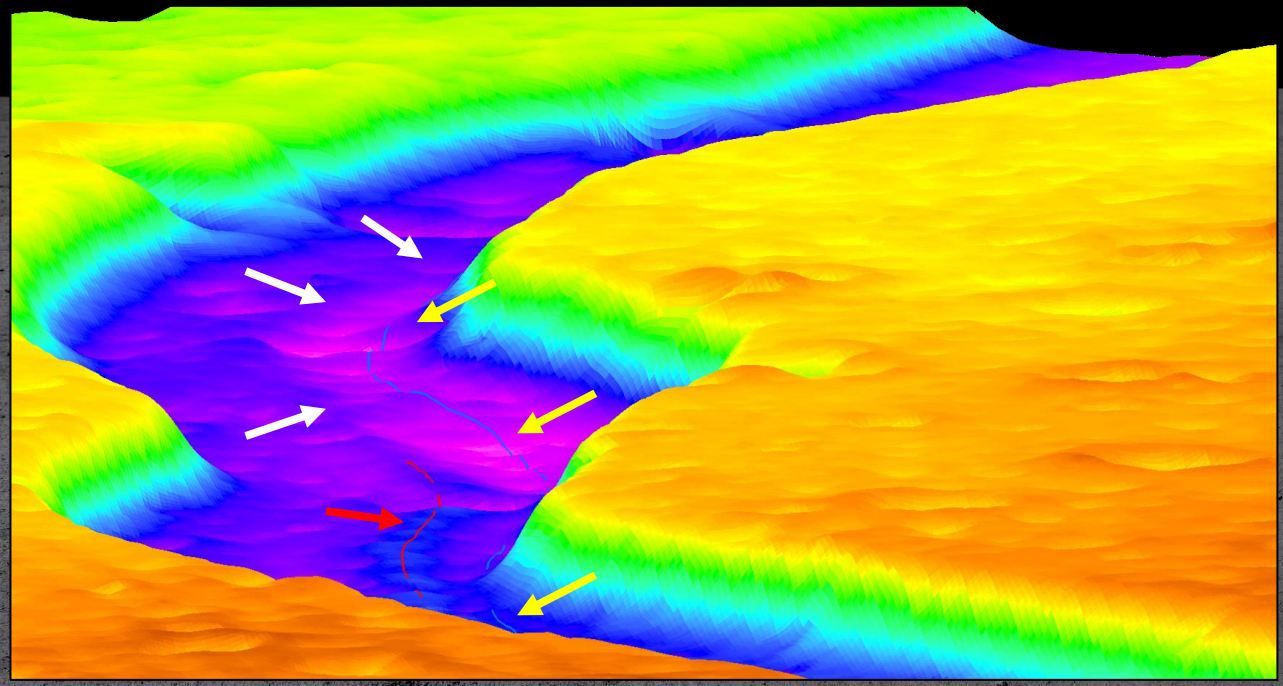
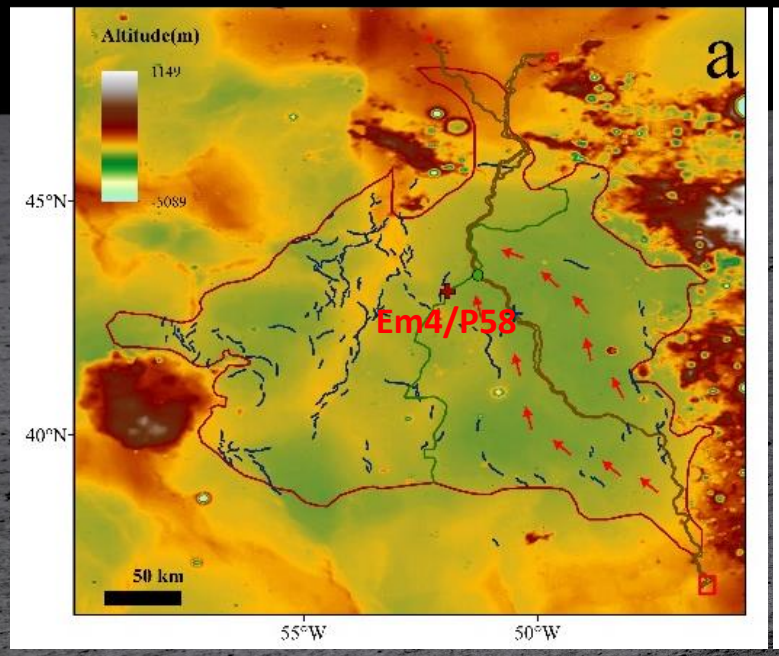


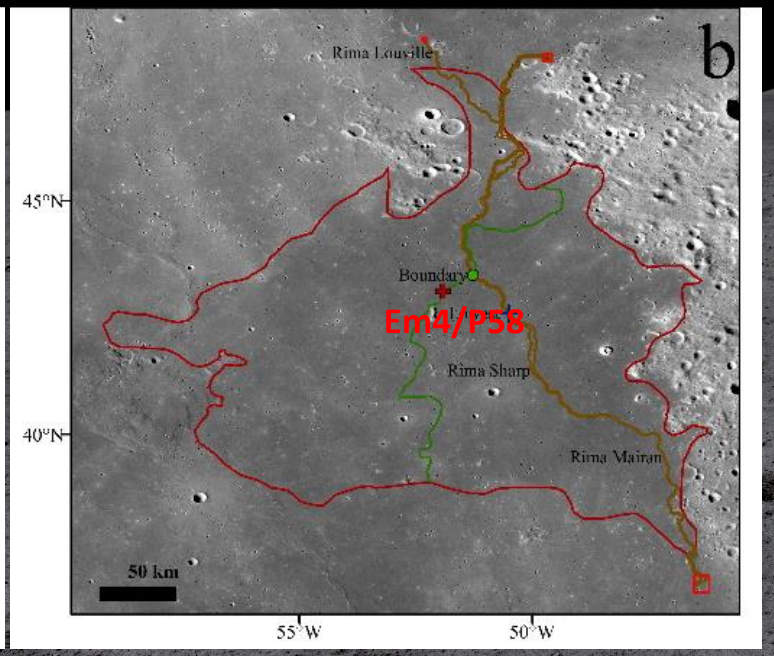
NAC DEM

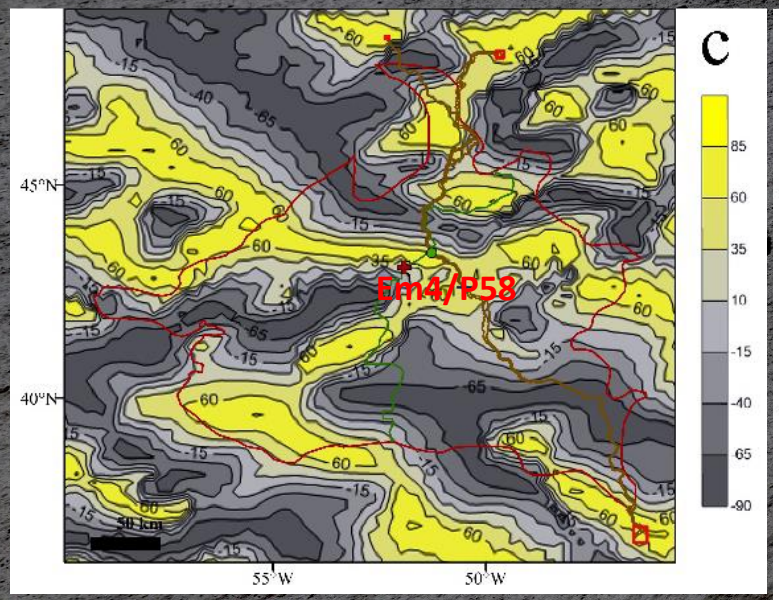
Lava pond & inner features within Rima Sharp were produced by Rima Mairan entering Rima Sharp

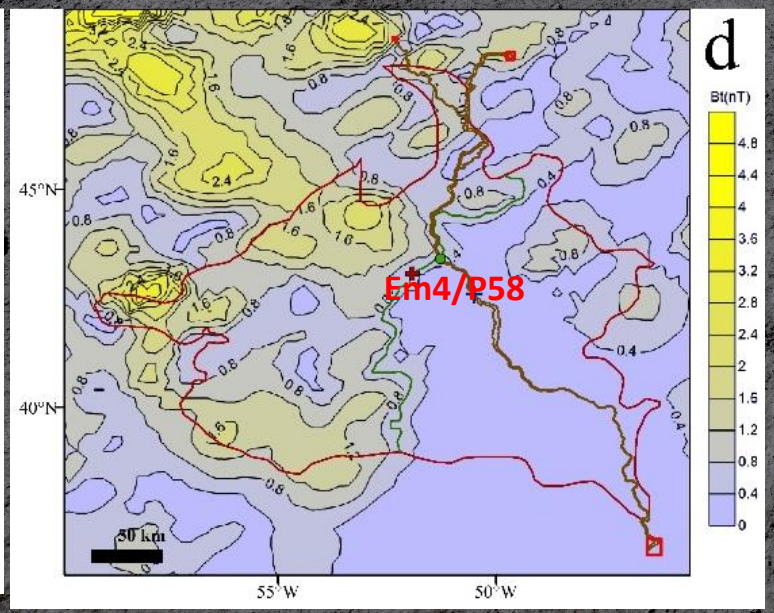
(Qian et al., 2021, GRL)

Evidence: Magnetic signature









Evidence

Magnetic signature based on Kaguya and Lunar Prospector measurements at altitudes of 10-45 km

a. DEM of Em4/P58 unit
b. Digital orthophoto map
c. Magnetic field inclination on P58 surface
d. Crustal magnetic field of P58 and lava boundary

- Green line: boundary of high and low magnetic field
- Red square: lava source vents

Hu, T., et al., 2021. Magnetic Signature of Basalts in the Chang'e-5 Sample Region: Implications for the
Earth Sp. Sci. Open Arch. DOI: 10.1002/essoa

Youngest Dated Lunar Mare Basalt

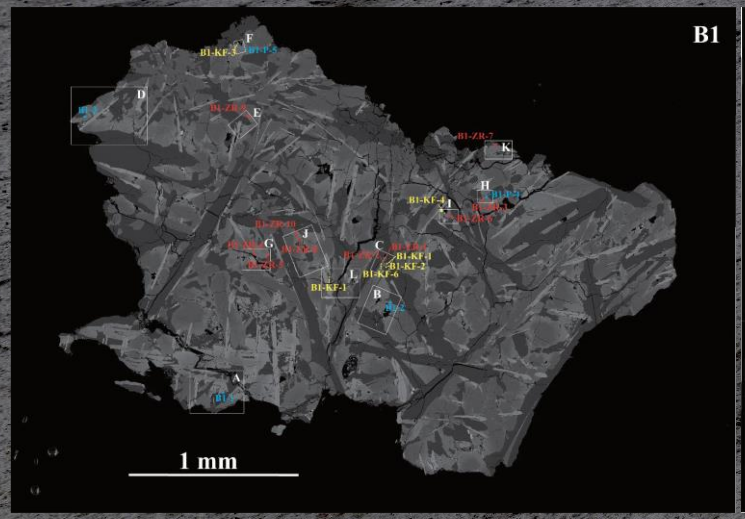
RESEARCH

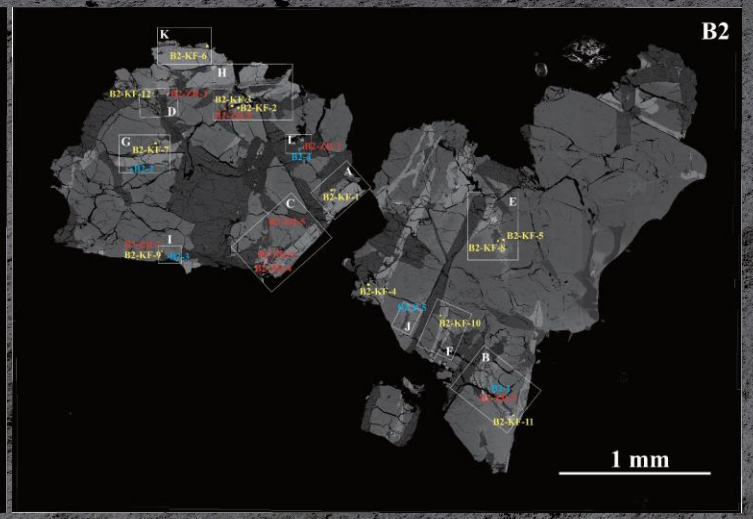
(Che et al., 2021, Science)

LUNAR GEOLOGY

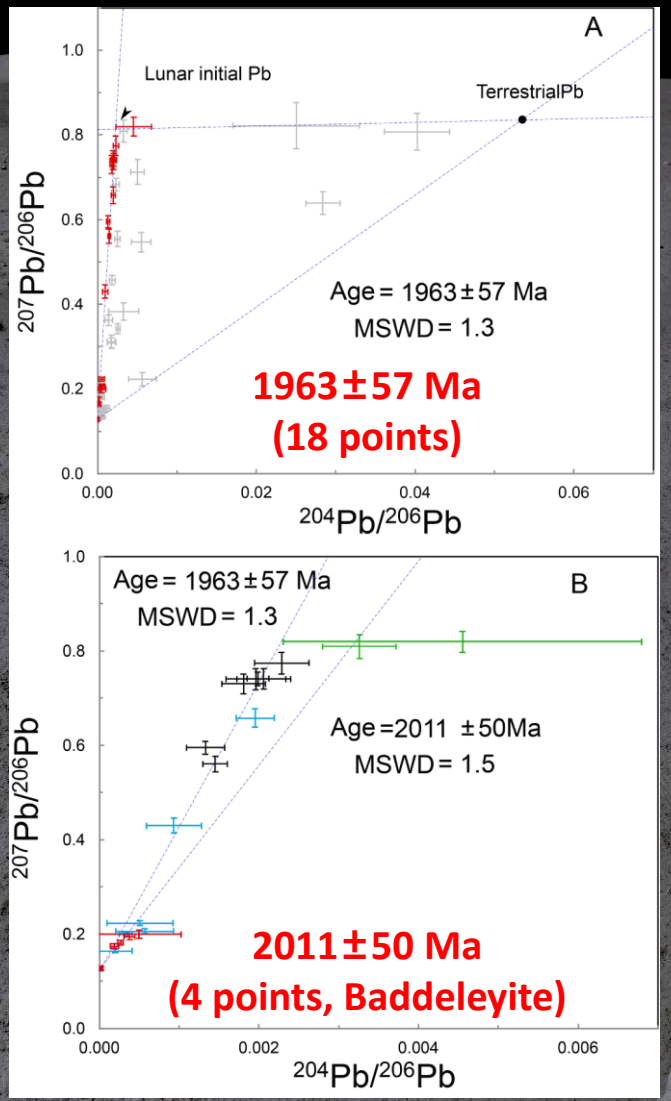
Age and composition of young basalts on the Moon, measured from samples returned by Chang'e-5

Xiaochao Che[1], Alexander Nemchin[1,2]*, Dunyi Liu[1,3]*, Tao Long[1], Chen Wang[1], Marc D. Norman[4], Katherine H. Joy[5], Romain Tartese[5], James Head[6], Bradley Jolliff[7], Joshua F. Snape[5], Clive R. Neal[8], Martin J. Whitehouse[9], Carolyn Crow[10], Gretchen Benedix[2,11], Fred Jourdan[2], Zhiqing Yang[1], Chun Yang[1], Jianhui Liu[1], Shiwen Xie[1], Zemin Bao[1], Runlong Fan[1], Dapeng Li[3], Zengsheng Li[3], Stuart G. Webb[8]





2 basalt fragments
(1963±57 Ma; 2011±51 Ma only Zi-rich minerals)



Youngest Dated Lunar Mare Basalt

Two billion-year-old volcanism on the Moon from Chang'E-5 basalts

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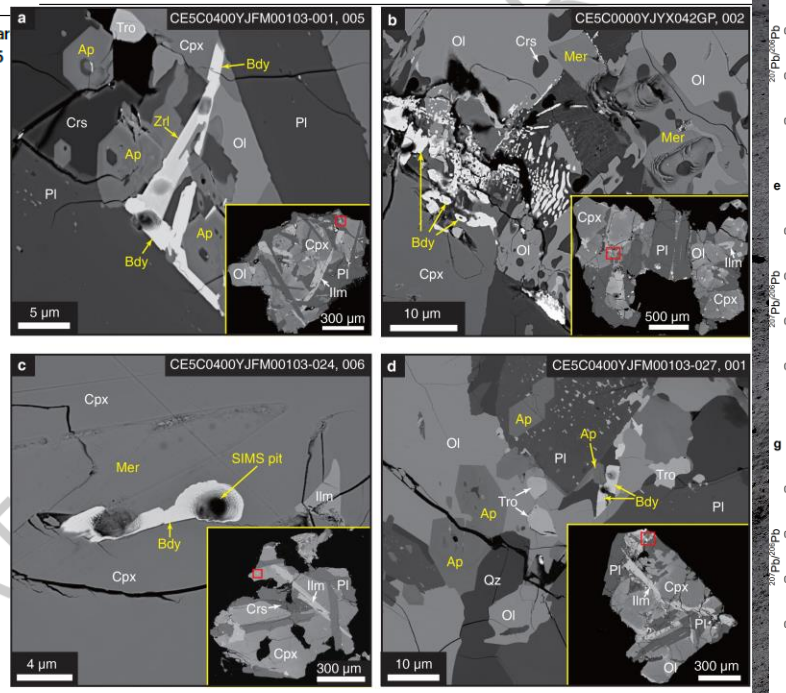
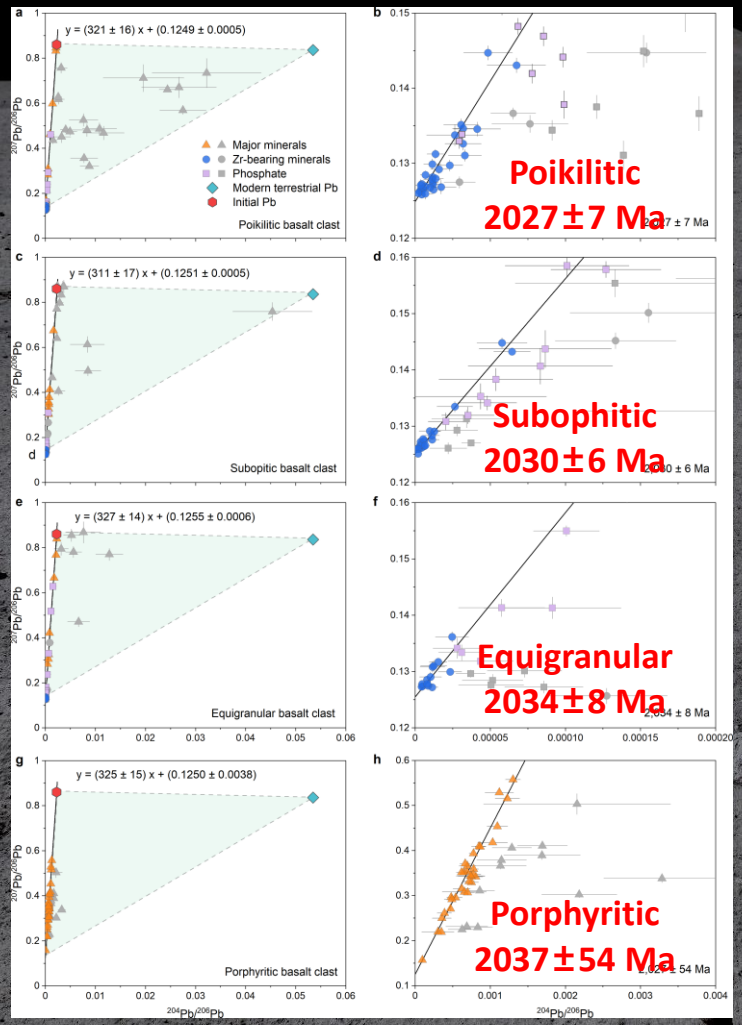
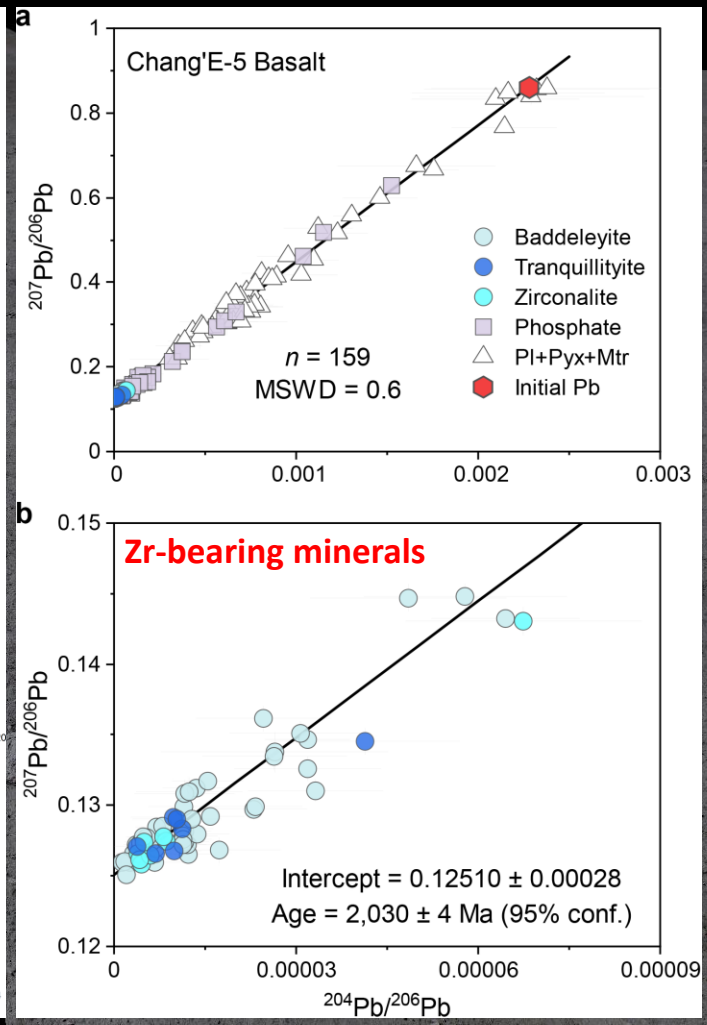
Qiu-Li Li, Qin Zhou, Yu Liu, Zhiyong Xiao, Yangting Lin, Jin-Hua Li, Hong-Xia Ma, Guo-Qiang Tang, Shun Guo, Xu Tang, Jiang-Yan Yuan, Jiao Li, Fu-Yuan Wu, Ziyuan Ouyang, Chunlai Li & Xian-Hua Li

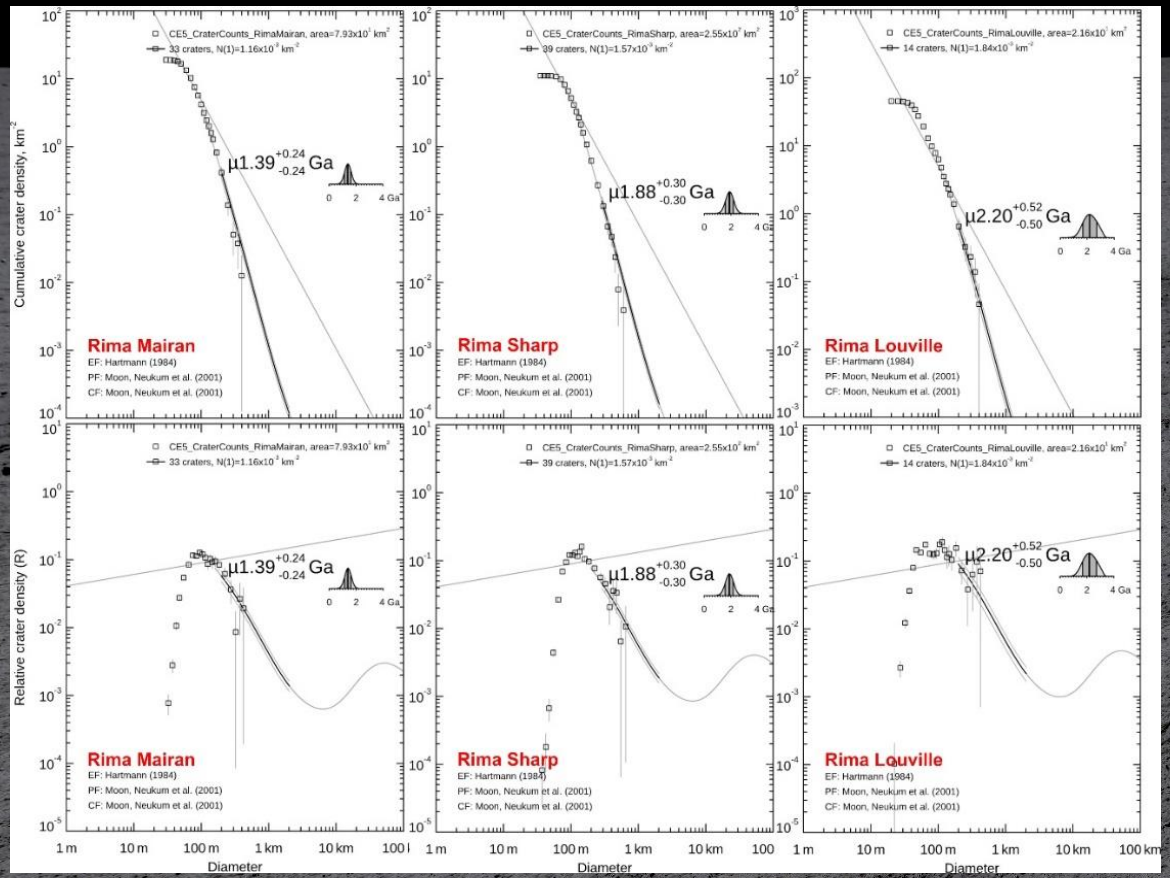


47 basalt fragments (2030±4 Ma)

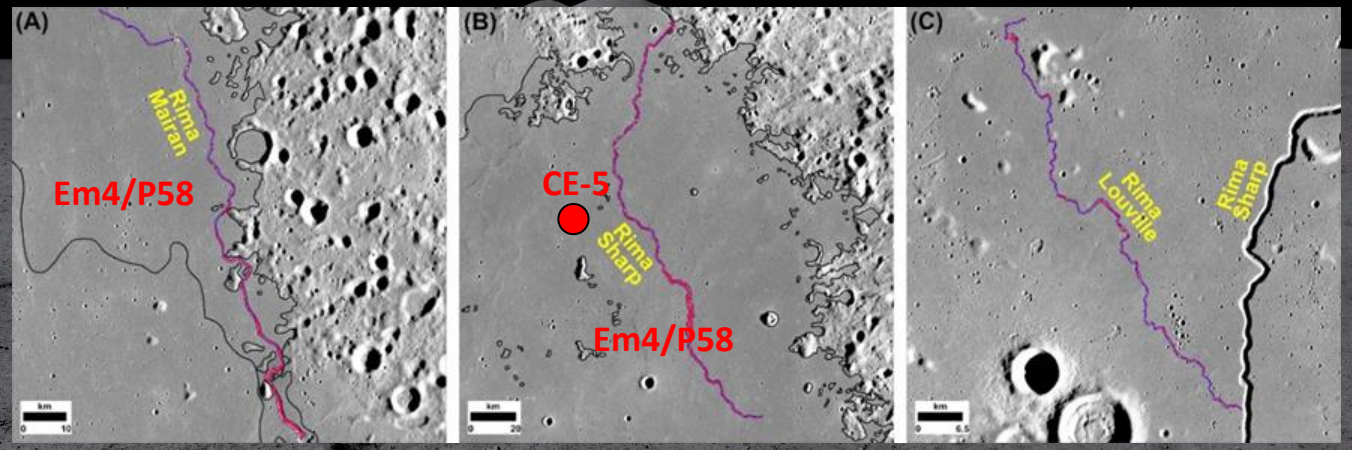




Evidence: CSFD measurements



(Qian et al., 2021, GRL)

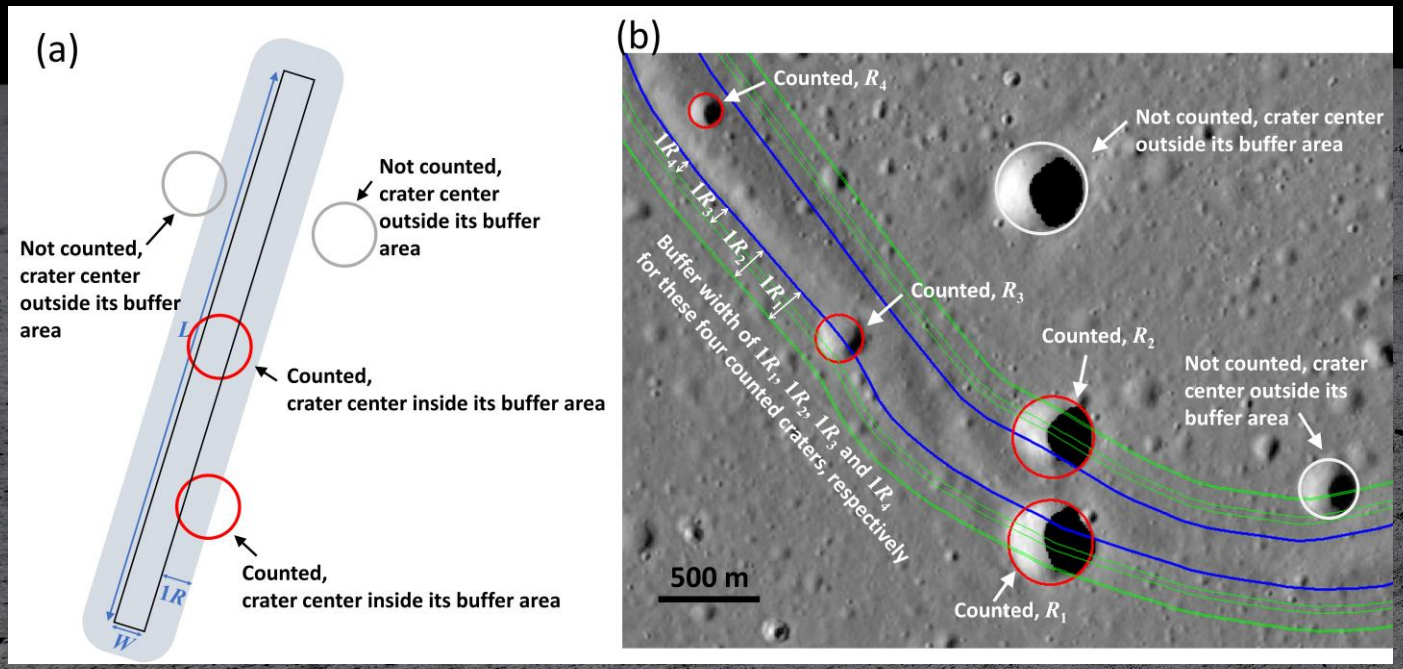


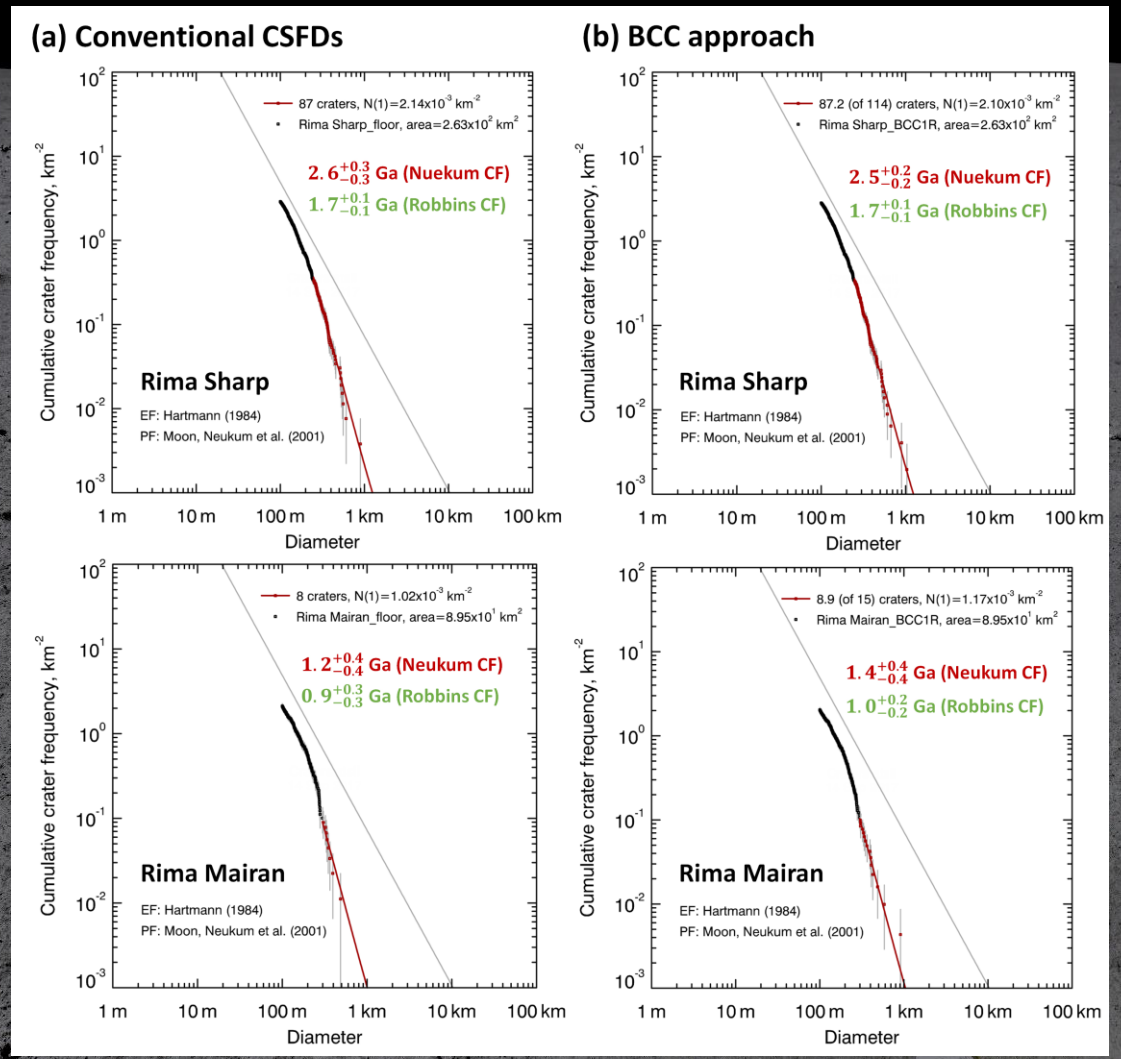
Rima Mairan: 1.4±0.2 Ga Rima Sharp: 1.9±0.3 Ga Rima Louville: 2.2±0.5 Ga

CE-5 Sample Age: 2.0 Ga
(Che et al., 2021, Science; Li Q. L., et al., 2021, Nature)

Sampled Chang'e-5 intermediate-Ti mare basalts represent the products of Rima Sharp eruptions

Evidence: Magnetic signature



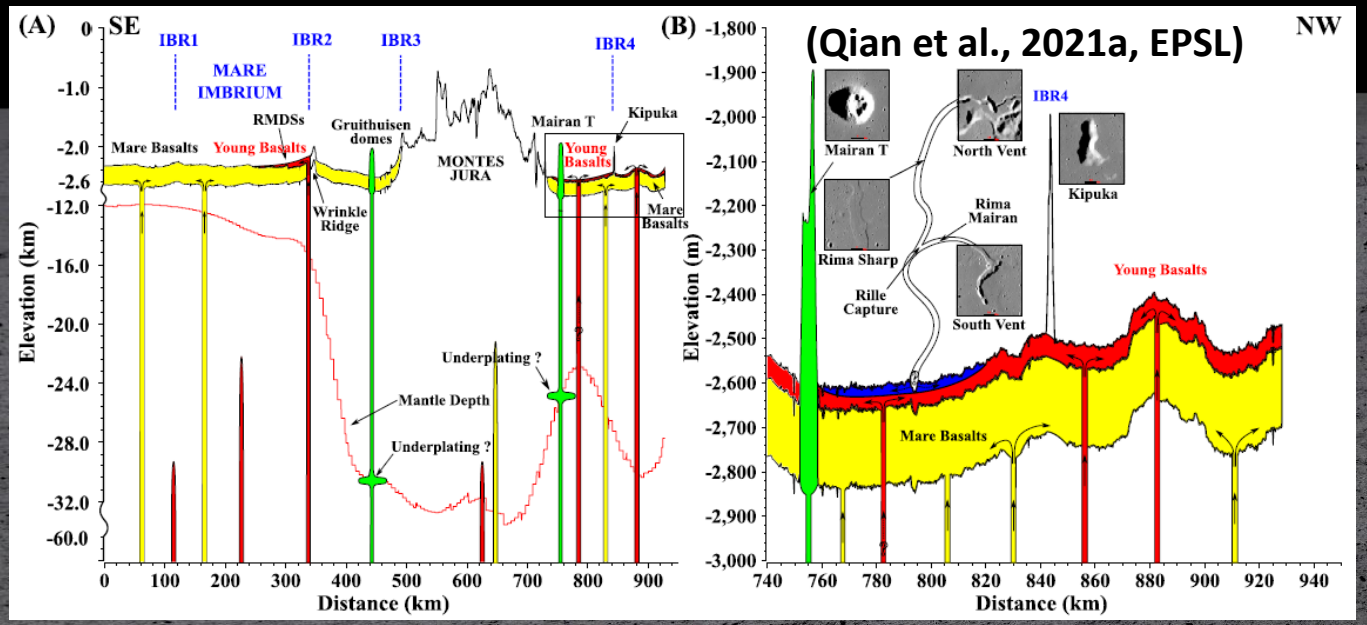


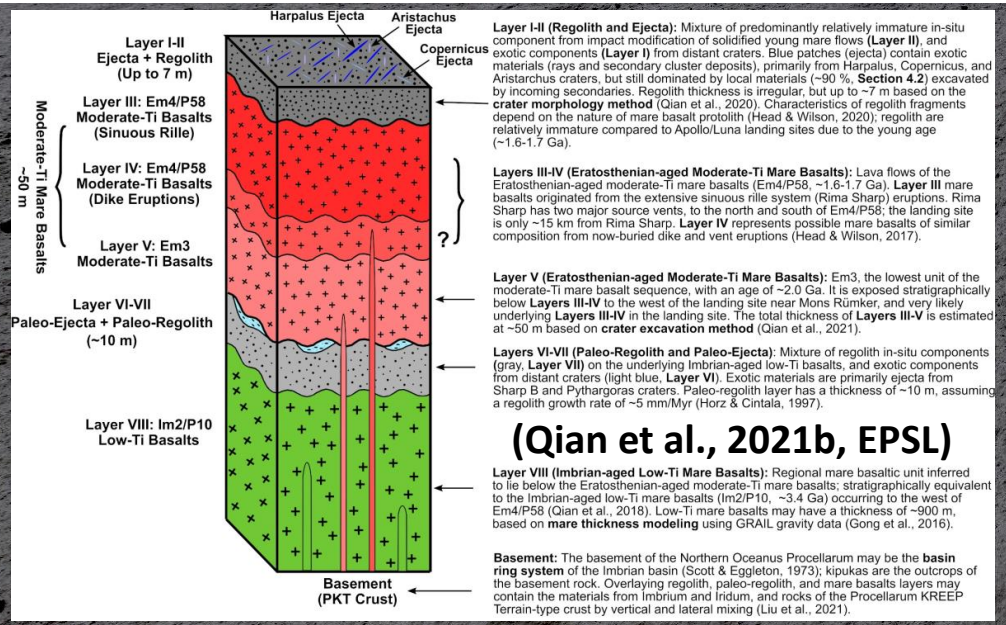
CE-5 Sample Age: 2.0 Ga
(Che et al., 2021, Science; Li Q. L., et al., 2021, Nature)

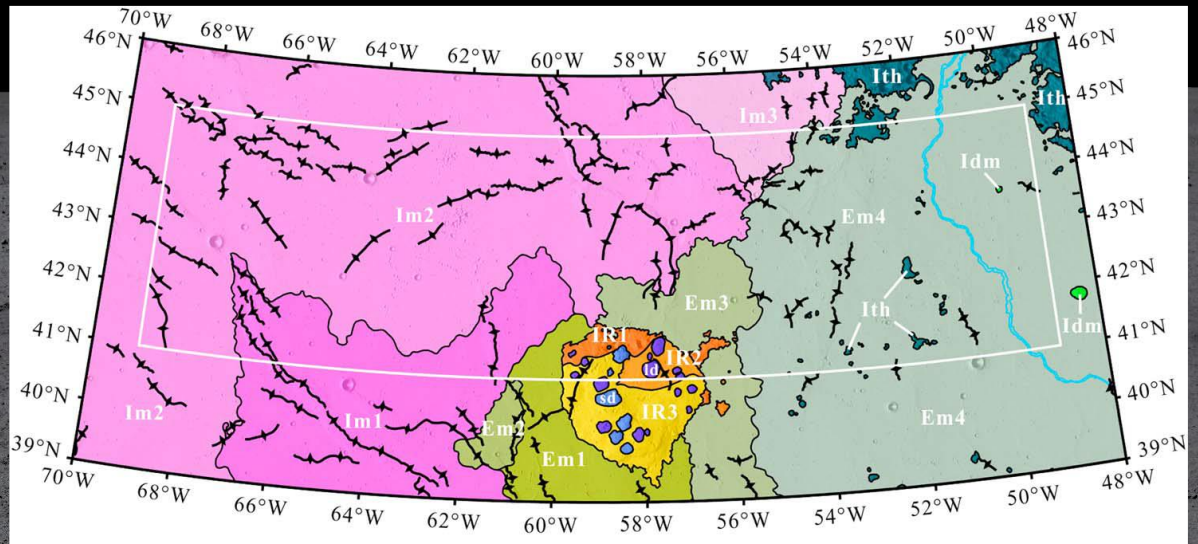
Sampled Chang'e-5 intermediate-Ti mare basalts represent the products of Rima Sharp eruptions

(Xu & Qiao, 2022, A&A)

Volcanic History of Northern Oceanus Procellarum



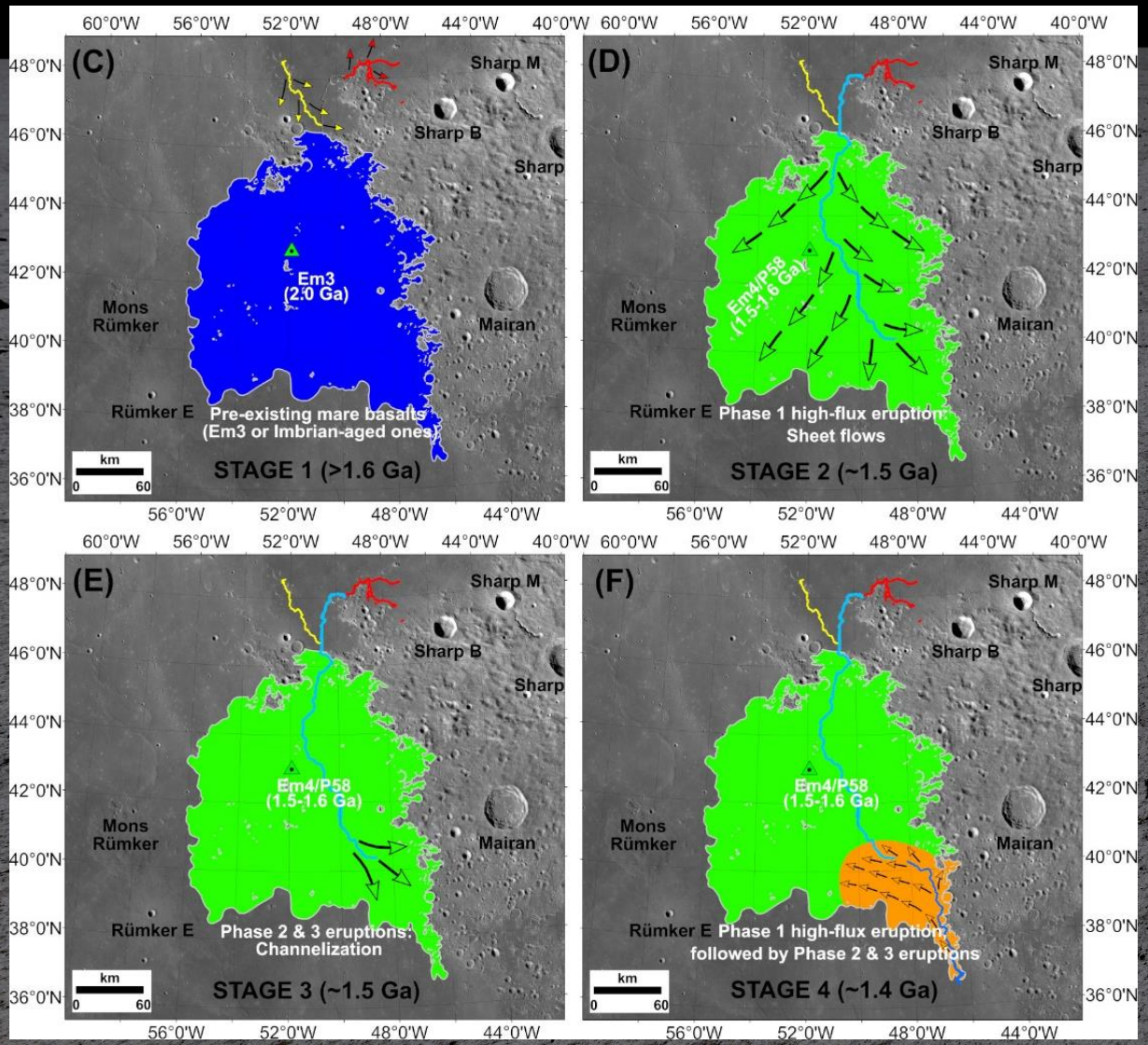




Geologic Era	Mare Materials	Rümker Plateau Materials	Dome Materials	
Eratosthenian	Em4 Em3 Em2 Em1			wrinkle ridges sinous rilles Ith highland materials
Imbrian	Im3 Im2 Im1	IR3 IR2 IR1	sd Id Idm	

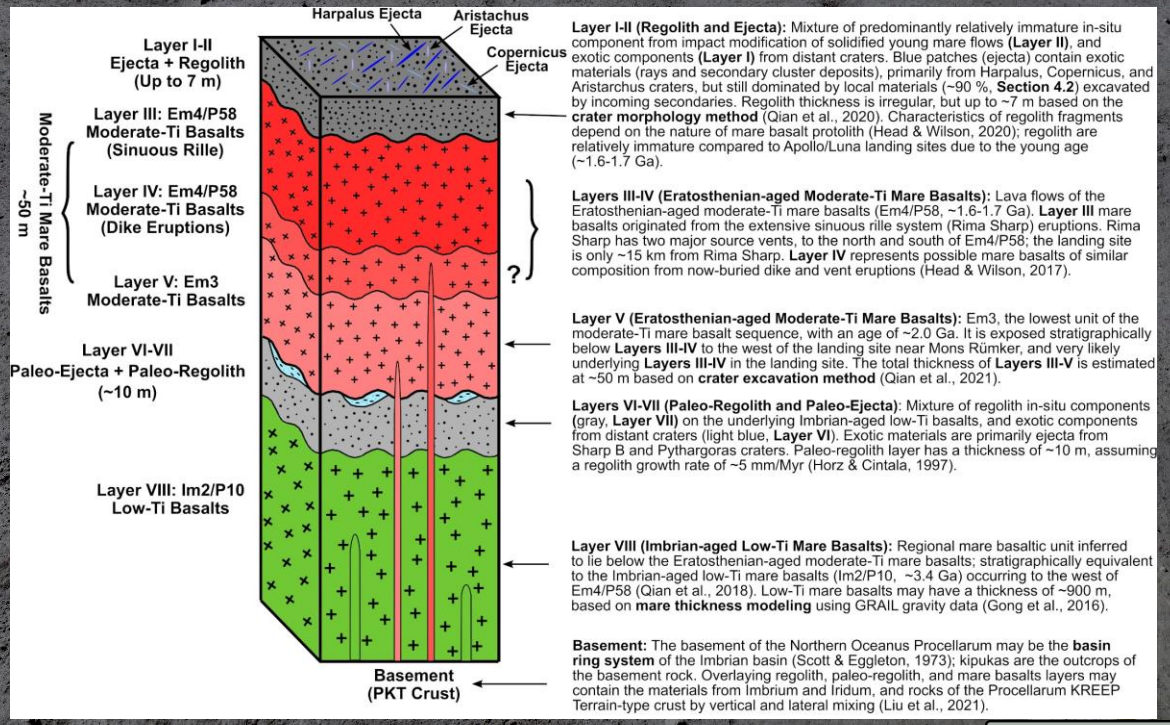
(Qian et al.,

Conclusion



(Qian et al., 2021, GRL)

- Qian, Y., Xiao, L., Head, J.W., Wilson, L., 2021. The Long Sinuous Rille System in Northern Oceanus Procellarum and Its Relation to the Chang'e-5 Returned Samples. Geophys. Res. Lett. 48, e2021GL092663.
- Pre-existing features, Post-formation deformation
- Origin of mare basalts: Chang'e-5 basalts represent the lava erupted from Rima Sharp, with an age of ~2.0 Ga
- yuqi_qian@cug.edu.cn; yuqi_qian@brown.edu



(Qian et al., 2021b, EPSL)