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Selection of units to obtain reliable calibration of the Martian cratering chronology: *lessons learned from Lunar Science*

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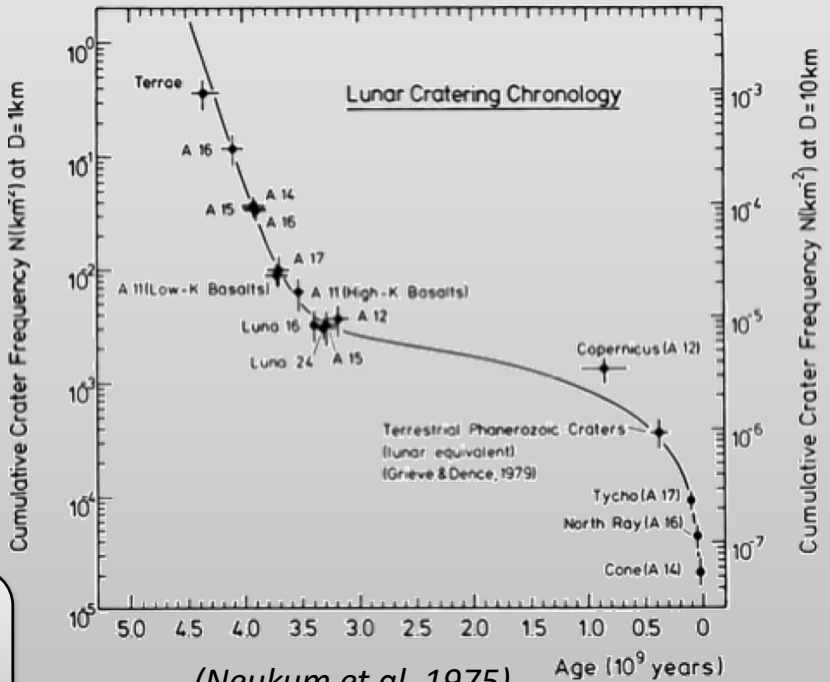
Chronology model for the Moon

(Stöffler & Ryder, 2001)

Crater counts linked to isotopically-dated Apollo and Luna samples, which provides calibrated absolute model ages (AMA)



(Neukum et al. 1975)

Chronology curve still debated: *Morbidelli et al, 2018; Robbins, 2014; Werner et al, 2014, etc…*

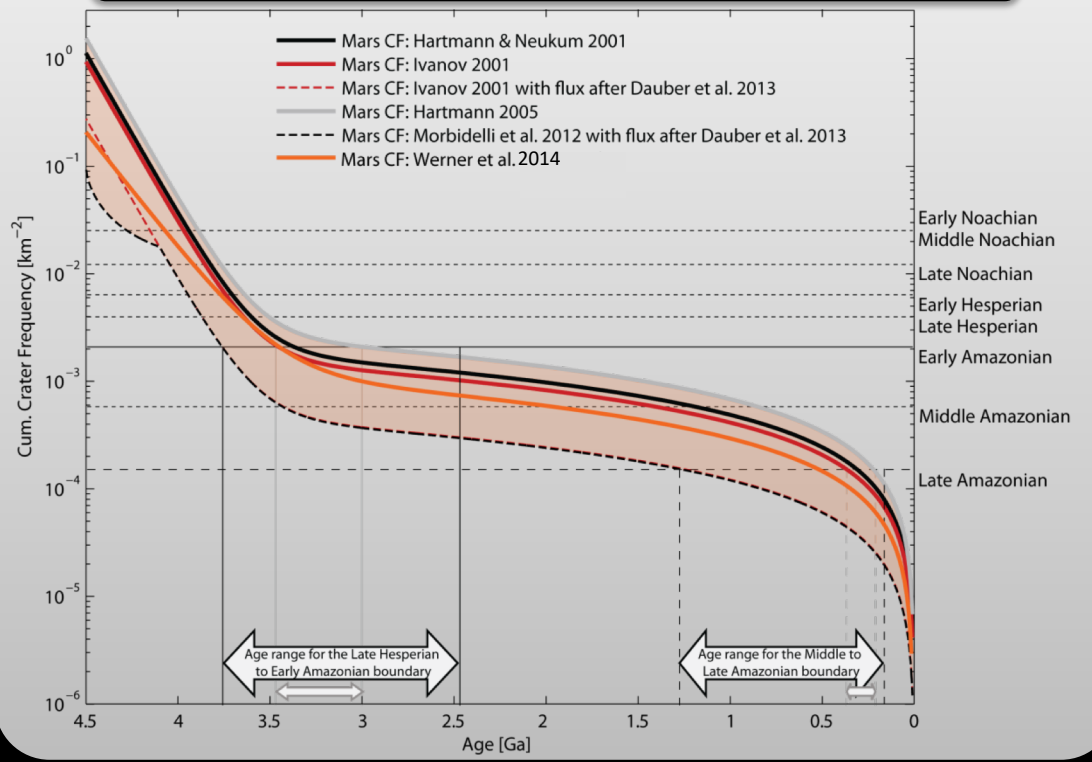
What do we already know on Mars/Cratering chronology?

From the Moon: Most of the points on the curve are before 3 billion years

From Mars:

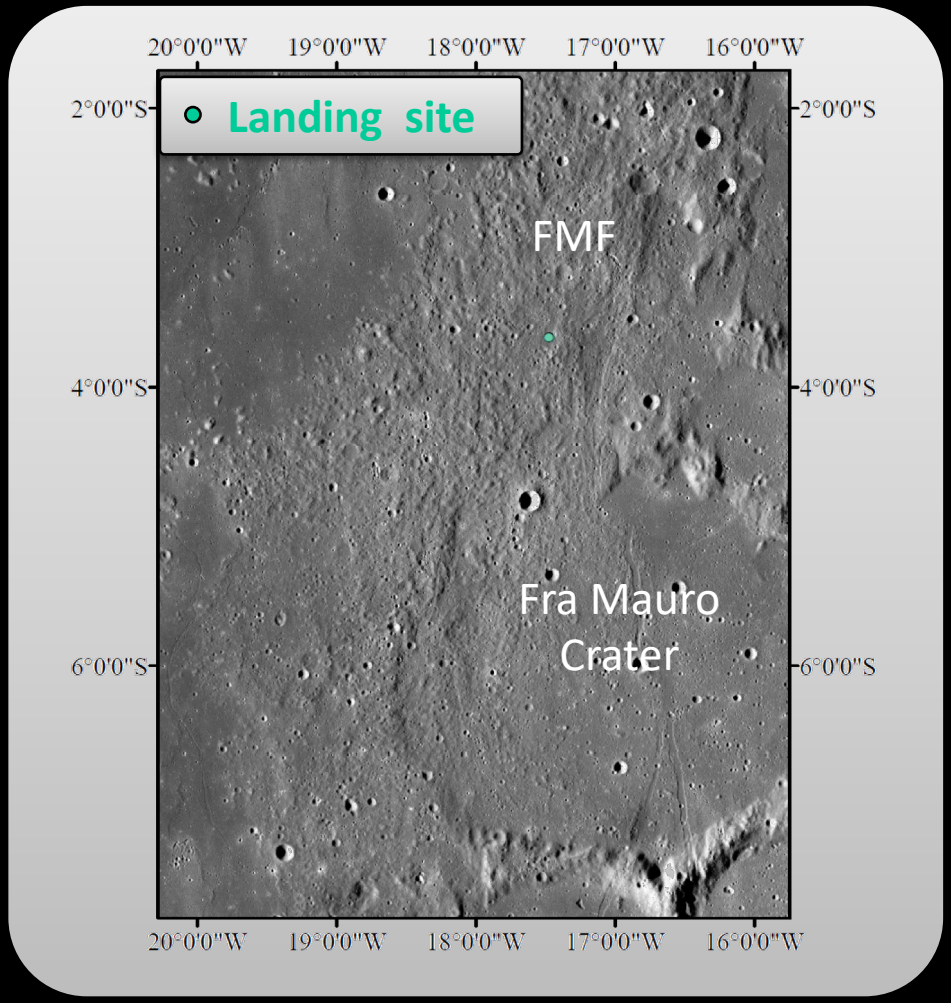
- Potential old age + exposition age from Gale Crater in situ datation *(Farley et al, 2014 - Science)*
- Small craters/recent impact rate *(Malin et al, 2006 – Science & Daubar et al, 2013 - Icarus)*
- A potential old age from Shergottite/Mojave Crater *(Werner et al, 2014 - Science)*
- Meteorites are <1.35 Gyrs or >3.9 Gyrs *(Nyquist et al, 2001 - Space Sci. Rev.)*

Large differences depending of model choosen



What do we want/need to learn thanks to a Sample Returned from Mars?

What do we need to know about the sample/its unit?



Example of Apollo 14
Fra Mauro Formation (FMF):

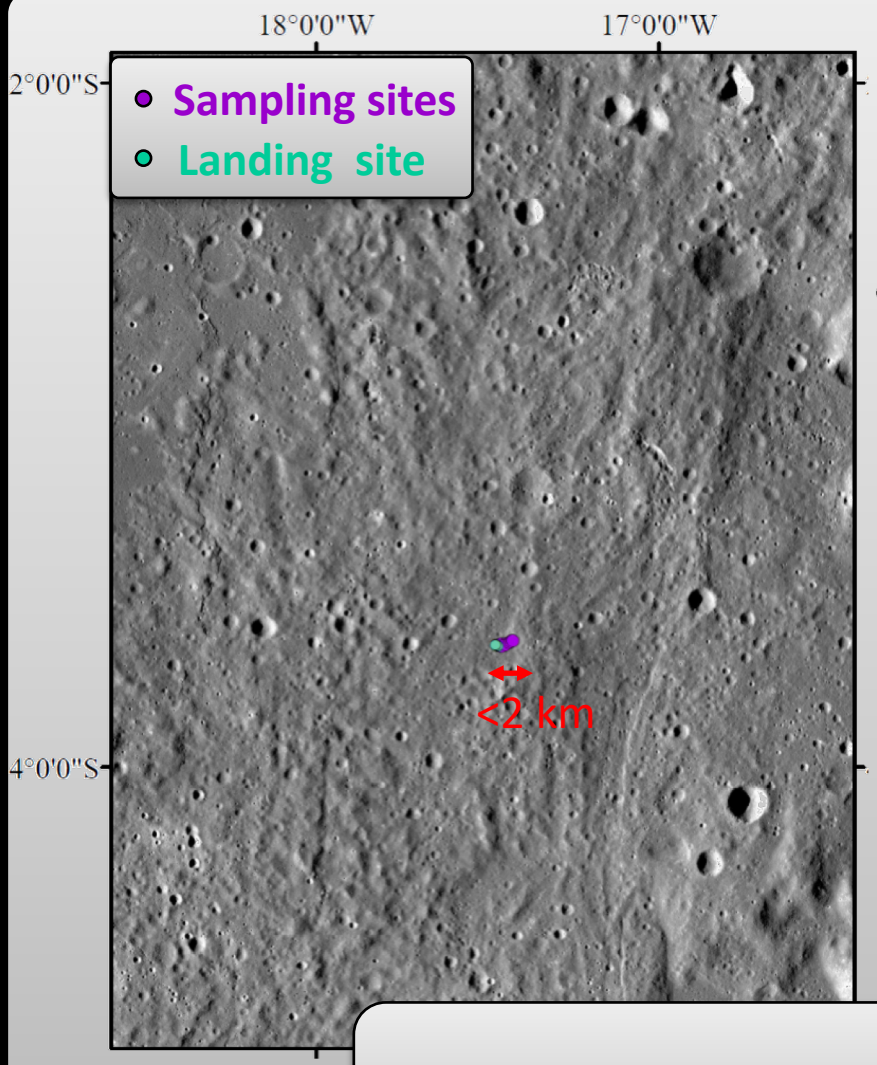
First Apollo landing selected for scientific reasons: study of ejecta (Cone Crater: young crater penetrating the regolith and Fra Mauro Crater: old rocks)

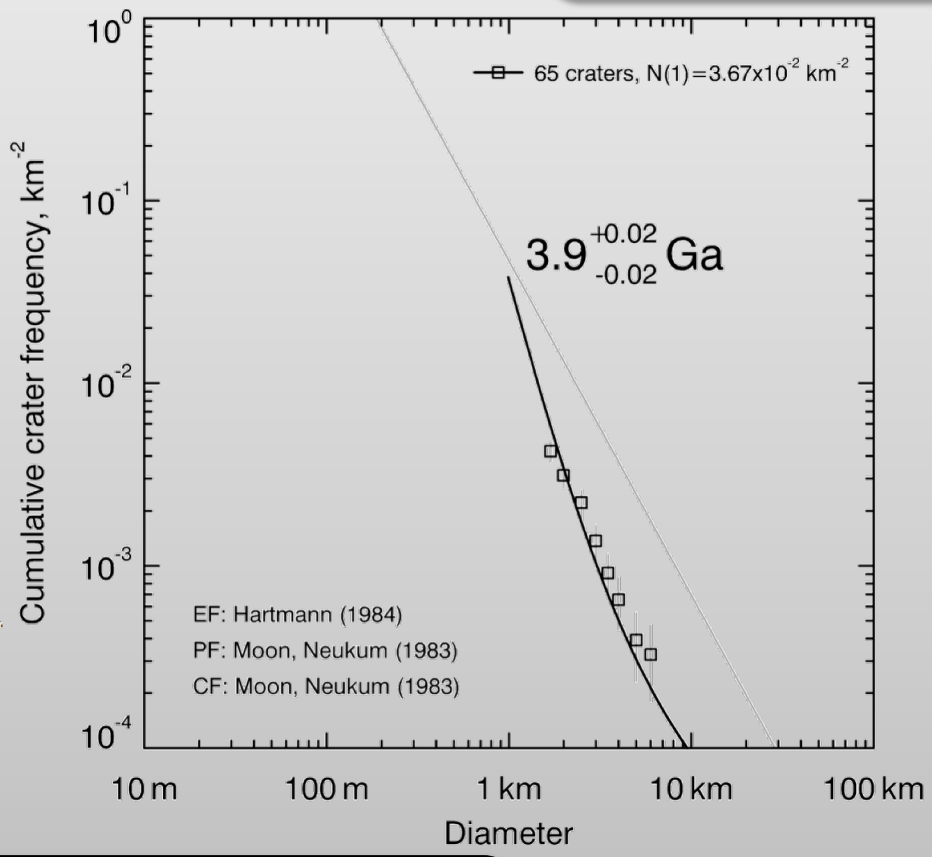
Example with A14: CSFD from *(Neukum, 1983)*:

N1983: 3,7x10^{-2}

R2014: 4,84x10^{-2}

B2018: 2,36x10^{-2}





Using Neukum, 1983 production function

Example with A14: CSFD from *(Robbins, 2015)*:

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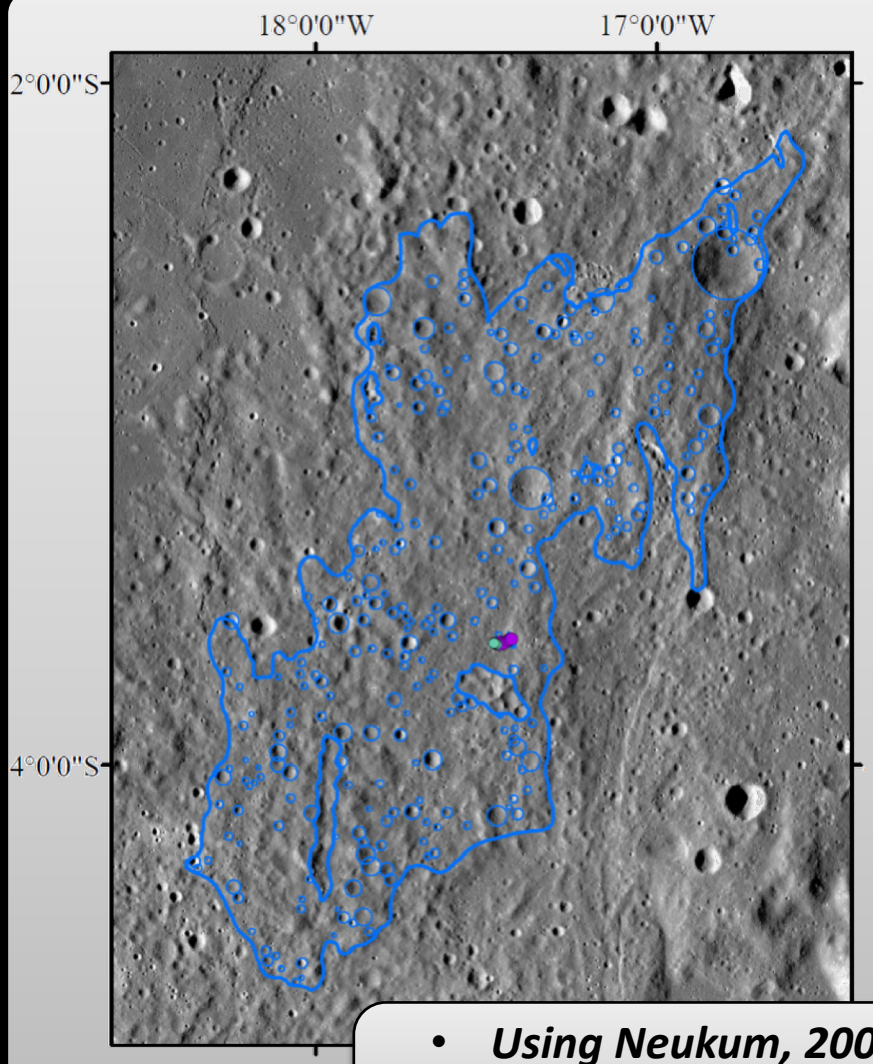

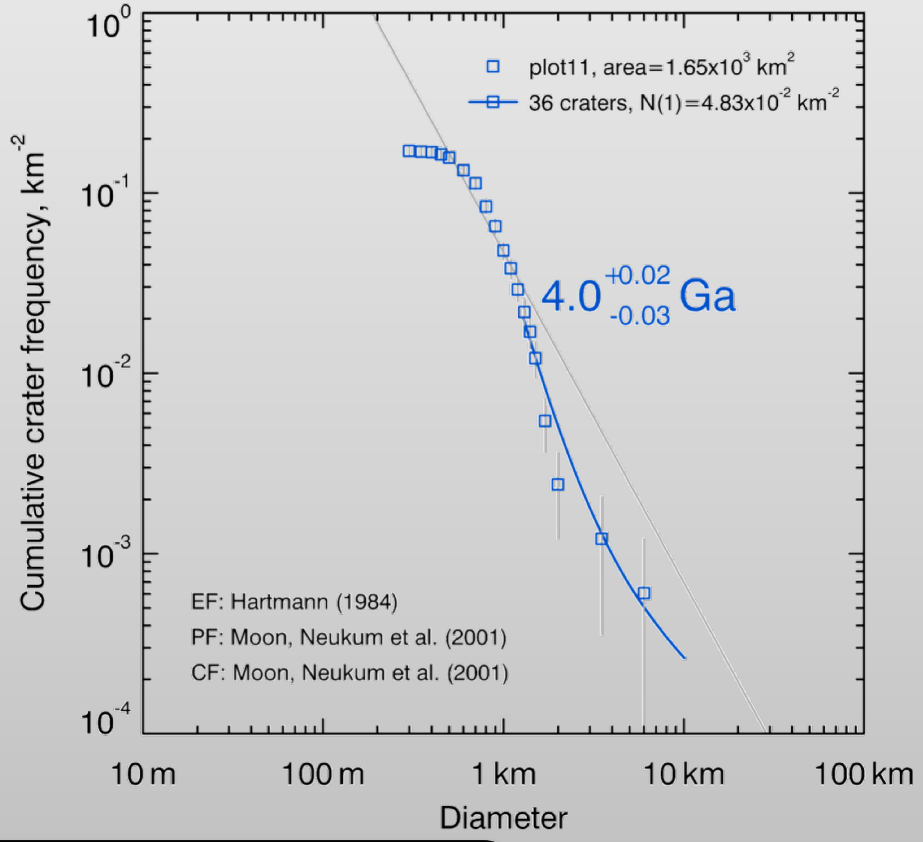

- ***Using Neukum, 2001 production function***
- ***The saturation is reached for craters <1 Km: loss of information***

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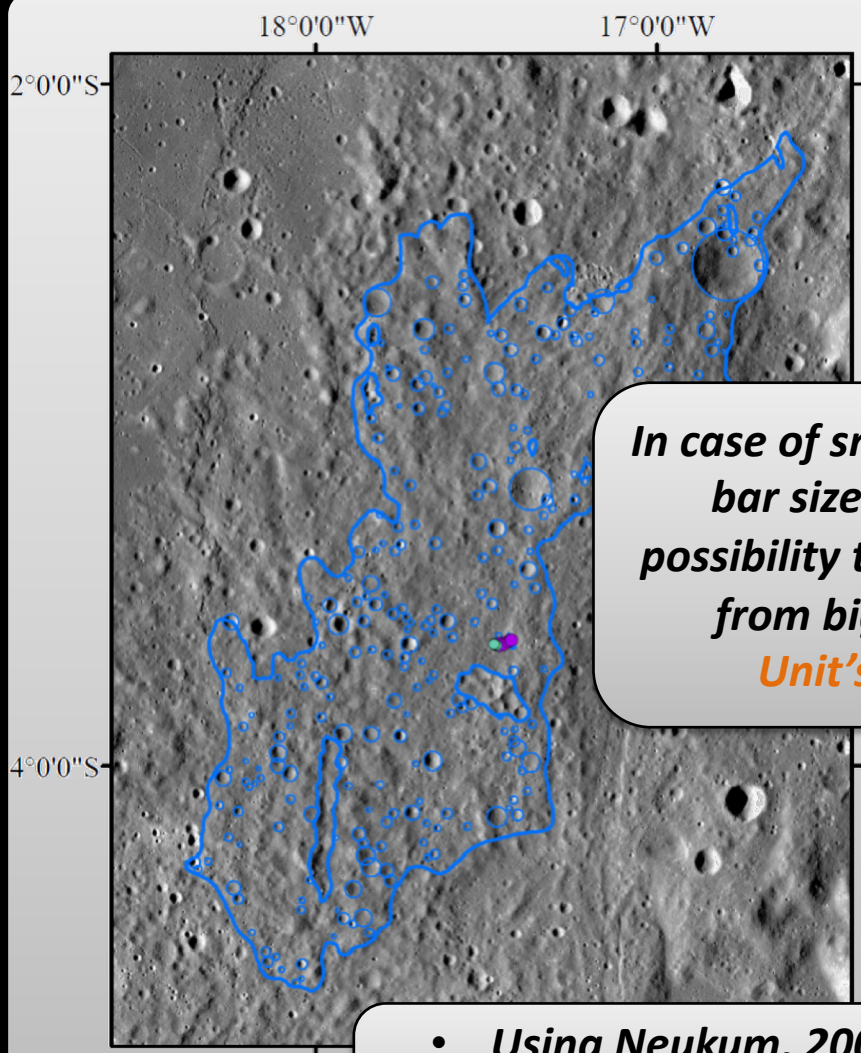
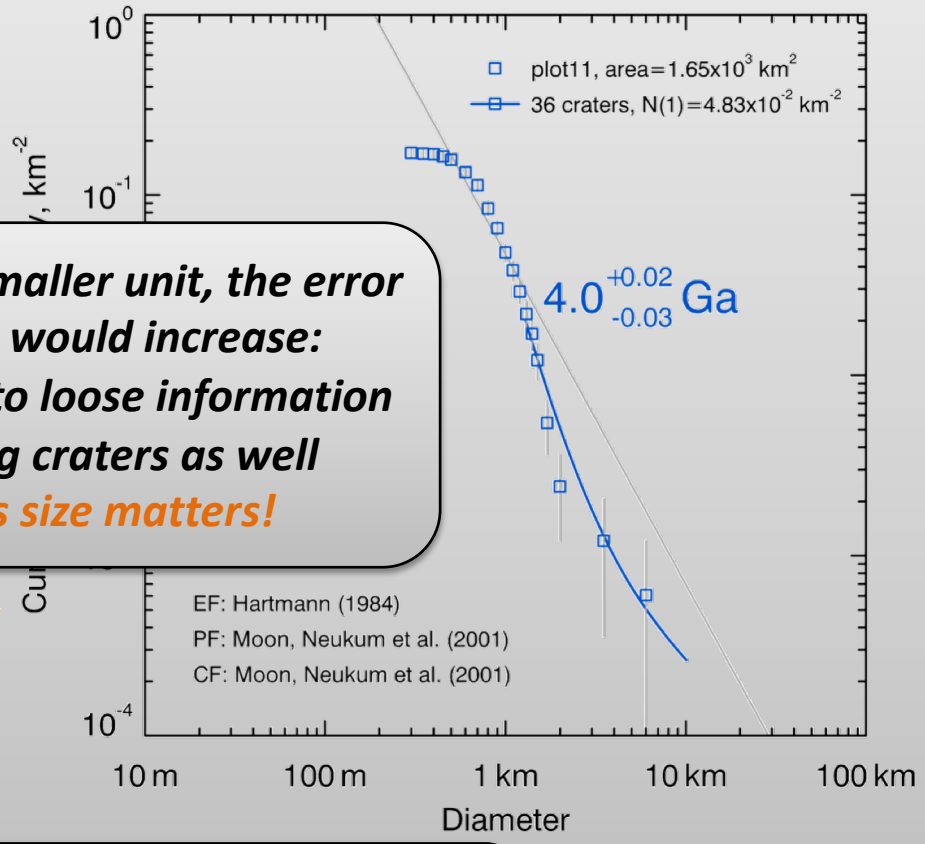
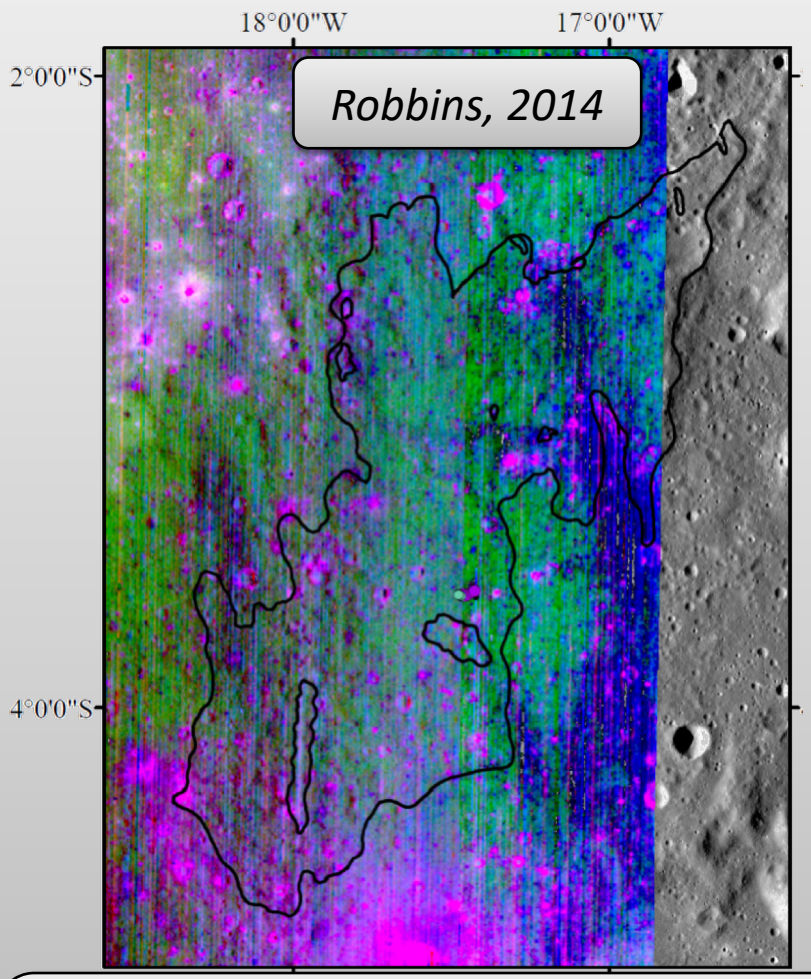


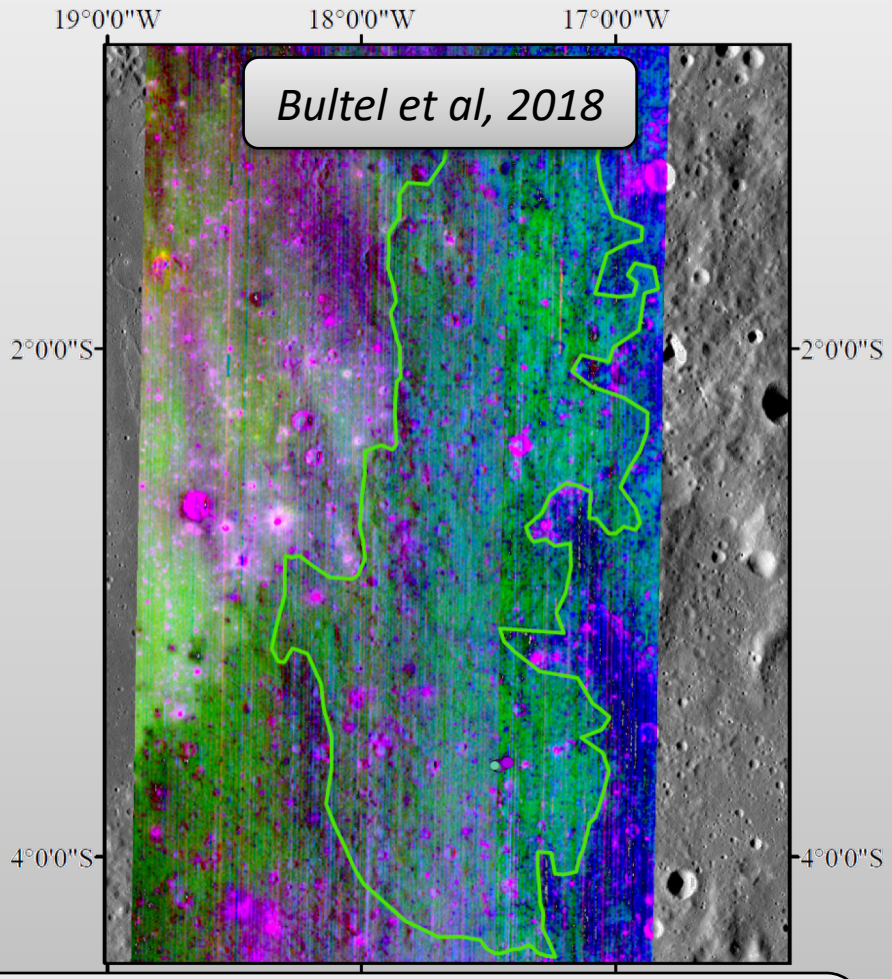


In case of smaller unit, the error bar size would increase: possibility to loose information from big craters as well
Unit's size matters!

- ***Using Neukum, 2001 production function***
- ***The saturation is reached for craters <1 Km: loss of information***

Example with A14: CSFDs :





Mapping with M3 data help to identify homogeneous unit (« spectrally speaking »). Previous were selection from morphology.

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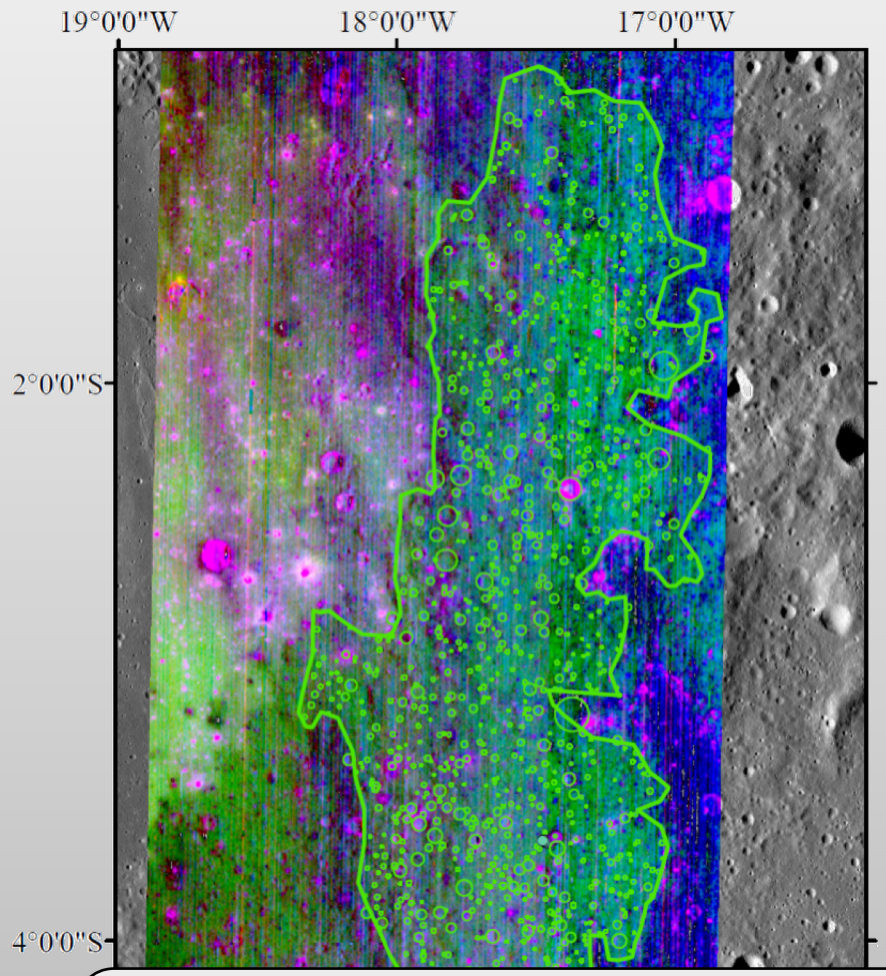
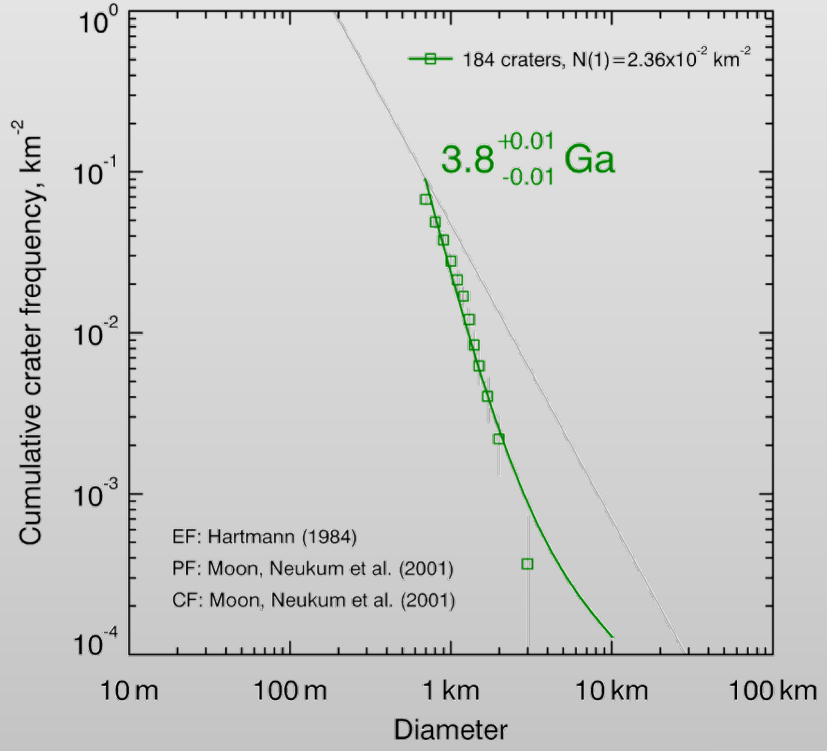
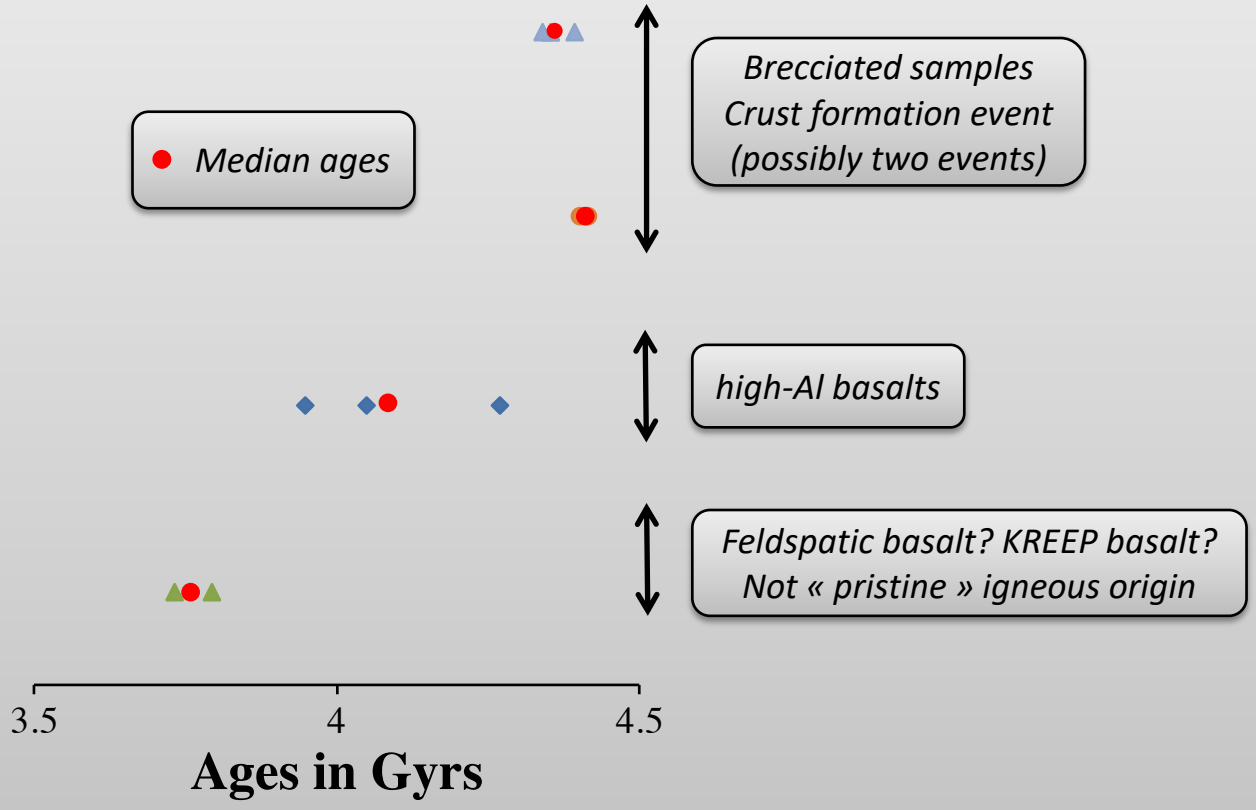




New unit determined, counting for craters >250m of diameter
Differently defined unit lead to different SFD

Example with A14: ages from samples *(reprocessed by V. Fernandes, perso. com.)*:

3 to 4 « events » registered by the samples
How many visible on the surface?



Multiple groups of ages: need to interpret what they represent
how to link them with surfaces unit(s)?

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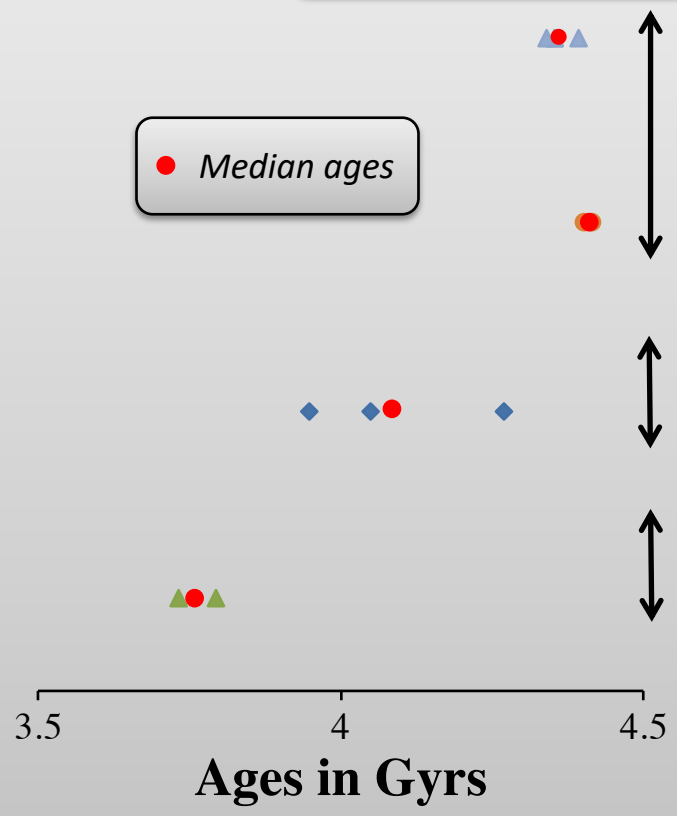

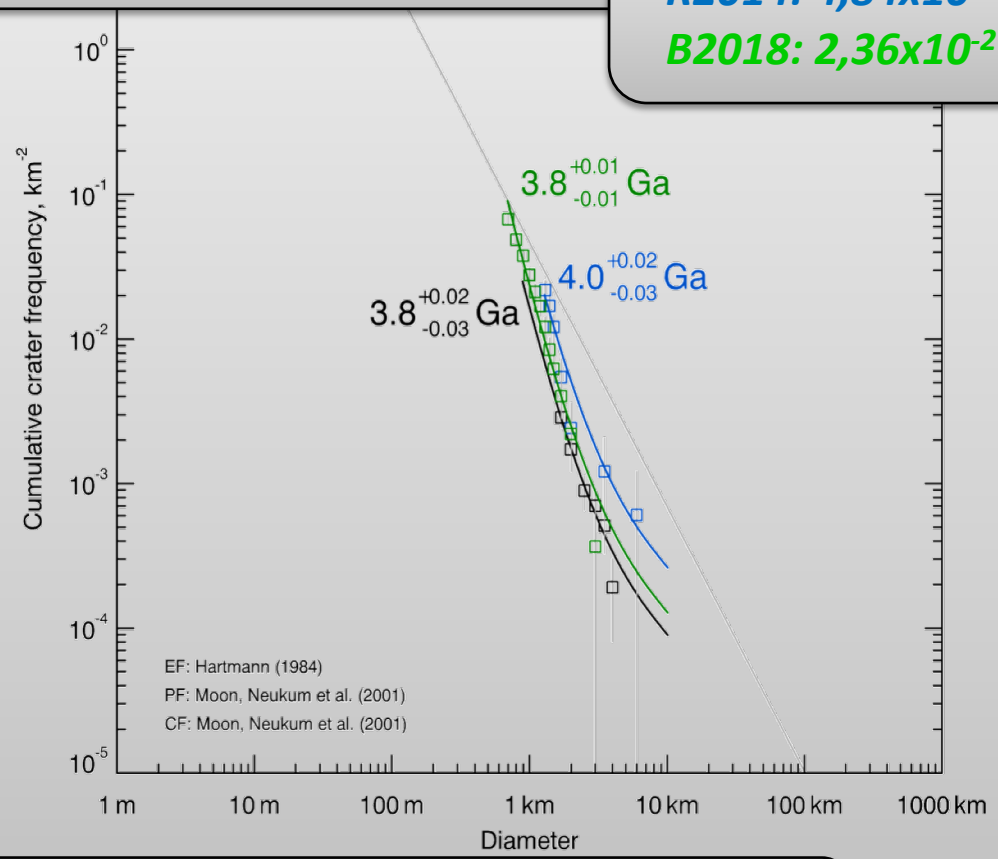

Multiple groups of ages: need to interpret what they represent
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Example with A14: CSFDs' interpretations

N1983: 3,7x10^{-2}
R2014: 4,84x10^{-2}
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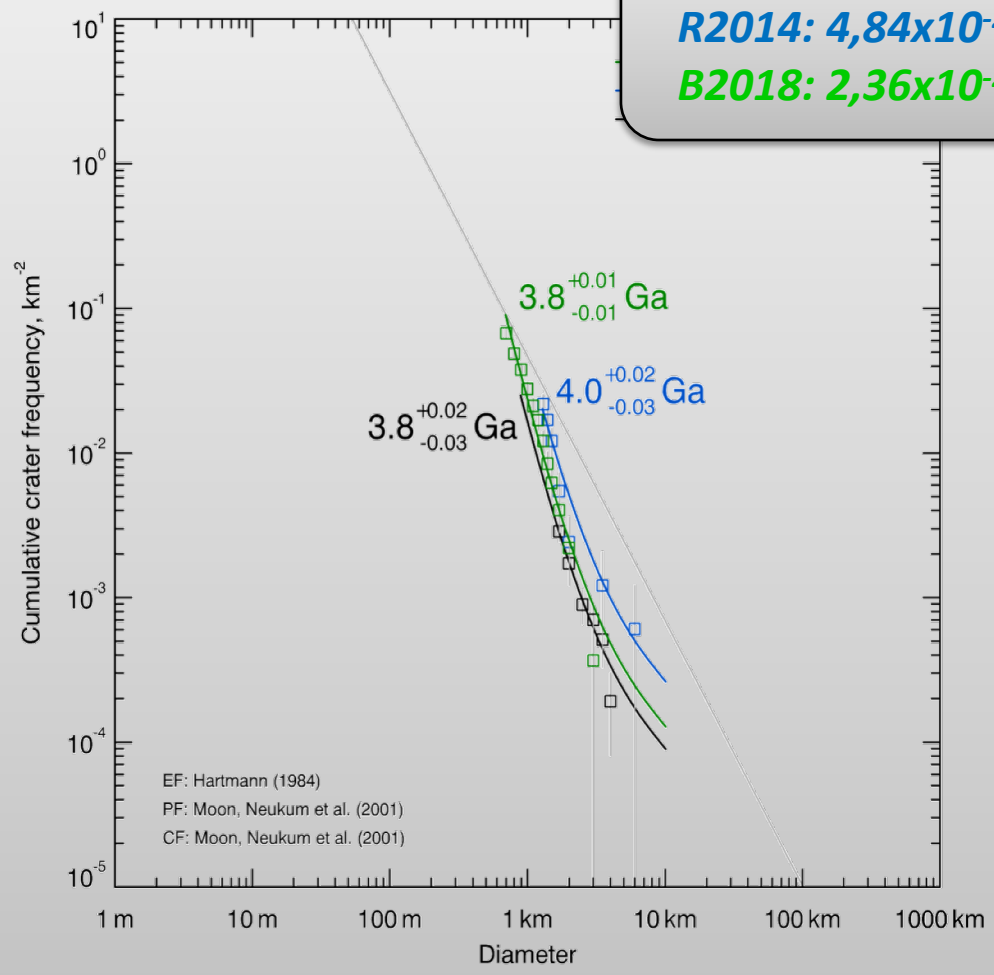
All results are consistent with saturation around 1Km

No resurfacing registered
vs.
3 to 4 « events » registered by the samples

Impossible to relate to multiple events

Brecciated material is unlikely leading to a new data point on the impact flux chronology curve



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3 to 4 « even

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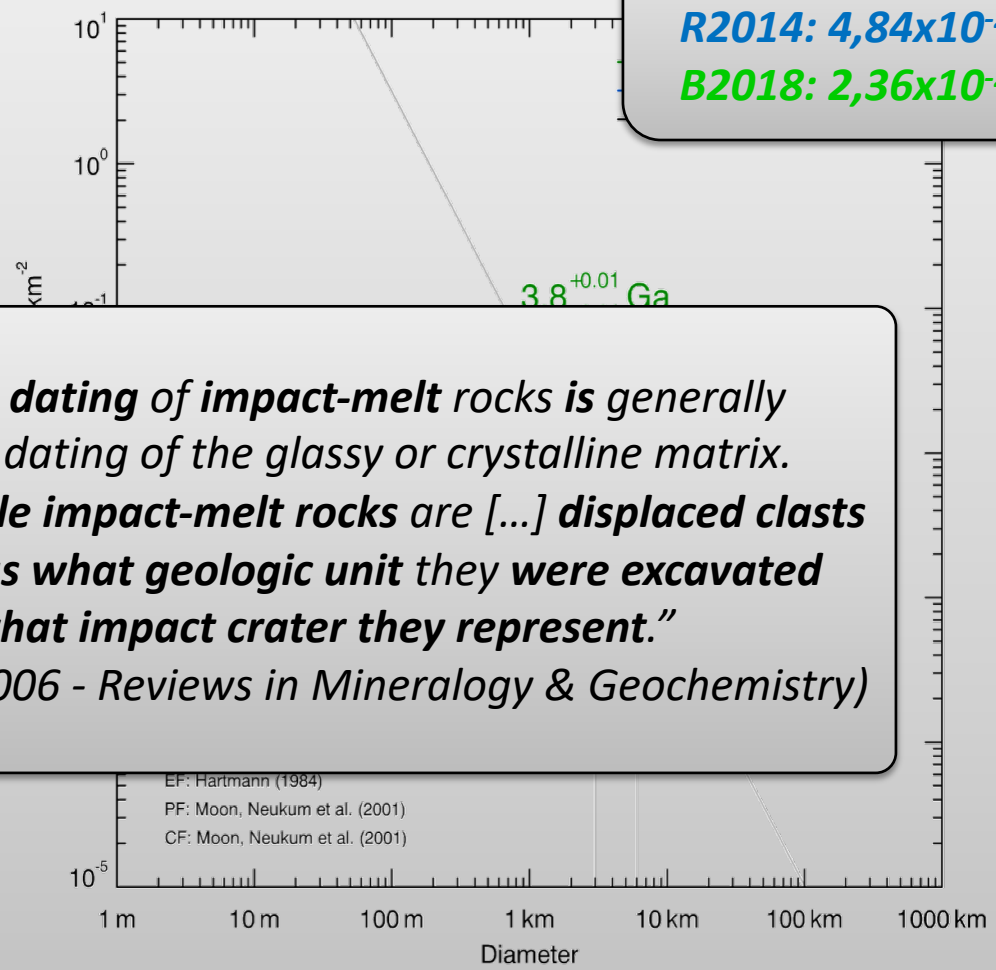
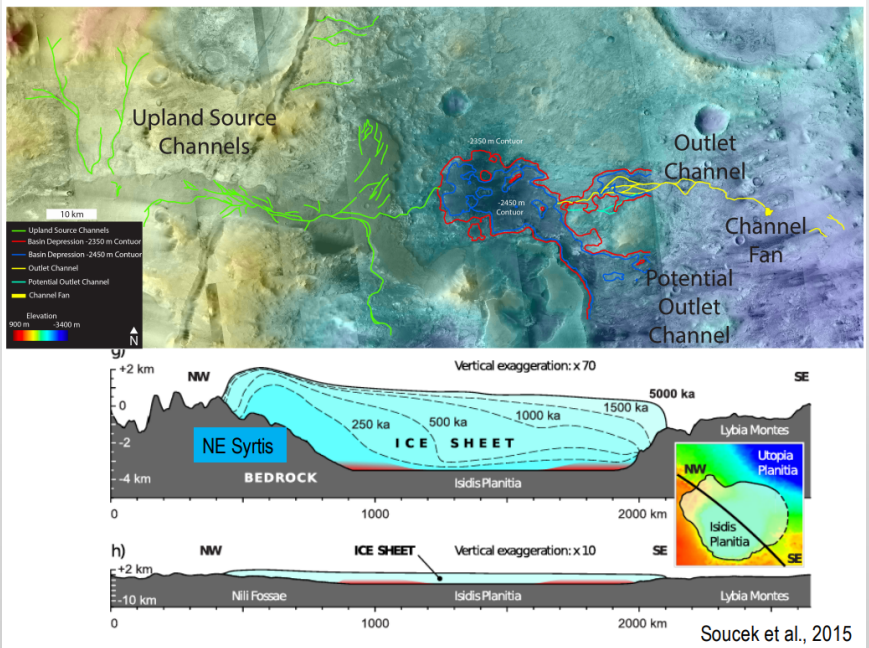


*"Radiometric age **dating** of **impact-melt** rocks **is** generally **possible** by direct dating of the glassy or crystalline matrix. However, since **datable impact-melt rocks** are […] **displaced clasts** […], it is **not obvious what geologic unit** they **were excavated from and what impact crater they represent**."*
(From Stoffler et al, 2006 - Reviews in Mineralogy & Geochemistry)

What about resurfacing?

Possible source of resurfacing make things even more complicated (presence of sediments, erosion by liquid water/ice/wind)

What do we need to know about the sample/its unit?



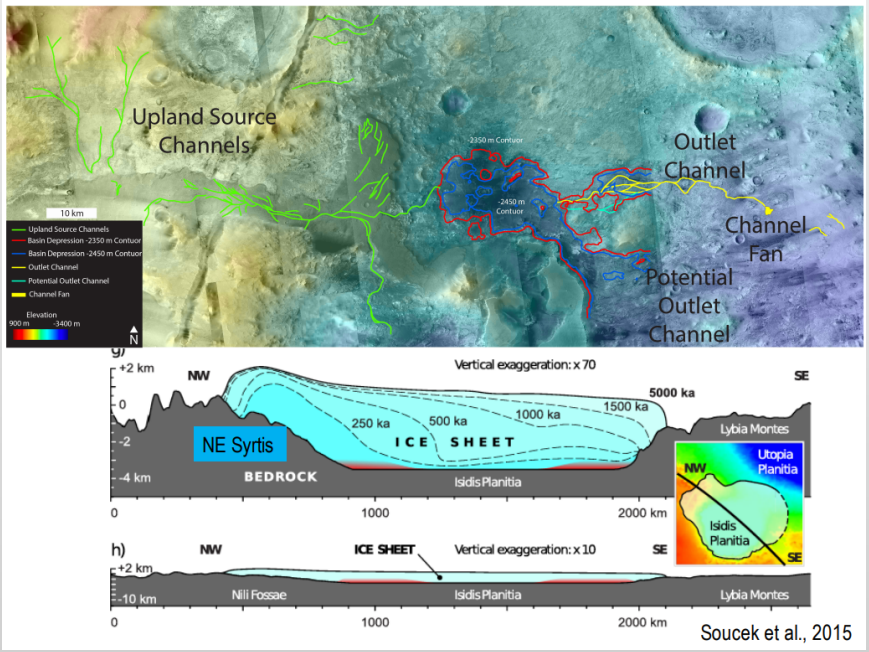
- Possibility of ice covering: lack of registration for a part of the flux
- Possibility of resurfacing by liquid water activity: loss of a part of the information + complication of the sfd

What about resurfacing?

Possible source of resurfacing make things even more complicated (presence of sediments, erosion by liquid water/ice/wind)

What do we need to know about the sample/its unit?

NEED: in place, unaltered volcanic rock, not related to impact process and from a ***defined**** *unit with « simple » CSFD (no resurfacing)*



Soucek et al., 2015

* *CSFD measurable* & a correspondence between remote sensing + in situ measurements that could confirm the link between the unit used to obtain the CSFD and the sample

Recommendations for the selection of units to obtain reliable calibration of the Martian cratering chronology

What do we need to know about the sample/its unit?

NEED: in place, unaltered volcanic rock, not related to impact process and from a ***defined**** *unit with « simple » CSFD (no complex resurfacing, complete record)*

** CSFD measurable* & a good correspondence between remote sensing + in situ measurements that could confirm the link between the unit used to obtain the CSFD and the sample

Additional point to check:
Size of the unit (not too small for big craters registration)
Avoid units with: secondaries, possible saturation, resurfacing events