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

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Calibration of the Martian cratering chronology: *lessons learned from Lunar Science*

### Chronology model for the Moon

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

 chronology curve still debated: Morbidelli *et al.*, 2018; Robbins, 2014; Werner *et al.*, 2014, etc...

(Stöffler & Ryder, 2001)

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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*)
  - 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):

- Sampling sites
- Landing site

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Using Neukum, 1983 production function

**N1983**: $3.7 \times 10^{-2}$

**R2014**: $4.84 \times 10^{-2}$

**B2018**: $2.36 \times 10^{-2}$
Example with A14: CSFD from (Robbins, 2015):

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

N1983: 3.7x10^{-2}
R2014: 4.84x10^{-2}
B2018: CSFDx10^{-2}
Example with A14: CSFD from (Robbins, 2015):

- **N1983**: $3.7 \times 10^{-2}$
- **R2014**: $4.84 \times 10^{-2}$
- **B2018**: CSFD$ \times 10^{-2}$

**In case of smaller unit, the error bar size would increase:** possibility to lose 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.
Example with A14: CSFDs:

N1983: $3.7 \times 10^{-2}$
R2014: $4.84 \times 10^{-2}$
B2018: $2.36 \times 10^{-2}$

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?**

**Median ages**

- Brecciated samples
- Crust formation event (possibly two events)

- high-Al basalts

- Feldspatic basalt? KREEP basalt? Not « pristine » igneous origin

**Ages in Gyrs**

- 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 how to link them with surfaces unit(s)?
Example with A14: CSFDs’ interpretations

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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“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)

* 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
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