Elucidating the History of the Moon’s Surface

High Spatial Resolution $^{40}$Ar/$^{39}$Ar Geochronology of Multigenerational Lunar Impact Melt Rocks

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Why study the moon?

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  – Early terrestrial record erased by crustal recycling

Artistic rendering of Hadean Earth (credit: Simone Marchi)
Heavily cratered lunar surface (credit: NASA)
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• Moon is an unique archive of early Solar System history
  – Early terrestrial record erased by crustal recycling
  – Implications for emergence of life

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Why study the moon?

• Lunar history can be extrapolated to other solid surfaces in Solar System
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• Lunar history can be extrapolated to other solid surfaces in Solar System
  – Lunar chronology ties crater size frequency distributions to radiometric time
The lunar surface
Lunar chronology

- Moon Formation
- LMO Solidification
- Crustal Rocks
  - FANs
  - Mg-Suite
- KREEP Source
- Zircon
- Mare Basalt Source
- Mare Volcanism

Credit: NASA
Argon geochronology

- $^{40}$K ($t_{1/2} = 1.25$ Ga) $\rightarrow$ $^{40}$Ca and $^{40}$Ar
- Neutron irradiation produces $^{39}$Ar from $^{40}$K
- $^{40}$Ar/$^{39}$Ar measured in unknown and compared to neutron fluence age monitor
Argon geochronology

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Schaen et al., 2020
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Alexander and Kahl, 1974
The UVLAMP $^{40}\text{Ar}/^{39}\text{Ar}$ method

- UV laser ablation microprobe (UVLAMP) analyses permit high-spatial resolution geochronologic investigations
  - Particularly useful for multi-generational materials
  - 193 nm wavelength, produces no collateral heating outside of ablation pit
  - Ancient nature of lunar materials require only tens of nanograms of ablated material
  - Sample targeting done in petrographic context
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Spur Crater – 15455 and 15445
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The Apollo 15 ‘white an black’ rocks

- Macroscopic fragments of plutonic rock hosted within a fragment-laden impact melt breccia
- The two samples are geochemically and petrographically linked
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15455,383 and 15455,386
15445
3668 ± 33 Ma
(n=8)
3668 ± 33 Ma (n=8)

3654 ± 86 Ma to 4078 ± 43 Ma
15445

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3922 ± 23 Ma (n=9)
15445

3668 ± 33 Ma (n=8)
3654 ± 86 Ma to 4078 ± 43 Ma
3922 ± 23 Ma (n=9)
3738 ± 29 Ma to 4028 ± 26 Ma
Conclusions

• High-spatial resolution UVLAMP $^{40}\text{Ar}/^{39}\text{Ar}$ analyses undertaken on the ‘white and black’ Apollo 15 samples
  – Protracted history of impact bombardment recorded spanning ca. 500 Ma
  – Impact melt generation in 15445 ca. 3670 Ma but ca. 3800 Ma in 15455
  – Despite geologic expectation, these samples may not record impact melt generation associated with the Imbrium basin forming impact
  – Powerful tool, especially when used as a complement to other high-precision chronometers such as U-Pb
Questions
Interpreting lunar ages

Young et al., 2013
Lunar zircon record

Borg et al., 2015
Zircons and phosphates from 15455

Crow et al., 2017

Nemchin et al., 2020