ORIGIN, EVOLUTION, AND EXPLORATION OF PLANETARY CRUSTS
Comparison of Ancient Planetary Crusts

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Earth-Moon System from the Galileo mission 1992
**Origin, Evolution, and Exploration of Planetary Crusts**

**Chronology of events:**
- An Age Constraint on the Giant Impact from Lunar Sample Chronology. **Lars Borg**
- New constraints on the timing of basin-forming impact events from excavated crustal rocks. **William Cassata**

**Processes forming new crust:**
- Importance of silicic magmatism on the Moon. **Justin Simon**

**Characteristics and structure of planetary crusts:**
- Crustal Stratigraphy Before the Imbrium Impact. **Carle Pieters**
- Surface roughness in the SPA. **Noah Petro**
- Evolution and stratigraphy of SPA. Insights from pyroxene composition and distribution. **Daniel Moriarty**

**Exploration of Planetary Crusts (missions and documentation-curation):**
- Scientific motivation for sample return from SPA basin. **Brad Jolliff**
- Micro-CT of Apollo samples. **Ryan Zeigler**
Origin, Evolution, and Exploration of Planetary Crusts

Selection, collection, preservation, curation and analysis of samples, place samples into a planetary context, understand how a planet works, identification of resources and potential hazards.

1. Accretion
   - Initial Hermetic state
   - Heat-producing elements, indigenous volatiles, styles and chronology of differentiation, mass and composition of primordial crust, mantle, core.

2. Primordial Differentiation
   - Shaping future planetary events, processes, and environments
   - Formation of mantle reservoirs for subsequent magmatism, growth of planetary crust, redistribution of heat-producing elements composition, establish volatile reservoirs, heat budget

3. Secondary and Tertiary Crust Formation
   - Partial Melting
   - Mantle Plume
   - Tertiary Melting

4. Robotic and Human Exploration
Outline

- Diversity of primary crust.
- Role of $fO_2$ and volatiles in primary crust diversity and crustal evolution.
- Links between $fO_2$, volatiles, style of primordial crust formation.
- Examples of future research and questions.
Composition and chronology of primary crust formation

- Angrites
- GRA06129/8 Brachinites
- Graphite (Mercury)
- Mars
- Eucrites and Diogenites
- FANs (Moon)

- 4.5 Ga
- 4.4 Ga
- 4.3 Ga
Role of oxygen fugacity 2

Ol + Qtz + La + (Ne)CA system \( (\text{Mg}^{\#(\text{liq})}=0.3-0.5) \)
After Longhi, 1999
Building planetary volatile reservoirs and their impact on primordial crust formation
Building planetary volatile reservoirs and their impact on primordial crust formation

- Angrite PB
- Earth
- Mars
- Moon & 4 Vesta
- Angrite PB
- IW-1
- Initial post-impact mantle f(O₂) value
- QFM
- f(O₂) upper limit
- Log₁₀ f(O₂)
Role of volatiles in primary crust formation $H_2O-S$
Mercury’s primary crust?

- Inexplicably dark surface
- Source of darkness unknown
- No ferrous iron detected in silicates
- Volatile-rich
  - K/Th value as high as mars
- Low oxygen fugacity
  - ΔIW -2.7 to -6.3
  - Elevated S abundances on surface
- Graphite has been suggested as a potential darkening agent given Mercury’s volatile-rich nature and graphite’s spectral properties
Links between $fO_2$, volatiles, style of primordial crust formation.

Small Bodies
- Increase metamorphism, melting, core formation
- Primitive crust reflecting degrees of partial melting and volatiles
- $fO_2$ IW+1 to IW-2
- H species dominated by $H_2$

Moon
- Graphite floatation crust and mafic cumulates
- Flotation crust
- $fO_2$ IW-1 to IW-6
- H species dominated by $H_2$ or H-C species

Mercury
- Primitive crust reflecting MO cumulate overturn melting
- Cumulate overturn and melting
- $fO_2$ IW+1 to QFM
- H species dominated by $H_2$ or $H_2O$

Mars
- Primitive crust reflecting MO cumulate overturn melting
- Cumulate overturn and melting
- $fO_2$ IW+1 to QFM
- H species dominated by $H_2$ or $H_2O$

Radius

Modified from Elkins-Tanton (2012)
Examples of future work and questions

- Thermal models for asteroid melting can be improved through the refinement of appropriate specific heat capacity and diffusivities, accurate peak temperatures from geothermometry, and more precise ages from high-resolution chronometers.

- What is the chronology of lunar accretion and primary crust formation?

- How does primordial differentiation influence the initiation, duration, and style of secondary crustal growth (e.g. Mg-suite vs FAN)?

- What is the origin of ancient felsic crust formation on small bodies, Moon, Mars, and Earth?

- How does accretion and differentiation influence indigenous volatile reservoirs?

- Where do volatile reservoirs reside in planetary interiors (crust, mantle, core, mineral phases)?

All these questions require the integration of substantial sample and experimental derived data with mission observations and modeling.
THANK YOU.

Earth-Moon System from the Chang’e 4 mission 2014