Impact Melt Sheet Composition, Age, and Igneous Differentiation?: Commercial Mission Goals

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Outline

• Scientific Background
• Outstanding Questions
• Mission Concepts
• Conclusions
Impact melt produced $\propto$ transient cavity diameter

Osinski et al. (2011)
320 km

Vaughan et al. (2013)
- Cumulative volume of impact melt ~5 vol.% of lunar crust.
- Could have contributed to compositional variations and may be represented in sample collection.
- Important to understand, but difficult to study.

Vaughan et al. (2013)
Ideal location for the investigation of basin impact melt deposits.
Ideal location for the investigation of basin impact melt deposits.

Spudis et al. (2014)
Maunder Formation
(Basin impact melt deposit)
Maunder Formation (Basin impact melt deposit)

Head (1974), Vaughan et al. (2013)
Cintala and Grieve (1998), Wilson and Head (2010), Vaughan et al. (2011,12), Osinski et al. (2011)

Maunder Formation
(Basin impact melt deposit)
Petrologic modeling favored a differentiated Orientale impact melt sheet.
Revisited with physical considerations, favoring a homogeneous melt sheet for crystal size of lunar impact melt samples (2 mm).
Spudis et al. (2014) suggested a thin undifferentiated impact melt sheet.
Shock physics code simulations predict yet a different structure with impact melt restricted largely to the mantle.
-\frac{d\rho}{dz}
Configuration 1

Homogeneous melt sheet

Crust

Mantle

<table>
<thead>
<tr>
<th>Depth (km)</th>
<th>Distance from Center (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 30</td>
<td>0 - 50</td>
</tr>
<tr>
<td>30 - 50</td>
<td>50 - 100</td>
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<tr>
<td>50 - 70</td>
<td>100 - 150</td>
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<td>70 - 90</td>
<td>150 - 200</td>
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<td>400 - 450</td>
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<td>190 - 210</td>
<td>450 - 500</td>
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<td>210 - 230</td>
<td>500 - 550</td>
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<td>230 - 250</td>
<td>550 - 600</td>
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</tbody>
</table>

\[ \rho = 2,550 \text{ kg/m}^3 \]

\[ \rho = 3,220 \text{ kg/m}^3 \]

\[ \rho = 3,050 \text{ kg/m}^3 \]

- ○○○ GRAIL Observed
- --- Modeled Anomaly
Configuration 3

- A: Crustal overflow cap
- A': Impact melt

ρ = 2,550 kg/m³

ρ = 3,330 kg/m³

- Crust
- Mantle

GRaIL Observed
- Modeled Anomaly

Distance from Center (km) vs. Free Air Anomaly (mGal)
Science to be Achieved by Landed Missions

1. What is the structure and distribution of the Orientale Impact melt?
   - What is the nature of the Maunder Formation facies?
   - Is Orientale impact melt exposed at the lunar surface or within ejecta?
   - Is the Orientale impact melt contained at depth?
   - What is the thickness and volume of the Orientale impact melt?

2. Did the Orientale impact melt undergo igneous differentiation?
   - What is the grain size distribution of the impact melt?
   - What is the composition of the melt?
   - Is there variability in impact melt composition vs. depth?
Landing Safety

Mare Orientale offers smooth, low-slope landing areas proximal targets of scientific interest.
Lander Mission

Short-term reconnaissance
Long-term monitoring

Target(s):
Maunder Formation facies/inner depression.

Possible surface actions:
- Evaluate physical properties.
- Investigate compositional characteristics.
- Chemical analyses.
- Radiometric dating.
- Deploy geophysical instrumentation.

Ji et al. (2018)
Lander Mission  
*Short-term reconnaissance*
*Long-term monitoring*

**Target(s):**
Maunder Formation facies/inner depression.

**Possible surface actions:**
- Evaluate physical properties.
- Investigate compositional characteristics.
- Chemical analyses.
- Radiometric dating.
- Deploy geophysical instrumentation.

*Ji et al. (2018)*
Rover Mission
Long-term monitoring
Regional Roving

Target(s):
Maunder Formation facies/inner depression.

Possible surface actions:
- Evaluate physical properties.
- Investigate compositional characteristics.
- Chemical analyses.
- Radiometric dating.
- Deploy geophysical instrumentation.
- Traverse geophysics.
Sample Return

Target(s):
Maunder Formation facies/inner depression.

Possible surface actions:
- Evaluate physical properties.
- Investigate compositional characteristics.
- Chemical analyses.
- Radiometric dating.
1. What is the structure and distribution of the Orientale Impact melt?
2. Did the Orientale impact melt undergo igneous differentiation?

Target(s): Maunder Formation facies/inner depression.

Possible surface actions:
1. Evaluate physical properties.
2. Investigate compositional characteristics.
3. Chemical analyses.
4. Radiometric dating.
5. Deploy geophysical instrumentation.
6. Traverse geophysics.

Scientific Yield:
- Impact melt grain size distribution (1).
- Peak shock pressure evaluation (1-3).
- Identification of siderophile enrichment (2-3).
- Age constraints (4).
- Subsurface density structure (5,6).
Conclusions

- Orientale is a compelling target for lunar landed science missions to investigate basin impact melt.
- Mare Orientale could provide safe areas for landing with proximal targets of scientific interest.
- Questions about the nature of basin impact melt can be answered to provide important insights for the process of basin formation and the geology and petrology of the Moon.
- Key scientific questions can be effectively addressed by both lander and rover missions and could be augmented by sample return.
- Scientific value can be derived even through short term landed reconnaissance.