Artificial Spatter Piles:

Constraining cooling and eruption rates in Idaho and on the Moon
Outline

1. What is spatter?
2. What can it tell us?
3. Experimental spatter piling up.
4. Can this be applied to real deposits?
Spatter is:

an accumulation of fluid clasts that retain some semblance of their own shapes.
Outline

1. What is spatter?
2. What can it tell us?
3. Experimental spatter piling up.
4. Can this be applied to real deposits?
Magmatic gas and vent region
Map based on Hooper (1997) volcano.oregonstate.edu/Columbia-river-flood-basalts
Basaltic eruptions are very common

But the timing is poorly constrained
• How does morphology relate to...
  — Chemistry
  — Process
  — Age
Spatter – the Goldilocks of basaltic morphologies

Theory: The degree of welding in a spatter pile is due to the accumulation rate of spatter clasts.
How do we get a cooling rate?
Volcanic glass is ductile and will anneal above the glass transition temperature.
Classification of basaltic eruptive products

Modified from a diagram in Sumner et al., 2005

Orvar Atli Porgeirsson / Barcroft Media

Cooling Rate
Lava flows show lateral consistency across long distances.
Classification of basaltic eruptive products

Cooling Rate
Classification of basaltic eruptive products
What can it tell us?
Classification of basaltic eruptive products

Accumulation Rate

Cooling Rate

What can it tell us?
Classification of basaltic eruptive products

Accumulation Rate

Cooling Rate

What can it tell us?
If we can put numbers on this diagram, can we constrain eruptive rates?
Outline

1. What is spatter?
2. What can it tell us?
3. Experimental spatter piling up.
4. Can this be applied to real deposits?
Location of field work

How do we get a cooling rate? -26
Location of field work

Devil’s Garden, OR

Craters of the Moon, ID

How do we get a cooling rate? - 27
How do we get a cooling rate?
Realistic rates?
Artificial spatter pile
Controlled cube experiments suggest we can find the boundary between spatter and tephra.
Characteristics that should be correlated with overall high heat in a deposit

More connections
More squashed clasts (lower w/l ratio)
Less void space
Data Collection

1. High temp.

2. Cooling rate

3. Time above 700°C
Data Collection

Spot 149° C

4. Surface temp
5. Fused surface area
What can it tell us?
Minimum conditions for welding

![Graph showing the relationship between surface temp (°C) and time above 700°C (min).}

The graph illustrates the time above 700°C (min) as a function of surface temp (°C). The data points are represented by red squares and gray squares, with a trend line showing the relationship. The y-axis represents the time above 700°C (min), while the x-axis shows the surface temp (°C).
Characteristics that should be correlated with overall high heat in a deposit

More connections
More squashed clasts (lower w/l ratio)
Less void space
More connection: Amount of fusion between clasts is dependent on starting temp and time above 700°C.
Squashed clasts: Temperature, time, and cooling rate are weakly correlated. Though can be overruled by shaping during flight.
**Void space:** Well correlated with time and temperature. High heat = less void space.
**Vesicle mode:** More vesicular at faster cooling rates, lower temp.... with caveats due to clast manipulation
Central cavity in clast: Found more often in cooler clasts or clasts that cooled quickly.

![Diagram showing the relationship between FLIR temp, cooling rate, and void space percentage.](image-url)
1. What is spatter?
2. What can it tell us?
3. Experimental spatter piling up.
4. Can this be applied to real deposits?
Cooling rate

Time above 700°C (m)

Cooling rate (°C/min)

Craters of the Moon spatter

Cooling rate 6-9°C/min

Time above 700°C 35 to 70 min

Landing temperature

Accumulation rate

Time to build cone
Craters of the Moon spatter

- Cooling rate: 6-9°C/min
- Time above 700°C: 35 to 70 min
- Landing temperature: 800-950°C
- Accumulation rate
- Time to build cone
Numerical model to examine thermal history of deposit

How can we calculate accumulation rate?
How can we calculate accumulation rate?
Cooling rate

Time above 700°C

Landing temperature

Accumulation rate

Time to build cone

Craters of the Moon spatter

Cooling rate 6-9°C/min

Time above 700°C 35 to 70 min

Landing temperature 800-950°C

Accumulation rate 0.5-2 m/h
30 meters high = between COTM - 0.5-2 m/h.
Can this be applied to other localities?

Artist's rendering of LRO spacecraft.

Credits: NASA

Marius Hills on the Moon
possible spatter cones

Celestron C9.25XLT, TeleVue 2.5x Powermate, Astronomik Red Type II, ImagingSource DMK21AF04.AS @30fps
882 frames used, 11 point auto MAP processing

© Oliver Pettenpaul - http://www.astro-imaging.de/astro
Application to planetary science

Figure 3. Digital Elevation Model (5 m contour intervals) derived from LROC NAC images of a volcanic dome with cone in the Marius Hills near the Constellation Program Region of Interest. Representative profiles across the lava flows are reproduced on the right.
Craters of the Moon spatter

<table>
<thead>
<tr>
<th>Craters of the Moon spatter</th>
<th>Moon spatter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling rate</td>
<td>6-9°C/min</td>
</tr>
<tr>
<td>Time above 700°C</td>
<td>35 to 70 min</td>
</tr>
<tr>
<td>Landing temperature</td>
<td>800-950°C</td>
</tr>
<tr>
<td>Accumulation rate</td>
<td>0.5-2 m/h</td>
</tr>
<tr>
<td>Time to build cone</td>
<td>15-60 h</td>
</tr>
</tbody>
</table>
1. By combining field observations, analytical experiments, and numerical modeling we have shown the boundary between explosive basaltic morphologies (cinder/spatter) can be quantified.
1. By combining field observations, analytical experiments, and numerical modeling we have shown the boundary between explosive basaltic morphologies (cinder/spatter) can be quantified.

2. Clast length/width, vesicularity, and fusion are correlated to thermal history of the deposit.
Grand Conclusions

1. By combining field observations, analytical experiments, and numerical modeling we have shown the boundary between explosive basaltic morphologies can be quantified.

2. Clast length/width, vesicularity, and fusion are correlated to thermal history of the deposit.

3. Cooling rates above 10°C/min correlated with no fusing of clasts.
Grand Conclusions

1. By combining field observations, analytical experiments, and numerical modeling we have shown the boundary between explosive basaltic morphologies can be quantified.

2. Clast length/width, vesicularity, and fusion are correlated to thermal history of the deposit.

3. Cooling rates above 10°C/min correlated with no fusing of clasts.

4. Lunar thermal regimes result is slower cooling, requiring slower accumulation rates, resulting in extended duration of deposition for the Marius Hills.
Thanks and Questions