# The Effect of Shock on the Amorphous Component in Altered Basalt

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## Introduction

The Martian surface contains a large proportion (up to 50 wt. %) of amorphous material whose nature and origin is not fully understood [1,2,3,4,5,6]. Mass-balance equations have been employed to constrain the geochemistry of the amorphous component [1,2,3,4]. Multiple hypotheses, most involving various aqueous processes, have been proposed to explain its origin [1,2,3,4,5,6]. Shock-metamorphism deserves further consideration when trying to unravel the nature of the amorphous component.

Teasing out the effect of shock will further constrain the contribution of aqueous alteration to the amorphous geochemistry, expanding our knowledge of the history of water on the Martian surface.

## Project Goals

1. Constrain the contribution of shock-induced amorphous phases on Mars by understanding the nature and origin of amorphous phases produced in a shock-metamorphosed and chemically weathered basalt.

2. Distinguish these shock-induced amorphous phases from other phases using the instruments onboard the *Curiosity* rover.

## Approach and Methodology

Using the same methods that were used for Gale Crater materials, we calculated the amorphous geochemistry of shock-metamorphosed basalt with various degrees of pre- and post-impact chemical weathering. The samples were collected from the Deccan Trap in India, a well-preserved impact crater into a basaltic target. Because of this, it is a valuable analogue for studying the Martian surface [7].

## Results

**Figure 1:** Bulk and calculated amorphous geochemistry (molar %) for the samples with the best fit XRD refinement patterns. This diagram illustrates mixing and weathering of primary igneous phases. Arrows represent the hypothesized processes by which the amorphous components were derived.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Bulk</th>
<th>Crystalline</th>
<th>Amorphous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthopyroxene</td>
<td>2.07</td>
<td>78.47</td>
<td>29.50</td>
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<tr>
<td>Plagioclase</td>
<td>2.77</td>
<td>69.41</td>
<td>30.79</td>
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<tr>
<td>Magnetite</td>
<td>0.29</td>
<td>9.24</td>
<td>8.95</td>
</tr>
<tr>
<td>Quartz</td>
<td>0.06</td>
<td>0.26</td>
<td>0.25</td>
</tr>
<tr>
<td>Fe-Ti-oxides</td>
<td>0.00</td>
<td>0.35</td>
<td>0.35</td>
</tr>
</tbody>
</table>

**Figure 2:** Example of mass balance calculations for the amorphous component in LC09-327.

**Table 3:** Crystalline phases and abundances determined using powder XRD at NASA’s Johnson Space Center.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Bulk</th>
<th>Crystalline</th>
<th>Amorphous</th>
</tr>
</thead>
<tbody>
<tr>
<td>orthopyroxene</td>
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<td>29.68</td>
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<td>plagioclase</td>
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<tr>
<td>magnetite</td>
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<td>9.55</td>
<td>9.17</td>
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<tr>
<td>quartz</td>
<td>0.10</td>
<td>0.35</td>
<td>0.25</td>
</tr>
<tr>
<td>Fe-Ti-oxides</td>
<td>0.00</td>
<td>0.35</td>
<td>0.35</td>
</tr>
</tbody>
</table>

**Figure 3:** Bulk and calculated amorphous geochemistry (molar %) for the samples with the best fit XRD refinement patterns. This diagram illustrates mixing and weathering of primary igneous phases. Arrows represent the hypothesized processes by which the amorphous components were derived.

**Al2O3**

**CaO+Na2O+K2O**

**FeO2+MgO**

**FeTiO3**

**SiO2**

**MgO**

**K2O**

**Na2O**

**CaCO3**

**Magnetite**

**Pigeonite**

**Calcite**

**Conclusions**

- Using our mass balance methods, different geologic processes can be identified for shocked basalt.

- It is likely that amorphous material on Mars consists of a mixture of different components produced by different processes including shock-metamorphism and low-temperature weathering.

- If the plagioclase/bulk rock amorphous phase (LC09-327) is part of the Rocknest amorphous component, then the remaining amorphous material would be composed of Si, Fe, Mg, Ca, Na, K, and volatiles (S and Cl). One possible mechanism for the formation of amorphous material with this composition is by incipient weathering of basalt at low pH [13].

## References