CRYSTAL-CHEMICAL ANALYSIS OF SOIL AT ROCKNEST, GALE CRATER. S.M. Morrison\textsuperscript{1} R.T. Downs\textsuperscript{1}, D.F. Blake\textsuperscript{2}, D.L. Bish\textsuperscript{3}, D.W. Ming\textsuperscript{4}, R.V. Morris\textsuperscript{4}, A.S. Yen\textsuperscript{4}, S.J. Chipera\textsuperscript{4}, A.H. Treiman\textsuperscript{7}, D.T. Vaniman\textsuperscript{8}, R. Gellert\textsuperscript{9}, C.N. Achilles\textsuperscript{4}, E.B. Rampe\textsuperscript{4}, T.F. Bristow\textsuperscript{2}, J.A. Crisp\textsuperscript{5}, P.C. Sarrazin\textsuperscript{10}, J.D. Farmer\textsuperscript{11}, D.J. Des Marais\textsuperscript{2}, E.M. Stolper\textsuperscript{12}, M.A. Wilson\textsuperscript{2}, N. Spanovich\textsuperscript{5}, R.C. Anderson\textsuperscript{5} and the MSL team. \textsuperscript{1}U. of Arizona (1040 E 4th St. Tucson, AZ 85721; shaunnamm@email.arizona.edu), \textsuperscript{2}NASA ARC, \textsuperscript{3}Indiana U., \textsuperscript{4}NASA JSC, \textsuperscript{5}JPL-Caltech, \textsuperscript{6}CHK Energy, \textsuperscript{7}LPI, \textsuperscript{8}PSI, \textsuperscript{9}U. Guelph, \textsuperscript{10}in-Xitu, \textsuperscript{11}Arizona State U., \textsuperscript{12}Arizona State U., \textsuperscript{13}Caltech.

**Introduction:** The CheMin instrument on the Mars Science Laboratory rover Curiosity performed X-ray diffraction analysis on Martian soil \cite{1} at Rocknest in Gale Crater. In particular, crystalline phases from scoop 5 were identified and analyzed with the Rietveld method \cite{2}. Refined unit-cell parameters are reported in Table 1. Comparing these unit-cell parameters with those in the literature provides an estimate of the chemical composition of the crystalline phases. For instance, Fig. 1 shows the Mg-content of Fa-Fo olivine as a function of the $b$ unit-cell parameter using literature data. Our refined $b$ parameter is indicated by the black triangle.

\begin{align*}
y &= -7.2604x + 76.063 \\
R^2 &= 0.9949
\end{align*}

![Figure 1. Mg-content of Fa-Fo olivine as a function of $b$ unit-cell parameter, indicating Fo56 for the composition of the Rocknest olivine with an error of 3%.](image)

**Composition as a Function of Unit-Cell Parameters:** Unit-cell parameters and chemistry were obtained from the literature for the target minerals, and relationships similar to Fig. 1 were observed. Some relationships, like that for olivine, are very well defined, whereas others, such as that for plagioclase in Fig. 2, reflect a larger range of solid solution. In the case of plagioclase, this range is a consequence of variation in Al-Si ordering and possibly of small amounts of K, not accounted for in this analysis. Augite and pigeonite were constrained to the Ca-Fe-Mg system. A simple binary plot, as shown in Fig. 1 and 2, did not fully describe the variations. Therefore, in both cases, Mg-content was estimated from the $b$ unit-cell parameter because it forms a linear trend (Fig. 3a). Ca and Fe were discriminated by the $\beta$ angle for augite (Fig. 3b) and by unit-cell volume for pigeonite (not shown).

**Chemical Composition of the Major Phases:** The following chemical compositions were obtained from the regressions illustrated in Fig. 1-3:

- olivine: ($\text{Mg}_{0.56(3)}\text{Fe}_{0.44})\text{SiO}_4$
- andesine: ($\text{Ca}_{0.52(12)}\text{Na}_{0.48}(\text{Al}_{1.51}\text{Si}_{2.48})\text{O}_8$
- augite: [$\text{Ca}_{0.77(4)}\text{Mg}_{0.67(10)}\text{Fe}_{0.56}]\text{Si}_2\text{O}_6$
- pigeonite: [$\text{M}_{1.40(9)}\text{Fe}_{0.22(10)}\text{Ca}_{0.38}]\text{Si}_2\text{O}_6$

\begin{table}[h]
\centering
\caption{Refined unit-cell parameters of the crystalline components from the Rocknest scoop 5 soil.}
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|}
\hline
Mineral & Wt.\% & 2$\sigma$ & $a$ (Å) & $b$ (Å) & $c$ (Å) & $\alpha$ (°) & $\beta$ (°) & $\gamma$ (°) \\
\hline
andesine & 42.9\% & 3.4\% & 8.175(5) & 12.868(8) & 7.117(5) & 93.46(6) & 116.31(2) & 90.16(4) \\
forsterite & 20.5\% & 2.6\% & 10.323(8) & 6.034(4) & 4.769(5) & 90 & 90 & 90 \\
 augite & 16.7\% & 3.5\% & 9.765(9) & 8.96(1) & 5.251(6) & 90 & 106.10(6) & 90 \\
pigeonite & 11.4\% & 3.9\% & 9.68(1) & 8.89(1) & 5.28(1) & 90 & 108.4(1) & 90 \\
\hline
\end{tabular}
\end{table}
Comparison with Bulk Chemistry Measured by APXS: The bulk chemistry of the crystalline component was computed from the estimated chemical compositions weighted by abundances and is shown in Table 2. Our results agree with those estimated by [3], to a standard deviation of 0.8 weight %, providing a measure of consistency between reported chemistry of martian meteorites and CheMin results. We assumed that the crystalline component, C, plus the “amorphous” component, A, summed to the total measured by APXS [4], T, where \( \alpha \) is a scaling factor:

\[
\alpha C + (1-\alpha)A = T
\]

Then \( \alpha \leq 0.63 \) to insure consistency with the APXS total (requires that all MgO is crystalline), implying that the amorphous component \( \geq 37 \% \) in the CheMin sample, compared with estimates of \( 36\% \) [3], and \( 27\% \pm 13.5 \% \) [2]. If we assume \( \alpha = 0.63 \) and subtract the CheMin crystalline component from the APXS total, we obtain the bulk composition of the amorphous components shown in Table 3. Our values agree with those from [3] to a standard deviation of 1.7 weight %.

Table 3. Amorphous component bulk composition (wt.% ) obtained by T-\( \alpha \)C

<table>
<thead>
<tr>
<th>Component</th>
<th>This study</th>
<th>[3]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO(_2)</td>
<td>36.2</td>
<td>35.3</td>
</tr>
<tr>
<td>Fe-oxides</td>
<td>34.1</td>
<td>29.4</td>
</tr>
<tr>
<td>SO(_3)</td>
<td>13.2</td>
<td>13.0</td>
</tr>
<tr>
<td>Al(_2)O(_3)</td>
<td>4.5</td>
<td>3.9</td>
</tr>
<tr>
<td>TiO(_2)</td>
<td>3.7</td>
<td>3.5</td>
</tr>
<tr>
<td>CaO</td>
<td>4.0</td>
<td>6.3</td>
</tr>
<tr>
<td>Na(_2)O</td>
<td>2.1</td>
<td>1.6</td>
</tr>
<tr>
<td>MnO</td>
<td>1.2</td>
<td>0.7</td>
</tr>
<tr>
<td>K(_2)O</td>
<td>1.0</td>
<td>1.3</td>
</tr>
</tbody>
</table>