Nano-scale Fracture Phenomena and TeraHertz Pressure Waves as the Fundamental Reasons for Geochemical Evolution

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During a preliminary experimental analysis four rock specimens were used:

- two made of **Carrara marble**, specimens P1 and P2;
- two made of **Luserna granite**, specimens P3 and P4;
- all of them measuring **6x6x10 cm³**.
Specimens P1 and P2 in **Carrara marble** following compression failure.

Specimens P3 and P4 in **Luserna granite** following compression failure.
Brittle Fracture Experiment on Carrara Marble specimen

Load vs. time and cps curve for P1 test specimen of Carrara marble.
Brittle Fracture Experiment on granite specimen

Load vs. time and cps curve for P3 test specimen of granite.
Neutron emissions were measured on nine Green Luserna stone cylindrical specimens, of different size and shape (D=28, 56, 112 mm; \(\lambda=0.5, 1.0, 2.0\))
Energy emission and stable vs. unstable stress-strain behaviour.
Subsequent stages in the deformation history of a specimen in compression

\( \sigma = 0 \)

\( \sigma_c \)

\( l \times \varepsilon_c \)

\( w = 0 \)

\( \delta = \varepsilon_c l = \frac{\sigma_c}{E} l \)

\( \sigma \)

\( l \times \varepsilon + w \)

\( w \)

\( \delta = \frac{\sigma}{E} l + w \)

\( \delta \geq w_c \)

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Stress vs. displacement response of a specimen in compression

- **Normal softening**
- **Vertical drop**
- **Catastrophic behaviour**
Catastrophic failure (single snap-back)

The grey area identifies the dissipated energy, $D$, (namely the fracture energy in tension) whereas the pink one represents the emitted energy, $E$. 

$D + E = R$
A global softening behavior perturbed by multiple local instabilities (snap-back)

The total released energy, $R$, is the sum of the dissipated and emitted energy: $D + E = R$. 
# WAVELENGTH vs FREQUENCY

![Wave diagram](image)

<table>
<thead>
<tr>
<th>λ (Metre)</th>
<th>10^{-9}</th>
<th>10^{-6}</th>
<th>10^{-3}</th>
<th>10^{0}</th>
<th>10^{3}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proteins</td>
<td><img src="image" alt="Proteins" /></td>
<td><img src="image" alt="Bacteria" /></td>
<td><img src="image" alt="Insects" /></td>
<td><img src="image" alt="Humans" /></td>
<td><img src="image" alt="Earthquakes" /></td>
</tr>
</tbody>
</table>

\[
\text{wave velocity} = \lambda \times f \approx 10^3 \text{ m s}^{-1}
\]
<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>NEUTRON EMISSION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LIQUIDS – Cavitation</strong></td>
<td></td>
</tr>
<tr>
<td>Iron chloride</td>
<td>up to 2.5 times the Background Level</td>
</tr>
<tr>
<td><strong>SOLIDS – Fracture</strong></td>
<td></td>
</tr>
<tr>
<td>Steel</td>
<td>up to 2.5 times the Background Level</td>
</tr>
<tr>
<td>Granite (Fe ~ 1.5%)</td>
<td>up to $10^1$ times the Background Level</td>
</tr>
<tr>
<td>Basalt (Fe ~ 15%)</td>
<td>up to $10^2$ times the Background Level</td>
</tr>
<tr>
<td>Magnetite (Fe ~ 75%)</td>
<td>up to $10^3$ times the Background Level</td>
</tr>
<tr>
<td>Marble</td>
<td>Background Level</td>
</tr>
</tbody>
</table>
Two different kinds of samples were examined: (i) polished thin sections from the external surface; (ii) small portions from the fracture surface.
Biotite (Granite): Fe concentration change

External Surf.:
Fe content = 21.2%

Fracture Surf.:
Fe content = 18.2%

Fe content decrease

-3.0%
Biotite (Granite): Al concentration change

Fracture Surf.:
Al content = 9.6%

External Surf.:
Al content = 8.1%

Al content increase
+1.5%
Biotite (Granite): Si concentration change

Fracture Surf.:
Si content = 19.6%

External Surf.:
Si content = 18.4%

Si content increase
+1.2%
Biotite (Granite): Mg concentration change

Fracture Surf.: Mg content = 2.2%

External Surf.: Mg content = 1.5%

Mg content increase +0.7%
# Biotite (Granite)

<table>
<thead>
<tr>
<th>Element</th>
<th>External surface mean value (wt%)</th>
<th>Fracture surface mean value (wt%)</th>
<th>Increase/ decrease with respect to biotite</th>
<th>Increase/ decrease with respect to the same element</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>21.2</td>
<td>18.2</td>
<td><strong>−3.0 %</strong></td>
<td><strong>−14 %</strong></td>
</tr>
<tr>
<td>Al</td>
<td>8.1</td>
<td>9.6</td>
<td><strong>+1.5 %</strong></td>
<td><strong>+18 %</strong></td>
</tr>
<tr>
<td>Si</td>
<td>18.4</td>
<td>19.6</td>
<td><strong>+1.2 %</strong></td>
<td><strong>+6 %</strong></td>
</tr>
<tr>
<td>Mg</td>
<td>1.5</td>
<td>2.2</td>
<td><strong>+0.7 %</strong></td>
<td><strong>+46 %</strong></td>
</tr>
<tr>
<td>K</td>
<td>6.9</td>
<td>7.1</td>
<td>NO VARIATIONS</td>
<td>NO VARIATIONS</td>
</tr>
</tbody>
</table>

\[
\text{Fe}_{26}^{56} \rightarrow 2 \text{Al}_{13}^{27} + 2n
\]

\[
\text{Fe}_{26}^{56} \rightarrow \text{Si}_{14}^{28} + \text{Mg}_{12}^{24} + 4n
\]
## Carrara Marble

<table>
<thead>
<tr>
<th>Element</th>
<th>External surface mean value (wt%)</th>
<th>Fracture surface mean value (wt%)</th>
<th>Increase/ decrease with respect to Carrara Marble</th>
<th>Increase/ decrease with respect to the same element</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca</td>
<td>13.4</td>
<td>9.8</td>
<td>– 3.6%</td>
<td>– 26%</td>
</tr>
<tr>
<td>Mg</td>
<td>0.7</td>
<td>0.3</td>
<td>– 0.4%</td>
<td>– 57%</td>
</tr>
<tr>
<td>O</td>
<td>45.8</td>
<td>36.8</td>
<td>– 9.0%</td>
<td>– 19%</td>
</tr>
<tr>
<td>C</td>
<td>40.1</td>
<td>53.1</td>
<td>+ 13.0%</td>
<td>+ 32%</td>
</tr>
</tbody>
</table>

\[
\text{Ca}^{40}_{20} \rightarrow 3\text{C}^{12}_6 + \text{He}^4_2
\]

\[
\text{Mg}^{24}_{12} \rightarrow 2\text{C}^{12}_6
\]

\[
\text{O}^{16}_8 \rightarrow \text{C}^{12}_6 + \text{He}^4_2
\]
IRON DEPLETION vs CARBON POLLUTION

Tectonic plate formation
(3.8 Billion years ago):
Fe (−7%) + Ni (−0.2%) =
=Al (+3%) + Si (+2.4%) + Mg (+1.8%)

Most severe tectonic activity
(2.5 Billion years ago):
Fe (−4%) + Ni (−0.8%) =
=Al (+1%) + Si (+2.4%) + Mg (+1.4%)
Conjecture about ferrous elements’ transformations in the Earth Crust

(1) \( \text{Fe}^{56}_{26} \rightarrow 2 \text{Al}^{27}_{13} + 2n \)

(2) \( \text{Fe}^{56}_{26} \rightarrow \text{Mg}^{24}_{12} + \text{Si}^{28}_{14} + 4n \)

(3) \( \text{Ni}^{59}_{28} \rightarrow 2 \text{Si}^{28}_{14} + 3n \)
Magnesium depletion and Carbon increment in the primordial atmosphere

The estimated Mg increase (~3.2%) is equivalent to the Carbon content in the primordial atmosphere:

\[
\text{Fe}_{26}^{56} \rightarrow \text{Mg}_{12}^{24} + \text{Si}_{14}^{28} + 4n \\
\text{Mg}_{12}^{24} \rightarrow 2\text{C}_{6}^{12}
\]

Assuming a mean density of the Earth Crust equal to 3.6 g/cm\(^3\) and a thickness of ~60 km, the mass increase in Mg (~3.5x10\(^{21}\) kg), and therefore in C, implies a very high atmospheric pressure.

- Primordial atmospheric pressure due to C increase = ~660 atm
- Primordial atmospheric pressure reported by other authors = ~650 atm (Liu, 2004)

Localization of Aluminum mines


Two piezonuclear fission reaction jumps typical of the Earth Planet:

- $\text{Fe}_{26}, \text{Co}_{27}, \text{Ni}_{28}$ (NI-FE)
- $\text{Mg}_{12}, \text{Al}_{13}, \text{Si}_{14}$ (SI-MA, SI-AL)
- $\text{C}_6, \text{N}_7, \text{O}_8$ (Atmosphere)
3.8 Billion years ago:
Ca (−2.5%) + Mg (−3.2%) =
= K (+1.4%) + Na (+2.1%) + O (+2.2%)

2.5 Billion years ago:
Ca (−1.5%) + Mg (−1.5%) =
= K (+1.3%) + Na (+0.6%) + O (+1.1%)
Conjecture about Alkaline-Earth elements’ transformations

(1) $\text{Mg}_{12}^{24} \rightarrow \text{Na}_{11}^{23} + \text{H}_{1}^{1}$

(2) $\text{Mg}_{12}^{24} \rightarrow \text{O}_{8}^{16} + 2\text{H}_{1}^{1} + \text{He}_{2}^{4} + 2n$

(3) $\text{Ca}_{20}^{40} \rightarrow \text{K}_{19}^{39} + \text{H}_{1}^{1}$

(4) $\text{Ca}_{20}^{40} \rightarrow 2\text{O}_{8}^{16} + 4\text{H}_{1}^{1} + 4n$
Acoustic, Electromagnetic, Neutron Emissions from Fracture and Earthquakes