Piezonuclear Reactions Produced by Brittle Fracture: From Laboratory to Planetary Scale

A. Carpinteri, O. Borla, G. Lacidogna, A. Manuello

Department of Structural Engineering & Geotechnics, Politecnico di Torino, Italy
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Dr. S. Invernizzi
Dept. of Structural Engineering & Geotechnics

Prof. R. Sandrone
Dept. of Environment, Land and Infrastructure Engineering

Prof. M. Ferraris, Dr. F. Smeacetto, Prof. C. Pirri, Dr. S. Guastella
Dept. of Applied Science and Technology

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FRACTURE OF FISSION AND DEUTERATED MATERIALS


CAVITATION OF LIQUID SOLUTIONS


FRACTURE OF INERT AND NON-RADIOACTIVE SOLIDS


(Continued)


LABORATORY EXPERIMENTS
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 Emission from Cavitation of Liquids and Fracture of Solids

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>Neutron Emission</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LIQUIDS</strong></td>
<td></td>
</tr>
<tr>
<td>Cavitation</td>
<td></td>
</tr>
<tr>
<td>Iron chloride</td>
<td>up to 2.5 times the Background Level</td>
</tr>
<tr>
<td><strong>SOLIDS</strong></td>
<td></td>
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<tr>
<td>Fracture</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>
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<tr>
<td>Basalts (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>
The equivalent neutron dose, at the end of the test on basaltic rock, was $2.62 \pm 0.53 \, \mu\text{Sv/h}$ (Average Background Dose = $41.95 \pm 0.85 \, \text{nSv/h}$).

$$\frac{\text{Effective Neutron Dose}}{\text{Average Background Dose}} \approx 50$$
A quantitative analysis was performed on the collected spectra in order to recognize specific variations in each element between external and fracture surfaces.

Two different kinds of samples were examined: (i) polished thin sections for the external surface; (ii) small portions of the fracture surface.
Phengite: Fe concentrations

External Surf.:
Fe content = 6.2%

Fracture Surf.:
Fe content = 4.0%

Fe content decrease
–2.2%
Phengite: Al concentration

Fracture Surf.:
Al content = \textbf{14.5}\%

External Surf.:
Al content = \textbf{12.5}\%

Al content increase
\begin{align*}
+2.0\%\nonumber
\end{align*}
Phengite: Si, Mg and K concentrations

Trends of the other chemical elements constituting the mineral chemistry in phengite are considered.

The Si, Mg, and K concentrations are reported for external and fracture surfaces. In this case, no appreciable variations can be recognized between the average values.
The results of these quantitative analysis represent a direct evidence that piezonuclear reaction has occurred in the rock specimens.

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

has occurred in the rock specimens.
Biotite: Fe concentrations

External Surf.:  
Fe content = 21.2%

Fracture Surf.:  
Fe content = 18.2%

Fe content decrease  
\(-3.0\%\)
Biotite: Al concentrations

Fracture Surf.:
Al content = 9.6%

External Surf.:
Al content = 8.1%

Al content increase
+1.5%
Biotite: Si concentrations

Fracture Surf.:
Si content = 19.6%

External Surf.:
Si content = 18.4%

Si content increase
+1.2%
Biotite: Mg concentrations

Fracture Surf.: Mg content = 2.2%

External Surf.: Mg content = 1.5%

Mg content increase +0.7\%
Therefore, the Fe decrease (−3.0%) in biotite is counterbalanced by an increase in Al (+1.5%), Si (+1.2%), and Mg (+0.7%). Considering these evidences, in analogy to the previous results, it is possible to conjecture that another piezonuclear reaction has been occurred in the biotite crystalline phase during the tests:

\[ \text{Fe}^{56}_{26} \rightarrow \text{Si}^{28}_{14} + \text{Mg}^{24}_{12} + 4 \text{ neutrons} \]
Basalt (Olivine): Fe concentrations

External Surf.: Fe content = 18.4%

Fracture Surf.: Fe content = 14.4%

Fe content decrease
- 4.0%
Basalt (Olivine): Si concentrations

Fracture Surf.: Fe content = 20.5%  
External Surf.: Fe content = 18.3%

Si content increase  
+ 2.2%
Basalt (Olivine): Mg concentrations

Fracture Surf.: Fe content = 22.8%

External Surf.: Fe content = 21.2%

Si content increase

+ 1.6%
Therefore, the Fe decrease (−4.0%) in olivine is counterbalanced by an increase in Si (+2.2%) and Mg (+1.6%). Considering these evidences, in analogy to the previous results, the following piezonuclear reaction is conjectured:

\[
\text{Fe}_{26}^{56} \rightarrow \text{Si}_{14}^{28} + \text{Mg}_{12}^{24} + 4 \text{ neutrons}
\]
Carrara Marble: O concentrations

X-ray Photoelectron Spectroscopy

External Surf.:
O content = 45.8%

Fracture Surf.:
O content = 36.8%

O content decrease
-9.0%
Carrara Marble: Ca concentrations

External Surf.:
Ca content = 13.4%

Fracture Surf.:
Ca content = 9.8%

Ca content decrease
-3.6%
Carrara Marble: Mg concentrations

External Surf.: Mg content = 0.7%

Fracture Surf.: Mg content = 0.3%

Mg content decrease –0.4%
Carrara Marble: C concentrations

Fracture Surf.:  
C content = 53.1%

External Surf.:  
C content = 40.1%

C content increase  
+13.0%
The Ca, Mg and O decreases (−3.6%), (−0.4%) and (−9.0%) in marble are counterbalanced by an increase in C (+13.0%). It is possible to conjecture that the following piezonuclear reactions have been occurred:

\[ \text{Mg}^{24}_{12} \rightarrow 2\text{C}^{12}_{6} \]
\[ \text{Ca}^{40}_{20} \rightarrow 3\text{C}^{12}_{6} + \text{He}^{4}_{2} \]
\[ \text{O}^{16}_{8} \rightarrow \text{C}^{12}_{6} + \text{He}^{4}_{2} \]
EARTH CRUST EVOLUTION
NEUTRON EMISSIONS FROM EARTHQUAKES


As reported in the literature, an average thermal neutron flux up to $10^0 \text{ cm}^{-2} \text{ s}^{-1}$ ($10^3$ times the background level) was detected in correspondence to earthquakes with a magnitude of the 4th degree in Richter Scale (Volodichev N.N., et al. (1999)).

Global seismic activity and neutron flux measurements in the period 1974-1988. Laboratory of Geophysical Precursors, Oblast' Murmansk, Apatity, Kola Peninsula, Russia (Sobolev et al. 1998).
Based on the disappearance of iron atoms (−25%) and the appearance of aluminium atoms after the experiments, our conjecture is that the following nucleolysis or piezonuclear “fission” reaction could have occurred:

$$Fe^{56}_{26} \rightarrow 2 Al^{27}_{13} + 2 \text{ neutrons}$$

The present natural abundance in the Earth’s Crust of aluminum (~8%) and iron (~4%) are possibly due to the above piezonuclear fission reaction.

This reaction would be activated where the environment conditions (pressure and temperature) are particularly severe, and mechanical phenomena of fracture, crushing, fragmentation, comminution, erosion, friction, etc., may occur.
If we consider the evolution of the percentages of the most abundant elements in the Earth Crust during the last 4 billion years, we realize that Iron and Nickel have drastically diminished, whereas Aluminum and Silicon have as much increased:

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

\[
\text{Ni}^{59}_{28} \rightarrow 2\text{Si}^{28}_{14} + 3 \text{ neutrons}
\]

It is also interesting to realize that such increases have developed mainly in the tectonic regions, where frictional phenomena between the continental plates occurred.
Most severe tectonic activity ($\sim2.5\times10^9$ years ago)
Localization of iron mines

Iron reservoirs
- More than 40 Mt/year
- from 10 to 40 Mt/year


Localization of Aluminum mines


Tectonic plate formation (~3.8×10^9 years ago)

3.8 Billion years ago:
Fe (−7%) + Ni (−0.2%) =
= Al (+3%) + Si (+2.2%) + Mg (+2%)

2.5 Billion years ago:
Fe (−4%) + Ni (−0.8%) =
= Al (+1%) + Si (+2.3%) + Mg (+1.5%)
(1) $\text{Fe}^{56}_{26} \rightarrow 2\text{Al}^{27}_{13} + 2$ neutrons

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

(3) $\text{Fe}^{56}_{26} \rightarrow \text{Ca}^{40}_{20} + \text{C}^{12}_{6} + 4$ neutrons

(4) $\text{Co}^{59}_{27} \rightarrow \text{Si}^{28}_{14} + \text{Al}^{27}_{13} + 4$ neutrons

(5) $\text{Ni}^{59}_{28} \rightarrow 2\text{Si}^{28}_{14} + 3$ neutrons

(6) $\text{Ni}^{59}_{28} \rightarrow \text{Na}^{23}_{11} + \text{Cl}^{35}_{17} + 1$ neutron

Earth’s Crust Evolution
Nickel depletion and salinity level increase in the Mediterranean Sea

Map of the salinity level in the Mediterranean Sea expressed in p.s.u.
The Mediterranean basin is characterized by the highest sea salinity level in the World.
Seismic map of the major earthquakes that have occurred over the last fifteen years in the Mediterranean Fault area.

\[ \text{Ni}_{28}^{59} \rightarrow \text{Na}_{11}^{23} + \text{Cl}_{17}^{35} + 1 \text{ neutron} \]
3.8 Billion years ago:
\[ \text{Ca} (-2.5\%) + \text{Mg} (-3.2\%) = \text{K} (+1.4\%) + \text{Na} (+2.1\%) + \text{O} (+2.2\%) \]

2.5 Billion years ago:
\[ \text{Ca} (-1.5\%) + \text{Mg} (-1.5\%) = \text{K} (+1.3\%) + \text{Na} (+0.6\%) + \text{O} (+1.1\%) \]
Atmosphere Evolution, Ocean Formation and Origin of Life

(7) \( \text{Mg}_{12}^{24} \rightarrow 2\text{C}_6^{12} \)

(8) \( \text{Mg}_{12}^{24} \rightarrow \text{Na}_{11}^{23} + \text{H}_1^1 \)

(9) \( \text{Mg}_{12}^{24} \rightarrow \text{O}_8^{16} + 2\text{H}_1^1 + \text{He}_2^4 + 2\text{n} \)

(10) \( \text{Ca}_{20}^{40} \rightarrow 3\text{C}_6^{12} + \text{He}_2^4 \)

(11) \( \text{Ca}_{20}^{40} \rightarrow \text{K}_{19}^{39} + \text{H}_1^1 \)

(12) \( \text{Ca}_{20}^{40} \rightarrow 2\text{O}_8^{16} + 4\text{H}_1^1 + 4\text{n} \)
Atmosphere Evolution, Ocean Formation and Origin of Life

\[
\begin{align*}
(7) \quad \text{Mg}^{24}_{12} & \rightarrow 2\text{C}^{12}_{6} \\
(8) \quad \text{Mg}^{24}_{12} & \rightarrow \text{Na}^{23}_{11} + \text{H}^{1}_{1} \\
(9) \quad \text{Mg}^{24}_{12} & \rightarrow \text{O}^{16}_{8} + 2\text{H}^{1}_{1} + \text{He}^{4}_{2} + 2\text{n} \\
(10) \quad \text{Ca}^{40}_{20} & \rightarrow 3\text{C}^{12}_{6} + \text{He}^{4}_{2} \\
(11) \quad \text{Ca}^{40}_{20} & \rightarrow \text{K}^{39}_{19} + \text{H}^{1}_{1} \\
(12) \quad \text{Ca}^{40}_{20} & \rightarrow 2\text{O}^{16}_{8} + 4\text{H}^{1}_{1} + 4\text{n}
\end{align*}
\]
Magnesium depletion in the Earth Crust and Carbon concentration in the primordial atmosphere

The assumed virtual Mg increase (~3.5%) can be confirmed by the Carbon content in the primordial atmosphere:

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

\[
\text{Mg}_{12}^{24} \rightarrow 2\text{C}_{6}^{12}
\]

Assuming a mean density of the Earth Crust equal to 3.6 g/cm³ and a thickness of ~60 km, the mass increase in Mg (~3.5×10^{21} kg) implies a very high atmospheric pressure due to the transformed carbon.

Primordial atmospheric pressure due to piezonuclear C content = ~650 atm

Primordial atmospheric pressure reported by other authors = ~650 atm

(Liu, 2004)

(7) $\text{Mg}^{24}_{12} \rightarrow 2\text{C}^{12}_6$

(8) $\text{Mg}^{24}_{12} \rightarrow \text{Na}^{23}_{11} + \text{H}^1_1$

(9) $\text{Mg}^{24}_{12} \rightarrow \text{O}^{16}_{8} + 2\text{H}^1_1 + \text{He}^4_2 + 2n$

(10) $\text{Ca}^{40}_{20} \rightarrow 3\text{C}^{12}_6 + \text{He}^4_2$

(11) $\text{Ca}^{40}_{20} \rightarrow \text{K}^{39}_{19} + \text{H}^1_1$

(12) $\text{Ca}^{40}_{20} \rightarrow 2\text{O}^{16}_8 + 4\text{H}^1_1 + 4n$
Calcium depletion in the Earth Crust and ocean formation

Global decrease in Ca (−4.0%) is counterbalanced by an increase in K (+2.7%) and in H₂O (+1.3%).

\[
\begin{align*}
\text{Ca}^{40}_{20} & \rightarrow \text{K}^{39}_{19} + \text{H}^1_1 \\
\text{Ca}^{40}_{20} & \rightarrow 2\text{O}^{16}_{8} + 4\text{H}^1_1 + 4 \text{ neutrons}
\end{align*}
\]

Considering a mean density of the Earth Crust equal to 3.6 g/cm³ and an average thickness of ~60 km, the partial mass decrease in Ca is about \(1.41 \times 10^{21}\) kg.

Considering a global ocean surface of \(3.607 \times 10^{14}\) m², and an average depth of 3950 m, we obtain a mass of water of about \(1.35 \times 10^{21}\) kg.
Greenhouse Gas Formation

(13) $^{16}\text{O}_8 \rightarrow C^{12}_6 + \text{He}^4_2$

(14) $^{27}\text{Al}_{13} \rightarrow C^{12}_6 + N^{14}_7 + 1 \text{ neutron}$

(15) $^{28}\text{Si}_{14} \rightarrow 2 N^{14}_7$

(16) $^{28}\text{Si}_{14} \rightarrow C^{12}_6 + O^{16}_8$

(17) $^{28}\text{Si}_{14} \rightarrow 2C^{12}_6 + \text{He}^4_2$

(18) $^{28}\text{Si}_{14} \rightarrow O^{16}_8 + 2H^1_1 + 2\text{He}^4_2 + 2 \text{ neutrons}$
SOLAR SYSTEM EVOLUTION
Two piezonuclear fission reaction jumps typical of the Earth Crust:

\[ \text{Fe}_{26}, \text{Co}_{27}, \text{Ni}_{28} \rightarrow \text{Mg}_{12}, \text{Al}_{13}, \text{Si}_{14} \rightarrow \text{C}_6, \text{N}_7, \text{O}_8 \]

Explanation for:

- Sudden variations in the most abundant elements (including Na\text{_{11}}, K\text{_{19}}, Ca\text{_{20}})
- Localization of the resources on the Earth’s Crust
- Very high Carbon content in the primordial atmosphere
- Great Oxidation Event (2.5 Billion years ago) and origin of oceans and life
- Production of neutrons (Rn, CO\textsubscript{2}) during earthquakes
- Evolution of the planets of the Solar System: Mercury, Mars, Jupiter, Saturn (and the Sun itself)
POSSIBLE APPLICATION FIELDS

- Short-term prediction and monitoring of **earthquakes**

- Evaluation of natural production of black carbon and CO$_2$ with their effects on global **pollution**

- Acceleration in the disposal of **radioactive wastes**

- Clean nuclear **energy production** (?)