Strain drop measurements of porous silica, charcoal and shale for probing crackling noise

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Abstract
SiO₂-based porous materials (Vycor, Gelsil), charcoal and shale have been measured under slow uniaxial compression at low constant force rates using a Diamond DMA (Dynamical Mechanical Analyzer, Perkin Elmer). The jerky evolution of the sample’s height with time was analyzed in order to determine the corresponding power-law exponents for the maximum velocity distribution ($\beta =2$), the energy (squared velocity) distribution ($\xi = -1.5$) as well as the modified Omori’s law ($p = 0.7$) of events. These power-law exponents are in good agreement with mean-field values.

For charcoal and shale we generally find significant lower values for the exponents $\beta$ and $\xi$. For charcoal a clear decay of aftershock activity was found with $p = 0.6$, whereas preliminary measurements for shale do not allow for a definite conclusion about the aftershock dynamics.

The results show that the failure dynamics of materials can be well studied by measuring strain drops under slow compression, giving reasons for hope that in near future it will be possible to study earthquake dynamics in the laboratory also at non-ambient conditions, i.e. at elevated temperature or with different pore fillings.

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Experimental setup and sample characteristics

The geometry of a typical compression experiment of porous materials using a Diamond DMA and DMA-7e (Perkin Elmer) is shown in Fig.1.

Table 1 summarizes the main characteristics of the samples.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Vycor 7.5</th>
<th>Gelsil 5</th>
<th>Gelsil 2.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average pore diameter (nm)</td>
<td>7.5</td>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td>Pore size (%)</td>
<td>40</td>
<td>54</td>
<td>36</td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>1.9</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Surface area (m²/g)</td>
<td>70</td>
<td>510</td>
<td>900</td>
</tr>
<tr>
<td>Surface fractal dimension $D_s$</td>
<td>2.3</td>
<td>2.24</td>
<td>-</td>
</tr>
<tr>
<td>Mass fractal dimension $D_m$</td>
<td>2.33</td>
<td>2.87</td>
<td>-</td>
</tr>
<tr>
<td>Approximate failure stress (MPa)</td>
<td>30</td>
<td>10</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Fig.1 Geometry of a typical compression experiment.

Comression experiments

Fig. 2, 5, 10, 15, 17 Compression experiments of different materials.
Fig. 3, 6, 11, 16, 18 Distribution of maximum drop velocities squared $N(v_{\text{max}}^2)$
Fig. 4, 7, 12 Distribution of maximum drop velocities $N(v_{\text{max}})$
Fig. 8, 13 Number of aftershocks per unit time $n_{\text{aft}}$, as function of time distance $t$ to a main shock (Omori’s law: $n_{\text{aft}} = k/t^{(1+p)}$).
Fig.9 Histogram of the data with noise contribution.

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