POROSITY OF ORDINARY CHONDRITE — IS IT A GOOD MEASURE OF A CONSOLIDATION STATE OF COMPOSITE MATERIALS OF CHONDRITE? — Kiyoshi Yomogida and Takafumi Matsui, Geophysical Institute, Faculty of Science, University of Tokyo, Bunkyo-ku, Tokyo 113, Japan.

We have measured the porosity of 5 ordinary chondrites (ALHA-77288, -77294, -78251, -78103 and META-78003) to reveal a nature of their solidification state. Although we do not have any measure suitable for representing a degree of the consolidation state of the composite materials of chondrite, the porosity is considered to be one of the physical quantities which characterize such a state. Because, the secondary effect such as due to impact process was shown to be negligible (1). We chose the fresh sample with few cracks for this measurement.

The intrinsic density, \( \rho_0 \), is measured by using the helium pycnometer (the model 1302 Helium-Air Pycnometer, Shimadzu Seisakusho LTD). The intrinsic density measured by this pycnometer is in good agreement with that of the pulverized sample but gives a relatively high value (about 20%) compared to that measured by the usual pycnometer (liquid is used instead of helium). The bulk (apparent) density, \( \rho_{\text{bulk}} \), is measured by the modified Archmedes method: The sample is wrapped by saran-wrap in order to avoid water to sink into the sample. Then the sample and saran-wrap are wrapped once again by clay. Changing the amount of the clay, we can obtain the linear relation between the weight and the volume of the sample plus saran-wrap plus clay. Extrapolation of this line to no clay limit gives an estimate of the bulk volume of the sample. Using the measured values of \( \rho_0 \) and \( \rho_{\text{bulk}} \), the porosity, \( \phi \), is estimated by the following relation: \( \phi = 1 - \frac{\rho_{\text{bulk}}}{\rho_0} \). The results are listed in Table 1. The porosity of chondrites is much larger than that of plutonic rocks (a few %) but fairly less than that of loose sand or gravel (> 30%). It is about the same as the porosity of sandstone or tuff. Irrespective of no available water, chondrites are solidified to a degree of terrestrial sandstone or tuff.

All the porosity data of chondrites reported to data (2,3,4), including this study, are plotted against their respective petrologic types in Fig. 1. We cannot find from this figure such a clear correlation that the porosity of chondrites varies with the petrologic type. This result may suggest that a sintering degree of the composite materials of chondrites is not controlled by the maximum metamorphic temperature which the materials have experienced, that is, the petrologic type.

In Fig. 2 is shown a theoretical estimate of the time required for the porosity of a mass of powdered olivine to be reduced to 15% from 30%. Sintering process proceeded by the usual creep mechanism assumed in this estimate: Coble creep, \( \dot{\varepsilon}_C = a \frac{\Omega W}{G} \frac{\sigma}{kT W} D_\varepsilon \) and power-law creep, \( \dot{\varepsilon}_P = b \frac{\Omega n}{kT} D_\varepsilon \), where \( \varepsilon \) is the strain, \( \Omega \) is the vacancy volume, \( W \) is the boundary width, \( G \) is the
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grain size, $k$ is the Boltzmann constant, $T$ is the absolute temperature, $\sigma$ is the applied stress, $D_w$ is the boundary diffusion constant, $D$ is the lattice diffusion constant ($D \propto \exp(-Q/kT)$, $Q$ is the activation energy.). Data required for this calculation are derived from Schwenn and Goetze (5). Composite materials of chondrites with the petrologic type 6 are expected to be well-consolidated to a degree of 15% under the available conditions within their parent bodies. Because, sizes of materials composing matrix of chondrite are usually submicron.

REFERENCES

Fig. 1. Porosity versus petrologic type.
(●: C, ▲: L, ■: H)
Table 1. Densities and porosity.

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>TYPE</th>
<th>VOLUME (cm$^3$)</th>
<th>WEIGHT (g)</th>
<th>DENSITY (g/cm$^3$)</th>
<th>POROSITY (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALHA-77288</td>
<td>H6</td>
<td>4.88</td>
<td>17.340</td>
<td>3.55</td>
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<tr>
<td>ALHA-77294</td>
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<td>ALHA-78251</td>
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<td>6.06</td>
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<td>ALHA-78103</td>
<td>L6</td>
<td>5.85</td>
<td>18.156</td>
<td>3.11</td>
<td>16.7</td>
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<tr>
<td>META-78003</td>
<td>L6</td>
<td>4.81</td>
<td>14.694</td>
<td>3.06</td>
<td>15.4</td>
</tr>
</tbody>
</table>

Fig. 2. Time required for the porosity of a mass of powdered olivine to be reduced to 15%.