Silicalites of Hydrothermal Origin in the Lower Cambrian Black Rock Series of South China*

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Abstract: A silicalite bed was found in the hanging wall and foot wall of the sulfide-rich bed of the Lower Cambrian black rock series in South China. Its origin was not described before. On the oxide (SiO₂-Al₂O₃, SiO₂-MgO, SiO₂-K₂O + Na₂O) diagrams for discriminating silicalites of chemical, biological and volcanic origins (Liu Xiufeng, 1991), most of the data points of silicalites fall within the areas representing silicalites of chemical and volcanic origins. On the Al-Fe-Mn diagram for discriminating silicalites of hydrothermal and biological origins (Yamamoto, 1987), the data points fall within the areas representing silicalites of hydrothermal and hydrothermal-biological origins. On the SiO₂-Fe₂O₃ diagram for discriminating silicalites of hydrothermal and hydrogenous origins (Bonatti, 1975), the data points mostly fall within the hydrothermal area. The ratios of SiO₂/Al₂O₃, SiO₂/(K₂O + Na₂O), SiO₂/MgO, and K₂O/Na₂O in the silicalites stand between those of volcanic sediments and of seafloor hydrothermal sediments. The total amount of rare-earth elements in the silicalites is low; the North American Shale-normalized REE patterns decline leftward with obvious negative Ce anomaly. The trace elements Mo, Zn, As, Sb, Se, U, and Ba are higher than those in non-hydrothermal sediments and U/Th ≥ 1. The present authors think that the silicalites are derived from seafloor hot brines which had attracted elements from igneous rocks.

Key words: silicalite; hot brine; black rock series; Lower Cambrian series; South China

Introduction

The existence of silicalite throughout the sulfide-rich bed in the Ni-Mo-PGE-bearing black rock series of the Lower Cambrian in South China was reported as early as in the 1970's (Fan Delian et al., 1973). Recently, in the middle to lower portions of the previously considered phosphorite bed in the Zhangjiajie area in northwestern Hunan Province, the authors found some blackish-grey silicalites. Li Shengrong et al. (1994) also reported their discoveries of silicalites and siliceous dolomite veins in the equivalent stratum. These discoveries provide evidence for the activity of siliceous fluid accompanying Ni-Mo-PGE mineralization.

In the literature, many genetic models concerning the enrichment of Ni, Mo and other metallic elements in the sulfide-rich bed of the black rock series have been proposed. Fan Delian (1983) and Fan Delian et al. (1984) suggested a hot brine + volcanic explosive material + extraterrestrial material model; Coveney and Chen Nansheng (1991) suggested a possibility of seafloor hot spring, terrestrial source material, orogenic exhalative, supergenic mineralization; Coveney et al. (1992a, b) suggested mantle source + diagenetic water or formation water or modern supergenic water possibilities. Recently, Long Hongbo et al. (1994) reported hydrothermal
hyalophane in the black rock series; Morowchick et al. (1994) and Li Shengrong (1994) also put forward a hot-brine model. These models are quite instructive. Except for the study of hyalophane by Long Hongbo (1994) and that of silicalite by Li Shengrong (1994), however, no enough attention has been paid to the genesis of the silicalite.

The petrology, petrochemistry and geochemistry data for the silicalite in this work lend great support to the hypothesis of hot-brine origin.

**Petrology and Petrochemistry**

The silicalite over the sulfide-rich bed (upper silicalite) is black and massive, containing carbonaceous-argillaceous streaks. Fissures parallel and vertical to bedding are well developed, making the rock occur in the form of rhombic blocks. The mineral association revealed by X-ray powder diffraction is microquartz + illite + pyrite. Pyrite grains are scattered in the rock. This bed is 10–20 m thick, but it is not persisting and in some locations it can thin out.

The silicalite below the sulfide-rich bed (lower silicalite) is blackish-grey in color with a yellowish-brown tint on the weathered surface. It exhibits massive texture with rhombic joints. Macroscopically, it is difficult to distinguish from phosphorite. It is composed mainly of microquartz with minor amounts of hydroxylapatite, illite and pyrite. In the Ganzhiping section of the Zhangjiajie area the bed discomformably overlies the dolomite of the Sinian system with a thickness of about 55 cm. No persisting extension is recognized in the region.

**Table 1. Chemical analyses of the silicalite (Wt.%)**

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Group</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>MgO</th>
<th>CaO</th>
<th>Na₂O</th>
<th>K₂O</th>
<th>P₂O₅</th>
<th>LOI</th>
<th>Σ</th>
<th>C-org</th>
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<tr>
<td>1</td>
<td>A</td>
<td>73.47</td>
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<td>3.58</td>
<td>0.62</td>
<td>0.37</td>
<td>0.17</td>
<td>1.29</td>
<td>13.12</td>
<td>96.53</td>
<td>9.00</td>
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<tr>
<td>2</td>
<td>A</td>
<td>63.37</td>
<td>5.50</td>
<td>5.03</td>
<td>1.63</td>
<td>1.99</td>
<td>0.52</td>
<td>2.24</td>
<td>0.13</td>
<td>15.54</td>
<td>95.95</td>
<td>8.32</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
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<td>6.42</td>
<td>9.10</td>
<td>1.53</td>
<td>0.73</td>
<td>0.46</td>
<td>3.04</td>
<td>0.43</td>
<td>20.59</td>
<td>96.79</td>
<td>9.76</td>
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<tr>
<td>4</td>
<td>A</td>
<td>53.94</td>
<td>8.45</td>
<td>7.59</td>
<td>1.43</td>
<td>0.37</td>
<td>1.12</td>
<td>3.47</td>
<td>0.72</td>
<td>20.58</td>
<td>98.17</td>
<td>9.89</td>
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<tr>
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<td>A</td>
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<td>0.74</td>
<td>0.62</td>
<td>0.33</td>
<td>1.97</td>
<td>0.11</td>
<td>9 (24)</td>
<td>91.32</td>
<td>9.89</td>
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<tr>
<td>6</td>
<td>A</td>
<td>70.25</td>
<td>9.52</td>
<td>1.71</td>
<td>1.07</td>
<td>0.42</td>
<td>0.36</td>
<td>3.05</td>
<td>0.20</td>
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<td>0.49</td>
<td>0.42</td>
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<td>0.44</td>
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<tr>
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<td>A</td>
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<td>0.04</td>
<td>2.59</td>
<td>0.06</td>
<td>0.001</td>
<td>0.14</td>
<td>0.09</td>
<td>0.13</td>
<td>1.50</td>
<td>99.08</td>
<td></td>
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</tbody>
</table>

Note: 1–5. Black streakish carbonaceous-argillaceous silicalite; 6–7. black carbonaceous-argillaceous silicalite; 8. black calcareous silicalite; 9–11. black silicalite. 1–4, 7. 8 are after Fan Delian et al. (1973); 5–6, 9. after Chen Nan-sheng et al. (1990); 10–11. this study. The contents of TiO₂, FeO and MnO in samples 10 and 11 are 0.07, 1.23, 1.53 and 0.03, 0.78, 0.01, respectively.

Chemical analyses of the silicalite are presented in Table 1. Serial Nos. 1–9 represent the samples of upper silicalite, and Nos. 10 and 11, lower silicalite. In samples 1–8, the data of group A are from the original analyses. It is seen from the table that most of the upper silicalite samples are enriched in organic carbon and other impurities, and those lower silicalite samples,