Sericite from the Silverton caldera, Colorado: Discussion

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Sericite is a common alteration product found in modern and fossil hydrothermal systems (McDowell and Elders, 1980; Lowell and Guilbert, 1970); it consists of mixed-layer illite/smectite (I/S) and has a high proportion of illite layers (Horton, 1985). Sericite from the Silverton caldera of the San Juan volcanic field in southwestern Colorado has recently been characterized with a variety of analytical techniques (Eberl et al., 1987). Eberl et al. (1987) should be commended for their multidimensional approach; however, we disagree with two critical interpretations made in their study. First, we think that the Silverton samples consist of two separate mineral phases, illite and illite-rich I/S. Second, we think that illitic I/S minerals contain layers with two distinct chemical compositions, layers with a smectite charge and layers with an illite charge. Thus, according to definitions in Zen (1962) and Garrels (1984), illitic I/S should be considered to be two thermodynamic phases, illite and smectite. Both issues are discussed below.

Our first difference in interpretation is that we believe there are two separate mineral phases in the Silverton samples. One phase is essentially pure illite (2M, polytype), and the other is illite-rich I/S (1M polytype). Using X-ray powder-diffraction (XRD) data, Eberl et al. (1987) deconvolved two to three peaks in the 17.8° 2θ region of the 2M, polytype (SG4, Table 1) formed at 322 °C during an event at 13.8 Ma. A more smectite-rich sample consisting only of the 1M polytype (RM35A) formed at 178 °C during an event at 20.3 Ma. Another sample containing both 2M, and 1M polytypes (RM28) yields an intermediate K/Ar age of 17.4 Ma and has intermediate oxygen-isotope values for the I/S, interpreted by Eberl et al. (1987) to be due to the mixture of the two different sericite minerals. Moreover, nine of the sixteen analyzed samples are mixtures of 2M, and 1M polytypes (Table 1 of Eberl et al., 1987). We interpret the deconvolved 10-Å component in the Silverton samples to be due to the 2M, mica phase and the 1M phase as I/S.

1. Mineralogical and isotopic data of Eberl et al. (1987) support the existence of two illitic clay phases and two clay-forming events. An illite-rich sample consisting only of the 2M, polytype (SG4, Table 1) formed at 322 °C during an event at 13.8 Ma. A more smectite-rich sample consisting only of the 1M polytype (RM35A) formed at 178 °C during an event at 20.3 Ma. Another sample containing both 2M, and 1M polytypes (RM28) yields an intermediate K/Ar age of 17.4 Ma and has intermediate oxygen-isotope values for the I/S, interpreted by Eberl et al. (1987) to be due to the mixture of the two different sericite minerals. Moreover, nine of the sixteen analyzed samples are mixtures of 2M, and 1M polytypes (Table 1 of Eberl et al., 1987). We interpret the deconvolved 10-Å component in the Silverton samples to be due to the 2M, mica phase and the 1M phase as I/S.

2. Eberl et al. (1987) correctly stated that if the concept of disarticulated illite particles is valid, then correlations between physical properties and \( P_1 \) (deconvolved XRD) should be better than between the same physical properties and \( P_i \) (conventional XRD). If our suggestion of two phases in the Silverton samples is correct, then physical properties should correlate better with \( P_1 \) (conventional XRD). For the Silverton samples, physical properties correlate somewhat better with conventional XRD data than deconvolved XRD data. Correlations between \( P_1 \) (decon-
Table 1. Isotopic temperature, K-Ar age, polytype, and mineral data for sericite samples from the Silverton caldera

<table>
<thead>
<tr>
<th>Sample</th>
<th>Isotopic temperature (°C)</th>
<th>K-Ar age (Ma)</th>
<th>Polytype</th>
<th>$P_t$ (conventional) (% illite in I/S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RM35A</td>
<td>178</td>
<td>20.3</td>
<td>$1M + R^*$</td>
<td>91.0</td>
</tr>
<tr>
<td>SG4</td>
<td>322</td>
<td>13.8</td>
<td>$2M_1$</td>
<td>97.2</td>
</tr>
<tr>
<td>RM28</td>
<td>62</td>
<td>17.4</td>
<td>$1M \Rightarrow 2M_1 + R^*$</td>
<td>96.7</td>
</tr>
</tbody>
</table>

Note: From Tables 1, 3, 9, and 11 of Eberl et al., 1987.

$^*$ $R = \text{random rotations of 60° and 120°}$

Diffracted intensities from these thin particles should be present in XRD patterns of all I/S minerals. Other XRD studies of pure I/S minerals, such as those of bentonite beds, do not show the presence of discrete 10-Å components (Reynolds and Hower, 1970; Hoffman and Hower, 1979; Altaner et al., 1984).

6. Finally, a possible explanation for the discrepancy between XRD and TEM estimates of $P_t$ is that the top and bottom tetrahedral sheets of each I/S crystallite are smectitic. The mineral composition (illite vs. smectite) of these sheets cannot be analyzed by using the XRD modeling technique. If the top and bottom tetrahedral sheets are smectitic, the additional smectite decreases the illite content estimated by XRD. This interpretation has recently been used to explain a discrepancy similar to that observed by Eberl et al. (1987) in which XRD estimates of illite content were significantly higher than those made using nuclear magnetic resonance (NMR) spectroscopy (Altaner et al., 1988).

Our second difference in interpretation is that we think illitic I/S minerals contain two types of layers with distinctive chemical compositions and, therefore, should be considered to be two thermodynamic phases, illite and smectite. We use terminology established by Sen (1962) and Garrels (1984), who define two-phase I/S as containing both illite and smectite compositions and one-phase I/S as a single composition for a given mineral. Eberl et al. (1987) and several previous investigators (Nadeau et al., 1984a, 1984b; Wilson and Nadeau, 1985; Nadeau and Bain, 1986; Inoue et al., 1987) have suggested that illitic I/S should be considered as one homogeneous phase, illite. This question is critical to thermodynamic studies of I/S minerals (Zen, 1962; Aagaard and Helgeson, 1983; Garrels, 1984).

Several lines of evidence support our interpretation that illitic I/S contains two chemically distinct types of layers and should be considered two phases.

1. NMR spectroscopy with inversion/recovery techniques permits direct analysis of the tetrahedral composition of expandable and dehydrated interlayer regions in I/S minerals. A recent NMR study of illitic I/S (Altaner et al., 1988) shows that expandable interlayers contain low-charge tetrahedral sites (layer charge $= -0.34$) and that dehydrated interlayers contain high-charge tetrahedral sites (layer charge $= 0.81$).

2. If illitic I/S minerals contain tetrahedral sheets having the same high-charge composition surrounding both hydrated and dehydrated interlayers, as suggested by the one-phase model of constant composition in illitic I/S, then introduction of K should irreversibly dehydrate the expanding interlayers. Introduction of K to a low-charge smectitic interlayer should not cause irreversible dehydration (MacEwan and Wilson, 1980, p. 203). K saturation of the Silverton samples does not irreversibly dehydrate the expandable layers (p. 917 in Eberl et al., 1987).

3. Values of layer charge for bulk I/S samples (−0.83 to −0.91, Table 8 of Eberl et al., 1987) are significantly less than values inferred for the dehydrated layers (−1,
Fig. 16 of Eberl et al., 1987). These differences are not predicted by the one-phase model of I/S and are compatible with the two-phase model of illitic I/S.

In summary, we think that data from both the Eberl et al. (1987) study and other studies strongly support our conclusions that two mineral phases are present in the Silverton samples (a discrete illite phase and an I/S phase) and that illitic I/S contains two chemically distinct layer types, illite and smectite. The first question could be further addressed by the nature of the size distribution of fundamental particles measured by TEM. Observation by TEM of a continuum of particle sizes would support Eberl et al.’s hypothesis, whereas observation of distinct populations of particles would support our hypothesis. Regarding the second question, further work needs to be done to determine if the chemically distinct layer types in I/S actually behave as two thermodynamic phases. Garrels (1984) presented compositions of natural waters that support the two-phase model. In addition, long-term phase equilibria experiments on illitic I/S by Rosenberg et al. (1985) support the two-phase model of I/S.

REFERENCES CITED


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