Structure of mixed-layer corrensite-chlorite revealed by high-resolution transmission electron microscopy (HRTEM)

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Abstract

Mixed-layer corrensite-chlorite in a glauconitic sandy-clayey rock has been investigated and the three-dimensional stacking structure of corrensite was determined for the first time using high-resolution transmission electron microscopy (HRTEM). We are also able to identify the corrensite-chlorite transition mechanism. The crystals consist of corrensite and chlorite packets excluding successive smectite layers, consistent with the result of XRD analysis previously reported for the same specimen. One-dimensional HRTEM imaging of corrensite with dark contrast corresponding to the cation sheets indicated two types of the smectite-like interlayers in corrensite, probably containing one atomic plane and without any distinct material, which results in the corrensite basal heights of ca. 26.5 and 24.4 Å, respectively, in TEM. Two-dimensional HRTEM imaging revealed that the polytypic stacking sequence in the chlorite-like layer [the two 2:1 layers and the brucite-like sheet (B-sheet) between them] in the corrensite unit is always IIbb type. The intralayer displacements of the two 2:1 layers in the unit are well ordered to show a “two-layer” character, which can be regarded as combination of two different one-layer chlorite polytypes belonging to IIbb. These regulated features of corrensite structure indicate that corrensite precipitated directly from solution probably in an environment with a high water/rock ratio, without inheriting smectite structures, during the smectite-to-chlorite transition. The number of the successive B-sheets in the corrensite-chlorite interstratification is always odd. Along with frequent observation of the transition from the smectite-like interlayer to the B-sheet and similarity of polytypic stacking sequence between corrensite and chlorite, this result strongly supports the transformation from corrensite to chlorite, by replacing the smectite-like interlayer with the B-sheet.

Keywords: Corrensite, chlorite, mixed-layer minerals, polytypic stacking sequence, transformation, HRTEM

Introduction

Corrensite is a trioctahedral 2:1 phyllosilicate with 1:1 ordered interstratifications of chlorite and smectite (or vermiculite) layers. The mineral name “corrensite” is usable for specimens with a high “rationality” for 00l reflections in their X-ray diffraction (XRD) patterns beside the low-angle 001 reflection with d ~ 28 Å, otherwise they are usually called mixed-layered or interstratified chlorite-smectite/vermiculite (Bailey 1982; Reynolds 1988). Geological occurrences of corrensite reported to date are diverse but often related to prograde or retrograde transition between smectite (saponite) and chlorite (Reynolds 1988; Beaufort et al. 1997; Drits et al. 2011). Among them, prograde transitions from smectite to chlorite in burial diagenesis, hydrothermal alteration, contact- or regional metamorphism, etc., in rocks with mafic compositions were given the most attention, as the counterpart of dioctahedral smectite to illite transitions.

Two modes were suggested or reported for such prograde smectite-to-chlorite transitions. In one of them the transition proceeds through mixed-layer smectite-chlorite (S-C), in which the content of chlorite layers continuously increases from 0 to 100% following the similar layer stacking sequences observed in illite-smectite subjected to burial diagenesis (Reynolds 1980; Bettison and Schifffman 1988; Chang et al. 1986). The second is stepwise evolution of the transition with gaps restricting possible concentration of the interstratified layer types in S-C structures (Drits and Sakharov 1976; Kossovskaya and Drits 1975; Inoue et al. 1984; Inoue 1987; Drits and Kossovskaya 1990; Inoue and Utada 1991). This stepwise evolution has been well explained by the formation of corrensite with a particular thermodynamical stability field and defined phase relations with smectite, vermiculite, and chlorite (Velde 1977; Reynolds 1988; Shau et al. 1990; Beaufort et al. 1997; Shau and Peacor 1992; Murakami et al. 1999). In this case, the clays with <50% or >50% chlorite layers should be interstratifications of either smectite-corrensite (S-Co) or corrensite-chlorite (Co-C), and a random S-C interstratification does not exist. It was suggested that the selection between the two different modes is related to water/rock ratios in the microenvironments where the transition proceeds (Shau and Peacor 1992; Bettison-Varga and Mackinnon 1997). However, it seems that important details of the transition, and its structural