New insights into the nature of glauconite

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ABSTRACT

Glauconite must be assessed as mica-rich mica-smectite R3 interstratified mineral, with the pure end-member mica also having intrinsic K-deficient chemical characteristics (K⁺ ∼ 0.8 apfu). This assertion is in accordance with our X-ray diffraction (XRD) and high-resolution transmission electron microscopy (HRTEM) studies and chemical analyses by electron probe microanalysis (EPMA) of mature glauconites in Cenozoic Antarctic sediments that indicate that: (1) It consists of a glauconite-smectite (R3 ordered) mixed-layer silicate, composed mainly of mica-type layers (>90%), but displaying slightly different proportions of Fe(III)-smectite layers (<10%). (2) More mature glauconite grains are characterized by major K⁺ and VIFe²⁺ (mica layers) and minor VIFe³⁺ (smectite layers) content in the interstratified glauconite-smectite. (3) Potassium is stabilized at the interlayer site by the octahedrally coordinated Fe²⁺. (4) Microtexture of the glauconite crystals are comparable with those of other micas and illite minerals, with straight, defect-free lattice fringes of ≈10 Å spacings glauconite packets characteristic of mica with minor interstratified poorly crystalline smectite layers. In addition, our new findings give insights into the glauconitization process and at the same time investigate the potassium-deficient character of the dioctahedral mica “glauconite.” These findings show that glauconite crystallizes by a layer-growth mechanism at the expense of a poorly crystalline smectite precursor and that smectite-to-glauconite transformations are accompanied by a gradually higher octahedral charge deficiency (Fe²⁺/Fe³⁺) stabilized by K⁺ uptake into the interlayer sheet.

Keywords: Glaucony, glauconite, interstratified glauconite-smectite, HRTEM, XRD

INTRODUCTION

“Glaucnite” sensu strictu is a dioctahedral, K- and Fe-rich 2:1 interlayer-deficient mica. According to the AIPEA (Association Internationale Pour l’Étude des Argiles; Bailey 1980), the mineral glauconite is defined by: (1) $\text{Al}^{3+}$ (or $\text{Fe}^{3+}$) > 0.2 atoms per formula unit (apfu) based on $\text{O}_8(\text{OH})_2$; (2) $\text{K}^+ > 1.2$ apfu, with $\text{Mg}^{2+}$ > $\text{Fe}^{2+}$ and $\text{Fe}^{3+}$ > $\text{Al}^{3+}$; (3) the basal reflection $d_{001}$ located between 14 Å and 10 Å, $d_{002}$ at 4.53 Å, $d_{003}$ at 3.33 Å, and $d_{004}$ at 1.51 Å; and (4) potassium occupying mostly the interlayer sheet (K⁺ > 0.6 apfu). The IMA (International Mineralogical Association; Rieder et al. 1998) described glauconite as a Fe-rich phyllosilicate (dioctahedral interlayer-deficient mica) mineral with a green color and representative formula: $\text{K}_{0.8} \text{R}_{0.5} \text{R}_3(\text{Al}_{0.2} \text{Si}_{2.7} \text{O}_{10}(\text{OH}))_5$ in which $\text{V}^{3+} + (\text{Fe}^{2+} + \text{Fe}^{3+}) > 0.15$ and $\text{Al}/(\text{V}^{3+} + \text{Fe}^{3+}) < 0.5$. The term “glauconite” (suggested nomenclature in Odin and Fullagar 1988) is used for the minerals of the “glaucony facies” (Odin and Létolle 1980), which cover a complete genetically related mineral series from Fe-rich smectite to Fe-rich illite, i.e., the glauconitic mica, which is the end-member type of the glaucony facies.

Although the precise process and timing of glauconite genesis is still under debate, diverse mechanisms have been involved to interpret the formation of glauconite (e.g., Galliher 1935; Burst 1958; Hower 1961; Ehlmann et al. 1963; Ojakangas and Keller 1964; Harder 1980; Odin and Matter 1981; Odin and Fullagar 1988). Odin and Matter (1981) and Odin and Fullagar (1988) summarized the state of knowledge on the glauconitization process, and proposed to date the widely accepted “precipitation-dissolution-recrystallization theory.” This theory includes a two-stage glauconitization model where mature glauconite formation involves two major phases: (1) the formation of a K-poor, Fe-rich glauconitic smectite [the Fe(III)-rich smectite precursor; Fig. 1], and (2) a gradual enrichment with K⁺ to form a K-rich glauconitic mica [the Fe(III)-smectite-to-glauconite reaction; Fig. 1]. Therefore, the glauconitization process is a low-temperature diagenetic phenomenon that can be classified based on the K₂O wt% (Odin and Matter 1981; Odin and Fullagar 1988) (Fig. 1). The degree of evolution of the glauconitization process depends on the residence time of glaucony grains in confined sub-oxic, partially reduced microenvironments at or near the sediment-water interface, and hence the sedimentation rate is a key factor (e.g., Amorosi 1995, 2012).

The differences between glauconite and other green-clay minerals, such as Fe-illite or celadonite, are very subtle, and hence, the nature of glauconite is still challenging. Odin and Matter (1981) discussed a compositional gap between illitic minerals (Fe₂O₃ < 10%) and glauconitic minerals (Fe₂O₃ > 15%). Later researchers, nevertheless, reported a compositional continuum between these two minerals (e.g., Ireland et al. 1983;