Berthierine and chamosite are iron-rich clay minerals that share similar chemical compositions. Berthierine forms at low temperature (25–45 °C) during early diagenesis and may transfer to chamosite at temperatures of ≥70 °C. Because the formation of berthierine and chamosite requires significant amount of Fe^{2+} supply, their presence in marine sediments is often used as a mineral proxy for ferruginous conditions in porewater. Recent studies reveal that the Precambrian oceans were characterized by pervasive ferruginous water-column conditions that may favor the formation of iron-rich clay minerals like berthierine and chamosite. To evaluate if ferruginous water-column conditions in the Precambrian ocean played a role on iron-rich clay mineral formation, we conducted an integrated petrographic, mineralogical, and geochemical study on the chamosite- and glauconite-bearing strata of the Mesoproterozoic Xiamaling Formation (~1.40–1.35 Ga) in North China. Petrographic, XRD, SEM, and EDS analyses show that the chamosites of the Xiamaling Formation was transferred from glauconite, with berthierine as an intermediate mineral phase during early diagenesis. Geochemical analyses indicate that a complete transformation from glauconite-dominated to chamosite-dominated end-members (samples) requires an addition of a large amount of Fe (16.9 wt%), Mg (2.4 wt%), and a small amount of Al (1.4 wt%), but a simultaneous release of Si (11.8 wt%) and K (6.0 wt%). Considering that the glauconite- and chamosite-bearing strata are devoid of iron-rich detrital minerals (e.g., biotite and iron oxides) and lack evidence of hydrothermal alteration, the required Fe^{2+} for glauconite-berthierine-chamosite transformation was most likely from Fe^{2+}-rich (ferruginous) seawater, which may have promoted glauconite-berthierine transformation at the very early diagenetic stage when Fe^{2+} exchange between porewater and seawater was still available. This interpretation is consistent with the high Fe_{OR}/Fe_{T} (but low Fe_{EP}/Fe_{OR}), Fe/Al, and V/Al ratios from the hosting strata that support ferruginous depositional environments. Because most Precambrian strata have passed the oil window temperature (~50–150 °C), the preservation of berthierine would be rare and chamosite should be the representative iron-rich clay mineral. Thus, the abundance of chamosite in fine-grained, marine siliciclastic sediments may be used as a mineral indicator of ferruginous water-column conditions.

**Keywords:** Glauconite, berthierine, chamosite, seawater redox conditions, Mesoproterozoic, Xiamaling formation

**INTRODUCTION**

Chamosite [(Fe^{2+}, Mg, Al)_{6}(Si_{4–2}Al)_{2}O_{10}(OH)_{8}] is an Fe-rich chlorite with 2:1+1 trioctahedral structures, and its presence in sedimentary rocks is commonly regarded as the result of berthierine transformation at temperature ≥70 °C during diagenesis (Young and Taylor 1989; Velde 1995; Hornibrook and Longstaffe 1996; Kozłowska and Maliszewska 2015). Berthierine [(Fe^{2+}, Mg, Al)_{6}(Si_{4–2}Al)_{2}O_{10}(OH)_{8}], a dark green to brown mineral (Hornibrook and Longstaffe 1996), shares similar chemical composition with chamosite, but has a trioctahedral 1:1 layered silicate structure that has a basal spacing of 0.7 nm (serpentine group) (Bhattacharyya 1983; Rivas-Sanchez et al. 2006). Berthierine is commonly considered to be characteristic of marine deposits (Taylor and Curtis 1995; Ryan and Hillier 2002; Taylor et al. 2002), although it was also reported from brackish-water deposits (Taylor 1990), coal beds (Iijima and Matsumoto 1982; Dai and Chou 2007; Zhao et al. 2016), laterites (Fritz and Toth 1997), and some hydrothermal deposits (Rivas-Sanchez et al. 2006).

Berthierine in marine sediments and sedimentary rocks is commonly thought to be formed through diagenetic recrystallization of glauconite, odinite, kaolinite, and iron oxide-hydroxide, or other similar precursor minerals (Odin et al. 1988; Drits et al. 2001; Rivard et al. 2013; Fu et al. 2015; Kozłowska and Maliszewska 2015; Mu et al. 2015). Formation of berthierine requires warm seawater (Hornibrook and Longstaffe 1996) and reducing diagenetic conditions with limited sulfate reduction (i.e., ferruginous but not euxinic), because the crystallization of berthierine requires the incorporation of reduced iron (Fe^{2+}) (Bhattacharyya 1983; Taylor 1990; Velde 1995; Fritz and Toth 1997; Sheldon and Retallack 2002; Worden and Morad 2003; Rivard et al. 2013). Chamosite, which has a Fe-rich berthierine precursor, would require similar