Diverse mineral assemblages of acidic alteration in the Rio Tinto area (southwest Spain): Implications for Mars

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Abstract

Earth analogs are indispensable to investigate mineral assemblages on Mars because they enable detailed analysis of spectroscopic data from Mars and aid environmental interpretation. Samples from four sites in the Iberian Pyrite Belt (El Villar, Calañas, Quebrantahuesos, and Tharsis) were investigated using mineralogical, chemical, and spectroscopic techniques, with a focus on clay minerals and alteration environments. They represent Earth analogs of areas on Mars that underwent acidic alteration. X-ray diffraction and transmittance mid-infrared data indicate that the rocks were subjected to several degrees of acid alteration corresponding to assemblages characterized by the following mixtures: (1) illite, chlorite, interstratified chlorite-vermiculite, kaolinite-smectite, and kaolinite; (2) illite, kaolinite, and alunite; and (3) jarosite and goethite. According to mineral stability data, these three assemblages correspond to pH values 7–5, 5–3, and <3, respectively. The lack of goethite in the illite-kaolinite-alunite assemblage suggests an alteration in reducing conditions. Illite was progressively dissolved by acidic alteration but is sufficiently resilient not to be diagnostic of the intensity of the alteration. Illite and kaolinite were the two most abundant phyllosilicate minerals observed, and the main reaction involving phyllosilicates was the alteration of illite to kaolinite. Mixed-layer phases appeared mainly in the mildest degree of acid alteration, with few exceptions. This suggests a transition from a mechanism dominated by transformation to a mechanism dominated by dissolution-precipitation as the intensity of the acid alteration increases. Our results highlight the sparse kaolinite-alunite occurrences on Mars as worthy of specific investigation. Acid alteration on Mars is expected to be patchy and/or consisting of fine alteration rims. Alunite occurrences on Mars in the absence of goethite may indicate an acid alteration in reducing conditions. Kaolinite produced through acid alteration on Mars is expected to exist mainly as an end-member phase of low crystallinity, which would enhance IR absorption and increase its visibility.

Keywords: Acid alteration, alunite, jarosite, kaolinite, Mars; Earth Analogs for Martian Geological Materials and Processes

Introduction

Aluminum-rich phyllosilicate deposits are relatively abundant on Mars, and some of them include kaolinite (Carter et al. 2013). They typically have the spectral character of kaolinite mixed with aluminum smectites (McKeown et al. 2011), also typically associated with deposits of amorphous silica and oxides/hydroxides. For example, in Mawrth Vallis, a widespread deposit contains spectral evidence for kaolinite, hydrated silica, and, occasionally, montmorillonite (Bishop et al. 2008; McKeown et al. 2009; Noe Dobrea et al. 2010). Other phyllosilicate deposits on Mars including kaolinite are found in Nili Fossae (Ehlmann et al. 2009), the Eridania Basin (Noe Dobrea and Swayze 2010), Sinus Meridiani (Wiseman et al. 2008), and in numerous small outcrops throughout the ancient crust (Wray et al. 2009).

Kaolinite-bearing units are typically observed overlying deposits of Fe/Mg-phyllosilicates, which are both thicker and more abundant globally on Mars than the kaolinite deposits (Carter et al. 2013). Observations suggest that the contact relationship between the two is either unconformable sedimentary contacts or an alteration front of the pedogenic or acidic character (Ehlmann et al. 2009; Michalski et al. 2013).

Age estimates of the aluminous clays, where they occur in large areas that allow for statistically significant crater counts, suggest that they date to the Late Noachian-Early Hesperian period (~3.5–3.7 Ga; BibRING et al. 2006; LOIZEAU et al. 2011). The later dates in this age range are the same as sulfate deposits and correspond to a time of high volcanic activity on Mars (Ehlmann et al. 2011). Sulfate deposits, among which jarosite and alunite have been identified, are considered to indicate a period of acidic alteration. To date, kaolinite has not been found in association with jarosite on Mars, but there is evidence of one intimate association of kaolinite and alunite (Ehlmann et