Interstratification of graphene-like carbon layers within black talc from Southeastern China: Implications to sedimentary talc formation

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ABSTRACT

Large deposits of unusual black talc interstratified with dolostone layers of the late Neoproterozoic Dengying Formation were discovered in Guangfeng County, Jiangxi Province, southeastern China. The black talc ore exhibits primarily oolitic structures and consists mainly of talc (30–70 wt%), dolomite, and quartz, with trace amounts of pyrite and apatite. The ooids are composed of nearly pure black talc crystals, most of which consist of ultrafine nano-plates. The black talc contains small amounts of carbon, which causes the black coloring. Raman spectra and X-ray photoelectron spectroscopy (XPS) results indicate structural disorder and chemical impurities within bonds (e.g., sp3 hybridized carbon and C–O bonds) in the carbonaceous material, instead of perfectly structured graphite or graphene. Isolated graphene-like carbon interlayers are present in the talc nano-crystals, as shown by Z-contrast transmission electron microscope (TEM) imaging. Based on previous studies on Mg-silicate precipitation from surface water, we propose a sedimentary formation mechanism for the black talc, in which tetrahedral–octahedral–tetrahedral (T-O-T) layers of Mg-silicates, 1–2 unit-cells thick, co-precipitated with abundant organic matter derived from microorganisms thriving in locally Al-depleted sea water with high concentrations of Mg2+ and SiO2 (aq), in a shallow marine or lagoonal environment. The involvement of organic matter may have facilitated the precipitation of Mg-silicate. Further diagenesis and re-crystallization of the biomass-coated precursor resulted in the formation of graphene-like layers in between neighboring talc nano-crystals with same orientation.

Keywords: Black talc, graphene-like carbon, interstratification structure, sedimentary talc

INTRODUCTION

Clay minerals are common components of altered mafic and ultramafic rocks, sediments, and soils, and they form through processes such as authigenesis, diagenesis, weathering, and hydrothermal alteration (Bergaya and Lagaly 2013). Structurally, clay minerals consist basically of tetrahedral (T) sheets composed of tetrahedra (with Si4+, Al3+, or Fe3+ in the tetrahedral centers) and octahedral (O) sheets composed of octahedra (with Al3+, Mg2+, Fe3+, Fe2+, or other cations in the octahedral centers), which are stacked in different ways with or without interlayer cations (e.g., kaolinite is a 1:1 or T-O type clay mineral with octahedra occupied by Al). Talc is a 2:1 (T-O-T) type clay mineral without interlayer cations that possesses the ideal chemical formula of Mg3Si2O5(OH)2, and which shows very limited substitution of Al3+ or Fe3+ for Mg2+ (Rayner and Brown 1973; Bergaya and Lagaly 2013). Talc is normally white, gray, or pale green in color and has a hardness of 1 on the Mohs hardness scale. The structure of talc is relatively simple and stable, with few variations and, therefore, the mineral exhibits less potential space for modifications than other 2:1 type clay minerals, such as smectite. Nonetheless, the discovery of the large black talc deposits in southern China, with estimated reserves of more than a half billion tons, has drawn attention on account of its huge reserves, unusual color, unique environment of formation, and potential for industrial applications (Fan 1990; Di 1993; Lei et al. 2012; Li et al. 2013).

The black talc deposits in Guangfeng County occur in the late Neoproterozoic Dengying Formation. The black talc ores occur in stratiform, stratoid, or lentoid shapes, and display primary oolitic structures. Some pisolithic or schistose ores, which are present in the cores of folds or near faults, are considered to be the results of dynamically transformed oolitic ores. The oolitic black talc ores consist mainly of black talc ooids that are cemented by micro-crystals of dolomite and quartz, with minor pyrite and apatite (Li et al. 2013).

Early studies on the black talc showed that the unusual black color of the talc at Guangfeng is due to the presence of carbonaceous matter (CM) (Fan 1990; Di 1993; Li et al. 2013), although the exact origin of the color has not been recognized. Our previous study roughly demonstrates the mineralogical characteristics and physicochemical properties of the black talc ores by utilizing multiple mineralogical analysis methods (Li et al. 2013). Nevertheless, the characteristics of the CM and its relationship to the talc crystals remain undefined.