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Cryptomelane formation from nanocrystalline vernadite precursor.

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Vernadite is a nanocristalline and turbostratic phyllomanganate which is ubiquitous in the environment. Its layers, built of MnO\textsubscript{6} octahedra connected through their edge, contain vacancies and (or) isomorphic substitutions, both creating a layer charge deficit that can exceed 1 valence unit per layer octahedron. In addition, vernadite has a high affinity for many trace metals (e.g., Co, Ni and Zn) and frequently contain heterovalent Mn cations which provides this mineral with the capacity to oxidize redox-sensitive trace elements (e.g., As, Se) and organic pollutants. As a result of these exceptional properties, vernadite controls the fate of many trace elements in soils and sediments.

In the environment, vernadite is often found associated with tectomanganates (“tunnel”-like structures) such as cryptomelane, of which it is thought to be the precursor. A sound description of the vernadite-to-cryptomelane transformation, at the atomic scale, is mandatory to be able to understand and thus model the fate of metals initially present in vernadite structure. To contribute to a better understanding of this transformation, we have synthesized vernadite samples having various Mn\textsuperscript{4+}/Mn\textsuperscript{3+} ratios (and thus various layer charge) and we have monitored their transformation, under conditions analogous to those prevailing in soils (dry state and ambient conditions, in the dark) over a time scale of ~10 years [1-2]. Initial samples were characterized using a combination of chemistry, thermogravimetric analyses and powder X-ray diffraction. Samples structural formula ranged between Na\textsuperscript{+}\textsubscript{0.06}(H\textsubscript{2}O)\textsubscript{0.30}Mn\textsuperscript{3+}\textsubscript{0.19}[Mn\textsuperscript{3+}\textsubscript{0.12}Mn\textsuperscript{4+}\textsubscript{0.71}Vac\textsubscript{0.17}O\textsubscript{2}] (where species under brackets form the layer – “Vac” stands for “layer vacancies”, and species on the left are in the interlayer space) and Na\textsuperscript{+}\textsubscript{0.27}(H\textsubscript{2}O)\textsubscript{0.30}Mn\textsuperscript{3+}\textsubscript{0.10}[Mn\textsuperscript{3+}\textsubscript{0.10}Mn\textsuperscript{4+}\textsubscript{0.76}Vac\textsubscript{0.14}O\textsubscript{2}]. Transformation was monitored using high-energy X-ray scattering (with both Bragg-rod and pair distribution function formalisms) and transmission electron microscopy (TEM and STEM). With time, layer Mn\textsuperscript{3+} was found to migrate in the interlayer, probably to reduce strains induced by its Jahn-Teller distorted coordination sphere. When the abundance of interlayer Mn\textsuperscript{3+} reached ~0.3 per layer octahedron, interlayer Mn\textsuperscript{3+} from adjacent layers were found to share their hydration sphere and to form cryptomelane domains (Fig. 1).

Figure 1. STEM observation of cryptomelane formed from vernadite precursor [2]. Bright spots are individual Mn atoms. Overlaid yellow octahedra at the bottom left of the image materialize MnO\textsubscript{6} octahedra.

This presentation will detail our recent contributions to the understanding of this transformation.

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