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The rapid expansion of environmental mineralogy in unconventional ways: Beyond the accepted definition of a mineral, the latest technology, and using nature as our guide

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Abstract

Environmental mineralogy is rapidly expanding in technological directions that allow for the detection, characterization, and understanding of non-crystalline and poorly crystalline phases, crystalline-amorphous mixed phases, and nanosized naturally occurring materials. Specifically, this article provides a perspective view of the broad range of structural complexity/heterogeneity observed in environmental minerals and amorphous materials, as well as our current understanding of how these materials can be best observed, evaluated, and described, and why this is important in the mineralogical sciences. The discussion is broken down into the assessment of short- and medium-range order in amorphous materials, and the nature of nanominerals and mineral nanoparticles, amorphous-nanocrystalline transitional phases, and mesocrystals. These materials do not fit one or more aspects of the most commonly used definitions of a mineral (although some of them are formally recognized as minerals, such as ferrihydrite and schwertmannite), yet they do fit other portions of these current definitions. Nevertheless, because these phases can be exceptionally minute in size, and/or not highly crystalline, and/or generally much less abundant than other mineral components in the system, they may be underappreciated and/or understudied, or, apparently as is often the case, completely missed. Yet they are often highly relevant to, and in many cases dominant in, important aspects of how the (bio)geochemistry of an environmental system operates. Furthermore, although it is important to analytically and experimentally characterize synthetic equivalent phases in the laboratory, often under conditions intended to mimic one or a few aspects of the real environment, we argue that it is imperative to study natural, intact (as much as possible) samples and make field measurements with much greater frequency than is currently practiced.

Keywords: Environmental mineralogy, synchrotron radiation, free electron laser, transmission electron microscopy, nanomineral, mineral nanoparticle, polyphasic nanomineral, prenucleation cluster, non-classical crystallization, mesocrystal