The definiton of "mineral", Part III: The 2000s

In Parts I and II, we tracked the definition of "mineral" through the various editions and incarnations of James Dwight Dana's *Manual of Mineralogy*. In *The 23rd Edition of the Manual of Mineral Science (after James D. Dana)*, Dana's scholarly heirs Cornelis Klein and Barbara Dutrow (the latter the president of the Mineralogical Society of America) wrote in **2008** that

A mineral is a naturally occurring solid with a highly ordered atomic arrangement and a definite (but not necessarily fixed) homogenous chemical composition. Minerals are usually formed by inorganic processes.

Klein and Dutrow then proceeded through a thoughtful two-page discussion of their definition. "Naturally occurring" excludes from mineralogy substances produced only in the laboratories of chemists and instead focuses on those substances that occur somewhere in nature. "Solid," they said, excludes both water and liquid mercury, counter in the latter case to Nickel's (1995) summary of the IMA[1] view on that issue (see Part II). Klein and Dutrow treated having a "highly ordered crystalline arrangement" as synonymous with "crystalline". They said nothing about Nickel's (1995) conditions whereby the IMA might accept an amorphous substance as a mineral. Klein and Dutrow's "definite (but not necessarily fixed) homogeneous chemical composition" allowed the variability of minerals like calcite, where the chemical formula $CaCO_3$ is "definite", but not so "fixed" as to preclude some substitution of Mg^{2+} or other 2+ cations for Ca^{2+}.

Klein and Dutrow devoted half a page to the issue of inorganic processes, conceding that many organsims generate substances that we call minerals (most noticeably the calcite and aragonite produced by numerous marine invertebrates such as molluscs). As they noted, there is now an entire field of study called "biomineralization". They nonetheless retained the second sentence of their definition.

Familiarity with the definitions of "mineral" from the 1800s covered in Part I of this series suggests that continued inclusion of "inorganic" (in its original sense) in the definition is a vestige of a bygone age. In the 1800s, humans saw the world as divisible between "the Animal, the Vegetable, and the Mineral", as James Dwight Dana put it in 1837. However, more recent science has shown that there is a vast world of microbial life in which the divison between "animal" and "vegetable" makes no sense, and we now appreciate that representatives from the animals, plants, and microbes all make or induce the precipitation of mineral substances. By 2008, Hazen et al. (*American Mineralogist* 93: 1693-1720) recognized biological processes as a major impetus for the diversity of Earth's minerals.

One can add to the anachronistic separation of biology from mineralogy the issue of what we mean by "inorganic". Mineralogists looking back to Emmons and Dana may see that word as meaning "un-organ-ized" and thus not pertaining to life. However, today the scientific view of the word "inorganic" is dictated by chemists, for whom it seemingly means compounds with C-H bonds, and for whom "inorganic" can mean compounds with either biological or non-biological origins (see the *SFMG* pages on "organic and inorganic"). Mineralogists have typically worked only with chemically inorganic compounds, but they have included some oxalates (e.g., whewellite) and hydrocarbons (e.g., evenkite and fichtelite) among minerals.

With all this in mind, and in particular with the increasing realization that many geologic materials are influenced by biological processes, it seems best in the twenty-first century to abandon the nineteenth-century division between biological and mineralogical in our definition of a mineral. Following Klein and Dutrow in at least some respects, and trying to keep peace with the IMA (where liquid mercury and clearly organic substances like evenkite ($C_{24}H_{50}$) were still minerals - see Mandarino & Back's *Fleischer's Glossary of Mineral Species 2004*), **a good modern definition** might be

A mineral is a homogeneous naturally occurring substance with a definite but not necessarily fixed chemical composition. Most minerals are solids with an ordered atomic arrangement, and most are inorganic in the chemical sense of that word.

[1] The International Mineralogical Association, and specifically its Committee on New Minerals and Mineral Names.