American Mineralogist, Volume 101, pages 889–906, 2016

Carbon mineral ecology: Predicting the undiscovered minerals of carbon

Robert M. Hazen[1,*], Daniel R. Hummer[1], Grethe Hystad[2], Robert T. Downs[3], and Joshua J. Golden[3]

[1]Geophysical Laboratory, Carnegie Institution, 5251 Broad Branch Road NW, Washington, D.C. 20015, U.S.A.
[2]Department of Mathematics, Computer Science, and Statistics, Purdue University Calumet, Hammond, Indiana 46323, U.S.A.
[3]Department of Geosciences, University of Arizona, 1040 East 4th Street, Tucson, Arizona 85721-0077, U.S.A.

Abstract

Studies in mineral ecology exploit mineralogical databases to document diversity-distribution relationships of minerals—relationships that are integral to characterizing "Earth-like" planets. As carbon is the most crucial element to life on Earth, as well as one of the defining constituents of a planet's near-surface mineralogy, we focus here on the diversity and distribution of carbon-bearing minerals. We applied a Large Number of Rare Events (LNRE) model to the 403 known minerals of carbon, using 82 922 mineral species/locality data tabulated in http://mindat.org (as of 1 January 2015). We find that all carbon-bearing minerals, as well as subsets containing C with O, H, Ca, or Na, conform to LNRE distributions.

Our model predicts that at least 548 C minerals exist on Earth today, indicating that at least 145 carbon-bearing mineral species have yet to be discovered. Furthermore, by analyzing subsets of the most common additional elements in carbon-bearing minerals (i.e., 378 C + O species; 282 C + H species; 133 C + Ca species; and 100 C + Na species), we predict that approximately 129 of these missing carbon minerals contain oxygen, 118 contain hydrogen, 52 contain calcium, and more than 60 contain sodium. The majority of these as yet undescribed minerals are predicted to be hydrous carbonates, many of which may have been overlooked because they are colorless, poorly crystalized, and/or water-soluble.

We tabulate 432 chemical formulas of plausible as yet undiscovered carbon minerals, some of which will be natural examples of known synthetic compounds, including carbides such as calcium carbide (CaC_2), crystalline hydrocarbons such as pyrene ($C_{16}H_{10}$), and numerous oxalates, formates, anhydrous carbonates, and hydrous carbonates. Many other missing carbon minerals will be isomorphs of known carbon minerals, notably of the more than 100 different hydrous carbonate structures. Surveys of mineral localities with the greatest diversity of carbon minerals, coupled with information on varied C mineral occurrences, point to promising locations for the discovery of as yet undescribed minerals.

Keywords: Carbonates, hydrocarbons, oxalates, formates, carbides, mineral ecology, philosophy of mineralogy