Scientists and philosopher team up, propose a new way to categorize minerals

December 21 2020

Credit: Pixabay/CC0 Public Domain

A diamond lasts forever, but that doesn't mean all diamonds have a common history.

Some diamonds were formed billions of years ago in space as the carbon-rich atmospheres of dying stars expanded and cooled. In our own planet's lifetime, high-temperatures and pressures in the mantle produced the diamonds that are familiar to us as gems. 5,000 years ago, a large meteorite that struck a carbon-rich sediment on Earth produced an impact diamond.

Each of these diamonds differs from the others in both composition and genesis, but all are categorized as "diamond" by the authoritative guide to minerals—the International Mineralogical Association's Commission on New Minerals, Nomenclature and Classification.

For many physical scientists, this inconsistency poses no problem. But the IMA system leaves unanswered questions for planetary scientists, geobiologists, paleontologists and others who strive to understand minerals' historical context.

So, Carnegie's Robert Hazen and Shaunna Morrison teamed up with CU Boulder philosophy of science professor Carol Cleland to propose that scientists address this shortcoming with a new "evolutionary system" of mineral classification—one that includes historical data and reflects changes in the diversity and distribution of minerals through more than 4 billion years of Earth's history.

Their work is published by the *Proceedings of the National Academy of Sciences*.

"We came together from the very different fields of philosophy and planetary science to see if there was a rigorous way to bring the dimension of time into discussions about the solid materials that compose Earth," Hazen said.

The IMA classification system for minerals dates to the 19th century when geologist James Dwight Dana outlined a way to categorize minerals on the basis of unique combinations of idealized compositions of major elements and geometrically idealized crystal structure.

"For example, the IMA defines quartz as pure silicon dioxide, but the existence of this idealized version is completely fictional," said Morrison. "Every specimen of quartz contains imperfections—traces of its formation process that makes it unique."

This approach to the categorization system means minerals with distinctly different historical origins are lumped together—as with the example of diamonds—while other minerals that share a common causal history are split apart.

"The IMA system is typical," said lead author Cleland, explaining that most classification systems in the natural sciences, such as the periodic table of the elements, are time independent, categorizing material things "solely on the basis of manifest similarities and differences, regardless of how they were produced or what modifications they have undergone."

For many researchers, a time-independent system is completely appropriate. But this approach doesn't work well for planetary and other historically oriented geosciences, where the emphasis is on understanding the formation and development of planetary bodies.

Differences in a diamond or quartz crystal's formative history are critical, Cleland said, because the conditions under which a sample was formed and the modifications it has undergone "are far more informative than the mere fact that a crystal qualifies as diamond or quartz."

She, Hazen, and Morrison argue that what planetary scientists need is a new system of categorizing minerals that includes historical "natural kinds."

Biology faced an analogous issue before Darwin put forward his theory of evolution. For example, lacking an understanding of how organisms are historically related through evolutionary processes, 17th century scholars debated whether bats are birds. With the advent of Darwin's work in the 19th century, however, biologists classified them separately on evolutionary grounds, because they lack a common ancestor with wings.

Because a universal theory of "mineral evolution" does not exist, creating such a classification system for the geosciences is challenging. Hazen, Morrison, and Cleland's proposed solution is what they call a "bootstrap" approach based on historically revelatory, information-rich chemical, physical, and biological attributes of solid materials. This strategy allows scientists to build a historical system of mineral kinds while remaining agnostic about its underlying theoretical principles.

"Minerals are the most durable, information-rich objects we can study to understand our planet's origin and evolution," Hazen said. "Our new evolutionary approach to classifying minerals complements the existing protocols and offers the opportunity to rigorously document Earth's history."

Morrison concurred, adding: "Rethinking the way we classify minerals offers the opportunity to address big, outstanding scientific mysteries about our planet and our Solar System, through a mineralogical lens. In their imperfections and deviations from the ideal, minerals capture the story of what has happened to them through deep time—they provide a time machine to go back and understand what was happening on our planet and other planets in our solar system millions or billions of years ago."

More information: Carol E. Cleland el al., "Historical natural kinds and mineralogy: Systematizing contingency in the context of necessity," *PNAS* (2020). www.pnas.org/cgi/doi/10.1073/pnas.2015370118

Provided by Carnegie Institution for Science