

Mineral Classification: Archetypes, Species, and Natural Kinds

A Session Proposal for IMA 2022 Meeting

Proposer: Carol Cleland

Cleland@colorado.edu

Description: Scientific disciplines carve the domains of phenomena that they investigate systematically into categories. These categories play important roles in scientific reasoning (prediction and explanation) about the domain of phenomena concerned. For example, the International Mineralogical Association's Commission on New Minerals, Nomenclature and Classification (IMA-CNMNC) recognizes more than 5700 different mineral species based on unique combinations of major element chemistry and crystal structure. Knowing that a mineral is diamond, for example, allows one to predict that it is extremely hard and an exceptionally good thermal conductor. Classification systems that are highly successful and fruitful for purposes of scientific reasoning are viewed as "carving nature at its joints"; their categories are dubbed "natural" (as opposed to, artificial or human) kinds by philosophers because they are judged to reflect real divisions in nature.

This proposed IMA 2022 session explores the scientific utility and fruitfulness of mineral classification systems by focusing on both the IMA-CNMNC standard mineral classification protocols and two recently proposed complementary approaches to mineral classification. On the one hand, Hawthorne et al. (2021) introduce the concept of a "mineral archetype," which defines a mineral as a pure form characterized by four intrinsic properties: "its name, its end-member formula and Z , its space group, and the bond topology of the end-member structure" [1]. Like the IMA system, the archetype concept of minerals classifies solid materials in terms of timeless (chemical and structural) properties, independently of their etiology (origin and evolution). In contrast with both the IMA system and the mineral archetype system, Hazen and colleagues have attempted to identify "historically" (in the sense of their origin and evolution) informative mineral categories [2,3]. Minerals are characterized by suites of diagnostic characteristics, including trace and minor elements, isotopes, fluid and solid inclusions, morphologies, optical properties, and other information-rich physical and chemical attributes, all coupled to that mineral's formation in the context of planetary evolution.

The mineral pyrite provides a useful example of the contrasts among these classification approaches. Archetype *pyrite* is pure FeS_2 with the ideal cubic ($Pa\bar{3}$; $Z = 4$) pyrite structure. The IMA-approved mineral species is similar to the archetype, but it embraces a range of major natural specimens that typically deviate from the idealized archetype. For example, the compositions of natural pyrite often include partial substitution of As for S and Co/Ni for Fe. By contrast, Hazen and colleagues suggest that "pyrite" encompasses 20 or more distinct natural kinds, each with a diagnostic combination of trace and minor elements, morphologies, paragenetic contexts (both abiotic and biotic), and other attributes associated with different formational histories [4,5].

This session will consider varied approaches to mineral classification, with a focus on several key questions:

- (1) To what extent are these and other approaches to classification mutually consistent? To what extent are they contradictory?

- (2) Are there phases that are currently IMA-approved species that do not have analogous archetype or natural kind equivalents? Are there natural solids that should be classified but are not currently recognized by the IMA-CNMNC? Is that a problem?
- (3) Is it valid to apply the concept of natural kinds to minerals [3,6]?
- (4) To what extent do these classification systems play central roles in the articulation and development of scientifically fruitful theories?

References:

- [1] Hawthorne et al. (2021) *Min. Mag.*, **85**, 125-131.
- [2] Hazen (2019) *Am. Min.*, **104**, 810-816.
- [3] Cleland et al. (2020) *Proc. Natl. Acad. Sci.*, **118**, e2015370118.
- [4] Gregory et al. (2019) *Econ. Geol.*, **114**, 771-786.
- [5] Hazen & Morrison (2021) On the paragenetic modes of minerals. *Am. Min.*, 106, *in press*.
- [6] Santana (2019) *Foundations of Chem.*, **21**, 333-343.

Session Format: The proposed session will begin with a discussion of the history of mineralogical classification systems, leading to the IMA-CNMNC system in place today, alternative approaches, and the roles of natural kinds in scientific reasoning. Five talks will be followed by a discussion of the session questions. All talks will be 15 minutes long, including 3 minutes for questions. The session will end with a 40-minute panel discussion among members of the audience and the speakers.

Tentative lineup:

Chair and Moderator:

Sergey Krivovichev (committed)

Proposed Speakers:

1. Mike Rumsey (committed but may need to be remote), History of the Development of mineralogical classification systems and nomenclature.
2. Carol Cleland (committed), Natural kind taxonomies: their nature, varieties, and roles in scientific reasoning.
3. Frank Hawthorne (thinking about it), Defining mineral species in terms of archetypes; we will find a replacement if necessary).
4. Robert Hazen (committed), An evolutionary system of mineral taxonomy based on mineral natural kinds.
5. Carlos Santana (committed), Mineralogy doesn't need a natural kind-based taxonomy of mineral kinds.