# Evolutionary system of mineralogy: Data-driven mineral classification

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Minerals preserve a vivid narrative of the physical, chemical, and biological histories of their origins and subsequent alteration, and thus provide our clearest window to the evolution of Earth and other worlds through billions of years of Cosmic history. Mineral properties, including trace and minor elements, ratios of isotopes, structural defects, external morphology, and other idiosyncratic attributes, represent information that points to specific paragenetic modes and subsequent environmental histories—information essential to understanding the co-evolving geosphere and biosphere. However, the present system of mineral classification, based on end-member chemical compositions and idealized crystal structures, is ill-suited to characterize the stages of planetary evolution.

A complementary evolutionary system of mineralogy is based on "natural-kind clustering" with multivariate correlations among numerous attributes for a wide range of condensed planetary materials. This system has the potential to amplify, though not supersede, the present classification system [1,2]. Some IMA "species" are split according to varied paragenetic modes (e.g., diamond, pyrite), some are lumped (e.g., amphibole, tourmaline groups), and non-crystalline condensed phases are included. Implementation of such a system will depend on the establishment of comprehensive and reliable open-access data resources on minerals and their attributes, coupled with thoughtful application of the diverse methods of cluster analysis.

Each stage of planetary evolution introduces new modes of mineral formation—new regimes of temperature, pressure, and composition that lead to the emergence of new species and to novel variations of species already present. The guiding principal of the evolutionary system of mineralogy is that each mineral sample is a rich storehouse of information. Each specimen possesses myriad physical and chemical attributes—data that point to its origin and subsequent alteration pathways through space and time. We thus embrace the inherent "messiness" of nature—the complexities that reveal the evolution of stars, planets, minerals, and life.

[1] Hazen (2019) *Am. Min.* **104**, *in press*. [2] Santana (2019) *Front. Chem.*, https//doi.org/10.1007/s10698-019-09338-3.