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An evolutionary system of mineralogy, Part VIII: The evolution of metamorphic minerals

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Abstract

Part VIII of the evolutionary system of mineralogy focuses on 1220 metamorphic mineral species, which correspond to 755 root mineral kinds associated with varied metamorphic rock types, most of which likely formed prior to the Phanerozoic Eon. A catalog of the mineral modes of 2785 metamorphic rocks from around the world reveals that 94 mineral kinds often occur as major phases. Of these common metamorphic minerals, 66 are silicates, 14 are oxides or hydroxides, 8 are carbonates or phosphates, 4 are sulfides, and 2 are polymorphs of carbon. Collectively, these 94 minerals incorporate 23 different essential chemical elements.

Patterns of coexistence among these 94 minerals, as revealed by network analysis and Louvain community detection, point to six major communities of metamorphic phases, three of which correspond to different pressure-temperature (*P*-*T*) regimes of metamorphosed siliceous igneous and sedimentary rocks, while three represent thermally altered carbonate and calc-silicate lithologies.

Metamorphic rocks display characteristics of an evolving chemical system, with significant increases in mineral diversity and chemical complexity through billions of years of Earth history. Earth's first metamorphic minerals formed in thermally altered xenoliths and contact zones (hornfels and sanidinite facies) associated with early Hadean igneous activity (>4.5 Ga). The appearance of new Hadean lithologies, including clay-rich sediments, arkosic sandstones, and carbonates, provided additional protoliths for thermal metamorphism prior to 4.0 Ga. Orogenesis and erosion exposed extensive regional metamorphic terrains, with lithologies corresponding to the Barrovian sequence of index mineral metamorphic zones appearing by the Mesoarchean Era (>2.8 Ga). More recently, rapid subduction and rebound of crustal wedges, coupled with a shallowing geothermal gradient, has produced distinctive suites of blueschist, eclogite, and ultrahigh-pressure metamorphic suites (<1.0 Ga). The evolution of metamorphic minerals thus exemplifies changes in physical and chemical processes in Earth's crust and upper mantle.

Keywords: Metamorphism, Barrovian sequence, philosophy of mineralogy, classification, mineral evolution, Hadean Eon, Archean Eon, network analysis, community structure analysis