Mercury (Hg) mineral evolution: A mineralogical record of supercontinent assembly, changing ocean geochemistry, and the emerging terrestrial biosphere

ROBERT M. HAZEN,†,‡, JOSHUA GOLDEN,† ROBERT T. DOWNS,† GRETHE HYSTAD,§ EDWARD S. GREW,¶ DAVID AZZOLINI,¶ and DIMITRI A. SVERJENSKY†,§

†Geophysical Laboratory, Carnegie Institution, 5251 Broad Branch Road NW, Washington, D.C. 20015, U.S.A.
‡Department of Geosciences, University of Arizona, 1040 East 4th Street, Tucson, Arizona 85721-0077, U.S.A.
§Department of Mathematics, University of Arizona, Tucson, Arizona 85721-0089, U.S.A.
¶Department of Earth Sciences, University of Maine, Orono, Maine 04469, U.S.A.
†Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, Maryland 21218, U.S.A.

ABSTRACT

Analyses of the temporal and geographic distribution of earliest recorded appearances of the 88 IMA-approved mercury minerals plus two potentially valid species exemplify principles of mineral evolution. Metacinnabar (HgS) and native Hg are the only two species reported from meteorites, specifically, the primitive H3 Tieschitz chondrite with an age of 4550 Ma. Since the first terrestrial appearance of cinnabar more than 3 billion years ago, mercury minerals have been present continuously at or near Earth’s surface.

Mercury mineral evolution is characterized by episodic deposition and diversification, perhaps associated with the supercontinent cycle. We observe statistically significant increases in the number of reported Hg mineral localities and new Hg species at ~2.8–2.6, ~1.9–1.8, and ~0.43–0.25 Ga—intervals that correlate with episodes of presumed supercontinent assembly and associated orogenies of Kenorland (Superia), Columbia (Nuna), and Pangea, respectively. In contrast, few Hg deposits or new species of mercury minerals are reported from the intervals of supercontinent stability and breakup at ~2.5–1.9, ~1.8–1.2, and 1.1–0.8 Ga. The interval of Pangean supercontinent stability and breakup (~250–65 Ma) is also marked by a significant decline in reported mercury mineralization; however, rocks of the last 65 million years, during which Pangea has continued to diverge, is characterized by numerous ephemeral near-surface Hg deposits.

The period ~1.2–1.0 Ga, during the assembly of the Rodinian supercontinent, is an exception because of the absence of new Hg minerals or deposits from this period. Episodes of Hg mineralization reflect metamorphism of Hg-enriched marine black shales at zones of continental convergence. We suggest that Hg was effectively sequestered as insoluble nanoparticles of cinnabar (HgS) or tiemannite (HgSe) during the period of the sulfidic “intermediate ocean” (~1.85–0.85 Ga); consequently, few Hg deposits formed during the aggregation of Rodinia, whereas several deposits date from 800–600 Ma, a period that overlaps with the rifting and breakup of Rodinia.

Nearly all Hg mineral species (87 of 90 known), as well as all major economic Hg deposits, are known to occur in formations ≤400 million years old. This relatively recent diversification arises, in part, from the ephemeral nature of many Hg minerals. In addition, mercury mineralization is strongly enhanced by interactions with organic matter, so the relatively recent pulse of new Hg minerals may reflect the rise of a terrestrial biosphere at ~400 Ma.

Keywords: Ocean geochemistry, cinnabar, tiemannite, biosphere, supercontinent cycle, mercury (Hg) isotopes

INTRODUCTION

The evolution of the mineral kingdom is a topic that has engaged Earth scientists for more than two centuries, since debates raged between supporters of steady-state uniformitarianism and episodic catastrophism (Rudwick 1972; Greene 1982). Radiometric measurements of the extreme antiquity of some mineral specimens (Strutt 1910), coupled with recognition of the deterministic evolutionary sequence of igneous rocks and their minerals (Bowen 1915, 1928), placed the chronology of Earth’s changing near-surface mineralogy on a more quantitative footing. Subsequent elaborations of these concepts point to the central importance of time as a dimension in mineralogical research (Ronov et al. 1969; Zhabin 1981; Nash et al. 1981; Wenk and Bulakh 2004; Krivovichev 2010; Tkachev 2011).

“Mineral evolution,” the study of Earth’s changing near-surface mineralogy through time, is an approach to Earth materials research that seeks to frame mineralogy in a historical context by focusing on a variety of Earth’s near-surface characteristics, including mineral diversity; mineral associations; the relative abundances of mineral species; compositional ranges of their major, minor, and trace elements and isotopes; and grain sizes

* E-mail: rhanen@ciw.edu