Needs and opportunities in mineral evolution research

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ABSTRACT

Progress in understanding mineral evolution, Earth’s changing near-surface mineralogy through time, depends on the availability of detailed information on mineral localities of known ages and geologic settings. A comprehensive database including this information, employing the mindat.org web site as a platform, is now being implemented. This resource will incorporate software to correlate a range of mineral occurrences and properties vs. time, and it will thus facilitate studies of the changing diversity, distribution, associations, and characteristics of individual minerals as well as mineral groups. The Mineral Evolution Database thus holds the prospect of revealing mineralogical records of important geophysical, geochemical, and biological events in Earth history.

Keywords: Philosophy of mineralogy, database, isotope geochemistry, origins of life, mineral data

INTRODUCTION

“Mineral evolution” seeks to frame mineralogy in an historical context by focusing on changes through time of various 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 and morphologies (Hazen et al. 2008; Hazen and Ferry 2010). This approach to mineralogy, which underscores similarities and differences in the evolution of terrestrial planets and moons and points to the co-evolution of the geosphere and biosphere, has received significant discussion (e.g., Rosing 2008; Perkins 2008; Vasconcelos and McKenzie 2009; Johnson 2009). However, the framework for a program of research that aims to achieve a systematic survey of Earth’s mineralogical history is thus far lacking. Here, our three objectives are: (1) to review recent examples of diverse efforts in mineral evolution research; (2) to describe the development of a comprehensive Mineral Evolution Database that ties ages and geologic settings to minerals from numerous localities; and (3) to pose a range of unanswered questions related to Earth’s changing near-surface mineralogy that could be addressed by employing such a database.

EXAMPLES OF MINERAL EVOLUTION RESEARCH

Many authors have already presented data on the temporal variation of individual or collective mineral properties without invoking the term “mineral evolution.” Although motivated by different questions, and implemented using varied types of geochemical and mineralogical data, these studies exemplify both the promises and challenges of mineral evolution research.

Isotope compositions

Geochemists have long recognized the importance of changing isotope ratios through time as records of major geophysical, geochemical, and biological events in Earth history. In the case of sulfur isotopes, changes in the range of $\delta^{34}S$ values with time have been linked to the evolution in the concentration of sulfate in the oceans and changes in the relative amounts of sedimentary pyrite formation in the marine environment and weathering on the continents (Monster et al. 1979; Canfield et al. 2000; Hächter et al. 2002; Berner 2006; Schroeder et al. 2008). Temporal changes in the range of $\Delta^{33}S$ ($=\delta^{33}S – 0.515\delta^{34}S$) have been tied to changes in atmospheric composition, specifically to the time when the accumulation of oxygen in the Paleoproterozoic atmosphere eventually led to conditions in which the production and preservation of mass-independent fractionations (MIF) of sulfur isotopes by photochemical reactions were inhibited (Farquhar...