Chromium mineral ecology

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ABSTRACT

Minerals containing chromium (Cr) as an essential element display systematic trends in their diversity and distribution. We employ data for 72 approved terrestrial Cr mineral species (http://rruff.info/ima, as of 15 April 2016), representing 4089 mineral species-locality pairs (http://mindat.org and other sources, as of 15 April 2016). We find that Cr-containing mineral species, for which 30% are known at only one locality and more than half are known from three or fewer localities, conform to a Large Number of Rare Events (LNRE) distribution. Our model predicts that at least 100 ± 13 (1σ) Cr minerals exist in Earth’s crust today, indicating that 28 ± 13 (1σ) species have yet to be discovered—a minimum estimate because our model assumes that new minerals will be found only using the same methods as in the past. Numerous additional Cr minerals likely await discovery using micro-analytical methods.

We propose 117 compounds as plausible Cr minerals to be discovered, including 7 oxides, 11 sulfides, 7 silicates, 7 sulfates, and 82 chromates. Depending on their compositions and crystal structures, new Cr minerals are likely to be discovered in various environments, including meteorites, basalt, evaporites, and oxidized Pb ore deposits.

Keywords: Chromium, mineral ecology, new minerals, statistical mineralogy

INTRODUCTION

Newly discovered mineral species have been an important focus of descriptive mineralogy. As mineral discovery becomes more difficult, it is useful to predict the number, nature, and localities of undiscovered minerals on Earth. Mineral ecology, which couples large mineralogical data resources (Hazen et al. 2015a, 2015b; Hystad et al. 2015a, 2015b) with statistical methods developed from ecology and lexicology (Baayen 2001; Evert and Baroni 2008), is now leading to predictions of Earth’s “missing” minerals (Hazen et al. 2016; Grew et al. 2016).

This study is focused on the ecology of Cr mineral species. Cr is a redox-sensitive first-row transition element that is of special interest because of its strategic importance (National Research Council 2008; Orcutt 2011) and environmental impact (Katz and Salem 1994; Pellerin and Booker 2000), as well as its critical roles in biology (Mertz 1969). Cr is a very common minor element in the crust, averaging ~138 ppm crustal abundance (Rudnick and Gao 2005), with upper crustal abundance of ~97 ppm (Rudnick and Gao 2005) and lower crustal abundance of ~215 ppm (Rudnick and Fountain 1995). Cr concentrations vary significantly among different rock types, ranging from ~20 ppm in granitic rocks, ~200 ppm in basaltic rocks, and to ~2000 ppm in ultramafic rocks (Henderson 1982; Allard 1995). While Cr is a common trace element in many rock-forming minerals (e.g., Duke 1976), it is also found as an essential element in 82 minerals (http://rruff.info/ima as of 1 March 2016; Lafuente et al. 2015). The limited number of species makes it possible to complete a comprehensive survey of Cr mineral species and their localities. A subsequent contribution will focus on the temporal distribution and tectonic settings of Cr minerals.

THE MINERALS OF CHROMIUM

Of all 82 Cr minerals currently discovered, 72 of them occur in terrestrial rocks (Table 1a), 15 species were discovered in meteorites (Table 2a), and 5 species were reported in both. Terrestrial Cr minerals are composed of 39 Cr6+ and 26 Cr3+ species, in addition to 3 Cr metals/Alloys and 4 minerals with undetermined Cr charges. Cr3+ minerals are mostly abiotic. Cr6+ occupies the octahedral sites of many minerals (e.g., spinel, garnet, tourmaline) by substituting for Fe3+, Mg2+, Ca2+, Al3+, or Ti4+. Therefore, the Cr6+ minerals exhibit various crystal structures, and occur in a broad range of environments, from igneous rocks (typical minerals: chromite, magnesiocrinite), metamorphic rocks (typical minerals: uvarovite, eskolaite), to hydrothermal veins (typical mineral: uvarovite). Cr3+ minerals are mostly biotic sensu lato, i.e., their occurrences are due to oxidation of Earth’s surface, which is in turn related to bioactivity. Cr3+ minerals can be found in evaporites (typical mineral: lopezite) and oxidized lead deposits (typical mineral: crocoite). The 7 terrestrial Cr minerals containing neither Cr3+ nor Cr6+ are 3 metals/Alloys, 2 carbides, and 2 sulfides, occurring in igneous or metamorphic rocks or in weathered meteorites. Cr minerals found in both meteorites and terrestrial rocks include...