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Gamma-enhancement of reflected light images as a routine method for assessment of compositional heterogeneity in common low-reflectance Fe-bearing minerals

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Abstract

The incorporation of impurity elements into minerals impacts their physical properties (e.g., reflectance, hardness, and electrical conductivity), but the quantitative relationships between these features and compositional variation remain inadequately constrained. Prior work has shown that gamma-enhancement of reflected light images represents a simple yet powerful tool to assess the compositional heterogeneity of single pyrite crystals, as it can enhance subtle differences in reflectance between distinct domains with different minor element concentrations. This study extends the gamma correction method to several other common Fe-bearing minerals, magnetite, garnet, wolframite, and tetrahedrite-tennantite, which all have far lower reflectance than pyrite. Gamma-enhanced optical images reveal clear variations in reflectance that are either systematic with increased minor element concentration, as the change in gray value on backscatter electron (BSE) images (in the case of magnetite, garnet, and tetrahedrite-tennantite) or contrasting (as in pyrite), yielding a convincing linkage between reflectance variation and compositional heterogeneity. Reflectance variation is an expression of the distribution of the average effective number of free electrons on the mineral surface that can re-emit light when excited by visible light. Gamma-enhanced images can reveal compositional heterogeneity in minerals such as wolframite where small atomic mass differences between substituting elements (Mn and Fe, in the case of wolframite) are virtually impossible to observe as a variation of gray values on BSE images. Results also demonstrate that Fe-rich domains in these minerals can be expected to have higher reflectance than Fe-poor domains whenever Fe is a major constituent. The greater reflectance is attributed to Fe ions having a greater effective number of free electrons than many other elements (e.g., Co, Ni, Si, Ca, Al, Mg, Mn, and As). This research highlights the utility of gamma correction as an inexpensive tool for routine evaluation of compositional heterogeneity in common Fe-bearing minerals, potentially obviating the necessity of a microbeam platform to correlate textures and composition.

Keywords: Gamma correction, compositional homogeneity, reflectance, magnetite, garnet, wolframite, tetrahedrite-tennantite