Trace and minor elements in galena: A reconnaissance LA-ICP-MS study

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ABSTRACT

Minor and trace elements can substitute into the crystal lattice of galena at various concentrations. In situ LA-ICP-MS analysis and trace element mapping of a range of galena specimens from different deposit types are used to obtain minor/trace element data, aimed at achieving insight into factors that control minor/trace element partitioning. The previously recognized coupled substitution \(\text{Ag}^+ + (\text{Bi}, \text{Sb})^{3+} \leftrightarrow 2\text{Pb}^{2+}\) is confirmed. However, the poorer correlation between Ag and (Bi+Sn) when the latter elements are present at high concentrations (\(\sim\)2000 ppm), suggests that site vacancies may come into play: \([2(Bi,Sb)^{3+} + \square \leftrightarrow 3\text{Pb}^{2+}]\). Galena is the primary host of Tl in all mapped mineral assemblages. Along with Cu, Tl is likely incorporated into galena via the coupled substitution: \((\text{Ag}, \text{Cu}, \text{Tl})^+ + (\text{Bi}, \text{Sb})^{3+} \leftrightarrow 2\text{Pb}^{2+}\). Tin can reach significant concentrations in galena (\(>\)500 ppm). Cd and minor Hg can be incorporated into galena; the simple isovalent substitution \((\text{Cd}, \text{Hg})^{2+} \leftrightarrow \text{Pb}^{2+}\) is inferred. This paper shows for the first time, oscillatory and sector compositional zoning of minor/trace elements (Ag, Sb, Bi, Se, Te, Tl) in galena from two epithermal ores. Zoning is attributed to slow crystal growth into open spaces within the vein at relatively low temperatures.

The present data show that galena can host a broader range of elements than previously recognized. For many measured elements, the data sets generated display predictable partitioning patterns between galena and coexisting minerals, which may be dependent on temperature or other factors. Trace element concentrations in galena and their grain-scale distributions may also have potential in the identification of spatial and/or temporal trends within individual metallogenic belts, and as markers of ore formation processes in deposits that have undergone superimposed metamorphism and deformation. Galena trace element geochemistry may also display potential to be used as a trace/minor element vector approach in mineral exploration, notably for recognition of proximal-to-distal trends within a given ore system.

Keywords: Galena, trace elements, laser ablation-inductively coupled plasma-mass spectrometry, compositional zoning, substitution mechanisms

INTRODUCTION

Galena is the most abundant and important lead ore mineral. Despite its simple chemical formula (PbS), several additional minor and trace elements can be incorporated into its simple cubic crystal structure. Many of these elements, such as Ag, Bi, Se, and Te, can be extracted economically as by-products from an ore containing galena. Others such as Sb, Cd, and Tl exist as impurities that may represent an environmental hazard that can be expensive to safely dispose of, or will incur a monetary penalty if present at high enough concentration in a Pb- or Pb-Zn-concentrate. A better understanding of the nature and distribution of minor/trace elements in galena is thus invaluable for the minerals industry.

Previous studies of galena (Bethke and Barton 1971; Blackburn and Schwendeman 1977; Tauson et al. 1986; Foord et al. 1988; Foord and Shawe 1989; Jeppsson 1989; Jeppsson 1995; Lueth et al. 2000; Chutas et al. 2008; Renock and Becker 2011) have shown that many minor/trace elements are able to substitute into the crystal lattice at a range of concentrations. Most published work has focused on elements such as Ag, Bi, or Sb that are known to occur at relatively high concentrations in some galena specimens (Van Hook 1960; Foord et al. 1988; Foord and Shawe 1989; Jeppsson 1989; Jeppsson 1995; Lueth et al. 2000; Costagliola et al. 2003; Chutas et al. 2008; Renock and Becker 2011). Marked gaps in our knowledge exist with respect to the ranges of concentration and inter-element correlations in galena from different types of deposit, and the laws that govern these distributions. Compositional data for galena in a sample suite representative of different styles of ore genesis is also invaluable for constraining the underlying mechanisms of element substitution better than they are at present.

Grain-scale compositional zoning is recognized in many sulfides, e.g., pyrite, arsenopyrite, and sphalerite (Hinchev et al. 2003; Chounard et al. 2005; Di Benedetto et al. 2005; Morey et al. 2008; Cook et al. 2009, 2013a, 2013b; Large et al. 2009), but has not yet been documented as such in galena, and has only been inferred from optical zoning (Ramdohr 1980).

This paper reports a reconnaissance study of elemental trace element analysis of galena from different types of galena-bearing...