Journal of Geochemical Exploration 169 (2016) 100–122

Contents lists available at ScienceDirect

Journal of Geochemical Exploration

journal homepage: www.elsevier.com/locate/gexplo

Characteristics of structurally superimposed geochemical haloes at the polymetallic Xiasai silver-lead-zinc ore deposit in Sichuan Province, SW China

Yongquan Li [a,*], Dehui Zhang [a], Li Dai [a], Guilong Wan [a], Benjun Hou [b]

[a] China University of Geosciences, Beijing 100083, China
[b] Sichuan Xiasai Silver Corporation Limited, Chengdu 610000, China

ARTICLE INFO

Article history:
Received 15 April 2016
Revised 20 June 2016
Accepted 8 July 2016
Available online 9 July 2016

Keywords:
Hydrothermal ore deposit
Structurally superimposed haloes
Polymetallic
Geochemical exploration

ABSTRACT

Hydrothermal ore deposits that are controlled by geological structures are often the product of multistage hydrothermal activities, and as a result, the primary alteration haloes usually overlap in the vertical direction. By distinguishing the hydrothermal stages associated with ore-forming processes, one can determine the timings of hydrothermal activities and use the results as a method for identifying blind orebodies. In order to increase the preserved resource of the Xiasai deposit, it is necessary to evaluate the exploring potential in depth or edge in the mine range, therefore, the primary geochemical haloes could be a good tool for mineral exploration in this place. Orebodies in the polymetallic Xiasai deposit are primarily controlled by structural features, which provide an opportunity to apply this method to investigate the structurally superimposed haloes in this silver-lead-zinc deposit. A total of 310 samples representing the stratigraphy and ore cross-sections have been analyzed for 30 elements (i.e., Cu, Pb, Zn, As, Sb, Bi, Hg, Cd, Be, B, Sn, Ag, Mo, Au, Y, Co, Cr, Sr, Se, Ba, Yb, V, Zr, Mn, Ti, Nb, La, Ni, W and Ga). The results of the analyses demonstrate that the mineralization in the Xiasai deposit is geochemically associated with the indicator elements Ag-As-Pb-Zn-Cu-Sb-Hg-Cd, and the secondary indicator elements include Bi-W-B-Sn-Au. The supra-ore haloes are characterized by a Hg-Ba-B-Sr association, the near-ore haloes are characterized by a Pb-Zn-Cd-Ag-Cu-Sb-As association, and the sub-ore haloes are characterized by a Bi-Sn-W-Mo-Mn association. The characteristics of the structurally superimposed haloes of the two main orebodies demonstrate that both orebodies formed via multistage ore-forming processes. The No. 1 and No. 2 orebodies may have undergone five and three timings of superimposed processes during mineralization in respectively. These results also suggest that the two orebodies may extend downward to great depths.

1. Introduction

In mineral exploration, there are two primary approaches that can be used to determine the presence of mineral deposits in a blind or obscured area. One can either adopt and apply a relevant mineral deposit model or search for and identify a primary geochemical halo surrounding a mineral deposit (Cameron et al., 2004; Carranza, 2008, 2011b; Carranza et al., 2009; Gray et al., 1991; Hronsky, 2004; Hronsky and Groves, 2008; McCuaig et al., 2010; Robertson and Taylor, 1987; Wang et al., 2007, 2013). A mineral deposit model usually provides systematic descriptions of the essential geological, geophysical and geochemical characteristics of a relevant type of mineral deposit (Carranza and Sadaghi, 2012; Cox and Singer, 1986; Roberts et al., 1988). The primary geochemical halo of a mineral deposit was defined originally by Safronov (1936) as 'an environment including enriched ore-forming and associated elements which is formed by hydrothermal ore processing'. Thus, research on primary haloes may form part of a mineral deposit model, but both the deposit model and primary halo approaches are based on studies of primary geochemical features of mineral deposits. These features are the essential mechanisms for metal precipitation or mineral formation and are indicative of chemical processes that occur during mineralization (Carranza and Sadaghi, 2012).

Since the primary geochemical halo theory was proposed in the 1930s, various methods and scales of geochemical exploration have been developed based on the theory (Beus and Gregorian, 1977; Distler et al., 2004; Gundobin, 1984; Ziaii et al., 2011; Wang et al., 2013). The scales of geochemical exploration can be classified as regional (Xie and Yin, 1993, Hannington et al., 2003), deposit (Carranza and Sadaghi, 2012) and orebody. The regional scale is a strategic method of mineral deposit exploration. The effective application and interpretation of lithogeochemical data for regional-scale exploration programs can be achieved by applying geographic information systems (GIS; Carranza et al., 1999; Cassard et al., 2008; Harris et al., 1999, 2000, 2001). The method is usually applied in mineral exploration for a country or a province, and the results are important for understanding the

* Corresponding author.
E-mail address: lyq@cugb.edu.cn (Y. Li).

http://dx.doi.org/10.1016/j.gexplo.2016.07.007
0375-6742/

general distribution of elements. Most studies have focused on deposit-scale exploration programs for primary geochemical haloes in mineral deposits, employing a traditional element zonality method to interpret lithogeochemical data. The deposit-scale method is important in the evaluation of the general potential for the prospecting of a specific deposit. The other orebody exploration scale is a relatively precise method. The basic principle originates from the deposit scale, and the research methods have improved over the past few decades. The orebody exploration scale method pays close attention to the potential to extend in depth for a particular orebody in a deposit, and their results are usually applied in the evaluation of the potential for prospecting at a great depth.

The structurally superimposed haloes method is an orebody-scale method for geochemical exploration that is based on the fact that in structural or fault zones, migration channels provide routes for hydrothermal ore fluid and may precipitate and concentrate some indicator elements, and therefore, the probability of locating prospecting elements associated with the blind ore is improved by sampling fault zones (Konstantinov and Strujkov, 1995; Liu et al., 2014). Some scientists have researched the axially zoned primary haloes in gold deposits and discovered that this zonality does not strictly follow the ideal model of a primary halo (Fig. 1). Some epithermal elements show very high concentrations near or below the orebody. A high concentration below the orebody is considered a result of another hydrothermal process below the orebody. This feature is in accordance with the theory of structurally superimposed haloes (Li et al., 1995, 1998 and 2006) that concludes hydrothermal ore deposits are often the product of multi-stage hydrothermal events and superimposed primary haloes (Fig. 2). The structurally superimposed haloes method is primarily applied in the exploration of blind orebodies in hydrothermal gold deposits, which are controlled by structure. This method has been applied to 30 large to medium-size hydrothermal gold (vein) deposits in China for resource exploration, and it has been shown to be effective for prospecting blind orebodies at great depths (Li et al., 1995; Wang et al., 2013).

The main motivation of the present work follows from the observation that few prior studies have applied this method to investigate other types of deposits. Along with exhausting of the preserved resource in mine area, it is necessary to know the exploring potential in depth and edge in the Xiasai deposit area. Based on foregoing discussion, the primary geochemical haloes could be a good tool for mineral exploration in the depth of the area. Orebodies in the polymetallic Xiasai silver-lead-zinc deposit are primarily controlled by structures, a large amount of multi-element lithogeochemical data was analyzed. The data provide a good opportunity to investigate the characteristics of structurally superimposed haloes in relation to hydrothermal mineralization because the Xiasai deposit is mainly hidden, but its geological and structural settings are well researched (Zou et al., 2008; Ying et al., 2006; Liu, 2003 and Lian et al., 2010), providing a basis for the interpretation of structurally superimposed haloes. Therefore, this study aims to characterize the structurally superimposed haloes of the Xiasai deposit and distinguish the timings of mineralization, ultimately to demonstrate prediction of exploration targets by applying multi-element lithogeochemical data.

2. Background on the polymetallic Xiasai silver-lead-zinc ore deposit

The Xiasai deposit is a large silver ore deposit with lead and zinc as byproducts (20 Mt. at 284.92 g/t Ag, 2.97% Pb, 2.4% Zn). Xiasai is located

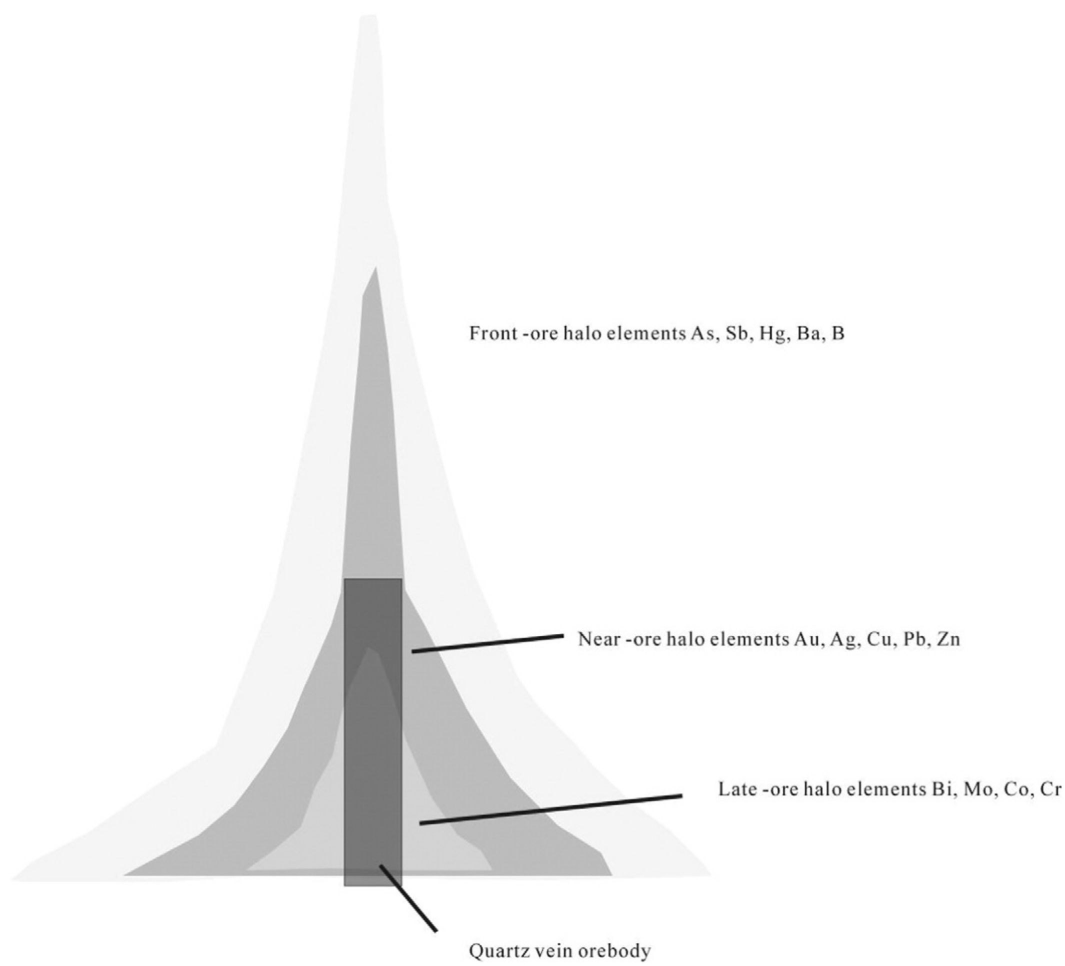

Fig. 1. Schematic diagram of an ideal model of a geochemical primary halo in a vertical section.