ARTICLE IN PRESS

Journal of Geochemical Exploration xxx (xxxx) xxx

Contents lists available at ScienceDirect

Journal of Geochemical Exploration

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

Hualgayoc mining district, northern Peru: Testing the use of zircon composition in exploration for porphyry-type deposits

M. Viala *, K. Hattori

Department of Earth and Environmental Sciences, University of Ottawa, Ontario, Canada

ARTICLE INFO

Keywords:
High-sulfidation gold
Amphibole
Peruvian Cordillera
Rare earth elements
Cerium anomalies
Laser ablation ICP-MS

ABSTRACT

The Hualgayoc district in the Cajamarca region, northern Peru, hosts several deposits, including the Cerro Corona Au + Cu porphyry deposit (0.55 Mt Cu, 99 t Au) and the Tantahuatay high-sulfidation epithermal Au deposit (74 t Au), plus other Au, Cu, Ag and base metal prospects. Previous studies have documented that zircon in igneous rocks associated with porphyry systems elsewhere in the world shows large positive Ce anomalies and small negative Eu anomalies, which reflect both the oxidized and hydrous nature of their parental magmas. This study presents the trace element compositions of magmatic zircon from igneous rocks associated with porphyry-style mineralization, as well as barren stocks, sills and volcanic rocks in the district, in order to investigate the usefulness of zircon composition in exploration for porphyry-type deposits. The compositions of the zircon suggest that all parental magmas in the Hualgayoc district are oxidized, and that the magnitude of Ce and Eu anomalies is independent of the spatial and/or temporal association of igneous rocks with mineralization. Although zircon composition is not sufficient to recognize specific intrusions as fertile to generate hydrothermal ore deposits, the composition, properly applied, may be useful to target areas containing oxidized igneous rocks for further detailed exploration.

1. Introduction

Porphyry-style Cu ± Au and high-sulfidation epithermal Au deposits are important sources of Cu and Au in our society. These deposits are typically associated with oxidized and hydrous arc magmas of intermediate to felsic composition (Ishihara, 1977; Streck and Dilles, 1998; Richards et al., 2012). The oxidation conditions of the metal-fertile magmas are considered to have fO_2 greater than one logarithmic unit above the fayalite-magnetite-quartz (FMQ) buffer (Wang et al., 2014; Shen et al., 2015; Hattori, 2018). This apparent association of mineralization with relatively oxidized magmas is attributed to the high capacity of oxidized magmas to extract metals and S from their magma source regions and to transport these elements to shallow crustal levels without immiscible separation of sulfides that may sequester metals and prevent partitioning to a magmatic-hydrothermal fluid (Botcharnikov et al., 2011; Zajacz et al., 2012).

Rare earth elements (REE) mostly have a valence charge of +3, but Eu is also 2+ in reduced magmas and Ce can be +4 in oxidized magmas (Burnham and Berry, 2014; Burnham et al., 2015; Smythe and Brenan, 2015). Since Eu^{2+} is preferentially incorporated into the Ca^{2+} site of plagioclase, a melt progressively loses Eu during plagioclase crystallization. Ce^{4+} is easily incorporated into the Zr^{4+} site of zircon whereas Eu^{2+} is not readily included into the crystal structure. Thus, the magnitude of Ce and Eu anomalies in zircon reflects magmatic redox conditions (Burnham and Berry, 2012; Smythe and Brenan, 2016). Previous studies on zircon compositions from porphyry Cu deposits show small negative anomalies of Eu, Eu/Eu*, and large positive Ce anomalies, expressed as high Ce^{+4}/Ce^{+3} (Ballard et al., 2002; Liang et al., 2006). Ballard et al. (2002) reported zircon from intrusions associated with porphyry-Cu mineralization in the Chuquicamata–El Abra area in northern Chile have Ce^{+4}/Ce^{+3} > 300 and Eu/Eu* (=$[Eu_{cn}]/[(Sm_{cn}*Gd_{cn})^{0.5}]$ where cn refers to chondrite normalized values) > 0.4. Liang et al. (2006) proposed a Ce^{+4}/Ce^{+3} ratio of 120 in zircon separating ore-bearing and barren porphyry intrusions based on the study of the Yulong Cu belt in eastern Tibet. Shen et al. (2015) noted that intermediate to large porphyry deposits (>1.5 Mt Cu) have higher Ce^{+4}/Ce^{+3} in zircon (>120) than small deposits (<1.5 Mt Cu) in the Central Asian Orogenic belt. Meng et al. (2018) also suggested Ce^{+4}/Ce^{+3} values for zircon from ore-bearing porphyry intrusions range between 30 and 3000 and Eu/Eu* between 0.2 and 0.8. Therefore, it has

* Corresponding author at: Department of Earth and Environmental Sciences, University of Ottawa, 25 Templeton Street, Ottawa, Ontario K1N 6N5, Canada.
E-mail address: mvial044@uottawa.ca (M. Viala).

https://doi.org/10.1016/j.gexplo.2021.106725
Received 19 November 2019; Received in revised form 22 December 2020; Accepted 1 January 2021
Available online 7 January 2021

Please cite this article as: M. Viala, K. Hattori, *Journal of Geochemical Exploration*, https://doi.org/10.1016/j.gexplo.2021.106725