Comparative geochemical study of scheelite from skarn systems: Implications for mineral exploration.

Ana Carolina R. Miranda and Georges Beaudoin
Department of Geology and Geological Engineering, Laval University

Summary

Scheelite ($CaWO_4$) is a hydrothermal mineral that occurs in numerous deposit types, including skarn, greisen, veins, porphyry, and orogenic gold. Scheelite crystal lattice hosts several trace elements including REE, Mo, Sr, Y, Nb, Na, which provide valuable information about physico-chemical conditions, pathway and source of the hydrothermal fluids. Recently, several studies have focused on understanding the factors that control the incorporation of trace elements into scheelite lattice, and thus using its composition as a discriminant between different types of deposits (Ghaderi et al 1999; Poulin et al 2018). In this study, we compare the composition of scheelite derived from reduced and oxidized skarns with distinct metallogenetic associations, in order to use scheelite as an indicator of fertility of a given deposit. Trace element composition reveal significant differences between scheelite from reduced and oxidized skarns. Scheelite from oxidized skarns has higher Mo, Ti and As, and lower HREE and Y concentrations relative to those from reduced skarns. Based on multivariate statistical analysis of trace elements results, it is possible to use scheelite in order to discriminate skarns deposits according to redox type, as well as according to metallogenetic association. Therefore, scheelite composition can also be used to constrain different genetic parameters of a given magmatic-hydrothermal system.

Method

In this study, the chemistry of scheelites from reduced and oxidized skarns from 20 localities with 8 different metallogenetic associations (Au, Cu, W, W-Au, W-Cu-Au, W-Cu, W-Cu-Mo and W-Sn) were investigated using electron microprobe analyzer (EPMA) and Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS). Gold, W-Au and W-Cu-Au mineralization are associated with reduced skarns, whereas Cu, W-Sn and W-Cu-Mo are related to oxidized skarns. The W and W-Cu mineralization occur in both skarn types. Petrographic descriptions were done to characterize mineralogical and textural relationships between scheelite and co-genetic minerals. Additionally, cathodoluminescence (CL) observation were carried out to investigate internal texture/zonation in single scheelite crystals. Chemistry analyses were performed on thin sections using EMP) at Université Laval; and Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) at UQAC. Analyses by EMPA were carried out using a CAMECA SX-100 electron microprobe, equipped with five wavelength-dispersive spectrometers (WDS) for major and minor elements. The LA-ICP-MS analyses, which included spots, lines and multi-elemental maps in order to measure the concentrations of minor and trace elements in scheelite. The geochemical data were processed using basic and multivariate statistical analyses.

Results

Overall, shape, size and the occurrence form of scheelite are similar in all scheelite-bearing skarn samples. Microscopically, scheelite associated with prograde stage is fine grained and varies from rounded to euhedral. Scheelite occurs as inclusions into garnet crystals, less often in pyroxene, and as disseminated free crystals. By contrast, scheelite associated with retrograde stage varies from fine to coarse grained, rounded to euhedral and occurs mostly disseminated. Mineral inclusions such as amphibole, biotite, pyrrhotite, apatite and magnetite are quite often in scheelite, especially in that associated with retrograde mineralizing stage. Cathodoluminescence images revel that oscillatory and patchy zoning, and dissolution are common textures in scheelite from skarn systems. Multielement maps revel that these textures are mainly caused by the differences in the concentration of Mo and Nb. Negative slope is the most common chondrite-normalized REE pattern in scheelite. Thus, scheelite associated with oxidized skarns is strongly depleted in HREE (La/Lu >400), whereas scheelite from reduced skarns is characterized by an enrichment in LREE (La/Lu <100). Principal component analyses (PCA) reveals that scheelite from skarns record different redox conditions (oxidized versus reduced skarns), and metallogenetic association. Scheelite from oxidized skarns contains higher Mo, As and Ti, and lower HREE and Y relative to scheelite from reduced skarns. Scheelite from Cu mineralization differs from all the others scheelites due to higher V contents. Scheelite from oxidized W-Cu and W-Sn is richer in Mg, which differs from that of W skarns. Scheelite from Au mineralization differs from that of W-Au and W-Cu-Au having lower Mn contents.

Conclusions

Our results support that scheelite can be used to track the redox conditions of a given system. This is particularly important because oxidized skarns occur mainly associated with non-carbonaceous or hematitic sedimentary rocks, whereas reduced skarns are found within carbonaceous rocks. Therefore, the use of scheelite as an indicator mineral at early exploration stages may support the definition of potential targets. Moreover, our results support that the aforementioned metallogenetic associations are mainly controlled by source and redox conditions of the magma, fractionation degree and specially fluid-rock interaction with wall rocks. Thus, scheelite composition can also be used to constrain different genetic parameters of a given magmatic-hydrothermal system.

References

Ghaderi, M., Palin, J. M., Campbell, I. H., and Sylvester, P. J., (1999) Rare earth element systematics in scheelite from hydrothermal gold deposits in the Kalgoorlie-Norseman region, Western Australia, Economic Geology, 4(3):423-437.

Poulin, R. S., Kontak, D. J., McDonald, A., McClenaghan, M. B. (2018) Assessing scheelite as an ore-deposit discriminator using its trace-element and REE chemistry. The Canadian Mineralogist 56:265-302.

Sciuba, M., Beaudoin, G., Grzela, D., Makavandi, S. (2019) Trace element composition of scheelite in orogenic gold deposits. Mineralium Deposita.