TIMING OF ORE MINERALIZATION USING ORE MINERALOGY AND U-PB DATING, IOCG SIN QUYEN DEPOSIT, NORTH VIETNAM

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Introduction

The Sin Quyen deposit in North Vietnam is composed of Fe-Cu-REE-Au-Ag bodies hosted in the Proterozoic intensely dislocated, crystalline, metamorphosed rocks of the Sin Quyen Formations. In the ore bodies magnetite, pyrite, pyrrhotite, chalcopyrite, cubanite and sphalerite has been identified as the major minerals and marcasite, tennantite, cubanite, arsenopyrite, galena, allanite, chevkinite, apatite, ilmenite, Bi-native, bismuthinite, electrum, native gold, and tellurides are the minor. The REEs occur mostly in the allanite, and minor in the chevkinite, monazite, apatite and uraninite. Uraninites are inhomogeneous in both optical properties and chemical composition. Uranium and ΣREE_2O_3 concentrations in the paragenetically earlier uraninite are of 84.55-85.97% in av, and of 1.9-8.0% respectively, whereas in paragenetically later uraninite, U and ΣREE_2O_3 concentrations are of 96.25-96.67% in av. and of 1.3-2.7% respectively. The thorium concentration in both mentioned early and late uraninites is very low (0.205 % in av). Electron microprobe "chemical" dating of the uraninite yield an age of 500±33 Ma (n = 35) for the paragenetically early uraninite and an age of 73±15 Ma (n = 6) for the paragenetically later ones. The minerals of older age, which is interpreted as the primary ore mineralization stage, correspond with the ages of a range of deposits along the East Gondwana margin. The measured $\delta^{34}S$ of sulfide minerals from -2.78 to +8.65 ‰ suggest hydrothermal origin of fluid which was responsible for transportation and crystallization.

Samples and methods

Forty-four samples were collected from the deposit. All samples were studied in detail using optical microscope both in transmitted and reflected light. Based on this investigation several samples were selected for the bulk chemical, EDS and WDS analyses. The bulk chemical analyses of the waste, concentrates and solid samples were carried out at ACME Laboratories in Vancouver Canada using ICP-MS method signed as AQ251. Electron microprobe measurements were carried out in the Critical Element Laboratory of the AGH-UST University in Krakow using the standards and characteristic library lines. For WDS measurements following condition were implemented: accelerating voltage of 15 kV, and a probe current of 40 nA, with a focused electron beam diameter of 3 μm. For better statistic of measurement and decreasing of detection limit following condition peak/background (in sec.) were used: U 120/60, Pb 180/90, Th 120/60. Original Jeol ZAF procedures were used for a final correction of all measured elements. Monazite crystal TS-Mnz (894.8 ± 5.3 Ma) was used as a reference material for microprobe standardization.

Timing of ore mineralization

The electron microprobe analyses and BSE images indicate two compositionally different generations of uraninite at Sin Quyen deposit. Moreover, the composition of the two generations is relatively constant. As virtually all Pb in uraninite is produced by the radiogenic decay of U and Th, the consistency in the composition of the two generations of uraninite offer the opportunity to determine the age of uraninite deposition and the formation of the Sin Quyen deposit.

Using the electron microprobe data and the original Jeol software, absolute age of uraninite was calculated. The Pb-rich uraninite yields ages of 430 Ma to 575 Ma with a mean weighted age of 500 ± 33 Ma (n = 33). As this uraninite grains are intergrown closely with magnetite and chalcopyrite, it is interpreted as the same stage of IOCG mineralization at Sin Quyen. The Pb-poor uraninite yields an age of 42-83 Ma (n = 6), which is interpreted as a recrystallization time, during the period the young hydrothermal event was taking place. Uraninite is commonly recrystallized following initial formation, resulting in a long tail of younger ages that have uncertain geological meaning. The age of ~42 Ma, as determined from the low-Pb uraninite corresponds to the final changes observed in the ore. Several other scientists also dealt with crystallization periods, e.g. Li et al. (2018), but they used zircon and monazite. The mentioned authors explained better the range of ore minerals development. The oxygen isotopes described by Li and co-workers show different genetic position of both these minerals which is in good agreement with crystals parameters of zircon e.g. elongation l/h close to 1.5. Such zircon crystal elongation is rather typical for metamorphic rocks, which are the host rocks for the Fe-Cu ores. The first stage of mineralization is related to the Na alteration dated for 841-836 Ma (Li et al., 2018). The δ^{18}O of zircon are higher than those presented in the magnetite, which in our opinion exclude simultaneous crystallization of these mineral. Fluid inclusions measurement show high temperature above 500 °C, that may be suggested participation of metamorphic ore magmatic derived fluids. Alteration of uraninite grains documented by WDS quantitative measurements and BSE images showing well visible alteration of uraninite grains suggests presence at least of two important stages, which are well documented by the uraninite age dating and fit well to the geological phenomena. The determination of absolute age provides new constraints on mineral timing, and enables a better understanding of the mineral paragenesis presented by Ta (1975) and McLean (2001). Three stages of magnetite – sulfide formation have been recognized. The first two are the main stages. According to mineralogical studies, most ores were precipitated during the skarn-metasomatic stage, which is the first stage. As the Pb- and REE-rich uraninite crystallized together with magnetite and allanite followed by massive chalcopyrite, pyrrhotite, pyrite and cubanite, and is characterized by high concentration of REEs, this uraninite is interpreted to be formed during the early stage of deposition. This is also supported by the positive correlation between U-Th and REE. The hydrothermal stage, as described by Ta (1975) and McLean (2001) as a major sulfide crystallization stage, is interpreted here as a continuation of the first metasomatic stage.

Conclusions

In the deposit, low grade uranium concentrations have been documented. In this work enrichment in U was confirmed by using both field and laboratory measurements. The first group includes two minerals from allanite group, and probably monazites (Ishihara et al. 2011), however because of inadequate relatively higher detection limits of both EDS and WDS analyses and low concentration of this element it is difficult to precisely determine the quantitative content of uranium in these minerals. The presence of uraninite in the association of magnetite-sulfide ores accompanying by allanite was documented in the deposit. In the case of Sin Quyen deposit, the relatively high concentration of U and REE in the waste suggest coexistence all of these elements in allanites. It can be suggested that mostly uranium oxides are responsible for uranium concentration in the deposit. In this work, three stages of mineralization have been documented in the deposit, which consists of copper ores containing some gold - silver enrichment. In the previous works (Li et al., 2018) high temperature Na-alteration stage 841-836 Ma was documented. The major stage is skarn-metasomatic, which developed in the late Precambrian and early Cambrian age (575-435 Ma). The younger stage is documented by age of uraninite II occurred during late Cretaceous-Paleocene age (83-42 Ma), however according to the data of fission-track analyses by Anczkiewicz et al. (2000) the last ductile deformation within the Red River Fault Zone took place about 25 Ma.

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