RELATION BETWEEN SOME SELECTED MAJOR AND TRACE ELEMENTS IN THE IOCG SIN QUYEN DEPOSIT, LAO CAI PROVINCE, NORTH VIETNAM

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Introduction

The Sin Quyen IOCG deposit is located in the Lao Cai province, 300 km north-western from Hanoi and one km from the Red River, which is the natural boundary with China. The deposit area is above 200 ha and composes of 17 ore bodies principally hosted in the Sin Quyen formation with 800 m thick, strikes between 280 to 320 degrees and steeply dipping and trending to the northeast. The Sin Quyen formation is built of gneiss, mica schist and locally marble. The ores are Au-rich copper and iron sulfides (chalcopyrite, pyrite, and pyrrhotite) and iron oxides (magnetite, hematite) with 0.9% and 5.4% of average grade for Cu and Fe respectively (Ishihara et al., 2011). Gold and silver are randomly occurring as an electrum mineral in a vein form in the ores. In the deposit REE bearing minerals are allanites, which occur in disseminated manner. The REE content in allanites of the deposit varies from 14 to 27%. The reserves were calculated during the exploration stage 550,000 t Cu, 334,000 t REE, 843,000 t S, 34.7 t Ag and 25.3 t Au (ESCAP 1990). The authors attempt to study the relations between several minor elements and major metals Cu, Fe, U, Au, Ag and REE present in the deposit and attempt to geochemically interpret the obtained correlation especially with coefficient higher than 0.7.

Samples and methods

In 2014 AGH-UST team made some geological survey on IOCG Sin Quyen deposit and collected 50 solid samples from massive ores, host rocks, reservoir sediments, Cu - and Fe-concentrates and from waste dumps. All the collected samples were analyzed by optical microscope and the chemical compositions of the selected solid samples were analyzed at Bureau Veritas Mineral Laboratories in Canada using the method assigned as AQ251. The concentrations of uranium and thorium of the samples were determined additionally by gamma spectrometer with HPGe detector. The correlation coefficients are summarized in Table 1.

Table 1*. Coefficients of correlation between analyzed elements in the solid samples (for n= 40).*

	Cu	Fe	Co	Ni	Au	Zn	Ag	Pb	S	Te	Bi	Cd	U	Th	V	REE
Cu	1															
Fe	0.53	1														
Co	0.46	0.59	1													
Ni	0.15	0.31	**0.90**	1												
Au	**0.83**	0.17	0.33	0.21	1											
Zn	0.67	0.39	0.26	0.04	0.49	1										
Ag	**0.94**	0.50	0.41	0.11	**0.74**	0.68	1									
Pb	**0.82**	0.46	0.41	0.16	**0.74**	0.64	**0.82**	1								
S	0.26	0.20	**0.83**	**0.77**	0.18	0.20	0.25	0.16	1							
Te	**0.94**	0.35	0.56	0.26	**0.69**	**0.70**	**0.93**	**0.82**	0.42	1						
Bi	**0.90**	0.14	0.51	0.23	**0.76**	0.60	**0.92**	**0.77**	0.40	**0.91**	1					
Cd	0.67	0.19	0.29	0.03	0.56	**0.89**	**0.73**	0.69	0.23	**0.69**	0.66	1				
U	**0.78**	0.41	0.35	0.11	**0.80**	0.62	**0.81**	**0.97**	0.09	**0.78**	**0.75**	**0.69**	1			
Th	0.08	0.14	0.15	0.18	0.03	0.14	0.18	0.03	0.20	0.04	0.09	0.04	0.03	1		
V	0.39	0.56	0.08	0.17	0.21	0.34	0.47	0.30	0.10	0.43	0.56	0.33	0.33	0.03	1	
REE	0.46	0.26	0.20	0.08	0.08	0.12	0.48	0.21	0.17	0.36	0.37	0.11	0.21	0.64	0.13	1

The clearly positive correlations (R≥0.7) for Cu are the pairs: Cu-Ag, Cu-Te, Cu-Bi, Cu-Au, Cu-Pb and Cu-U. The high correlation coefficients between Cu and Ag, Te, Bi, Pb and Au are resulted from the similarity of their geochemical property. The elements belong to the chalcophile group and they are easily to bond with sulfur to form the stable minerals. Cu in the deposit occurs predominantly in chalcopyrite and bornite in massive ores. Though Au and Ag are the precious metals, but the metals and Cu have many common chemical properties such as ion radius 0.68Å (Au), 0.67Å (Ag) i 0.57Å (Cu) and belong to the chalcophile group. In the study deposit Au and Ag often occur together with chalcopyrite, bornite in the electrum mineral formed as the vein forms consistent. The intergrowth between minerals containing the elements such as

chalcopyrite, pyrite, gold, uraninite, allanite, and magnetite is presented in Fig. 1a and 1b. Bismuth and tellurium are typical chalcophile elements, which occur as tetradymite mineral (Bi_2Te_2S). In the deposit Bi and Te occur as trace elements and they can occur in chalcopyrite, bismuthinite and pyrite.

Iron (Fe) is the most contributing compositional element in the studied deposit. The concentration of Fe in the deposit varies in very broad interval from a hundredth percent to more than 40 % with 5.4% of average. However, there is no strong correlation between this element and other elements. The reasons can be connected with the geochemical properties of Fe and the conditions, in which the deposit was formed. Iron is the main element in the earth and it can be crystalized at various temperatures during magma crystallization and bound with different elements creating different stable minerals. Depending on the conditions iron can occur with valences 2+ or 3+ and has ion radius of 0.74 Å or 0.64 Å respectively. The Cu and Fe ores in the Sin Quyen deposit were formed principally in the skarn zones. In the conditions with the mentioned geochemical properties Fe element can bond with sulphur or oxygen and other elements to form different resistant compounds, suggesting the strong correlation between Fe and the other elements can be observed only in the specific intervals of Fe concentration. From the mineralization of view, the Sin Quyen deposit is divided in different zones, which are characterized with the dominating minerals. In the Sin Quyen deposit the principal iron minerals are chalcopyrite, bornite, magnetite, pyrrhotite, and pyrite.

Co and Ni belong to the siderophile group and they often accompanying with Fe. In the magmatic crystallization processes the elements crystallise on the earlier stage. Similar to Fe, Co and Ni can occur also in the 2+ and 3+ state and the ion radius at 2+ and 3+ for Co and Ni amount to 0.61 Å, 0.74 Å and 0.55 Å and 0.69 Å respectively, additionally nickel, cobalt and iron are easily to bound with sulfur, so the strong correlation between Fe, Co and Ni should be observed. In the IOCG Sin Quyen deposit the concentration of Co and Ni is up to 330 ppm and 240 ppm respectively. These values are far lower in comparison with Fe concentration range (1.20% to 40%), in consequence there is very strong correlation between Co and Ni (R=0.9) but no with Fe.

In the studied deposit the correlation coefficients of U-Pb, U-Ag, U-Au, U-Cu, U-Te and U-Bi are higher than 0.7. The correlation coefficient of U-Pb pair is equal to 0.97, such high correlation coefficient probably is connected with the almost Pb principally generated from the uranium decay series.

There is a significant REE and S reservoir in the deposit but no strong correlation between the elements with Cu, Fe and the other.

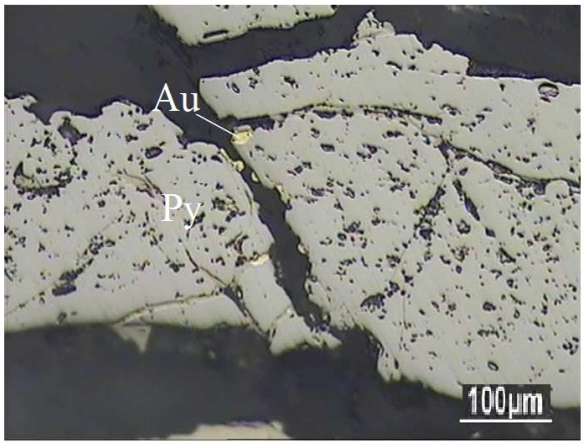

Fig.1a Au in pyrite (in reflect light).

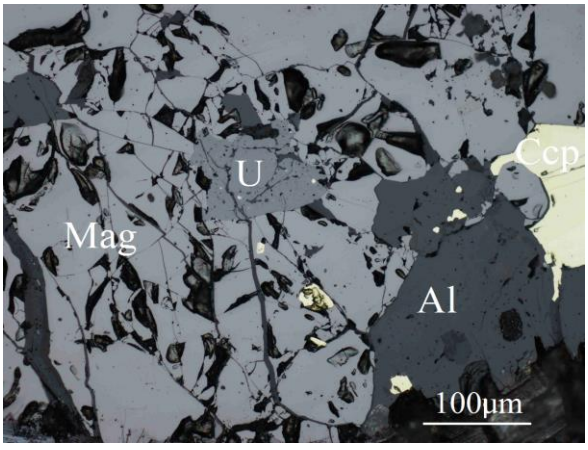

Fig.1b. Intergrowth of uraninite (U) with magnetite (Mag), chalcopyrite (Ccp); allanite (Al).

Conclusions

The correlation coefficient is higher than 0.7 is only observed for the elements having similar properties and they are classified to the chalcophile or siderophile groups. The bearing REE mineral allanite formed independently from the Cu and Fe bearing minerals.

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