

C. PHAM-NGOC, D. ISHIYAMA and T. A. TRAN, 2014. Mineralization of Indium in Northern Vietnam: A Study on Mineralogy and Geochemistry of the Na Bop and Lung Hoai Deposits in the Cho Don and Cho Dien Mining Area. *Acta Geologica Sinica* (English Edition), 88(supp. 2): 194-196.

Mineralization of Indium in Northern Vietnam: A Study on Mineralogy and Geochemistry of the Na Bop and Lung Hoai Deposits in the Cho Don and Cho Dien Mining Area

C. PHAM-NGOC^{1,3}, D. ISHIYAMA^{2,3} and T. A. TRAN⁴

¹ Graduate School of Engineering and Resource Science, Akita University, Akita 0108502, Japan

² Faculty of International Resource Science, Akita University, Akita 0108502, Japan

³ New Frontier Leader Training Program for Rare Metals and Resource, Akita University, Akita 0108502, Japan

⁴ Institute of Geological Sciences, Vietnam Academy of Science and Technology, Ha Noi, Vietnam

1 Introduction

The Cho Don (including the Na Bop, Na Tum, Pu Sap, Ba Bo and Lung Vang deposits) and Cho Dien (including the Phia Khao, Lung Hoai, La Poanh, Bo Pen, Binh Chai, Deo An, Bo Luong deposits) mining areas are characterized by the large reserve and high grade of Pb-Zn ore and indium in Cho Dien district, Bac Kan Province, northeast Vietnam (Fig. 1). Total ore reserves in these mining areas reach up to 20.1 Mt of ores, in which there are 0.99 Mt of metals (Pb+Zn) (Dovzhikov et al., 1965; Tran et al., 2012, Nguyen et al., 2000). Some earlier studies classified ore deposits in the Cho Don and Cho Dien mining areas into Mississippi Valley type deposits (MVTs). Some of the later studies assign them to Pb-Zn hydrothermal deposits classified into magmatic hydrothermal system based on the mineral assemblage and trace elements characteristics. The aim of this study is to clarify the type of the Na Bop deposit in the Cho Don mining area and the Lung Hoai deposit in the Cho Dien mining area based on the characteristics of mineralogy, geochemistry and formation environment.

2 Outline of Geology of Ore Deposits

The geology of the Cho Don and Cho Dien mining areas consists of Devonian shale, claystone, limestone, Permian-Triassic schist, chert, dolomitized, granitoid and gabbroid. Pb-Zn veins of the Na Bop and Lung Hoai deposits are located mainly in Permian-Triassic dolomitized and siliceous carbonate rocks. The strike and dip of Pb-Zn veins are NE-SW and nearly vertical,

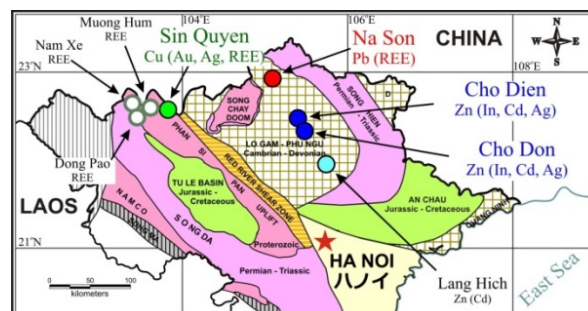


Fig. 1. Simplified geological map of northern Vietnam with the distribution of major Pb-Zn-Cu mineralization.

respectively. The ores of both deposits are Zn rich ores.

3 Mineralogical Characteristics of Ore Deposits

The ores of the Na Bop deposit are classified into sph-rich and po-rich ores. The po-rich ore occurs as clots in sph-rich ore. There is a possibility that the po-rich ore was formed prior to the formation of sph-rich ore. The mineral assemblages of the po-rich ore and sph-rich ore are po-asp >> sph-gn-py-cpy and sph >> po-asp, respectively. Gangue minerals are anhydrous carbonates (Cal, Dol and Ank), euhedral Cal and Dol and graphite. The euhedral Cal and Dol were formed at the earlier stage of the mineralization and partially dissolved by po. Graphite is included in the anhydrous carbonate and sometimes, surrounded by asp (Pham-Ngoc et al., 2011, Pham-Ngoc, 2013).

The ores of the Lung Hoai deposit are classified into massive sph ore and banded ore consisting alternation of

* Corresponding author. E-mail: phamngocan87255@yahoo.com

asp and sph. The mineral assemblages of the massive sph and banded ores are sph >> py-cpy and sph-asp >> gn-py-cpy, respectively. Py and cpy occur as inclusions in large grain of sph. Asp shows euhedral shape and is cut by sph. Py and cpy also occur as inclusions in sphalerite.

4 Chemical Characteristic of Ores and Minerals of the Na Bop and Lung Hoai Deposits

Po-rich samples of the Na Bop deposit and asp-rich samples of the Lung Hoai deposit are characterized by higher Pb/Zn ratio compared with Pb/Zn ratio of sph-rich ores of both deposits. Indium content in the ores ranges from 1.1 to 83.0 ppm for the Na Bop deposit and from 2.3 to 5.4 ppm for the Lung Hoai deposit. The Indium potentials estimated for the Cho Don and Cho Dien mining areas are 1500 and 300 tons, respectively).

Sphalerite from the Na Bop deposit is characterized by high FeS content (13.2 - 18.7 mole.%). FeS content of sphalerite from Lung Hoai deposit varies in a wide range (4.2 - 15.7 mole.%). The Indium contents in the sph of the Na Bop deposit range from 0.1 to 0.2 wt.%, while those of the Lung Hoai deposit is less than 0.07 wt.%. The As content of asp from the Na Bop deposit decreases from 29.6 - 31.5 at.% at core to 28.4 - 31.1 at.% at rim, while the As content of asp from the Lung Hoai deposit increases from 28.0 - 29.5 at core to 30.6 - 31.2 at.% at rim.

5 Formation Environment of the Na Bop and Lung Hoai Deposits

Based on the As content of asp geothermometer (Krerschmar and Scott, 1976) and the mineral assemblage of sph-py and po, the formation temperatures of the Na Bop and Lung Hoai deposits were estimated to be about 300°C and 200°C, respectively (Fig. 2). The $\log f_{S_2}$, $\log f_{O_2}$, $\log f_{CO_2}$ of the Na Bop deposit are -10.9, -36.0 to -33.5 and -0.1 to 2.4, respectively. Those of the Lung Hoai deposit are -16.3, -45.3 to -43.6 and -1.7 to 0, respectively, (Figs. 3 and 4). The total pressure of the system ($P_{H_2O} + P_{CO_2}$) of the Na Son deposit (337 bars) is higher than the Lung Hoai deposit (17 bars). It suggests that the Na Son deposit was formed deeper than the Lung Hoai deposit.

The $\delta^{34}\text{S}$ values of the sulfide minerals from the Na Bop and Lung Hoai deposits range from +2.1 to +5.9‰ and from -5.4 to +0.1‰. The positive values of $\delta^{34}\text{S}$ of the sulfide minerals from the Na Bop deposit suggest a magmatic origin for the sulfur in the Na Bop deposit, while the negative values of the $\delta^{34}\text{S}$ of the sulfide minerals from the Lung Hoai deposit suggest the

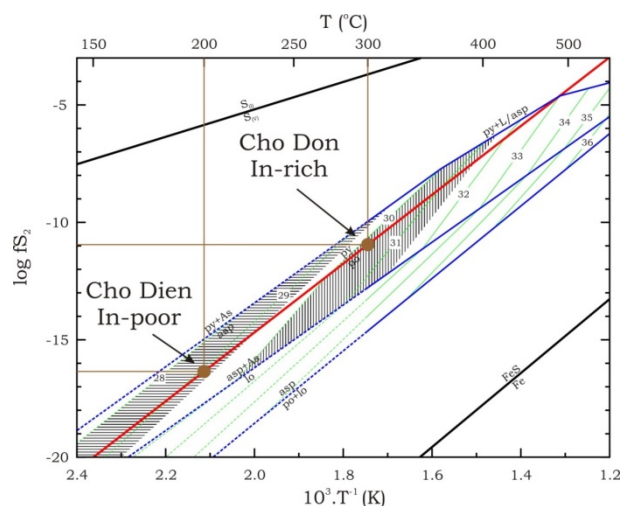


Fig. 2. Diagram of T vs $\log fS_2$ modified after Ulrich Kerschmar and Scott, S.D., 1976.

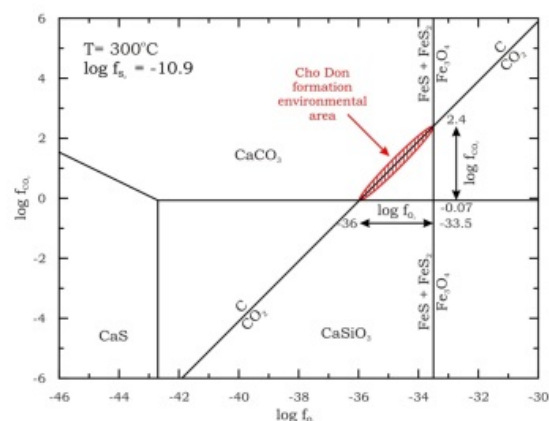


Fig. 3. Phase diagram shows the $\log f_{\text{CO}_2}$ and $\log f_{\text{O}_2}$ of the Cho Don deposit at 300°C and $\log f_2 = -10.9$.

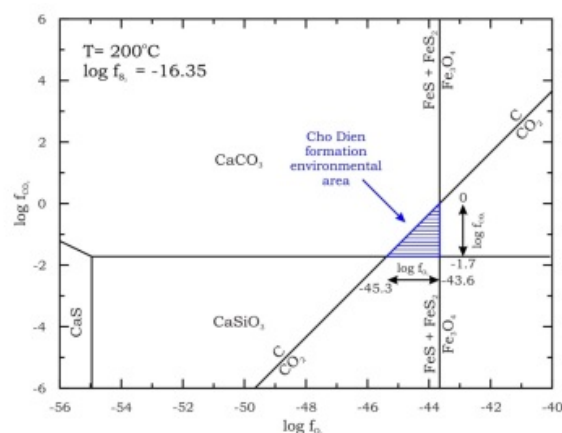


Fig. 4. Phase diagram shows the $\log f_{\text{CO}_2}$ and $\log f_{\text{O}_2}$ of the Cho Don deposit at 200°C and $\log f_2 = -16.35$.

sedimentary origin for the sulfur in the Lung Hoai deposit.

6 Discussions and Conclusions

Whereas MVT deposits are not associated with po-asp and occur low formation temperature environment (50 to 225°C, with average being about 120°C, Guilbert and Park, 1986), Pb-Zn vein type deposits associated with magmatic hydrothermal system such as Toyoha deposit, Japan, contain po-asp assemblage with a large amount of sph and were formed under higher formation temperatures (200 to 360°C). The Na Bop and Lung Hoai deposits have signatures of Pb-Zn vein deposits associated with magmatic hydrothermal system based on the abundant presence of po-asp and high formation temperature (300 and 200°C, respectively). Because of the higher concentration of indium in the Na Bop deposit compared with the Lung Hoai deposit, the mineralization of indium was possibly associated with the magmatic hydrothermal system.

References

Dovzhikov, A.E., Bui, P.M., Vasilevskaya, E.D., Zhamoida, A.I.,

- Ivanov, G.V., Izokh E.P., Le, D.H., Mareichev, A.M., Nguyen V.T., Nguyen, T.T., Tran, D.L., Pham, V.Q., Pham, D.L., 1965. Geology of Northern Vietnam. Nauka i Tekhnika, Hanoi (in Russia).
- Nguyen, K.Q. et al., 2000. Geological map, Bac Kan sheet (F-48-XVI). Department of geology and minerals of Vietnam, Ha Noi.
- Pham-Ngoc, C., Ishiyama, D., Tran T.A., and Sera K., 2011. Mineralogical and geochemical characteristics of rare metals-bearing Na Bop, Lung Hoai, Na Son and Sin Quyen base metal deposits, Northern Vietnam. NMCC Annual Report, 18: 49-55
- Pham-Ngoc, C., 2014. Geological and Geochemical characteristics of rare metals-bearing Pb-Zn deposits, Northeast Vietnam. Master thesis. Akita University, Japan.
- Tran, T.A., Gas'kov, I.V., Tran, T.H., Nevol'ko, P.A., Pham, T.D., Pham-Ngoc, C., 2012. Complex deposits in the Lo Gam structure, northeastern Vietnam: mineralogy, geochemistry, and formation conditions. Russian Geology and Geophysics, 53: 623-635.
- Ulrich Kersschmar and Scott, S.D., 1976. Phase relations involving arsenopyrite in the system Fe-As-S and their application. Canadian Mineralogist, 14: 364-386.