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THE APPEARANCE OF COPPER-BEARING MINERALIZATION IN THE REGION OF MUANG XAY, LAOS

PRZEJAWY MINERALIZACJI MIEDZIONOŚNEJ W REGIONIE MUANG XAY, LAOS

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Abstract. Geotectonic events in the Indochina Peninsula, associtted with the Indosinian orogeny between the Paleozoic and Mesozoic, has created many fold structures and fault areas in the territory of Laos. Magmatic processes and Earth's crust deformation enabled arising of rich Cu mineralization. A prospective area for the occurrence of Cu, Ag and Au minerals is the folded region on Muang Xay, northern Laos. The main purpose of geological research of the Muang Xay area was the recognition of chemical and mineralogical composition of rock samples and the evaluation of the area of potential geological resources. During field reconnaissance in 2018, the rock samples were taken from an abandoned mine. It was concluded that primary rocks suffered intense Na-metasomatic processes, preserving primary copper sulphides – bornite, chalcocite and covellite. The content of Cu is up to 49.64% and Ag up to 119.5 ppm. As a result of metasomatism of igneous rocks, diorite or andesite types – albitite was formed. Albitite is composed of medium-grained albite, Mg-chlorite and Cu-carbonates. The prospective research shows that the Muang Xay region has a high potential of metalliferous deposits.

Key words: geological prospection, copper sulphides, Muang Xay folded belt, Na-metasomatism, Laos.

Abstrakt. Wydarzenia geotektoniczne na półwyspie Indochińskim, związane z orogenezą indochińską, na przełomie paleozoiku i mezozoiku, doprowadziły do powstania licznych struktur fałdowych oraz stref uskokowych na terenie Laosu. Procesy magmatyczne oraz deformacje skorupy ziemskiej umożliwiły powstanie bogatej mineralizacji miedzionośnej. Obszarem perspektywicznym występowania minerałów miedzi, srebra oraz złota jest region fałdowy Muang Xay na terenie północnego Laosu. Badania na górzystym obszarze Muang Xay przeprowadzono w celu określenia składu mineralnego oraz chemicznego skał, a także oceny perspektyw złożowych regionu. W czasie prac terenowych w 2018 r. opróbowano nieczynne wyrobiska górnicze. Ustalono, że skały pierwotne ulegały intensywnym procesom Na-metasomatozy z zachowaniem obecności pierwotnych siarczków miedzi – bornitu, chalkozynu, kowelinu. Zawartość Cu w badanych próbkach wynosi do 49,64%, natomiast Ag do 119,5 ppm. W wyniku procesów metasomatozy skał magmowych typu diorytu lub andezytu powstały albityty zbudowane ze średnioziarnistego albitu, magnezowego chlorytu oraz węglanów miedzi. Przeprowadzone badania prospekcyjne wskazują na wysoki potencjał złóż metalonośnych w regionie Muang Xay.

Słowa kluczowe: prospekcja geologiczna, siarczki miedzi, pas fałdowy Muang Xay, Na-metasomatoza, Laos.

INTRODUCTION

Lao People's Democratic Republic is the least recognized geologically country of South-East Asia. The long-lasting political and cultural isolation, absence of qualified research staff, and lack of funds for geological survey operation caused that only 55% of the country area has been covered with geological maps (Kyophilvong, 2009). Due to cooperation between the regional commission of UN-UN-ESCAP (*United Nations Economic and Social Commission for Asia and the Pacific*) and the Laotian Geological Survey, better coverage of the country area with geological maps is going to be done. The effects of undertaken prospective-research works in cooperation with Russia, France, Vietnam and Japan was the assignation and discovery of places where gold, copper and other mineral raw materials occur (Masa-

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haru, 2006). Copper and gold deposits are associated with the occurrence of 3 folded belts and created fracture zones, during subduction and accretion of terranes, between the late Permian and early Triassic. Copper-bearing mineralization is associated with two, so far discovered, types of deposits: porphyry-type Cu-Au and skarn Cu deposits. Porphyry Cu-bearing mineralization is related to Late Paleozoic granitoids (mainly tonalites with diorites), found in the Sukhothai belt, northern Laos. Skarn-type Cu deposits occur in areas of connection between magma bodies and carbonate rocks, mainly in the central part of the country. Copper ore resources in Laos are estimated at 10 million tons. Traces of rich Cu-mineralization with a stockwork form are related to Paleozoic-Mesozoic rocks altered by high intensity Na-metasomatism (Fong-Sam, 2014).

During field works, carried out in 2018 in the region of Muang Xay, an abandoned mine was examined and sampled (Fig. 1). An exploratory drift with no roof support was caved in a hillside and operated as artisanal mining up to the time of collapse. Examination of the sampled excavation indicated that it was operated for a short time (a few months) in 2017. In the explored hill, there are other drift-like constructions in similar condition and size. The main purpose of those constructions was prospection of primary gold deposits.

Fig. 1. Abandoned mine with marked sampling points: 1 (A002); 2 (C001); 3 (A001); 4 (D002) Photo by K. Zglinicki, 2018

Nieczynne wyrobisko górnicze z naniesionymi punktami poboru próbek: 1 (A002); 2 (C001); 3 (A001); 4 (D002). Fot. K. Zglinicki, 2018

Ten samples of metasomatized rocks from walls and top were collected. Analysis of the mineral and chemical composition was carried out.

GEOLOGICAL SETTINGS OF MUANG XAY REGION

Geological settings of the Laotian territory is very poorly recognized. The poor recognition is caused by high mountain rating, occurrence of hard-access places covered by protected, unspoilt monsoon forest, absence of qualified geologists and long isolation (Kyophilvong, 2009). Tectonostratigraphic history of the Indochina Peninsula is related to processes of subduction and accretion of terranes(?), derived from the Gondwana – Sibumasu island arc (acronym of China–Siam–Burma–Malaysia–Sumatra) with Indochina blocks, Qamdo-Simao and South China blocks (SCB) during closing of the Paleo-Thetys Ocean from the late Permian to early Triassic (Metcalfe, 2002; Searle *et al.*, 2012; Wang *et al.*, 2016). The effect of tectonic evolution, called the Indochina orogeny (Sone, Metcalfe, 2008), was the creation of the complex tectonic structure of northern Laos, represented by Simao, Sukhothai and Indochina blocks (terranes?). Tectonic boundaries between the block are faults and suture zones – Nan-Dien Bien Phu Suture Zone (NNE–SSW) and Thruong Son Belt, and Song Ma Suture (NW–SE). In Laos, there are many smaller fault zones separating individual lithological series (Wang *et al.*, 2017).

In the territory of northern Laos, there are geological formations aged from the Proterozoic to Quaternary (Fig. 2), where sediments of four main stratigraphic units dominate: early and late Paleozoic and early and late Mesozoic (Wang *et al.*, 2017). Sedimentation of clastic and carbonate sediments proceeded in the Muang Xay basin, paleogeographically connected with the Simao, Vientiane and Khorat basins. Early Paleozoic (Cambrian–Ordovician) rocks form a deep-marine, volcano-sedimentary sequence, metamorphosed in low pressure and low to medium temperature conditions (Wang *et al.*, 2016). Accumulation of those sediments proceeded in a deep basin created due to large-scale tectonic movement of the region. The late Paleozoic (Silurian–Devonian) sequence is represented by shallow-marine (shelf) deposits: sandstones, mudrocks and shales with intebeds of volcanic sediments. During Carboniferous sedimentation of shallow-marine fine-grained sandstones, carbonates with interbeds of coal and cherts were also deposited. Change of the tensional style from extensive to compressive in the northern part of the region was caused by subduction. It is contributed to the creation of granitoid intrusions and andesite volcanism at the turn of Late Carboniferous and Early Permian. In the early Mesozoic, in continental conditions (locally shallow-marine), sedimentation of red sandstones and conglomerates with thin inserts of coal took place. The late Paleozoic and early Mesozoic sedimentary series is separated from the late Mesozoic igneous series by two main fault zones: Nan-Dien

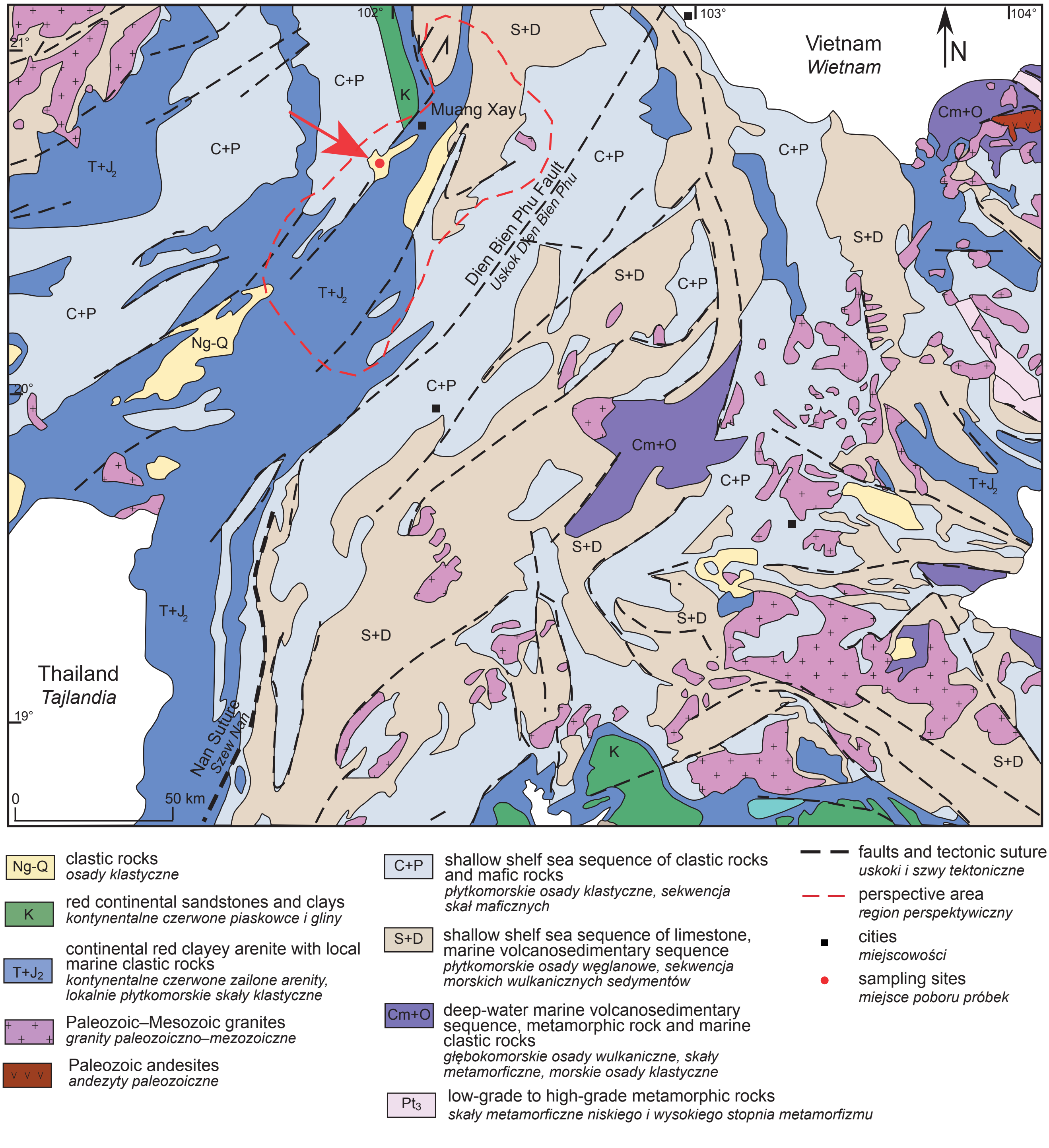

Fig. 2. Geological structure of northern Laos (after DGM, 1991; Wang *et al.*, 2016, modified)

Budowa geologiczna północnego Laosu (wg DGM, 1991; Wang i in., 2016, zmodyfikowana)

Bien Phu Suture Zone and Truong Son Belt. Igneous complexes evolved in the north-western part of Laos in the contact zone of a N–S granitoid range, in the Dien Bien Phu segment, in the Nan and Dien Bien Phu sutures, and along the north-western extension of the Truong Son range. Granitoid rocks from the Nan Suture are interpreted as syn-tectonic granitoids that formed during subduction of the Sibumasu block under the Indosinian block. The Troung Son granitoids are described as syn-tectonic or from forge? within plate granitoids, formed during subduction of the Indochinian block under the South China block (SCB). Sediment series of late Mesozoic sedimentary series was formed in land conditions and is represented by red sandstones with interbeds of claystones, mudstones, conglomerates and gypsum. Late Mesozoic sediments are limited mainly to the Vientiane basin and Muang Xay fold belt in northern Laos. Neogene–

Quaternary sediments are locally represented by sands and gravels, mainly of fluvial origin (Wang *et al.*, 2016; Wang *et al.*, 2017).

METHODOLOGY AND FIELD WORK RANGE

The research area is located in the mountainous province of Oudomxay, Muang Xay district, between 20°36'30" and 20°37'30'N, and 101°51'40" and 101°53'23"E" (Fig. 3). A closed excavation was found in a fault zone, on the south hillside at the elevation of 1104 m a.s.l. Driving from Muang Xay to the location takes about 1.5 hour. The Muang Xay region, in which is the excavation located, has been selected by the British Geological Survey (BSG) and the Laotian Geological Survey (PDR) as a potential place with copper and zinc ore deposits (DGM, 1991; Phommakaysone, 2012).

Samples were taken from an abandoned and collapsed drift (1.5 m in height, 1 m in width, 3 m in length). Before roof collapsing in 2017, the hillside was explored by local people. The goal of this exploration was probably the primary gold mineralization. Samples for laboratory analysis were taken from accessible sites from the walls and roof. The distance between sampling sites was about 10 to 15 cm. During fieldwork, 10 samples were collected, each weighs about 1 kg. These samples represent three types of rock: a) with no visible sulphide mineralization and lack of malachite-azurite zones, b) with sulphide impregnation and malachite-azurite zones (Fig. 3), c) with fragments of sulphide veins.

Fig. 3. Rock samples taken from an abandoned mine, with visible copper-bearing mineralization. Photo by K. Zglinicki, 2018

Próbki skał pobrane z nieczynnego wyrobiska górniczego z widoczną mineralizacją azurytem i malachitem. Fot. K. Zglinicki, 2018 r.

Microscopic observations with polarized light (reflected and transmitted), using LU Plan Fluor lenses (from ×2.5 to ×50), was carried out at the Faculty of Geology, University of Warsaw (petrographic microscope Nikon Eclipse E600 POL). Geochemical analysis of rocks was done in the ACME Labs certified laboratory in Vancouver, Canada. In order to determine main oxides and elements, LF300 and MA270 analytical programmes (www.acmelab.com) were used. The resulting solutions were analyzed using ICP-ES and MS. Due to high Cu content in samples (above the detection limit, 10%), AAS analysis (MA401 programme) and titration of Cu (GC820 programme) have been done. Microstructure observations of copper minerals were carried out using a scanning electron microscope ΣIGMA VP with two EDS detectors (SDD XFlash | 10) at the Faculty of Geology. Analysis was done with the acceleration voltage of 20 kV in high vacuum. Samples were sputtered with carbon.

Chemical composition of minerals was determined using an electron probe microanalyzer CAMECA SX-100 equipped with wave dispersion spectrometers. Analysis of sulphide minerals were conducted with the focused electron beam with the acceleration voltage of 15 kV and the current beam 10 nA. For the rest of minerals, the current beam was 20 nA. Spectrometers equipped with crystals (TAP, LIF, PET, LPET) were used to analyze the spectra of elements. The standards used in the Inter-Institute Analytical Complex for Minerals and Synthetic Substances of the University of Warsaw were applied for the research. Detection limits, reference materials and standard deviation are presented in Appendix 1 [3].

RESULTS OF ANALYSIS

PETROLOGY AND MINERALOGY

The rocks studied are brown-red to grey-white in colour. Massive rocks are characterized by fissility and numerous internal, diagonal fractures. Surface of the rocks is covered in 80% by copper carbonates (malachite and azurite). The rocks are cut by a 4-cm thick mineral vein, black to blue-violet in colour. Deep brown-red colour is due to occurrence of iron oxides, confirmed by microscope observations. The rocks poorly react with 10% acetic acid, when pulverised react strongly with 35% hydrochloric acid, tinging solution yellow. The residue forms mineral sludge, from grey to white in colour, and grain sze up to 0.5 mm.

[3] Appendix can be found in the online version of this article (https://biuletynpig.pl).

Based on microscope observations, the rocks contain albite. The size of crystals is up to 0.5 mm, with dominant crystals of up to 0.25 mm. Crystal creates two twinning types: multiple and polysynthetic. Albite is characterized by big porosity. A netting of larger and smaller veins is filled with malachite, azurite, calcite and chlorites. There are small agglomerations of quartz; malachite forms small columns and needles, creating radial concentrations in thicker veins. Malachite, together with Fe-oxides, surrounds the grains of Cu sulphides. Azurite forms platy and columnar crystals, filling single veins. Chlorites are represented by aggregates up to a few mm, usually with iron oxides. There are single crystals of rutile, titanite, apatite, garnet (grossular) and chrysocolla. The rocks contain primary copper sulphides, such as bornite, chalcocite, digenite and covellite (Tab. 1). Cu-mineralization shows impregnation and breccia-type texture, and an unsorted (porphyritic) and zonal texture. The rocks have been intensely altered by Na-metasomatism, which is shown by the granoblastic and porphyroblastic texture with no orientation. Albitization was accompanied by hydrothermal processes leading to the creation of secondary Cu-mineralization represented by malachite and azurite. The rocks have been classified as albitite.

COPPER SULPHIDES

Bornite (Fig. 4A, B) occurs as xenomorphic crystals up to 7 mm. They are pink-orange to lilac in colour, with no visible anisotropy. It forms paragenesis with chalcocite and covellite. Its optical relief is higher than that of the surrounding chalcocite, which replaces bornite. Between the bornite-

Table 1

Chemical composition of copper sulphides (wt%)

Skład chemiczny siarczków miedzi (% wag.)

Element	1	2	3	4	5	6	7	8	9	10	11	12	13	14
S	25.90	25.88	25.97	26.45	25.93	26.55	20.67	20.86	21.01	21.54	21.41	22.80	34.42	34.19
Cu	62.08	62.59	63.01	62.51	62.89	61.84	78.89	79.03	98.87	78.13	77.65	75.76	65.84	66.14
Fe	11.05	11.03	11.00	10.90	10.93	11.24	0.08	0.07	0.00	0.31	0.08	1.35	0.16	0.02
Co	0.00	0.00	0.00	0.00	0.06	0.00	0.04	0.01	0.00	0.00	0.03	0.00	0.00	0.00
Zn	0.04	0.04	0.06	0.06	0.01	0.00	0.02	0.00	0.06	0.04	0.27	0.13	0.00	0.00
Pb	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Se	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.04	0.00
Au	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag	0.11	0.09	0.18	0.05	0.11	0.02	0.00	0.02	0.27	0.04	0.06	0.22	0.21	0.25
Total	**99.20**	**99.67**	**100.24**	**99.99**	**100.02**	**99.67**	**99.72**	**100.00**	**100.24**	**100.10**	**99.93**	**100.27**	**100.69**	**100.66**

1–6 bornite; 7–10 chalcocite; 11–12 digenite; 13–14 covellite

Table 2

Chemical composition of samples

Skład chemiczny próbek skał

Oxide/Element	Unit	A001	A002	C001	D001	D002
SiO_2	wt%	52.21	56.10	39.60	40.91	10.91
Al_2O_3	wt%	18.59	18.14	11.86	11.86	3.63
Fe_2O_3	wt%	4.38	3.84	4.13	5.89	9.32
MgO	wt%	4.19	3.69	1.79	2.16	0.81
Na_2O	wt%	5.44	6.30	4.83	4.64	1.10
K_2O	wt%	0.73	0.47	0.19	0.14	0.07
TiO_2	wt%	0.76	0.79	0.60	0.64	0.23
P_2O_5	wt%	0.13	0.12	0.11	0.10	0.05
MnO	wt%	0.09	0.08	0.06	0.06	0.02
Cr_2O_3	wt%	0.007	0.008	0.003	0.006	<0.002
LOI	wt%	6.7	5.6	8.9	8.3	11.6
Total	**wt%**	**94.85**	**96.58**	**72.86**	**75.44**	**38.11**
Cu	wt%	4.12	2.69	24.15	21.69	49.64
Zn	ppm	120	99	54	117	29
Pb	ppm	15.3	12.4	114.1	28.7	26.6
Ni	ppm	26.1	24.9	11.3	9.1	4.3
Co	ppm	20	18	12	11	4
Mo	ppm	0.9	1.3	38.8	3.6	3.0
Ag	ppm	15.1	10.3	77.4	42.3	119.5
Se	ppm	<5	<5	10	26	71

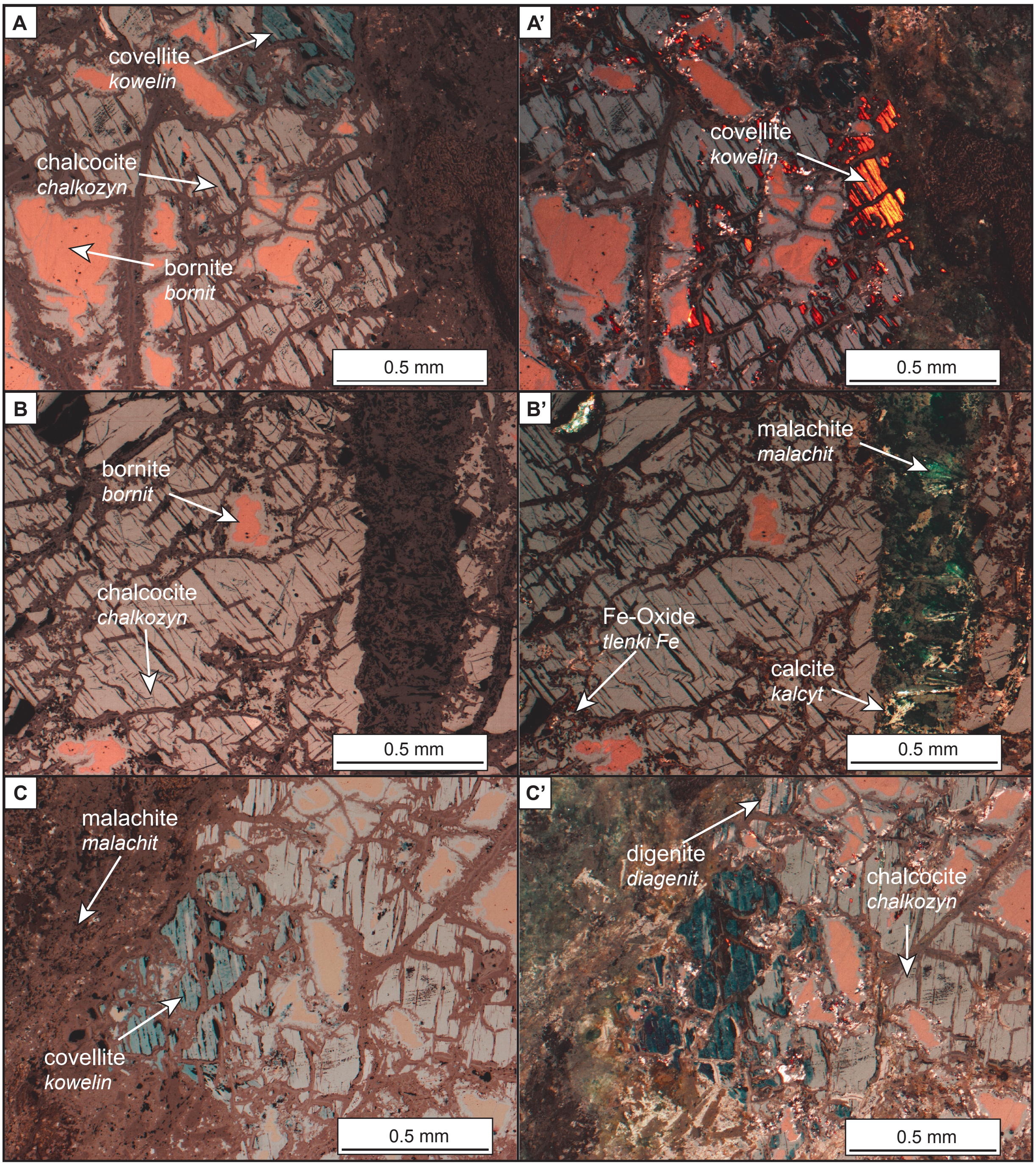

Fig. 4. Photomicrographs of thin-sections in reflected light, 1N and crossed nicols

Magnification ×5; (a) **A–A'** replacement of bornite by chalcocite; **B–B'** copper-bearing secondary mineralization; **C–C'** covelinization of chalcocite and digenite

Mikrofotografie płytek cienkich w świetle odbitym, 1N i nikole skrzyżowane

Powiększenie ×5; **A–A'** zastępowanie bornitu chalkozynem; **B–B'** wtórna mineralizacja miedzionośna; **C–C'** kowelinizacja chalkozynu i digenitu

chalcocite-covellite triplet, there is an irregular netting up to 2 mm in width, filled with aggregates of iron oxides and copper carbonates. Bornite usually contains (average) 62.77% Cu, 26.04% S, 11,30% Fe and smaller amounts of Ag, up to 0.18% (Tab. 1). There are no traces of Zn, Se, Au and Co.

Cu_2S-CuS group (Fig. 4A, B) is represented by chalcocite-digenite. Chalcocite crystals are represented by xenomorphic plates with characteristic furrows, irregularly creating intergrowths with digenite. The size of chalcocite-digenite crystals fluctuates between 0.1 and to 7 mm. Along cleavage surfaces, chalcocite and digenite undergo covellinization. Chalcocite usually contains (average) 78.91% Cu, 21.38% S and 0.16% Fe. Additions of Ag are up to 0.27%. Digenite contains (average) 77.27% Cu, 22.25% S and

1.35% Fe. The content of Ag is up to 0.26%. Co, Pb, Se and Au are below the detection limit.

Covellite (Fig. 4C) forms platy crystals up to 0.1 mm, replacing chalcocite, and creates lamellar structures intergrowing with chalcocite. It shows intensive red anisotropy. The chemical compositions is usually as follows: 65.99% Cu, 34.30% S, 0.09% Fe and 0.23% Ag. There are no significant amounts of Zn, Pb, Au and Se.

Malachite (Fig. 4B, C) and **azurite** form, in turn, intensely green and deep blue crystals. They fill veins with iron oxides and occur as column-, needle- and table-shaped crystals. There are no traces of Au in these minerals. Elements such as Pb, Se, Co and Ti are below the detection limit.

CHEMICAL COMPOSITION OF ROCK SAMPLES

The chemical analysis was conducted for rock samples: 1) without sulphide mineralization (samples A001-002); 2) with sulphide impregnation and a malachite-azurite zone (C001, D001); 3) with a sulphide vein (D002). Sum of oxides in rock samples is not 100%, which can be due to incomplete melting/fusion of minerals or oxides of each element.

Rocks with no visible sulphide mineralization consist of SiO_2 up to 56.10%, Al_2O_3 up to 18.59%, Na_2O up to 0.73%, and K_2O up to 0.73%. The Cu content is 4.12%, Zn up to 120 ppm, and Ag up to 15.1 ppm. Rocks of the second group have a smaller amount of main oxides: SiO_2 up to 40.91%, Al_2O_3 up to 11.86%, Na_2O up to 2.16%, and K_2O up to 0.14%. The copper content is up to 24.15%. There is also Zn (117 ppm) and Ag (77.4 ppm). Rocks with sulphide veins have the smallest amounts of main oxides: SiO_2 up to 10.91%, Al_2O_3 up to 3.63%, Na_2O up to 1.10%, and K_2O up to 0.07%. The copper content is up to 49.64%, while Zn is up to 29 ppm, and Ag up to 119.5 ppm. There are very small traces (ppm) of Pb, Ni, Co, Mo and Se.

DISCUSSION

PRIMARY ROCKS

The intensity of albitization caused the total absence of original texture of the rocks. At this stage of research, it is impossible to determine the characteristics of "primary rock". In all probability, metasomatic processes had altered intermediate igneous rocks, such as andesites or diorites of Carboniferous-Permian age (DGM, 1991), initially enriched with copper sulphides. In altered rocks, there are relict conglomerates of grains. The high content of CuO (up to 2%) in chlorites (App. 2) can be evidence for a previous high concentration of Cu and dissolution of rocks enriched with copper sulphides. The albitites contain single chalcocite grains surrounded by chrysocolla, which probably formed by dissolution of copper sulphides and plagioclases.

SODIUM METASOMATOSE OF ROCKS

Na-metasomatic process can occur in granitoids or mafic rocks and is controlled by solutions migrating through systems of veins and fractures (Engvik *et al.*, 2014). Albitization caused a change of primary minerals and chemical composition of rock. Intensive migration of fluids originated in dissolution of primary rocks triggered deformation of altered rocks. The effect of Na-metasomatose was the formation of albite $An_{1–3}$, $Ab_{97–99}$, $Or_{0–1}$ (App. 3). Dissolution of mafic Fe-enriched minerals caused the formation of Mg-chlorite and iron oxides filling veins of fractures. Hematite is responsible for the red colour of altered rocks. Dissolution of feldspars (plagioclases), confirmed by Norberg *et al.* (2011, 2014), leads to dissolution of Fe^{3+} and Ti, and to the formation of rutile and titanite. Moreover, the formation of rutile during metasomatic processes is associated with the limitation of Fe-Ti oxides in ilmenite (Austrheim *et al.*, 2008). It could be assumed that the pressure of infiltrating solutions caused by process of breccia-making and dissolution of primary sulphides. The result of infiltration was the fdevelopment of veins cutting the rocks, composed of needle- and column-shaped crystals of copper carbonates. Analogical process of changes by Na-metasomatose was observed in the Sveconorwegian Bamble Sector in southern Norway (Engvik *et al.*, 2014).

PROSPECTIVE VIEWS

Geological events related to subduction and accretion of terranes, which created the Indochina Peninsula, caused intense tectonic and magmatic activity in northern Laos. The effect of these events was the formation of many igneous bodies and fault & fold zones, which are associated with rich prospective Cu-mineralization in Laos. It is supposed that there are so far undiscovered igneous bodies and magma-sediment covers in the Muang Xay region. Rich stockwork Cu-mineralization in albitites can be a mark of pre-existing diorite/andesite rocks. It is assumed that Carboniferous-Permian rocks of the Muang Xay fold zone host primary copper deposits (porphyry type) related to andesite volcanism of subduction zones.

Additionally, metasomatic processes in "primary rock" can cause the formation of such deposits as apatite, rutile and hydrothermal pyrrhotite-apatite and magnetite-apatite (Engvik *et al.*, 2014). The British Geological Survey (BGS) and the Laotian Geological Survey (PDR) have stated the Muang Xay region as a potential place of copper and zinc deposits, without any source of metallogenic processes. The prospective area has been set down due to analysis of excavations and exposed rocks.

PROPOSED RESEARCH

High content of Cu in the samples shows high ore potential of the region. For better determination, detailed geological prospection with a geophysical gravimetric method, based on a change in the gravitational field, evaluation of the altered zone and dispersion of altered rocks, enriched in Cu-mineralization, carrying out of shallow drillings and measurements of bulk density of obtained cores, and sampling in a set of regular prospecting grid are necessary to be done. It is essential to determine the character of fluids causing metasomatic changes – for this purpose analysis of fluid inclusions and isotope analysis of Sr, S, O and Cu should be carried out among others. The analyses will make possible determination of metallogenic processes in the region and could define the direction of mineralization and metasomatic processes. Research can run a preparatory programme, aiming at discovery, identification and documentation of ore deposits in the Muang Xay region.

SUMMARY

The Muang Xay fold belt is a perspective region for copper-bearing mineralization in primary rocks (diorite or andesite). The studied rocks contain from 2.69 to more than 49.64% Cu. The following Cu-minerals were identified: bornite, chalcocite, covellite and malachite. Primary rocks with copper sulphides underwent an intense Na-metasomatism process. As a result of metamorphic transformation of rocks, medium-crystalline albite was formed accompanied by iron oxides, and magnesium chlorite enriched in copper and copper carbonates. Albitization was accompanied by hydrothermal processes leading to the formation of secondary copper-bearing mineralization, mainly carbonate. The rock was classified as albitite with a granoblastic, porphyroblastic structure and a random texture. The rock material requires further detailed analyses to determine the conditions of the metallogenic processes, and to determine the nature of the fluids and the primary rock.

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PODSUMOWANIE

Górzysty pas fałdowy Muang Xay stanowi perspektywiczny region występowania bogatej mineralizacji miedzionośnej w skałach pierwotnych (dioryty/andezyty). Na podstawie przeprowadzonych badań ustalono, że skały zawierają od 2,69 do ponad 49,64% miedzi. Zidentyfikowano następujące minerały miedzionośne: bornit, chalkozyn, kowelin i malachit. Skały pierwotne z siarczkami miedzi były poddane intensywnym procesom Na-metasomatozy. W wyniku przemian metamorficznych skał powstał średniokrystaliczny albit, któremu towarzyszą tlenki żelaza, magnezowy chloryt wzbogacony w miedź oraz węglany miedzi. Albityzacji towarzyszyły procesy hydrotermalne, prowadzące do powstania wtórnej mineralizacji miedzionośnej, głównie węglanowej. Skałę sklasyfikowano jako albityt o strukturze granoblastycznej, porfiroblastycznej i teksturze bezładnej. Materiał skalny wymaga wykonania dalszych szczegółowych analiz, w celu ustalenia zachodzących procesów metalogenezy, określenia charakteru fluidów oraz skały pierwotnej.