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Distribution of Cu, As and Pb at the Phayaung Taung Gold Mine and their Environmental Assessment for Soil and Water

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Abstract

Phayaung Taung area is mainly composed of metasedimentary rocks such as phyllite, schist and quartzite of Precambrian age. Gold mineralization is associated with the gangue and ore minerals such as minerals, quartz Pyrite, Chalcopyrite, Azurite Hematite, and Goethite. X-ray Fluorescence (XRF) result suggests that SiO_2 (52.18 to 99.62 wt%), Al_2O_3 (0.44 to 27.28 wt%), and Fe_2O_3(1.0 to 8.65 wt%) consisted in the gold ore sample. Arsenic (As), Copper (Cu), and Lead (Pb) concentrations of ore samples were increased while Al and Fe concentrations were increased. As well as Arsenic concentrations of gold ore and grab samples are high in quartzite samples and low in phyllite and showing that a good relationship with their lead concentrations. . The As, Cu and Pb content were assessed by laboratory tests and found to be slightly above the standard content near the Gold Mine area and below the standard content when away from the area. Therefore, concerning the area of Phayaung taung Gold Mine that our research indicates; (a) Arsenic, Cu, and Pb are associated with gold ores in quartzite rock, (b) Soil samples obtained 1km away from the mining site are rich in As, Cu, and Pb, (c) the pH of the leachate of these soils show neutral to alkaline and it suggested these soils will not be caused acidic by mining activities. (The soil at the mining lease and its surrounding the mining area will not be acidic by mining activities in the current study because the result of pH from the leachate of these soil from natural to alkaline.), (d) Hydrothermal alteration characterized by muscovite formation is associated with As, Cu, and Pb, (e) clay and ferrihydrite -$(Fe^{3+})_2O_3 \cdot 0.5H_2O$ have been shown to form as adsorbent as As, Cu and Pb were formed by sedimentation and could not affect to water and soil.

Key Words: *Phayaung Taung, arsenic, copper, lead, Myanmar*

ဖယောင်းတောင်ရွှေသတ္တုတွင်း၌ ကြေးနီ၊အာဆင်းနစ်နှင့်ခဲပျံ့နှံ့မှုတို့အားလေ့လာခြင်းနှင့် ၎င်းတို့၏မြေဆီလွှာနှင့်ရေတို့တွင် ပတ်ဝန်းကျင်းထိခိုက်မှုရှိ/မရှိ အကဲဖြတ်ဆန်းစစ်ခြင်း

ကျော်ဇောထွန်း၊ ဘူမိဗေဒအရာရှိ
သတ္တုတွင်းဦးစီးဌာန

စာတမ်းအကျဉ်း

ဖယောင်းတောင်ရွှေသတ္တုတွင်းသည် မိုးကုတ်အသွင်ပြောင်းရပ်ဝန်း၊ Precambrian သက်တမ်းရှိသော Phyllite၊ Schist၊ Quartzite ကဲ့သို့သောအသွင်ပြောင်းကျောက်များဖြင့် ဖွဲ့စည်းထားသည့် ဒေသရပ်ဝန်း ဖြစ်ပါသည်။ ရွှေသတ္တုအား သလင်းကြောများအတွင်း Pyrite၊ Chalcopyrite၊ Azurite Hematite နှင့် Goethite တို့ဖြင့်တွဲ၍ ဖြစ်ထွန်း ကြောင်း တွေ့ရှိရပါ သည်။ XRF များ ဖြင့်စမ်းသပ်တိုင်းတာချက်အရ သတ္တုပါဝင်သော ကျောက်များ တွင် SiO_2 (52.18 to 99.62 wt%), Al_2O_3 (0.44 to 27.28 wt%)andFe_2O_3(1.0to8.65 wt%) တွေ့ရှိရပြီး Aluminum(Al)နှင့် Iron(Fe) များလျှင် As၊ Pb နှင့် Cu တို့ပါဝင်နှုန်းတိုး လာပါ သည်။ ထို့အတူ Quartzite ကျောက်နှင့် Phylliteများတွင် As ပါဝင်နှုန်း နှိုင်းယှဉ် ရာတွင် Quartzite ကျောက်တွင်ပိုမိုပါဝင်ပြီး Phyllite များတွင် နည်းပါးစွာပါဝင် ပါကြောင်း နှင့် As ပါဝင်မှုများလျှင် Pb ပါဝင်မှုလည်း များပြားပါသည်။ As၊ Pb နှင့် Cu တို့ပါဝင်မှုများကို ဓာတ်ခွဲ စမ်းသပ်ချက်အရ အကဲဖြတ်ရာ ဖယောင်းတောင် ရွှေသတ္တုတွင်း ဧရိယာအနီးတွင် သတ်မှတ်စံနှုန်းထက် အနည်းငယ် ကျော်လွန်ပါဝင်နေပြီး ဧရိယာနှင့် ဝေးသွားသည့် အချိန်တွင် သတ်မှတ် စံနှုန်း ထက် လျော့နည်းလာသည်ကို လေ့လာ တွေ့ရှိရပါသည်။ သို့ဖြစ်ပါ၍ မိမိသုတေသန ပြုလုပ်ခဲ့ သည့် ဖယောင်းတောင်ရွှေသတ္တုတွင်း ဧရိယာနှင့် စပ်လျဉ်း ၍ ရွှေပါဝင်သည့် Quartzite ကျောက်များနှင့် တွဲ၍ As ၊ Pb နှင့် Cu တွေ့ရှိရပါကြောင်း၊ မြေနမူနာတွင် (၁)ကီလိုမီတာ အဝေးထိ As၊ Pb နှင့် Cu တွေ့ရှိ ရသော်လည်း pH level neutral to alkaline ဖြစ်နေပြီး ac-id အခြေအနေသို့ ပြောင်းလဲ သွားခြင်း မရှိပါကြောင်း၊ As၊ Pb နှင့် Cu တို့သည် ဘူမိဗေဒ Hy-drothermal alteration သဘောတရားအရ လချေးဖြူ (muscovite) တို့ဖြင့် တွဲဖက် ပါ ဝင်နေခြင်းနှင့် မြေစေး(Clay)နှင့် ferrihydrite –$(Fe^{3+})_2O_3 \bullet 0.5H_2O$ တို့သည် As, Cu နှင့် Pb တို့အား အနည်ကျ စုပ်ယူဖွဲ့စည်းထားသကဲ့သို့ ဖြစ်နေသဖြင့် ရေနှင့် မြေဆီလွှာအား ထိခိုက်မှုမရှိပါ ကြောင်း လေ့လာတွေ့ရှိ ခဲ့ရပါသည်။

Content

1. Introduction

Myanmar is included as one of the countries which are rich in mineral resources and occurrences in the world. The Phayaung Taung goldmine is one of the largest-scale gold mines in Myanmar. In the study area, Phayaung Taung gold deposits formed within (MMB) the Mogok metamorphic belt (Win, Enami and Kato, 2016). The study area is geologically located between the Shan scarp to the east and the Sagaing strike-slip fault to the west. Shan scarp region is mainly composed of the fossiliferous plateau limestone group (age: Cambrian to Cretaceous); Sandstone Mud and stones formed as gold (Cenozoic sediments). A major strike-slip fault (Sagaing Fault) was observed within the Central Myanmar region where younger rock units such as sandstone, mudstone, shale (Cenozoic sediments), and some basalt. Fault criteria of Sagaing Fault system can occur in that place (Robinson *et al.*, 2014). The igneous activity, plutonic intrusive bodies are observed at north-northwestern parts of the study area. Rich ore shoots occur only at the axial portion of synclinal and anticlinal drag fold in Kinn Sandy phyllite occurring at the central part of the Main worksite. The Department of Geological and Mineral Exploration (DGSE) explored geophysical survey, geological mapping, trenching, pitting, drilling, and finally tonnage calculation in 1984. The total ore reserves and grade of Phayaung Taung gold deposit is estimated as 3.7 Mt at 4 g/t. In 1996, No.2 Mining enterprise with joint venture Sun Cheoung Co ltd carried out limited exploration and assessment drilling. After that in 1997, No.2 Mining Enterprise enters is changed to another joint venture with Myanmar Golden Point family Co., Ltd, a private national company that still operates the mines until now. Following years saw the extension of the underground workings with the mine shaft and open-pit also reaching a maximum depth of about 84 meters at various levels. These mining activities, that would have exposed sulfide minerals to the atmosphere as well as create soil and slag heaps, may have the potential to cause metal contamination in the surrounding area as these minerals break down and disperse.

There are several direct or indirect ways to pollute the environment by natural means such as weathering and human activities such as mining and metal refining, fuel and energy production, iron and steel production, aerospace industries, and other reasons (Kumari *et al.*, 2016). Toxic metals, which are widespread in nature, are used in industrial wastes, for example, arsenic reduces the amount of oxygen and hydrogen oxide, so it can be released into groundwater by oxidizing arsenic or its effects from groundwater. In Australia, there are examples of massive environmental damage caused by mining-related melting (Lottermoser, Ashley, and Lawie, 1999). In the past, the mining and smelting of pyrite-chalcopyrite-sphalerite caused pollution by acid mine drains (Lottermoser, Ashley and Lawie, 1999). Currently, mining in Myanmar poses a threat to the environment. In my research, Mandalay Region; Whether the soil in the residential area of Phayaung Taung gold mining is polluted or non-polluted. First, the focus of the main process was on whether the original ore ores and untethered contained toxic minerals and whether they could be harmful to the environment. Gold ores occur under the Chaungmagyi group (phyllite, schist, quartzite of the Precambrian period). Mine ore are mainly included chalcopyrite, hematite, pyrite and bornite, azurite-malachite, and a few bismuths. Gold is associated with intermediate minerals such as hematite, malachite, and scorodite. Pb, Fe, Cu, and mineral wastes are going to rivers and streams near the mining site, damaging water and soil. The land's sloppy topography shows that metal contamination from the mine site can be easily transported to a nearby stream. Geochemical status and distribution of trace metals can be predicted through potential mineralization methods; Metal stages directly or indirectly. We can decide whether the direct method involves XRD and SEM to calculate the mineral components. Similarly, the purpose of this research is to examine and detect metal contamination determined by XRF. Soils were measured with ICP-MS to determine the presence of toxic minerals along with the water in the creek near the mine.

2. Objectives of Research

The study aims to the mechanisms of contamination by metal discharges from point pollution sources (ore, country rocks, waste dumps), estimate to the extent of contamination with sediments and soils. This study's main objectives are: To understand geologic processes during gold mineralization concerning structural conditions and alteration patterns of ore bodies. The overall purpose of this research is to provide a full geochemical analysis and to illustrate the findings through spatial distribution in the region to distinguish what areas are potentially at risk.

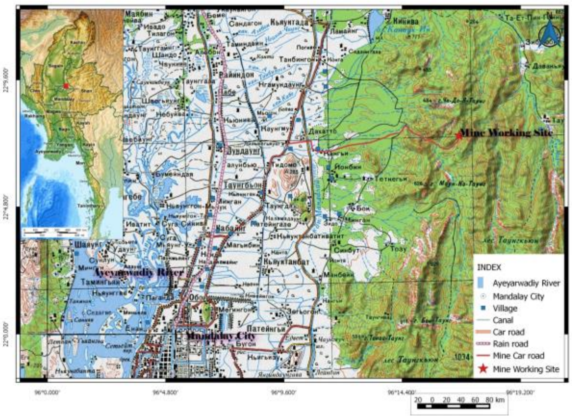


Fig. 1 Location map of study area, Phayaung Taung gold deposit

3. Material and Method

(1) Site and Sampling

The study area, Phayaung Taung, is situated in Mandalay region, about 32 km northeast of Mandalay city in Central Myanmar between North latitude N 22° 07' to 22° 11' and East longitude E 96° 12' to 96° 17', in UTM zone 47 Q. It lies about 8.0km due east of Dahattatw village which is a 19km junction from Mandalay to Mogok main car road **Fig 1**. Phayaung Taung area is accessible by an all-weather motor road. Geological data were recorded during the fieldwork; Systematic samples include thirty-one samples, were collected from Mines work site such as (7) ore, (12) Grab, and 12 Waste. **Fig.2(a)** As well as (14) soil samples were collected from the lower part of Kimun Chaung **Fig.2(b)**.

(2) Analytical Methods for Rock samples

Whole-rock geochemical composition trace elements were examined by using X-ray fluorescence (ED XRF) spectrometer SHIMADZU EDX-7000 and major elements were used WDXRF spectrometer Rigaku Supermini-200. Rigaku MiniFlex-2 X-ray diffract meter (XRD) analysis was used to determine the chemical composition of minerals. To confirm the chemical constituents of high concentration samples, used scanning electron microscope(SEM)JEOL JSM-6700F. **Fig.3(a)**

(3) Analytical Methods for Soil samples

Soil samples were air-dried and separated grain sizes and grind the soil mass and agglomerates except for small and medium gravels. After grinding, samples were sieved through a non-metallic 2 mm eye sieve. Then, soil samples were mixed with 40 ml of deionized water and 4.0 g of soil using the shaking table for about 2 hours to understand the leachability of the metal. After this, a 15ml solution water sample was filtered with a Millipore Millex-HP 0.45 μm filter. After this step, the sample was tested with inductively coupled plasma-mass spectrometry (ICP-MS) **Fig.3(b)**.

4. Result

(1) Mineralogical Characteristics of rocks

The dried samples were examined under a Scanning Electron Microscope (SEM) and the spectrum of quartz (black in Fig.4) the proportion of major elements (S, Si, Al, Fe, and P) and minor elements (As, Cu, Pb, Au, Cd, and Se) in this figure. Energy dispersive spectroscopy is used to recognize every selected mineral in a sample by each element. The X-ray diffraction (XRD) result shows that the mineralogy of crystalline compounds in rocks Quartz is the most abundant having the highest peak. Other could be defined such as a metamorphosed ultramafic rock within nickel-iron arsenide mineral (Oregonite-Ni_2FeAs_2), weathered hydrothermal oxidized lead ore Plattnerite (PbO_2), and gold indicator mineral is an iron sulfide Pyrite (FeS_2). The trace secondary minerals (Parasibirskite-$Ca_2B_2O_5 . H_2O$), a tourmaline group mineral (Schorl-$NaF_3Al_6(BO_3)_3$ Si_6 $O_{18}(OH)_4$), Muscovite $KAl_2(Si_3Al(O_{10}(OHF)_2$ and other clay minerals of Aluminosilicates (e.g. Kaolinite) are found in phyllite sample.

Minerals were defined on the XRD diffractogram at d-specific such as Oregonite

2.314 Å, 2.119 Å, and 1.991Å, Plattnerite 3.5 Å, 2.8 Å, and 1.856 Å, and 1.51 Å, while pyrite is defined at d-spacing 2.709Å, 2.423 Å, and 1.633Å **Fig.5**.

(2) Geochemistry

According to the investigation of rock geochemistry by using XRF analysis, the major elements used of WD XRF (Table. 1). As a result of WD XRF data characterized by the wide range of SiO_2 (52.18 to 99.62 wt %), Al_2O_3

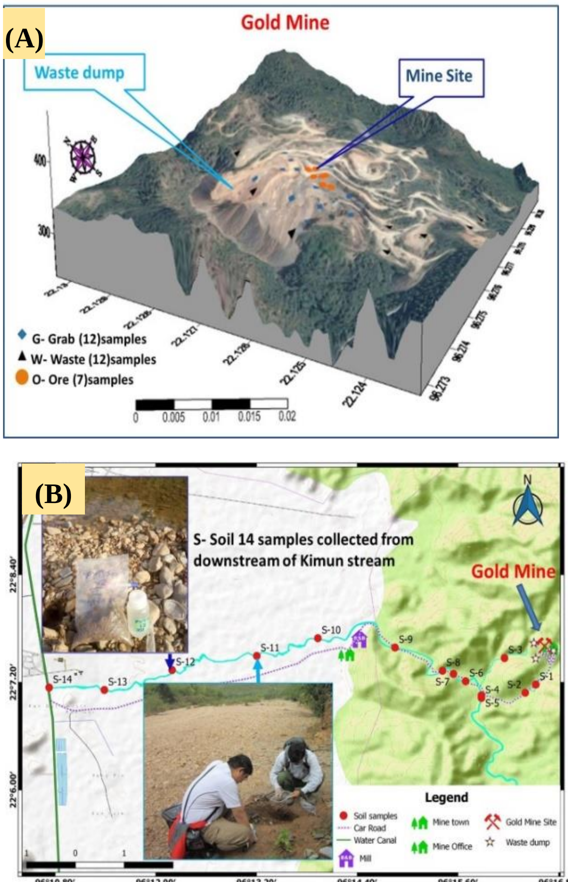


Fig.2 Location Map of Sampling Sites

(0.44 to 27.27 wt %) and TiO_2, K_2O, Al_2O_3, and Fe_2O_3 contents (Table. 1). Quartz range is high in quartzite samples PYT-2, PYT-4, PYT-5, and PYT-6 and very low amount in phyllite samples PYT-1 and PYT-3 contents **Fig.6**. Based on the XRF, the arsenic content is higher in the quartzite sample type. It also has a good correlation with phosphorus and lead. As the content of Al and Fe in ore samples increases, As, Contains more Cu and Pb. Quartzite, schist, and phyllite are three types of ores. The quartzite sample is highly correlated with other elements. The higher the Fe_2O_3 content, the higher the content of other elements **Fig.7**.

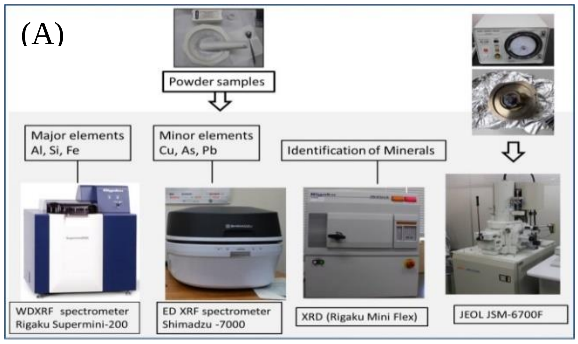


Fig.3(a) Analytical method for rock samples

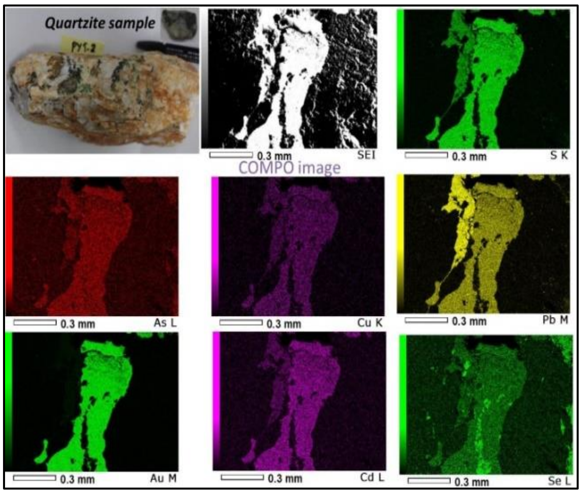


Fig.4 SEM result for quartz samples

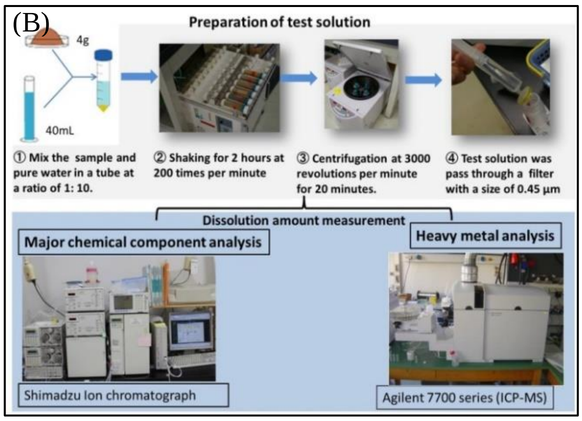


Fig.3(b) Analytical method for rock samples

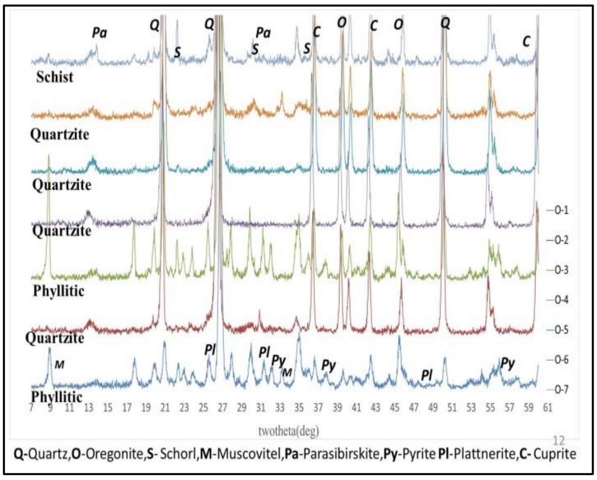


Fig.5 XRD result for quartz, Phyllitic and Schist samples

5. Discussion

(1) Chemical Weathering

The study found that muscovite-illite path along the Al-K axis and high Al content. Al's high concentration was found to be associated with aluminosilicate fragments (Khider and McQueen, 2005). Since the CIA has a value of 70 (Figure 8 for the medium to high CIA), it indicates medium to deep weather conditions. The path leading to illite differs from the standard meteorological line similar to Al-Ca + Na (Nesbitt and Young, 1982) due to the syn- or post-depositional K-enrichment in the muddy parts. (Fedo, Nesbitt and Young, 2016) As a result, climate change affected rock samples, such as metasomatism / regional metamorphism **Fig.8**. That's why, alteration modes observed as silicification, chloritization, sericitization, and alteration of clay materials are playing a large role in the adsorption of Pb, As and Cu.

Table.1 XRF result of host rock ore samples

%	PYT-1	PYT-2	PYT-3	PYT-4	PYT-5	PYT-6	PYT-7
Na_2O_3	0.53	0.18	0.37	0.12	0.09	0.31	0.36
MgO	1.14	0.28	0.61	0.11	0.14	0.37	0.77
Al_2O_3	27.27	6.3	22.9	0.44	1.41	14.2	9.43
SiO_2	52.18	89.91	61.91	99.62	97.53	68.79	84.71
K_2O	7.05	0.79	6.13	0	0.25	1.29	0.77
P_2O_5	0.04	0.09	0.01	0.01	0.02	0.23	0.08
CaO	0	0.28	0	0.21	0.27	0.38	0.29
TiO_2	1.14	0.11	1.27	0	0.02	0.12	0.33
MnO	0.02	0.02	0.12	0.02	0.16	0.04	0.09
Fe_2O_3	8.65	1.12	3.19	0	0	7.46	2.84
Total	**98**	**99.07**	**96.49**	**99.8**	**99.87**	**93.2**	**99.68**

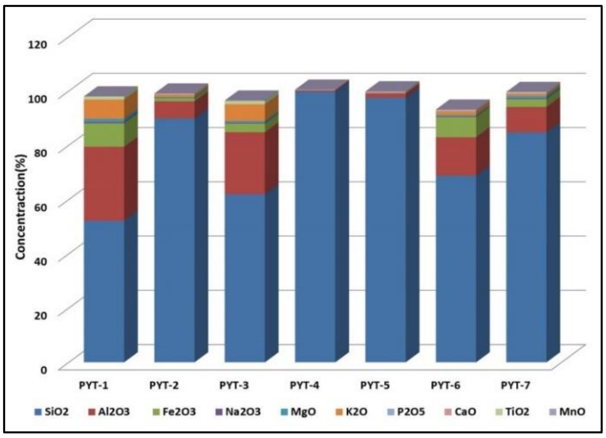


Fig.6 WD XRF major elements concentration of host rock ore samples

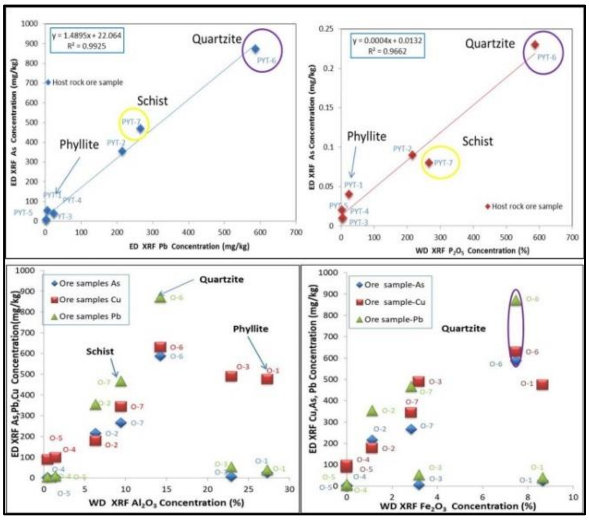
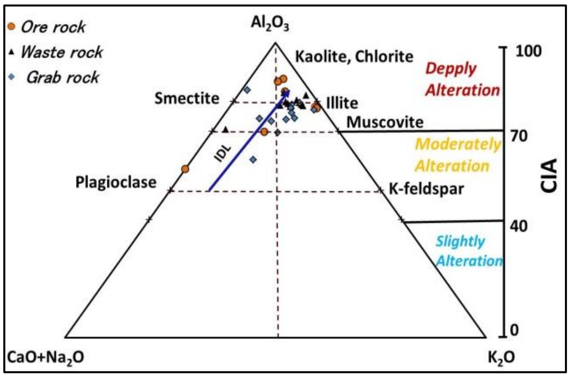


Fig.7 Correlation between WD XRF results performed on host rock ore samples



CIA-chemical index of alteration, IDL- Ideal weathering Line (*Kamal Khider.2005)*

Fig.8 Al2O3, CaO+Na2O, K2O plot showing the paleo weathering trend (IDL- Ideal weathering Line) of host rocks

(2) Discussion and interpretations of rock samples

The metal content of As as measured by XRF shows higher concentrations (7 mg/kg), especially in quartzite rock PYT -6, the almost high outline of ore body sample Grab-11 and Grab-12 (<5 mg/kg) **Fig.9**. On the top of the waste dump site, Waste samples are high rage >7 mg/kg. Large concentrations of Pb were found in the host rock ore samples and waste rock samples < 5mg/kg **Fig.9**. Concentrations of Pb and As were higher in the Central and Intermediate zones. Everything rock sample mostly higher concentrations of Cu >20mg/kg **Fig.10**. Due to these large concentrations are likely to hold the highest potential for metal distribution.

(3) Discussion and interpretations of Soil samples

Sulfide minerals at the surface that exposed to the atmosphere tend to become oxidized or break down, releasing metals into groundwater. Oxidation of these minerals is commonly sulfuric acid from pyrite's breakdown as shown in (Eqn 1). During this (Eqn 1) and (Eqn 2), oxidation is slow and takes time for reaction. But in (Eqn 3) iron (III) ion ("ferric iron") when oxidizing, it may take so quickly.

$$2FeS_2 + 7O_2 + 2H_2 \rightleftharpoons 2Fe^{2+} + 4SO_4^{2-} + 4H^+ \text{(Eqn 1)}$$

$$4Fe^{2+} + O_2 + 4H^+ \rightleftharpoons 4Fe^{3+} + 2H_2O \qquad \text{(Eqn 2)}$$

The iron (III) ion ("ferric iron") can also oxidize pyrite:

$$FeS_2(s) + 14Fe^{3+} + 8H_2O \rightleftharpoons 15Fe^{2+}(aq) + 2SO_4^{2-}(aq) + 16H^+ \text{(Eqn 3)}$$

In the research area, pyrite, chalcopyrite, and intermediate iron are associated with quartz. If the oxidation state is in contact with O_2 in the atmosphere (at low pH) and high SO_4 and Fe content (Eqn-1) (Eqn-3), it may cause. On the other hand, the behavior for the effluent of my soil sample is at pH (6.7 to 8.4). These solutions dissolve the acid and reduce the toxins produced by sulfide oxidation. In fact, the effluents collected from these samples are not as decisive as AMD's. The effluent output indicates ferrihydrite (Fe $(OH)_3$). The absence of Fe in ferrihydrite precipitation at pH can explain the absence of Fe and ferrihydrite precipitation with low toxicity.

(3.1) Investigation Levels of ICP MS analysis of leachates samples

The result of the leaching tests by ICP-MS is presented in (Fig 11). A number of 11 samples are indicating leachable values higher than the acceptable concentration for As in soil guidelines values. This ICP-MS result was recorded maximum concentration of 0.136 mg/L **Fig.11(a)**. However, the water leaching test of ICPMS showed the lowest values Pb and it is higher than the acceptable concentration; only two points Pb-0.051 mg/L **Fig.11(b)** recovered. Similarly, soil sample Cu also had the highest concentration is only one-point Cu-0.165 mg/L **Fig-11(c)**. Therefore, from the soil leaching tests carried out near the source of mine worksite and mine mill, they had recovered the highest concentration of (As). According to the ICPMS result As, Cu and Pb concentration from soil was suggested that were gradually decreased when far away from Mining Site.

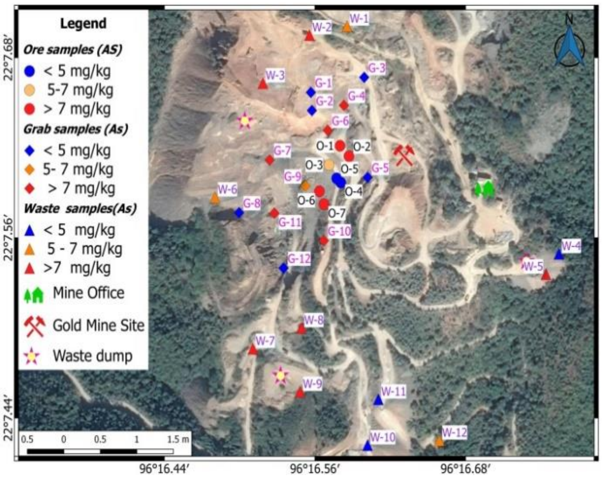


Fig.8 X-ray Fluorescence Analysis for (As)

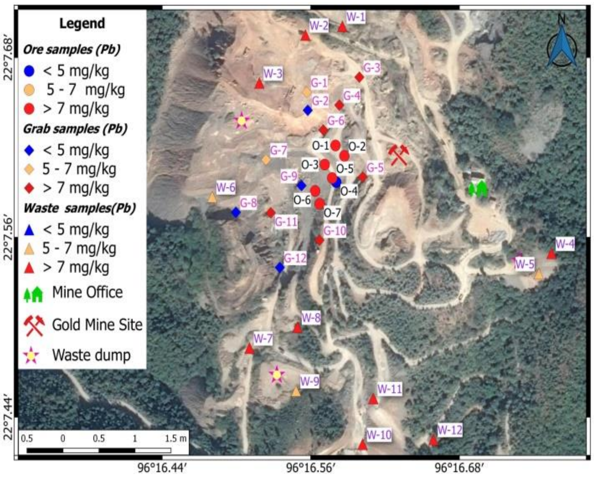


Fig.9 X-ray Fluorescence Analysis for (Pb)

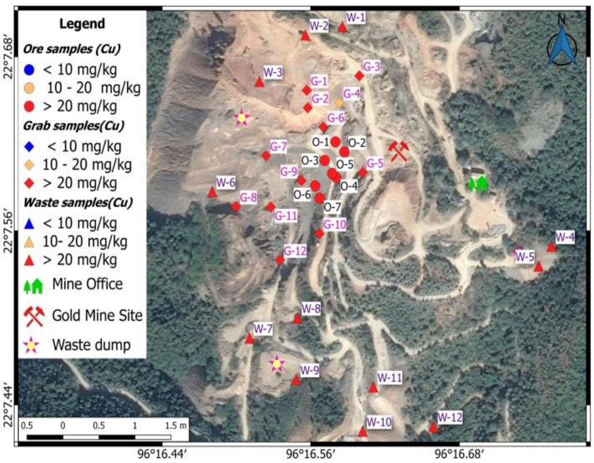


Fig.10 X-ray Fluorescence Analysis for (Cu)

(3.1) Transportation and accumulation

According to the result of Arsenic As, Cu and Pb concentration were gradually decreased when the location where is far away from the working site. Transported elements or minerals from ordinary rock of mine work site to stream channel were exposed to mountains' base due to fast flowing. On a flat plain at slows flow stages, minerals are down by accumulation **Fig.12**.

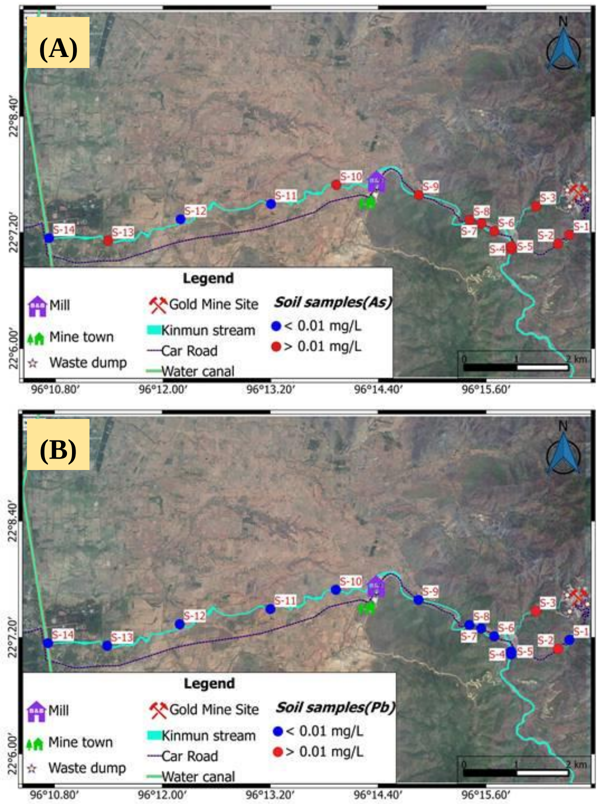


Fig. 11 (a) As and (b) Pb Classified post map showing soil samples ICP-MS analysis.

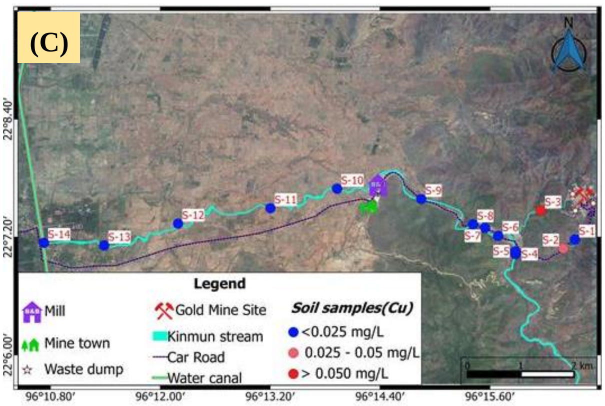


Fig. 11 (c) Cu Classified post map showing soil samples ICP-MS analysis.

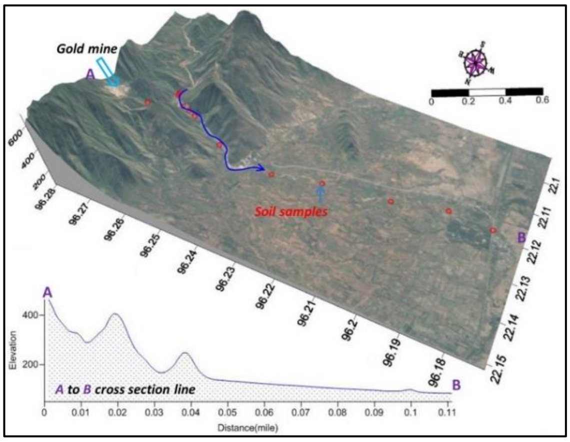


Fig. 12 The sloppy topography and water flow direction of the study area

6. Conclusions

Phayaung Taung Mining Gold is mainly associated with sulfides (chalcopyrite, pyrite) and bismuthite in quartzite and phyllite rocks. Soils obtained within 1 km of the mining site were found the contents of As, Cu, and Pb. Hematite is often associated with As, Pb, and Cu, whether ferrihydrite (Fe $(OH)_3$) is due to precipitation at the site or as a substitute for sulfides.

Ferrihydrite and clay seem to be important in controlling the movement of many elements. This study area indicates an increase in metal transport, depending on the degree of control of ferrihydrite (Fe $(OH)_3$). The Kimun Chaung stream soil samples overall, pH scale showing neutral to alkaline and It does not produce acid. It is important to consider that these processes can occur at slow precipitation at the Kimun Chaung stream than at the mine site area.

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