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Characterization of gold ore from Tanggamus mine Lampung Province

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Abstract. The present paper reports the characterization of gold ore from Tanggamus mine Lampung Province by chemical and geological analysis. The presence high content of Fe and S indicated that the ore is sulfides which is form as pyrite crystal confirmed by XRD and SEM analysis. Au trace element detected by fire assay and wet analysis comprises of 4 ppm in an amount. It is not yet clear that the existence of Au with minor of amount, merely the possibility Au associated with pyrite or quartz matrices as micro inclusion. The gold ore is classified as refractory ore.

1. Introduction

The Tanggamus gold ore deposit is located on the southern tip of the island of Sumatra direct in west from Bandar Lampung, which consists mainly of the volcano-sedimentary rock unit. Hulu simpang formation rocks show that the mineralogical composition of rocks varies from acid to base while alteration processes are characterized by crystallization of chlorite, carbonate (epidemic), epidote, silica, and clay mineral groups and associated with metal mineral deposits such as pyrite, chalcopyrite, sphalerite, magnetite, galena, tetrahidrite and gold [1,2]. The reserves of Tanggamus ore are estimated about 605.927 Mt [3].

In general, gold ores can be classified as free gold, free milling and refractory, depending on the response to cyanide leaching [4,5]. The illustrative-drawing can be seen in Figure 1. The types of free gold and free milling are also classified as "visible gold" that can be seen directly or through the milling process ahead. Gold refractory is also classified as "invisible gold, but this definition includes a native gold type found in micro-inclusions in sulfide or oxide crystals that are not detected by conventional microscopy techniques [6]. Lack of knowledge about the characteristics of gold ores will be causing optimum recovery not fulfilled.



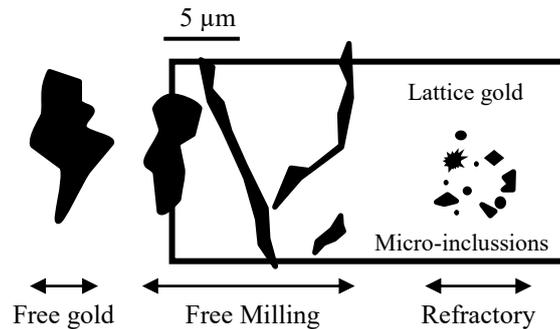


Figure 1. The illustrative drawing of the difference types of Au associated with oxides or sulfides

Nowadays, most gold are recovering by cyanidation at industrial scale and amalgamation at artisanal/small miner. Other processes proposed including halogenation e.g. bromination and iodination; chlorination; thio-ligan complexation [7] etc. could be an alternative, although the economic value still needs to be studied. When found in electrum (AuAg, conc. Ag>18%) or native form (AuAg; conc. Ag 8-13%) is usually easy after sufficient ore comminution. The presence of gold in other forms such as Au is contained within sulfides crystal, commonly pyrite (FeS_2), arsenopyrite (FeAsS) and galena (PbS) often describe as refractories ore.

Efforts to characterize gold ores are influential not only for geology but also for economics. Analysis methods for "trace metals" that contribute data on concentration, homogeneousness, mineralogy and distribution between crystals will be very interesting to study as a fundament for assessing the use of beneficence concentration and extraction methods. The aim of this subject was to approach, cautiously and comprehensive of gold ore in chemical and mineralogical characterizations pairing several analytical techniques in order to guidance to an enrich proficiency of their properties. The preliminary research will be proposed to next gold processing process method.

2. Materials and Methods

2.1. Materials

50 kg of gold ore was carried from mine located in Lengbukai, West Kelumbayan, Tanggamus Regency, Lampung Province. Gold ores were crushed and ground by jaw crusher and ball mill. The chemical analysis was carried out using high-performance spectrometry X-ray Fluorescence (XRF, PANalytical Epsilon 3 XLE with Rh anode material and Si-drif detector (>135eV@5.9 keV)), wet chemical analysis using Atomic Absorption Spectrometer (AAS, Shimadzu type AA-7000 Japan), and Induced Couple Plasma – Optical Emission Spectrometer (ICP-OES, Agilent 5100) for Au, Pd, Pt elements after fire assay and digestion in aqua regia. The X-ray Diffraction (XRD) was performed on PANalytical X'Pert3 Powder, with following conditions of operation: radiation Cu $K\alpha$ (20 mA, 40 kV); goniometer speed of 0.05° 2θ per step with 29.8450 seconds per step of counting time and collected $10 - 79.9^\circ$ 2θ . The interpretation using X'pert High Score Plus (HSP) with ICDD PDF2 and PAN-ICSD database. The studies for finding of the chemical composition, grain size, mineralogical association and liberation assortment was performed with inverted optical microscope Nikon type Eclipse MA 100 and Scanning Electron Microscope (SEM) Phenom World type Phenom ProX with CeB6 cathode.

2.2. Methods

The collected ores were crushed to reduce particle size below $4000 \mu\text{m}$. After crushing, the ore was divided using riffle splitter into two part samples. One part of the sample was ground in order to allow better study with respect to liberation. After grinding, the sample was divided using the coning quartering method into 2 small parts. The sampling method was carried out in Duplo method to ensure

the homogeneous sample. Further, one of the small parts of the sample was dried at 120° C for 24 hours in order to divest the water on the ore surface. The dried sample was classified into the following particle sizes: (+149) μm ; (-149+105) μm ; (-105+74) μm ; (-74+53) μm ; (-53) μm .

3. Results and discussions

3.1. Particle Size

Figure 2 showed the results of particle size distribution of the gold ore before and after crushing and milling. It is ascertained that after using the jaw crusher there was a considerable difference in particle size distribution between coarse (+149 μm) and fine (-53 μm) fractions. Efforts to reduce particle size of ore are needed to ensure better evaluation of mineral liberation ranges. A ball mill is used to overcome this deficiency. Furthermore, degree of liberation and fines ranges are subject to consider, since the material has more than 20 % in fine fraction (< 53 μm).

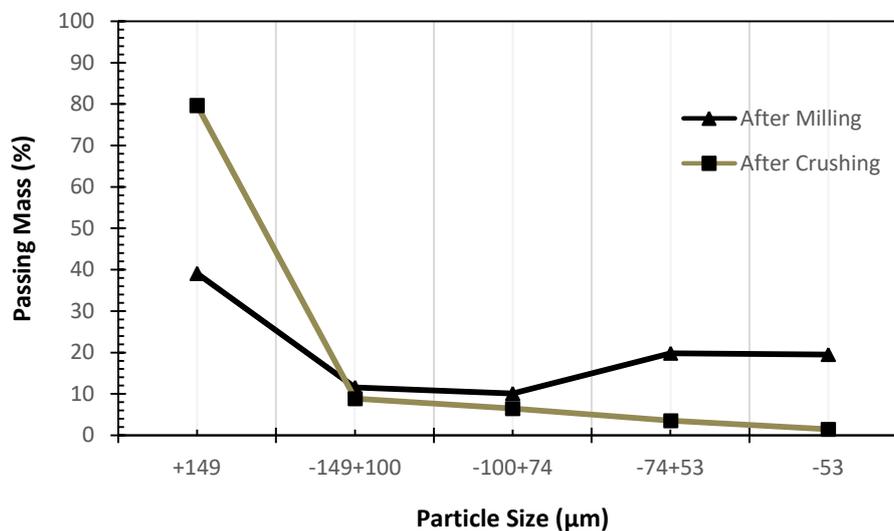


Figure 2. Particle size distribution results of gold ore sample before and after milling.

3.2. Chemical composition

The results of the chemical analysis by XRF of the gold ore for each fraction showed in Table 1. The results signalize the presence of Si as the main element followed by Fe and S. It was also noted that the Ag and Ti presence, which is component of great interest due to its economic value. The high presence of S indicated that the ore is sulfides. Moreover, Au was not detected and the presence of As will interfere with the gold dissolution process and environmental issue [8,9,10].

Table 1. The chemical composition of the particle size distribution of the gold-bearing ore using XRF

Element*	Unit	Fraction (μm)				
		+149	-149+100	-100+74	-74+53	-53
Mg	%	0.521	0.344	0.357	0.373	0.397
Al	%	8.685	8.399	8.407	8.508	9.812
Si	%	34.344	34.843	34.457	34.561	34.394
P	%	0.507	0.464	0.443	0.430	0.466
S	%	16.086	17.937	17.451	16.661	13.564

Element*	Unit	Fraction (μm)				
		+149	-149+100	-100+74	-74+53	-53
K	%	3.141	2.884	2.841	2.827	3.650
Ca	%	1.081	1.048	1.104	1.111	1.076
Ti	%	0.354	0.315	0.324	0.331	0.404
Mn	%	0.785	0.659	0.587	0.530	0.481
Fe	%	32.300	31.264	32.024	32.639	33.378
Zn	%	0.174	0.096	0.123	0.107	0.141
As	%	0.494	0.450	0.467	0.472	0.505
Ag	%	0.322	0.265	0.256	0.240	0.233
Sn	%	0.115	0.174	0.204	0.223	0.170
Eu	%	0.274	0.248	0.032	0.223	0.226
Pb	%	0.664	0.487	0.558	0.604	0.932

*Element with the concentration in ppm not showed

Table 2 shows the results of wet chemical composition analysis by AAS and ICP OES. The result points out the presence of Au as the minor elements, that Pd and Pt were not detected. It is also prominent the Fe, as mayor element followed As, Zn and Ag confirmed the XRF result. The presence of Cu depends on detection limits of the instrument that is confirmed using XRF.

Table 2. The chemical composition of the gold ore using AAS and ICP OES

Elements	Au	Pd	Pt	Ag	Cu	Zn	Fe*	As
Concentration (ppm)	4.03	<0.01	<0.02	90	144	607	26.41	1692

* concentration in %

3.3. X-Ray Diffraction

Figure 3 shows the result of XRD analysis of the bulk material at fine fraction < 53 μm in size. In this figure is viable to track of the presence of minerals as quartz, pyrite, and hematite. The micrograph results confirmed the presence of quartz and pyrite showed Figure 4. The presence of that minerals have also confirmed through the geological approach of Hulu simpang formation rocks. The metallic Au frequently co-exists in the same host mineral, but distribution within the pyrite and arsenopyrite[6], quartz, hematite is predominantly not uniform [6].

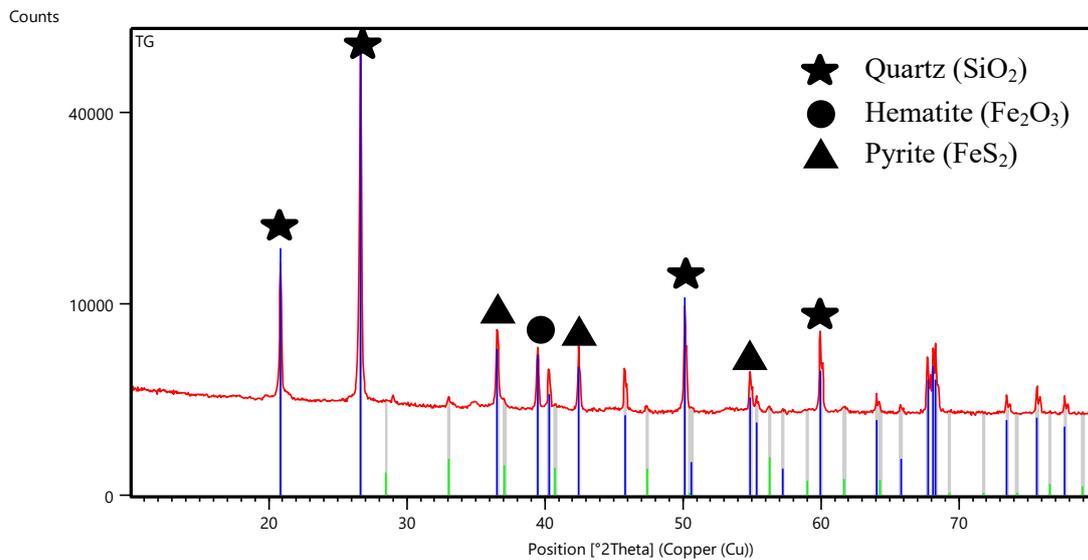


Figure 3. XRD pattern of TG gold ore. Radiation Cu K α (20 mA, 40 kV)

3.4. Optical and Scanning Electron Microscope

Complementary optical microscope and SEM-BSE-EDS point analyses were carried out to determine the nature of the micro-inclusions contained in the heterogeneous sulfides phase. Figure 4 shows the mineralogical analysis of the ore was pyrite and quartz. Au does not seem to be visible, we assume Au is associated on the pyrite phase. To be more aware of the existence of gold, enlargement is needed using SEM BSE and EDS which is easy to see the difference in atomic weight between Au and another element. As the show's in figure 5 (a) pyrite matrix is confirmed which is consist of Fe as the main element followed S, O, and Si. Figure 5 (b) shows the point of very light shape, that Galena (PbS) micro inclusions were detected (Fig. 5).

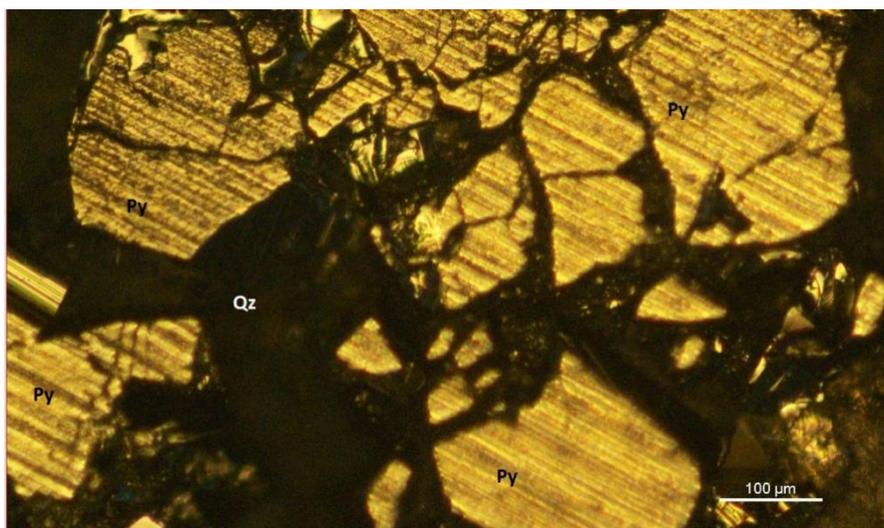


Figure 4. Presence of quartz and pyrite.

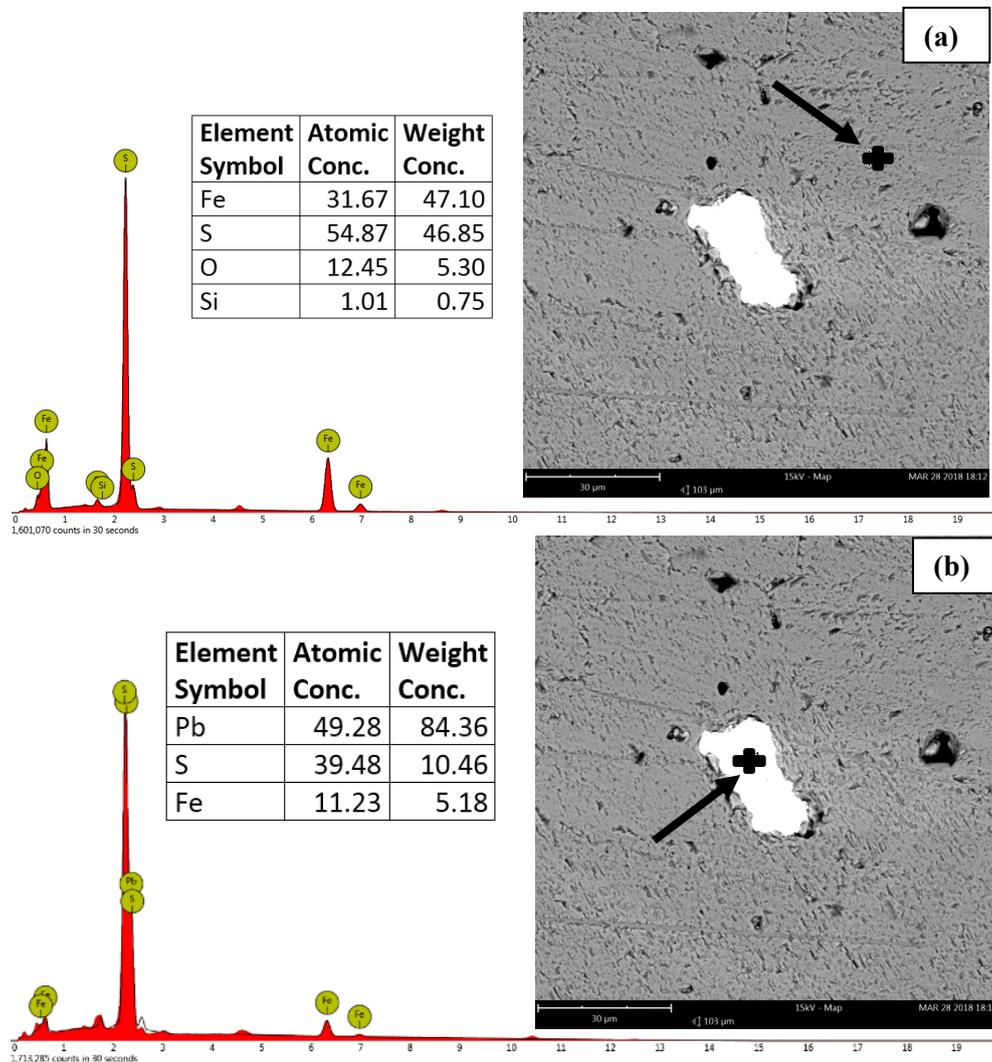


Figure 5. BSE and EDS

Au is very difficult to be detected even using SEM analysis, although by ICP analysis Au was detected with minor concentration. This study concludes that Tanggamus gold ore classification was refractory ore with high sulfides mineral. The SEM-EDS analysis is still necessary on the other side of the surface sample specimen. The possibilities presence of Au is in pyrite, arsenic, galena or quartz crystal as micro inclusion. In addition, a more appropriate method of analysis is diagnostic leaching, where this method will provide information on the presence of Au in certain crystals precisely, even with more complicated-stages. Direct cyanide moreover amalgamation was not economically method that is Au difficult to be dissolved. It is proposed that the ore can be extracted with the complete processes including comminution, flotation, oxidation, and leaching extraction.

4. Conclusions

This paper shows that each analytical technique has evidence-information that has been confirmed mutually. The Au presence was only detected after analyzing by fusion process followed by digest and ICP. It needs to the fully establish the nature of Au in sulfides ores by the multi-analytical approach.

Direct observation when Au is well visible using back scattered electron image and EDS Mapping or scan line or point can reveal micro-inclusion on the host of the crystal.

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