SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING

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PHYSICAL AND CHEMICAL CHARACTERIZATION OF COMPLEX GOLD ORE FROM PERANGGIH DEPOSIT

By

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DECLARATION

I hereby declared that I have conducted, completed the research work and written dissertation entitled “Physical and Chemical Characterization of Complex Gold Ore from Peranggih Deposit”. I also declared that is has not been previously submitted for the award of any degree or diploma or other similar title of this for any other examining body or University.

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ABSTRAK

Dalam kajian ini, bijih emas diperoleh dari deposit Peranggih, Pahang dengan kebenaran dari pihak Lombong Emas Selinsing. Proses pra-konsentrasi dijalankan menggunakan meja "Mozley" untuk memantau samada emas itu boleh dipisahkan oleh graviti kerana ketumpatannya yang berat selain untuk menghapuskan sebarang kekotoran. Satu kajian pencirian dilakukan ke atas sampel pukal, pecahan saiz, dan sampel pra-konsentrasi untuk mengenal pasti komposisi mineral-mineral melalui analisis XRD, XRF, SEM / EDX dan kajian mikroskop optik. Konsentrasi dan tailing dari pemisahan graviti dihantar ke XRF dan SEM untuk melihat komposisi mineral dan butirannya. Dari analisis XRF dan SEM/EDX, terdapat beberapa unsur penting dalam sampel, dengan kuartza tertinggi, diikuti oleh aluminium, kalium, besi dan lain-lain. Bagi kaedah pengujian, dua kaedah telah dijalankan untuk menentukan kandungan emas dalam sampel, iaitu analisis "Fire Assay" dan ujian "Bottle Roll". Kedua-dua kaedah ini memerlukan AAS untuk menentukan kepekatan emas di dalam larutan hamil yang diperolehi. Analisis "Fire Assay" dijalankan untuk keseluruhan emas di dalam sampel sementara ujian "Bottle Roll" menentukan emas "free mill". Kandungan gred pukal adalah 0.036 g/t dan gred emas "free mill" yang diperoleh adalah 0.531 g/t.

PHYSICAL AND CHEMICAL CHARACTERIZATION OF COMPLEX GOLD ORE FROM PERANGGIH DEPOSIT

ABSTRACT

In this study, the gold ore was obtained from Peranggih deposit, Pahang by the permission of Selinsing Gold Mine Manager. A pre-concentration process was conducted using Mozley table in order to observe whether the gold can be separated by gravity due to its heavy density and to eliminate any impurities. A characterization study was done on bulk, size fractions and pre-concentrate samples in order to identify the minerals composition via XRD, XRF, SEM/EDX analysis and optical microscope study. The concentrate and tailing from gravity separation was sent to XRF and SEM to observe the mineral composition and grain. From the XRF and SEM/EDX analysis, a few significant elements were found in the sample, with the highest is quartz, followed by aluminium, potassium, iron and others. This result was also supported by SEM/EDX. As for assaying method, two methods were conducted in order to determine the gold content in the sample, which is fire assay analysis and bottle roll test. Both of this method need AAS to determine the concentration of gold inside the pregnant solution obtained. The fire assay should be able to determine the overall amount of gold inside the sample while bottle roll test only able to leach out the free mill gold. The head grade obtained is 0.036 g/t and the free milling gold obtained is 0.531 g/t.

CHAPTER 1

INTRODUCTION

1.1 Background

Gold is one of the valuable mineral that can be mined and can produced high profit due to its rising price in the market. In this thesis, the gold ore sample was obtained the Peranggih, Pahang which is the new site of Selinsing Gold Mine Manager Sdn Bhd, located approximately 10 km North of the mine. Figure 1.1 and 1.2 show the location of the mine on the map of Malaysia and the location of the Peranggih in relation to Selinsing Property and gold plant respectively.

Figure 1. 1 : Location of Selinsing Gold Mine Manager on the map of Malaysia

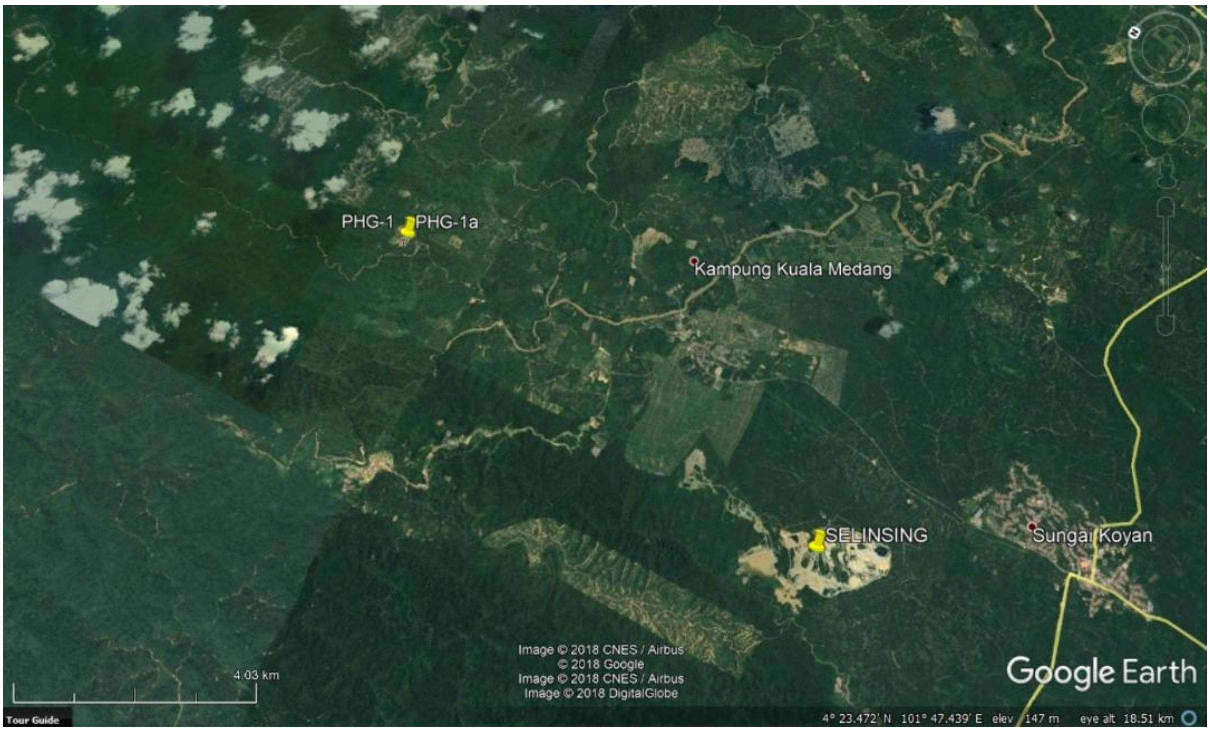

Figure 2. 1 : Location of the Peranggih Area in relation to Selinsing Property and gold plant

The orange lines show in the Figure 1.1 refer to the gold veins that run through the Peninsular Malaysia with the central gold is identified 20 km wide, specifically in Kelantan and North Pahang. Based on the information from the geologist of Selinsing Gold Mine Manager, the gold ore in Peranggih area are classified as High Grade (HG) gold ore.

1.2 Problem Statement

The mineral formation of gold varied with the location of deposit. In this research, the complex gold ore is obtained from the Peranggih Deposit located at Pahang. Different type of ore will have different mineral composition and phase. Furthermore, a newly opened site, the mineral composition of the sample from this site are still foreign and only can be referred according the near area. Associated mineral of the complex gold ore also need to be determine along with the grade of the gold ore. Also, how the gold ore present also need to be studied, either they exist as free gold or interlocked with other minerals. All of this are important to determine the best and most efficient method in extracting the gold ores and prevent waste and unneeded process.

1.3 Objective

The objectives of this research are:

1) To study the physical and chemical characteristics of gold ore and its associate minerals.
2) To study minerals composition and mineral phases of gold ore sample from Peranggih.
3) To determine the gold content from the bulk ore samples using Fire Assay technique.

1.4 Thesis Outline

This thesis contains 5 chapters and begin with the introduction of the research. Chapter 1 contain the background of the research and the aim and follow by the chapter 2 which is the literature review. The source of the literature review come from the research and article from previous study and to protect the person's copyright, all the facts are cited.

Next is chapter 3, the methodology, which explain all the method used in order to complete this research., started from collecting the sample from the site until the final analysis. The results are shown in chapter 4 after all the data have been analyse. Flowchart is included in chapter 3 in order to show the flow of the research.

The final chapter is the conclusion which conclude whether the research achieved all the objective of this research. This chapter have a few suggestions for future research that can be done for better result.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Gold was among the earliest metals to be mined in light of the fact that it normally happens in its native form, that is, not joined with different element, since it is lovely and perpetual, and on the grounds that flawless product can be produced using it.

Gold is one of the most inert metal existed and has a very high density of 19.32 grams per cubic centimetre. As it does not oxidize under ordinary conditions, gold is also known as a 'noble' metal which is an alchemistic term used for that kind of metals beside silver (Ag) and platinum (Pt). In the periodic table, gold is located in Group 3 – 12, classifying it as a 'Transition Metal' which is known for it's characteristic for being ductile, malleable and good conductors of electricity and heat (Kirkemo, Newman and Ashley, 1932).

The word 'gold' came from an Anglo-Saxon word, 'geolo' which mean yellow. There is also belief that the word itself came from the Sanskit 'jval' meaning 'to shine' (Kucha and Plimer, 2001). The chemical symbol used for gold, Au, was derived from Latin word, 'aurum' meaning 'shining dawn'. Gold is a transition metal with the atomic number 79 in the periodic table that is soft, shiny, yellow, heavy, malleable and ductile and usually present in gold nuggets or powders in rocks and alluvial deposits and one coinage metal.

Gold can be shaped into various form of shaped and pattern because of its characteristic of being malleable and ductile. It can be hammered into very thin sheets or leaves, cast, carved, polished, drawn out into thin wire and joint with other metals through process alloying. This is one of the important characteristic that make gold as one of the highly valued material. Gold also is known as good electricity and heat conductor but rarely used as it price is quite high and there is more economical replacement such as copper.

2.2 Peranggih

Peranggih was historically mined in the late 1980's and into the early 1990's by local artisanal miners. Using traditional sluicing and residual tailing, the gold was recovered and other evidence proved that substantial work had been done throughout this period. Figure 2.1 show the local geology of the Peranggih area.

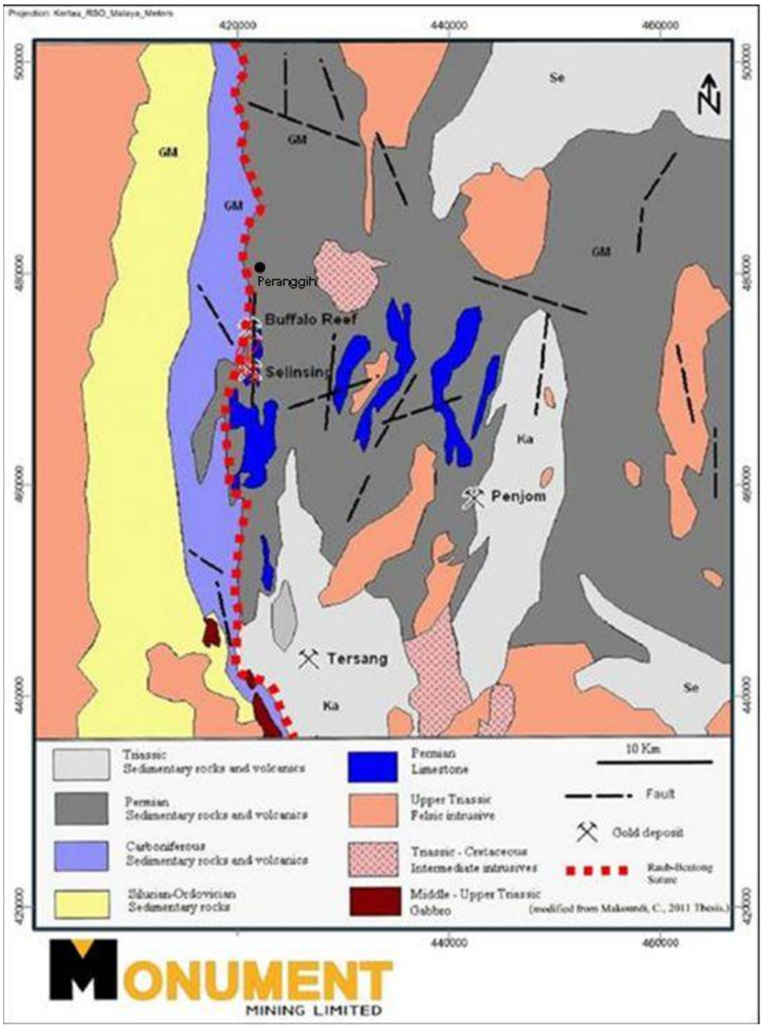

Figure 2. 2 : Local geology of the Peranggih area (Monument Mining, 2017)

In 2014, exploration drilling was conducted at Peranggih, providing encouraging result and been followed by soil sampling, trenching and other reconnaissance mapping. This was done in order to study the extent and boundary of the system there. It was determined that the gold mineralization is associated with a hydrothermal breccia system which is different compared to hydrothermal veins system that occur at Selinsing and Buffalo Reef, but still in the same regional shearing structuring (Monument Mining, 2017).

The recoveries exceed 80% and ranging up to 98% based on the sampling, assaying and cyanide leach test work that had been done. The system extends over a distance of approximately 1.2 kilometres in length with varying widths of between 25 to 50 meters with a halo of lower grade mineralization surrounding the identified areas of high gold grade mineralization (Monument Mining, 2017).

With the aim to carry out resource definition drilling around an area selected for bulk sample test work, further exploration work is conducted. Furthermore, identification of other target areas within the same Peranggih oxide system also can could been achieved by conducting regional exploration and this can provide additional oxide mill feed sources for Selinsing Gold Mine Manager.

According to the plan, the company want to mine a bulk sample of up to 50,000 tonnes and feed it to the present Selinsing oxide gold processing plant in order to establish average grade of the close spaced drilled area as soon as the construction of the access road to Peranggih has been finished. Table 2.1 show the highlight of the best intercepts at Peranggih - Close Spaced RAB Drilling in 2017

Table 2. 1 : Highlight of the best intercepts at Peranggih - Close Spaced RAB Drilling in 2017 (Monument Mining, 2017)

HOLE ID*	**From(m)**	**To (m)**	**Drilled Width (m)**	**~True Width (m)**	**Au g/t**
1_PGC006	2	8	6.0	4.3	3.07
1_PGC007	0	10	10.0	6.7	2.94
1_PGC019	0	10	10.0	7.7	2.28
1_PGC020	0	5	5.0	3.9	2.68
1_PGC428	1	10	9.0	6.6	3.14
1_PGC429	1	10	9.0	8.0	2.34
1_PGC430	0	10	10.0	8.7	2.49

*all vertical holes

2.3 Gold Mineralogy

Mineralogy is the branch of geology related to the study of mineral. Mineral is defined as a natural occurring chemical compound, solid and mostly inorganic, has fixed chemical formula and orderly crystalline structure. From a metallurgical point of view, gold ores usually divided into two major types which are free-milling and refractory types.

These two types of gold have different method of treatment and recoveries. Free-milling ore usually are easy to treat and can be recovered 90 % through conventional cyanide leaching while the latter are quite hard to treat and give low recoveries or only acceptable recoveries with the usage of more reagent or more complex process (Vaughan, 2004).

2.3.1 Gold Properties

In order to process the ores efficiently, the mineralogy of the gold must be studied properly. This is to avoid unnecessary steps during the mining or processing of the ores. The physical and chemical properties of gold are as shown in the Table 2.2 and Table 2.3 respectively.

Table 2. 2 : Physical Properties of Gold

Properties	Observation
Color	Bright yellow
Luster	Metallic
Streak	Golden yellow
Hardness	2.5 – 3 (on Mohs Scale)
Cleavage	None
Fracture	Hackly
Specific gravity	19.3
Malleability	High
Ductility	High
Melting point	1060 ºC
Common associate minerals	Quartz, pyrite ,arsenic, calaverite, sylvanite, sulphide mineral

Table 2. 3 : Chemical Properties of Gold

Properties	Observation
Chemical Formula	Au
Activity	Chemically inactive and extremely resistant to chemical action
Reactivity with acids	Can be dissolved by Aqua regia, a mixture of nitric and hydrochloric acid
Isotopes	Has one stable isotope, ^{197}Au
Reactivity with Non-metals	Does not react with Non-metal except halogens which will produce halides
Alloys	Silver and platinum

2.3.2 Geology of the Gold-belt in Malaysia

The geology of the gold-belt are categories into 4 elements which are stratified rocks, volcanic and hypabyssal rock contemporaneous with stratified rocks, plutonic rock intrusive into the foregoing and recent alluvium. The examples of stratified rocks are limestone, calcareous shale or in a few cases is referred as the calcareous slate, quartz, shale and chert.

The volcanic rock which is grouped as the Pahang Volcanic Series is in the range from rhyolites to dolerites and this applies specifically to the rock found in connection with gold deposits in several places such as Pulai in Kelantan, Merapoh, near Kuala Lipis and Raub. This kind of rock has fine grained intergrowth of quartz, feldspar and muscovite and will be referred as muscovite-aplite with the grain is finer than a common aplite. The plutonic rocks are granite, hornblende-granite, syenite and diorite. There are also some cases that have been reported about discovery of cassiterite with gold near Kuala Lipis and in the Benom Range, which is at the south of Kuala Lipis. Rutile, zircon and ilmenite also present in the concentrates.

There are also several famous localities where gold and tin ore are discovered along in concentrates on the west of the Main Range while at Benton gang Manchis on the east of the Main Range, gold has been found with tin ore. Others minerals found in the concentrate are ilmenite, both coloured and colourless zircon and monazite. This concentrate is attractive and scattered which is probably a common concentrate on other Asiatic mines. There are also other old gold-workings which are the most important being at Selinsing located further up the Jelai River. In 1903, European Company had carried out and underground work while at the north of Selinsing, the Buffalo Reef was opened in 1900 just only to be abandoned not long after that because of abundance of stibnite contained.

2.4 Classification of Gold Ores

Based on the study, the gold ores can be classified into 11 types with very different ore have their own special mineralogical characteristics, resulting different type of extraction method used in plant (Zhou, Jago and Martin, 2004). Most of the gold ores mined in Malaysia are in form of placers, free milling, oxidized and carbonaceous form. To ensure the highest efficiency, it is best to identify first the nature and the type of the gold ores before mining or processing them. The classification of gold ores is shown in Table 2.4.

Table 2. 4 : Classification of Gold (Zhou, Jago and Martin, 2004)

Ore Types	Mode of Occurrence of Gold
Placer	• Easy to liberated or has been liberated due to processing • Normally ranges from 50-100µm in size
Oxidized ores	• Usually occurs as either liberated or in the alteration product of sulfide minerals • Degree of gold liberation generally increased by oxidation
Silver-rich ores	• Usually occur as electrum • Some ores may be containing kustelite and native silver
Copper sulfide ores	• Occur as coarse liberated particles • Fine particles locked in pyrite and copper sulphides
Quartz vein-lode ores	• Occur mainly as native gold in quartz-veins, lodes or stockwork. some telluries and occasionally aurostibite and maldonite • Usually occurs as liberated gold particle but may be contain disseminated gold
Iron sulfide ores	• Occur as liberated particles, attachments to and inclusions in sulfide • commonly in pyrite, less commonly in marcasite and pyrrhotite, and as sub-microscopic gold in sulfide minerals
Arsenic sulfide ores	• occurs as liberated particles and inclusions • Sub-microscopic gold in arsenopyrite and oxidized products
Antimony sulfide ores	• Occurs mainly as native gold • Minor to moderate amount of aurostibite, either liberated or locked in sulfides
Bismuth sulfide ores	• Occurs mainly as native gold • Minor to moderate amount of maldonite • Sub-microscopic gold can be present in sulfides
Telluride ores	• Occurs as native gold and gold telluries • Either liberated or locked in sulphides • Sub microscopic gold may be present

Carbonaceous-sulfide ores	• Occurs mainly as fine-grained gold particles, sub-microscopic gold in sulphides • Surface gold absorbed onto the surface of carbonaceous matter FeOx.

Based on the mode of occurrence, three categories of gold are decided which are microscopic gold, sub-microscopic gold and surface gold as shown in Table 2.5 in which they are classified by their natures and carriers.

Table 2. 5 : Classification of Gold by their natures and carriers (Zhou, Jago and Martin, 2004)

Form	Microscopic gold	Sub-microscopic gold	Surface gold
Nature	Visible under microscope	Invisible under microscope	Invisible under microscope
Carrier	All gold minerals: native gold and electrum are the most common ones and Calaverite, Aurostibite, and Maldonite are less common	Arsenopyrite, Pyrite, Marcasite, Chalcopyrite, Enargite, Realgar, Loellingite, Acanthite FeOx, Clay minerals	Carbonaceous matter, FeOx, Stained quartz, Activated carbon, Clay minerals, Wood chips, Pyrite, Arsenopyrite

2.5 Characterization of Gold

In the course of the most recent two decades, characterization of complex gold ores has turned out to be more critical as the free-milling oxide ores end up depleted and more accentuation is put on the improvement of complex refractory sulphide deposits.

The main purpose of characterization technique for gold minerals has moved progressively a long way from dreary manual methodology towards electronic structures attempting to increase to cost’s efficiency. Also, this help to increase the chances of successful characterization and limit the effect that small non-representative samples can have to examination of heterogeneous gold ores.

The advancement of characterization technique for gold ores has created along various roads controlled by the sort of gold's type and its conduct under various preparing conditions. There are two brood occurrences of gold, characterized by their simplicity of determination with different procedures. The most well-known gold occurrence is referred to as visible gold and characterized as gold that is identifiable by ordinary microscopy. This occurrence of gold includes all free-milling gold and dominant part of refractory gold. Besides visible gold, there is also type of gold's occurrence known as 'invisible gold', used to referred for sub-microscopic or molecular gold. This type of gold occurrence usually occurs as colloidal particles or in solid solution within a mineral matrix.

The characterization usually involves a few process such as sample collection, physical properties study, sample preparation, X-ray analysis and Optical microscopy analysis. Each of the process are important in order to determine the characterisation of the ore.

2.6 Gravity Concentration

Separation by density difference is a process that is as old as recorded history.According to (Wills, 1992), gravity concentration methods are used with the aim to separate the minerals based on their specific gravity by their relative movement in response to gravity and one or more other forces. There were many machine and gravity separator that had been built and adapted this principle such as jigs, spirals, shaking table, Knelson concentrator and others but mozley separator was commonly used for laboratory scale of work

2.5.1 Mozley Table

Small and easy to use, mozley table will allow even a relative unskilled operator to get the data required for a recovery grade curve in a short time The mechanism of Mozley table as shown in Figure 2.3.

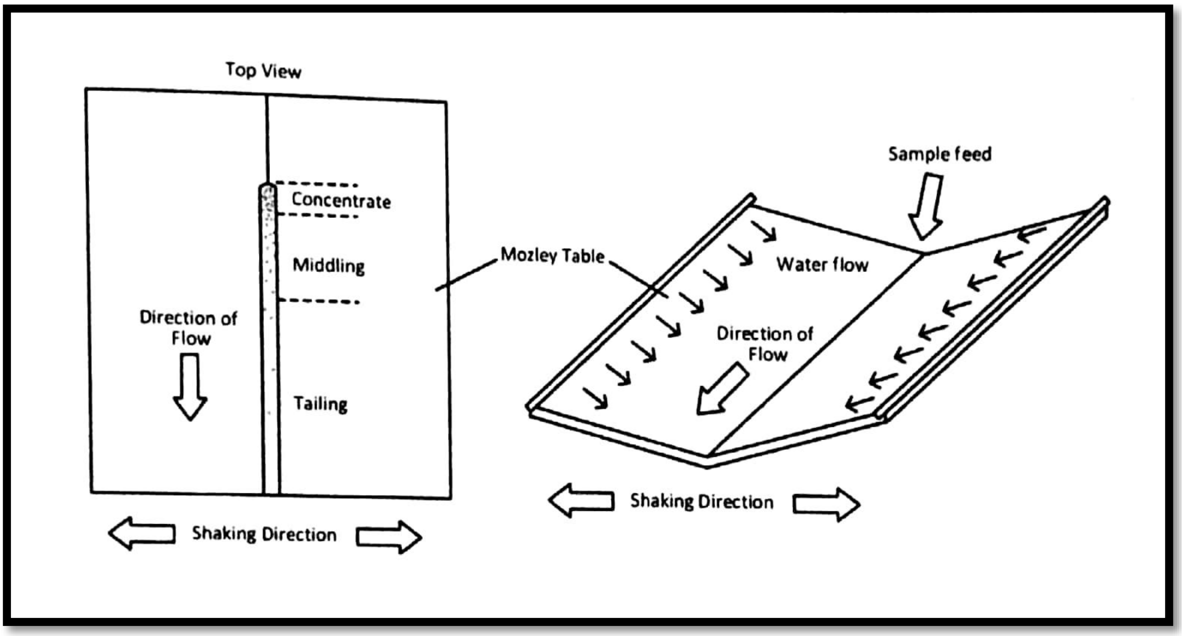

Figure 2. 3: Mozley table mechanism

2.6.2 Panning for Gold

Although panning might be the hardest method to separate the gold but due to its mobility and inexpensive cost, it might suitable for some places and situation. With 16 inches in diameter at the top and 2.5 inches deep, the standard gold pan is usually made of stiff sheet iron with the rim is flared outward at an angle of about 50 from vertical. Although normal frying pan or other cooking utensils can be used, it might be not too effective.

2.7 Gold Assaying Method

A crucial part while working on precious metal is the ability to determine accurately the amount of the specific metal at all times in order. This is important to control and minimise metal losses besides avoiding "giving away" precious metal for which a customer is not paying (Peter Raw, 1997). Because of that, assaying method need to be conducted in order to determine the amount of gold metal contained in an ore, and there are two types of gold assay that can be used, which are dry assaying method and wet assaying method. Dry assaying method involve fusing the powdered with or without fluxes while wet assaying method is by the agency of liquids.

2.7.1 Fire Assay

Fire assay is the basic technique used which is suitable for determining accurately the gold concentration of 0.001 to more than 50g/t, although there are need to remove non-metallic impurities before sampling. Fire assay had been crucial process in many studies due to its ability to provide bulk gold balance information thus complimenting the mineralogical info collected from other method (Zhou, Jago and Martin, 2004).

According to (Hoffman, Clark and Yeager, 1998), the basic procedure of fire assay includes mixing the powdered samples with the weight varying from range 10 g to 50 g with the flux. The most important factor need to be considered during conducting fire assay analysis is the flux composition as the lead button might not form if there were mistake. The composition of flux shown in Table 2.6 is according to (Marsden and House, 1992).

Table 2. 6: Composition of flux

Chemical Compound	**Weight(g)**
Sodium Carbonate (Na_2CO_3)	40
Lead Monoxide (PbO)	40
Calcium Fluoride (CaF_2)	10
Sodium Borate ($Na_2B_4O_7$)	30
Silica (SiO_2)	30-40
Flour	5.5

As stated in (Peter Raw, 1997), when the mixture fired inside the furnace with high temperature ranging from 1000 ºC to 1200 ºC, the precious metal does not oxidise, unlike base metal. After a duration of 1 hour, the fusion occurred and the molten is poured into a mould and left at room temperature to let it cool down as in Figure 2.4. The slag that separate the impurities inside the mixture need to be removed and the lead button formed at the bottom contain gold and other precious metals which form Au-Ag-Pb alloy is collected (Hoffman, Clark and Yeager, 1998).

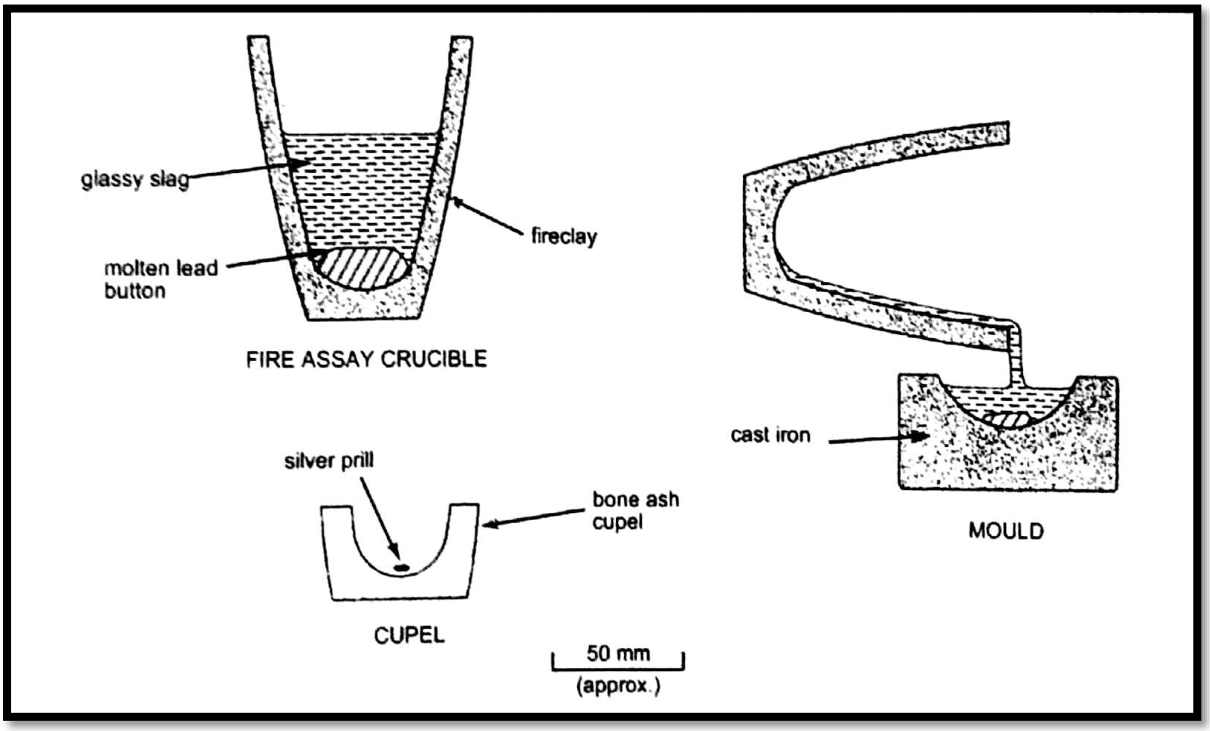

Figure 2. 4: Fire assay procedure

The slag then is removed and the lead button is placed in the cupel that made from bone ash. The bead later fired inside the furnace at 1000 ºC for 1 hour. This process is known as cupellation process in which the cupel will absorb the lead, leaving behind a bead, known as silver prill that contain gold and some of platinum group elements (Hoffman, Clark and Yeager, 1998).

The process parting which means dissolving the bead in nitric acid is conducted and leaving behind a bead which can be weighed as gravimetric finish (Hoffman, Clark and

Yeager, 1998). Another possible method was by dissolving the entire bead in the acid (Aqua Regia) and determine the gold content by using Atomic Absorption Spectroscopy (AAS) (Hoffman, Clark and Yeager, 1998). One of the advantage of using fire assay technique is the ability to use a relatively large ore sample from which to concentrate these metals, in addition to eliminating virtually all the associated gangue minerals (Haffty, Riley and Goss, 1977).

2.7.2 Aqua Regia Dissolution

Aqua regia is Latin word for “royal water” and is extensively used by both the major bullion refiner and small scale refiner and it offer the chance to produce 99.99 % pure gold in one simple process. The process involves dissolving 5 g to 50 g (or possibly higher) of sample in a mixture of hydrochloric acid and nitric acid with a ratio of 3:1 (Hoffman, Clark and Yeager, 1998). Both the acids used carries different function in order to dissolve the complete the process. The chloride ions from the hydrochloric acid will form a stable combination complexes with the Au^{3+} while nitric acid will act as oxidizing agent.

Reaction equation (Marsden and House, 1992):

$$\mathrm{Au\ (s) + 3NO_3\ (aq) + 6H^+\ (aq) \rightarrow Au^{3+}\ (aq) + 3NO_2\ (g) + 3H_2O\ (l)}$$

$$\mathrm{Au^{3+}\ (aq) + 4Cl^-\ (aq) \rightarrow AuCl_4^-\ (aq).}$$

While this happen, the non-metal mineral will not dissolve and form a sludge. The sludge solution was filtered to separate the sludge and obtain the gold pregnant solution. This solution can be either analysed directly by Atomic Adsorption Spectroscopy (AAS) or concentrated by solvent extraction and then analysed by Atomic Adsorption Spectroscopy (AAS) (Hoffman, Clark and Yeager, 1998).

Compared to the other method, this method is more cost effective and usually used to monitor the plant operation in order to avoid loss of gold during the processing (Marsden and

House, 1992). Although the gold concentration obtained from this method is quite low compared to fire assay and other analysis, but good side is that the result is obtained faster in a few hours (Hoffman, Clark and Yeager, 1998).

2.7.3 Bottle Roll Test

A cyanide bottle roll test is a usual step in evaluating the gold recovery possible by cyanide leaching. In a bottle roll test, the prepared ore is moderately agitated in a cyanide lixiviant. The test outcomes offer information on estimated recovery rates, reagent consumption and accurately predict the results obtainable from pilot and industrial plants. The recovery results are measured maximums because attrition grinding creates fines and liberates recoverable values that would not be liberated from the material through a static leach. Bottle roll tests are conducted on ores as coarse as 50 mm.

The cost to conduct the cyanide bottle roll test is cheaper compared to column percolation heap leach amenability test. The most vital thing to conduct the experiment is to ensure the pH of the solution ranging from 10.5 to 11 before run. Then, the solution is run in a bottle for 24 hours and finally the solution is filter to obtain the pregnant solution for Au, NaCN and pH.

There are several information and data obtaining from the preliminary bottle roll test including the amenability to heap cyanidation processing, presence of coarse (visible) gold particles and gold bearing sulphides minerals, clay content which indicate agglomeration before heap leaching, ‘preg-robbing’ character of ore and the degree of to which values are liberated from the various particles size.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The samples were collected from the new site which located at Peranggih, near Kuala Medang, Pahang. The sample was taken at the area located between Phg-1 which a coordinate of (N 04^{0} 20.478’, E 101^{0} 47.907’) to Phg-1a which coordinate at (N 04^{0} 20.474’, E 101^{0} 47.905’) as in Figure 3.1.

Figure 3. 1: Location which the samples were taken.

3.2 Materials and reagents

There are a few materials and chemical reagents used during this research, mostly for gold assaying method. For fire assay analysis, Sodium Carbonate, Litharge, Borax, Silver Nitrate and flour were used to prepare the flux. The nitric acid and hydrochloric acid then used to dilute the silver prill obtain for Atomic Absorption Spectroscopy analysis. For Bottle Roll Test, Sodium Cyanide was used along with lime to prepare the sample and then for solvent extraction process, Diisobutyl Ketone, Aliquot 336 and Potassium Chloride were added later for Atomic Absorption Spectroscopy analysis

3.3 Preparation of Ore

The samples taken then arranged according to their order. The coding used was PGH, the P stand for Peranggih and HG for high grade. Most of the samples taken were rock and soil as the Peranggih site do not have stockpile. The samples then weighed bag by bag and the total of samples was around 100 kg.

3.3 Sampling

Sampling method was crucial as any error in doing sampling may affect the result of our research and it varies depend on the location and procedure. At the Peranggih, we used grab sampling while cone and quartering and riffle splitter were used in the communition and pilot laboratory.

3.3.1 Grab Sampling

The sampling method used at the site was grab sampling even though it was not too accurate but it was the easiest and cheapest. We took 2 batches of 30 samples from every different point to make sure the entire location shown by the geologist was covered. The second batch was taken for preparation in case some mistake or error happens.

3.3.2 Cone and Quartering Sampling

Cone and quartering sampling was conducted after the samples were crushed using jaw and cone crusher. The product from the cone crusher was built into cone-shaped by lifting the 4 corners of the canvas and the top of the cone was flattened and cut into 4 parts using the cone and quartering splitter. Two opposite corners were taken as sample and the other two corners were collected and put into sample bag as revision sample. Cone and quartering was done until the samples were reduced to 3 kg.

3.3.3 John's Riffle Sampling

The John's Riffle was used after the samples were reduced until around 3 kg via cone and quartering. John's Riffle was one of splitter's equipment and it the design was like an open V-shaped metal box which contain a series of chutes mounted at the right angles to long axis to give a series of rectangular slot of equal area of opening. The samples that pass through the John's Riffle were split into two trays, with equal amounts. This process was repeated until the small amount of feed required was achieved. The mechanism of John's Riffle is shown in Figure

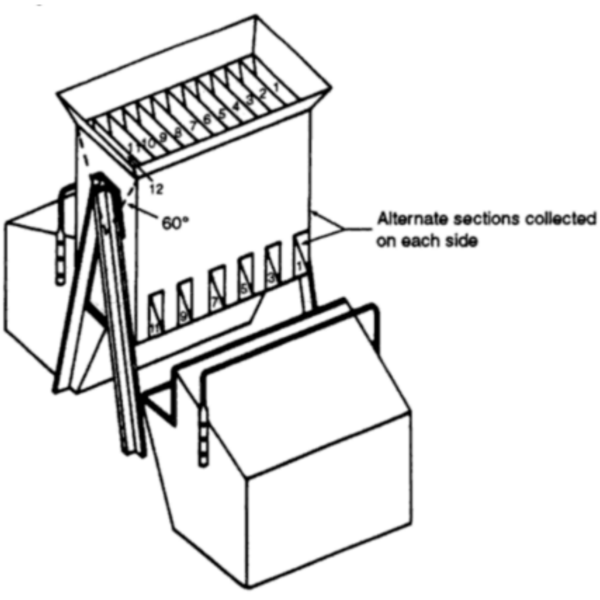

Figure 3. 2: John's Riffle Mechanism

3.4 Crushing

Crushing is the first stage of comminution in mineral processing and metallurgy. For crushing, jaw crusher was used as primary crusher and cone crusher as secondary crusher.

3.4.1 Jaw Crusher

The samples were fed into the jaw crusher and being crushed into smaller size. The jaw crusher used was a single toggle jaw crusher and the reduction ratio for the jaw crusher was 5:1. The jaw's arc-like motion was caused by the single-toggle pivots located at the base of the swing plate. Before using it, make sure to blow the jaw crusher with the air gun to clean it up to avoid any contamination from other mineral. The size of the Open Side Setting (OSS) was 3.2 cm while the diameter of the gate was 11 cm x 15.3 cm. The samples were crushed when they pass through between the fixed and a swing moveable plate, producing a product with a size around 150 to 300 mm.

3.4.2 Cone Crusher

Before using the cone crusher, the samples were sieved first in order to separate them into different size fraction using Galvin sieve shaker. The sizes of the sieves used were 14 mm and 6.7 mm and the samples retained by these two sieves were proceeding to the secondary crusher which was cone crusher. The cone crusher used was Marcy GV- roll crusher with reduction ratio 3:1. Some of the feed had to be crushed using hammer as the size is too big and cannot pass through the cone crusher.

3.5 Grinding

Grinding was one of the important processes in communition. For grinding, agate mortar was used to grind the sample to achieve -75μm for X-Ray Fluorescence (XRF) and X-Ray Diffraction (XRD) analysis. This was done to check whether the sample might be contaminated by iron in the ring mill during the process or not. For the remaining bulk sample, they were grinded using ring mill to achieve -75µm.

3.5.1 Ring Mill

The samples were put into the ring mill carefully and neatly to avoid any loss. Then the samples were grinded for about 10 seconds for 4 times. This was to make sure that the samples were properly grinded and to avoid any overheat of the ring mill. After that, the samples were put into their own sample bag for further analysis.

3.5.2 Agate Mortar

Agate mortar was used to grind the samples for X-Ray Fluorescence (XRF) and X-Ray Diffraction (XRD). Like mention above, contamination of iron for the sample might affect the result of the analysis. To prevent it, pestle and mortar was used as there was likely any chance of contamination from this type of grinding. The samples then were divided and proceed to X-Ray Fluorescence (XRF) and X-Ray Diffraction (XRD) analysis.

3.6 Sieving

After grinding was done, the samples then proceed for sieving. For sieving, 5 different size fractions were chosen which are 90µ**,** 75µ, 50µ and 38µ running for about 15 minutes to make sure the sample was properly sieved. All the safety equipment such as ear plug and face mask must be wear all the time to avoid damage to ears and prevent small dust particle from entering the mouth and nose.

Once it was done, the mass of sample from each size fractions were taken to construct the graph of particle size distribution and analyzed. The result was important to determine the quantitative data of the size and for making the polish section required for study of mineral liberation and SEM analysis.

3.7 Physical and Chemical Characterization Methods

3.7.1 Fire Assay Analysis

Fire assay are known as one of the separation methods in which valuable metals are isolated from different types by dissolution in other molten metals, normally lead, nickel, or tin. Fire assay has been and keeps on being central to the determination of valuable metals. For fire assay analysis, the sample first was dried in the oven with temperature 110 ºC for 2 hours. Meanwhile, the flux was prepared by mixing a certain amount of sodium carbonate (NaCO), litharge (PbO), borax ($Na_2B_4O_7 \cdot 10H_2O$), flour and silver nitrate (AgNO). This process must be done in the furnace due to chemical hazard that might happen.

After the sample dried, mix the sample and the flux together in a plastic bag and shake it properly to make sure it was homogenous. If this was not done properly, the lead button might not form. The mixture then pours into the crucible provided and put into the furnace. The time for calcining process was only 1 hour but the sample was left for 1 day as the time taken for the furnace to reach 1100 ºC was too long and also to allow it to cool down until it reach room temperature when it was done.

The lead button then separated from the slag produced, which contain impurities inside the sample and disposed properly. After that the lead button proceeds for cupellation process. The process of cupellation was quite similar to calcining process, which differ in terms of time, temperature and tools used. For cupellation, cupel was used to place the lead button and later put into the furnace. The temperature for cupellation process was 957 ºC for 1 hour and 15 minutes. Same as calcining process, the sample was left for a day.

Silver prill produced from the cupellation process was weighed and proceed for acid digestion process. The prill was put into a test tube and 5 ml of nitric acid (HNO) was added and heated until it reaches 100 ºC. Then followed by 15 ml of hydrochloric acid (HCl) and