SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING

UNIVERSITI SAINS MALAYSIA

MINERAL LIBERATION STUDIES OF COMPLEX SULPHIDE GOLD ORE FROM PAHANG, MALAYSIA

By

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Dissertation submitted in partial fulfillment

of the requirements for the degree of Bachelor of Engineering with Honours

(Mineral Resources Engineering)

Universiti Sains Malaysia

JUNE 2018

DECLARATION

I hereby declared that I have conducted completed the research work and written dissertation entitled "Mineral Liberation Studies of Complex Sulphides Gold Ore in Pahang, Malaysia". I also declared that is has not been previously submitted for the award of any degree or diploma or other similar of this for any other examining body of University.

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ACKNOWLENGDEMENTS

First of all, I would like to offer my sincere gratitude to my supervisor, Dr Suhaina bt Ismail, who is one of the best lecturer at School of Materials and Mineral Resources Engineering (SMMRE), Universiti Sains Malaysia (USM). She was the one who lend me her hand by giving and sharing her knowledge, experience and personal guidance for my project. She always gives support and great advice so that I always stay focus on the final year project (FYP). Special thanks for her continuous supporting.

A special acknowledgement to the School of Materials and Mineral Resources (SMMRE) Universiti Sains Malaysia for providing a good environment and excellent facilities for the final year students to run their experiment and analysis. Moreover, I would like to give my special thanks to all the staff and technicians especially En. Mokhtar, En. Hasnor, En. Khairi, En. Junaidi, En. Kemuridan and En. Zaini whom had helped me by giving information and assistant throughout my sample preparation and lab analysis.

Honestly, special thanks to my family and friends for providing me with the support needed to finish up my final year project. They are always there to help me out and stay by my side whenever I am feeling down or stressed during all this time. They were one of the greatest gifts that I have until now. Lastly, I would like to express my appreciation to those whom had offered help directly or indirectly. Thank you for the guidance and support

TABLE OF CONTENTS

Contents **Page**

LIST OF TABLES

LIST OF FIGURES

KAJIAN LIBERASI MINERAL BIJIH EMAS SULFIDA KOMPLEKS DARI PAHANG, MALAYSIA

ABSTRAK

Dalam kajian liberasi mineral bijih emas sulfida kompleks di Pahang, Malaysia, sampel mentah dari Selingsing Gold Mine Manager digunakan untuk dianalisis. Daerah Selinsing terkenal dengan pembentukan bijih emas berhampiran Pusat Semenanjung Malaysia. Objektif kajian ini adalah untuk mengkaji pencirian mineral dan komposisi bijih emas sulfida kompleks di Pahang, Malaysia. Pengenalpastian dan kuantifikasi mineral dianalisis menggunakan XRD sementara komposisi mineral ditentukan menggunakan analisis XRF. Sebelum menjalani analisis XRF, nilai LOI sampel perlu dikira terlebih dahulu. Nilai LOI adalah 3.46% yang dianggap sebagai rendah yang bermaksud sampel mengandungi jumlah organik yang rendah. Dari analisis XRF, sampel kebanyakannya terdiri daripada Silicon Oksida yang merupakan mineral Kuarza dengan nilai 32.73% dan yang kedua tertinggi adalah Aluminium Oksida dengan nilai purata 10.05%. Kajian morfologi sampel dilakukan melalui kajian “polished section” menggunakan SEM/EDX dan mikroskop optik. Struktur sampel tergilap kebanyakannya berbentuk tidak sekata dan berbentuk serpihan manakala sampel pukal hanya mempunyai bentuk serpihan di bawah SEM / EDX. Bijih berwarna yang paling cerah dianggap sebagai emas, Au kerana emas adalah unsur paling berat dalam jadual berkala. Ferum (Fe) dan Kuprum (Cu) agak sukar untuk dibezakan menggunakan SEM kerana berat atomnya hampir sama dengan menyebabkan warna kelabu bagi kedua-dua elemen hampir sama. Untuk membezakannya, EDX diperlukan. Akhir sekali, analisis pembebasan mineral dilakukan menggunakan perisian Image J. Nilai pembebasan mineral kira-kira 20% dari 150 μm bermakna sampel kebanyakannya dibebaskan pada saiz tersebut dan ke bawah.

MINERAL LIBERATION STUDY OF COMPLEX SULPHIDE GOLD ORE

ABSTRACT

In the study of mineral liberation of complex sulphide gold ore in Pahang, Malaysia, raw sample from Selingsing Gold Mine Manager is used for analysis. The Selinsing district is famous with the occurrence of gold ore near the Central Belt of Peninsular Malaysia. The objective of this study is to study the mineral characterisation and composition of complex sulphide gold ore in Pahang, Malaysia. The mineral identification and quantification were carried out using the XRD while the mineral composition is determined using the XRF analysis. Before the XRF analysis, loss on ignition of the sample need to be determined first. The LOI value is 3.46%. The LOI value means that the sample contain low amount of organic matters. From the XRF analysis, the sample mostly consist of Silicon Oxide which is Quartz mineral with the value of 32.73% and the second most is Aluminium Oxide with the average value of 10.05%. The morphological study of the sample was done through the study of polished section using the SEM/EDX and optical microscope. The structure of the polish sample are mostly irregular shape and flaky while loose bulk sample only look flaky grain under the SEM/EDX. The lightest coloured grain is considered as gold, Au since gold is the heaviest element in the Periodic Table. Iron (Fe) and Copper (Cu) are quite hard to differentiate using the SEM since their atomic weight is almost the same thus the grey colour intensity of the two element almost the same. To differentiate them, EDX is needed. Lastly, the mineral liberation analysis is done using the Image J software. The highest value of mineral liberation stays about 20% at 150 μm size fraction.

Chapter 1

Introduction

1.1 Significant of Research work

In the state of Pahang, the gold deposits are mostly sulphide gold ore. The gold mineralisation is hosted by widespread occurrence of low regional grade metamorphism and subdivided into three at the Buffalo Reef, which are North, Centre and South.

The ore deposit and mineralogy are associated with the occurrence of gold mineral in massive sulphide to placer and paleoplacer deposits. Sulphide complex gold can occur in a wide range of particle sizes. Because cyanide cannot always leach sulphide-associated gold, regrinding the ore is typically required to expose the free gold for recovery by intensive leaching. Critically, the size at which one can efficiently liberate gold from the host mineral of the particle will determine the process to use for optimal gold recovery.

1.2 Problem Statements

The different occurrence of geological structure between Buffalo Reef and Raub-Bentong Suture the mineralogy of sulphide gold ore is also differ in soil or hard rock in present of gold mineralization.

When gold associates with sulphides, it can either full encapsulated by the sulphide particle or partially liberated, for example exposed on the edge of the sulphide mineral. Sulphide complex gold can occur in a wide range of particles size. Because cyanide cannot always leach sulphide associated gold, regrinding the ore is typically required to expose the free gold for recovery by intensive leaching.

Critically, the size at which one can efficiently liberate gold from the host mineral of the particle will determine the process to use for optimal gold recovery.

1.3 Objectives

The objectives of this project are:

- To study the mineral characterisation and composition of complex sulphide gold ore from Pahang, Malaysia (Mineral phase identification and quantification using X-pert High Score plus Software).
- To study the mineral liberation of complex sulphide gold ore in Pahang, Malaysia.
- To study the morphology of the complex sulphide gold ore sample using SEM/EDX and Polarizing Microscope.

1.4 Scope of Study

This project primarily focused on the bulk characterisation and size fractions characterisations. The samples used for this project are high graded sample which obtained from the Buffalo Reef's stockpile from Selinsing Gold Mine Manager, Pahang. During the sample collection phase, random grab sampling technique is used.

The bulk characterisation consist of particles size analysis, elemental composition using XRF, mineral phase identification using XRD, and morphological study using optical microscopes and SEM/EDX (12 size fractions of polished sections).

1.5 Thesis Organisation

This thesis contains five chapters, that begins with introduction on the research background and the objectives of the project followed by chapter two which is the literature review on the general related facts related to the project title which is Mineral Liberation studies of complex sulphide gold ore in Pahang, Malaysia. Literature review was obtained from two different sources, one is from articles and the other one is from journals/thesis of previous researcher and cited to protect the individual’s copy right.

Chapter three explained in detail about the methodology used in conducting this project, starting from the proper sampling method, followed by the comminution, pre-assessment of polish section, x-ray diffraction, x-ray fluorescence and scanning electron microscope. The results and discussion have been elaborated in the chapter four after all the data and result have been completely analysed.

Finally, chapter five is the conclusion of this project and also includes the recommendation for the future work.

Chapter 2

Literature Review

2.1 Mineral

Mineral is a naturally occurring chemical compound, usually in crystalline form and not produced by life process. Every mineral each has different chemical composition and atomic structure arrangements. Minerals are well known by their diverse chemical and physical properties. The distinction between minerals in chemical composition and crystal structure differentiate the various mineral species. Mineral changes according to changes in temperature and pressure. Minerals can be described by their various physical properties, which are related to their chemical structure and composition. Common characteristics of the mineral which differentiate one mineral from another include crystal structure and habit, hardness, lustre, diaphaneity, colour, streak, tenacity, cleavage, fracture, parting, specific gravity, magnetism, taste or smell, radioactivity, and reaction to acid. Hence, for further understanding in mineral and mining industrial which plays a major role in world economic, mineral is divided into two types of mineral, ore mineral and gangue mineral. Ore mineral is the mineral which is mined for its economic value, which also means for profit while gangue mineral is the commercially worthless material that surrounds, or is closely mixed with, an ore mineral in an ore deposit. Ore mineral also classified into two groups which are metallic and non-metallic minerals.

2.1.1 Gold Mineral

Gold is a chemical element with the symbol Au in the periodic table with the atomic number 79 and atomic mass of 196.967. Gold has a density of 19.3 g/cm3 and form in solid state and the melting point and boiling point for pure gold is 1064°C and 2969.85°C respectively. Gold is one of the most well-known mineral, distinguished for its economic value and special properties such as its attractive colour and resistance to tarnish. Trace amounts of gold are found almost everywhere, but large deposits are found in only a few locations. Gold in its natural mineral form almost regularly has traces of silver, and may also accommodate traces of copper and iron. A gold nugget is usually consist of 70 to 95 percent gold, while the remainder is mostly silver. Pure gold is bright golden yellow, but the greater the silver content, the whiter its colour is. Much of the gold mined is actually from gold ore rather than actual gold specimens. The ore is often brown, iron-stained rock or massive white quartz, and usually contains only minute traces of gold. Gold is frequently associated with pyrite and other sulphides and sometimes could not be recognized because its association with these resembling minerals. To extract the gold, the ore is crushed, then the gold is separated from the ore by various methods.

About 78% of gold is consumed or recycled throughout the year is used in the production of jewellery. In coinage or in the financial stores of governments, about 10% of gold is used. The remaining 12% is used in a broad scope of other uses which include electronics, medicine, dentistry, computers, awards, pigments, gilding, and optics. The current live price of the gold is RM 164.34 per gram and the price will keep on increasing and decreasing according to time since the market price for the gold is no fixed.

2.1.2 Gold geology and gold formation

Gold is relatively scarce in the earth, but it occurs in various kinds of rocks and in many different environment. Even though gold is scarce, gold is concentrated by geologic processes to form commercial deposits of two principal types, lode deposits, which is primary deposits and placer deposits which is secondary deposits.

Lode deposits are targets for the hard rock prospector seeking gold at the site of its deposition from mineralizing solutions. One of the hypothesis proposes which is highly accepted that many gold deposits, especially those found in the volcanic and sedimentary rocks formed from circulating ground waters driven out by the magma intruded into the earth's crust within about 2 to 5 miles of the surface. Another hypothesis suggests that gold-bearing solutions may be expelled from magma as it cools, precipitating ore materials as they move into cooler surrounding rocks. This hypothesis is applied particularly to gold deposits located in or near masses of granitic rock, which represent solidified magma.

Placer deposit is an accumulation of valuable minerals formed by gravity separation during sedimentary process. Placer materials must be both dense and resistant to weathering processes. To accumulate in placer mineral particles must be significantly denser than quartz (SiO2) and mainly form in river or stream sediments. Typical locations for alluvial gold placer deposit are on the inside bends of rivers and creeks. In natural hollows, at the tie break of slope on a stream, the base of an escarpment, water fall and other barrier.

Alluvial placers are formed by redeposition of dense particles of a site where water velocity remains below that required to transport them further. To form a placer deposit, the particles desired must show a marked density contrast with the gangue material, which able to be transported away from the trap site. Most alluvium is geologically very young (quaternary in age) and is often referred to as "cover" because these sediments obscure the underlying bedrock. Most sedimentary material that fills a basin that is not lithified in typically lumped together as alluvium(Mitchell, Evans and Styles, 1997).

2.2 Sulphide gold ore in Malaysia

Malaysia had already established itself as one of the important producer before the development of the great gold-fields. The majority of the gold production apparently came from the states of Pahang and Kelantan within the Central Belt. Gold mineralization in the Central Gold Belt is generally categorized as a low mesothermal lode gold deposit due to its tectonic and geological setting. In Raub, Selinsing and Buffalo Reef are among the old alluvial mining goldfields which are actively being revisited for the existent of low grade bulk-mineable gold deposits. The focus coverage area of study is Buffalo Reef. Small scale mining at Buffalo Reef dates back to the early 1900s.The buffalo Reef deposit occurs approximately 1 km to the east of the Raub-Bentong Suture, a major geological and is dominated by eastern assemblage of conglomerate and sandstone of Denovian age. Low grade regional metamorphism up to Greenschist facies occurs throughout the area. The sedimentary rocks have subsequently been intruded by granitic bodies of approximately Jurassic age. Outcropping rocks of these intrusive bodies occur to the east of Buffalo Reef and generally from the elevation highs.

Gold mineralization at Buffalo Reef is structurally controlled and associated with Permian sediment within a 200 m wide shear zone that parallels the north- south trending Raub-Bentong Suture. Mineralization occurs overall total strike length of 2.6 km. Rocks, within the Buffalo Reef shear zone have typically undergone silica-sericite-pyrite alteration to varying degrees (Kamar Shah Ariffin, 2006).The occurrence is within moderately to steeply east-dipping veins and fracture zones, which range in thickness from 1 m up to 15 m in thickness, although local flexures in the veins can host mineralization up to 25 m in thickness. Veins which badinage in some areas, are generally composed of massive quartz with 1-5% sulphide minerals, namely pyrite and arsenopyrite along with varying amounts of stibnite, the stibnite generally occur in association with elevated gold grades. However the presences of gold does not necessarily indicate high stibnite levels.

Table 1: Size Range of Alluvial gold in Penjom area, Kuala Lipis, Pahang (British Geological Survey, February 1997)

Site	Size Range (μm)	Average (μm)
MA105	283-719	439
MA106	197-551	306
MA 107	241-822	383
MA108	222-745	364
MA109	356-827	525
MA110	281-804	534
MA111	120-518	245

2.3 Site Background (Selinsing Gold Mine Mining Manager)

2.3.1 Selingsing Gold mine

The Selinsing gold deposit is located in the northwest Pahang, approximately 50km north of Raub Town in central Malaysia. The selinsing deposit are located to the east of the Raub-Bentong Suture zone.The Selingsing Gold Mine Project contains an indicated mineral resource of 4.82 million tonnes at 1.49 g/t Au using cut-off grade of 0.59 g/t Au for contained gold of 231,000 oz and an inferred mineral resource of 10.32 million tonnes at the grade of 1.17 g/t Au for contained ounces of 3888,000 at the similar cut of grade (Makoundi *et al.*, 2014). The Geological survey of Malaysia which undertook the geological mapping in 1993 reported that Selingsing gold deposit is located within Permo-Triassic sediments in close proximity to Post-Triassic granites and the Pahang volcanic series composed chiefly of Carboniferous to Triassic tuffaceous rocks.

C. Makoundi et al. / Gondwana Research xxx (2013) xxx–xxx

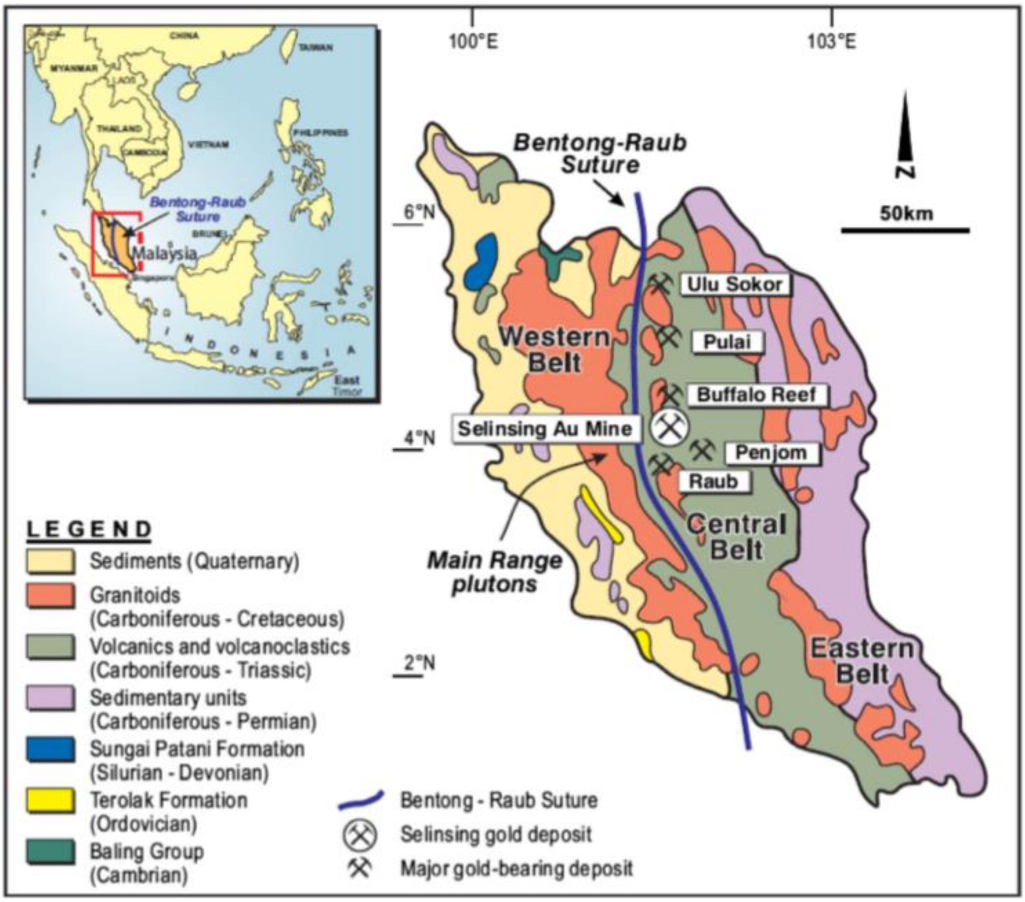

Figure 2.1: Map showing the location of the Selinsing and other gold deposits, Bentong-Raub Suture Zone, the Western, Central, and Eastern Belts in Peninsular Malaysia. Modified from Makoundi (2012,p.19).

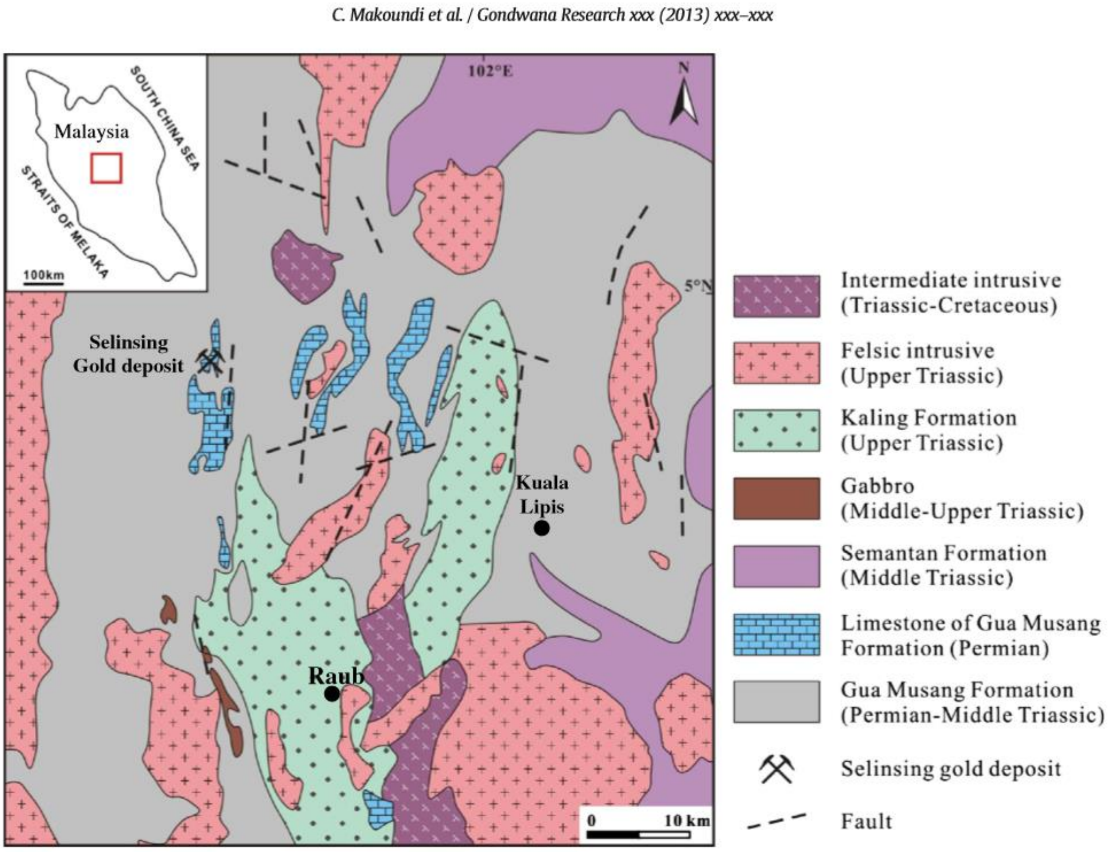

Figure 2.2: District-scale geological map of the Selinsing gold deposit, Central Malaysia

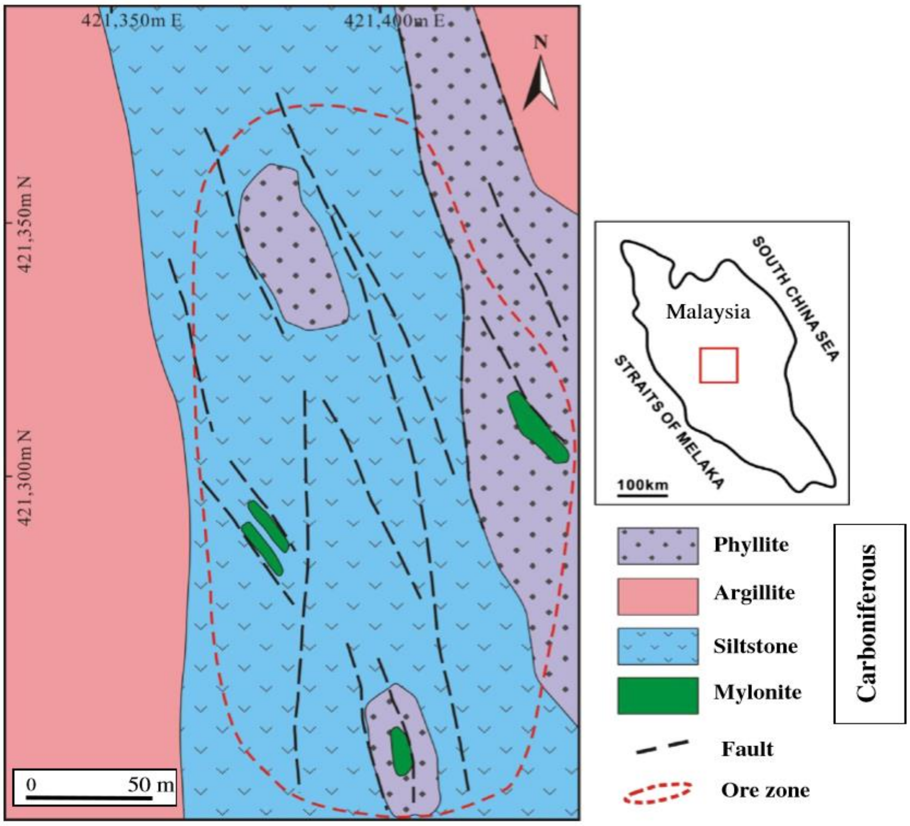

Figure 2.3: Deposit-scale geology of the Selinsing gold deposit, Malaysia (Makoundi, 2012).

2.4 Applied Mineralogy

Applied mineralogy related to gold involves in determining the mineral characteristics that have a bearing on exploration, mineral processing and hydrometallurgy. Applied mineralogy involves using ore textures and specific minerals as tracers to gold deposits, and using specific assemblages of silicate and/or ore minerals as indicators of favourable environments for deposition of gold. Applied mineralogy in connection with mineral processing and hydrometallurgy plays a major role when gold is recovered by leaching techniques and floatation. The adequate data from ore characteristic which is the type of mineral associates with the gold ore can determine the mineral processing and the used of reagents. Knowledge of ore characteristics that affect gold recoveries can help in designing a flow sheet and can indicate whether maximum recoveries have been obtained.

2.4.1 Process Mineralogy

Process Mineralogy can be considered as the practical application of mineralogical knowledge to aid mineral exploration, and to predict and optimise how an ore can best be mined and processed. It link mineral processing and traditional mineralogy together and is a specialisation within the field of applied mineralogy. Process Mineralogy is being applied in areas such as geometallurgy, ore characterisation, process design and optimisation, driven by today's increasingly complex ore bodies and the rising pressure to reduce operational cost. Responsible environmental management also demands a greater understanding of the minerals and their textures in order to reduce risk. The aim of process mineralogy is to identify, diagnose and predict processing characteristics of an ore that are mineralogically controlled or influenced, and to understand either the benefits of these that can be harnessed, or the limitations that need to be catered for. The mineralogy and, most critically the texture of an ore dictates how the ore can be mined and processed optimally, as well as highlighting potential environmental ramifications in doing so.

Process mineralogy is utilised in all stages of the mining cycle, including; exploration, mine planning, mineral processing, tailings management, and metallurgy. It is closely linked to geometallurgy, being fed directly in to a geometallurgical predictive model, which spans the whole process.

Rock and mineral properties that can be identified through process mineralogy techniques include; gangue and target mineralogy, key element deportment, grain size and shape, deleterious minerals and elements (for example swelling clays, refractory minerals, arsenic) and mineral associations.(Cropp and Goodall, 2013)

Process mineralogy is used to identify the ore minerals, and make an early assessment of potentially problematic minerals in mineral exploration. In early stages, knowledge of the mineralogy can be used to provide indicators and vectors guiding location of the ore bodies. Knowledge of the mineralogical and textural characteristics of the rock and ore increases as a resource moves from an exploration target through to a known resource and reserve. This includes expanding on the recovery potential for certain minerals or elements, and making predictions on how the ore may behave during processing.

2.4.2 Particle size analysis

Size analysis is the initial step and fundamental part in laboratory testing procedure. It is important in determining the quality of grinding and establishing the degree of liberation of the values from the gangue at various particle sizes. A sieve analysis (or gradation test) is a practice or procedure used to assess the particle size distribution (also called gradation) of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass. The results are presented in a graph of percent passing versus the sieve size. On the graph the sieve size scale is logarithmic. To find the percent of aggregate passing through each sieve, first find the percent retained in each sieve. To do so, the following equation is used,

$$\% \, Retained = \frac{Wsieve}{Wtotal} \, x \, 100\% \text{--(2.1)}$$

Where,

Wsieve = Weight of aggregate in the sieve

Wtotal = Total weight of the aggregate

Then, Cumulative % Passing = 100% - %Cumulative Retained

2.4.3 Elemental Composition

Mineral is made up from arrangement of atoms from inorganic substance and it compile with the abundance of other mineral existing within the mineral. Ore deposit can occur either in rock or soil material and it depend on the process it undergoes. A rock can be defined as a solid substance that occurs naturally because of the effects of three basic geological processes: magma solidification; sedimentation of weathered rock debris; and metamorphism. While the soil is the result of the weathered rock which undergoes chemical and biological weathered process. A mineral deposit is an abnormal concentration of minerals within the earth's crust. Mineralogist are really need to identify the mineral proportions of the minerals contain in order to control the economic mineral value. For example, in a deposit that contains 0.5% copper, all this copper may occur as coarse grains of the mineral chalcopyrite (CuFeS2) such a deposit may also contain 0.5% copper, but if all this copper occurs as a minor constituent in pyroxene (i.e. if the copper forms part of the structure of the pyroxene) then that copper is economically unrecoverable and the deposit is of no commercial value. (Merig P.Jones, 1987)

There are a few techniques which can implies for mineral composition study, which is X-ray Fluorescence and Scanning Electron Microscope (SEM-EDX). In gold process mineralogical analysis, it can be classified into 2 categories, conventional and advanced instrumental techniques. For SEM, it classified as the advanced instrumental and gives high quality images of particle textures, such as surface morphology, pore structure, permeability and coating with an energy dispersive X-ray spectrometer (EDX), in addition to its capability of being used for gold scanning.

For XRF, method for the production of a series of certified gold reference materials is presented. These reference materials are intended for use in the analysis of the elemental composition of gold alloys using a non-destructive X-Ray Florescence (XRF) spectrometry method. The chemical composition of the reference materials covers the complete range of conventional coloured and white carat gold jewellery alloys. The XRF method based on this series of reference materials produces analytical results which are comparable with those obtained when using traditional chemical methods of analysis. In X-ray fluorescence spectroscopy, the process begins by exposing the sample to a source of x-rays. As these high energy photons strike the sample, they tend to knock electrons out of their orbits around the nuclei of the atoms that make up the sample. When this occurs, an electron from an outer orbit, or “shell”, of the atom will fall into the shell of the missing electron. Since outer shell electrons are more energetic than inner shell electrons, the relocated electron has an excess of energy that is expended as an x-ray fluorescence photon. This fluorescence is unique to the composition of the sample. The detector collects this spectrum and converts them to electrical impulses that are proportional to the energies of the various x-rays in the sample’s spectrum.

2.4.3 Phase Analysis (XRD)

Phase analysis of mineral is crucial procedure in determine the analysis present by the particular mineral. Analysis of minerals is quite different from analysis of rocks. Analysis of mineral is more complicated because the individual mineral are much smaller than rocks and it is therefore difficult to obtain enough sample of mineral to perform the analysis procedure. Individual minerals may be chemically zoned. That is there may be differences in the chemical composition of the mineral from its centre to its outermost shell. Mostly the phase analysis is carry out using laboratory equipment such as x-ray diffraction, Induced-plasma membrane, electron microscope study and many more. The principle of x-ray diffraction is standard guide to determine the phase analysis. When a monochromatic x-ray beam with wavelength is incident on the lattice planes in a crystal planes in a crystal at an angle, diffraction occurs only when the distance travelled by the rays reflected from successive planes differs by a complete number n of wavelengths. By varying the angle, the Bragg's Law conditions are satisfied by different d-spacing in polycrystalline materials. Plotting the angular positions and intensities of the resultant diffraction peaks produces a pattern which is characterised of the sample. Where a mixture of different phases is present, the diffractogram is formed by addition of the individual patterns (Goodall, Scales and Butcher, 2005).

The uses of x-ray diffraction (XRD) can determine the grade control in order to optimize concentrator feed and operational efficiency. The mineralogy of ore sample is often not considered or at best inferred from visual geological logging of sampled material because not all the mineral contaminants cannot be identified visually or by chemical analysis which not recommended. The information provided by XRD will lead to creation of maps of spatial distribution of minerals. Common practice in grade control include the chemical analysis of ore and waste for key elements. The result will be analyse and conclude as cluster analysis for the raw scans which include phase identification and quantification. It can be used to simplify data processing significantly by automatically sorting closely related scans into clusters. It can reduce the amount of data that has to process. After completion of the cluster analysis of all the characteristic ore mineral, the result can be sorted and filtered all following of similar sample with varying mineralogy before quantitative analysis is applied. The most characteristics scans of each cluster are used for phase identification. Phase identification was performed using Xpert Highscore plus software.

2.5 Comminution and Sizing

Comminution is the reduction of solid materials from one average particle size to a smaller average particle size, by crushing, grinding, cutting, vibrating, or other processes. In geology, it occurs naturally during faulting in the upper part of the Earth's crust. In industry, it is an important unit operation in mineral processing, ceramics, electronics, and other fields, accomplished with many types of mill. In dentistry, it is the result of mastication of food. In general medicine, it is one of the most traumatic forms of bone fracture.

Within industrial uses, the purpose of comminution is to reduce the size and to increase the surface area of solids. It is also used to free useful materials from matrix materials in which they are embedded, and to concentrate minerals

There are several methods of comminution. Comminution of solid materials requires different types of crushers and mills depending on the feed properties such as hardness at various size ranges and application requirements such as throughput and maintenance. The most common machines for the comminution of coarse feed material are the jaw crusher (1m > P80 > 100 mm), cone crusher (P80 > 20 mm) and hammer crusher. Primary jaw crusher product in intermediate feed particle size ranges (100mm > P80 > 20mm) can be ground in Autogenous or Semi-Autogenous (AG or SAG) mills depending on feed properties and application requirements. For comminution of finer particle size ranges (20mm > P80 > 30 μm) machines like the ball mill, vertical roller mill, hammer mill, roller press or high compression roller mill, vibration mill, jet mill and others are used

2.6 Polished Section

Polished section A specimen of an ore (opaque) mineral after it has been prepared for examination under a reflected light microscope by light reflected from its polished surface. A sample of the mineral is mounted in a cold-setting epoxy resin, sawn to produce a flat surface, and then inverted, ground, and polished in a number of stages using diamond-impregnated fluids and a rotating lap fitted to a polishing machine. Conventional 0.03mm thin sections are prepared in the same way to give 'polished thin sections', used in the identification of opaque minerals. Polished sections are also required in the electron-probe micro-analyser to enable analyses of minerals to be carried out.

2.7 Thin Section

In optical mineralogy and petrography, a thin section (or petrographic thin section) is a laboratory preparation of a rock, mineral, soil, pottery, bones, or even metal sample for use with a polarizing petrographic microscope, electron microscope and electron microprobe. A thin sliver of rock is cut from the sample with a diamond saw and ground optically flat. It is then mounted on a glass slide and then ground smooth using progressively finer abrasive grit until the sample is only 30 μm thick. The method involved using the Michel-Lévy interference colour chart. Typically quartz is used as the gauge to determine thickness as it is one of the most abundant minerals.

When placed between two polarizing filters set at right angles to each other, the optical properties of the minerals in the thin section alter the colour and intensity of the light as seen by the viewer. As different minerals have different optical properties, most rock forming minerals can be easily identified. Plagioclase for example can be seen in the photo on the right as a clear mineral with multiple parallel twinning planes. The large blue-green minerals are clinopyroxene with some exsolution of orthopyroxene. Thin sections are prepared in order to investigate the optical properties of the minerals in the rock. This work is a part of petrology and helps to reveal the origin and evolution of the parent rock. A photograph of a rock in thin section is often referred to as a photomicrograph.

2.8 Gold Recovery Methods

There are various methods to recover the gold from the ore either in chemically or physically extraction. The methods considered predominantly include the physical detachment of gold from "gangue" mineral utilizing gravity separation techniques. Gold has a high specific gravity (19.3 g/$cm3$) in relationship to most normal gangue minerals and along these lines it appropriate for gravity processing. The high volume of throughput of alluvial gold ore is the appropriate for this sort of mineral processing. The factor of certain gold grain qualities impacts the productivity of gold recovery methods particularly for the 11 gravity separation. The impact of density upon the conduct of a gold grain will diminish as the surface zone to mass proportion increments. Gold is ordinarily flakier with diminishing grain size and not circular.

The malleability of gold keeps the state of gold keep up as opposed to cracking because of stacking and effect. This unpredictable shape prompts porosity; pits and pores are regularly infilled with bring down density material bringing down the density of the composite molecule. The flaky shape, porosity and hydrophobic surface properties can regularly cause the gold to buoy and it is a noteworthy issue for fine grained gold. The mineralogical character of the gold is frequently not considered when arranging a processing plant if the gold is relating admirably to standard gravity and cyanidation process. Be that as it may, if the recovery level of gold is poor (<80%) the mineral is named "refractory" and an itemized mineralogical examination winds up fundamental (JMitchell,Ej Evans,& MT Styles,1997).

One example of gold recovery methods is shaking table. The wet table is the basic type of shaking table which is water as a medium of separation. It comprises of a level table or deck with parallel riffles to trap the heavy minerals. The deck is vibrated longitudinally and slanted horizontally amid activity. A punctured pipe sustains wash water from the upslope side. The slurry feed is presented at the top upslope corner. The minerals in the encourage isolate. The heavy minerals sink to the deck, move along the riffles and are released over the finish of the deck. The light mineral, entrained in the water, ignore straight the riffles and down to the base and so to the tailings. It is appropriate and successful in the handling of material in the size range 3mm to 15μm. (Hanif, 2014)

2.9 Mineral Liberation

Minerals are formed during various geological occurrence which can be associated with many type of minerals. Mineral liberation can be define either in research study or in industrial scale, in industrial scale, mineral liberation is define as the release of the valuable minerals from their waste gangue mineral and in research study, the mineral liberation is focus of determine the size fraction which the focused mineral available at. Mineral liberation can be conducted using the comminution process and followed by sieving for size fraction analysis. The determination of size fraction which the mineral available at can determine the proper flow sheet of mineral comminution process.

Breakage of the rock break during either blasting, comminution or during the passage way of the process, particles are produced with a continuous size distribution from the coarsest particle in the product to the finest (which is theoretically a particle of zero size). The continuity of this particle size distribution may be broken when the fragmented material is subjected an imposed process such as screening or hydraulic classification, in which case any products of the process will have their own unique size distribution that will differ from the that of the original material.

The textural relationships between minerals within an ore, and their relation to process selection requires the introduction of the concept of liberation size. This is the size to which an ore must be crushed or ground to produce separate particles of either value mineral or gangue that can be removed from the ore (as concentrate or tailings) with an acceptable efficiency by a commercial unit process. Liberation size does not imply pure mineral species, but rather an economic trade-off of grade and recovery. Liberation size is a function of the relevant physical or chemical process and may differ greatly between processes (Mills, 2006).

The liberation size of pyrite for both flotation and leaching (and gravity concentration if it is included in the mill flowsheet) is therefore a most important parameter. This information is extremely difficult to determine without quantitative mineralogical studies. Size reduction for liberation naturally produces a size range of particles. This range is dependent upon the type of size reduction method used, and the hardness, texture, friability and degree of weathering of the rock and its constituent minerals.

Chapter 3

Methodology

3.1 Introduction

The methods of conducting this project were divided into a few steps which are sample collecting (at Selingsing Gold Mine Manager), preparation step, processing step, analysis step and results. Each step is carried out at different workplace. The preparation and processing step are carried at the Comminution Workshop while the analysis step is carried out in the Laboratory.

During the sample collecting step, the sample from the Buffalo Reef which are High Grade and Low Grade, both situated inside the Selingsing Gold mine. The sample collecting is done using the Random Grab Sampling. Sampling method must be efficient to obtain the representative sample. After sampling, the sample is crushed using the Jaw Crusher and Cone Crusher in the Comminution Workshop in USM to liberate the gold ore. The liberated gold ore undergoes Cone and Quartering Sampling Method to divide the sample for different analysis steps.

The analysis steps includes polish Section, thins Section, loss on Ignition (LOI), XRD, XRF and SEM/EDX. The outcome of the analysis is considered as a result for this project.

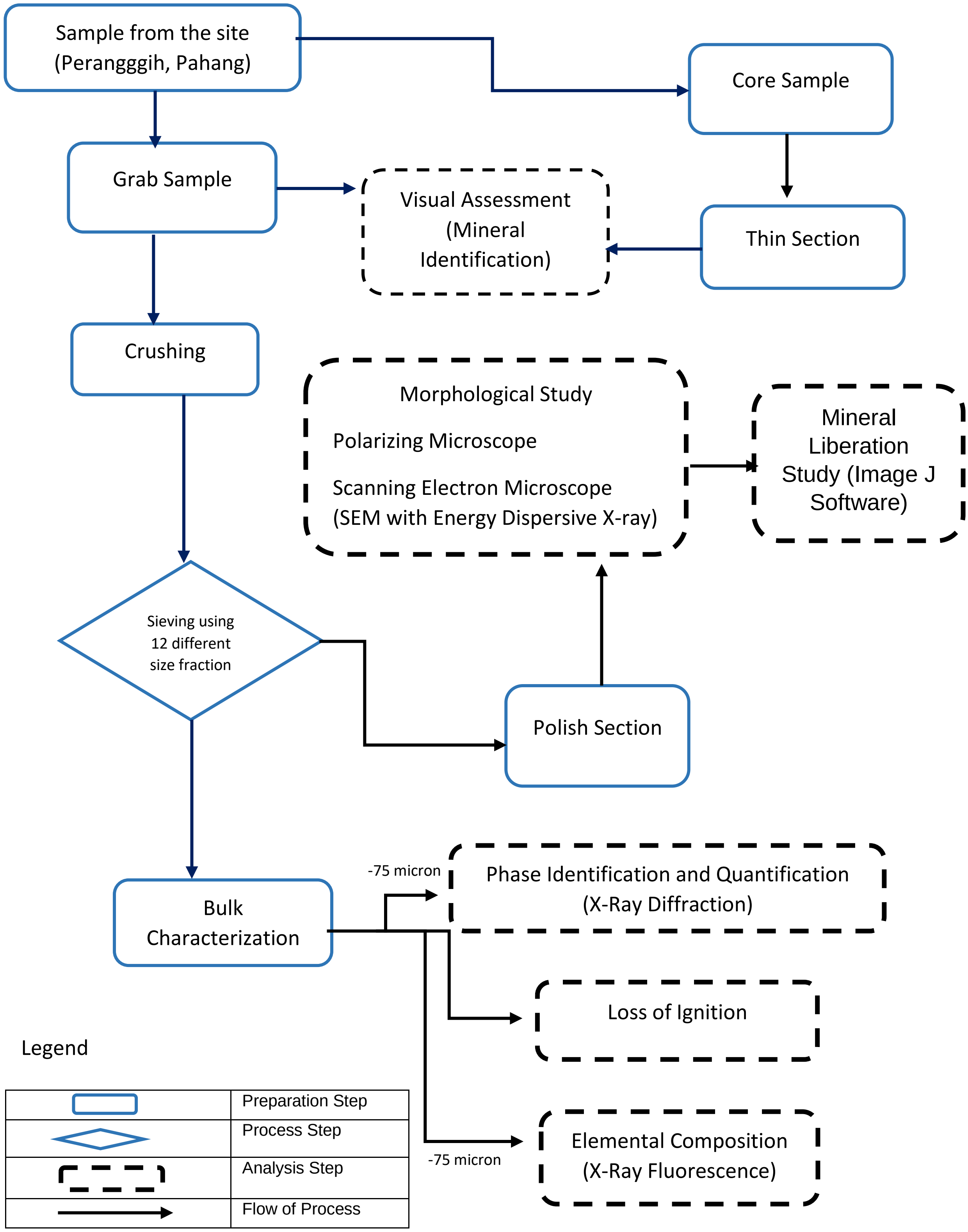

Figure 3.1: Flowchart display the general procedure used for gold process mineralogical study

3.2 Raw Material

The gold ore is collected from the Selingsing Gold Mine Manager directly from the stockpile of the Buffalo Reef. The location of the stockpile is at the coordinate of N 04º15.577' and E 101º46.784' on google earth coordinates. The sample collected using Random Grab Sampling Method. The samples are collected from 30x different spot of the stockpile randomly. The samples are kept in the plastic bags which are labelled based on the collection site, grades and number of bags, for example HG2-1 1, HG indicates the grade, 2-1 is the stockpile and 1 is the number of bags. The sample is greyish to black in color with the size range of ±5mm to ±9cm (powder size to rock size). A total of 68.6kg of HG2-1 sample is collected and 1.86kg of the sample is allocated for mineral characterization.

3.3 Site Sampling

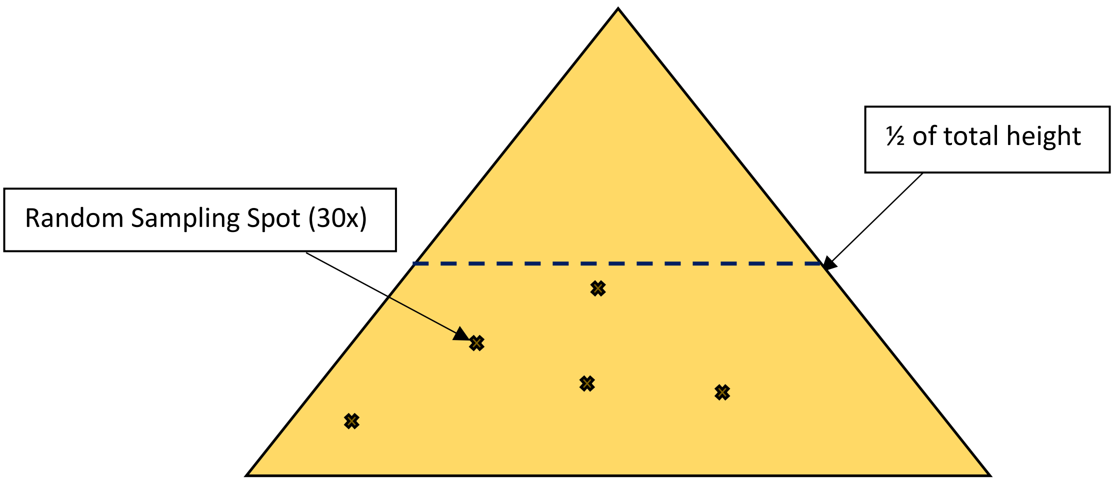

Figure 3.2: Random Sampling Method

Tools needed for random sampling method are shovels (for sample gathering), plastics bags (for storing sample) and permanent marker pen (for labelling the sample bags). The samples from the stockpile is collected randomly, about 30 samples, but the collecting location must not exceed half of the total height of the stockpile. The samples collected is stow in the plastic bags and labelled based on their collection spot and number of bags.

Figure 3.3: Sample from SGMM

3.4 Lab Sample preparation

Crushing is a processing of reducing the size of the ore. The samples undergoes crushing steps to liberate the gold ore from the host rock. The crushing steps included Jaw Crusher and Cone Crusher.

3.4.1 Jaw Crusher

Figure 3.4: Primary crushing using Jaw Crusher

Jaw Crusher is a Primary crusher which is "V" shaped crusher. The model of Jaw crusher is SVEDALA which is single toggle crusher. The jaw crusher consist of stationary plate and motion plate. The motion plate moves in circular motion which continuously collide the samples to the stationary plate. The reduction ratio of the primary jaw crusher is 5:1. Large and rocky samples is crushed using the jaw crusher to obtain a smaller size