MINERAL CHARACTERIZATION OF CASSITERITE ORE FROM SELECTED AREA IN MALAYSIA

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MINERAL CHARACTERIZATION OF CASSITERITE ORE FROM SELECTED AREA IN MALAYSIA

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DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled 'Mineral Characterization of Cassiterite Ore from Selected Area In Malaysia'. I also declare that it has not been previously submitted for the award of any degree and diploma or other similar title of this for any other examining body or University.

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LIST OF ABBREVIATIONS

SEM	Scanning Electron Microscope
EDX	Energy Dispersive X-Ray
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence
OM	Optical Microscopy
SnO_2	Tin Oxide
USM	University Sains Malaysia

MINERAL CHARACTERIZATION OF CASSITERITE ORE FROM SELECTED AREA IN MALAYSIA

ABSTRAK

Dalam kajian ini, pencirian dan pemprosesan tin telah dijalankan. Tujuan penyiasatan ini adalah untuk memeriksa kewujudan tin dan mineral berat yang lain dalam granite pegmatite. Sampel telah dikeringkan dan dihancurkan menggunakan mesin-mesin penghancur seperti penghancur rahang, penghancur kon, dan mesin ring mill yang ada di dalam makmal. Selepas itu, persampelan telah dijalankan dan empat wakil sampel dari sampel asal telah diambil dan dihantar untuk analisis XRF yang bertujuan mengetahui kandungan mineral di dalam sampel asal. Seterusnya, analisis taburan saiz partikel telah dijalankan untuk melihat kecirian mineral dari empat sampel yang saiznya berbeza. Sampel tersebut telah dihantar untuk analisis XRF untuk mengetahui kandungan mineral selepas pemprosesan. Pengunaan mikroskop optik di bawah cahaya polarasi digunakan untuk mengetahui kecirian mineral dalam sampel dibuat. Pengekstrakan sampel in diperoleh dengan menggunakan meja Mozley. Selepas itu, pengekstrekan sampel in dihantar untuk analisis mesin XRD dan XRF. Keputusan daripada mesin XRD dan XRF dianalisis untuk mengetahui fasa dan peratusan jisim oksida timah dan sebatian lain.Analisis melalui mesin SEM telah digunakan juga untuk melihat keamatan warn mineral yang ada di dalam sampel. Keputusan menunjukkan bahawa terdapat banyak mineral berat dalam sampel apabila warn putih boleh dilihat dalam keputusan SEM. Keputusan XRD menunjukkan kandungan silika di dalam sampel. Oleh itu, mineral berat susah untuk dikenal pasti. Keputusan dari analisis XRF menunjukkan bahawa kehadiran tin dalam sampel tersebut. Mineral-mineral beat seperti besi dan alumina juga dapat dilihat. Dengan ini,

kandungan tin dalam sampel dikira dan didapati kandungan tinggi yang diperoleh adalah 3.572%. Kandungan ini boleh ditinggikan dengan menggunakan kaedah yang lebih efisyen seperti penggunaan pengkonsentrat pilin. Daripada analisis tersebut, didapati bahawa tin boleh dilombong jikalau kandungan tin ditingkatkan melebihi 70%.

MINERAL CHARACTERIZATION OF CASSITERITE ORE FROM SELECTED AREA IN MALAYSIA

ABSTRACT

In this research, characterization and processing of tin have been performed. The aim of this studyis to identify the presence of tin and other heavy minerals in the raw sample. Sample is dried and crushed using jaw crusher, cone crusher and ring mill which are there in the laboratory. Then, after sampling was done and four representative sample from the raw sample was taken and sent for XRF analysis to identify mineral compositions in the raw sample. Next, particle size distribution is performed to see the characterization of minerals from four samples with different sizes. The samples are sent for XRF analysis to get the identification of minerals after processing. The optical microscope under polarized light is used to see the characterization of all the mineral in the sample. The concentrate sample is obtained after using Mozley table. The concentrate of the sample is then sent for analysis using XRD and XRF machine. The result from the XRD and XRF machines is analysed to identify the phases and mass percentage of tin oxide and other compound in the each sample. SEM machine is used to observe the heavy minerals based on the intensity of the mineral colour in the sample. Result shows that there are many heavy minerals in the sample when there is bright colour analysis is shown in the SEM result. XRD result shows the high content of silica. Hence, heavy minerals are hard to be determine. Analysis of the XRF result shows that there is tin present in the sample. Besides tin, there are some other heavy minerals too that are present such as ferrum oxide and

aluminum oxide. Thus, the highest percentage of tin in the sample is about 3.572%. The concentration can be increased if more efficient process is used such as spiral concentrator. Based on the analysis, the tin is mineable should the concentration is increased up to 70%.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The identification and characterization of minerals is of fundamental importance in the development and operation of mining and mineral processing systems (Hope et al., 2001), and it is very important in choosing a suitable flowsheet for recovering the constituent metals. It is also critical in optimizing actual plant for improving performance. According to Cook (2000), the growing need for detailed information about the mineralogical composition of a mineral deposit therefore determines that mineral characterization studies form an integral and often critical part of investigations of deposits. Knowledge of mineralogical/chemical composition, size, morphology and association with other minerals is therefore expected to provide insights and information on the characteristics, type, nature and amount of minerals and elements present within the ore at different locations that would permit an assessment and determination of the optimal processing route for its constituent minerals/metals.

This methodology has been developed to optimize the exploration of the mineral resource by providing a better knowledge of the ore characteristics and its behaviour in the process (Sant'Agostino et al., 2001). Since different minerals from different locations within an ore deposit have different mineralogical compositions with different characteristics and complexities, their qualitative and quantitative distributions vary from location to location within an ore deposit, and from deposit to deposit, which could lead to variations in their recovery processes. Hence, complex sulphide ores have globally attracted the attention of researchers in different disciplines with totally different approaches and methods in characterizing complex sulphide ores (Eymery and Ylli, 2000; Kahn et al., 2001; Hope et al., 2001) for understanding the recovery processes of their constituent minerals and metals.

Tin is obtained chiefly from the mineral cassiterite, where it occurs as tin dioxide, SnO_2. The most common method of processing cassiterite is hydraulic-gravity processing (as in Bolivia, Indonesia, Malaysia and Thailand) with sluice boxes or jigs. This method is believed to be less efficient with increasing fineness and decreasing density of heavy minerals (Funtua, et. al, 1997). However, this method is comparatively cheaper than the flotation or chemical method (leaching).

Tin is one of the metals that had been used for more than 5000 years. It was used as tools and weapons and now used to make modern appliances such as cans packaging food and tin-lead solder in electronic parts. Tin is a white metal at room temperature, soft and easily alloys with other metals. Tin also has a low melting point and able to be shaped.

Historically, Malaysia was the biggest tin producers in the world. Tin ore occurs mainly in alluvial and hardrock. Most of the alluvial tin ore are located on the western side beginning in the north and stretching southward through Ipoh to Melaka and mined by the gravel pump and opencast methods.

The Peninsular Malaysian tin industry was once one of the world's largest and most important producers of tin within the South Asian Tin Belt, but the collapse of the tin price in 1985 caused the closure of several tin mines throughout the country. The majority of the tin was extracted from alluvial or placer tin deposits in the Malaysian states of Perak and Selangor. These alluvial tin deposits were formed because of extensive weathering, which typically makes geological work difficult in tropical climates. Since the increase in global tin consumption and the subsequent increase in price of tin, there has been renewed interest in developing many previously abandoned tin fields and new resources in Malaysia, which has resulted in the reactivation of several previously abandoned tin fields and new resources in Malaysia. (Ariffin, 2009)

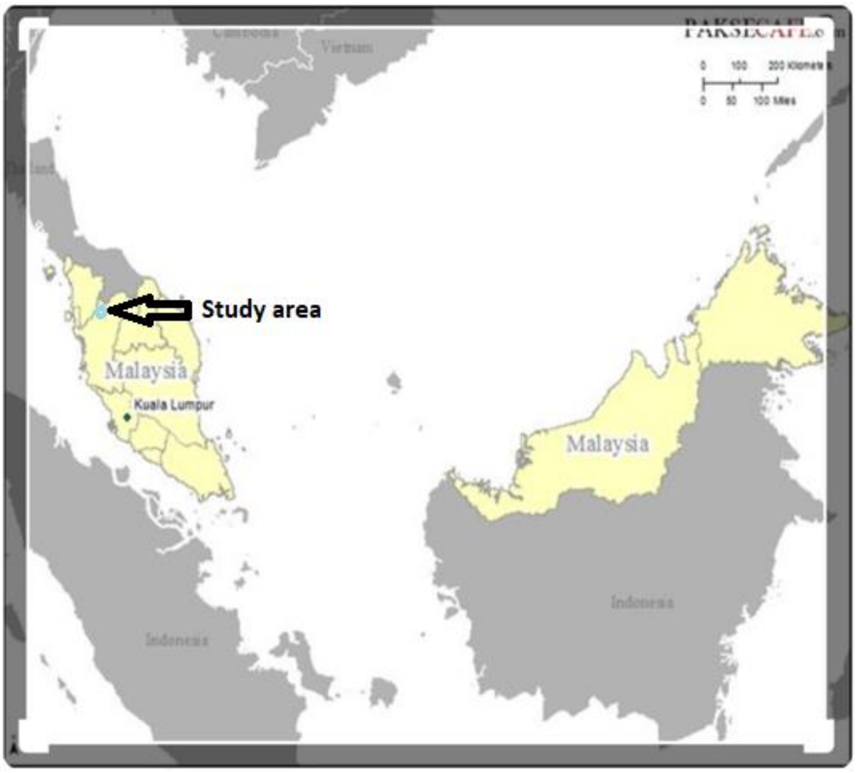

Figure 1.1 Location of study area

Around 5000 years ago, at the beginning of the Bronze Age, bronze, a coppertin alloy, transformed tin into a "strategic metal," elevating tin to a position of prominence. Tin, along with steel, copper, iron, and aluminium, remained a major metal during the Industrial Revolution, and it is still used today. Tin has seen a rebirth in recent decades, owing to the rapid development of the electronics sector, with around 50 % of current tin output being utilized as (lead-free) solder. Tin alloys are finding more and more high-tech applications, such as in superconducting magnets, improved solar cells, and liquid crystal displays, to name a few examples. (Lehmann, 2020)

Now, worldwide tin mine production amounts to approximately 300 000 t Sn/year, with Indonesia and China dominating the market, and Myanmar catching up with these two countries in recent years. The total cumulative historic tin output can be estimated to be approximately 27 million tonnes of tin (up to 2020). In fact, granitic rocks, such as granites and their volcanic and subvolcanic equivalents, account for more than 99 % of the world's tin output, which comes from ore deposits that are either directly (primary deposits) or indirectly (placers) associated to them. Tin is or was recovered as a by-product of the mining of base-metal massive sulphide deposits, which is or was a minor amount of tin (such as Kidd Creek, Canada, or Neves Corvo, Portugal). In the past century, only four well-defined regions have produced approximately 85 percent of the cumulative historic tin mine output: the Southeast Asian tin belt (Malaysia, Thailand, Indonesia, and Myanmar) with a 40-45 % share of total world tin production, the South China tin province (20 %), the Central Andean tin belt (Bolivia and southernmost Peru) with 14 %, and the Cornwall tin province with (7 %). (Lehmann, 2020)

Consequently, the primary objective of this study is to provide comprehensive data about the physical and chemical characteristics of fine tin from the tin scrubber. These include mineral morphology, phase analysis, elemental composition and degree of liberation, with a view to finding out and understanding the best possible practice or extraction route by which tin could possibly be extracted (Ogwuegbu, et. al, 2011).

1.2 Background of Study

The purpose of this research is to investigate the mineral characterization of Cassiterite ore deposit in Pengkalan Hulu, Perak. There are eight sample were taken at

PPM Tin Mining site, where six sample from outcrop body at different place, one sample from stockpile and one sample obtained from concentrate of shaking table.

Once upon a time, Peninsular Malaysia was one of the largest and most important tin producers in the world within the South Asian Tin Belt, before the collapse of the tin-price which forced the closure of many tin mines in 1985. Main production was from alluvial or placer tin deposits from states of Perak and Selangor. However, the source of many of these alluvial deposits can be traced to the primary tin veins and ore bodies located at contact zones of tin-bearing granites and other rocks (Yeap, 1978; Rajah, 1979). These alluvial tin deposits resulted from deep weathering which normally hampers geological work in tropical climates. The surge in demand of metals including tin worldwide and higher price these days has witnessed a renewal of interest in developing of many, previously abandoned tin fields and new resources in Malaysia, especially alluvial type tin deposits even at a small operational scale.

Thus, samples from PPM Tin Mining site can be used as research to identify mineral characterization of cassiterite ore.

1.3 Problem Statement

The study of ore grade and volume, valuable mineral association and gangue minerals of tin deposit are important for economic evaluation, mineral processing design and the genesis of ore deposit for exploration purpose. So that, these research is to analyse the characterization of the cassiterite by mineralogy and geochemistry. Each sample taken has different physical characteristics that make it difficult to identify the cassitrite content in the sample. Although all samples were taken from the fault zone as Figure 1.2 below, visual observation on each samples are impossible to identify the present of cassiterite inside the sample also difficult to distinguish all or related constituents of mineral.

Figure 1.2 Fault zone at sampling area

Other, lack of info of cassiterite mineralogy of ore at sampling area gave some challenging to identify area that contain cassiterite. Most of outcrop body there have similar pattern and already weathered. Associated mineral may create adding value of complexity of the processing such as iron ore. A few tin deposits in Malaysia were associated with significant tungsten and amang deposit, where a proper study is required to identify the characterization of the ore mineral.

However, as the liberation size may be below 105 µm and given that the separation process of the shaking table, magnetic separator or high tension are only suitable for mineral separation in a relatively coarser size range, using the same methods for separation of fine cassiterite is quite challenging. Fine grinding needs to be conducted to get a high quality tin concentrate and a great loss of tin cannot be avoided when treating the ore by gravity concentration. (Nevertheless Siqing Liu, 2011)

Based on the above facts, a two-stage separation, with a low intensity magnetic separator and a shaking table were selected to test the ore. This study focuses on mineralogy, geochemistry, and simple physical metallurgy study to characterize the orebody.

1.4 Study Area

The raw sample used for the study is an unprocessed cassiterite from the grab sampling. The sample is collected at cassiterite mine at PPM Tin Minng Sdn. Bhd which is located M2HF+73, 33100 Pengkalan Hulu, Perak. This is a mine that processes Tin. The mine is accessible by land and will take around 21 minutes of driving with the distance of 18.8km from Pekan Baling, Kedah and around 1 hour 57 minutes of driving with the distance of 124km from Universiti Sains Malaysia, Nibong Tebal, Penang (USM) to arrive at the location. The collected raw sample is then brought to USM pilot laboratory to be characterize and process to identify the presence of tin and extract it.

Figure 1.3 Host rock at sampling area

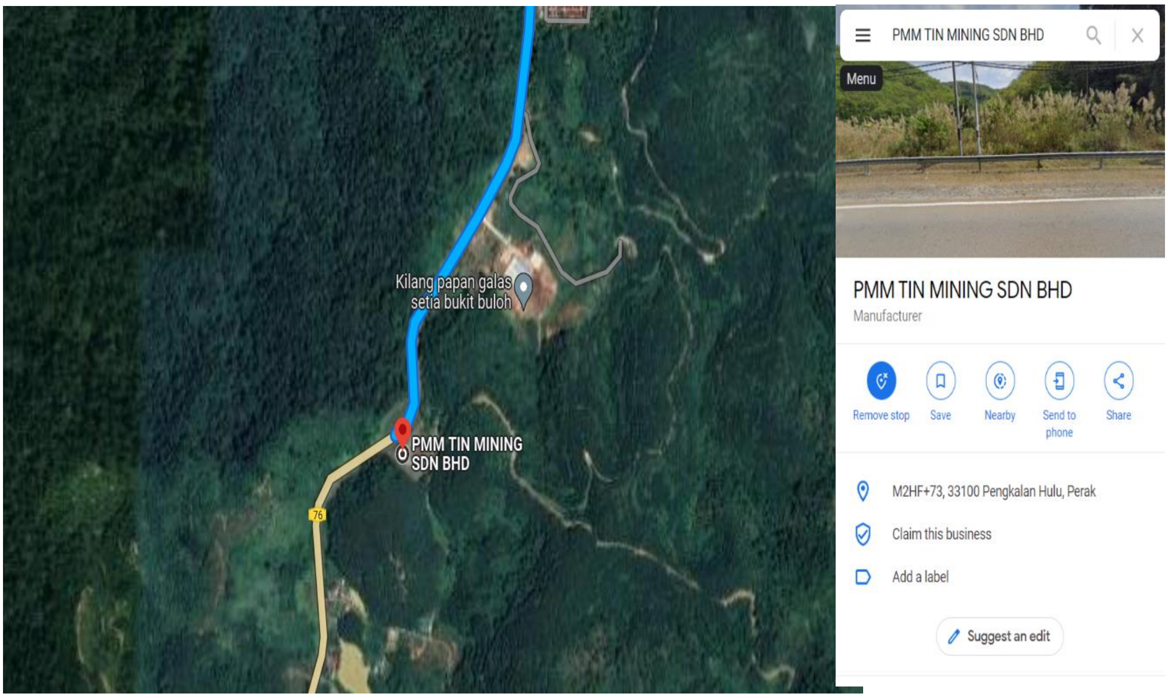

Figure 1.4 Location of PPM Tin Mining Sdn. Bhd, Perak

1.5 Objectives

a) To characterize the mineralogical of cassiterite ore using the application of XRD, XRF Micro-XRF, ICPMS and SEM-EDX.

b) To study and identify the other associate mineral.

c) To study the mineralogy of ore concentrate under the reflected light microscope and SEM analysis by prepared polished section.

1.6 Thesis Outline

Systematic writing in this study includes several things.

Chapter 1 is about introduction. This chapter describes the background of the project, study area, and problem statement and objectives of the project. Next, Chapter 2 is about literature review. This chapter describes more on the types of the pegmatite stone, and the ways used to increase the purity tin. There is also theoretical explanation on how a tin is extract from a pegmatite stone. Chapter 3 is about methodology. This chapter describes the theoretical relationship that has been described in the previous chapter with problems / cases, a detailed description and flow chart of research activities conducted, detailed explanation of techniques, procedures and formulae that used to conduct the research. Then Chapter 4 is about results and discussion. This chapter contains the results of characterizations together with the data obtained from the physical processing method. The data will be analysed and discussed in order to achieve the objectives of the study. Finally, Chapter 5 is about conclusions and recommendations. This chapter contains conclusions and includes recommendation for the future works based on the result of the analysis.

1.7 Scope of research

The scope of this research be focus to investigate and study the raw sample where eight sample at differences place are taken from PPM Tin Mining SDN. BHD. site where the properties of this ore will be tested. For this project, the first step is sampling. From the sampling, each sample are divided into two big samples which are used to characterization and reference. For characterization, the mineral will characterize by physical property (sieving and SEM-EDX), chemical property (X-ray fluorescence analysis, XRF, Micro-XRF and ICP-MS) and mineralogical study (X-ray diffraction analysis, XRD).

CHAPTER 2

LITERATURE RIVIEW

2.1 Introduction

Tin is a technologist's metal, in the sense that whilst its various applications reach into all aspects of life, most people are usually unaware of its presences.

Long before history was recorded, tin was associated with the technological advance of mankind. Archaeological evidence confirms that tin was one of the earliest metals known to human society. The main reason for the importance of tin in early times was the discovery of its hardening effect on copper to form bronze. This alloy could be sharpened to give a cutting edge and hence could be fabricated into efficient tools and weapons. From this early Bronze Age to the Space Age of today, tin has continued to play an important role out of all proportion to the gross tonnage produced and used (Falcon, 1982).

Cassiterite (Sn02) is known as tinstone. It is the only tin mineral that is in sufficient abundance in the earth's crust to have any commercial value. When chemically pure, which is rare, cassiterite contains 78.6 per cent tin but, when contaminated with impurities, the tin content varies between 73 and 75 per cent (Barry, etc. al, 1983)

Cassiterite is mainly found in two types of deposits. In the first, it occurs as a primary accessory constituent of certain late-stage granitic intrusions, and is found in veins and fissures both in the granite and surrounding country rock. The second type of deposit is of a secondary origin and occurs as alluvial or placer and detrital deposits (Falcon, 1982).

There is a clear association of cassiterite with highly acidic granitic rocks, and it is an interesting and significant fact that at not a single tinfield in the world has cassiterite been found in situ except near granite or granite rocks. Because cassiterite is a chemically stable mineral, each type of primary deposit contributes to the secondary accumulations that are at present the major source of tin (Falcon, 1982).

2.2 South-East Asian Tin Belt

The South-East Asian Tin Belt is a broadly arcuate zone extending southward from northwestern Thailand and eastern Myanmar/Burma, through the two countries' shared border, through peninsular Malaysia and into the Indonesian islands of Singkep, Bangka, and Belitung. This belt is a distinct metallogenic province that contributed more than 75% of the world's tin production during the twentieth century. The majority of that production originated in alluvial and eluvial deposits. (Hosking, 1977; Jackson & Helgeson, 1985)

The Thai-Malaysian Tin-Tungsten Belt stretches for approximately 3500 km from Northern Burma's Shan States to Belitung Island in Indonesia. Tungsten mineralization is more abundant in the belt's northern reaches, while tin is the only metal found south of the Thai-Malaysian border. The belt is predominantly composed of Palaeozoic and Lower Mesozoic shelf sediments composed of quartzose sandstones and argillites with important major carbonate units and, in particular, intercalated 14 volcanics in Malaysia. Minor deeper water sediments are detected in the area, primarily to the north and west. (Hosking, 1977; Jackson & Helgeson, 1985)

Three zones of tin-bearing granitic intrusions split the belt, each corresponding to a tin belt. In eastern Malaysia, a string of Permo-Triassic high-level granites may be discovered, whereas Late Triassic deep-seated granitic rocks can be found in the

Indonesian "tin islands," on the west coast of Malaysia, and in the western province of Thailand. Cretaceous granites are mapped in southern Thailand and along the Burmese-Thai border and these probably continue into Sumatra. The vast majority of the tin produced in the belt comes from alluvial deposits, which are found across the region. Several separate tiny cassiterite-bearing quartz vein swarms and disseminations within the granite batholiths of the region appear to have resulted in the formation of these deposits. (Hosking, 1977; Jackson & Helgeson, 1985)

Primary deposits such as the cross-cutting cassiterite bearing quartz veins of Sungai Lembing and the stratabound sulphide and/or magnetite deposits of Laboo in southern Thailand, Manson Lode, Bukit Besi, Machang Setahun, and Pelepah Kanan on the east coast of Malaysia, and Kelapa Kampit on Belitung Island have not contributed significantly to the region's tin production. Primary tungsten deposits account for the vast majority of tungsten mineralization, with a small number of significant deposits and a larger number of minor vein type occurrences. Khao Soon is a ferberite occurrence hosted by quartz veins and the enclosing sediments within a shale-quartzite sequence in southern peninsular Thailand, and it is one of the world's largest deposits. Doi Mook is the other main tungsten mine in Thailand, and it is classified as a "skarn type" scheelite deposit in limestone. It is the country's secondlargest tungsten producer. The Mawchi deposit in Burma, which consists mostly of a 15 cassiterite-wolframite-scheelite-bearing quartz lode system inside a granitic host, is, or was, the region's other significant tin-tungsten producer. (Hosking, 1977; Jackson & Helgeson, 1985)

The vast majority of tin mined has come from alluvial deposits in a few locations. The Kinta Valley in western Malaysia is the greatest of these. Bangka Island in Indonesia is the next most important, followed by the Kuala Lumpur area on

Malaysia's west coast. The Phuket-Phang Nga area in southern peninsular Thailand is the fourth largest, followed by Belitung Island in Indonesia, and the east coast of Malaysia. These two places had substantial contributions from primary resources of tin. These two places had substantial contributions from primary resources of tin. Other large alluvial fields are located on the Indonesian island of Singkep, in northwestern Malaysia, in southeastern peninsular Thailand, and in southwestern peninsular Myanmar/Burma. The majority of these alluvial deposits appear to have originated from a few minor cassiterite-bearing quartz vein swarms or disseminations near the borders of each of the main belts' granites. (Hosking, 1977; Jackson & Helgeson, 1985)

2.3 GEOLOGY

The sample utilized in this research were obtained within west coast of peninsular Malaysia. The samples are from PPM Tin Minng site at Pengkalan Hulu, Perak which is near Gunung Paku where maybe have similar pattern of mineral associated.

2.3.1 General Geology of Gunung Paku

Gunung Paku is mainly associated with widespread occurance of sheet-like quartz veining systems parallel to the strike of the host rocks and confined with narrow N-S trending fault zone (Ariffin, 2009). Figure 2.1 show the general geology of the Gunung Paku. The mineralization formed within a thick sequence of metasedimentary rock that belongs to the Baling Palaeozoic Age.

The host rock is weakly metamorphosed argilite experienced strong tropical weathering that resulted in a thick sequence of light brown to light grey oxidized profile. The mineralized veins range from simple quartz-cassiterite, quartz-tourmaline-cassiterite to complex quartz-cassiterite-polymetallic sulfide veins. Wall rock alterations as seen in Gunung Paku are mainly consisting of silicification, tourmalinization chloritization, sericitization and kaolinization; normally adjacent to mineralized quartz veins and brecciated-fault gouge zones (Ariffin, 2009).

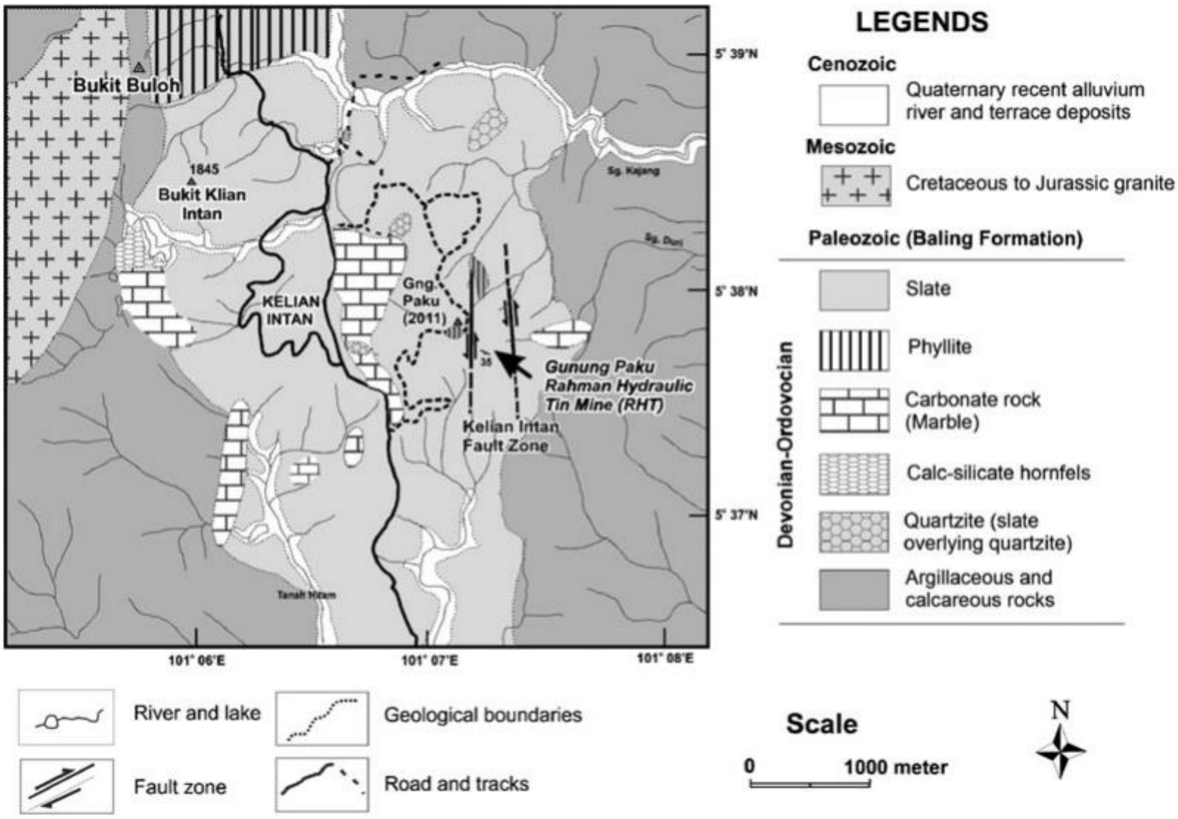

Figure 2.1 Geological Map of The Gunung Paku Tin Deposit (Ariffin, 2009)

The veins are categorized as barren quartz veins, tourmaline cassiterite quartz veins and complex sulfide tin-rich quartz veins. Rutile, pyrite, chalcopyrite, arsenopyrite, cassiterite, scorodite, trippkeite, and covellite are usual metallic minerals that went with the tin mineralization. The primary tin sources had been subjected to deep and intense tropical weathering to form thick alluvial deposit (Ariffin, 2009).

2.3.2 General Geology of Lembah Kinta

Limestones constituted the bedrock over the greater portion of the Lembah Kinta. It formed striking hills rising from the alluvial plain which is the most common rock in the calcareous series. Limestone deposited in a clear sea but during the period of deposition, muddy and sandy allows the limestone to crytalline into marble, and the argillaceous beds to schist and quartzite respectively.

Arillaceous and arenaceous were formerly though to be part of the Triassicsystem. The southwestern part of Tronoh there are sedimentary beds which form part of the quartize range exposed on the Seputeh and Part Road west of Seputeh beyond the area mapped.

Granite which is forms the Main range and the Kledang Range has been intruded into sedimentary rocks of known Carboniferous and Triassic age in other parts of Malaysia. The granite is thus post-Triassic and form evidence obtained by Dutch geology in Borneo it is probable that it was intruded in late Mesozoic time, possibly during the Cretaceous period.

The whole of Lembah Kinta floor is covered by alluvium and is also widespread along the river valleys in the granite hill. It is not depicted on the map, for the nature of the bedrock beneath, it is generally known either from exposures or from samples obtained by boring carried during prospecting work.

On the eastern side of the valley near Gopeng not only the plain covered alluvium, there are alluvium of the valley. These hillocks approximately reach 80 meters above sea level and the beds forming them were probably deposited most of the alluvium of the valley had been laid down (Ingham, 1960).

2.4 Tin

Table 2.1 Tin in Brief (The International Tin Council, 1974)

Tin	
Tin metal	Malleable, soft, low melting point, chemically inert, non-toxic
Tin uses	Tinplate : 40-45% Solder : 20-25% Bearing metals :5-10% Bronze : 4-6%
Tin ore	Only economic ore is cassiterite (tin oxide, SnO_2). 78.6% tin. Brown, hard, brittle, specific gravity 7.0
Ore occurrence	As primary lodes, or as secondary alluvial or eluvial deposits.
Main producers (1973)	Malaysia : 38.9% Bolivia : 15.4% Indonesia : 12.1% Thailand :11.2% Australia : 6.0% Others ; 16.4%
Main consumers (1973)	U.S.A. : 27.9% Japan :18.4% U.K. : 7.9% Germany, F.R. : 7.5% France : 5.3% Others : 33.0%
International control	International Tin Council (I.T.C) Fourth International Tin Agreement (from 1at July, 1971) signed by 7 major world producers and 22 consumer nations. However, excludes U.S.A which is world's largest consumer.

2.4.1 Physical Properties of Tin

Tin or Stannum that has a chemical symbol, Sn, is a very soft and ductile metal with a 'white' colour similar to that of silver (Barry, etc. al, 1983). The metal is less dense compare to iron and has a low melting point. The melting and boiling points of tin are 232°C and 2625+5 °C respectively. The properties make tin has one of the longest ranges as liquid among all metals. In addition, because of its low vapour pressure and lack of toxicity liquid tin is used in the production of float glass (Wright, 1982). Tin is also has a high luster and is physically weak, being easy to cut with a knife. However, it is very malleable and can be beaten into very thin sheets or foil like gold. Its almost total inertness is most useful chemical property. The inertness have being immune to attack by the air and by most organic acids such as are found in foods. It is also absolutely non-toxic (The International Tin Council, 1974).

Two characteristics of the metal are the cry when it is deformed and its susceptibility to "tin pest' at low temperatures. The cry is due to twinning of the crystals and is the extreme example of acoustic emission which is known in may metals and other materials; the use of acoustic emission in non-destructive testing is described by Arrington (5). 'Tin pest' is due to the existence of two allotropes a (grey) tin, a semiconductor with diamond lattice structure and density ca. 5.8, and ß (white) tin, metallic with an uncommon tetragonal lattice structure (for metal) and density ca. 7.3 g cm 3; the transition temperature used to be stated firmly as 13.2 °C, but it is now said to be about 18 °C. The change from metallic to grey tin is very slow near to the transition temperature, it can be induced by mechanical deformation and is catalysed by a-tin; once started it is accompanied by swelling and disintegration and looks like a nasty disease. The existence of a third allotrope, y-Sn, said to be brittle and to exist above 160 °C is now generally discounted (Wright, 1982).

The only economically commercial ore of tin is the mineral cassiterite which is tin dioxide, represent chemically by formula SnO_2. The amount of tin in cassiterite is 78.6 %, the balance being the oxygen to which it is chemically attached. Cassiterite is a transparent mineral, which have variety of colours ranging from white to black but usually brown or black in colour. The mineral crystal lies in tetragonal system which is very brilliant, but exceptionally brittle so that it can only rarely be used as gem stones. The specific gravity of cassiterite is around 7 and the hardness on the Mohs' scale is about 6 to 7 (Barry, etc. al, 1983).

2.5 Amang

Amang is a term that are widely accepted in Malaysia for the mixed of heavy minerals which remain as by product after tin oxide (cassiterite) has been extracted from tin ore. During the processing of tin ore, heavy minerals that are channeled to the tailing contain some tin mineral, cassiterite (Sn0). After some period of time passed, these heavy minerals and tin accumulated in the amang. The reservoirs of amang generate significant economic interest. This due to the present of valuable minerals in amang that are economically beneficial to the mineral industries.

Other than tin, amang also comprise of various heavy minerals which are valuable to be recover. Heavy minerals refer to the minerals with specific gravity (SG) greater than the SG of quartz which is 2.7 g/cm? (Reyneke & Van Der Westhuizen, 2001). Heavy minerals that are commonly exist in amang are rutile (TiO_2), xenotime (YPO_4), monazite ([Ce,La,Nd,Gd, Th] PO_4), ilmenite ($FeTiO_3$), Zirconia ($ZISiO_4$) and struverite (Nb. Ta. TiO_2).

2.6 Tin Metal

Tin is one of the few metals that have been used since the Bronze Age. In past of times, tin was used to alloy with copper to make bronze that have improve properties compare to pure copper. Tin is chemically inert metal that are ductile, soft, malleable silvery-white in color and it has highly crystalline structure. Specific gravity for tin is 7.31 g/cm? and it has a low melting point of 232 °C. It Mohs scale of hardness is between 6 to 7. Major usage of tin is in making tin plate and as a solder for electronic parts, machinery and plumbing. It is highly resistant to corrosion and used as a coating to cover of other metals.

In nature, tin does not ensue as native element. It occurs in oxide mineral like cassiterite (SnO2) or in various sulphide minerals such as teallite (PbSnS2) and stannite (CuFeSnS4). Generally, the main source for tin is from cassiterite. Cassiterite in the earth crust is sufficiently abundance making it the only tin mineral that have economic value. In it chemically pure state, cassiterite contains about 78.6 percent tin (Falcon, 1982). But this is rarely condition and usually tin content in cassiterite varies between 73 to 75 percent.

The source of cassiterite can be found in two types of tin deposits. The first type of deposits is known as hard rock deposits, the cassiterite associated with intrusions of granites and occurs as primary accessory constituent. The tin veins and ore bodies located at contact zones of tin-bearing granites and others rocks (Ariffin, 2009). Tin deposits can be classified into three types of tin-bearing mineral assemblages which are stanniferous pegmatites, quartz-cassiterite and sulphide-cassiterite (Taylor, 1979)

Stanniferous pegmatites formed in the areas where mineralization is associated with deep-seated intrusions of acid granites. The pegmatite consists of the quartzmicrocline type. The cassiterite mineral is irregularly spread through the pegmatite body as large black or dark brown dipyramidal crystal. This type of deposit is mined in the Republic of Congo, and Nigeria.

The quartz-cassiterite deposits in the same areas as stanniferous pegmatites deposits and occurs with the same acidic granitiod intrution. The cassiterite commonly associated with wolfromite and consist of regular quartz veins, and stockworks. Most of the tin deposits in the southeastern Asian consist of the quartz-cassiterite type.

The sulphide-cassiterite deposits are rich in sulphides of silicates that rich in iron. In occurance depend on the first two type of deposit. This type of deposits includes the skarn deposits of cassiterite associated with chlorite, arsenopyrite, and pyrholite, tourmaline, hydrothermal tin-silver deposit and hydrothermal tin-lead-zinc deposits.

The second types of tin deposit is placer deposits, also known as secondary deposit. Placer deposits become the most source of tin production from South East Asia. There are two types of places deposits which is alluvial and elluvial deposits. Both types of deposits are econimcally vital and provide up to 70 percent of the world tin supply. The formation of placer deposits is from erosion of the primary tin deposits. The alluvial tin deposit is one of the main source for tin mining in Malaysia.

2.7 Heavy Mineral Associated with amang

As mention earlier, valuable minerals in amang was categorized as heavy mineral and have a high specific gravity which is higher than specific gravity 2.7g/cm? of quartz (Reyneke & Van Der Westhuizen, 2001). The specific gravity of valuable minerals in amang usually higher than 4. The heavy minerals occur in various igneous and metamorphic rocks in low concentrations Heavy minerals are mechanically resistant to weathering and chemically stable. Due to this properties, the heavy minerals will accumulate in inner bank of meandering river channel and along coastal of shorelines. This is because flows of water is faster in outer bank of a meander. The light mineral will travel more compare with heavy minerals. Then, deposition of heavy minerals in inner bank of meander will formed.

2.7.1 Ilmenite

Figure 2.2 Ilmenite Ore Samples From Australia and China (Christoper Shaffer, 2019)

Ilmenite ($FeTiO_3$) is a titanium-iron oxide mineral with idealized formula. It color is weakly magnetic black or steel-gray. It is the most momentous ore source for titanium. Specific gravity for ilmenite was in range 4.5 to 5.5 and it has a Mohs scale hardness of 5 to 6. Ilmenite is concentrated into layers by a process called "magmatic segregation" and formed as a primary mineral in mafic igneous rocks. Magmatic segregation is a general term referring to any process by which one or more minerals become locally concentrated (segregated) during the cooling and crystallization of a magma.

The heavy crystal of ilmenite are deposited to the bottom of the magma chamber and form layers. As a result, an ore body formed with titanium rich and it can be found in Russia, Brazil, Canada, Sri Lanka, Norway, Australia, China, South Africa, Malaysia, Thailand, India, Sierra Leone, and the United States.ilmenite is mined from sand that formed from weathering of ilmenite-bearing rocks. Ilmenite also present in amang and it constitutes the major minerals in amang up to 80 percent (Yasir et al, 2007)

As titanium usage is increasing, ilmenite become important to the industries. Ilmenite sand are used to clean diecasting dies in sandblasting. Ilmenite ore are commonly used as a flux to line the blast furnace hearth refractory in steel making. Titanium dioxide is used in paint industry as a base pigment due to the good endurance, high opacity and great luster. Beside, titanium oxide are used to provide colour as pigment in ceramic, paper, plastics, and cosmetics. The application of titanium alloys are used in aircraft parts, surgical implants and in high-performance alloys due to it properties. Titanium has a properties of non-corrosive, light weight, high melting point (>800° C), and has a good strength.

2.7.2 Rutile

Figure 2.3 Rutile quartz raw rough

Rutile is an oxide mineral made principally out of titanium oxide with idealized formula (TiO_2). It is a typical embellishment mineral in igneous rock, essentially in granite and pegmatites, and in metamorphic rocks. It is the most stable polymorph of Ti02 at all temperature and is a wine-red crystalline. Rutile or Titanium Oxide, (TIO_2) mineral is used in creating ceramics in high refraction options, and of course refined to produce titanium.

It has specific gravity of 4.2 to 4.4 and a Mohs scale hardness of 6 to 6.5. It form an vital constituent of heavy minerals deposits and one of the minerals recover from heavy minerals deposit for it value. Rutile varies in color includes metallic-gray, golden-yellow, brownish-red, dark-red and reddish-black.

Rutile is one of the favored minerals for the generation of titanium dioxide white pigment, predominantly through the chloride producing process. Titanium minerals are monetarily important because it is a source in titanium metals production through Kroll process. Titanium has light weight, good strength, and good thermal and