SCHOOL OF MATERIAL AND MINERAL RESOURCES ENGINEERING

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PROCESSING OF TIN FROM PEGMATITE

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DECLARATION

I declare that the thesis has been composed fully by my hardwork. I hereby declare that I have conducted, completed the research work and written the dissertation entitled "Processing of Tin from Pegmatite".

I also declare that it 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. I confirm that the work submitted is my own and the appropriate credit has been given within this thesis where reference has been made to the work of others.

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Signature : Date :

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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

PENGEKSTRAKAN TIN DARI PEGMATITE

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 ini diperoleh dengan menggunakan meja Mozley. Selepas itu, pengekstrekan sampel ini 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 warna mineral yang ada di dalam sampel. Keputusan menunjukkan bahawa terdapat banyak mineral berat dalam sampel apabila warna 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 berat 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 efisien seperti penggunaan pengkonsentrat pilin. Daripada analisis tersebut, didapati bahawa tin boleh dilombong jikalau kandungan tin ditingkatkan melebihi 70%.

EXTRACTION OF TIN FROM PEGMATITE

ABSTRACT

In this research, characterization and processing of tin have been done. The aim of this study is to identify the presence of tin and other heavy minerals in the granite pegmatite. 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 done 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 aluminium oxide. Thus, the highest percentage of tin in the sample is about 3.572%. The concentration can be increase if more efficient process is used such as spriral concentrator. Based on the analysis, the tin is mineable if the concentration is increased up to 70%. .

CHAPTER 1

INTRODUCTION

1.1 Research Background

Tin is a soft type of metal with silvery-white in colour. In the Latin term it is known as stannum with the symbol of Sn. Tin is located in Group 14 and Period 5 in the periodic table. It has 50 atomic numbers and it has p-block. Tin has a solid state at 20°C. The electron configuration of a tin is $4d^{10}\ 5s^2\ 5p^2$. Figure 1.1 shows the atomic structure of a tin. (Royal Society Of Chemistry,2017)

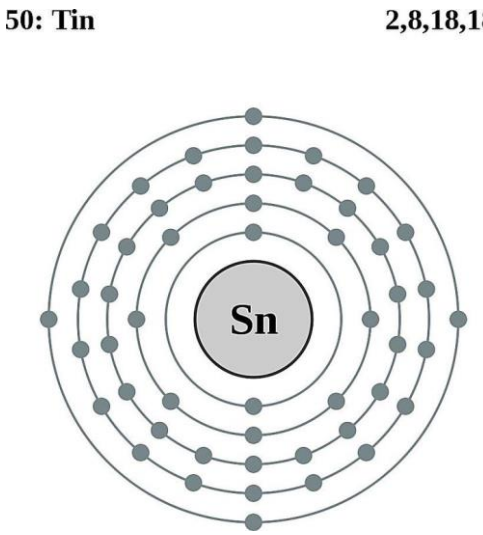

Figure 1.1 : Atomic Structure of a Tin . (Royal Society Of Chemistry,2017)

Tin has a melting point about 231.928°C. Meanwhile the boiling point of a tin is about 2586°C. The density of a tin is roughly about $7.287 gcm^{-3}$. Relative atomic mass of a tin is 118.710. Tin is usually obtained from the mineral cassiterite which is made up of about 80% tin where it contains tin dioxide,SnO_2.Tin is very light where it can melt easily. Tin is rarely used as pure metal because its too soft. Hence, tin is combined with other metals to form alloy that will benefit the tin properties in many other way. Tin has low toxicity level and also

high resistance towards corrosion. The malleable properties that tin has ensure it to easily press and shape without breaking. Besides that, the ductile properties that it has able to stretch without tearing. There are two types of chemical structure in tin. Both chemical structure of tin are as shown in the Figure 1.2 and Figure 1.3. (Bentor and Yinon.2018)

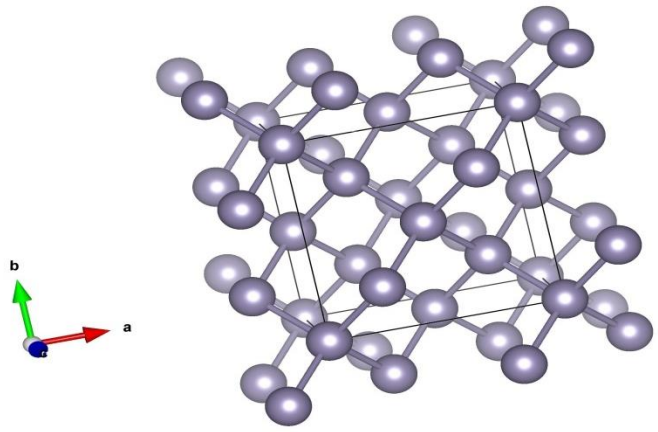

Figure 1.2 : Chemical structure of α-tin . (Bentor and Yinon.2018)

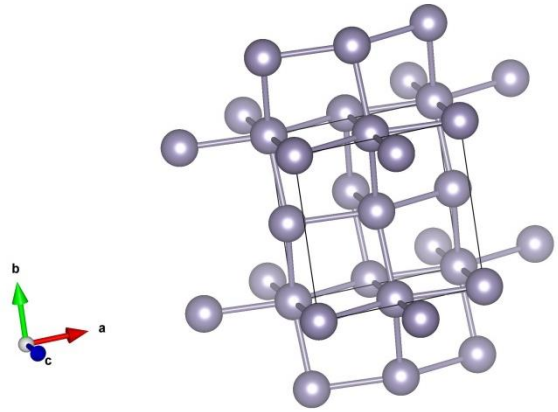

Figure 1.3 : Chemical structure of β-tin . (Bentor and Yinon.2018)

Tin are mostly found in alluvial deposits, riverbeds and former riverbeds where usually it is because erosion of ore bodies containing the metal occurs. World largest producers of tin are China and Indonesia. Tin are usually smelted with carbon so that low purity of tin and CO_2 gas are produced using temperatures which are up to 2500°F (1370°C). It will then be refined

to high purity which are more than 99% through liquation, boiling or electrolytic methods. (Royal Society Of Chemistry,2017)

Many of today's items are made up of tin such as tin cans and tin foil are actually misnomers. In fact, the tin cans are made from a compound referred as tin plate which is a steel sheet metal where it have been coated with a thin layer of tin onto it. This is really efficient because this combines the strength of tin with the tin's luster, corrosion resistance and also low toxicity. About 90% of tin plate is used to make tin cans for food and drinks, oil, paints, fuel, cosmetics and other chemicals too. The industry is the largest consumer of tin worldwide although it makes up a small coating on tinplate. During the 20^{th} century, tinfoil may have been made from tin for a short period of time but today we can see that it is largely made from aluminium.

Besides that, the use of tin can be seen back at many centuries. Example such as bronze artefact (alloy of copper and tin), mirrors, and sickles have been found in present day from Egypt to China. Tin is also used to be alloyed with lead for hundreds of years in order to make things such as pewter kettles, pots, plates and cups. Since there is negative health effects of lead, pewter is now made from alloying tin, cobalt and antimony. In the modern era, tin is used to solder for the electronics industry. It is used in many types of purities and alloys where mostly with lead or indium. Tin has low melting point. Hence, it is suitable for bonding materials during soldering.

Tin is now used in large scale as an alloy. Babbitt bearings (often alloyed with copper, antimony or lead). In automobile parts (alloyed with iron) and dental amalgams (alloyed with silver). Next in aerospace industry, tin is used to be alloyed with aluminium and titanium. Zircaloys are the mixture of tin and zircon which is used in nuclear reactors. (Terence Bell, 2018)

Pegmatite is one type of igneous rock. It is a common plutonic rock which has variable coarseness and texture that is composed of interlocking crystals of many different sizes. This pegmatite is formed during the final stage of the magma's crystallization. This rock is said to be extreme since they contain large crystals and they also might contain minerals that are rarely found in other types of rocks.

A rock is said to be a pegmatite rock when it contains almost all crystals that has at least one centimetre in diameter. Actually the name "pegmatite" has nothing related to the mineral composition of the rock. Basically, most of the pegmatites will have composition which is similar to a granite stone where mostly quartz, feldspar and mica can be found. That is the reason why it is sometimes called "granite pegmatites" just to indicate their mineralogical composition. Meanwhile, there can be composition such as "gabbro pegmatite","syenite pegmatite" and any other types of plutonic rock name combined with "pegmatite". Figure 1.4 shows the image of a pegmatite. (Hobart M.King,2016)

Figure 1.4 : Pegmatite rock (Hobart M.King,2016)

There are some valuable minerals found sometimes in pegmatite such as spodumene (an ore of lithium) and beryl (an ore of beryllium). These types of minerals are rarely found in other types of rocks. Pegmatites also can be source of gemstones. It can be said that some of the

world's best topaz, tourmaline and aquamarine deposits have been found in pegmatites stones. (Aakanksha Gaur et al,1998)

Slow rate of crystallization happens when there are large crystals in the igneous rocks. Meanwhile, this contributes to low viscosity fluids which allow ions to be very mobile when there is large crystals. We can see that at the early stage of magma's crystallization when it is melted, there is significant amount of dissolved water and also other types of volatiles such as chlorine, fluorine and carbon dioxide. Automatically the water will be removed during the melt from the early crystallization process, so that its concentration in the melt will grow to crystallization progresses. In fact, there is no overabundance of water and this will separate the water from the melt. (Aakanksha Gaur et al,1998)

Pegmatites are usually formed from the water that separates from the magma at the late stages of crystallization. Not only that, pegmatite can also form in the fractures which develop into margins of the batholith. Hence, that's the way of pegmatite dikes are formed. This dikes and pockets are small in size where the mining operations which exploit them are also in small range. In an underground operation which follows a dike or exploits a small pocket will ensure the mining of the pegmatites be done. Besides that, it can be done at an outcrop because pegmatite can be easily found by people. Dozens of worker and continuous activity for many years are not needed for mining as it does not support large mining operations. (Aakanksha Gaur et al,1998)

1.2 Problem Statement

Extracting tin from pegmatite is an extremely challenging process in mineral processing industry. This is because not all pegmatite stones give us tin ore. Anyhow, there are some tin that can be find in pegmatite stones. There is certain percentage of tin present in veinlet

granite and might be profitable to the company if a proper characterization and processing circuit design can be outlined to concentrate the tin recovery. Hence, a proper extraction of tin from this pegmatite granite veins/veinlet is an important factor to increase the percentage of tin and make it profitable for the mining industry. There might be some other minerals be interlocking with the minerals in the pegmatite. Besides that, there might be some other valuable minerals too that can be found in the pegmatite stone while tin is being extracted. This ensure us to figure out all those minerals in the pegmatite granite is really necessary so that a proper processing circuit can be designed.

It can be said that the mining industry nowadays extract tin by normal processing flow circuit which might cause some of the valuable minerals to be thrown away. The steps of the process flow design must be design efficiently to make the tin concentrate to be extracted easily. There is high wastage of valuable minerals when a proper way is not being done. Tin is usually needed in small amount where it can be said as minor constituent for the alloys but it is really important on account in the way it is being extracted for the improvements to the matrix metal.

In mining, high grading refers to mining out the portions of the orebody that has the highest grade of material to be mined. Hence, the problem of extracting and process flow is the big issue to extract the tin and from the vein/veinlet of granite. There might be other valuable minerals also that can be extracted when this proper process circuit is designed. Therefore, in this study the extraction of tin from the vein/veinlet of pegmatite granite will be carried out with high recovery.

1.3 Study Area

The raw sample used for the study is an unprocessed pegmatite stone from the blasting area. The sample is collected at granite quarry belongs to Mutual Way Development & Construction Sdn. Bhd which is located Lot P.T. 408, P.T. 64972, Jalan Menglembu, 31450, Ipoh, Perak, Kampung Baru Menglembu, 31450 Menglembu, Perak. This is a quarry that processes cement. The quarry is accessible by land and will take around 13minutes of driving with the distance of 7.1km from Ipoh,Perak and around 1 hour 48 minutes of driving with the distance of 119km 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 1.5 : Pegmatite sampling at blasting site

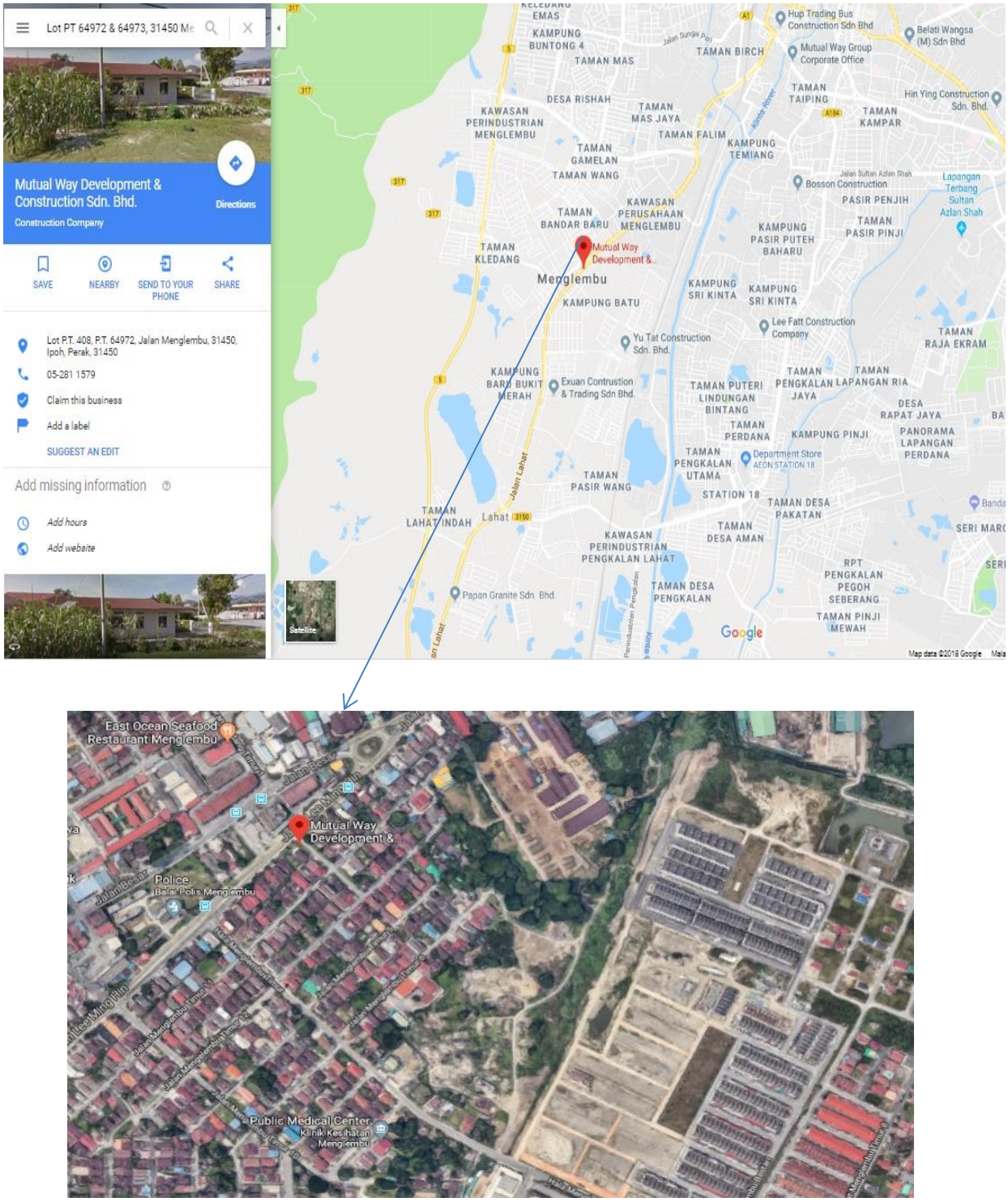

Figure 1.6 : Location of Mutual Way Development & Construction Sdn. Bhd, Perak

1.4 Objectives

The main objectives of this study are :

- To characterise tin and other valuable minerals in the granite vein/veinlet.
- To study the possibility extraction of tin with a high recovery from granite.
- To design a process circuit for high recovery of tin if it is present.

1.5 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.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Tin

Tin is a soft and silvery-white metal which are very light and also easy to melt since its very soft. Tin is rarely used as a pure metal, hence it is combined with other metals in order to make alloys that possess tin's numerous beneficial properties (Bell,2018). The discovery of tin was unknowns as the time and the location that been discovered was dated long time away. Weapons and tools which includes tin was discovered around 3,000 BC by human's many years ago. The oldest man-made object is tin and it is contained in bronze. Bronze contain both copper and tin. Based on history, it tells us that tin is extracted for the trading and manufacturing in Spain and Britain Islands where that is the place it is found the most. The 49th most rich element in this earth's crust in tin where it has 2 parts per million compared with 75 parts per million for zinc, 50 parts per million for copper and lastly 14 parts per million for lead.

Basically tin has 10 stable isotopes. The three most common isotopes that tin has are ^{116}Sn, ^{118}Sn, and ^{120}Sn (Royal Society Of Chemistry, 2017). These isotopes are the easiest elements that can be detected by the NMR spectroscopy. NMR spectroscopy is where the research of methodology which can explore the magnetic properties in the atomic nuclei. This is really helpful in determining the chemical and physical properties of the molecules and also atoms. Tin can be extracted from different ores. The most common source of tin is cassiterite. Tin can be recovered in small quantity from sulfides such as cylindrite, stannite, franckeite, and tealite (Gloria Lotha,2018).

Uses of tin is really wide as time goes on. It applies a very thin protective coating to other material such as steel and copper. The process is called electroplating or by dipping them into molten tin. Early decades of 20^{th} century, there food cans were done by handmade n is soldered. It protects the steel cans by ensure the food does not react with the steel which might rust. Then plastic, composite containers and cans which are made up of aluminum does the job instead. Tin is widely used cause it is rustproof where it can make things such as hair grips, paper clips, and safety pins. Besides that, tin is used in the production of different alloys such as bronze, solders, pewter and etc (Geoscience Australia,2015).

2.2 Introduction to Pegmatite

It is an intrusive rock which has extreme coarse grained texture. This will the develop at the final stage of magma crystallization. As longer the time taken then it will form a large crystals. This causes some rare minerals to be associate with it where this minerals cannot be found in other rocks (Khattak,2015). Crystals that at least one centimeter long can be found in pegmatite stone. It has composition which are almost same as granite where many quartz, mice and feldspar can be found. This is why we can call it as granite pegmatites (Gaur,2003).

Pegmatites will serve as a source rock for the valuable minerals. Example of valuable minerals are such as spodumene and beryl which are really rarely to be found. The growth of large crystals in pegmatites causes slow rate of crystallization. The low-viscosity fluids are the reason behind this. In fact, at the early stage of magma crystallization, there is presence of water in the melt where it contains volatile such as fluorine, chlorine and carbon dioxide. This water will be remained at the early stage of crystallization as the crystal start to form, then the water will separate and be removed from the melt. The water contains big sum of dissolved ions. Next, the water will move freely and ended up to be more mobile than that of

the melt where it will produce large crystals when crystallizes which are called pegmatite (Richard,2007).

2.3 Mineralogy of Pegmatite

Basically the mineralogy of pegmatite in most of the occurrence can be said that the mineral feldspar, quartz and mica will be dominating where it will be together with “granitic” characteristics. In addition, pegmatite can include a lot of minerals to be in the form of granite and also granite-associated hydrothermal systems, mineralization styles with granite-associated. Example such as greisens and some kind of skarn associate minerals.

Anyhow it is impossible to to quantify those mineralogy in the pegmatite because pegmatite has a variety of mineralogy and it is really difficult in estimating the abundance of the minerals where there are only one trace amount. The reasons are because it is really hard to count and do sampling mineral grains in the rock where they might have crystals in the length of centimeters to meters across in a sample rock (Khattak,2015).

Figure 2.1 : Coarse-grained igneous rock of a pegmatite. It is a sample of alkali granite pegmatite from Northern Norway which composed of alkali feldspar (pink), biotite (black), and quartz (grey) (Khattak,2015).

Garnet where commonly spessartine or almandine can be commonly found in the minerals of pegmatite intruding the carbonate-bearing and mafic sequences. Granitic domes in the

pegmatites are in Archaean Yilgarn Craton where it intrudes ultramafic and mafic rocks that contains brown, orange, and red almandine garnet. Niobium and tantalum minerals are mostly found in the combination with spodumene, tourmaline, lepidolite, and cassiterite in the great Greenbushes Pegmatite in the Yilgarn Craton of Western Australia. This rock is considered as the typical metamorphic pegmatite without the combination of granite. There are also pegmatite called syenite pegmatite which has quartz depleted in it and has large feldspathoid crystals (Khattak,2015).

2.4 Geochemistry of Pegmatite

The representative of a pegmatite sample is really difficult due to the large size in its constituent mineral crystals. Usually, a bulk of 50 to 60kg of sample rocks will be crushed to obtain a repeatable and meaningful result. Thus, pegmatite can be characterized by the individual minerals sampling where it should contain pegmatite and make comparisons according to the chemistry of the minerals. As in geochemistry, the pegmatites usually have common major elements characteristics where it can be said almost to a granite, but when it is found to be combined with granitic plutons then it is said to might have pegmatite dike with different trace element composition where it is rich in large-ion lithophile which are not comparable elements such as born, beryllium, potassium, uranium, lithium, aluminium, thorium, cesium, and other types of minerals (Khattak,2015).

Usually, the rich minerals in unusual trace elements will cause the crystallization of the equal different types of rare minerals such as columbite, beryl, tourmaline, zinnwaldite, tantalite and many others. We can see that most of the cases there will be no specific genetic occurrence that represents the rare minerals in a pegmatite. In fact, there is possibility to see some of the cause and links of genetics in between. Example such as tourmaline-bearing

granite dikes and the tourmaline-bearing pegmatites in a specific area which influence of the composite granite intrusion where it happens in Mount Isa and Australia (Khattak,2015).

2.5 Pegmatite dykes or pegmatite dike

Pegmatite will crystallize at the margins and also in the fracture of a rock because it form from the melt where water is separated. Hence, the water will enter the fractures which will form crystal and produce pegmatite dikes or pegmatite dykes. This mining is done to explore the gemstones and minerals that cannot be found in other rock types (Khattak,2015).

Figure 2.2 : Pegmatite dikes (Khattak,2015).

2.6 Rare minerals associated with pegmatites

When the crystallization happen, the ions which have no role in the rock formation of a common rock will be dissolved in water so that it is separated from the melt and this ions will crystallize to form rare Earth minerals such as beryllium, lithium from small ions and meanwhile from large ions it might have tantalum, niobium and columbium which produces minerals such as tantalite, columbite and also niobite (Khattak,2015).

Figure 2.3 : Multicoloured tourmaline crystal in the Himalaya pegmatite. (Khattak,2015).

Figure 2.4 : Tourmaline Pegmatite in Haapaluoma, Finland where tourmaline is black and plagioclase is white and quartz is grey in colour. (Khattak,2015).

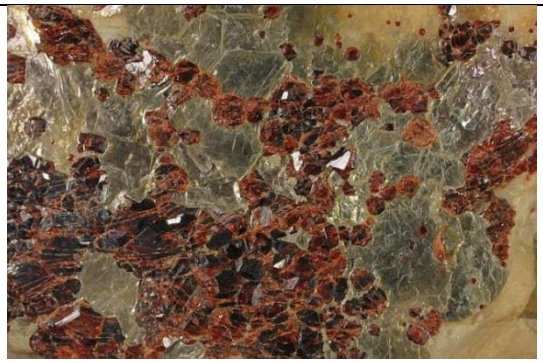

Figure 2.5 : *Sample of* Spessartine (Mn-garnet) where it can be seen sodic plagioclase and muscovite in pegmatite. (Khattak,2015).

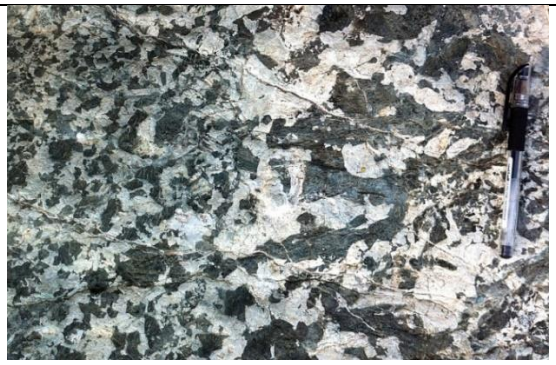

Figure 2.6 : Gabbroic pegmatite where white is plagioclase and black is pyroxene. (Khattak,2015).

Figure 2.7 : Pegmatite from Senja,Norway. It contains two common minerals (biotite and garnet) (Khattak,2015).

Figure 2.8 : Tonalite Pegmatite from Senja, Norway where biotite (black), plagioclase (white), quartz (grey) is found. (Khattak,2015).

Figure 2.9 : Large feldspar crystal with greenish amazonite at Aust-Agder, Norway. (Khattak,2015).

Figure 2.10 *:* Pegmatite with plagioclase, epidote, and muscovite at Romsdal, Norway (Khattak,2015)..

2.7 Occurrence of Pegmatite

Pegmatite occurs near the greenschist-facies of metamorphic belts and within major cratons. When economic mineralization is found then the pegmatite localities is recorded. Pegmatite will try to concentrate around granitic bodies which are around the zones of low mean strain shodow and around the zones of extension. Example such as around the strain shadow of large rigid granite body. In fact, pegmatite can be easily found in the contact zone of granite, directly with some greisens which can be said as a final stage of magmatic hydrothermal effect of syn-metamorphic granitic magmatism. There is also some skarns which react with granites to host pegmatites (Richard,2007). Porphry and aplite dikes and veins might intrude pegmatites and the rocks's wall adjacent into intrusions which will create a confuse sequences of felsic intrusive apophyses in the aureole of certain granites (Khattak,2015).

Figure 2.11 : Proterozoic pegmatite swarm in the headwall of the cirque with small mountain glacier at the northeastern Baffin Island, Nunavut. (Khattak,2015).

2.8 Economic importance

Pegmatites are really important because they frequently contain rare earth minerals and also gemstones. Example of gemstones are such as tourmaline, fluorite, topaz, aquamarine, apatite, and corundum often along with tin and tungsten minerals. Primary source of lithium such as lithiophyllite, spodumene and lepidolite are pegmatites. Primary source for caesium is pollucite where it is a mineral from a zoned pegmatite. Besides that, mineral such as beryllium comes from non-gem quality beryl which is also in pegmatite. Next, the molybdenum, bismuth and tin have also been found from pegmatite but it can be said that it is not important source of these metals (Khattak,2015).

Figure 2.12 : Rare earth mineral in a Pegmatite stone (Khattak,2015).

Figure 2.13 : Alkaline pegmatite with blue corundum crystals at Rio de Janeiro, Brazil (Khattak,2015).

2.9 Uses of pegmatite

Pegmatites are usually used as architectural purpose such as for dimension stones and slabs. This is to produce granite for the use of architecture. The pegmatites will be cut into slab and polis it for the building facing, tile, countertops and other decorative stone products if the pegmatite is looking attractive. Hence, it will be then sold as granite. Besides that, it is used to mine for rare minerals and gemstones such as topaz and tourmaline which will usually be in pegmatite where cannot be found in any other rocks. Crystals which are large and has excellent quality material can also be found in pegmatite. Pegmatite is also said to be the host rock for many rare mineral deposits. It can be commercial source for minerals such as bismuth, beryllium, boron, cesium, lithium, molybdenum, tantalum, tin, niobium, and many more other types of minerals. We can see that most of the cases the mining operations will be very small which will operate less than dozen of people. In fact, when there is nice crystal, the minerals will be a valuable mineral specimen rather than just selling it as an ore. Basically, pegmatites are mined for the industrial mineral purposes. Mica can be largely found from pegmatite. It is used to make electronic device components, retardation plates, optical filters, circuit boards, detector window and also many other things. Feldspar is the

another type of mineral that is usually being mined from pegmatite and is used as a primary ingredient to make glass and ceramics. This is to make filler in many products (King,2005).

Figure 2.14 : Polished pegmatite countertop (King,2005).

2.10 Application of Tin

In our everyday items, there are many things that are related to tin such as “tin cans”, “tin foil”, solders, coatings, bronzes and bearing alloys which are all based on the empirical knowledge gathered in the past many years but it is still being refined and is being developed to meet the technological needs of the upcoming era. Besides that, there are many new industrial uses which follow the scientific determination of the properties and doing research in exploring those properties (Bell, 2018).

2.10.1 Tinplate

About 30% of the total tin consumption is the use of tin to do tinplate. Tin cans are actually made up of a compound which is referred as tinplate. This tinplate is actually a steel sheet metal which has been coated with a thin layer of tin of about 0.00004 inch thick. It can combine very efficiently the strength of steel with the luster, resistance, corrosion, and low toxicity of the tin. About 90% of the tinplate can be seen used for making of tin cans for the manufacturing of food and drinks, fuel, cosmetics, oil, paints and many other chemicals. Tin

can only make up a small coating on tin plate and the industry is the largest consumer of tin in this world (Barry,2017). Besides tinplate, tinfoil which is also made up from tin for just a small purpose in the 20th century have now been transformed with now being made from aluminum (Emsley,2013). Before the 20th century, tinplate was designed specially in tinning plants by immersing the individual sheets in a bath of molten tin.

The hot-dip method has been developed into a electroplating process where tin will be plated directly on a moving steel strip. The is now a electrolytic tinplate line that operates and speeds up to 600 metres (2,000 feet) per minute where it has annual product capacity of about 300,000 tons where it sum up to 1,800 tons of tin. It can be said that about 90% of all the tinplate will find a way into packaging industry and the remaining of it will be used in the engineering field. We know that most of the tinplate cans will be used in the manufacturing of the foods and will be a host for other products. Tinplate is extensively used for the production of beverage cans. Europe produces and fills approximately 40,000 million cans per annum for beverages (beers, carbonated soft drinks, water, wine), of which almost half are made of tinplate and all are internally lacquered (Blunden and Wallace,2003).

Meanwhile, the traditional tinplate is built up from three piece of metals which is in cylindrical body formed from a rectangular blank and with a soldered and locked side seam whereas with two ends where one seamed on the by the can maker and another by the packer after the can is filled. This type of can will be virtually replace with one of welded side seam. In fact, there is new type of two-piece tinplate container where it is wall-ironed seamless body and with a drawn was developed especially for soft-drinks and beer market but it have been advanced in food packaging. Hence, tinplate can be a traditional product but it is continuously evolving. Example such as 1965, the thickness of a can wall was 0.25 millimetre (0.01 inch) but in 1990 about 0.18 millimetre and in two-piece can about 0.10 to 0.15 millimetre was used (Barry, 2017).

2.10.2 Tin and tin-alloy coatings

Properties of tin have make it ideal for the use of it in coating. Tin alloys can be seen being used many years ago. The bronze artifacts (bronze is an alloy of tin and copper), mirrors, sickles, and hatchets have been found in locations from present-day Egypt to China. Besides that, tin was also being alloyed with lead for few hundred years just to make pewter kettles, cups, pots, and plates. The negative effect of lead make us to do pewter by alloying tin, cobalt and antimony. In the modern application, tin is being used as a solder for the electronic devices in the industry. It is used in various purities and alloys (lead or indium). The reason behind this is because tin has low melting point which make them suitable for the bonding of materials. Tin coatings is easily produced by just immersing the suitable metal object into a bath of molten tin. Tin coatings will be present in good appearance and tightly adherent if it is in hot-dipped. Tin coating can also be done by electroplating the metal with its salt in an aqueous solution. Bright and matte-finish tin coatings will be produced. Value of tin as a coating metal have been developed in a wide range of tin-alloy coatings where they have their own properties and applications. Tin alloys can be found in many other applications. Example such as Babbitt bearings which are usually alloyed with copper, antimony, or lead. In automobile parts it is used to alloy with iron. Tin is alloyed with silver in the dental amalgams. Next, tin is also alloyed with titanium and aluminum for the aerospace metals because it is highly resistant to corrosion and tarnish (Barry, 2017). Alloys of zirconium is also frequently referred as zircaloys where it is used mainly in nuclear reactor. Appearance of tin-copper coatings also ranges from bronze to white colour where it depends on the proportion of copper and tin (Bell, 2018).

2.10.3 Tin-based solders

The second large wide used of tin is in the solders of joining metals. Most common solders are usually the alloy of tin and lead. This is because these metals can be alloyed in a wide range of proportions with an infinite number of composition can be done. Most of the solders contain about 30% to 70% of tin where minor addition will be done for special purposes. Usually about 62% tin and 38% lead alloy which melts at 183℃ (361℉) will be used for the tin-lead solders for melting for the use in certain wipe-soldering and molding applications. The wide use of solders is to make electrical connections in the electronics and electrical industries (Juan,1991).

In the modern era, the electronics is now being assembled in high speed with an automated production line. This is so that it can simultaneously solder connection in large numbers. The further develop electronics is the surface-mounted technology where the components which are not attached with wire leads is soldered directly on the circuit board. The tin-based solders have now been developed into specific applications. Example such as the lead-free solders is produced in the domestic water system for the drinking of water since lead is dangerous for heath. Hence, this is essential with high tin alloy using few percent of silver and copper. Meanwhile, it can be said that the use of tin will grow for the use of other new application which will develop in the future. This is because tin has no detrimental effects and it can be said that it will replace other types of products where it will make it more environmentally friendly.

Harmful metal such as lead, cadmium, and mercury can be replaced by tin since tin is even more environmentally friendly. Example of one new application is the formulation of the tin-silver solders to replace the tin-lead solders in the electronics industry worldwide. Besides that, lead shot in shotgun shells have also been replaced with the use of tin. Tin based

compound for the use in refuse disposal landfill sites is also being develop where it is underway. Hence, this compound can interact with the heavy metals such as cadmium and lead to prevent the rain water from carrying them into the surrounding water table or soil (Barry, 2017).

2.10.4 Low-temperature casting alloys

Solders are usually used as low melting point to cast alloys. Besides that, it is widely used because of its properties which is said to be fusible alloy. More complex alloy system then the simple solders, fusible alloys might contain cadmium, antimony, bismuth and may be gallium and indium. In fact, based on their low melting points, fusible alloys have different properties. Example such as the careful selection of the metals, where alloys can grow on solidification and remain dimensionally stable or shrink into predetermined degrees. Fusible alloys which expand on solidification will be used in machines to embed small and complex objects where it must be held fast. In addition, alloys are used in pipe bending and to form temporary internal mandrel and also support which can be melted out at low temperature after it is used. Fusible alloys system that melt at price temperature will also be produced. This can be used as safety thermal fuse such as fire detection and fire control apparatus. Temperature indicator in test bearings also can be used where other forms of temperature indication will not be employed. Besides that, fusible alloy is also used in sealing materials for the application, example such as double-glazing panels (Barry, 2017).

2.10.5 Bronze

Bronze is form from the alloying of copper and tin and now bronze is still an important industrial use for tin. (Royal Society Of Chemistry, 2017) Cast bronze usually contain about

more than 12 percent tin but for the process to make musical instruments and bells will take about 20 percent for tonal qualities. Bronze which are leaded will contain about 15 percent lead and is used in heavy-duty bearings. Zinc that contain alloys are known as gunmetals is really cheap than the tin bronze. Hence, it is used for valves and to fit the stream and water lines (Barry, 2017).

2.10.6 Pewter

The traditional use of tin have been transformed by the modern technologies into pewter ware. The composition of the alloy has changed in big scale and mainly with the replacement of lead. The modern pewter has high contain of tin-alloy where it is about 90 to 97 percent tin and with the small addition of copper and antimony. The elements that are added is then harden and then have been strengthen the soft tin in it. In the traditional way, the pewter is cast into a metal mold which are usually of iron or gun metal. The high-quality of pewter is still made in this way but the centrifugal casting in rubber molds and the pressure die-casting will be employed for mas production. Large quantity of pewter is produced from the pewter sheet where it is rolled from cast slabs. The pewter sheet can easily work and be drawn, spun or hammered into different types of shapes. The household goods, jewelry, and ornaments is less use in pewter alloy (Barry, 2017).

2.10.7 Tin-alloyed cast iron

There is about 0.1 percent of tin is used in automobiles where that's the small addition to improves the wear resistance, uniformity and hardness of the iron castings. The most common use is for cylinder blocks, axles, transmission components, brake drums and many other industrial applications such as the hydraulic lifting (Barry, 2017).