The Characteristics of Tsunami Deposit based on Mineralogy Studies

by:

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17676

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Perak Darul Ridzuan

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil and Environmental Engineering Programme
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Approved by,

____

(Dr. Siti Habibah Shafiai)

UNIVERSITI TEKNOLOGI PETRONAS
BANDAR SERI ISKANDAR, PERAK
September 2016

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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NURUL ATIQAH BINTI ZUL KAMAL

ABSTRACT

The December 26, 2004 tsunami phenomena that brought by Indian Ocean earthquake, struck the North West Coast of Malaysia has left important imprints in the inundated areas in the form of distinct sedimentary deposits, called as tsunami deposits. Peninsular Malaysia North West coast in Kedah is one of the area that have been affected by the tsunami disaster. This paper covers study of minerals presence in tsunami deposit in Kedah, Malaysia coast, namely Kuala Teriang, Langkawi and Kota Kuala Muda with the minerals content at the area that not affected by tsunami which is Pantai Teluk Batik, Perak as well as comparison with available data of minerals content in tsunami deposit from other established paper.

The main objective of this project is to provide latest documentation on characteristics of Tsunami deposit layers based on its mineralogical composition. Desk study are done to gather the information on minerals that presence in tsunami deposit sediment. Field work was done at Kuala Teriang, Langkawi and Kota Kuala Muda in Kedah. Deposit layer was measured by excavating the selected locations and spades as well as rectangular steel plate used as tools. The mineralogical composition determined by X-ray diffractometry (XRD) using equipment named PANalytical X'Pert Pro and Bruker which then analysed using Match Software. This paper will discuss the study of minerals in the deposit by gathering information on minerals content in tsunami deposit at different location, also by providing latest information about tsunami deposit at Malaysia coast where focus at Kota Kuala Muda and Kuala Teriang, Kedah and compare the minerals with previous studies.

ACKNOWLEDGEMENT

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CHAPTER 1

INTRODUCTION

1.1 Background study

On 26th December 2004, a powerful M 9.1-9.3 earthquake occured at the coast of Sumatra, Indonesia which cause massive displacement of water and developed the phenomena of Indian Ocean Tsunami (Hawkes *et al.,* 2007). Peninsular Malaysia North West coast in Kedah is one of the area that have been affected by the tsunami disaster. Even though government carried out various awareness campaigns, it still not enough since our country need to improve the mitigation measures and risk assessment. To evaluate the tsunami hazard, the study of tsunami deposit sediment is very important. According to Jaffe and Gelfenbeum (2005), tsunami deposit is the layer of sediment that is deposited as the result of tsunami that preserved in the geologic record. This paper will discuss the study of mineralogy in the deposit sediment. The identification of mineral in tsunami deposit will give contribution to the establishment of likely source materials and might constitutes a powerful sedimentological tools to recognise tsunami deposit. Thus, this study is expected to give mineralogical documentation which will be as guideline or reference for educational purpose by providing latest information about tsunami deposit at Kedah coast

1.2 Problem Statement

The December 26, 2004 tsunami phenomena that brought by Indian Ocean earthquake, struck the North West Coast of Malaysia left important imprints in the inundated areas in the form of distinct sedimentary deposits, called as tsunami deposits. The various characteristics of sedimentary makes generalizations about what characterizes a tsunami deposit and their properties become difficult.

Thus, it is important to understand what a common or how defining characteristic is, what characteristics are possible but rare, and what characteristics are inconsistent with tsunami deposition at the involved study area.

The need of the study is to identify the minerals of tsunami deposit sediment in Malaysia coast. By knowing characteristics of tsunami deposit in term of its mineralogy, it will help in identify its sediment provenance and transport reconstruction. Plus, mineral studies may help to determine the sources from which the sediments were eroded and the might be helpful in interpreting older tsunami records.

1.3 Objective

The main objective of this project is to provide latest documentation on characteristics of Tsunami deposit layers. There is sub-objective that correlated with the main objective:

a) To perform desk study on mineralogy characterisation and its location

b) To gather info on mineral composition at Malaysia Coast

c) To compare the result using previous literature review

1.4 Scope of study

This study covers the desk study comparison between minerals content in post tsunami deposit at three area in Kedah, Malaysia coast, namely Kuala Teriang, Langkawi and Kota Kuala Muda in Kedah, with the minerals content at the area that not affected by tsunami which is Pantai Teluk Batik, Perak as well as comparison with available data of minerals content in tsunami deposit from other established papers. Establised papers that have been referred for the study are such as listed below:

1) Costa, P. J. M., Freire de Andrade, C., Freitas, M. C., Oliveira, M. A. and Cascalho, J., 2014, "Application of microtextural and heavy mineral analysis in the study of onshore tsunami deposits – examples from Portugal, Scotland and Indonesia".

2) Jagodzi´nski, R., Sternal, B., Szczuci´nski, W., Lorenc S., 2009: Heavy minerals in the 2004 tsunami deposits on Kho Khao island, Thailand.

3) Nakamura, Y., Nishimura, Y., Putra, P.S., 2012. Local Variation of Inundation, Sedimentary Characteristics and Mineral Assemblages of the 2011 Tohoku-Oki tsunami on the Misawa Coast, Aomori, Japan.

4) Nallusamy, B., Babu, S., Sundarajan, Seralathan, P., Rao, R.B. and Das, P.N.M., 2010, “Effect of tsunami in the illimenite population: An examination through X-ray diffraction, scanning electron microscopy and inductively coupled plasma

Besides that, the tsunami deposit sediments are studied for its mineralogy by using the X-ray Diffraction (XRD) Analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Tsunami

In Japanese pronunciation, “tsunami” comes from Chinese character origin which are “Jin” and “Bo” with the meaning of harbour and wave respectively. However, in for Chinese speaker, it is said to be as “Hai xiao” with the meaning of “sea roaring” (Shi & Smith, 2003). According to Morton *et al.,* (2007), tsunamis are the phenomena formed by earthquakes, volcanic eruptions or landslides. Submarine geological process will cause disturbance at the water surface, or the tsunami source, which propagates toward the coasts. In the deep ocean, tsunami is usually small, but it becomes huge and more dangerous toward shallow area and water depth will cause variation to velocity and will causes coastal destruction (Remali *et al.,* 2013).

2.1.1 Historical tsunami in Malaysia

Our world’s surface is divided into a dozen of tectonic plates which move each other. The 26^{th} of December 2004, with magnitude 9.1-9.3, the Sumatra-Andaman Earthquake cause a powerful tsunami that affected all coasts of the Indian Ocean. In the case of Sumatra-Andaman earthquake, the Indian plate is sinking about 5 cm per year causes the upper plate to be dragged and deformed up to a certain limit. The plates are rebound when the strain reaches the limit which cause an earthquake (Remali *et al.,* 2013). The tsunami caused by Sumatra-Andaman Earthquake killed over 300,000 people, and caused loss of property and livelihood. This tsunami also strike some of the Malaysian Peninsular located along the west coast involved Penang, Langkawi Islands and Kota Kuala Muda in Kedah, Perak and Selangor with 68 people died and property losses amounted to about $25 million (Colbourne,2005).

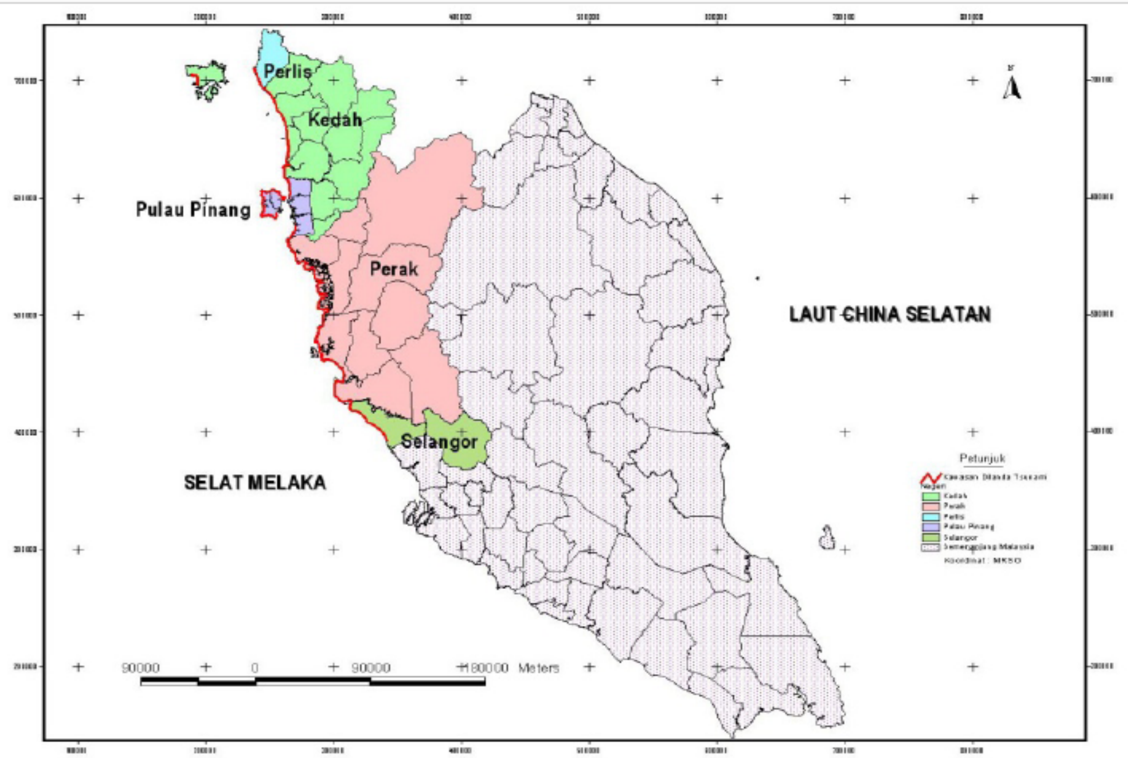

Figure 2.1: Tsunami affected area along west coast of Peninsular Malaysia involved Kedah, Penang, Perak and Selangor (Department of Irrigation and Drainage, 2005).

2.2 Characteristics of Tsunami Deposit

Tsunami often left the sheets of sand known as tsunami deposit which give various sedimentary characteristics that can be study to collect beneficial information. According to Morton *et al.,* (2007), tsunami deposition usually is caused by high velocity with long period of waves that will bring the sediment from beach or shore as well as from erosion area from landward. Besides that, tsunamis can reach more than 10 m of flow depths, which tend to transport the sediment in suspension and lead to distribution of load over wide and broad region.

Based on the recent tsunami deposits documentation, there are various characteristics of tsunami deposit such as grain sizes, thickness, geometry, presence of foraminifera and minerals composition. However, this literature review only focus on mineralogy composition in tsunami deposit.

2.2.1 Minerals in tsunami deposit

The composition of the tsunami deposit shows the transportation of sediment from local coastal environment (Jaffe *et al.,* 2003). Minerals usually found in non-carbonate beach sand, for instance quartz and feldspar make up some part of siliciclastic tsunami deposits (Razzhigaeva *et al.,* 2006). On June 23, 2001, tsunami at Playa Jahuay, Peru recorded the tsunami deposit contained heavy minerals (Jaffe *et al.,* 2003). Razzhigaeva *et al.,* (2006) noted that at Sibao, on Simeulue Island, Indonesia, the coarse grained deposit were composed of carbonate material, and the fine-grained fractions consisted mainly by quartz. Magnetite, zircon, rutile, monazite, amphibole, ilmenite, garnet,and sillimanite which categorized as heavy minerals recognized in the deposits (Razzhigaeva *et al.,* 2006).

2.2.2 Heavy Minerals

According to Jaffe *et al.,* (2003), tsunami deposits usually shows the presence of heavy minerals at the lowest part of its sand layer and generally fined upward. There various heavy minerals such as Ilmenite and Leucoxene, Xenotime, Kyanite, Sillimanite and Andalusite, Staurolite, Garnet, Chromite, Magnetite, Cassiterite, Columbite-Tantalite Rutile, Zircon, Monazite, Wolframite and Scheelite (Elsner,2011).

Heavy minerals is known as minerals having greater density than quartz, with a density of 2.65 g/cm3 of most common rock-forming soil mineral (Elsner, 2011). Heavy minerals not only form in sedimentary rocks but also found in loose materials, ranging from clay to sand to gravel (Haredy, 2003). Minerals that have less density than heavy minerals, e.g. mostly mica minerals, dolomite, aragonite, anhydrite, magnesite and quartz, are known as light minerals (Elsner, 2011)

Table 2.1: Summarize type of mineral in tsunami deposit at other locations

Location	Type of minerals	References
Misawa Coast, Aomori Japan	i) Heavy minerals assemblages- orthopyroxene and clinopyroxene, magnetite associated with minor amount of olivine and hornblade ii) Light minerals- Plagioclase and quartz	Nakamura *et al.,* 2012
Kho Khao Island, Thailand	Tourmaline, zircon, muscovite, biotite, limonite, opaque (non-transparent heavy minerals) with major minerals compose of total 99% of HM Besides that, it also contains chlorites, amphiboles, epidotes, garnets and rutile Tourmaline contains around 37.8% to 77.8%. Limones, opaque and muscovite have same maximum content about 69% with avg value of 20.7%, 17.7% and 16.3% respectively. Biotite and zircon with small concentrations of 4.8% and 1.3% average. Being grouped into 3 pairs because of same variations: 1) Tourmalines and zircon (Tu + Zi) - Both are transparent and close to spherical 2) Micas (muscovite and biotite) (Ms + Bi) - Plenty flake shape and almost same density 3) Limonites and opaque (opq + Li) - Non-transparent heavy minerals	Jagodzinski *et al.,* 2009
Salgados and Boca de Rio Tsunami at Lhok Nga, Indonesia	-Heavy minerals dominated more than 90% by andalosite > tourmalines> staurolite> garnet >zircon -90% of heavy minerals composed of amphiboles>andalusite	Costa *et al.,* 2014

Coastal zone of Western Thailand - Phang Nga province and Phuket Island	1) Composed mainly of siliciclastic sand with an admixture of carbonates. 2) 70% mostly subrounded mineral grains (quartz, feldspars, heavy minerals)	Szczucinski *et al.,* 2012
Kerala Coast, India	1) Pre-tsunami- Ilminenite (50%) and rutile (50%) 2) Post tsunami – ilmenite (20 and 41%), rutile (25% and 16%), pseudorutile and pseudobrookite (55 and 50 %).	Nallusamy *et al.,* 2010
Los Lances Bay, Andalusia, Southwest Spain	1) Mostly orthopyroxenes (12-33%)	Cuven *et al.,* 2013
Ban Bang Sak, west coast of Southern Thailand	1) Minerals such as calcite, aragonite, magnesium calcite and halite (40.6%)	Brill *et al.,* 2013

2.3 X-Ray Diffraction

X-Ray Diffraction is one the tools that can be used to study the minerals content in tsunami deposit. X-ray powder diffraction is most widely used for the identification of unknown crystalline materials as for example, the minerals content.

2.3.1 Theory of X-ray diffraction (XRD)

In term of geological sciences, X-ray crystallography have been utilized as one of revolution in X-ray Diffraction technology. XRD's ability to recognize and characterize individual crystal structures is a great method to any mineralogical study (Khonder & Lakhani, 2015). The characteristics of its crystal structure give every minerals unique XRD pattern which function to determine types of minerals that present in each sample of soil or sediment etc. (Khonder & Lakhani, 2015)

According to website page *Geochemical Instrumentation and Analysis X-ray Powder Diffraction* (Dutrow and Clark, n.d.), X-ray diffraction (XRD) is one of approach that can be used to identify and quantifying the minerals in rocks, soils and particulates. The characteristics of X-ray diffraction pattern in each mineral and compound will have its own 'fingerprint' that can be matched and compared with a database of over 250 000 candidate phases that have been recorded. The basic theory or concept of how the XRD work is when monochromatic X-rays are projected onto a crystalline material at an angle (θ), which rays travel and reflected with different wavelength. The incident beams will be scattered uniformly when the X-rays interact with a single particle and when it interact with solid material, it will go to a few directions and will cause diffraction.

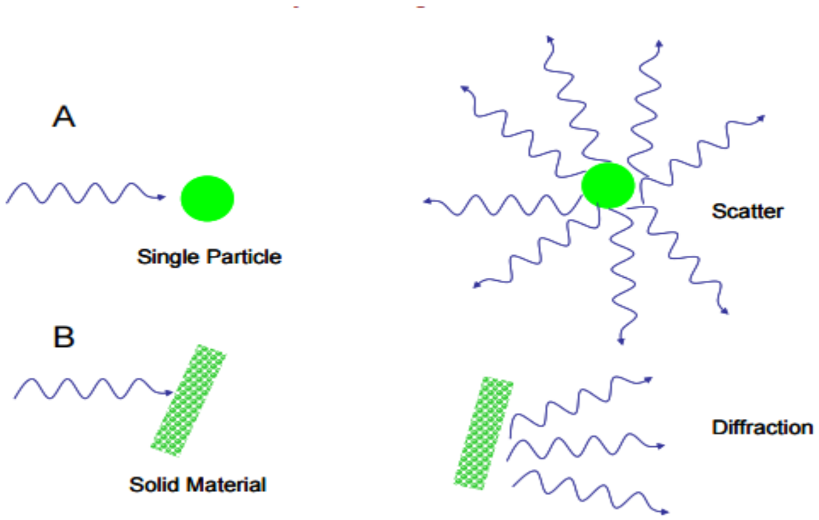

Figure 2.2: X-ray interact with material
(source:http://www.asdlib.org/onlineArticles/ecourseware/Bullen_XRD/LearningActivity_Diffraction_BraggsLaw.pdf)

Relationship of the angle at which a beam of X-rays of a particular wavelength diffracts from a crystalline surface are discovered by Sir William H. Bragg and Sir W. Lawrence Bragg. It is known as Bragg's Law. Variation of angle θ, the Bragg's Law conditions $2d\sin\theta = n\lambda$ are resulted by different d-spacings. Besides that, peak that produce from diffraction will results in different pattern and characteristics which represents total individual patterns.

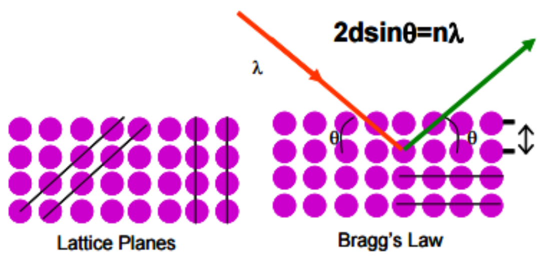

Figure 2.3: Illustration of Bragg's Law Theory

CHAPTER 3

METHODOLOGY

3.1 Area of study

The study area only focus at tsunami affected area in Kedah which are Kota Kuala Muda and Kuala Teriang, Langkawi.

Based on studies done by Kohet *et al.,* (2009), the run up height and distance observed for tsunami 2004:-

- Kota Kuala Muda: 3.8 m (Run up height) and inundation distance (100.524m)
- Kuala Teriang: 3.091m (run up height) and inundation distance (27.038m)

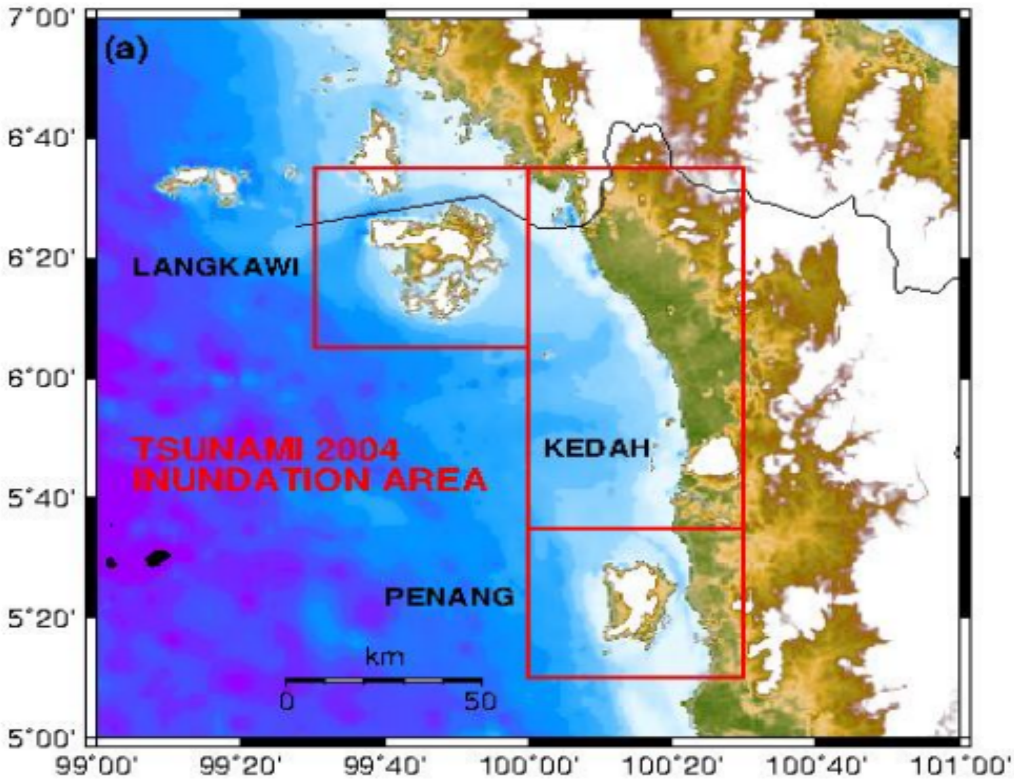

Figure 3.1: The inundation areas of tsunami and locations in northwest Peninsular Malaysia mainly in Kedah. (Picture source: *http://www.met.gov.my/*)

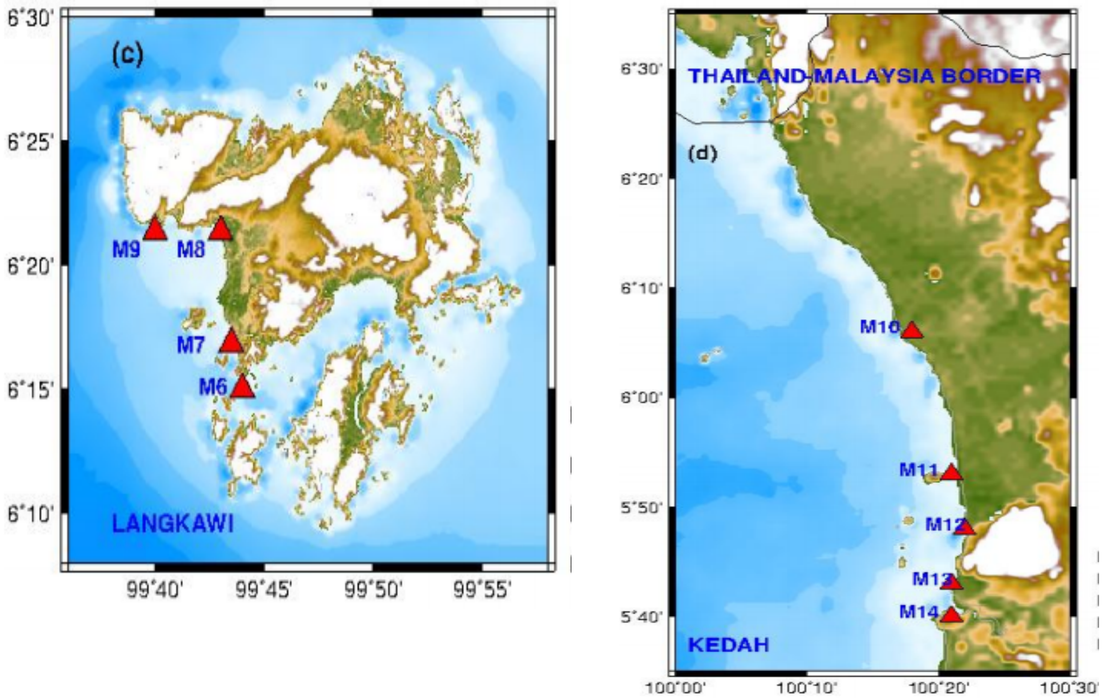

Figure 3.2: M8 (Kuala Teriang) and M14 (Kota Kuala Muda) shows the location of study area (Picture source: *http://www.met.gov.my/*)

3.2 Location of sample

The coordinate and satellite map pictures of locations are shown to give information about the area of sample taken.

3.2.1 Tsunami sample

Table 3.1: Location and Coordinate of tsunami sample

Location	Coordinate	
	Latitude	Longitude
Kuala Teriang (Area A)	N6° 21.669'	E99° 42.767'
Kota Kuala Muda (Area B)	N5° 36.284'	E100° 20.476'
Kuala Teriang (Area C)	N6° 21.674'	E99° 42.776'

3.2.2 Location of beach soil sample taken at Teluk Batik

Pantai Teluk Batik in Perak does not affected with tsunami. Thus, sample of the beach soils are taken there to show the difference between minerals contain in basic soils and tsunami sample. The coordinate of location where sample of beach soils taken is 4°11'08.6"N 100°36'32.5"E.

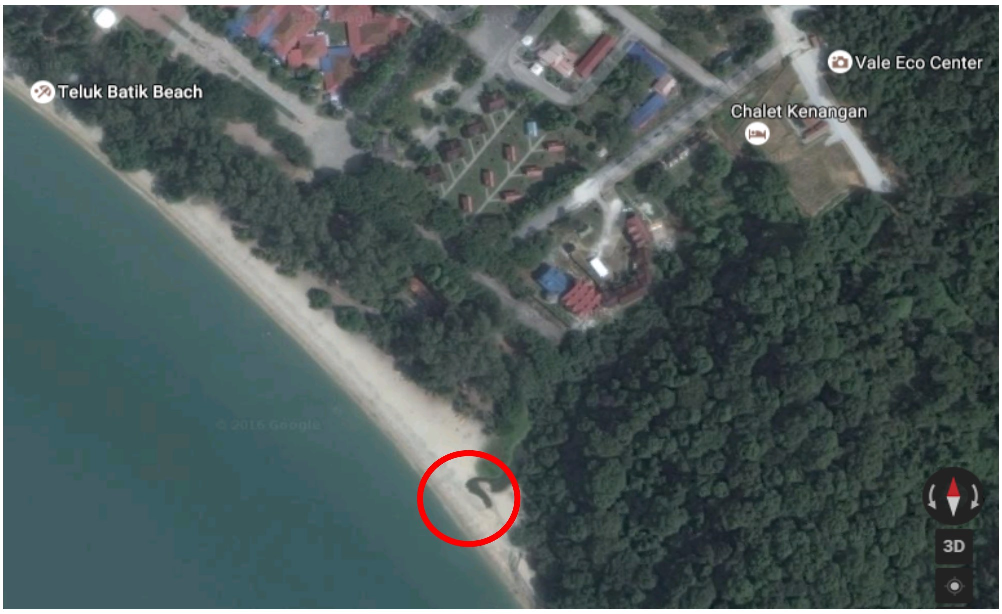

Figure 3.3: Location of soil beach taken at Teluk Batik

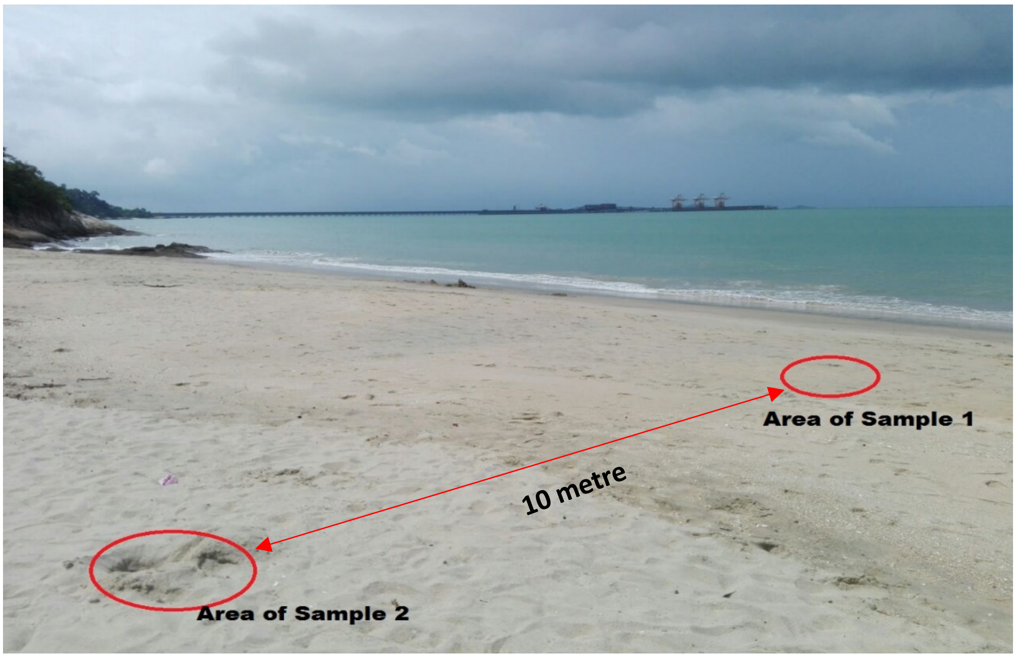

Figure 3.4: Position of 2 sample taken for beach soils at Teluk Batik, Perak.

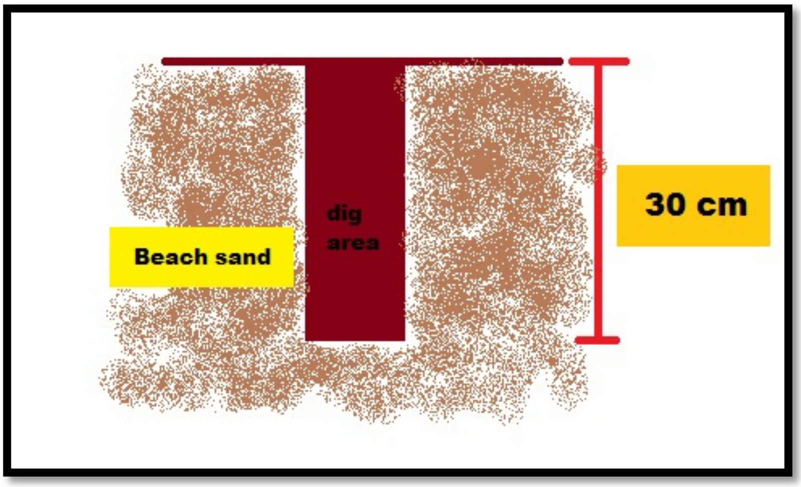

Figure 3.5: Illustration of depth of sample taken for beach soil

3.3 Desk study, XRD lab and analysis of minerals using software

Desk study are done to gather the understanding of minerals in tsunami deposit sediment. The related article, journal, past research and manuals became the reference for the desk study. The information from past fieldwork is used as the basis preparation for further investigation. Desk studies with aid of maps and satellite images were used to get view of land use for this research. For tsunami deposit sample, the deposit layer was measured by excavating the selected locations which are at Kuala Teriang, Langkawi and Kota Kuala Muda in Kedah. Spades and rectangular steel plate used as tools. For non-tsunami tsunami, Teluk Batik is the location where the sample is taken. After placing the samples at the safe place, the samples were taken to the XRD lab to gets it raw data.

The mineralogical composition was determined by X-ray diffractometry (XRD) performed on a PANalytical X'Pert Pro and Bruker. To identify minerals by diffraction it is good to have a fine specimen where the particles can form uniform intensity by randomly oriented. Generally, data should be collected from 2° to 70°, for phase identification with a step size of 0.02 °. Next, when the raw data have been collected, it will be analysed using Match! Software. Firstly, after running the raw data in the software, the background need to be removed. Then the data will be smoothen.

After that, compare the mineral data to reference data in PDF-4+ database, open resources database or use the common filters for the mineral related. The match phases of pattern can be compared graphically and in term of percentage of mineral presence.

3.4 Experimental Set up

The sample collected will undergo experimental process by X-Ray Diffractometry (XRD) performed using XRD equipment which known as PANalytical (scan range of 2° to 70°, time 0.01 seconds, continuous scan type) and Bruker D2 Phaser (scan range of 8° to 90°, time 0.1 seconds, continuous scan type). The expected outcome for the experiment is mineral composition. To know the mineral composition that present in each sample, the XRD raw data were analysed using search and match software called Match! 3. The results were validated using literature review of past research.

Summary Flow of process

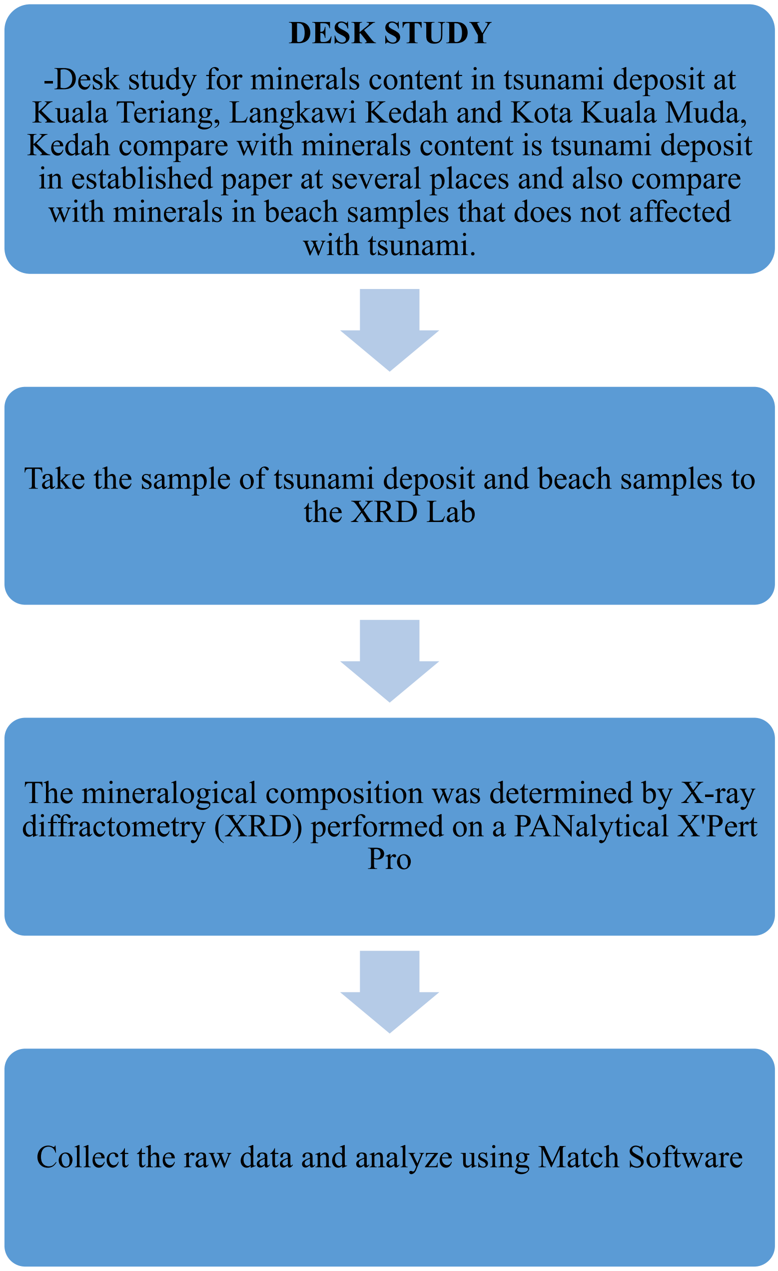

Figure 3.6: Flow Chart of Desk Study and Lab Work

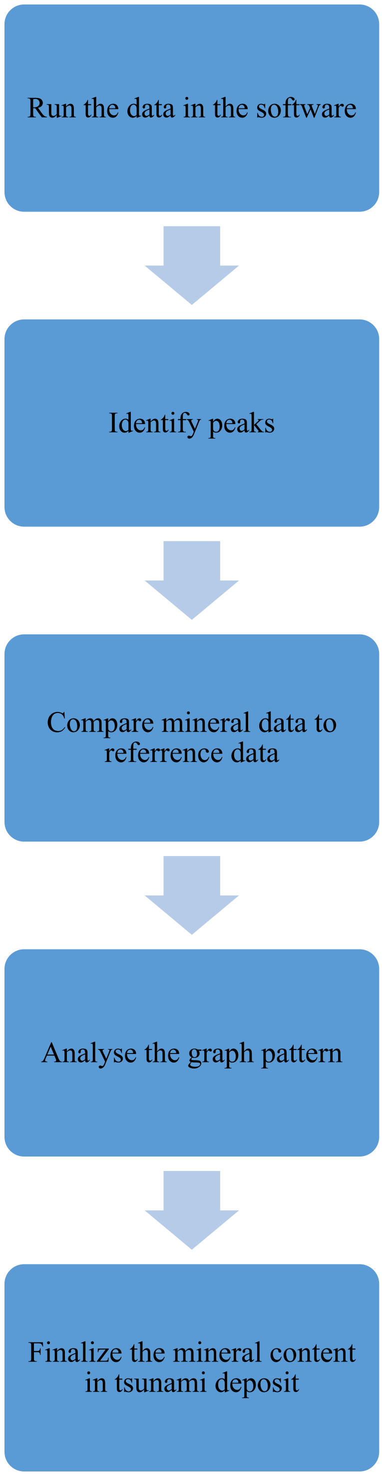

Figure 3.7: Flow Chart of Minerals Analysation using Match! Software

3.5 Gantt chart

Table 3.2: Gantt Chart for FYP I and FYP II

FYP 1														
Month	May			June				July				August		
Week	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Activities														
Title confirmation														
Extended proposal														
Preparation fieldwork														
Proposal Defence														
Field work														
Sample Analysis/ Laboratory														
Interim draft report														
Submission Interim report														
FYP 2														
Month	September			October				November				December		
Week	W 1	W2	W3	W4	W5	W 6	W7	W8	W9	W10	W11	W12	W13	W14
Activities														
Project Works Continues														
Submission of Progress Report														
Project Works Continues														
Pre-Sedex														
Submission of Final Draft Report														
Submission of Dissertation (soft Bound)														
Submission of Technical Paper														
Viva														
Submission of Project Dissertation (Hard Bound)														

CHAPTER 4

RESULTS AND DISCUSSION

In this section, results presented are the XRD data analysis of tsunami deposit sample Kuala Teriang, Langkawi and Kota Kuala Muda Kedah as well as XRD data analysis of two beach soil samples of Teluk Batik,Perak.

4.1 Tsunami Deposit Sample

4.1.1 Area A

- Kuala Teriang, Langkawi (sample : S1T)

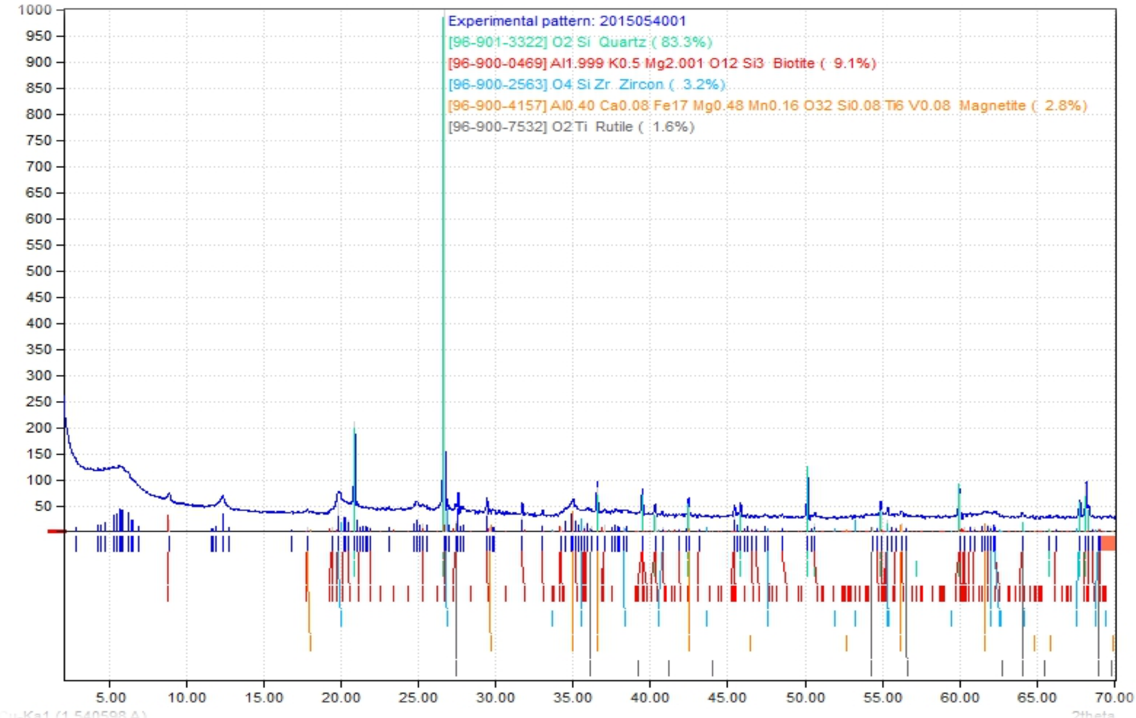

Figure 4.1: The XRD data analysis shows the presence of Quartz (83.3%), Biotite(9.1%) ,Zircon(3.2%),Magnetite (2.8%) and Rutile (1.8%)

- Kuala Teriang, Langkawi (sample : S1M)

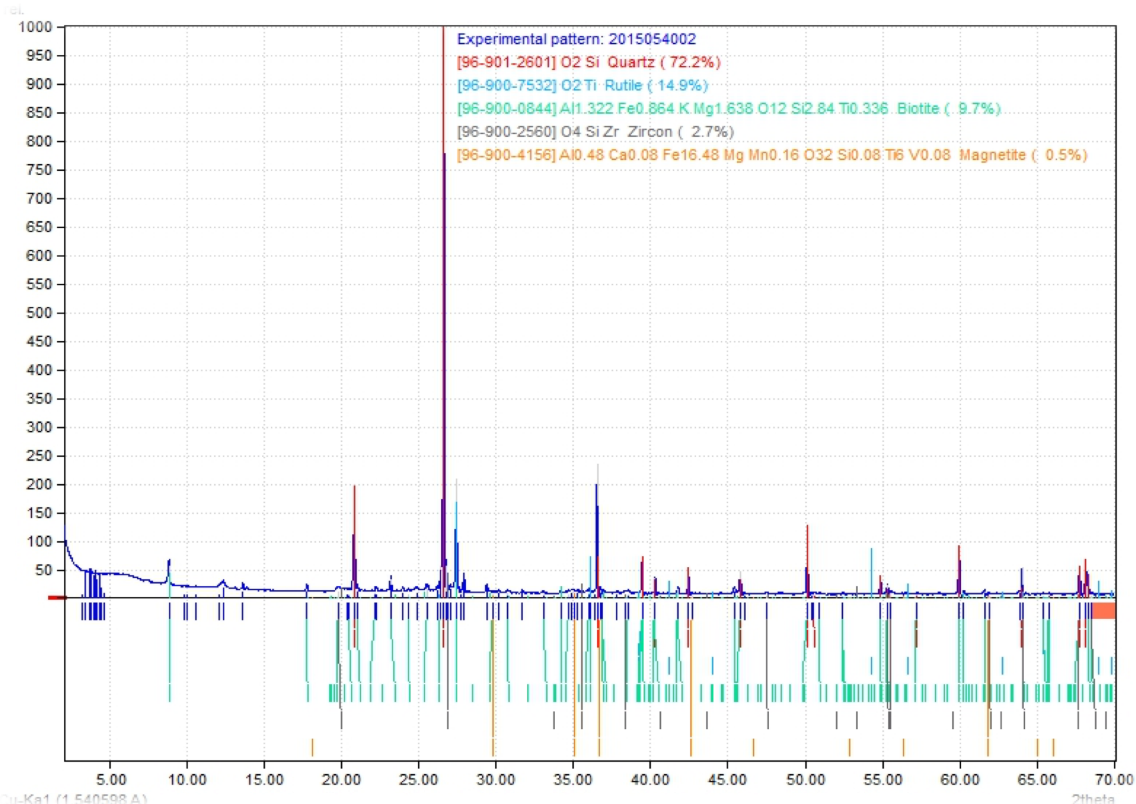

Figure 4.2: The XRD data analysis shows the presence of Quartz (72.2%), Rutile(14.9%), Biotite (9.7%), Zircon (2.7%) and Magnetite (0.5%)

- Kuala Teriang, Langkawi (sample : S1B)

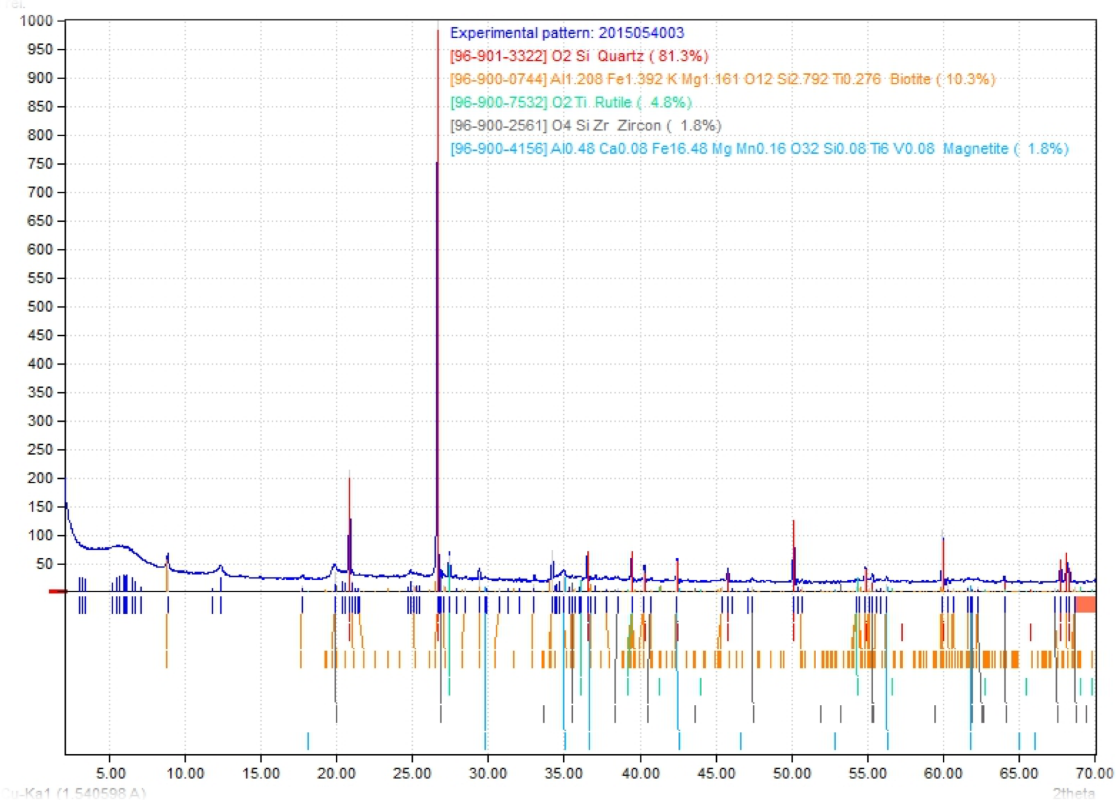

Figure 4.3: The XRD data analysis shows the presence of Quartz (81.3%), Biotite (10.3%), Rutile (4.8%), Zircon (1.8%) and Magnetite (1.8%)

4.1.2 Area B

- Kota Kuala Muda, Kedah (sample : S2T)

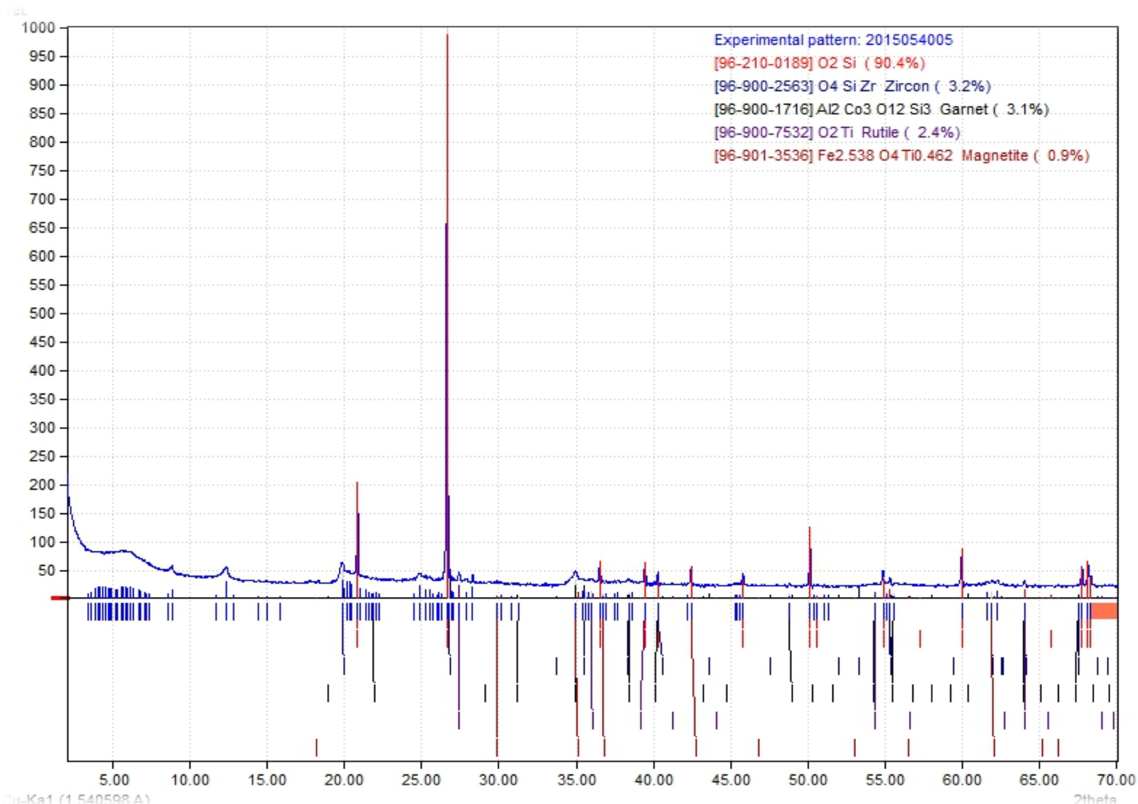

Figure 4.4: The XRD data analysis shows the presence of Quartz (90.4%), Zircon (3.2%), Garnet (3.1%), Rutile (2.4%) and Magnetite (0.9%)

- Kota Kuala Muda, Kedah (sample : S2M)

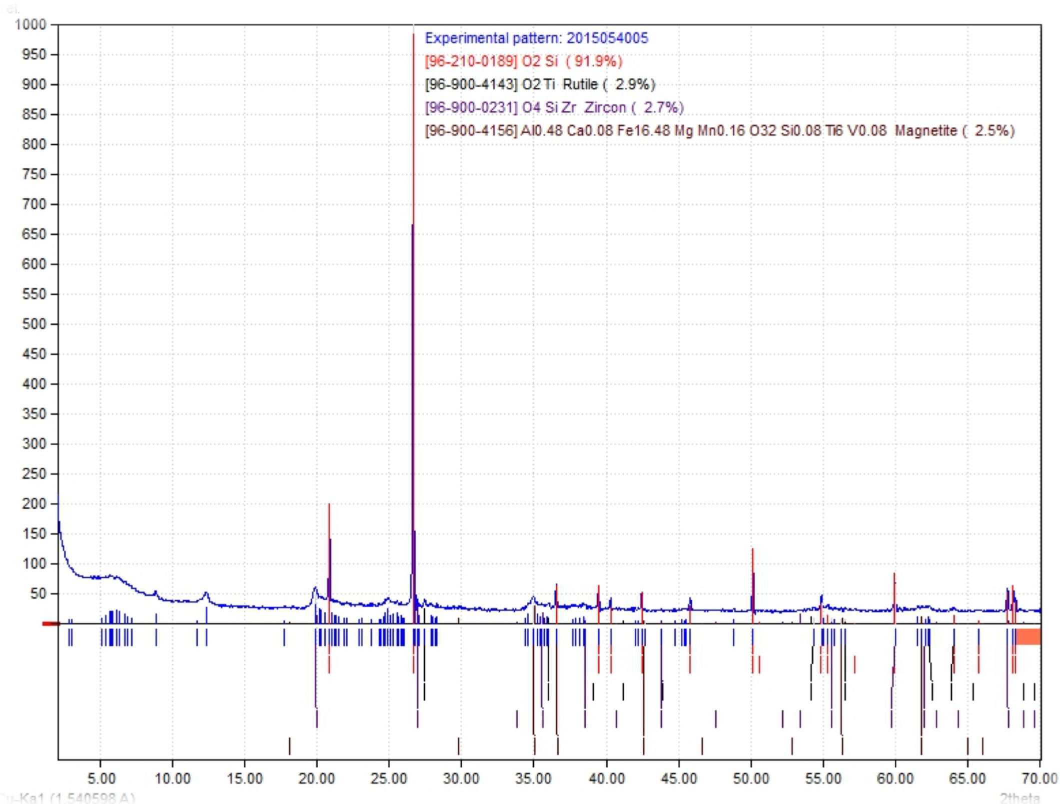

Figure 4.5: the XRD data analysis shows the presence of Quartz (91.9%),Rutile (2.9%), Zircon (2.7%) and Magnetite (2.5%)

- Kota Kuala Muda, Kedah (sample : S2B)

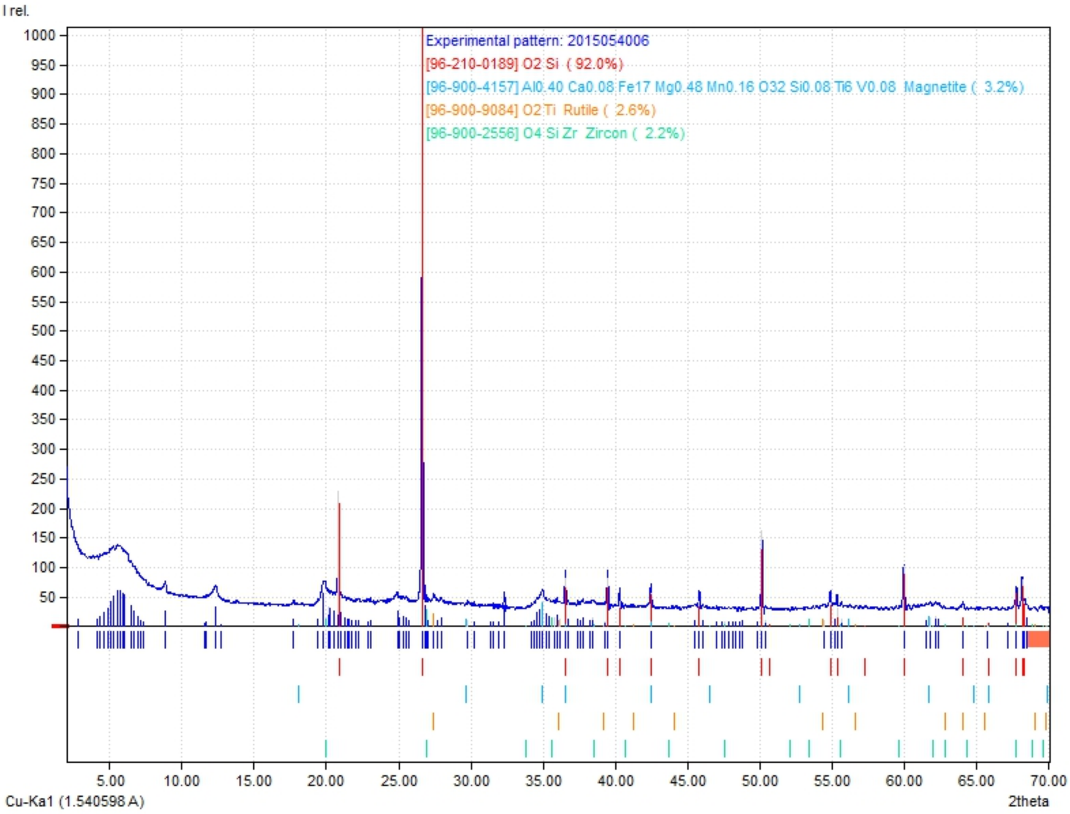

Figure 4.6: the XRD data analysis shows the presence of Quartz (92.0%), Magnetite (3.2%), Rutile (2.6%) and Zircon (2.2%).

4.1.3 Area C

- Kuala Teriang, Langkawi (sample : S3T)

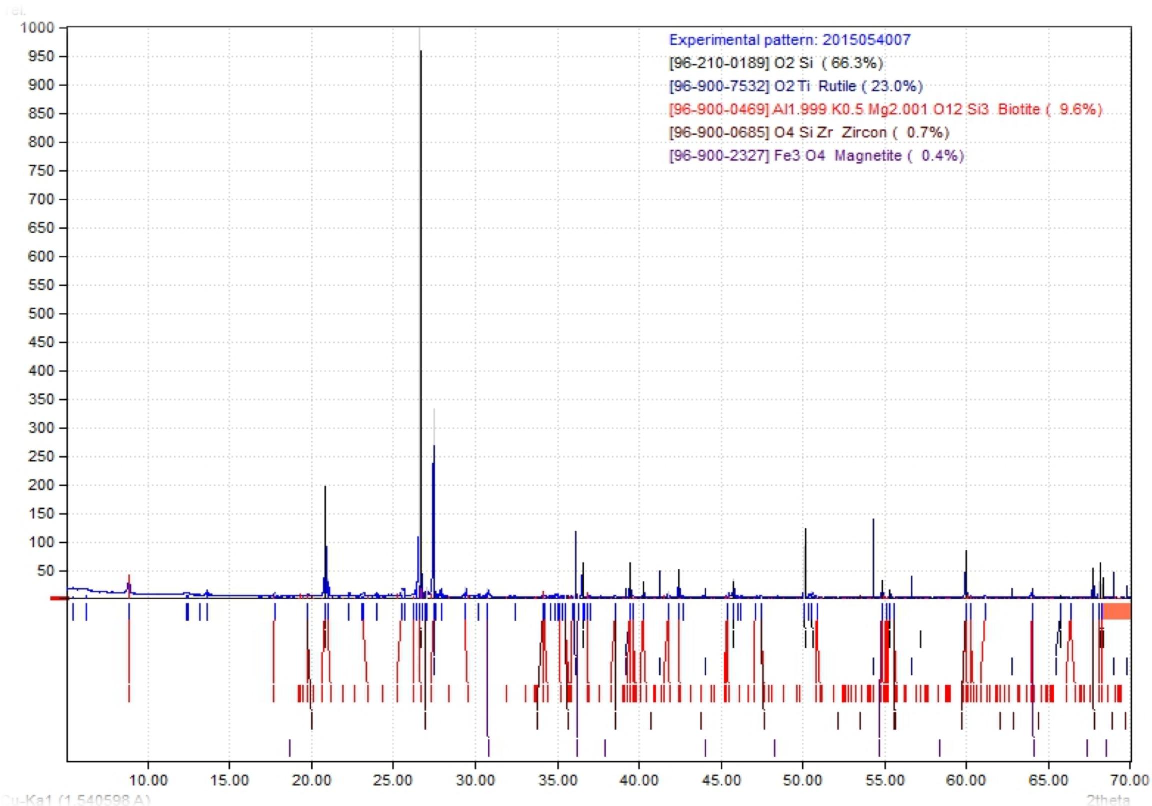

Figure 4.7: The XRD data analysis shows the presence of Quartz (66.3%), Rutile (23.0%), Biotite (9.6%), Zircon (0.7%) and Magnetite (0.4%)

- Kuala Teriang, Langkawi (sample : S3M)

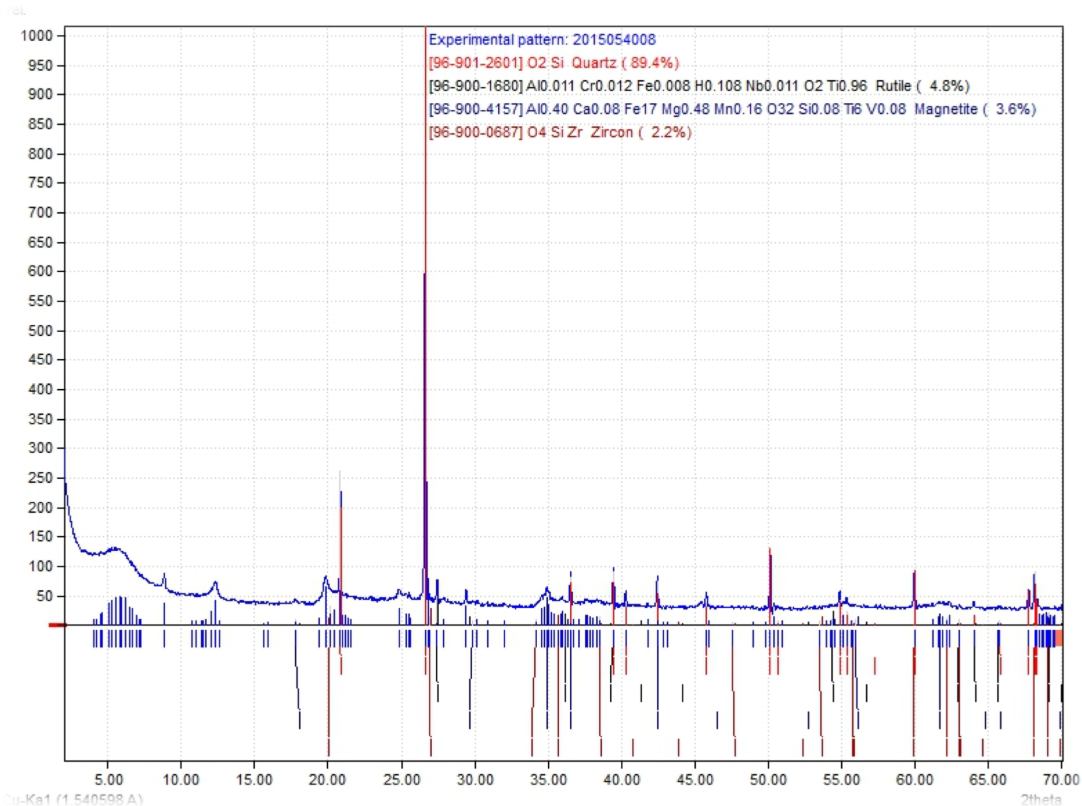

Figure 4.8: The XRD data analysis shows the presence of Quartz (89.4%), Rutile (4.8%), Magnetite (3.6%) and Zircon (2.2%).

- Kuala Teriang, Langkawi (sample : S3B)

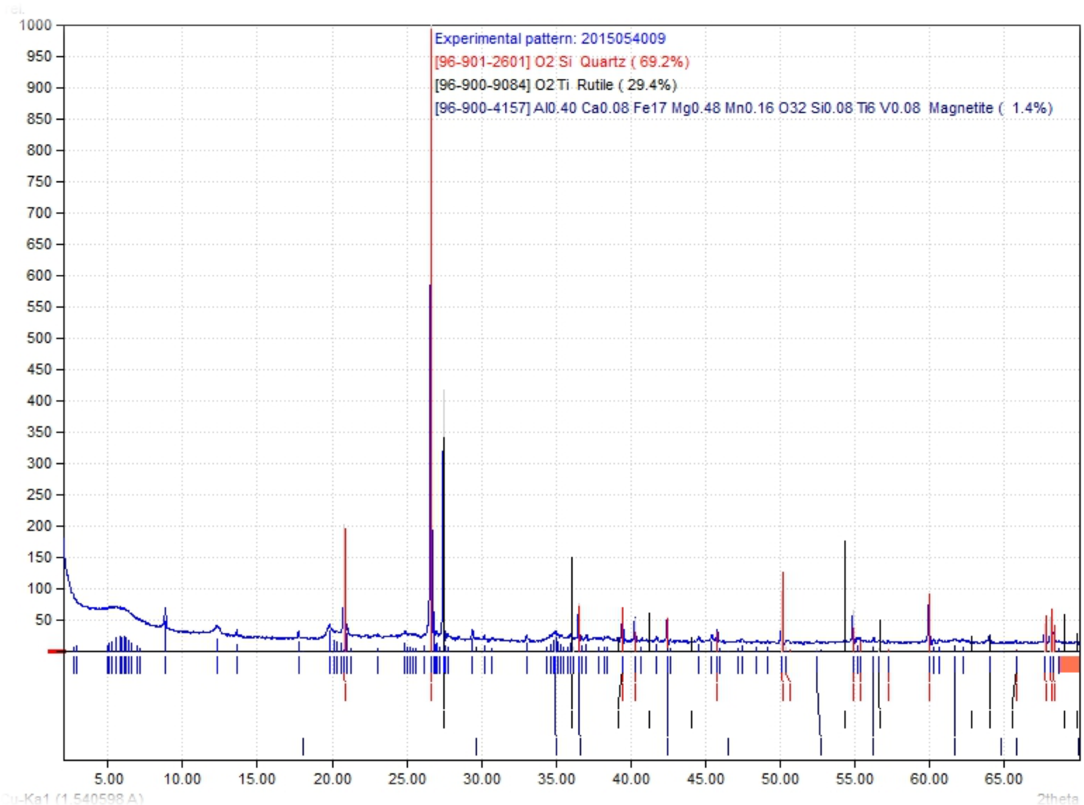

Figure 4.9: The XRD data analysis shows the presence of Quartz (69.2%), Rutile (29.4%) and Magnetite (1.4%)

4.2 Beach Soil Sample

4.2.1 Pantai Teluk Batik, Perak (Sample 1)

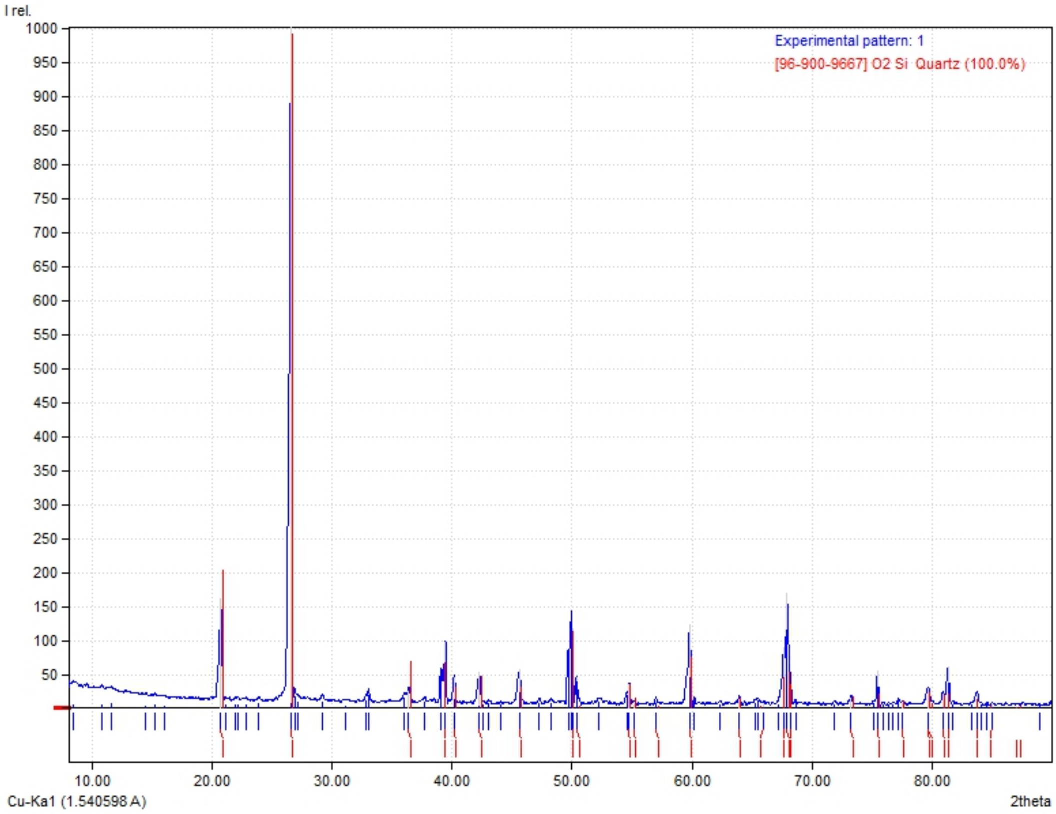

Figure 4.10: The XRD data analysis shows the presence of Quartz (100 %)

4.2.2 Pantai Teluk Batik, Perak (Sample 2)

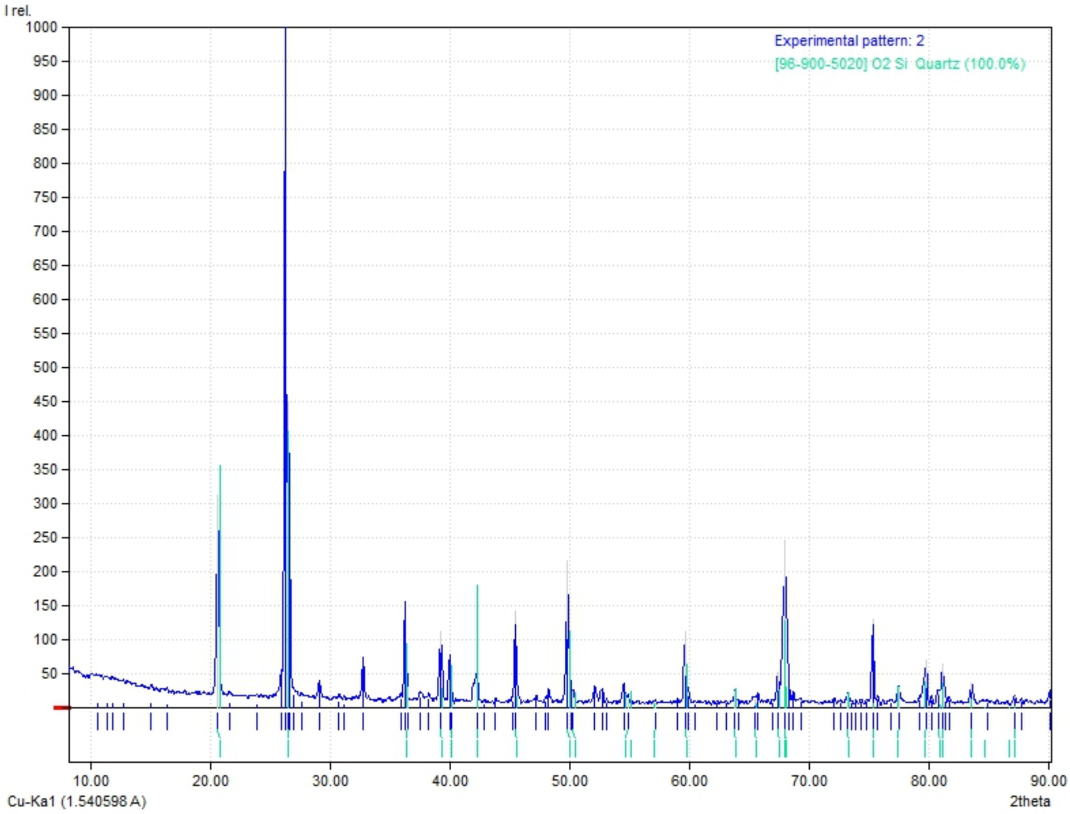

Figure 4.11: The XRD data analysis shows the presence of Quartz (100.0%)

4.3 Discussion

For overall XRD result at Area A (Kuala Teriang), it shows the major presence of Quartz (83.3%) but smaller concentration for Biotite (9.1%), Zircon (3.2%), Magnetite (2.8%) and Rutile (1.6%) for sample S1T, the presence of Quartz (72.2%), Rutile (14.9%), Biotite (9.7%) and very low presence of Magnetite (0.5%) for sample S1M while for sample S1B, it shows the high presence of Quartz (81.3%), Biotite (10.3%), Rutile (4.8%), Zircon (1.8%) and followed by small percentage of Magnetite (1.8%).

Meanwhile, the XRD results for area C (Kuala Teriang), shows that the presence of Quartz (66.3%), Rutile (23.0%) and followed by Biotite (9.6%), Zircon(0.7%) and Magnetite (0.4%) in sample S3T, the high presence of Quartz (89.4%), Rutile (4.8%), Magnetite (3.6%) and Zircon (2.2%) in sample of 3M and presence of Quartz (69.2%), Rutile (29.4%) and Magnetite (1.4%) for sample S3B.

The observation of results from Kuala Teriang between area A and C, shows that instead of quartz and biotite, heavy minerals such as Zircon, Magnetite and Rutile also present in the samples. The fact that heavy minerals were located at farther away from coast due to high specific gravity thus, with the presence of these heavy minerals, it shows that there were big wave action such as tsunami that travel from deep water. The big wave starts to transform as it approach the shallow water near the shore where depth and velocity of water is decrease, the height of wave become increase. This action brought the heavy minerals near the shore.

Area C which is closer to the shore compared to area A, have higher percentage of heavy minerals such as Rutile with 23.0 % (sample S3T) and 29.4% (sample S3B). For the area A, the heavy minerals that present in each samples are low might be due to a few factors such as the topography and bathymetry of the location.

Next, for overall XRD results at Area B (Kota Kuala Muda), it shows the major percentage of Quartz (90.4%), slightly presence of Garnet (3.1%), Rutile (2.4%) and Magnetite (0.9%) for sample S2T, the presence of Quartz (91.9%), Rutile (2.9%), Zircon(2.7%) and Magnetite (2.5%) for sample S2M as well as the presence of Quartz (92.0%), low presence of Magnetite (3.2%), Rutile (2.6%) and Zircon (2.2%) in the sample S2B.

For area B, it can be observed from the results that the percentage of heavy minerals presence in each samples are very low with the range of 0.9% ~3.2%. This probably the study area a bit far from run up height and inundation distance of tsunami affected area. Besides that, it might be different shape of coastline that vary the impact where only some of the areas faced strong effect from tsunami wave. This as well explain why only small percentage of heavy minerals have been brought by the wave. There might be some effect from sampling method where the sample might be disturbed during the collection.

Table 4.1: Summary of minerals content in tsunami sample in Kuala Teriang, Kuala Muda and in beach soil sample of Teluk Batik, Perak.

Location	Sample	Minerals
Area A (Kuala Teriang, Langkawi)	S1T	Quartz (83.3%) Biotite (9.1%) Zircon (3.2%) Magnetite (2.8%) Rutile (1.6%)
	S1M	Quartz (72.2%) Rutile (14.9%) Biotite (9.7%) Magnetite (0.5%)
	S1B	Quartz (81.3%) Biotite (10.3%) Rutile (4.8%) Zircon (1.8%) Magnetite (1.8%)
Area B (Kota Kuala Muda, Kedah)	S2T	Quartz (90.4%) Garnet (3.1%) Rutile (2.4%) Magnetite (0.9%)
	S2M	Quartz (91.9%) Rutile (2.9%) Zircon (2.7%) Magnetite (2.5%)
	S2B	Quartz (92.0%)

		Magnetite (3.2%) Rutile (2.6%) Zircon (2.2%)
Area C (Kuala Teriang, Langkawi)	S3T	Quartz (66.3%) Rutile (23.0%) Biotite (9.6%) Zircon (0.7%) Magnetite (0.4%)
	S3M	Quartz (89.4%) Rutile (4.8%) Magnetite (3.6%) Zircon (2.2%)
	S3B	Quartz (69.2%) Rutile (29.4%) Magnetite (1.4%)
Basic Beach soil (Pantai Teluk Batik, Perak)	Sample 1	Quartz (100 %)
	Sample 2	Quartz (100 %)

For overall discussion, based on the observation at these three locations (A, B and C), zircon, rutile or magnetite or all these three minerals are presence in samples. Zircon, rutile and magnetite are known as heavy minerals. Rutile is mineral in a variety of metamorphic and igneous rocks and occurs as a detrital mineral in clastic sediments and the main formula of rutile is TiO2 (Meinhold, 2010). According to Elsner (2011), zircon have high stability in chemical and physical terms which also known as mineral placer where it have high resistance in weathering. While, magnetite is one of heavy minerals that also have high physical and chemical resistance (Elsner, 2011).

Even though the results shows low overall percentage presence of zircon, rutile and magnetite, but with the presence of these minerals in the sample, it shows that these minerals probably being brought by strong wave action (tsunami) thus left as tsunami deposit. Heavy minerals are seldom found because it consist of high density minerals and only can be brought by strong wave. In several studies of tsunami deposits that found on land, the presence of heavy minerals has been reported as one of the characteristics is the 2001 tsunami in Misawa Coast Japan (Nakamura et al., 2012) and the 2004 tsunami in Indonesia, India, and Thailand (eg. Costa *et al.*, 2006; Nallusamy *et al.,* 2010; Szczucinski *et al.,* 2012).

Moreover, Kudrass (1987) proposed a model that produce 'sweeping' action of the waves that push the heavy minerals towards land which concentrate them in the beach sands and causing the depletion in their concentrations in the offshore shelf sand . Switzer et al., (2012) said that when tsunami strike the shoreline they experience very large growth in wave amplitude and very high velocity at the shore face. Tsunami waves then inundate the coast causing rapid short-duration inundation and high shear stress and erosion. Sediments are mobilized from a variety of onshore and offshore environments during the high-energy passage of tsunami waves, and they can undergo small coastal dune systems and carry sediment into the coastal plain. It follows that the internal sedimentology of any wash over sediments deposited on the coastal plain will reflect the conditions of the source area immediately preceding the depositional event. This explain why denser minerals (heavy minerals) can be found inland.

Besides that, biotite minerals present in a few samples such as in sample S1T, S1M, S1B and S3T. Biotite is a large group of black mica minerals that commonly found in metamorphic rock. Biotite is one of the minerals that appeared in tsunami deposit. According to Jagodzinski et al, (2009), tourmaline, zircon, muscovite, biotite, limonite, opaque (non-transparent heavy minerals) with major minerals compose of total 99% of HM along with minority minerals of chlorites, amphiboles, epidotes, garnets and rutile.

Basically, tsunami deposit and basic beach soils composition are different. It can be shown by the sample of beach soil taken at Pantai Teluk Batik. XRD result for the beach soil samples at Pantai Teluk Batik, Perak consists of two points which refer to sample 1 and sample 2. For both sample 1 and 2, it shows that the sample totally composed of quartz with 100% result. Based on *Coastal Care* by Orrin H. Pilkey, it is said that most of the beaches is composed by minerals quartz and feldspar in general. Cook (1969) also said that the material on the beaches mostly consists of micas, feldspars, other silicates and quartz. Quartz is the most common mineral and composed of silicon dioxide. Some of the minerals known as very unstable and decompose behaviour however, minerals such as Quartz is known as the common mineral in many beaches because it is harder and durable, which make it more stable (Cook, 1969). Besides that, since quartz is more resistant minerals, it tend to survives both transport by rivers to the coast better than any other common mineral which tend to make it stay behind. Thus, it resulting in high percentage in each sample tested.

The tsunami deposits and beach soils can be distinguished which related to heavy minerals or minerals that commonly presence in tsunami deposit. This difference may be referred to the process of sediment transport and deposition. Beach sediments usually transported along the bottom as a bed load. However, a tsunami is where the process of sediments transport in bed load and suspension. Heavy minerals are different from the most common mineral such as quartz in term of its hydrodynamic properties (Jagodzinski, 2008; Komar, 2007) which might contribute into the difference of minerals distribution in each sediment.

CHAPTER 5

CONCLUSION

Study have been done in order to gather information on characteristics of tsunami deposit. Based on results observation and discussion, it can be conclude that the characteristics of tsunami deposit is the presence of heavy minerals. Heavy minerals that have been recorded in tsunami deposit from previous studies are orthopyroxene, clinopyroxene, magnetite, tourmaline, zircon, garnets, rutile, andalosite and staurolite. Other than that, minerals such as muscovite, biotite, limonite, amphiboles, calcite, aragonite, magnesium calcite and halite also found in the tsunami deposit.

The minerals are vary based on its locations. It has been observed that the heavy mineral is one of the tsunami deposit characteristics since it present in the sample from Kota Kuala Muda and Kuala Teriang meanwhile, the basic beach soils at Teluk Batik only show the presence of quartz since it does not affected by tsunami. The heavy minerals that manage to be identified at the study area are rutile, magnetite, zircon and garnet. This also have been supported by previous study which also showed the presence of heavy minerals in their studies. This finding is useful for further studies by providing latest information about tsunami deposit which can give contribution to the establishment of likely source materials and this might constitutes a powerful sedimentological tools to recognize tsunami deposit. To enhance the further studies, it is recommended to choose the area that have past research data so that the local deposit in the same area can be used for a comparison and contrasting with current study and further extensive field and laboratory studies are necessary to confirm the minerals in tsunami deposit.

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