THERMAL CONDUCTIVITY OF SOME GRANITE SAMPLES

By

MOHD RIZAN BIN ABDULLAH (10245)

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Thermal Conductivity of Granite Samples

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Mohd Rizan b Abdullah

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Approved by:

AP DR ESWARAN PADMANBHAN
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
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ABSTRACT

This report discusses the research that has been done on order to understand Thermal Conductivity of Granite and starts to make a relationship on any occurrence in the reservoir

Thermal conductivity is one of the important parameters that describe heat flow. The objective of this research is to measure thermal conductivity of several granite samples from two different locations which is from Ipoh-Lumut Highway and Lata Kinjang.and also to see the other parameters that affect thermal conductivity.

Scientists from Newcastle University were investigating potential sources of geothermal energy, which is becoming increasingly popular in the search for low-carbon energy resources. Granite can be particularly useful as it can be rich in radioactive elements that generate heat as they decay. Hopes have been raised for the viability of geothermal energy in the UK, after exploratory drilling in Weardale, County Durham, revealed record levels of permeability in granite. The scientists believe the find is not unique to the Weardale granite, as there are similar granites worldwide which may display equally high levels of permeability.

This research focuses more on lab activities such as coring, thin section, XRD (X-ray Difrraction), XRF (X-ray fluorescence), Thermal Conductivity, Microscopy Polarization Image via Thin section and FE SEM.

ACKNOWLEDGEMENT

I am heartily thankful to my supervisor, AP Dr. Eswaran Padmanabhan, whose encouragement, guidance and support from the initial to the final level enabled me to complete this final year project. Without his guidance, encouragement, and his generosity in sharing all his knowledge to assist me throughout two semesters, this report will not be realized. I would also like to express my gratitude to the all lab technicians for assisting me in executing experiments throughout the period of completing this project. Many thanks also goes to Dr Sonny Irawan and Ms. Mazwin Jasamai for also helping me to understand on how to solve problems and challenges confronted in this final year project. Special thanks also honored towards Mr. Yasir, Phd student, for sharing his knowledge on the commercial and economics of mud additives.

Finally, an honorable mention goes to friends for their understandings and supports for me in completing this project. Without the help of these people which a have been mentioned above, I would face many difficulties while doing this project.

Mohd Rizan B Abdullah

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

A motley crew of small companies and radical entrepreneurs have responded to the latest oil shock (although this shock is a permanent one and not just an Arab oil embargo) by looking for other ways to produce the energy the world has come to depend on and desperately needs for future growth.

Thermal conductivity of an object is one of the important properties which describe heat flow between two locations within it. Thermal conductivity shows the ability of the material which allows heat to go through them. Heat flow studies in geological systems are of paramount interest to the oil and gas industry. Such studies give an indication on the thermal maturity of the hydrocarbon reserves and also provide a better enhanced understanding of the reservoir (Padmanabhan et al, 2010). Heat can be transferred through conduction, convection and radiation (Beardsmore & Cull, 2001).

Plus, hopes have been raised for the viability of geothermal energy in the UK, after exploratory drilling in Weardale, County Durham, revealed record levels of permeability in granite. Scientists from Newcastle University were investigating potential sources of geothermal energy, which is becoming increasingly popular in the search for low-carbon energy resources. Granite can be particularly useful as it can be rich in radioactive elements that generate heat as they decay. The permeability of the rock is important, as heat is extracted by pumping "working fluids" such as water into the rock and drawing it back up again. A permeability of almost 200 darcies — a unit of permeability — was recorded. This is far higher than most prolific oil and gas reservoirs, and on a par with water wells in the Chalk that supplies London. The scientists believe the find is not unique to the Weardale granite, as there are similar granites worldwide which may display equally high levels of permeability.

1.2 PROBLEM STATEMENT

Although the researchers like Professor Paul Younger has revealed the highest permeability ever recorded for granite anywhere in the world, there are lack of information on the thermal conductivity of granite. Thermal conductivity of granite for any path of heat flow varies whereby mainly depends on their mineralogy and the orientation, porosity and permeability and also the rock's types.

The capability of the same rock to transfer heat from one location to another will varies since the positioning or the grain distribution, mineral contents, grain sorting and size of a rock is not the same

Granite is a popular rock in which to site repositories, and the higher than expected permeability of the rock suggests that safety estimates previously made may have to be reconsidered. Although repositories will obviously be located in areas where there is no large-scale faulting, more care will have to be taken to ensure that excavations will not enter ground that is more permeable than expected. The discovery that granite can in places be as permeable as the Chalk Aquifer is a little disquieting for repository construction in granite. If these structures are avoided, it ought to be possible to construct successful repositories in granite. However, it will require more detailed geological mapping than might otherwise have been undertaken - which is not entirely bad news for us geologists of course. Plus, there are complicating factors and others often make it difficult to unambiguously interpret igneous fabrics(Hutton, 1988; Paterson et al., 1998).

1.3 OBJECTIVES AND SCOPE OF STUDY

Information obtained from the rocks will provide some idea on the thermal conductivity in granite. As such, the implication on fractured reservoir in gradient is the evident. On the other hand, this research will cover the study of historical data, factors involved and the prediction of the future trend. Below is how the objectives and scope of study are being narrowed down, to its particulars tasks and details.

Objectives

a To determine the rock parameters that affects the thermal conductivity of granite and set a theoretical base for thermal conductivity estimation.

b To compare thermal conductivity from two different locations

c To determine the permeability of granite for geothermal energy potential.

1.3.1 Scope of study

This project focuses on the literature review on the properties of granite samples – a product of weathered basaltic rocks. This will cover the important parameters such as petrophysical properties, mineralogy, composition, fracture via thin section, and thermal conductivity. Then, the scope will be narrowed down and specifically into experimenting directly with obtained granite samples on its composition in order to know the potential of hydrocarbon.

1.3.2.1 The Relevancy of the Project

This project is relevant to the study of Petroleum Geoscience and Reservoir Engineering as well as the field of Formation Evaluation. This project is also relevant to the recent interest evaluation geothermal gradients in SEA (South East Asia).

1.3.2.2 Feasibility of the Project within the Scope and Time frame

The project starts by collecting materials such as books, journals and technical papers specifically on thermal conductivity of granite (igneous rocks). Research has been done according to schedule in Gantt-Chart. It appears highly possible to successfully complete the project within time period indicated.

CHAPTER 2

LITERATURE REVIEW

In order to obtain a good understanding of the study, a lot of literature review had been performed since the beginning of the project. It includes the understanding and knowledge from journals, trusted articles, reference books, research-based websites and other available resources.

GRANITE'S THERMAL CONDUCTIVITY

The interior heat of the earth is transmitted to its surface mainly by three mechanisms: radiation, convection and conduction [1]. In the earth's lithosphere conduction of heat generally dominates among these mechanisms. Reference [2] in evaluating the permanent heat flow form the Earth's interior to its surface, estimated that 17% of the heat flow can be attributed to the earth's cooling, whereas 83% would be attributed to radiogenic heat production. The basic concept of heat flow defines this property as a temperature difference between two locations resulting in a heat flow q. The magnitude of q depends on the thermal conductivity of the material and the distance between the two locations mentioned earlier. Heat flow studies provide information on the occurrence and nature of geothermal resources, oil source rock maturation, secondary migration of petroleum and subsurface structures [3], [4] and [5]. Heat flow studies in geological systems are paramount interest to the oil and gas industry. The studies give an indication on the thermal maturity of the hydrocarbon reserves and also provide a better enhanced understanding of the reservoir.

Fourier's law of heat conduction defines heat flow density q, specific energy flow rate as the product of the thermal conductivity tensor λ and temperature gradient $\partial T/\partial x$. $q = \lambda . \partial T/\partial x$ [6]. Thermal conductivity can be measured by transient heating of a material with a known heating power generated from a source of known geometry and measuring the temperature change with time. The method assumed isotropic materials. Theoretical discussion for measuring thermal conductivity with cylindrical sources is found in Blackwell (1954), Carslaw and Jaeger (1959), de Vries et al. (1958), Von Herzen and Maxwell (1959), Kristiansen (1982), and Vacquier (1985).

In practice, the correct choice of a time interval is difficult. During the early stage of heating, the source temperature is affected by the contact resistance between the source and the surrounding material. During the later stage of heating, boundary effects of the finite length of the source affect the measurement.[7].

Thermal conductivity is an intrinsic material property for which the values depend on the chemical composition, porosity, density, structure, and fabric of the material [8]. In marine geophysics, mainly thermal conductivity profiles of sediment and rock sections are used , along with temperature measurements, to determine heat flow. Heat flow is not only characteristic of the material, but an indicator of type and age ocean crust and fluid circulation processes at shallow and great depths [7].

Based on previous studies done, there are two major factors affecting thermal conductivity; dominant mineral content and porosity. These properties and characteristics of rock are determined by its formation, deposition and metamorphism. Although theses processes characterized the three basic types of rocks, but the randomness and irregularity of grain distribution and mineral content is differ between mineral facies thus result in significant difference in thermal conductivity values [9].

In the case of steady state one-dimensional heat conduction with no heat generation, temperature profile through each layer becomes linear as shown in Figure 1. Heat transfer through composite systems is usually described by an overall heat transfer coefficient. Simply, the overall heat transfer coefficient is related to the total thermal resistance [10]

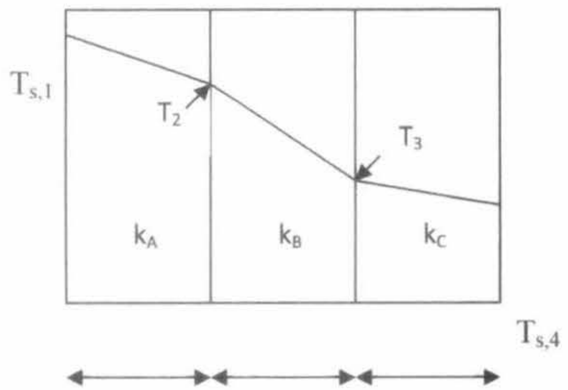


Figure 1: Heat transfer through composite systems.

MINERALOGY

Granite was in felsic group due to 65% silica content in it. This igneous rock was categorized in plutonic (intrusive) rock as it cools slowly underground producing coarse-grained (phaneritic) igneous rock [11]. Granite primarily consists of orthoclase and plagioclase feldspars, quartz, hornblende, biotite, muscovite and minor accessory minerals such as magnetite, garnet, zircon and apatite. Rarely, a pyroxene is present [12]. True granite according to modern petrology contains both plagioclase and orthoclase feldspars. When a granitoid is devoid of orthoclase the rock is referred to as alkali granite or *adamellite*. When a granitoid contains <5% orthoclase it is known as a granodiorite, or tonalite when pyroxene is present. A granite containing both muscovite and biotite micas is called a binary or *two-mica* granite. Two-mica granites are typically high in potassium and low in plagioclase, and are usually S-type granites or A-type granites[13].

Mineral	Thermal conductivity (w/mk)
quartz	7
Feldspar	2.3
Amphibole	2.25
Mica	0.7

Figure 2: Thermal conductivity of some granite-forming minerals. (different sources)

	λ in W m⁻¹ K⁻¹	c in kJ kg⁻¹ K⁻¹	Ref
Hematite	11.2 - 14.7	0.61	C, M, D
Magnetite	4.7 - 5.3	0.6	C, M, D
Pyrite	19.2	0.5	C, H
Fluorite	9.5	0.85	C
Chlorite	4.2 - 5.14	0.6	C, M
Halite	5.3 - 10	0.79 - 0.84	M
Apatite	1.37 - 1.4	0.7	C, M
Calcite	3.25 - 3.9	0.79 - 0.83	C, M
Dolomite	3.9 - 5.5	0.86 - 0.93	C, M
Anhydrite	4.6 - 5.75	0.52 - 0.62	C, M
Quartz	5.6 - 13	0.7 - 0.74	C, H, M, B
Vitreous silica	1.36	0.7	C
Olivines	3.16 - 5.06	0.55	C
Muscovite	1.7 - 2.32	0.76	C, H, M
Biotite	1.17 - 1.73	0.77	C, H
Clay min. (mean)	2.9		Q
Feldspar	2.3		B
Orthoclase	2.31 - 3.2	0.67 - 0.75	C, H, M
Plagioclase (mean)	2.31		H

Figure 3: Thermal properties of some rock forming minerals (Melnikov et al, 1975)

FOURIER'S LAW

In physics, **thermal conductivity**, *k*, is the property of a material that indicates its ability to conduct heat. It appears primarily in Fourier's Law for heat conduction.

First, we define heat conduction by the formula:

$$H = \frac{\Delta Q}{\Delta t} = k \times A \times \frac{\Delta T}{x}$$

where is the rate of heat flow, *k* is the thermal conductivity,

A is the total cross sectional area of conducting surface,

ΔT is temperature difference and

x is the thickness of conducting surface separating the 2temperatures.

Thus, rearranging the equation gives thermal conductivity,

$$k = \frac{\Delta Q}{\Delta t} \times \frac{1}{A} \times \frac{x}{\Delta T}$$

(Note: $\frac{\Delta T}{x}$ is the temperature gradient)

In other words, it is defined as the quantityof heat, ΔQ, transmitted during time Δt through a thickness x, in a direction normal to a surface of area A, due to a temperature difference ΔT, under steady state conditions and when the heat transfer is dependent only on the temperature gradient.

Alternatively, it can be thought of as a flux of heat (energy per unit area per unit time) divided by a temperature gradient (temperature difference per unit length). Typical units are SI: W/(m·K) and English units: Btu/(hr·ft·°F). To convert between thetwo, use the relation 1 Btu/(hr·ft·°F) = 1.730735 W/(m·K).[14],[15],[16]

CHAPTER 3
METHODOLOGY

3.1 Research Methodology

Some boulder rocks of Permo-Triassic granites were taken form Yasir, a PhD student form UTP and a rock have been chosen to be done as my sample for petrophysical studies, thin section, and coring. These activities will be done at Rock Physics and Rock Machines Lab at 15-00-12. This lab works will be guided by technicians, Samsudin or Najib and the PhD student, Yasir.

Here are the pictures that have been taken in the lab:

Figure 4: Sample Rocks taken from Lata Kinjang

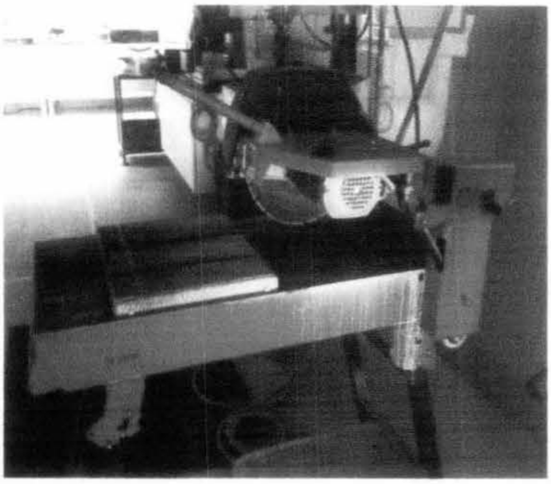


Figure 5: Rock Cutting Machines (boulder to block size)

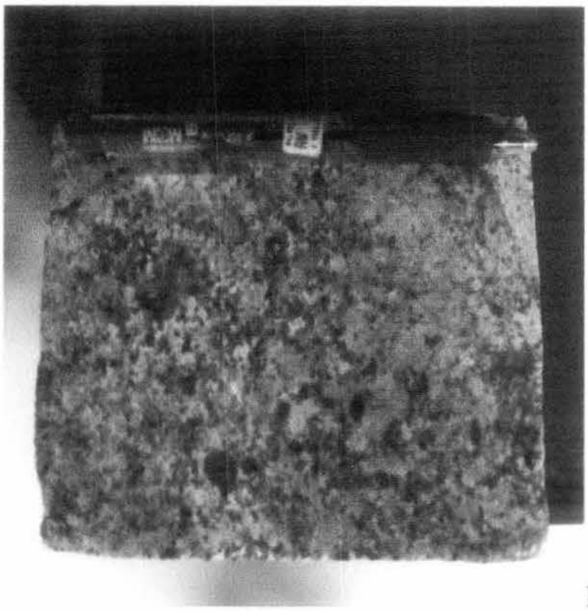


Figure 6:Block size-15cm X 10cm X 5cm dimensions

Figure 7: Rock chips- fragmented rock after cutting

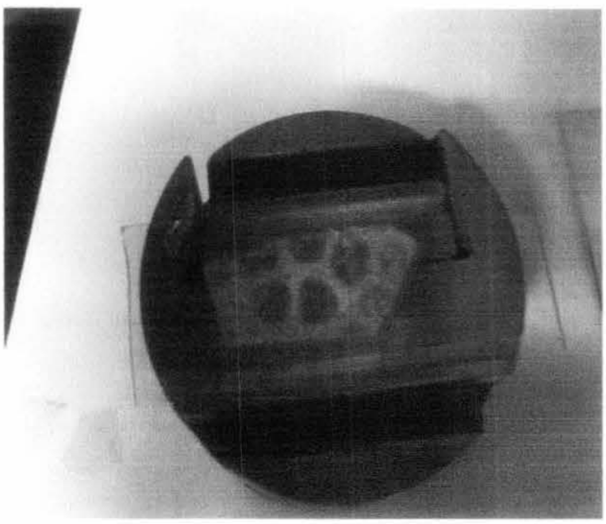


Figure 8: Thin Section from rock chips.

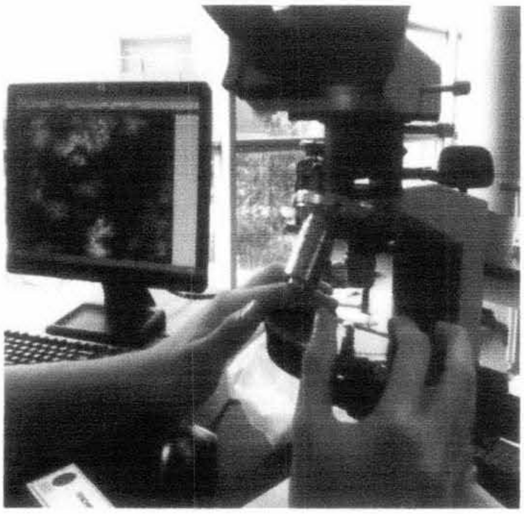


Figure 9:Microscopy Image Polarization

Figure 10: Thermal Conductivity Experiment

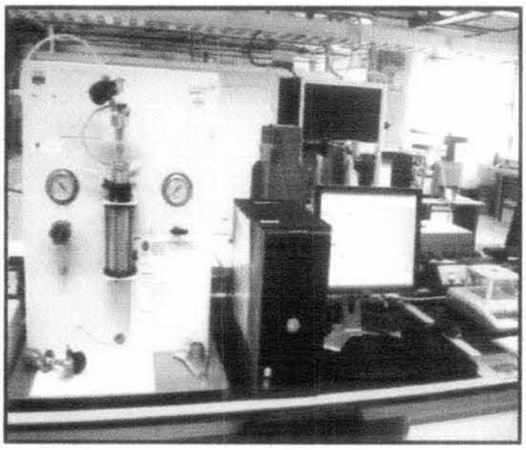


Figure 11: POROPERM test

Figure 12: X-Ray Fluorescence (XRF)

Figure 13: X-Ray Diffraction (XRD)

3.2 Equipment

Tools / Apparatus	Description
Cutter / crusher / Grinder	Cutter tools are required for sample procurements where all the rock samples will be cut into block with the same sizes using rock cutting machine (Figure 3.2). Crusher tools are used to crush sample into powder for XRD & XRF analysis.
Metal Block	A metal block will be used to calibrate the equipments before proceeding with the actual experiments. Calibration will be done for every different samples to ensure the equipments are working properly.
Stopwatch /Timer	Stopwatch will be used to determine sample heating duration will took place.
Needle Probe	Needle probe is used to estimate thermal conductivity values for rock samples. Then measurements will be taken between two locations with several different directions. The length and location for these several different directions would be kept constant.
X-Ray Diffraction (XRD) **Brand: Bruker** **Model: D8 Advance**	XRD tool will be used to characterize the structure, crystallite size (grain size) and grain orientation. Sample type: Powder type 2 thetha: 3° to 60°, Scanspeed: 1°/sec
X-Ray Fluorescence (XRF) **Brand: Bruker** **Model: S4 Pioneer**	XRF tool will be used to determine and analyze the chemical elements qualitatively and quantitatively by measuring their characteristic radiation. Sample type: Liquid and Solid
Field Scanning Electron **Model: VP1430**	FESEM tool can produce very high resolution images of sample surface. It will be use to visualize the sample's surface in a high magnification and map the elements content on the specific area.
Thin Section	Analyzed thin section of sample rock for mineralogy and its porosity.

Table 1: Tools and apparatus required for research study

3.3 Project Works

The project activities flow is shown in Figure 1.

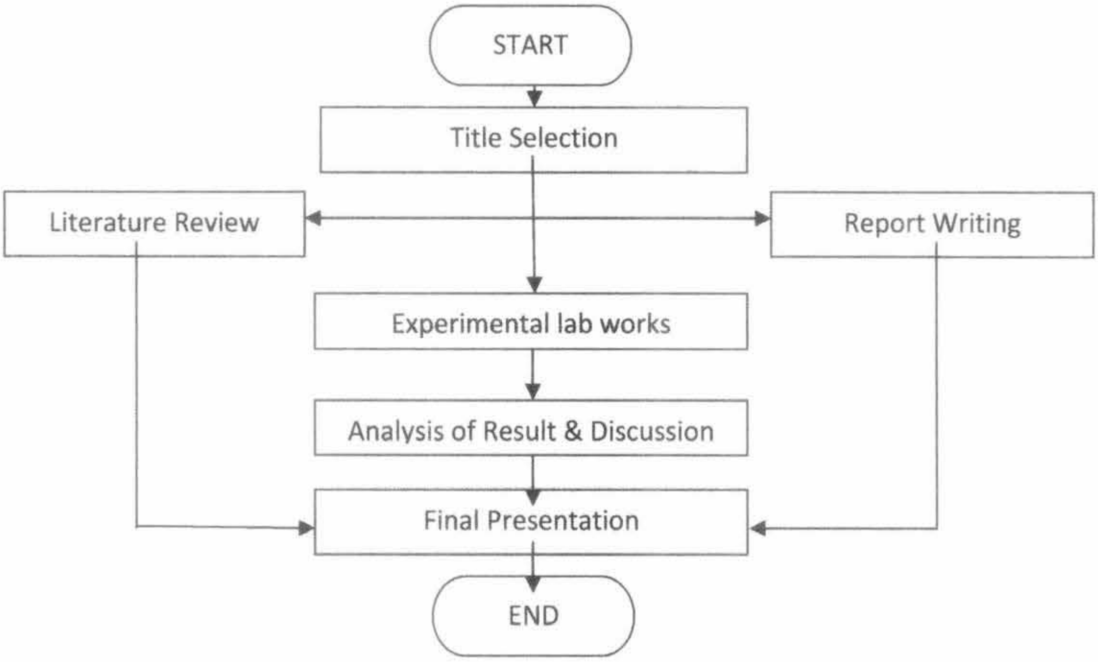


Figure 14: Project Activities Flow Chart

a) Core Sample

Procedure for core sampling:

1. Mark the rock sample with marker pen after measured the length of the sample needed.
2. Cut the sample with rock cutting machine.
3. Make the core sample with 1.5" diameter by using coring machine. (keep the fragments of the rock after finish the coring)
4. Cut the sample with trimming machine to make all the samples with same height. (keep the fragments of the rock after trimming)

b) Thin Section

Procedure for thin section:

1. Cut sample in slice by geological cutter (2-4mm).
2. Polish 1 side of sample & let it dry.
3. Polish 1 side of sample on a glass slide by using polishing machine.
4. Use hot plate to heat up the epoxy on the glass slide to stick the slide sample on the glass (make sure no bubble seen on the back of glass).
5. The sample on glass need to be cut using precision cutter until 0.1mm sample obtained (frequently measure the sample thickness by using micrometer).
6. Polish the sample using polishing machine until the desired thickness obtained.
7. Samples are ready to be analyzing below the microscope.

c) Thermal Conductivity

Experimental set-up for the linear conductive heat transfer system is :

1. Making lines for each face (6 surfaces) on the block for 10cm
2. Calibrate temperature for the two needle probe so that both T1 and T2 are equally before measurement
3. 40 watt of heat being applied.
4. Time consuming was 15 seconds.
5. Put the needle probe on the edge of each line and T1 and T2 were taken.
6. Heat transfer being calculated.

d) X-Ray Diffraction (XRD)

1. Sample positioning and focusing can be performed easily using the standoff pointer provided with all systems and through the collimator laser pointer which allows the user to quickly locate measurement locations. This is particularly helpful when using the Automated Stress Mapping option.
2. The 4-Point bending fixture and Proto strain bridge are used for quick and easy determination of the effective x-ray elastic constant for new materials as per ASTM 1426-91, "Standard Test Method for Determining the Effective Elastic Parameter for X-ray Diffraction Measurements of Residual Stress".
3. The Proto Portable Electro Polisher is specifically for x-ray diffraction work, making material removal efficiently.
4. Continuous Research and Development from software available to match the plot obtained from XRD result.

e) X-Ray Fluorescence (XRF)

1. To turn on the power to the unit, depress the POWER ON switch on the control panel; the unit will only function when the TIME SWITCH is rotated away from zero.
2. The filament of the x-ray tube should be illuminated. Wait 5 minutes, and then depress the X-RAYS ON switch. The x-ray machine needs to run with X-RAYS ON for about an hour to heat up enough to begin emitting photons.
3. Once count levels are high (100's per second) you should be able to obtain diffraction data.
4. Data acquisition is automated through a Lab View Program on the computer which controls the stepper motor.

f) Field Scanning Electron Microscope (FESEM)

1. Both samples in pieces form were coated with gold.
2. Samples are put in the chamber inside of SEM for 5 minutes to let it in vacuum condition.
3. As gas molecules interfere with the electron beam and with the emitted secondary and backscattered electrons used for imaging.
4. Samples were computerized in order for images capturing and for elemental mapping.

g) POROPERM

The experiments taken using the RPS machine could only take place after the author have taken a couple of measurements below, strictly to follow these steps:

a) Get two blocks of cleaned core plug
b) Measure the diameter, length and weight of the core plug
c) Using the POROPERM® device, the core plugs are to be put in the core holder vertically in the machine, confining pressure is applied of up to 1000 psi.
d) The system in the computer would automatically display the graphs and characteristics of the core plug.
e) Record the porosity and permeability readings in the results section.
f) Saturate the core plug with distilled water in a manual pump sucker for at least 6 hours. In the author's experiment, he saturated it for one whole day.

3.4 Key Milestone

No	Action Item	Action By	Date	Note
1	Briefing & update on students progress	Coordinator / Students / Supervisors	8 FEB	WEEK 3
2	Project work commences	Students		WEEK 1 -14
3.	Submission of Progress Report	Students	16 MARCH	WEEK 8
4.	PRE-EDX combined with seminar/ Poster Exhibition/ Submission of Final Report (CD Softcopy & Softbound)	Students / Supervisor / Internal Examiner / Coordinator	4 APRIL	WEEK 11
5.	EDX	Supervisors / FYP Committee	11 APRIL	WEEK 12
6.	Final Oral Presentation	Students / Supervisors	20 APRIL 2011	WEEK 13
7.	Delivery of Final Report to External Examiner / Marking by External Examiner	FYP Committee / Coordinator	20-27 APRIL 2011	WEEK 14
8.	Submission of hardbound copies	Students	04 MAY 2011	WEEK 16

Table 2: Key Milestone

3.5 Gantt Chart

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	**Briefing & update on students progress**	■	■	■													
2	**Project work commences**		■	■	■	■	■	■	■	■	■	■	■	■	■		
3	**Submission of Progress Report**								●								
4	**PRE-EDX combined with seminar/ Poster Exhibition/ Submission of Final Report (CD Softcopy & Softbound)**											■					
5	**EDX**												■				
6	**Final Oral Presentation**													●			
8	**Delivery of Final Report to External Examiner / Marking by External Examiner**														●		
10	**Submission of hardbound copies**																●

Table 3: Gantt Chart

CHAPTER 4

RESULTS AND DISCUSSIONS

Throughout the end of this Final Year Project, the outcomes were:

a) Microfabrics

Fabric characteristics differ in the various facies types. Granite sample from Ipoh-Lumut Highway (around Batu Gajah) has particle size below 2.3mm which is fine to medium grain size. It is highly fracture granite. Granite sample from Lata Kinjang has bigger grain size. Basically, granite has hornblende mineral(black dots) around 5-8 %, Quartz (gray) 20-30 %, and feldspar (crystal) 30-35%.

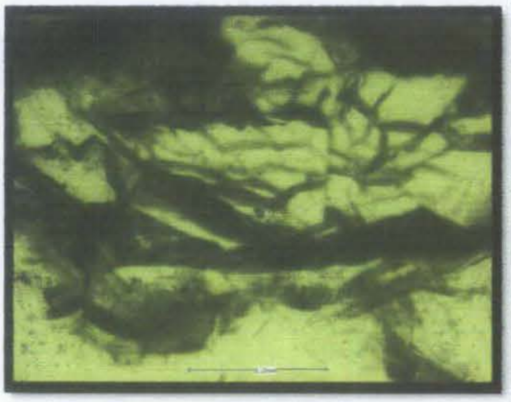
b) Field characteristics

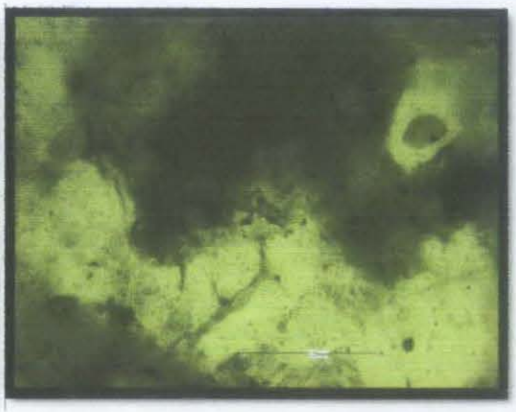
Granite rocks from Ipoh-Lumut Highway has joint due to tension , structure and blasting to make roads. While granite rocks from Lata Kinjang are from river which is deposited rocks.

MICROSCOPY IMAGE

TC1: LATA KINJANG SAMPLE

TC3: IPOH-LUMUT HIGHWAY SAMPLE





TC1 **TC3**

Figure 15: Thin Section images

Thin Section Discussions

Based on Figure 15, the images have been polarized to know the shapes for the minerals and elements. Thin section images for TC1 shows variety of minerals which are quartz, mica, feldspar and amphibole. Fracture appear in TC1 because of broken glass beads While, thin section images for TC3, there images shows the existence of silica and the orientation of elements. There are also presences of fracture which can be seen from TC3.

XRF RESULTS AND DISCUSSIONS:

TC1 (LATA KINJANG)

O	Al	Si	K	Fe	F	Al2 O3
-1000 KCps	12.2KCps	87.2KCps	17.5KCps	30.5KCps	-1000KCps	12.2KCps
51	7.95	38.2	2.03	0.523	4.006	15

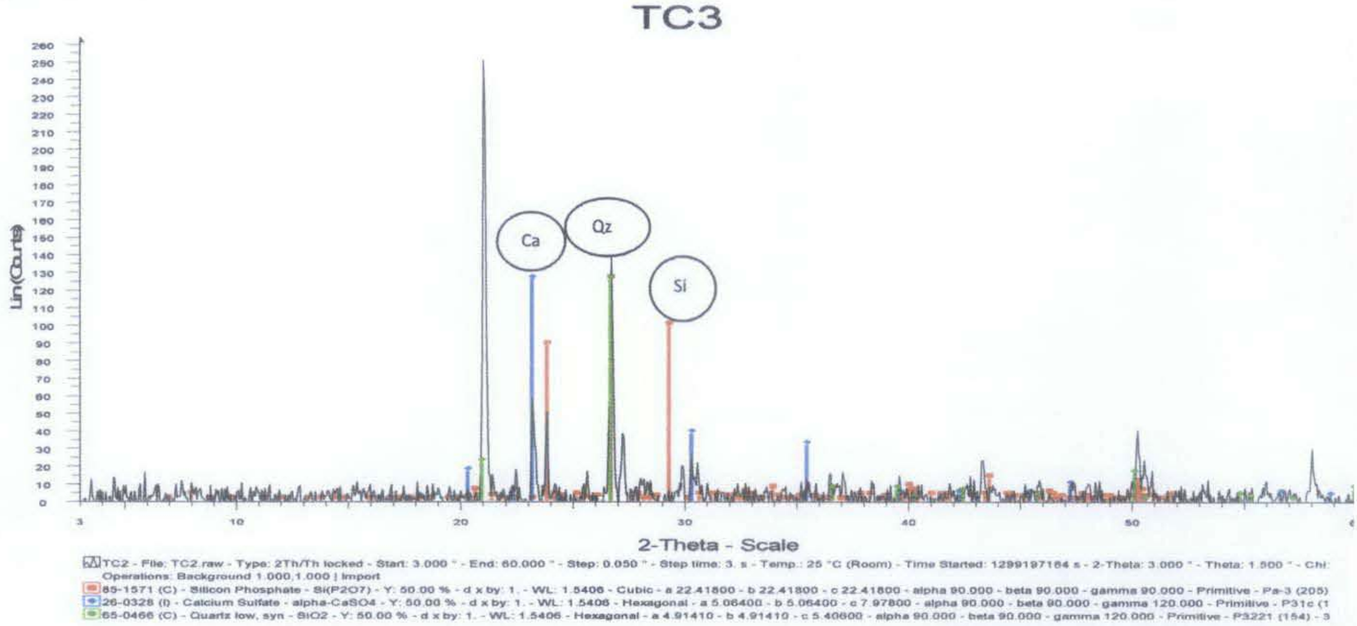
TC3 (IPOH-LUMUT HIGHWAY)

O	Al	Si	K	Ca	Fe	Rb	Na2O
-1000 KCps	15.7KCps	80.1KCps	45.1KCps	5.6 KCps	25.6KCps	13.5KCps	0.2KCps
50	9.83	34.6	4.94	0.62	0.454	0.0331	3.823

Table 4: Quantitative Elements from XRF

XRF was run in order to re-analyze the element content quantitatively inside the sample. For sample TC3, based on Table 4, showing that this sample contain several of elements much more than sample TC1. Main content in both samples, TC1 and TC3 are Oxygen (O) which is around 50 % and Silica (Si) around 34-38 %. Basically, in feldspar mineral, it consists of Potassium (K), Calcium, (Ca), Silica (Si), and Iron (Fe). Rubidium (Rb) is a radioactive mineral which is useful for radiometric dating. Radiometric dating is a technique used to date materials such as rocks, usually based on a comparison between the observed abundance of a naturally occurring radioactive isotope and its decay products, using known decay rates.

XRD RESULTS:



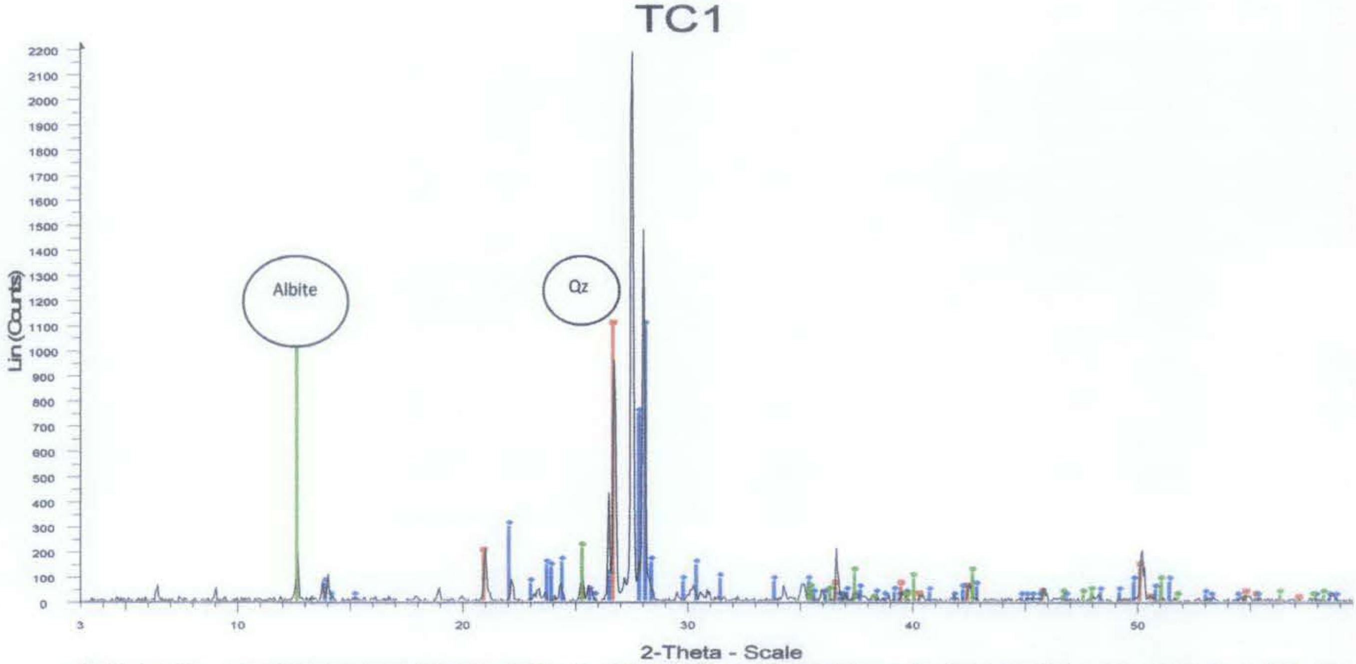


Figure16:Qualitative Elements from XRD

Based on XRD result (Figure 16), shows the qualitative of overall elements. The TC1 main content consists of quartz and albite while TC3 main contents are silica, calcium, quartz. Basically both samples have slight difference in minerals distribution which leads to some differences in thermal conductivity.

POROPERM RESULT:

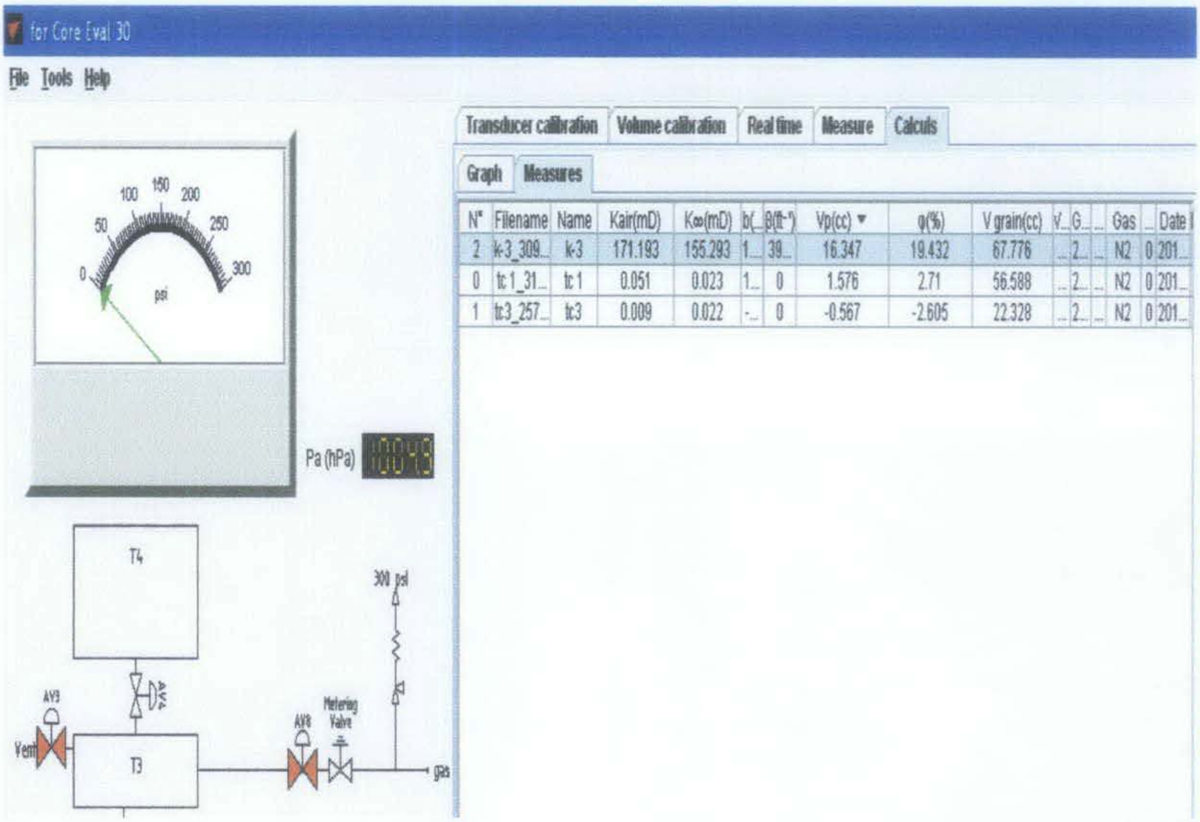


Figure 17: Results of POROPERM

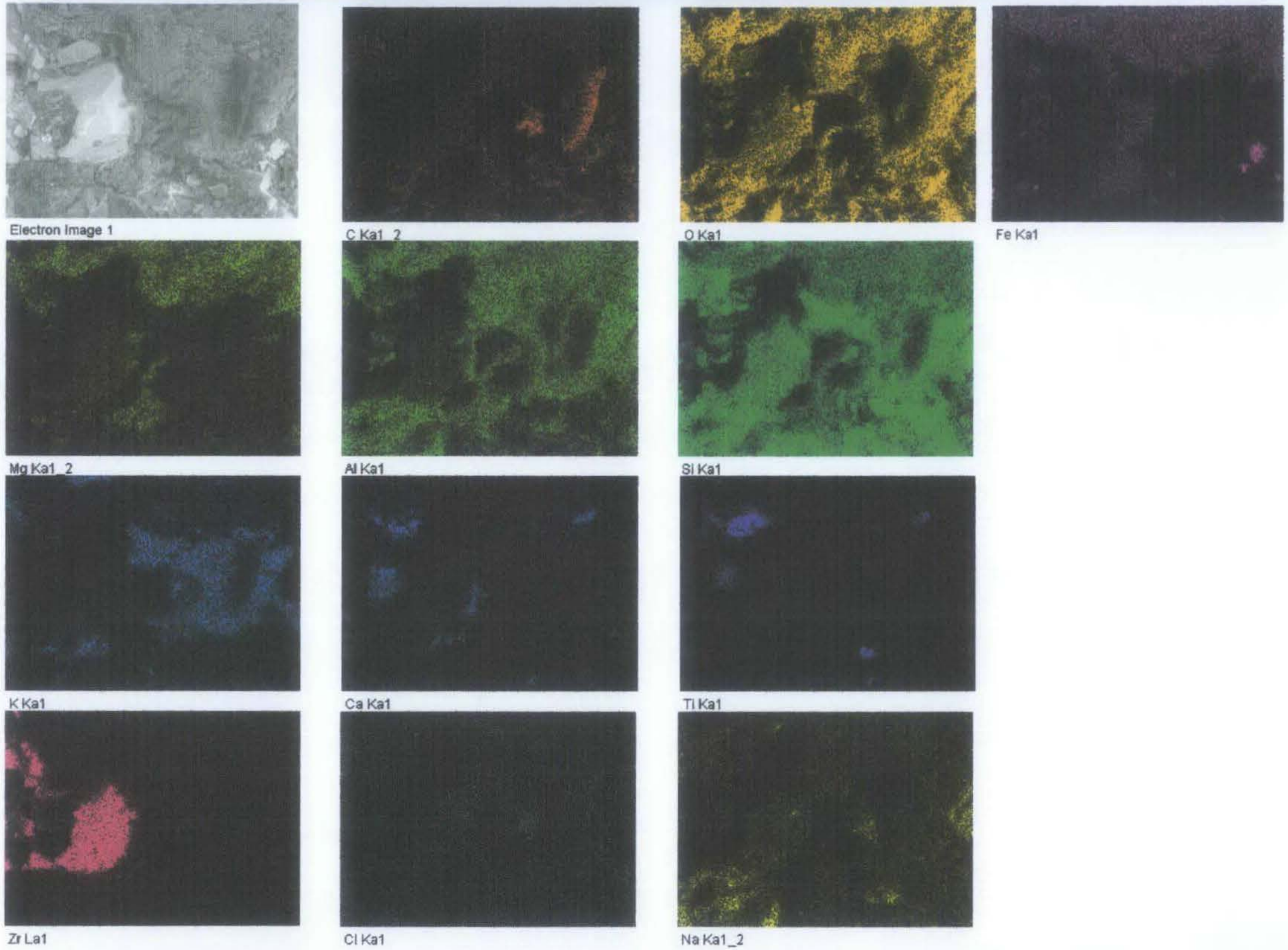
Permeability for both samples shows zero mili Darcy while porosity is around 2% (low) as they are very strong and tight granites.

SAMPLE	FACE	k
		W/(m.K)
TC1 (Lata Kinjang)	1	0.37
		0.25
		0.22
		0.15
		0.13
		0.11
		0.10
	k avg	0.19
	2	0.25
		0.32
		0.25
		0.32
		0.37
		1.11
		0.32
	k avg	0.42
	3	0.97
		0.32
		0.49
		0.97
	k avg	0.69
	4	0.97
		0.46
		0.15
		0.15
	k avg	0.43
	5	0.74
		0.44
		0.32
		0.32
	k avg	0.46
	6	0.56
		0.37
		0.44
		0.37
	k avg	0.44
	total k avg	0.44

SAMPLE	FACE	k
		W/(m.K)
2 (Ipoh-Lumut Highway)	1	0.28
		0.28
		0.19
		0.14
		0.11
		0.07
		0.07
	k avg	0.16
	2	0.08
		0.10
		0.15
		0.44
		2.22
		0.44
		0.28
	k avg	0.53
	3	1.19
		1.06
		1.06
		1.06
	k avg	1.09
	4	1.11
		1.11
		1.11
		1.11
	k avg	1.11
	5	0.28
		0.28
		0.28
		0.22
	k avg	0.27
	6	0.56
		0.25
		0.20
		0.17
	k avg	0.3
	total k avg	0.58

Table 5: TC results. TC1 (Lata kinjang sample) shows overall k avg 0.44 while TC3 (Ipoh-Tronoh highway sample) shows overall k avg = 0.58 at 40 watts.

Figure 18: TC1 mapping



Comment: The pink colour shows the elements of zirconium and the purple one is titanium element. Both elements make this rock

Spectrum processing :

No peaks omitted

Processing option : All elements analyzed (Normalised)

Number of iterations = 6

Standard :

C CaCO3 1-Jun-1999 12:00 AM

O SiO2 1-Jun-1999 12:00 AM

Na Albite 1-Jun-1999 12:00 AM

Mg MgO 1-Jun-1999 12:00 AM

Al Al2O3 1-Jun-1999 12:00 AM

Si SiO2 1-Jun-1999 12:00 AM

Cl KCl 1-Jun-1999 12:00 AM

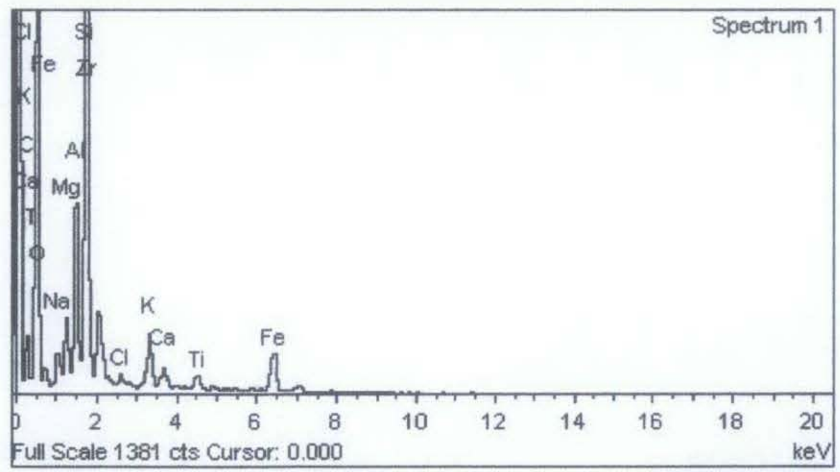
K MAD-10 Feldspar 1-Jun-1999 12:00 AM

Ca Wollastonite 1-Jun-1999 12:00 AM

Ti Ti 1-Jun-1999 12:00 AM

Fe Fe 1-Jun-1999 12:00 AM

Zr Zr 1-Jun-1999 12:00 AM

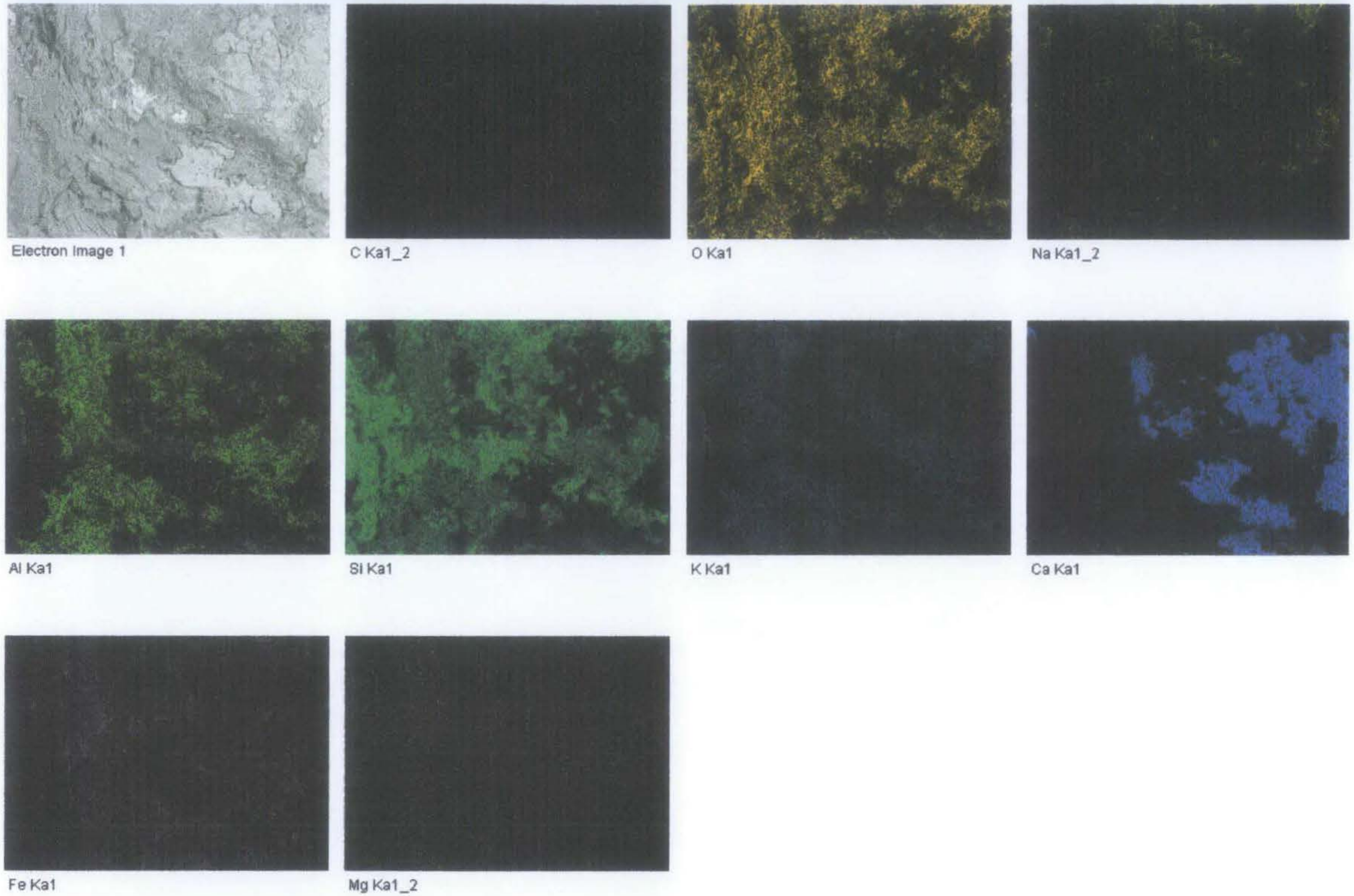


Element	Weight%	Atomic%
C K	33.76	45.66
O K	42.17	42.82
Na K	0.79	0.55
Mg K	1.25	0.84
Al K	2.94	1.77
Si K	10.09	5.83
Cl K	0.22	0.10
K K	1.32	0.55
Ca K	0.44	0.18
Ti K	0.57	0.19
Fe K	3.13	0.91
Zr L	3.34	0.59
Totals	100.00	

Comment: For the Energy Dispersive Xray, TC1 has Silica as its major elements besides carbon and oxygen.

Figure 20 TC3 mapping

30/03/2011 10:44:45



Comment: Since the elements of titanium or zirconium are not exist for this TC3, this rock is easily to be fracture and fragile. Same as TC1, the elements are Silica, Aluminium Iron, Magnesium, Oxygen and so on with different colours for each respective boundaries.

Spectrum processing :

No peaks omitted

Processing option : All elements analyzed (Normalised)

Number of iterations = 5

Standard :

O SiO2 1-Jun-1999 12:00 AM

F MgF2 1-Jun-1999 12:00 AM

Na Albite 1-Jun-1999 12:00 AM

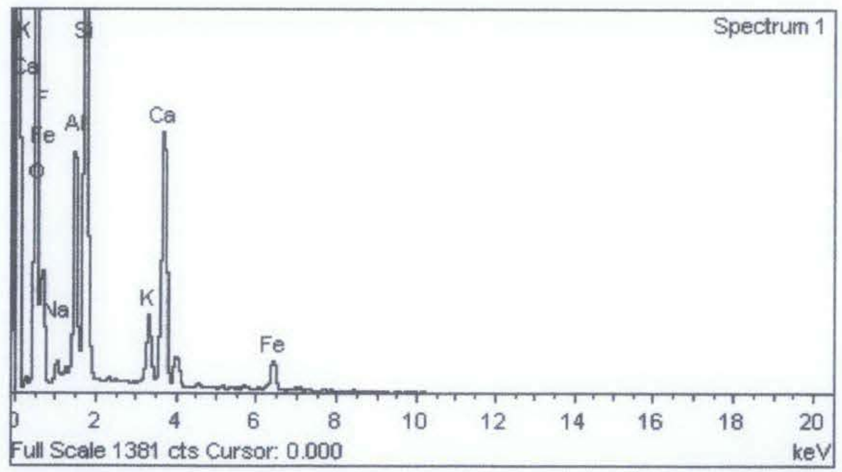
Al Al2O3 1-Jun-1999 12:00 AM

Si SiO2 1-Jun-1999 12:00 AM

K MAD-10 Feldspar 1-Jun-1999 12:00 AM

Ca Wollastonite 1-Jun-1999 12:00 AM

Fe Fe 1-Jun-1999 12:00 AM



Element	Weight%	Atomic%
O K	44.12	56.16
F K	18.30	19.61
Na K	0.75	0.67
Al K	4.93	3.72
Si K	18.31	13.27
K K	2.13	1.11
Ca K	8.91	4.53
Fe K	2.54	0.93
Totals	100.00	

Comment: Same like TC1, TC3 has Silica as its major elements besides carbon and oxygen.

CHAPTER 5

CONCLUSIONS

- Thermal conductivity for granite was found an average of 0.44 W/mK for Lata Kinjang sample and 0.58 W/mK from Ipoh-Lumut Highway
- Different fabric elements are encountered in the resulting thermal conductivity.
- The permeability of granite for both samples is very low, so it may be hard to find geothermal energy through granite in Malaysia region.

RECOMMENDATIONS

- Further studies need to be done to estimate optimal temperature condition for hydrocarbons in granite.
- All information will be forwarded to PhD student, Yassir for extra researches to determine the impact of fabrics on thermal conductivity of some granitic rocks.
- More samples from other locations need to be experimented to discover the potential of geothermal energy.

CHAPTER 6

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