

**DEVELOPMENT OF NOVEL TECHNIQUE FOR PORE PREDICTION  
USING MODIFIED EATON EQUATION**

By

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FINAL PROJECT REPORT

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for the Degree  
Bachelor of Engineering (Hons)  
(Electrical & Electronic Engineering)

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# **CERTIFICATION OF APPROVAL**

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A project dissertation submitted to the  
Department of Electrical & Electronic Engineering  
Universiti Teknologi PETRONAS  
in partial fulfilment of the requirement for the  
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TRONOH, PERAK

September 2012

## **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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Nadiatuliman Jamaludin

## **ABSTRACT**

The project aims to assist drillers for pore pressure prediction in the sea during operation of drilling. The importance to measure pore pressure was because it can help the drillers in terms of preparation to build a well that will give maximum revenues and also safe. Through Eaton's equation, pore pressure can be predicted whether the area is subnormal, normal, or abnormal. Through data that I obtained, it is inadequate to show all types of pressures. Overall the result obtained is from abnormal zone. This project will help drillers to reduce time consuming on drilling process. Apart from that, productions of well would also be maximized, without forgetting the safety aspect.

## **ACKNOWLEDGEMENTS**

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## **LIST OF ABBREVIATIONS**

TVD	- True Value Depth
RHOBC	- Density
GUI	- Graphical user Interface
KB	- Kelly Bushing
MATLAB	- Matric Laboratory
FYP	- Final Year Project
Mpa	- Mega Pascal
Psi	- Pounds per square inch

# CHAPTER 1

## INTRODUCTION

### 1.1 Background of Study

#### 1.1.1 Baram Delta, Malay Basin

To carry on this project, a data log well called BTY1: Baram Delta located in Malay basin was obtained as shown in Fig. 1. The Malay basin is also infamously known of its capable of having oil and gas fields that mostly located at the southwestern part.

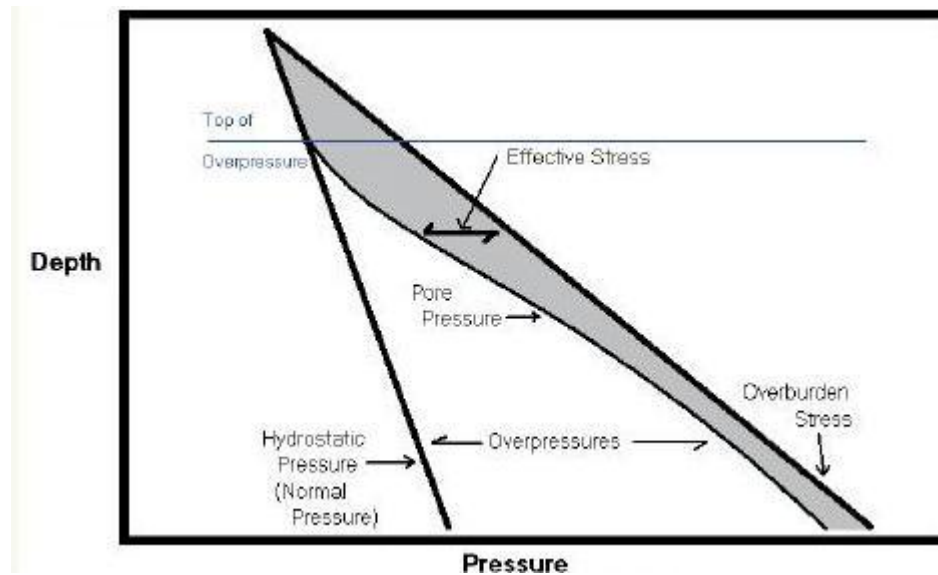


**Fig. 1 – The Baram Delta, Malay basin[1]**

The basic data input provided are the true value depth of the well, pressure, velocity, and effective stress. These data input comes with corresponding unit of their own, for example, the true value depth is in meters(m), the pressures is in Mpa, velocity is in m/sec, and effective stress is in Pascals(Pa). There are 120 different of depth starting from 3037m until 3232m. Every depth has their corresponding of pressure, effective stress, RHOBC, and velocity that is different. Using well logging, these basic data is acquired from well BTY 1 and used as default data for research.

### 1.2.1 Pressures Terminology

Fluid pressures in the pore spaces of rocks are critical to several aspects of petroleum exploration and production. However, a general understanding of some basic concepts has been obscured by a lack of consistency in terminology. Fig. 2 illustrates several concepts of pressures. The hydrostatic line gives the pressure due to a column of water. An important concept is that, for a simple porous rock with pore spaces continuously connected to the surface, the pressure of the fluid in the pore space is just the pressure exerted by the weight of the overlying fluids. This normal or hydrostatic pressure is simply the pressure due to a column of water [1].



**Fig. 2 – Pressures plotted against depth[1]**

The overburden stress is the pressure of the fluid in the pore space of the rock. This pressure can be higher than hydrostatic pressure. The point at which pore pressures exceed hydrostatic pressures is the “top of overpressure”. In overpressure, fluids are trapped in the pores and bear part of the weight of the overlying solids [1]. Any pressure over the hydrostatic pressure is overpressure.

The second definition is effective stress. It is a difference between overburden stress and pore pressure – essentially the amount of overburden stress that is supported by the rock grains [1].

Another concept implied is that pore pressure does not reach overburden stress. As pore pressure approaches overburden stress, fractures in the rock open and release fluids and pressures.

## **1.2 Problem Statement**

It is costly to operate drilling. Therefore, drillers should take wise action during the drilling process in order to avoid any incidents that could be wasted. If a tool is lost or a drill string breaks, the obstruction in the well is called junk or fish. It cannot be drilled through. Some reservoir rocks can be damaged by forcing drilling mud into them. This can be caused by using too heavy and overbalance while drilling. The drilling mud clogs pores or causes chemical or physical changes in the rock. This decreases permeability of the rock near the well bore. Formation damage prevents or reduces production from the reservoir rock when the well is completed.

Lost circulation occurs when a very porous and permeable formation is encountered in the subsurface. The drilling mud flows into the formation without building up a filter cake. During lost circulation, more mud is being pumped down the well than is flowing back up. An unexpected pressure in the subsurface can cause a blowout. The overbalance is lost and the fluids flow out of the subsurface rocks into the well in what is called a kick. [6] As the water, gas, or oil flows into the well, it mixes with the drilling mud, causing it to become even lighter and exert less pressure on the bottom of the well. The diluted drilling mud is called gas cut, salt-water cut, or oil cut. The blowout preventers are immediately thrown to close the hole.

Kick is a flow of formation fluids into the wellbore during drilling operations. The kick is physically caused by the pressure in the wellbore being less than that of the formation fluids, thus causing flow. This condition of lower wellbore pressure than the formation is caused in two ways. First, if the mud weight is too low, then the hydrostatic pressure exerted on the formation by the fluid column may be insufficient to hold the formation fluid in the formation. This can take place if the mud density is suddenly lightened, or if a drilled formation has a higher pressure than anticipated. This type of kick might be called an underbalanced kick. The second way a kick can occur is if

dynamic and transient fluid pressure effects, usually due to motion of the drill string or casing, effectively lower the pressure in the wellbore below that of the formation. This second kick type could be called an induced kick. Sometimes the blowout occurs so fast that the drillers do not have time to throw the blowout preventers, thus the results are disastrous. Slides and cables are located on the rig to evacuate the crew in such an emergency. If the blowout preventers are thrown in time, heavier drilling mud is pumped into the well through a choke manifold to circulate the kick out. A kick and possible blowout is detected by several different methods during drilling.

As subsurface fluids enter the well during a kick, more fluids will be flowing out of the well than are circulating into the well. The sudden increase of fluid flow out of the well or rise of fluid level in the mud pit is detected by instruments. The drilling mud can also be continuously monitored for sudden changes in weight, temperature, or electrical resistivity that would indicate the mud is being cut by subsurface fluids. A blowout can also be caused by raising the drill string out of the well. The drill string displaces a volume of drilling mud in the well. As the drill string is raised, the level of drilling mud falls in the well and the pressure is decreased on the bottom of the well. If the level of the drilling mud is not maintained in the well, overbalance could be lost and a blowout could occur.

### **1.3 Objective and Scope of the project**

#### ***1.3.1 Main Objective***

- To predict pore pressure using Eaton's equation
- To evaluate Eaton's equation using existing data
- To develop GUI to assists drillers to predict pore pressure

# CHAPTER 2

## LITERATURE REVIEW

### 2.1 General Knowledge on Drilling

The purpose of drilling process is to create a feasible wellbore in order to allow flow of formation fluids through the production. The formation fluids include natural resources such as ground water, natural gas, or petroleum. The works mainly focus on petroleum. To drill, a drilling rig is needed. It is a machine that creates holes (usually called boreholes) or shafts in the ground and consists of several parts; the main part is hoisting system as shown in Fig. 3, circulation system, well control system and electrical system. The rig components are working in harmony. If considered as a factory, all of the components are buckles of a chain. Due to the uniqueness each single part of the rig system is significantly very important [17].

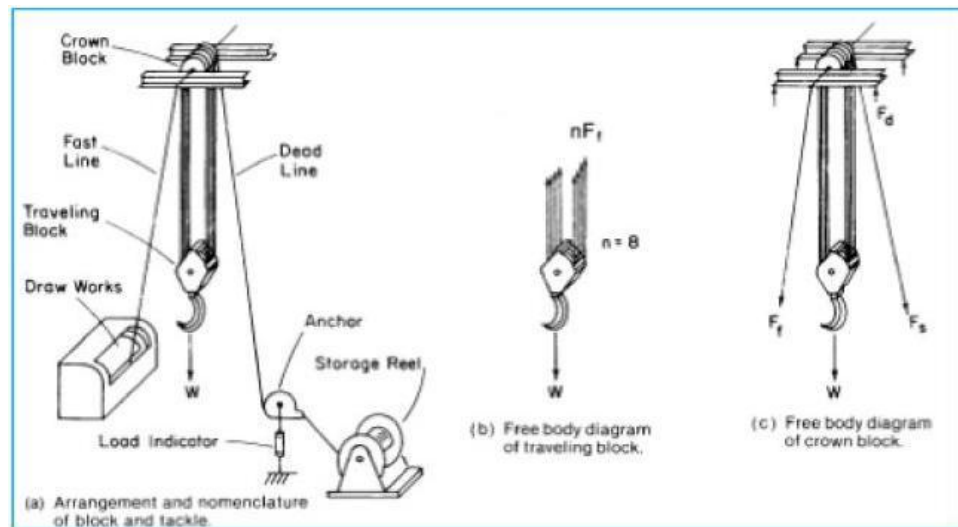
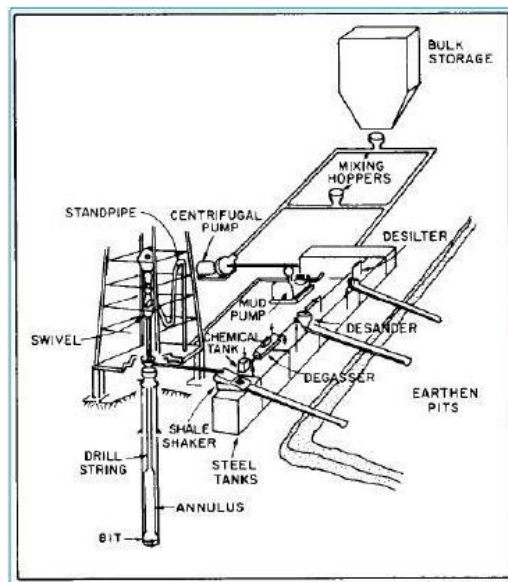


Fig. 3 – Hoisting system in drilling rig[17]



The function of hoisting system is to provide a means of lowering or raising drillstrings, casing strings, and other subsurface equipment into or out of the hole. The Principle components of the hoisting system are the derrick and substructure, the block and tackle, and the draw works. Two routine drilling operations performed with the hoisting system are called *making a connection* and *making a trip*. Making a connection refers to the periodic process of adding a new joint of drillpipe as the hole deepens. Making a trip is refers to the process of removing the drillstring from the hole to change a portion of the downhole assembly and then lowering the drillstring back to the hole bottom. A trip is made usually to change a dull bit. The steps involved in coming out of the hole.

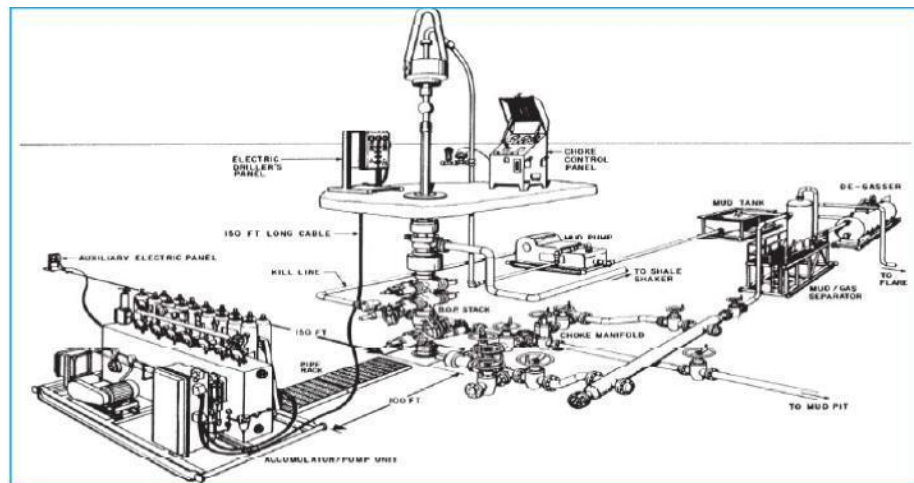


**Fig. 4 - Circulation system [17]**

A major function of the fluid-circulating system is to remove the rock cuttings from the hole as drilling progresses. A schematic diagram illustrating a typical rig circulating system is shown in Fig.4. The drilling fluid is most commonly a suspension of clay and other materials in water and is called *drilling mud*. The drilling mud travels from the steel tanks to the mud pump, from the pump through the high-pressure surface connections to the drillstring, through the drillstring to the bit, through the nozzles of the

bit and up the annular space between the drillstring and hole to the surface, and through the contaminant-removal equipment back to the suction tank.

The principal components of the rig circulating system include mud pumps, mud pits, mud-mixing equipment, and contaminant-removal equipment. With the exception of several experimental types, mud pumps always have used reciprocating positive displacement pistons. Both two-cylinder (duplex) and three-cylinder (triplex) pumps are common. The duplex pumps generally are *double-acting* pumps that pump on both forward and backward piston strokes. The triplex pumps generally are *single-acting* pumps that pump only on forward piston strokes. Triplex pumps are lighter and more compact than duplex pumps, their output pressure pulsations are not as great, and they are cheaper to operate. For these reasons, the majority of new pumps being placed into operation are of the triplex design. The overall efficiency of a mud-circulating pump is the product of the mechanical efficiency and the volumetric efficiency.



**Fig. 5 - Well control system [17]**

The well control system as shown on Fig. 5, prevents the uncontrolled flow of formation fluids from the wellbore. When the bit penetrates a permeable formation that has a fluid pressure in excess of the hydrostatic pressure exerted by the drilling fluid, formation fluids will begin displacing the drilling fluid from the well. The flow of formation fluids into the well in the presence of drilling fluid is called a *kick*. The well control system permits detecting the kick, closing the well at the surface, circulating the well under pressure to remove the formation fluids and increase the mud density, moving the

drillstring under pressure, and diverting flow away from rig personnel and equipment. Failure of the well control system results in an uncontrolled flow of formation fluids and is called a *blowout*. This is perhaps the worst disaster that can occur during drilling operations. Blowouts can cause loss of life, drilling equipment, the well, much of the oil and gas reserves in the underground reservoir, and damage to the environment near the well. Thus, the well control system is one of the most important systems on the rig.

Safety and efficiency considerations required constant monitoring of the well to detect drilling problems quickly. Devices record or display parameters such as depth, penetration rate, hook load, rotary speed, rotary torque, pump rate, pump pressure, mud density, mud temperature, mud salinity, gas content of mud, hazardous gas content of air, pit level and mud flow rate. In addition to assisting the driller in detecting drilling problems, good historical records of various aspects of the drilling operation also can aid geological, engineering, and supervisory personnel. This unit provides detailed information about the formation being drilled and fluids being circulated to the surface in the mud as well as centralizing the record keeping of drilling parameters. The mud logger carefully inspects rock cuttings taken from the shale shaker at regular intervals and maintains a log describing their appearance. Additional cuttings are labeled according to their depth and are saved for further study by the paleontologist [13].

Drilling rigs can be mobile equipment mounted on trucks, tracks or trailers, or more permanent land or marine-based structures (such as oil platforms, commonly called 'offshore oil rigs' even if they do not contain a drilling rig). Drilling rigs can be in small size portable and also huge, capable of drilling through thousands of meters of the Earth's crust. In early oil exploration, drilling rigs were semi-permanent in nature and the derricks were often built on site and left in place after the completion of the well [17]. In more recent times drilling rigs have been expensive custom-built machines that can be moved from well to well.

Drilling technology has advanced steadily since the 19th century [15]. However, there are several basic limiting factors which determine the depth, to which a bore hole can be sunken [12], [13]. Therefore, some parameters need to be recorded and monitored during the course of drilling. According to the information, several necessary actions will

be taken. Pore pressure is one of the most important parameters to be monitored during drilling.

Drilling fluid is a fluid that is used as the aid during drilling. There are several type of drilling fluids such as air, water (non inhibitive), water-based, oil-based mud and synthetic-based fluid. Drilling fluids can be applied to remove cuttings from well, control subsurface formation pressures, maintain wellbore stability, cool, lubricate, and support the bit and drilling assembly [13].

Casing is a large diameter pipe that is assembled and inserted into a recently drilled section of a borehole and typically held into place with cement. It is necessary to case a well because walls of an oil/gas well are usually lined with steel tubes in order to seal off fluids from the borehole and to prevent the walls of hole from sloughing off or craving. Sections of individual casings that are screwed together and cemented in hole are called casing strings.

Casing design is a process which seeks to have a balance between needs of the subsurface formations and casing strings to be run in hole and cemented in place as shown in Fig.6. The objective is to ensure that the casing design intent is not exceeded by the predicted and subsequent actual, operating envelope.

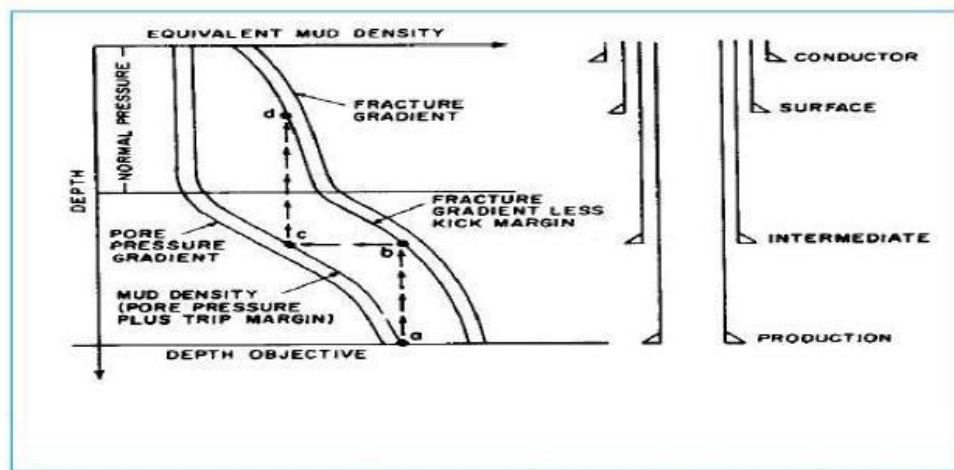


Fig. 6- Casing parameters [17]

## **2.2 Importance of Pore Pressure Prediction**

Pore pressure prediction is not only important on deciding the mud weight, but also to determine the number of casing strings and casing seat selection which have the huge impact in well integrity and economics. Pressure is the exertion of force upon a surface by an object, fluid, or something in contact with it [13]. There are several types of pressure, such as confining pressure, pore pressure, effective pressure, and hydrostatic pressure. In many of today's high cost offshore areas, overpressure zones present significant challenges to optimizing the drilling process. The main overpressure causes are under compaction, fluid expansion, fluid migration and tectonics [7], [18]. Pore pressure or formation pressure is the pressure experienced by the pore fluids in the pore spaces of subsurface formations.

At any depth the overburden pressure is the summation of weight of grains and pore pressure. Pore pressure prediction methods preciseness is based on their capacity to account for the causes of the above overpressure. In normal pressurized formations, porosity decreases with depth as the pore fluids are expelled out of pores due to the increment over burden weight. Thus, the pore fluid expulsion maintains the effective communication of pore fluids with the surface. So at any depth pore pressure is simply the same as the hydrostatic pressure of the water column. In other words, pore pressure in normal compacted sediments is entirely due to the density and height of the fluid column. In abnormal overpressured formations, the pore water expulsion is intercepted by rapid sedimentation and the absence of permeable pore networks. Thus, when the pore fluid experiences pressure above the normal hydrostatic pressure, over pressures develops. Knowledge of pore pressure is vital in declining the drilling mud weight to be used. Drilling mud in the borehole creates hydrostatic head to balance the formation pressure during drilling.

## **2.3 Pore Pressure Origins**

Pore pressure, sometimes called formation or formation-fluid pressure, is defined as the pressure contained in the pore space of subsurface rock. Pore pressures can be

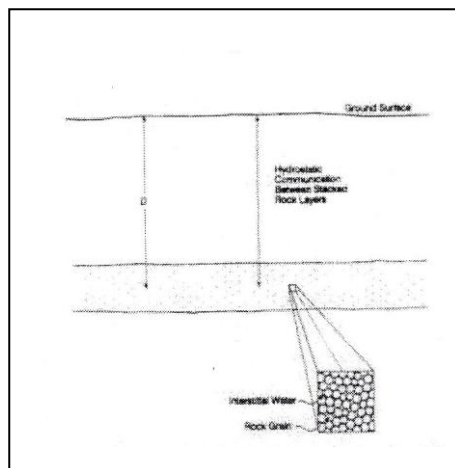
classified by the magnitude of the corresponding pressure gradient in a given area as normal, subnormal, and abnormal.

### 2.3.1 Normal Pore Pressure

Normal pressure gradients correspond to the hydrostatic gradient of fresh or saline water. Fig. 7 shows a normally pressured rock where a formation stratum was deposited in a marine environment. The bulk rock includes the grain framework or matrix plus interstitial water within the pore space. Assuming that the porosity is interconnected and extends back to the ground surface through the overlying sediments, the pore pressure at a point in the rock element is the product of the vertical depth,  $D$  and the hydrostatic gradient of the pore water,

$$p_n = g_n D \quad (1)$$

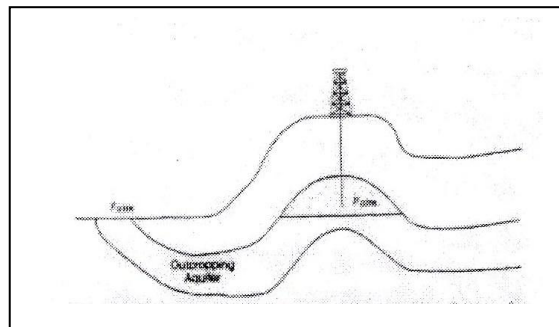
Where  $p_n$  and  $g_n$  are normal pore pressure and normal pressure gradient respectively. What is considered normal pressure depends on the geographic area or depositional basin.



**Fig. 7 - Demonstration of a normal-pore-pressure environment[9]**

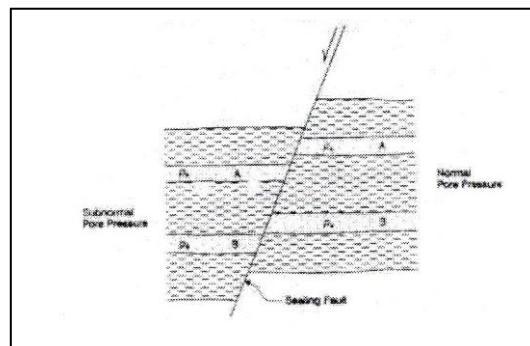
### 2.3.2 Subnormal Pore Pressure

A subnormal pore pressure is less than what would be considered normal for the area. One reason for subnormal pressures is seen in areas displaying uneven surface terrain characteristics. Fig. 8 depicts an aquifer outcropping below the surface drilling location that results in a piezometric water table at some depth below the Kelly bushing (KB) datum of the rig. The Pore pressure above the water level is near atmospheric, which lowers the pore pressure gradient of the rock to virtually nothing. These occurrences are common in mountain regions and create severe lost-circulation problems at shallow depths.



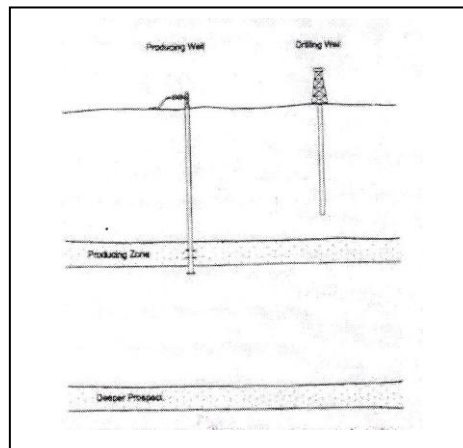
**Fig. 8 - Subnormally pressured aquifer resulting from a depressed outcrop[9]**

One cause of subnormal pressures is gross earth movements. Fig. 9 shows a series of rock strata on each side of sealing tension or normal fault. Sands A and B retain their original pressure at the greater depth if the fault plane does not leak and other means of thermal or hydraulic repressuring are not provided to the downthrown side. The sands to the left of the fault will be subnormal if those on the right are normally pressured.



**Fig. 9 - Subnormal pore pressure resulting from a sealed normal fault[9]**

Not all subnormal pore pressures occur naturally. Some are manmade, specifically those resulting from production. Subnormal pressures resulting from reservoir depletion are increasingly common in mature development areas. Fig. 10 shows a deep prospect being drilled in a field that has produced for some period from the shallower horizon. The productive formation may have had a normal or even an abnormal pore pressure when discovered, but production has drawn down the average reservoir pressure to a level that can create problems in the later development program. Well plants may need to incorporate another casing string to reach objective depth.



**Fig. 10 - Reservoir pressure depletion as a reason for subnormal pore pressure[9]**

### ***2.3.3 Abnormal Pore Pressure***

An abnormal pore pressures are formation pressures that are higher than normal for an area. The term could apply to either abnormally high or abnormally low pressures. Other common terms for this phenomenon are “geopressures” and “overpressures”.

Drilling problems and well costs generally increase in overpressured rock. Abnormally pressured shales create hole-in-stability problems that usually can be remedied with higher mud densities. Abnormally pressures formations with good permeability require mud densities equivalent to or slightly in excess of the pore pressure if the intent is to keep formation fluids from entering the wellbore. Regardless of the

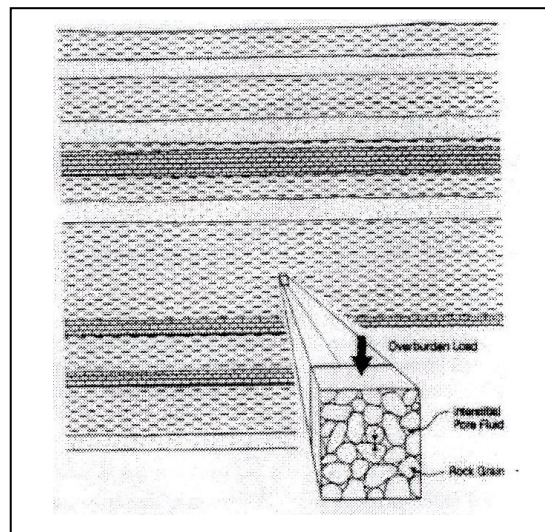


source, all abnormal pressures require some means of sealing or trapping the pressure within the rock body. Otherwise, hydrostatic equilibrium back to a normal gradient would be restored eventually.

Abnormally pressures also associated with massive salt beds. Rather than serving as a geopressure source, the impermeable nature of rock salt provides a highly effective seal for any subsequent processes, such as diagnosis and thermal expansion of pore fluids. Dense rock encountered in a drilling operation is a warning to an operator that something may be changing with respect to the current pore pressure gradient. Hard, tight rock can isolate pressure from above as well as below and may be an indication of rapid transition from a high-pressure environment to a lower or even normal pressure regime.

## 2.4 Overburden and Stress Concepts

Normally compacted or undercompacted rock at any burial depth must support the weight of overlying rocks and pore fluids. The overburden load expressed in terms of gradient is the geostatic or overburden-stress gradient,  $g_{ob}$ . Fig. 11 shows a sedimentary rock element containing mineral grains and pore fluid in the matrix interstices.



**Fig. 11 - Overburden support in a sedimentary-rock element[9]**

The overburden stress imposed on the element,  $\sigma_{ob}$ , is opposed by vertical stress in the matrix framework,  $\sigma_{ve}$ , and by pore pressure, giving

$$\sigma_{ob} = \sigma_{ve} + P_p \quad (2)$$

Unlike liquids, which can withstand only internal loads which are equal in all directions (isotropic distribution), solids can support differing loads in a variety of directions. When solid is subjected to external forces for example, the forces exerted on a rock sample by the jaws of a press, it reacts by redistributing elementary internal loads, called stresses.

# CHAPTER 3

## METHODOLOGY

### **3.1 Research Methodology**

Detailed literature review is focused on the pore pressure prediction using Eaton's method. For the literature reviews as well as brief research about the topic are carried out on several resources such as books, journals, magazines, and also internet. After literature review, well log data will be collected. The data is then plotted using excel and then using MATLAB. New pore pressure profile will be constructed using various pressure gradient of psi/ft. The research methodology is separated into four main stages and the activities planned for each stage are explained one by one. The first stage is preliminary research work on the project including the preparation of proposal. Then, the second stage is the manipulation of the data obtained from Baram Delta, Malay Basins. On the third stage, data is being analyzed to obtain a result. The final stage is where the conclusion is made and the documentation that compiles all the research works.

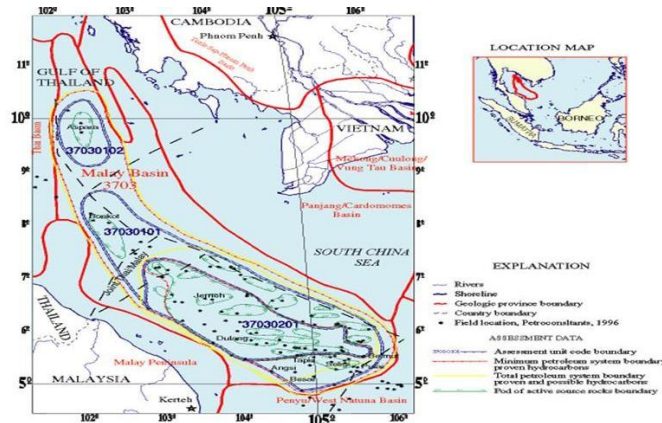
#### ***3.1.1 Preliminary Research Work***

This stage involves compilation and review of information from various books, journals and technical papers on related topics. Important information required for the project such as how drilling works, and categories of pressures. This information is to be used to conduct the literature review and for next stages of the project and also to enhance the knowledge upon related topic. Instructions and tutorials on MATLAB software are also reviewed.

#### ***3.1.2 Data Manipulation***

The research data is obtain from an example well of BTY 1 (Fig. 12), located in Malay basin. The basic data input provided are density porosity, neutron porosity, depth,

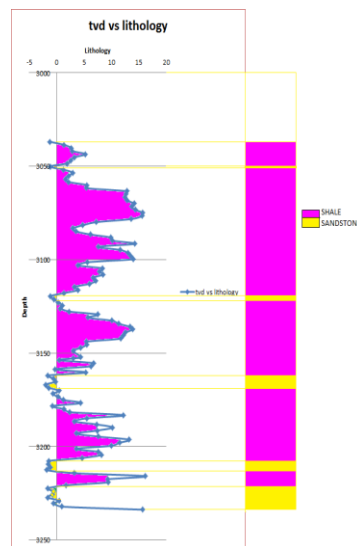
permeability, lithology, volume of shale, formation velocity, porosity and temperature. Malay basin is also infamously known of its capable of having oil and gas fields that mostly located at the southwestern part. Using this well log, basic data is acquired from well BTY 1 and be used as default data for research.



**Fig. 12 – Malay Basins [3]**

### 3.1.3 Data Analyzing

There are two types of sand from the data obtained from well BTY1, which are sandstone and shale. From the data, lithology versus true value depth (tvd) was plotted as shown in Fig. 13. From this graph, sandstone and shale can be identified respectively according to the lithology indication. For shale part, the area is pink in color while the sandstone part, the area is yellow in color.



**Fig. 13 – Lithology vs tvd plot**

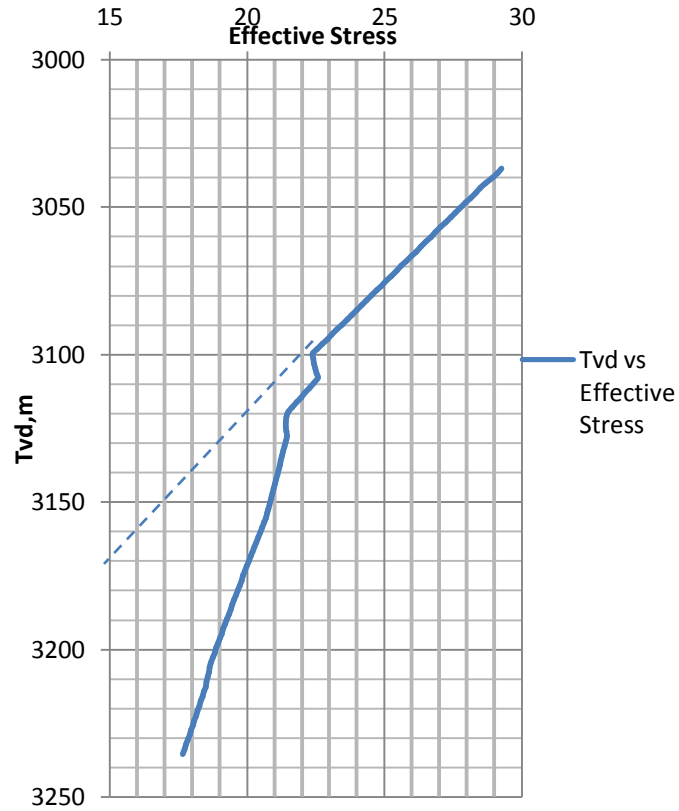
Using Eaton's Equation:

$$\frac{\sigma_{eff,obs}}{\sigma_{eff,n}} = \left( \frac{V_{ps,obs}}{V_{ps,n}} \right)^{E_{ps}} \quad (3)$$

Where

$\sigma_{eff,obs}$	= observed effective stress
$\sigma_{eff,n}$	= normal effective stress
$V_{ps,obs}$	= observed velocity
$V_{ps,n}$	= normal velocity
$E_{ps}$	= Eaton's Exponent

From this equation, Eaton's exponent first need to be determines. In order to determine the Eaton's exponent, from Fig. 13, one point of depth has been chosen, that is 3137m. from this chosen depth, we can determined the four parameters as stated in Eaton Equation, which are observed effective stress, normal effective stress, observed velocity, and normal velocity by plotting Effective Stress vs Tvd in Fig. 14 and Velocity vs Tvd in Fig. 15.



**Fig. 14– Effective stress vs True Value Depth (Tvd) plot**

From this graph, the value for effective stress and velocity at corresponding depth 3137m can be found. Then, apply the value obtained into Eaton’s Equation to determine the Eaton exponent.

At depth 3137m,

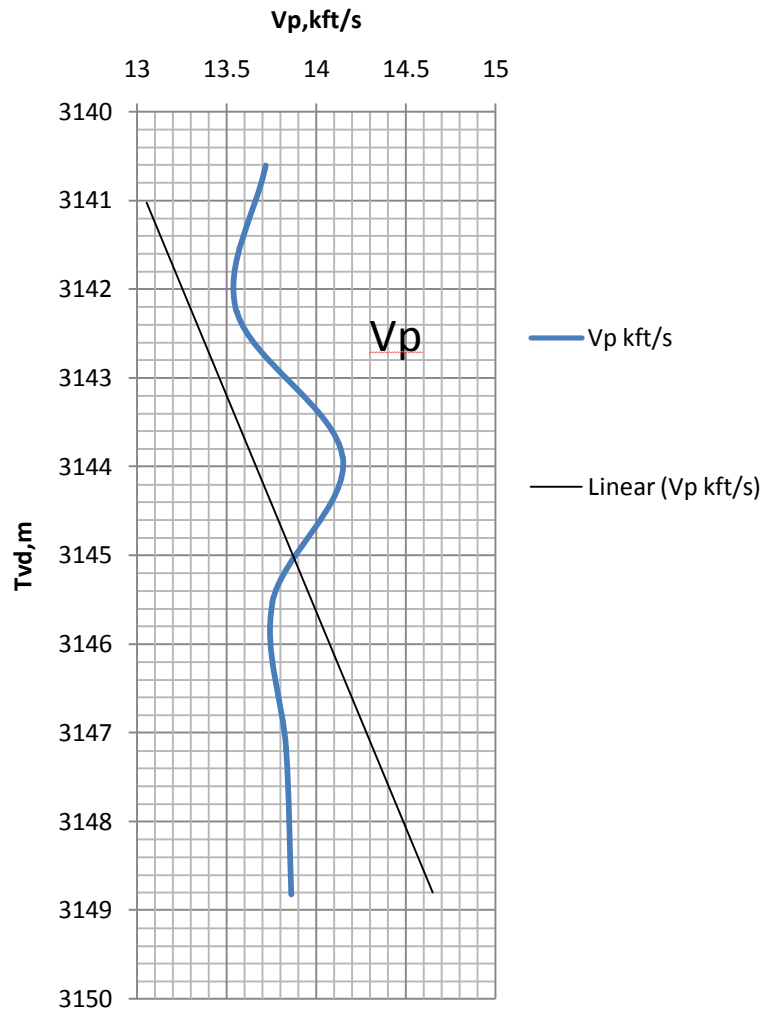
$$\frac{\sigma_{eff,obs}}{\sigma_{eff,n}} = \left( \frac{V_{ps,obs}}{V_{ps,n}} \right)^{E_p}$$

$$\left| \log \left( \frac{21.2}{20.5} \right) \right| = \left| \log \left( \frac{4140}{4088} \right)^{E_p} \right|$$

$$\left| \log \left( \frac{21.2}{20.5} \right) \right| = \left| E_p \log \left( \frac{4140}{4088} \right) \right|$$

$$E_p = \left| \frac{\log \left( \frac{21.2}{20.5} \right)}{\log \left( \frac{4140}{4088} \right)} \right|$$

$$\mathbf{E_p = 2.656}$$



**Fig. 15 – Velocity vs True Value Depth (Tvd) plot**

The value of Eaton's exponent obtained is 2.656 is nearly to the perfect Eaton exponential. Pore pressures are accurately predicted using Eaton exponent of 3.0 [4]. By using the exponential obtain, we can predict the pore pressure of the other area by again apply the corresponding value of Effective Stress and Velocity into Eaton's Equation to find the observed effective stress.

Pore pressure can be found by using equation:

$$\sigma_{ob} = \sigma_v + \alpha P_p \quad (4)$$

Where

- $\sigma_{ob}$  = Overburden pressure, psi
  - $\sigma_v$  = Effective stress, psi
  - $\alpha$  = Biot's constant, ( $0 < \alpha < 1$ )
- As for this prediction  $\alpha = 1$ .

Then, to determine the overburden pressure is by using this equation:

$$P(z) = p_o + g \int_0^z \rho(z) dz \quad (5)$$

Where

- $\rho(z)$  = Density of the overlying rock at depth z
- $g$  = Acceleration due to gravity
- $p_o$  = Pressure at the surface

Once the overburden pressure is obtain, pore pressure can be predicted and plot the graph versus Tvd to compare with the Fig. 16 below to determine whether the area is abnormal pressure, normal pressure or subnormal pressure.

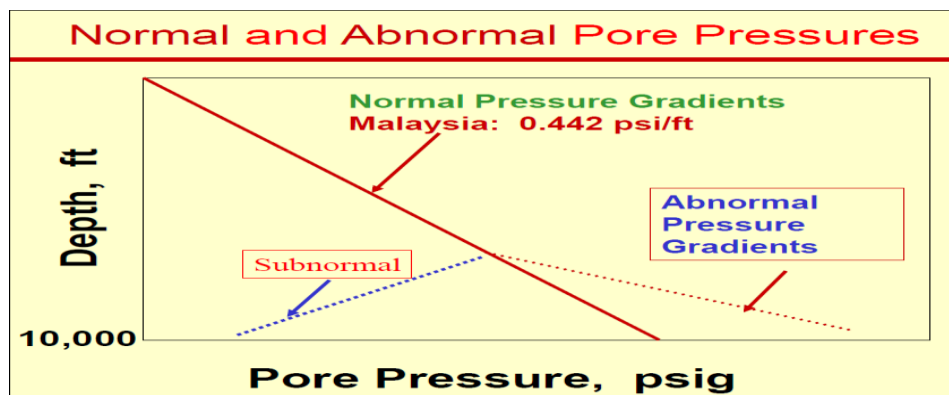
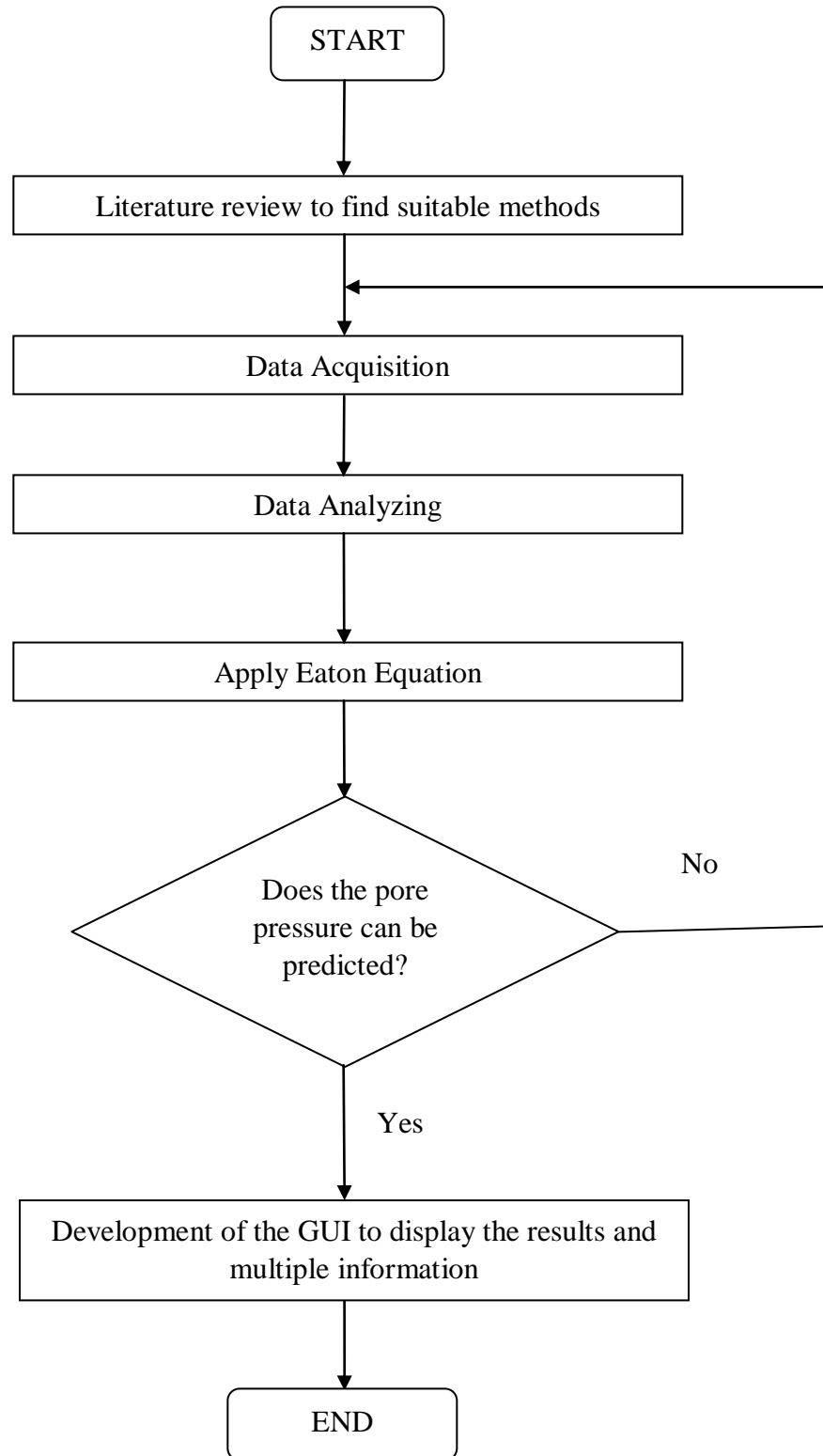


Fig. 16 – Pore Pressure vs Depth plot



### 3.2 FLOW CHART

The following flow chart explains the methodology in executing the project:



### 3.3 PROJECT DURATION

In order to effectively monitor the progress of this project, a Gantt chart consists of one semester duration had been constructed.

#### 3.3.1 FYP 1

**Table 1: Gantt chart for FYP 1**

Activities	FINAL YEAR PROJECT 1													
	WEEK NO.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Title selection	█													
Study the topic		█	█											
Literature review				█	█									
Extended proposal				█	█									
Viva: Proposal defense and Progress Evaluation						█	█							
Run and analyze the simulation based on example						█	█							
Data gathering								█	█					
Study and analyze data										█				
Develop pressure modelling										█	█	█		
Final report													█	

### 3.3.2 FYP 2

**Table 2: Gantt chart for FYP 2**

	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
Project Work Continues	[Blue bar]							MID-SEMESTER BREAK								
Submission of Progress Report									[Blue bar]							
Project Work Continues									[Blue bar]							
Pre-EDX												[Blue bar]				
Submission of Draft Report													[Blue bar]			
Submission of Dissertation														[Blue bar]		
Submission of Technical Paper														[Blue bar]		
Oral Presentation															[Blue bar]	
Submission of Project Dissertation																[Blue bar]

### **3.4 Tool Required**

Software required for plotting graph purposes are as per below:-

- MATLAB
- Microsoft Excel

# CHAPTER 4

## RESULT & DISCUSSION

### 4.1 Data Gathering

Based on the data obtained as shown in Fig. 17, the hydrostatic pressure is in Mpa unit. It is converted into Psi to calculate overburden pressure.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
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39																			
40																			

Fig. 17 – Data obtained from Baram Delta, Malay Basin

#### **4.1.1 Result of calculating overburden**

Using equation (5), overburden pressure was calculated. The result of the calculation from depth 3037m until 3093m as shown in Table 3 below.

<b>Tvd (m)</b>	<b>Pressure (Mpa)</b>	<b>RHOBC</b>	<b>Overburden (psi)</b>
3037	30	2.40	<b>4770.22</b>
3039	30	2.42	<b>4801.42</b>
3040	31	2.44	<b>4837.70</b>
3042	31	2.51	<b>4889.29</b>
3043	31	2.54	<b>4926.42</b>
3045	31	2.51	<b>4954.01</b>
3047	32	2.51	<b>4987.17</b>
3048	32	2.47	<b>5012.13</b>
3050	32	2.45	<b>5042.46</b>
3052	32	2.47	<b>5077.13</b>
3053	33	2.52	<b>5117.13</b>
3055	33	2.50	<b>5146.08</b>
3057	33	2.53	<b>5184.20</b>
3058	33	2.56	<b>5220.10</b>
3060	33	2.55	<b>5251.39</b>
3062	34	2.54	<b>5281.88</b>
3063	34	2.58	<b>5321.10</b>
3065	34	2.59	<b>5354.06</b>
3067	34	2.58	<b>5386.04</b>
3068	35	2.57	<b>5416.80</b>
3070	35	2.57	<b>5449.12</b>
3072	35	2.58	<b>5482.48</b>
3073	35	2.57	<b>5513.33</b>
3075	35	2.56	<b>5544.07</b>
3077	36	2.56	<b>5576.55</b>
3078	36	2.58	<b>5611.63</b>
3080	36	2.55	<b>5639.15</b>
3082	36	2.49	<b>5661.94</b>
3083	37	2.54	<b>5702.17</b>
3085	37	2.52	<b>5730.44</b>
3086	37	2.51	<b>5761.92</b>
3088	37	2.57	<b>5802.90</b>
3090	37	2.59	<b>5838.29</b>
3091	38	2.59	<b>5870.20</b>
3093	38	2.56	<b>5897.85</b>

**Table 3 – Calculated Overburden pressure**

#### 4.1.2 Result of calculating Effective Stress

To calculate pore pressure predicted using equation (2), first need to calculate Effective stress using Eaton equation (3), then the value is converted into psi unit. The result from the calculation to find Effective stress is shown in Table 4 below (From depth 3037m until 3091m). Pore pressure can be calculated by rearranged equation (2) by subtracting values from Table 4 from result from Table 3. The result is shown in Table 5.

DEPTH	V OBS	V NORM	EFF STRESS OBS	EFF STRESS NORM		EFFECTIVE STRESS
				OBSERVED	CALCULATED	
3037	4017	4018	29.20	29.10	29.22	<b>4237.90</b>
3039	4018	4019	29.00	29.10	29.02	<b>4208.87</b>
3040	4020	4021	29.00	29.10	29.02	<b>4208.87</b>
3042	4052	4001	29.10	29.40	29.10	<b>4220.60</b>
3043	4082	3960	28.90	28.10	28.90	<b>4191.59</b>
3044	4978	4890	28.10	27.70	28.10	<b>4075.56</b>
3045	4270	3980	27.70	26.60	27.70	<b>4017.54</b>
3047	4380	4020	27.10	26.30	27.10	<b>3930.52</b>
3048	4385	4121	27.20	26.30	27.20	<b>3945.03</b>
3050	4393	4125	27.50	26.90	27.50	<b>3988.54</b>
3052	4178	4210	27.30	27.40	27.86	<b>4040.59</b>
3053	4257	4220	27.50	27.70	26.87	<b>3897.12</b>
3055	4279	4280	27.20	27.10	27.22	<b>3947.47</b>
3057	4338	4340	27.00	26.90	27.03	<b>3920.82</b>
3058	4429	4431	27.10	26.80	27.13	<b>3935.24</b>
3060	4244	4245	26.50	26.80	26.52	<b>3845.90</b>
3062	4163	4150	26.40	26.50	26.18	<b>3797.32</b>
3063	4101	4104	26.30	26.40	26.35	<b>3821.91</b>
3065	4078	4045	26.30	26.10	25.74	<b>3733.06</b>
3067	4131	4157	25.90	25.80	26.34	<b>3819.60</b>
3068	4049	4050	25.70	25.60	25.72	<b>3729.91</b>
3070	4020	4021	25.50	25.40	25.52	<b>3700.91</b>
3072	4038	4010	25.50	25.60	25.03	<b>3630.74</b>
3073	4117	4023	25.40	25.30	23.89	<b>3464.76</b>
3075	3978	3980	25.20	25.10	25.23	<b>3659.83</b>
3077	4009	4020	24.70	24.80	24.88	<b>3608.60</b>
3078	4018	4021	24.60	24.50	24.65	<b>3575.01</b>
3080	4009	4008	24.40	24.30	24.38	<b>3536.58</b>
3082	4182	4192	24.30	24.20	24.45	<b>3546.84</b>
3083	4221	4222	24.20	24.10	24.22	<b>3512.12</b>
3085	4311	4320	24.00	24.10	24.13	<b>3500.24</b>
3086	4255	4226	23.80	23.90	23.37	<b>3389.76</b>
3088	4231	4230	23.70	23.60	23.69	<b>3435.24</b>
3090	4172	4171	23.50	23.40	23.35	<b>3386.23</b>
3091	4118	4120	23.20	23.10	23.23	<b>3369.22</b>

**Table 4 – Calculated Effective stress**

#### 4.1.2 Result of calculating Pore pressure

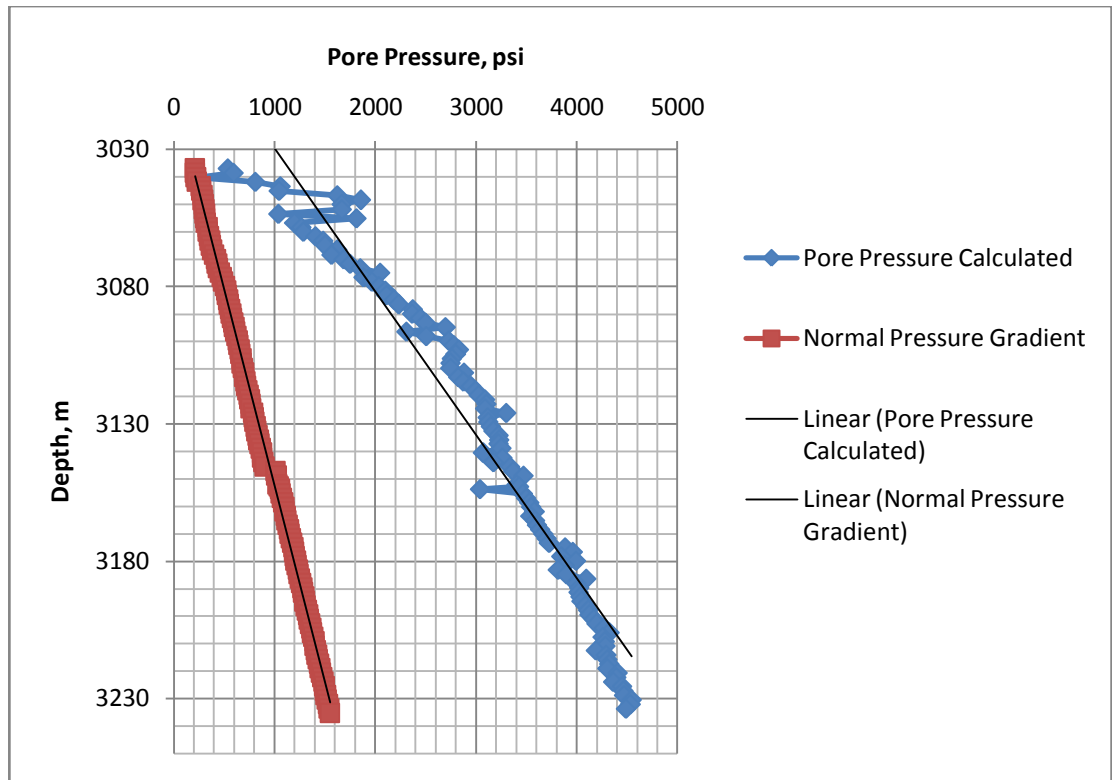
The calculated Pore pressure is obtained from the value of Overburden pressure minus the value of Effective stress. While the observed Pore pressure is already given from the data obtained.

DEPTH (m)	OVERBURDEN(psi)	PORE PRESSURE (psi)	
		OBSERVED	CALCULATED
3037	4770.22	4390.91	<b>532.32</b>
3039	4801.42	4418.57	<b>592.55</b>
3040	4452.50	4837.70	<b>243.63</b>
3042	4889.30	4492.70	<b>668.70</b>
3043	4926.42	4524.92	<b>734.83</b>
3044	4934.03	4532.22	<b>858.47</b>
3045	4954.01	4557.09	<b>936.47</b>
3047	4987.17	4589.17	<b>1056.65</b>
3048	5012.13	4621.25	<b>1067.10</b>
3050	5042.46	4653.33	<b>1053.92</b>
3052	5077.13	4685.41	<b>1036.54</b>
3053	5711.13	4717.49	<b>1814.01</b>
3055	5146.08	4759.47	<b>1198.61</b>
3057	5184.20	4781.65	<b>1263.38</b>
3058	5220.10	4813.73	<b>1284.86</b>
3060	5251.40	4845.81	<b>1405.50</b>
3062	5281.88	4877.89	<b>1484.56</b>
3063	5321.10	4909.96	<b>1499.19</b>
3065	5354.06	4942.04	<b>1621.00</b>
3067	5386.04	4974.13	<b>1566.44</b>
3068	5416.80	5006.20	<b>1686.89</b>
3070	5449.12	5038.28	<b>1748.21</b>
3072	5482.48	5070.30	<b>1851.74</b>
3073	5513.33	5102.53	<b>2048.57</b>
3075	5544.07	5134.34	<b>1884.24</b>
3077	5576.55	5166.35	<b>1967.95</b>
3078	5611.63	5198.37	<b>2036.62</b>
3080	5639.15	5230.38	<b>2102.57</b>
3082	5661.94	5262.40	<b>2115.10</b>
3083	5702.17	5294.41	<b>2190.05</b>
3085	5730.45	5326.42	<b>2230.21</b>
3086	5761.92	5358.44	<b>2372.16</b>
3088	5802.90	5390.46	<b>2367.66</b>
3090	5838.30	5244.47	<b>2452.07</b>
3091	5870.20	5454.48	<b>2500.98</b>
3093	5897.85	5486.50	<b>2699.34</b>
3095	5931.93	5518.51	<b>2311.00</b>
3096	5964.40	5550.50	<b>2508.41</b>
3098	5998.09	5582.45	<b>2726.04</b>

**Table 5 – Calculated Pore pressure**

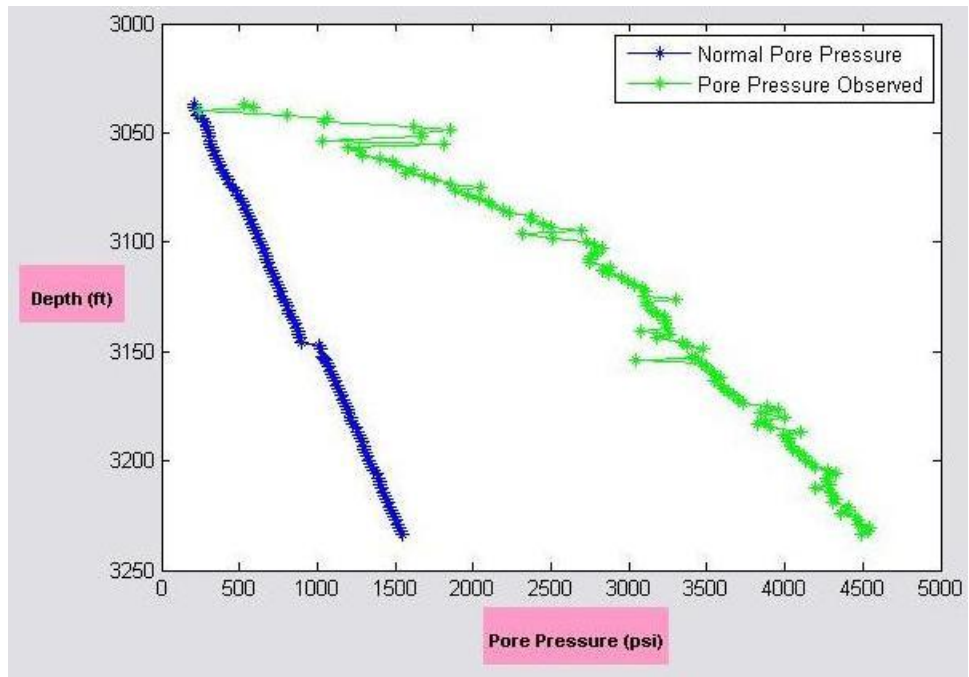


The pore pressure calculated result is then plotted versus depth as shown in Fig. 18 below. To compare it with Fig. 16, the normal pressure gradient also plotted. The normal pressure gradient is given from the data obtained.

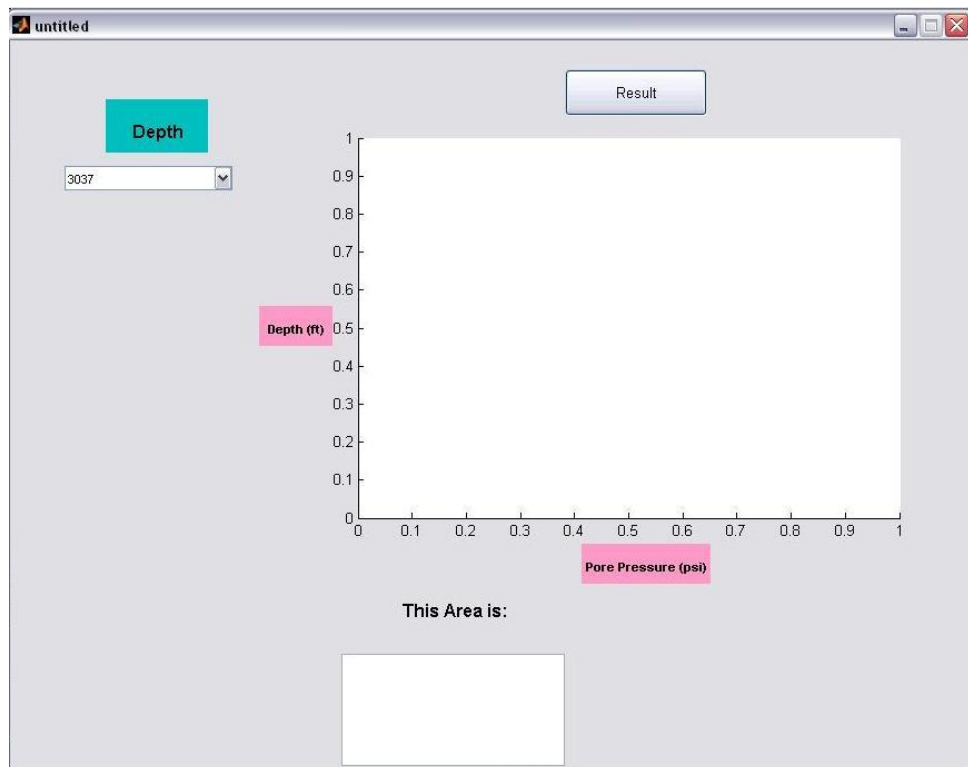


**Fig. 18 – Pore pressure observed and Normal pore pressure vs depth using Microsoft Excel**

This result is then further applied to MATLAB in order to find all other results from different depth. The graph of Normal pressure gradient and Pore pressure calculated vs depth of all different depth is now plotted in MATLAB as shown in Fig. 19. Eventually, Graphical User Interface (GUI) was created to assists drillers in order to predict pore pressure as shown in Fig. 20.

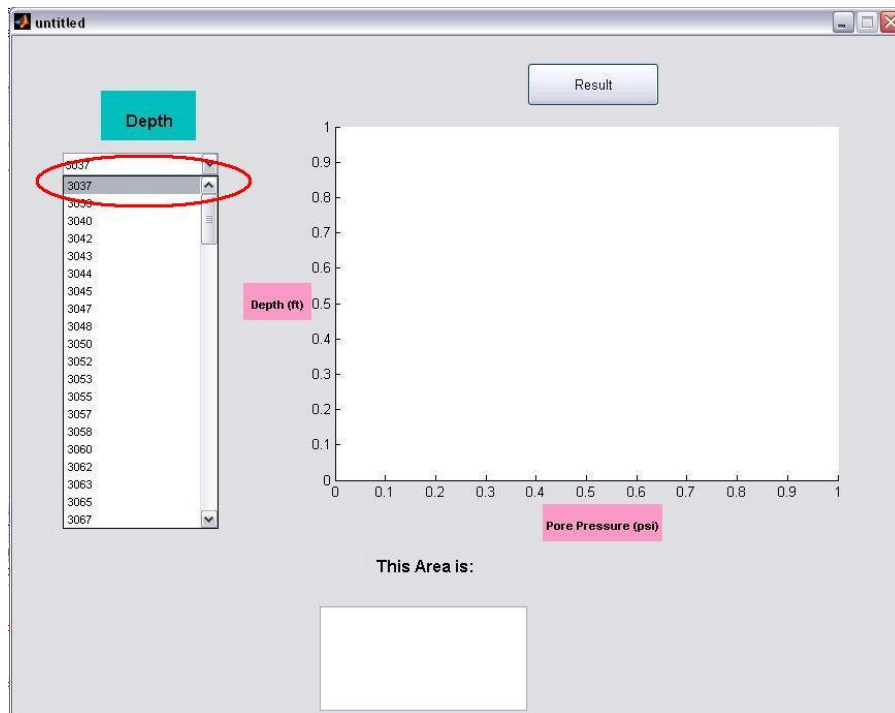


**Fig. 19 – Normal pore pressure and Pore pressure Observed vs depth using MATLAB**

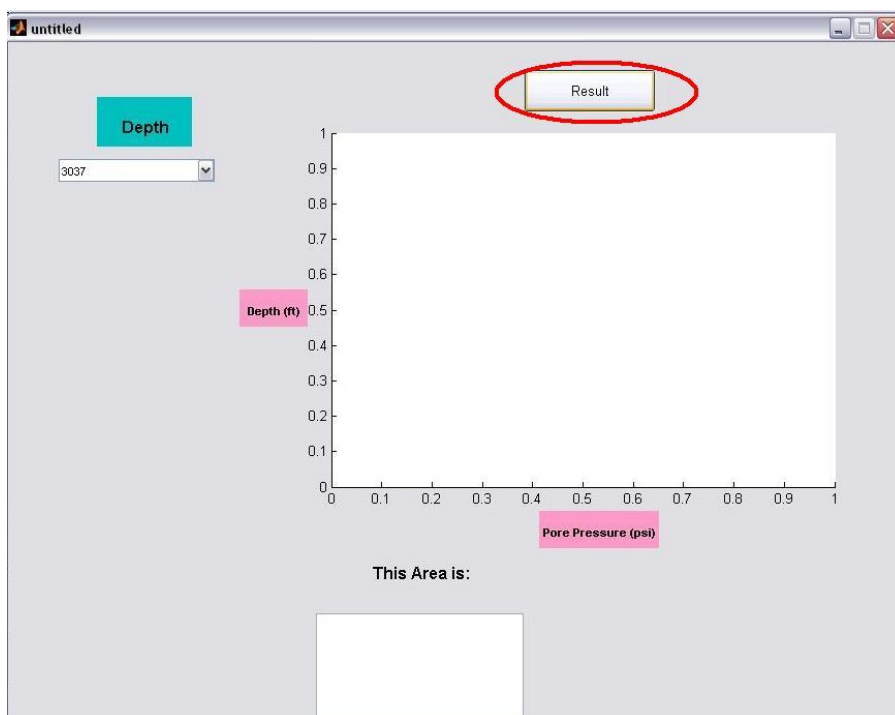


**Fig. 20 – GUI assists drillers to predict Pore pressure**

Using the GUI, drillers can select their desired depth in order to know the pressure at the corresponding depth as shown in Fig. 21. After select their desired depth, click the “Result” button, to display the graph as shown in Fig.22.

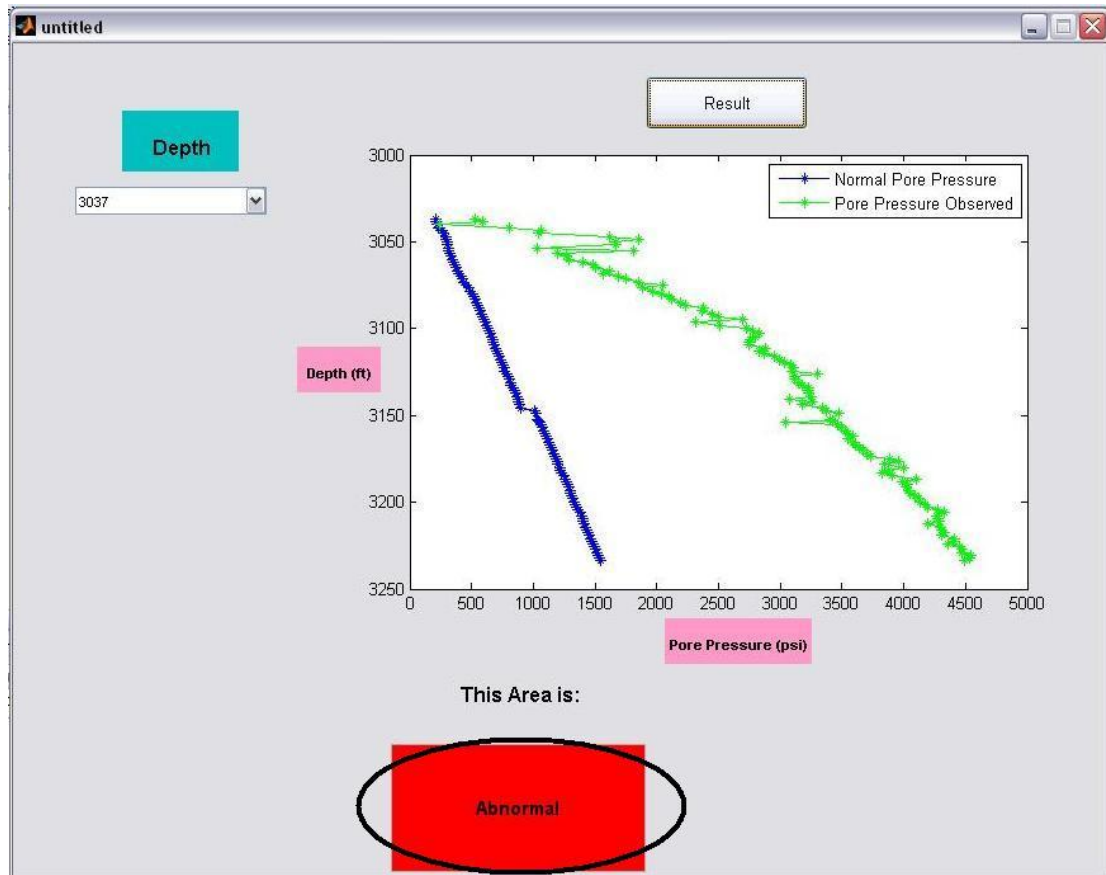


**Fig. 21 – Drillers select their desired depth**



**Fig. 22 – Drillers click “result” to display the graph**

Once the graph has been displayed, the GUI will automatically indicate the corresponding pressure at the depth as shown in Fig. 22.



**Fig. 22 – GUI will show the corresponding pressure of the depth, which is  
Abnormal**

## **4.2 Discussion**

### ***4.2.1 Selection of Eaton exponent***

An Eaton exponent was selected from a few points of different depth as shown in Fig. 24. From the graph lithology if it is a positive value, the area is from shale; if the value is from negative side, it is from sandstone zone. The result from the calculation, the value of Eaton exponent found was 2.656, namely approaching value 3.0. Pore pressures are accurately predicted using an Eaton exponent of 3.0 [18]. The value of 2.656 is the nearest value to the 3.0 that is why 2.656 is chosen as Eaton exponent.

### ***4.2.2 Geological setting of the Baram Delta province***

The stratigraphy of Baram Delta system can be considered to consist of two major layers: prodelta shales overlain by a deltaic sand-shale sequence. However, the three delta systems have built outward from the Crocker-Rajang accretionary complex and are deposited adjacent to the northwest Borneo active margin [5]. This unusual geological setting has resulted in complex present-day geology that is the product of interaction between sedimentary and tectonic deltaic process and underlying basement-associated tectonic process [6]. The northwest Borneo active margin can be considered to have experienced two main tectonic phases: subduction accretion and continental collision. [4]. According to Tan and Lamy, 1990; James 1984; Sandal,1996, subduction and accretion along the northwest Borneo active margin ceased in the middle Miocene following the collision of the leading edge of the South China Sea continental realm with Borneo. The proximity of the northwest Borneo active margin has caused extensive uplift and inversion in the proximal and eastern parts of the Baram Delta province, with the degree of uplift increasing toward the hinterland [6]. Thus, the active margin setting and geographical location of the Baram Delta province have combined to force the rapid progradation of the deltaic systems and cause fast deposition of mostly fine-grained sediments. However, the active margin setting has also caused widespread inversion and resulted in large volumes of fluid migrating through the deltaic systems.

# CHAPTER 5

## CONCLUSION & RECOMMENDATION

### 5.1 Conclusion

The results of this study provide a very helpful tool to the drillers. The ultimate goal of any pore pressure prediction strategy is to develop accurate predrill prediction techniques. Accurate pore-pressure prediction is particularly critical in the Baram Delta province. The Baram Delta province, overpressures are observed in almost every field. However, this project is able to predict the pore pressure using Eaton's Method during drilling. Technically, GUI will be developed to assist drillers in order to predict the pore pressure without wasting time. All the objectives of this project was achieved in the end of FYP 2.

### 5.2 Recommendation

For my data obtained, it can only show the pressure of abnormal zone. Technically, a lot of data from different depth is needed. As for this study, it only obtained a data from a depth range from 3037 m until 3232 m. This range is very small compared to the actual well in the offshore. To get a good result, data should be vary in large range. Comparison can be made if the data is come from different range to show the other types of pressure such as normal and subnormal.

Other than that, GUI can also be improved by adding new features in it. As for this project, it is only a basic tool for driller to know the pressure in certain depth. In the future, the new features can be added for example temperature, porosity, density and many more.

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## APPENDICES

```
function varargout = untitled(varargin)
% UNTITLED M-file for untitled.fig
%     UNTITLED, by itself, creates a new UNTITLED or raises the
existing
%     singleton*.
%
%     H = UNTITLED returns the handle to a new UNTITLED or the
handle to
%     the existing singleton*.
%
%     UNTITLED('CALLBACK',hObject,eventData,handles,...) calls the
local
%     function named CALLBACK in UNTITLED.M with the given input
arguments.
%
%     UNTITLED('Property','Value',...) creates a new UNTITLED or
raises the
%     existing singleton*. Starting from the left, property value
pairs are
%     applied to the GUI before untitled_OpeningFcn gets called.
An
%     unrecognized property name or invalid value makes property
application
%     stop. All inputs are passed to untitled_OpeningFcn via
varargin.
%
%     *See GUI Options on GUIDE's Tools menu. Choose "GUI allows
only one
%     instance to run (singleton)".
%
% See also: GUIDE, GUIDATA, GUIHANDLES

% Edit the above text to modify the response to help untitled

% Last Modified by GUIDE v2.5 03-Aug-2012 16:09:01

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                  'gui_Singleton',  gui_Singleton, ...
                  'gui_OpeningFcn', @untitled_OpeningFcn, ...
                  'gui_OutputFcn',  @untitled_OutputFcn, ...
                  'gui_LayoutFcn',  [], ...
                  'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargin
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT

% --- Executes just before untitled is made visible.
function untitled_OpeningFcn(hObject, eventdata, handles, varargin)
```

```

% This function has no output args, see OutputFcn.
% hObject     handle to figure
% eventdata   reserved - to be defined in a future version of MATLAB
% handles     structure with handles and user data (see GUIDATA)
% varargin    command line arguments to untitled (see VARARGIN)

% Choose default command line output for untitled
handles.output = hObject;

% Update handles structure
guidata(hObject, handles);

% UIWAIT makes untitled wait for user response (see UIRESUME)
% uiwait(handles.figure1);

% --- Outputs from this function are returned to the command line.
function varargout = untitled_OutputFcn(hObject, eventdata, handles)
% varargout    cell array for returning output args (see VARARGOUT);
% hObject     handle to figure
% eventdata   reserved - to be defined in a future version of MATLAB
% handles     structure with handles and user data (see GUIDATA)

% Get default command line output from handles structure
varargout{1} = handles.output;

% --- Executes on selection change in popupmenu1.
function popupmenu1_Callback(hObject, eventdata, handles)
% hObject     handle to popupmenu1 (see GCBO)
% eventdata   reserved - to be defined in a future version of MATLAB
% handles     structure with handles and user data (see GUIDATA)

% Hints: contents = cellstr(get(hObject,'String')) returns
% popupmenu1 contents as cell array
%           contents{get(hObject,'Value')} returns selected item from
% popupmenu1

% --- Executes during object creation, after setting all properties.
function popupmenu1_CreateFcn(hObject, eventdata, handles)
% hObject     handle to popupmenu1 (see GCBO)
% eventdata   reserved - to be defined in a future version of MATLAB
% handles     empty - handles not created until after all CreateFcns
% called

% Hint: popupmenu controls usually have a white background on
% Windows.
%           See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUiControlBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

% --- Executes on button press in pushbutton2.
function pushbutton2_Callback(hObject, eventdata, handles)

%% Input the data values from excel sheet

```

```

data=xlsread('Pore pressure coding.xlsx','Sheet1');
Pressure      = data(:,1);
RHOBC         = data(:,2);
TVD           = data(:,3);
ESO           = data(:,4);
VO            = data(:,5);
VN            = data(:,6);
%% Equation to be Calculated

OB = 145.0377.*Pressure + 0.052.*RHOBC.*TVD;
ES = [ESO./(VO./VN).^2.656].*145.0377;
Pore_pressure = OB - ES;
observed = Pressure.*145.0377;
% Dv=TVD(2,3);

plot(Pore_pressure,TVD,'-r*','Color','red');
grid on;
hold on;
%pause(0.3)
plot(observed,TVD,'-.g','Color','green');
legend('Normal Pore Pressure','Pore Pressure Observed',2);

[r1 c1] = size(Pore_pressure)
Mx = zeros(r1,c1);
for i = 1 : r1
    for j = 1 : c1

        if(observed(i,j) == Pore_pressure(i,j))
            pause(0.3);
            Mx(i,j) = 1;
            pause(0.3);
            set(handles.edit2,'String','');
            set(handles.edit2,'String','Normal');
            set(handles.edit2,'FontSize',11);
            set(handles.edit2,'FontWeight','bold');
            set(handles.edit2,'BackgroundColor','red');

        else if (observed(i,j) > Pore_pressure(i,j))
            Mx(i,j) = 2;
            pause(0.3);

            set(handles.edit2,'String','');
            set(handles.edit2,'String','Abnormal');
            set(handles.edit2,'FontSize',11);
            set(handles.edit2,'FontWeight','bold');
            set(handles.edit2,'BackgroundColor','red');
            v = get(handles.popupmenu1,'Value');
            x = num2str(v);
            %% Select the values from pop-up-menu
switch x
    case '1'
        Dv=TVD(1,1)
        Cv= Pore_pressure(1)
        hold on;
        plot(Cv,Dv,'X','Color','blue');

    case '2'

```

```

plot (Cv,Dv, 'r*')
Dv=TVD(2,1)
Cv= Pore_pressure(2)
hold on;
plot (Cv,Dv, '*', 'Color', 'blue');

case '3'
plot (Cv,Dv, 'r*')
Dv=TVD(3,1)
Cv= Pore_pressure(3)
hold on;
plot (Cv,Dv, '*', 'Color', 'blue');

case '4'
plot (Cv,Dv, 'r*')
Dv=TVD(4,1)
Cv= Pore_pressure(4)
hold on;
plot (Cv,Dv, '*', 'Color', 'blue');

case '5'
plot (Cv,Dv, 'r*')
Dv=TVD(5,1)
Cv= Pore_pressure(5)
hold on;
plot (Cv,Dv, '*', 'Color', 'blue');

case '6'
plot (Cv,Dv, 'r*')
Dv=TVD(6,1)
Cv= Pore_pressure(6)
hold on;
plot (Cv,Dv, '*', 'Color', 'blue');

case '7'
plot (Cv,Dv, 'r*')
Dv=TVD(7,1)
Cv= Pore_pressure(7)
hold on;
plot (Cv,Dv, '*', 'Color', 'blue');

case '8'
plot (Cv,Dv, 'r*')
Dv=TVD(8,1)
Cv= Pore_pressure(8)
hold on;
plot (Cv,Dv, '*', 'Color', 'blue');

case '9'
plot (Cv,Dv, 'r*')
Dv=TVD(9,1)
Cv= Pore_pressure(9)
hold on;
plot (Cv,Dv, '*', 'Color', 'blue');

case '10'
plot (Cv,Dv, 'r*')
Dv=TVD(10,1)
Cv= Pore_pressure(10)
hold on;
plot (Cv,Dv, '*', 'Color', 'blue');

```

```

case '11'
    plot(Cv,Dv,'r*')
    Dv=TVD(11,1)
    Cv= Pore_pressure(11)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');

case '12'
    plot(Cv,Dv,'r*')
    Dv=TVD(12,1)
    Cv= Pore_pressure(12)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');

case '13'
    plot(Cv,Dv,'r*')
    Dv=TVD(13,1)
    Cv= Pore_pressure(13)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');

case '14'
    plot(Cv,Dv,'r*')
    Dv=TVD(14,1)
    Cv= Pore_pressure(14)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');

case '15'
    plot(Cv,Dv,'r*')
    Dv=TVD(15,1)
    Cv= Pore_pressure(15)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');

case '16'
    plot(Cv,Dv,'r*')
    Dv=TVD(16,1)
    Cv= Pore_pressure(16)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');

case '17'
    plot(Cv,Dv,'r*')
    Dv=TVD(17,1)
    Cv= Pore_pressure(17)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');

case '18'
    plot(Cv,Dv,'r*')
    Dv=TVD(18,1)
    Cv= Pore_pressure(18)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');

case '19'
    plot(Cv,Dv,'r*')
    Dv=TVD(19,1)
    Cv= Pore_pressure(19)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');

case '20'
    plot(Cv,Dv,'r*')
    Dv=TVD(20,1)
    Cv= Pore_pressure(20)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');

```

```

case '21'
    plot (Cv,Dv, 'r*')
    Dv=TVD(21,1)
    Cv= Pore_pressure(21)
    hold on;
    plot (Cv,Dv, '*', 'Color', 'blue');
case '22'
    plot (Cv,Dv, 'r*')
    Dv=TVD(22,1)
    Cv= Pore_pressure(22)
    hold on;
    plot (Cv,Dv, 'X', 'Color', 'blue');

case '23'
    plot (Cv,Dv, 'r*')
    Dv=TVD(233,1)
    Cv= Pore_pressure(2)
    hold on;
    plot (Cv,Dv, '*', 'Color', 'blue');
case '24'
    plot (Cv,Dv, 'r*')
    Dv=TVD(24,1)
    Cv= Pore_pressure(24)
    hold on;
    plot (Cv,Dv, '*', 'Color', 'blue');
case '25'
    plot (Cv,Dv, 'r*')
    Dv=TVD(25,1)
    Cv= Pore_pressure(25)
    hold on;
    plot (Cv,Dv, '*', 'Color', 'blue');
case '26'
    plot (Cv,Dv, 'r*')
    Dv=TVD(26,1)
    Cv= Pore_pressure(26)
    hold on;
    plot (Cv,Dv, '*', 'Color', 'blue');
case '27'
    plot (Cv,Dv, 'r*')
    Dv=TVD(27,1)
    Cv= Pore_pressure(27)
    hold on;
    plot (Cv,Dv, '*', 'Color', 'blue');
case '28'
    plot (Cv,Dv, 'r*')
    Dv=TVD(28,1)
    Cv= Pore_pressure(28)
    hold on;
    plot (Cv,Dv, '*', 'Color', 'blue');
case '29'
    plot (Cv,Dv, 'r*')
    Dv=TVD(29,1)
    Cv= Pore_pressure(29)
    hold on;
    plot (Cv,Dv, '*', 'Color', 'blue');
case '30'
    plot (Cv,Dv, 'r*')
    Dv=TVD(30,1)
    Cv= Pore_pressure(30)
    hold on;
    plot (Cv,Dv, '*', 'Color', 'blue');
case '31'

```

```

        plot(Cv,Dv,'r*')
        Dv=TVD(31,1)
        Cv= Pore_pressure(31)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '32'
        plot(Cv,Dv,'r*')
        Dv=TVD(32,1)
        Cv= Pore_pressure(32)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '33'
        plot(Cv,Dv,'r*')
        Dv=TVD(33,1)
        Cv= Pore_pressure(33)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '34'
        plot(Cv,Dv,'r*')
        Dv=TVD(34,1)
        Cv= Pore_pressure(34)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '35'
        plot(Cv,Dv,'r*')
        Dv=TVD(35,1)
        Cv= Pore_pressure(35)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '36'
        plot(Cv,Dv,'r*')
        Dv=TVD(36,1)
        Cv= Pore_pressure(36)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '37'
        plot(Cv,Dv,'r*')
        Dv=TVD(37,1)
        Cv= Pore_pressure(37)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '38'
        plot(Cv,Dv,'r*')
        Dv=TVD(38,1)
        Cv= Pore_pressure(38)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '39'
        plot(Cv,Dv,'r*')
        Dv=TVD(39,1)
        Cv= Pore_pressure(39)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '40'
        plot(Cv,Dv,'r*')
        Dv=TVD(40,1)
        Cv= Pore_pressure(40)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '41'
        plot(Cv,Dv,'r*')
        Dv=TVD(41,1)

```



```

Cv= Pore_pressure(41)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '42'
plot(Cv,Dv,'r*')
Dv=TVD(42,1)
Cv= Pore_pressure(42)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '43'
plot(Cv,Dv,'r*')
Dv=TVD(43,1)
Cv= Pore_pressure(43)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '44'
plot(Cv,Dv,'r*')
Dv=TVD(44,1)
Cv= Pore_pressure(44)
hold on;
plot(Cv,Dv,'X','Color','blue');

case '45'
plot(Cv,Dv,'r*')
Dv=TVD(45,1)
Cv= Pore_pressure(45)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '46'
plot(Cv,Dv,'r*')
Dv=TVD(46,1)
Cv= Pore_pressure(46)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '47'
plot(Cv,Dv,'r*')
Dv=TVD(47,1)
Cv= Pore_pressure(47)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '48'
plot(Cv,Dv,'r*')
Dv=TVD(48,1)
Cv= Pore_pressure(48)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '49'
plot(Cv,Dv,'r*')
Dv=TVD(49,1)
Cv= Pore_pressure(49)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '50'
plot(Cv,Dv,'r*')
Dv=TVD(50,1)
Cv= Pore_pressure(50)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '51'
plot(Cv,Dv,'r*')
Dv=TVD(51,1)
Cv= Pore_pressure(51)

```

```

        hold on;
        plot(Cv,Dv,'*', 'Color','blue');
case '52'
    plot(Cv,Dv,'r*')
    Dv=TVD(52,1)
    Cv= Pore_pressure(52)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '53'
    plot(Cv,Dv,'r*')
    Dv=TVD(53,1)
    Cv= Pore_pressure(53)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '54'
    plot(Cv,Dv,'r*')
    Dv=TVD(54,1)
    Cv= Pore_pressure(54)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '55'
    plot(Cv,Dv,'r*')
    Dv=TVD(55,1)
    Cv= Pore_pressure(55)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '56'
    plot(Cv,Dv,'r*')
    Dv=TVD(56,1)
    Cv= Pore_pressure(56)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '57'
    plot(Cv,Dv,'r*')
    Dv=TVD(57,1)
    Cv= Pore_pressure(57)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '58'
    plot(Cv,Dv,'r*')
    Dv=TVD(58,1)
    Cv= Pore_pressure(58)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '59'
    plot(Cv,Dv,'r*')
    Dv=TVD(59,1)
    Cv= Pore_pressure(59)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '60'
    plot(Cv,Dv,'r*')
    Dv=TVD(60,1)
    Cv= Pore_pressure(60)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '61'
    plot(Cv,Dv,'r*')
    Dv=TVD(61,1)
    Cv= Pore_pressure(61)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');

```

```

case '62'
    plot(Cv,Dv,'r*')
    Dv=TVD(62,1)
    Cv= Pore_pressure(62)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '63'
    plot(Cv,Dv,'r*')
    Dv=TVD(63,1)
    Cv= Pore_pressure(63)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '64'
    plot(Cv,Dv,'r*')
    Dv=TVD(64,1)
    Cv= Pore_pressure(64)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '65'
    plot(Cv,Dv,'r*')
    Dv=TVD(65,1)
    Cv= Pore_pressure(65)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '66'
    plot(Cv,Dv,'r*')
    Dv=TVD(66,1)
    Cv= Pore_pressure(66)
    hold on;
    plot(Cv,Dv,'X', 'Color', 'blue');

case 67'
    plot(Cv,Dv,'r*')
    Dv=TVD(67,1)
    Cv= Pore_pressure(67)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '68'
    plot(Cv,Dv,'r*')
    Dv=TVD(68,1)
    Cv= Pore_pressure(68)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '69'
    plot(Cv,Dv,'r*')
    Dv=TVD(69,1)
    Cv= Pore_pressure(69)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '70'
    plot(Cv,Dv,'r*')
    Dv=TVD(70,1)
    Cv= Pore_pressure(70)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '71'
    plot(Cv,Dv,'r*')
    Dv=TVD(71,1)
    Cv= Pore_pressure(71)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '72'

```

```

        plot(Cv,Dv,'r*')
        Dv=TVD(72,1)
        Cv= Pore_pressure(72)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '73'
        plot(Cv,Dv,'r*')
        Dv=TVD(73,1)
        Cv= Pore_pressure(73)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '74'
        plot(Cv,Dv,'r*')
        Dv=TVD(74,1)
        Cv= Pore_pressure(74)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '75'
        plot(Cv,Dv,'r*')
        Dv=TVD(75,1)
        Cv= Pore_pressure(75)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '76'
        plot(Cv,Dv,'r*')
        Dv=TVD(76,1)
        Cv= Pore_pressure(76)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '77'
        plot(Cv,Dv,'r*')
        Dv=TVD(77,1)
        Cv= Pore_pressure(77)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '78'
        plot(Cv,Dv,'r*')
        Dv=TVD(78,1)
        Cv= Pore_pressure(78)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '79'
        plot(Cv,Dv,'r*')
        Dv=TVD(79,1)
        Cv= Pore_pressure(79)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '80'
        plot(Cv,Dv,'r*')
        Dv=TVD(80,1)
        Cv= Pore_pressure(80)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '81'
        plot(Cv,Dv,'r*')
        Dv=TVD(81,1)
        Cv= Pore_pressure(81)
        hold on;
        plot(Cv,Dv,'*', 'Color', 'blue');
case '82'
        plot(Cv,Dv,'r*')
        Dv=TVD(82,1)

```

```

Cv= Pore_pressure(82)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '83'
plot(Cv,Dv,'r*')
Dv=TVD(83,1)
Cv= Pore_pressure(83)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '84'
plot(Cv,Dv,'r*')
Dv=TVD(84,1)
Cv= Pore_pressure(84)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '85'
plot(Cv,Dv,'r*')
Dv=TVD(85,1)
Cv= Pore_pressure(85)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '86'
plot(Cv,Dv,'r*')
Dv=TVD(86,1)
Cv= Pore_pressure(86)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '87'
plot(Cv,Dv,'r*')
Dv=TVD(87,1)
Cv= Pore_pressure(87)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '88'
plot(Cv,Dv,'r*')
Dv=TVD(88,1)
Cv= Pore_pressure(88)
hold on;
plot(Cv,Dv,'X','Color','blue');

case '89'
plot(Cv,Dv,'r*')
Dv=TVD(89,1)
Cv= Pore_pressure(89)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '90'
plot(Cv,Dv,'r*')
Dv=TVD(90,1)
Cv= Pore_pressure(90)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '91'
plot(Cv,Dv,'r*')
Dv=TVD(91,1)
Cv= Pore_pressure(91)
hold on;
plot(Cv,Dv,'*','Color','blue');
case '92'
plot(Cv,Dv,'r*')
Dv=TVD(92,1)
Cv= Pore_pressure(92)

```

```

        hold on;
        plot(Cv,Dv,'*', 'Color','blue');
case '93'
    plot(Cv,Dv,'r*')
    Dv=TVD(93,1)
    Cv= Pore_pressure(93)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '94'
    plot(Cv,Dv,'r*')
    Dv=TVD(94,1)
    Cv= Pore_pressure(94)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '95'
    plot(Cv,Dv,'r*')
    Dv=TVD(95,1)
    Cv= Pore_pressure(95)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '96'
    plot(Cv,Dv,'r*')
    Dv=TVD(96,1)
    Cv= Pore_pressure(96)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '97'
    plot(Cv,Dv,'r*')
    Dv=TVD(97,1)
    Cv= Pore_pressure(97)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '98'
    plot(Cv,Dv,'r*')
    Dv=TVD(98,1)
    Cv= Pore_pressure(98)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '99'
    plot(Cv,Dv,'r*')
    Dv=TVD(99,1)
    Cv= Pore_pressure(99)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '100'
    plot(Cv,Dv,'r*')
    Dv=TVD(100,1)
    Cv= Pore_pressure(100)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '101'
    plot(Cv,Dv,'r*')
    Dv=TVD(101,1)
    Cv= Pore_pressure(101)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');
case '102'
    plot(Cv,Dv,'r*')
    Dv=TVD(102,1)
    Cv= Pore_pressure(102)
    hold on;
    plot(Cv,Dv,'*', 'Color','blue');

```

```

case '103'
    plot(Cv,Dv,'r*')
    Dv=TVD(103,1)
    Cv= Pore_pressure(103)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '104'
    plot(Cv,Dv,'r*')
    Dv=TVD(104,1)
    Cv= Pore_pressure(104)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '105'
    plot(Cv,Dv,'r*')
    Dv=TVD(105,1)
    Cv= Pore_pressure(105)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '106'
    plot(Cv,Dv,'r*')
    Dv=TVD(106,1)
    Cv= Pore_pressure(106)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '107'
    plot(Cv,Dv,'r*')
    Dv=TVD(107,1)
    Cv= Pore_pressure(107)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '108'
    plot(Cv,Dv,'r*')
    Dv=TVD(108,1)
    Cv= Pore_pressure(108)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '109'
    plot(Cv,Dv,'r*')
    Dv=TVD(109,1)
    Cv= Pore_pressure(109)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '110'
    plot(Cv,Dv,'r*')
    Dv=TVD(110,1)
    Cv= Pore_pressure(110)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '111'
    plot(Cv,Dv,'r*')
    Dv=TVD(111,1)
    Cv= Pore_pressure(111)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '112'
    plot(Cv,Dv,'r*')
    Dv=TVD(112,1)
    Cv= Pore_pressure(112)
    hold on;
    plot(Cv,Dv,'*', 'Color', 'blue');
case '113'
    plot(Cv,Dv,'r*')

```

```

        Dv=TVD(113,1)
        Cv= Pore_pressure(113)
        hold on;
        plot(Cv,Dv,'*','Color','blue');
    case '114'
        plot(Cv,Dv,'r*')
        Dv=TVD(114,1)
        Cv= Pore_pressure(114)
        hold on;
        plot(Cv,Dv,'*','Color','blue');
    case '115'
        plot(Cv,Dv,'r*')
        Dv=TVD(115,1)
        Cv= Pore_pressure(115)
        hold on;
        plot(Cv,Dv,'*','Color','blue');
    case '116'
        plot(Cv,Dv,'r*')
        Dv=TVD(116,1)
        Cv= Pore_pressure(116)
        hold on;
        plot(Cv,Dv,'*','Color','blue');
    case '117'
        plot(Cv,Dv,'r*')
        Dv=TVD(117,1)
        Cv= Pore_pressure(117)
        hold on;
        plot(Cv,Dv,'*','Color','blue');
    case '118'
        plot(Cv,Dv,'r*')
        Dv=TVD(118,1)
        Cv= Pore_pressure(118)
        hold on;
        plot(Cv,Dv,'*','Color','blue');
    case '119'
        plot(Cv,Dv,'r*')
        Dv=TVD(119,1)
        Cv= Pore_pressure(119)
        hold on;
        plot(Cv,Dv,'*','Color','blue');
    case '120'
        plot(Cv,Dv,'r*')
        Dv=TVD(120,1)
        Cv= Pore_pressure(120)
        hold on;
        plot(Cv,Dv,'*','Color','blue');

    end

else
    Mx(i,j) = 3;
    pause(0.3);
    set(handles.edit2,'String',' ');
    set(handles.edit2,'String','Sub-normal');
    set(handles.edit2,'FontSize',11);
    set(handles.edit2,'FontWeight','bold');
    set(handles.edit2,'BackgroundColor','red');
end
end
end
end
end

```



```

function edit2_Callback(hObject, eventdata, handles)
% hObject      handle to edit2 (see GCBO)
% eventdata    reserved - to be defined in a future version of MATLAB
% handles      structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit2 as text
%         str2double(get(hObject,'String')) returns contents of edit2
%         as a double

% --- Executes during object creation, after setting all properties.
function edit2_CreateFcn(hObject, eventdata, handles)
% hObject      handle to edit2 (see GCBO)
% eventdata    reserved - to be defined in a future version of MATLAB
% handles      empty - handles not created until after all CreateFcns
%              called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

```

**APPENDIX A**  
**YOUR APPENDIX HEADING**