Acoustic Impedance and Porosity Relationship to Identify Reservoir Rock in Wichian Buri Sub-Basin, Phetchabun Province

Nanthana Yodlee *, AkkhapunWannakomol

Running head: *Acoustic Impedance and porosity relationship to identify reservoir rock in Wichian Buri Sub-basin, Phetchabun Province*

Abstract : *The objective of this research is to identify reservoir rocks of Wichian Buri Sub-basin by using acoustic impedance and porosity relationship. The study area is mainly confined to Wichian Buri Sub-basin, Wichian Buri district, Phetchabun province, Thailand. The main research activities are : (1) the acoustic impedance data of compressional sonic logs from selected wells computing, and (2) qualitative data analysis by cross-plotting among acoustic impedance, porosity and depth for recognition of lithological units to identify reservoir rock.*

The result of qualitative analysis showed that relationship between acoustic impedance and depth, relationship between porosity and depth, relationship between acoustic impedance of short spacing delta-time and depth and lithological description can be explained petroleum system of Wichian buri sub-basin as Unit Three tends to be source and reservoir rock whilst Unit Four tends to be source rock.

Keywords: ACOUSTIC IMPEDANCE CONTRAST / POROSITY / RESERVOIR IDENTIFICATION / WICHIAN BURI SUB-BASIN / PHETCHABUN PROVINCE

I. Introduction

One of the main problems occurred during a petroleum field exploration is the reservoir rock identification. The relationship between acoustic impedance and porosity is one of a useful tool for solving this problem. In order to understand the origin of the formation of the Wichian Buri sub-basin, therefore, the discussion in this chapter focuses upon the physiography, geological setting, structure and geological history of not only the Wichian Buri sub-basin, but also covering the Phetchabun Basin and neighboring area.

This study concentrated on data analysis only within 3 formations, namely; Unit Three, Unit Four and Nam Duk Formation in Wichian Buri sub-basin, Petchabun Province. One well drilled in Wichian buri Sub-basin is allowed from Department of Mineral Fuels (DMF) Thailand to use in this study but is not allowed to show its name, so this allowed well is named A-1 in this study. A-1 drilled in 1990-1991

II. Materials and Methods

Materials

In order to study acoustic impedance and rock properties, many sources of data were used and analyzed. Some of required and used data and listed as follows. **Well information**

One well drilled in Wichian buri Sub-basin is allowed from Department of Mineral Fuels (DMF) Thailand to use in this study but is not allowed to show its name, so this allowed well is named A-1 in this study. A-1 drilled in 1990-1991.

Lithological classification

Four rock types found in A-1 well drilled in the study area were classified for this study: metaclaystone, claystone, greywacke and sandstone based on lithologic log report. Sandstone is classified as reservoir rock and the others are non-reservoir rock.

Logging data

There are four log types; gamma ray, neutron, density, and sonic used in the quantitative and qualitative studies.

Gamma ray data

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The gamma ray log is a record of a formation's radioactivity emanating from naturally occurring uranium, thorium and potassium. Amongst the sedimentary rocks, shales present the strongest radiation. Therefore, the gamma ray logging data can be used to identify shale and correlate facies.

Neutron data

The neutron log provides a reaction of formation's neutron bombardment. This log is a measure of free pore-water which is related to a formation's hydrogen index. It is also used quantitatively to measure porosity and qualitative to discriminate between gas and oil. The neutron log usually combined with the density log to present the subsurface lithology indicators.

Density data

The density log is a record of a formation's bulk density. The bulk density can be used as an indicator of the volume of free fluid enclosed in the formation. This log is used to calculate porosity and acoustic impedance, and hydrocarbon density quantitatively. It is also used as a lithology indicator.

Sonic data

The sonic log shows a formation's interval transit time. The main use of the log is in seismic applications, calibration and generation of synthetics seismic data. It is also an essential parameter in the time to depth conversion of seismic data. When a transmitter of the sonic tool sends out a sound pulse, the log measures the arrival time of the pulse. The compressional (P) wave arrives ahead of the shear (S) wave and is consequently recorded first. The compressional wave travels in the same direction of motion. It propagates through the body of a medium. The particle motion of shear wave is perpendicular to the direction of propagation. The velocity of this wave is approximately one-half the velocity the compressional wave.

A-1 well was logged by Schlumberger and for Wireline Schlumberger Tools which run in A-1 well:

DT is short spacing delta-time (10'-8' spacing; microsec/ft)
DTLN is short spacing delta-time (10'-8' spacing; microsec/ft)
DTLF is long spacing delta-time (12'-10' spacing; microsec/ft)

Porosity data

Porosity data is typically derived from the density log which measures the bulk density of the formation. The porosity can be defined as the percentage of voids to the total volume of rock.

It is notable that a formation with high porosity indicates a good potential of reservoir quality.

Acoustic impedance data

The acoustic impedance is seismic velocity multiplied by density (Sheriff, 1997). The density data are obtained from the density log whilst the velocity data can be derived from the sonic log. The acoustic impedance data can imply rock properties which vary with lithology, porosity, fluid content and depth.

III. Methods

In this study, the process of data analysis has been divided into two parts; quantitative and qualitative. The quantitative analysis is defined as an analysis of lithological properties with statistic expression. For qualitative analysis, it is expressed as reservoir rock potentiality without any measurements. In quantitative analysis, all logging data had been cross-plotted so that the acoustic impedance response to lithology variations can be studied. Qualitative analysis in this study aims to apply acoustic impedance data to recognize reservoir rock potential. Both quantitative and qualitative were used for stratigraphic unit and lithologic classification.

IV. Quantitative analysis

The data that used in quantitative study were acoustic impedance and porosity. This data were cross-plotted on a graph, on which the x-coordinate represents the value of one data type and the y-coordinate the value of the others. This cross-plot can be used to understand how two data types are related. It is also useful for observing an aberrant data. The correlation coefficient, R, is the statistic symbol that is most commonly used to express the relationship between two data types. The correlation coefficient provides a measure of the linear relationship between two data types.

V. Qualitative analysis

In this study, acoustic impedance of short spacing delta-time (DT, DTLN) and long spacing delta-time (DTLF) data had been mainly used to determine the reservoir rock identification in Wichian Buri Sub-basin, Phetchabun province. These acoustic impedance data were cross-plot with depth and porosity to observe the relationship amongst them. Therefore, these observed relationships were then used in lithologic and stratigraphic identification as well.

VI. Results and Discussions

Results from cross-plot among acoustic impedance, porosity, and depth of A-1 well data can be summarized as follows.

Quantitative analysis

Relationship between acoustic impedance and porosity

The relationship between acoustic impedance and porosity had been plotted on the x and y-axes respectively (Figures 1 - 10 for lithologic identification and Figures 11 – 18 for stratigraphic unit identification). Results from Cross-plots showed that acoustic impedance and porosity had a linear relationship with its corresponding linear equation as showed in each Figure for all rock types. The coefficients also showed a higher value in the dataset of the reservoir rocks than that in the non-reservoir rocks. Consequently, they were selected for further analyses.

Table 1 and table 2 summarized the correlation coefficient obtained from cross-plotting between acoustic impedance and porosity to lithologic and stratigraphic identification in A-1 well respectively.

Relationship between acoustic impedance of short spacing delta-time (DT, DTLN) and long spacing delta-time (DTLF)

The dataset of acoustic impedance of short spacing delta-time (DT, DTLN) and long spacing delta-time (DTLF) were cross-plotted and x- and y-axes were represented to acoustic impedance of short spacing delta-time (DT, DTLN) and long spacing delta-time (DTLF) respectively (Figures 19 - 24 for lithologic identification and Figures 25 – 29 for stratigraphic unit identification). The cross-plots indicated that the correlation coefficients were generally greater than 0.5 and there was a linear relationship between acoustic impedance of short spacing delta-time (DT, DTLN) and long spacing delta-time (DTLF) with its corresponding linear equation as showed in each Figure.

Table 3 and table 4 summarized the correlation coefficient obtained from cross-plotting between acoustic impedance of short spacing delta-time and long spacing delta-time to lithologic and stratigraphic identification in A-1 well respectively. As noticeable from cross-plotting, sandstone and claystone have higher correlation coefficient values than greywacke and metaclaystone in lithologic identification. For stratigraphic unit identification it was found that unit three and unit four had higher correlation coefficient values than Nam Duk Formation.

Qualitative analysis

Relationship between acoustic impedance and depth

The data were cross-plotted on the graph, on which the x-axis represented the value of the acoustic impedance of short spacing delta-time (DT, DTLN) and long spacing delta-time (DTLF) and the y-axis represented the depth respectively (Figures 30 - 32 for lithologic identification and Figures 33 - 35 for stratigraphic unit identification).

Relationship between porosity and depth

In this plot the x-axis represented the value of porosity data and the y-axis represented the depth respectively (Figure 36 for lithologic identification and Figure 37 for stratigraphic unit identification).

Furthermore, there was a plot between acoustic impedance (DTLF) and depth comparing to lithological description as showed in Figure 38 to support two above plotting results. As a result among sonic velocity log tools Acoustic Impedance of short spacing delta-time (12'-10' spacing; microsec/ft) DTLF was the best tool used for lithologic and stratigraphic identification purpose because the others that plot with the same method tended in the same way and could not use for this purposes. Figure 4.10 can also depict the petroleum system as Unit Three (From 290 m to 490 m) could be source and reservoir rock, Intrusive Unit (From 490 m to 530 m) is heat source, Unit Four (From 530 m to 700 m) is source and Namduk Formation (From 700 to 910 m).

The acoustic impedance data reflects the reservoir rock possibility as it can show higher value range than the others. As a result, acoustic impedance can be used as a tool to depict petroleum system as Unit Three (From 290 m to 490 m) is source and reservoir, Intrusive Unit (From 490 m to 530 m) is heat source, Unit Four (From 530 m to 700 m) is source, and Namduk Formation (From 700 m to 910 m).

VII. Conclusions and Recommendations

Acoustic impedance and porosity data can be used for evaluating reservoir rocks.

Linear relationships between acoustic impedance from logging data and porosity can be observed in the Wichian Buri Group and Nam Duk Formation with their corresponding linear equations.

The result of cross-plot between acoustic impedance of short spacing delta-time (10'-8' spacing; microsec/ft) (DT, DTLN) and long spacing delta-time (DTLF) (12'-10' spacing; microsec/ft) suggests relationship trend lines between short spacing delta-time and long spacing delta-time are in the same way.

The recommendations for further study in this area are addressed below;

This research had been studied under limited logging and other essential data, thus it might have some errors. Therefore, if acoustic impedance, porosity, and/or lithologic logs are more available, relationship among acoustic impedance, porosity, depth, and lithology of this study area should be restudied.

Other kinds of cross-plot among acoustic impedance, porosity, permeability, depth, lithology data should be conducted and tested to verify results of the study and may give other new approaches to identify source rock more easily.

VIII. Acknowledgement

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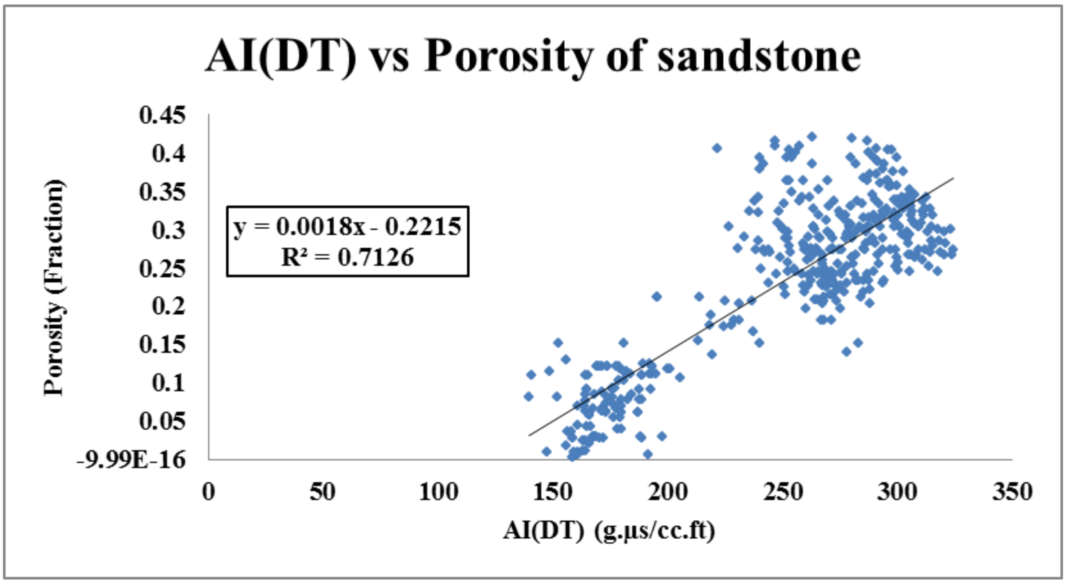


Figure 1 A cross-plot showing a relationship between acoustic impedance (AI (DT)) and porosity of sandstone in well A-1

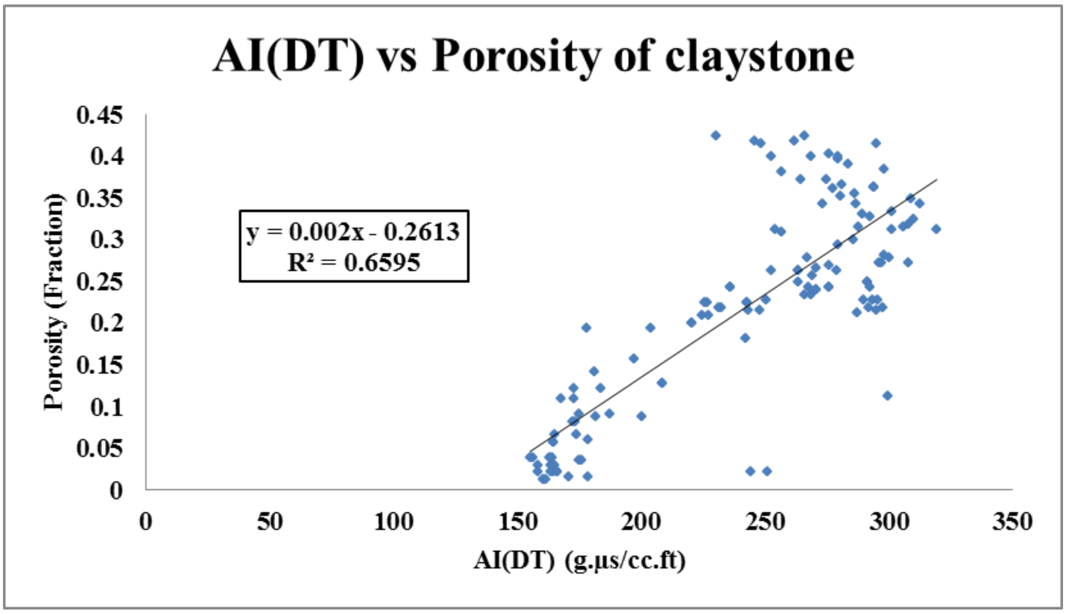


Figure 2 A cross-plot showing a relationship between acoustic impedance (AI (DT)) and porosity of claystone in well A-1

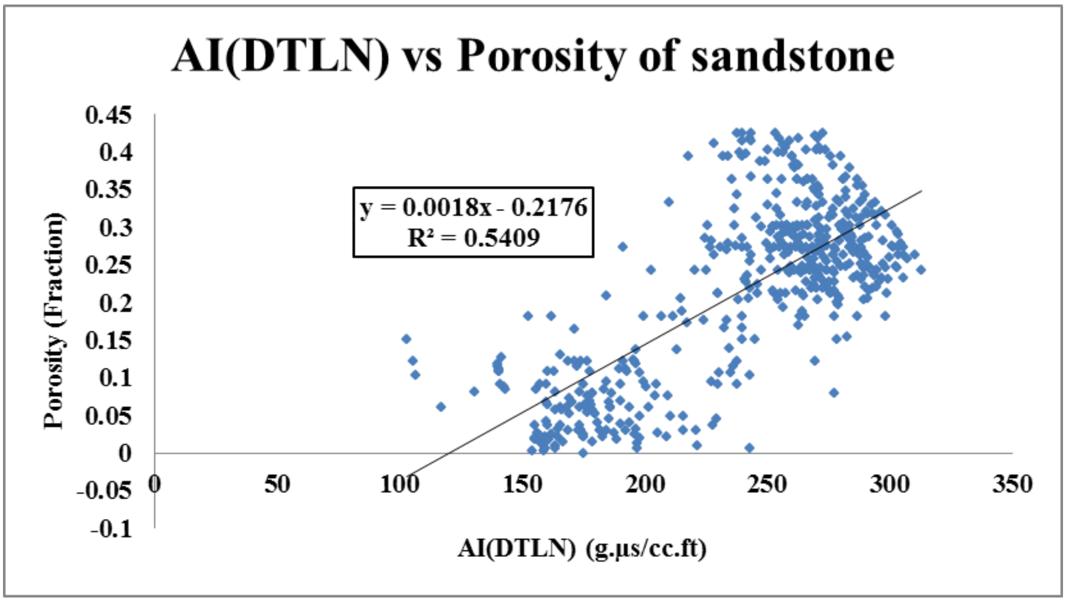


Figure 3 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and porosity of sandstone in well A-1

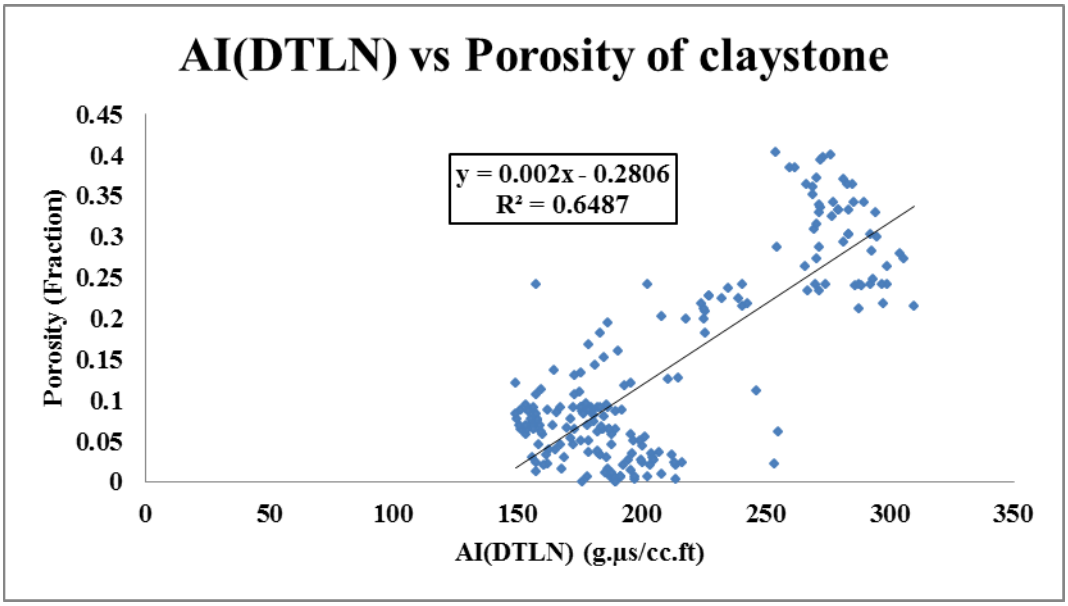


Figure 4 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and porosity of claystone in well A-1

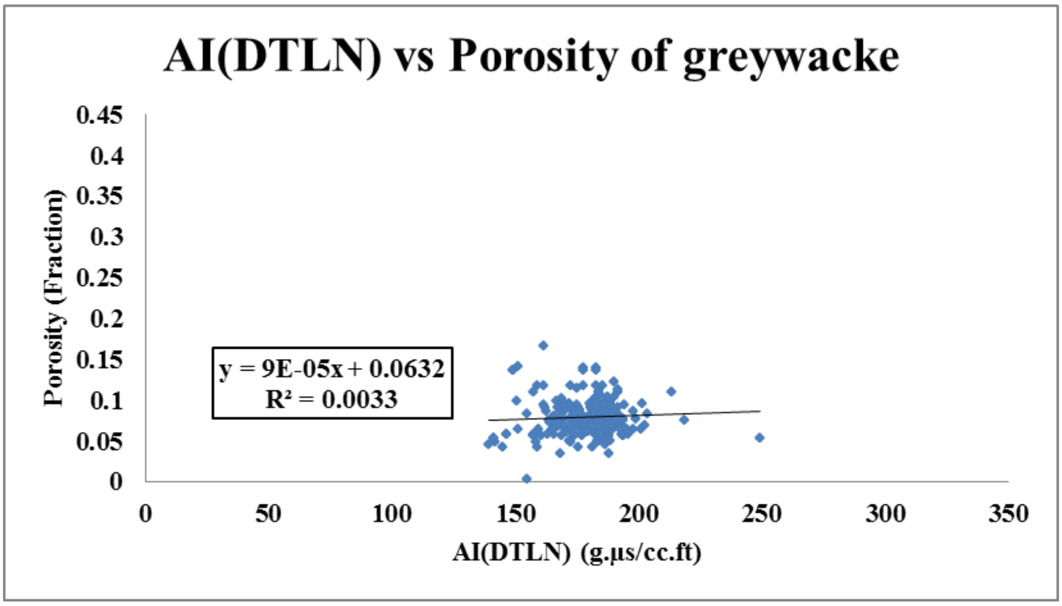


Figure 5 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and porosity of greywacke in well A-1

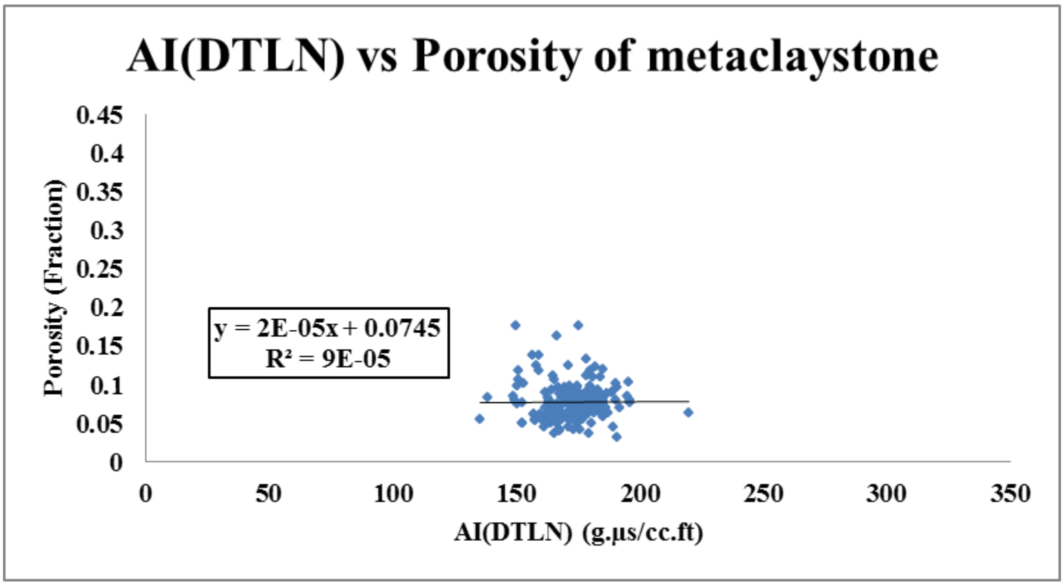


Figure 6 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and porosity of metaclaystone in well A-1

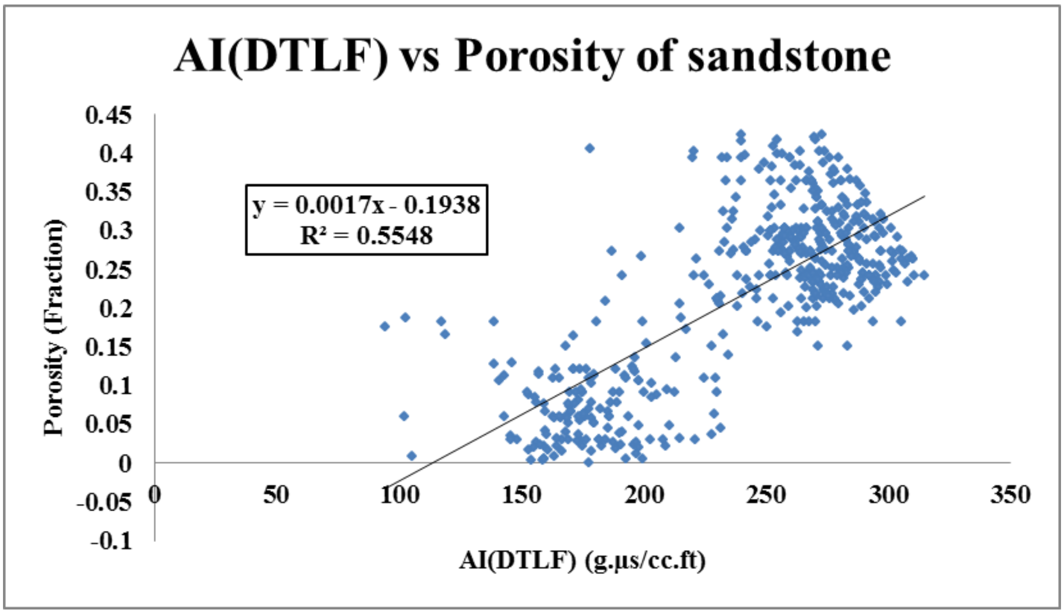


Figure 7 A cross-plot showing a relationship between acoustic impedance (AI (DTLF)) and porosity of sandstone in well A-1

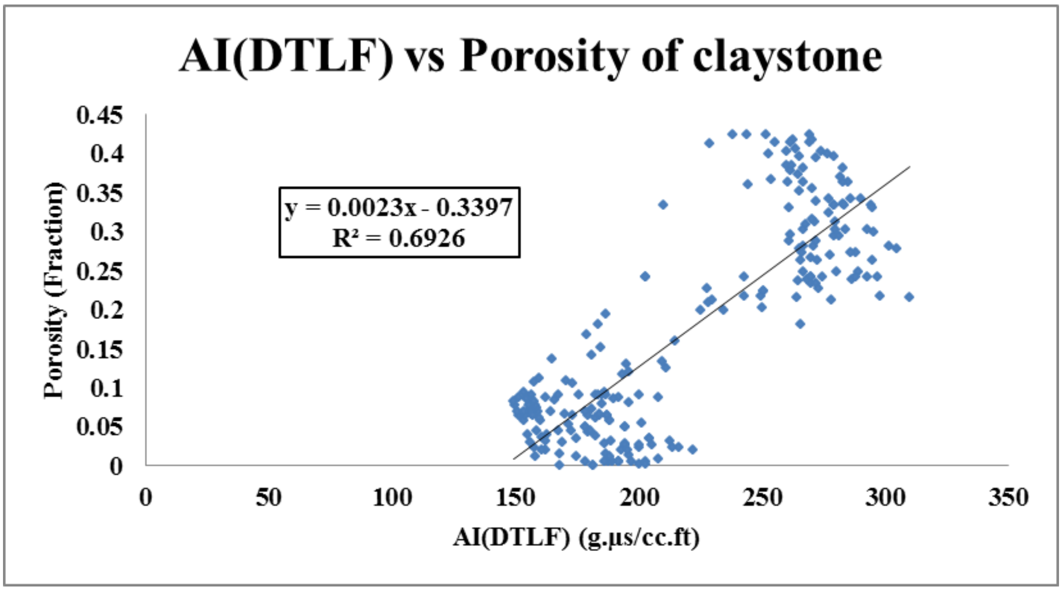


Figure 8 A cross-plot showing a relationship between acoustic impedance (AI (DTLF)) and porosity of claystone in well A-1

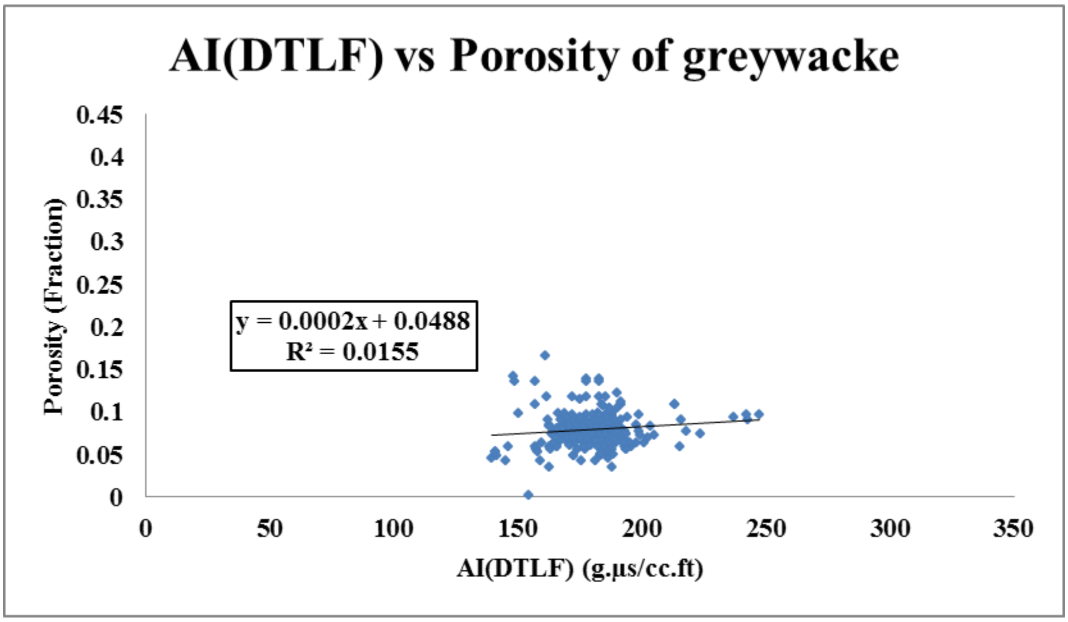


Figure 9 A cross-plot showing a relationship between acoustic impedance (AI (DTLF)) and porosity of greywacke in well A-1

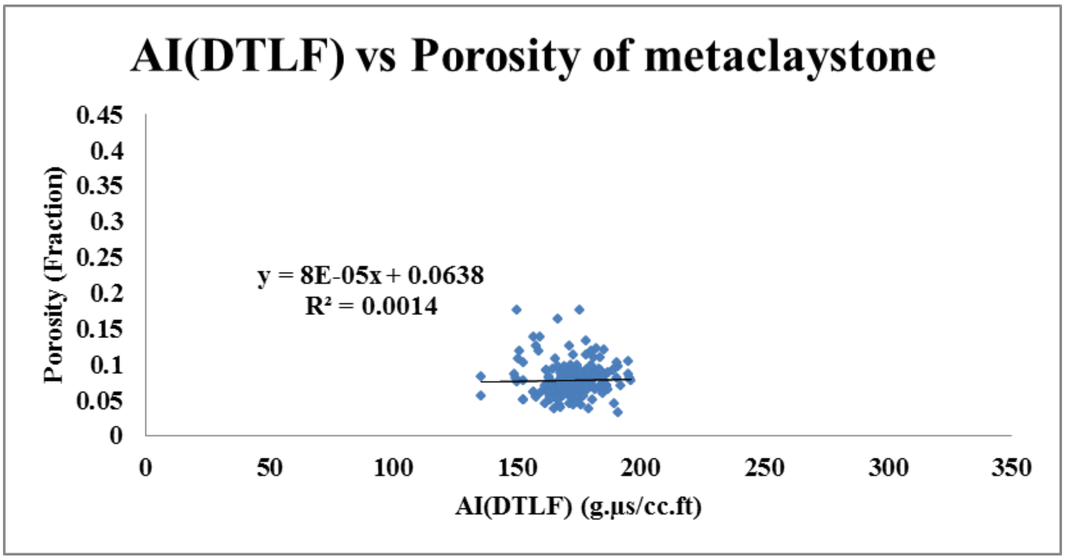


Figure 10 A cross-plot showing a relationship between acoustic impedance (AI (DTLF)) and porosity of metaclaystone in well A-1

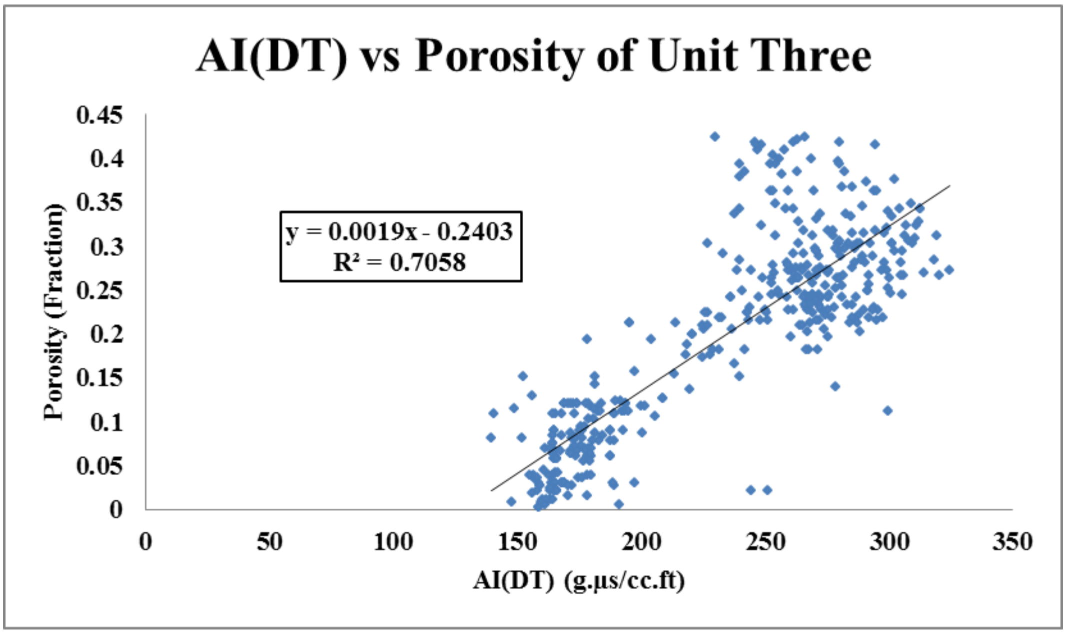


Figure 11 A cross-plot showing a relationship between acoustic impedance (AI (DT)) and porosity of unit three in well A-1

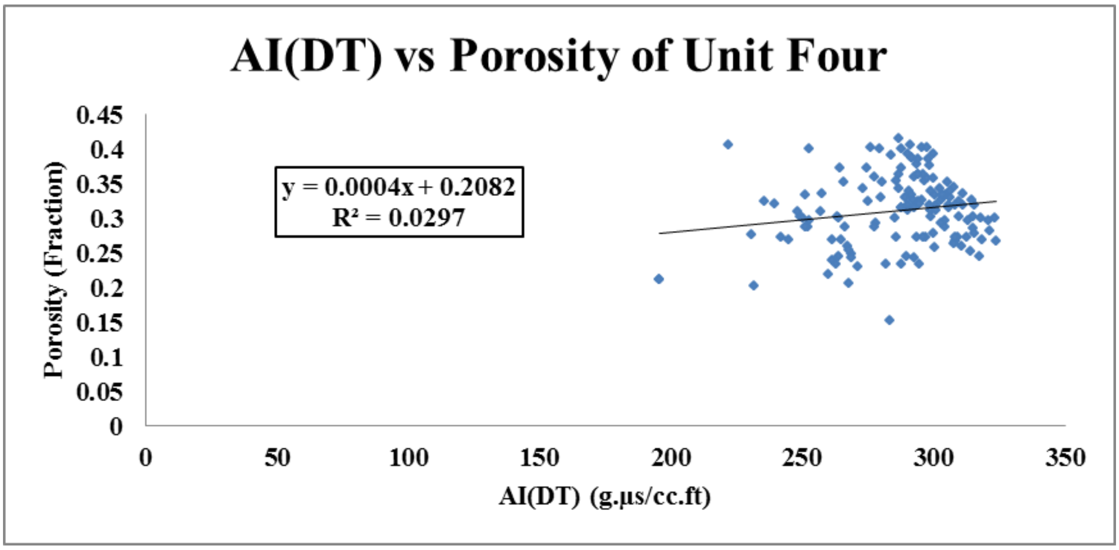


Figure 12 A cross-plot showing a relationship between acoustic impedance (AI (DT)) and porosity of unit four in well A-1

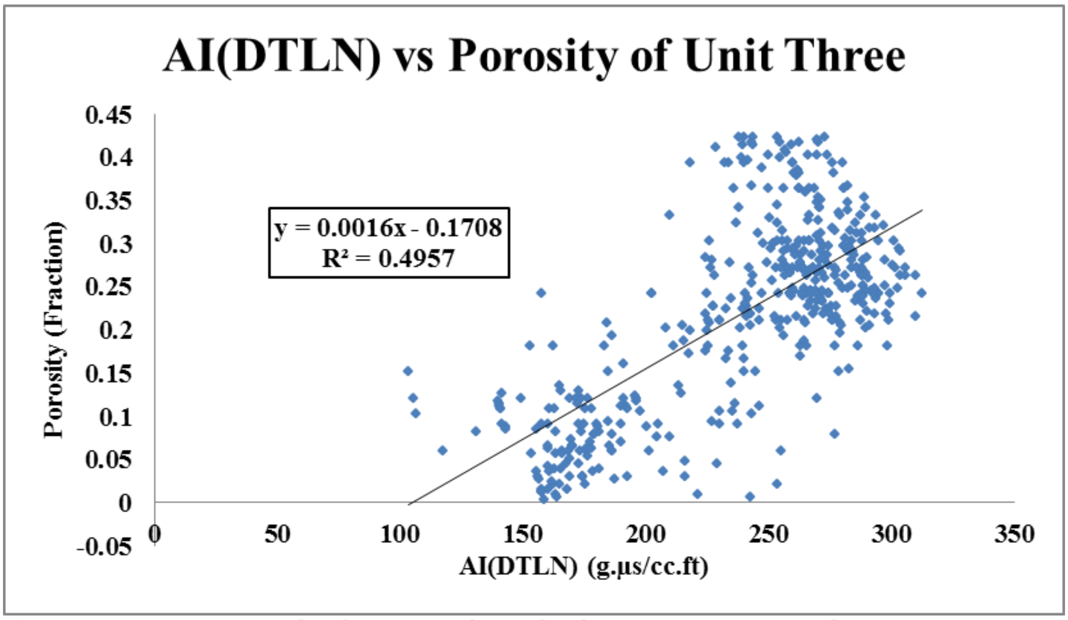


Figure 13 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and porosity of unit three in well A-1

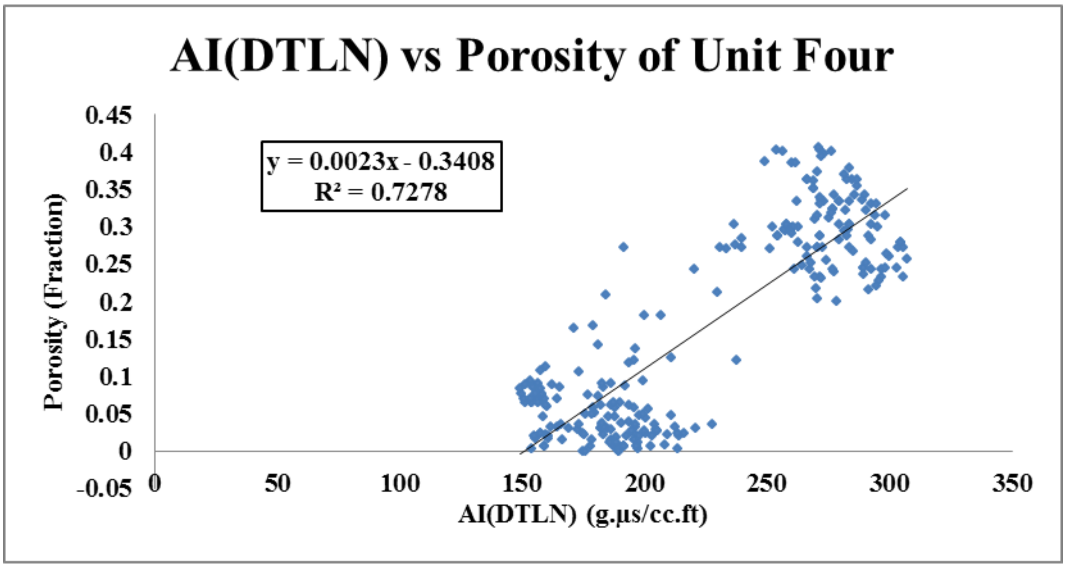


Figure 14 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and porosity of unit four in well A-1

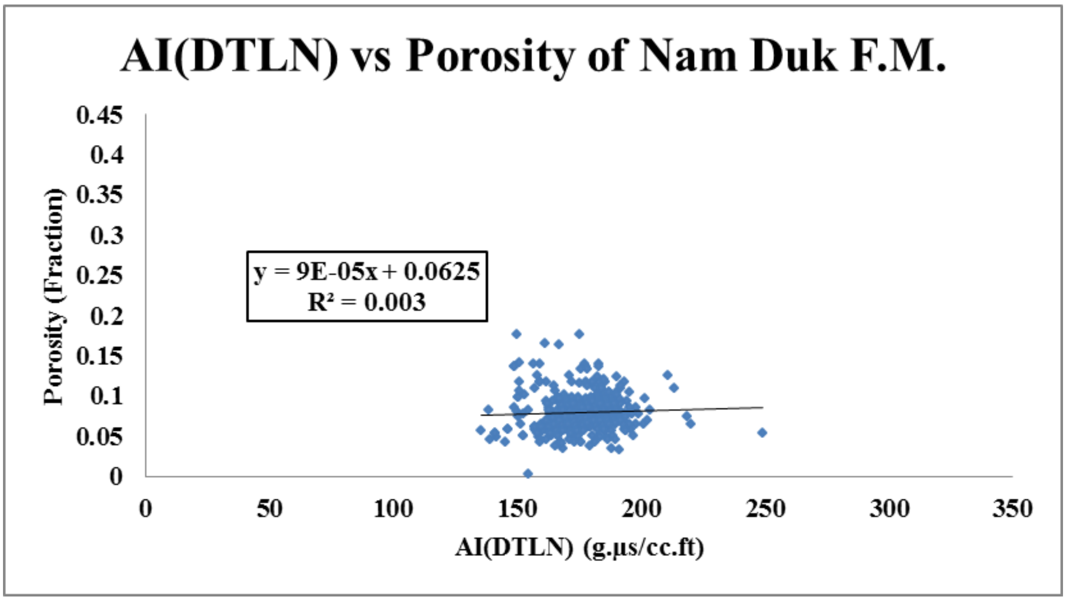


Figure 15 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and porosity of Nam Duk Formation in well A-1

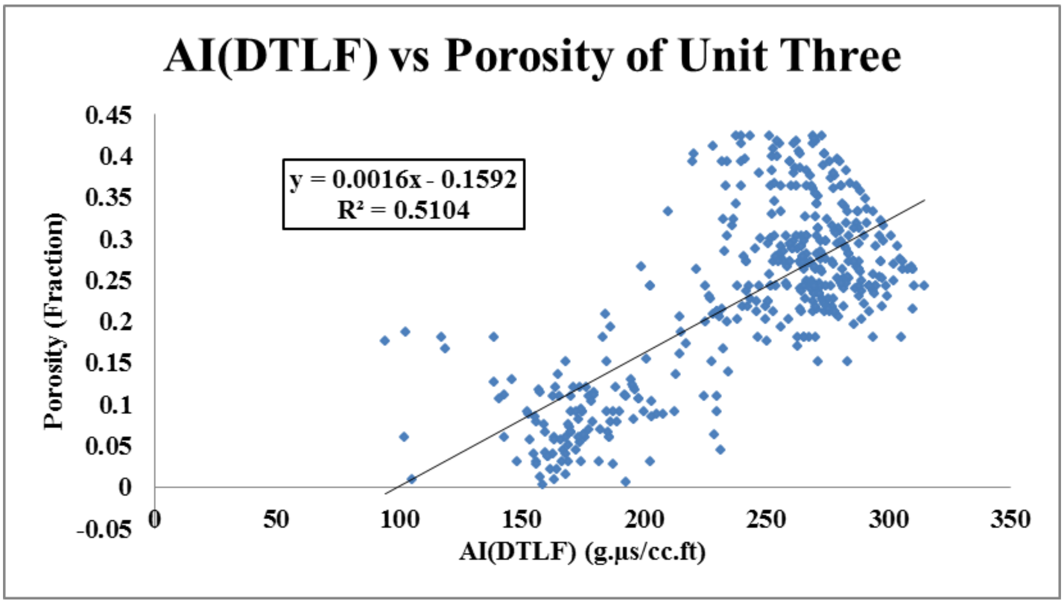


Figure 16 A cross-plot showing a relationship between acoustic impedance (AI (DTLF)) and porosity of unit three in well A-1

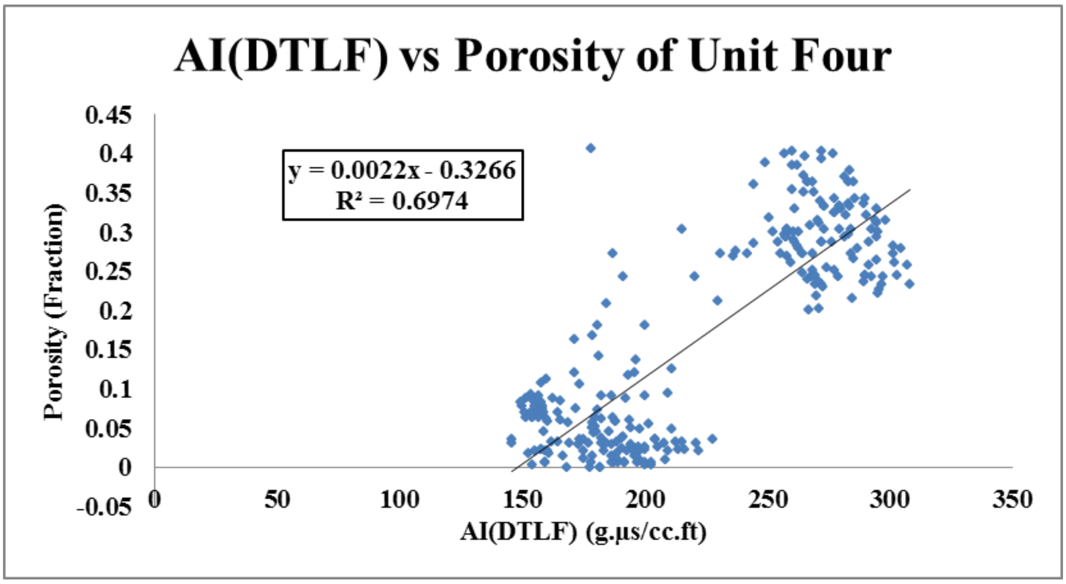


Figure 17 A cross-plot showing a relationship between acoustic impedance (AI (DTLF)) and porosity of unit four in well A-1

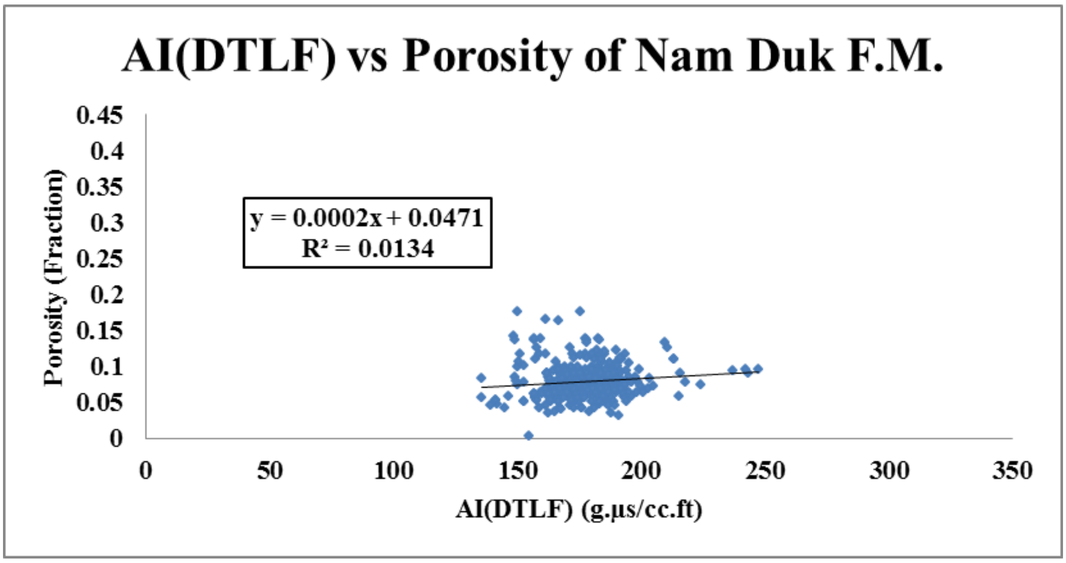


Figure 18 A cross-plot showing a relationship between acoustic impedance (AI (DTLF)) and porosity of Nam Duk Formation in well A-1

Table 1 Summary of correlation coefficients obtained from the linear relationship between acoustic impedance and porosity in lithologic identification

Sonic Log Type	Non-reservoir						Reservoir	
	Claystone		Metaclaystone		Greywacke		Sandstone	
	Number of data	Correlation Coeff.	Number of data	Correlation Coeff.	Number of data	Correlation Coeff.	Number of data	Correlation Coeff.
DT	258	0.659	-	-	-	-	864	0.712
DTLN	416	0.648	392	0.00009	486	0.003	1086	0.54
DTLF	462	0.692	382	0.001	490	0.015	1034	0.554

Table 2 Summary of correlation coefficients obtained from the linear relationship between acoustic impedance and porosity in stratigraphic unit identification

Sonic Log Type	Unit Three		Unit Four		Nam Duk F.M.	
	Number of data	Correlation Coeff.	Number of data	Correlation Coeff.	Number of data	Correlation Coeff.
DT	838	0.705	284	0.029	-	-
DTLN	942	0.495	522	0.727	924	0.003
DTLF	936	0.51	536	0.697	904	0.013

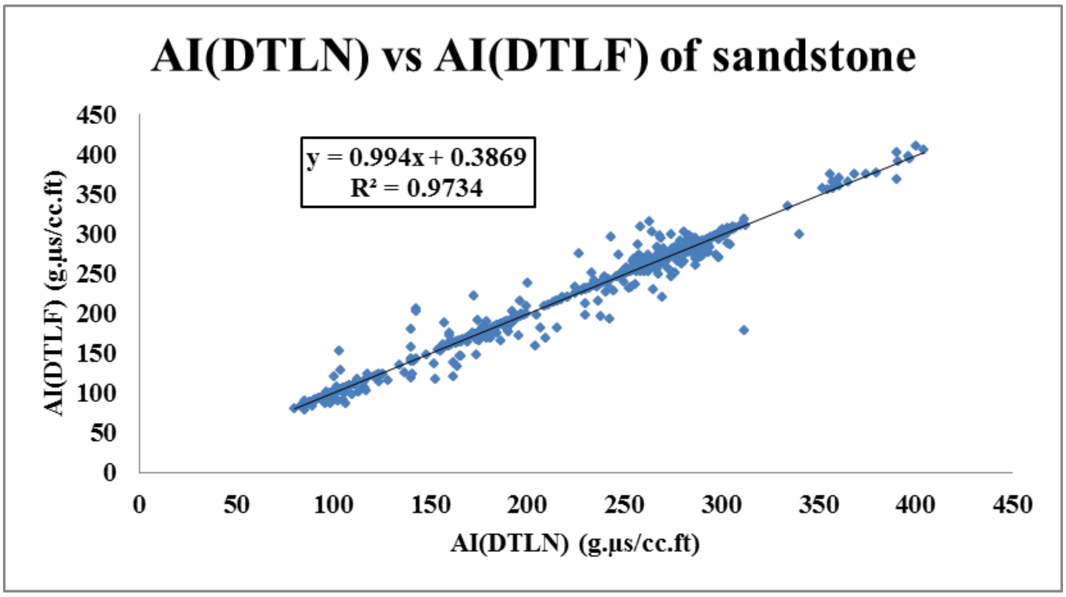


Figure 19 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and AI (DTLF) of sandstone in well A-1

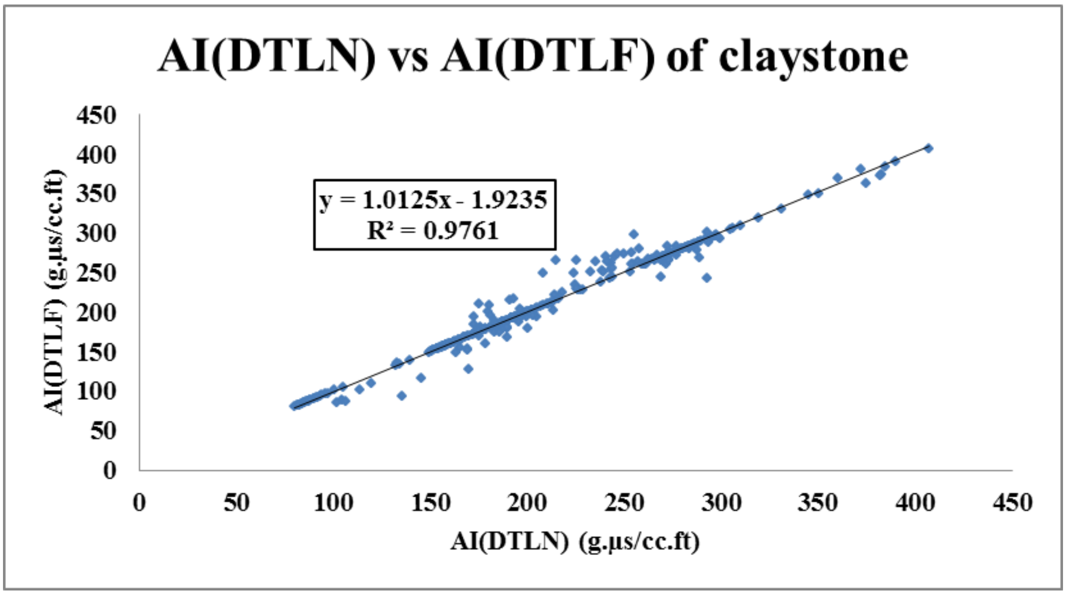


Figure 20 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and AI (DTLF) of claystone in well A-1

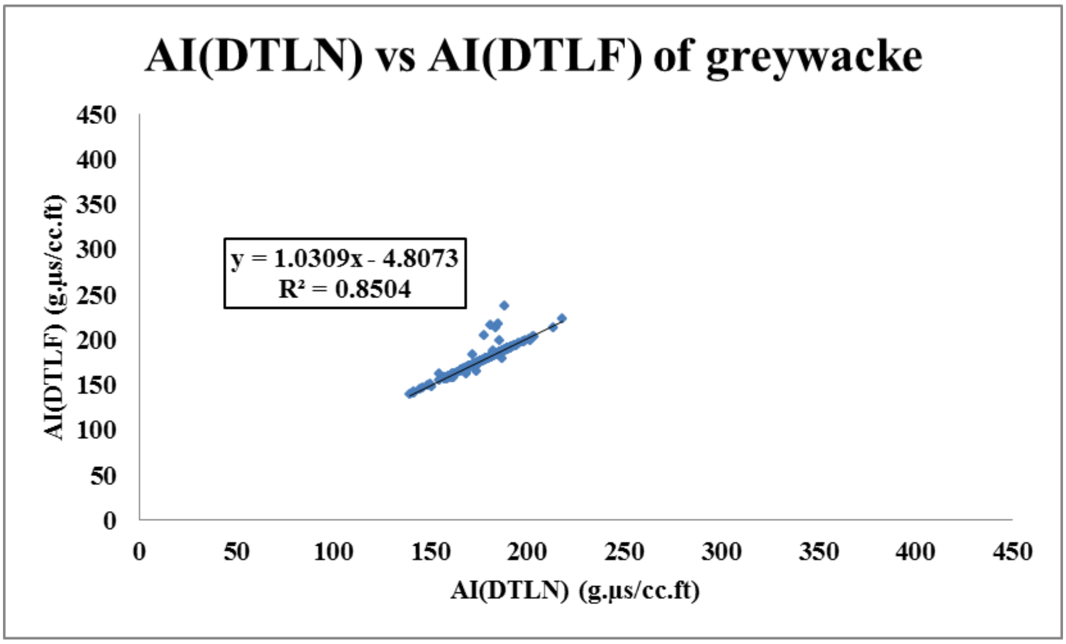


Figure 21 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and AI (DTLF) of greywacke in well A-1

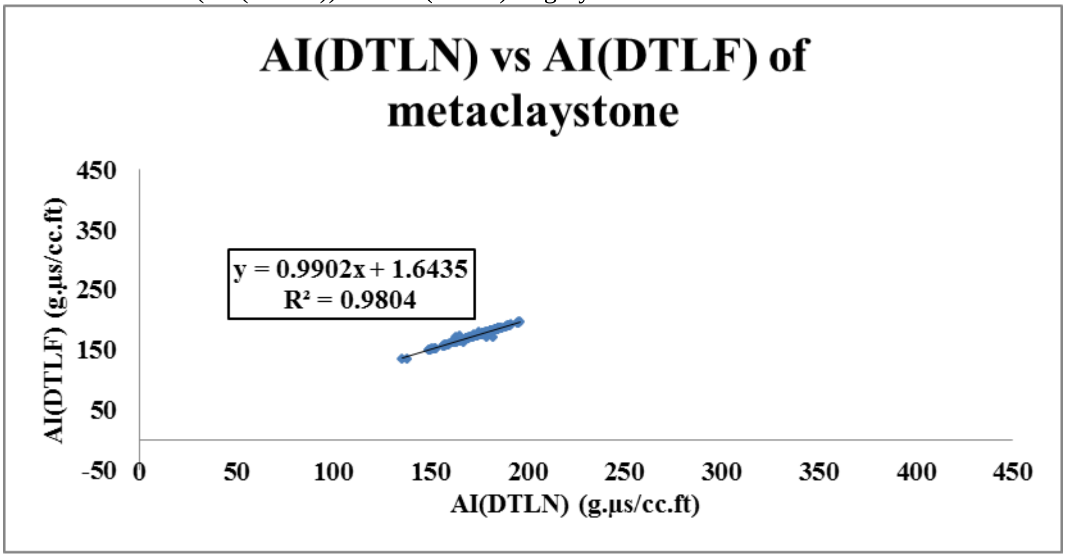


Figure 22 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and AI (DTLF) of metaclaystone in well A-1

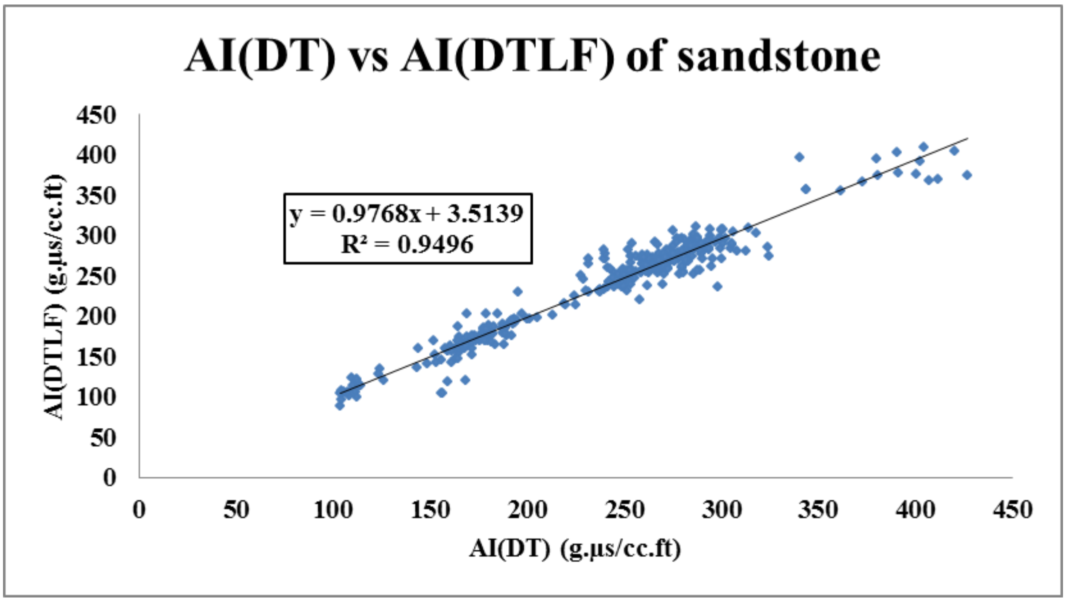


Figure 23 A cross-plot showing a relationship between acoustic impedance (AI (DT)) and AI (DTLF) of sandstone in well A-1

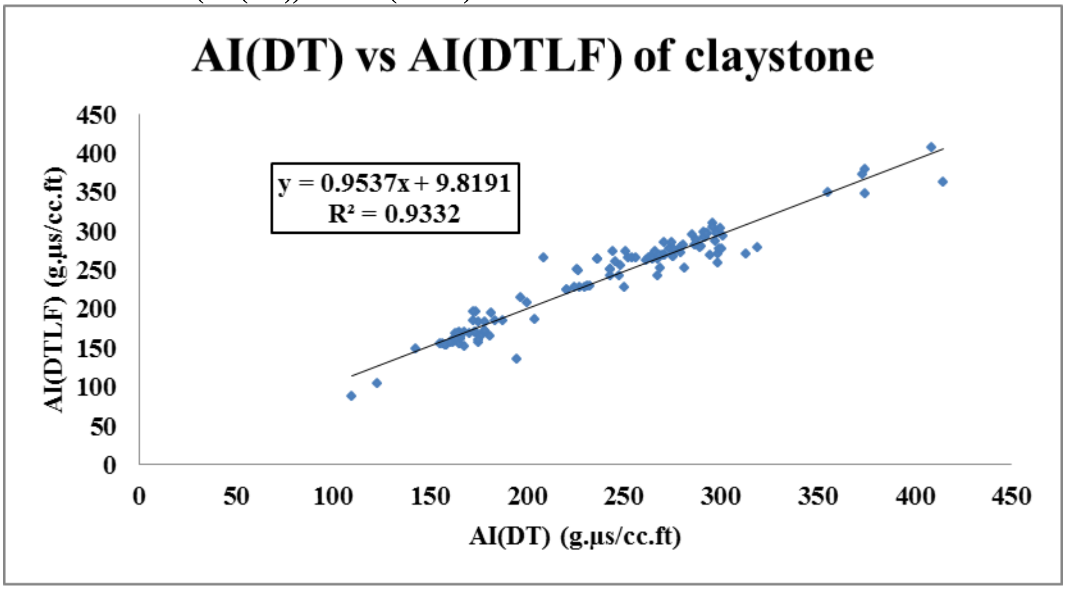


Figure 24 A cross-plot showing a relationship between acoustic impedance (AI (DT)) and AI (DTLF) of claystone in well A-1

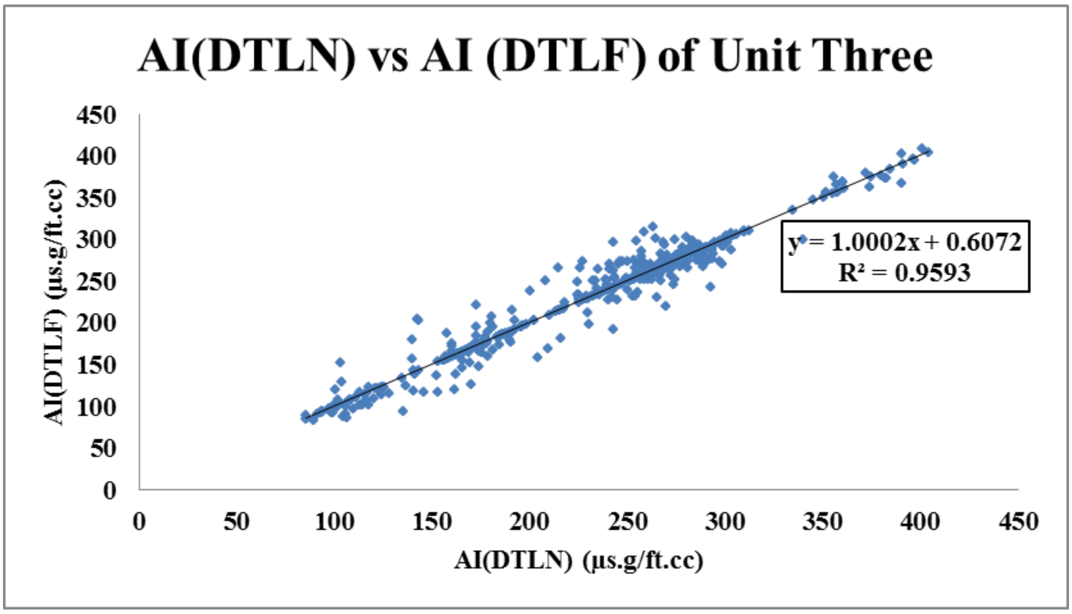


Figure 25 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and AI (DTLF) of unit three in well A-1

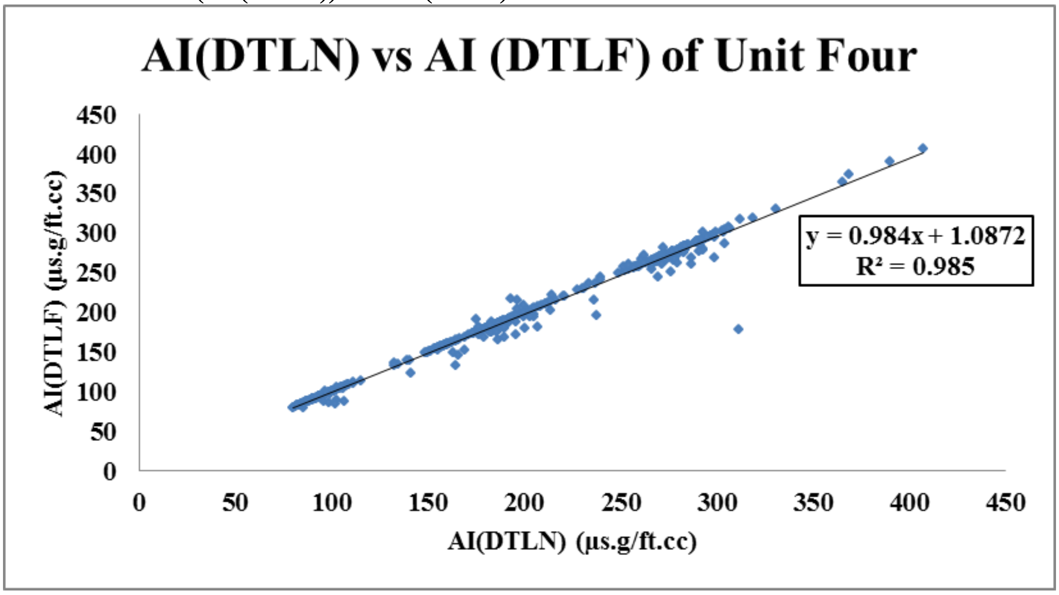


Figure 26 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and AI (DTLF) of unit four in well A-1

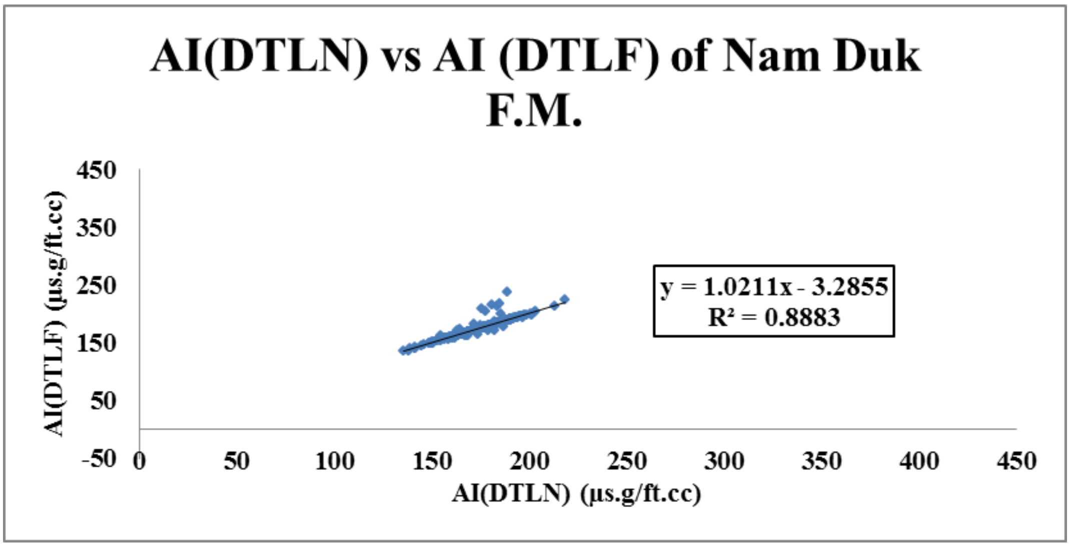


Figure 27 A cross-plot showing a relationship between acoustic impedance (AI (DTLN)) and AI (DTLF) of Nam Duk Formation in well A-1

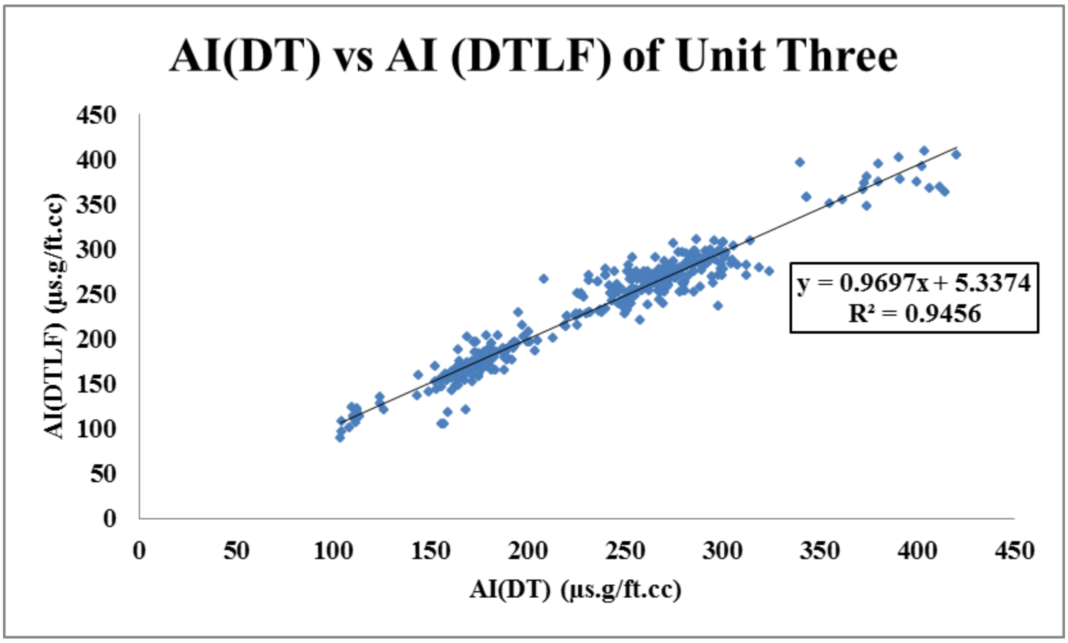


Figure 28 A cross-plot showing a relationship between acoustic impedance (AI (DT)) and AI (DTLF) of unit three in well A-1

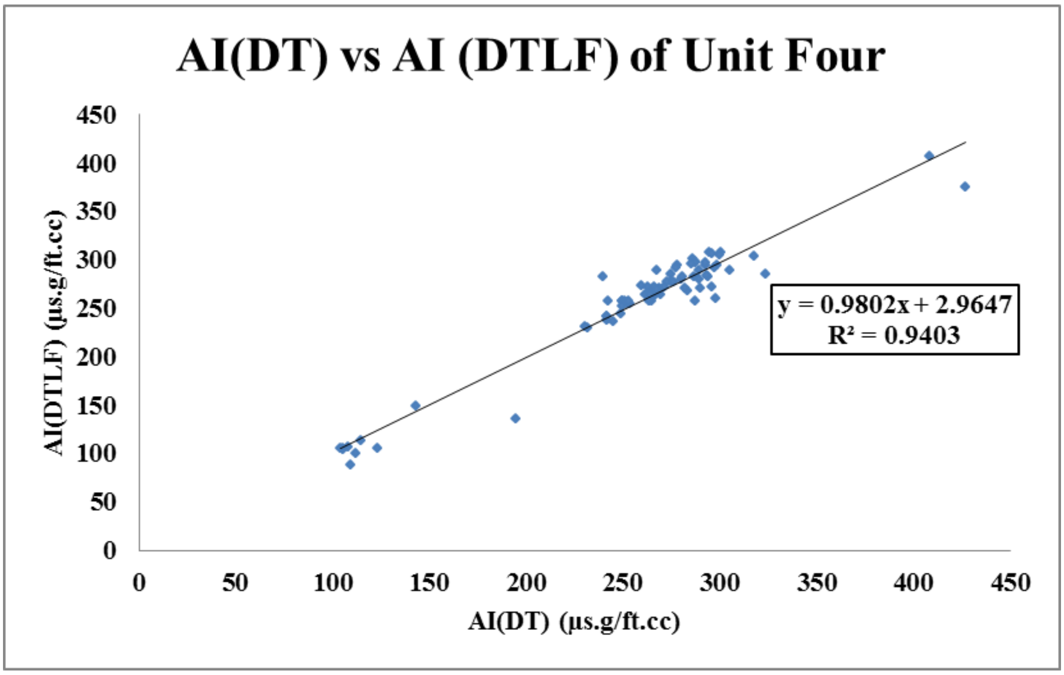


Figure 29 A cross-plot showing a relationship between acoustic impedance (AI (DT)) and AI (DTLF) of unit four in well A-1

Table 3 Summary of correlation coefficients obtained from the linear relationship between acoustic impedance of DT, DTLN, DTLF in lithologic identification

Sonic Log Type	Non-reservoir						Reservoir	
	Claystone		Metaclaystone		Greywacke		Sandstone	
	Number of data	Correlation Coeff.	Number of data	Correlation Coeff.	Number of data	Correlation Coeff.	Number of data	Correlation Coeff.
DTLN & DTLF	588	0.976	380	0.98	468	0.85	1278	0.973
DT & DTLN	234	0.957	-	-	-	-	754	0.96
DT & DTLF	244	0.933	-	-	-	-	768	0.949

Table 4 Summary of correlation coefficients obtained from the linear relationship between acoustic impedance AI and AI in stratigraphic unit identification

Sonic Log Type	Unit Three		Unit Four		Nam Duk F.M.	
	Number of data	Correlation Coeff.	Number of data	Correlation Coeff.	Number of data	Correlation Coeff.
DTLN & DTLF	1038	0.959	790	0.985	890	0.888
DT &DTLN	834	0.963	156	0.929	-	-
DT &DTLF	850	0.945	164	0.94	-	-

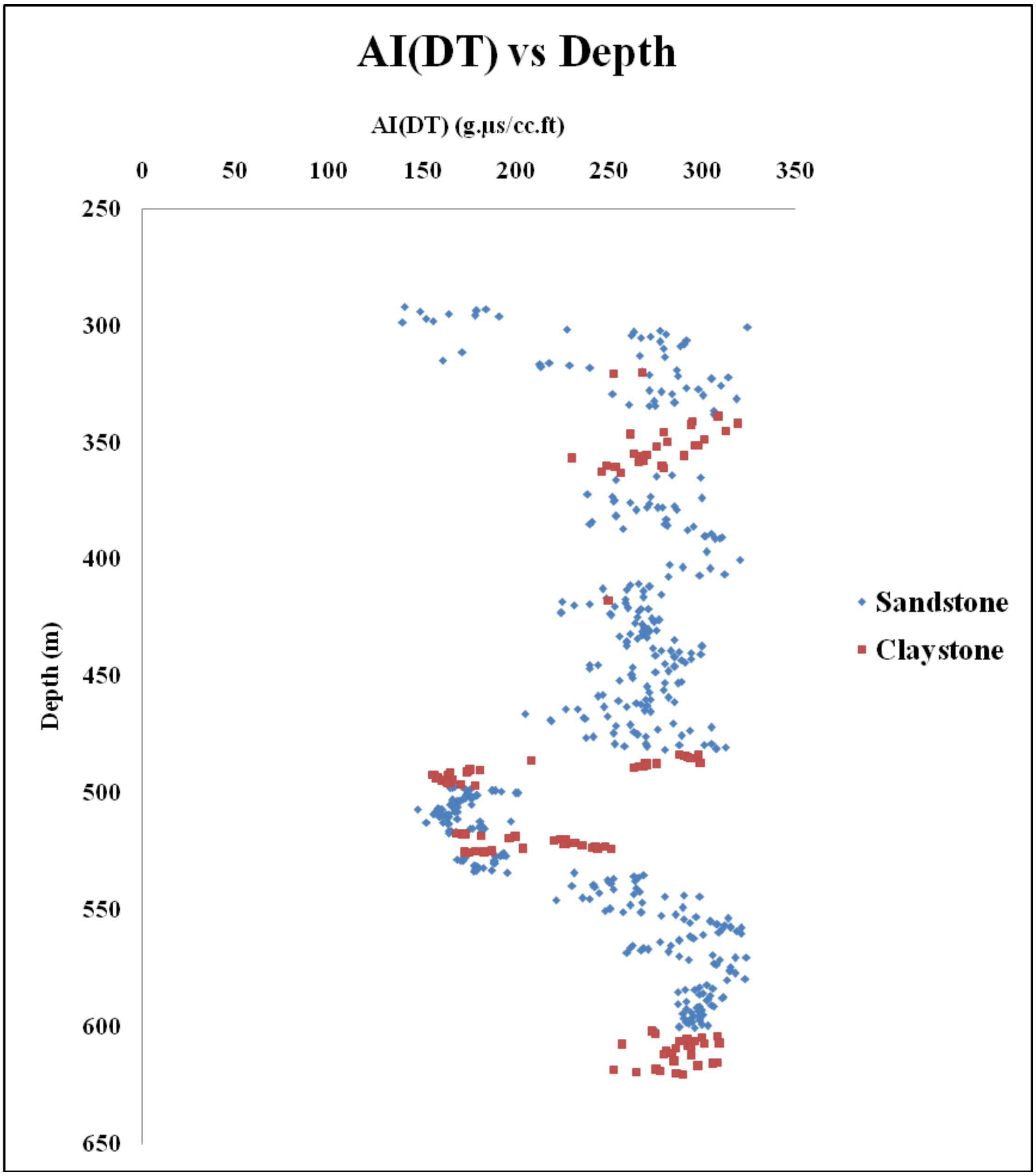


Figure 30 Relationship between acoustic impedance (AI (DT)) and depth in lithologic identification

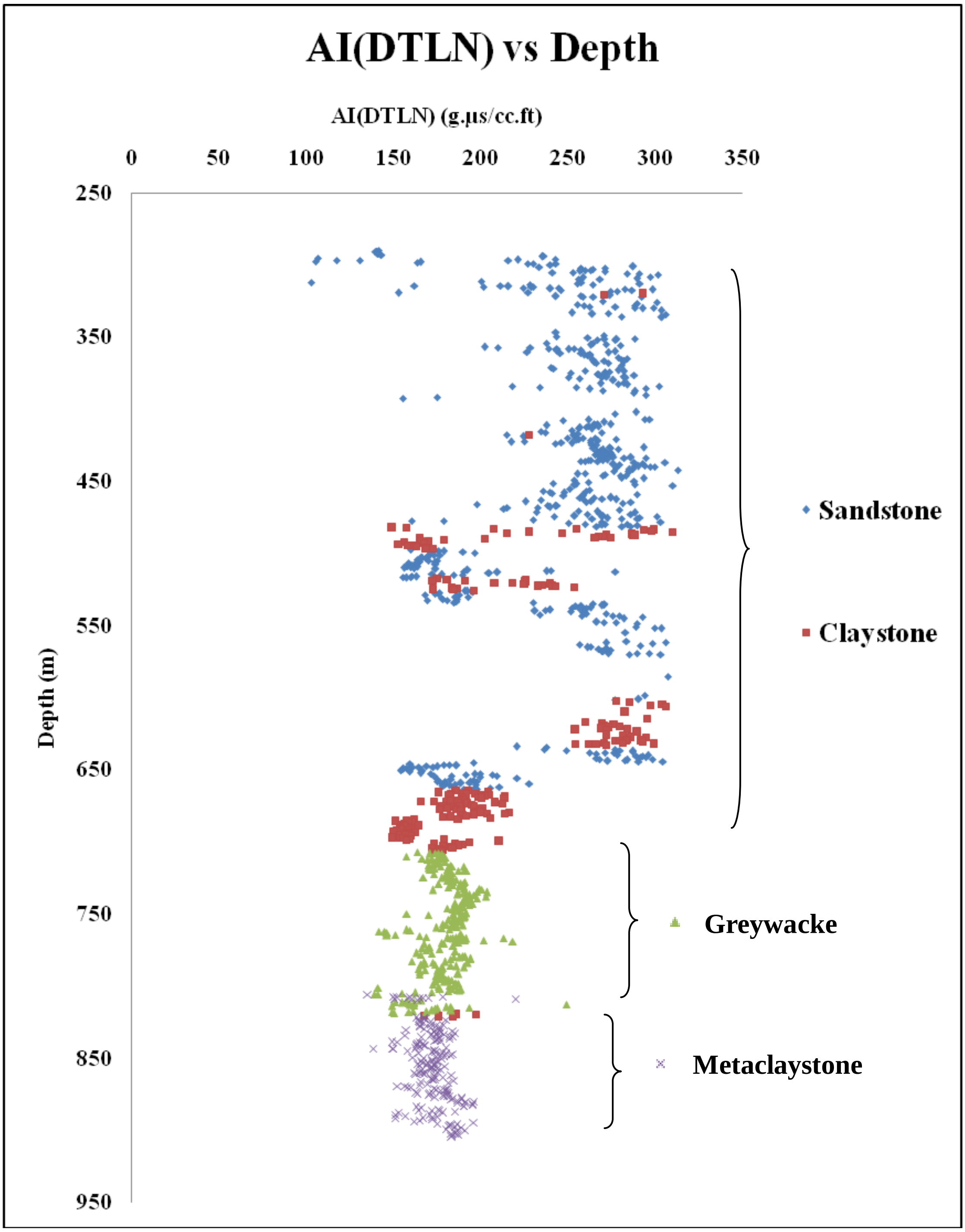


Figure 31 Relationship between acoustic impedance (AI (DTLN)) and depth in lithologic identification

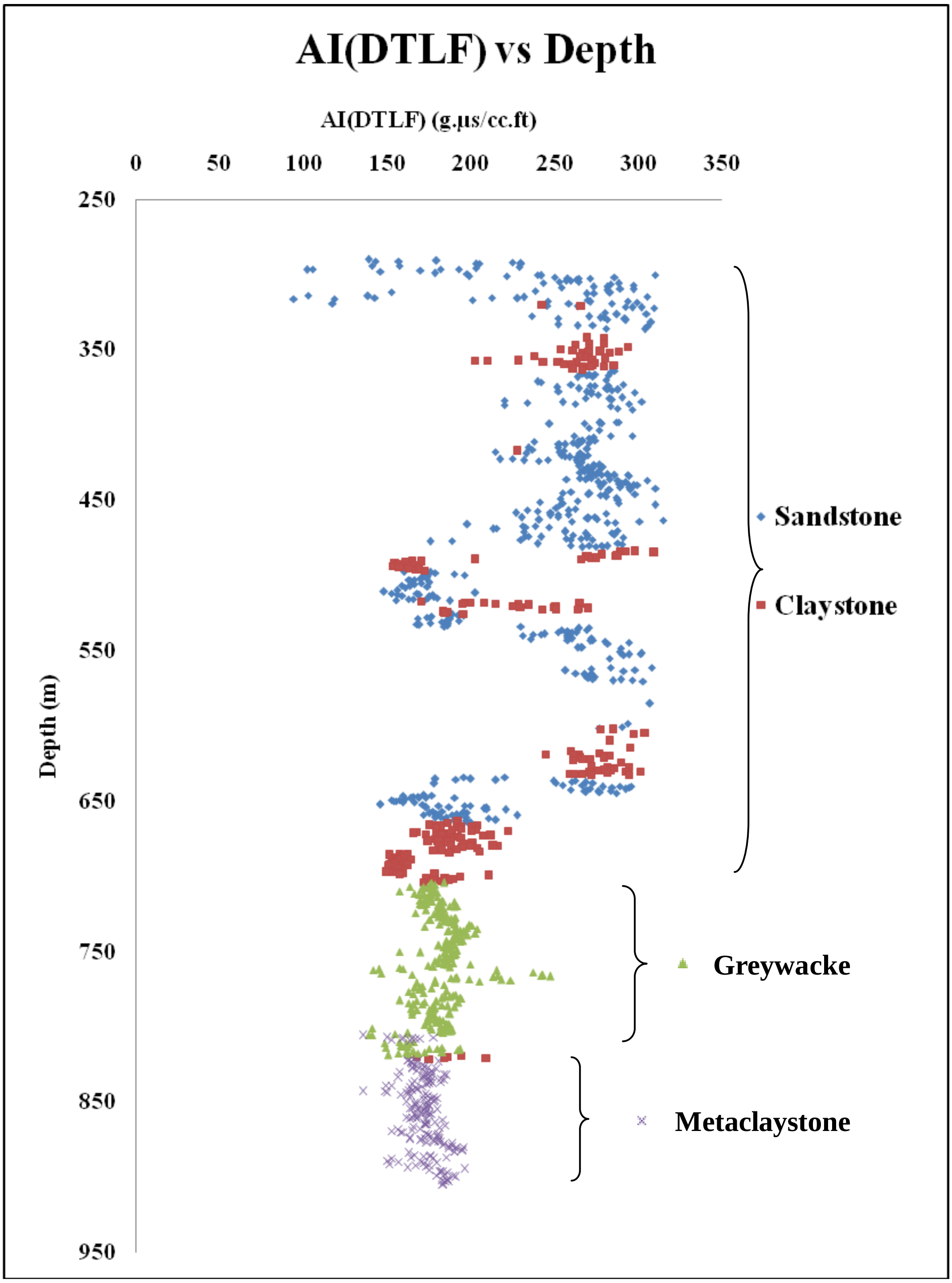


Figure 32 Relationship between acoustic impedance (AI (DTLF)) and depth in lithologic identification

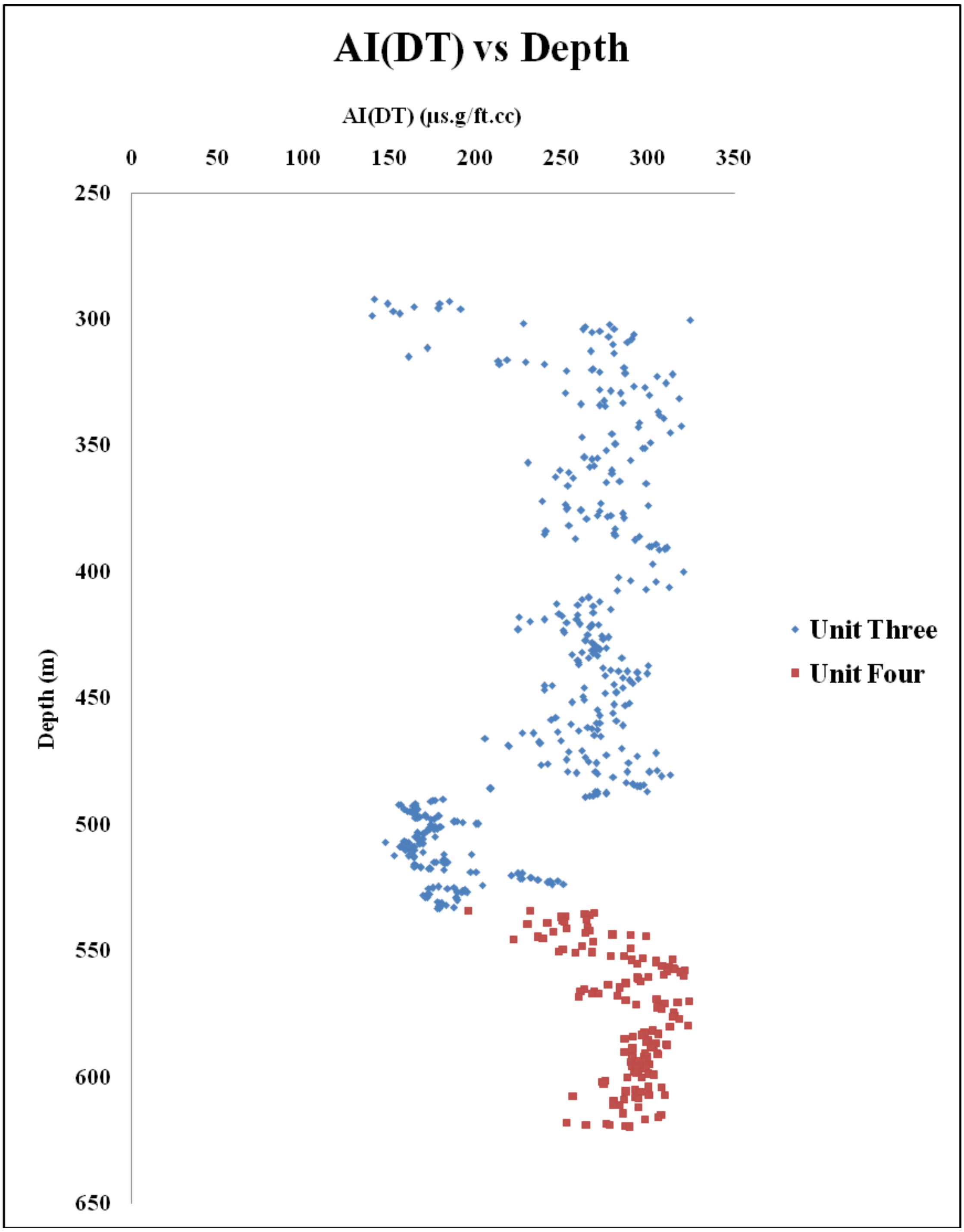


Figure 33 Relationship between acoustic impedance (AI (DT)) and depth in stratigraphic unit identification

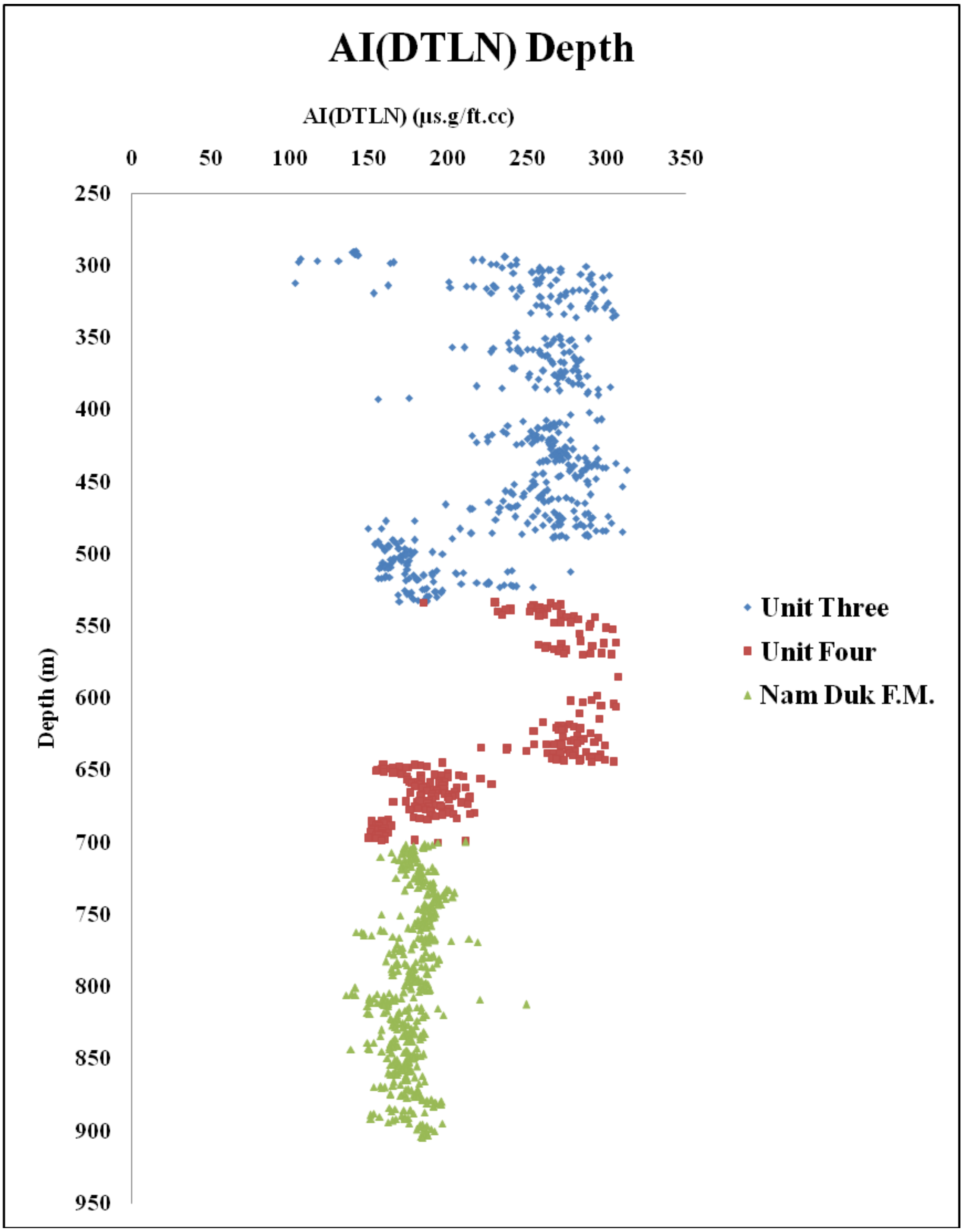


Figure 34 Relationship between acoustic impedance (AI (DTLN)) and depth in stratigraphic unit identification

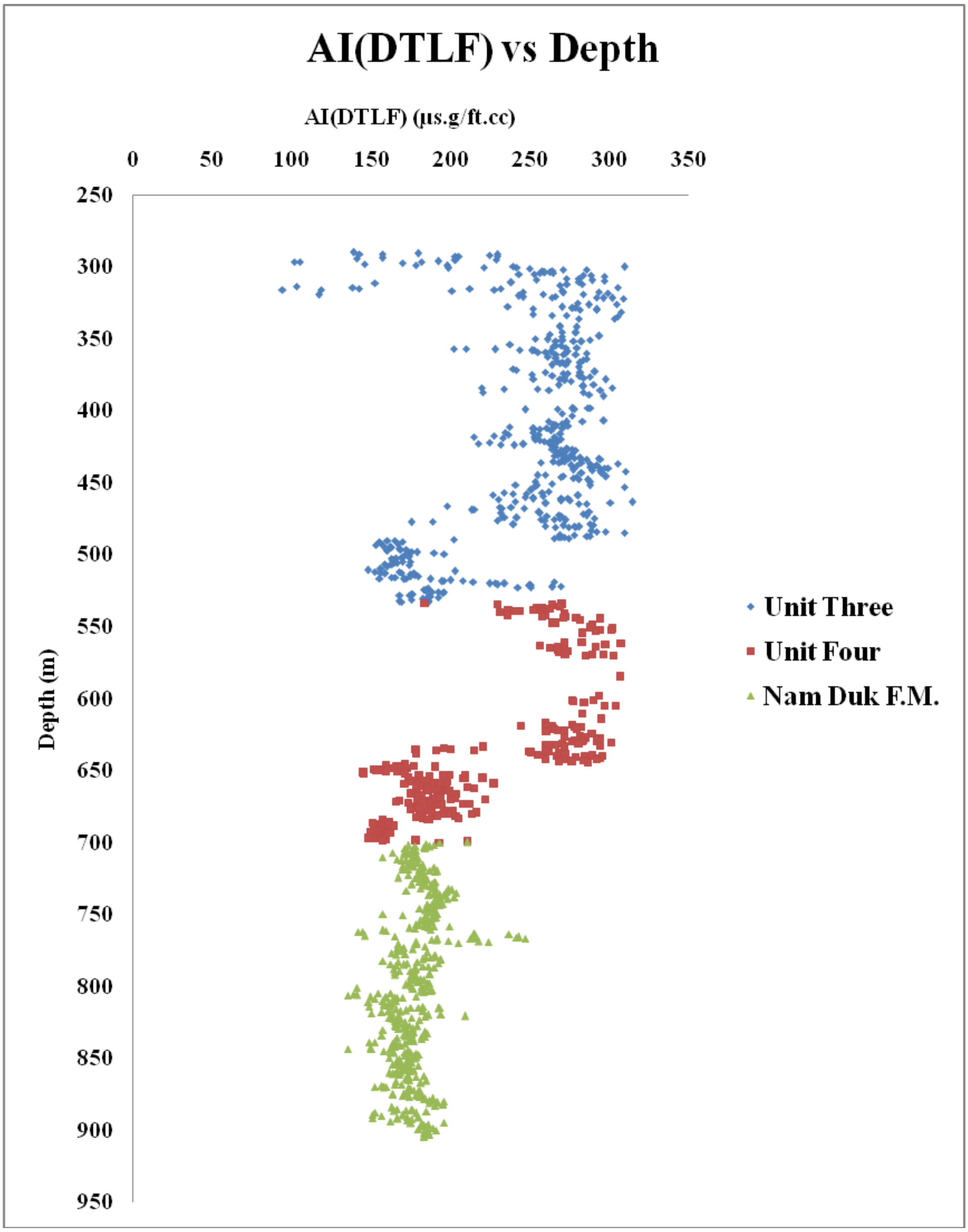


Figure 35 Relationship between acoustic impedance (AI (DTLF)) and depth in stratigraphic unit identification

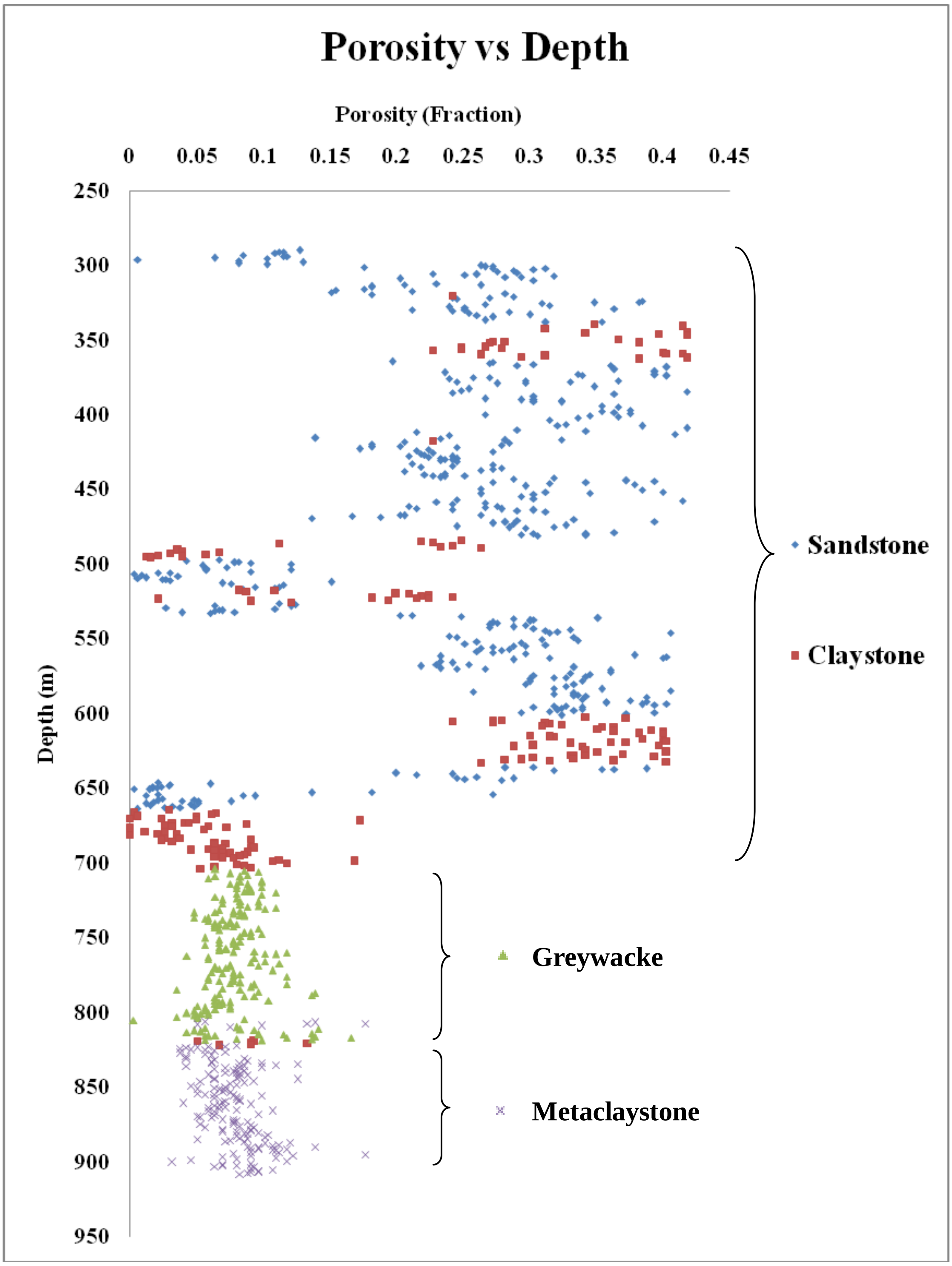


Figure 36 Relationship between porosity and depth in lithologic identification

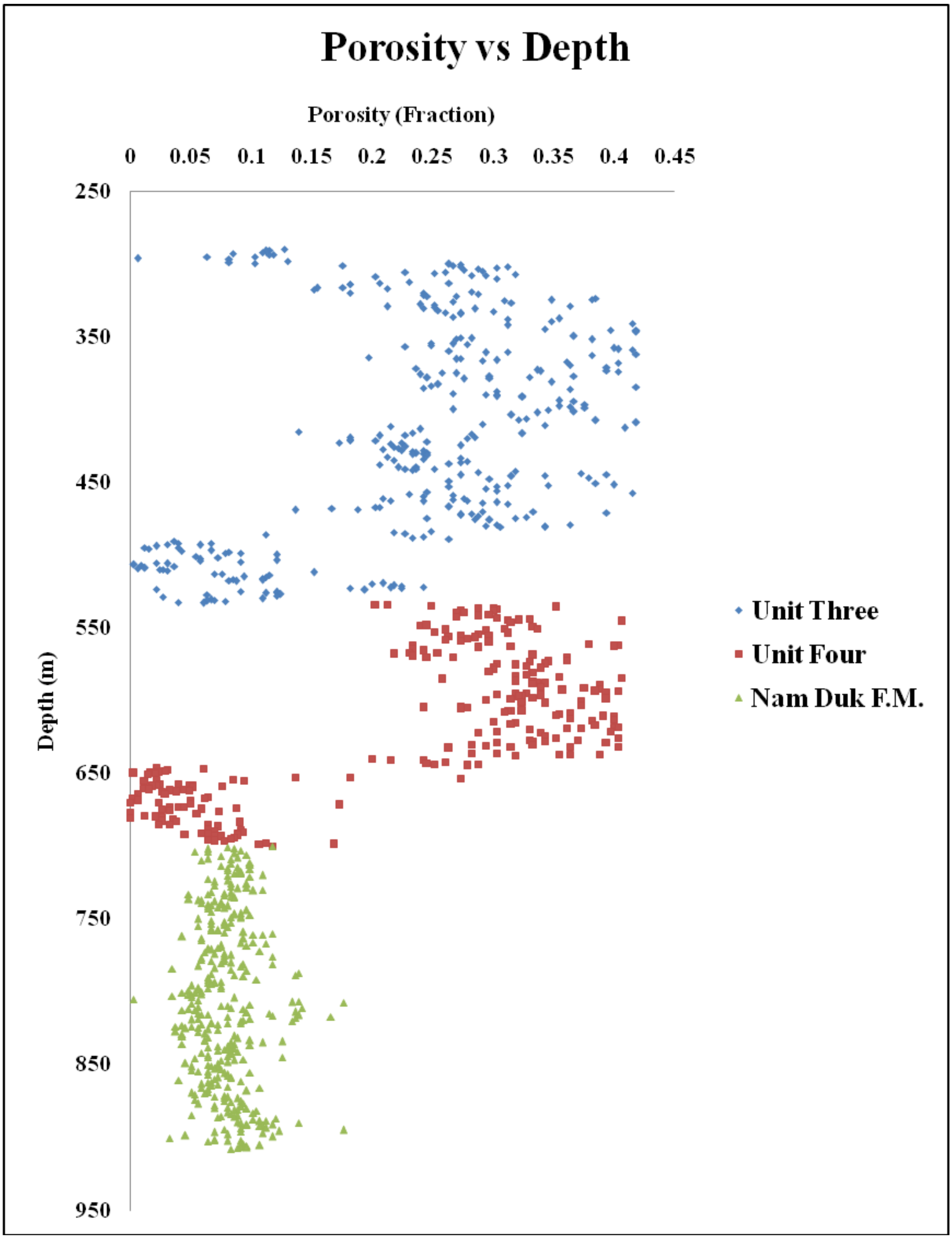
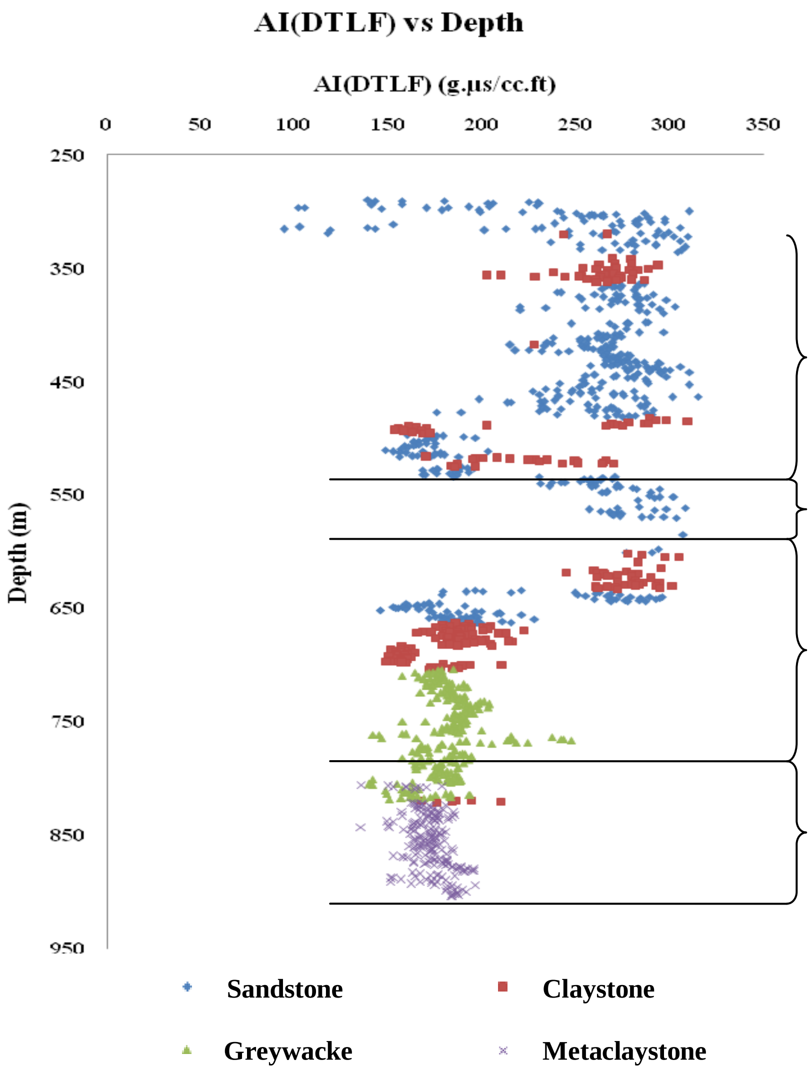


Figure 37 Relationship between porosity and depth in stratigraphic unit identification



Formation	Petroleum system	Lithology	Environment of Deposition
UNIT THREE	Source And Reservoir	Claystone interbedded with sandstone and siltstone, F sand and weathered volcanics.	Fluvial/Deltaic Lacustrine
INTRUSIVE	Heat source/ Fracture Intrusive	Diorite, diabase	
UNIT FOUR	Source	Predominantly claystione with minor Interbeded of siltstone and sandstone	Lacustrine
Nam Duk F.M.		Varicoloured silty claystone with interbeds of lithic or quartzose sandstone and weathered fine grained volcanics	

Note: For Unit Three, sandstone is reservoir rock and claystone is source rock.

Figure 38 Acoustic impedance & depth and lithology description in well A-1