APPENDIX A

Seismic Acquisition Parameters

The 3D Karewa survey was operated by the Todd Petroleum Mining Company Limited in 2006. The duration of survey was 16 days between April 6, 2006 and April 21, 2006 (Todd Energy, 2006).

A-1) Survey Definition

Acquisition mood:	3D
Source: :	2 x 2500 in^3
Source depth:	6 m
Streamers:	4 x 4050 m
Streamer spacing:	100 m
Streamer depth:	7 m
Near trace offset:	98 m

A-2) Systems

Source type:	Bolt 1500LL / 600B guns
Streamer type:	RDH-Solid and Syntron / Teledyne LDA
Recording system:	Syntrak / gAs
Navigation:	SkyFix.XP and StarFix.HP
Float positioning:	Seatrack 220 / 320 RGPS

A-3) Sourse Details

Source type:	Bolt 1500LL/600B air guns
Air pressure:	1800 psi
Volume:	2500 in^3
Number of sources:	2
Number of sub-arrays:	3 per source
Source separation:	50 m
Sub-array separation:	10 m
Source length:	14 m
Gun synchronization:	± 1.5 ms
Shot interval:	18.75 m
Depth:	6 m
Depth control:	Fixed depth ropes
Depth monitoring:	AG and Syntron depth transducers
Spacing control:	Spread-ropes on sliding collars
Near field signatures:	7 phones per subarray
Compressors:	5 x Hamworthy 565
Source controller:	GCS-90, version 4.76

A-4) Seismic Acquisition System Details

Recording System:	PGS gAS
Amplitude resolution:	24 bit
Data Channels:	324 per streamer
Auxiliary Channels:	48 attached to streamer 1
Tape Transports:	6 x IBM 3590 cartridge drives
Tape Format:	SEG D, 8036, 3 byte integer
Recording Media:	3590 tapes
Record Length:	5120 ms
Deep water delay:	0 ms
Sample Rate:	2 ms
High Cut Filter:	206 Hz / 276 dB/octave
Low Cut Filter:	3 Hz / 12 dB/octave
Gain Setting:	12 dB
Amplifier:	Voltage Mode Differential
Input Range:	0-2048 mV
A/D Converter:	Delta-Sigma Architecture, with 23 bits
Distortion:	< 0.0005 % (-106 dB)
Cross-Feed Isolation:	equal or better than 110 db
Power Consumption:	7.5 W per module
Polarity Convention:	SEG

A-5) Streamer Details

Type of streamer:	RDH-S and Syntron/Teledyne LDA *)
Number of streamers:	4
Streamer sensitivity:	20 V/bar
Streamer length:	4050 m
Number of groups:	324 per streamer
Group interval:	12.5 m
Group length:	12.5 m
Hydrophone type:	T-2
Streamer depth control:	Digibird 5011
Number of compass-birds:	17 per streamer

A-6) Survey Datum

Survey datum:	New Zealand Geodetic Datum 1949 (NZGD49)
Ellipsoid:	International 1924
Semi major axis:	6378388 m
1/Flattening:	297
GPS datum:	WGS84
Ellipsoid:	WGS84
Semi major axis:	6378137 m
1/Flattening:	298.257223563
Geoid height, EGM96 model:	29.0 m

A-7) Map Projection

Projection:	New Zealand Map Grid
Projection Method:	New Zealand Map Grid
Latitude of Origin:	41º S
Longitude of Origin:	173º E
False Northing:	6023150 m
False Easting:	2510000m

APPENDIX B

Well Log Conditioning

B-1) Selection of well logs

The well used in this study area is the Karewa-1 well. All the important well logs were run in this well including gamma ray, compressional sonic slowness, shear sonic slowness, density, and porosity. The available logs (Figure B-1 and Figure B-2) are Gamma Ray Induction (GRI), Gamma Ray Latero Log (GRL), Gamma Ray Neutron (GRNU), Bit Size (BIT), Spontaneous Potential (SP), Calibrated Downhole Force (CDF), Density Caliper (CLD), Resistivity Caliper (CLI), Density Correction (DRH), Density (FDC), Litho-Density (LDL), Compensated Neutron Porosity (CNL), Thermal Neutron Porosity (TNPH), Compressional Monopole (DTC), Shear Monopole (DTS), Shear Upper Dipole (DTSU), HALS Latero log Deep (HLLD), HALS Laterolog Shallow (HLLS), Deep Latero Log (LLD), Medium Latero Log (LLS), Micro Inverse (MINV), Micro Normal (MNOR), Photoelectric (PEF), Flushed Zone Resistivity (RXO), and Tension (TNS).

In this study, only few well logs were used as final input, such as the compressional sonic velocity, the shear sonic velocity, the gamma ray, the density, and the porosity log. The quality checks and log conditioning are important. The quality of the well log data can be affected by the tool problems, calibration errors, borehole conditions, changing borehole sizes, missing sections, and lithology. The missing sections were replaced by the estimated values from other logs using empirical relationships, and bad data points have been removed to ensure the high quality of input well logs.

From the available logs, different thus exist (Figure B-1 and Figure B-2). Of these only one log of each type was selected for further calculation (Figure B-3). For example, three gamma ray logs were run by induction, laterolog, and neutron tools (Figure B-1). The responses of induction and laterolog gamma ray logs are almost the same, and the neutron gamma ray log was run only in shallow zone. So the gamma ray log run using induction tool was selected for further use (Figure B-3). Of the caliper logs, two types were available (Figure B-1): the density caliper and the resistivity caliper. In this case, the density caliper was chosen for differentiating between sand and other lithologies (Figure B-3). From the density log types, two density logs were available (Figure B-1): the density (FDC) and the litho-density (LDL). Their responses are also similar, but the density (FDC) was run only in deeper zone. So the litho-density (FDC) log was selected (Figure B-3). For resistivity measurements, two deep resistivity logs are available (Figure B-2): the deep laterolog (LLD) and the HALS deep laterolog (HLLD), two shallow resistivity logs were available (Figure B-2): the medium laterolog (LLS) and the HALS shallow laterolog (HLLS), and two micro resistivity logs were available (Figure B-2): the micro inverse (MINV) and the micro normal (MNOR). The responses of the deep resistivity logs are almost same, and the same observed for the medium (or shallow) and the micro resistivity logs. However, the LLD and LLS logs were run in a deep interval. Consoquently, HLLD, HLLS, and MINV were selected as deep, shallow and micro resistivity logs (Figure B-3). From the shear sonic slowness type, two logs are available: shear monopole (DTS) and shear upper dipole (DTSU). The shear monopole (DTS) has quality problems, and the shear upper dipole (DTSU) did not cover the entire well depth. Both logs were corrected. In the neutron log type, two neutron logs are available: the compensated neutron (CNL) and the thermal neutron (TNPH) log. Both logs overestimate the porosity. So, none of them are chosen. The other logs which were run for only once have been accepted for further use, only if they had no casing problems, erroneous data, and spikes.

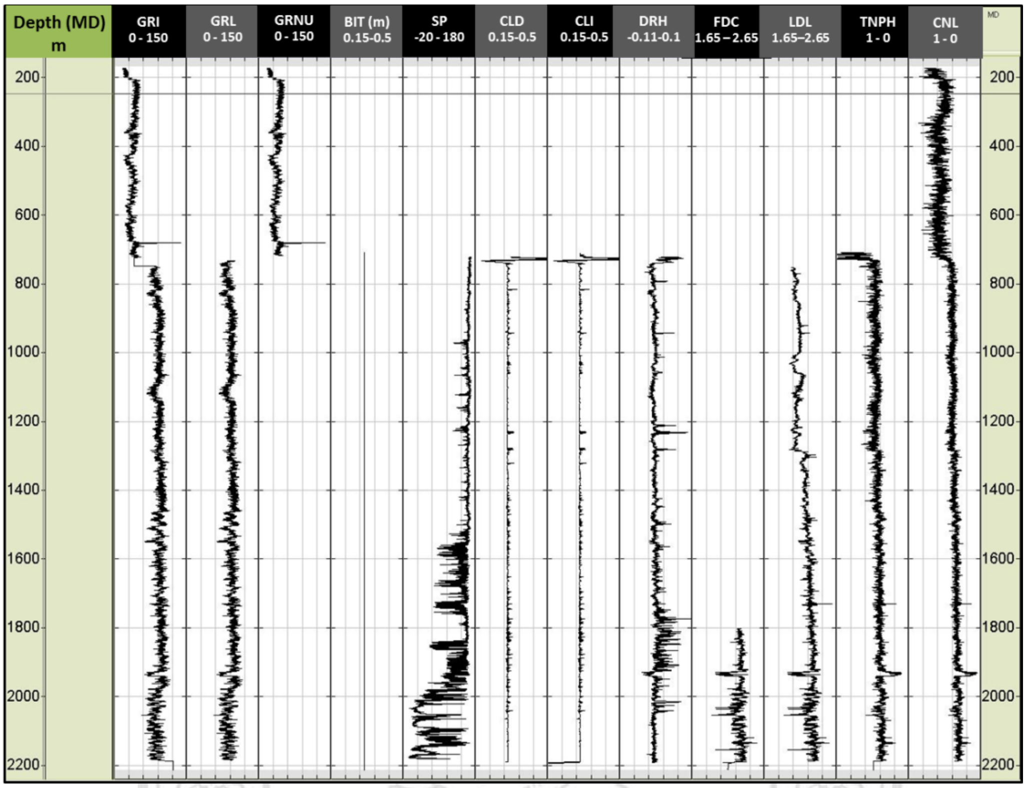

Figure B-1: Available well logs (Gamma ray, Bit Size, SP, Caliper, Density, Density Correction, and Neutron Porosity)

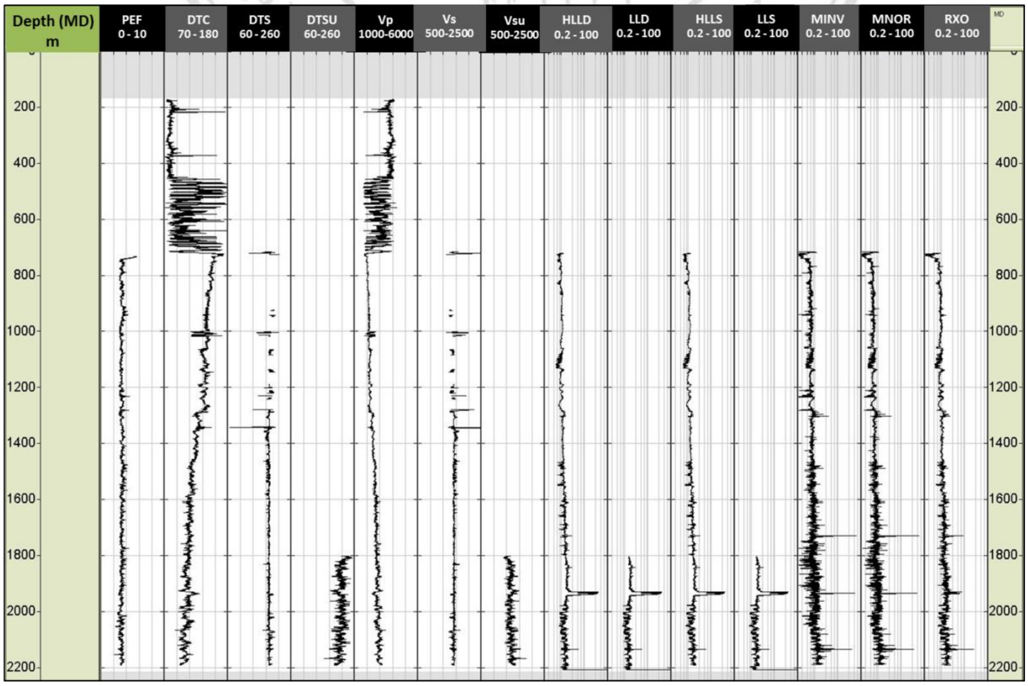

Figure B-2: Available well logs (Photoelectric, Sonic, Shear Sonic, Sonic Velocity, Shear velocity, and Resistivity)

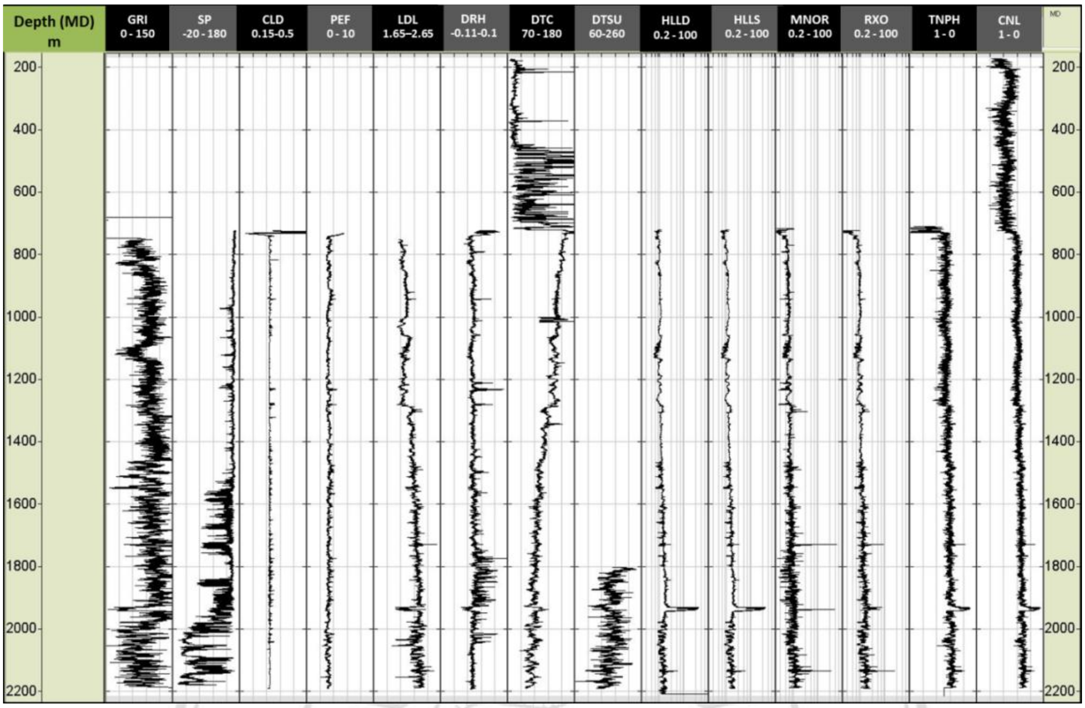

Figure B-3: Selected well logs

B-2) Despiking

A smooth log does not exist in the real world. Noises such as spikes always occur and affect the log data. So the despiking of logs is sometimes very important in log editing. Spikes may occur in various ways including those due to casing joints, tool problems, bad hole effects, and natural features such as thinly bedded porous layers or coals. Spikes should be removed or corrected except if they are caused by a natural phenomenon. The best way to identify a spike is to look at other logs at the same depth and judge geologically.

In the Figure B-4, five depth points were marked initially as spikes like features, also can be seen in other logs there. At the points A (1730m MD), a big spike is seen in the micro normal resistivity (MNOR) log (Figure B-4). The response increased around 300 times. The responses of density, deep, and shallow resistivity logs increased moderately and the responses of gamma ray, SP, TNPH, and CNL decreased. The caliper showed a very small washout. The layer is very thin (less than 1m) at the spike in MNOR log. The spike might be because of the invaded zone with a porosity decrease of tight sand. So it has been removed

At point B (1937m MD), a big spike is seen in the micro normal resistivity (MNOR) log. The response increased around 300 times. This spike is located in the Mangaa C1 Sand. The responses of density and shear sonic velocity logs increased moderately and the responses of other logs did not change too much. So the spike in MNOR might be because of lithology change. So it has been removed.

At point C (2137m MD), a big spike is seen in the micro normal resistivity (MNOR) log again. The response increased around 200 times in comparison to the surrounding measurement. The responses of density, compressional velocity, and resistivity logs are increased, whilst the responses of gamma ray, SP, and porosity logs are decreased. Other logs also changed a little. So that spike might be due to a compacted thin sand and not removed.

At point D (2155m MD) which is located in a sandstone zone, a spike is seen in the density (LDL) log (Figure B-4). The response decreased about 0.4 g/cc. The responses of SP, and photoelectric logs increased slightly and the responses of gamma ray, and resistivity logs decreased slightly. The other logs did not change too much. This layer might hold saline water. So it was not a spike and not removed.

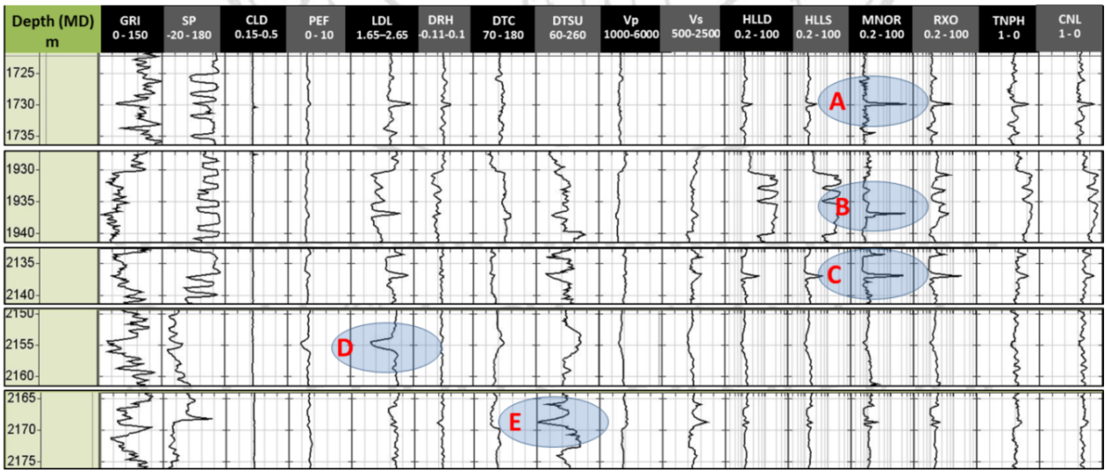

Figure B-4: Despiking of logs

At point E (2169m MD) which is located in a sandstone zone, a big spike is seen in the shear sonic log, and as well as in the shear velocity logs (Figure B-4). The response increased about 500m/s in the shear velocity log. The response of the SP log decreased sharply, the response of photoelectric, and porosity logs decreased slightly and the responses of resistivity logs increased slightly. The other logs do not change too much. This layer might be a thin over-pressured sandstone with fresh water. So it was not a spike and not removed.

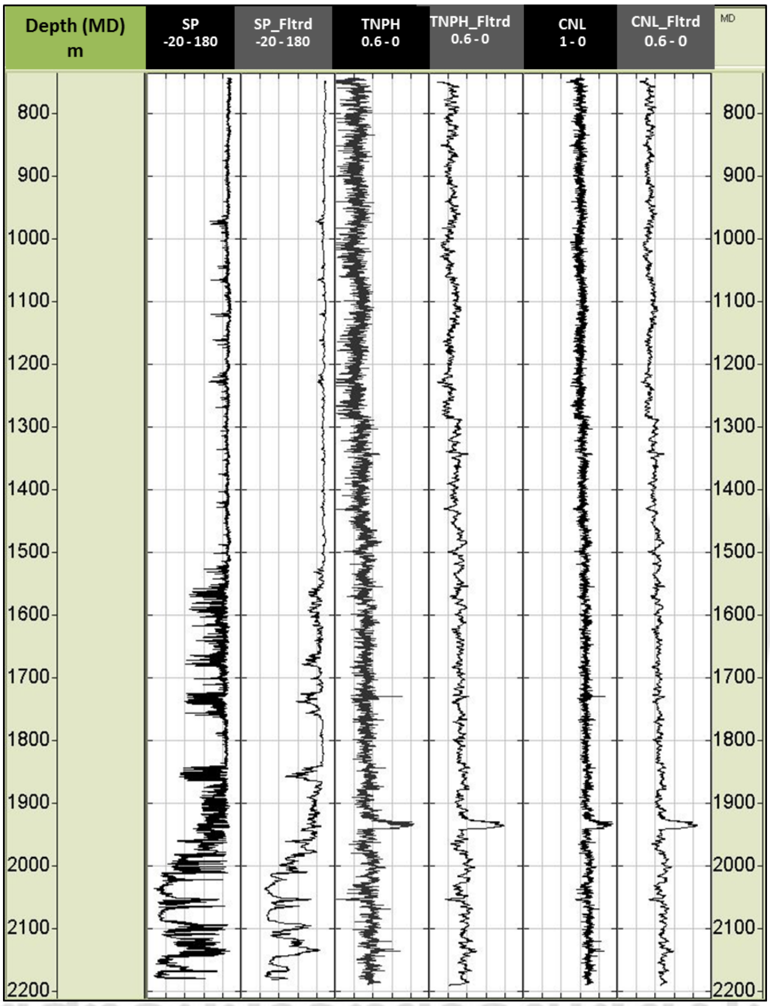

Figure B-5: The porosity logs after filtering

B-3) Spurious Data Removal and Log Filtering

Some logs contained spurious data especially at the end of the logs. In the Figure B-3, the spurious data can be observed in deep resistivity (HLLD) and porosity (TNPH) logs. After careful checking of all the logs, spurious data was removed from the bottom of the logs.

Log filtering is necessary if the log data contains too much noise and unusual data points. In this study, the SP log was too much noisy. It was filtered (smoothed) using a Gaussian function with 3m window and showed in Figure B-5. The porosity logs (TNPH and CNL) also contained some unusual data points. From the Figure B-6, it can be observed that most of the data points lied above modified Hashin-Shtrikman line which means the lithologies are acting like a suspension. This is unlikely although possible for neutron porosity as the lithology mainly consists of claystone and sandstone (Conoco Northland Ltd., 2002-2003) and the neutron porosity only sees hydrogen atoms for porosity calculation. So the log filtering (smoothing) was applied using a Gaussian function with 3m window for TNPH and CNL porosity logs (Figure B-5) although it cannot solve the problem properly.

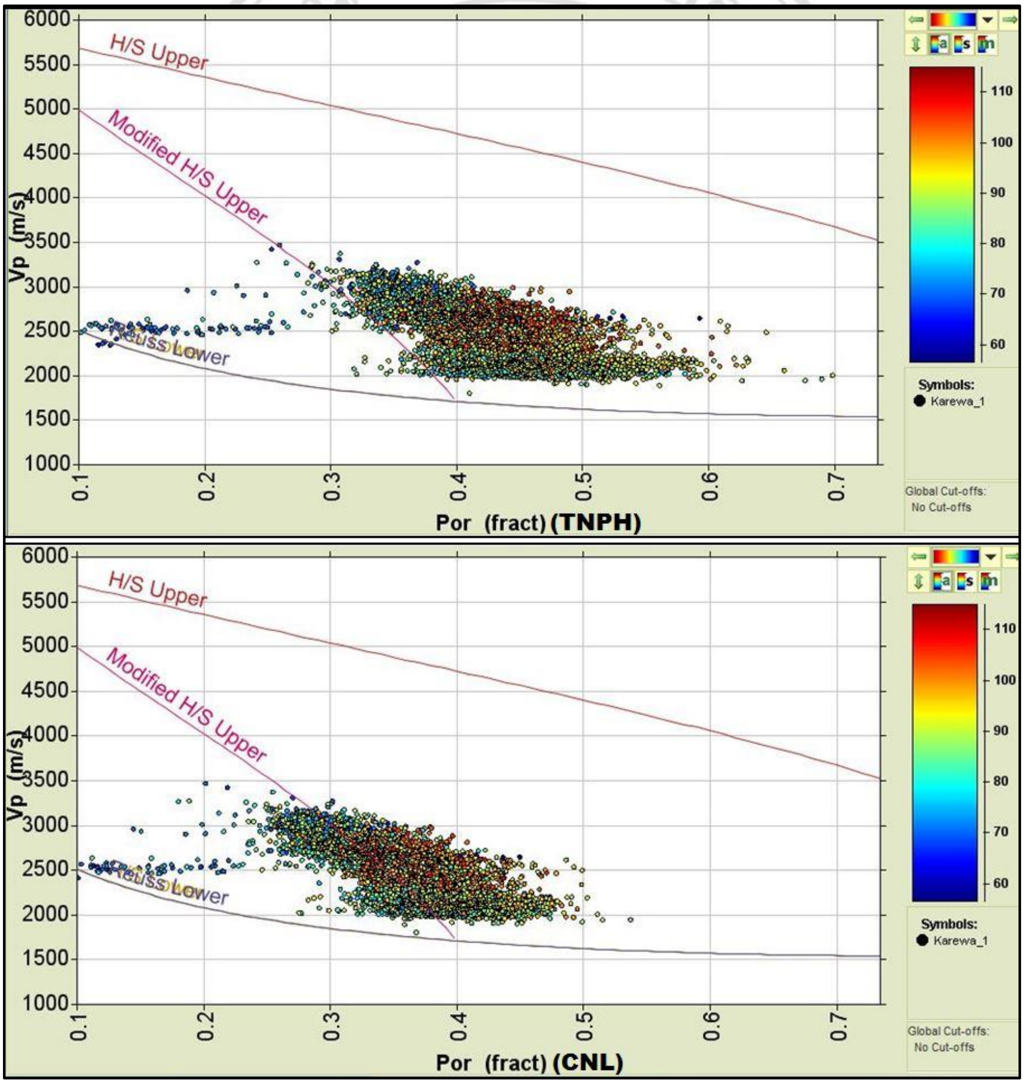

Figure B-6: Crossplot of compressional velocity (Vp) and Porosity (TNPH and CNL)

B-4) Porosity Log Conditioning

As the porosity logs are essential for many purposes, they should be judged carefully. The porosity logs can be predicted from other logs such as density and sonic logs. Again a porosity log can be calculated from two or more porosity logs using root mean square (RMS) rules.

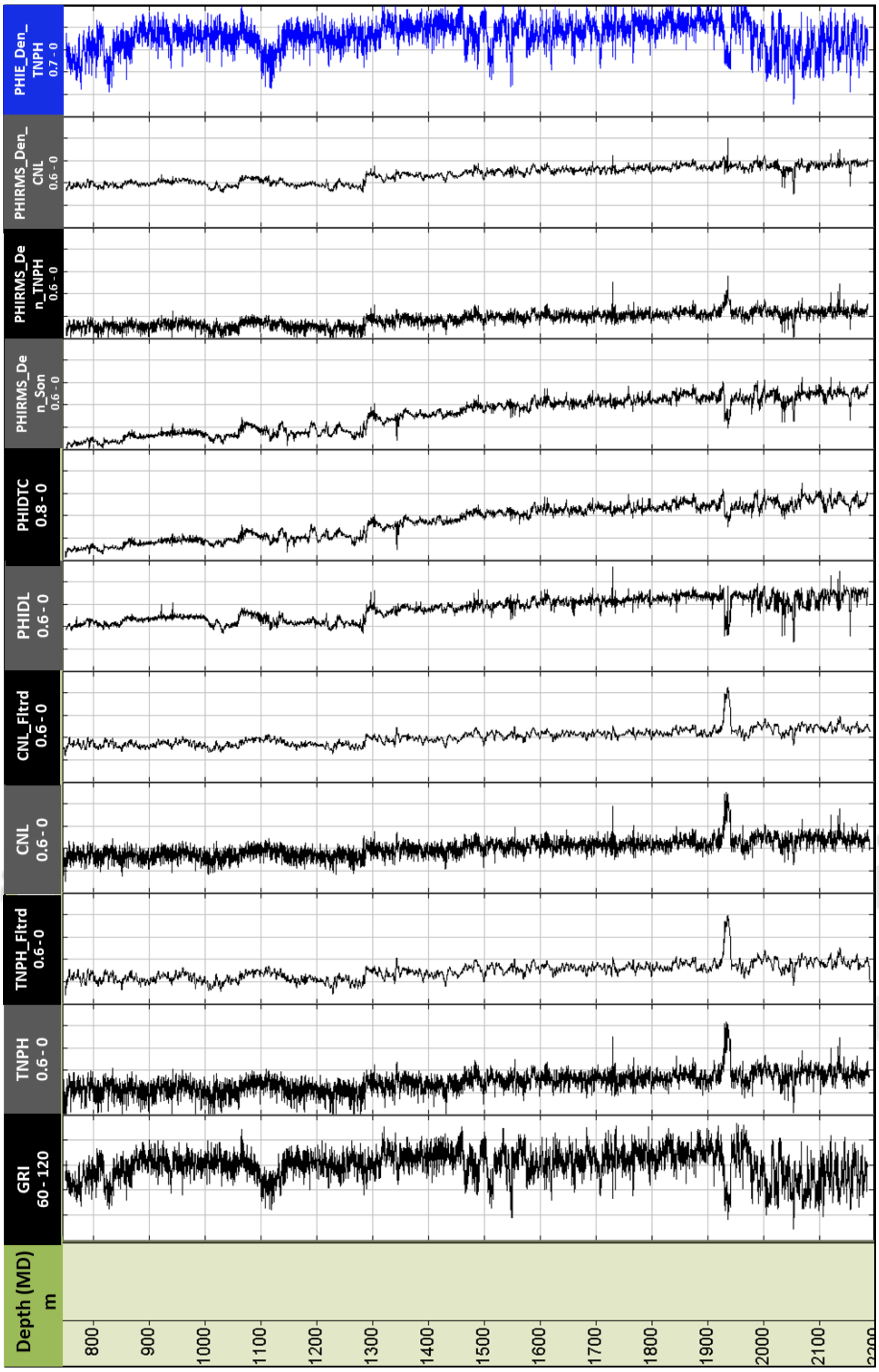

Figure B-7: Available, filtered, and predicted porosity logs. A gamma ray log is shown to roughly identify the sqand and shale/claystone.

B-4-1) Neutron Porosity Log Filtering

The problem with thermal neutron porosity (TNPH) and compensated neutron porosity (CNL) is mentioned earlier in section B-3. Most of their data points lay above modified Hashin-Shtrikman line (Figure B-6). The lithology of the study area consists mainly of claystone with sandstone interbed, and the claystone contains a lot of bound water. As the neutron porosity logs see hydrogen atoms in layers, the neutron logs measures more total porosity in claystone and less porosity in sandstone. After editing the other problems such as casing problems and removal of spurious data earlier, a Gaussian filtering (smoothing) was applied with 3m window. They were renamed as TNPH_Filtered and CNL_Filtered (Figure B-7).

B-4-2) Porosity from Density Log

A porosity log was predicted using the density log and named as PHIDL (Figure B-7). The requirements were a density log, information on the density of matrix and fluid. The density log was used for this prediction. As the lithology is mainly formed by clastic sediment, quartz is assumed as matrix and water is assumed as fluid. The porosity generator from density log tool of RokDoc was used for density log prediction.

B-4-3) Porosity from Sonic Log

A porosity log was predicted using the sonic log and naming it as PHIDTC (Figure B-7). The requirements were a compressional log, the sonic slowness value of matrix and fluid. The edited density log is used for this prediction. As the lithology is mainly formed by clastic sediment, quartz is assumed as matrix and water is assumed as fluid. The value of sonic slowness is 55 µsec/ft and 188 µsec/ft (Crain, 2016) for quartz and saline water respectively.

B-4-4) RMS Porosity Logs Calculation

A set of RMS porosity logs were calculated using the root mean square rule (Figure B-7). PHIRMS_Den_Son log was calculated using the density porosity log (PHIDL) and the sonic porosity log (PHIDTC). PHIRMS_Den_TNPH log was calculated using the density porosity log (PHIDL) and filtered thermal neutron porosity log (TNPH_Filtered). PHIRMS_Den_CNL log was calculated using the density porosity log (PHIDL) and compensated neutron porosity log (PHIDTC).

B-4-5) Effective Porosity Log

A total porosity log is required to calculate the effective porosity log. Seven total porosity logs are available. Among them the TNPH_Filtered and CNL_Filtered logs overestimate porosity, so they are not used for effective porosity log calculation. The sonic porosity log (PHIDTC) was calculated using sonic velocity log which also might have erroneous data, so it might produce wrong porosity values. It is not used for effective porosity log calculation. The density porosity log (PHIDL) also shows a clear trend and can differentiate between shale and sand zones (Figure B-7) although it is estimated from density log only. It is also not used for effective porosity log calculation. The RMS porosity logs were estimated from the density porosity, the sonic porosity, and the neutron porosity logs. Of these RMS porosity logs the PHIRMS_Den_Son log is not used for effective porosity log calculation as the density porosity and the sonic porosity logs were estimated from the density and the sonic logs respectively where none of them is not original porosity log, thus not reliable. The PHIRMS_Den_TNPH and the PHIRMS_Den_CNL show almost similar trend for porosity trend. Of these two porosity logs the PHIRMS_Den_TNPH is used for effective porosity log calculation (Figure B-7).

The shale volume log and shale porosity is also required to calculate the effective porosity log. In the section 4.1.3 the gamma ray value equal to 110 is used for shale cutoff. So from the total porosity log (PHIRMS_Den_TNPH), the porosity equal to 33% (0.33) is taken as shale porosity (ϕ_{sh}) for where gamma ray value is 110. Then an effective porosity log (PHIE_ Den_TNPH) is calculated (Figure B-7).

CURRICULUM VITAE

Author's Name	Mr. S. M. Ariful Islam
Date/Year of Birth	December 31, 1990
Place of Birth	Dhaka, Bangladesh
Education	(2016) M.Sc. in Petroleum Geophysics, Chiang mai University, Thailand (2013) B.Sc. in Petroleum and Mining Engineering, Shahjalal University of Science and Technology, Bangladesh
Scholarship	August 2015 to Nevember 2016 by PTT EP (Thailand)
Publication	Islam, S.M.A., Islam, M.S., Hossain, M.M., 2014. Investigation of fluid properties and their effect on seismic response: A case study of Fenchuganj gas field, Surma Basin, Bangladesh, International Journal of Oil, Gas and Coal Engineering. v. 2, n. 3, p. 36-54. Islam, S.M.A., Islam, M.S., Hossain, M.M., 2014. Reservoir characterization by investigating the reservoir fluid properties and their effect on seismic response of Fenchuganj Gas Field, Bangladesh, Fundamentals of Renewable Energy and Applications, v. 5, doi: 10.4172/20904541.1000144

Experience	Internship at Titas Gas Field under Bangladesh Explorartion and Production Company Limited (BAPEX)