CHAPTER 4

Well Log Conditioning and Rock Physics Analysis

If seismic amplitudes are explained or interpreted using models generated from well data, and supported by the previous study then this can be described as the 'rock-physics'(Simm and Bacon, 2014). Well log data is important for different tasks such as from identifying the formation tops of seismic data to inversion process. In this chapter, the well log conditioning was done mainly by RokDoc software although some figures were taken from Petrel and IP software.

4.1. Well Log Conditioning

4.1.1 Correction of Casing Problems

A 30” conductor was set at 206m MD and then a 13 3/8” was set at 742m MD. So the logs are affected by the casing problems. From Figure 3-3, it can be seen very clearly that the gamma ray (GRI), density caliper (CLD), resistivity (HLLS, HLLS, MNOR, RXO), porosity (TNPH and CNL), compressional sonic slowness (DTC) and as well as compressional sonic velocity logs are affected above 743m MD.

4.1.2 Prediction of Shale and Clay Volume

The shale volume prediction is important to identify shale and sandstone zones and to determine the porosity from density and neutron logs. The volume of shale and clay can be predicted using the gamma ray log. The volume fraction generator tool of RokDoc software was used for this prediction. For shale and clay volume prediction gamma ray values equal to 68 and 110 were set for sandstone and shale cut-off respectively. The shale volume log (VShale) and clay volume log (VClay) is shown in Figure 4-9**.**

4.1.3 Compressional Sonic Log Correction and Vp Log Prediction

Only one compressional sonic log is available in Karewa-1 well. A compressional sonic velocity log was made using the compressional sonic slowness log and named as Vp. This compressional sonic slowness as well as sonic velocity logs contain erroneous data between 1000 to 1020m MD and shows some sharp peaks there. In other logs there is no sign of this change (Figure 4-1-(a)).

From the crossplot of Vp and density (LDL) log the erroneous data can be identified and corrected. To identify the erroneous data points in the erroneous zone a crossplot (Figure 4-1-(b)) is made of Vp and the density log between 834m to 1104m MD, which is lithologically a claystone with sandstone interbeds. In Figure 4-1-(c), the erroneous data points are marked in log data. From this crossplot, a power equation is found and expressed the best fit relation between Vp and density.

$$V_p\left(\frac{m}{s}\right) = 1010.285 * RHO(\frac{g}{cc})^{0.9919162} \text{……..……………………….. (Eq. 3-1)}$$

Using the Equation 4-1, the Vp is predicted using density log between 834m to 1104m MD and later converted to a compressional sonic log (Figure 4-1-(d)) to remove erroneous data.

4.1.4 Shear Sonic and Shear Velocity Log Prediction

In the Karewa-1 well, two shear sonic logs are available. The DTS log was ran using a shear monopole tool and the DTSU was run using shear upper monopole tool. Some problems are found in the DTS. It has gaps in many depths and does not have any compaction trend (Figure 4-2). The DTS was converted into shear velocity log and named as Vs. From the crossplot of density and shear velocity in Figure 4-3-(a) it can be observed that the shear velocity (Vs) does not change much. Similar observations characterize the crossplot of compressional velocity (Vp) and shear velocity (Vs) of Figure 4-3-(b). This is why these shear sonic (DTS) and sonic velocity (Vs) is counted out.

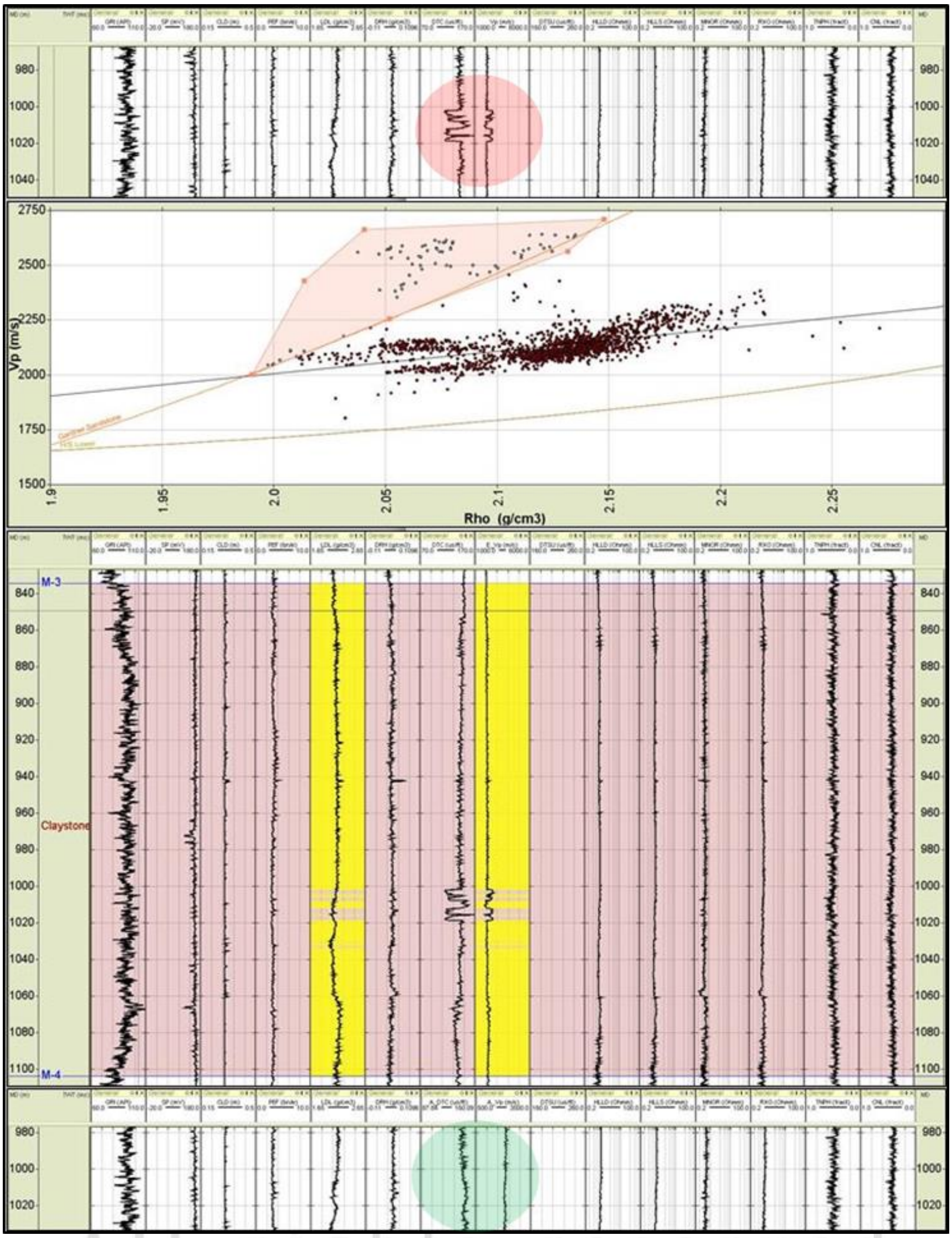

Figure 4-1: (a) Erroneous data problems of sonic logs, (b) Crossplot of sonic velocity and density to identify the erroneous data of sonic logs, (c) problems identified in log data by crossplot, and (d) corrected sonic logs

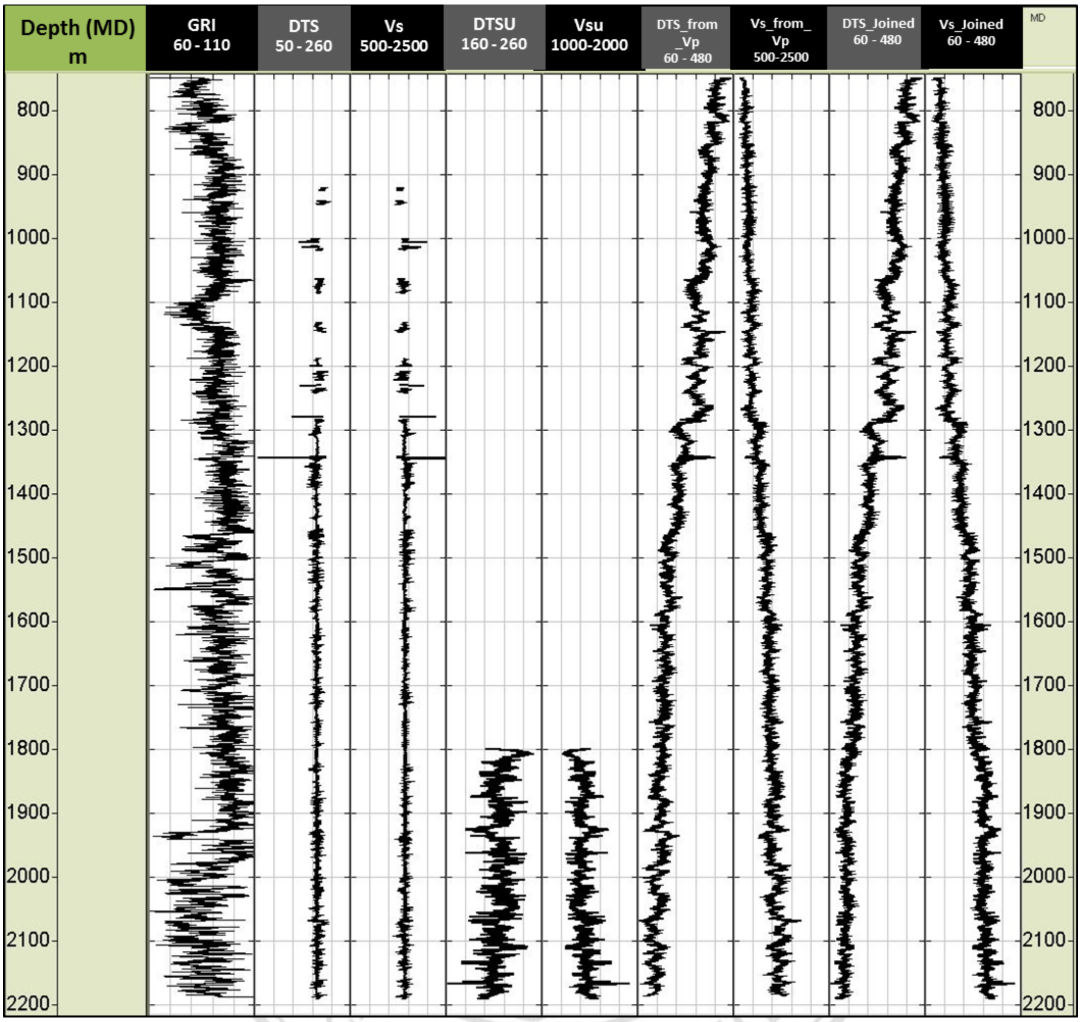

Figure 4-2: Shear sonic logs before and after correction and extraction

The other shear sonic log (DTSU) does not contain gaps and erroneous data and has compaction trend but it was run for a limited depth range between 1800m to 2191m MD (Figure 4-2). This log was also converted to shear velocity and named Vsu. In Figure 4-4-(a) the wide range of shear velocity distribution can be observed even for the small amount data range, and again in Figure 4-4-(b) the trend of Greenberg-Castagna shale and sand is observed.

As the DTSU and Vsu were run for limited depth range, it is necessary to extract shear velocity logs for the whole well from the compressional sonic velocity log (Vp). For this purpose the shear velocity prediction tool of RokDoc was used. The corrected compressional sonic velocity (Vp) log was used as input. The Greenberg-Castagna empirical method was used for this log estimation. After predicting the shear velocity log, it was renamed as Vs_from_Vp (Figure 4-2). This estimation is not based on the fluid substitution. Thus it cannot highlight gas bearing sand correctly.

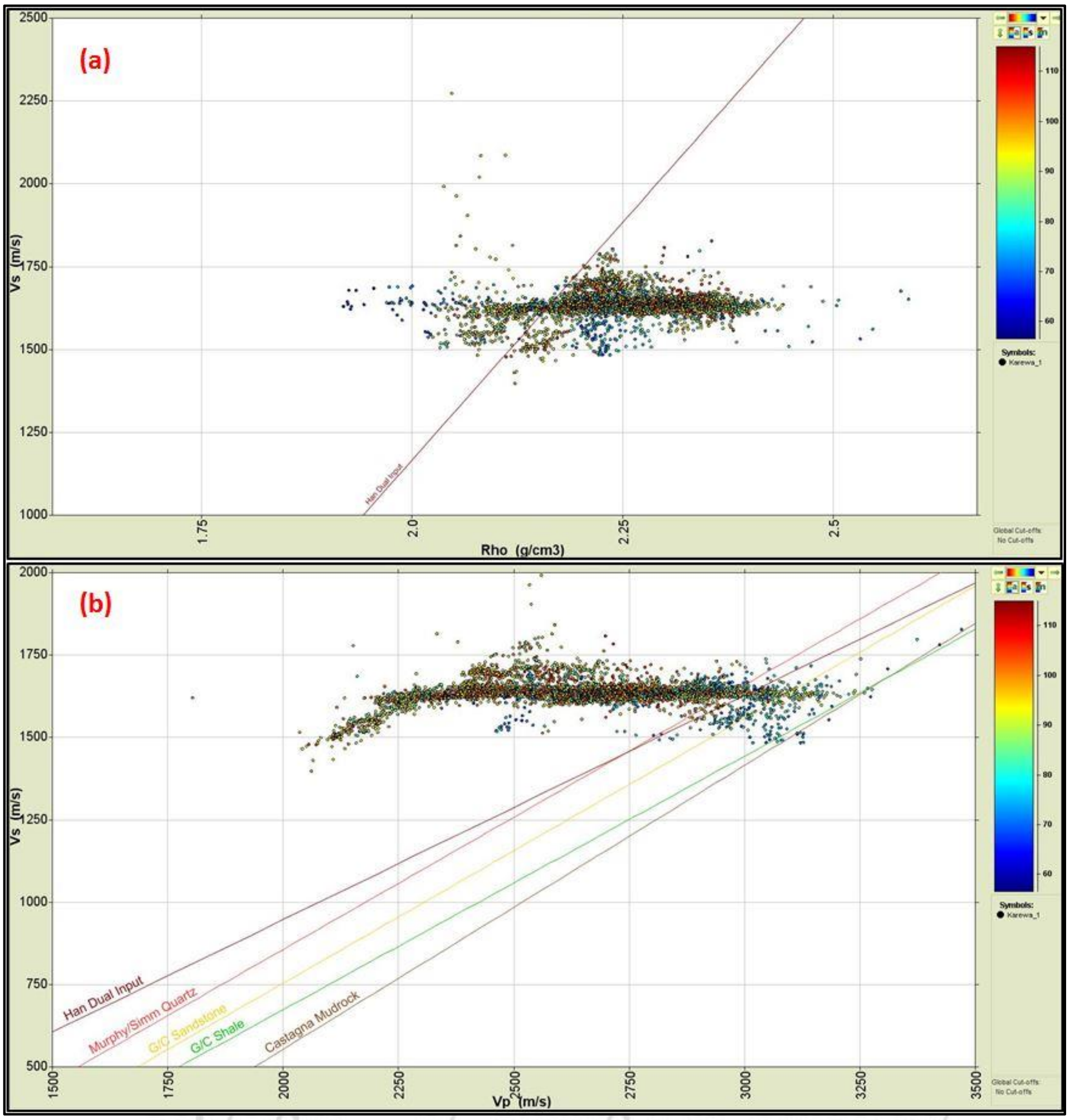

Figure 4-3: Crossplot of erroneous shear sonic velocity with density and compressional velocity: (a) shear velocity vs. density, and (b) Shear velocity vs. compressional velocity

The Vs_from_Vp log is predicted fully from a compressional sonic velocity log. However, a real shear sonic velocity log (Vsu) is available from 1800m to 2191m MD. It is therefore be more realistic to use a joined Vs log can be made using the Vs log consisting of a Vs_from_Vp log for the depth above 1800m MD and the Vsu log for the depth below 1800m MD. The joined shear sonic log was created and named Vs_Joined (Figure 4-2).

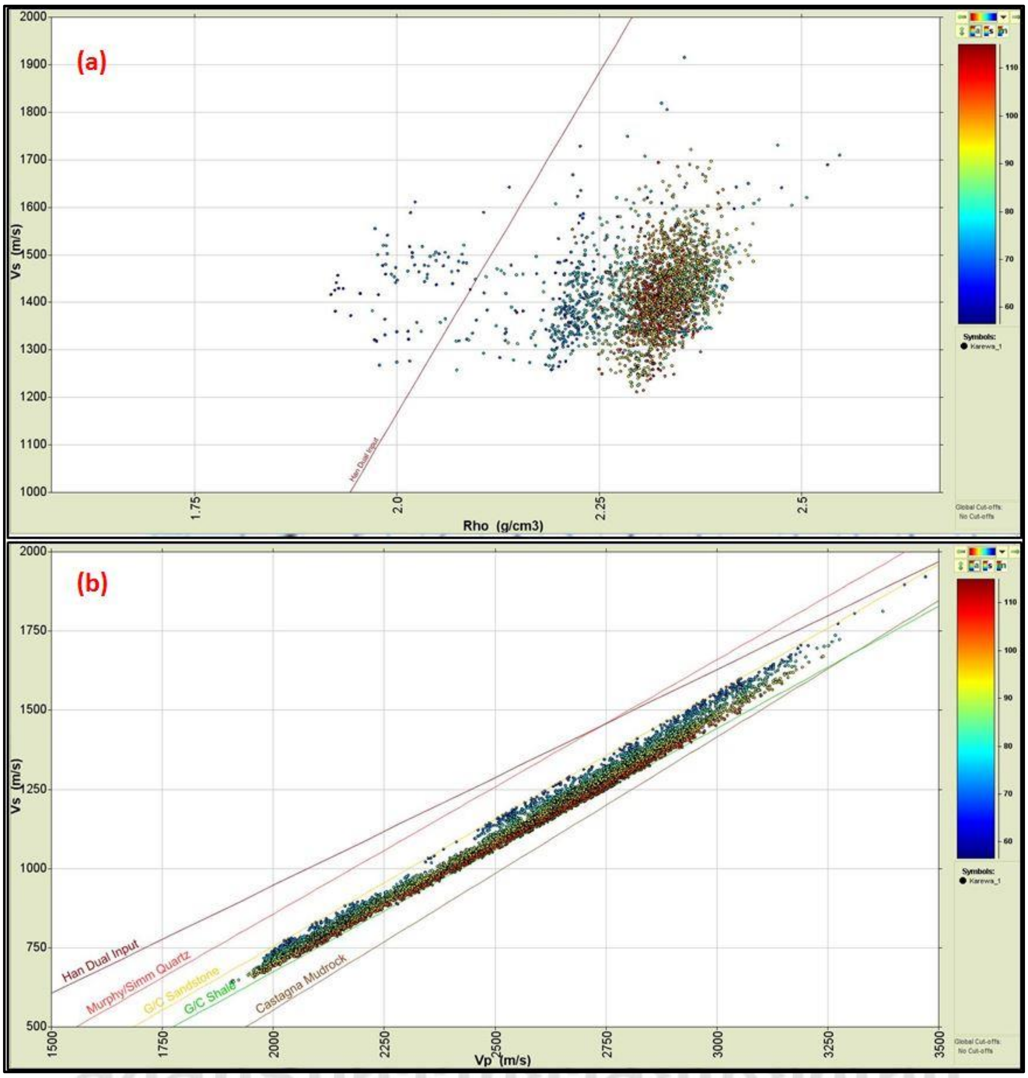

Figure 4-4: Crossplot of correct shear sonic velocity (for limited depth range) with density and compressional velocity: (a) shear velocity vs. density, and (b) Shear velocity vs. compressional velocity

4.1.5 Effective Porosity Log

A thermal neutron porosity log and a compensated neutron porosity log is avalibale in this study. Porosity logs are also estimated from density and sonic logs. A set of RMS porosity logs are also estimated using density porosity log, sonic porosity log, thermal neutron porosity (TNPH) log, and compensated neutron porosity (CNL) log. Among them RMS porosity logs gives best estimation for porosity. It is used to calculate effective porosity log (Figure 4-9). The details is described in Appendix B.

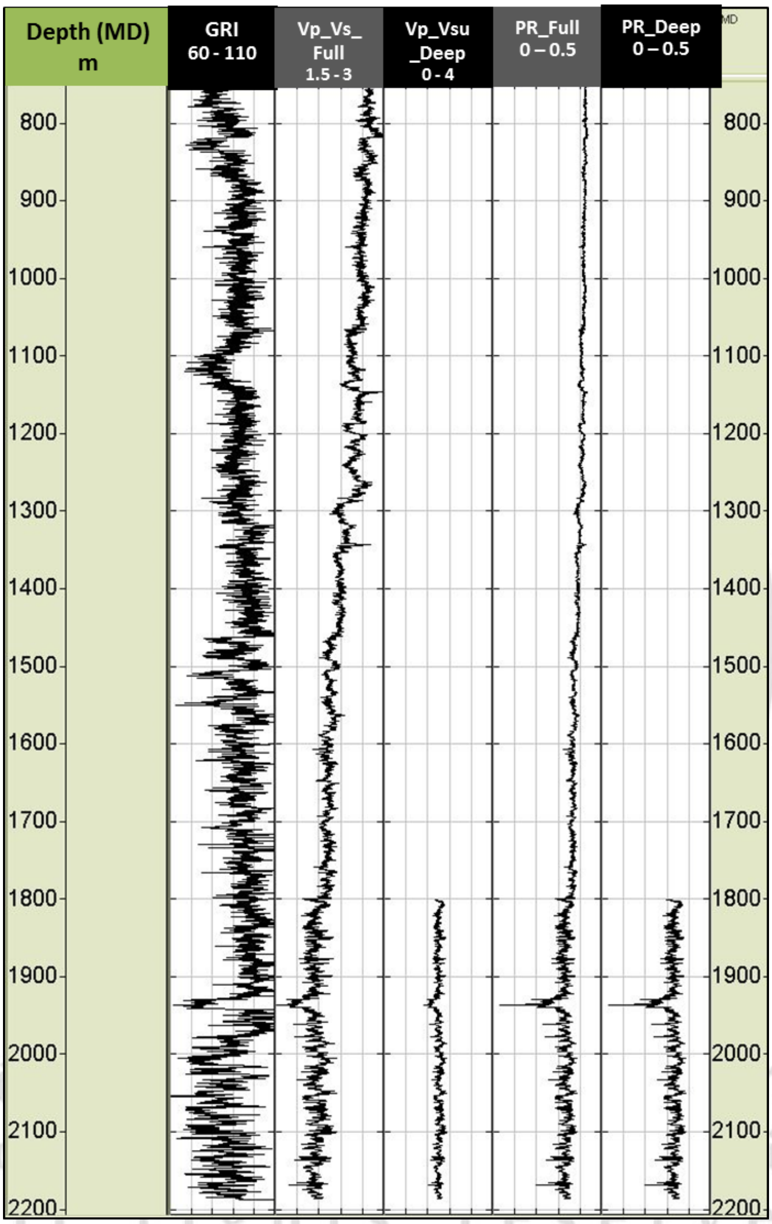

Figure 4-5: Extracted velocity ratio and Poisson's ratio logs

4.1.6 Velocity Ratio Calculation

A velocity ratio is used to rock physical analysis such as lithology prediction and data quality checking. It is also important to calculate the Poisson's ratio. As far two shear velocity logs are available: original shear velocity (Vsu) between 1800m to 2191m MD and joined shear velocity (Vs_Joined) for full interval. To compare the original shear velocity (Vsu) and the the edited compressional velocity (Vp) logs, Vp is clipped from 1800m to 2191m MD. Two velocity ratio logs are calculated using these two pairs of Vs and Vp and named as Vp_Vs_Full for whole section and Vp_Vs_Deep for the zone between 1800m to 2191m MD (Figure 4-5). These velocity ratio logs are used to analysis other rock physical characteristics in later sections (section 4.2).

4.1.7 Poisson's Ratio Calculation

The calculation of the Poisson's ratio can help to determine the lithology from crossplots and to calculate it the compressional and the shear velocity logs are required. Using the velocity ratios calculated in section 4.1.6, two Poission's ratio logs are calculated (Figure 4-5). These Poisson's ratio logs are used to predict the lithology and to analysis other rock physical characteristics in later sections (section 4.2).

4.2 Rock Physics Analysis

In this section crossplots are made to analyze the rock physical properties. In Figure 4-13, the crossplot of velocity ratio (Vp/Vs) and Poisson's ratio (σ) is made to identify the gas sand. From the Figure 4-6-(a) and 4-6-(b), it can be observed that the lithology is mainly sandstone and shale (or claystone). Hydrocarbon bearing sandstone can also be observed from Figure 4-7. Again, the Gardner sandstone and Gardner shale can be differentiated from the Figure 4-8.

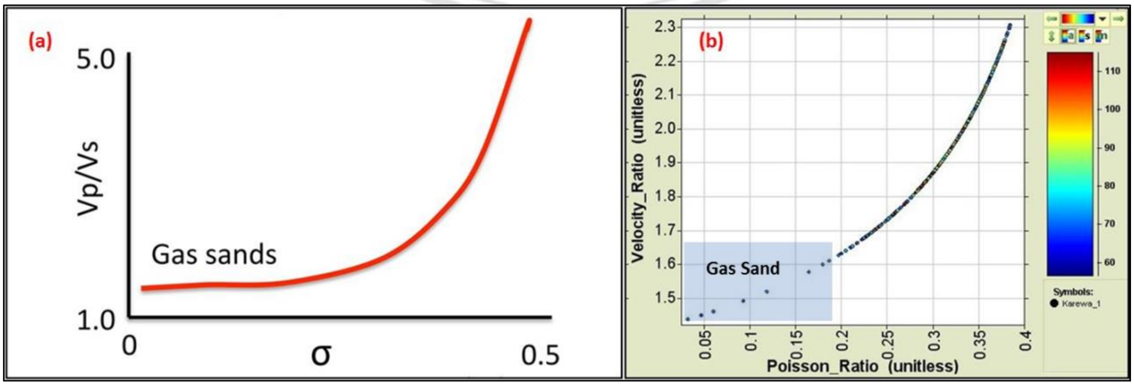

Figure 4-6: Crossplots of velocity ratio and Poisson's ratio to identify the gas sand: (a) Ideal crossplot of velocity ratio and Poisson's ratio, and (b) Study data crossplot

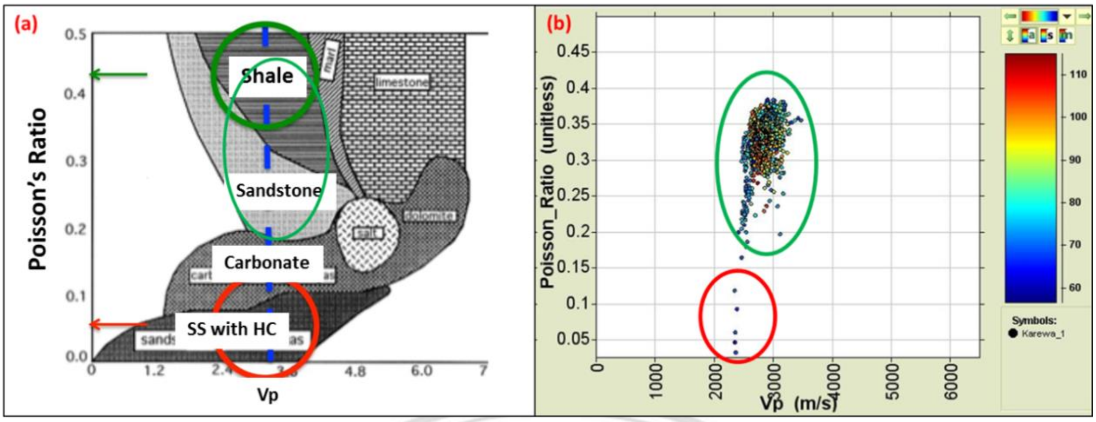

Figure 4-7: Crossplots of Poisson's ratio and compressional velocity to predict the lithology: (a) Ideal crossplot, and (b) Study data crossplot

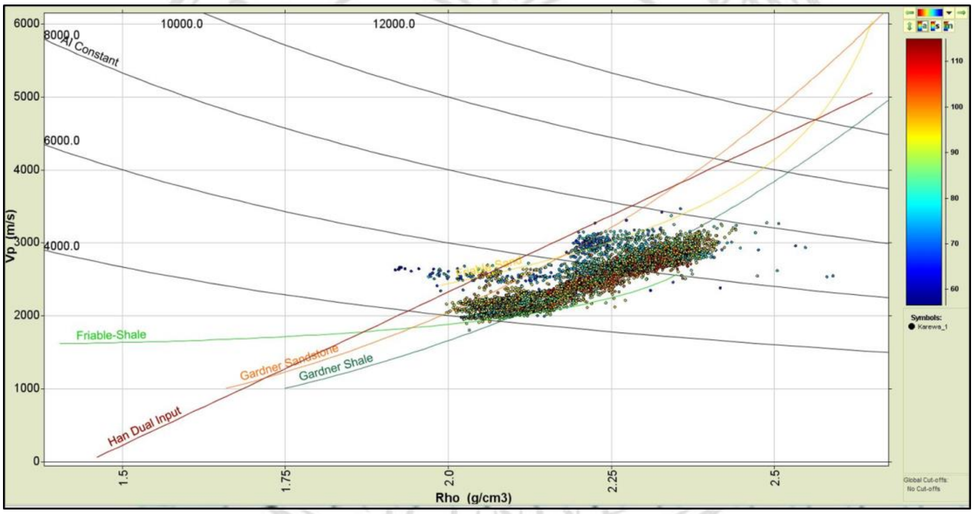

Figure 4-8: Crossplots of compressional velocity and density to identify the Gardner shale and sand trend

After completing all log corrections, conditioning and rock physics analysis the final logs are shown in Figure 4-9. In Table 4-1, the starting and ending depth of logs are shown.

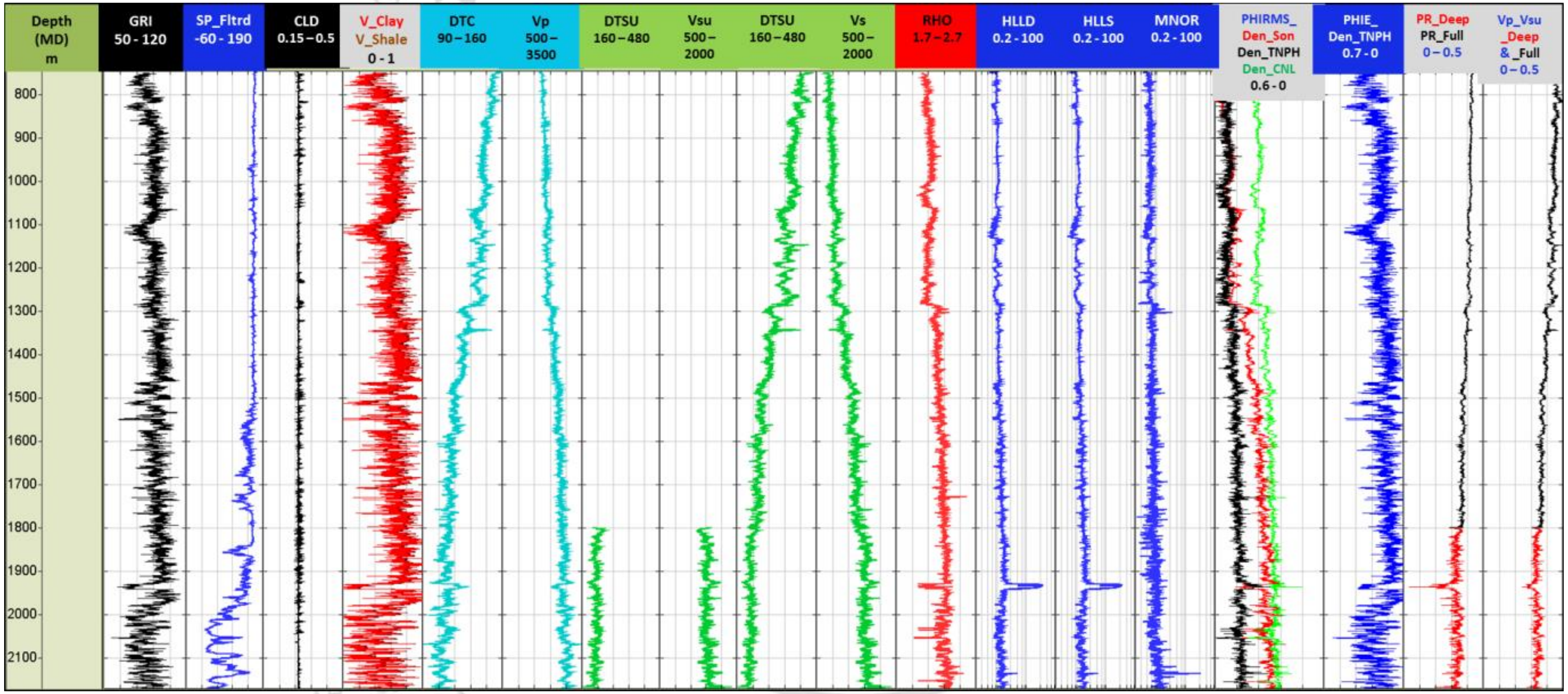

Figure 4-9: Final log view after well log conditioning

Table 4-1: Starting and ending depths of finally selected logs after all correction

Name of Logs	**Start Depth, m (MD)**	**End Depth, m (MD)**
Gamma Ray (GR)	750.0344	2186.7092
SP (SP)	743.024	2180.3084
Caliper (CLD)	743.024	2191.586
Photoelectric (PEF)	743.024	2191.586
Density (RHO)	752.0156	2186.7092
Density Correction (DRH)	743.024	2192.6528
Sonic Slowness (DTC)	743.024	2186.8616
Shear Slowness (DTSU)	1800.5276	2191.2812
Sonic Velocity (Vp)	743.024	2186.8616
Shear Velocity (Vsu)	1800.5276	2191.2812
Deep Resistivity (HLLD)	743.024	2208.6548
Shallow Resistivity (HLLS)	743.024	2191.586
Micro Resistivity (MNOR)	743.024	2190.3668
Flushed Resistivity (RXO)	743.024	2186.7092
Thermal Neutron (TNPH)	743.024	2189.7572
Compensated Neutron (CNL)	743.024	2189.7572