Sabah Basin

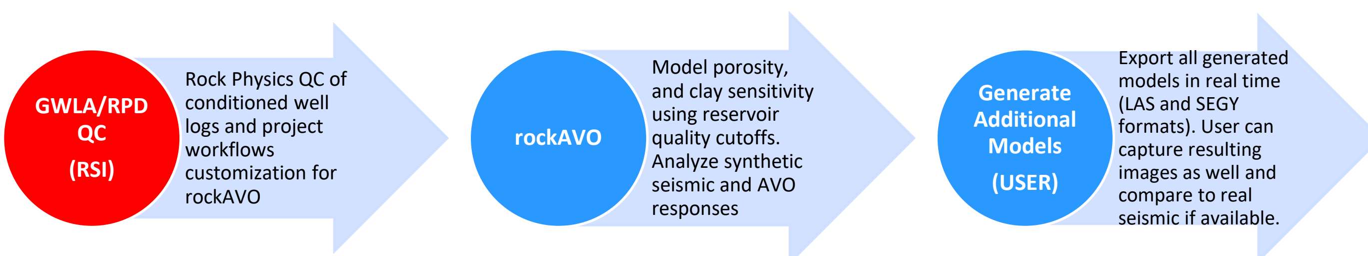
rockAVO Background Work and Deliverables

- *Geophysical Well Log Analysis* (GWLA) and *Rock Physics Diagnostics* (RPD) provided a consistent set of well log data ready for quantitative interpretation purposes.

- Rock physics Diagnostics indicated that the Intermediate Stiff, the Soft Sediment, and the Stiff Sediment models provided a good fit to the measured data trends in the bulk density versus velocity domain for the lithologies interpreted in wells of this study. The particular model used is indicated by a marker in the logplot views in this report.

- **rockAVO** provides an interactive visualization tool so that multiple hydrocarbon properties, porosity and clay content scenarios can be modelled in real time, and in addition to the existing deliverables of the conditioned well log data.

- Main workflow can be generalized in three main steps



LFP Workflow Details

Workflow: LFP

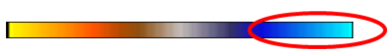
Run Restore Values

			Description
ModelTop	*m*	2060	Defines top depth of modeling interval
ModelBase	*m*	3260	Defines bottom depth of modeling interval
AVAPickDepth	*m*	3120	Depth for extracting AVO signature from synthetics
GOC	*m*	3140	**Defines the Gas- Oil contact depth**
WaterSaturation		0.2	Water Saturation. Gas and Oil cases will be 1-Sw
PorosityShift		0	Controls porosity scenario*
ClayShift		0	Controls lithology (VQuartz scenario)*
WaveletType		Ricker	Controls wavelet type
SeismicFrequency	*Hz*	25	Dominant seismic frequency
ClayCutOff		0.45	Reservoir quality clay cutoff for **fluid sub marker**
PorosityCutOff		0.04	Reservoir quality porosity cutoff for fluid sub marker
GasGravity		0.8	Gas gravity parameter
OilGravity		41.5	Oil gravity parameter
GasOilRatio	*L/L*	29	GOR parameter
CalciteCutOff		0.5	**Reservoir quality calcite cutoff for fluid sub marker**
OffsetIncrement	*m*	100	**Seismic geometry parameter (offset increment)**
NTraces		40	**Seismic geometry parameter (number of traces)**
AmpMuteAngle	*degree*	37	**Amplitude mute for synthetic modeling**
BackgroundShale		0.3	**Clay cutoff to define background data in crossplots**

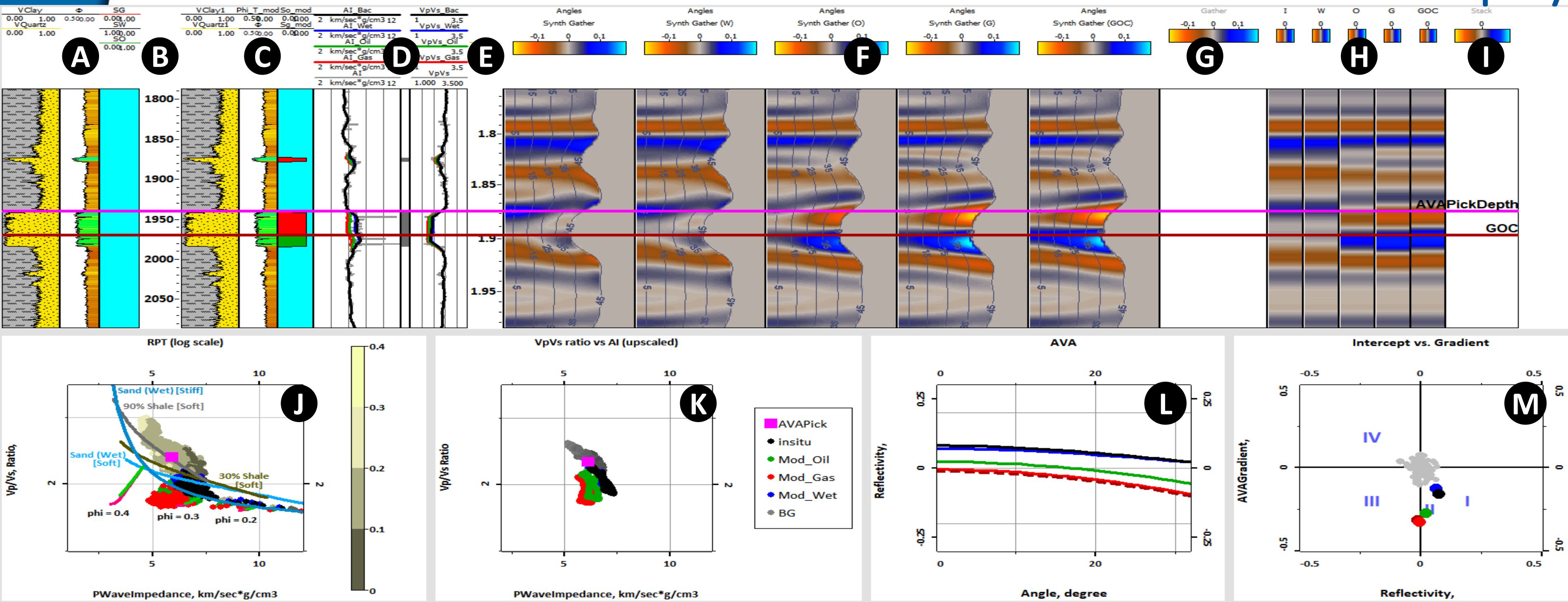
***All parameter default values are the RSI-recommended inputs for a base case where only fluid content changes (clay and porosity remain as *in situ*)**

Modelling Description and Parameterization

- Perturbational models are defined based on the clay volume and porosity cut-offs. The suggested values for the clay volume and porosity cut-offs vary by well but are generally 40% and 10%, respectively.
- In these wells quartz is used to balance the clay modelling, when clay is increased the quartz is decreased by an equal amount.
- Full Offset Synthetics created using Ray Tracing method.
- Synthetics generated for all fluid models on upscaled elastic curves Backus smoothed on variable window size based on velocities and Dominant Frequency.
- No multiples or mode conversions are included.
- Seismograms are generated using a Ricker wavelet with a dominant frequency that can vary as per user selection.
- Synthetic and AVA parameters included in the workflows that can be modified are:
  - Offset range: by modifying number of traces and offset increment
  - Amplitude Mute
- Increase in impedance is a peak (blue)



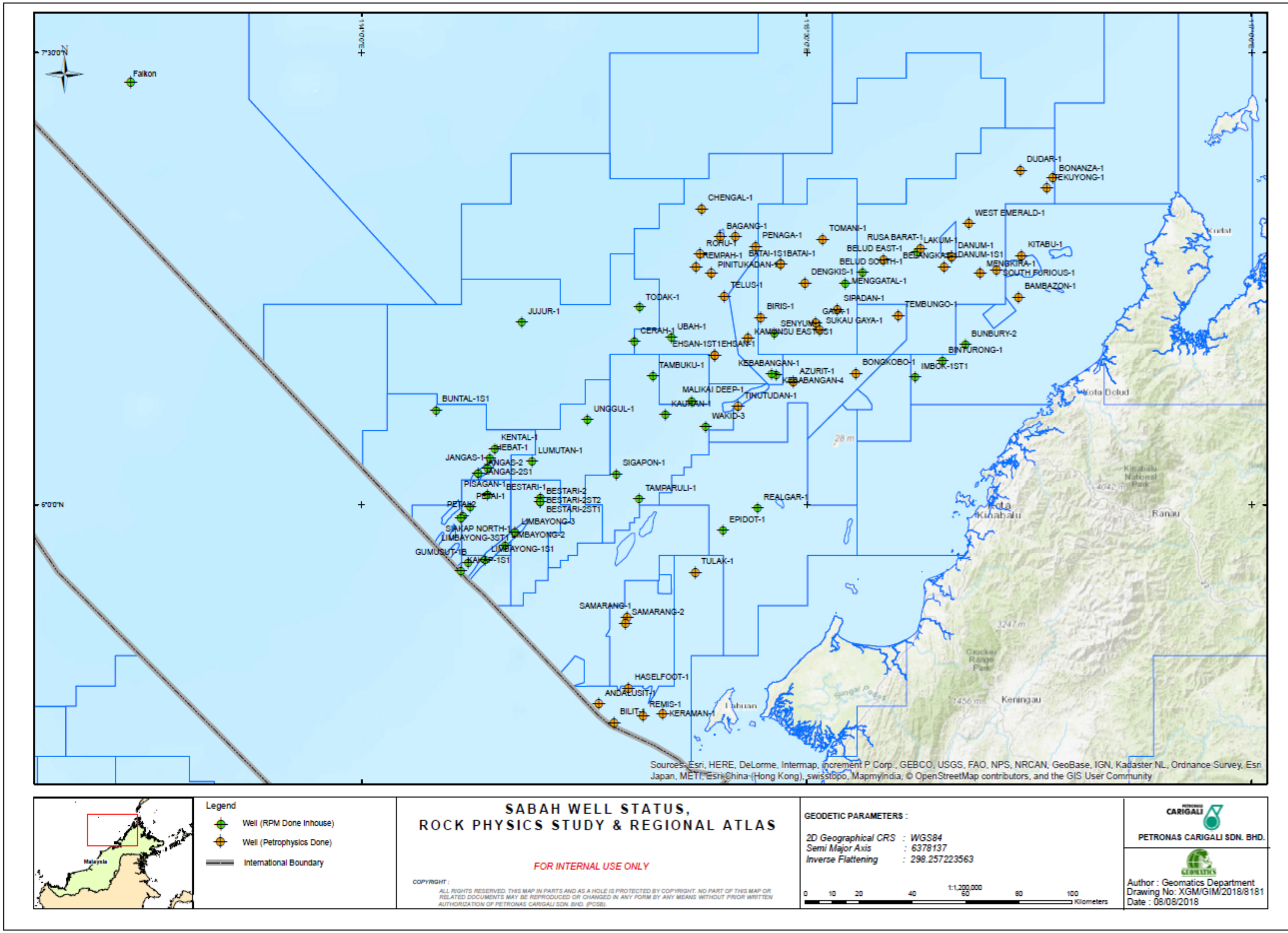
rockAVO Montage View* (LFP version) Main Display



A. In situ Scenarios: Mineralogy track (VClay, VQuartz, VCalcite); Total Porosity (left, 0.5 to 0 fract); and Saturations (right, 0 to 1 fract: green for oil, red for gas, and cyan for water)
B. Measured Depth (m)
C. Modelled Mineralogy track (e.g. VClay at the expense of VQuartz), Total Porosity (left, 0.5 to 0 fract) and Saturations based on marker (right, 0 to 1 fract: green for oil, red for gas, and cyan for water)
D. Upscaled p-wave impedance (left, in this case 0 to 15 km/s*g/cc) and Vp/Vs ratio (right, 1 to 3.5 ratio)
E. Computed two-way time (secs)
F. Synthetic gather seismograms based on modelling parameters (in situ Sw, 100% wet, oil, gas, and gas-oil contact cases)
G. Optional track for importing seismic gather data
H. Synthetic stack seismograms based on modelling parameters (in situ Sw, 100% wet, oil, gas, and gas-oil contact cases)
I. Optional track for importing seismic stack data
J. Well log scale P-Impedance vs Vp/Vs ratio crossplot (magenta dot indicates the values for the selected AVA Pick depth). RPT is overlaid to the data for comparison
K. Upscaled P-Impedance vs Vp/Vs ratio crossplot
L. Angle versus reflectivity plot for the depth selected in the AVA Pick depth input
M. Intercept versus gradient plot for the depth selected in the AVA Pick depth input

* - view has been stretched to fill screen

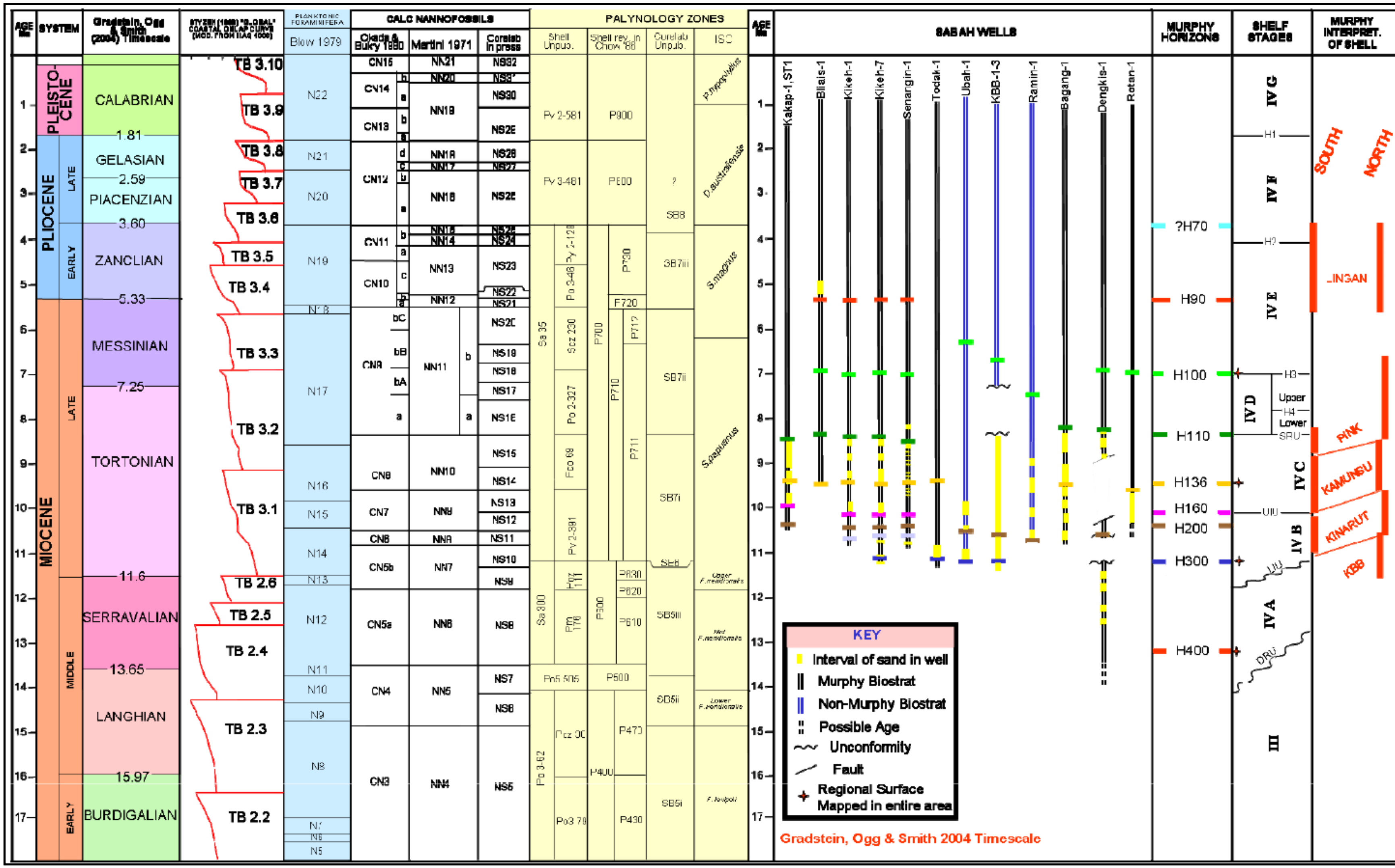
Overview Location Map



Wells List

Andalusit-1	Bongkobo-1	Kitabu-1	Sipadan-1
Azurit-1	Chengal-1	Mengkira-1	South Furious-1
Bagang-1	Danum-1	Penaga-1	Sukau Gaya-1
Bambazon-1	Danum-1S1	Pinitukadan-1	Tekuyong-1
Batai-1	Dengkis-1	Remis-1	Telus-1
Batai-1S1	Ehsan-1	Rempah-1	Tembungo-1
Belangkas-1	Ehsan-1 ST1	Rohu-1	Tinutudan-1
Belud East-1	Haselfoot-1	Rusa Barat-1	Tomani-1
Bilit-1	Hebat-1	Samarang-1	Tulak-1
Biris-1	Kamunsu East-1 ST1	Samarang-2	West Emerald-1
Bonanza-1	Kental-1	Shrumbu-1	

Regional Stratigraphic Chart



Chengal-1 final geological report

Single Well Report

Andalusit-1

Andalusit-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is fair. Client's petrophysical interpretation was not provided for this well. Full elastic logs available only in the interval(1200m-T.D.) except density runs only starting from 2350m.
- Vp and Vs was edited using the RPD in some intervals especially from top intra IVC blue to the T.D.
- In some intervals due to the bad hole conditions, Rhob was edited using the RPD.
- Density was fully modelled using the RPD in the interval 1200-2350m.
- Although the density run starting at about 4400m to the T.D. looks not following the normal compaction trend(sharp drop in the porosity profile) so we decided as per Petronas request to leave as it with no edit or correction.
- Other logs include Gamma, Neutron, Caliper, Deep and Shallow resistivity, and Photoelectric factor which all run for the full logging run except Neutron runs only starting from 2300m to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Miocene marine sands in the IVC stage. These are a series of turbiditic fine to very fine sands.
- The well penetrated many good sand layers in the IVC stage especially in the Intra IVC blue zone where the main gas bearing sand could be observed with total porosity up to 21% .

Volume of hydrocarbons:

- Interpreted gas saturation was best in the Intra IVC blue zone in the interval 4040-4055 m and 4500-4210 with values up to 60% and 52% respectively.

Water saturation (Sw):

- Water sample obtained from the well yielded a salinity of a bout 14000ppm which reflected in a water resistivity value of a bout 0.153ohm at 214. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.8 and Saturation exponent (n)=2 (Based on the final well report)

Andalusit-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that from the point where the elastic logs started down to the T.D. the Stiff sand model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for sand rich intervals while the soft sediment model honor more the elastic trend for the clay rich intervals. In the interval starting from 3900m to the T.D the clay rich intervals agrees more with the stiff model for the all the elastic domains when compared to the measured data .

Fluid properties:

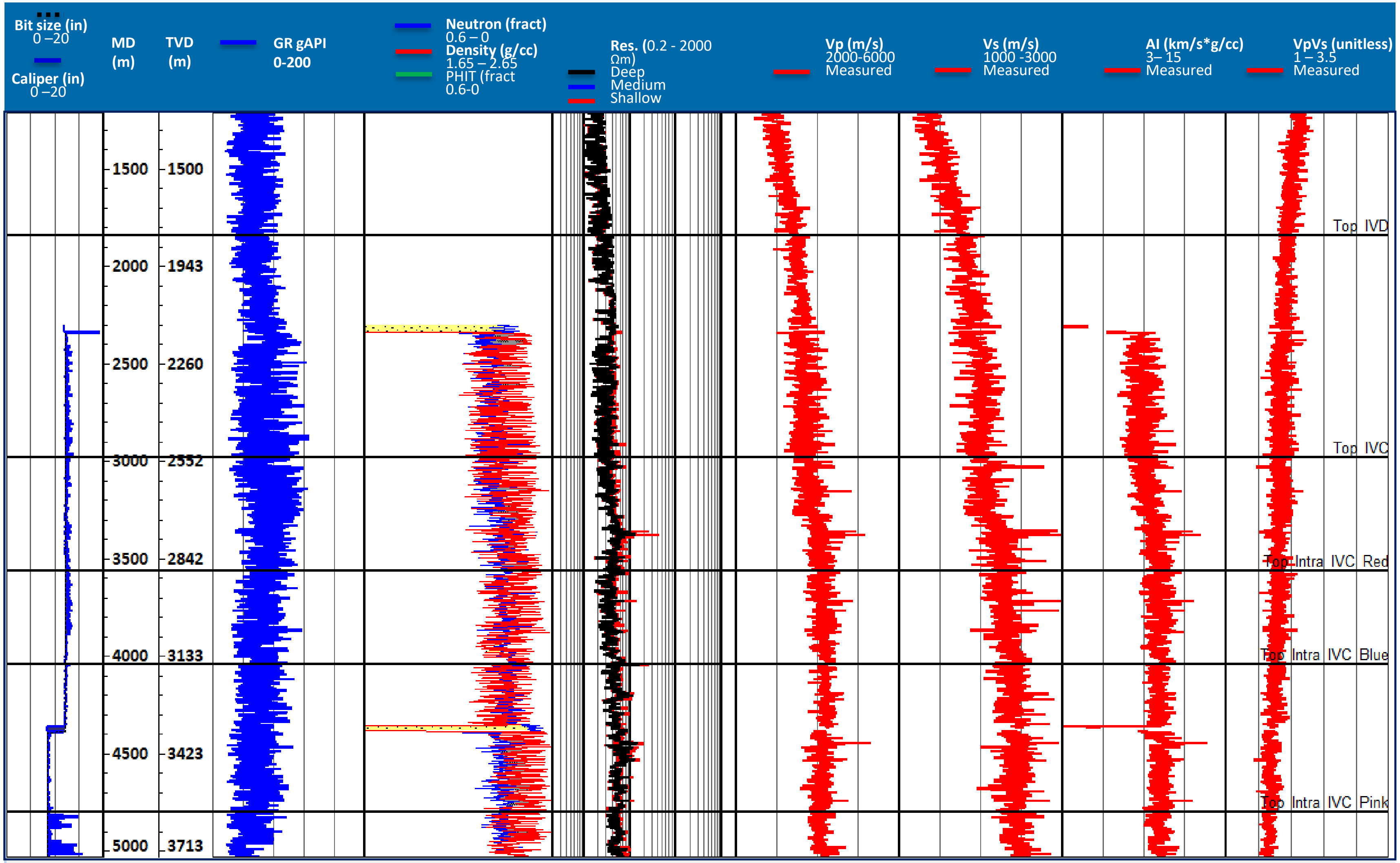
Fluid properties used in substitution have been taken from PVT report of nearby well Samarang-1(test#2). Main parameters used in this modeling are:

- Brine salinity: 14000ppm[Water sample]
- Gas gravity: 0.84[PVT analysis]
- Oil Gravity: 37.7 API[PVT analysis]
- Gas / Oil ratio: 566 (L/L) [PVT analysis]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the IVC stage using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with poor to fair discrimination with the brine sands.
- AVA class I was observed near the gas sands @4170m for all fluid cases at in situ reservoir conditions with very poor fluid discrimination.
- By upgrading the reservoir quality(increasing porosity and decreasing clay content) no significant change for the AVA class could be noticed for all fluid cases but the fluid discrimination between the hydrocarbon and brine cases enhanced a bit.

Andalusit-1 Input Logs



Additional data includes pressure, temperature data, cuttings descriptions and final geological report.

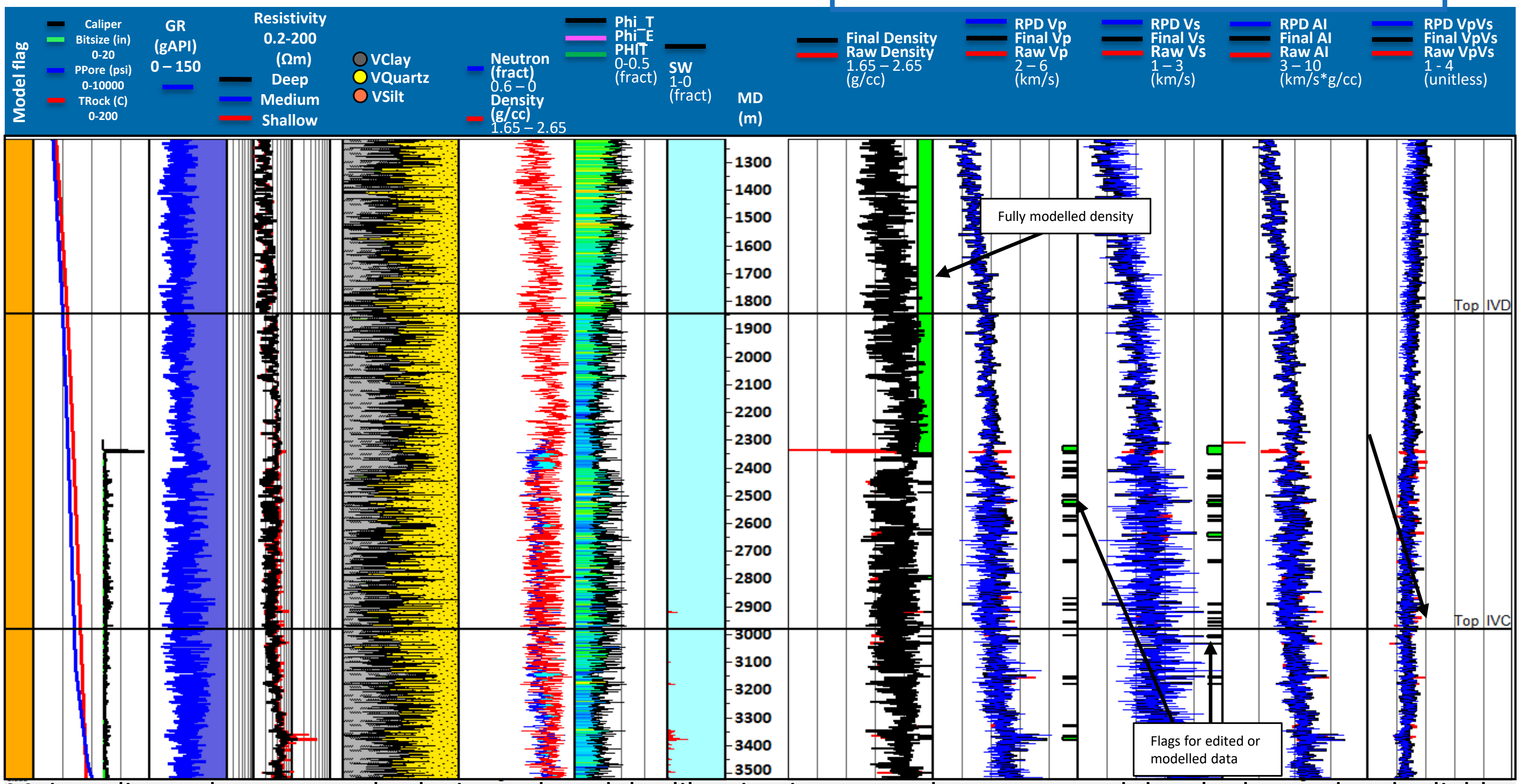
Andalusit-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of Elastic logs to 3500 m

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

model type flag

- Unconsolidated rock model
- Stiff rock model



Major edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (Stiff sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) for sand rich intervals and soft model for clay rich ones, with good correlation with the measured data.

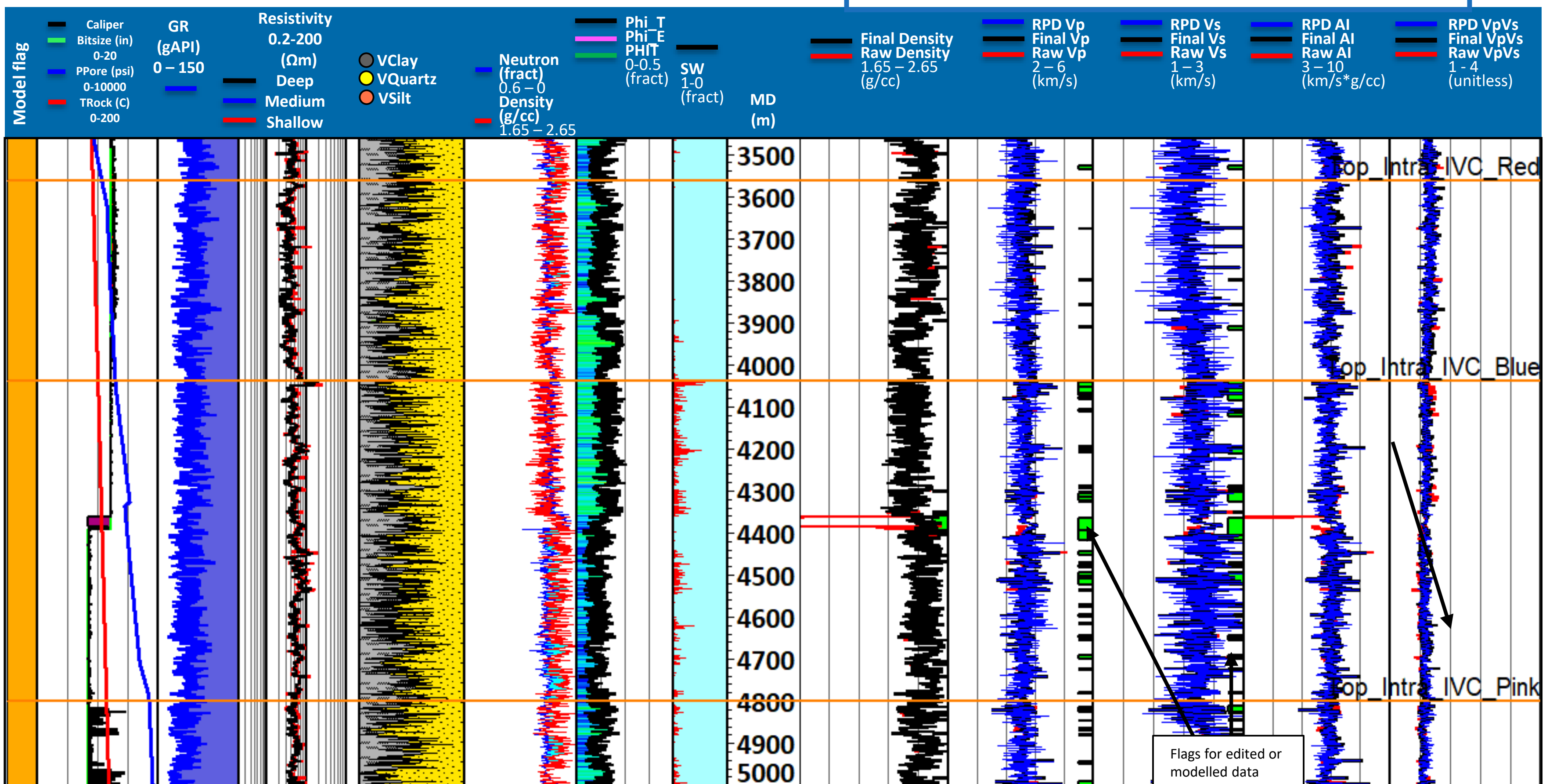
Andalusit-1 Geophysical Well Log Analysis (GWLA) – Interval From 3500 m(MD)to the end of the elastic logs

Equivalence between RSI and Petronas naming.
Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

model type flag

- Unconsolidated rock model
- Stiff rock model

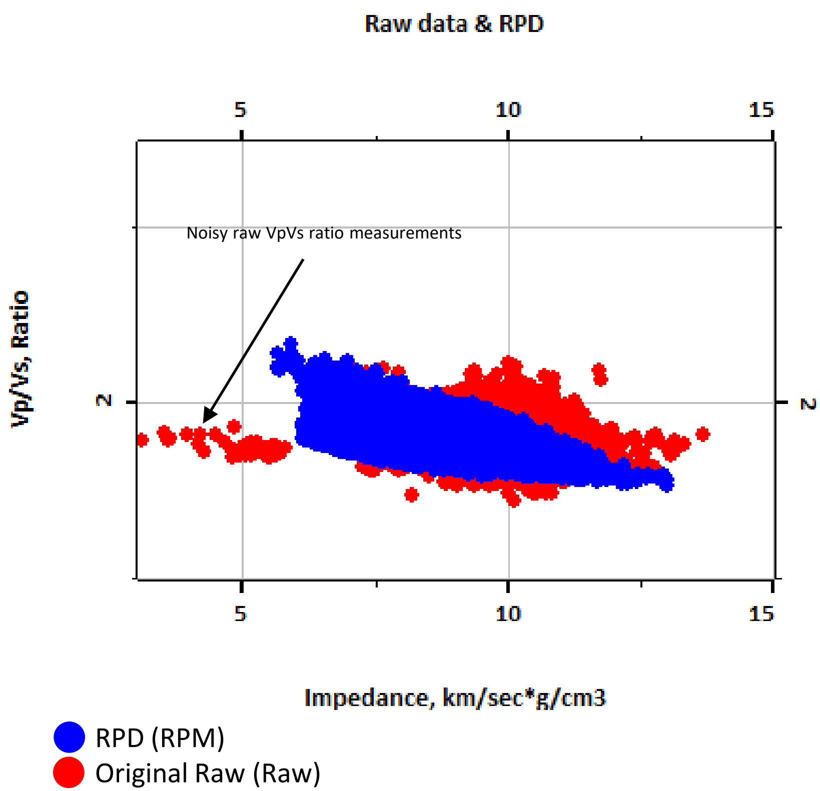


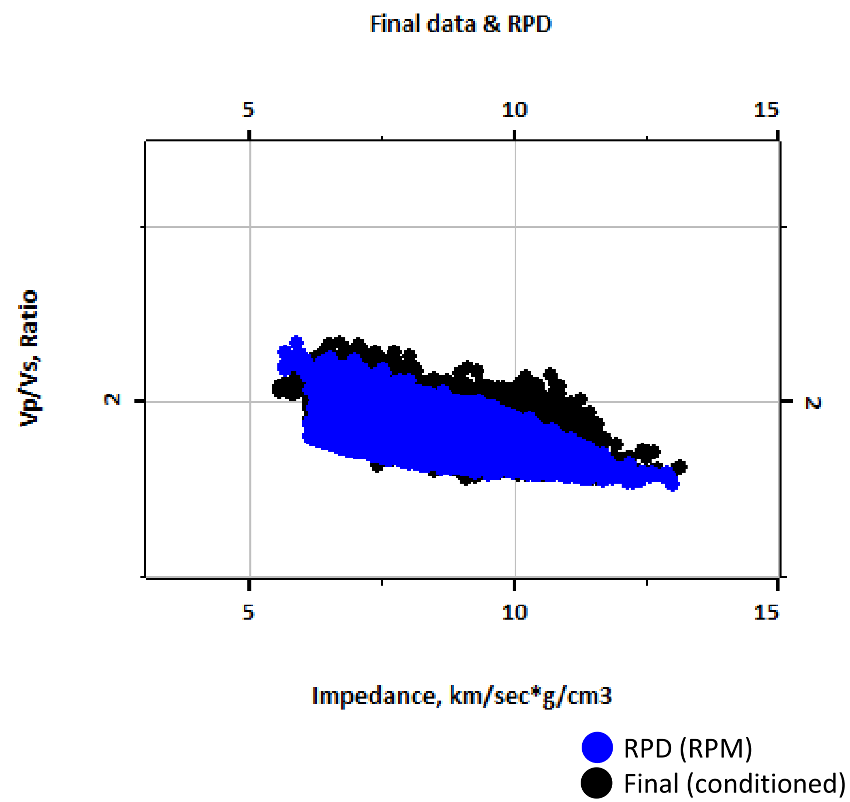
Major edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (Stiff sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) for sand rich intervals and soft model for clay rich ones, with good correlation with the measured data.

Andalusit-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

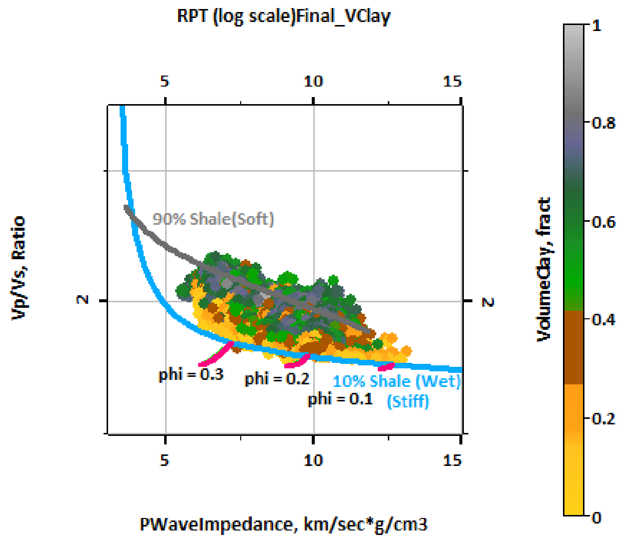


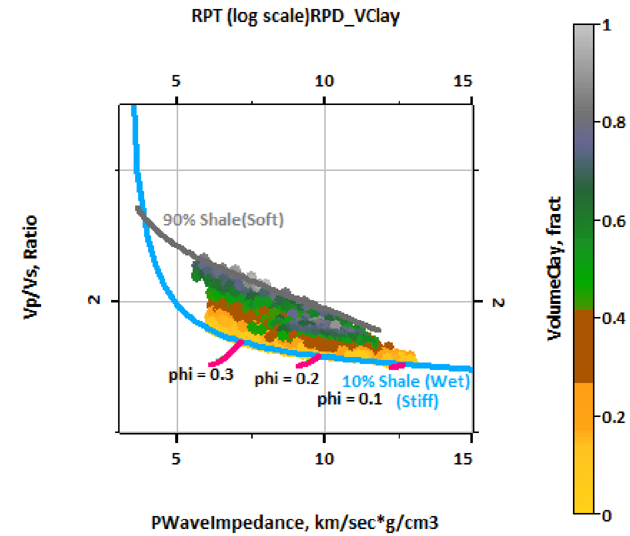


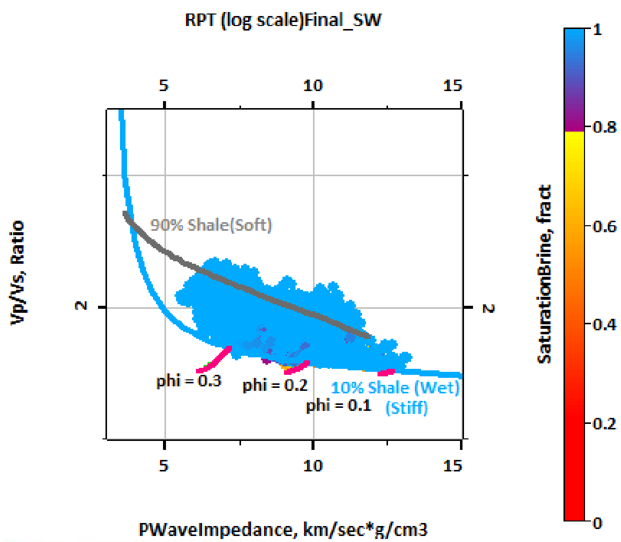
Andalusit-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

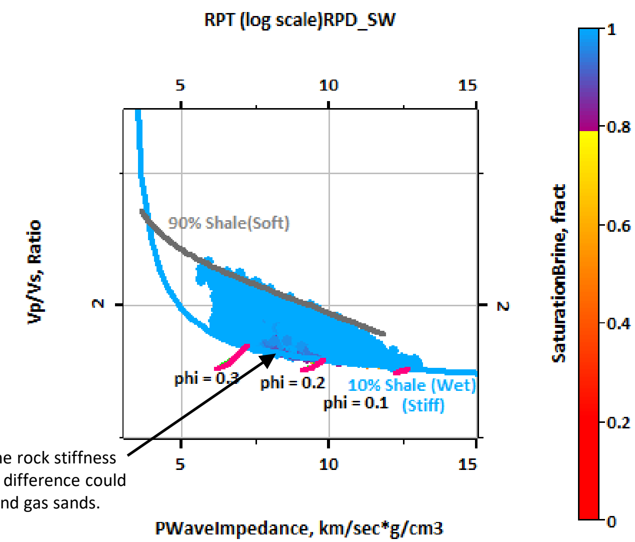
RPT cross plot shows the correlation between the rock physics model lines(soft/Stiff sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









Due to the burial depth and the rock stiffness for the deeper sand only minor difference could be observed between wet and gas sands.

RPD(Modelled)data

Azurit-1

Azurit-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is poor especially the velocity measurements. Client's petrophysical interpretation was fully provided as a reference.
- Vp was heavily edited using the RPD in the intervals(2100-2280 and 2360-2400m) due to unreliable measurements when compared to nearby wells' velocity trend.
- Vs was edited in some intervals to maintain consistency in the VpVs ratio in clay and sand rich intervals.
- Other logs include Gamma, Neutron, Caliper, Deep, Shallow and Medium Resistivity, and Photoelectric factor which all run for the full logging run.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is the late Miocene intervals(2295-2630m). These are a series of turbiditic fine to very fine soft sands.
- The well penetrated only two thin sand intervals in Kinarut formation while more well-developed sand in Kamunsu formation and all had some gas content.
- The penetrated Kebabangan thin sand sections were all brine saturated.

Volume of hydrocarbons:

- Interpreted gas saturation was best in the 2316-2323 m sand with values up to 40% with some residual gas saturation(1-5%) down to 2339m.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the section below the gas saturated sand yielded a formation water salinity of 29000 PPM. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.85 and Saturation exponent (n)=2 (as in the final geological report).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to the measured data and also when compared to good measured data in the nearby reference wells.

Fluid properties:

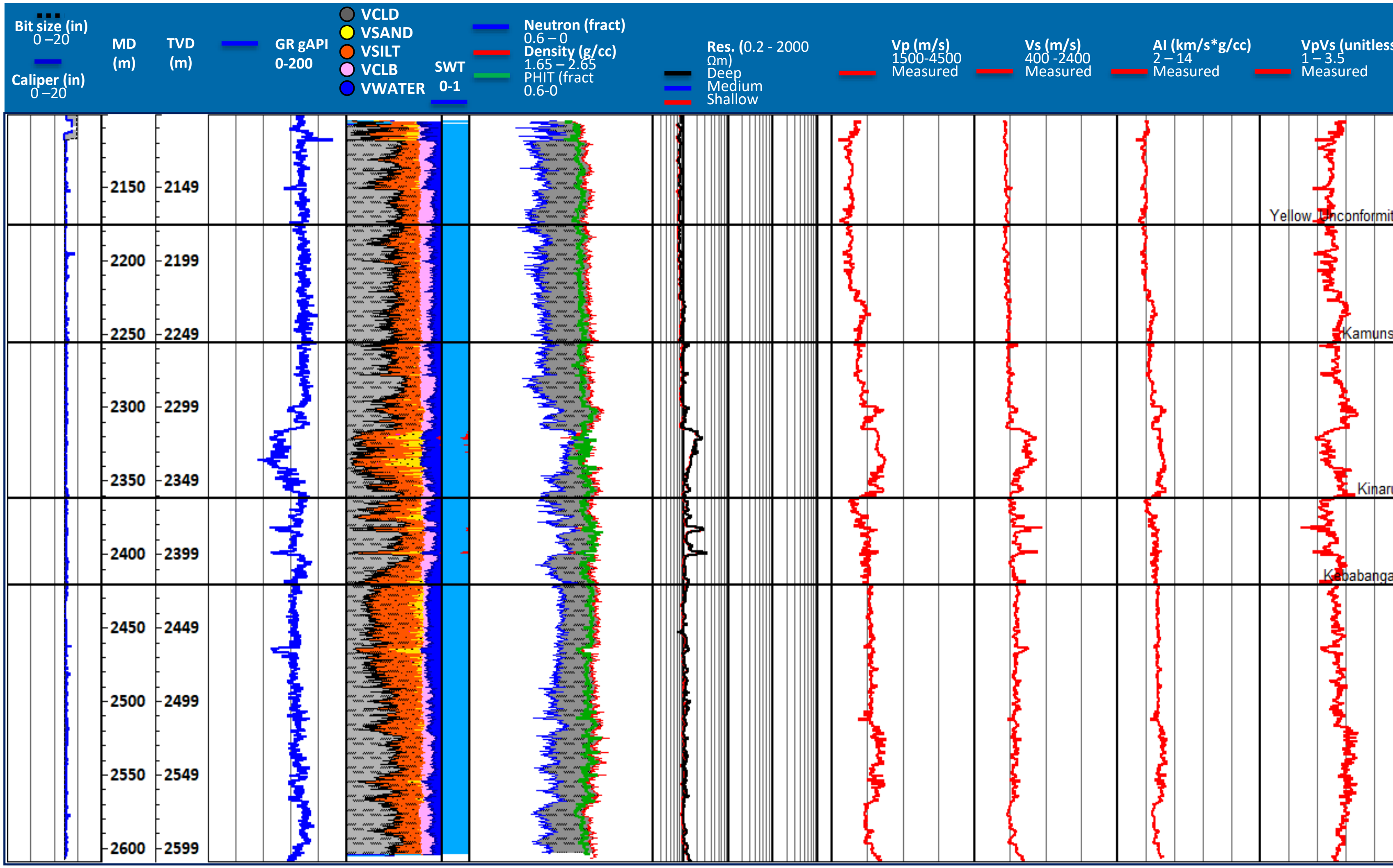
Fluid properties used in substitution have been taken from PVT well reports. Main parameters used in this modeling are:

- Brine salinity: 29000 ppm
- Gas gravity: 0.797[PVT analysis]
- Oil Gravity: 45.8 API[PVT analysis]
- Gas / Oil ratio: 200 (L/L) [Assumed based on area results]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different late Miocene sands(Kebabangan, Kamunsu and Kinarut formations)using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination with the brine sands.
- No significant change occurred by decreasing the porosity of the reservoir interval.
- AVA class II was observed near the Kamunsu sands @ 2315m for all hydrocarbon cases at in situ porosity compared to class I for the brine case.

Azurit-1 Input Logs



Additional data includes pressure, temperature data, cuttings descriptions and final geological report.

Azurit-1 Geophysical Well Log Analysis (GWLA) – Interval from 2100m to the end of logs

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

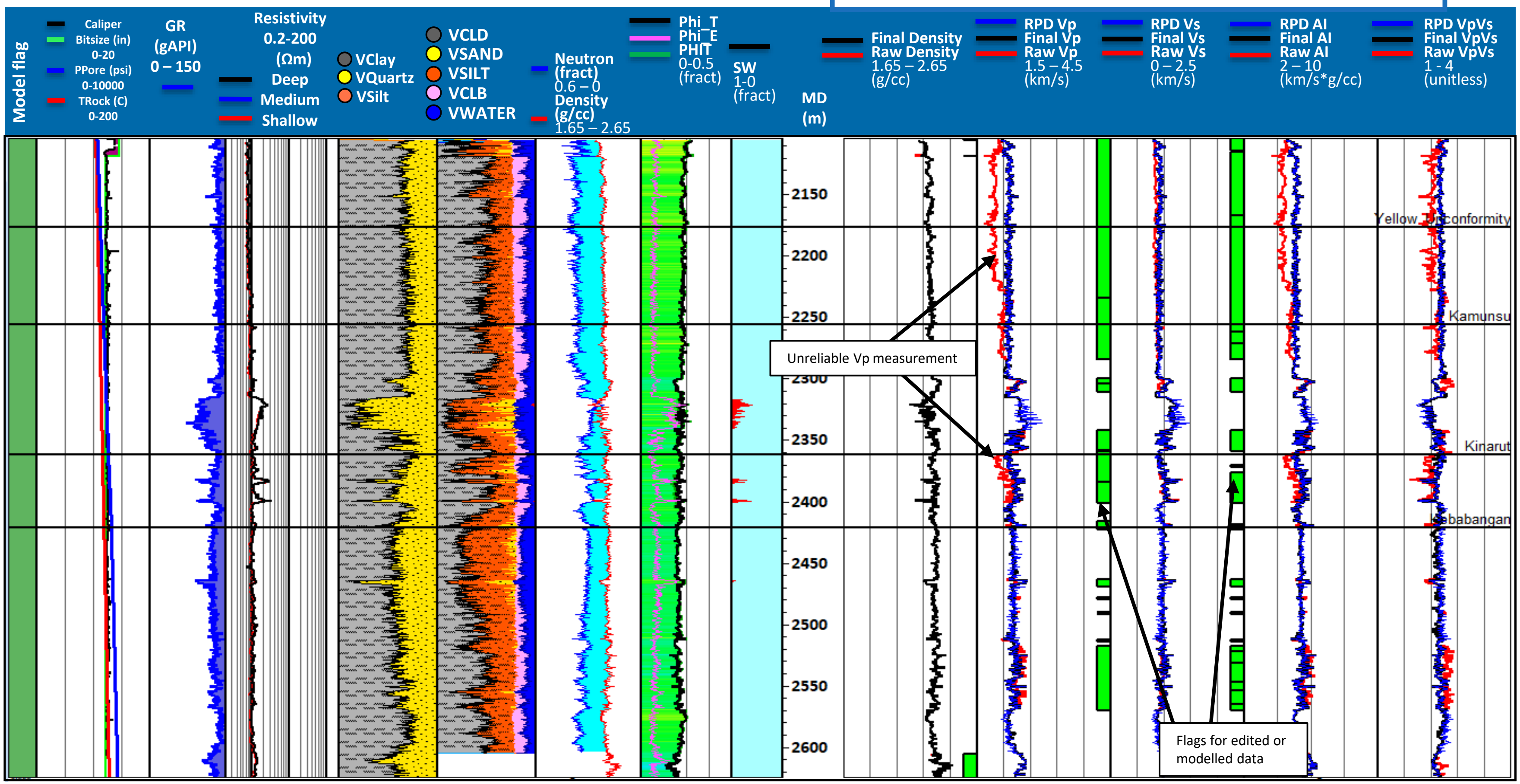
Final edited (Conditioned) curve

Original Raw (Raw) curve

model type flag

Unconsolidated rock model

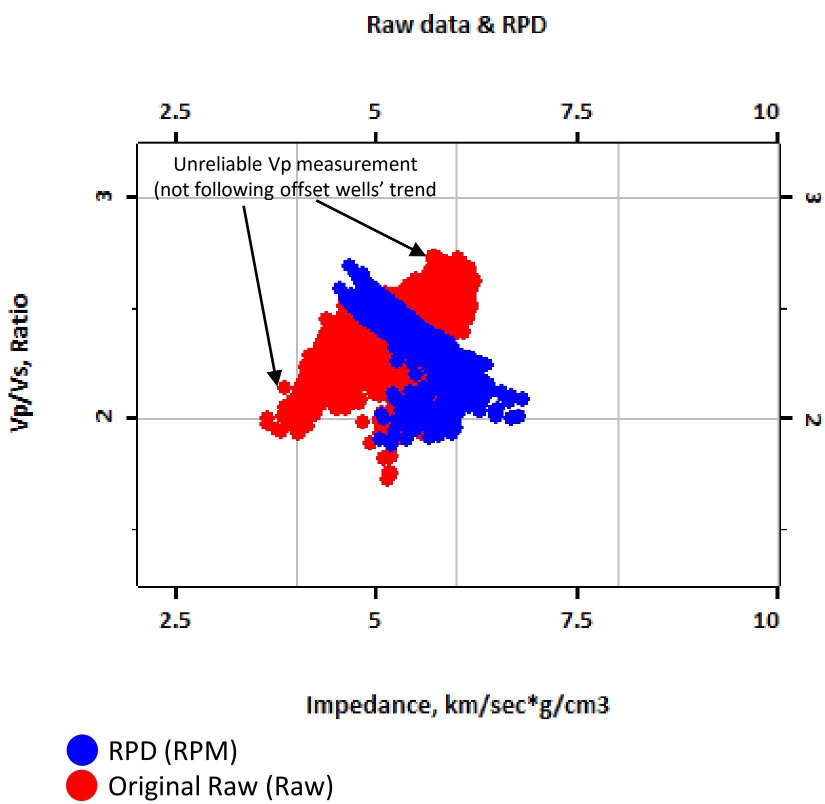
Stiff rock model



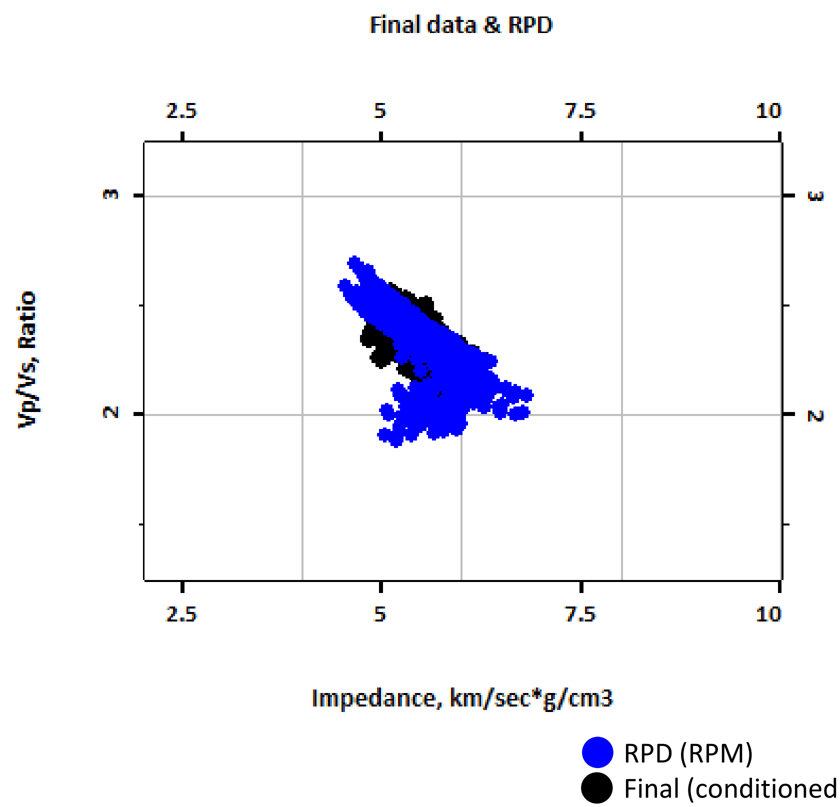
Major edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

Azurit-1,Rock Physics Diagnostics (RPD)
Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.



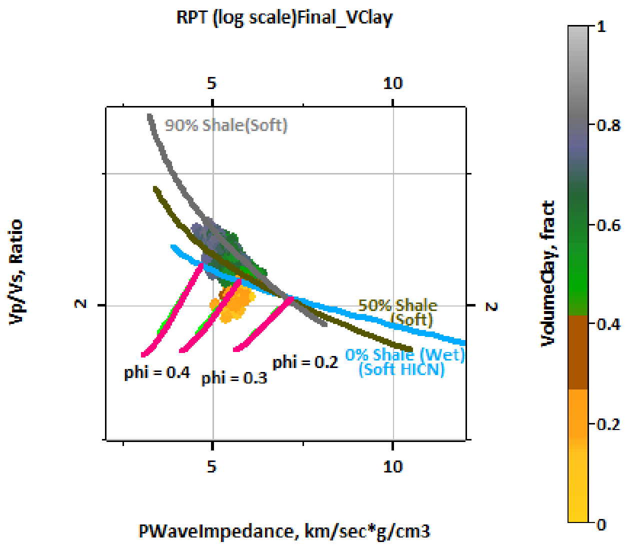
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

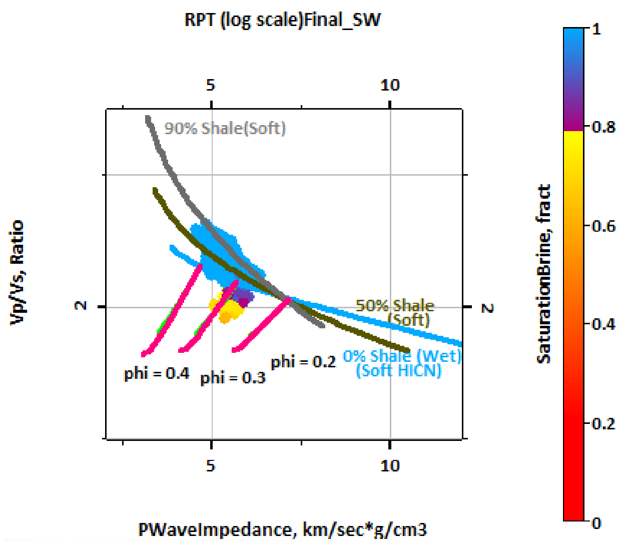


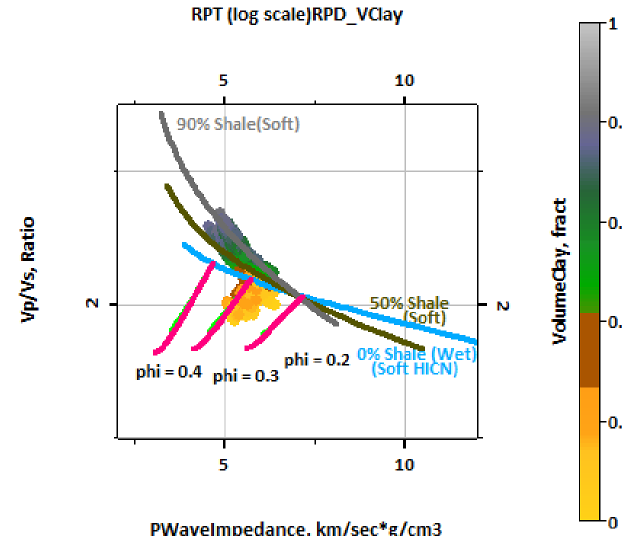
Azurit-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

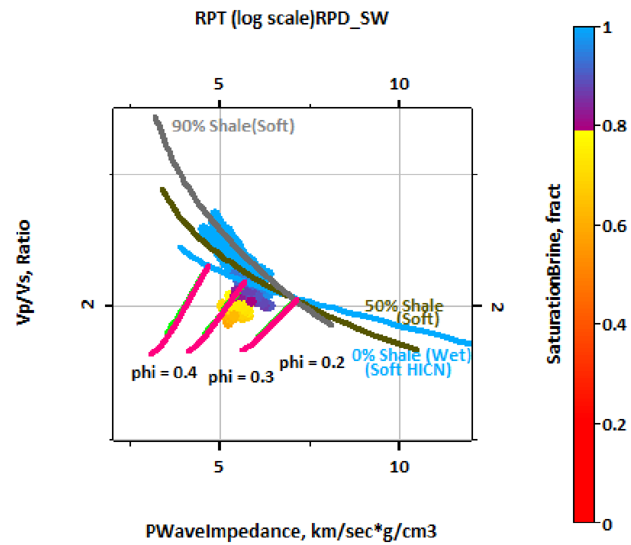
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Bagang-1

Bagang-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is good. Client's preliminary petrophysical interpretation was fully provided as a reference.
- From 3160-3220 the RHOB was completely calculated using regression relation with GR and then VP and VS were predicted via RPD.
- From 3400-3420m and 3480-3500m where RHOB measurement was affected by the bad hole conditions, RHOB was calculated from GR using a regression relation then VP and VS were predicted via RPD.
- Vp was fully modelled using the RPD in the interval 3190-3532 m.
- Vs was missing in the interval 3160-3532m so it was fully modelled using a granular media model(soft sediment), also was edited in some intervals in the gas sand zone(2945-3015m) using the same model.
- Other logs include Gamma, Neutron, Caliper, Deep, Shallow and Medium Resistivity, and Photoelectric factor which all run for the full logging run.

Clay volume (VClay):

- This volume was derived from both linear Gamma Ray method and in some zones a combination of both Gamma Ray and Neutron/Density crossplot applied (where measured data is not affected by hole conditions)

Reservoir characteristics:

- In terms of lithology the primary reservoir targets are the H200 sands. These are a series of turbiditic sands, distributed in lobe/channel complexes. This target is Late Miocene.

Volume of hydrocarbons:

- Interpreted gas saturation was best in the 2950-3010 m sand with values up to 60%.
- Residual gas saturation was interpreted in some sands in the repeated H200 sands.

Water saturation (Sw):

- Two different formation water salinities were interpreted: in the 17" hole an Rw= 0.147 Ohmm @ 108F (30,000 ppm) was used, whereas an Rw=0.24 Ohmm @155F (12,000 ppm) was estimated in the 12 ¼" hole those values were derived from Pickett plot since no Salinity analysis was available. Water saturation was calculated using Simandoux's equation with Archie's constants used were (a)=1, Cementation exponent (m)=1.85 and Saturation exponent (n)=1.85

Bagang-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore, and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both quartz rich and clay rich intervals when compared to the measured data.

Fluid properties:

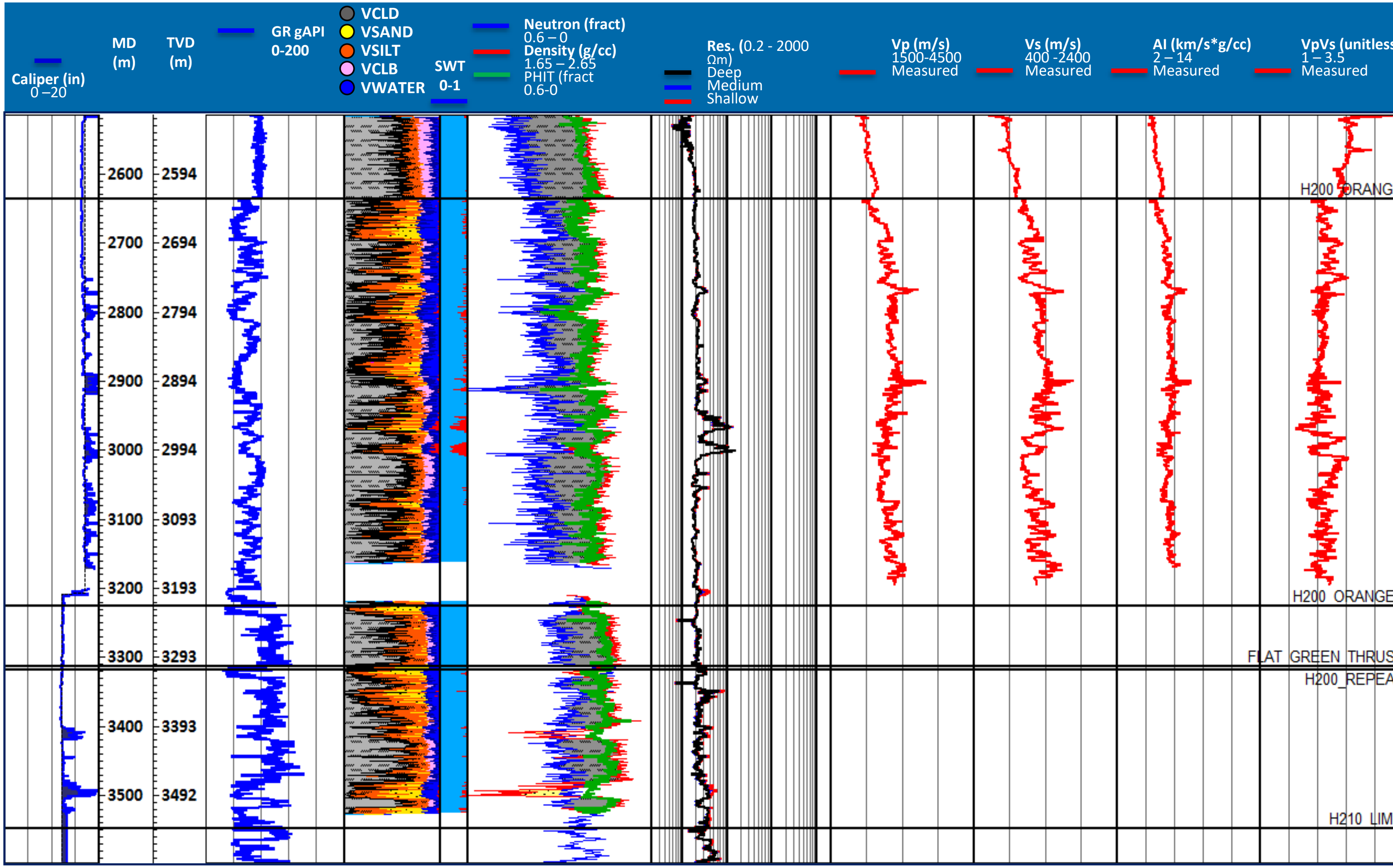
Fluid properties used in substitution have been taken from Tomani-1 well PVT report. Main parameters used in this modeling are:

- Brine salinity: 12000-30000 ppm
- Gas gravity: 0.64
- Oil Gravity: 35 API [Assumed]
- Gas / Oil ratio: 100 (L/L)[Assumed]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different H200 sands using the final modelled elastic curves as an input(RPD curves).
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains.
- By downgrading the reservoir quality(decreasing the porosity and increasing the clay content) the discrimination between the different fluid cases will be hard on the AVA Xplot.

Bagang-1 Input Logs



Additional data includes pressure, temperature data and cuttings descriptions.

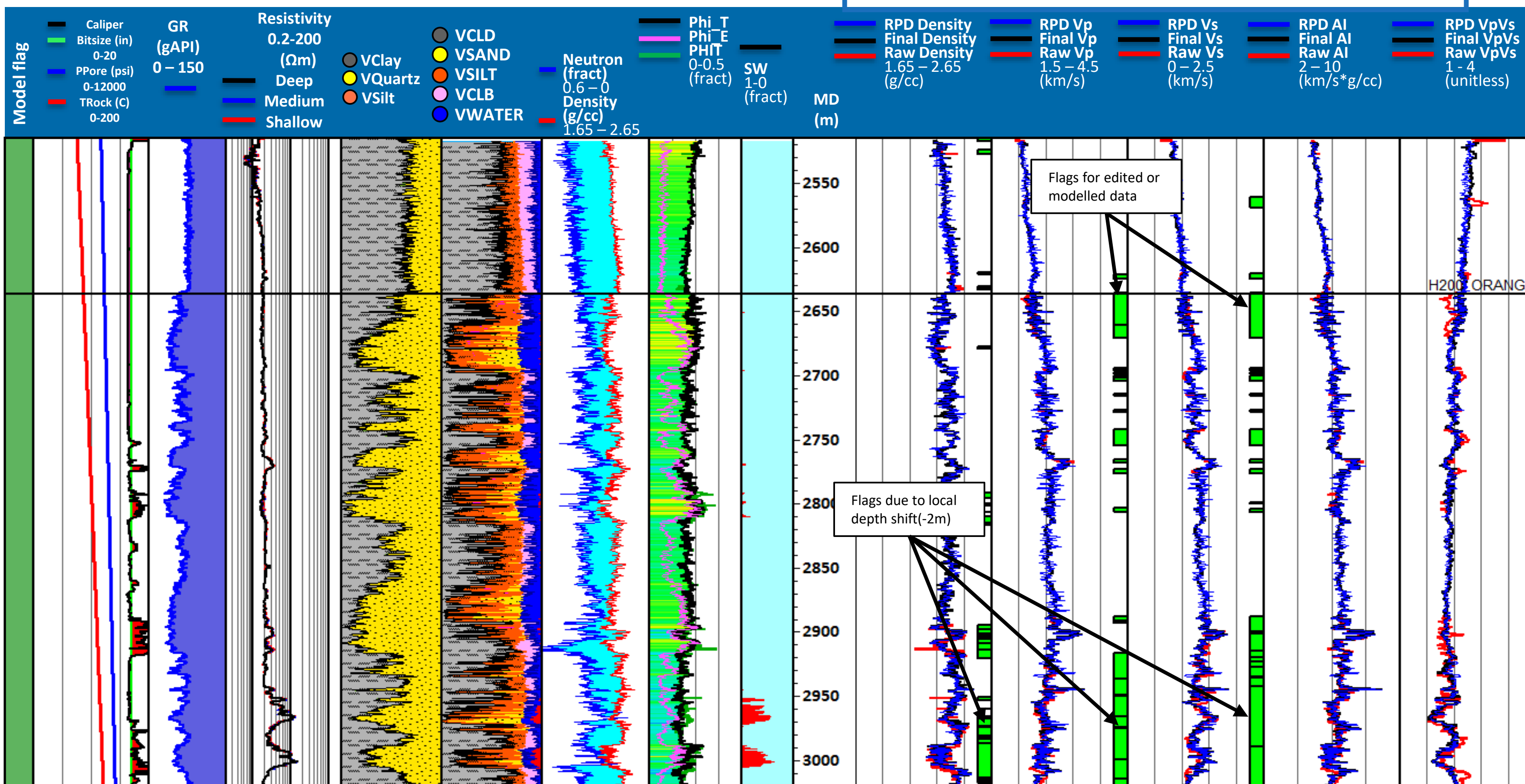
Bagang-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of logs to 3025 m

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming.
Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve



Some edits to the measured data and model calibration is strong. The casing gap was filled via regression equation using GR to predict RHOB then VP and VS were estimated from RPD. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

Bagang-1 Geophysical Well Log Analysis (GWLA) – Interval from 2950 m to the end of logs

model type flag

Unconsolidated rock model

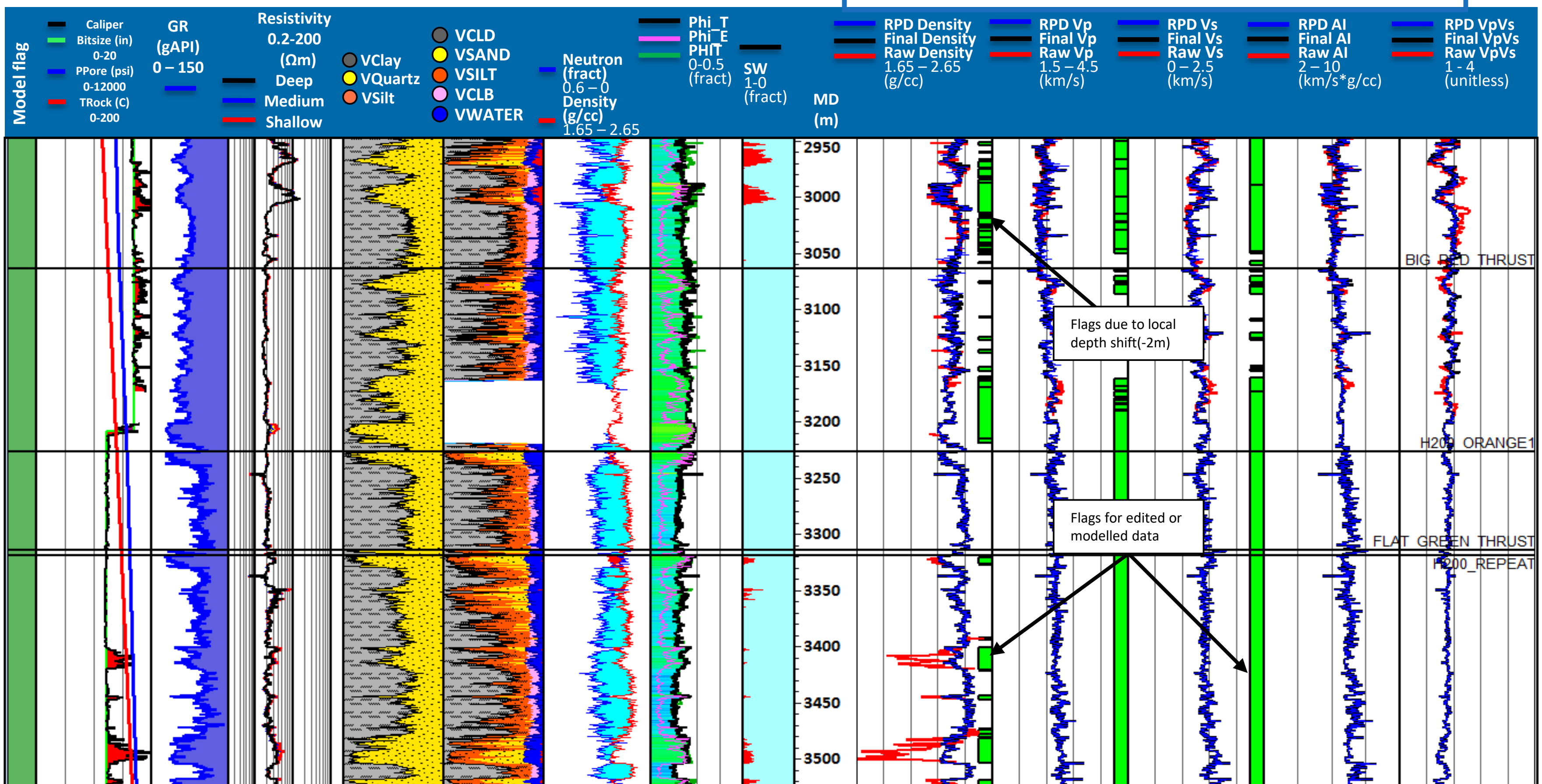
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

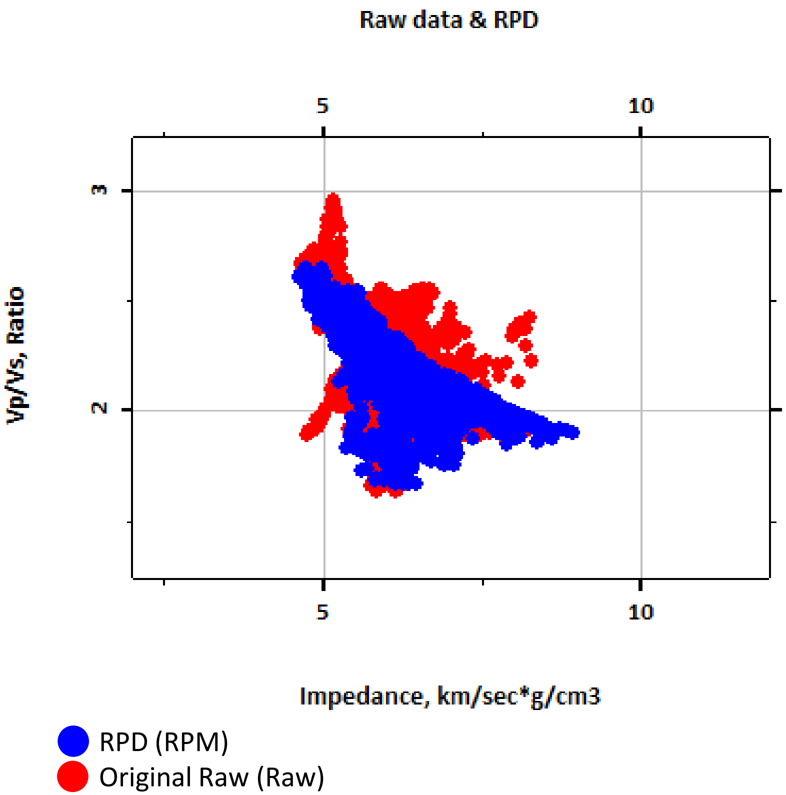
Original Raw (Raw) curve



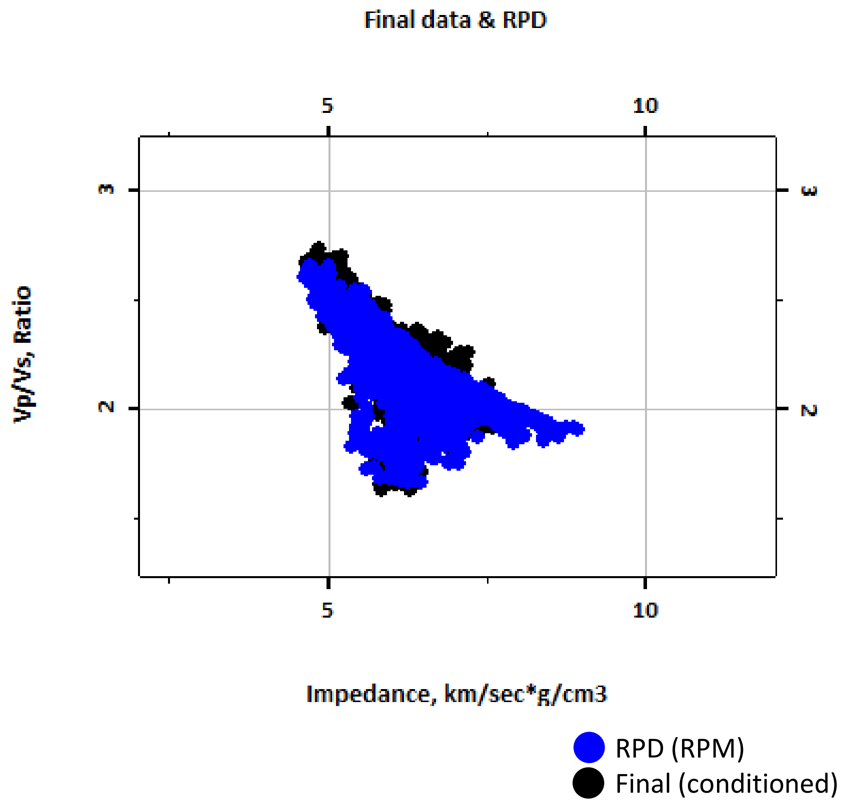
Some edits to the measured data and model calibration is strong. The casing gap was filled via regression equation using GR to predict RHOB then VP and VS were estimated from RPD. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

Bagang-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.



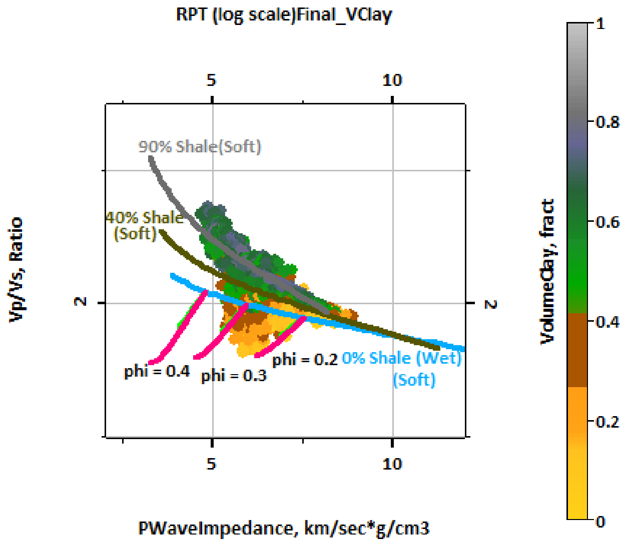
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

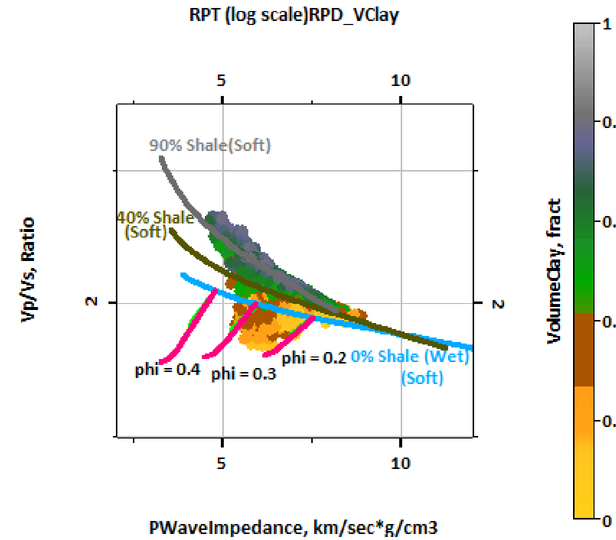


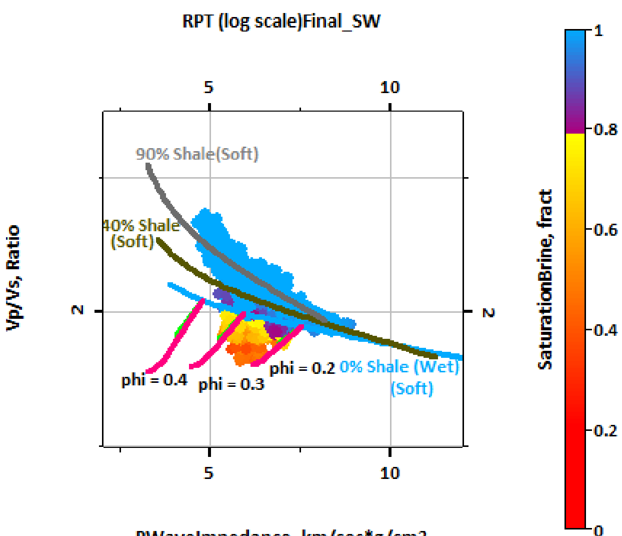
Bagang-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

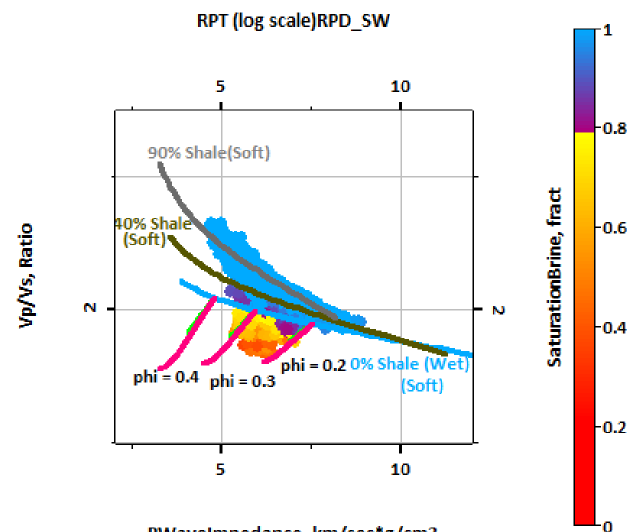
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Bambazon-1

Bambazon-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- There is substantial washout present in this borehole, impacting the data measurements. Generally only the measured compressional velocity is good quality, with some spikes. Density and compressional velocity is available from 115m – 2590m, no quality shear is available.
- The Vp has been smoothed on a three sample window (0.45m). The Vp is impacted in some spots by the washouts. Edits have been made from density in some places or by Faust from deep resistivity where density measurements are also compromised.
- The density is heavily impacted by washouts, the effect is present over the full wellbore, though is more obvious in shale zones. Nearly all of the density has been replaced by the RPD model from Vp.
- Other logs include Neutron, run over select zones, and Gamma Ray, Deep and Shallow resistivities run over the full logging run from 115m – 2590m.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method with Neutron/Density in places.

Reservoir characteristics:

- In terms of lithology the reservoir targets there is a Stage IVC Limestone interbedded with a thin sandstone laying unconformably on a Stave IVA sandstone. Both sandstones have good gas saturations. Stage IVA continues to the base of the well and is interbedded with sand and claystone units.
- The IVC sandstone porosity is around 26%. The porosities in the IVA tend to vary with clay presence and depth, ranging from 15-27%.

Volume of hydrocarbons:

- There is around 70% gas saturation where there is porosity in the IVC sand and the top 70m of the IVA sand. There are oil shows reported deeper in the section, though no response seen on the logs.

Water saturation (Sw):

- Rw has been calculated from Pickett plot and using the reported salinity of 16900ppm. Rw used is 0.196 at 137° F for a salinity of 17000ppm.

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that from the point where the elastic logs started down to the T.D. the Soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich zones in the few zones where density measurements are good quality. The shear model calibration was aided by comparison to the Greenberg-Castagna results, which provided a good match in analog wells. Analog wells used in this calibration are Bongkobo-1 and Rusa Barat-1, given similarity in trends, however velocity in Bambazon-1 is significantly faster than seen in other wells..

Fluid properties:

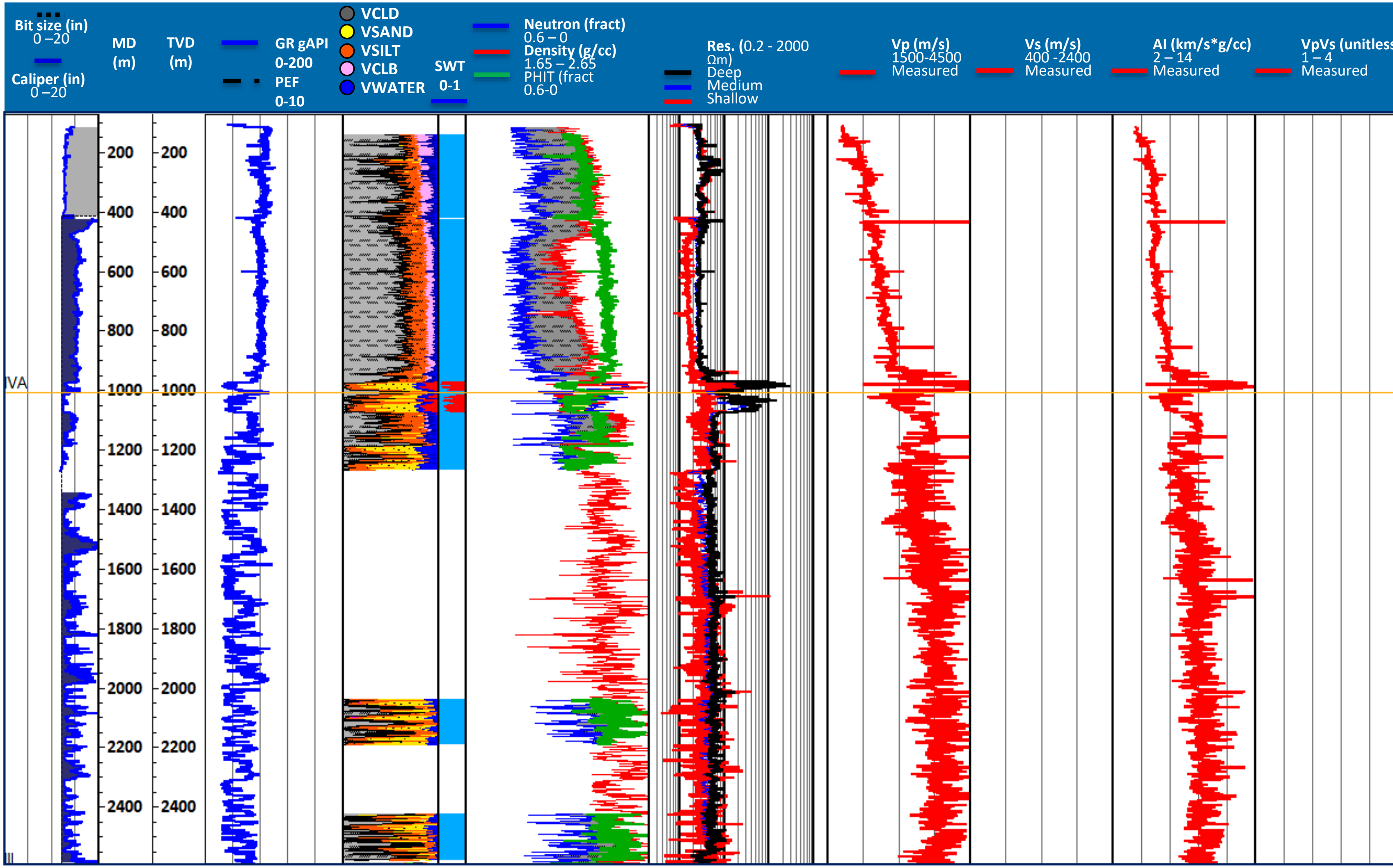
Fluid properties used in substitution have been taken from regional data and in reporting for this well. Main parameters used in this modeling are:

- Brine salinity: 17000ppm [from Pickett and reports]
- Gas gravity: 0.64 [Tomani-1 PVT]
- Oil Gravity: 31 API [Bambazon-1 report]
- Gas / Oil ratio: 200 (L/L)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the Stage IVC sand and all Stage IVA sands using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios.
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with poor to fair discrimination with the brine sands.
- The IVC sand AVA response is dominated by the limestone and shows no fluid discrimination. The top of the IVC is also dominated by the base limestone response and shows a Class IV AVA response, strongly negative with a slightly positive gradient with good fluid discrimination. Increasing porosity exaggerates this response. The other sands in the section show a negative intercept that varies with porosity and a flat gradient and fair fluid discrimination.

Bambazon-1 Input Logs



Additional data includes mud weight, temperature data, fluid data, and final geological report.

Bambazon-1 Geophysical Well Log Analysis (GWLA) – Top of logs to 1250m

model type flag

Unconsolidated rock model

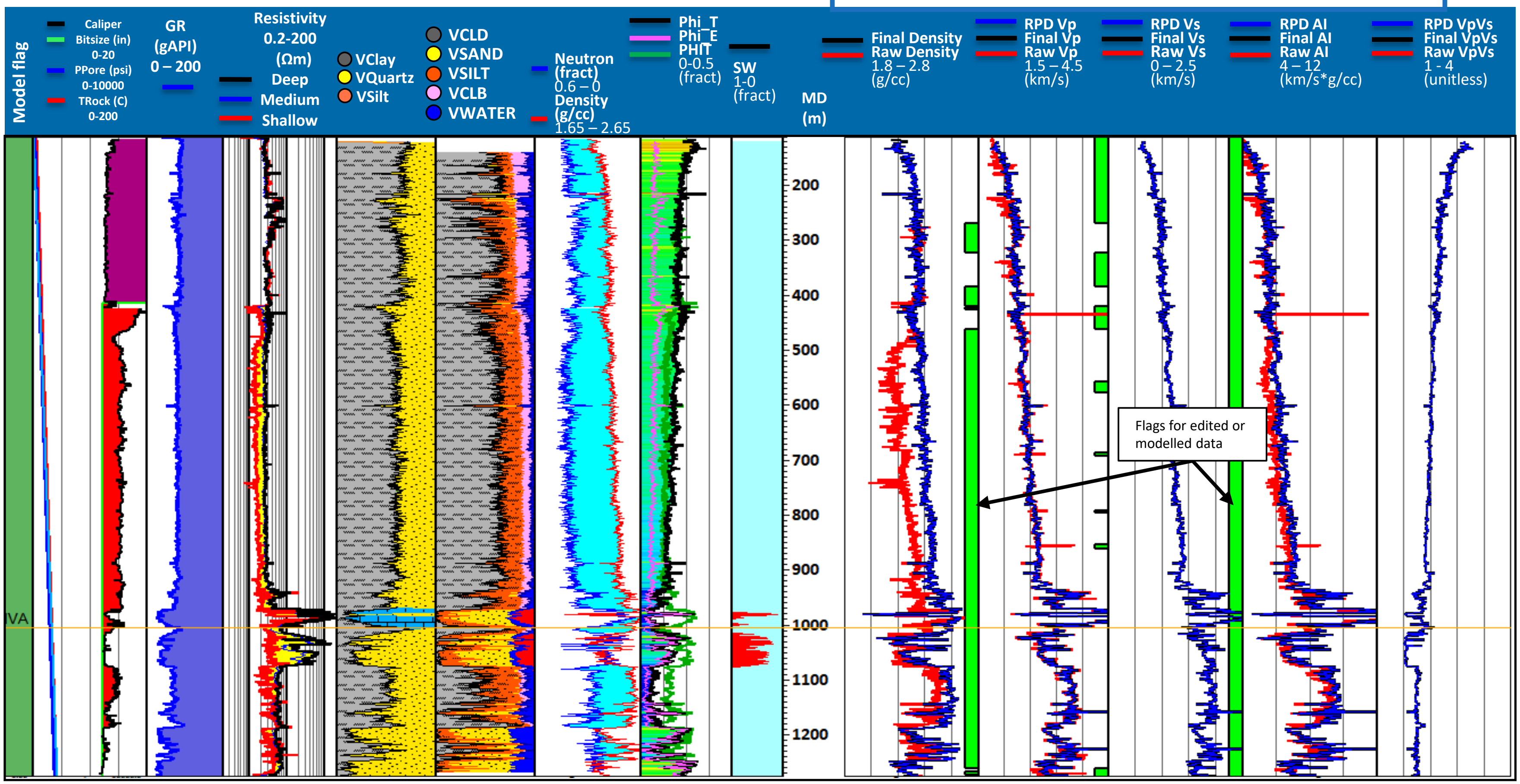
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve



Vp is generally strong, no Vs measured, density is heavily impacted by washouts. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and Vs) with good correlation with the measured data, and using analog wells and Greenberg-Catagna calibration for Vs.

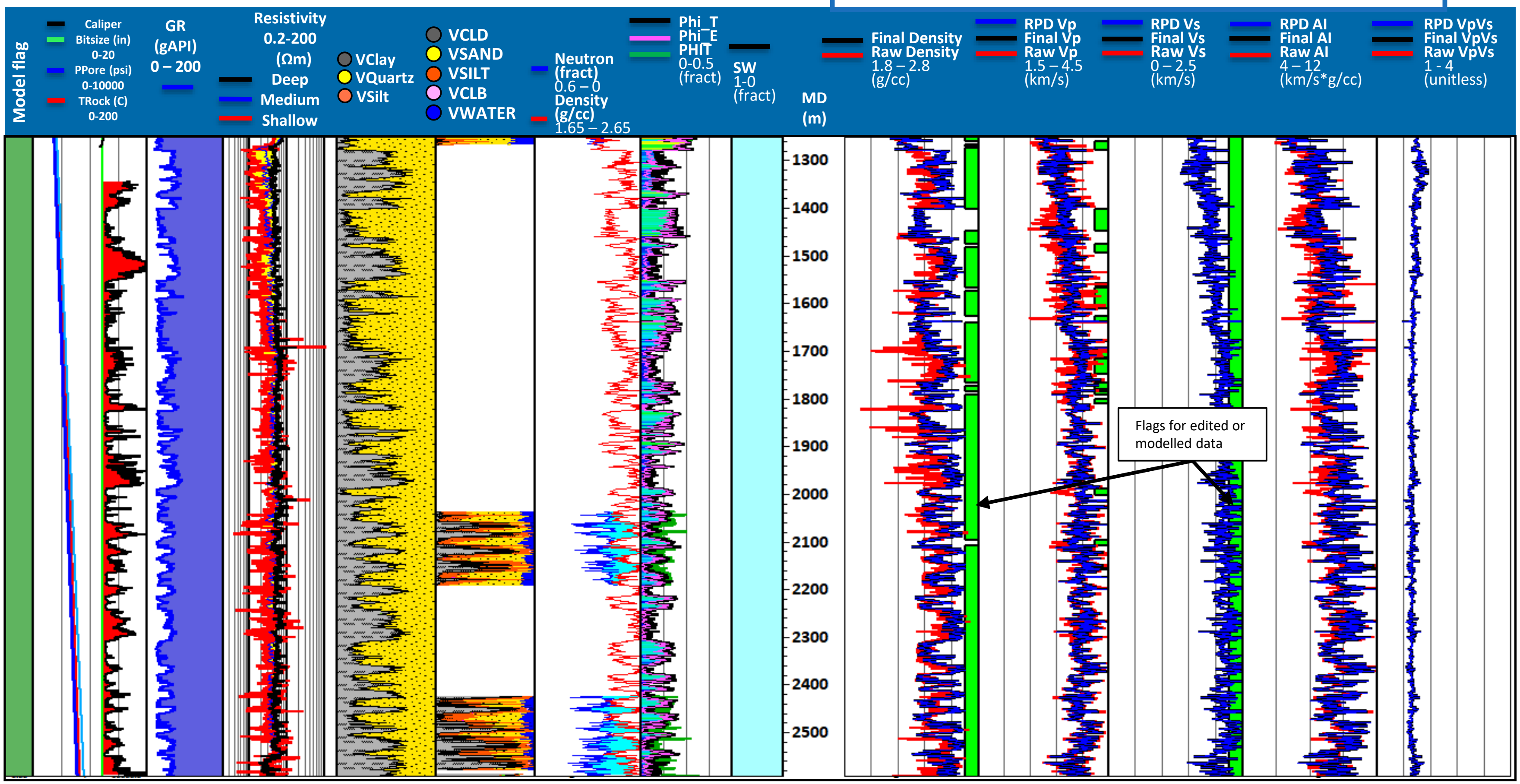
Bambazon-1 Geophysical Well Log Analysis (GWLA) – 1250m to TD (2596m)

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

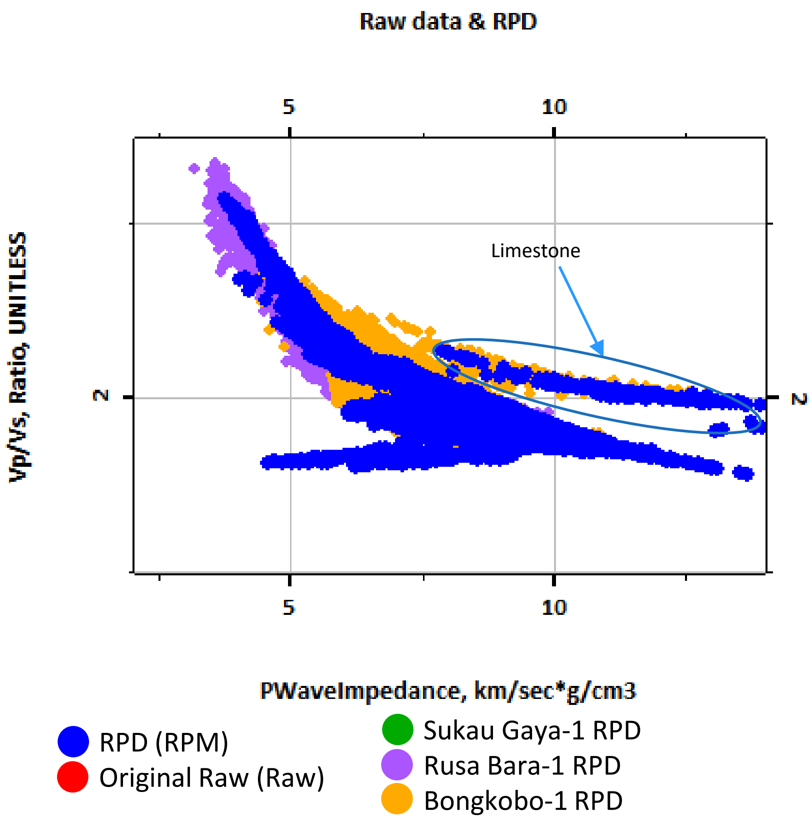


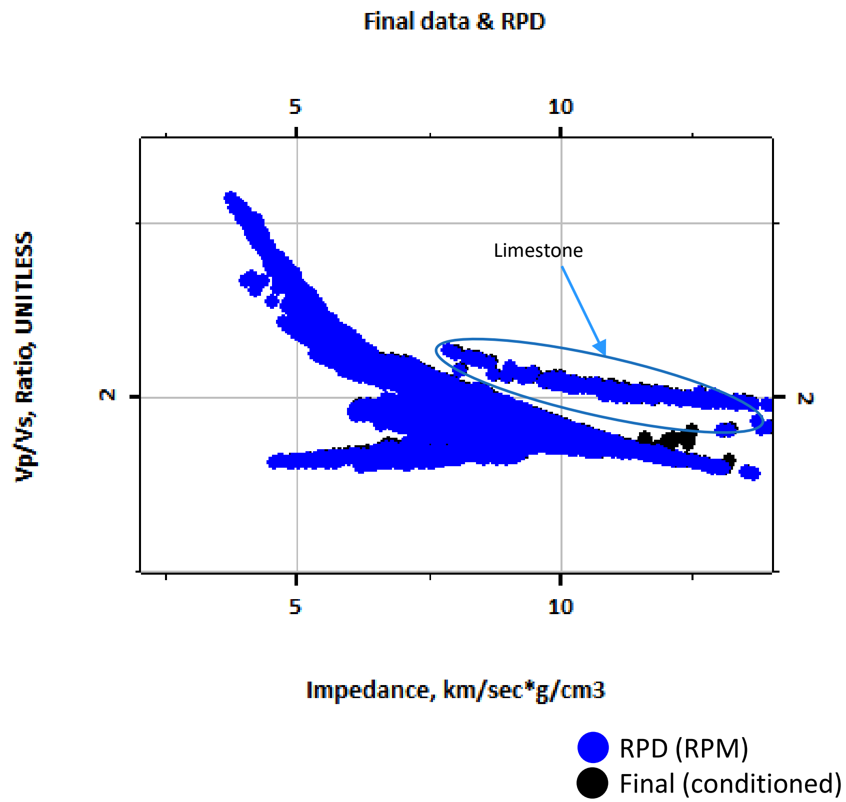
Vp is generally strong, no Vs measured, density is heavily impacted by washouts. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and Vs) with good correlation with the measured data, and using analog wells and Greenberg-Catagna calibration for Vs.

Bambazon-1,Rock Physics Diagnostics (RPD)
Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the analog wells with similar trends in the elastic data, given the measured shear in Bambazon-1 is not viable.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

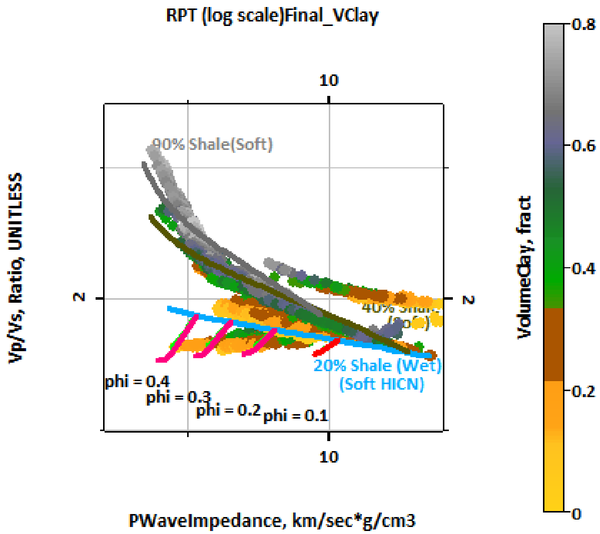


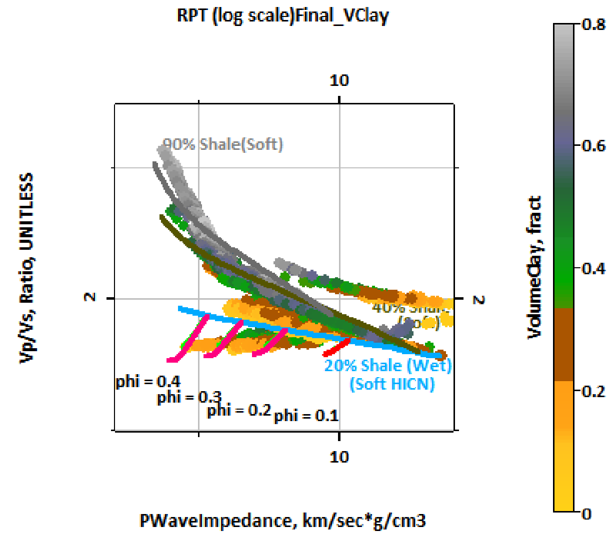


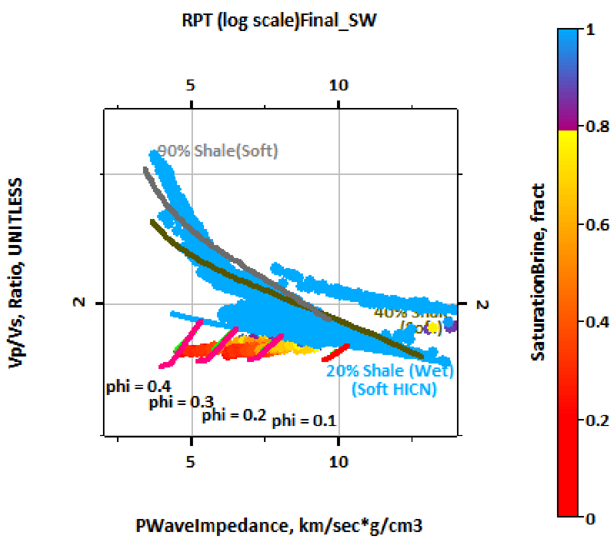
Bambazon-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

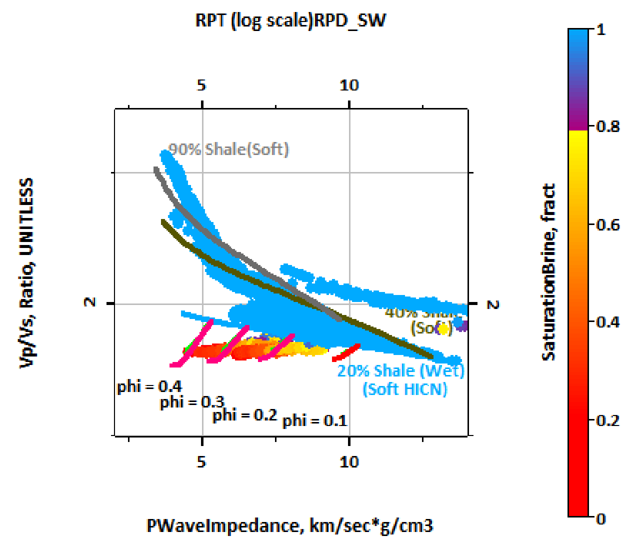
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Batai-1

Batai-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- Data quality is fair, some measurements are impacted by borehole conditions. One casing gap is present from 1802-1854 m.
- Density measurements are available from 1537 m to TD (2266 m). Particularly, in the 1690-1715m, 1727-1730m, and 1744-1756m sections, sands exhibited very high porosities, in some samples above the theoretical porosity upper limit (46%). Using porosity trends that included other wells in the area provided an estimate of porosities in these facies, where measurements were highly affected by the borehole conditions. Once porosity was estimated using a regional trend, density was calculated via the mass-balance equation, and then Vp and Vs were derived using rock physics models.
- Good compressional slowness runs from 1526 m to TD and is high quality. Shear slowness is also good quality and is present from 1537 m to TD. RSI edits to both include filling the casing gap and local predictions, particularly at the H110 sand.
- Other logs include Gamma, Neutron, Caliper, Deep, Shallow and Medium Resistivity, and Photoelectric factor which all run for the full logging run.

Clay volume (VClay):

- This volume was estimated via a combination of linear Gamma Ray method, Neutron/Density crossplot, and interpolation.

Reservoir characteristics:

- In terms of lithology the primary reservoir targets are the H200 sands. These are a series of turbiditic sands, distributed in lobe/channel complexes. The secondary targets are the H110 and H136 sands. All targets are Late Miocene.
- The H110 sand is 38m thick, unconsolidated 38% porosity at the base and fining upwards. Trace biotite, pyrite, calcite, and carbonaceous material are present. H136 has no reservoir.
- H200A-H200B contain thin interbedded unconsolidated sandstones. sands H200 1m as, 1m oil
- There is indication in the reporting of more oil pay present in deeper H200C and H300 sands, though no logs are present.

Volume of hydrocarbons:

- In the H200A zone there is of 0.9m net gas pay from 1940-1980m maximum gas saturation is around 36%. In the H200B zone there is 1.2m net oil pay from 2085-2130m, maximum oil saturation is 32%.

Water saturation (Sw):

- Water saturation was estimated using Archie's equation. Archie parameters reported in the Final Geo report are a=1,m=1.85,n=1.85; Rw = 0.15 Ohmm @ 150 DegF, 21000ppm NaCl.

Batai-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore, and indicated that in terms of P & S-wave velocity versus porosity space, the Soft sediment model proved to be the best predictor for all lithologies in most of the well. These models have been used to edit the Vp, Rhob, and Vs data where necessary and to perturb the rock for changes to VClay and Phi_T at the Rock physics modelling (RPM) stage of the project.

Fluid properties:

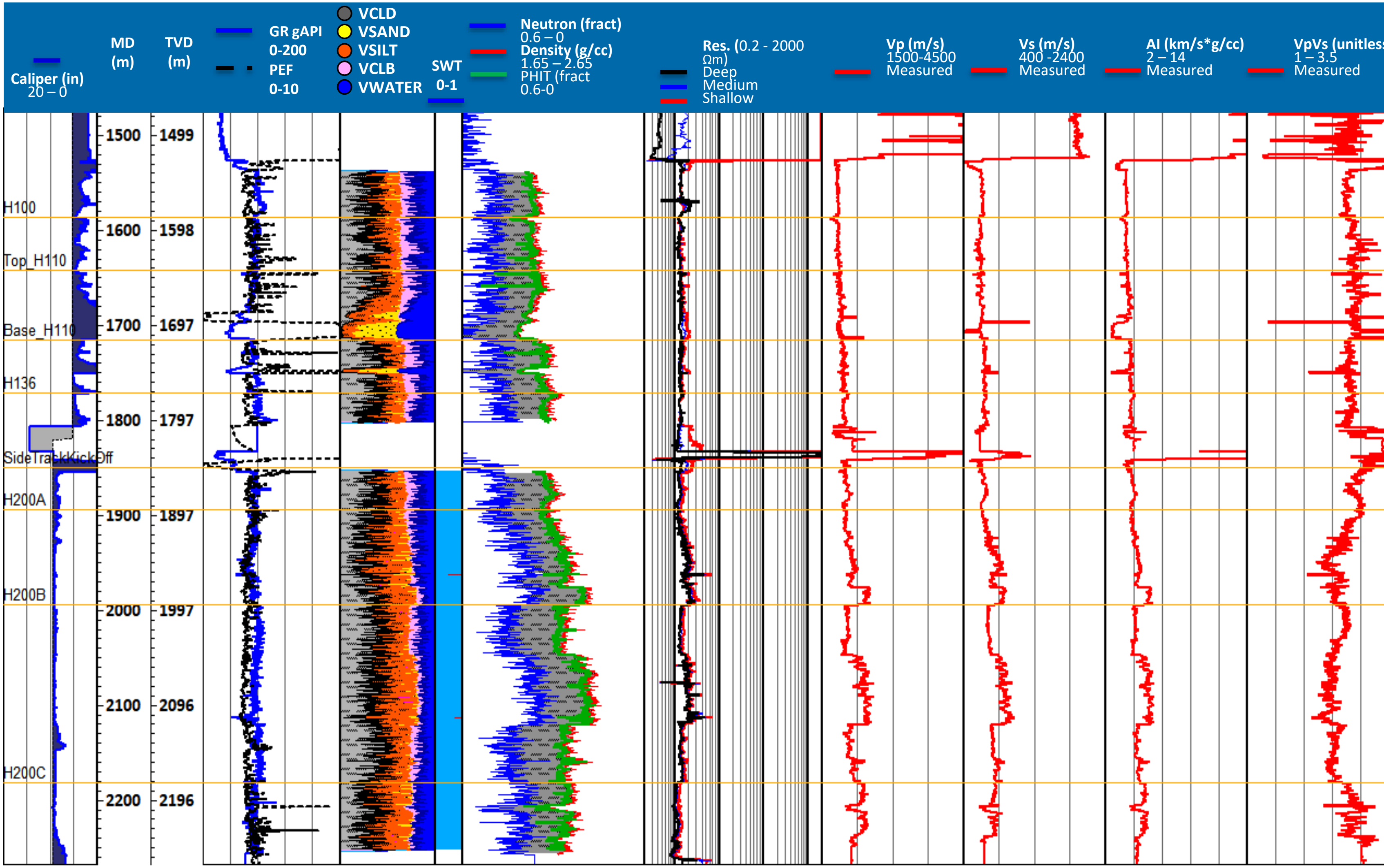
Fluid properties used in substitution have been taken from PVT well reports. Main parameters used in this modeling are:

- Brine salinity: 20000 ppm
- Gas gravity: 0.75 (gas @ 1963m)
- Oil Gravity: 44.4 API (oil @ 2113m)
- Gas / Oil ratio: 178 (L/L) (oil @ 2113m)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the H110 and H200A sands using the established rock physics models.
- The standard Gassmann's fluid substitution method was used to perturb the different modelling scenarios.
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Hydrocarbon sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale.

Input Logs – Batai-1



Additional data includes core analysis, pressure and temperature data, cuttings descriptions, VSP, and MDT fluid data

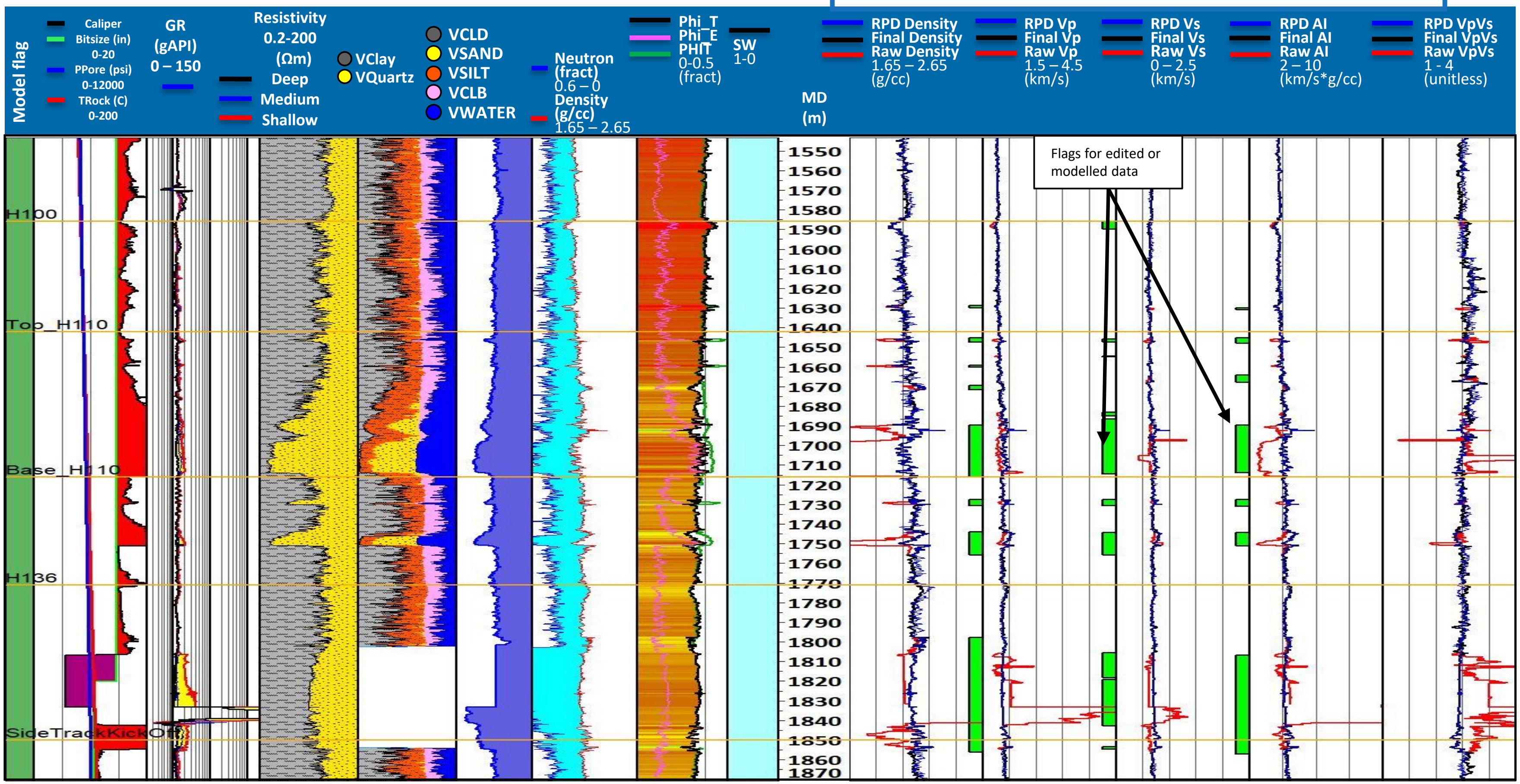
Batai-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of logs to 1850 m

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve



Some edits to the measured data and model calibration is strong. The casing gap was filled via Faust from resistivity to Vp then density and Vs from RPD. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and Vs) with good correlation with the measured data. Porosity in sands in the 1680-1760 m section were estimated using a depth trend due to the poor borehole conditions, and density, Vp, and Vs were consequently derived using rock physics modelling.

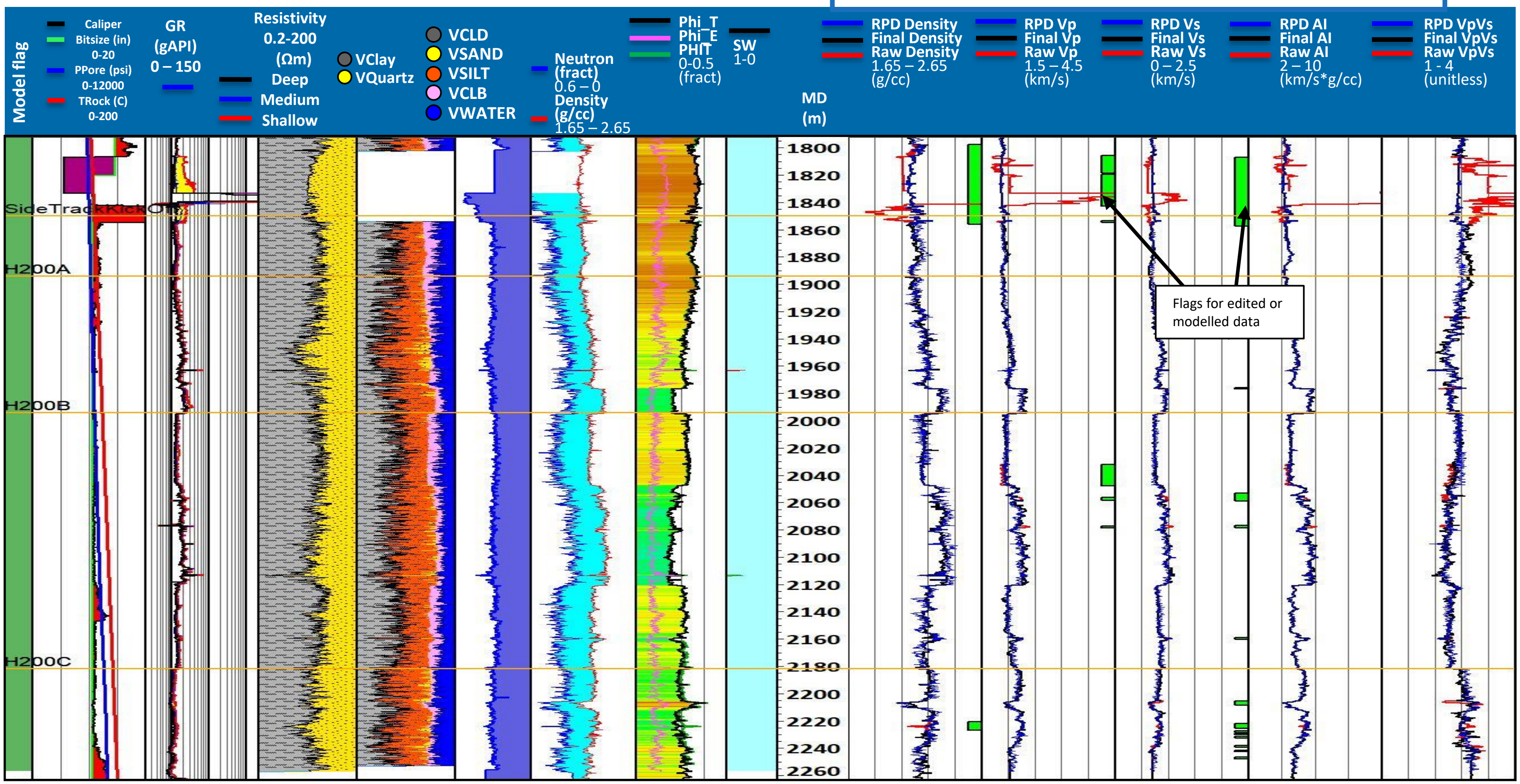
Batai-1 Geophysical Well Log Analysis (GWLA) – Interval from 1800 m to end of logs

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

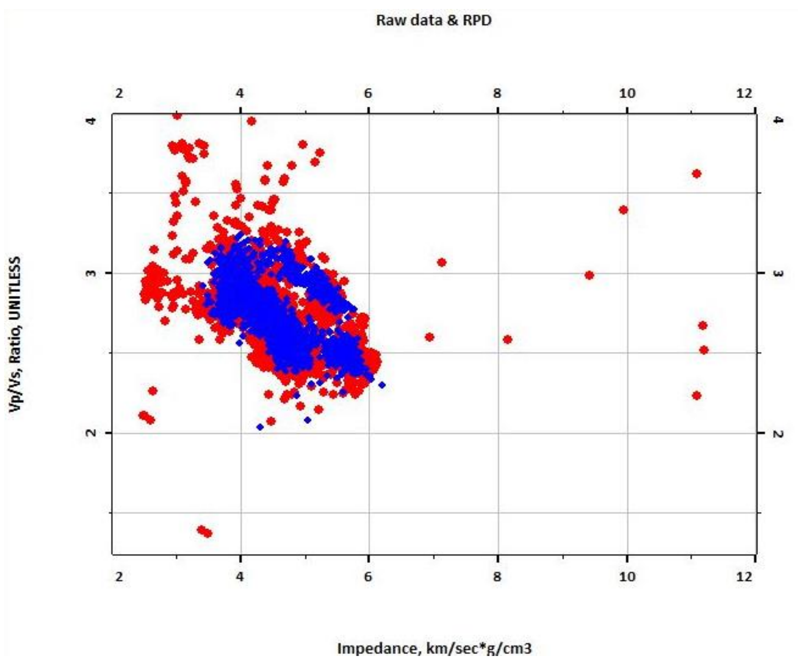


Some edits to the measured data and model calibration is strong. The casing gap was filled via Faust from resistivity to Vp then density and Vs from RPD. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and Vs) with good correlation with the measured data.

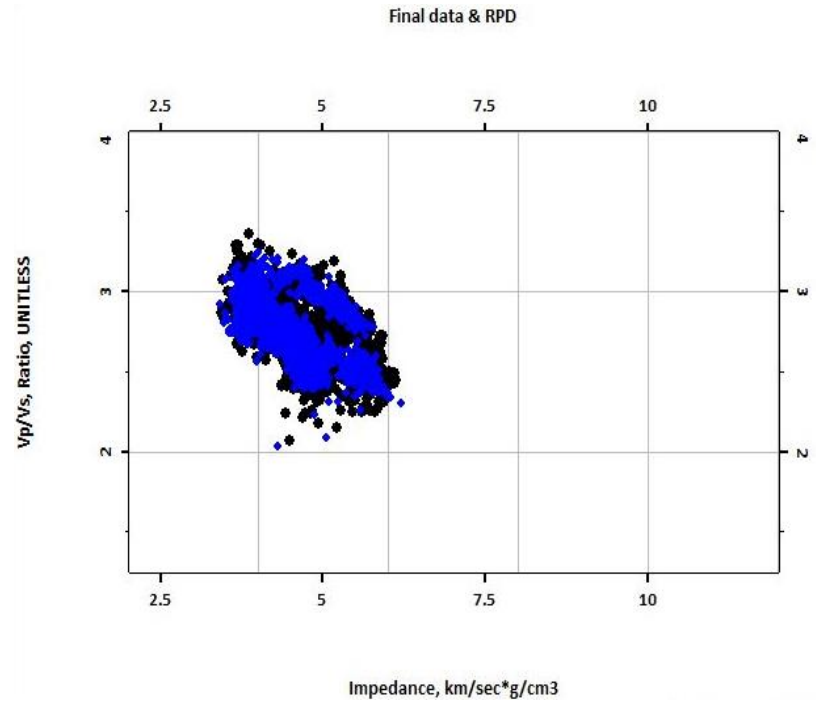
Batai-1,Rock Physics Diagnostics (RPD)
Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.



RPD (RPM)
Original Raw (Raw)

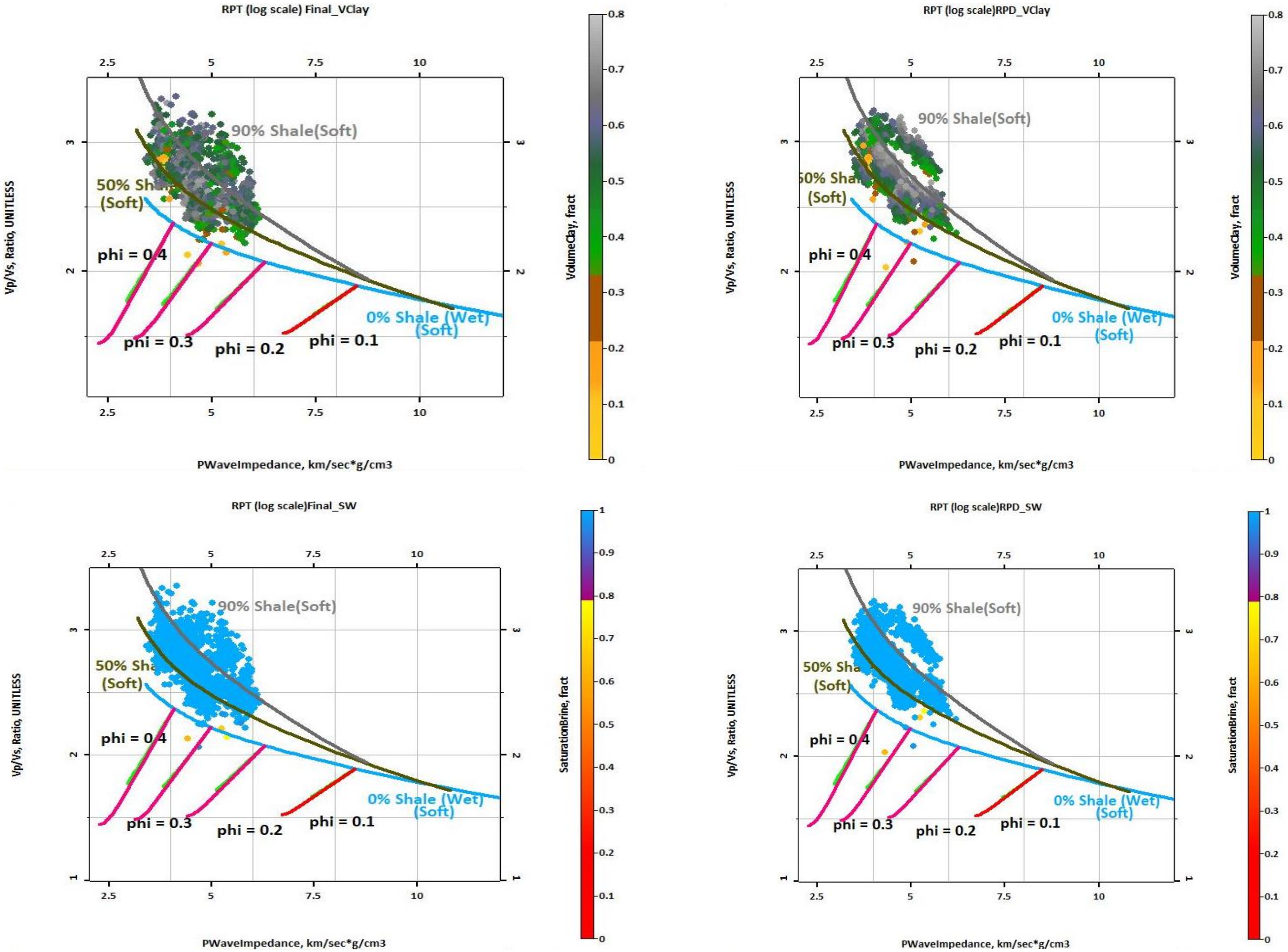


RPD (RPM)
Final (conditioned)

Batai-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data



RPD(Modelled)data

Batai-1S1

Batai-1S1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- The section from well top to 1850m is copied from the main hole (Batai-1), as this is where the sidetrack kicks off. This report will focus on the section below 1850m.
- Data quality is fair, some measurements are impacted by borehole conditions. One casing gap is present from 2180-2201 m.
- Density measurements are available from 1852 m to TD (2519 m). The major RSI edit was to fill the casing gap, and other edits were made to account for washouts, and bedding effects. Density correction values in these sections can reach up to 0.14 g/cc, as indicated by the density correction curve.
- Compressional slowness runs from 1848 m to TD and is fair quality. Shear slowness is present from 2200 m to TD. Vp/Vs shows an erratic behavior along with anomalous values in various sections of the well. The general trend in the Vp/Vs ratio has been captured, which correlates with the mother wellbore, but various edits were performed on the Vs log to account for the erratic behavior in the Vp/Vs ratio.
- Other logs include Gamma, Neutron, Caliper, Deep and Shallow Resistivity, and Photoelectric factor which all run for the full logging run.

Clay volume (VClay):

- This volume was estimated via a combination of linear Gamma Ray method, Neutron/Density crossplot, and interpolation.

Reservoir characteristics:

- In terms of lithology the primary reservoir targets for the sidetrack well are the Late Miocene slope turbidite H300 sands. The H200 sands are secondary targets.
- The H200A sands are generally unconsolidated thin lamina amongst claystones and siltstones. As we go deeper in the section, the sands encountered are thicker, but also siltier. The best reservoir rocks in this section are the thin sands encountered in the H200A & B.
- The H200B and H200C sands tend to be consolidated thin lamina within claystones and siltstones. The sands are mostly very thin and porosities range from 30-35%.
- H300A sands include both consolidated and unconsolidated sediments with some local moderate quartz cement. The very top of this reservoir is tight, with calcite stringers, and a high calcareous content in general. This high impedance event has been identified as a seismic marker. Porosity is highly variable in H300A.
- H300B, C and D sands are mostly consolidated, with occasional calcite or quartz cement.
- H300B and D sands are blocky and well developed with porosities in the 25-30% range.

Volume of hydrocarbons:

- There is gas and gas condensate present in all sands from H200A through H300C. Gas accumulations are generally low and thin, less than a meter and below 40%, though in H200B there is a 2m gas sand with 65% gas. H300D is fully brine saturated. Oil shows are reported though not calculated.

Water saturation (Sw):

- Water saturation was estimated using Archie's equation. Archie parameters reported in the Final Geo report are a=1,m=1.85,n=1.85; Rw = 0.15 Ohmm @ 150 DegF, 21000ppm NaCl.

Batai-1S1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore, and indicated that in terms of P & S-wave velocity versus porosity space, the Soft sediment model proved to be the best predictor in clay-rich and sand facies. However, in more consolidated, and slightly cemented sands (i.e. H200B & D), an Intermediate Stiff Sediment Model with a variable Coordination Number with depth was more suitable based on the elastic behavior of these samples. These models have been used to edit the Vp, Rhob, and Vs data where necessary and to perturb the rock for changes to VClay and Phi_T during the Rock physics modelling (RPM) stage of the project.

Fluid properties:

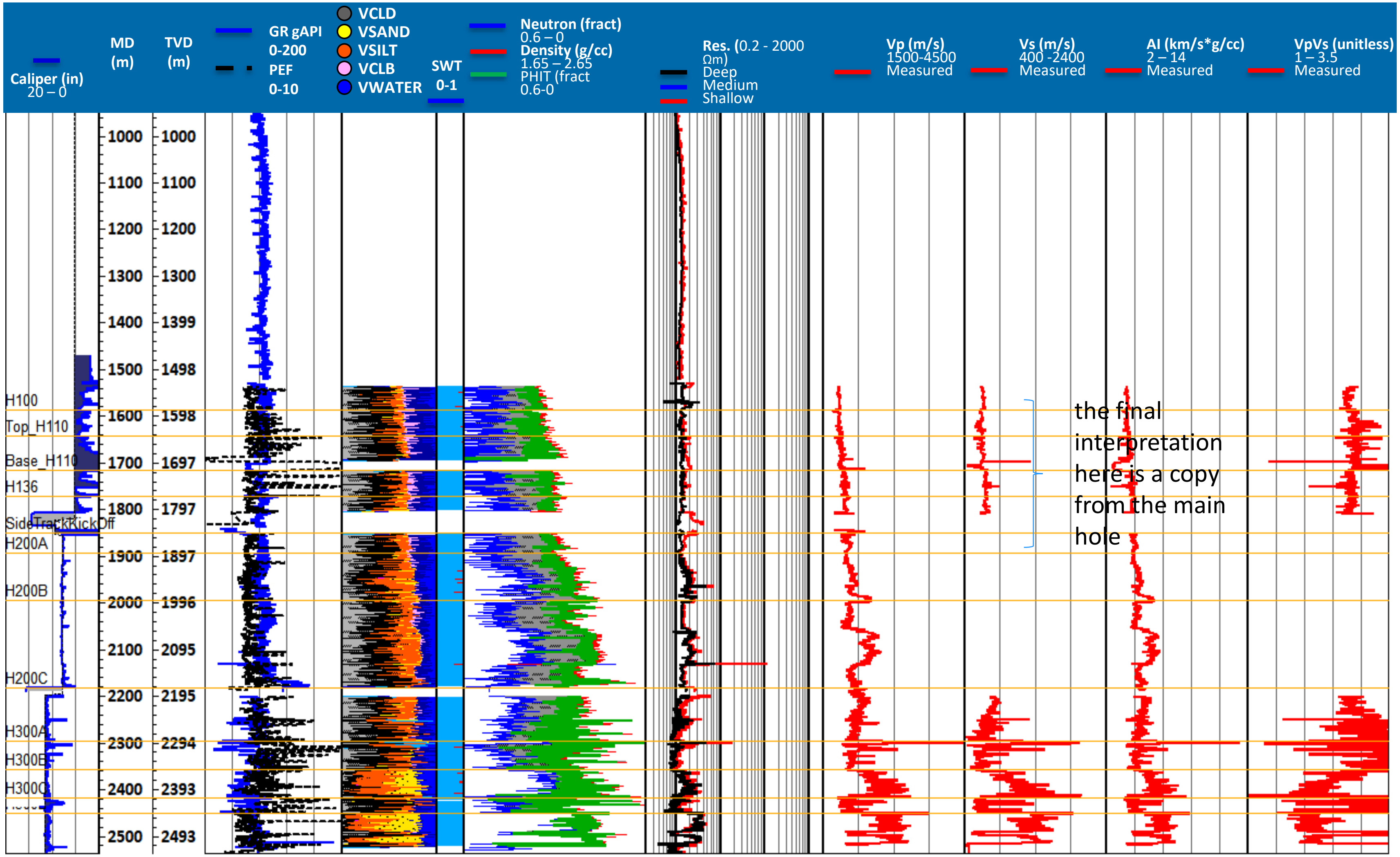
Fluid properties used in substitution have been taken from the PVT well report for the main hole (Batai 1). Main parameters used in this modeling are:

Brine salinity:	20000 ppm
Gas gravity:	0.75 (gas @ 1963m)
Oil Gravity:	44.4 API (oil @ 2113m)
Gas / Oil ratio:	178 (L/L) (oil @ 2113m)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the H200, and H300 sands.
- The standard Gassmann's fluid substitution method was used to perturb the different modelling scenarios.
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Hydrocarbon sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale.

Input Logs – Batai-1S1



Additional data includes core analysis, pressure and temperature data, cuttings descriptions, VSP, and MDT fluid data

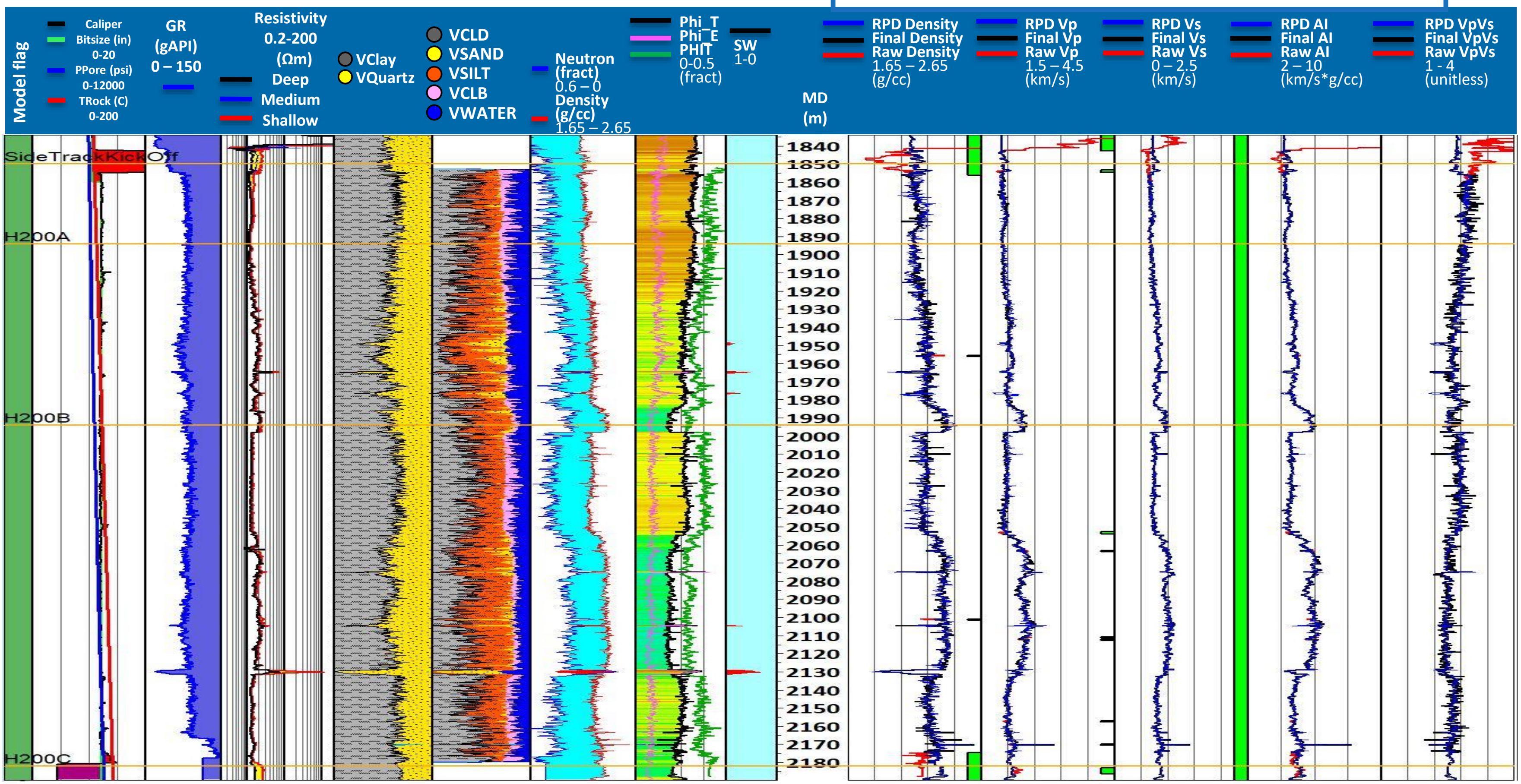
Batai-1S1 Geophysical Well Log Analysis (GWLA) – Interval from 1840 m to 2180 m

model type flag

Unconsolidated rock model
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve
Final edited (Conditioned) curve
Original Raw (Raw) curve



No edits to the measured data here. Shear velocity is estimated from the model using the same parameters from the main hole. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and Vs) with good correlation with the measured data.

Batai-1S1 Geophysical Well Log Analysis (GWLA) – Interval from 2180 m to end of logs

model type flag

Unconsolidated rock model

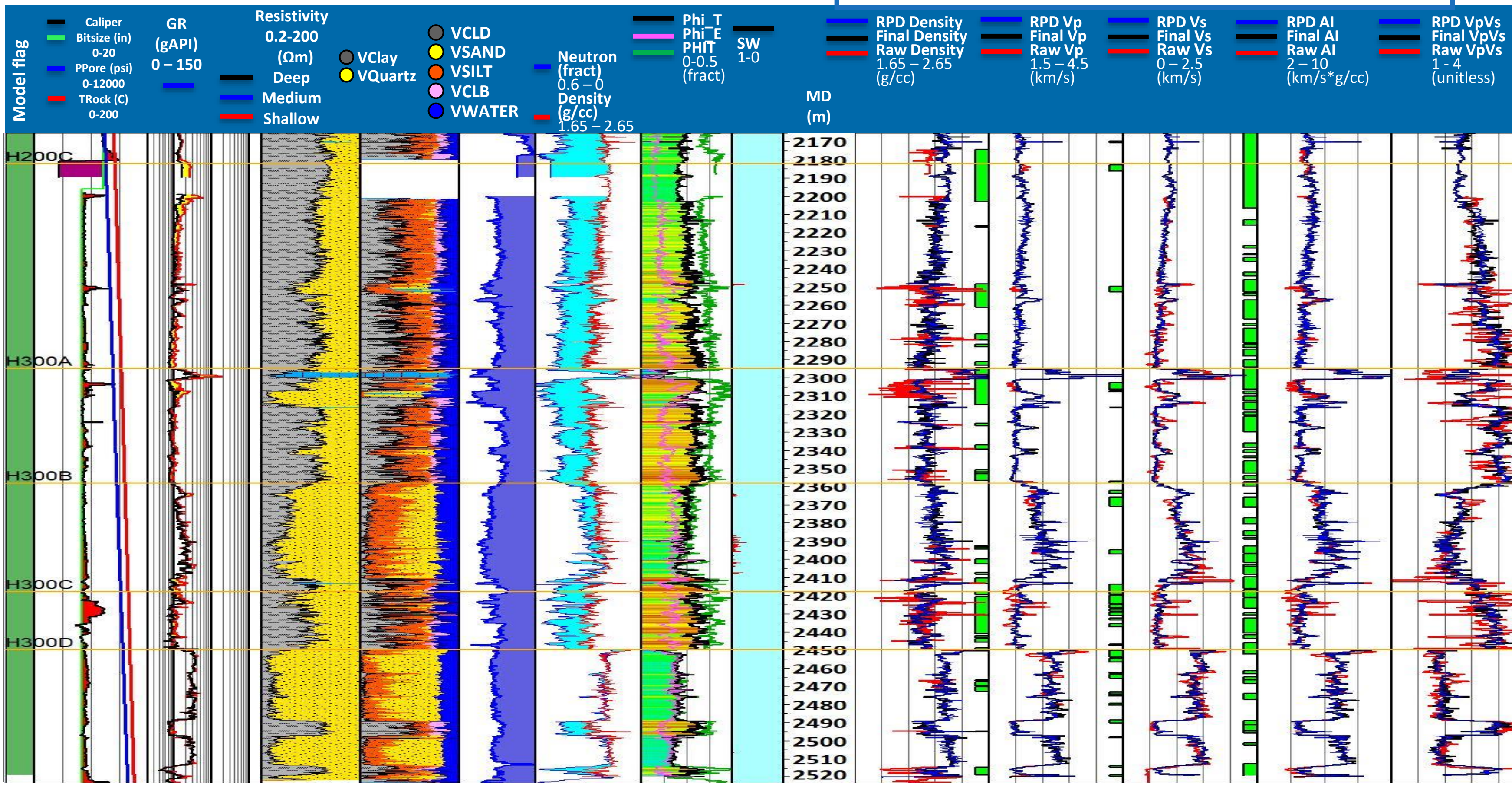
Stiff rock model

Equivalence between RSI and Petronas naming.
Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

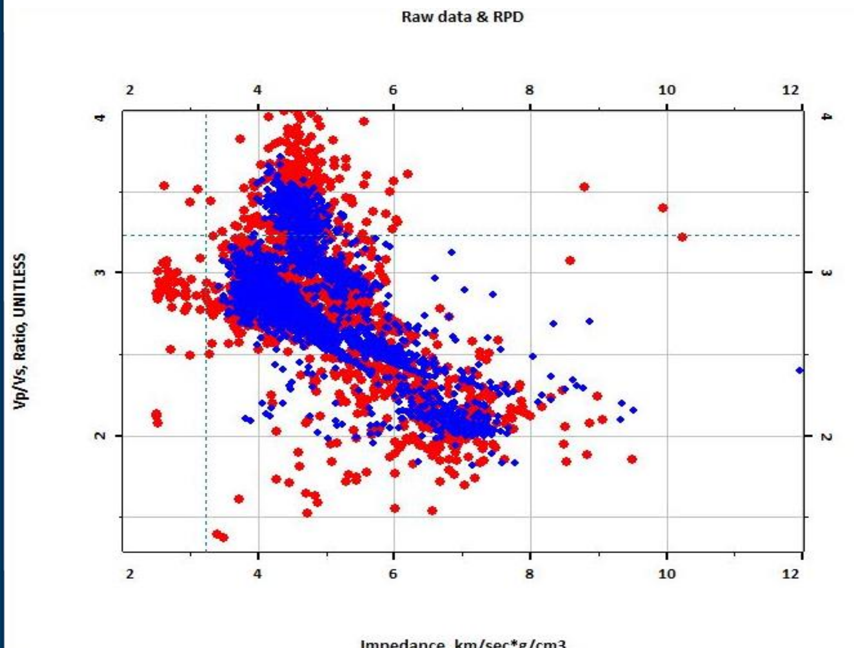
Original Raw (Raw) curve



More edits to the measured data, primarily density and shear. Model calibration is strong. The shear data showed anomalously low values in the H200C and H300A intervals and an erratic behaviour throughout most of the section. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and Vs) with good correlation with the measured data.

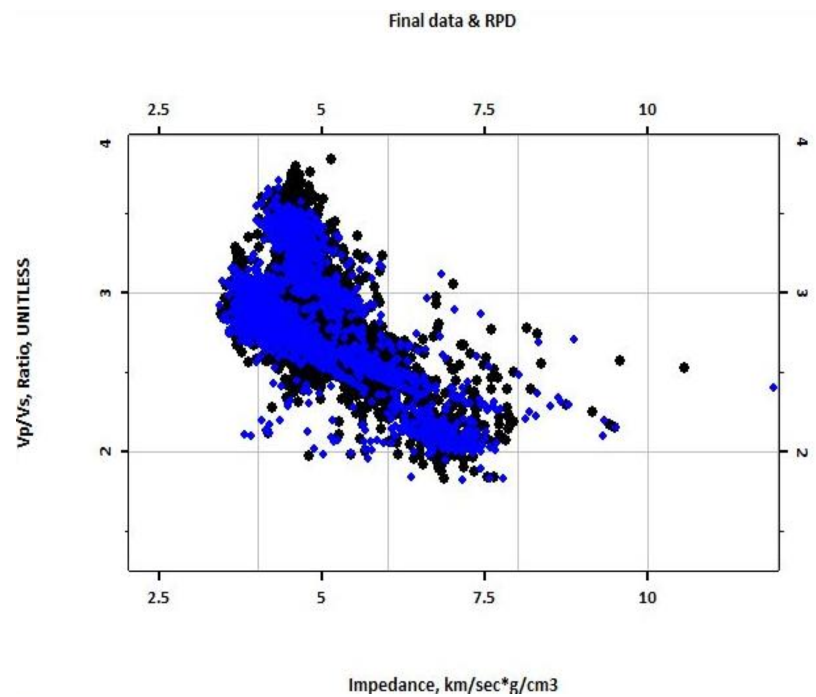
Batai-1S1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.



RPD (RPM)
Original Raw (Raw)

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

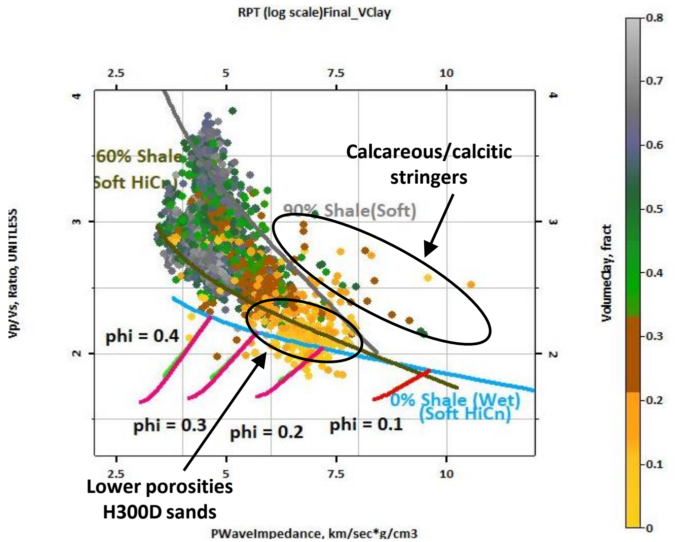


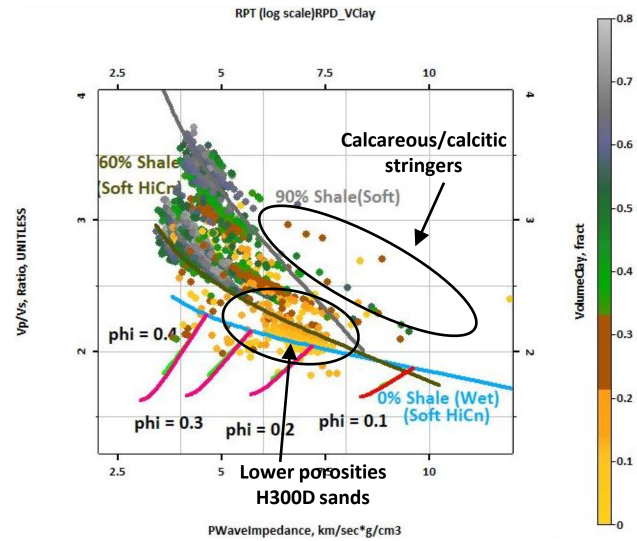
RPD (RPM)
Final (conditioned)

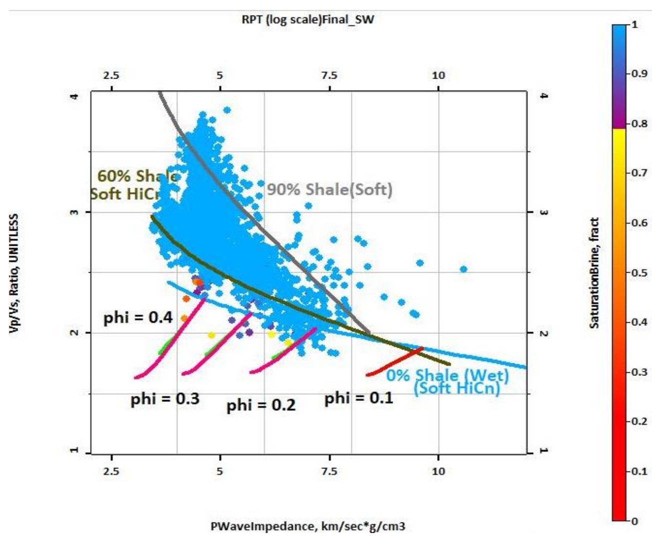
Batai-1S1,Rock Physics Diagnostics (RPD) Rock Physics Models, Full Well

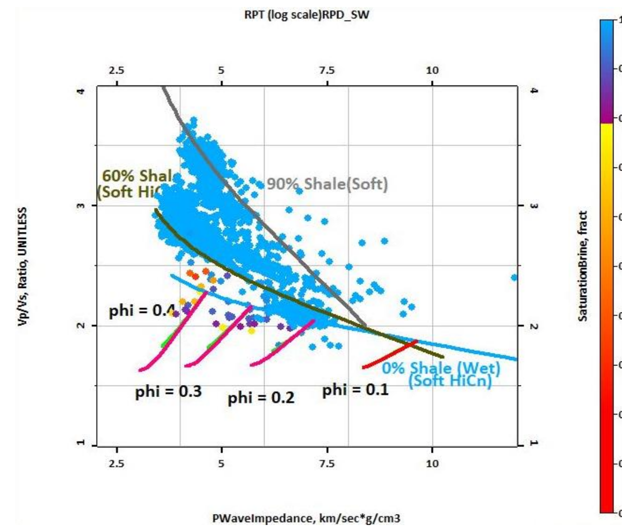
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Belangkas-1

Belangkas-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- Data measurements are fair. There are no usable measurements in the carbonate section. Usable elastic data begins at 495m and continues down to 2687m. There is substantial washout present in this borehole, impacting the data measurements. Generally only the measured density is good quality, with some spikes. No shear is available.
- Vp data is nulled until 495m and almost all other data replaced by RPD model results from RHOB due to significant washouts in shales and frequent spikiness. Edits have been made from density in some places or by Faust from deep resistivity where density measurements are also compromised.
- The density is generally robust and appears to not be impacted by the washouts except in a couple places. is heavily impacted by washouts, the effect is present over the full wellbore, though is more obvious in shale zones. Nearly all of the density has been replaced by the RPD model from Vp.
- Other logs include Neutron which begins at 1200m, and Gamma Ray, and Deep and Shallow resistivities run over the full logging run from 152m – 2688m.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method with Neutron/Density in places.

Reservoir characteristics:

- Primary objective turbidite sands between upper Miocene foreset sequence and the regional intermediate unconformity (RIU). Secondary objective is the mid Miocene below RIU. All reservoirs are Stave IVC and IVB and include an extensive series of interbedded claystones, sandstones, and siltstones.
- Reservoir porosity varies with sorting and compaction and ranges from 15-25%.

Volume of hydrocarbons:

- This well is fully brine saturated.

Water saturation (Sw):

- Rw has been calculated from Pickett plot and determined Rw is 0.15 at 126° F for a salinity of 25000ppm.

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that from the point where the elastic logs started down to the T.D. the Soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich zones in the few zones where density measurements are good quality. The shear model calibration was aided by comparison to the Greenberg-Castagna results, which provided a good match in analog wells. Analog well used in this calibration is Bongkobo-1, given similarity in trends.

Fluid properties:

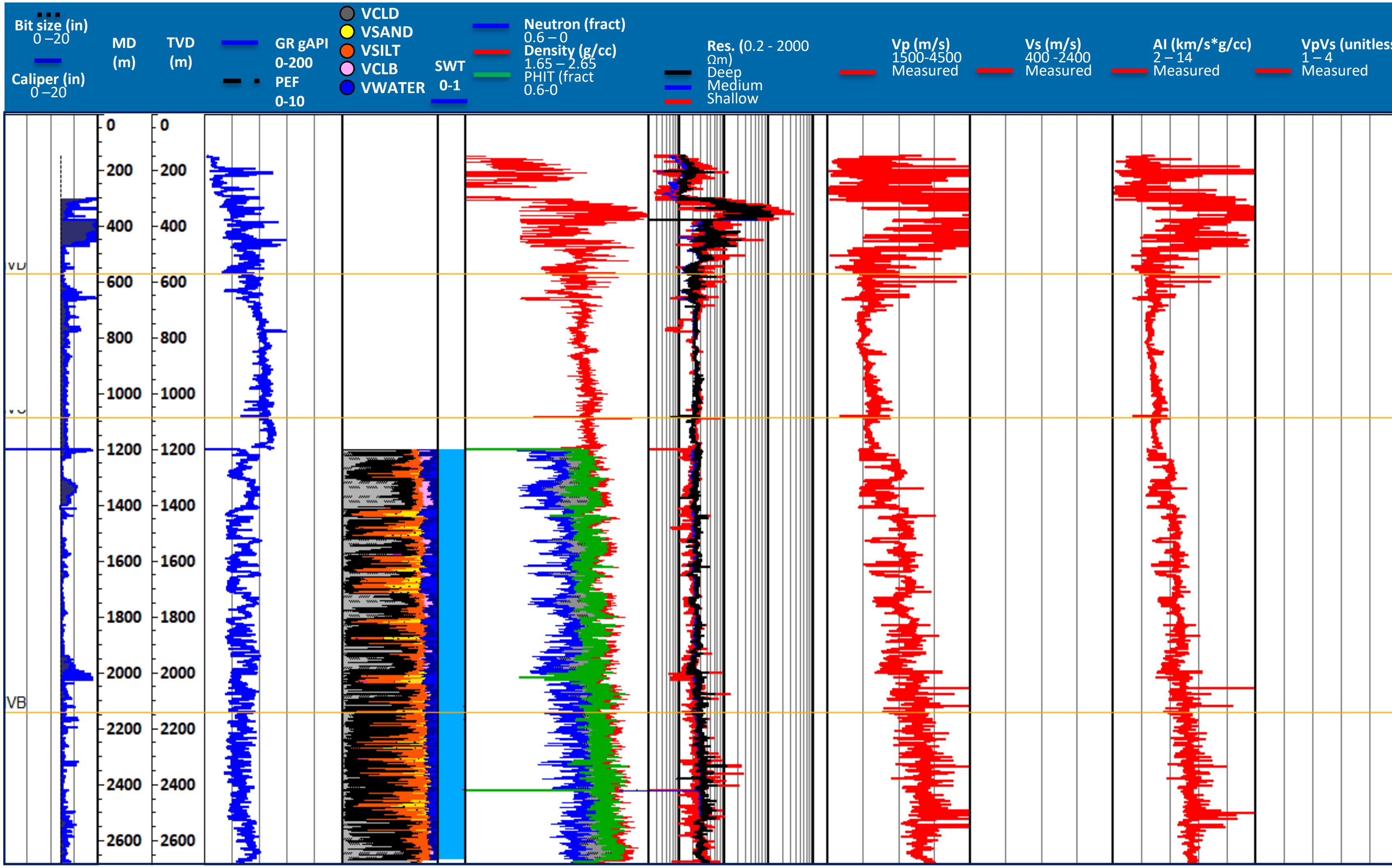
Hydrocarbon properties used in substitution have been taken from the nearby Danum-1 PVT report. Main parameters used in this modeling are:

- Brine salinity: 25000ppm [from Pickett and reports]
- Gas gravity: 0.82 [Danum-1 PVT]
- Oil Gravity: 38.9 API [Danum-1 PVT]
- Gas / Oil ratio: 500 (L/L) [Danum-1 PVT]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the Stage IVC and Stage IVB sands using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios.
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with poor to fair discrimination with the brine sands.
- The sands generally show a weak Class III AVA response that becomes stronger as porosity increases. The IVB sands show an undistinguished AVA response due to the lack of bounding shale.

Belangkas-1 Input Logs



Additional data includes mud weight, temperature data, fluid data, and final geological report.

Belangkas-1 Geophysical Well Log Analysis (GWLA) – Top of logs to 1800m

model type flag

Unconsolidated rock model

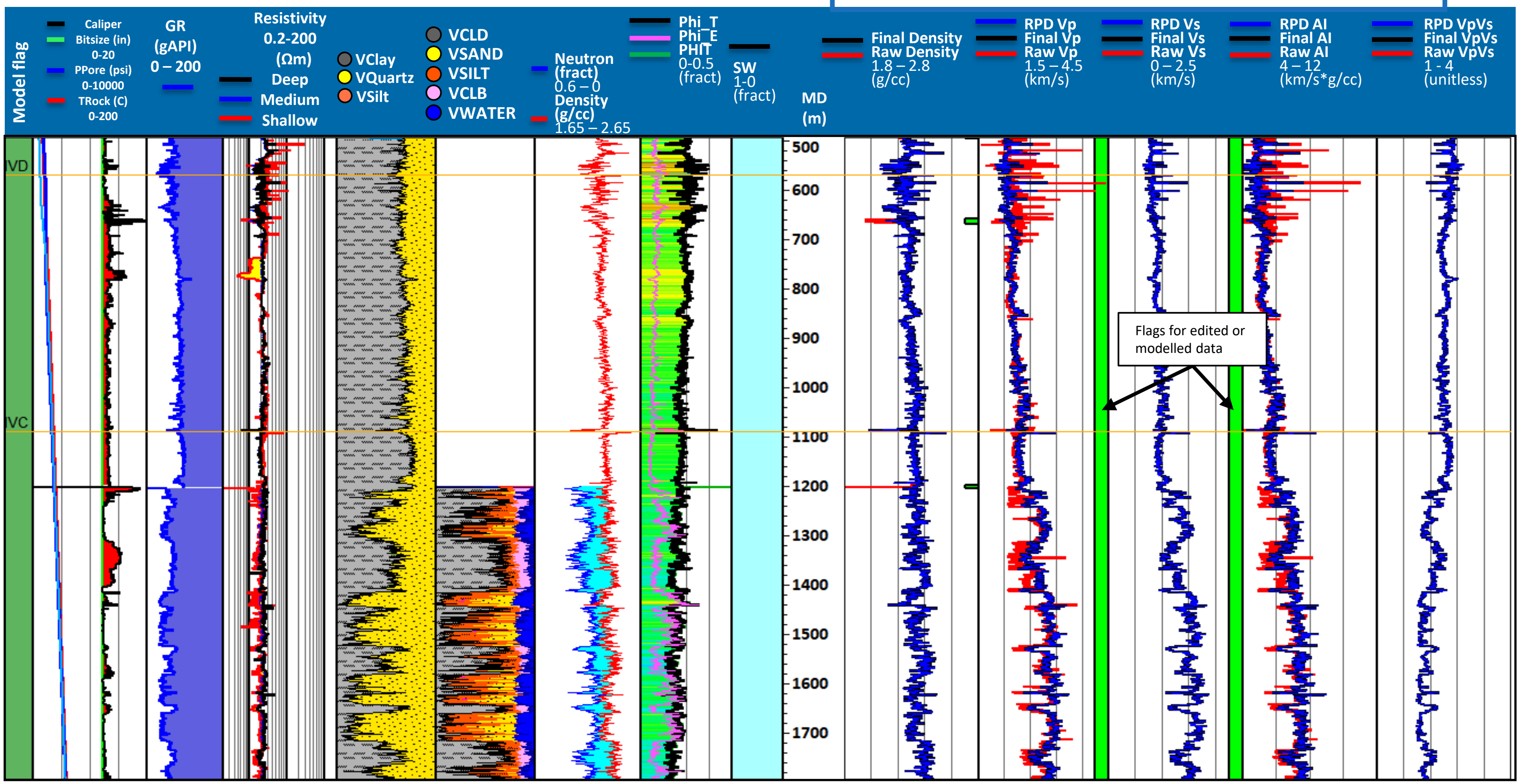
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve



Density is generally strong, no Vs measured, Vp is heavily impacted by washouts. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and Vs) with good correlation with the measured data, and using analog wells and Greenberg-Catagna calibration for Vs.

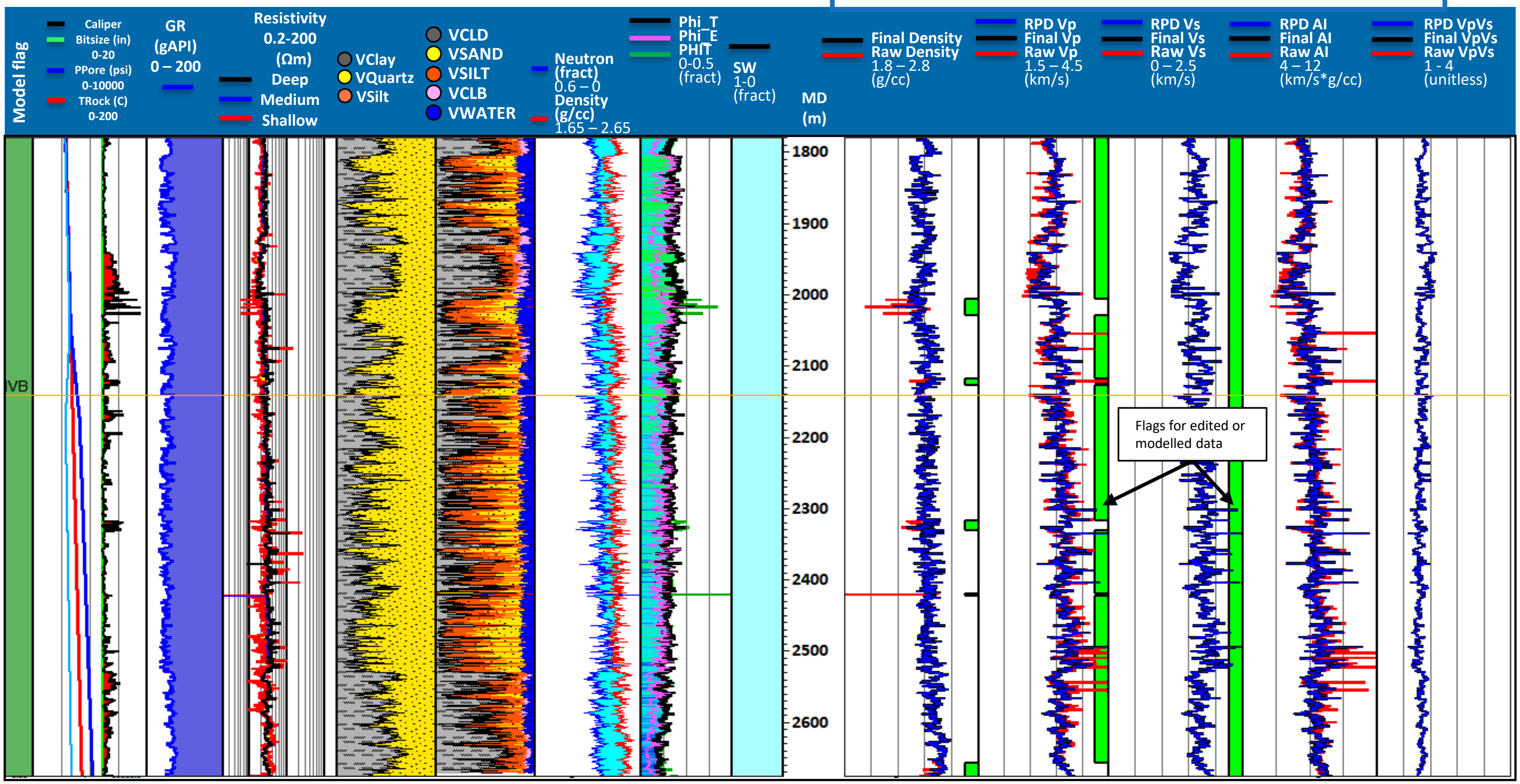
Belangkas-1 Geophysical Well Log Analysis (GWLA) – 1250m to TD (2596m)

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

model type flag

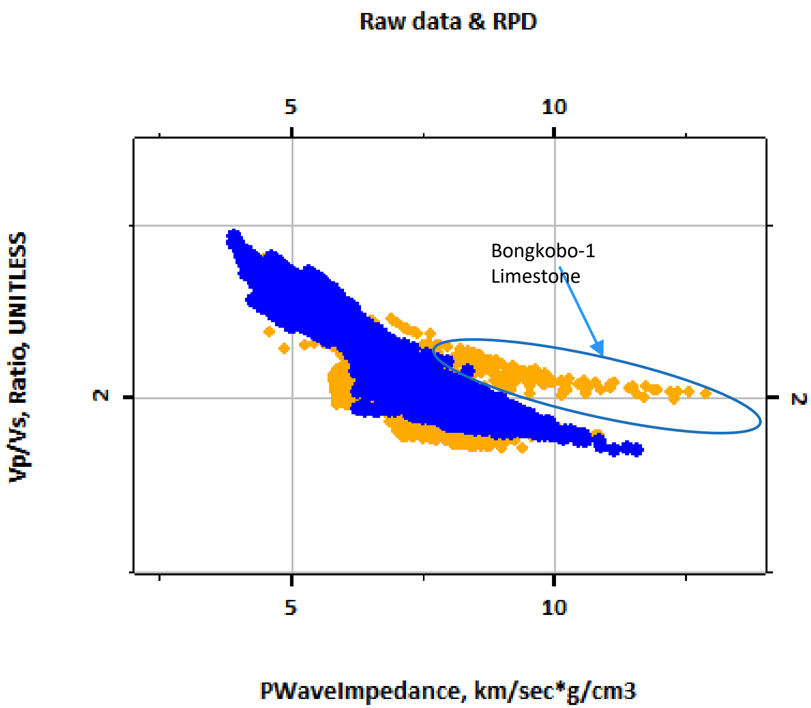
- Unconsolidated rock model
- Stiff rock model



Density is generally strong, no Vs measured, Vp is heavily impacted by washouts. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and Vs) with good correlation with the measured data, and using analog wells and Greenberg-Catagna calibration for Vs.

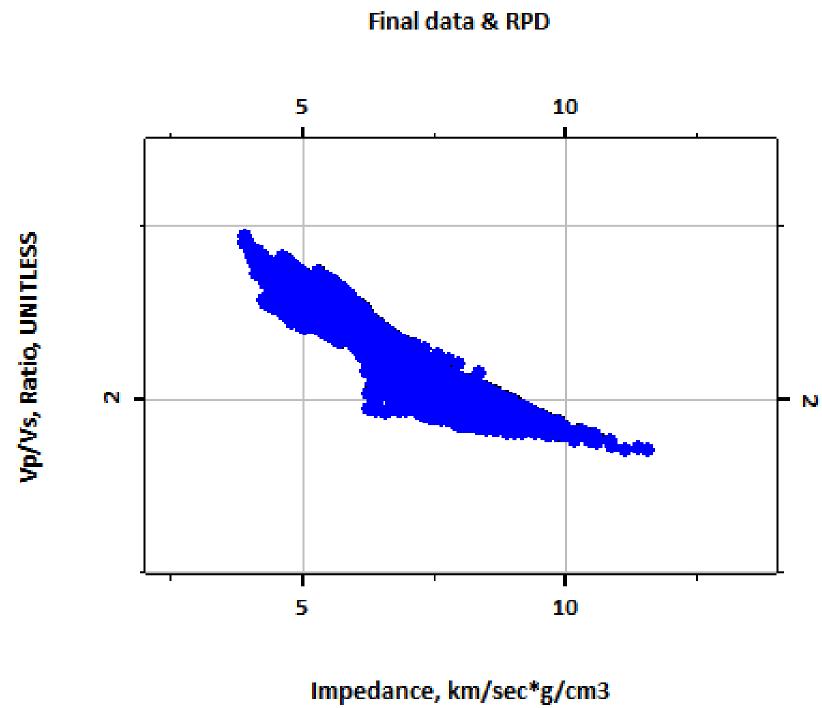
Belangkas-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the analog wells with similar trends in the elastic data, given there is no measured shear in Belangkas-1.



RPD (RPM)
Original Raw (Raw)
Bongkobo-1 RPD

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

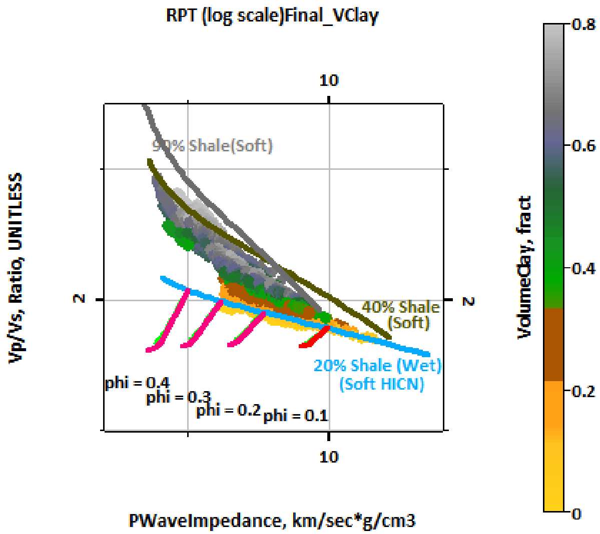


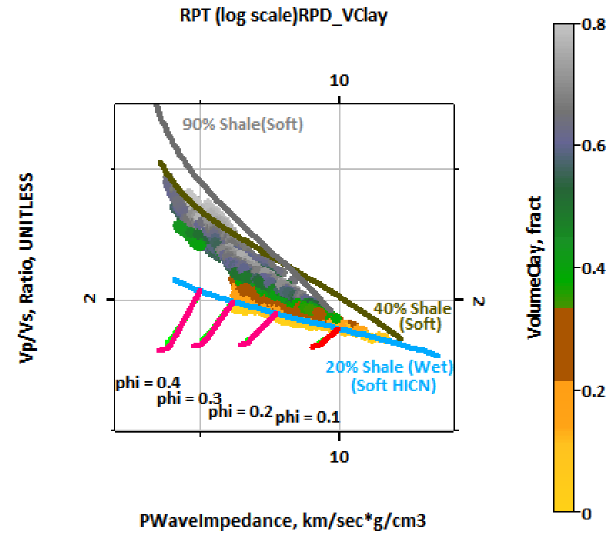
RPD (RPM)
Final (conditioned)

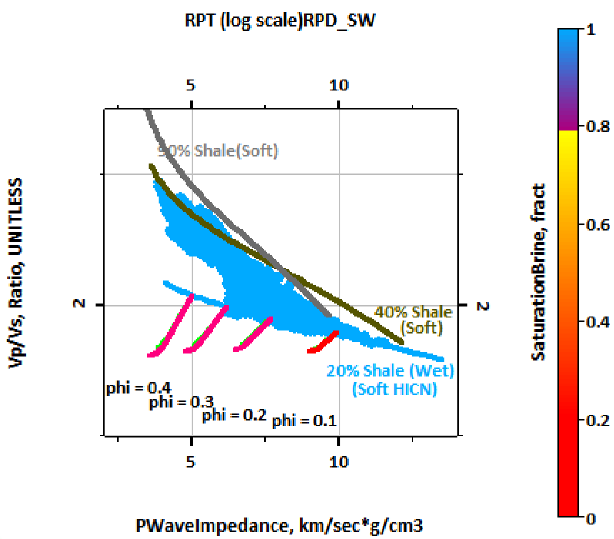
Belangkas-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

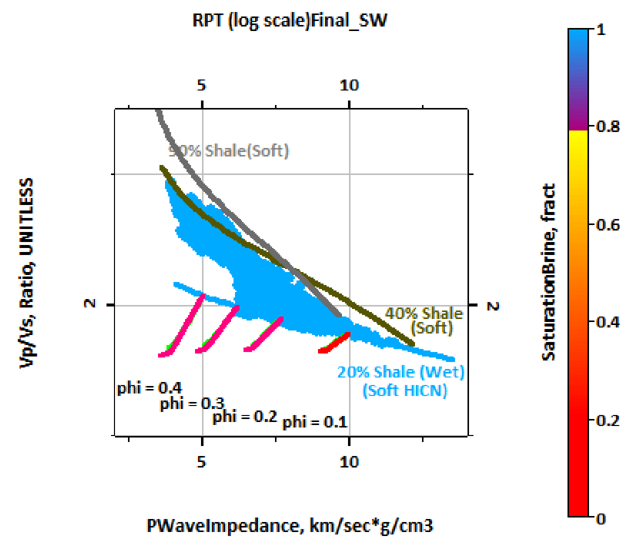
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Belud East-1

Belud East-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- Data quality is good. Most of the well logs are available in the 1400-2143 m section. Vs was unavailable for the entire well.
- Due to operational problems, only 3.2 m of core data were recovered out of the 14.3 m planned.
- In general, the density measurements were interpreted as of high quality, except for sections where borehole rugosity and mild wash-outs were present, particularly in the non-reservoir section (e.g. 1500-1515 m, 1720-1730 m). A mud invasion correction was applied on the density log in sections within the 1900-2143 m interval. Core and the RMS neutron-density porosities were used to correct the invasion-affected density log and estimate total porosities accordingly.
- Compressional wave slowness log is of good quality. A local depth shift was applied in the 1511-1514 m, 1862-1864, 1892-1897 m, 1947-1958 m sections.
- Other logs include, Neutron, Caliper, Deep and Flushed Zone Resistivities, and Photoelectric factor.

Clay volume (VClay):

- This volume was estimated via a combination of linear Gamma Ray method, and Neutron/Density crossplot.

Reservoir characteristics:

- In terms of well objectives, the primary reservoir target was the sands present in the Lower Stage IVD Section (1892-2143 m). This section is characterized by a stacked package of sandstones, siltstones and claystones deposited in a deep water environment.
- Sands can be separated into different units based on pressure compartmentalization.
- Sand5B and Sand7 show perhaps the best reservoir properties in the well with porosities of 24-28% and with well-developed sad bodies with thickness as high as 17 m.
- Towards the base of the Lower Stage IVD section, sands become siltier and less-developed; thus decreasing their reservoir properties.

Volume of hydrocarbons:

- From 1892 m depth, there are several sands with hydrocarbon content, attested by sample analysis and PVT results. Based on PVT analyses, gas was tested at 1959.2 m, 2007.1 m, 2050 m, 2110.2 m, and 2137.3 m. On the other hand, oil was sampled at 1967.8 m, 1986 m, and 1986.4 m.
- A GOC was interpreted at around 1961m based on the behavior of the density, neutron, and resistivity logs and supported by the PVT results.
- An OWC was interpreted at approximately 1970 m.
- In general, gas and oil saturations have been interpreted as high as 90% and 78% respectively. Below 2048 m, and especially within Sand8 target, reservoirs are interpreted with lower hydrocarbon saturation content, based on poorer reservoir characteristics.

Water saturation (Sw):

- Water saturation was estimated using Archie's equation. Archie's parameters were interpreted using the Pickett Plot analysis yielding salinities of 7000 ppm (0.33 Ohmm @195F), with a=1, m=1.9, and n=1.9.

Belud East-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore, and indicated that in terms of P & S-wave velocity versus porosity space, the Soft sediment model proved to be the best predictor in clay-rich and sand facies. However, based on the elastic behavior of certain sands, an Intermediate Stiff Sediment Model with a variable Coordination Number with depth was more suitable in this type of facies. These models have been used to edit the Vp and Rhob data where necessary and to perturb the rock for changes to VClay and Phi_T during the Rock physics modelling (RPM) stage of the project. Due to the unavailability of Vs data, this log was entirely modelled using Granular Media models.

Fluid properties:

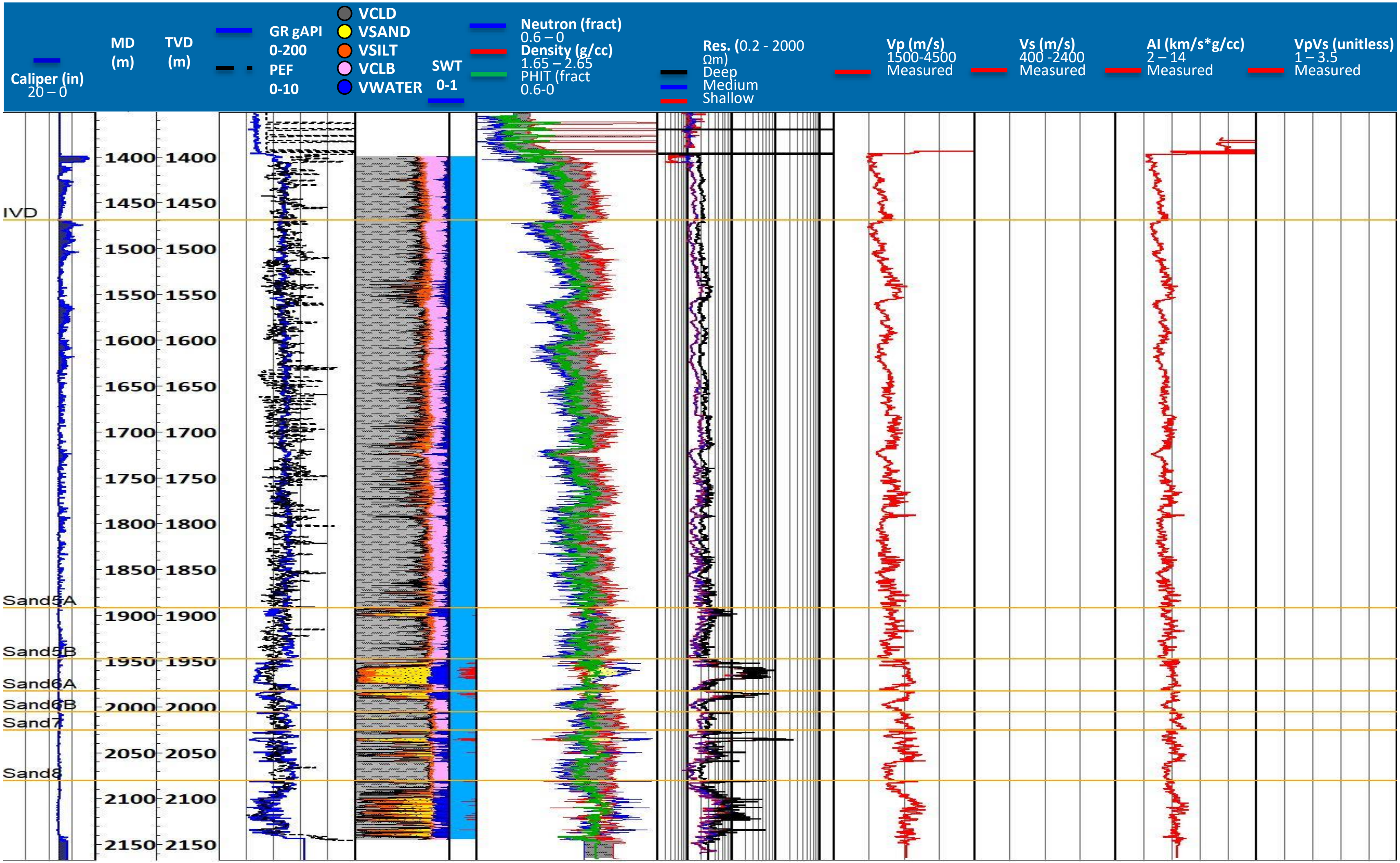
Hydrocarbon properties used in substitution have been taken from PVT well reports from this well. Main parameters used in this modeling are:

- Brine salinity: 7000 ppm
- Gas gravity: 0.65
- Oil Gravity: 37.41 API
- Gas / Oil ratio: 174 (L/L)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the Lower Stage IVD sands.
- The standard Gassmann's fluid substitution method was used to perturb the different modelling scenarios.
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Hydrocarbon sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale.

Input Logs – Belud East-1



Additional data includes pressure, core data, well reports.

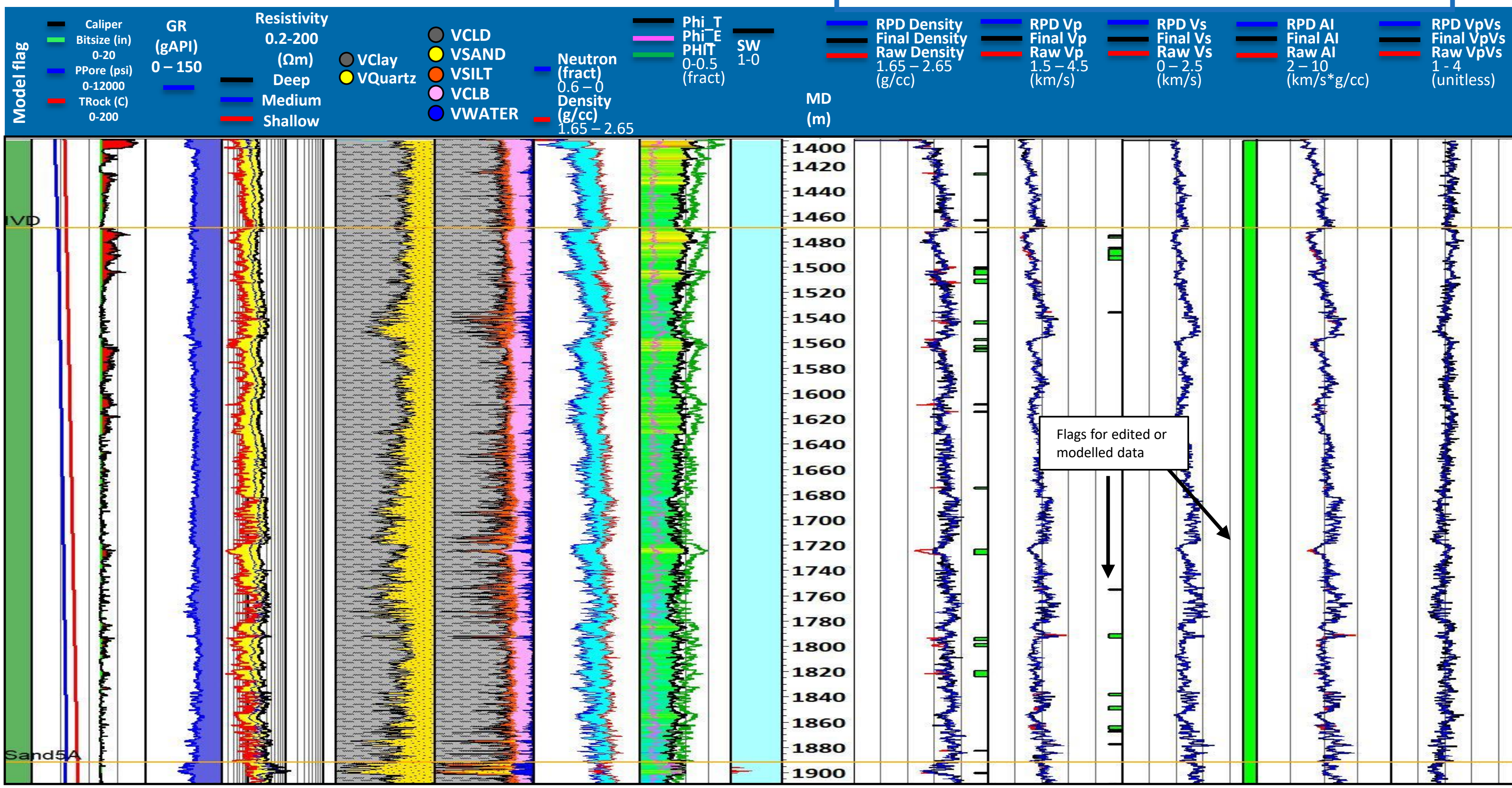
Belud East-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of logs to 1900 m

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

model type flag

- Unconsolidated rock model
- Stiff rock model



Granular media model (soft sand with variable Coordination Number) was used for the Rhob and Vp curves prediction with good correlation with the measured data. Vs was not acquired in the well and thus, it was fully estimated using granular media and Vs trends from analogue wells. In some sections, a local depth shift was applied in the Vp using density and neutron curves as references.

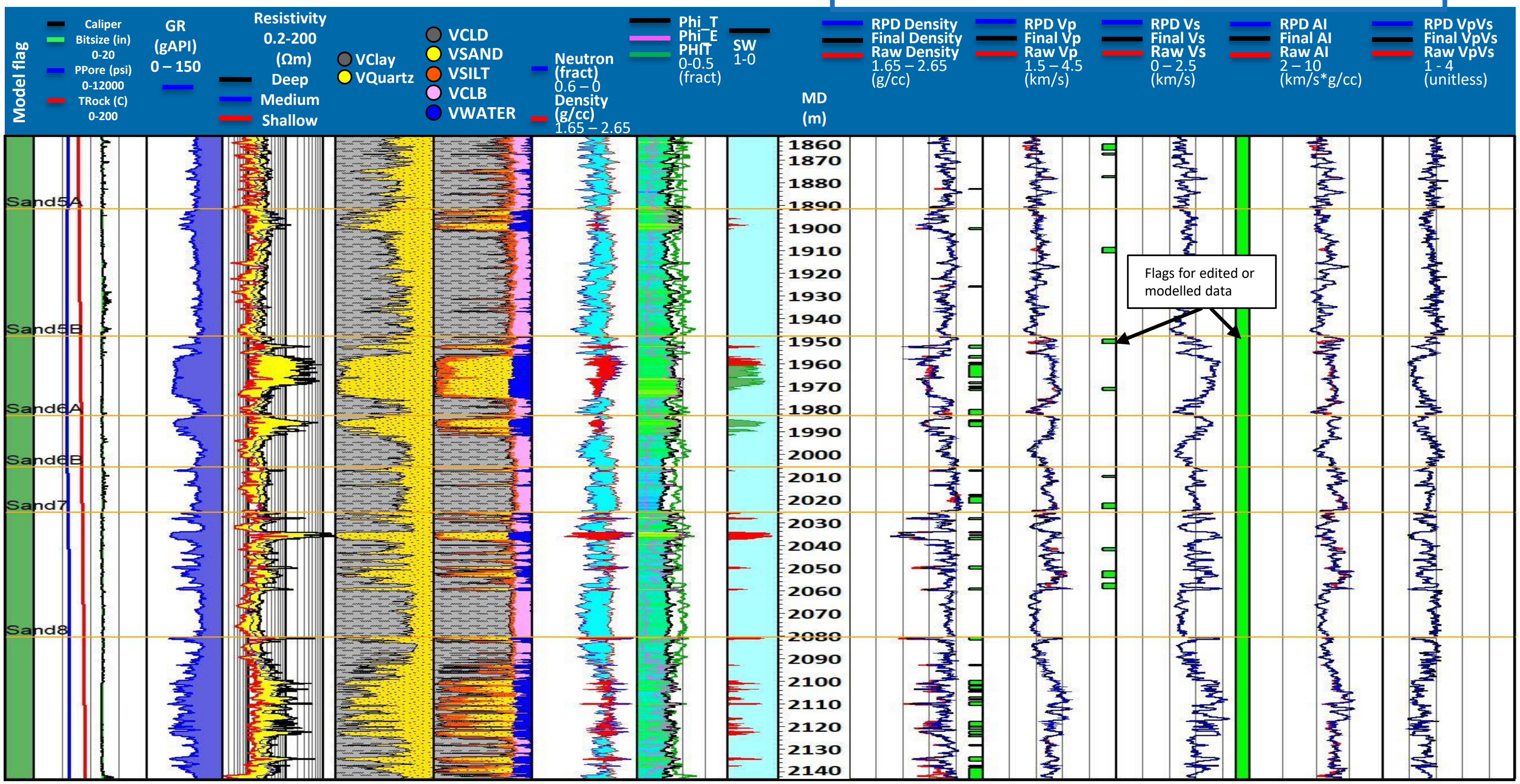
Belud East-1 Geophysical Well Log Analysis (GWLA) – Interval from 1900 m to end of logs

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming.
Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

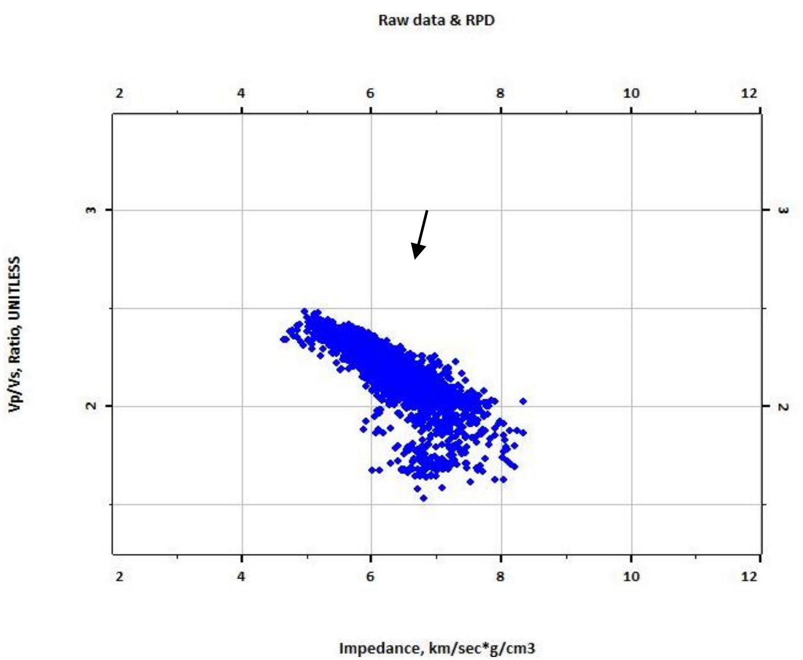


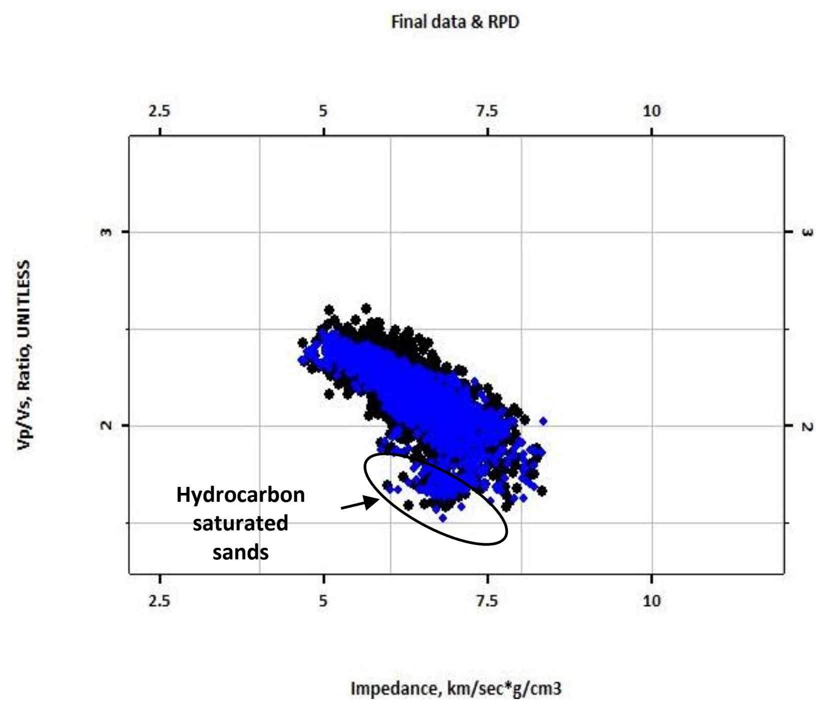
In general, elastic data is of good quality. Density was corrected due to drilling mud invasion in sands within the 1900-2143 m interval using core porosity data and the RMS neutron-density porosity as calibration. A remnant depth shift in the Vp curve was observed in localised sections which was corrected using density and neutron curves as references.

Belud East-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing only the RPD model estimated elastic variables. No Vs raw data was acquired in the well

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.



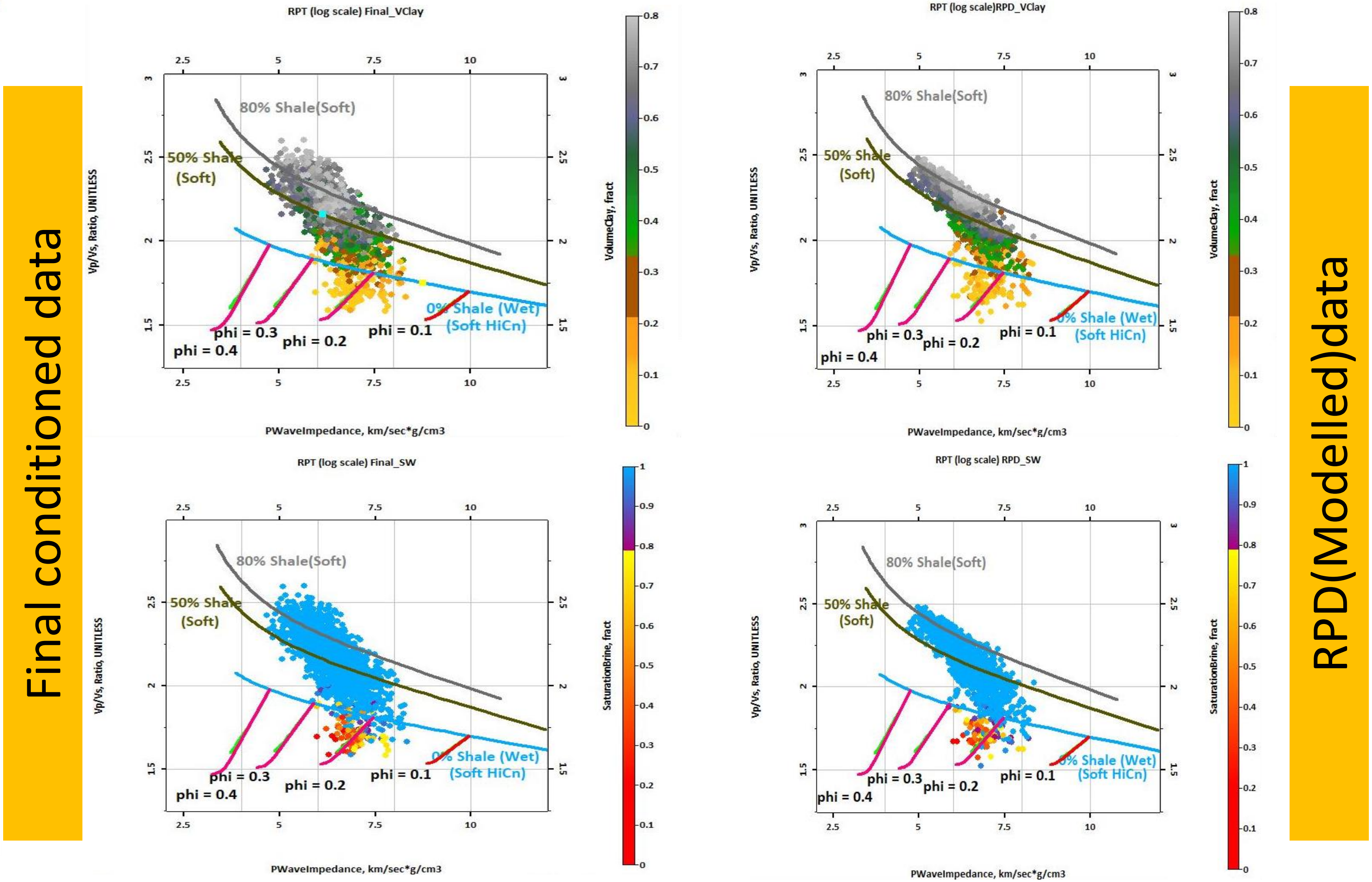


- RPD (RPM)
- Original Raw (Raw) – Vs is not available in this well

- RPD (RPM)
- Final (conditioned)

Belud East-1,Rock Physics Diagnostics (RPD) Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.



Bilit-1

Bilit-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is fair. Client's petrophysical interpretation was fully provided as a reference. Full elastic logs available only in the interval(2055m-T.D.)
- Vp and Vs was edited in many intervals throughout the wellbore using the RPD in order to have consistent measurement since the raw data produced noisy VpVs ratio .
- In some intervals due to the bad hole conditions, Rhob was edited using the RPD.
- Other logs include Gamma, Neutron, Caliper, Deep and Shallow resistivity, and Photoelectric factor which all run for the full logging run.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Miocene marine sands in the IVC stage. These are a series of turbiditic fine to very fine soft sands.
- The well penetrated many good sand layers in the IVC stage especially Sand 4 where the main gas bearing sand with total porosity up to 21% .

Volume of hydrocarbons:

- Interpreted gas saturation was best in the Sand4 zone in the interval 1600-1610 m sand with values up to 75% with some other gas accumulation in the Sand2 and Sand2 zones but up to 40% of gas saturation.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the section below the gas saturated sand(1670-1740m)yielded a formation water salinity of 26500 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.85 and Saturation exponent (n)=2 (assumed based on nearby wells' information).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to the measured data and when compared to good measured data in the nearby reference wells.

Fluid properties:

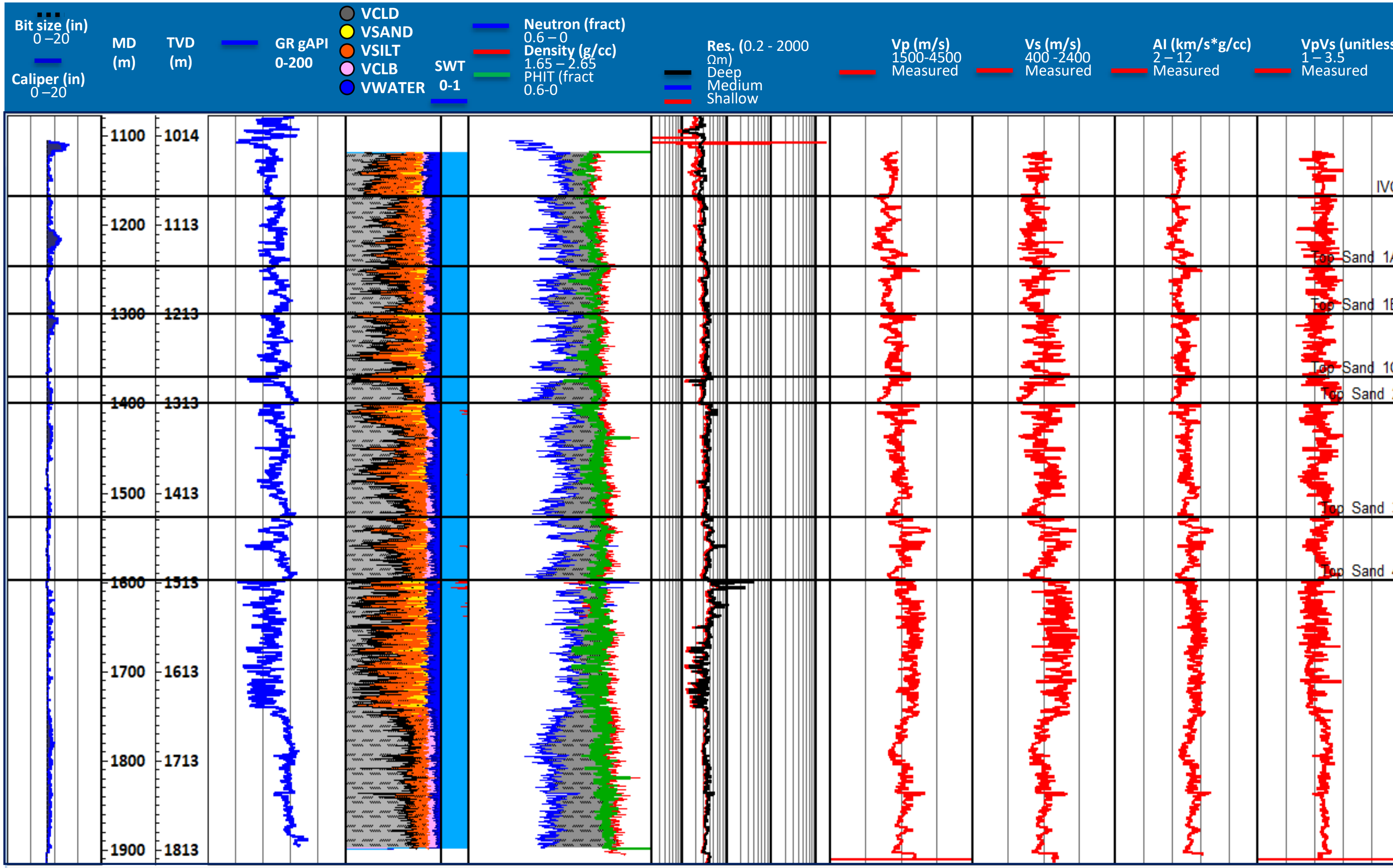
Fluid properties used in substitution have been taken from PVT report of nearby well Samarang-1(test#2). Main parameters used in this modeling are:

- Brine salinity: 26500 ppm[Pickett plot]
- Gas gravity: 0.84[PVT analysis]
- Oil Gravity: 37.7 API[PVT analysis]
- Gas / Oil ratio: 566 (L/L) [PVT analysis]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the IVC stage using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination with the brine sands.
- AVA class IIP was observed near the gas sands top @ 1600m for all hydrocarbon cases at in situ reservoir conditions compared to class II for the brine case.
- By upgrading the reservoir quality(increasing porosity and decreasing clay content) no significant change for the AVA class could be noticed for all fluid cases.

Bilit-1 Input Logs



Additional data includes pressure, temperature data, cuttings descriptions and final geological report.

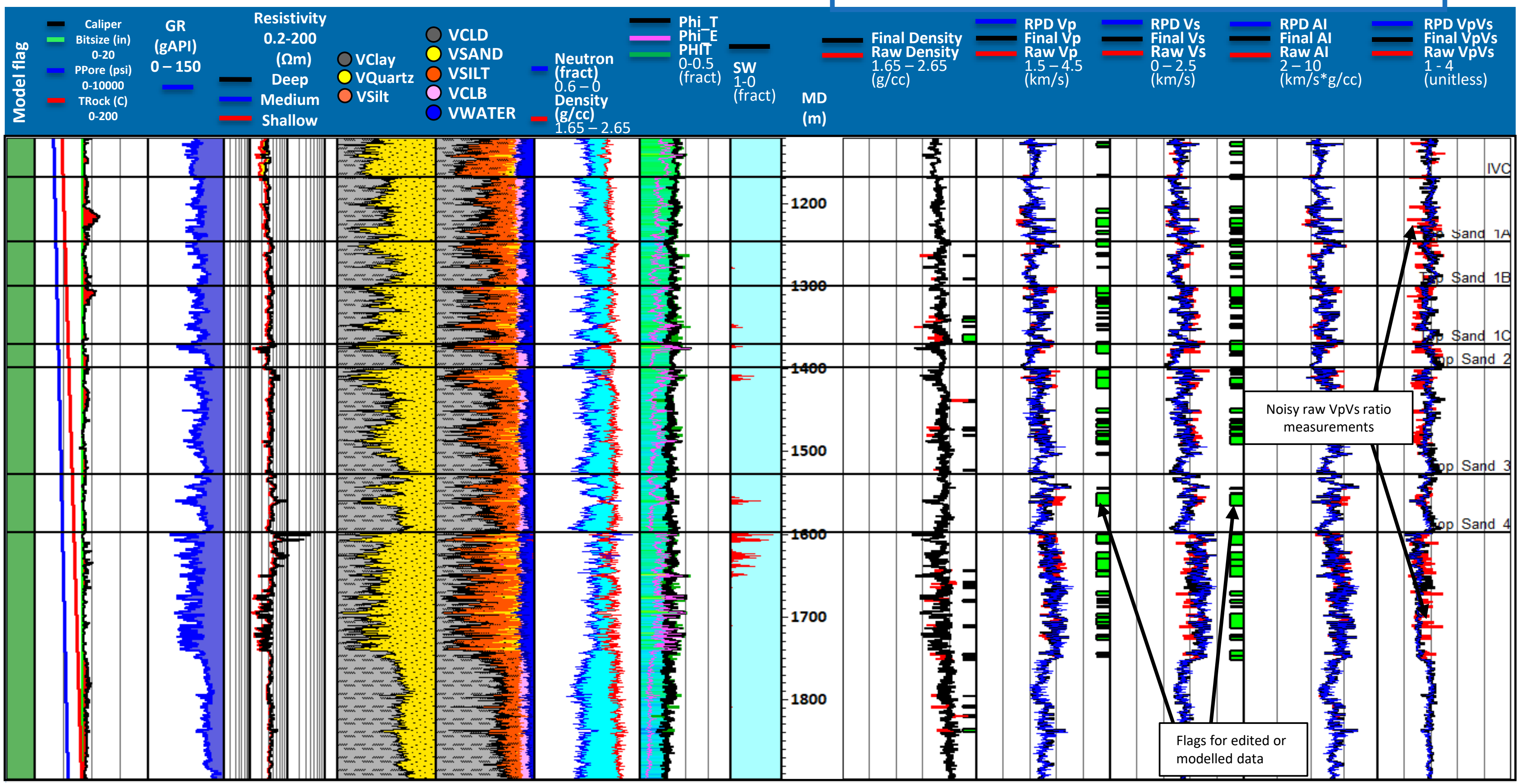
Bilit-1 Geophysical Well Log Analysis (GWLA) – Interval from1100m to the end of logs

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

model type flag

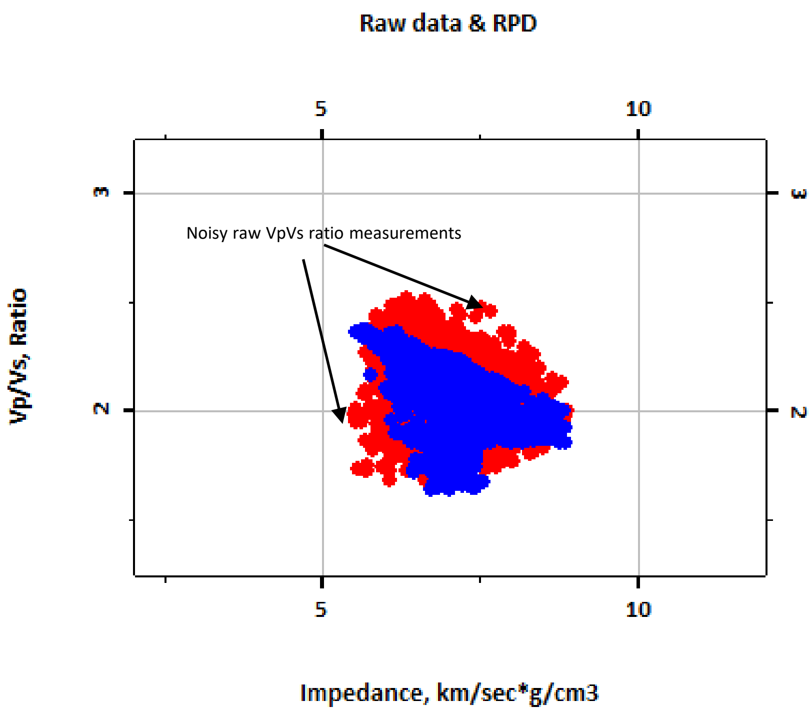
- Unconsolidated rock model
- Stiff rock model



Major edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

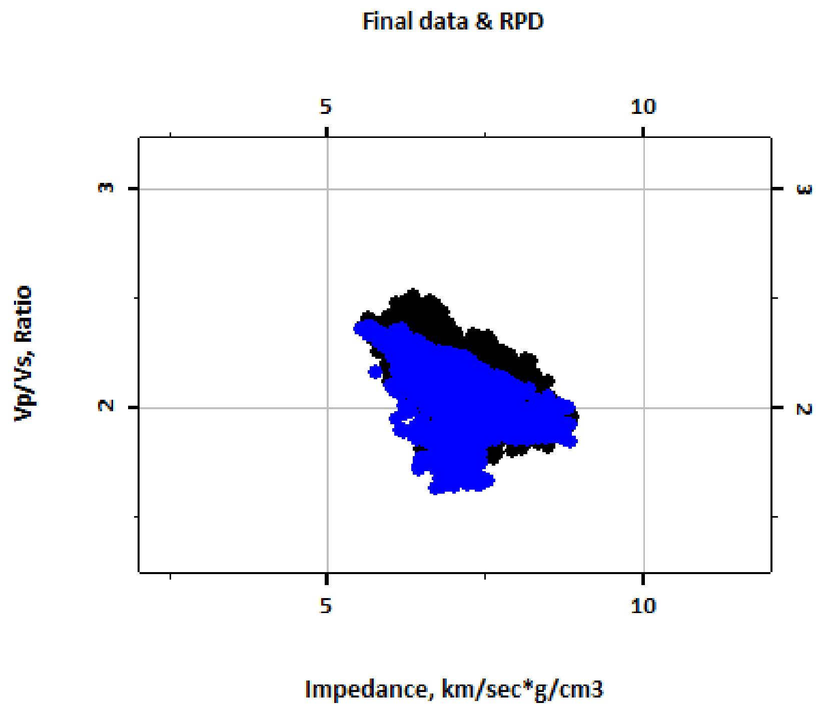
Bilit-1,Rock Physics Diagnostics (RPD)
Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.



RPD (RPM)
Original Raw (Raw)

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

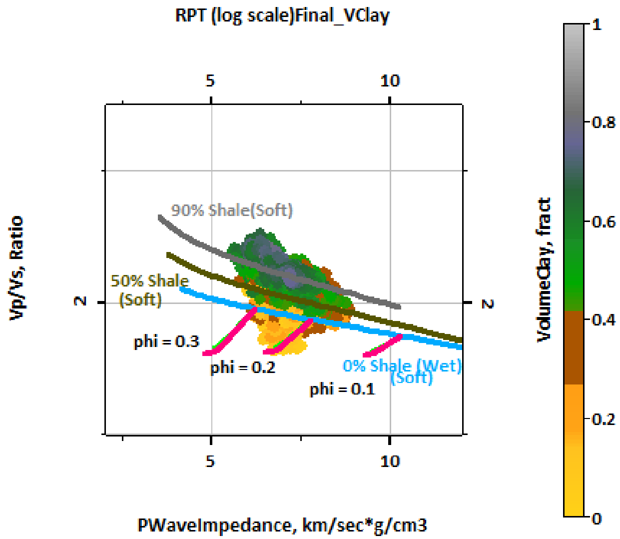


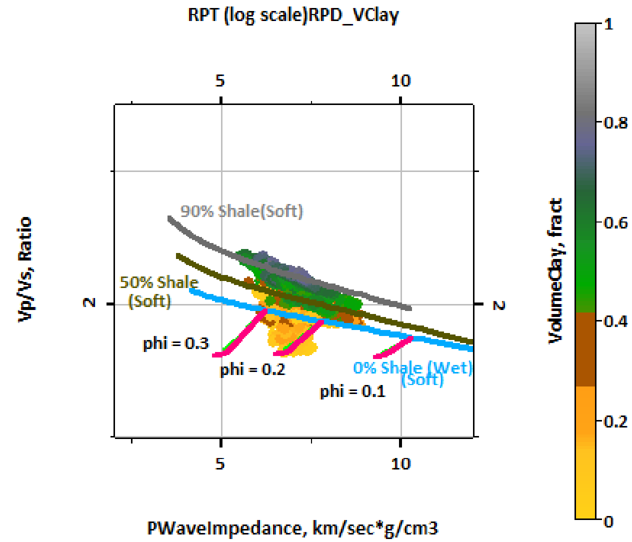
RPD (RPM)
Final (conditioned)

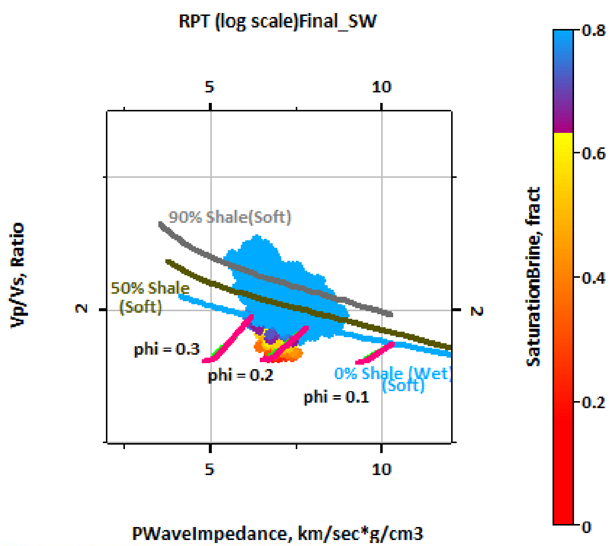
Bilit-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

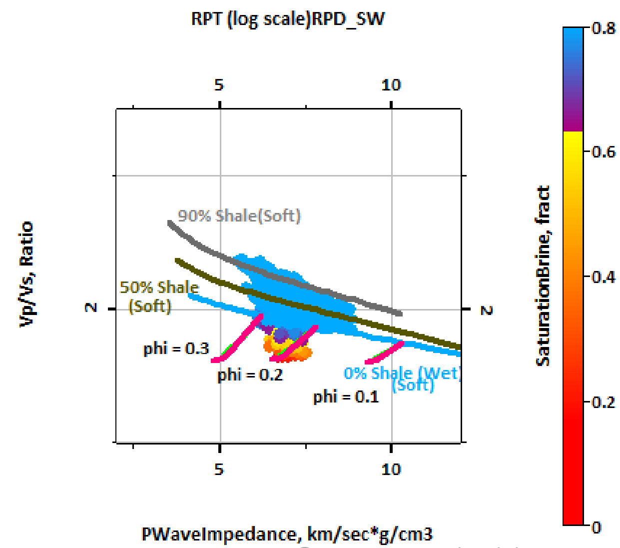
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Biris-1

Biris-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is fair. Client's petrophysical interpretation was fully provided as a reference. Vs was heavily edited in the main sand reservoir interval using the RPD due to bad measurement.
- Vp and Vs was edited in some intervals in the reservoir section using the RPD in order to have consistent VpVs ratio results.
- Other logs include Gamma, Neutron, Caliper, Deep, Shallow and Medium Resistivity, and Photoelectric factor which all run for the full logging run.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is the Biris sands(1801-1856m). These are a series of turbiditic soft sands, distributed in lobe/channel complexes with increasing in clay content towards the base of the section.

Volume of hydrocarbons:

- Interpreted gas saturation was best in the 1812-1831 m sand with values up to 85% with some residual gas saturation(1-5%) down to 1840m.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the section below the gas water contact yielded a formation water salinity of 25000 PPM. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.9 and Saturation exponent (n)=1.9 (as in the final geological report).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore, and indicated that from the mudline down to about 1200mBML the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both cleaner sand intervals and clay rich intervals while in the deeper horizons the soft sand model with higher coordination number proved to be the best elastic logs predictor in the clean sand intervals when compared to the measured data.

Fluid properties:

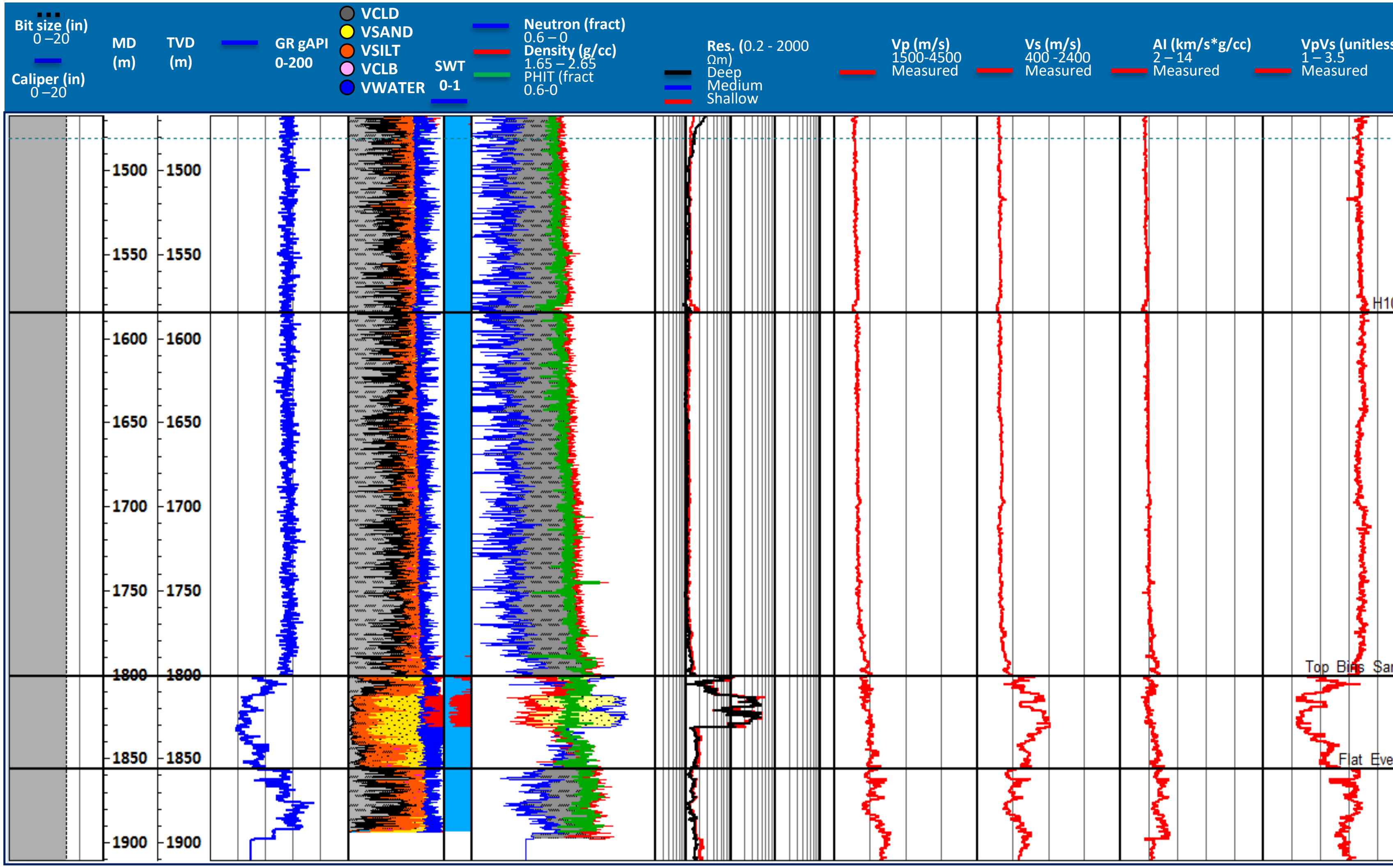
Fluid properties used in substitution have been taken from PVT well reports. Main parameters used in this modeling are:

- Brine salinity: 25000 ppm
- Gas gravity: 0.784[PVT analysis]
- Oil Gravity: 44 API[Assumed based on area results]
- Gas / Oil ratio: 200 (L/L) [Assumed based on area results]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different H200 sands using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale with good discrimination with the brine sands.
- No significant change occurred by decreasing the porosity of the reservoir interval.

Biris-1 Input Logs



Additional data includes pressure, temperature data, cuttings descriptions and final geological report.

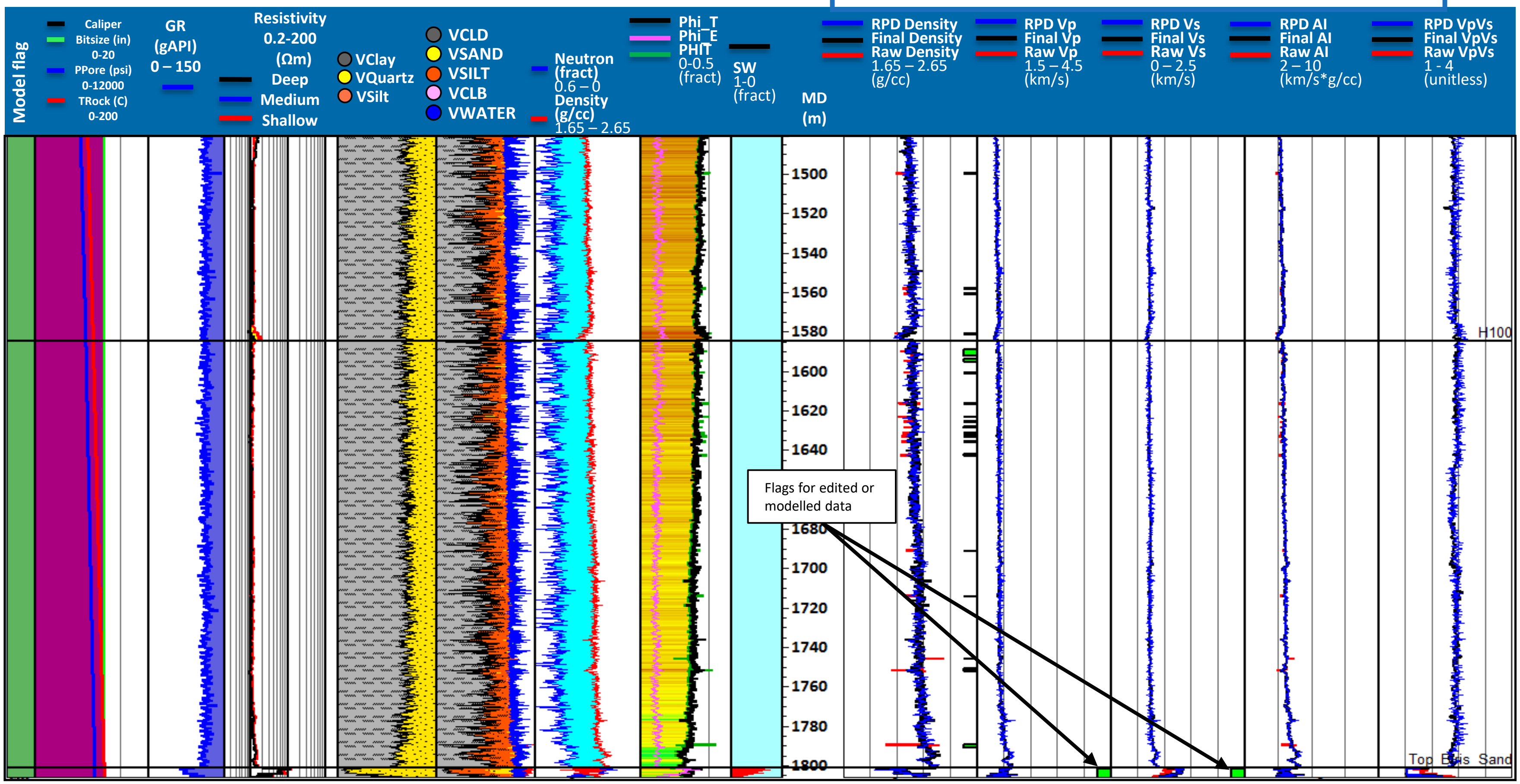
Biris-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of logs to 1800m

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming.
Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve



Minor edits to the measured density and model calibration is strong. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

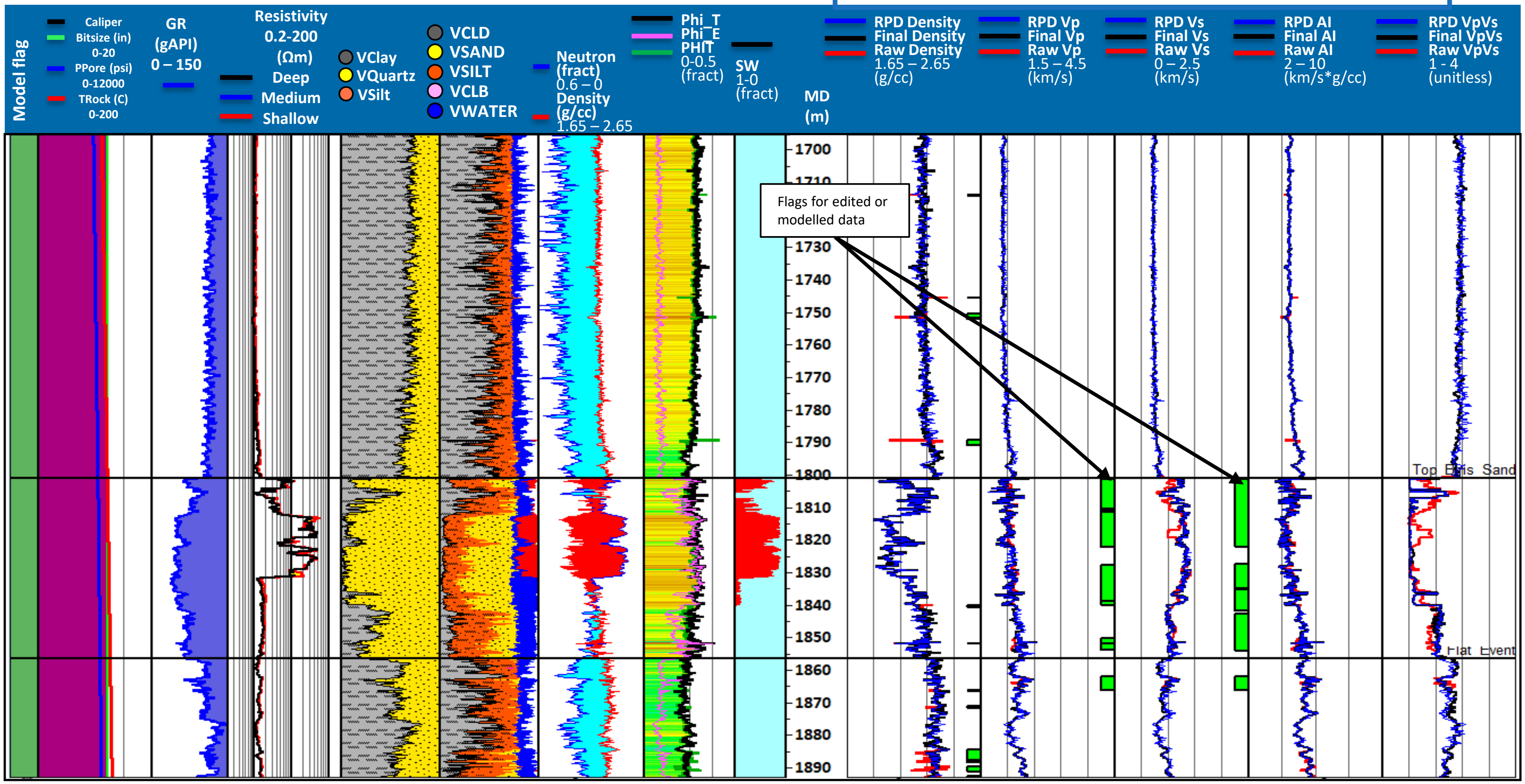
Biris-1 Geophysical Well Log Analysis (GWLA) – Interval from 1700 m to the end of logs

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

model type flag

- Unconsolidated rock model
- Stiff rock model

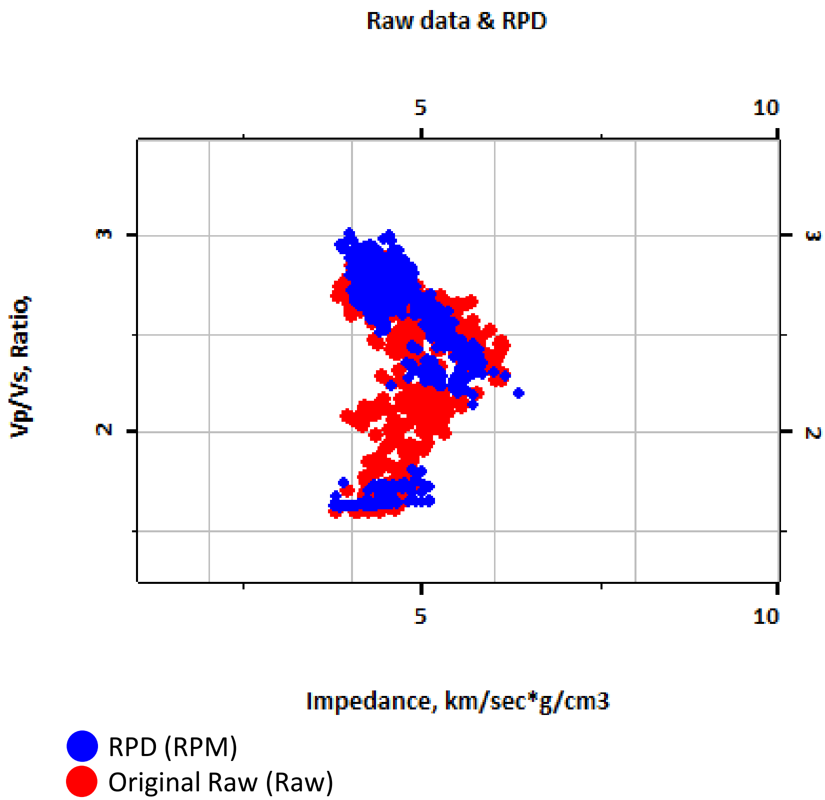


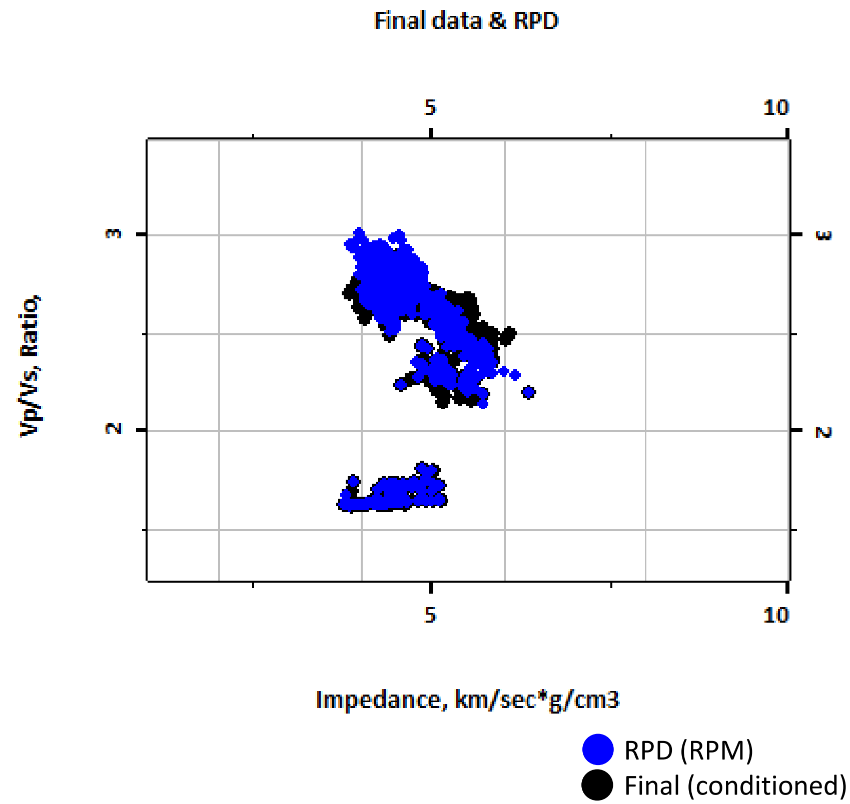
Major edits to the measured Vp and Vs in the reservoir section. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

Biris-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

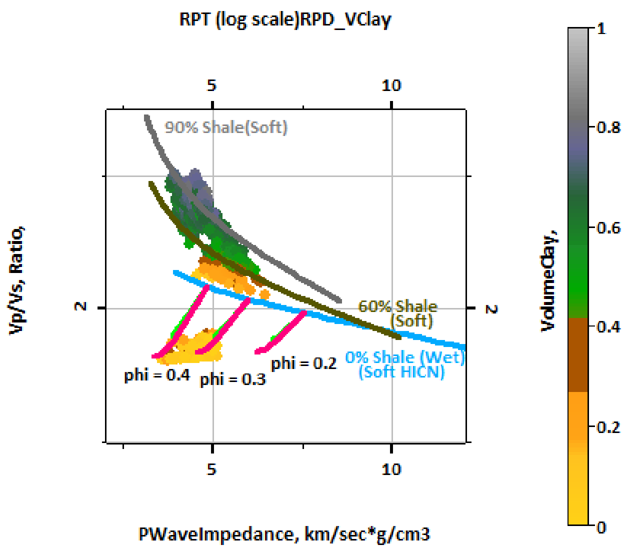


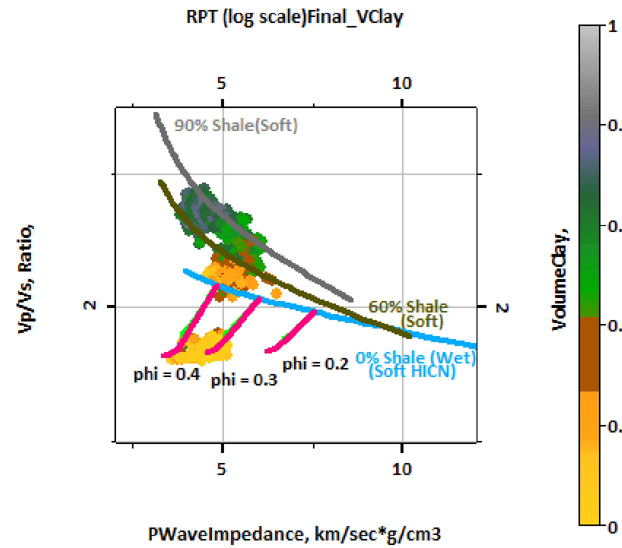


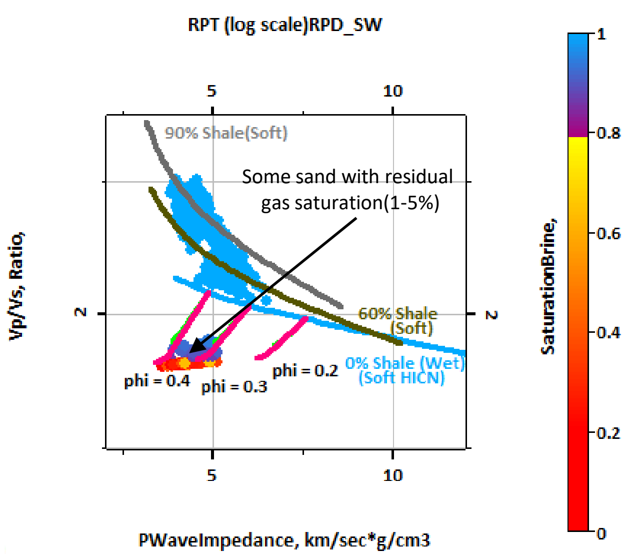
Biris-1,Rock Physics Diagnostics (RPD) Rock Physics Models, Full Well

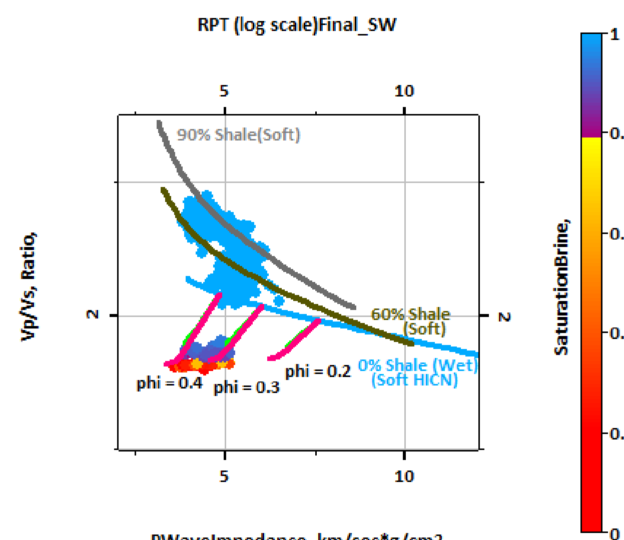
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Bonanza-1

Bonanza-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality is poor especially the density but the data availability is fair. Client's petrophysical interpretation was not provided for this. Full elastic logs except VS were available throughout the wellbore covering the interval (400m-T.D.)
- Elastic logs(VP and Rhob)were totally affected by the bad hole conditions above 425m so no reliable response could be obtained to establish a rock physics model for that interval.
- Shear wave velocity(VS)was fully modelled in the well using the RPD after the model was carefully calibrated based on the offset wells behaving elastically the same especially(Danum-1 and Bilit-1 to the south) The resulted Vs matched in trend all the nearby wells
- Density was heavily edited in many intervals using the RPD due to the bad hole conditions especially above 1000m.
- Vp also was edited using the RPD in some intervals especially where the hole was affected by washouts as in the interval(450-550m).
- Vp was -1m depth shifted reference to all other set of logs.
- Elastic curves in the bad Vp and Density measurements intervals were filled using deep resistivity to predict Vp via Faust equation then density and Vs were estimated using the RPD.
- Other logs include Gamma, SP, Caliper and Deep resistivity, which all run for the full logging run to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Miocene marine sands in the IVD stage. These are a series of turbiditic fine to very fine soft sands.
- The well penetrated many good sand layers in the IVD stage especially in the interval 700-1000 where total porosity reached up to 35% .

Volume of hydrocarbons:

- All sand reservoirs penetrated in the IVD sequence were 100% brine saturated.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the clean wet sand(900-950m)yielded a formation water salinity of 15500 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.85 and Saturation exponent (n)=1.85 (assumed based on nearby wells' information).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to good measured data in the nearby reference wells and other wells on the same elastic trend.
- Elastic behavior for the well was carefully calibrated with the nearby wells and other wells honoring the same elastic trend for the well(P-Wave impedance depth trend) And concluded that the well elastically behaves similar to Danum-1 well and Bilit-1(even though it is far but elastically honoring Bonanza-1 elastic trend) , so S-wave velocity completely modelled in the well based on the same model and parameters used in the offset wells which resulted in a matched trend with the calibrated nearby wells.

Fluid properties:

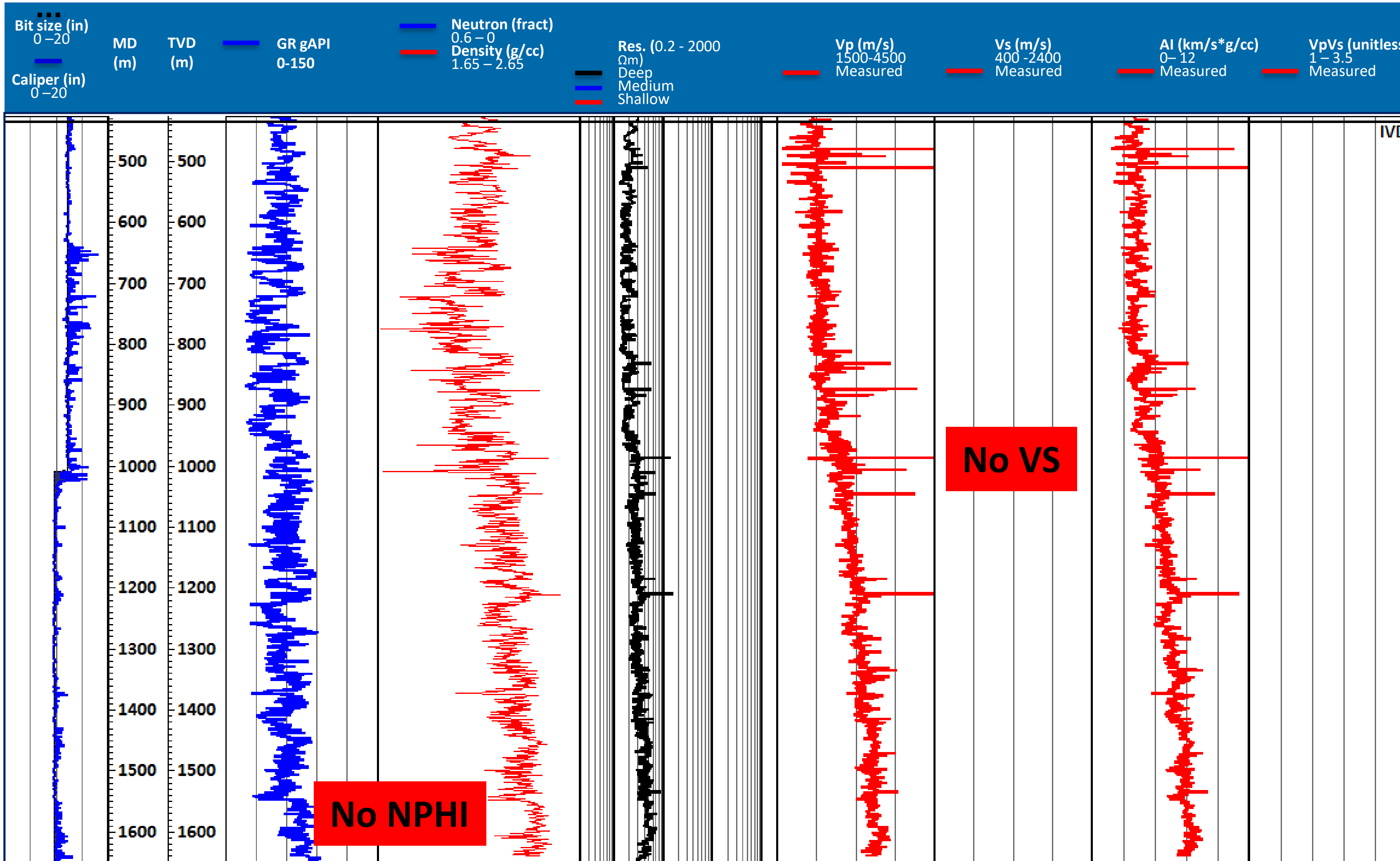
Fluid properties used in substitution have been taken from PVT report of nearby well Danum-1, Main parameters used in this modeling are:

- Brine salinity: 15500 ppm[Pickett plot]
- Gas gravity: 0.82[PVT analysis]
- Oil Gravity: 38.9 API[PVT analysis]
- Gas / Oil ratio: 500 (L/L) [PVT analysis]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the IVD stage using the final modelled elastic curves as an input.
- Gassmann’s fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination with the brine sands.
- AVA class III was observed near a good porosity sand @ 1227m for all hydrocarbon cases at in situ reservoir conditions while the brine case following the background response.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) no significant change for the AVA class could be noticed for all fluid cases.

Bonanza-1 Input Logs



Additional data includes final geological report. No VS and Neutron logs recorded in the well.

Bonanza-1 Geophysical Well Log Analysis (GWLA) – Interval from 425 to 1000 m

model type flag

Unconsolidated rock model

Stiff rock model

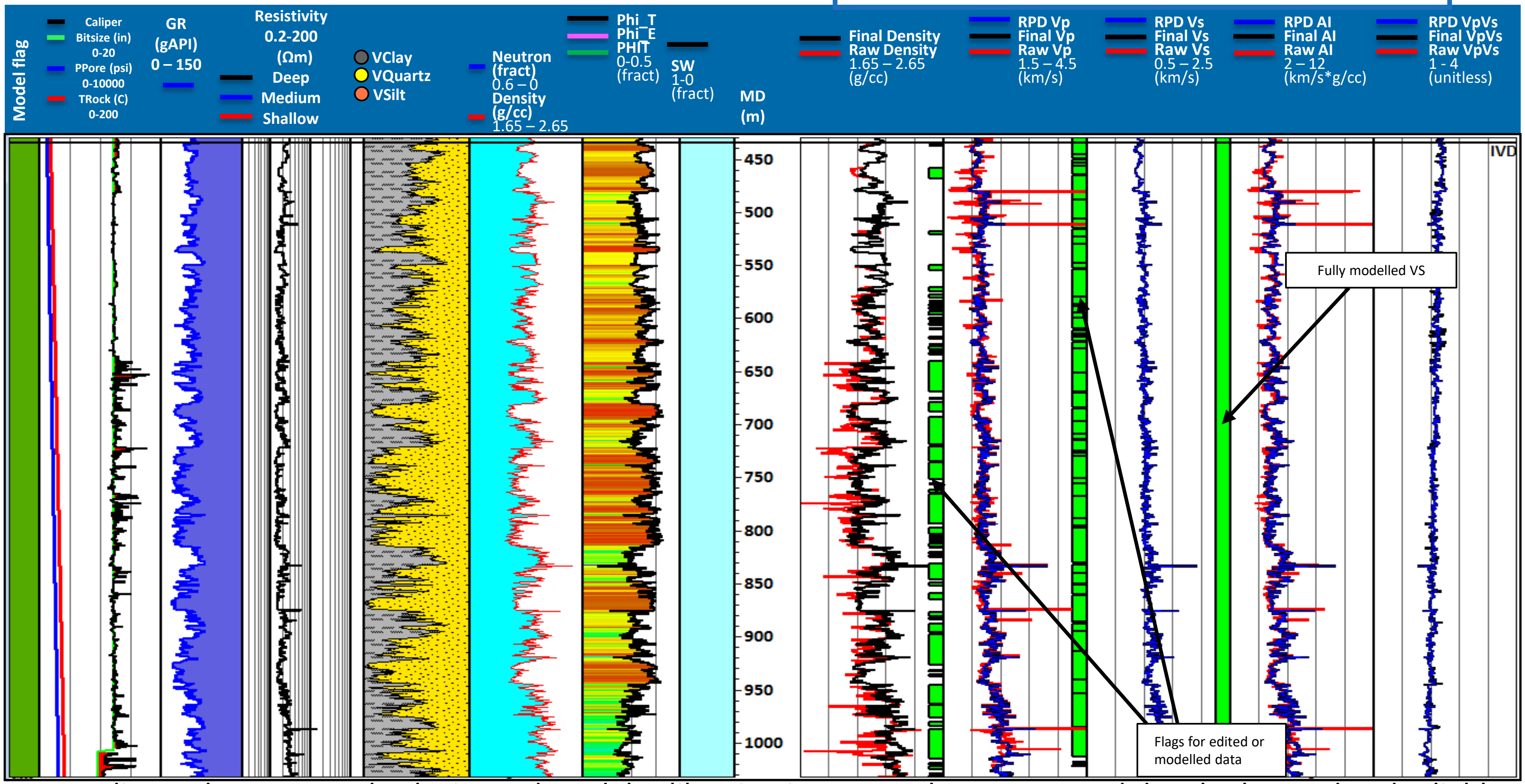
Above depth of 425m(MD) no reliable logs were available to establish a rock physics model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve



Many edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (Soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) for both sand and clay rich intervals, with good correlation with the measured data in the well(VP and Rhob)and in the nearby wells. VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells

Bonanza-1 Geophysical Well Log Analysis (GWLA) – Interval from1000m to the end of logs

model type flag

Unconsolidated rock model

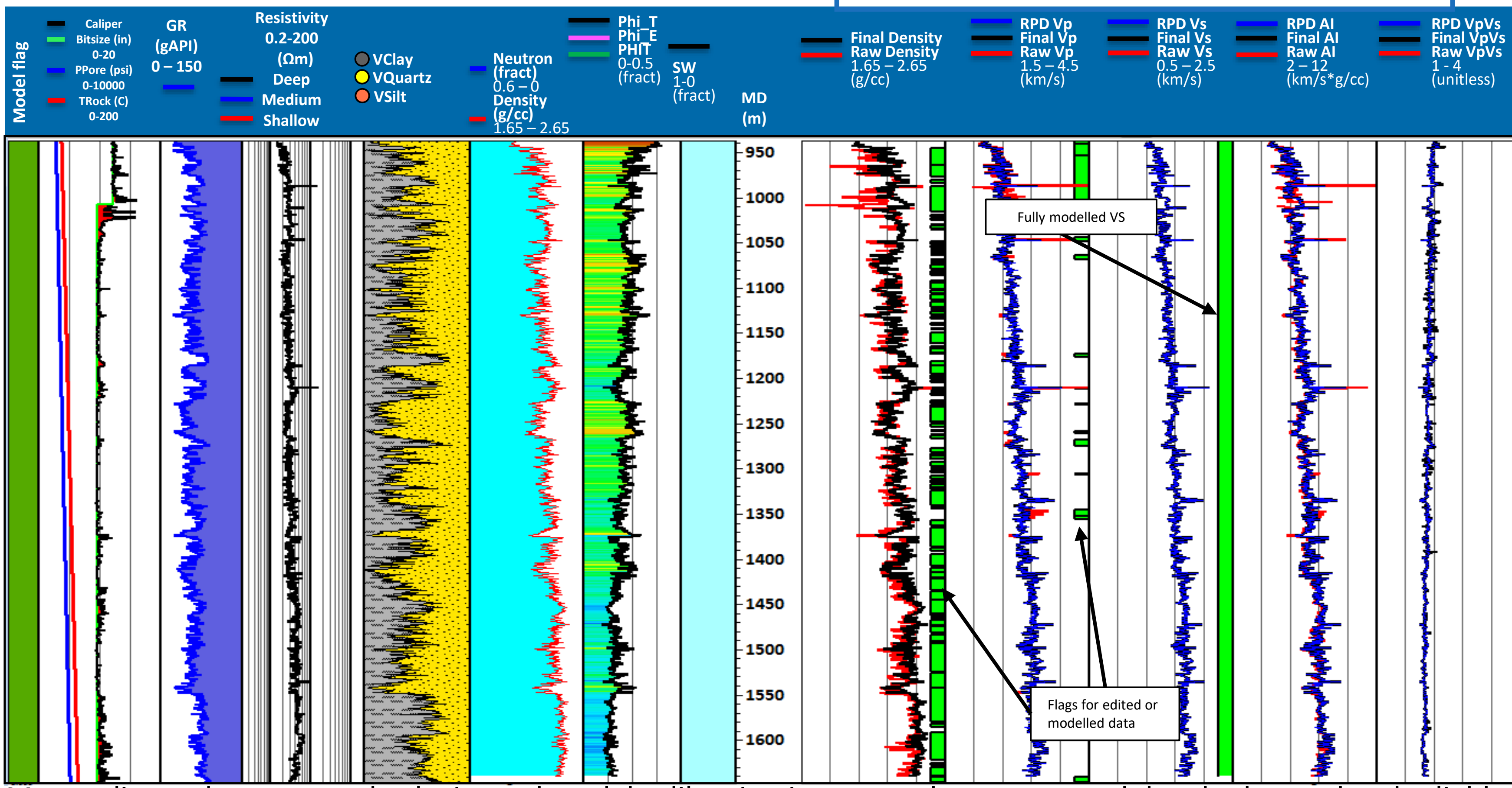
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve

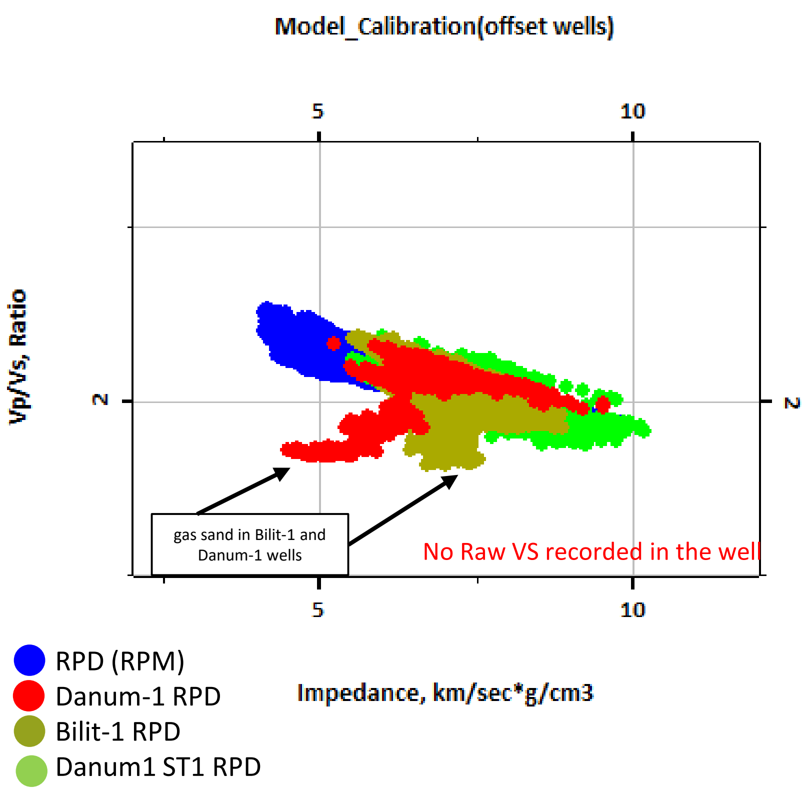


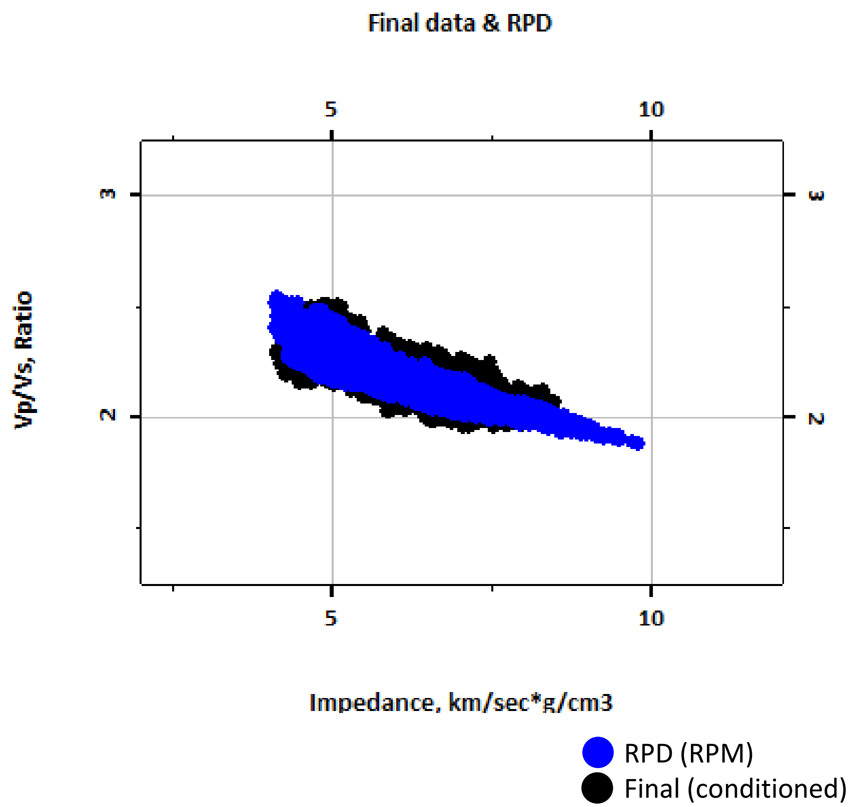
Many edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (Soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) for both sand and clay rich intervals, with good correlation with the measured data in the well(VP and Rhob)and in the nearby wells. VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells

Bonanza-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the good calibration for the Bonanza-1 well RPD with the nearby wells Danum-1, Bilit-1 and Danum-1 ST1.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data(Rhob and Vp ere conditioned while VS is totally modelled).

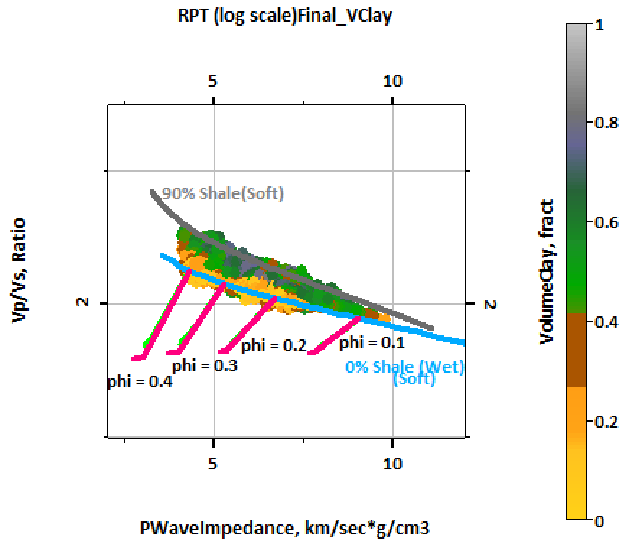


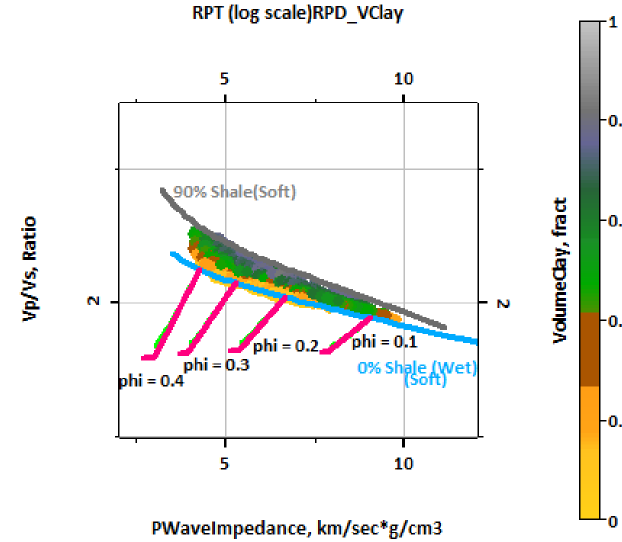


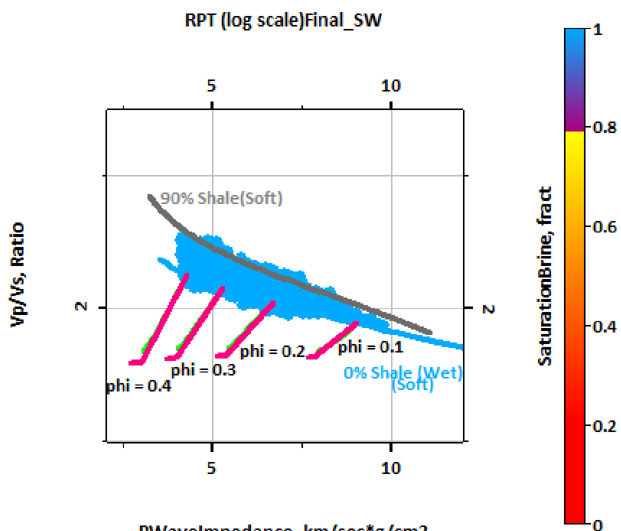
Bonanza-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

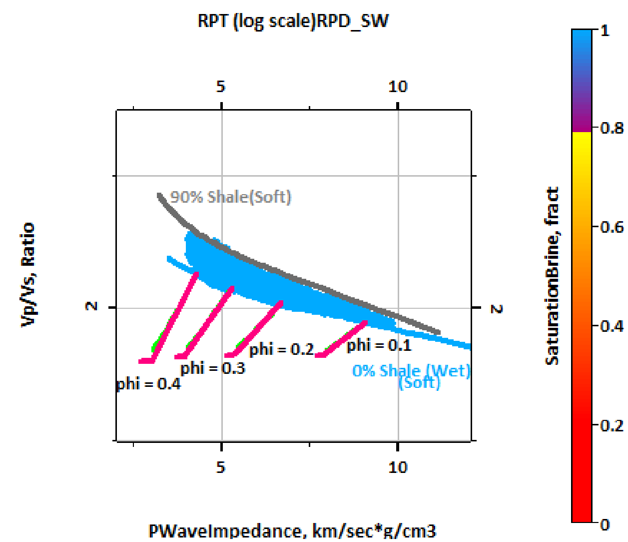
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Bongkobo-1

Bongkobo-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is high. Full elastic logs available only in the interval 1163m – 2588m.
- The only edits to Vp and Vs are around the hard streaks that have been interpreted as predominantly calcite bearing. The Vp/Vs is consistently higher than any anticipated mineralogy.
- RHOB is only edited at the top casing section at 1200m.
- Other logs include Neutron run over the same interval as the elastic logs and Gamma Ray, and Deep resistivity run over the full logging run from 92m – 2604m.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method with Neutron/Density in places.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Stage IVD shallow marine sands correlating to the H3 and K2 sands.
- Clean sand porosities range from 20%-33%, but average 19%.
- Additionally the hard streaks have been interpreted as calcite dominated, largely based on the high values of the measured Vp/Vs response. There is no information in the well reporting to indicate streak composition. The strongest streak at 1464m has a density of 2.73 g/cc, suggesting some composition heavier than calcite (some dolomite was interpreted here, but no where else, as all other densities are less than 2.71 g/cc). Some siderite is a possibility. Given the ambiguity for the purposes of this atlas study the interpretation erred on the side of simplicity.

Volume of hydrocarbons:

- The well is fully brine saturated.

Water saturation (Sw):

- Rw calculated assuming a salinity of 24000ppm and using the calculated temperature curve.

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that from the point where the elastic logs started down to the T.D. the Soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich.

Fluid properties:

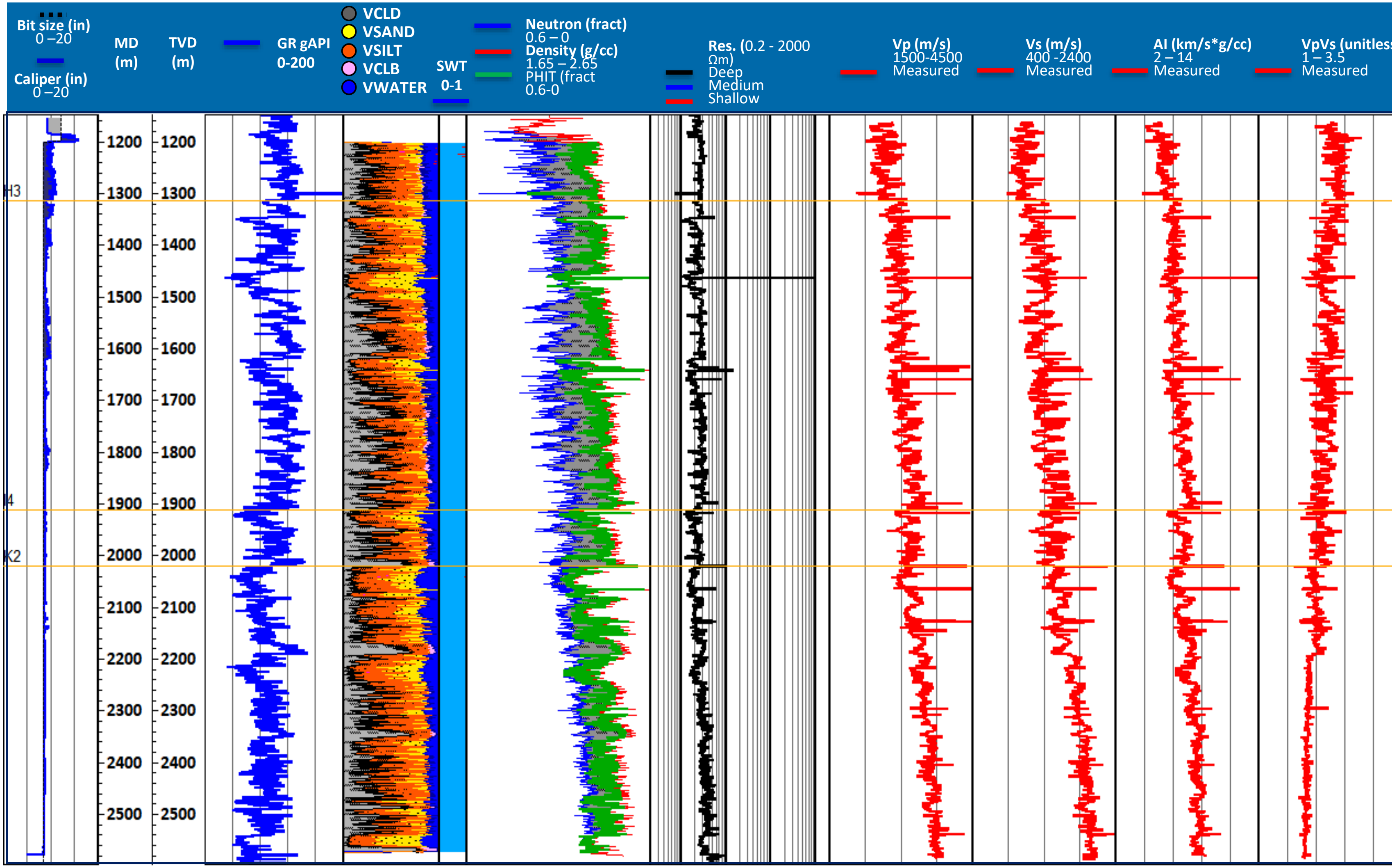
Fluid properties used in substitution have been taken from regional data. Main parameters used in this modeling are:

- Brine salinity: 24000ppm [from Rw]
- Gas gravity: 0.797 [Azurit-1 PVT]
- Oil Gravity: 44 API
- Gas / Oil ratio: 200 (L/L)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the IVC, IVD, and IVB stages using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with poor to fair discrimination with the brine sands.
- All sands show a Class II or weak Class III AVA response, with a close to zero or negative intercept and offset response either flat or weakly negative.
- Increasing porosity increases the negative amplitude, and decreasing clay makes the offset response more negative.

Bongkobo-1 Input Logs



Additional data includes mud weight, temperature data, deviation survey, cuttings descriptions and final geological report.

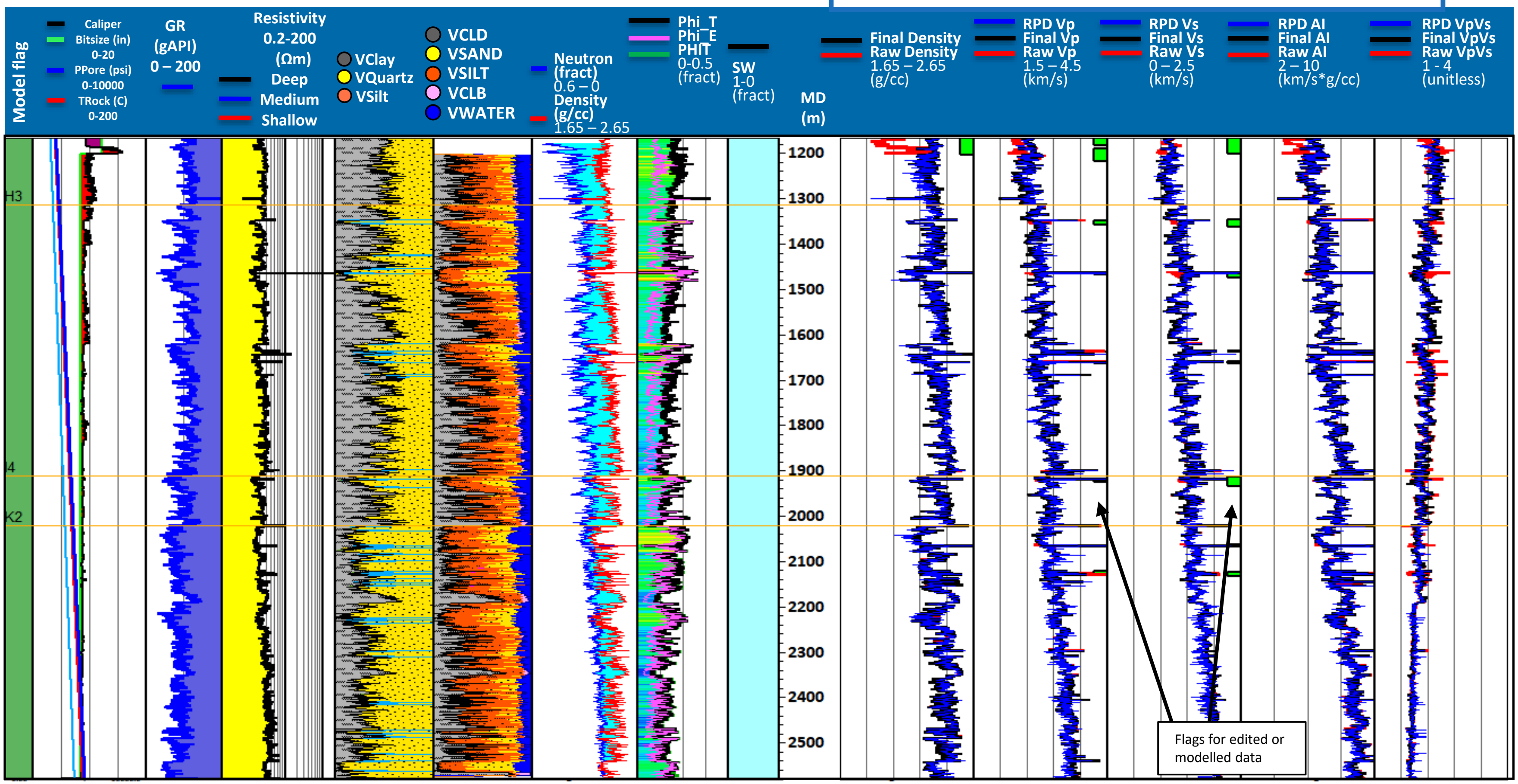
Bongkobo-1 Geophysical Well Log Analysis (GWLA) – Interval 1163m – 2588m

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

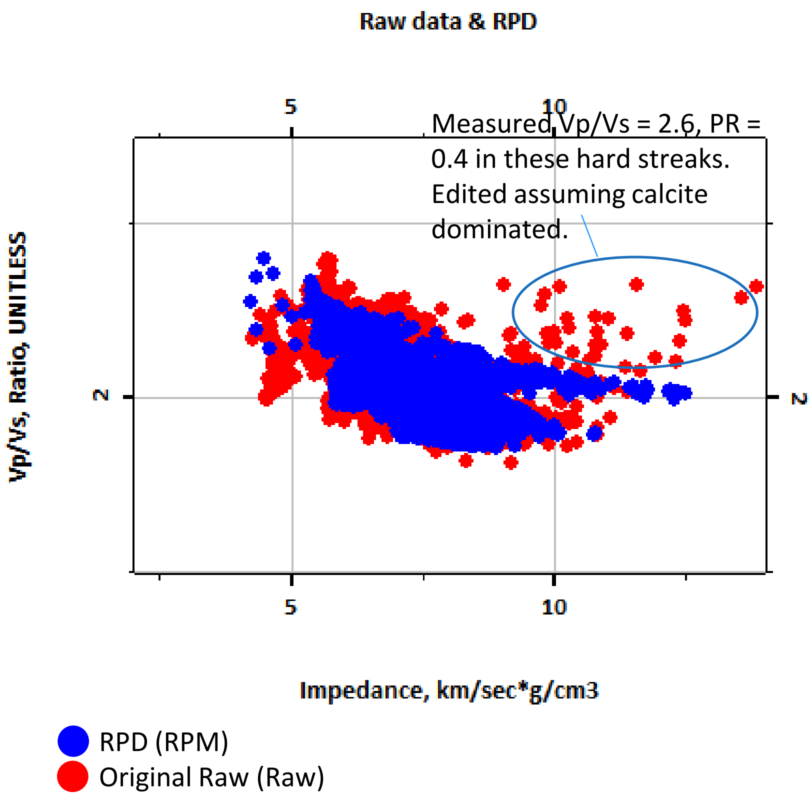


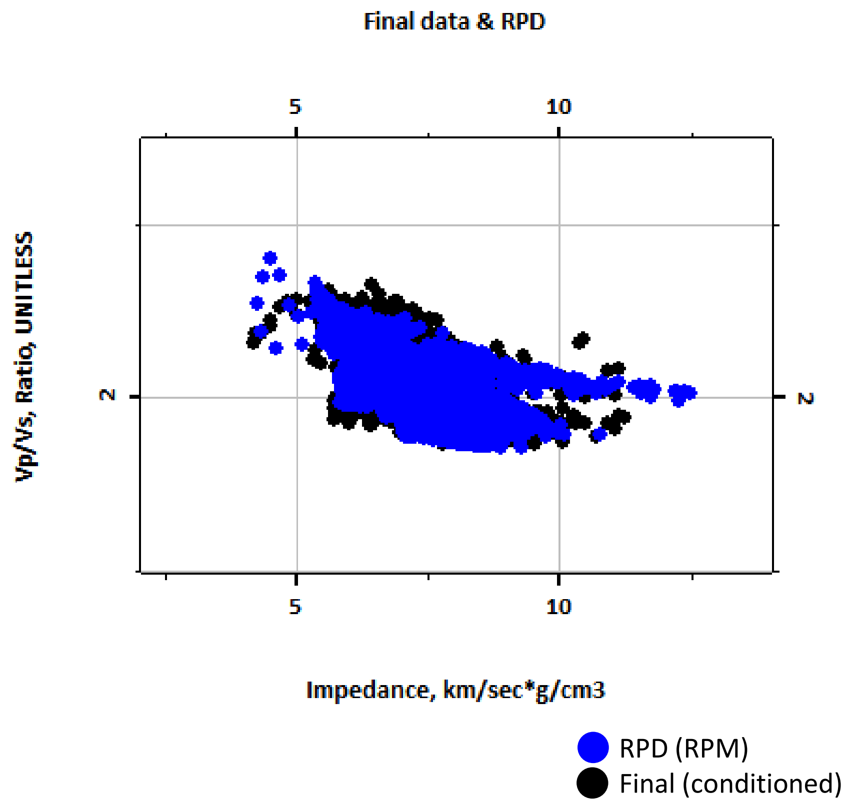
Only edits at the top casing zone and for high Vp/Vs ratio response in compressional and shear velocities where hard streaks occur. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

Bongkobo-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

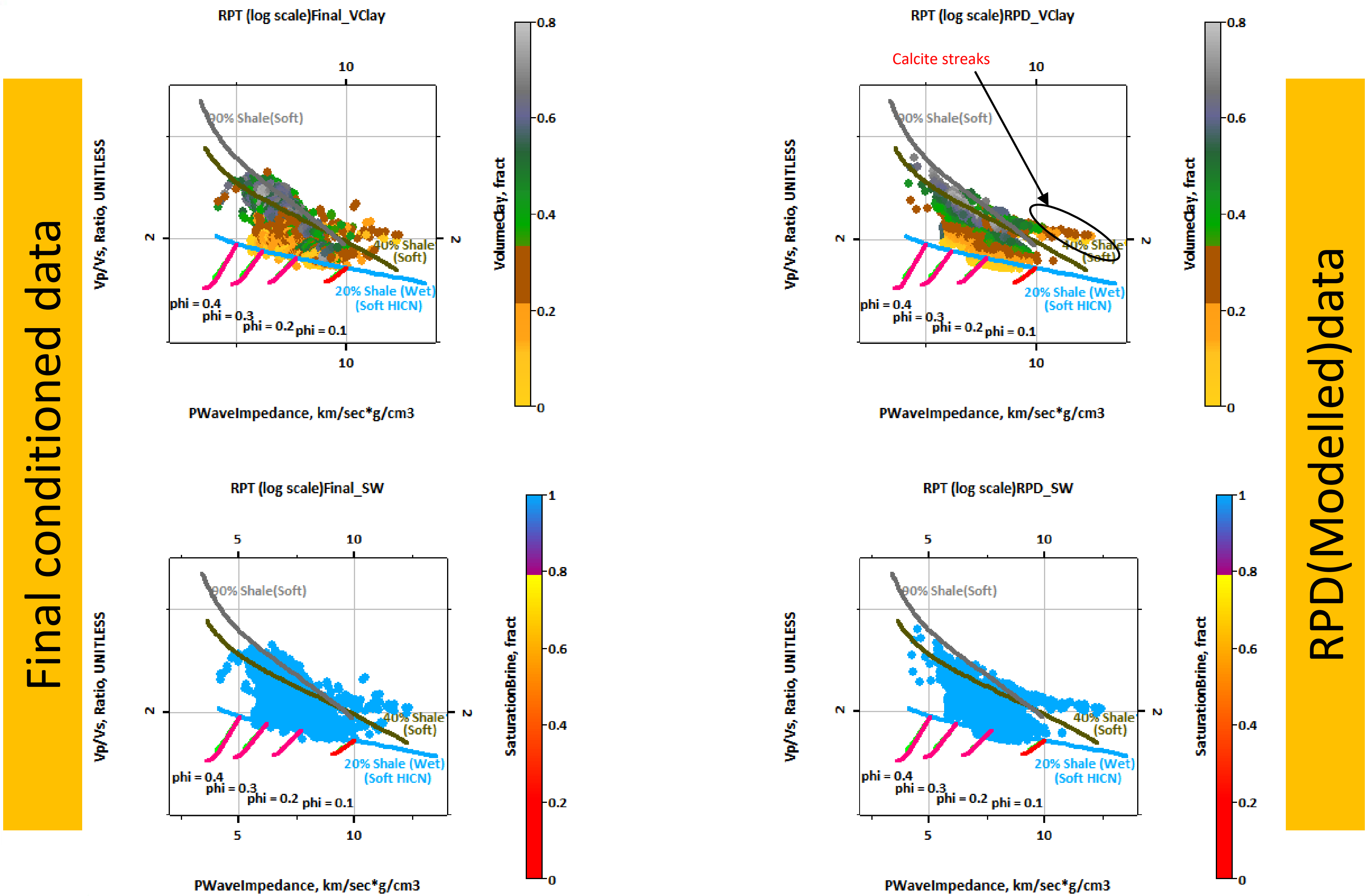
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.





Bongkobo-1,Rock Physics Diagnostics (RPD) Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.



Extraordinary Results. By Any Measure.

Chengal-1

Chengal-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is good. Client's preliminary petrophysical interpretation was fully provided. In the 3205-3225 m gap section, the GR was used to estimate VClay while following the interpreted clay content trend of the underlying.
- From 3204-3230 the RHOB was completely calculated using regression relation with GR and then VP and VS were predicted via RPD.
- Vs measurement was corrected in some intervals especially in the zone(3440-3485m)dut to inconsistent VpVs ratio results, soft sediment model was used in the correction.
- Other logs include Gamma, Neutron, Caliper, Deep, Shallow and Medium Resistivity, and Photoelectric factor which all run for the full logging run.

Clay volume (VClay):

- This volume was derived from both linear Gamma Ray method.

Reservoir characteristics:

- In general, the well is characterized by a column with a low net to gross ratio, with only a few sand bodies, typically thin (below 2m thick), particularly in the Orange H136-Yellow H160 section.
- Towards the Blue H300 marker, two sands were encountered with thicknesses not greater than 11 m. These sands were interpreted as wet with average porosities above 23%.

Volume of hydrocarbons:

- Intervals with best sand developments in the well were interpreted as 100% water saturated. Above 3200 m, a few sands were interpreted with gas saturation values between 45-65%.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the 3425-3500 m section yielded a formation water salinity of 14000 PPM. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.85 and Saturation exponent (n)=1.85

Chengal-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore, and indicated that from the mudline down to about 1400mBML the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both cleaner sand intervals and clay rich intervals while in the deeper horizons the soft sand model with higher coordination number proved to be the best elastic logs predictor in the clean sand intervals when compared to the good reliable measured data .

Fluid properties:

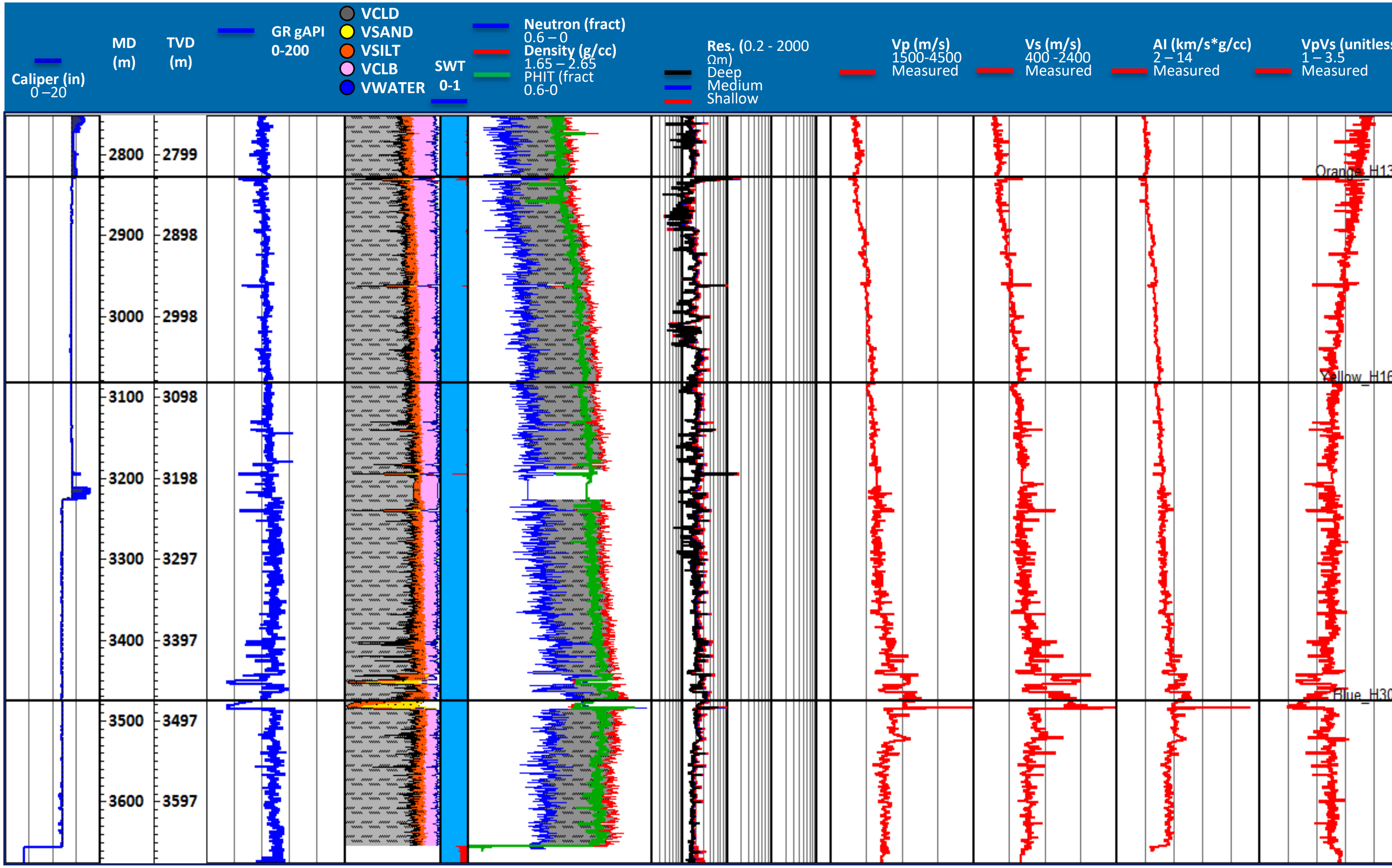
Fluid properties used in substitution have been taken from Tomani-1 PVT well report. Main parameters used in this modeling are:

- Brine salinity: 14000 ppm
- Gas gravity: 0.64
- Oil Gravity: 35 API [assumed]
- Gas / Oil ratio: 100 (L/L) [assumed]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in sands within the Orange H136, Yellow H160, and Blue H300 events.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale.
- By downgrading the reservoir quality(decreasing the porosity and increasing the clay content) the discrimination between the different fluid cases will be hard on the AVA Xplot.

Chengal-1 Input Logs



Additional data includes pressure, temperature data and cuttings descriptions.

Chengal-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of logs to 3250 m

model type flag

Unconsolidated rock model

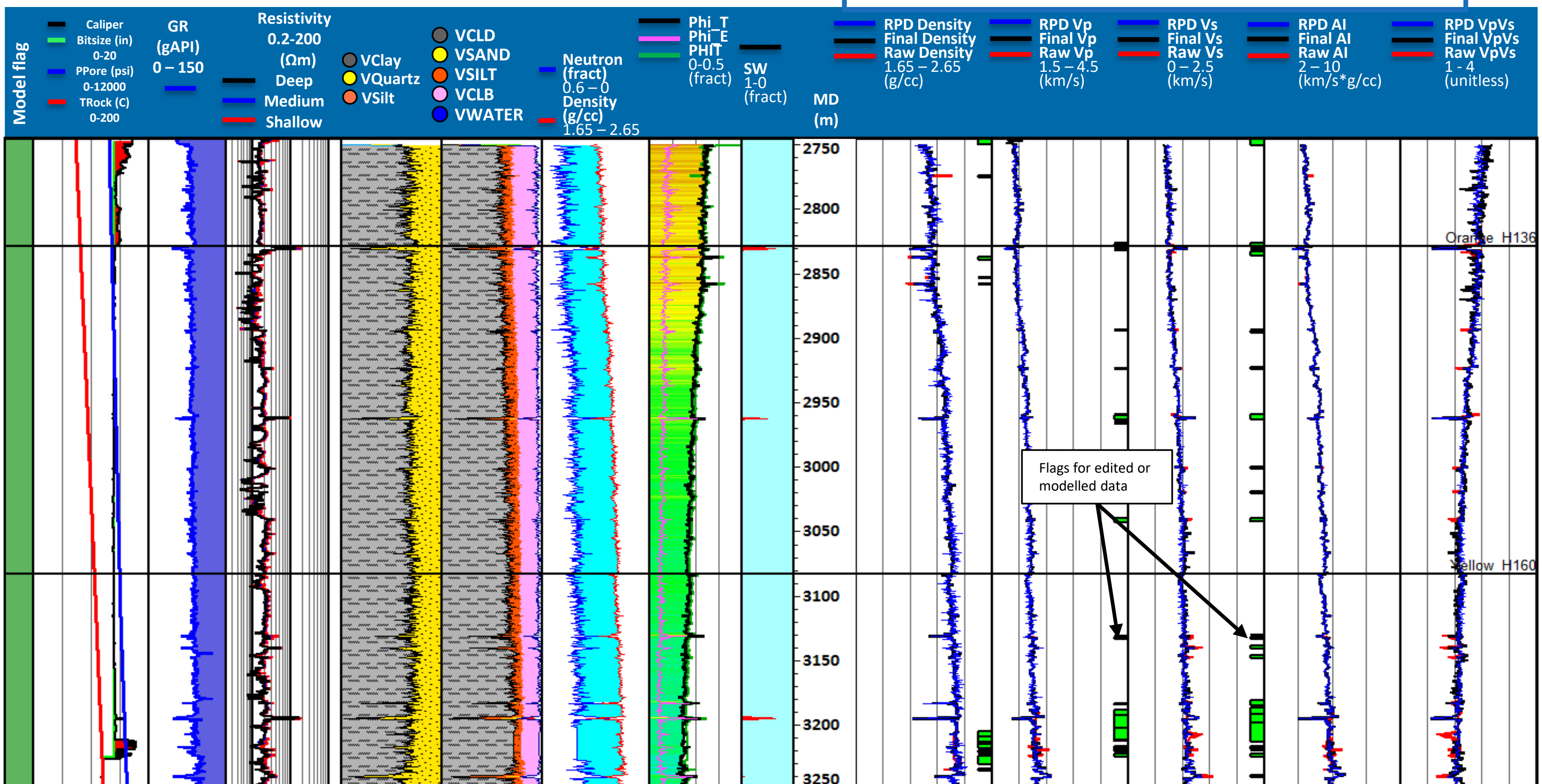
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve



Some edits to the measured data and model calibration is strong. The casing gap was filled via regression equation using GR to predict RHOB then VP and VS were estimated from RPD. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

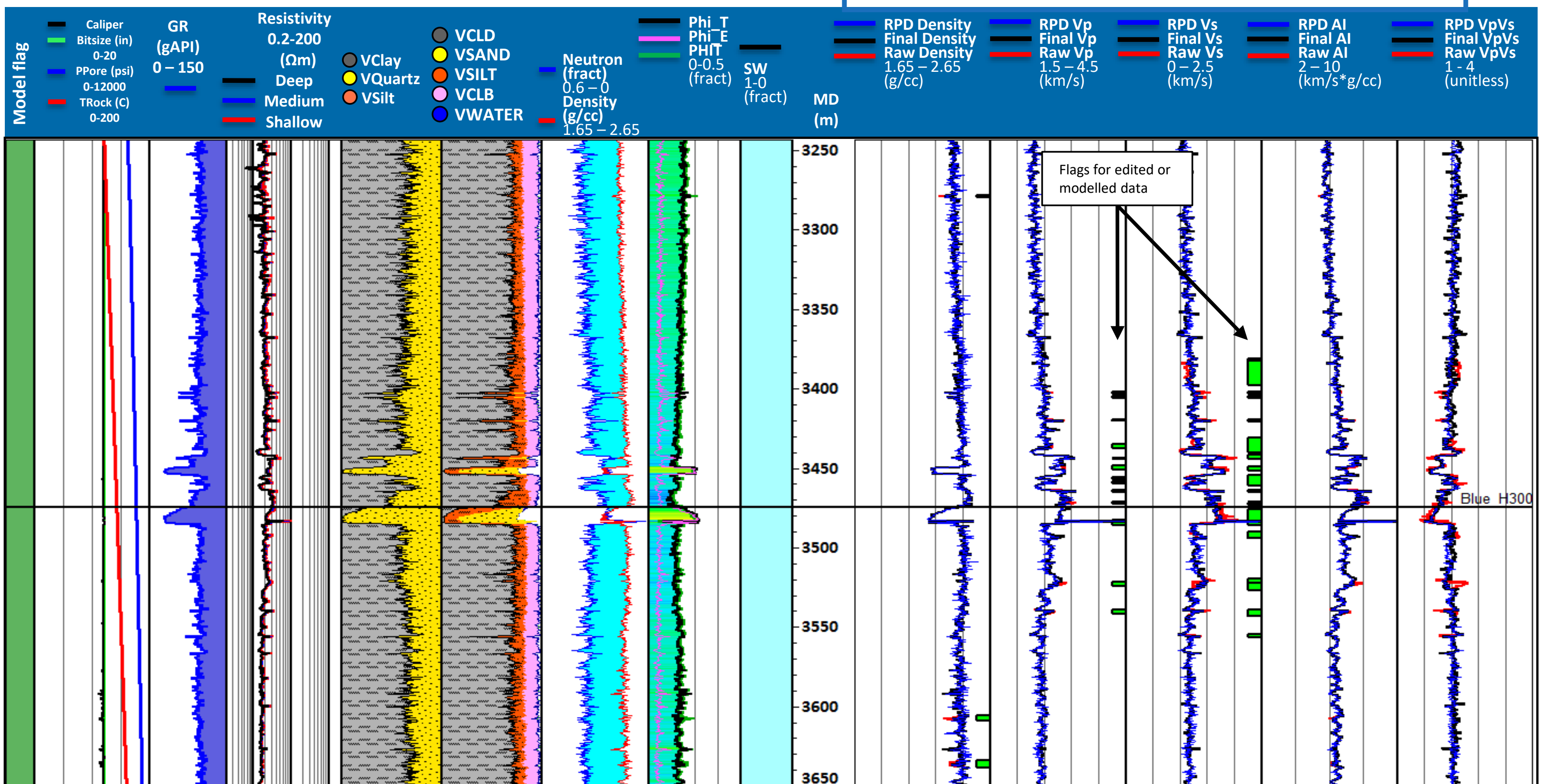
Chengal-1 Geophysical Well Log Analysis (GWLA) – Interval from 3250 m to the end of logs

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

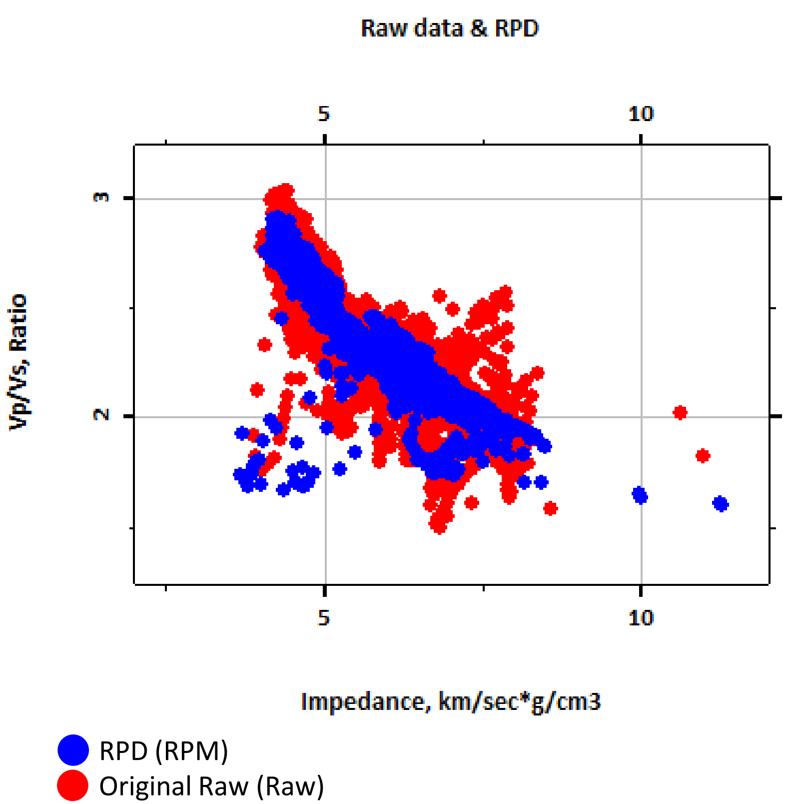
- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve



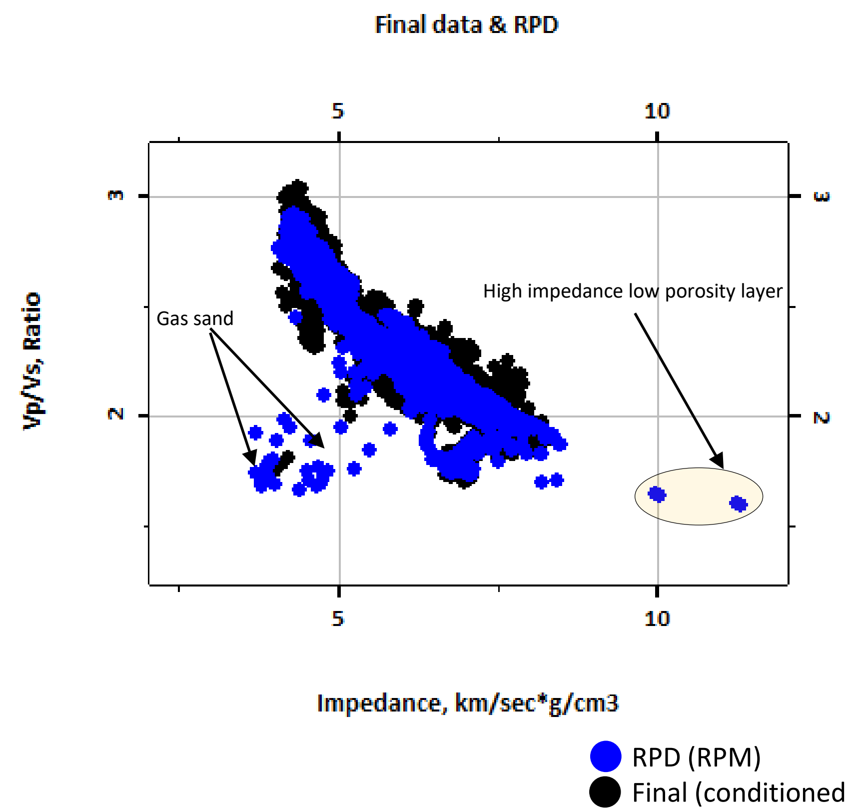
Some edits to the measured data and model calibration is strong. The casing gap was filled via regression equation using GR to predict RHOB then VP and VS were estimated from RPD. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

Chengal-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.



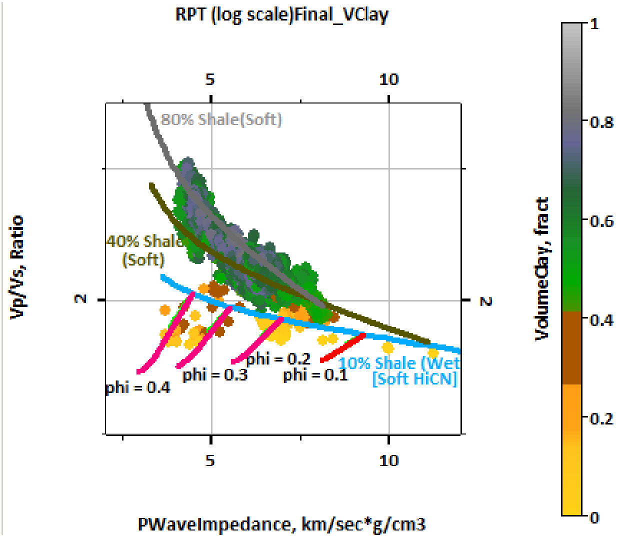
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

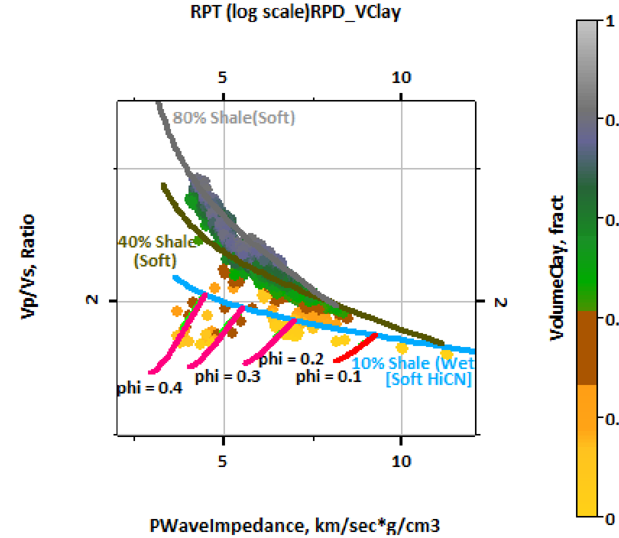


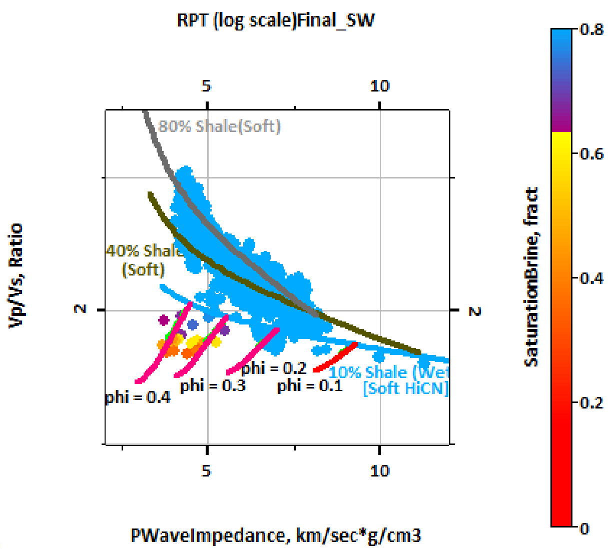
Chengal-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

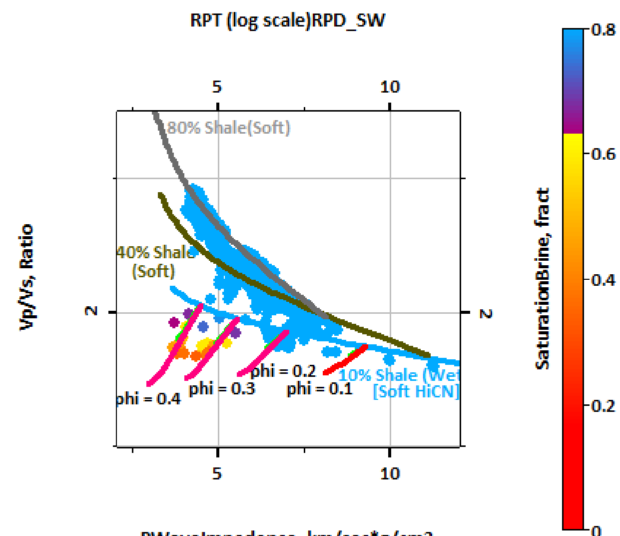
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Danum-1

Danum-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is fair and only limited in the interval(800-1430m MD). Client's petrophysical interpretation was fully provided as a reference.
- Vs measurements had a lot of spikes every where mainly in the interval(880-1100m MD) so it was edited using the RPD.
- Vp was edited in some intervals especially in the gas reservoir section using the RPD in order to have consistent VpVs ratio results and normal shale and sand trends(wet and gas).
- Rhob was fully modelled in the bad hole interval(880-896m MD) using the RPD.
- Other logs include Gamma, Neutron, Caliper, Deep Resistivity, and Photoelectric factor which all run for the full logging run.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is the IVD sands and some clean sand intervals in the Tembungo shale zone.
- IVD reservoir characterized by blocky sand intercalated with soft claystones, total porosity for the sand intervals reached to 26%.
- The sand reservoir in the Tembungo zone was just limited to the interval(1355-1367m MD) and characterized by total porosity reached to 25%.

Volume of hydrocarbons:

- Interpreted gas saturation in the IVD sands down to about 1038m MD was about 40-50% in average.
- Interpreted oil saturation in the sand section of the Tembungo zone was about 35-50% in average.

Water saturation (Sw):

- Water saturation was calculated using Simandoux's equation. Rw was calculated to be 0.207 Ωm using a Pickett plot and a temperature of 105^{o}F yielded an equivalent formation water salinity of 21000 PPM. Archie's constants (assumed) used was (a)=1, Cementation exponent (m)=1.85 and Saturation exponent (n)=1.85.

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore, and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to the measured data.

Fluid properties:

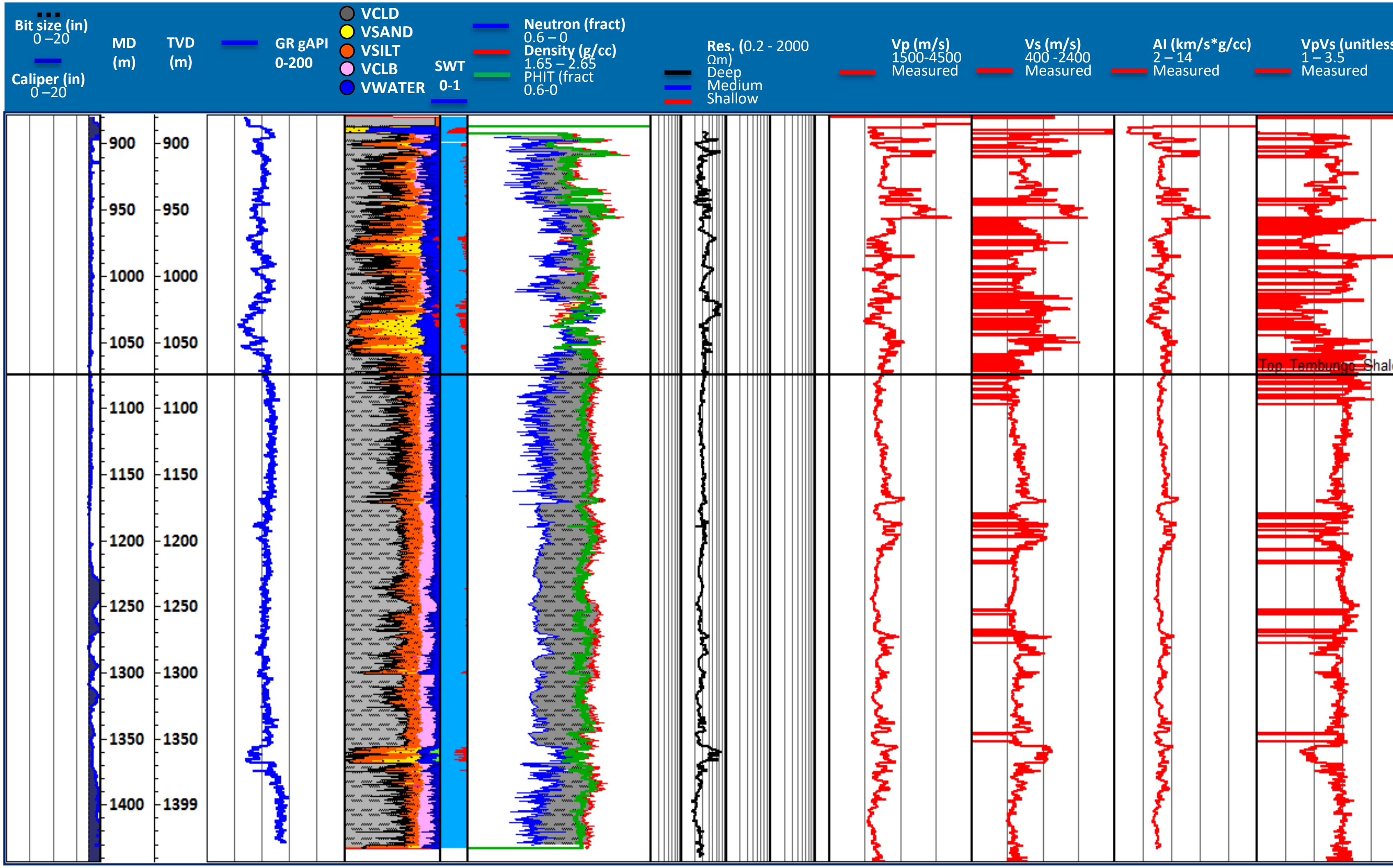
Fluid properties used in substitution have been taken from the well PVT report. Main parameters used in this modeling are:

- Brine salinity: 21000 ppm
- Gas gravity: 0.82
- Oil Gravity: 38.9 API
- Gas / Oil ratio: 500 (L/L)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different sand intervals of Tembungo zone and IVD zone using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale with very good discrimination with the brine sands at the in-situ reservoir conditions.
- An AVA class IV was observed near the top of the IVD gas sand(1017 m MD) for all hydrocarbon cases with good fluid discrimination in the AVA response especially between wet and the hydrocarbon cases at in-situ porosity and Vclay.
- An AVA class II was observed near the top of the Tembungo oil sand(1355 m MD) for all hydrocarbon cases with fair fluid discrimination in the AVA response especially between wet and the hydrocarbon cases at in-situ porosity and Vclay.

Danum-1 Input Logs



Additional data includes pressure, temperature data, cuttings descriptions and final geological report.

Danum-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of logs to 1430m

model type flag

Unconsolidated rock model

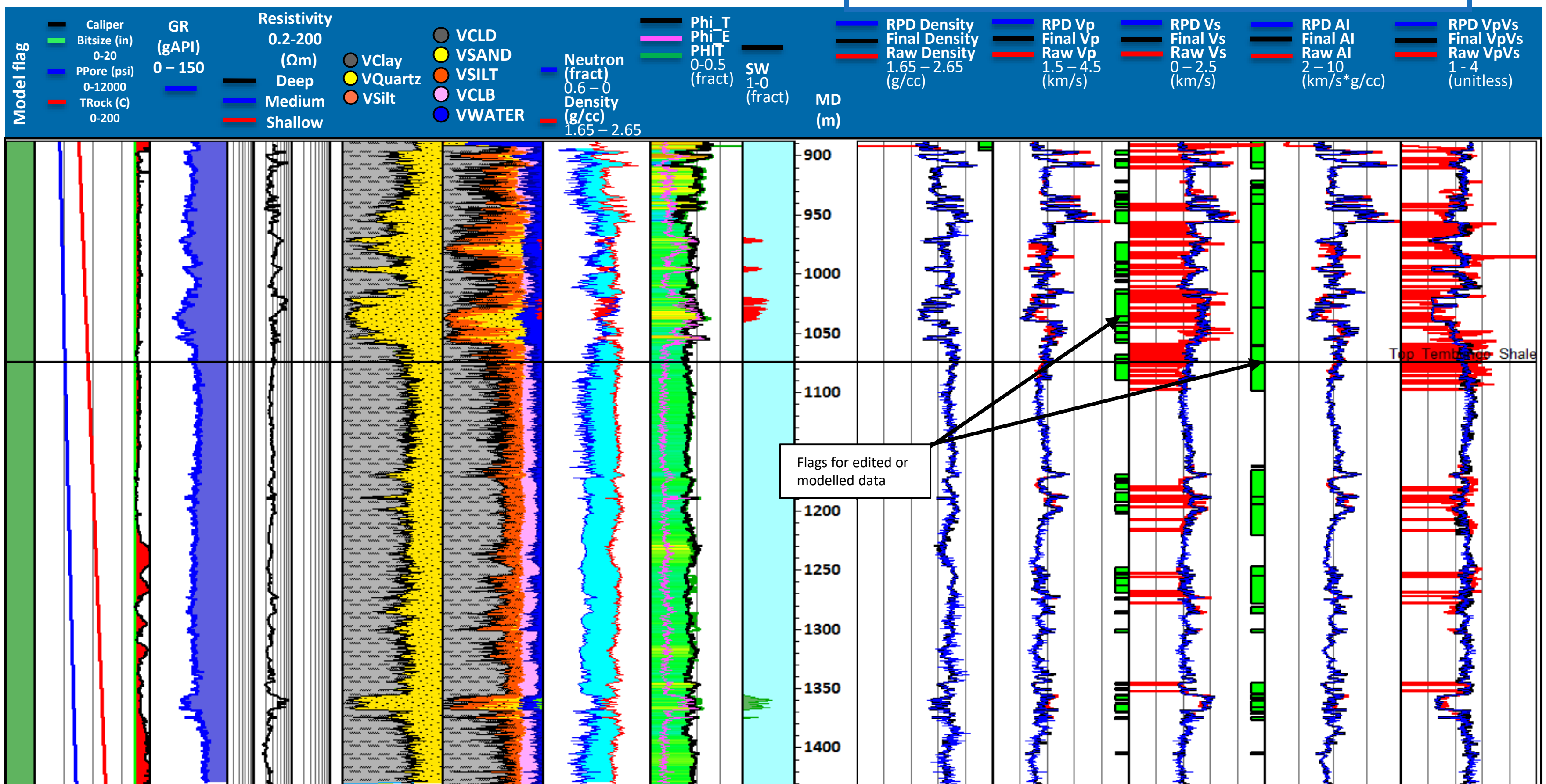
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve

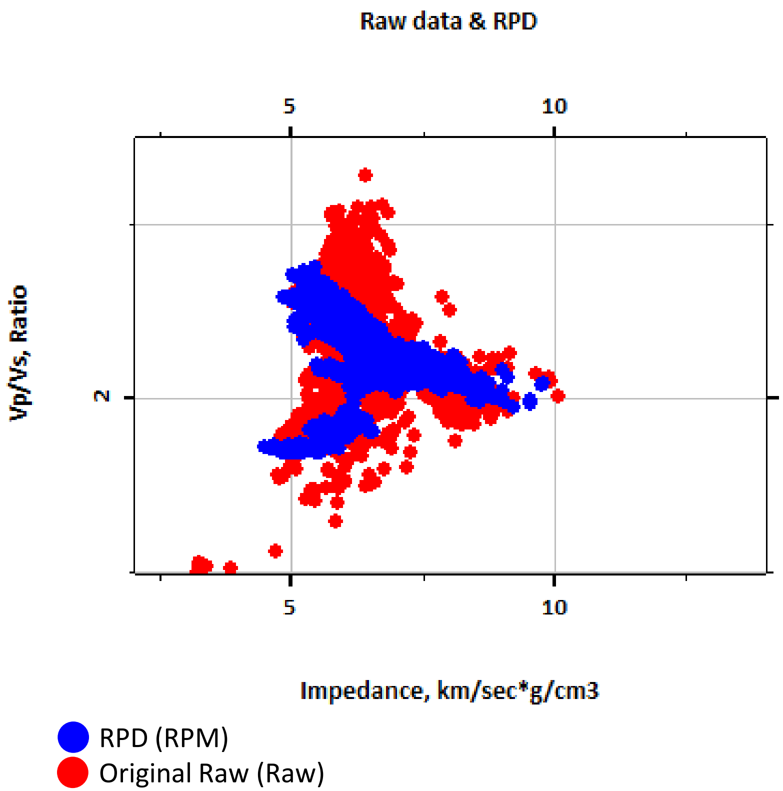


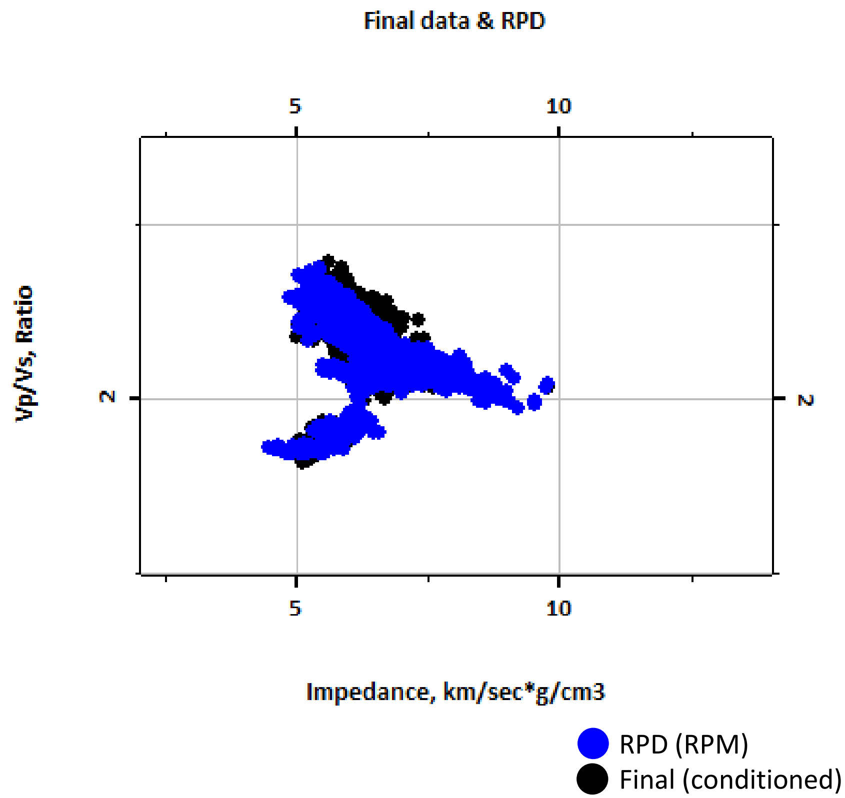
Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data. Vp and Vs were edited in many intervals to keep consistency in the VpVs ratio results between clay rich and quartz rich zones and between the different reservoir fluid cases(brine, oil and gas intervals).

Danum-1 ,Rock Physics Diagnostics (RPD)
Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

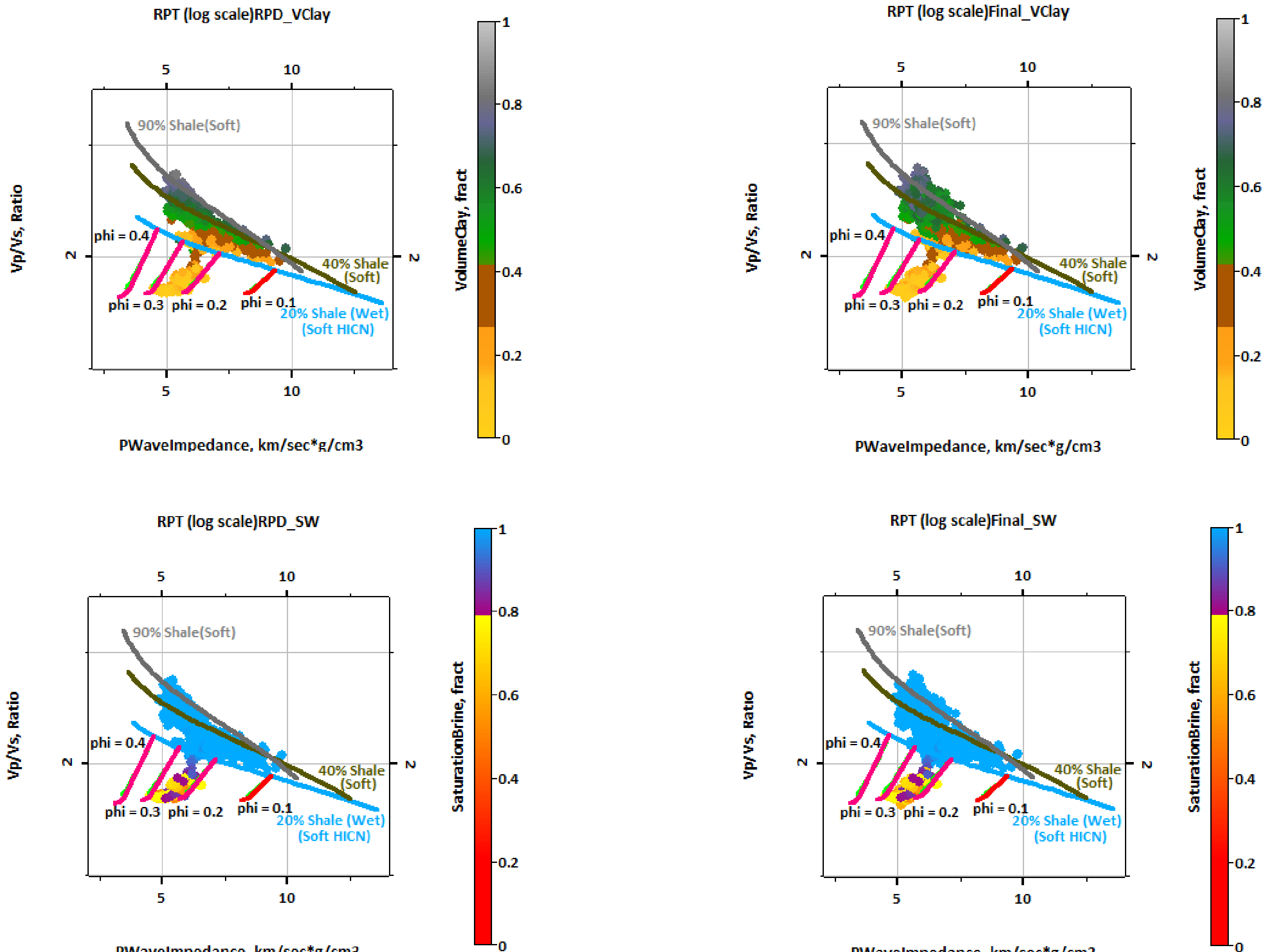




Danum-1 ,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data



RPD(Modelled)data

Danum-1 ST1

Danum-1 ST1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is fair. Client's petrophysical interpretation was fully provided as a reference.
- Main logs started in the side track hole from about 1450m to the T.D
- Vp and Vs was edited in some intervals especially in shales using the RPD in order to have consistent VpVs ratio results and normal shale and sand trends.
- Some shales in the interval from 1580m to 2050m were affected by local over pressure.
- Rhob was fully modelled in the gap intervals(2420-2440 and 2570-2615m MD) using the RPD.
- No elastic logs were available in gap interval(2590-2600m MD)so VP was calculated from deep resistivity via Faust equation then VS and Rhob were predicted using the RPD.
- Other logs include Gamma, Neutron, Caliper, Deep Resistivity, and Photoelectric factor which all run for the full logging run.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is the IVC sands(1500-2500m). The formation comprises of predominantly water bearing sandstones interbedded with claystone layers.

Volume of hydrocarbons:

- IVC sands were found to be 100% water bearing.

Water saturation (Sw):

- Water saturation was calculated using Simandoux's equation. Rw was calculated to be 0.25 Ωm using a Pickett plot and a temperature of 164 ^{o}F yielded an equivalent formation water salinity of 11000 PPM. Archie's constants (assumed) used was (a)=1, Cementation exponent (m)=1.85 and Saturation exponent (n)=1.85.

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore, and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to the measured data.

Fluid properties:

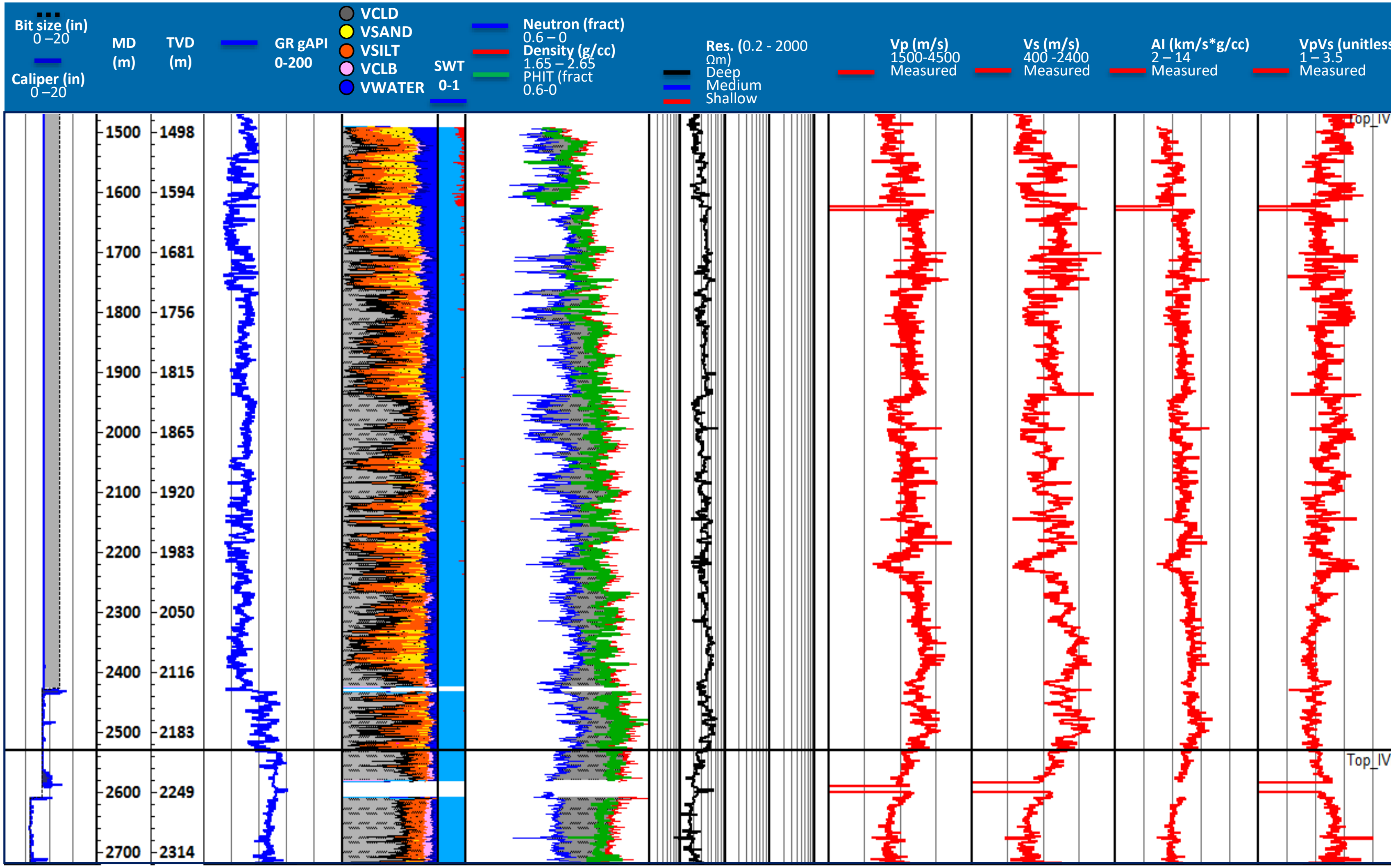
Fluid properties used in substitution have been taken from PVT report of Danum-1 well. Main parameters used in this modeling are:

- Brine salinity: 11000 ppm
- Gas gravity: 0.82[PVT analysis]
- Oil Gravity: 38.9 API[PVT analysis]
- Gas / Oil ratio: 0.82 (L/L) [PVT analysis]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different IVC sands using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale with good discrimination with the brine sands.
- No significant change occurred by decreasing the porosity of the reservoir interval.

Danum-1 ST1 Input Logs



Additional data includes pressure, temperature data, cuttings descriptions and final geological report.

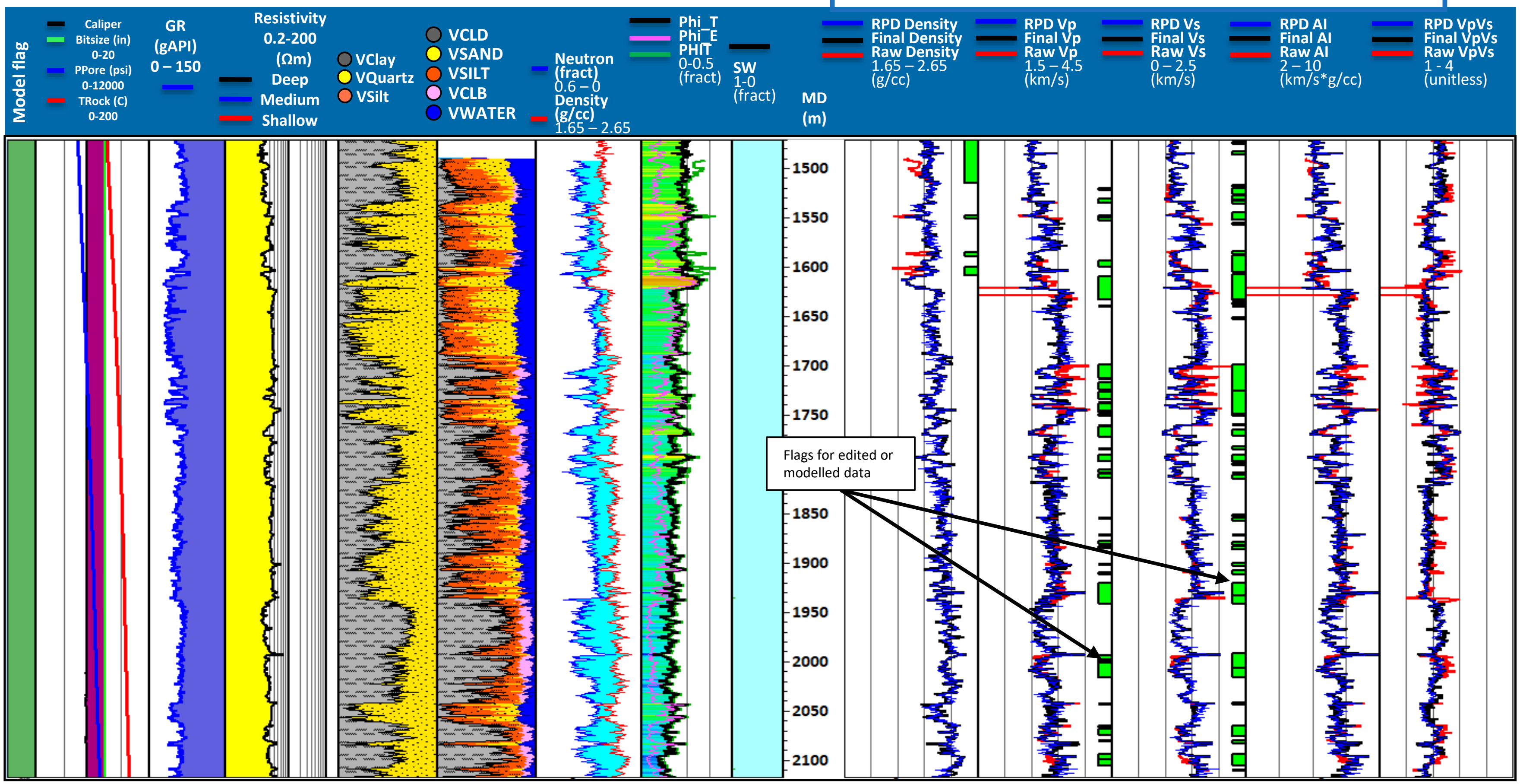
Danum-1 ST1 Geophysical Well Log Analysis (GWLA) – Interval from Top of logs to 2100m

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

model type flag

- Unconsolidated rock model
- Stiff rock model



Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data. Vp and Vs were edited in many intervals to keep consistency in the VpVs ratio results between clay rich and quartz rich zones.

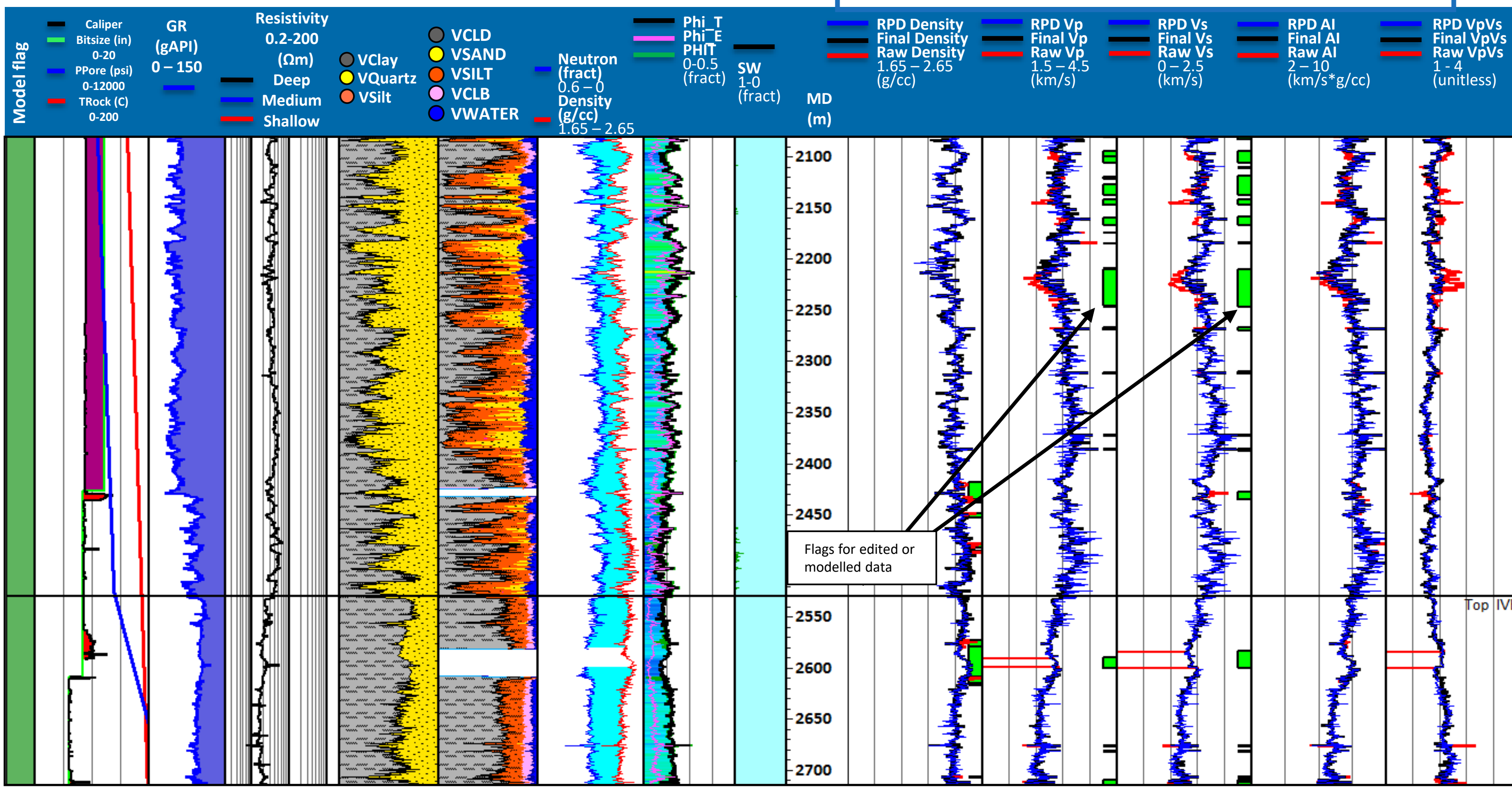
Danum-1 ST1 Geophysical Well Log Analysis (GWLA) – Interval from 2100 m to the end of logs

model type flag

Unconsolidated rock model
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve
Final edited (Conditioned) curve
Original Raw (Raw) curve

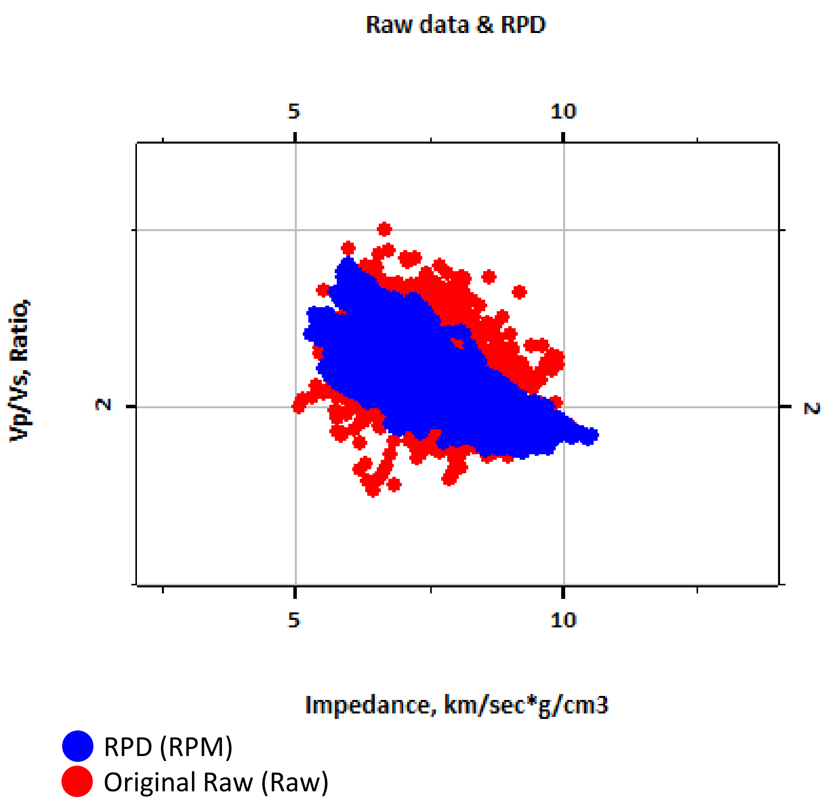


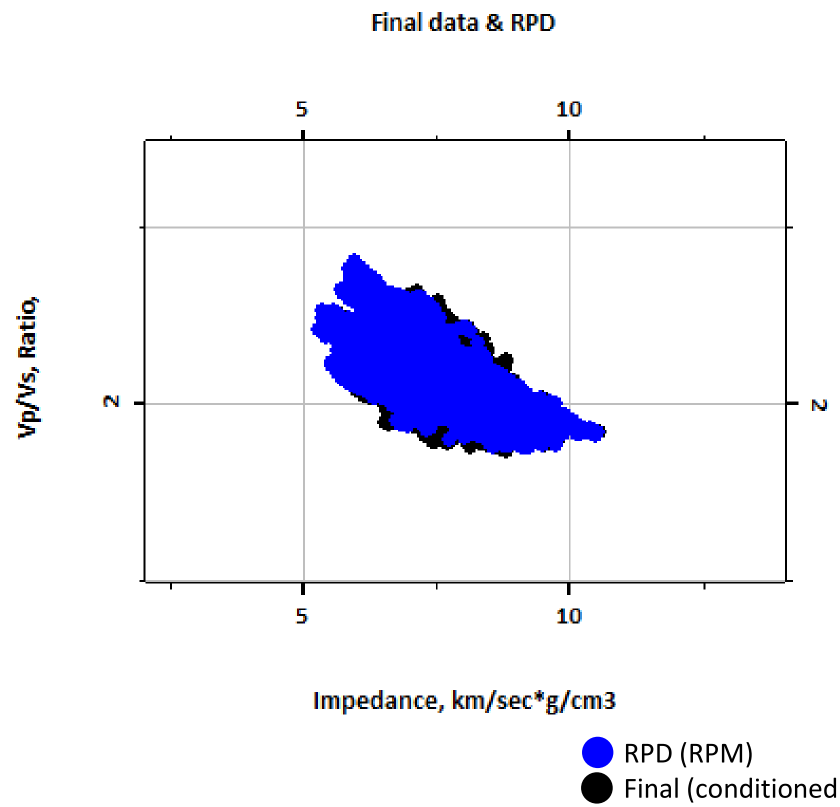
Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data. Vp and Vs were edited in many intervals to keep consistency in the VpVs ratio results between clay rich and quartz rich zones.

Danum-1 ST1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.



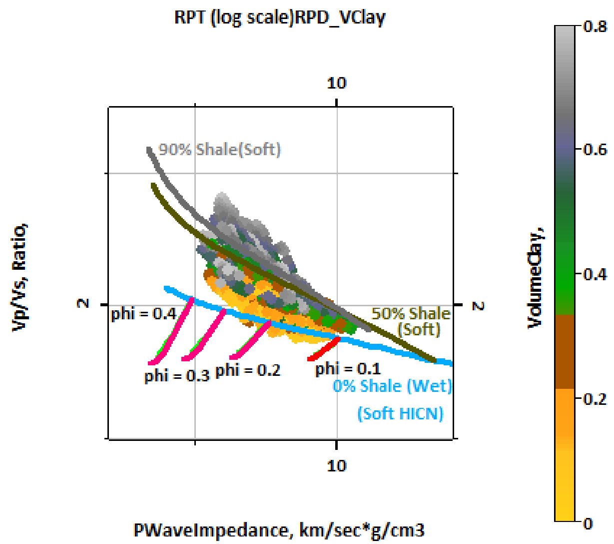


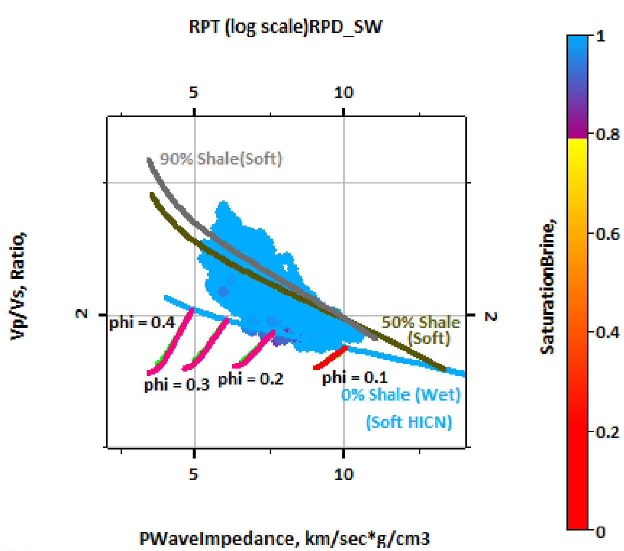
Open

Danum-1 ST1,Rock Physics Diagnostics (RPD) Rock Physics Models, Full Well

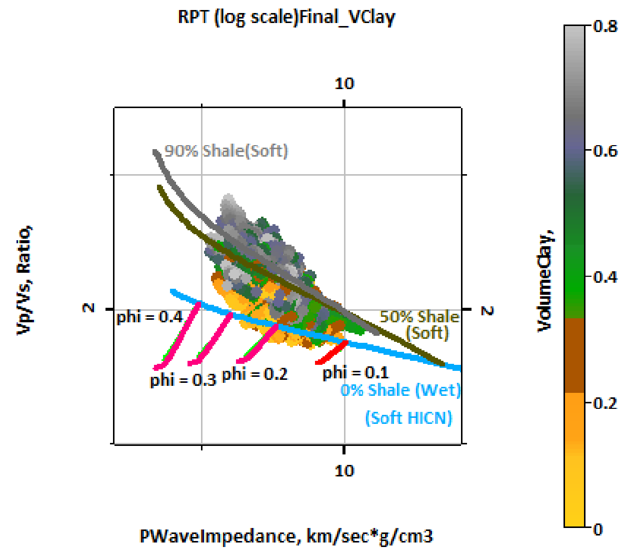
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

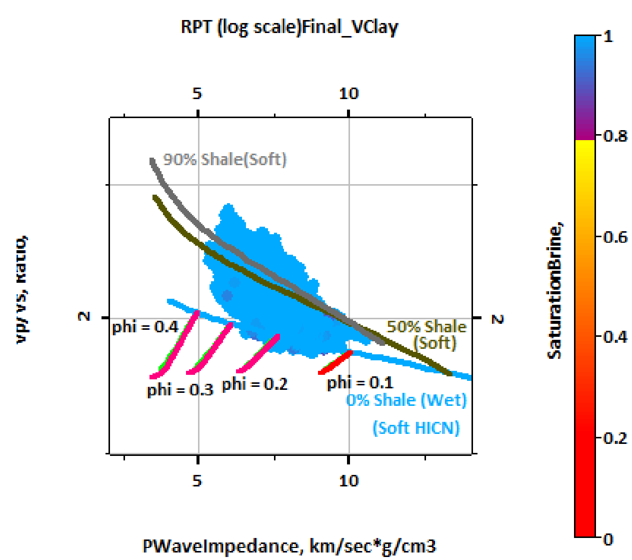
Final conditioned data





RPD(Modelled)data





Dengkis-1

Dengkis-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- Logs comprising the shallower H110 and H160 sands (secondary objective of the well) seems to be not available. Log data runs in the H200 sands, as defined by the Blue Marker H200.
- Data quality is good. One casing gap is present from 2580-2610 m, where Vp was predicted using resistivities and density was estimated using rock physics models.
- Density measurements are available from 1988 m to TD (2984 m). In general, the density measurements were interpreted as of high quality and only a few edits were applied. In the 1988-2606 m section, the density log used is from a wireline array, whereas in the 2606-2984 m interval, the density log is LWD. Particularly the wireline density log was very noisy and incompatible with the frequency content of the LWD density section and with rest of the logs of the well log suite. Therefore, a smoothing filter (harmonic average) was applied to the wireline density log.
- Both compressional and shear wave slowness logs run from 1988 m to 2595 m. Compressional and shear wave velocities were then estimated in the 2595- 2984 m section using the density log and rock physics models. Both Vp and Vs were depth shifted very locally, in the 2464-2480 m section.
- GR was depth shifted in the 2620-2653 m section based on the resistivity and density neutron responses in the same interval. Approximately a 4-m depth shift was applied. Also a shift in the GR values (increase) was applied close to the casing shoe (2599-2611 m) to account for the suppressed values of gamma counts that could lead to misleading interpretations.
- Other logs include, Neutron, Caliper, Deep and Flushed Zone Resistivities, and Photoelectric factor.

Clay volume (VClay):

- This volume was estimated via a combination of linear Gamma Ray method.

Reservoir characteristics:

- In terms of well objectives, the primary reservoir target was the pre-H200 sands. These are a series of turbiditic sands, distributed in lobe/channel complexes. The secondary targets are the shallower H110 to H160 sands. All targets are Late Miocene.
- The well is claystone/siltstone dominated. Sand bodies are scattered throughout the column; however these sands tend to be very thin, no thicker than 1-1.5 m, and interpreted as relatively silty. A 2-m limestone stringer was encountered close to the bottom of the well, at the top of the Orange Horizon cc707 section.
- Perhaps the best reservoir sands encountered in the well are towards the base of the Red Horizon cc660. The deepest sand is around 11-m-thick with 28-30% porosity. Similar although thinner sands, with a tubular shape in the gamma response, can be encountered above but with less porosity in the majority of cases.
- There is indication in the reporting of oil shows present in sands in the H200 Blue Marker, Red Horizon cc660, Green Horizon cc626 sections.

Volume of hydrocarbons:

- The well was interpreted as mostly wet. Thin events might contain residual oil saturation based on well logs and also on oil shows, vaguely depicted in the report. These residual oil saturations were interpreted to be present in very local, thin sand bodies, within the H200 Blue Marker, Red Horizon cc660, Green Horizon cc626, and Cyan Horizon cc660 sections.

Water saturation (Sw):

- Water saturation was estimated using Archie's equation. Archie's parameters were interpreted using the Pickett Plot analysis while considering the water samples depth collected in the well at 2170 m and at around 2395 m (water test information is vaguely reported in the well). This analysis yielded values of a=1, m=1.9, and n=1.9, and an Rw of approximately 0.23 Ohm-m at 187°F (~10,000 NaCl ppm).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore, and indicated that in terms of P & S-wave velocity versus porosity space, the Soft sediment model proved to be the best predictor in clay-rich and sand facies. However, based on the elastic behavior of certain samples, an Intermediate Stiff Sediment Model with a variable Coordination Number with depth was more suitable. These models have been used to edit the Vp, Rhob, and Vs data where necessary and to perturb the rock for changes to VClay and Phi_T during the Rock physics modelling (RPM) stage of the project.

Fluid properties:

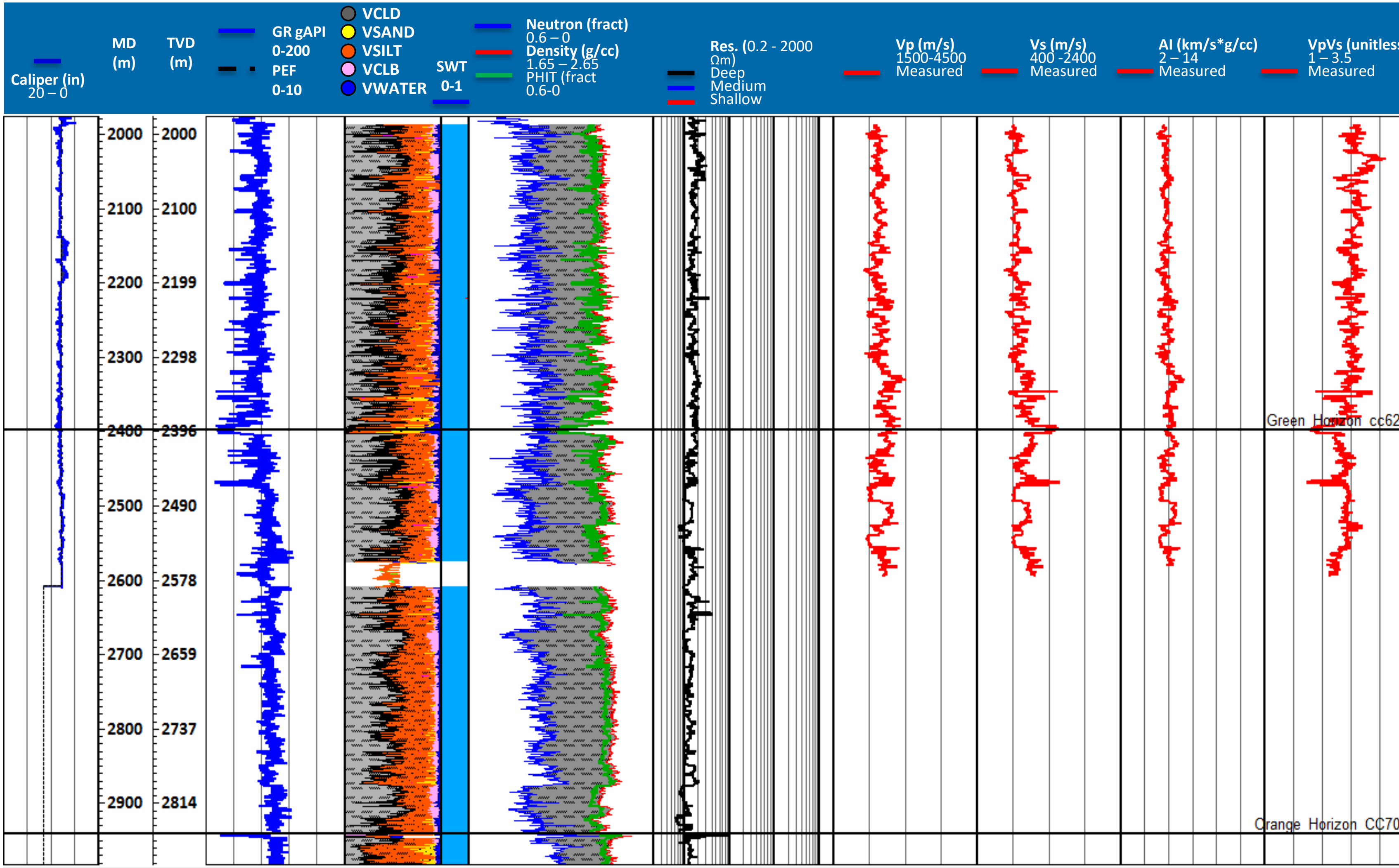
Hydrocarbon properties used in substitution have been taken from PVT well reports from wells nearby Dengkis-1, particularly from Belud East-1. Main parameters used in this modeling are:

- Brine salinity: 10000 ppm
- Gas gravity: 0.65
- Oil Gravity: 37.41 API
- Gas / Oil ratio: 174 (L/L)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in sands within the H200 Blue Marker, Red Horizon cc660, Green Horizon cc626, and Cyan Horizon cc660 sections using the established rock physics models.
- The standard Gassmann's fluid substitution method was used to perturb the different modelling scenarios.
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Hydrocarbon sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale.

Input Logs – Dengkis-1



Additional data includes pressure data and well reports.

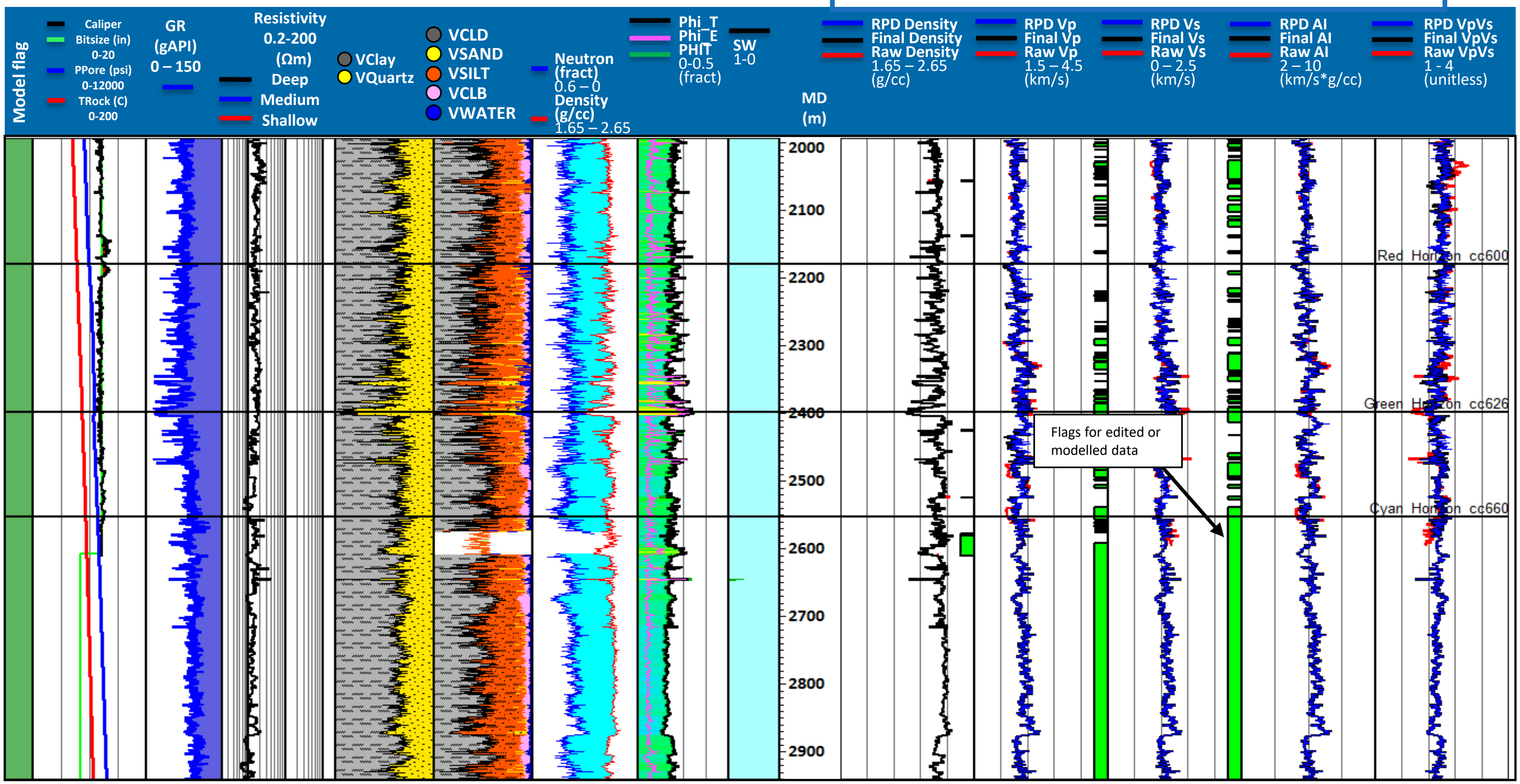
Dengkis-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of logs to end of logs

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

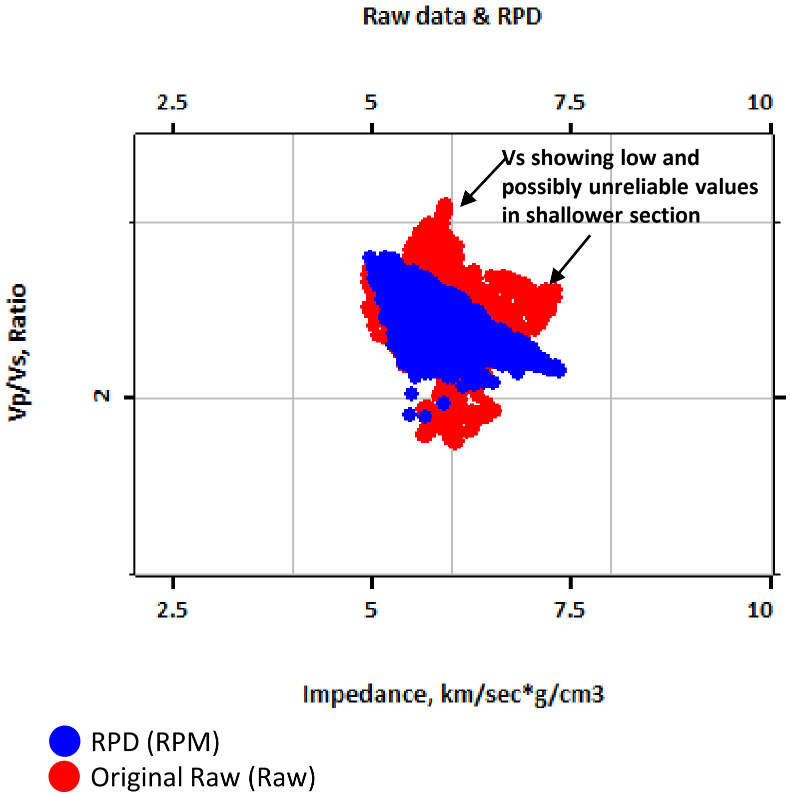


The casing gap was filled via Faust from resistivity to Vp then density and Vs from RPD. Granular media model (soft sand) was used for all elastic curves prediction (Rhob, Vp and Vs) with good correlation with the measured data.

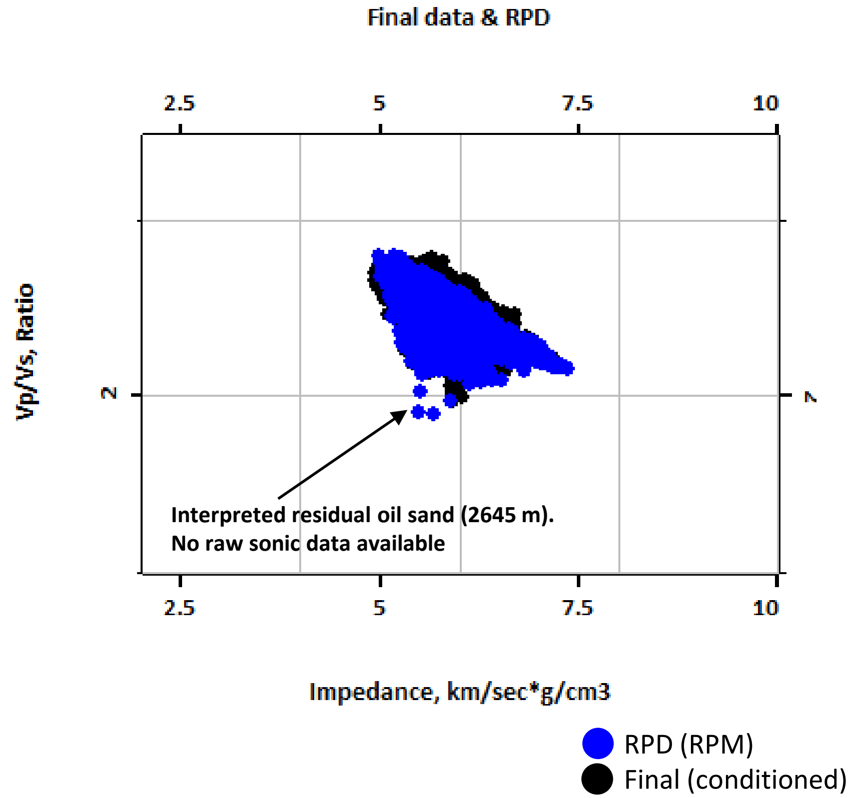
Sonic data was not available below 2595 m and was fully estimated based on model calibration with good measured data in the well in addition to calibrating the model with the near by wells as Tomani-1 well.

Dengkis-1,Rock Physics Diagnostics (RPD)
Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.



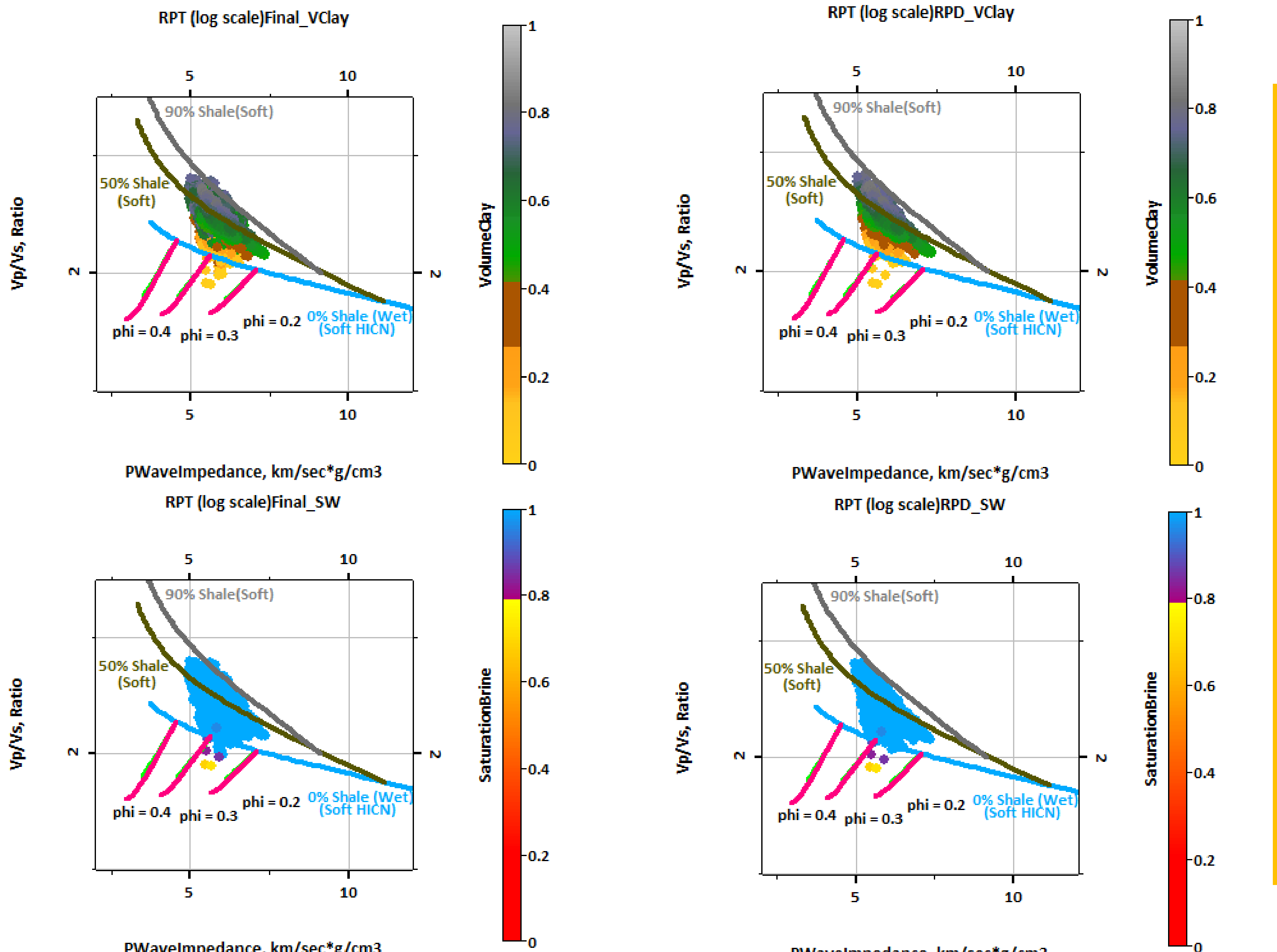
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.



Dengkis-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data



RPD(Modelled)data

Extraordinary Results. By Any Measure.

Ehsan-1

Ehsan-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- Data quality is overall very good, although the shear in the LWD section appears to be in error and has been edited. Some other edits have been made for minor bedding effects and a washout section.
- Good density measurements are available from 2200 -2700m. The measurements are high quality. Edits include to fill the casing gaps at 2825m and 3460m, and the 2914-3089m and 3587-3649m washout sections. All edits made from rock physics diagnostics (RPD) from VP.
- Good compressional slowness runs from 2600-3700m and is high quality. Edits are for minor depth matching or bedding effects using the RPD from RHOB. Casing gaps have been filled with Faust or from shear.
- Shear slowness is also high quality in the wireline section, though measurements appear compromised in the LWD section from 2867-3732m and has been replaced using the model from RHOB. Other edits are minor.
- Other logs include Gamma, Neutron, Deep, Shallow and Medium Resistivity, which all run for the full logging run. Caliper is present from 2852m to TD.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the reservoirs are the Kamunsu, Kinarut, and Kebabangan fan sands.
- Both Kamunsu and Kinarut comprise some well-developed sandstone packages, fining upwards, within interbedded claystone siltstone sections. Clean sandstone porosities average 33% and 23% in Kamunsu and Kinarut respectively.
- Kebabangan fans in the Upper level are very well developed, with many blocky sandstones with porosities around 13%-15% interrupted by interbedded claystone and siltstone. Lower Kebabangan reservoirs are not well developed, one 8m sandstone with 13% porosity is present amongst interbedded siltstones and claystones.

Volume of hydrocarbons:

- No hydrocarbon is present in this well, likely due to lack of seal.

Water saturation (Sw):

- Reported salinity for this well is 20000ppm, though no water test is available.

Ehsan-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that in terms of P & S-wave velocity versus porosity space, the Soft sediment model proved to be the best predictor for all lithologies. Model correlation is strong for the most part, though the measured shear in the LWD section from 2867-3732m appears compromised, showing an overall flat response and lower than expected readings; the shear model here attempts to honor to overall response in the shales where the response is expected to be slower. These models have been used to edit the Vp, Rhob, and Vs data where necessary and to perturb the rock for changes to VClay and Phi_T in the Rock physics modelling (RPM) portion of the project.

Fluid properties:

Fluid properties used in substitution have been assumed, no downhole fluid samples have been taken for this well or the sidetrack. Main parameters used in this modeling are:

Brine salinity: 20000 ppm

Gas gravity: 0.6 (assumed based on “dry gas” reported for Ehsan-1S1)

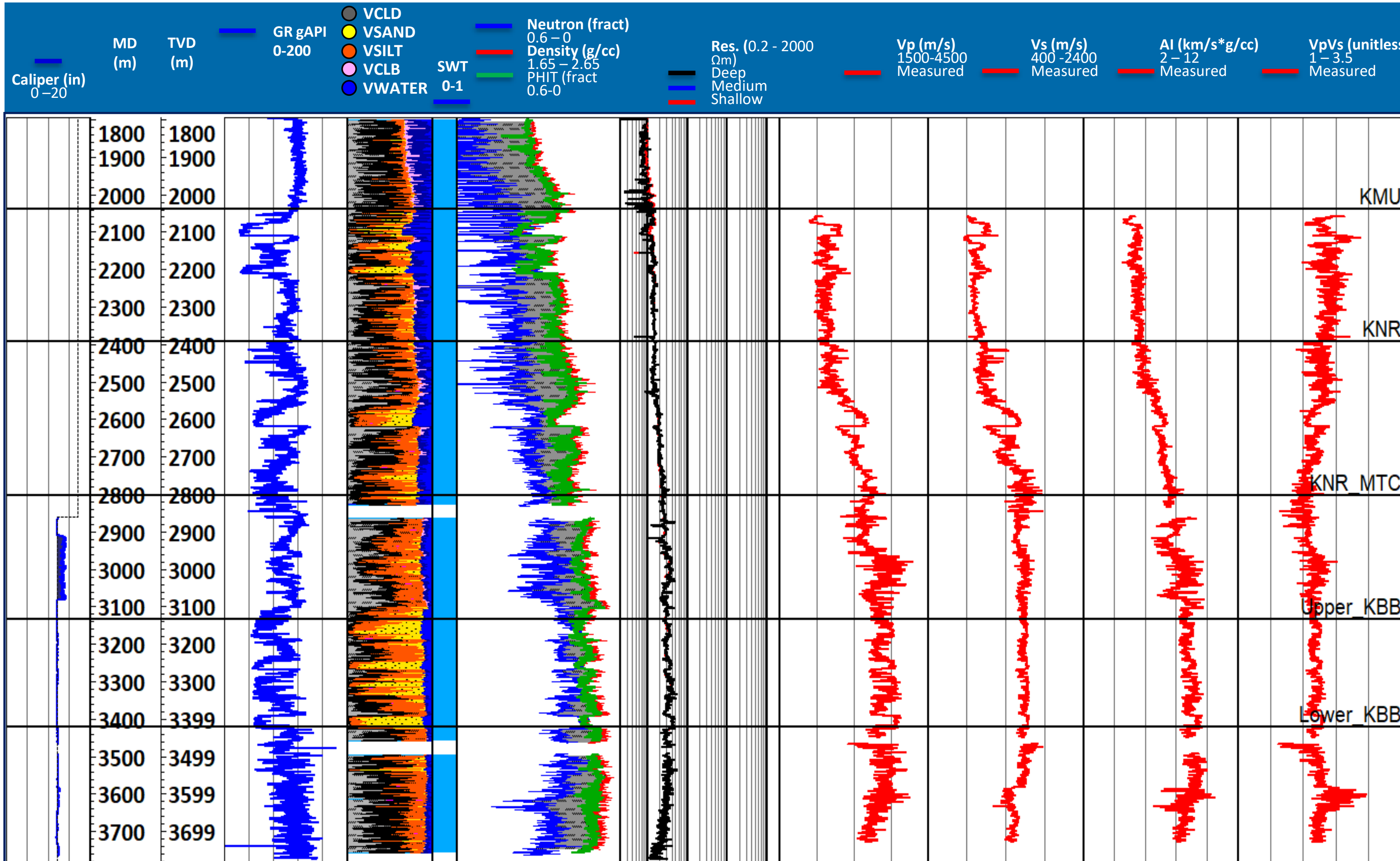
Oil Gravity: 35 API (assumed)

Gas / Oil ratio: 100 (L/L) (assumed)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the Kamunsu, Kinarut, and Kebabangan fan sands.
- The standard Gassmann’s fluid substitution method was used to perturb the different modelling scenarios.
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Hydrocarbon sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale.
- AVO analysis at an interface defined at 1575m revealed a class II response for all the fluid cases well separated from the background trend all at the insitu reservoir conditions.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) No change to the AVO response for all fluid scenarios could be observed.

Ehsan-1 Input Logs



Additional data includes pressure, temperature data and cuttings descriptions (Final geological report).

Ehsan-1 Geophysical Well Log Analysis (GWLA) – Interval Interval from 2030 to 2800 m

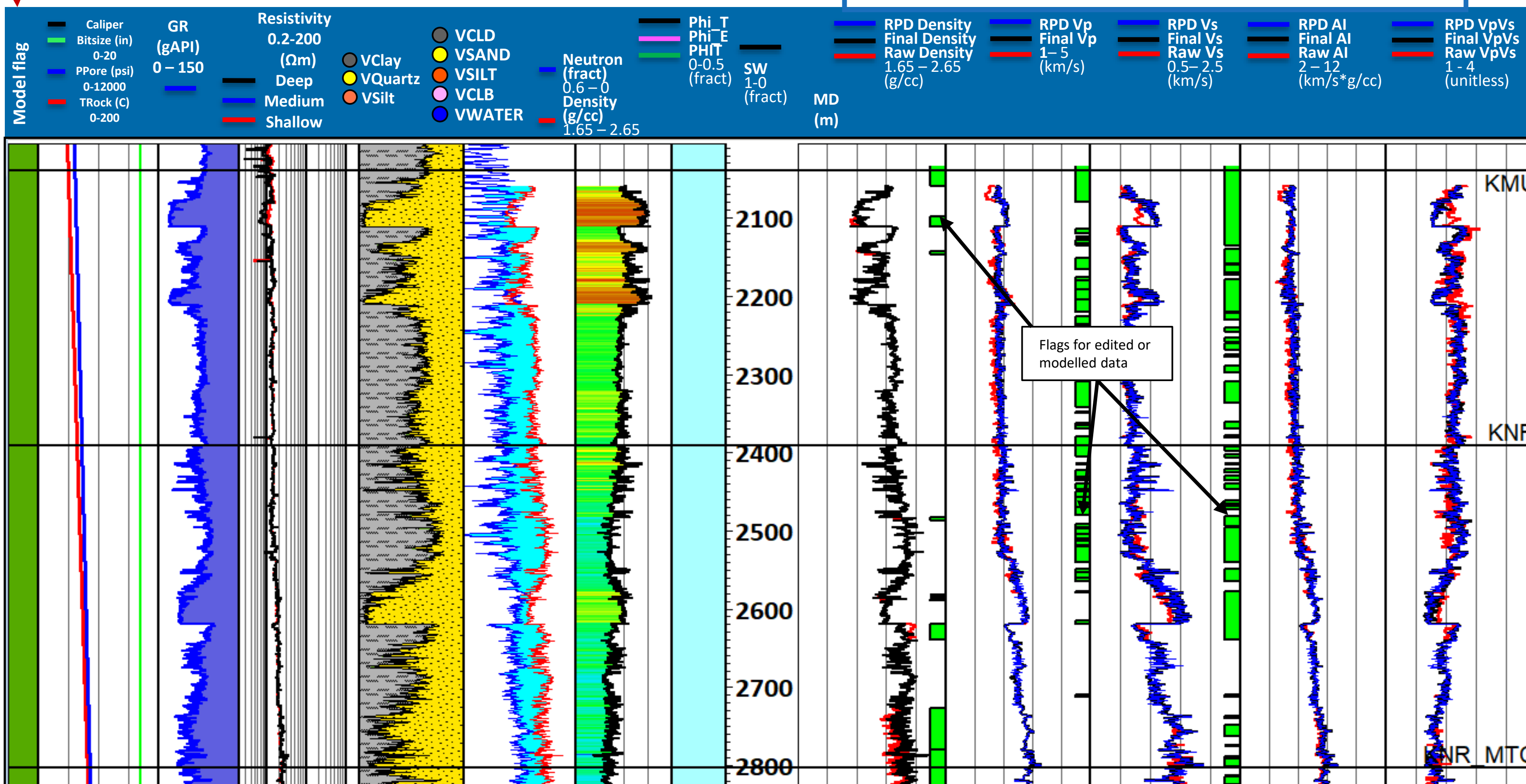
model type flag

- Unconsolidated rock model
- Stiff rock model

Above depth of 2030m(MD) no reliable logs were available to establish a rock physics model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve



Some edits to the measured data and model calibration is strong. The casing gaps were filled from resistivity via Faust equation to predict Vp then density and Vs from RPD. Granular media model (soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) in the clean reservoir rocks and the clay rich intervals as well with good correlation with the measured data.

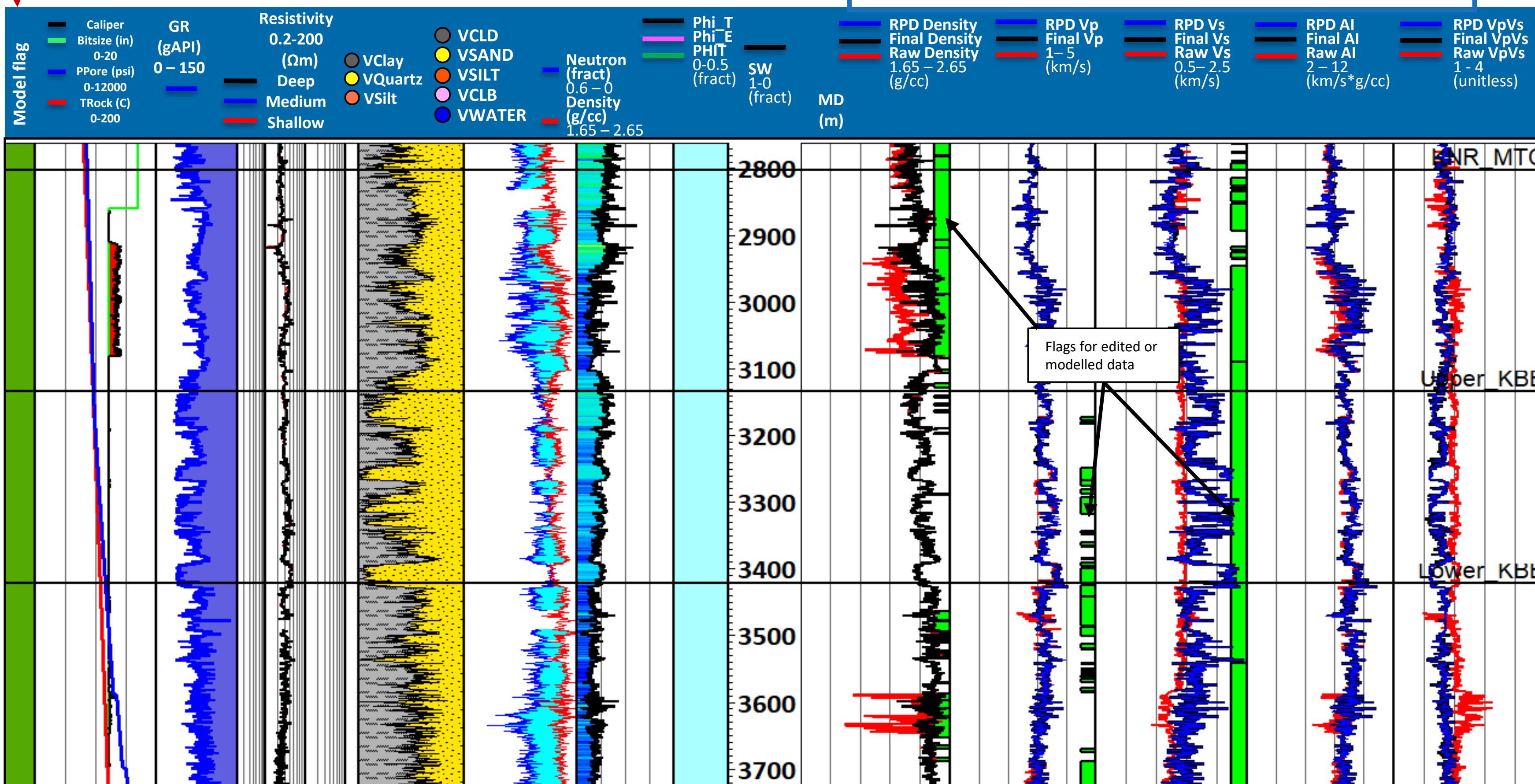
Ehsan-1 Geophysical Well Log Analysis (GWLA) – Interval Interval from 2800 to the end of logs

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

model type flag

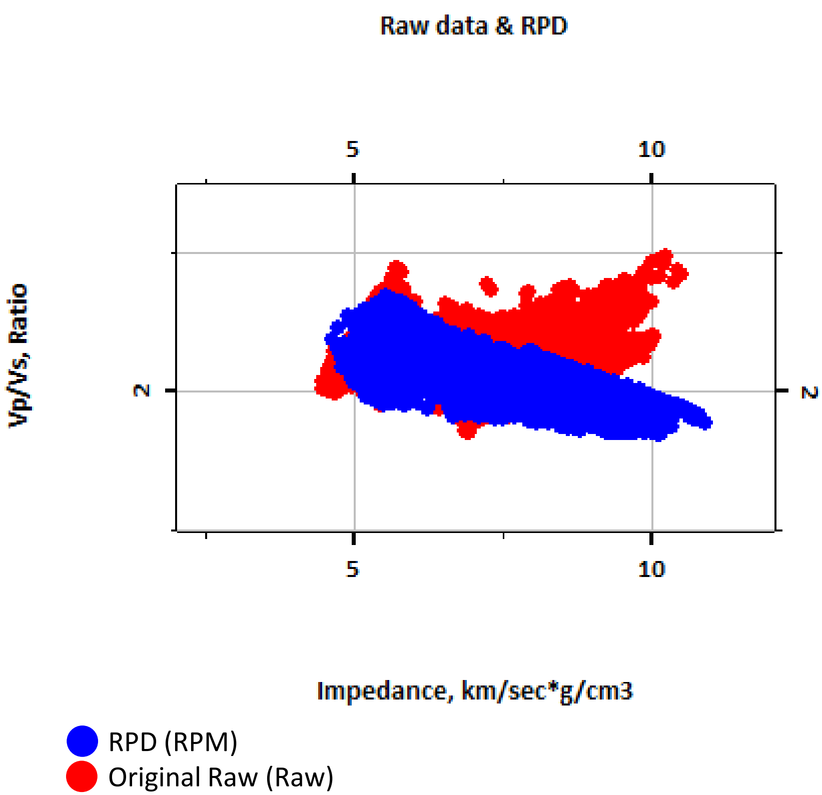
- Unconsolidated rock model
- Stiff rock model



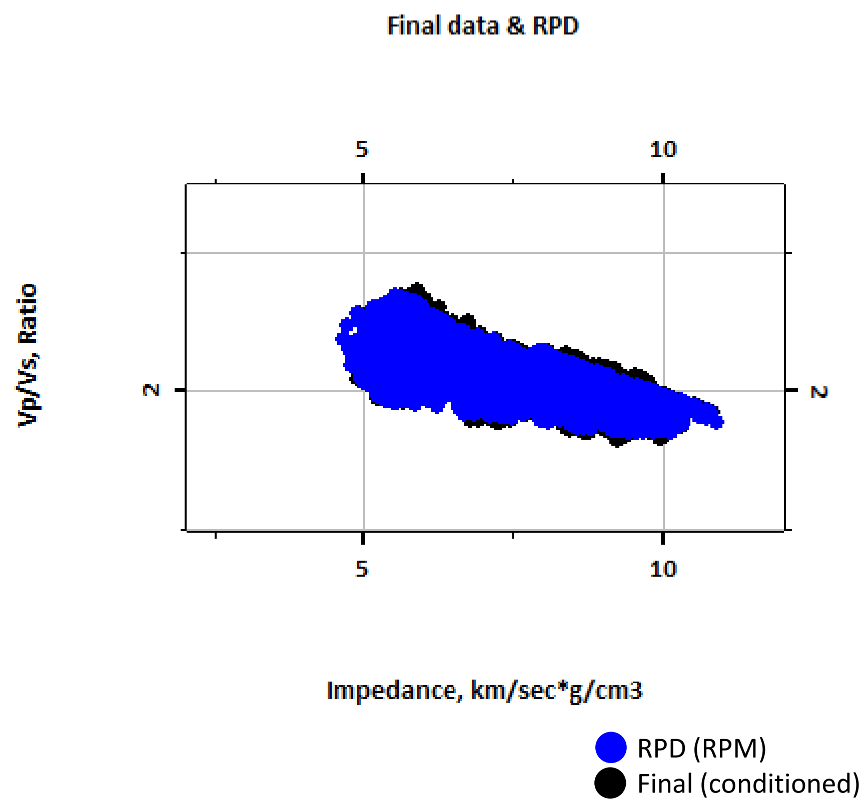
Some edits to the measured data and model calibration is strong. The casing gaps were filled from resistivity via Faust equation to predict Vp then density and Vs from RPD. Granular media model (soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) in the clean reservoir rocks and the clay rich intervals as well with good correlation with the measured data.

Ehsan-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.



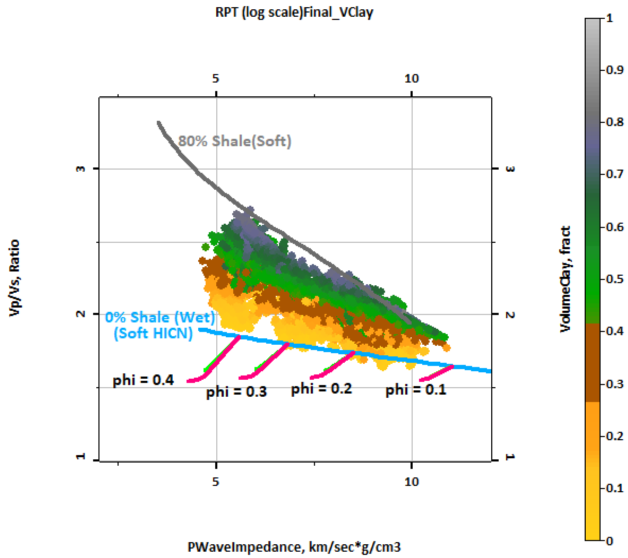
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

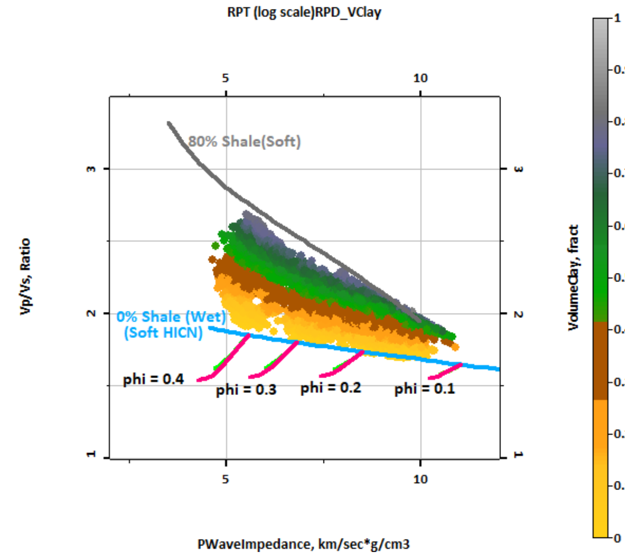


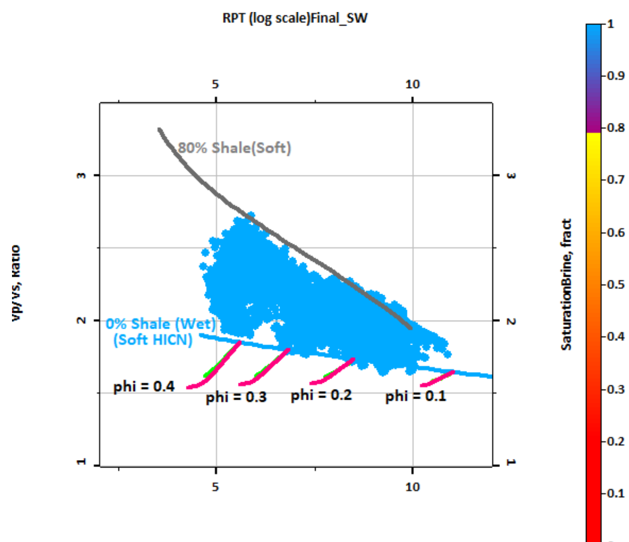
Ehsan-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

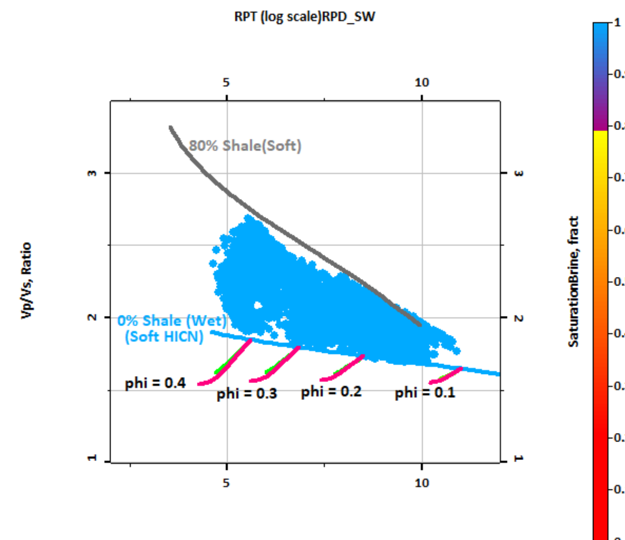
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Ehsan-1ST1

Ehsan-1ST1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- Most of the input data for this sidetrack is identical to the main hole data from top to the TD of the main hole at 3784m; this includes the Thrust Belt and the Subthrust Upper Kebabangan. Therefore all interpretation and final curves are copied from the main only down to 3784m. See main hole report for comments on this upper section (top-3784m).
- Data quality is overall good where present. Data is present from 3784m to TD at 4540m. No shear is available in this section, and limited compressional sonic.
- Density is predicted in the casing gaps at 3880m and 4160m, but otherwise unedited.
- Compressional sonic is not available in the final hole section from 4137 to TD and has been predicted from either RHOB using the rock physics diagnostics, or from Resistivity using Faust.
- No shear sonic is available and has been fully predicted from the rock physics models from RHOB.
- Other logs include Gamma, Neutron, Deep, Resistivity, which all run for the full logging run. Caliper is present from 3884m-4160m.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the reservoirs are in the Thrust Zone and the Subthrust Upper Kebabangan fans.
- The argillaceous sands in the Thrust Zone are of indeterminate origin. They are blocky and stiff with porosity around 8%.
- The Subthrust Upper Kebabangan fan sands are very similar in geometry to their counterparts in the upthrown section, except porosities here are lower. They are blocky sandstones with interbedded siltstones and claystones in between. Porosities here are around 11% with good calibration to core porosity and XRD data.

Volume of hydrocarbons:

- There are low amounts of gas present in the Subthrust Upper Kebabangan, with gas saturations less than 35%.

Water saturation (Sw):

- Reported salinity used for this well is 20000ppm, Simandoux's equation was used for the water saturation calculation.

Ehsan-1ST1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that in terms of P & S-wave velocity versus porosity space, the Soft sediment model proved to be the best predictor for clay rich intervals while soft model with higher coordination numbers for the quartz rich ones. Shear calibration is very limited calibration provided by the wireline data at the base of the main hole, from 3734m-3745m. These models have been used to edit the Vp, Rhob, and Vs data where necessary and to perturb the rock for changes to VClay and Phi_T in the Rock physics modelling (RPM) portion of the project.

Fluid properties:

Fluid properties used in substitution have been assumed, no downhole fluid samples have been taken for this well or the sidetrack. Main parameters used in this modeling are:

Brine salinity: 20000 ppm

Gas gravity: 0.6 (assumed based on "dry gas" reported for Ehsan-1ST1S1)

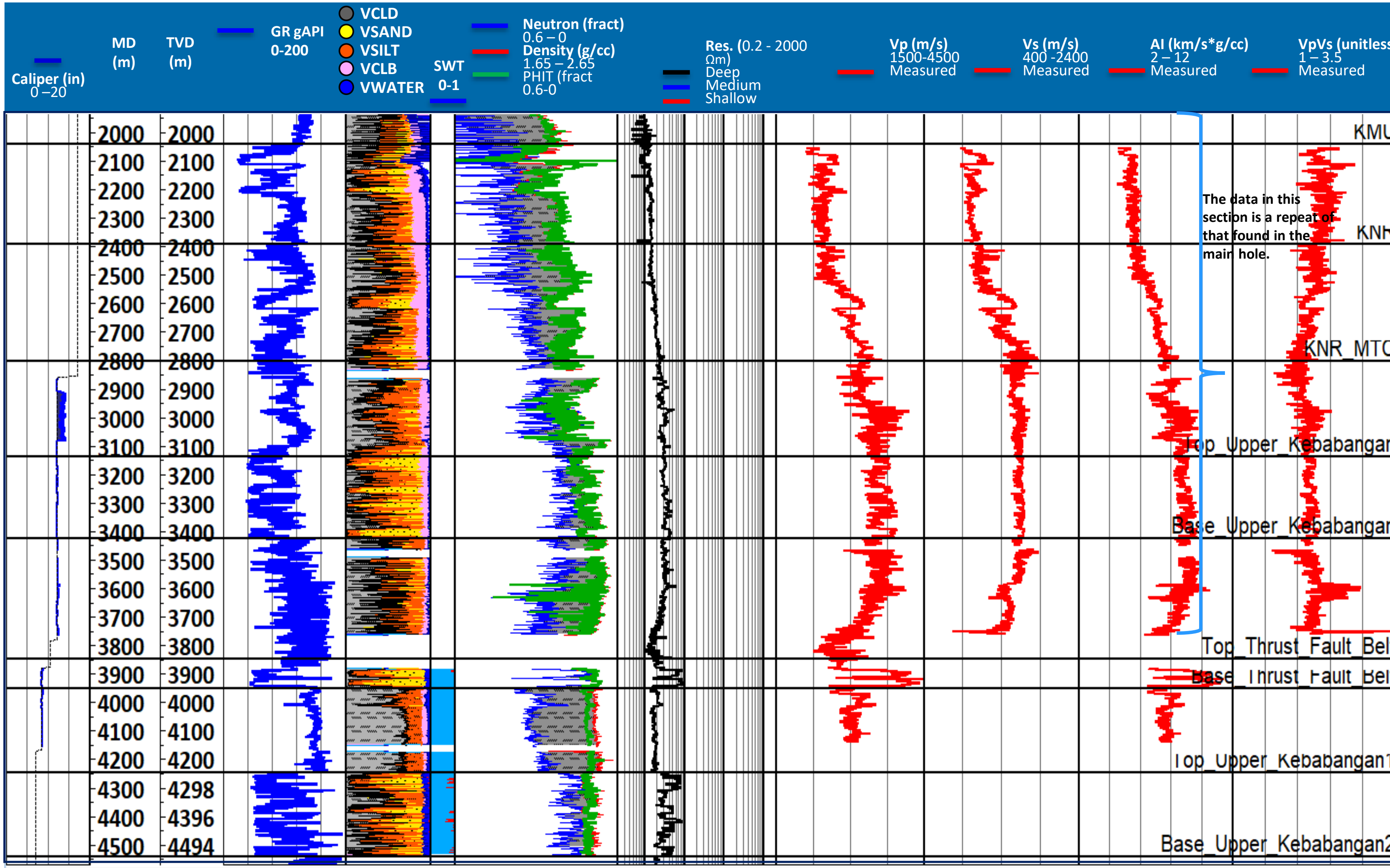
Oil Gravity: 35 API (assumed)

Gas / Oil ratio: 100 (L/L) (assumed)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the Thrust Zone and Subthrust Upper Kebabangan fan sands using the final modelled curves as input.
- The standard Gassmann's fluid substitution method was used to perturb the different modelling scenarios.
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Hydrocarbon sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale.
- AVO analysis at an interface defined at 4275m revealed a class IIP response for all the fluid cases well separated from the background trend all at the insitu reservoir conditions.
- By upgrading the reservoir quality(increasing porosity and decreasing clay content) No change to the AVO response for all fluid scenarios could be observed.

Ehsan-1ST1 Input Logs



Additional data includes core analysis, pressure and temperature data, cuttings descriptions, VSP, and MDT fluid data

Ehsan-1ST1 Geophysical Well Log Analysis (GWLA) – Interval Interval from 2030 to 3300 m

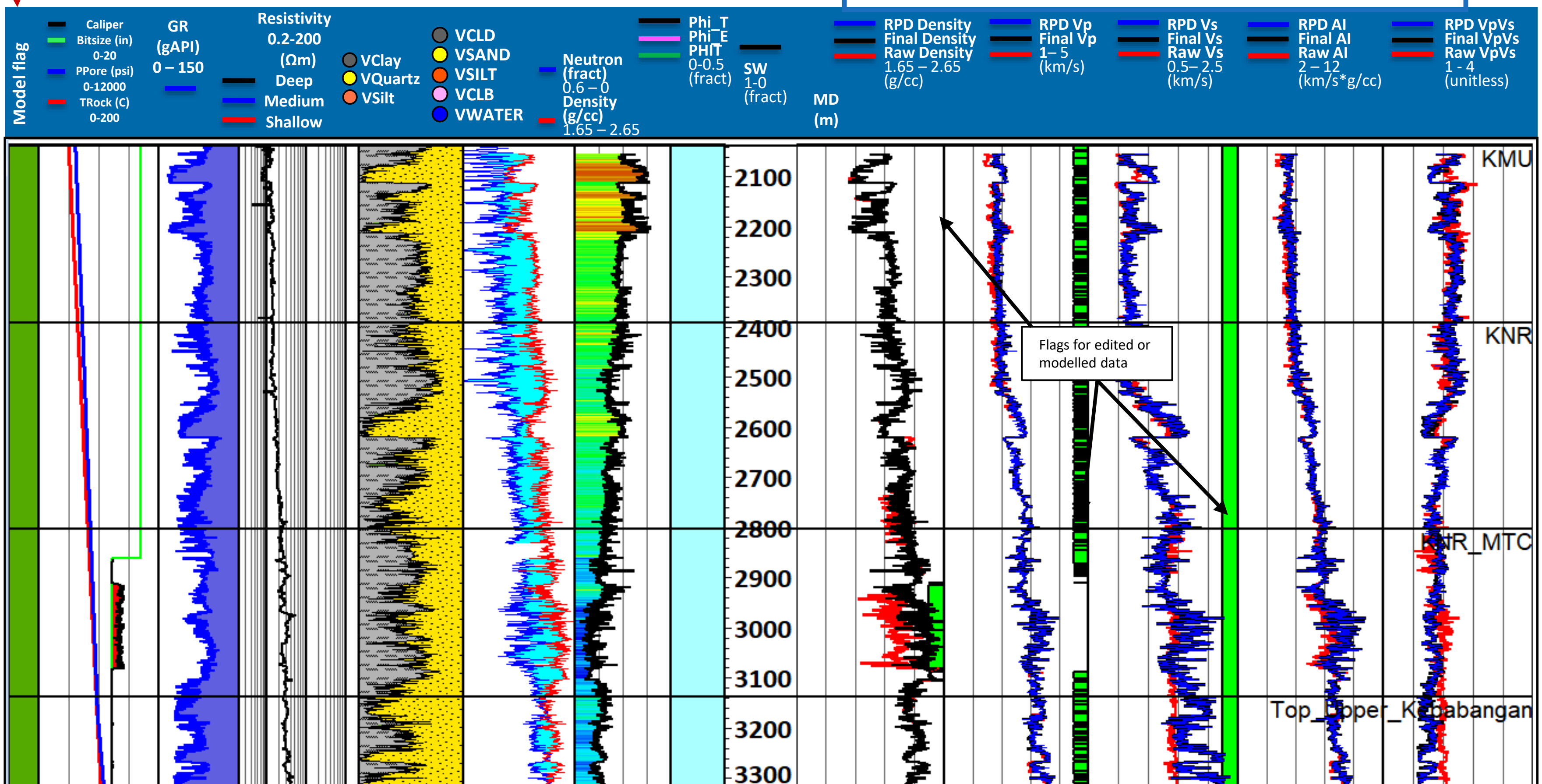
model type flag

Unconsolidated rock model
Stiff rock model

Above depth of 2030m(MD) no reliable logs were available to establish a rock physics model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve
Final edited (Conditioned) curve
Original Raw (Raw) curve



Some edits to the measured data and model calibration is strong. The casing gaps were filled from resistivity via Faust equation to predict Vp then density and Vs from RPD. Granular media model (soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) in the clean reservoir rocks and the clay rich intervals as well with good correlation with the measured data.

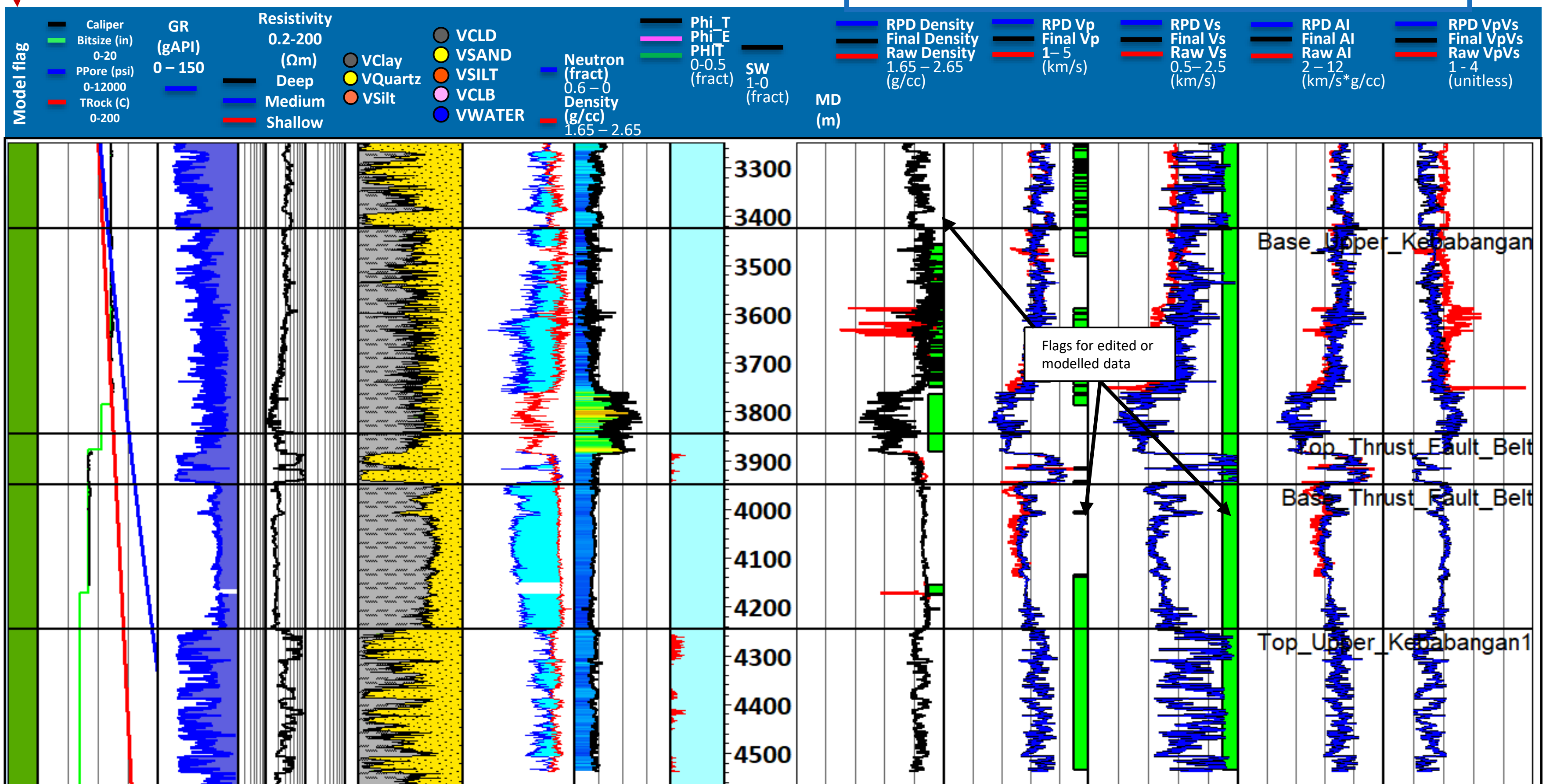
Ehsan-1ST1 Geophysical Well Log Analysis (GWLA) – Interval Interval from 3300 to the end of logs

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

model type flag

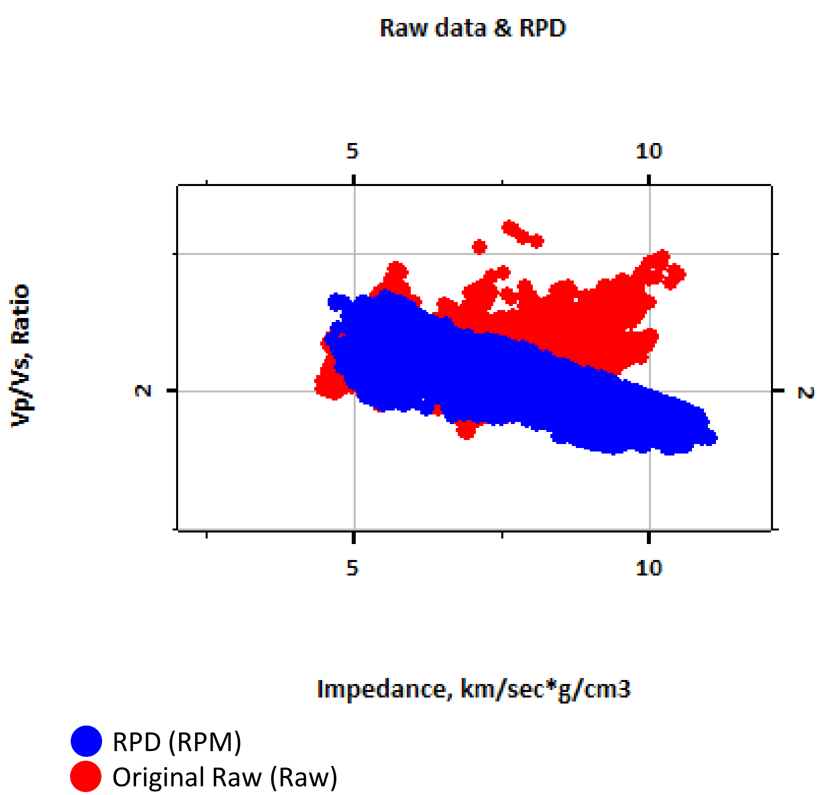
- Unconsolidated rock model
- Stiff rock model



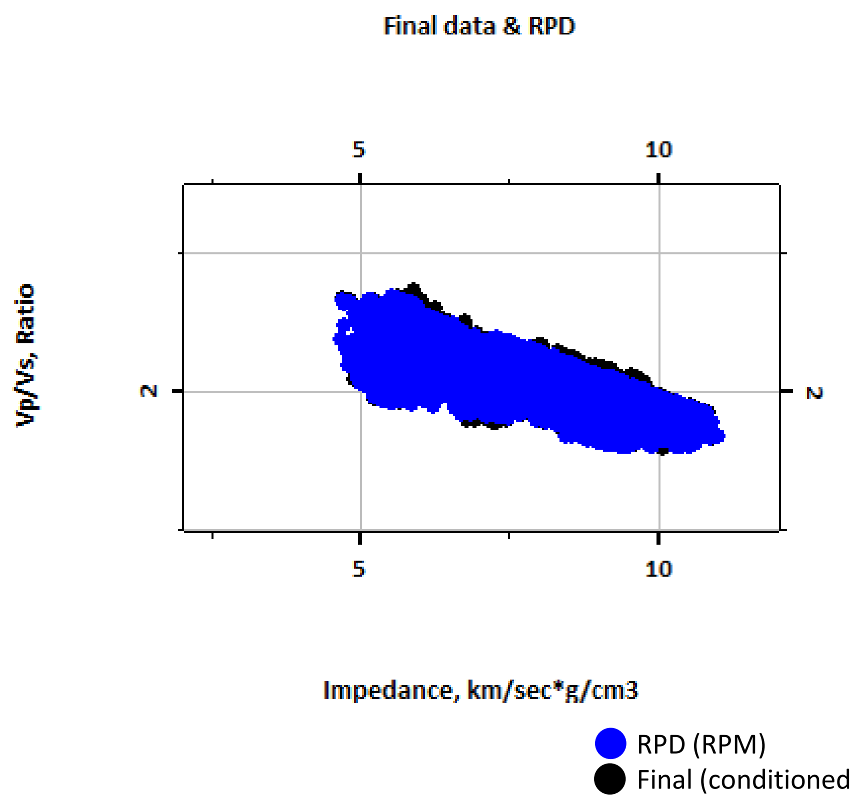
Some edits to the measured data and model calibration is strong. The casing gaps were filled from resistivity via Faust equation to predict Vp then density and Vs from RPD. Granular media model (soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) in the clean reservoir rocks and the clay rich intervals as well with good correlation with the measured data.

Ehsan-1ST1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.



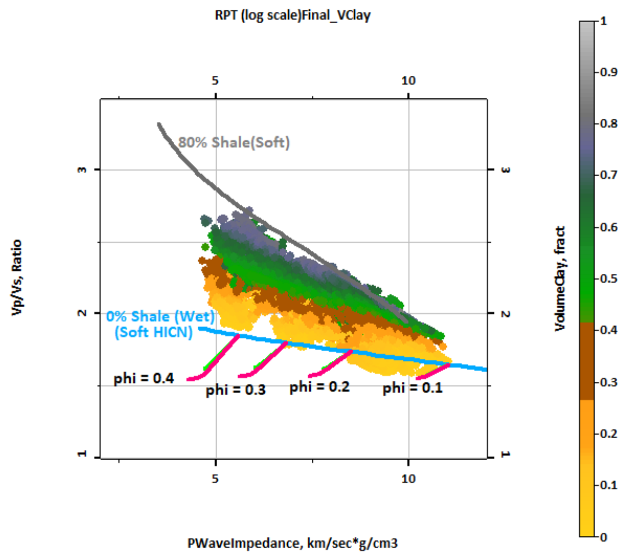
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

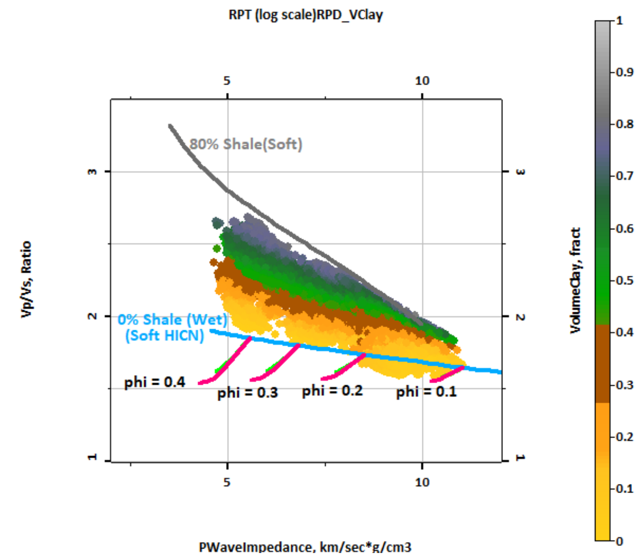


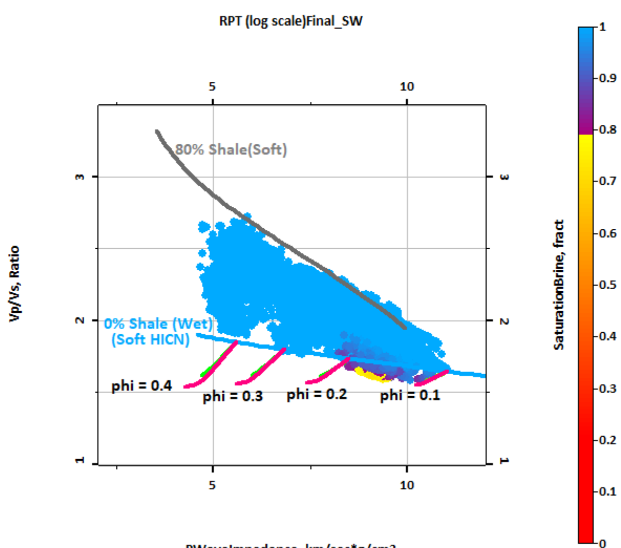
Ehsan-1ST1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

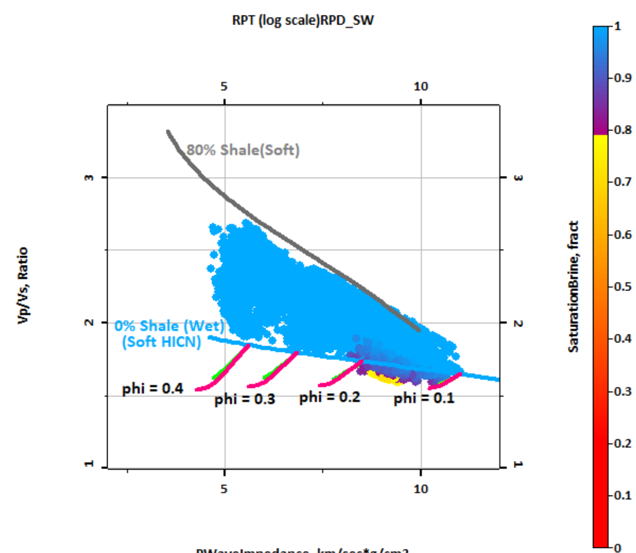
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Haselfoot-1

Haselfoot-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality is poor but the data availability is fair. Client's petrophysical interpretation was not provided for this well(except for fast track SW and PHIT). Full elastic logs except VS were available throughout the wellbore covering the interval (300m-T.D.)
- Elastic logs(VP and Rhob)were totally affected by the bad hole conditions in the interval(300-750m) so no reliable response could be obtained to establish a rock physics model for that interval.
- Shear wave velocity(VS)was fully modelled in the well using the RPD after the model was carefully calibrated based on the nearby wells especially(Andalusit-1).
- Density was heavily edited in many intervals using the RPD due to the bad hole conditions
- Vp also was edited using the RPD in some intervals especially where the hole was affected by washouts.
- Other logs include Gamma, Neutron, Caliper, Deep and Shallow resistivity, which all run for the full logging run to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is the Miocene marine sands. These are a series of turbiditic fine to very fine sands intercalated with many claystone layers.
- The well penetrated many good sand layers especially the thin ones with gas saturation above the IVF stage top with total porosity up to 34%.
- Many other blocky sand layers penetrated in the IVF, IVE and IVD stages but all were wet.
- .

Volume of hydrocarbons:

- Intervals with best sand developments in the well were interpreted as 100% water saturated. Above the IVF stage top some sands were interpreted with gas saturation values between 40-65%.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the section clean wet sand section(1450-1600m)yielded a formation water salinity of 30000 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=2 and Saturation exponent (n)=2 (assumed).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that from the point where the elastic logs started down to the T.D. the Stiff sand model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for sand rich intervals while the soft sediment model honor more the elastic trend for the clay rich intervals.
- Elastic behavior for the well was carefully calibrated with the nearby wells and concluded that the well elastically behaves similar to Andalusit-1 well , so S-wave velocity completely modelled in the well based on the same model and parameters used in the offset well.

Fluid properties:

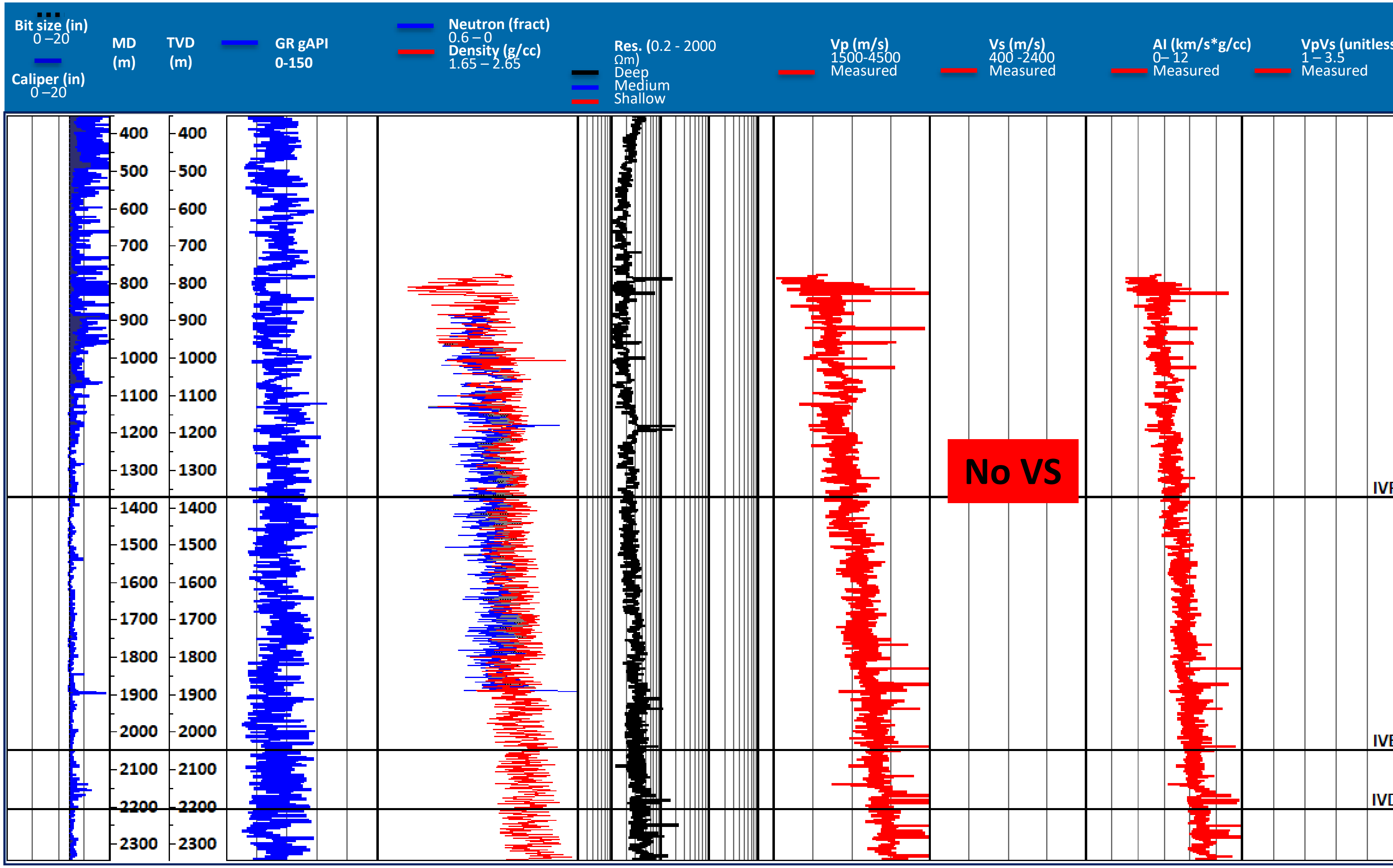
Fluid properties used in substitution have been taken from PVT report of nearby well Samarang-1(test#2) and Haselfoot-1(DST). Main parameters used in this modeling are:

- Brine salinity: 30000ppm
- Gas gravity: 0.586[DST]
- Oil Gravity: 37.3 API[PVT analysis]
- Gas / Oil ratio: 566 (L/L) [PVT analysis]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the different stages stage using the final modelled elastic curves as an input.
- Gassmann’s fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with very good discrimination with the brine sands.
- AVA class IV was observed near a gas sand layer@1175m for all hydrocarbon cases at in situ reservoir conditions with good fluid discrimination with the wet case which showed class II AVA response.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) no significant change could be observed for all the modelled cases.

Haselfoot-1 Input Logs



Additional data includes final geological report. No VS recorded in the well.

Haselfoot-1 Geophysical Well Log Analysis (GWLA) – Interval from 750 to 1550 m

model type flag

Unconsolidated rock model

Stiff rock model

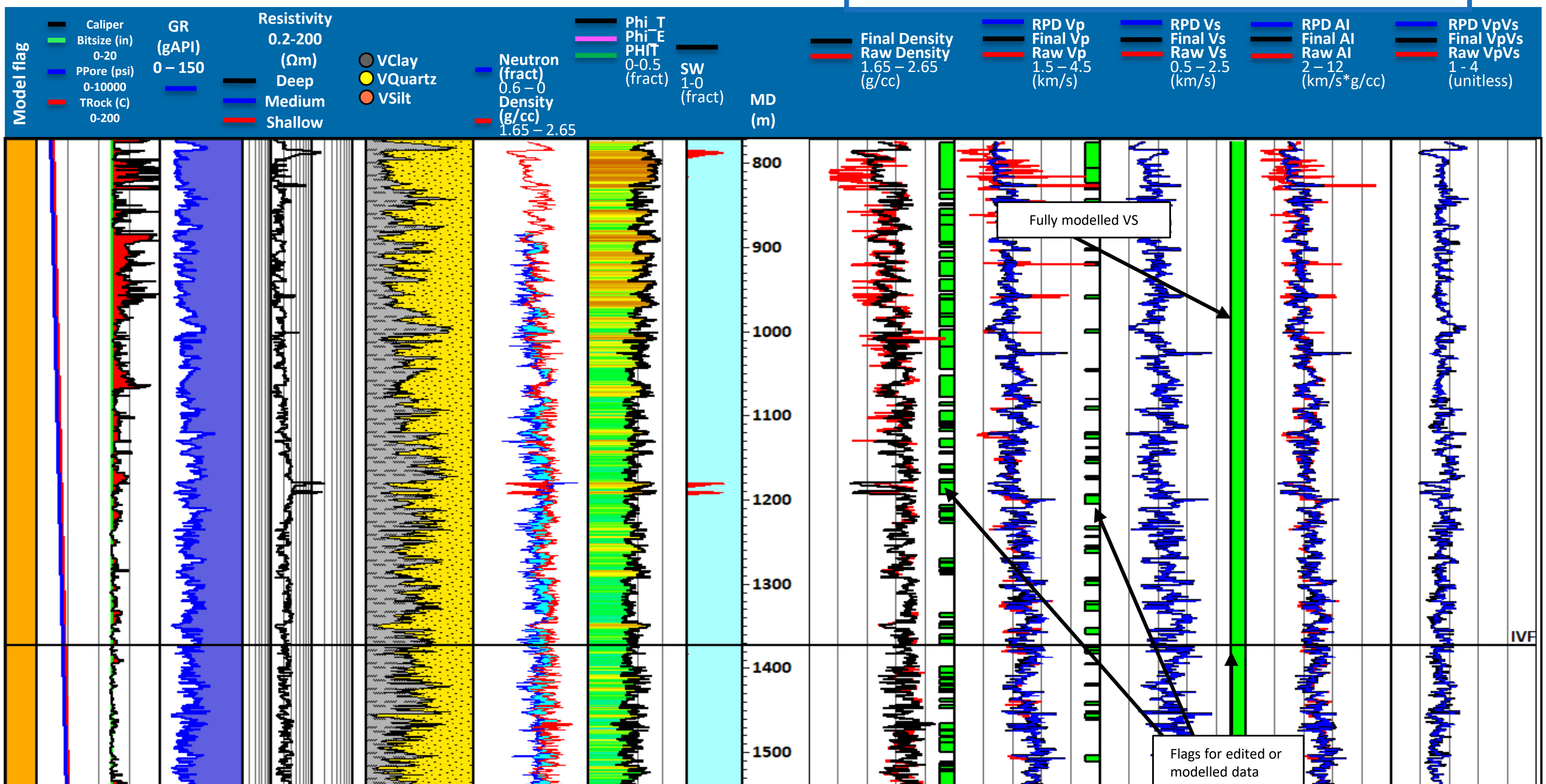
Above depth of 750m(MD) no reliable logs were available to establish a rock physics model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve



Many edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (Stiff sand) was used for all elastic curves prediction (Rhob, Vp and VS) for sand rich intervals and soft model for clay rich ones, with good correlation with the measured data and the nearby wells.

VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells

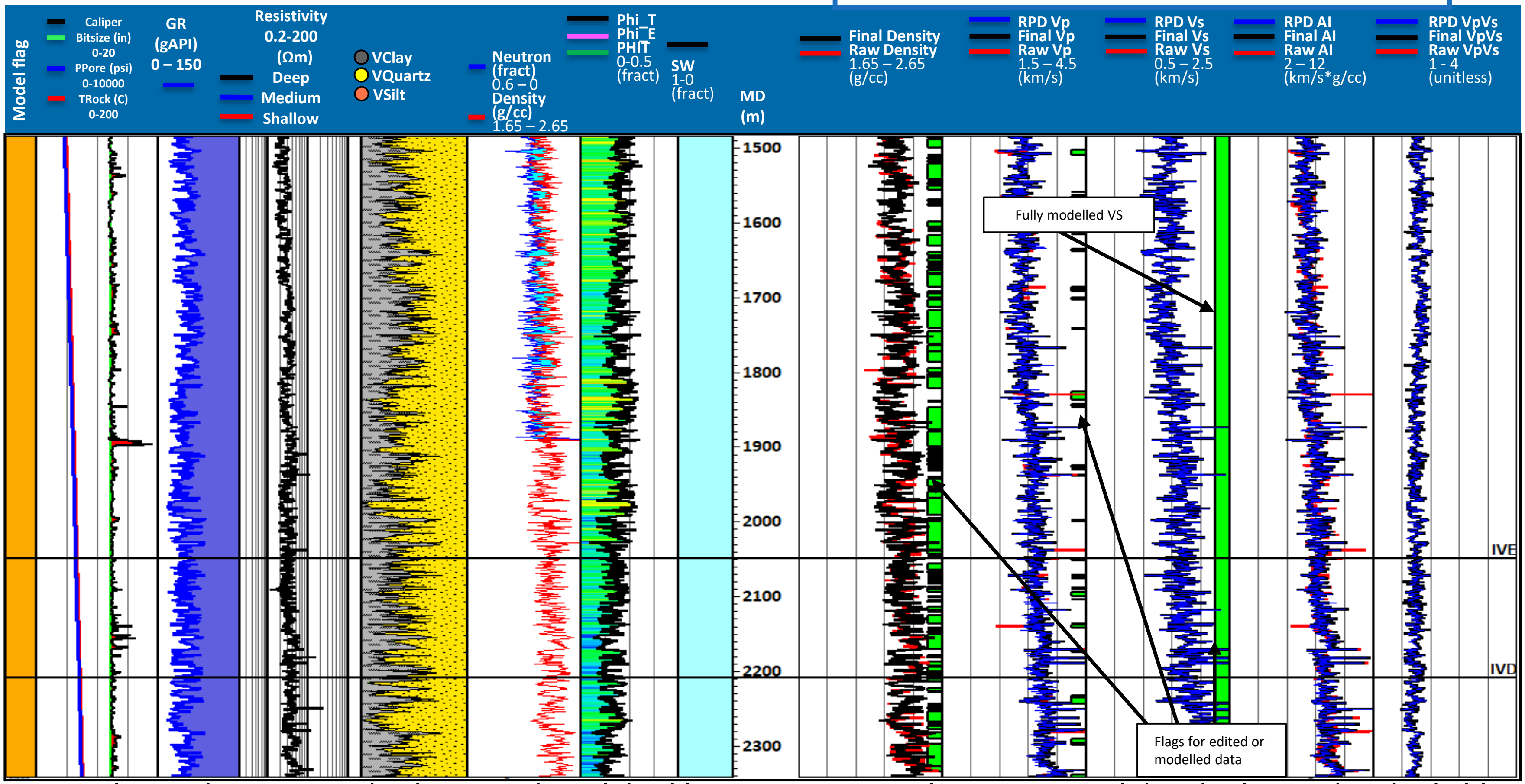
Haselfoot-1 Geophysical Well Log Analysis (GWLA) – Interval from1500m to the end of logs

model type flag

Unconsolidated rock model
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

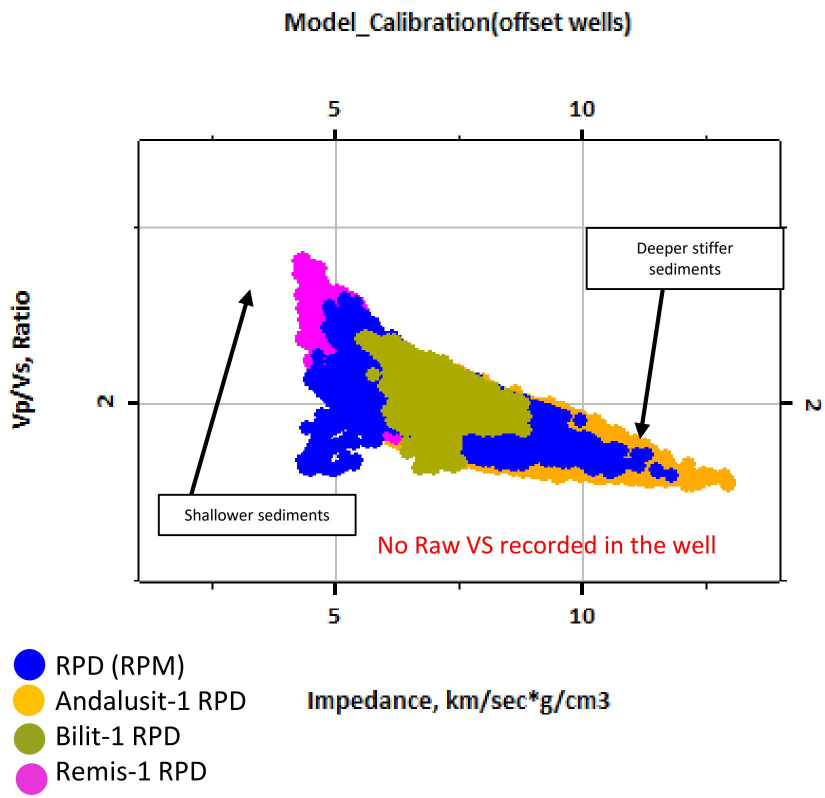
RPD Modeled (RPM) curve
Final edited (Conditioned) curve
Original Raw (Raw) curve



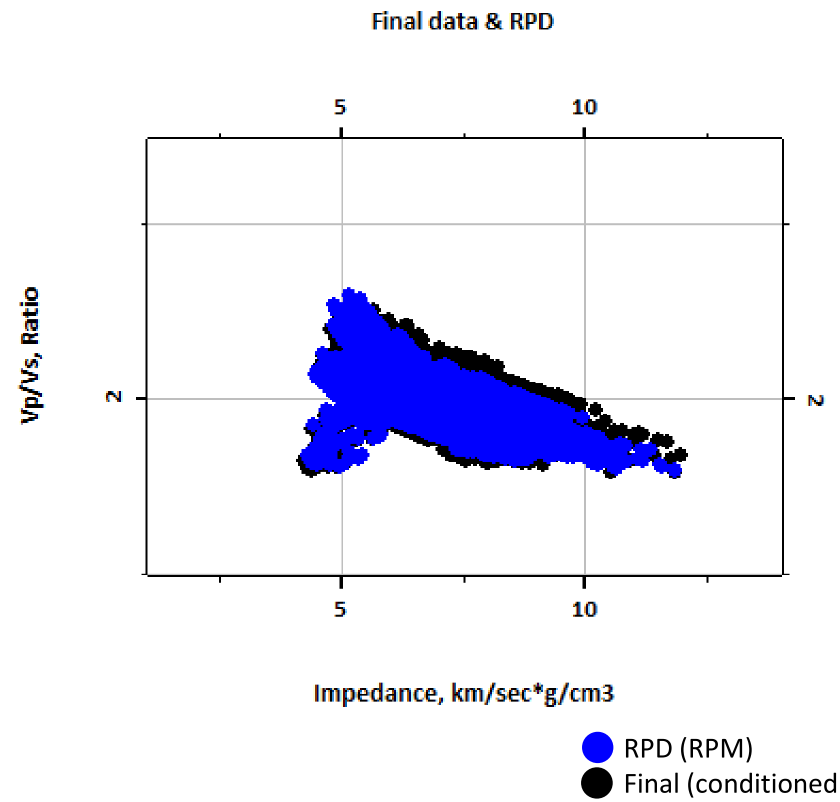
Many edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (Stiff sand) was used for all elastic curves prediction (Rhob, Vp and VS) for sand rich intervals and soft model for clay rich ones, with good correlation with the measured data and the nearby wells.
VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells

Haselfoot-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the good calibration for the Haselfoot-1 well RPD with the nearby wells Andalusit-1, Bilit-1 and Remis-1.



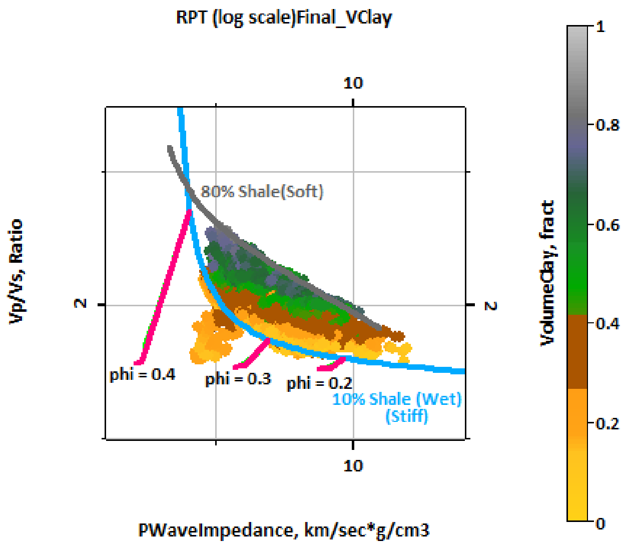
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data(Rhob and Vp ere conditioned while VS is totally modelled).

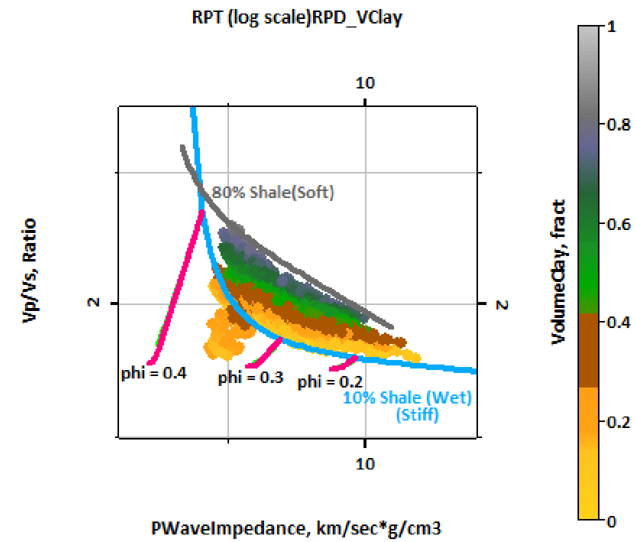


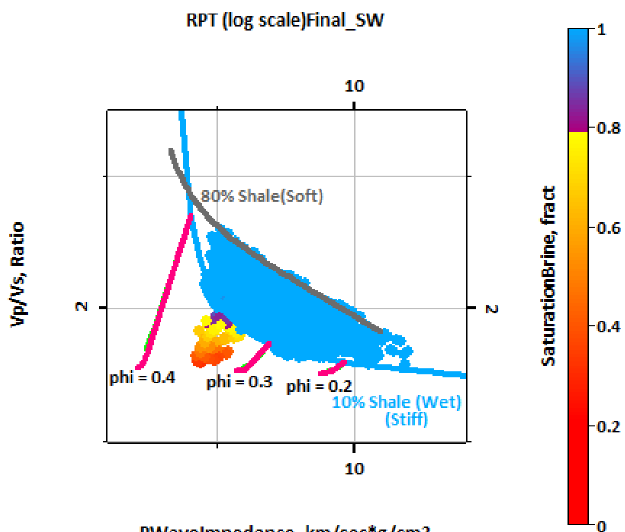
Haselfoot-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

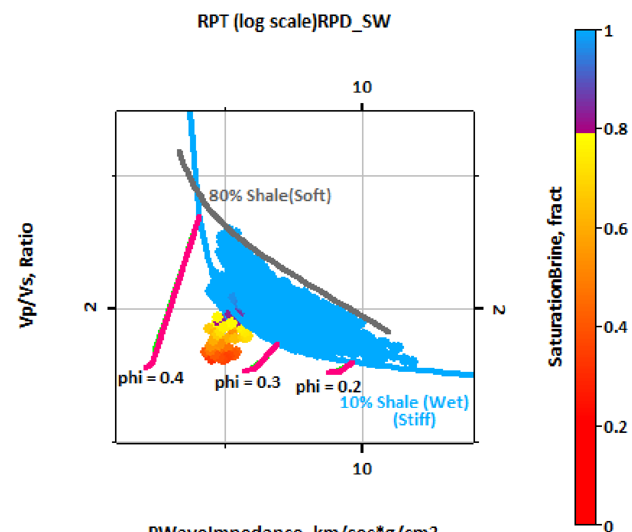
RPT cross plot shows the correlation between the rock physics model lines(soft/Stiff sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Hebat-1

This well has been processed by Petronas QI – please refer to internal reports regarding details.

Hebat-1 Geophysical Well Log Analysis (GWLA) – Full Well

model type flag

Unconsolidated rock model

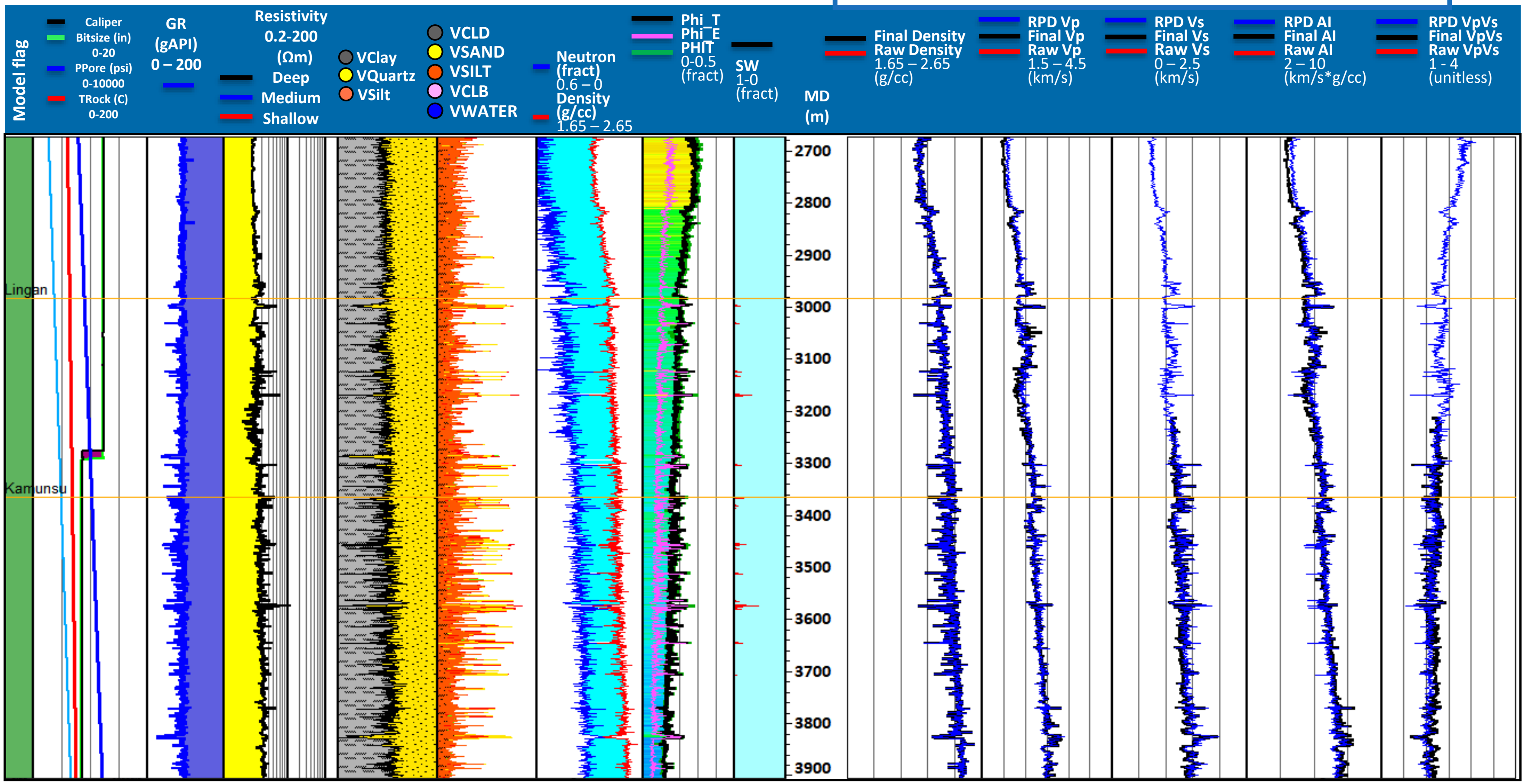
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

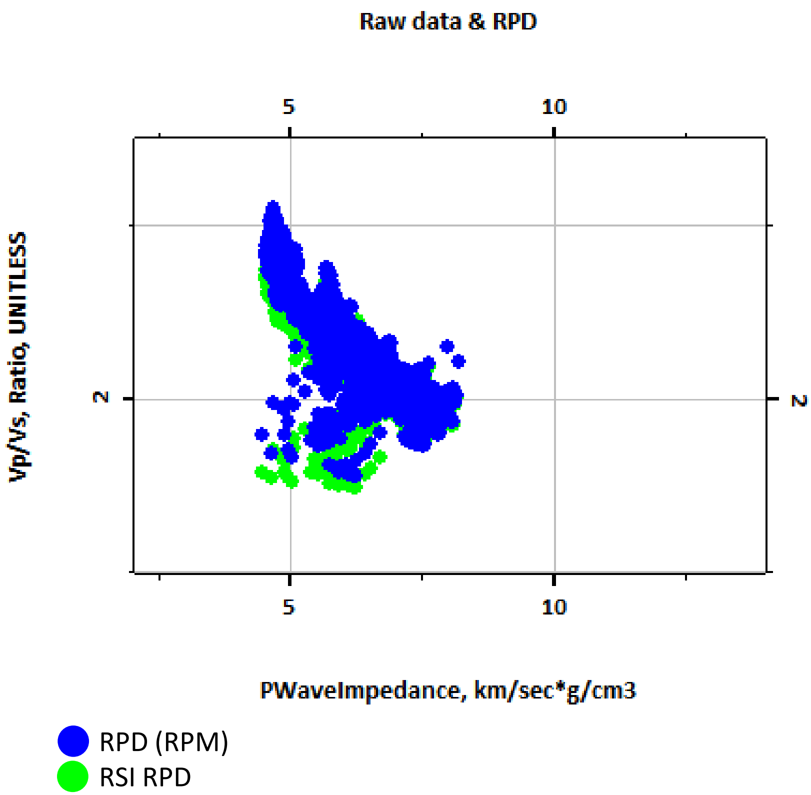
Final edited (Conditioned) curve

Original Raw (Raw) curve

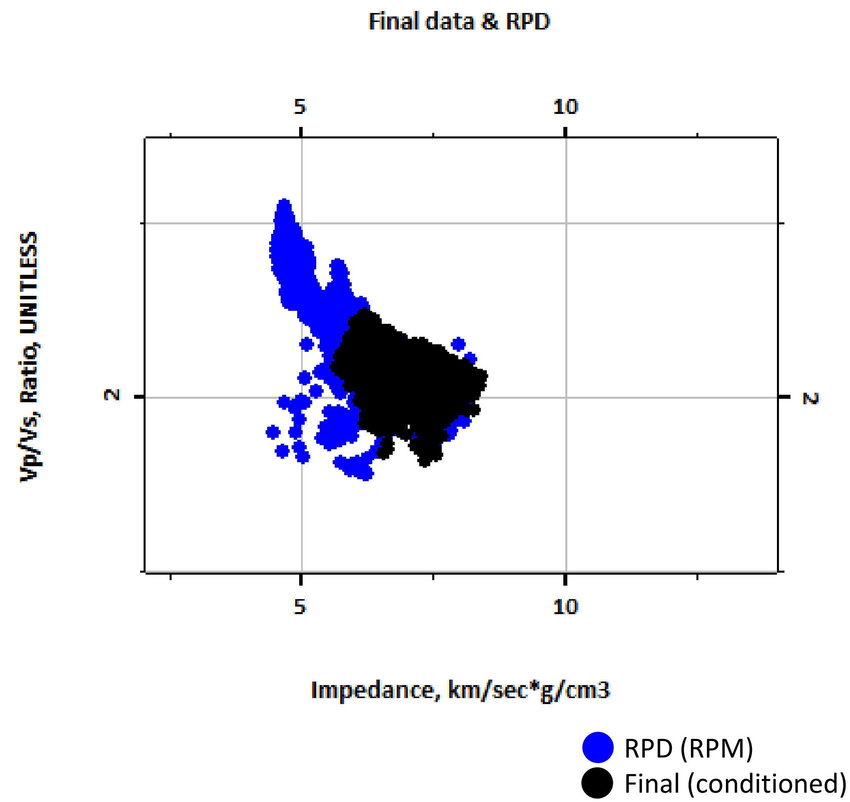


Hebat-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the analog wells with similar trends in the elastic data, given the measured shear in Hebat-1 is not viable.



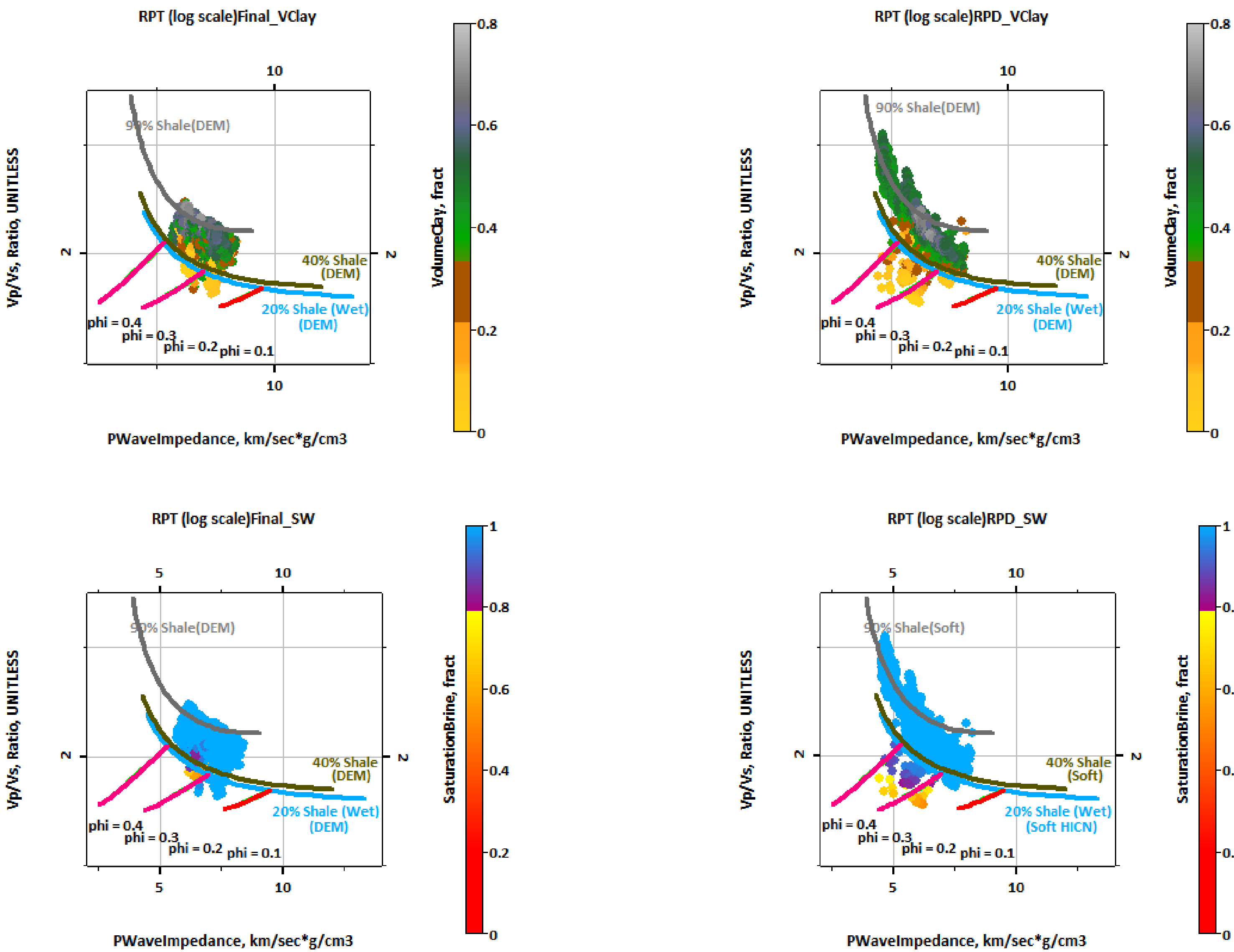
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.



Hebat-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data



RPD(Modelled)data

Kamunsu-East-1ST1

Open

Kamunsu-East-1ST1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality is poor especially the density and the sonic(in the reservoir section)but the data availability is fair. Client's petrophysical interpretation was provided for this well(for reference only). Full elastic logs except VS were available throughout the wellbore covering the interval (1850m-T.D.)
- Elastic logs(VP and Rhob)were totally affected by the bad hole conditions above 1850m so no reliable response could be obtained to establish a rock physics model for that interval.
- Shear wave velocity(VS)was fully modelled in the well using the RPD after the model was carefully calibrated based on the offset wells behaving elastically the same especially(Biris-1 and Tomani-1 wells) The resulted Vs matched in trend all the nearby wells especially when comparing the shale trend and the gas sand trends.
- Density was replaced with the modeled one in several intervals in the section(1900-2300m)since the original one was not honoring the density trend in the area when compared to many nearby wells with good measured data.
- Vp was also totally replaced with the modelled one in the gas sand interval since it was very lazy and not showing any true measurement after carefully calibrated the model with the good measured data present in the well and also in the offset wells.
- Elastic curves in the bad Vp and Density measurements intervals were filled using deep resistivity to predict Vp via Faust equation then density and Vs were estimated using the RPD.
- Other logs include Gamma, SP, Caliper, shallow and Deep resistivity, which all run for the full logging run to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Miocene marine sands found in the IVD stage(Kamunsu sand). These are a series of turbiditic fine to very fine soft sands.
- The well penetrated very good blocky gas sand layers in the main objective of the well(stage IVD) with good total porosity reached to 30%.

Volume of hydrocarbons:

- The gas saturation calculated in the well was in Stage IVD sand layerS with saturation of about 60-80%.
- Very small oil leg detected in the well based on the PVT and the log response with oil saturation of about 25-40%.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the clean wet sand(below the OWC)yielded a formation water salinity of 12000 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.8 and Saturation exponent (n)=1.8 (assumed based on the final geological well report).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to good measured data in the nearby reference wells and other wells on the same elastic trend.
- Elastic behavior for the well was carefully calibrated with the nearby wells and other wells honoring the same elastic trend for the well(P-Wave impedance depth trend) And concluded that the well elastically behaves similar to Tomani-1 well and Biris-1 well, so S-wave velocity completely modelled in the well based on the same model and parameters used in the offset wells which resulted in a matched trend with the calibrated nearby wells and very well behaved model when compared to the modelled results in the most nearby wells.

Fluid properties:

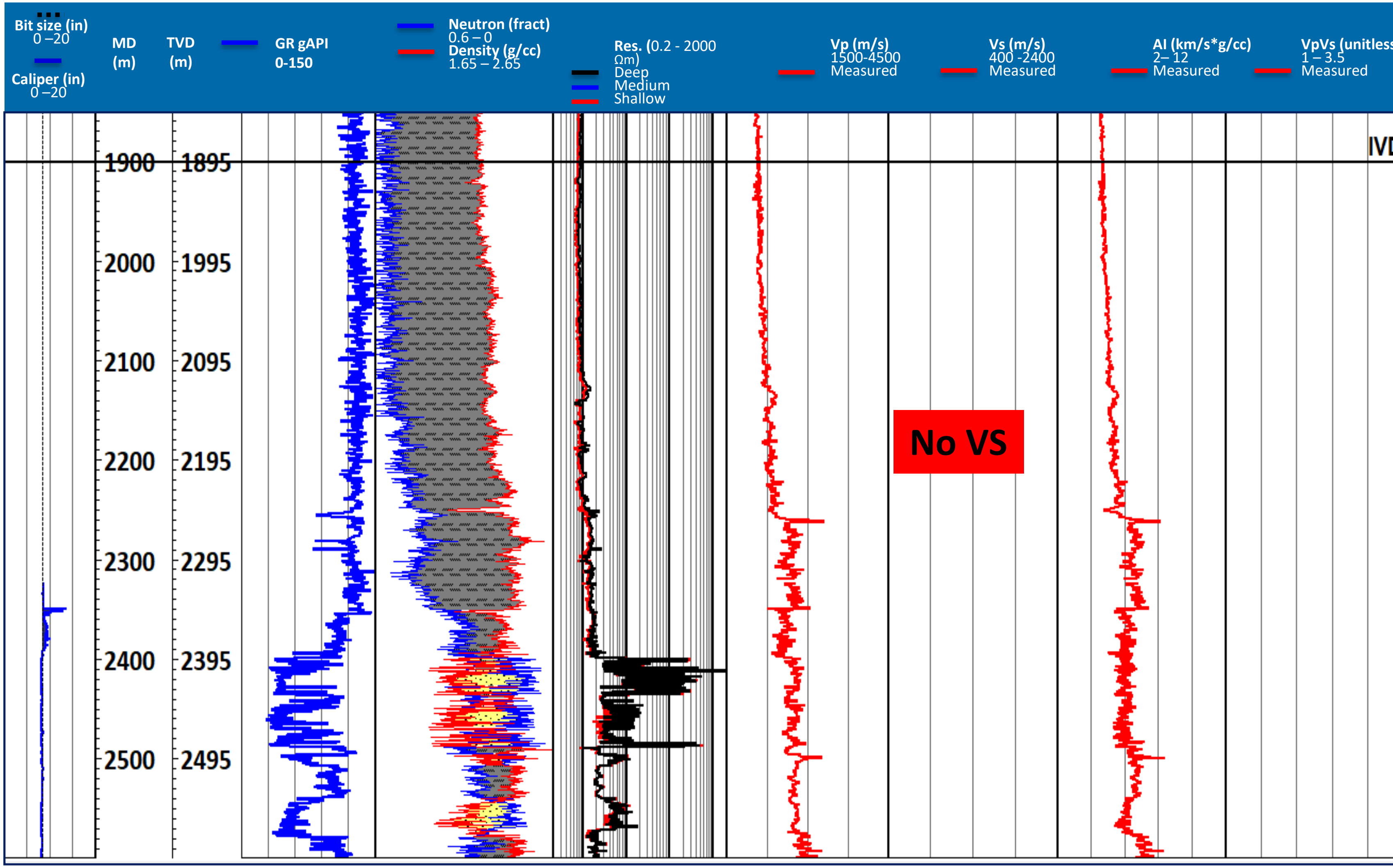
Fluid properties used in substitution have been taken from PVT report of the well, Main parameters used in this modeling are:

- Brine salinity: 12000 ppm[Pickett plot]
- Gas gravity: 0.639[PVT analysis]
- Oil Gravity: 35 API[PVT analysis]
- Gas / Oil ratio: 200 (L/L) [Assumed]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the Kamunsu sands of the IVD stage using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination with the brine sands.
- AVA class III was observed near the top of the Kamunsu gas sand@ 2395m for the gas case while class II observed for the oil and wet cases at in situ reservoir conditions.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) no significant change for the AVA class could be noticed for all fluid scenarios.

Kamunsu-East-1ST1 Input Logs



Additional data includes final geological report. No VS run found in the well.

Kamunsu-East-1ST1 Geophysical Well Log Analysis (GWLA) Interval from 1850 to End of the logs

model type flag

Unconsolidated rock model

Stiff rock model

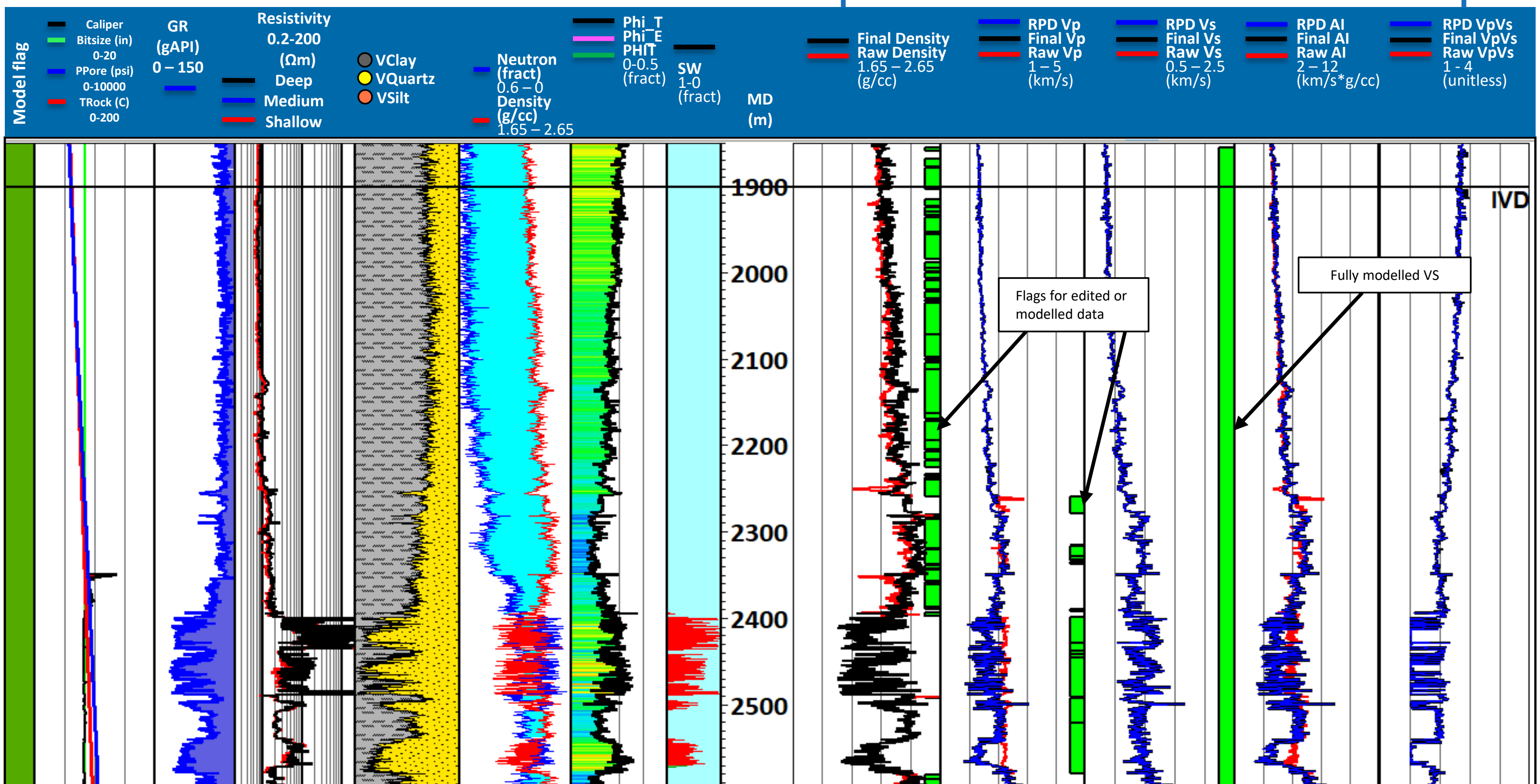
Above depth of 1850m(MD) no reliable logs were available to establish a rock physics model

Equivalence between RSI and Petronas naming.
Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

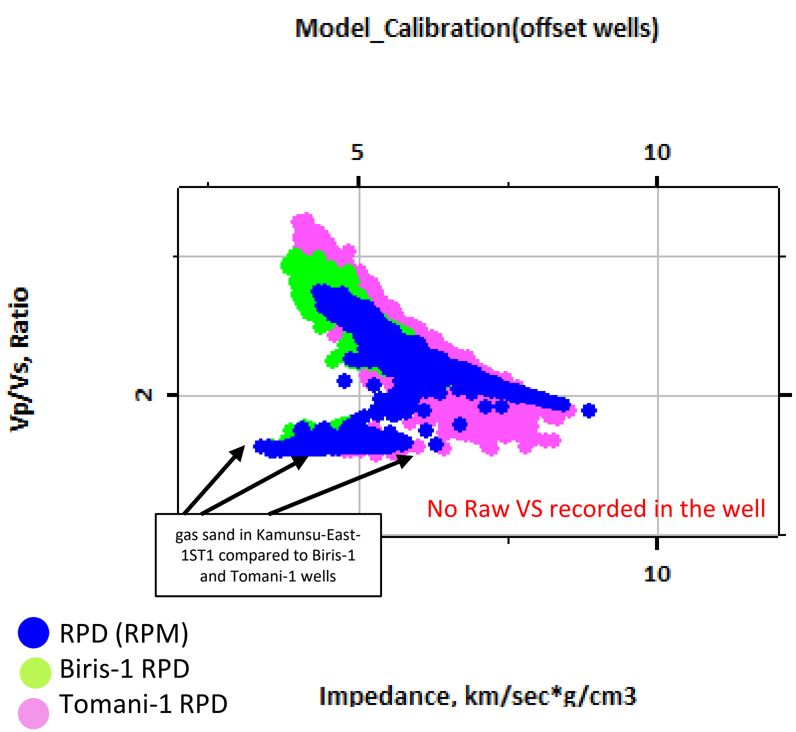
Original Raw (Raw) curve



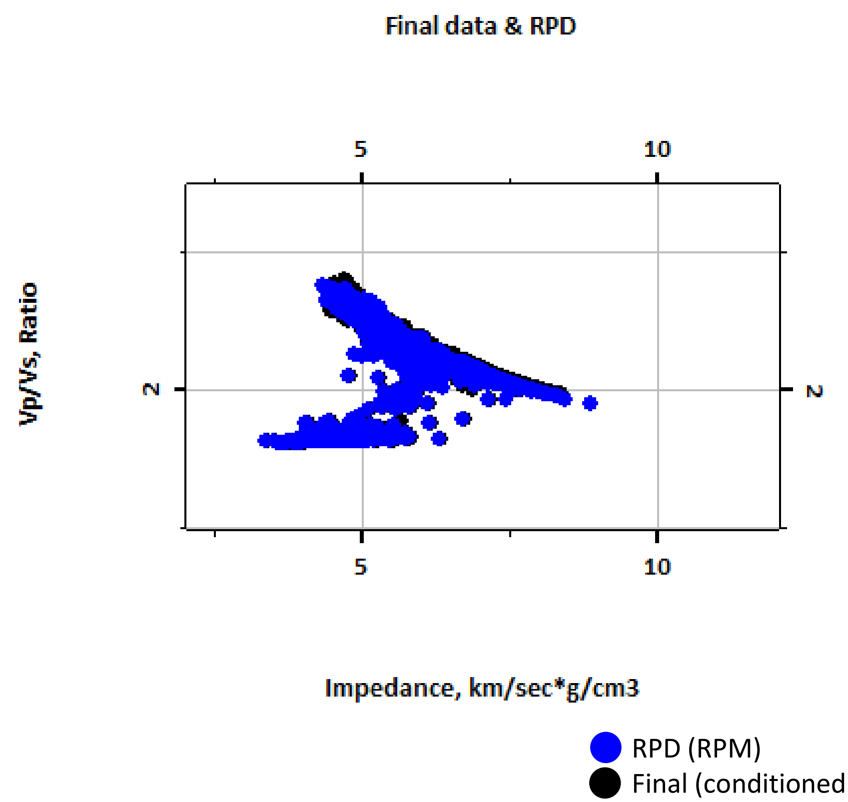
Many edits to the measured Density and VP, model calibration is strong where measured data looks good and reliable. Granular media model (Soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) for both sand and clay rich intervals, with good correlation with the measured data in the well(VP and Rhob)and in the nearby wells(Tomani-1 and Biris-1 wells).VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells.

Kamunsu-East-1ST1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the good calibration for the Kamunsu-East-1ST1 well RPD with the nearby wells Biris-1 and Tomani-1 wells.



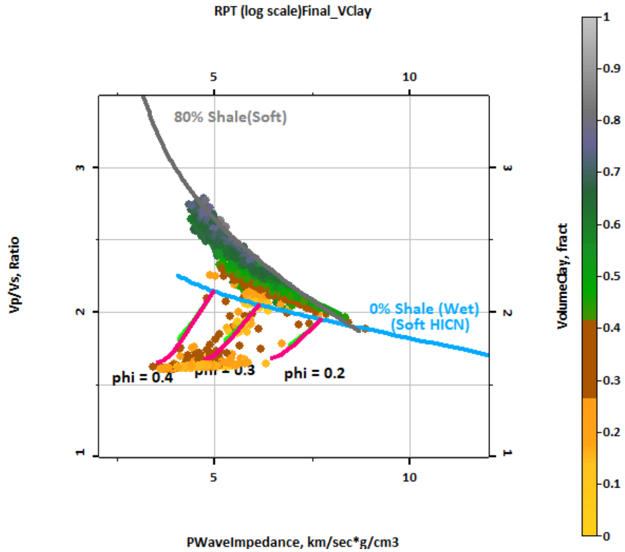
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data(Rhob and Vp ere conditioned while VS is totally modelled).

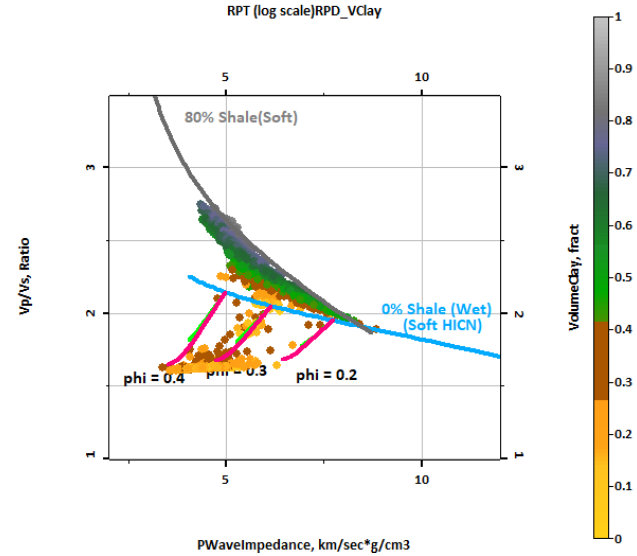


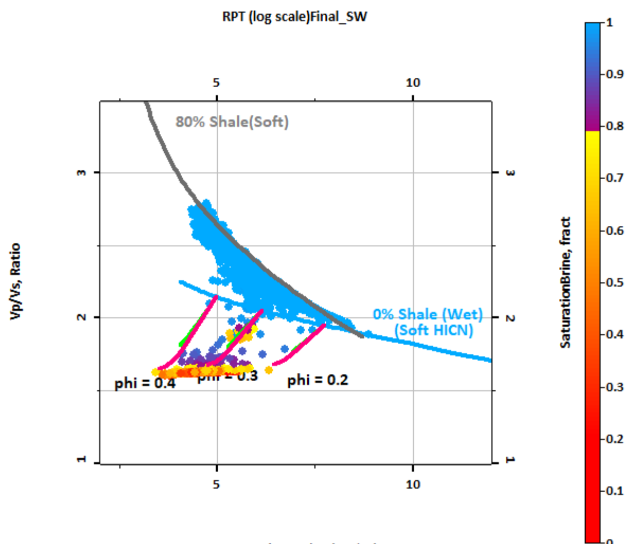
Kamunsu-East-1ST1,Rock Physics Diagnostics (RPD) Rock Physics Models, Full Well

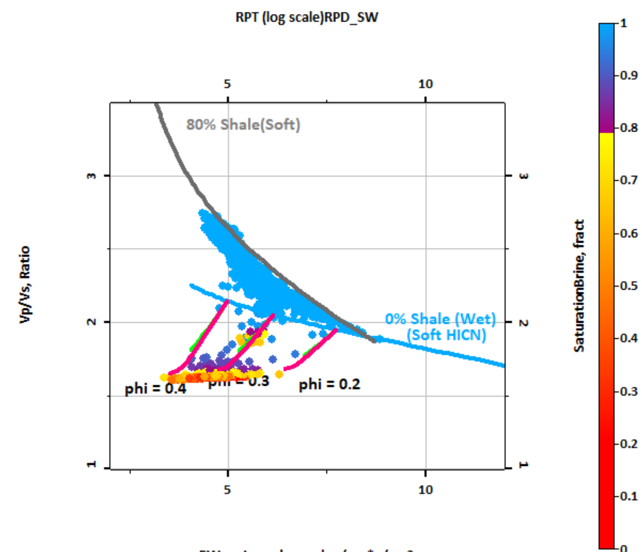
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Kental-1

This well has been processed by Petronas QI – please refer to internal reports regarding details.

Kental-1 Geophysical Well Log Analysis (GWLA) – Full Well

model type flag

Unconsolidated rock model

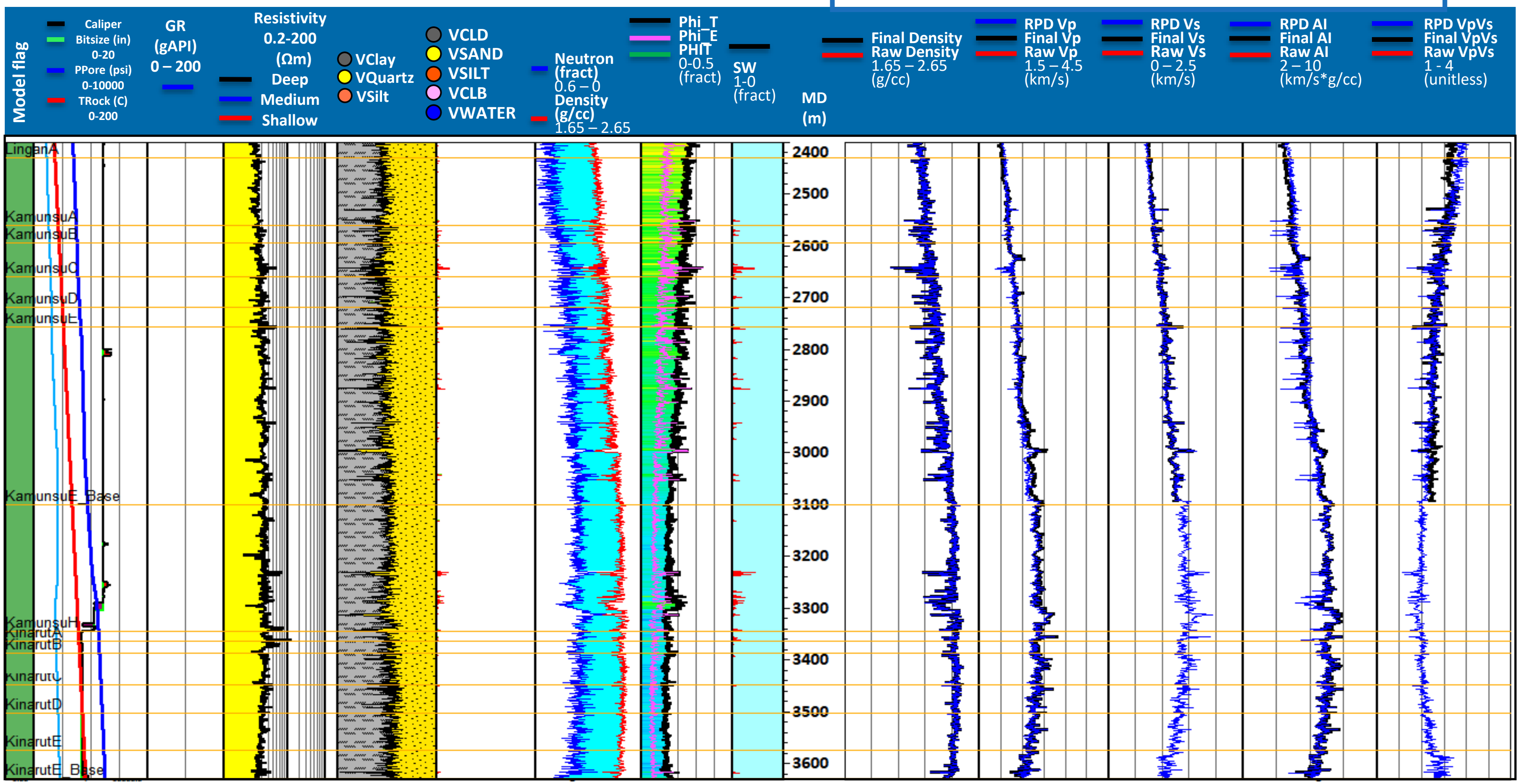
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve

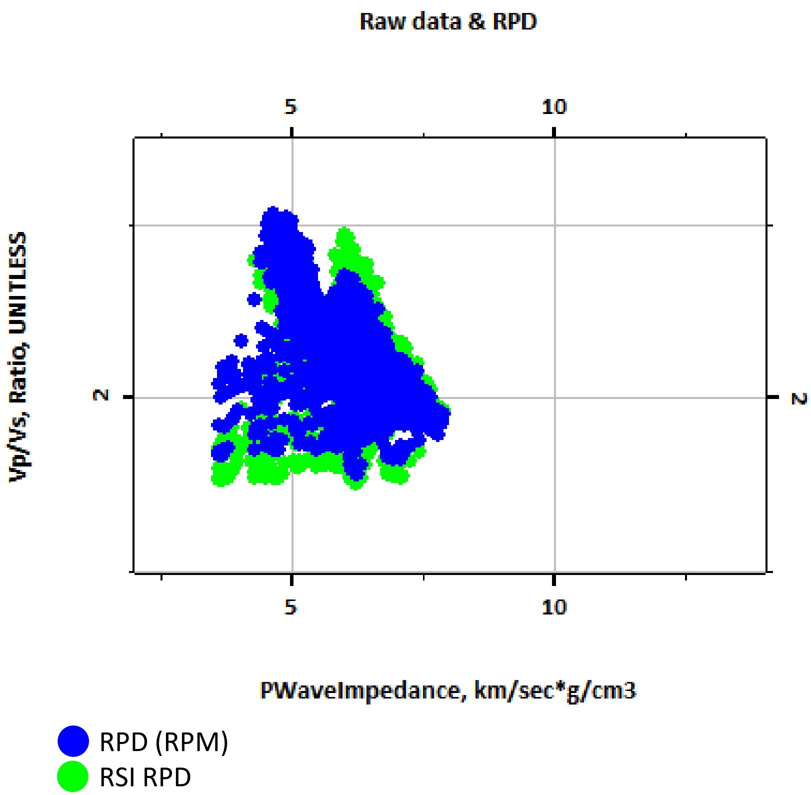


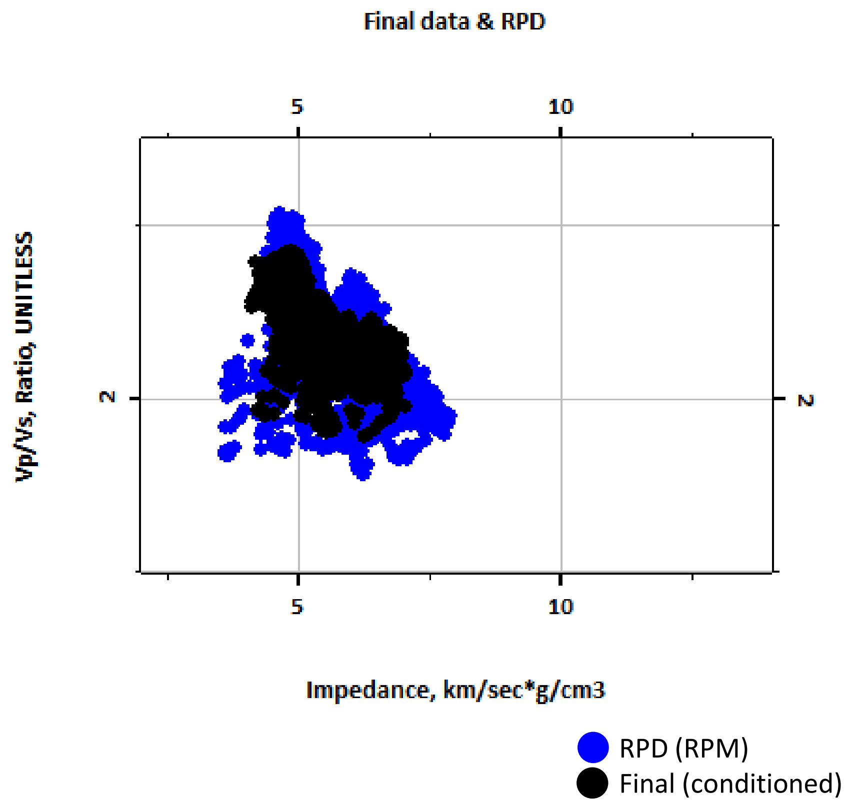
Extraordinary Results. By Any Measure.

Kental-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the analog wells with similar trends in the elastic data, given the measured shear in Sipadan-1 is not viable.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

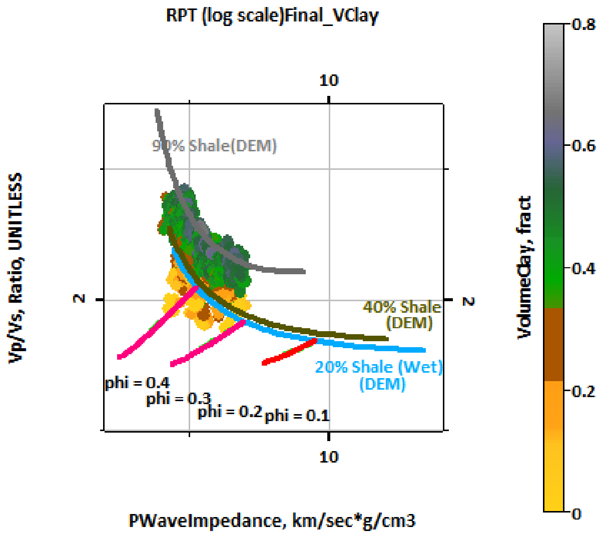


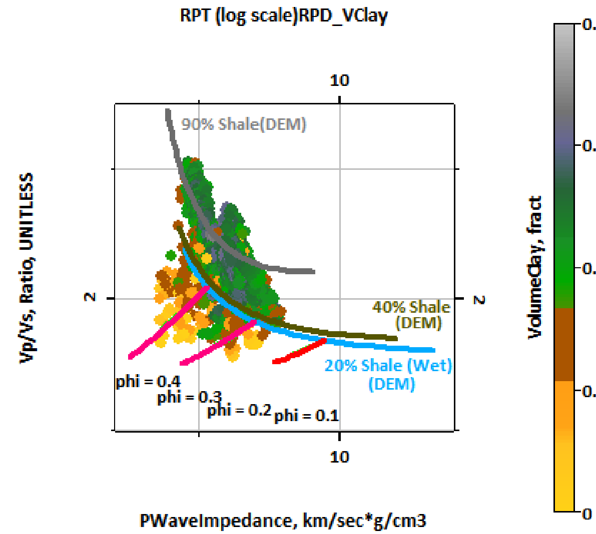


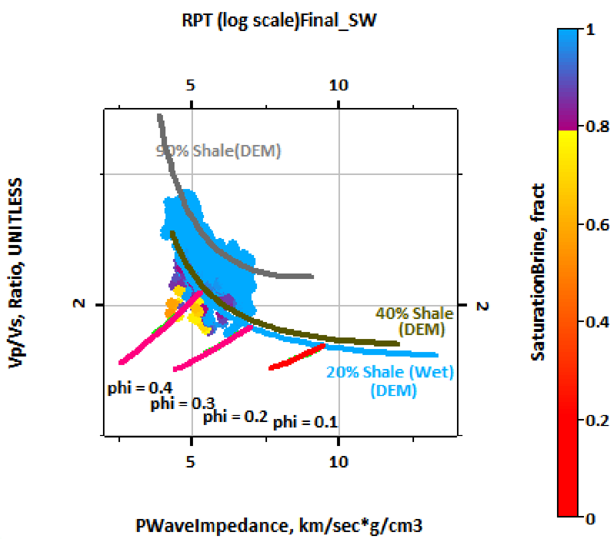
Kental-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

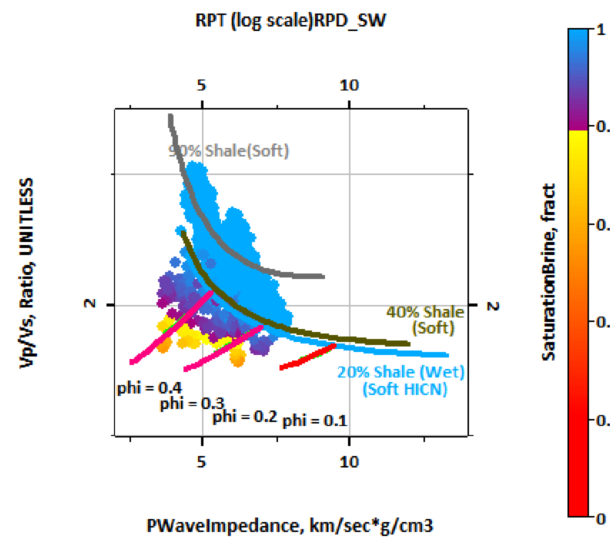
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Kitabu-1

Kitabu-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is high. Full elastic logs available only in the interval 1205m-TD (2255m).
- Vp is mostly unedited, Vs is edited only for some spikiness.
- RHOB is only edited at the top casing section at 1200m.
- Other logs include Neutron run over the same interval as the elastic logs and Gamma Ray, and Deep and Shallow resistivity run over the full logging run from

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method with Neutron/Density in places.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Miocene channelized marine fan sands in the IVC stage, secondary targets are IVD turbidites. These are a series of turbiditic fine to very fine sands, interrupted by siltstones.
- The average porosity of the IVD sands are 28% in both the upper and lower, and up to 25% in the IVC sands.

Volume of hydrocarbons:

- The well is fully brine saturated

Water saturation (Sw):

- Rw for the well was based on Pickett Plot analysis and also guided by well report information – this showed a water resistivity value of 0.1 Ωm at 182° F at the IVC 330 sand at 1600mDF, revealing a salinity of 24000ppm. Water saturation was calculated using Simandoux's equation with constants (a)=1, Cementation exponent (m)=1.9 and Saturation exponent (n)=1.9 (Based on the final well report).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that from the point where the elastic logs started down to the T.D. the Soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich. There are two distinct trends in the elastic data when comparing the IVD Toeset1 and Toeset2 sands. The shallower Toeset2 has a relatively higher shear response than the deeper Toeset1. These differences are captured in the rock physics response (see RPD crossplots).

Fluid properties:

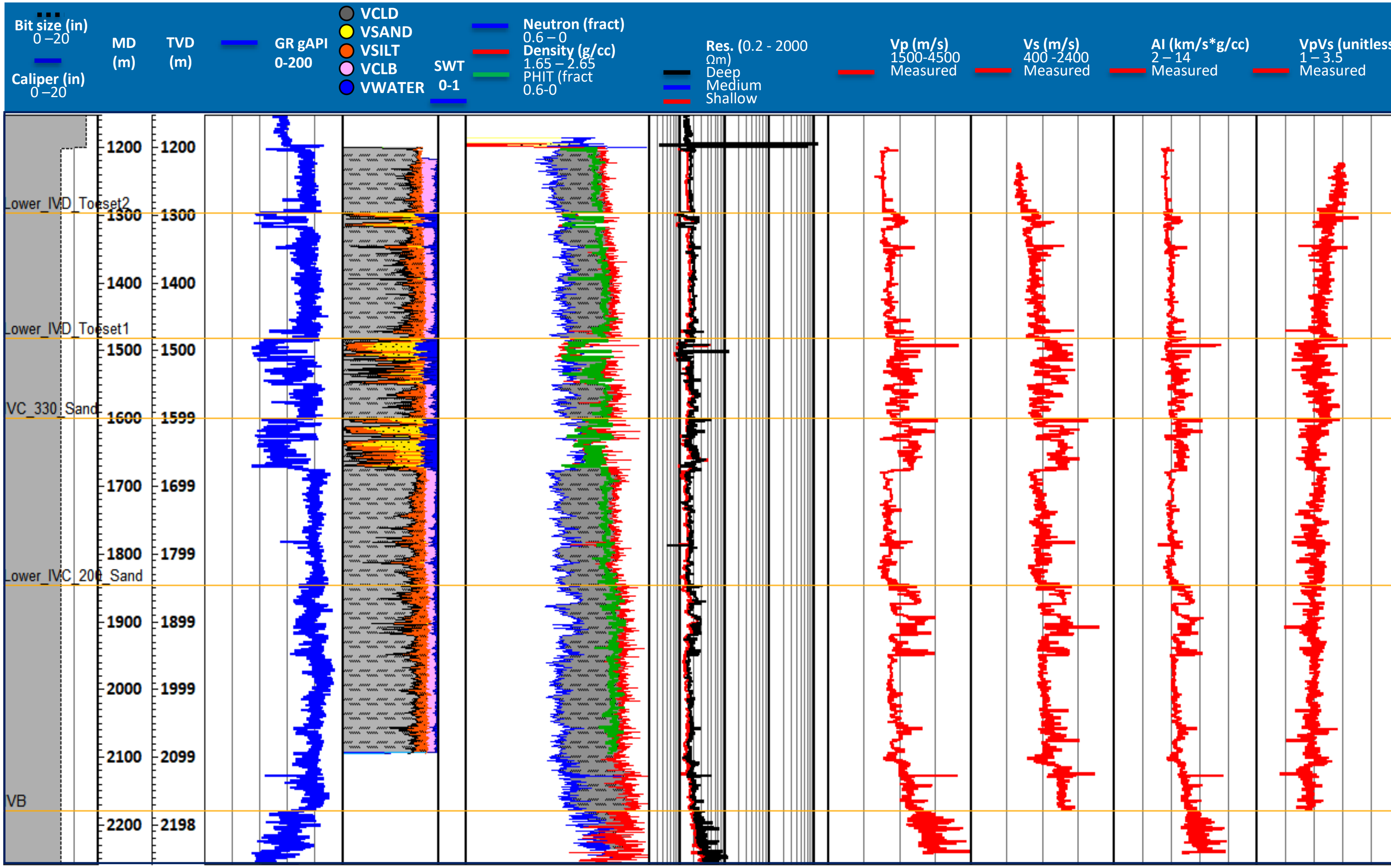
Fluid properties used in substitution have been taken from regional data. Main parameters used in this modeling are:

- Brine salinity: 24000ppm[from Rw]
- Gas gravity: 0.78
- Oil Gravity: 44 API
- Gas / Oil ratio: 200 (L/L)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the IVC, IVD, and IVB stages using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with poor to fair discrimination with the brine sands.
- The primary target IVC sands shows no AVA response in the hydrocarbon cases, intercept is zero and offset response is nearly flat, however there is separation with the wet case as it shows a positive intercept. With increasing porosity the intercept of the hydrocarbon cases become slightly negative, though offset remains flat.
- The IVD sands show a Class III AVA response with increasing amplitude with increasing porosity.

Kitabu-1 Input Logs



Additional data includes pressure, temperature data, deviation survey, cuttings descriptions and final geological report.

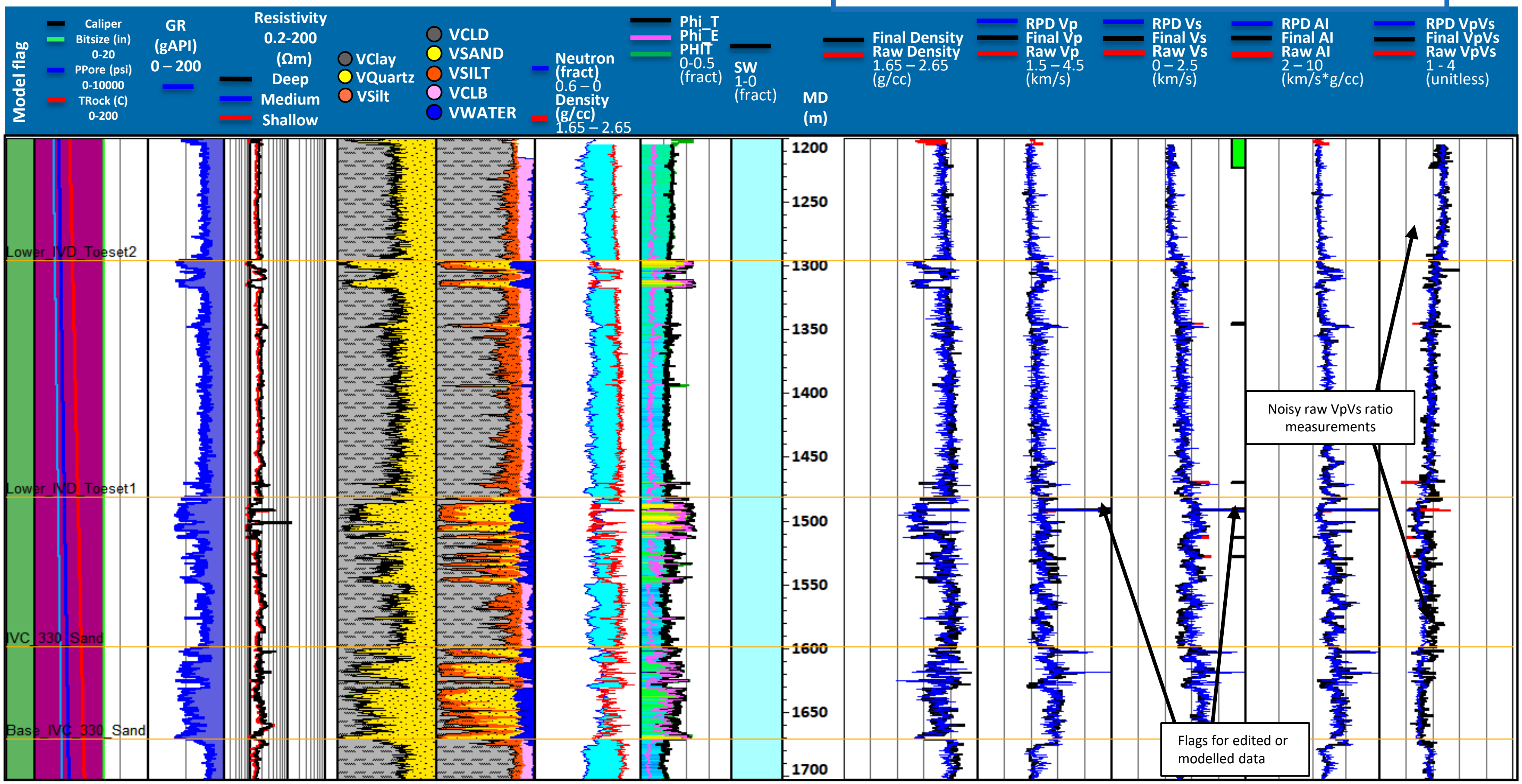
Kitabu-1 Geophysical Well Log Analysis (GWLA) – Interval 1200m – 1700m

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

model type flag

- Unconsolidated rock model
- Stiff rock model



Only edits for spikiness primarily in the shear velocity and some in the compressional. Model calibration is strong where measured. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

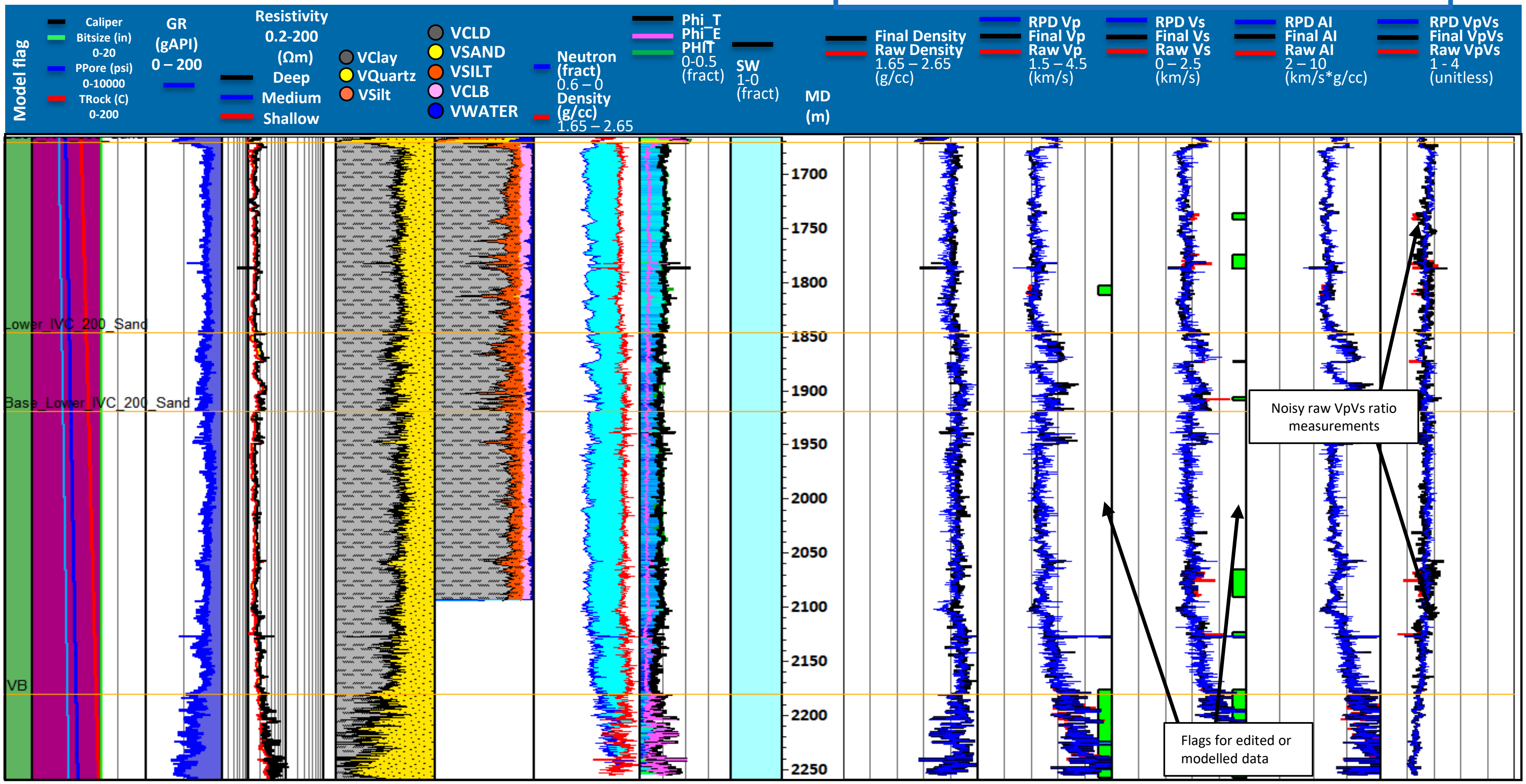
Kitabu-1 Geophysical Well Log Analysis (GWLA) – Interval from 1700m to the end of logs

model type flag

Unconsolidated rock model
Stiff rock model

Equivalence between RSI and Petronas naming.
Petronas equivalent curve name in parentheses

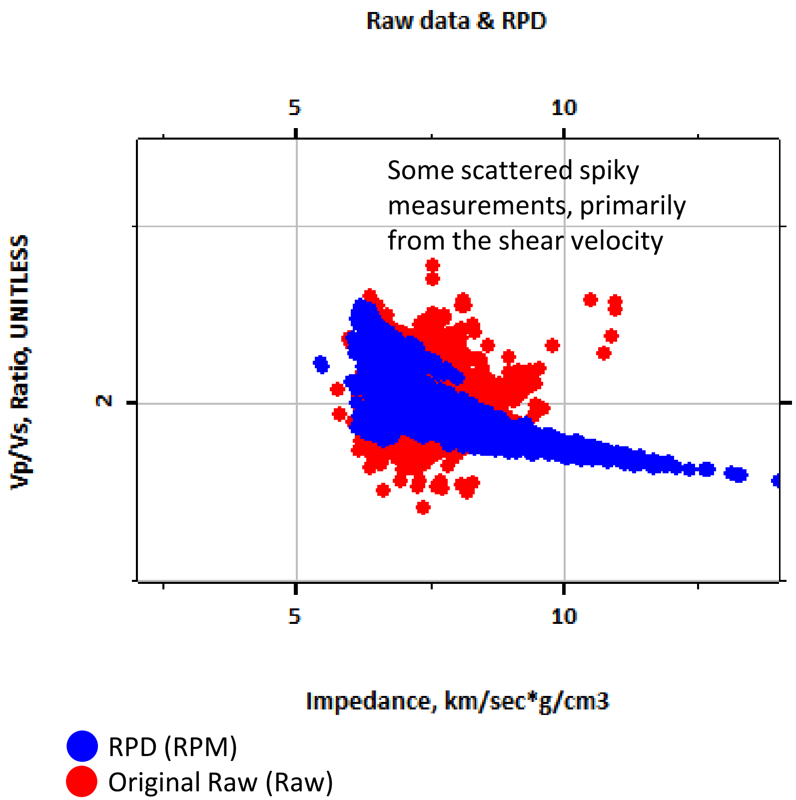
RPD Modeled (RPM) curve
Final edited (Conditioned) curve
Original Raw (Raw) curve



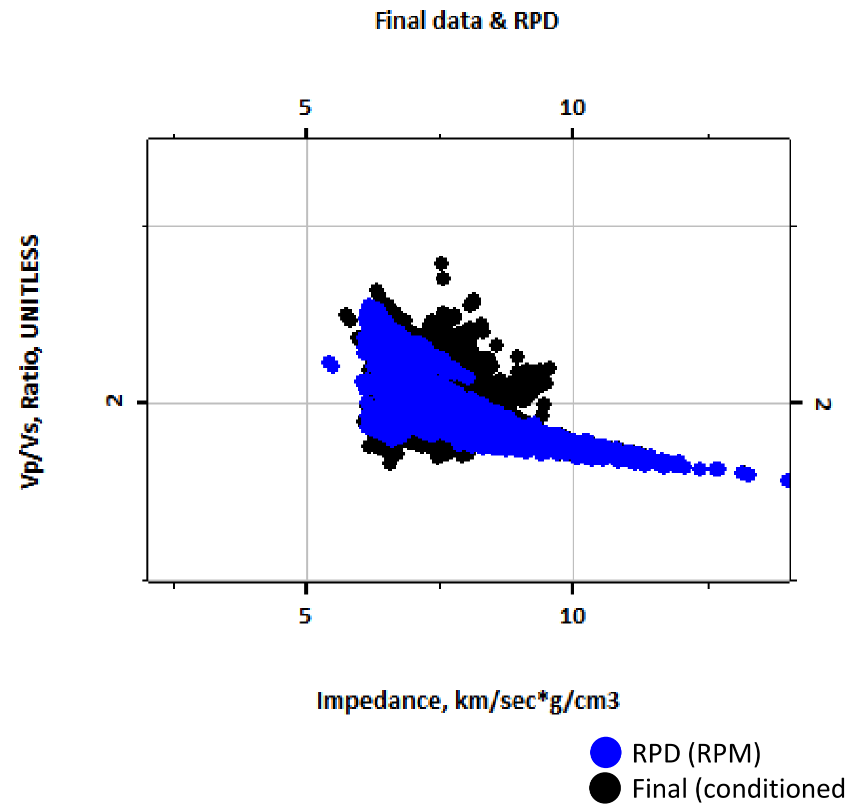
Only edits for spikiness primarily in the shear velocity and some in the compressional. Model calibration is strong where measured. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

Kitabu-1,Rock Physics Diagnostics (RPD)
Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

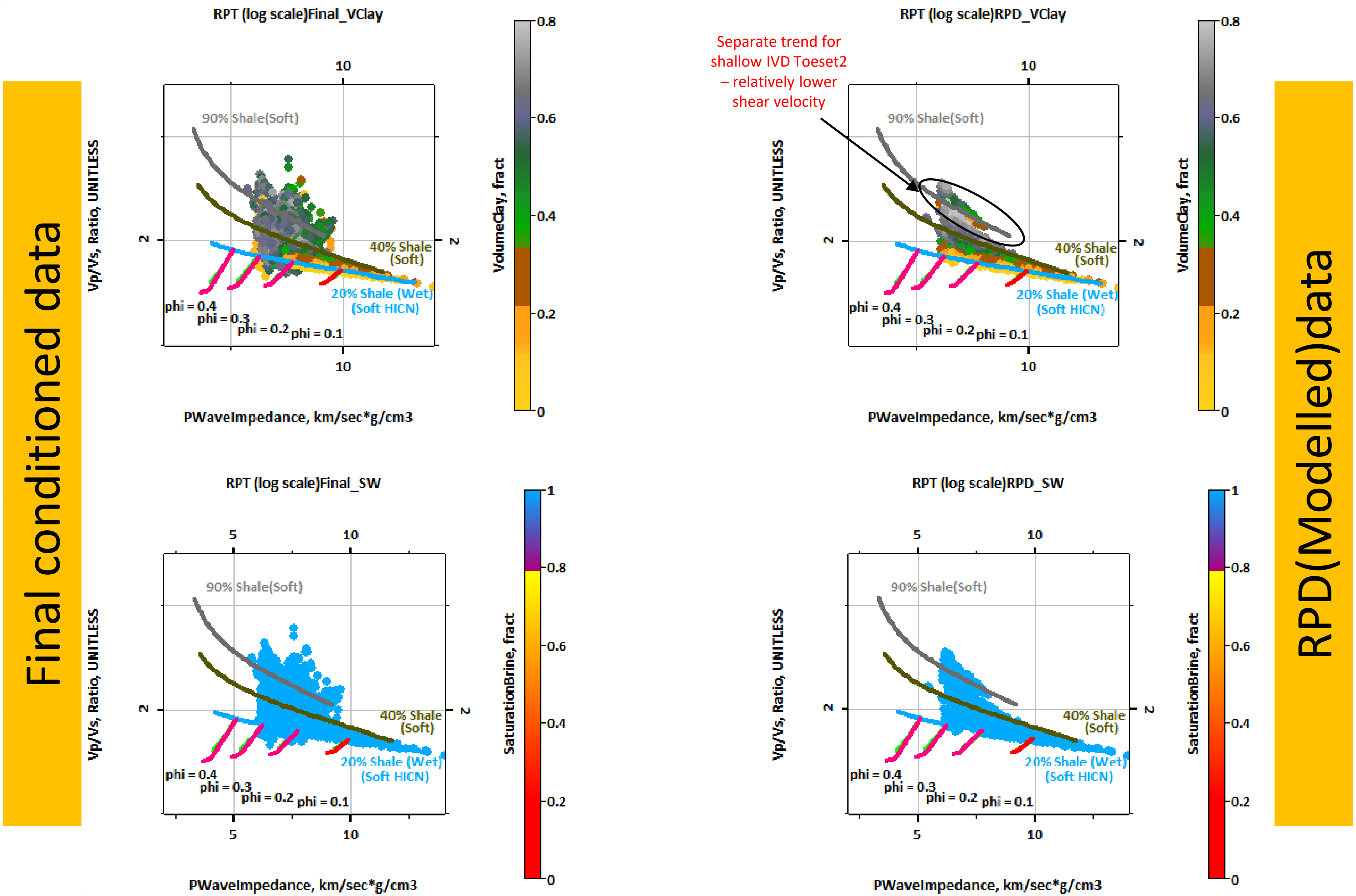


P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.



Kitabu-1,Rock Physics Diagnostics (RPD) Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.



Mengkira-1

Mengkira-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality is poor especially the density but the data availability is fair. Client's petrophysical interpretation was not provided for this. Full elastic logs except VS were available throughout the wellbore covering the interval (400m-T.D.)
- Elastic logs(VP and Rhob)were totally affected by the bad hole conditions above 460m so no reliable response could be obtained to establish a rock physics model for that interval.
- Shear wave velocity(VS)was fully modelled in the well using the RPD after the model was carefully calibrated based on the offset wells behaving elastically the same especially(Danum-1 nearby and Bilit-1 to the south) The resulted Vs matched in trend all the nearby wells especially the final modelled results for Bonanza-1 and West Emerald(most closest wells to the north)
- Density was heavily edited in many intervals using the RPD due to the bad hole conditions especially below 3000m and above 1000m.
- Vp also was edited using the RPD in some intervals especially where the hole was affected by washouts as in the interval(1000-2000m).
- Elastic curves in the bad Vp and Density measurements intervals were filled using deep resistivity to predict Vp via Faust equation then density and Vs were estimated using the RPD.
- Starting at depth about 2800-2900m(MD) the well started to be impacted by over pressured causing sudden drop in the P-wave impedance records.
- Other logs include Gamma, SP, Caliper, shallow and Deep resistivity, which all run for the full logging run to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Miocene marine sands in the IVD and IVC stages. These are a series of turbiditic fine to very fine soft sands.
- The well penetrated many good sand layers in the IVC stage especially in the interval 1600-2800 where total porosity reached up to 22%, while the sand layers in the IVD stage characterized by being very loose and non cemented with a total porosity reached up to 35% .

Volume of hydrocarbons:

- All sand reservoirs penetrated in the IVD and IVC sequences were 100% brine saturated.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the clean wet sand(1220-1270m)yielded a formation water salinity of 29000 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.8 and Saturation exponent (n)=1.8 (assumed based on nearby wells' information).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to good measured data in the nearby reference wells and other wells on the same elastic trend.
- Elastic behavior for the well was carefully calibrated with the nearby wells and other wells honoring the same elastic trend for the well(P-Wave impedance depth trend) And concluded that the well elastically behaves similar to Danum-1 well and Bilit-1(even though it is far but elastically honoring Mengkira-1 elastic trend) , so S-wave velocity completely modelled in the well based on the same model and parameters used in the offset wells which resulted in a matched trend with the calibrated nearby wells and very well behaved model when compared to the modelled results in the most nearby wells(Bonanza-1 and West Emerald-1).

Fluid properties:

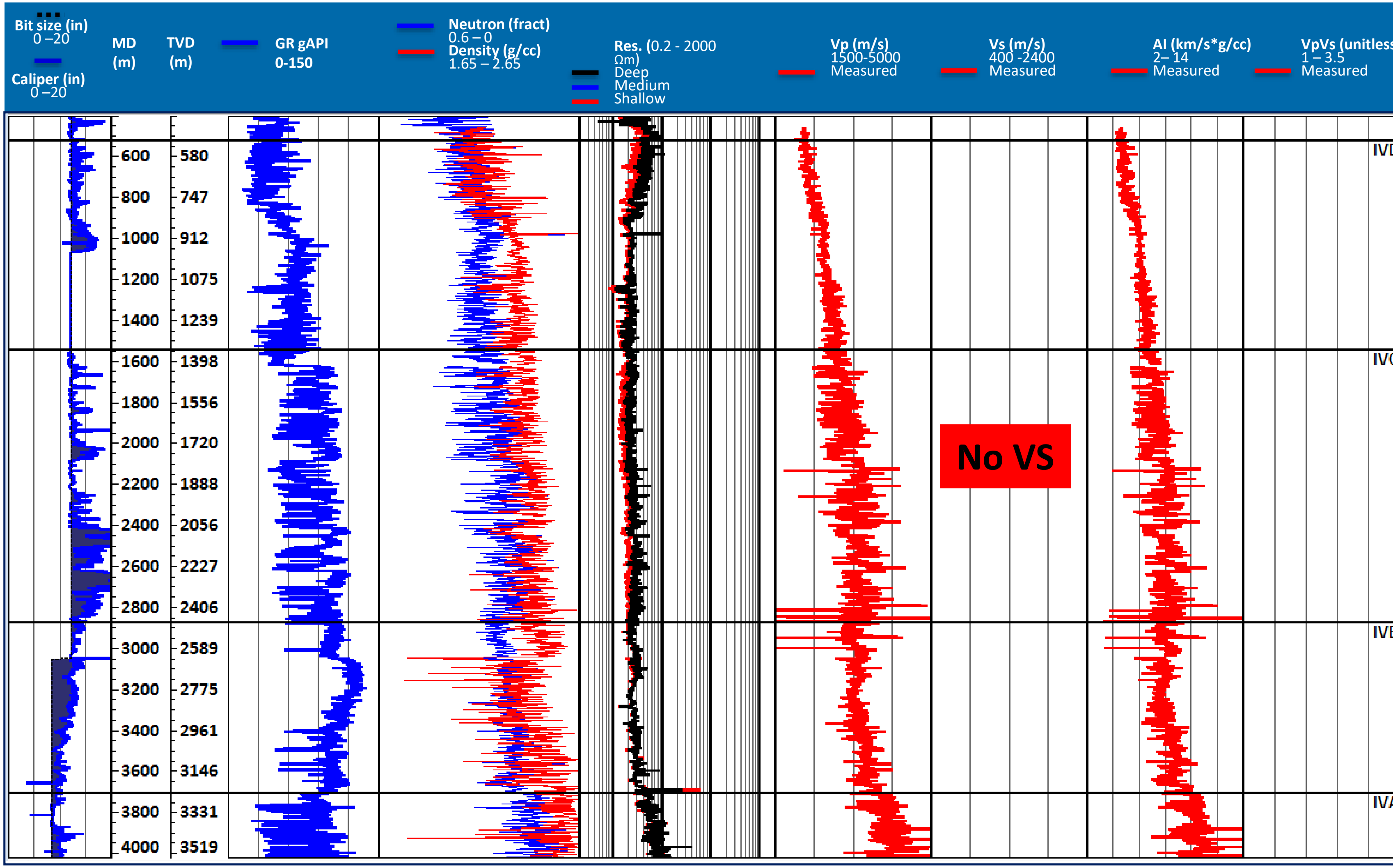
Fluid properties used in substitution have been taken from PVT report of nearby well Danum-1, Main parameters used in this modeling are:

- Brine salinity: 29000 ppm[Pickett plot]
- Gas gravity: 0.82[PVT analysis]
- Oil Gravity: 38.9 API[PVT analysis]
- Gas / Oil ratio: 500 (L/L) [PVT analysis]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the IVD and IVC stages using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination with the brine sands only in the IVC and IVD stages.
- AVA class IV was observed near a good porosity shallow sand(stage IVD) @ 710m for all fluid cases at in situ reservoir conditions.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) hydrocarbon cases started to behave as class III AVO response.
- AVA class IV was also observed near a low porosity deep sand(stage IVA) @ 3750m for all fluid cases at in situ reservoir conditions.
- By upgrading the reservoir quality(increasing porosity and decreasing clay content) no significant change for the AVA class could be noticed for all fluid cases but the separation between the wet and hydrocarbon cases enhanced a bit.

Mengkira-1 Input Logs



Additional data includes final geological report, Core and XRD reports. No VS recorded in the well.

Mengkira-1 Geophysical Well Log Analysis (GWLA) – Interval from 400 to 1100 m

model type flag

Unconsolidated rock model

Stiff rock model

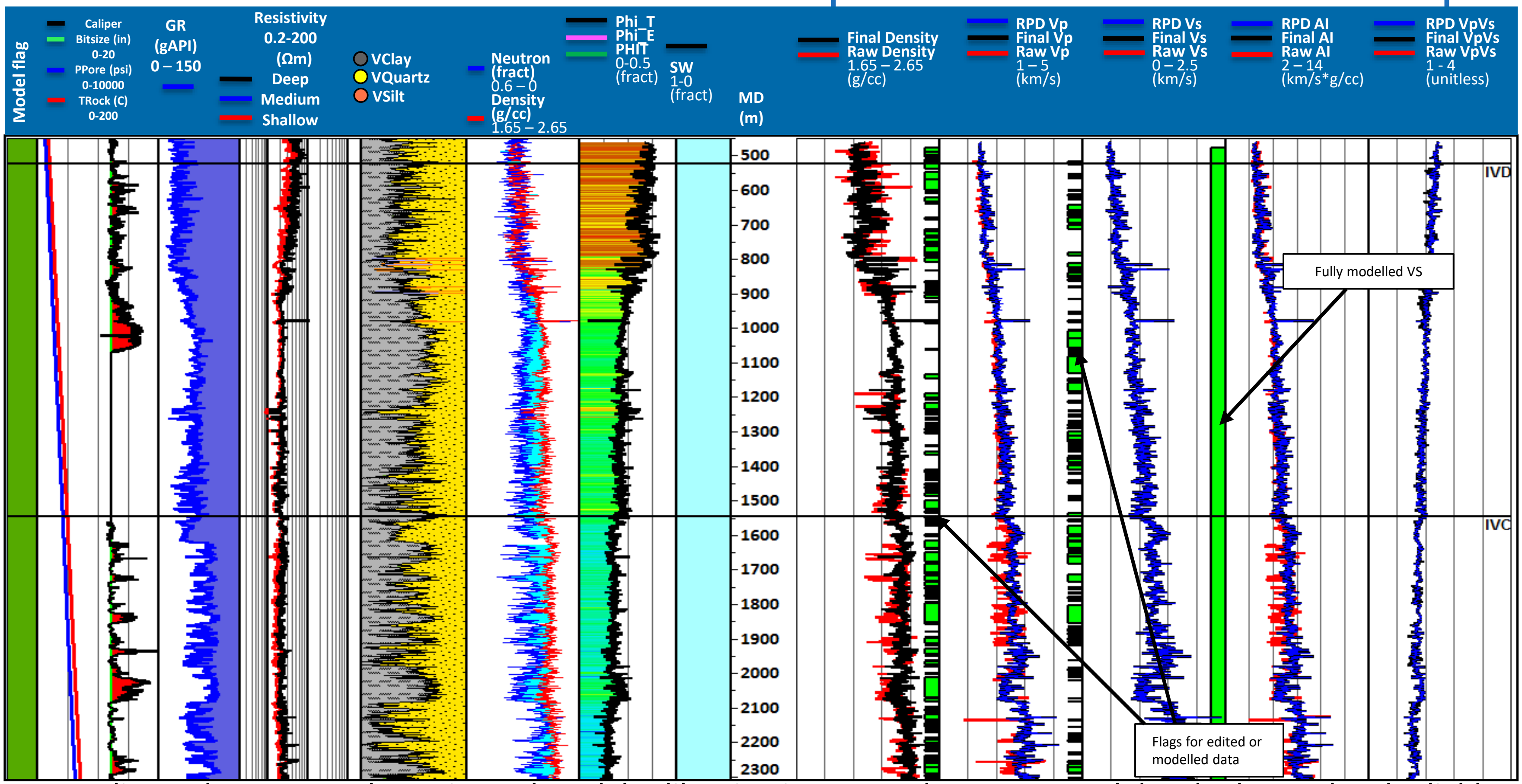
Above depth of 460m(MD) no reliable logs were available to establish a rock physics model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve



Many edits to the measured Density and model calibration is strong where measured data looks good and reliable. Granular media model (Soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) for both sand and clay rich intervals, with good correlation with the measured data in the well(VP and Rhob)and in the nearby wells. VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells.

Mengkira-1 Geophysical Well Log Analysis (GWLA) – Interval from1100m to the end of logs

model type flag

Unconsolidated rock model

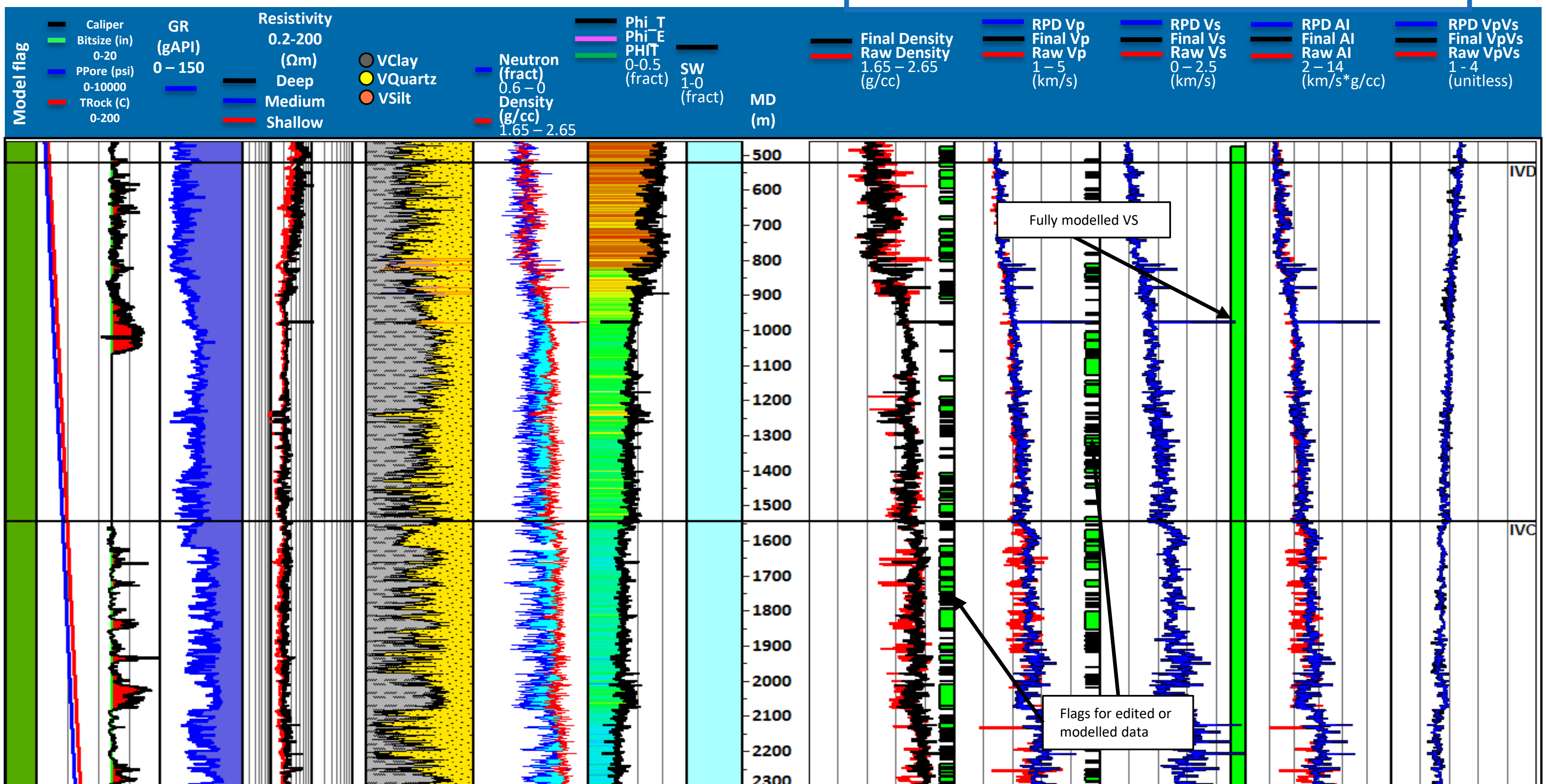
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

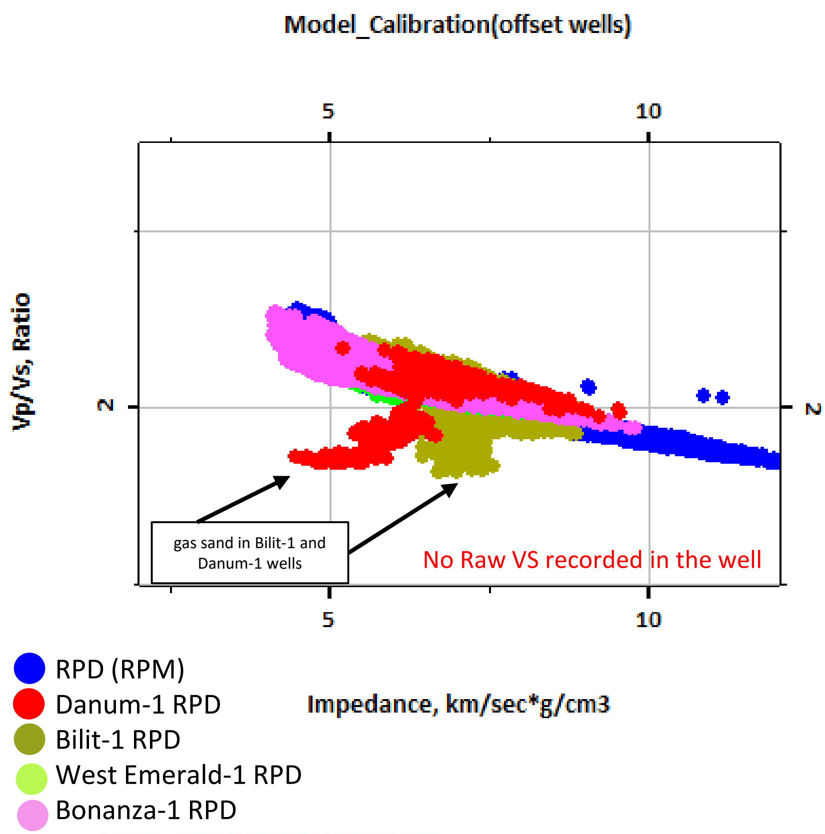
Original Raw (Raw) curve



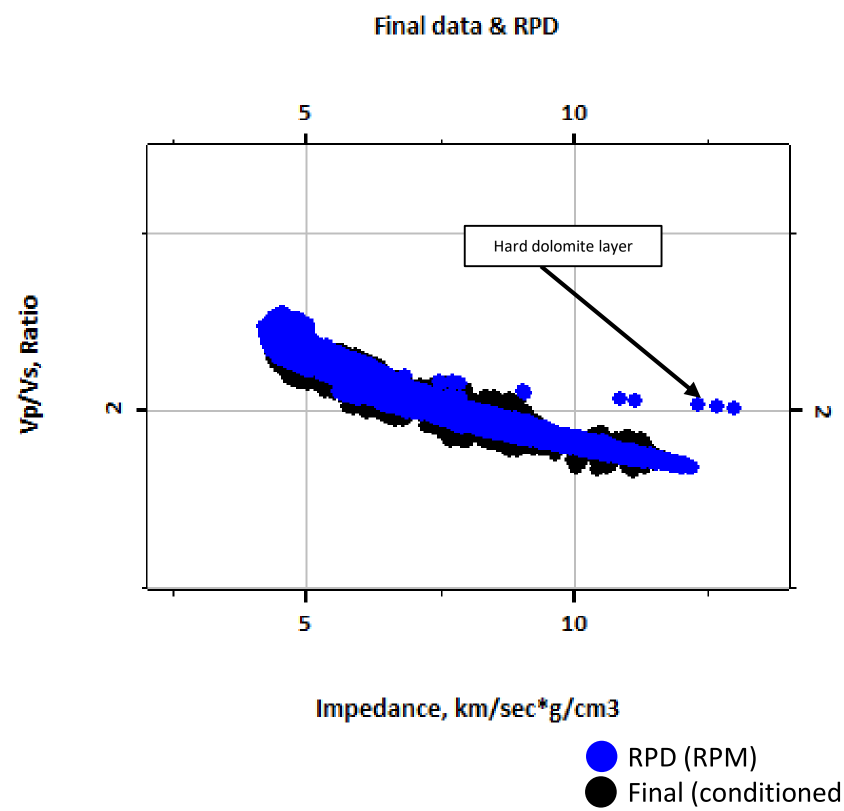
Many edits to the measured Density and model calibration is strong where measured data looks good and reliable. Granular media model (Soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) for both sand and clay rich intervals, with good correlation with the measured data in the well(VP and Rhob)and in the nearby wells. VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells.

Mengkira-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the good calibration for the Mengkira-1 well RPD with the nearby wells Danum-1, Bilit-1, West Emerald-1 and Bonanza-1 well.

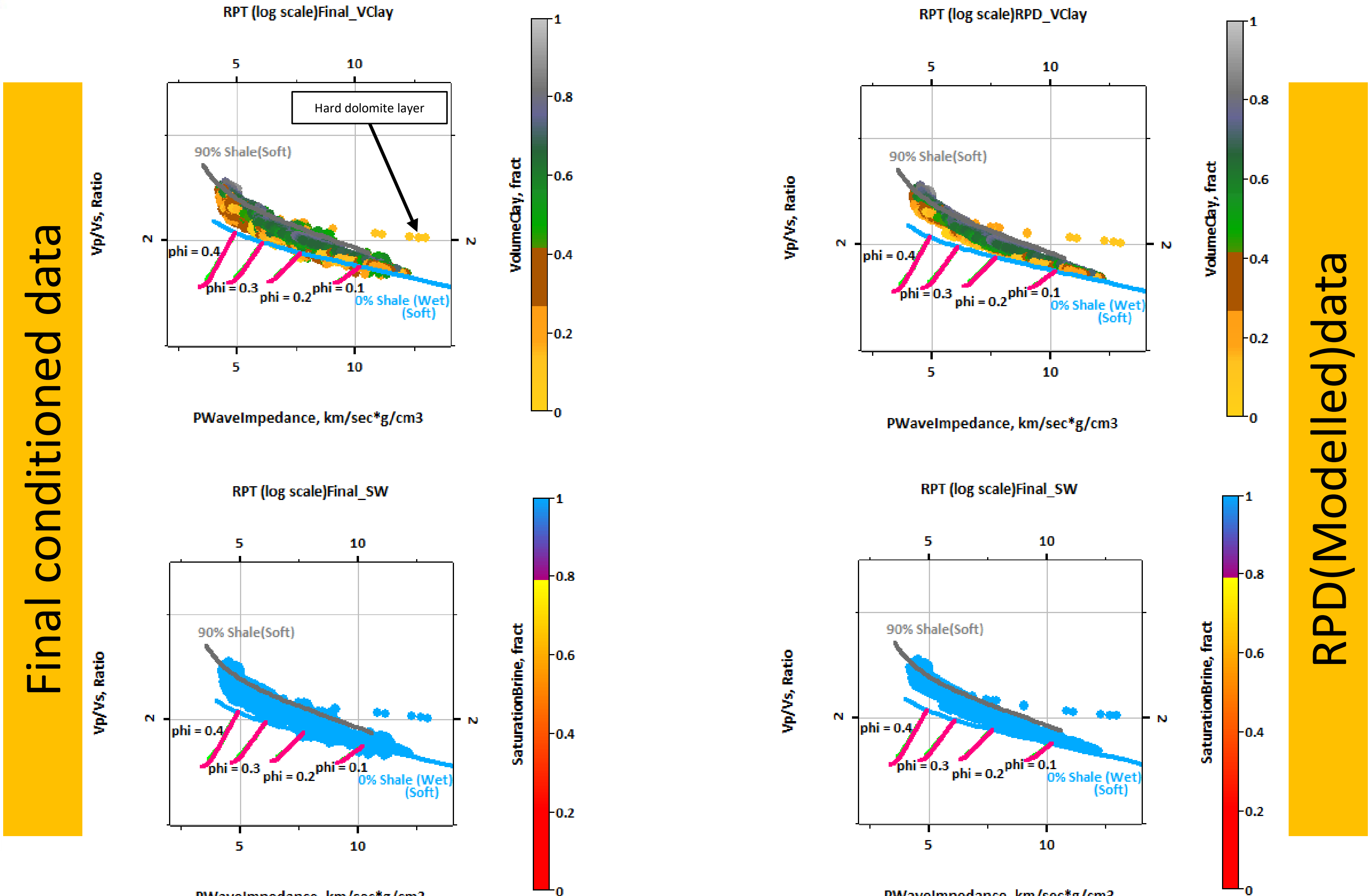


P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data(Rhob and Vp ere conditioned while VS is totally modelled).



Mengkira-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.



Penaga-1

Penaga-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality is average. Where sonic data is measured it is generally high quality, though due to drilling problems sonics were not acquired in the 8 ½" section (2780m-TD). Client's volume shale, total porosity, and total water saturation were provided as a reference.
- Vp was acquired from well top to 2780m. The measurement is generally high quality, though the most trouble is in the faulting zone above and below the Blue interval at 2450m. The borehole is not in good shape and both density and Vp are highly effected. The Vp has been predicted from resistivity using calibrated Faust. Using this model the resulting shear from RPD is consistent with the measurement. There are also some casing points edited. The zone below 2780m was predicted from density using the RPD, except in rare cases where measured density is low quality the Faust relationship from resistivity was used.
- Similar to Vp the Vs is acquired from well top to 2780m. Vs was edited in some intervals to maintain consistency in the VpVs ratio in clay and sand rich intervals, as well as the zone below 2780m. All edits are made using the RPD model.
- Density has been acquired for the full wellbore. The entire log has been smoothed on a 4 sample (0.6m) window to maintain consistency with sonic logs and reduce variability in the RPD sonic curves. Other edits are for casing gaps and at the Blue interval fault zone mentioned previously where there is significant borehole damage. All edits are made using the RPD.
- Other logs used in the analysis include Gamma, Neutron, Caliper, Deep, Shallow and Medium Resistivity, which are run for the full logging run; and Photoelectric factor which is run from well top to 2780m.

Clay volume (VClay):

- This volume was derived from a combination of the linear Gamma Ray and Neutron/Density crossplot methods.

Reservoir characteristics:

- In terms of lithology the primary reservoir targets are the Supra-Thrust Blue interval and the repeated Sub-Thrust Blue interval – they are Upper Miocene distributary channels. Porosity in the upper ranges from 12-16%, in the lower from 7-9%. Both sands contain a large amount of calcite, in cement and replacement, which has been calibrated by the XRD results. Additional calcite is present in places throughout the wellbore.

Volume of hydrocarbons:

- Interpreted gas saturation is present in a couple thin sands. Low gas saturation has been interpreted in the upper Blue interval at 2450m, less than 30% gas. This interpretation is supported by geological report indicating 5.8m of net pay in this zone. However, gas log shows no more than 5% Total Gas, possibly due to tight reservoir.

Water saturation (Sw):

- Deriving a Rw from Pickett plot analysis is difficult given the highly cemented reservoir and lack of clear wet zones. Therefore, Rw is calculated from assumed NaCl of 24000 ppm based on regional trends. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.8 and Saturation exponent (n)=1.8.

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to the measured data and also when compared to good measured data in the nearby reference wells.

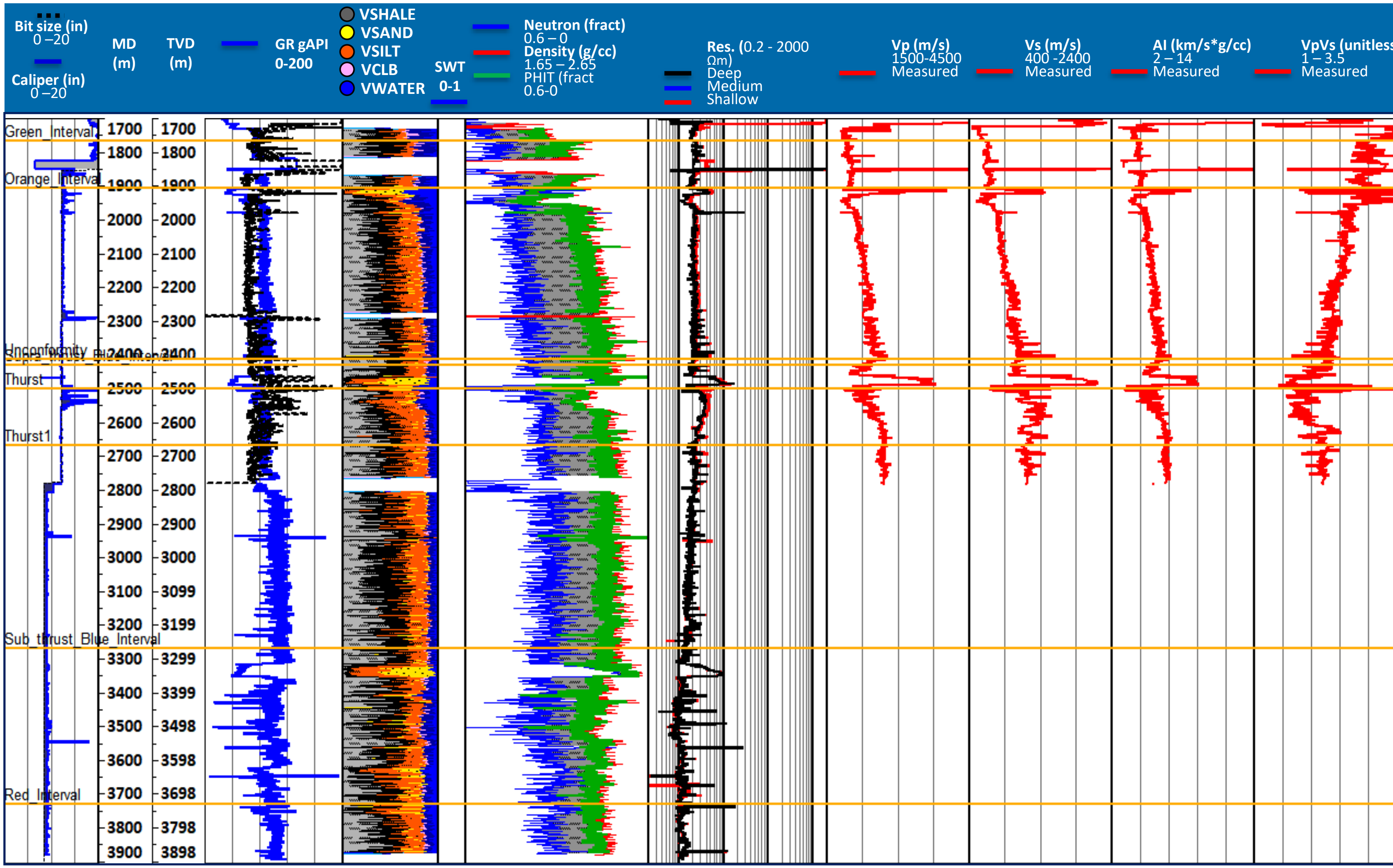
Fluid properties:

- Fluid properties used in substitution have been taken from nearby Batai-1 PVT results. Main parameters used in this modeling are:
- Brine salinity: 24000 ppm [Rw]
- Gas gravity: 0.784 [Batai-1 PVT]
- Oil Gravity: 44° [Batai-1 MDT]
- Gas / Oil ratio: 200 (L/L) [Assumed based on area results]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the Upper Miocene sands in the two primary Blue intervals as well as the shallower Orange interval using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination with the brine sands.
- At in situ conditions the Blue interval shows a Class I or Class IIP response (the gas case does cross over at 30°), fluid discrimination is minimal. However, when increasing porosity by 10 PU the oil and gas cases become Class II. At decreasing porosity the response is a very bright Class I with no fluid discrimination.

Penaga-1 Input Logs



Additional data includes pressure, temperature data, cuttings descriptions, petrographic thin section analysis and final geological report.

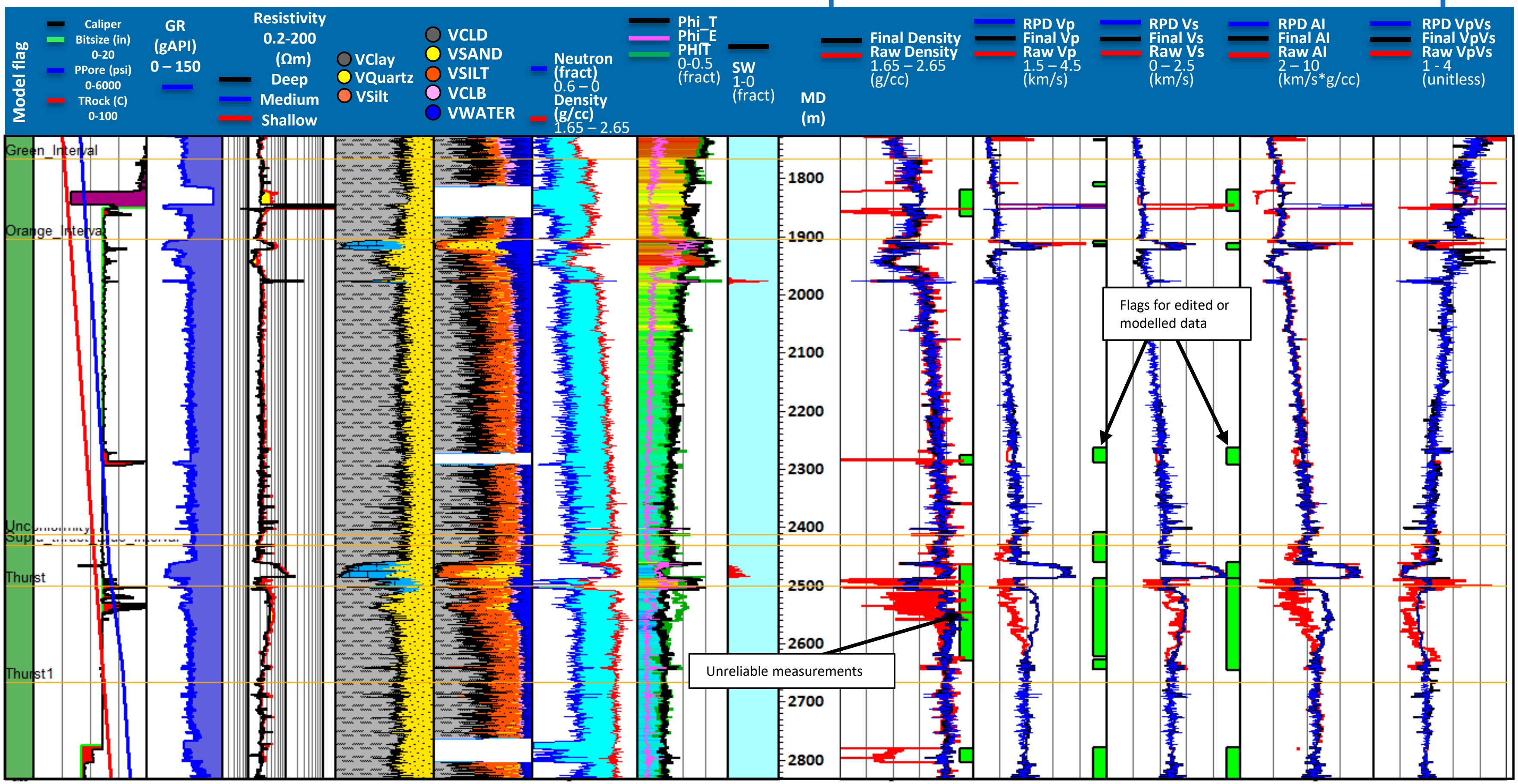
Penaga-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of logs to 2810m

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve



Some minor edits to all logs for casing gaps and other troubles, the primary edit is in the thrust zone below the 2450m Blue sand. Model calibration is strong where measured data looks good and reliable. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

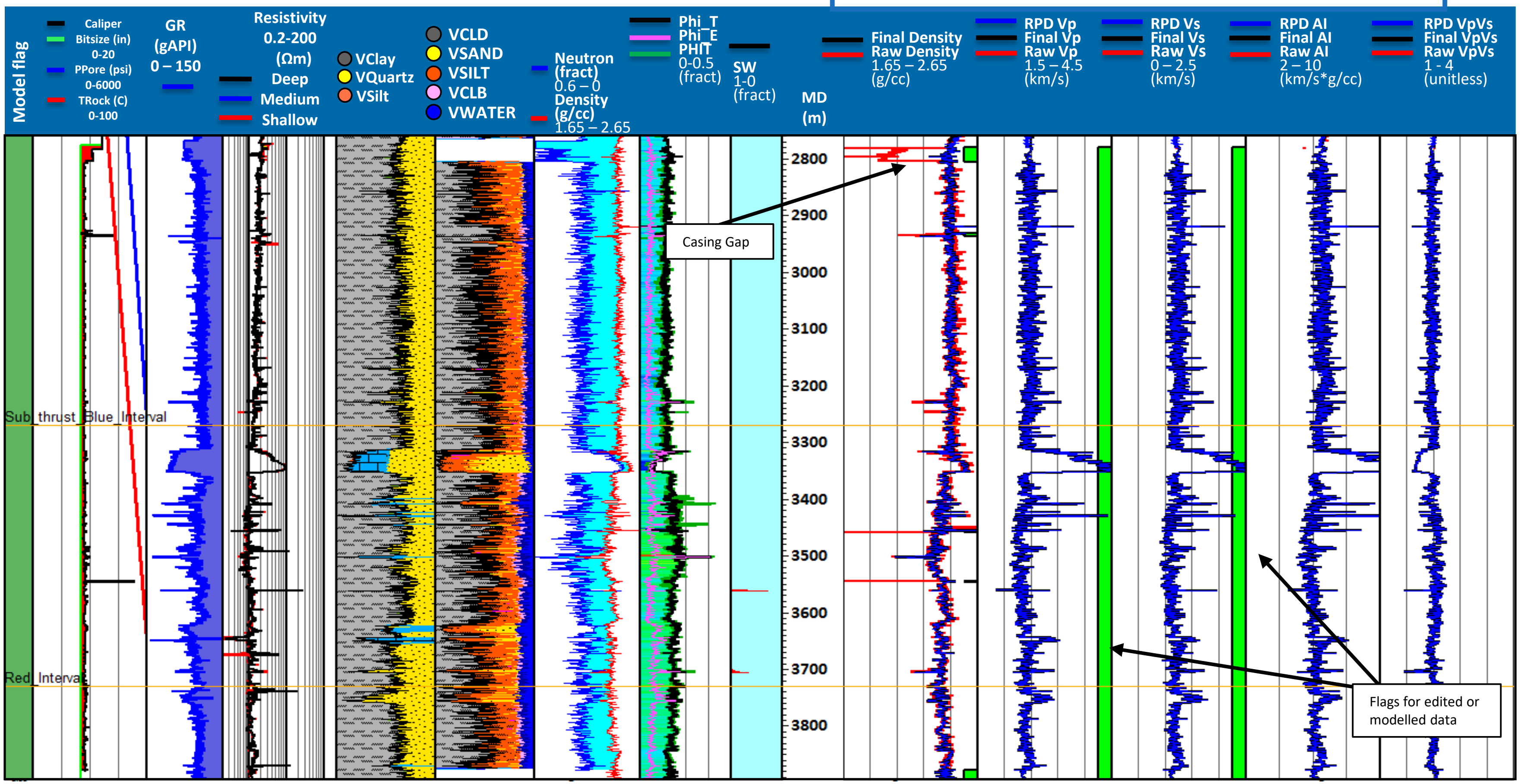
Penaga-1 Geophysical Well Log Analysis (GWLA) – Interval from 2810m to TD

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

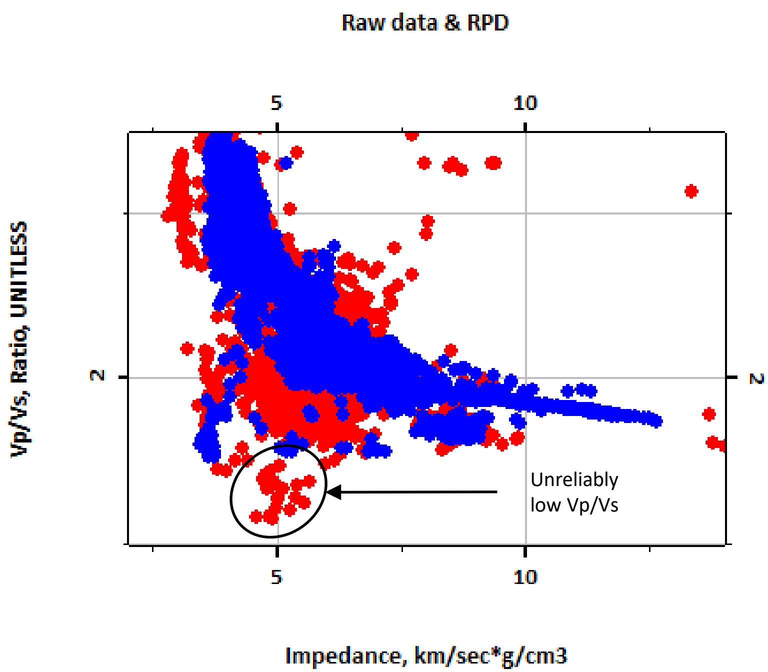


All sonic data is predicted from the RPD in this zone, except where RHOB is unreliable the Faust relationship from resistivity has been used to predict Vp and then RHOB and Vs are from RPD.

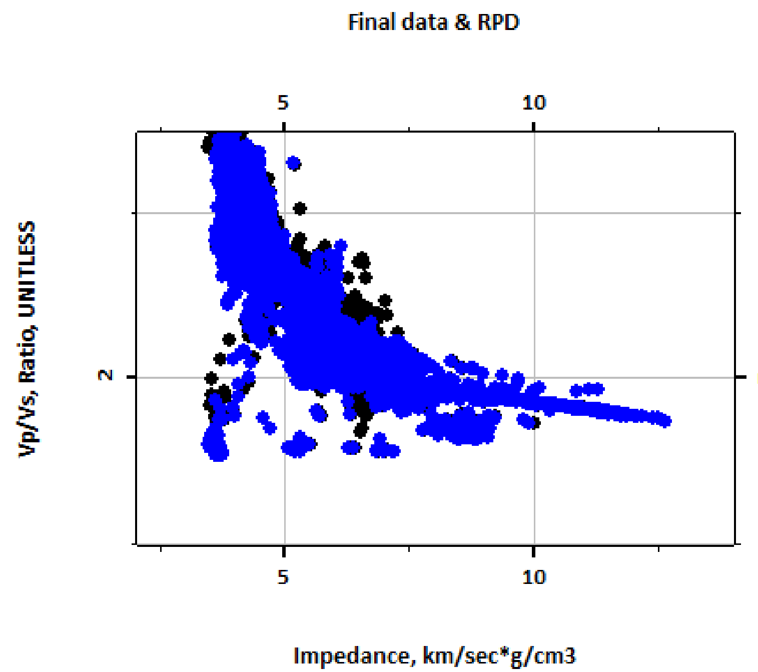
Penaga-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.



RPD (RPM)
Original Raw (Raw)

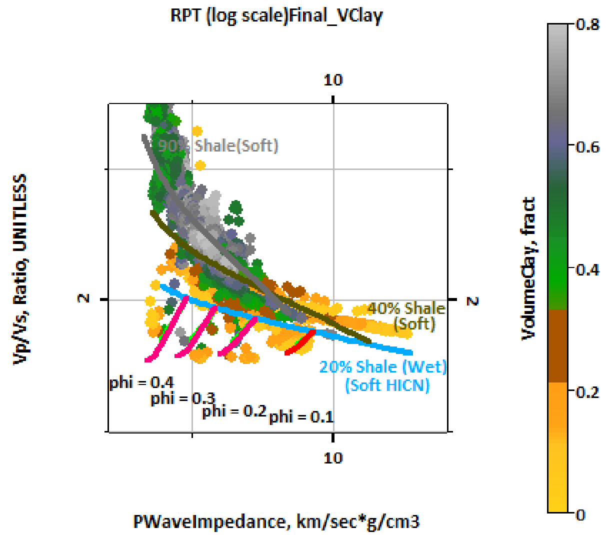


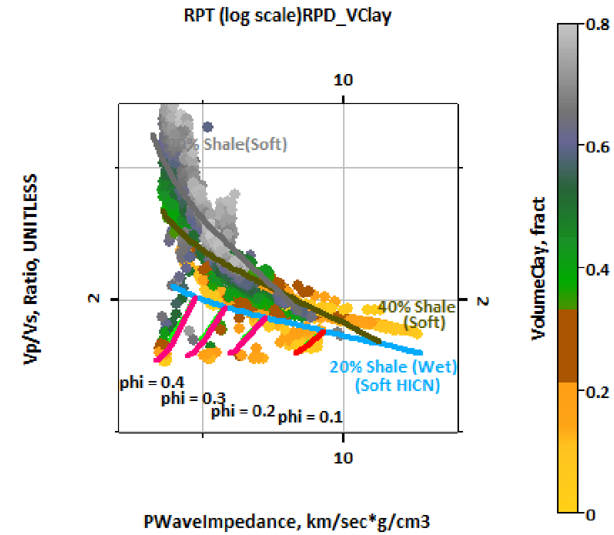
RPD (RPM)
Final (conditioned)

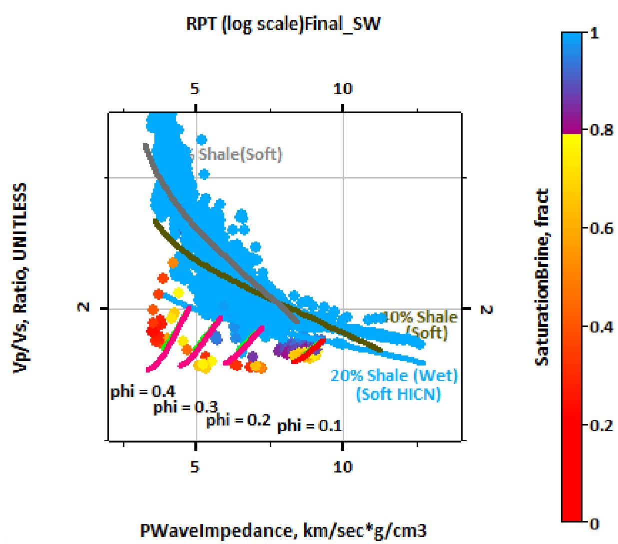
Penaga-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

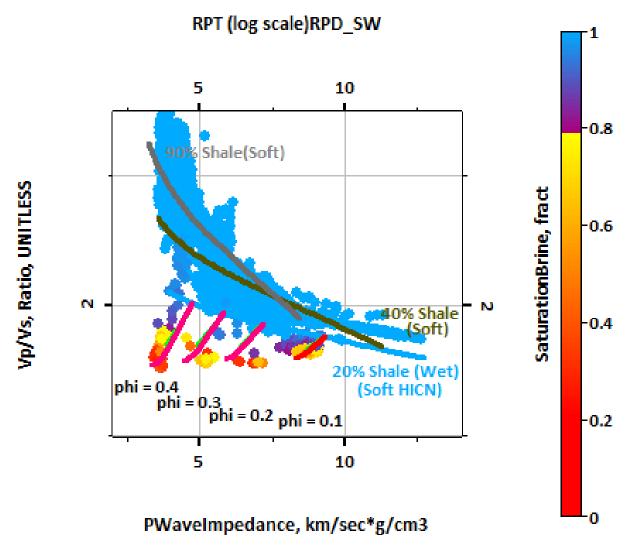
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Pinitukadan-1

Pinitukadan-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- A suite of logs was provided where the GR log has the most of data. GR data availability goes from 1480m to 2710m. Resistivity is also available in almost the whole borehole, measured from 1550m to 2710m.
- The elastic log suite was provided from about 2030m to 2700m. Three sections were spliced together. The measured data presents two sections with major gaps present in the density log. The compressional velocity log is absent above about 2250m. Quality of data seems fair and is most unreliable in the gap sections.
- Data in gap interval is either not available or is not reliable. The density log is believed to be more reliable. Compressional data shows somewhat different signature noise wise in the middle interval.
- Volumetric interpretation was provided from about 2050 to bottom of the well. Interpretation is missing in the gap intervals.

Clay volume (VClay):

- Volume of clay was calculated from gamma ray log and density-neutron suite. The mudlog was not provided for this well and could not be used for lithological calibration purposes.

Reservoir characteristics:

- Well developed sand interval appear from 2030m to 2400m in the study section ranging in porosity from 27% to 31%. The well increases dramatically in clay content below 2400m approximately. This sand intervals could not be associated with any geological top since no reports were provided for this well.

Volume of hydrocarbons:

- All sands in this well were interpreted as water bearing.

Water saturation (Sw):

- Water saturation was estimated using Simandoux's equation. Parameters used for the calculation of water saturation were estimated from the Pickett Plot. Estimated parameters used for water calculation are a=1,m=1.81,n=2.0; Rw = 0.26 Ohmm @ 216 DegF. Conversion charts were used for water salinity estimation resulting in an approximated value of 8000ppm NaCl.

Pinitukadan-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Rock physics diagnostics (RPD) and elastic log data editing:

- The rock physics diagnostics (RPD) was performed from top to bottom for this well and has indicated the soft sediment model proved to be the best predictor for all lithologies in the studied section of the well. This model have been used to edit the Vp, Rhob, and Vs data where necessary and to perturb the rock for changes to VClay and Phi_T at the Rock physics modelling (RPM) stage of the project.

Fluid properties:

Fluid properties used in substitution have been taken from main average values known in the area. Specific information for oil and gas parameters was not found in the reports. Salinity was estimated from Pickett Plot analysis . Main parameters used in this modeling are:

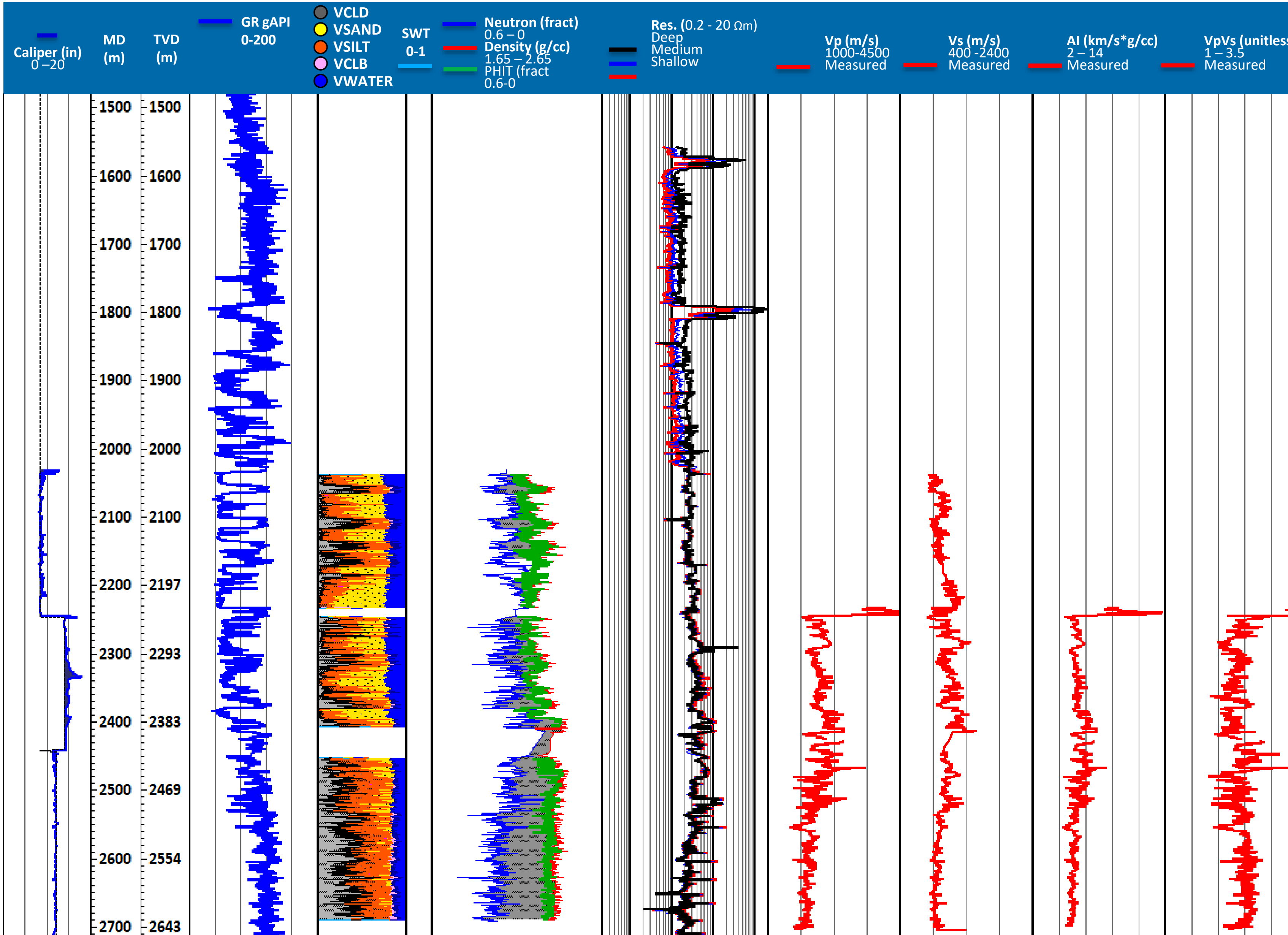
- Brine salinity: 8000 ppm (from Pickett plot analysis)
- Gas gravity: 0.7
- Oil Gravity: 44.4 API
- Gas / Oil ratio: 178 (L/L)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling can be performed in the sands present in this well. The sand intervals could not be associated with any geological top defined interval due to the lack of final geological report data. Perturbational modelling can calculate the effect in elastic properties with change of porosity, volume of clay, and fluid content of the rock. In general, gas saturated sands show lower Vp/Vs ratios and lower p-wave impedance (AI) values than wet sands at log scale. Fluid substitution is performed via Gassmann's model.

- Particular AVO responses will depend on the selected modeling interval, porosity and fluid content of the rock. As an example, the sand package from 2110m to 2140m was gas substituted allowing the water saturation to be reduced to 20%. Porosity was preserved for this exercise. This exercise showed much lower values for VpVs ratio and lower values for Acoustic Impedance compared to the wet case. Good separation of Gas and wet case was also observed in the upscaled data. AVO analysis at an interface defined at 2117m revealed a strong class III signature well separated from the background trend, while the wet case showed intercept and gradient values close to zero, leaving the points in the background trend.

Pinitukadan-1 Input Logs



Geological final reports were not provided for this well.

Pinitukadan-1 Geophysical Well Log Analysis (GWLA)

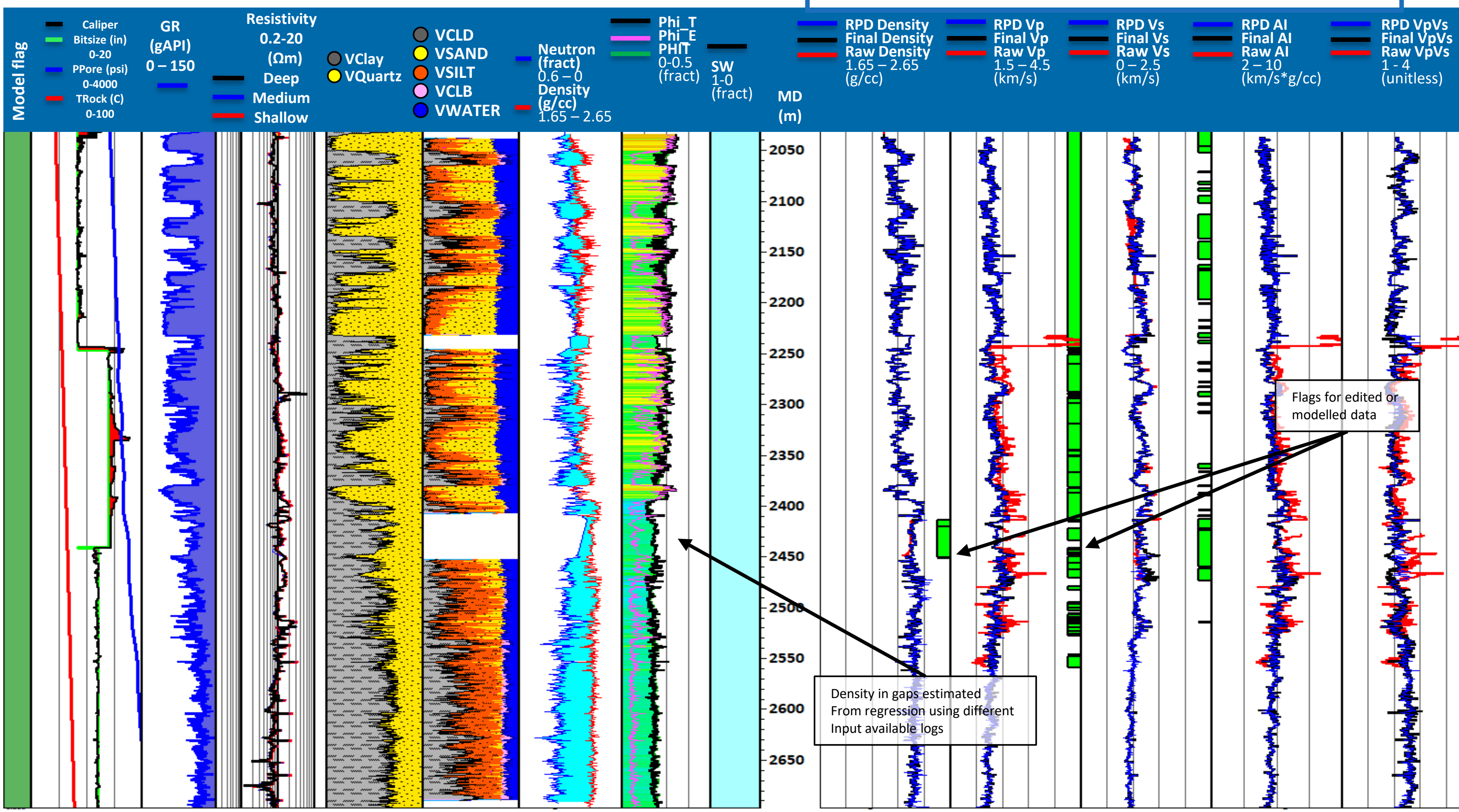
Interval from Top of logs (1708m) to 2160 m

model type flag

Unconsolidated rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

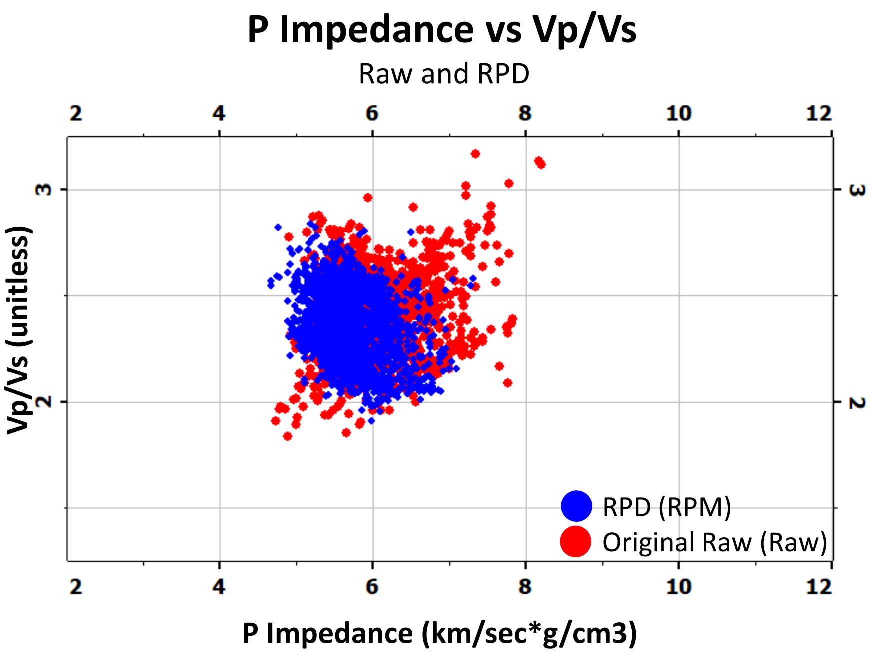


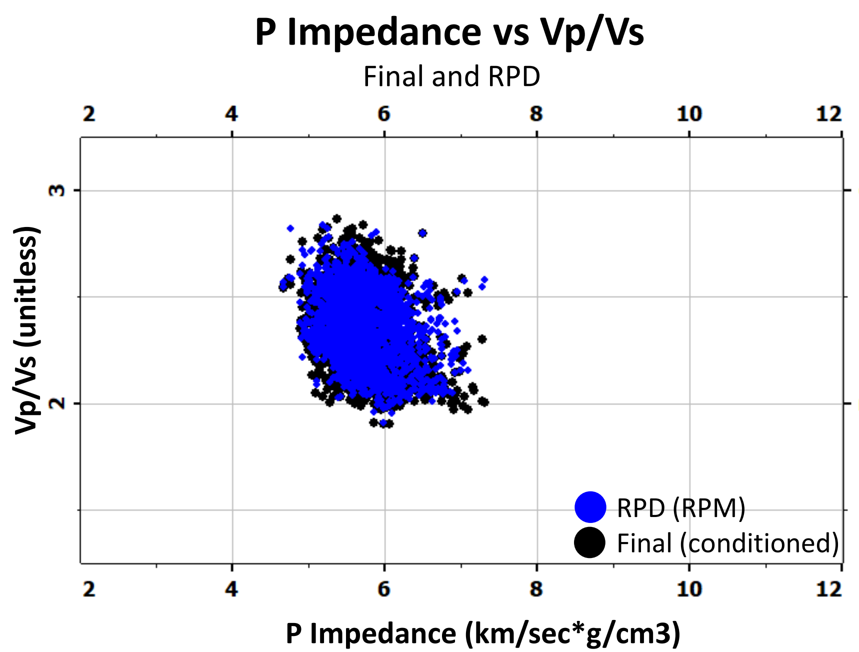
GWLA results for well Pinitukadan-1. Density is considered the most reliable log together with the shear data log for this well. Density was synthetically generated in the gap sections from resistivity and GR logs. Other editions were made using the unconsolidated contact rock physics model.

Pinitukadan-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

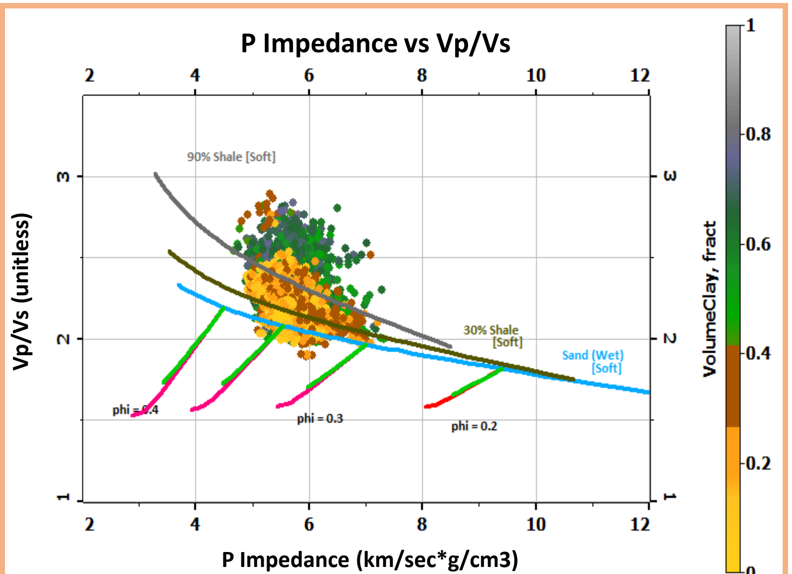


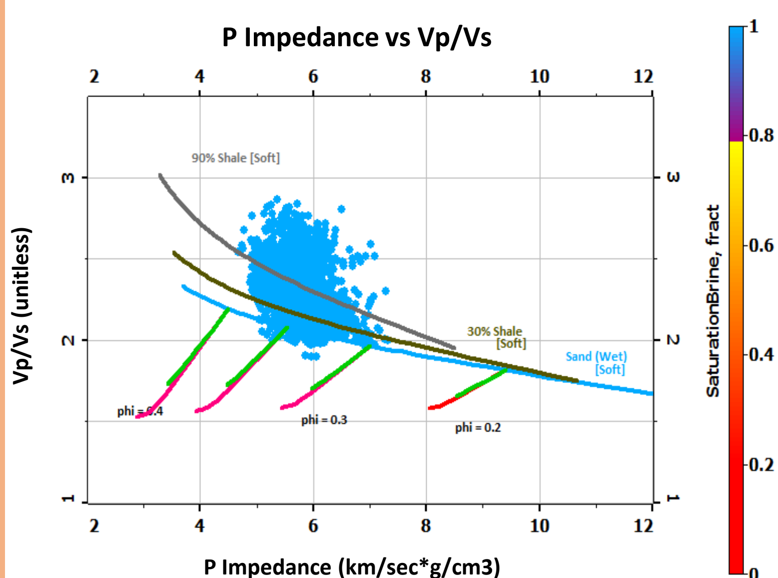


Pinitukadan-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Interval from 1700m to 2355m

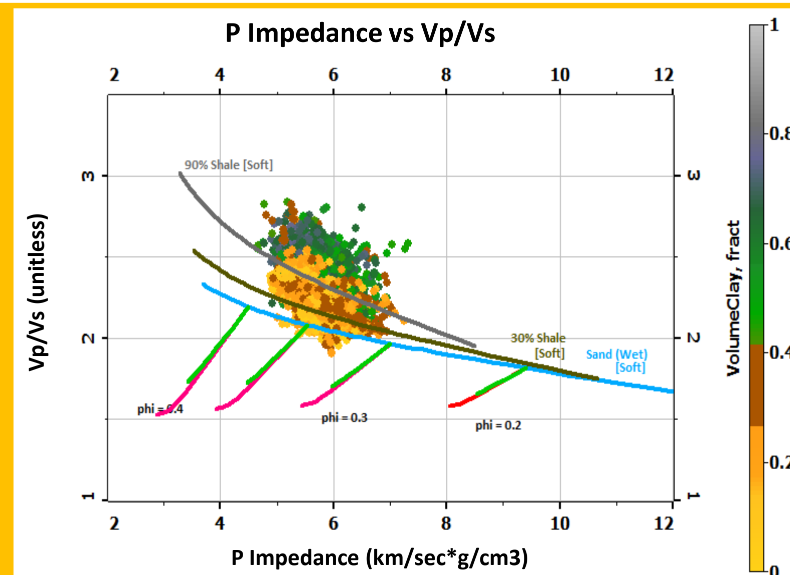
Cross plots Showing the Rock Physics Template lines, overlaid to both, the final (conditioned) elastic data to the left and the modelled data (RPM) to the right, color coded by clay volume (Top row) and water saturation (Bottom row).

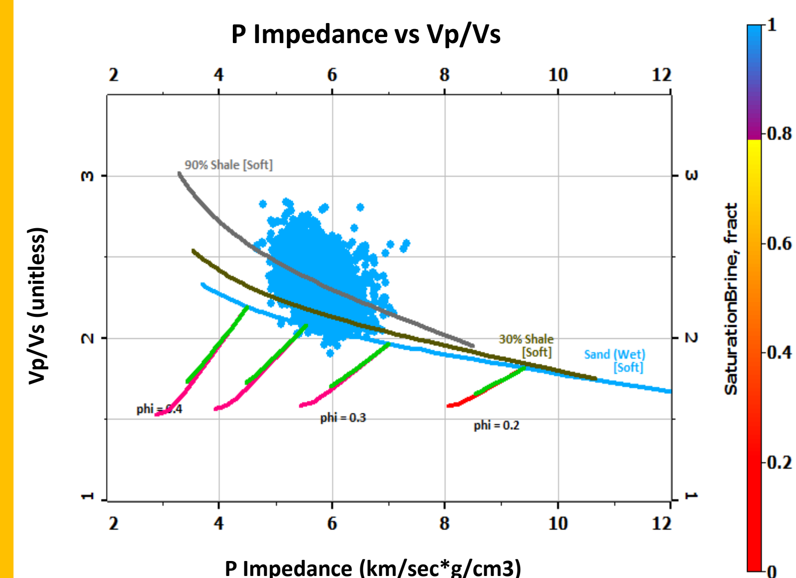
Final conditioned data





RPD (Modeled data)





Remis-1

Remis-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is fair. Client's petrophysical interpretation was not provided for this well. Full elastic logs except VS were available throughout the wellbore covering the interval (200m-T.D.).
- Shear wave velocity(VS)was fully modelled in the well using the RPD after the model was carefully calibrated based on the nearby wells especially(Andalusit-1).
- Vp and Rhob were edited using the RPD in some intervals especially where the hole was affected by washouts.
- Other logs include Gamma, Neutron, Caliper, Deep and Shallow resistivity, which all run for the full logging run to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Miocene marine sands in the IVC stage. These are a series of turbiditic fine to very fine sands intercalated with claystone beds.
- The well penetrated many good sand layers in the IVC stage especially in the interval(600-1000m) with total porosity reached to about 32% but all was water bearing.

Volume of hydrocarbons:

- All interpreted sand reservoirs in the IVC stage in the well were 100% brine saturated.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the section clean wet sand section(1000-1200m)yielded a formation water salinity of 2900 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.2 and Saturation exponent (n)=2 (assumed).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that from the point where the elastic logs started down to the T.D. the Stiff sand model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for sand rich intervals while the soft sediment model honor more the elastic trend for the clay rich intervals.
- Elastic behavior for the well was carefully calibrated with the nearby wells and concluded that the well elastically behaves similar to Andalusit-1 well , so S-wave velocity completely modelled in the well based on the same model and parameters used in the offset well.

Fluid properties:

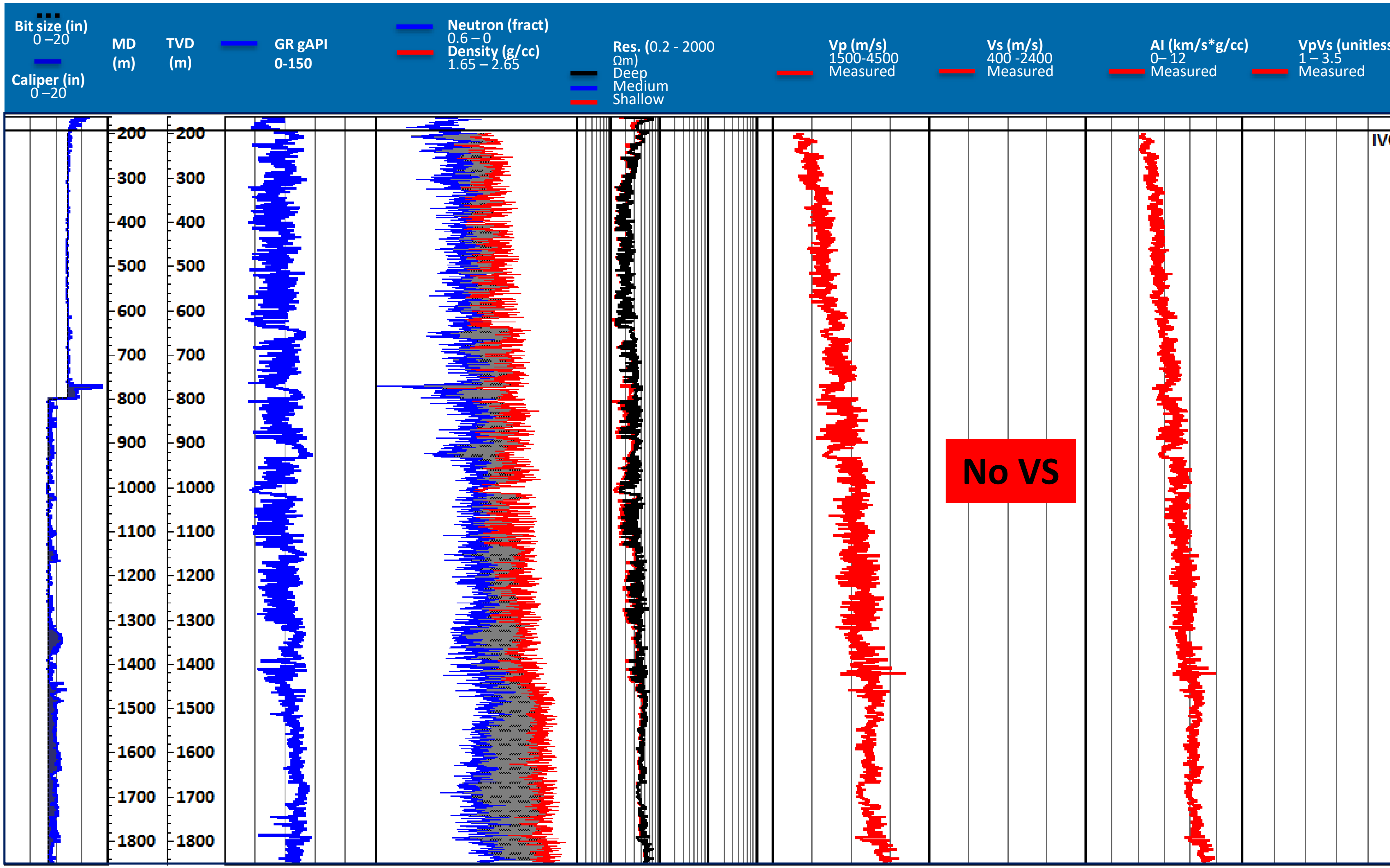
Fluid properties used in substitution have been taken from PVT report of nearby well Samarang-1(test#2) and Haselfoot-1(DST). Main parameters used in this modeling are:

- Brine salinity: 29000ppm
- Gas gravity: 0.586[DST]
- Oil Gravity: 37.3 API[PVT analysis]
- Gas / Oil ratio: 566 (L/L) [PVT analysis]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the IVC stage using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with very good discrimination with the brine sands.
- AVA class II was observed near a good porosity sand layer@800m for all hydrocarbon cases at in situ reservoir conditions with good fluid discrimination with the wet case which showed class I AVA response.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) hydrocarbon cases started to show class IIP AVA response while the wet case remain the same with no significant change.

Remis-1 Input Logs



Additional data includes final geological report. No VS recorded in the well.

Remis-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of Elastic logs to the end of logs

model type flag

Unconsolidated rock model

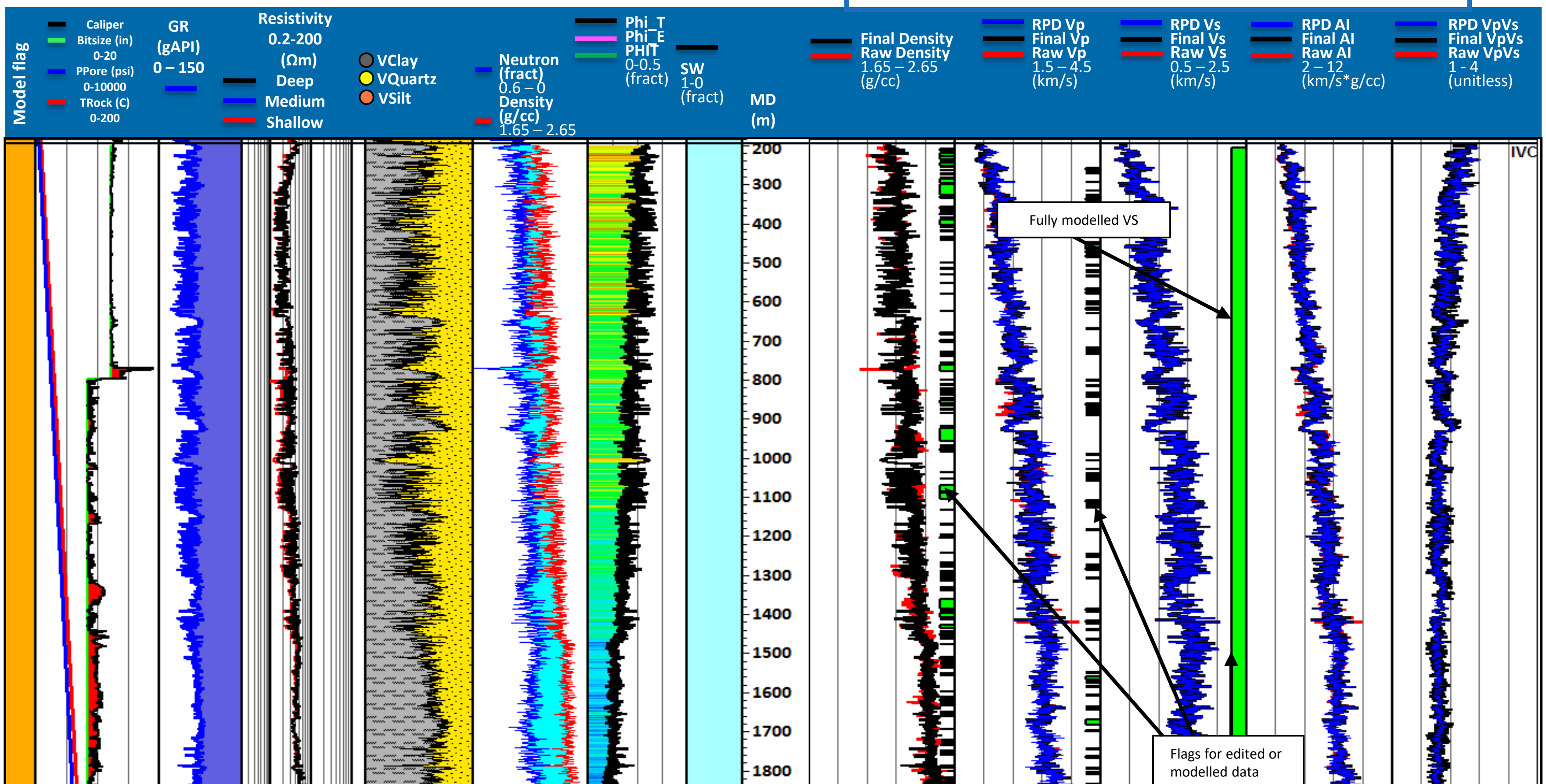
Stiff rock model

Equivalence between RSI and Petronas naming.
Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve



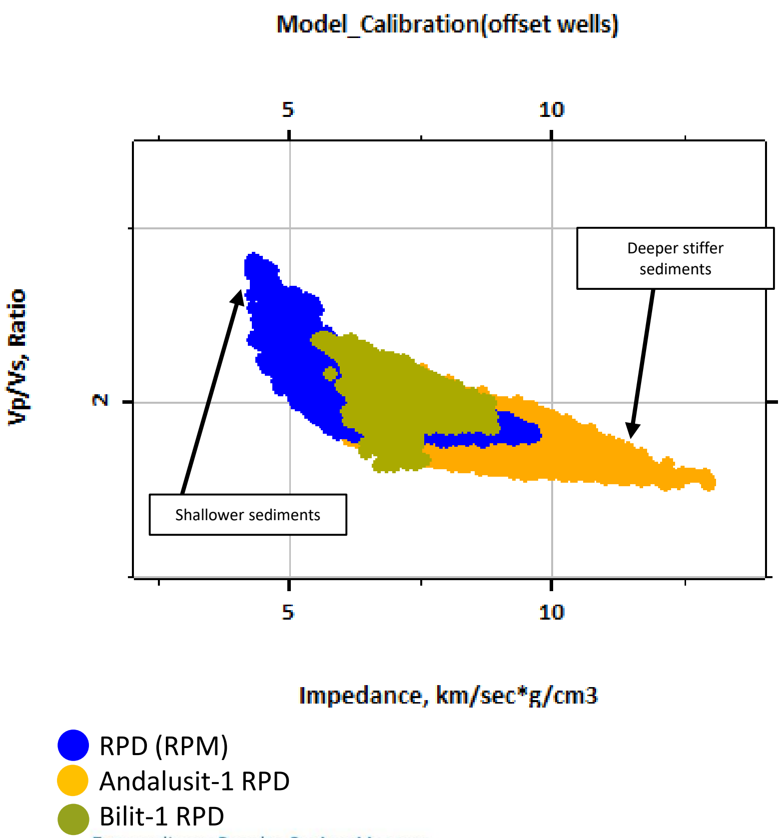
Many edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (Stiff sand) was used for all elastic curves prediction (Rhob, Vp and VS) for sand rich intervals and soft model for clay rich ones, with good correlation with the measured data.

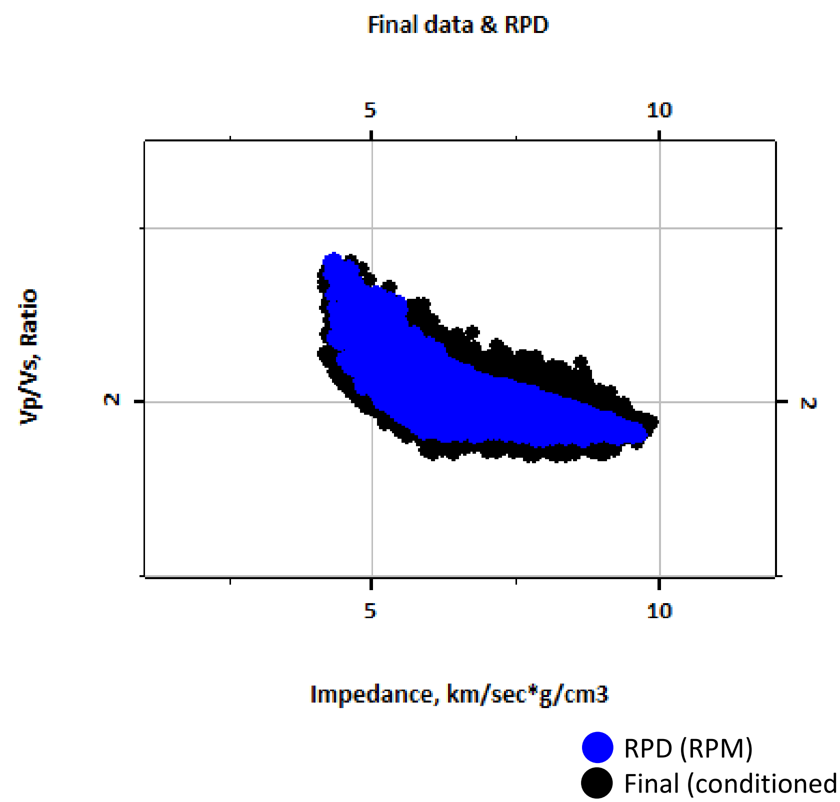
VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells

Remis-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the good calibration for the Remis-1 well RPD with the nearby wells Andalusit-1 and Bilit-1.

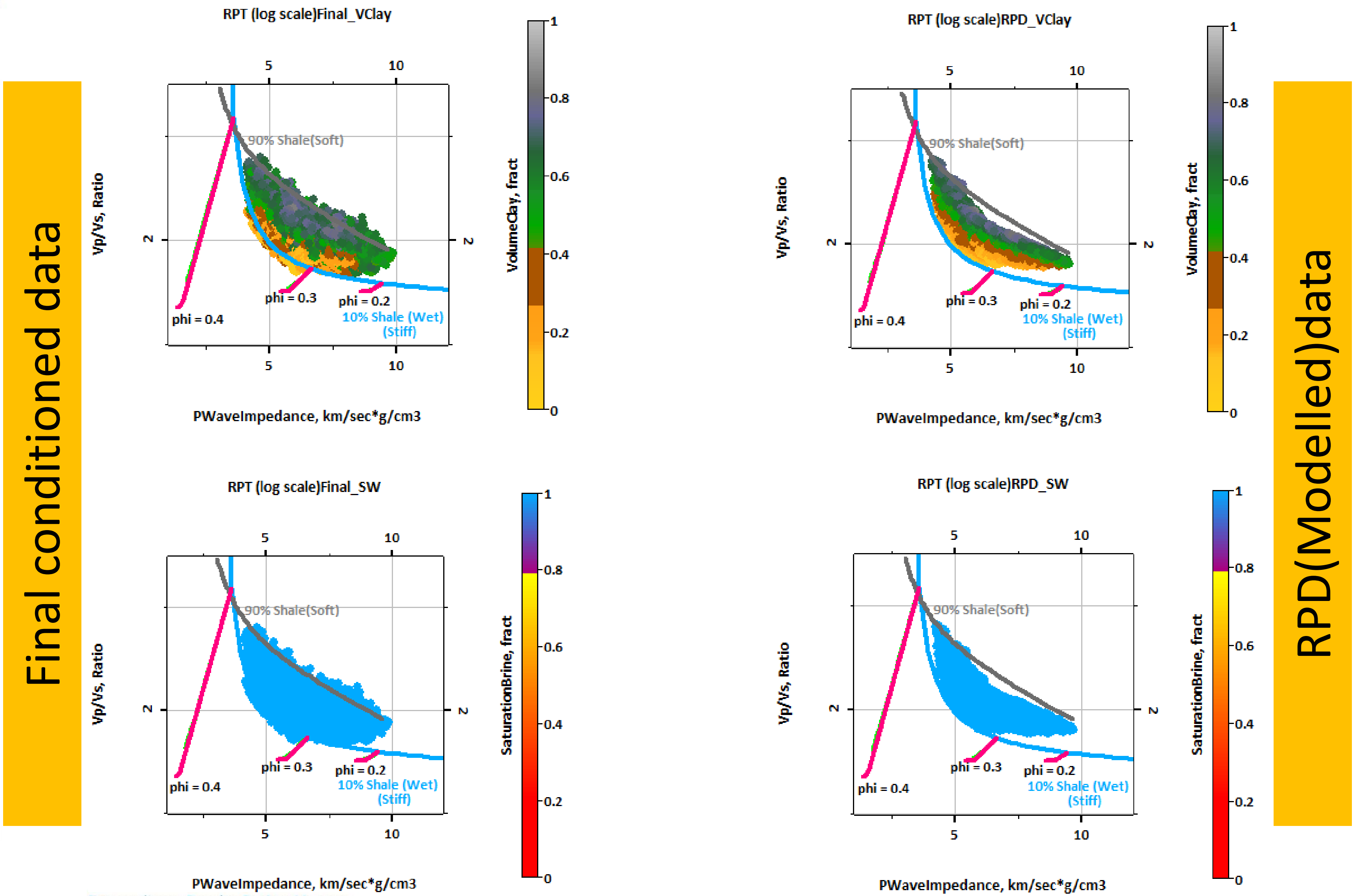
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data(Rhob and Vp ere conditioned while VS is totally modelled).





Remis-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.



Rempah-1

Rempah-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is strong. Client's volume shale, total porosity, and total water saturation were provided as a reference.
- Vp was lightly edited in most of the well, for some erratic behavior, however the most noteworthy edit is from 2960-3060m where the Vp trend is lower than all other responses. At first look it appears to be an overpressure response, however this effect is not seen in resistivity, shear log or in the reported MDT pressure data, which has samples throughout this section. The Vp depth trend is most like the Chengal-1 and only in this section does the Rempah-1 Vp diverge from the trend. Edits use RPD, except in the casing gap at 2800 the Faust relationship has been used.
- Vs was edited in some intervals to maintain consistency in the VpVs ratio in clay and sand rich intervals. All edits are made using the RPD model.
- Other logs used in the analysis include Gamma, Neutron, Caliper, Deep, Shallow and Medium Resistivity, which are run for the full logging run; and TCMR, and Photoelectric factor which are run from 2800m-TD.

Clay volume (VClay):

- This volume was derived from a combination of the linear Gamma Ray and Neutron/Density crossplot methods.

Reservoir characteristics:

- In terms of lithology the primary reservoir targets are the late Miocene intervals of H160 and H200, these represent Kinarut reservoirs according to the accompanying well report chart. There are a series of turbiditic fine to very fine soft sands.
- The well penetrated multiple H160 sands (gas saturated), but the bulk of the reservoirs are in the H200 sands, there are three primary sections, Upper (gas saturated with GWC), Middle (oil saturated) and Lower H200 (gas saturated). There is also reservoir at the MTD marker, where porosities are not as well developed and the rock is slightly stiffer, there is some gas present.

Volume of hydrocarbons:

- Interpreted gas saturation was best in the H200 Upper and Lower gas sands, where gas volume is around 75%, The H200 Upper contains 10m of high gas then another 10m of low residual gas saturations below the GWC. The H200 Middle contains about 40% oil in a poorly developed sand.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the section below the gas saturated sand yielded a formation water salinity of 24000 PPM. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=2 and Saturation exponent (n)=2, though these values are adjusted slightly in the residual gas zone of the H200 Upper to 1.95, 1.95 as the other logs were indicating more gas presence.

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to the measured data and also when compared to good measured data in the nearby reference wells.

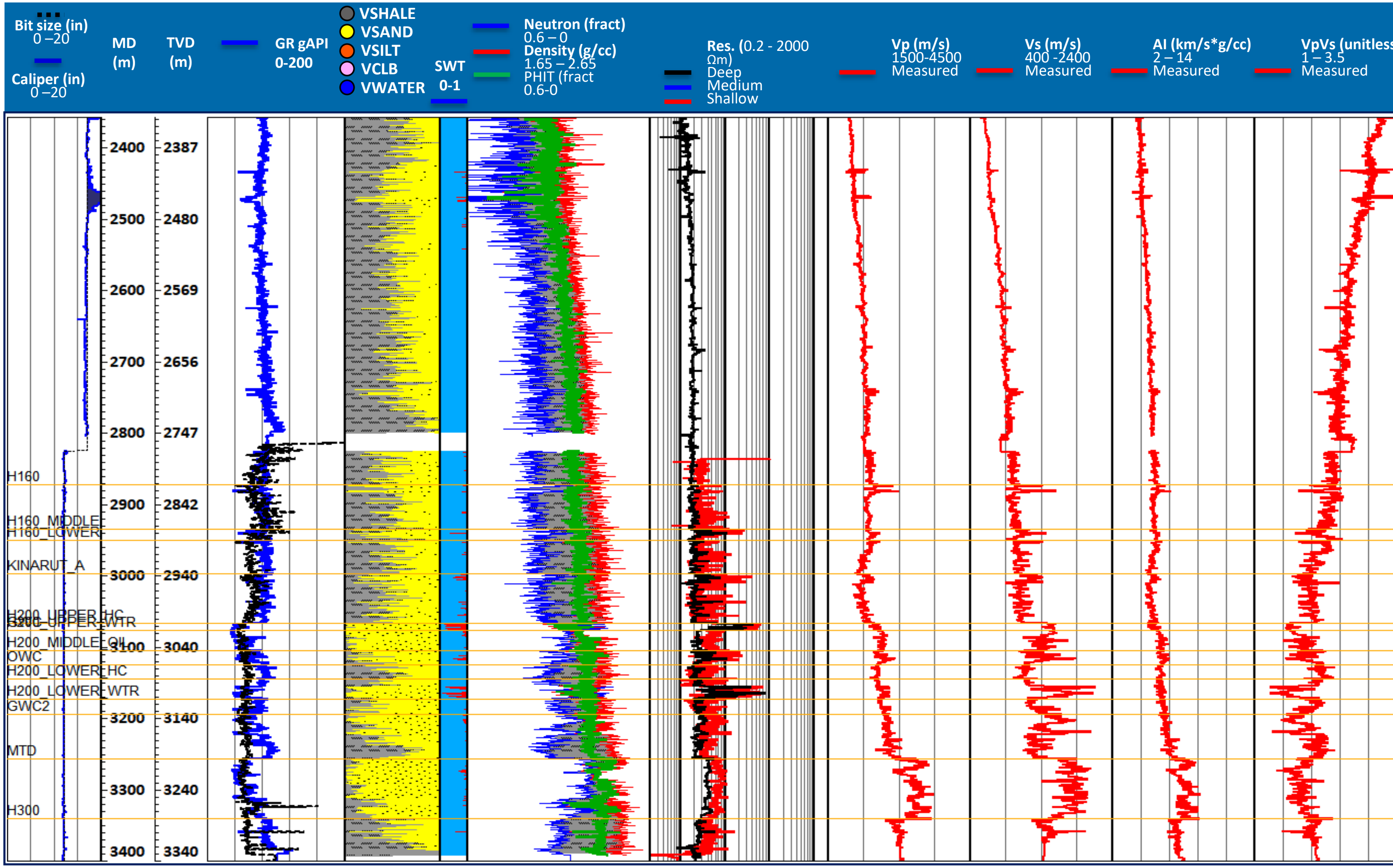
Fluid properties:

- Fluid properties used in substitution have been taken from multiple sources. The gas gravity is from the PVT report in the nearby Batai-1 well, while the oil API is taken from the Rempah-1 MDT Formation fluid sampling report which provided a confident oil gravity for the sample at 3116.2m . Main parameters used in this modeling are:
- Brine salinity: 24000 ppm [Rw]
- Gas gravity: 0.784 [Batai-1 PVT]
- Oil Gravity: 36° [Rempah-1 MDT]
- Gas / Oil ratio: 200 (L/L) [Assumed based on area results]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different late Miocene sands (H160, H200, MTD) using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination with the brine sands.
- No significant change occurred by decreasing the porosity of the reservoir interval.
- The top of the H200 sand shows a Class II AVA response for all fluids, except the brine case has a clearly positive response. With increasing porosity the hydrocarbon cases enter a clear Class III response with good separation between fluids.

Rempah-1 Input Logs



Additional data includes pressure, temperature data, cuttings descriptions, petrographic thin section analysis and final geological report.

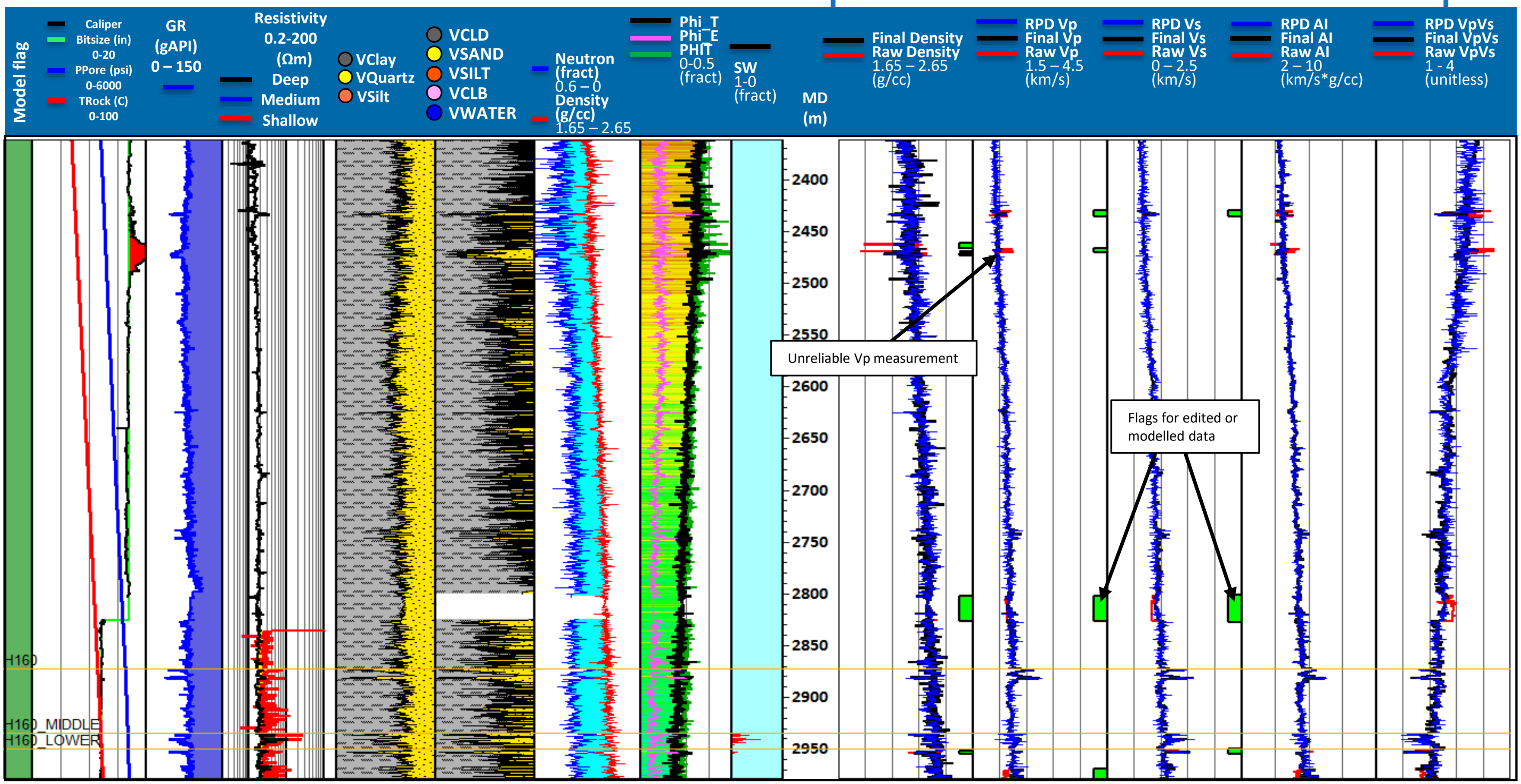
Rempah-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of logs to 2960m

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

model type flag

- Unconsolidated rock model
- Stiff rock model



Some minor edits to the measured logs in washouts and at the casing gap, where first Vp is estimated from a calibrated Faust relationship then other logs predicted from rock models. Model calibration is strong where measured data looks good and reliable. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

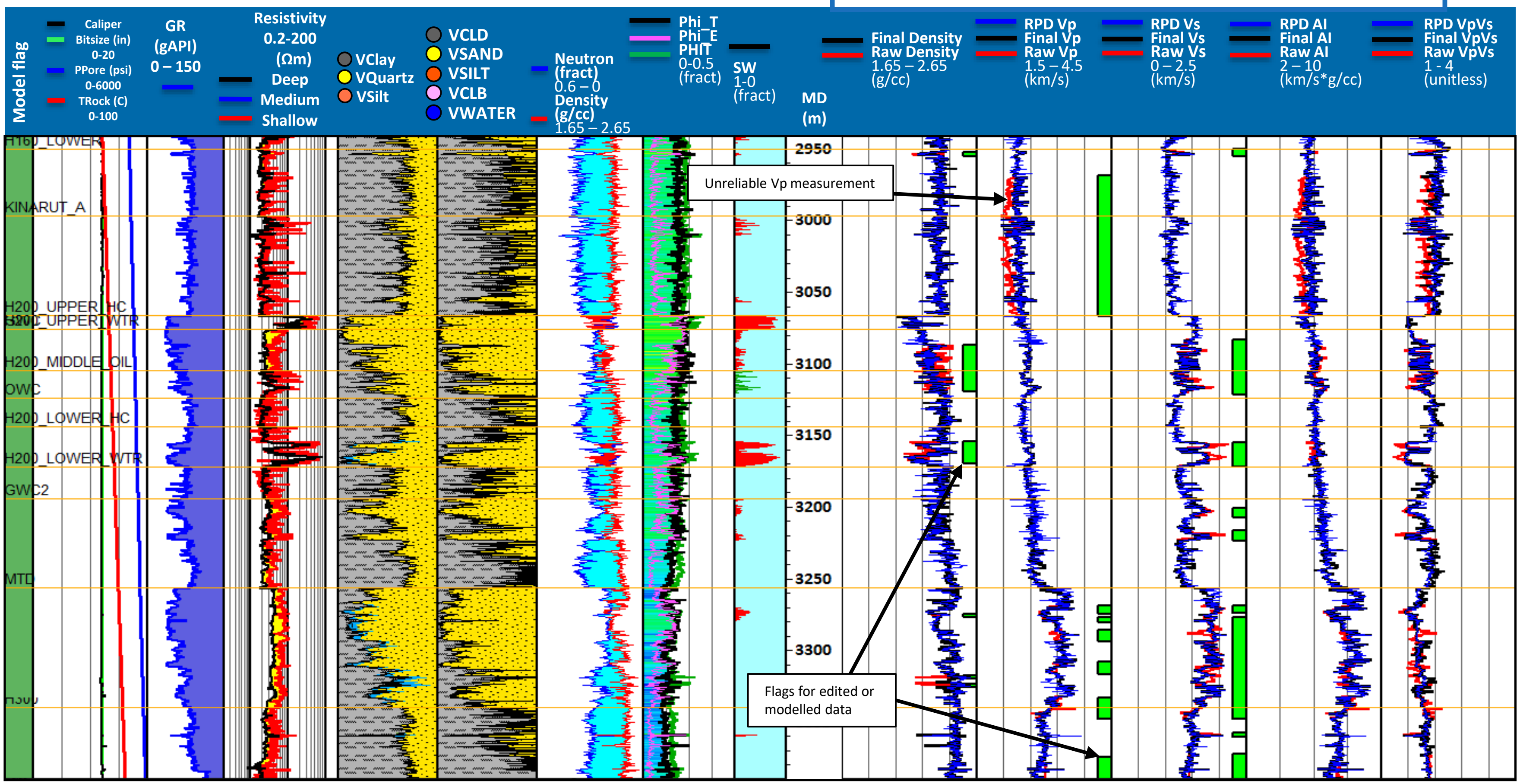
Rempah-1 Geophysical Well Log Analysis (GWLA) – Interval from 2960m to TD

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

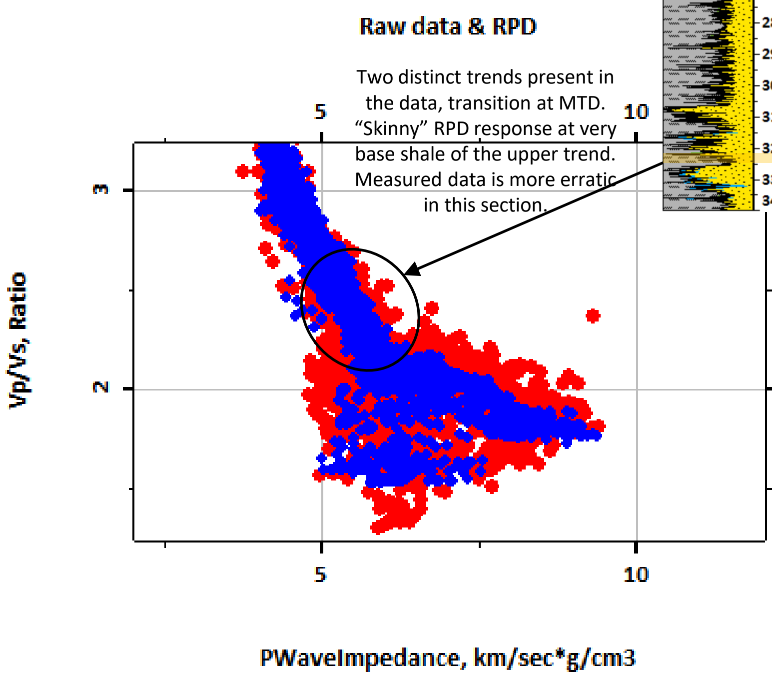
- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

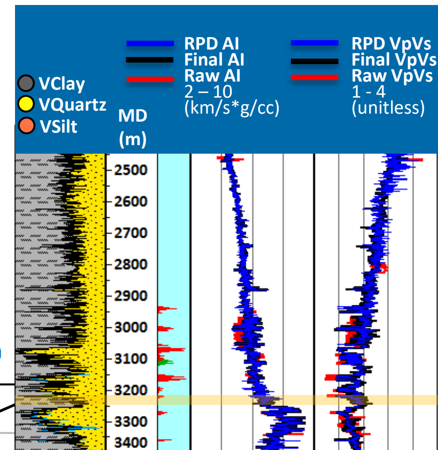


Some minor edits to the measured logs for erratic behaviour and resolution effects. Noteworthy edit to Vp log from 2960-3060m, above the top H200 sand; viewing the Vp log alone looks like an overpressure effect however this effect is not seen in resistivity, shear log or in the reported MDT pressure data, which has samples throughout this section. Also note calculated Phi_T compares well to TCMR log (not shown). Model calibration is strong where measured data looks good and reliable. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

Rempah-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

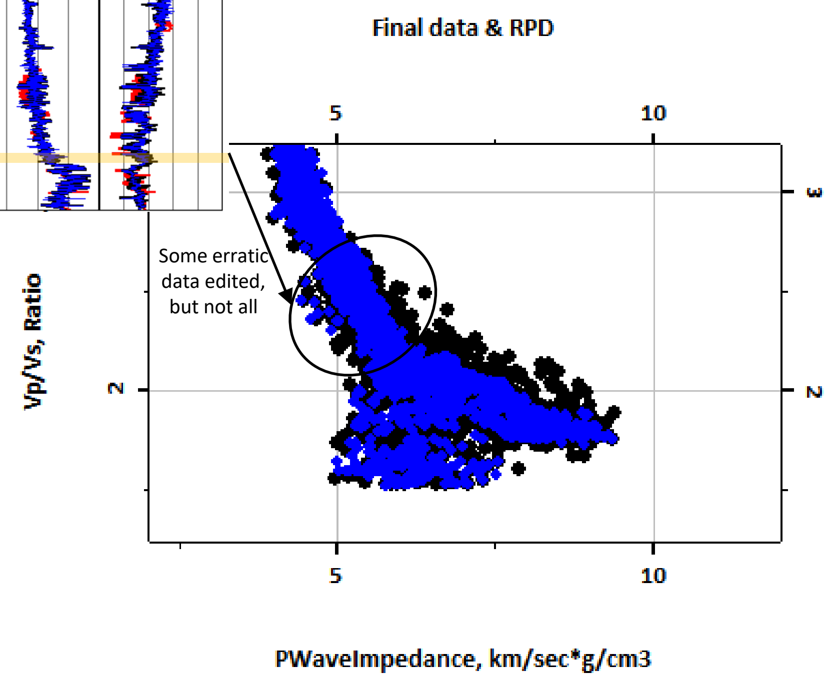
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.





RPD (RPM)
Original Raw (Raw)

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

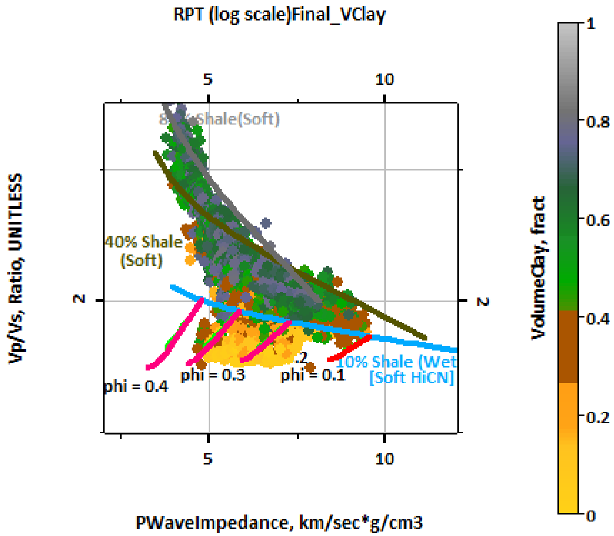


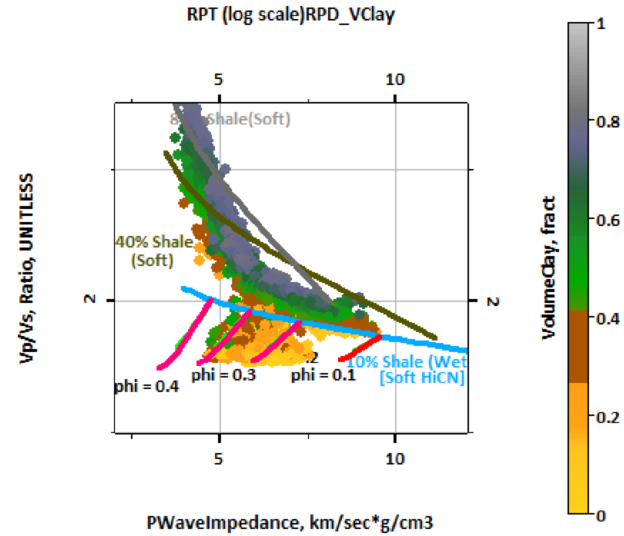
RPD (RPM)
Final (conditioned)

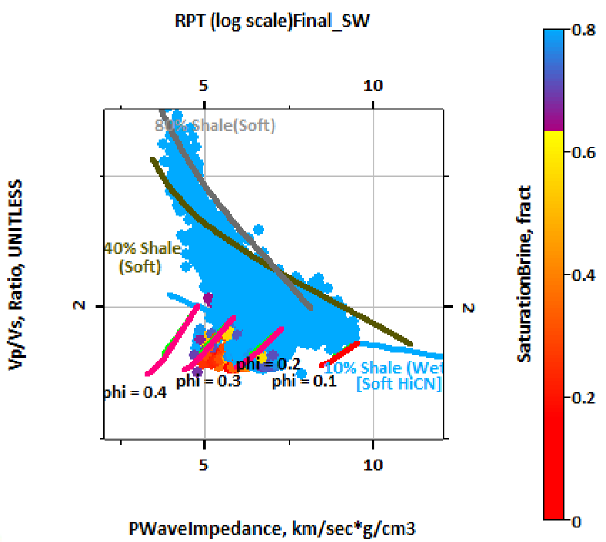
Rempah-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

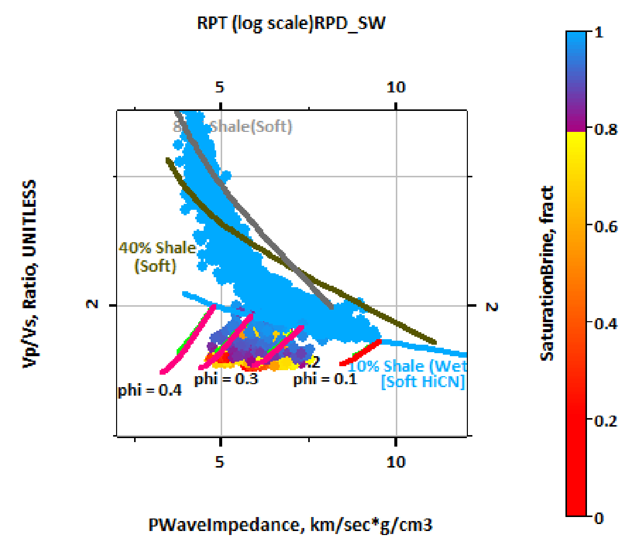
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

ROHU-1

ROHU-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is good. Client's preliminary petrophysical interpretation was fully provided. Elastic logs(Rhob,Vp and Vs)were available from2300m to the T.D.(3370m MD)
- Vs measurement was corrected in some intervals especially in the zone(3028-3075m)dut to inconsistent VpVs ratio results, soft sediment model was used in the correction.
- Rhob was edited in some intervals due to the bad hole conditions using the RPD.
- Other logs include Gamma, Neutron, Caliper, Deep, Shallow and Medium Resistivity, and Photoelectric factor which all run for the full logging run.

Clay volume (VClay):

- This volume was derived from both linear Gamma Ray method.

Reservoir characteristics:

- In general, the well is characterized by a column with a low net to gross ratio, with only a few sand bodies, typically thin (below 2m thick) except sand intervals in the section(3040-3200m) where it becomes more thicker.
- Total porosity for the sand encountered in the well ranged from 20% to 35% .

Volume of hydrocarbons:

- Intervals with best sand developments in the well were interpreted as 100% water saturated. Above 3000 m, a few sands were interpreted with gas saturation values between 45-75%.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. A formation water salinity of 26500 PPM was used . Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.80 and Saturation exponent (n)=1.80(Assumed based on the nearby wells)

ROHU-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore, and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both quartz rich and clay rich intervals when compared to the measured data.

Fluid properties:

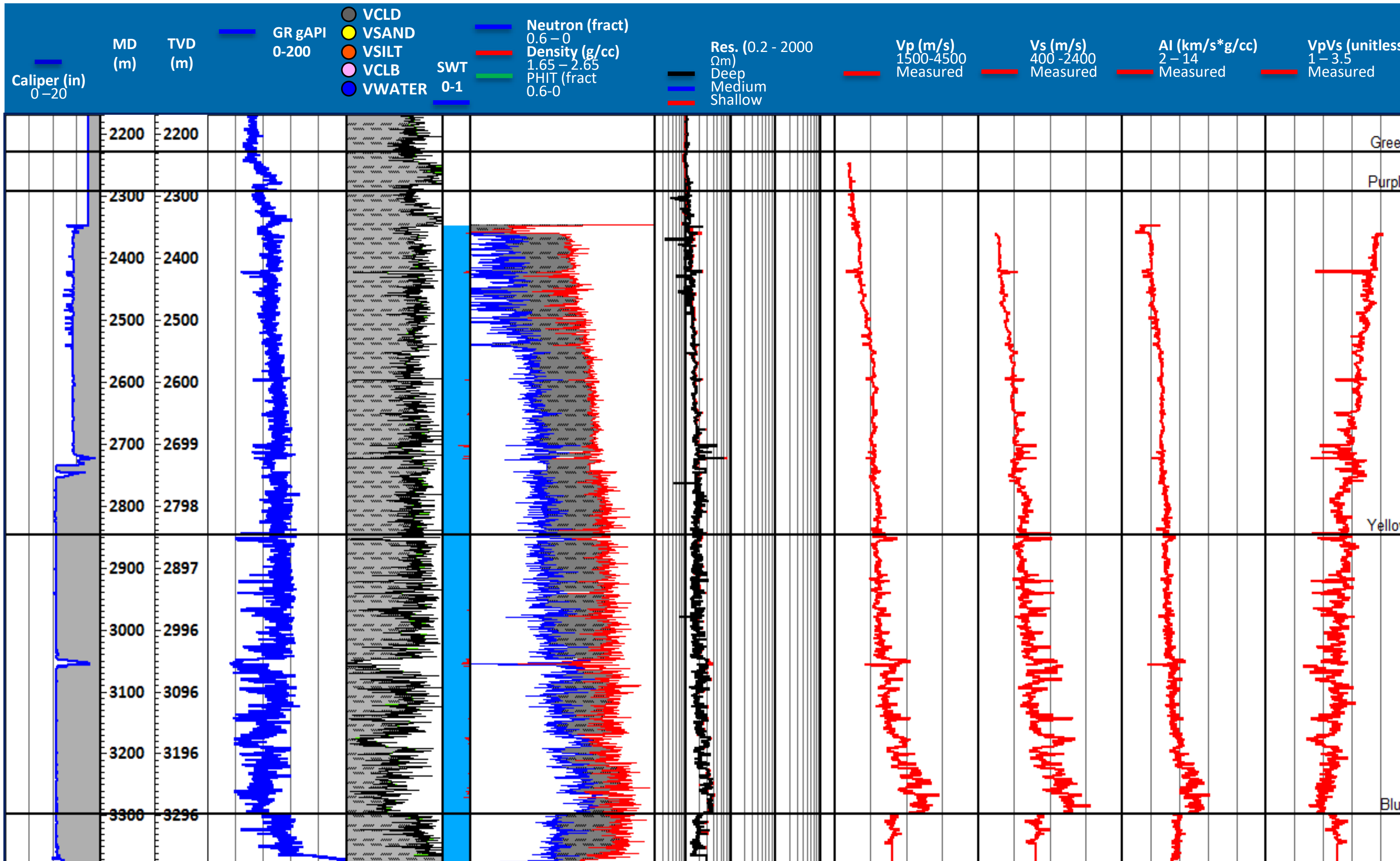
Fluid properties used in substitution have been taken from Tomani-1 PVT well report. Main parameters used in this modeling are:

- Brine salinity: 26500 ppm
- Gas gravity: 0.64
- Oil Gravity: 35 API [assumed]
- Gas / Oil ratio: 100 (L/L) [assumed]

Rock physics modelling (lithology, fluid and porosity):

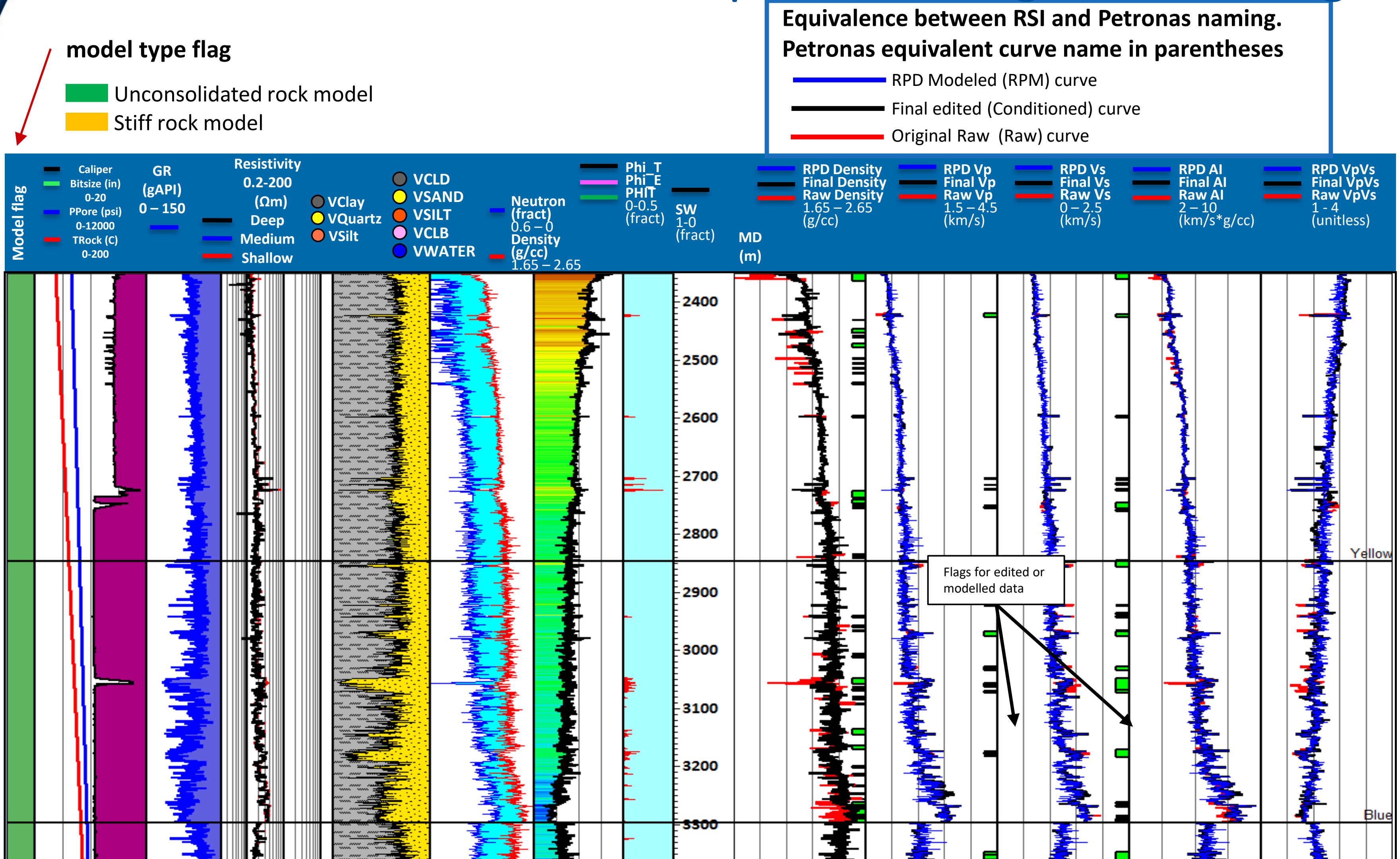
- Perturbational modelling was performed in sands within the purple, Yellow and Blue events.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination between the hydrocarbon cases(oil and gas) and the wet case at the insitu reservoir conditions.
- AVA class II was observed near a good porosity sand layer@2840m for all hydrocarbon cases at in situ reservoir conditions with good fluid discrimination with the wet case which showed class I AVA response.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) hydrocarbon cases started to show class IIP AVA response while the wet case remain the same with no significant change.

ROHU-1 Input Logs



Additional data includes pressure, temperature data and cuttings descriptions.

ROHU-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of elastic logs to end of logs

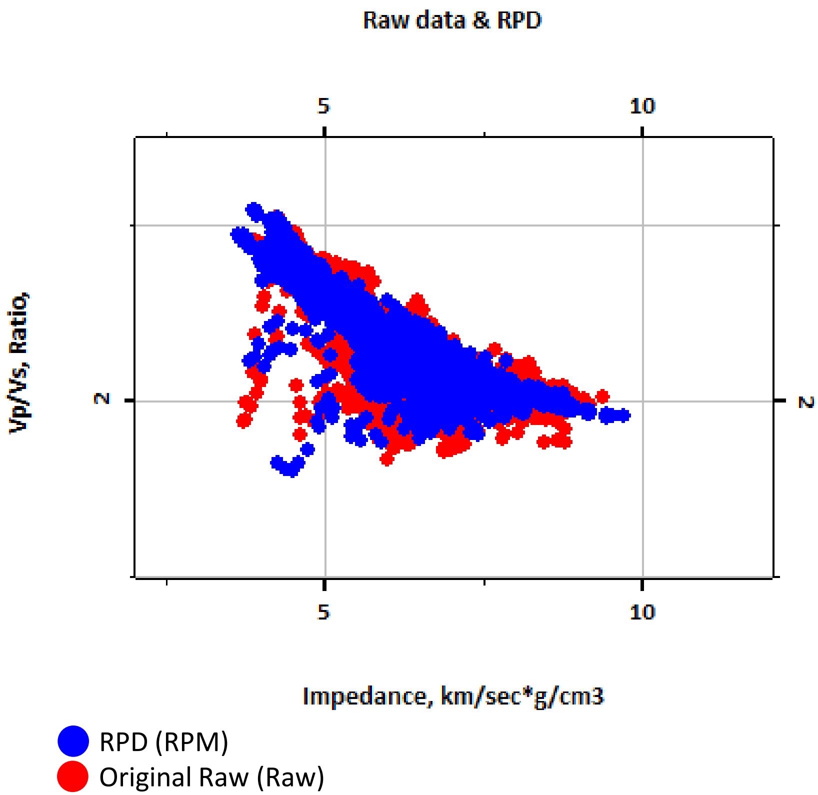


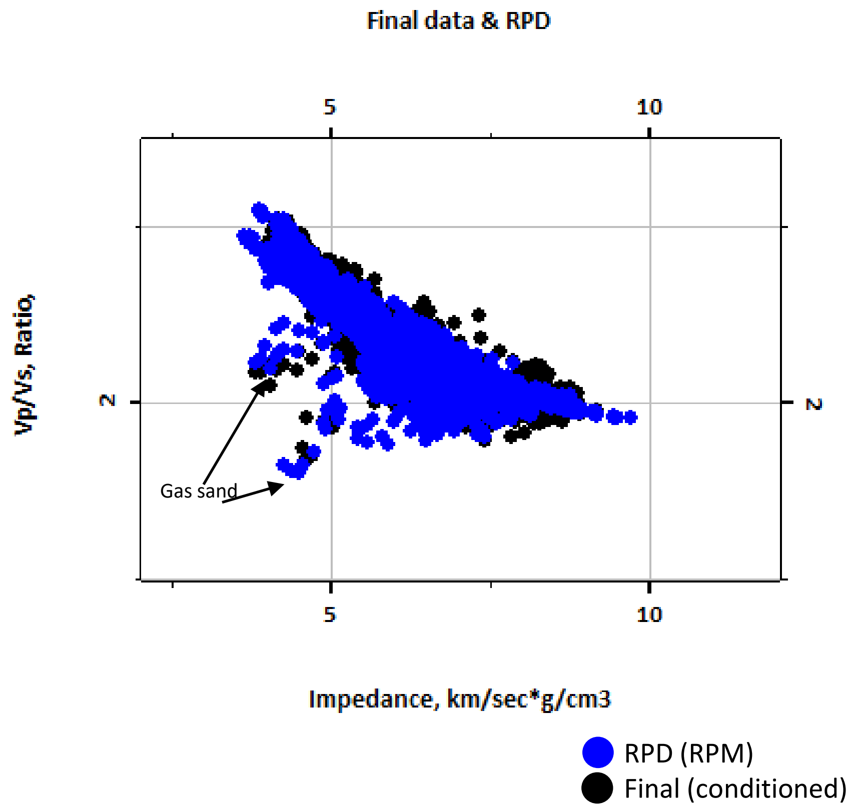
Some edits to the measured data and model calibration is strong. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data and the nearby wells especially(Chengal-1)

ROHU-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

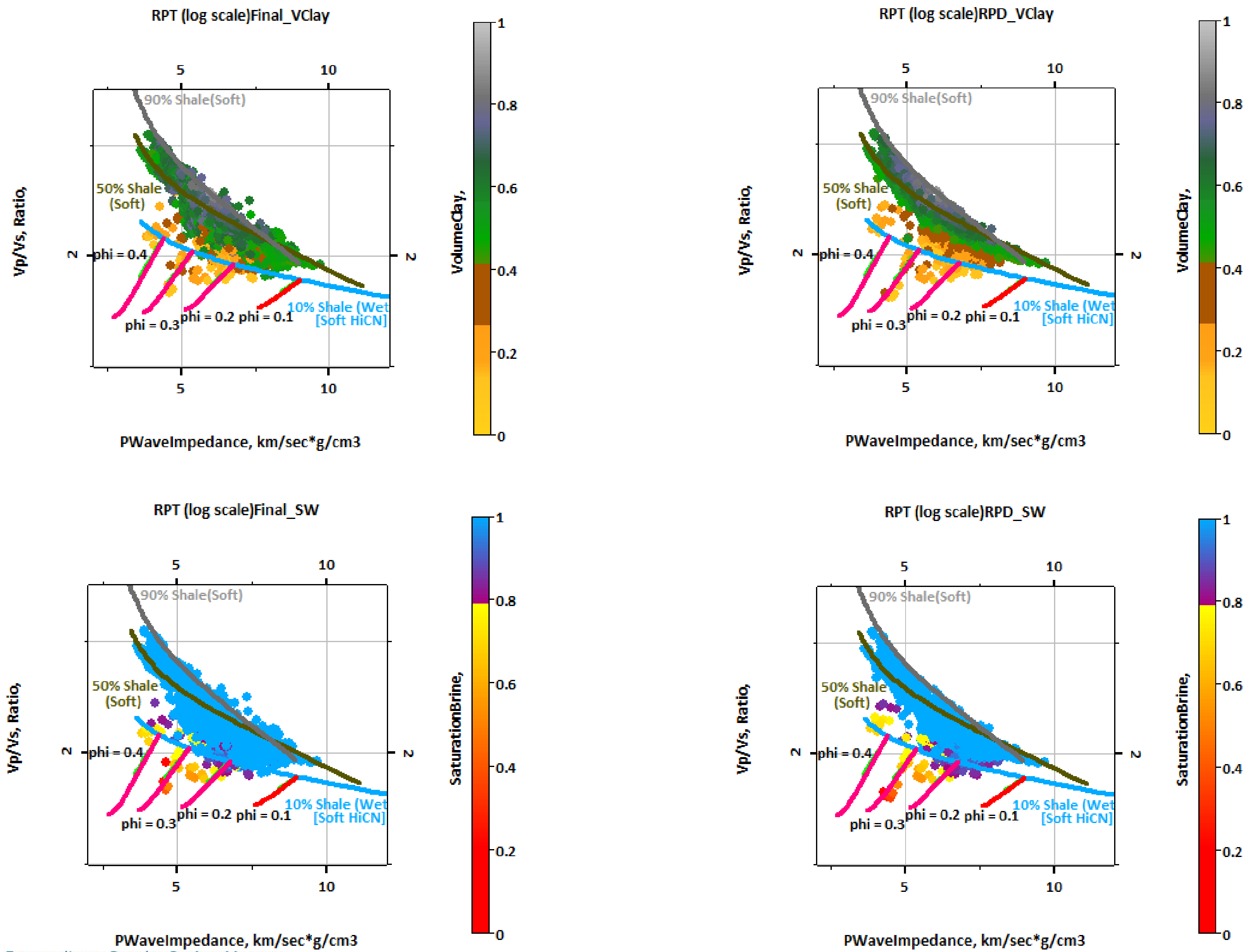




ROHU-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data



RPD(Modelled)data

Rusa Barat-1

Rusa Barat-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability are poor especially the density. Client's petrophysical interpretation was provided for this well(for reference).
- Density log was only available in the interval(600-1500m), while the VP measurements cover till the T.D.
- Elastic logs(VP and Rhob)were totally affected by the bad hole conditions above 600m so no reliable response could be obtained to establish a rock physics model for that interval.
- Shear wave velocity(VS)was fully modelled in the well using the RPD after the model was carefully calibrated based on the offset wells behaving elastically the same especially(Danum-1 and Mengkira-1 wells) The resulted Vs matched in trend all the nearby wells .
- Density was completely modelled below 1500m to the T.D. using the RPD after the model was carefully calibrated with the nearby wells for the same penetrated section.
- Vp also was edited using the RPD in some intervals especially where the hole was affected by washouts as in the interval(700-1100m).
- Elastic curves in the bad Vp and no Density measurements intervals were filled using deep resistivity to predict Vp via Faust equation then density and Vs were estimated using the RPD.
- Below the depth of 1500m(MD) the well started to be impacted by some local over pressure causing sudden drop in the P-wave impedance records.
- Other logs include Gamma, Caliper, shallow and Deep resistivity, which all run for the full logging run to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Miocene marine sands. These are a series of turbiditic fine to very fine soft sands.
- The well penetrated many good sand layers especially in the interval 700-1200 where total porosity reached up to 34%.

Volume of hydrocarbons:

- All sand reservoirs penetrated in the well were 100% brine saturated.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the clean wet sand(800-1250m)yielded a formation water salinity of 39000 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=2 and Saturation exponent (n)=2 (assumed based on nearby wells' information).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to good measured data in the nearby reference wells and other wells on the same elastic trend.
- Elastic behavior for the well was carefully calibrated with the nearby wells and other wells honoring the same elastic trend for the well(P-Wave impedance depth trend) And concluded that the well elastically behaves similar to Danum-1 well and Mengkira-1 well(even though it is far to the north east but elastically honoring Rusa Barat-1 elastic trend) , so S-wave velocity completely modelled in the well based on the same model and parameters used in the offset wells which resulted in a matched trend with the calibrated nearby wells and very well behaved model when compared to the modelled results in the most nearby wells.

Fluid properties:

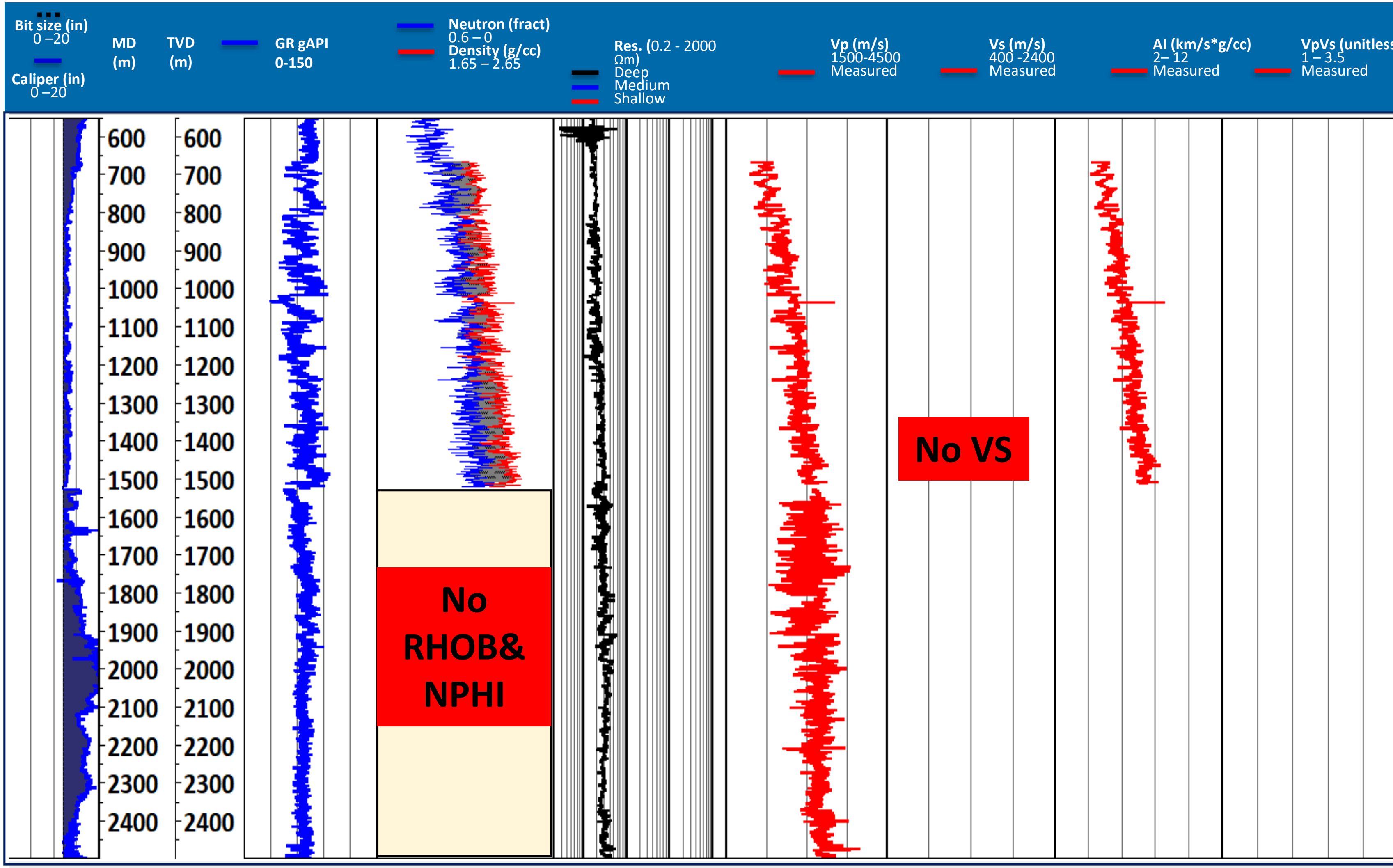
Fluid properties used in substitution have been taken from PVT report of nearby well Danum-1, Main parameters used in this modeling are:

- Brine salinity: 39000 ppm[Pickett plot]
- Gas gravity: 0.82[PVT analysis]
- Oil Gravity: 38.9 API[PVT analysis]
- Gas / Oil ratio: 500 (L/L) [PVT analysis]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination with the brine sands only in the IVC and IVD stages.
- AVA class IV was observed near a good porosity shallow sand@ 915m for all hydrocarbon cases while class II for the wet case all at in situ reservoir conditions.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) hydrocarbon cases started to behave as class IIP AVO response while the wet case as class I.

Rusa Barat-1 Input Logs



Additional data includes final geological and core reports. No VS recorded in the well and also no RHOB/NPHI in the section(1500-T.D.)

Rusa Barat-1 Geophysical Well Log Analysis (GWLA) – Interval from 650 to 1500 m

model type flag

Unconsolidated rock model

Stiff rock model

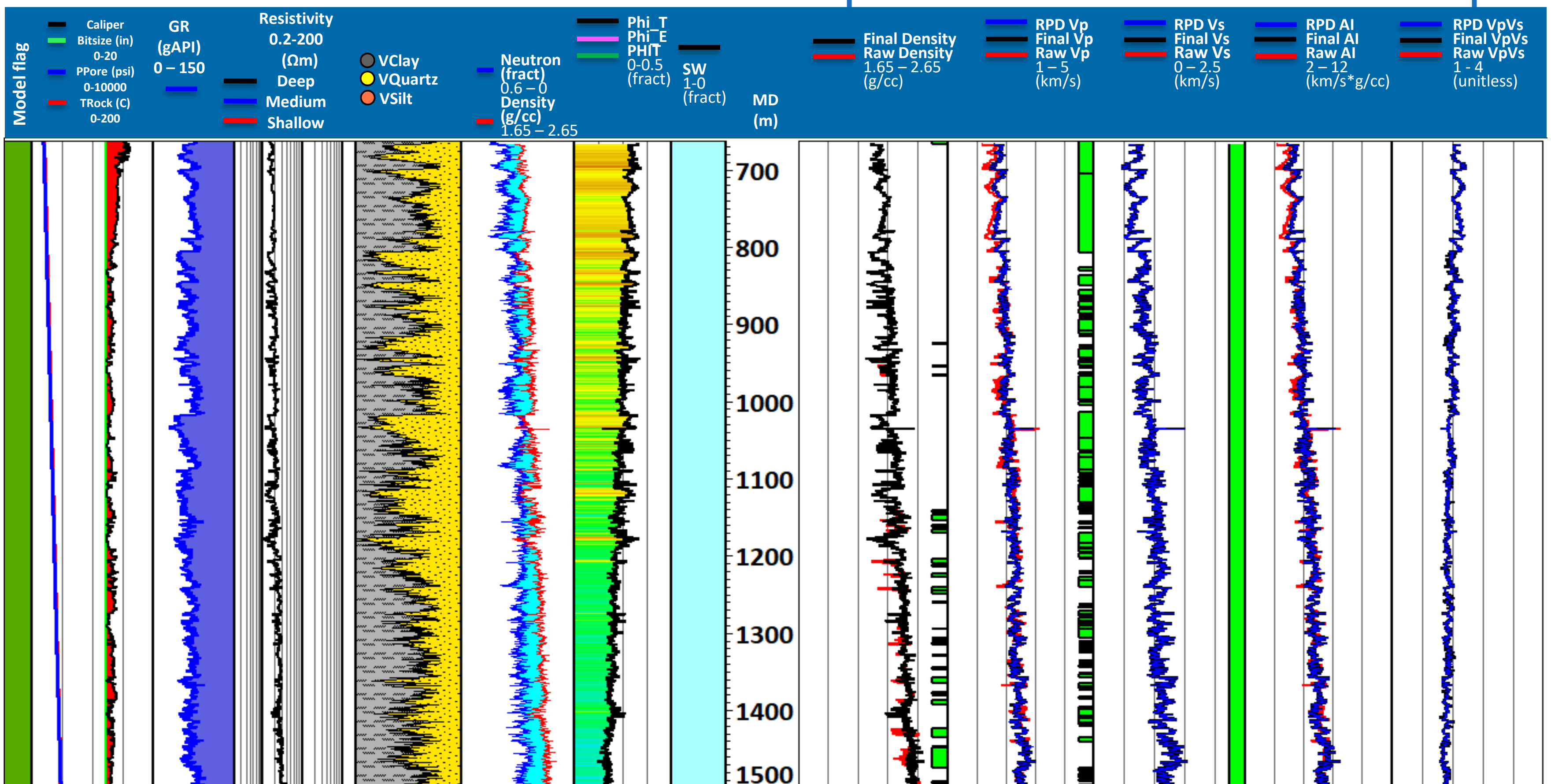
Above depth of 600m(MD) no reliable logs were available to establish a rock physics model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve



Many edits to the measured Density and model calibration is strong where measured data looks good and reliable. Granular media model (Soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) for both sand and clay rich intervals, with good correlation with the measured data in the well(VP and Rhob)and in the nearby wells. VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells.

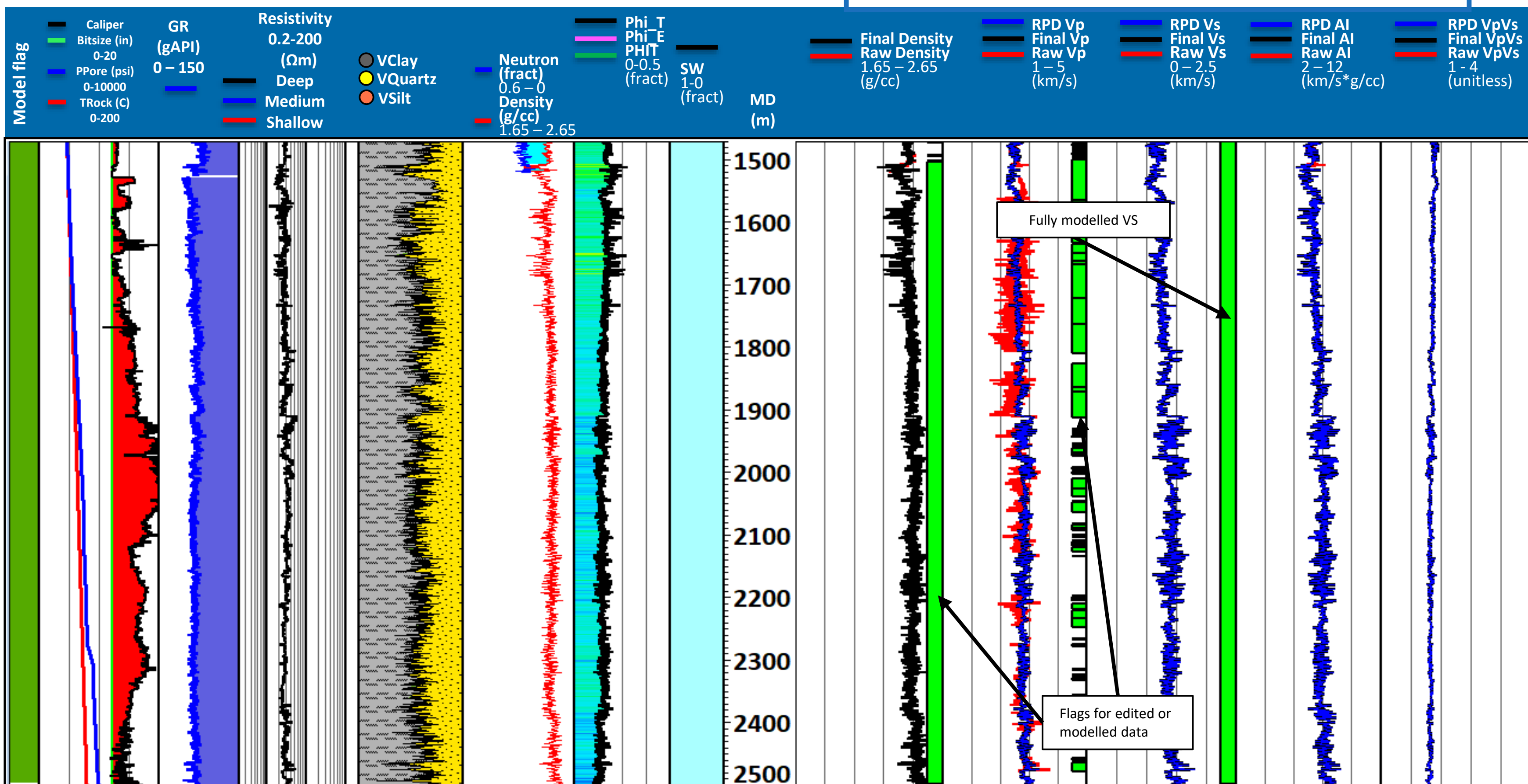
Rusa Barat-1 Geophysical Well Log Analysis (GWLA) – Interval from1500m to the end of logs

model type flag

Unconsolidated rock model
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve
Final edited (Conditioned) curve
Original Raw (Raw) curve

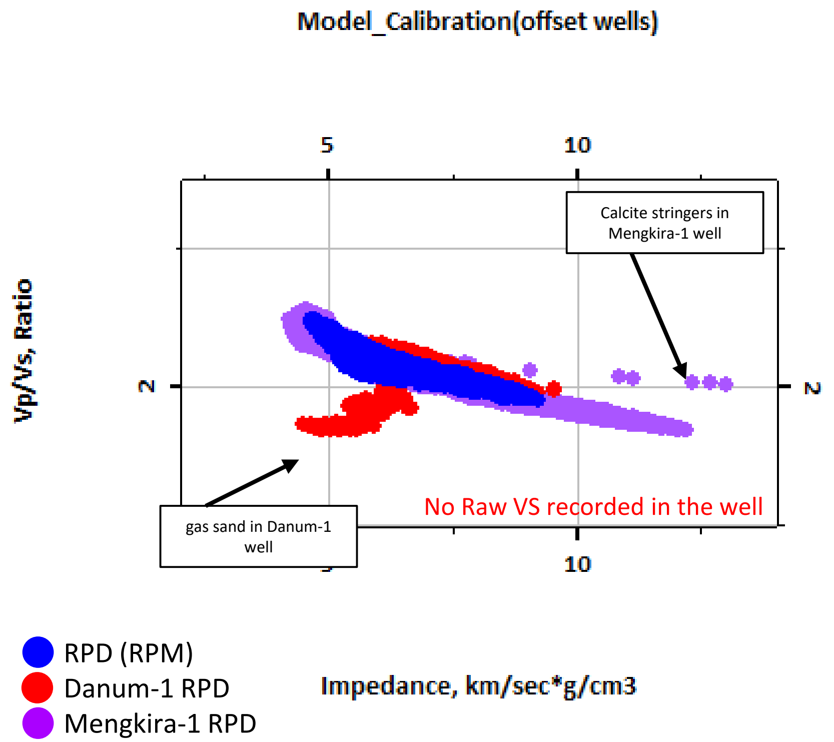


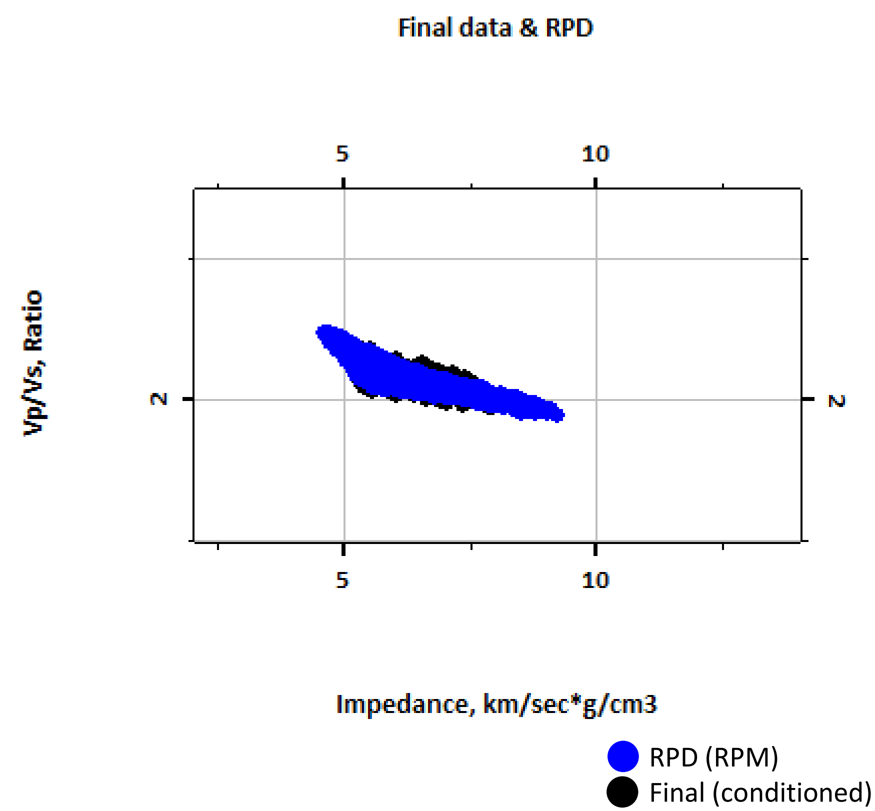
Many edits to the measured Density and model calibration is strong where measured data looks good and reliable. Granular media model (Soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) for both sand and clay rich intervals, with good correlation with the measured data in the well(VP and Rhob)and in the nearby wells. VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells.

Rusa Barat-1,Rock Physics Diagnostics (RPD)
Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the good calibration for the Rusa Barat-1 well RPD with the nearby wells Danum-1 and Mengkira-1.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data(Rhob and Vp ere conditioned while VS is totally modelled).

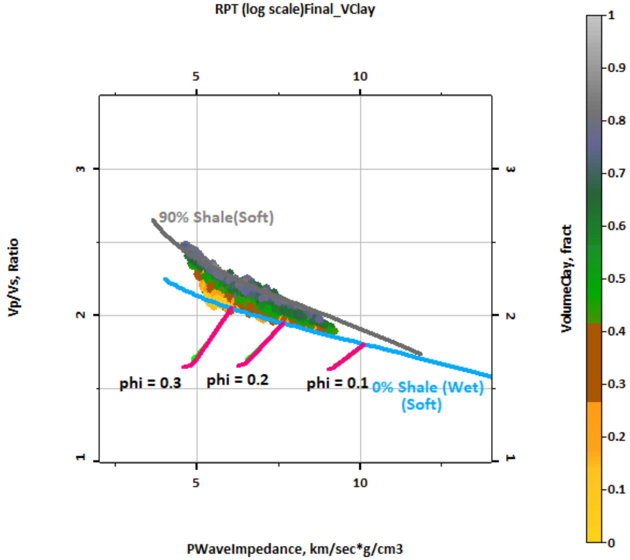


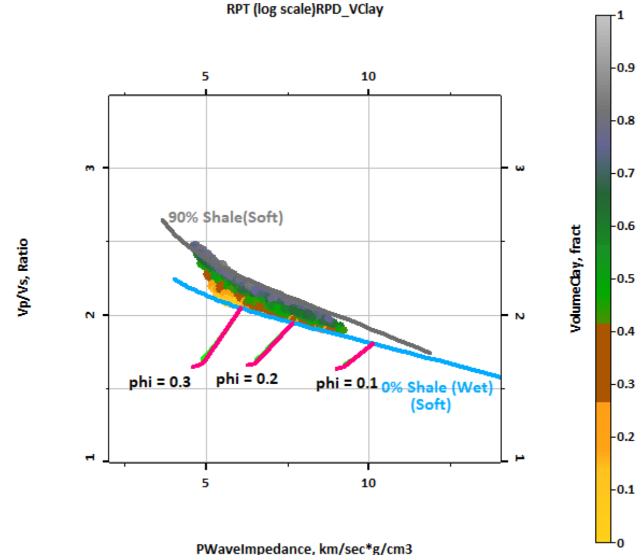


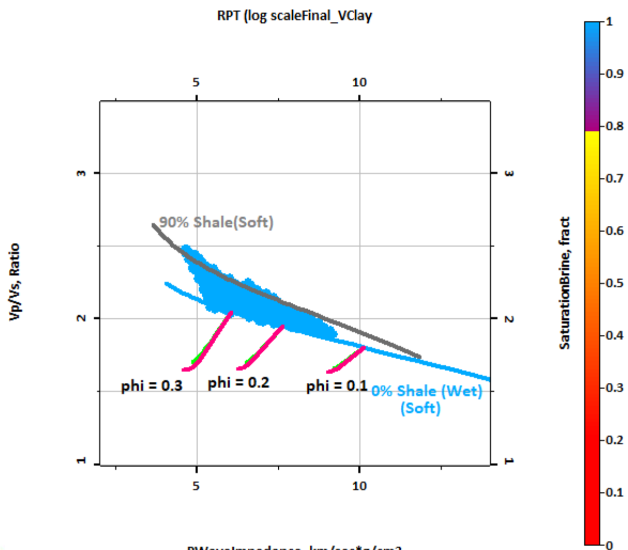
Rusa Barat-1,Rock Physics Diagnostics (RPD) Rock Physics Models, Full Well

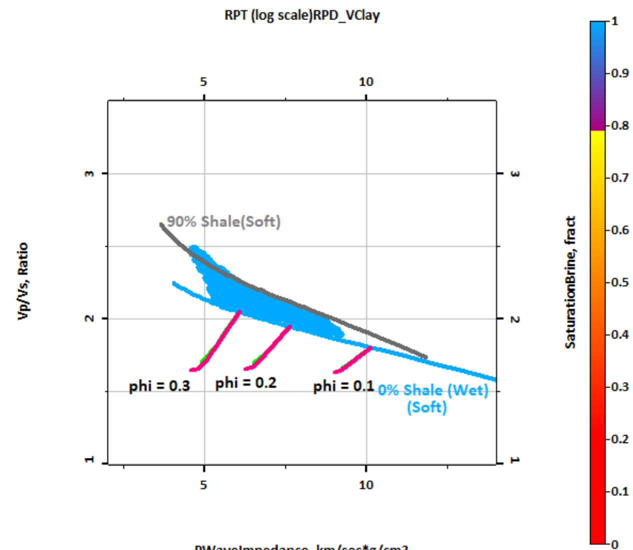
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Samarang-1

Samarang-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality is poor but the data availability is fair. Client's petrophysical interpretation was not provided for this well(except for fast track SW and PHIT not for the whole well interval). Full elastic logs except VS were available throughout the wellbore covering the interval (600m-T.D.)
- Elastic logs(VP and Rhob)were totally affected by the bad hole conditions above 600m so no reliable response could be obtained to establish a rock physics model for that interval.
- Shear wave velocity(VS)was fully modelled in the well using the RPD after the model was carefully calibrated based on the nearby wells especially(Andalusit-1 and Haselfoot-1).
- Density was heavily edited in many intervals using the RPD due to the bad hole conditions
- Vp also was edited using the RPD in some intervals especially where the hole was affected by washouts.
- Vp was bulk shifted by +500 m/sec in the deep 6" hole since the raw measurement run with a different tool resulted in a compressional velocity that is not following the normal compaction trend of the area.
- Elastic curves in the gap intervals was filled using deep resistivity to predict Vp via Faust equation then density and Vs was estimated using the RPD.
- Other logs include Gamma, Neutron, Caliper, Deep and Shallow resistivity, which all run for the full logging run to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is the Miocene marine sands. These are a series of turbiditic fine to very fine sands intercalated with many claystone layers.
- The well penetrated many good sand layers especially the section(1400-2400m) with many sand bodies saturated with oil and gas and with total porosity up to 30%.
- Many other blocky sand layers penetrated in deeper stages but all were wet and with lower total porosity ranges.

Volume of hydrocarbons:

- Intervals with sand developments in the well below 2300m(MD) were interpreted as 100% water saturated. Above that depth many sands interpreted as gas or oil saturated with hydrocarbon saturation reached to 75%.

Water saturation (Sw):

- Water sample obtained from the well yielded a salinity of a bout 31000ppm which reflected in a water resistivity value of a bout 0.11ohm at 135F. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=2 and Saturation exponent (n)=2 (assumed)

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that from the point where the elastic logs started down to the T.D. the Stiff sand model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for sand rich intervals while the soft sediment model honor more the elastic trend for the clay rich intervals.
- Elastic behavior for the well was carefully calibrated with the nearby wells and concluded that the well elastically behaves similar to Andalusit-1 and Haselfoot-1 wells , so S-wave velocity completely modelled in the well based on the same model and parameters used in the offset wells.

Fluid properties:

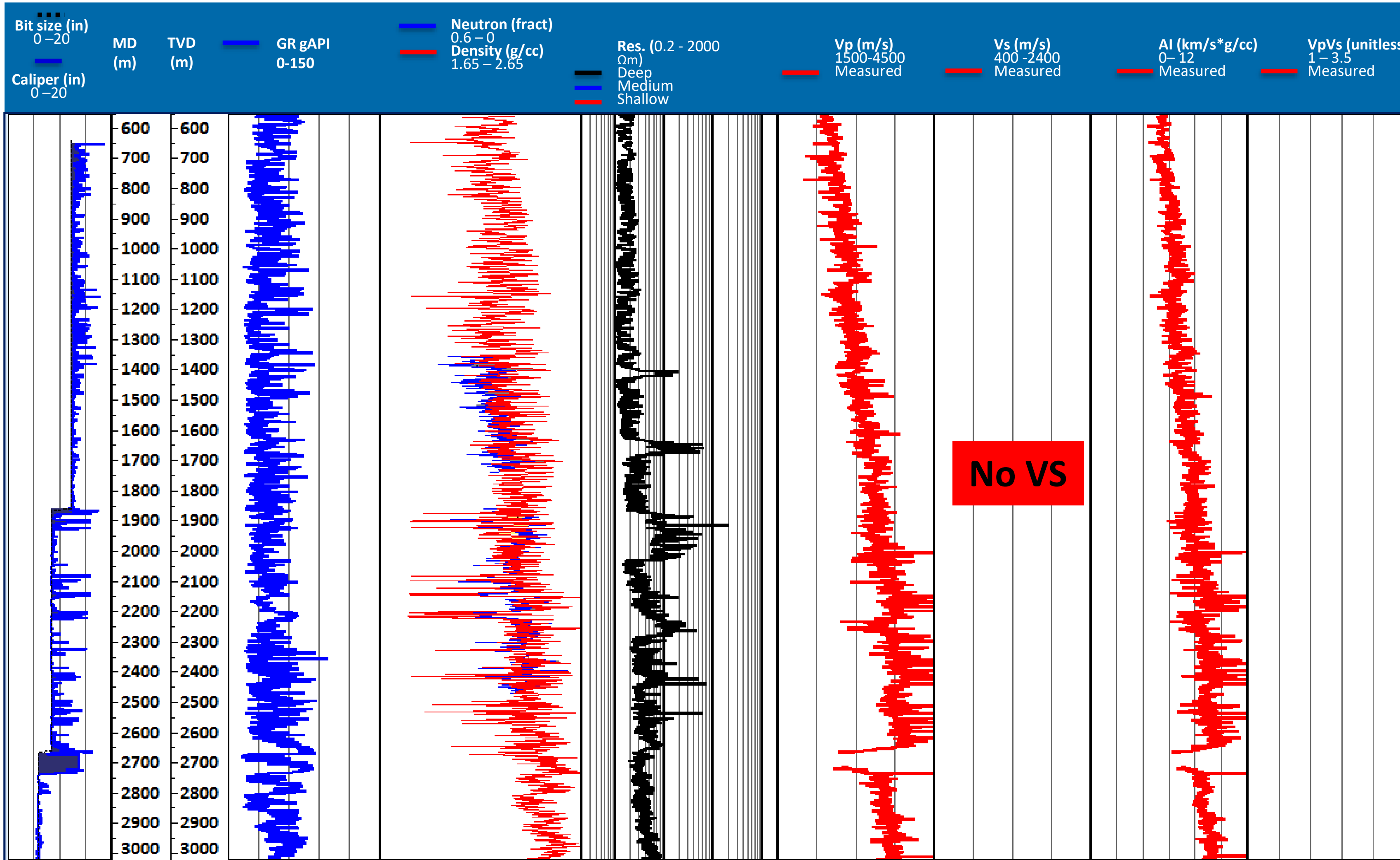
Fluid properties used in substitution have been taken from Samarang-1(DST). Main parameters used in this modeling are:

- Brine salinity: 32000ppm
- Gas gravity: 0.625
- Oil Gravity: 37.9 API
- Gas / Oil ratio: 874 (L/L)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the different stages using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with very good discrimination with the brine sands.
- AVA class IV was observed near a gas sand layer@2230m for all fluid cases at in situ reservoir conditions with good fluid discrimination with the wet case.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) no significant change could be observed for all the modelled cases.

Samarang-1 Input Logs



Additional data includes final geological report. No VS recorded in the well.

Samarang-1 Geophysical Well Log Analysis (GWLA) – Interval from 600 to 1800 m

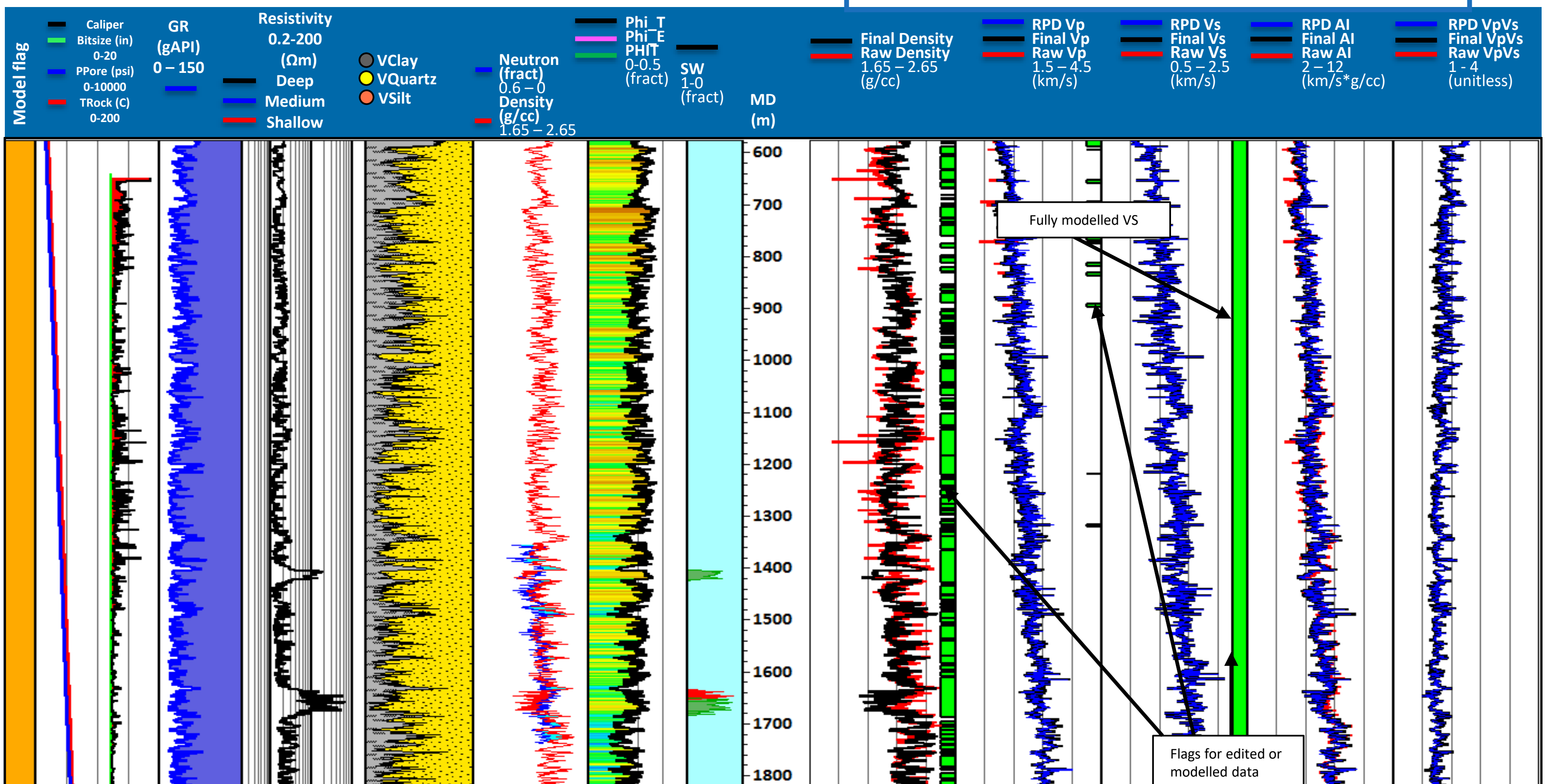
model type flag

- Unconsolidated rock model
- Stiff rock model

Above depth of 550m(MD) no reliable logs were available to establish a rock physics model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve



Many edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (Stiff sand) was used for all elastic curves prediction (Rhob, Vp and VS) for sand rich intervals and soft model for clay rich ones, with good correlation with the measured data and the nearby wells.
VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells

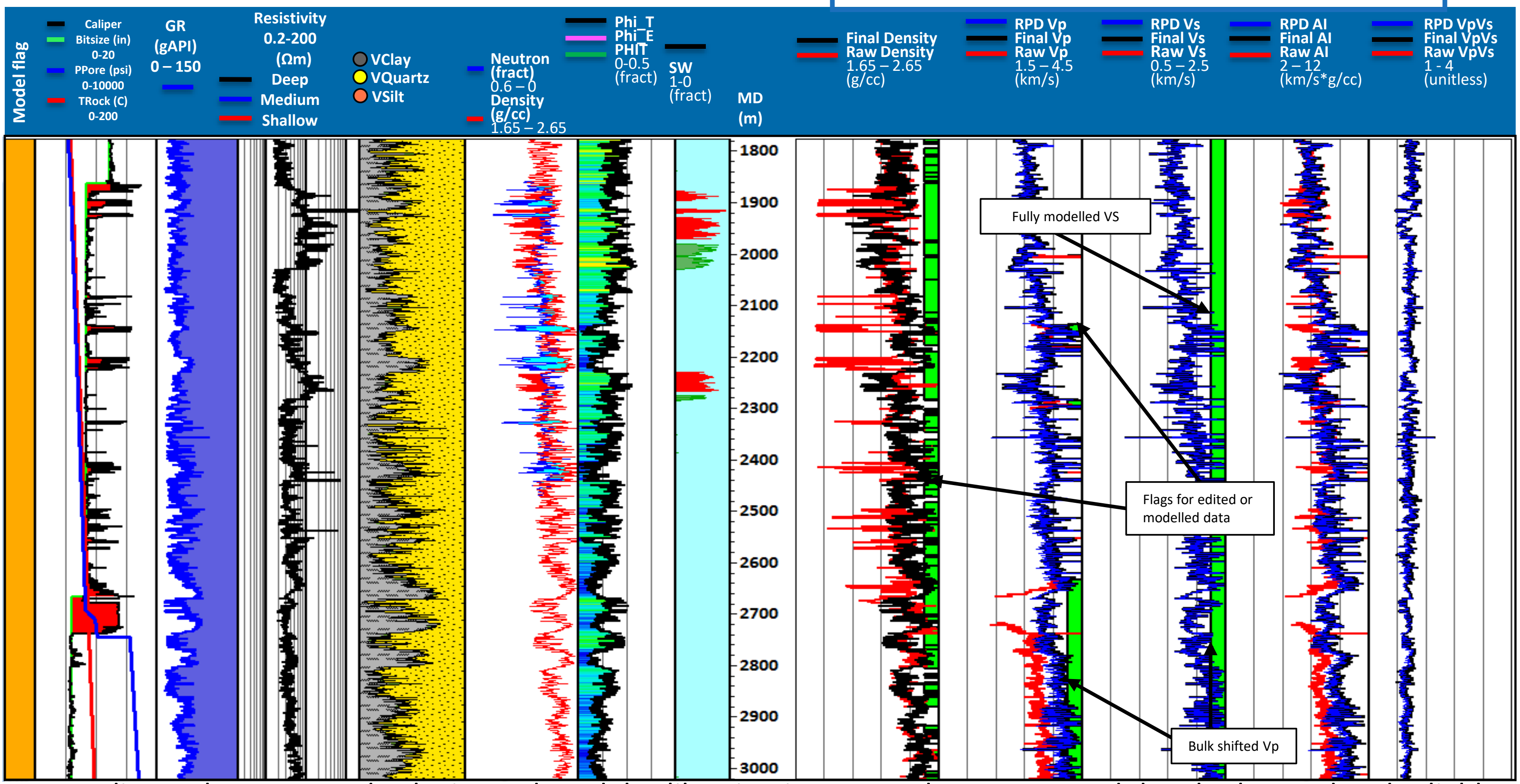
Samarang-1 Geophysical Well Log Analysis (GWLA) – Interval from1500m to the end of logs

model type flag

Unconsolidated rock model
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

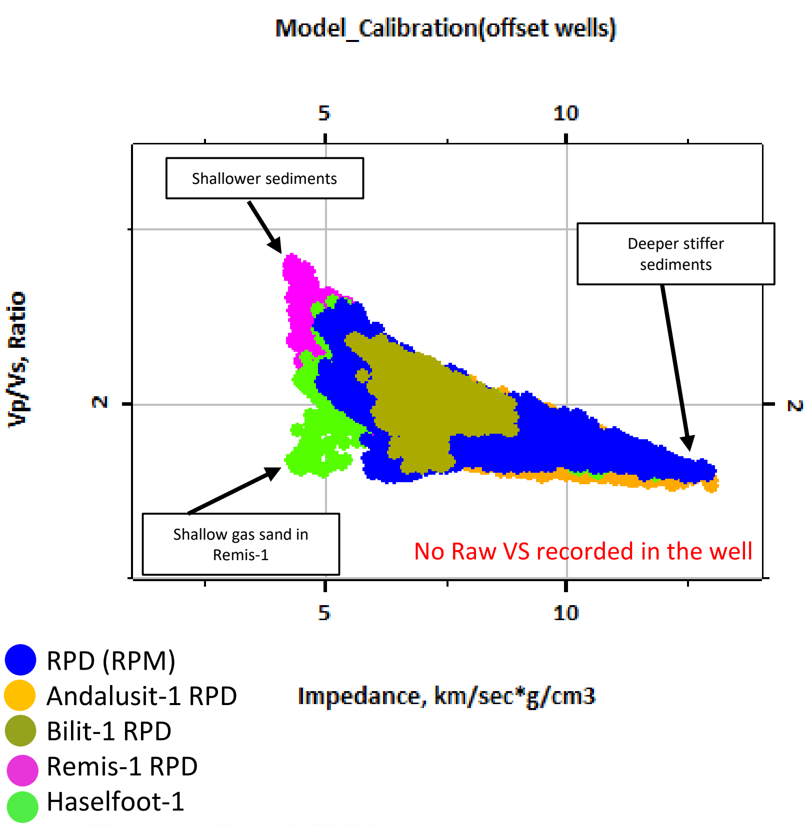
RPD Modeled (RPM) curve
Final edited (Conditioned) curve
Original Raw (Raw) curve



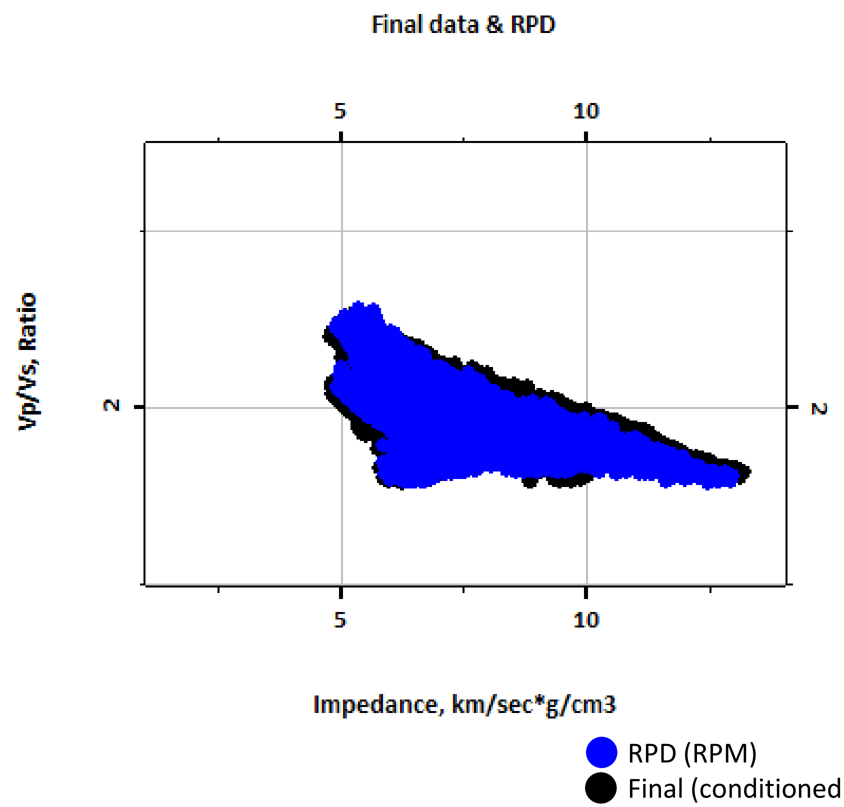
Many edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (Stiff sand) was used for all elastic curves prediction (Rhob, Vp and VS) for sand rich intervals and soft model for clay rich ones, with good correlation with the measured data and the nearby wells.
VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells

Samarang-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the good calibration for the Samarang-1 well RPD with the nearby wells Andalusit-1, Bilit-1, Remis-1 and Haselfoot-1.

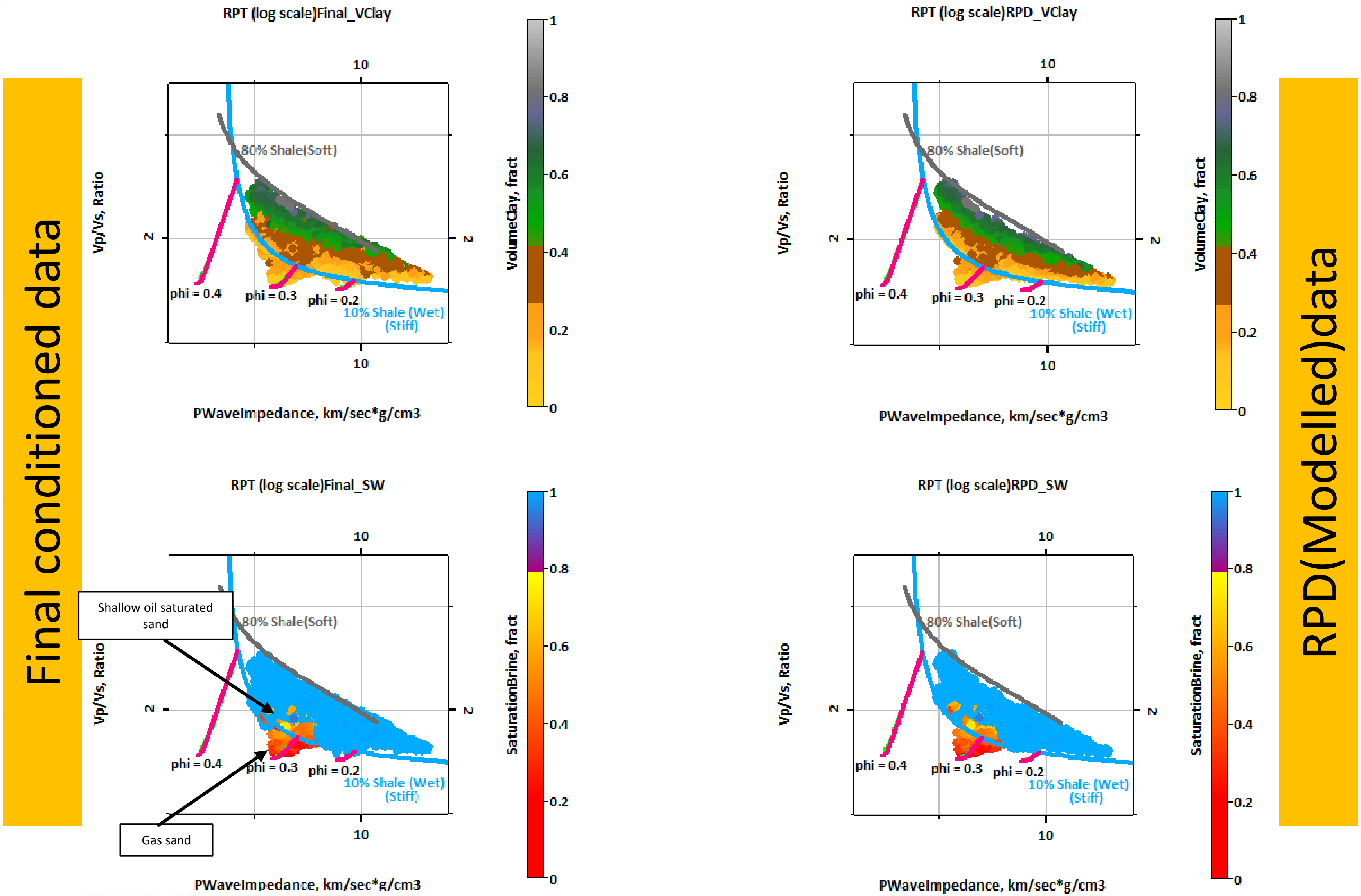


P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data(Rhob and Vp ere conditioned while VS is totally modelled).



Samarang-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft/Stiff sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.



Samarang-2

Samarang-2 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality is poor especially the density but the data availability is fair. Client's petrophysical interpretation was not provided for this well(except for fast track SW and PHIT not for the whole well interval). Full elastic logs except VS were available throughout the wellbore covering the interval (700m-T.D.)
- Elastic logs(VP and Rhob)were totally affected by the bad hole conditions above 700m so no reliable response could be obtained to establish a rock physics model for that interval.
- Shear wave velocity(VS)was fully modelled in the well using the RPD after the model was carefully calibrated based on the nearby wells especially(Andalusit-1 and Haselfoot-1) The resulted Vs matched in trend all the nearby wells(Anadlusit-1, Haselfoot-1 and Samarang-1 wells).
- Density was heavily edited in many intervals using the RPD due to the bad hole conditions
- Vp also was edited using the RPD in some intervals especially where the hole was affected by washouts as in the interval(1865-1920m).
- Elastic curves in the gap intervals was filled using deep resistivity to predict Vp via Faust equation then density and Vs was estimated using the RPD.
- Other logs include Gamma, Neutron, Caliper, Deep and Shallow resistivity, which all run for the full logging run to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is the Miocene marine sands(stages IVE, IVD and IVC). These are a series of turbiditic fine to very fine sands intercalated with many claystone layers.
- The well penetrated many good sand layers especially the section(800-2000m) with local sand bodies saturated with oil and gas and with total porosity up to 28%.
- Many other blocky sand layers penetrated in deeper stages but all were wet and with lower total porosity ranges.

Volume of hydrocarbons:

- Intervals with sand developments in the well below 2000m(MD) were interpreted as 100% water saturated. Above that depth some sands interpreted as gas or oil saturated with hydrocarbon saturation reached to 65%.

Water saturation (Sw):

- Water sample obtained from the well yielded a salinity of a bout 34000ppm which reflected in a water resistivity value of a bout 0.092ohm at 164.5F. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=2 and Saturation exponent (n)=2 (assumed)

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that from the point where the elastic logs started down to the T.D. the Stiff sand model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for sand rich intervals while the soft sediment model honor more the elastic trend for the clay rich intervals.
- Elastic behavior for the well was carefully calibrated with the nearby wells and concluded that the well elastically behaves similar to Andalusit-1 and Haselfoot-1 wells , so S-wave velocity completely modelled in the well based on the same model and parameters used in the offset wells which resulted in a matched trend with the calibrated nearby wells.

Fluid properties:

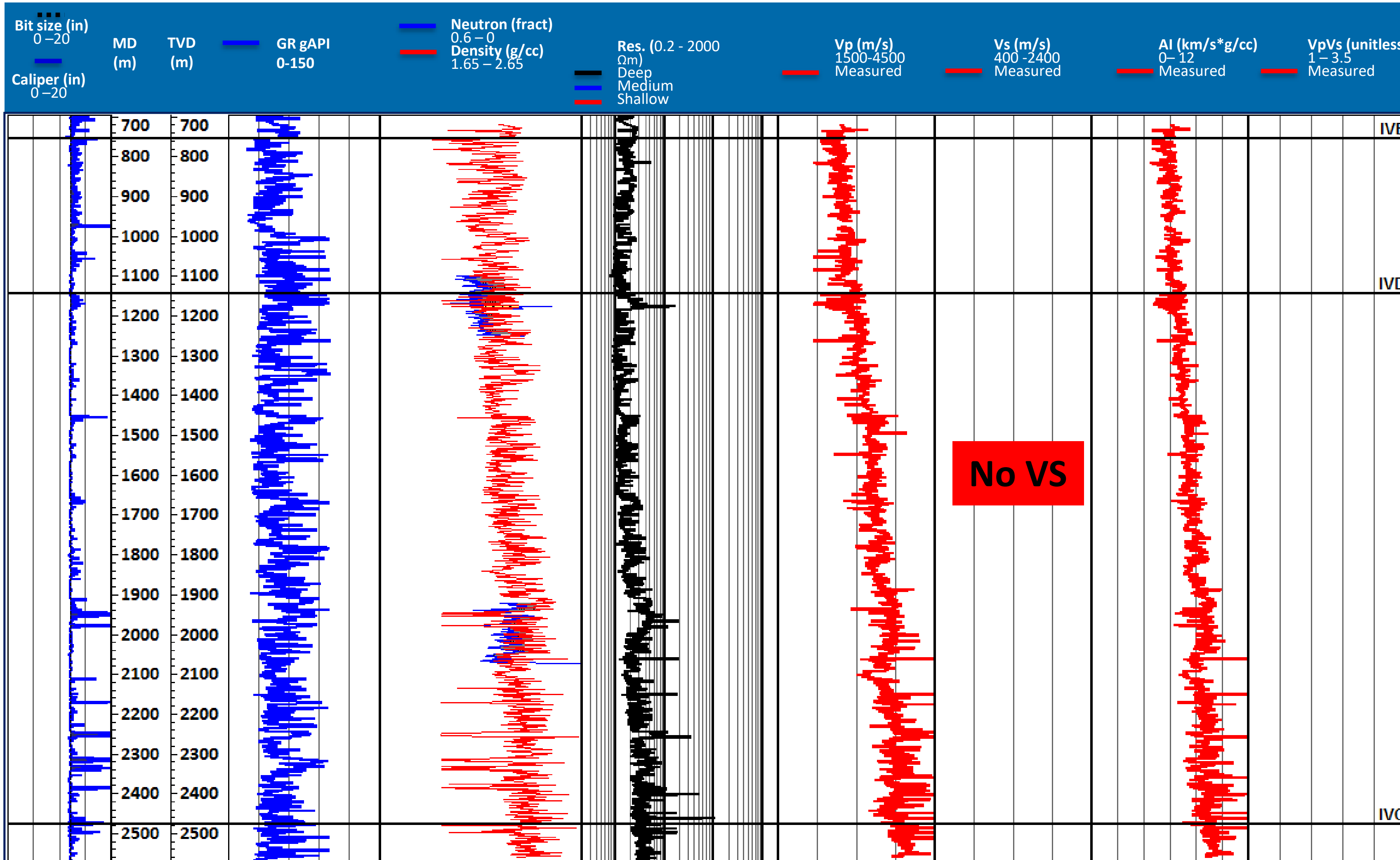
Fluid properties used in substitution have been taken from Samarang-1(DST). Main parameters used in this modeling are:

- Brine salinity: 34000ppm
- Gas gravity: 0.61
- Oil Gravity: 40.5 API
- Gas / Oil ratio: 615 (L/L)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the different stages(IVE, IVD and IVC) using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with very good discrimination with the brine sands.
- AVA class II was observed near a gas sand layer@1170m for all fluid cases at in situ reservoir conditions with good fluid discrimination with the wet case.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) the hydrocarbon cases started to change polarity and behave like class IIP AVO response with no significant change to the wet case.

Samarang-2 Input Logs



Additional data includes final geological report. No VS recorded in the well.

Samarang-2 Geophysical Well Log Analysis (GWLA) – Interval from 700 to 1600 m

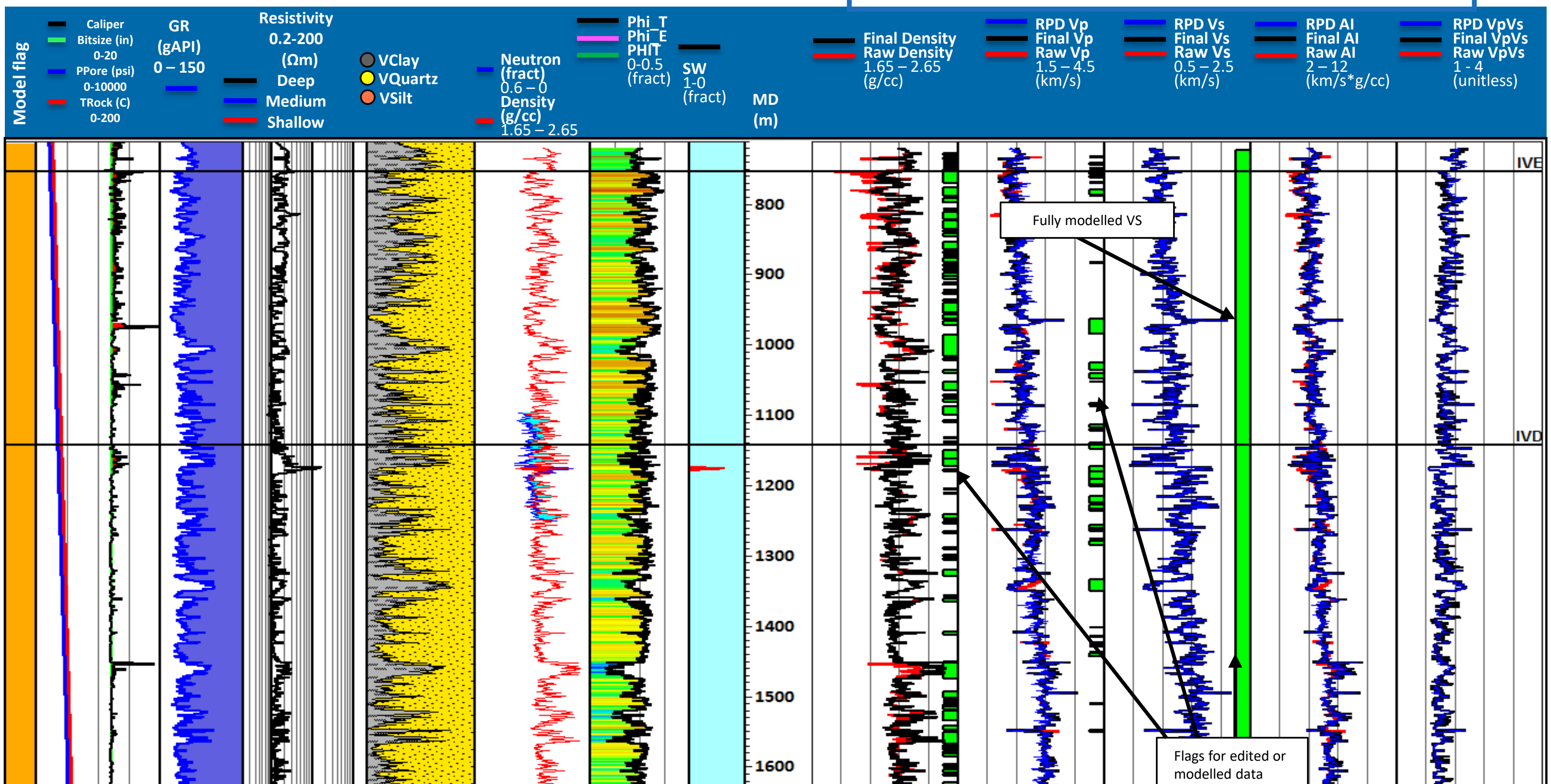
model type flag

Unconsolidated rock model
Stiff rock model

Above depth of 700m(MD) no reliable logs were available to establish a rock physics model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve
Final edited (Conditioned) curve
Original Raw (Raw) curve



Many edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (Stiff sand) was used for all elastic curves prediction (Rhob, Vp and VS) for sand rich intervals and soft model for clay rich ones, with good correlation with the measured data and the nearby wells.
VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells

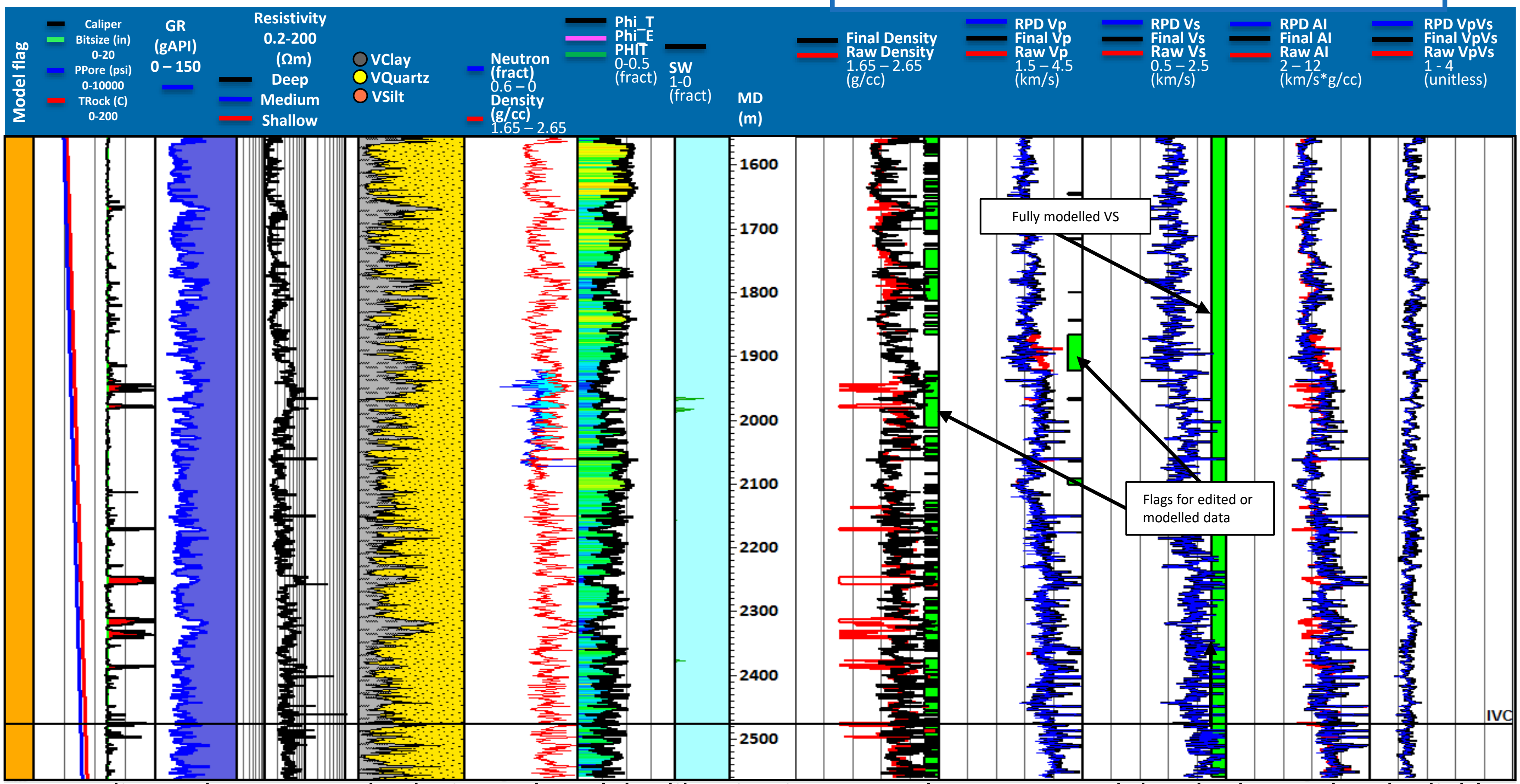
Samarang-2 Geophysical Well Log Analysis (GWLA) – Interval from1550m to the end of logs

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve



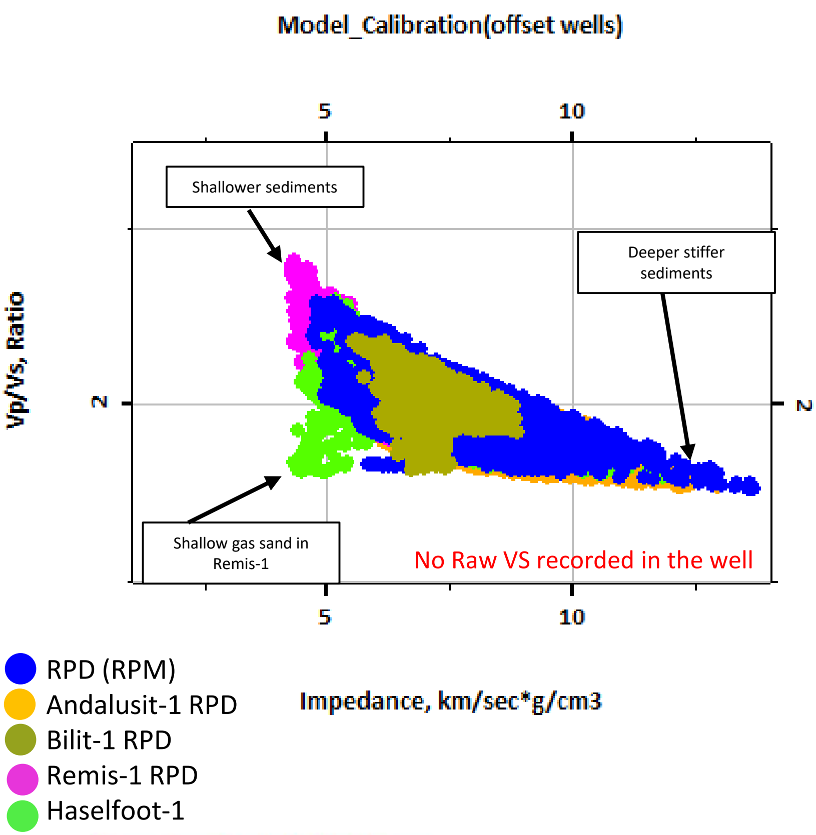
Many edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (Stiff sand) was used for all elastic curves prediction (Rhob, Vp and VS) for sand rich intervals and soft model for clay rich ones, with good correlation with the measured data and the nearby wells.

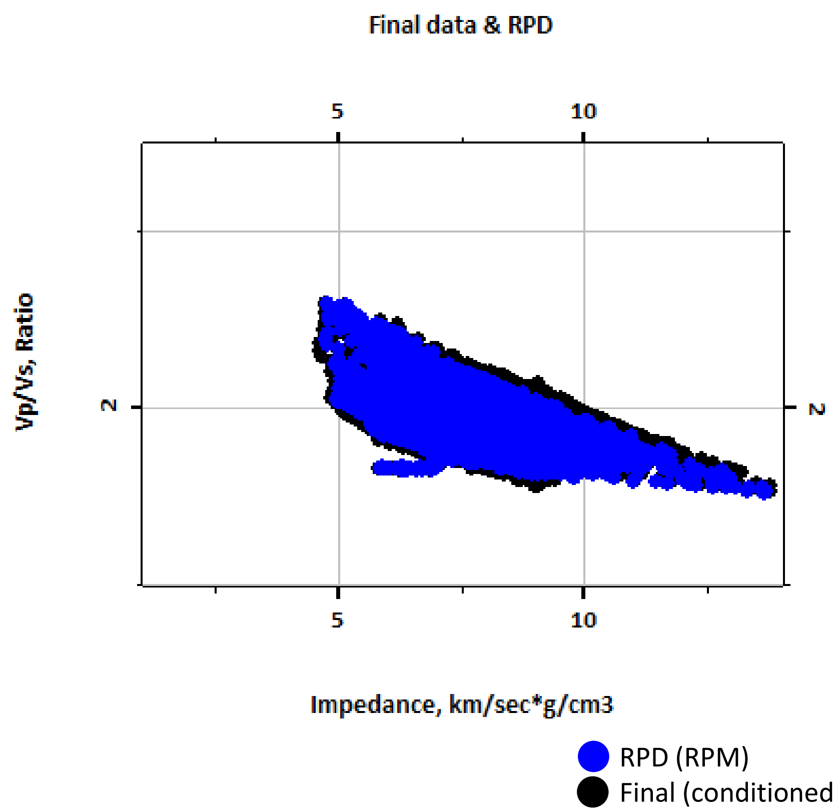
VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells

Samarang-2,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the good calibration for the Samarang-2 well RPD with the nearby wells Andalusit-1, Bilit-1, Remis-1 and Haselfoot-1.

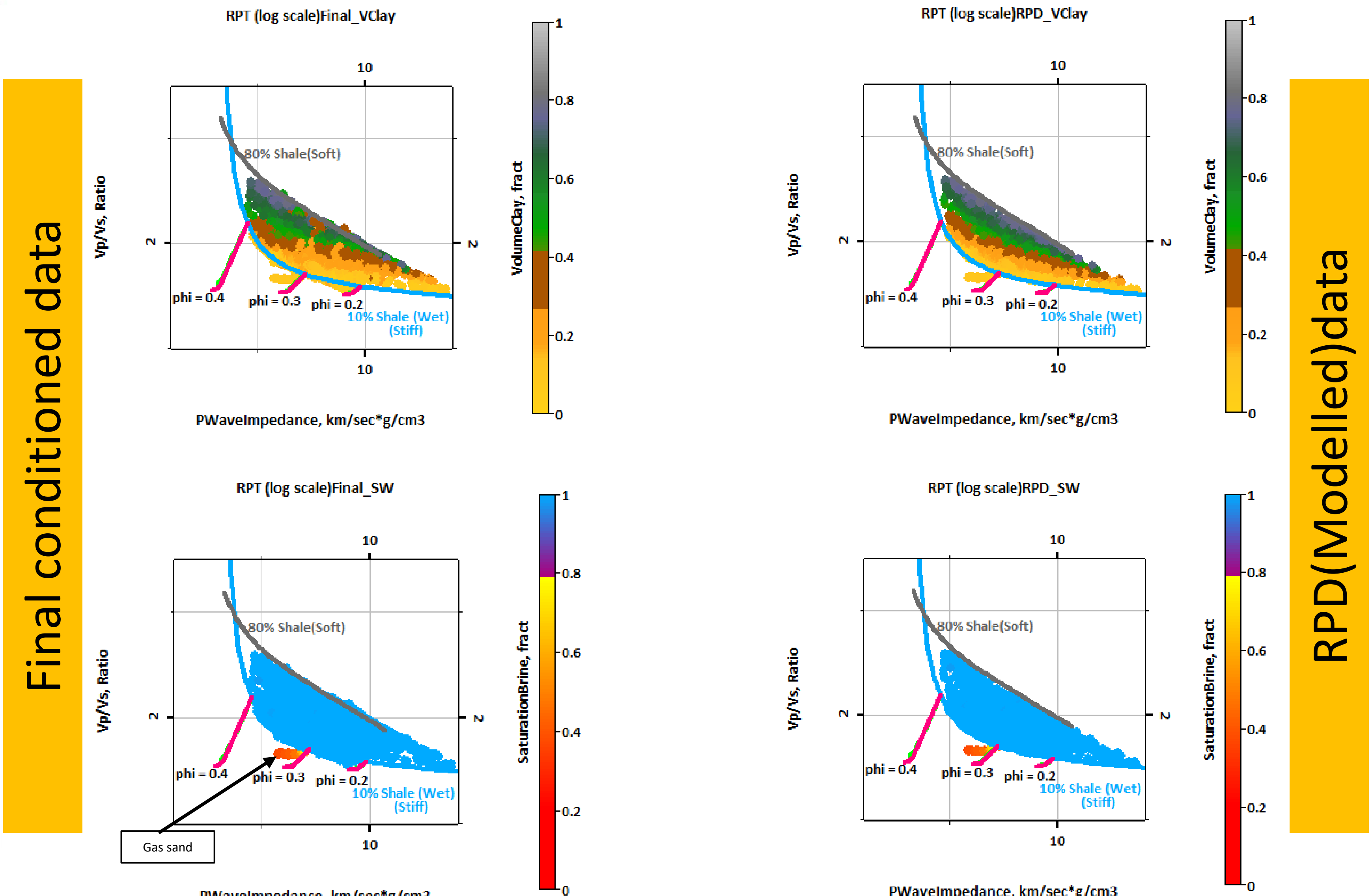
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data(Rhob and Vp ere conditioned while VS is totally modelled).





Samarang-2,Rock Physics Diagnostics (RPD) Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft/Stiff sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.



Shrumbu-1

Shrumbu-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is fair. Client's petrophysical interpretation was provided for this well for reference but only porosity and water saturation. Full elastic logs available only in the interval(2120m-T.D.)
- Vp and Vs was heavily edited using the RPD in some intervals especially from the top of the elastic measurement to the Mid Blue top.
- In some intervals due to the bad hole conditions, Rhob was edited using the RPD.
- Due to the lack of any reliable measurement in the gas sand interval(2140-2155m)density was fully modelled using a regression relation with the clay volume(calibrated with other intervals in the well where measurements look stable), then using the RPD velocity was predicted.
- Other logs include Gamma, Neutron, Caliper, Deep and Shallow resistivity, and Photoelectric factor.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Miocene marine sands in the orange and blue sequence. These are a series of turbiditic fine to very fine sands.
- The well penetrated many good sand layers especially the gas sand in the orange sequence with porosity up to 39% while other gas blocky sands could be observed in the blue sequence with porosity up to blue zone where the main gas bearing sand could be observed with total porosity ranged from 20-30%.

Volume of hydrocarbons:

- Interpreted gas saturation was best in top Orange zone in the interval 2142-2149 m with values up to 65%.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the clean wet sand interval(2379-2409m)yielded a formation water salinity of 17500 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.8 and Saturation exponent (n)=1.8 (based on the final well report).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to the measured data and when compared to good measured data in the nearby reference wells.

Fluid properties:

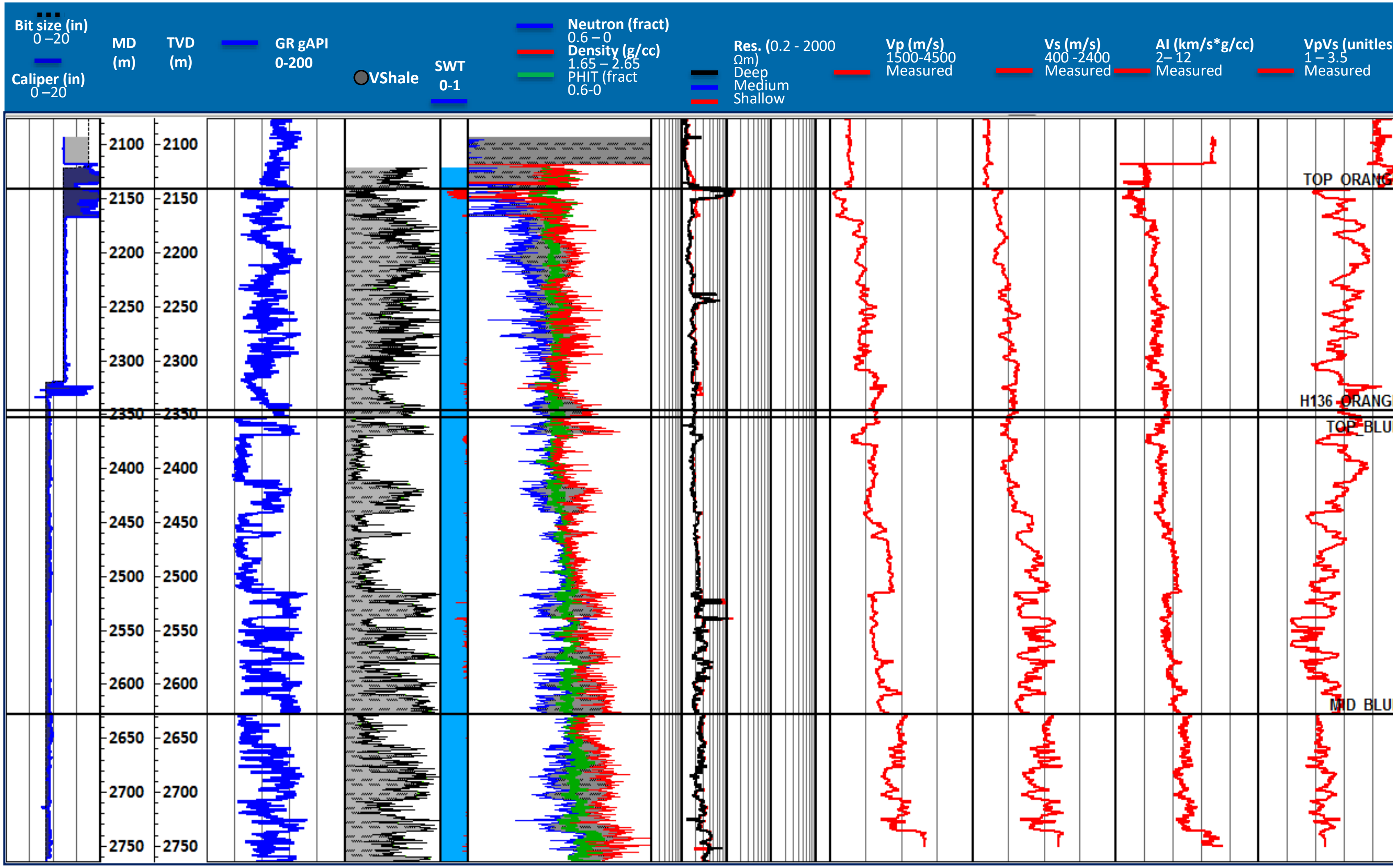
Fluid properties used in substitution have been taken from PVT report of nearby well Tomani-1. Main parameters used in this modeling are:

- Brine salinity: 17500 ppm[Pickett plot]
- Gas gravity: 0.64
- Oil Gravity: 35 API [Assumed]
- Gas / Oil ratio: 100 (L/L)[Assumed]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the IVC stage using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination with the brine sands.
- AVA class III was observed near the gas sands @ 2220m for all hydrocarbon cases at in situ reservoir conditions compared to class II for the brine case.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) no significant change for the AVA class could be noticed except the oil case move to be more as class II response.

Shrumbu-1 Input Logs



Additional data includes pressure, temperature data, cuttings descriptions and final geological report.

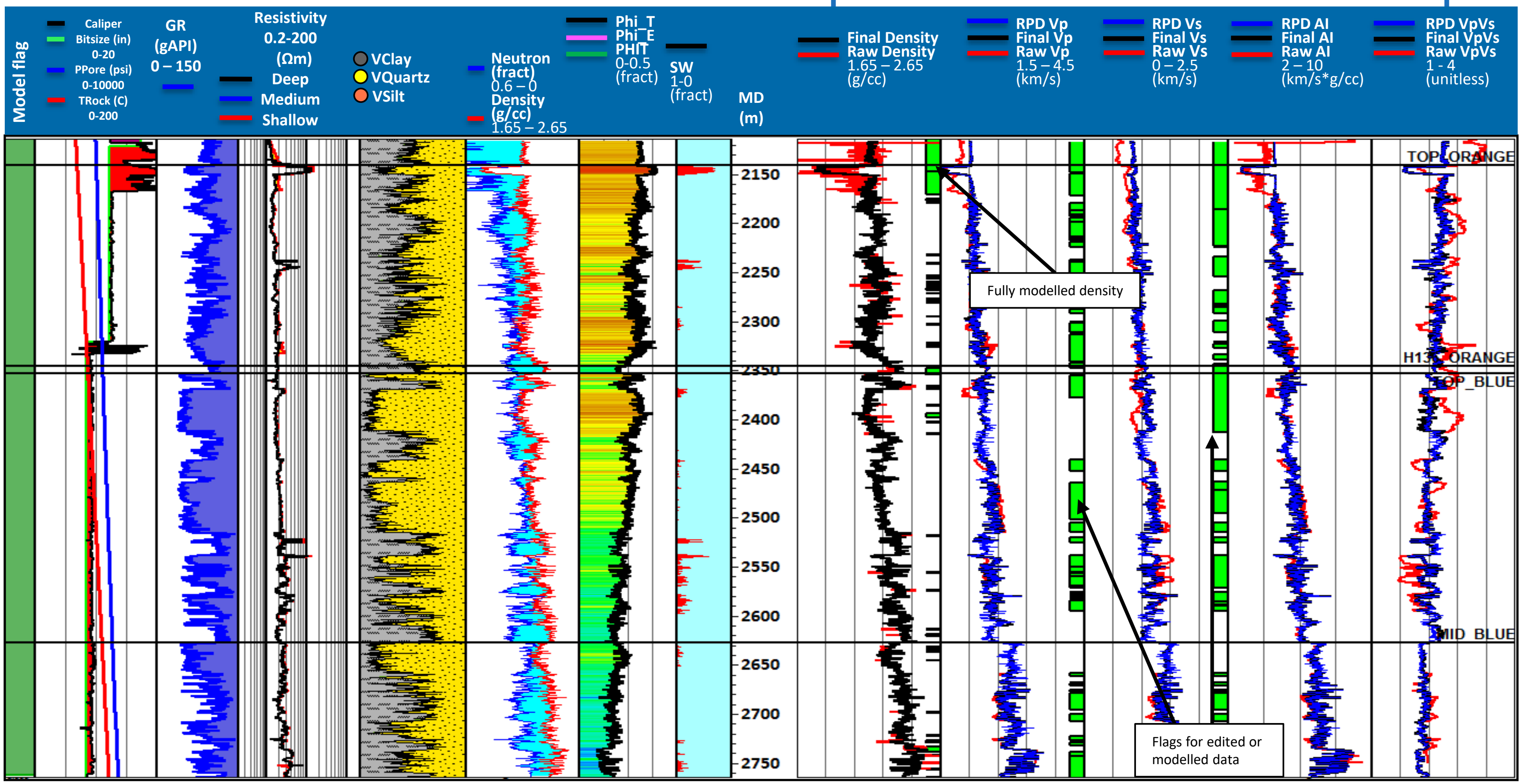
Shrumbu-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of Elastic logs to end of logs

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming.
Petronas equivalent curve name in parentheses

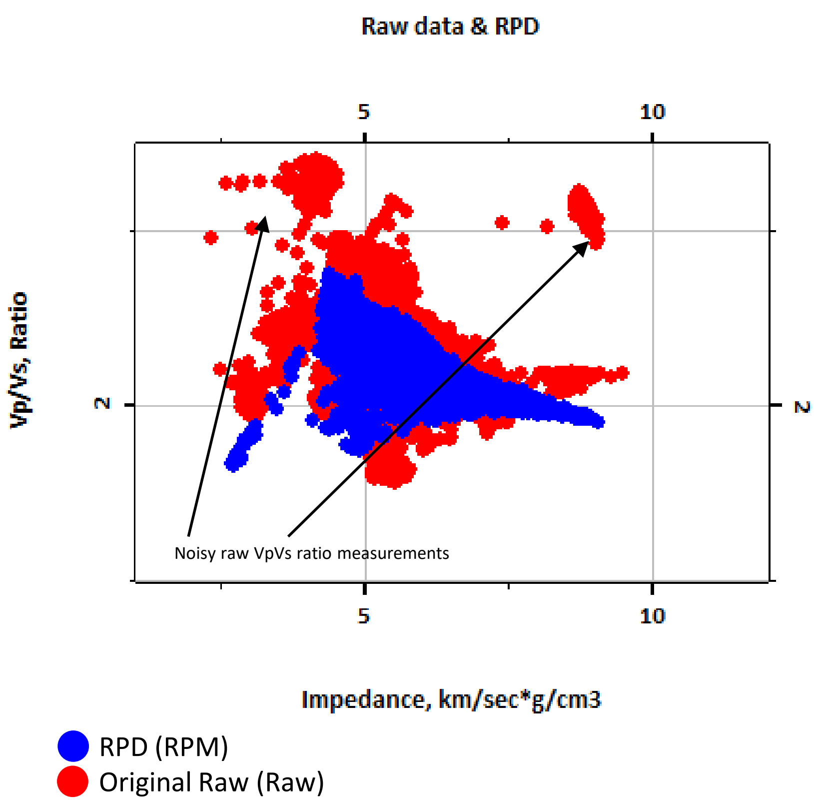
- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve



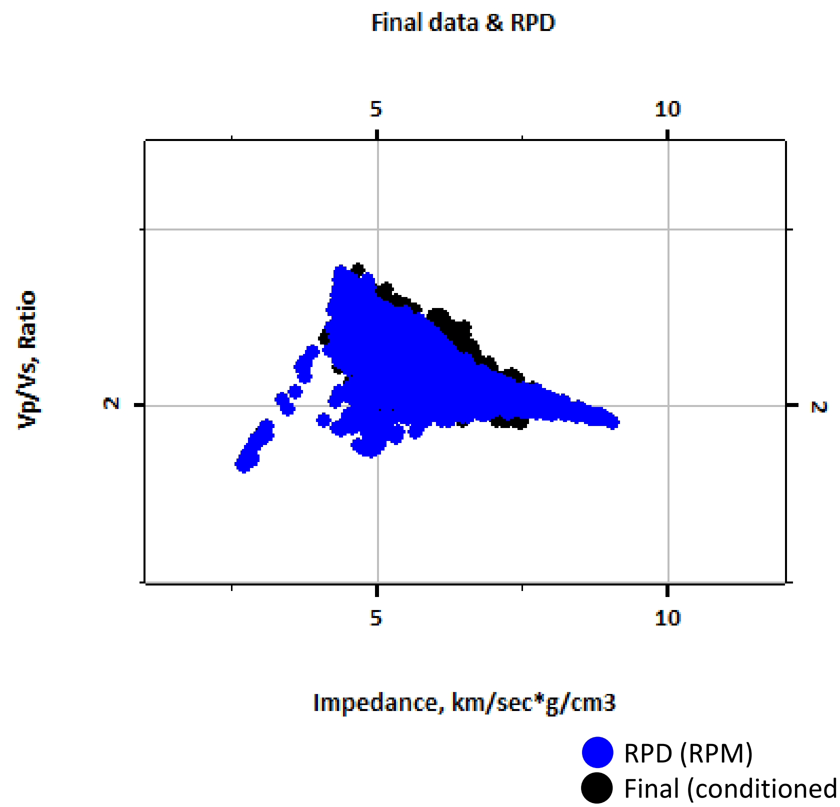
Major edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

Shrumbu-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.



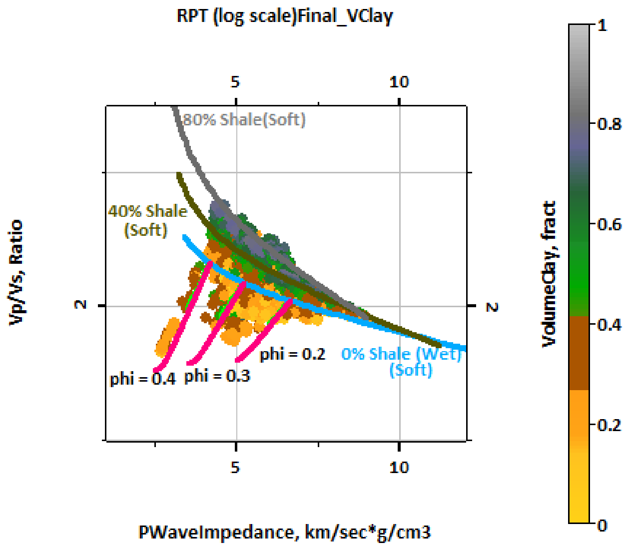
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

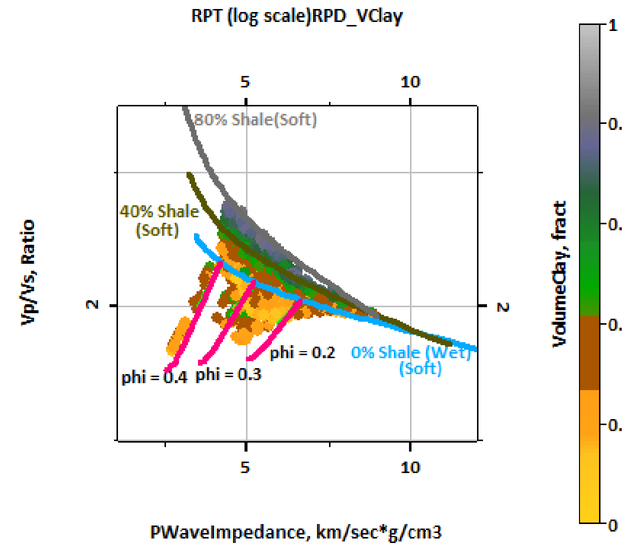


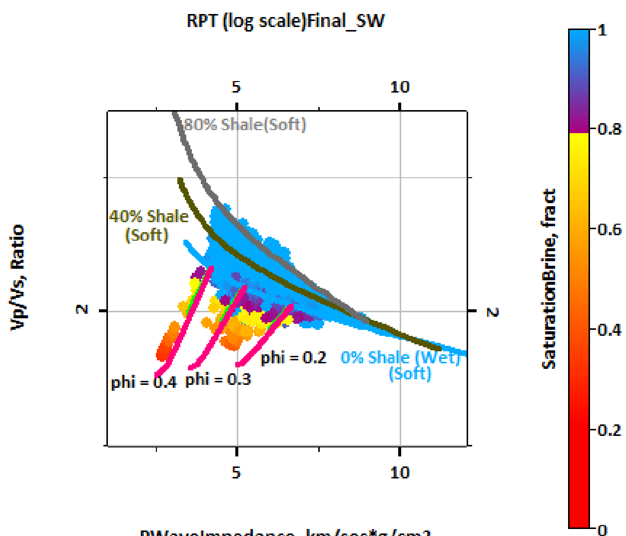
Shrumbu-1,Rock Physics Diagnostics (RPD) Rock Physics Models, Full Well

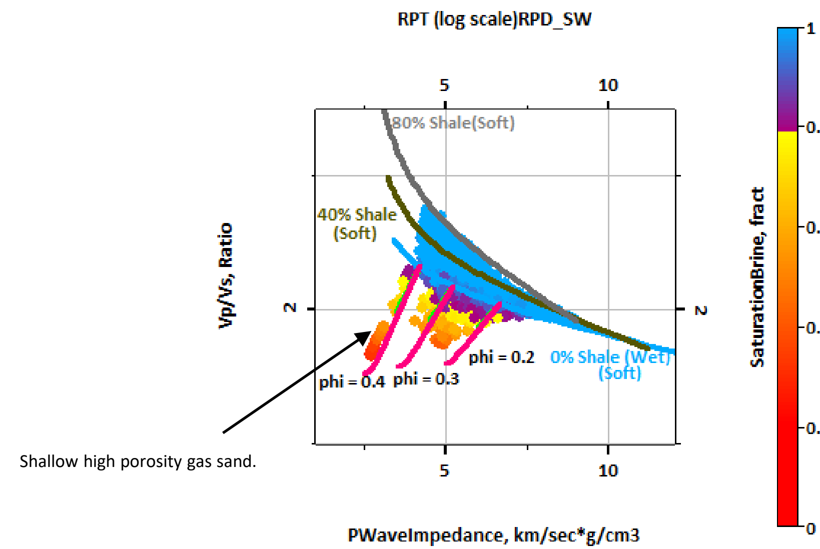
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Sipadan-1

Sipadan-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is fair. Density and compressional velocity is available from 932m – 1782m, no quality shear is available.
- There are a few minor edits to Vp.
- The density suffers from general spikiness in places, but more significantly measured density was increased by a factor of 1.03 in the zone from well top to 1500m. This edit has been made based on comparing Vp/Rhob, Phi_T/Depth, and Vp/Depth trends with this well and Tomani-1, Biris-1 and Sukau Gaya-1 where the trends are otherwise very similar (as well as comparing to the response below the casing at 1500m) – applying this correction to Rhob made all trends consistent and reasonable.
- Other logs include Neutron and PEF (though not usable) run over the same interval as the elastic logs and Gamma Ray, and Deep resistivity run over the full logging run from 595m – 1782m.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method with Neutron/Density in places.

Reservoir characteristics:

- In terms of lithology the reservoir targets, Feeder Channel, Intra Stage IVD, and Lower Stage IVD, are sandstones interbedded with claystones.
- Porosities in the clean zones range from 26% - 36%, with an average around 33%.

Volume of hydrocarbons:

- There are some minor gas shows indicated in the reporting though there is no indication in the log response of any hydrocarbon presence. The well is interpreted as fully brine saturated.

Water saturation (Sw):

- Rw has been calculated from Pickett plot as 0.25 Ohmm at the clean sand at 1390m, temperature is 174° F for a salinity of 10000ppm.

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that from the point where the elastic logs started down to the T.D. the Soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich zones. Primary analog wells for calibrating models are Tomani-1, Biris-1 and Sukau Gaya-1.

Fluid properties:

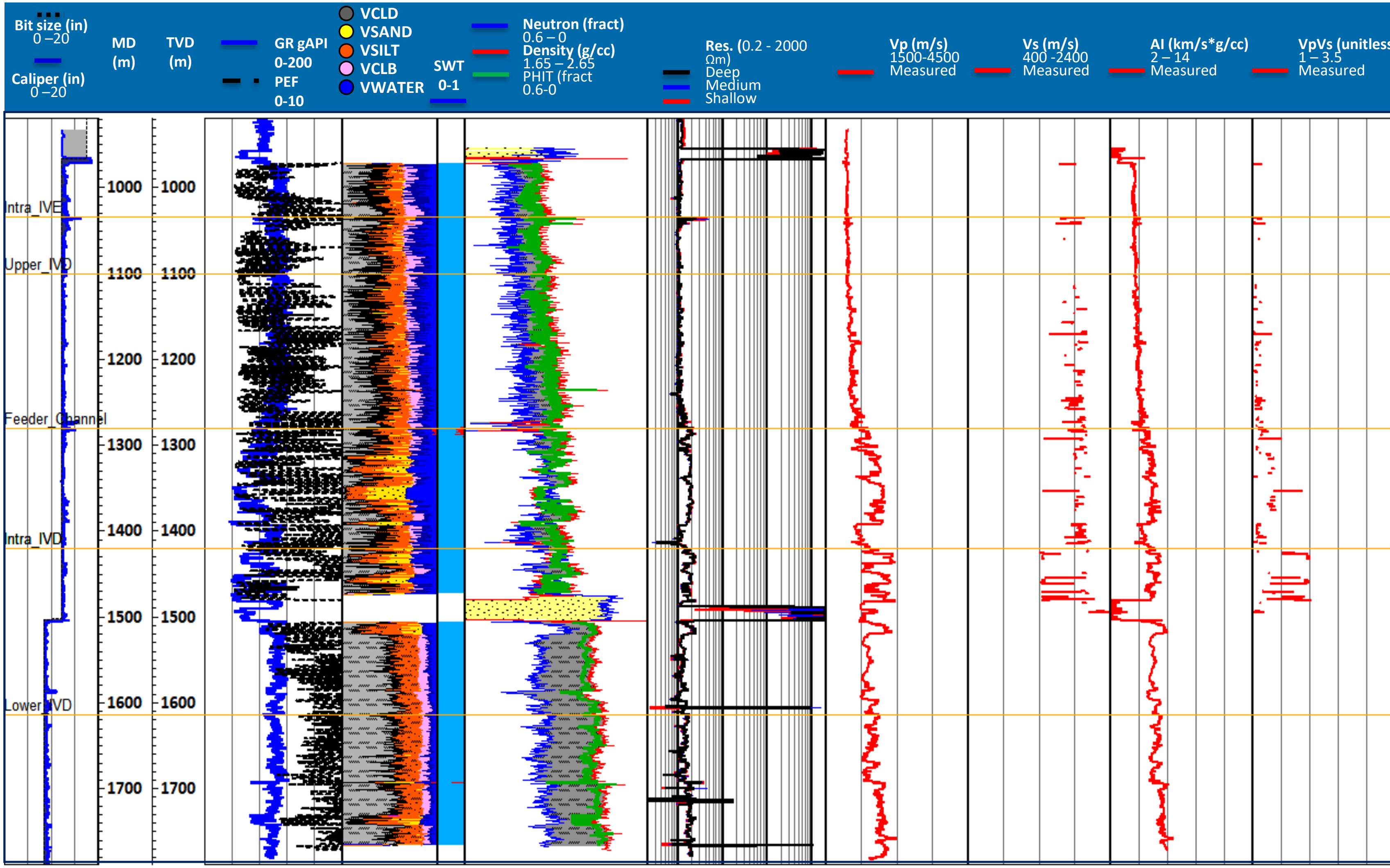
Fluid properties used in substitution have been taken from regional data. Main parameters used in this modeling are:

- Brine salinity: 10000ppm [from Pickett]
- Gas gravity: 0.64 [Tomani-1 PVT]
- Oil Gravity: 44 API
- Gas / Oil ratio: 200 (L/L)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the Feeder Channel, Intra Stage IVD, and Lower Stage IVD reservoirs (there is no reservoir present in the Upper IVD) using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with poor to fair discrimination with the brine sands.
- The major reservoir in the Feeder channel at 1345m shows a Class III AVO response with strong separation among fluids. With decreasing porosity the amplitude of the response decreases, though remains a Class III and fluid separation is not diminished much.

Sipadan-1 Input Logs



Additional data includes mud weight, temperature data, deviation survey, cuttings descriptions and final geological report.

Sipadan-1 Geophysical Well Log Analysis (GWLA) – Full Well

model type flag

Unconsolidated rock model

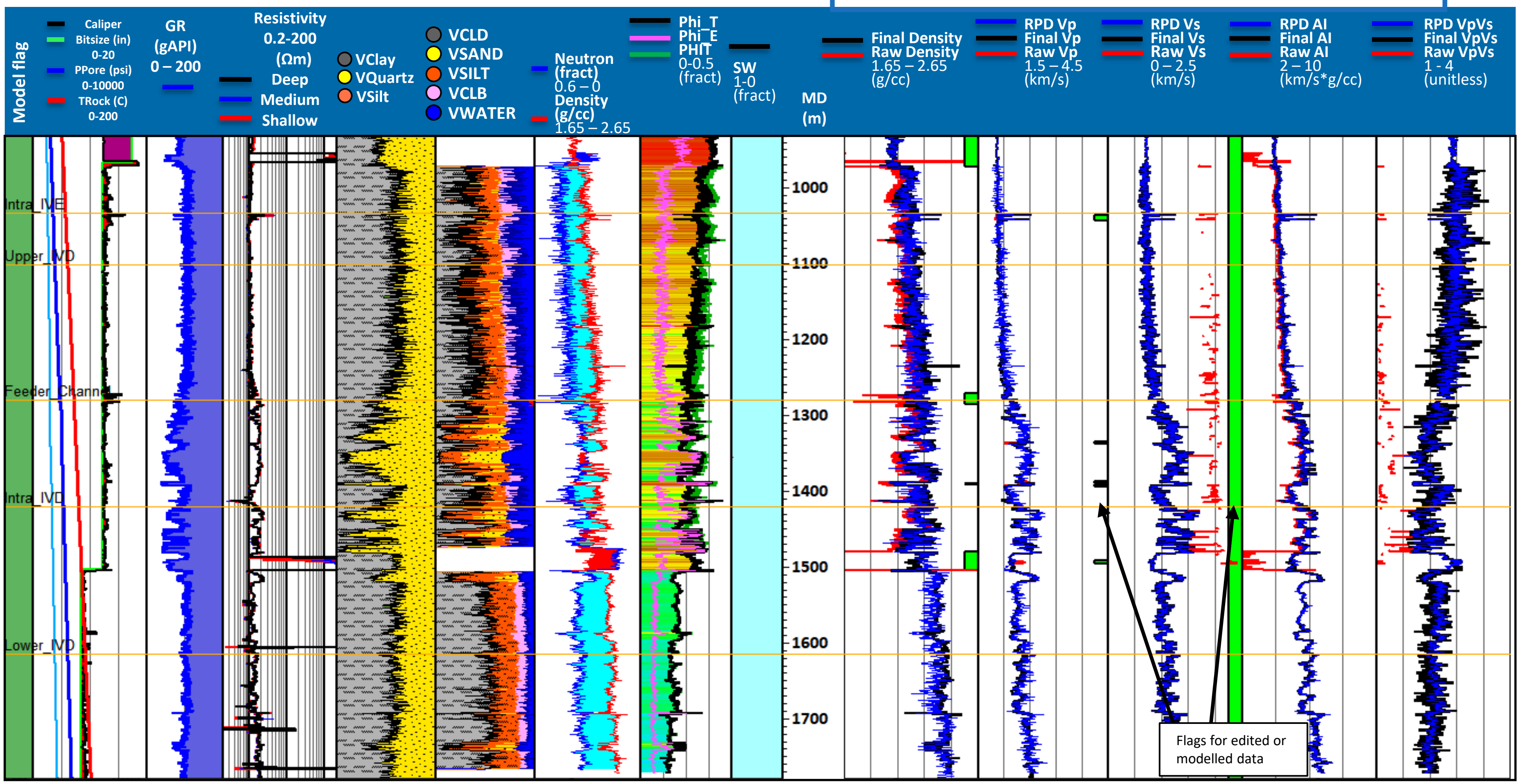
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve



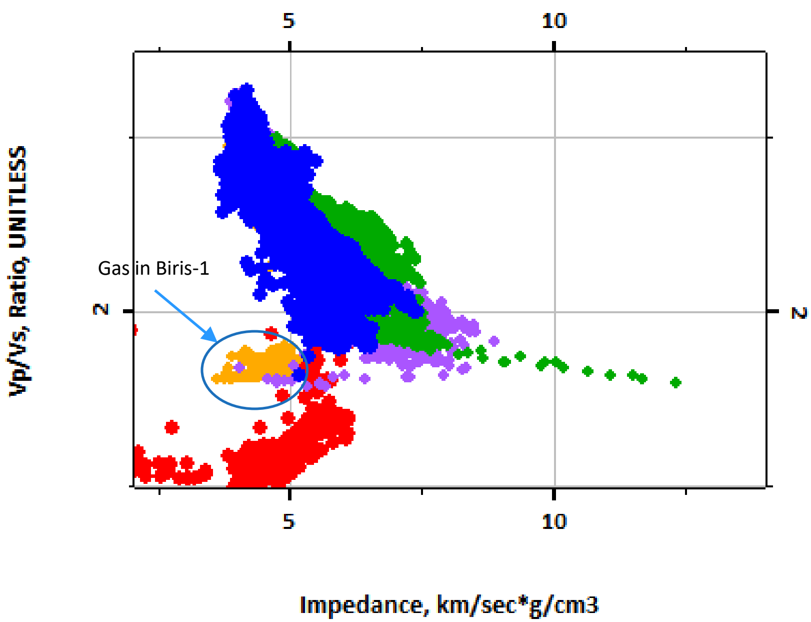
Some minor edits to the Vp response – major edit is to the density response in the shallow section. Comparison of trends between upper and lower well sections as well as to wells showing similar Vp trends (primarily Sukau Gaya-1, Tomani-1, and Biris-1) reveal the density should be increased by a factor of 1.03. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data.

Sipadan-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the analog wells with similar trends in the elastic data, given the measured shear in Sipadan-1 is not viable.

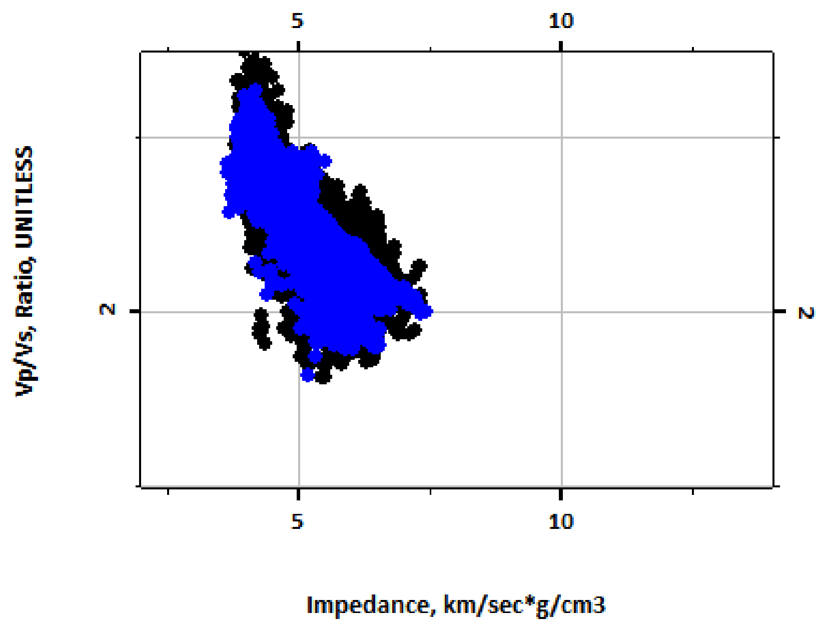
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

Raw data & RPD



RPD (RPM)
Original Raw (Raw)
Sukau Gaya-1 RPD
Tomani-1 RPD
Biris-1 RPD

Final data & RPD

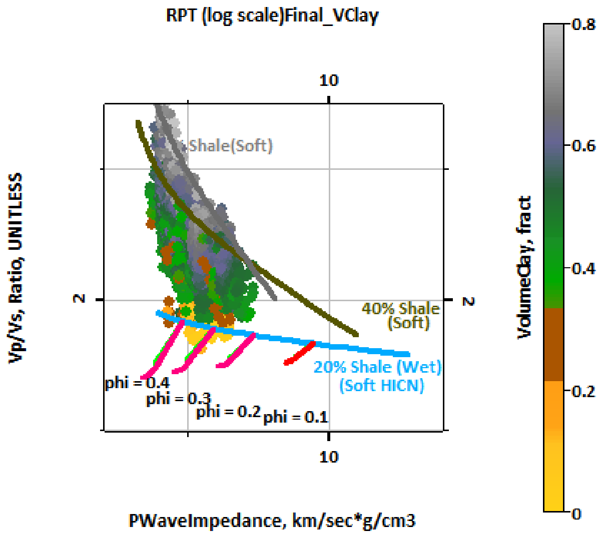


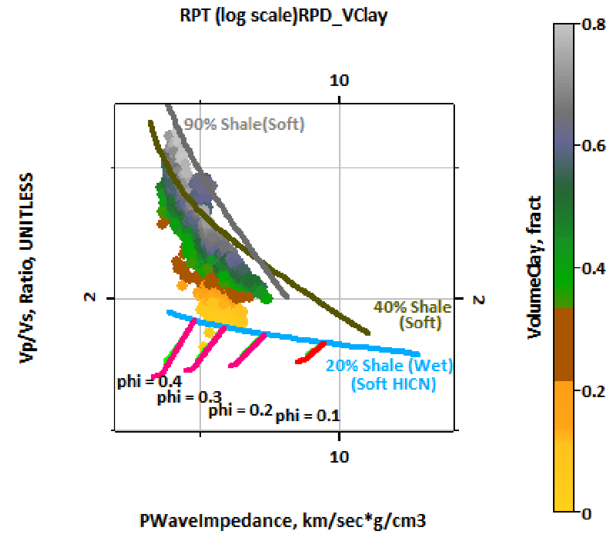
RPD (RPM)
Final (conditioned)

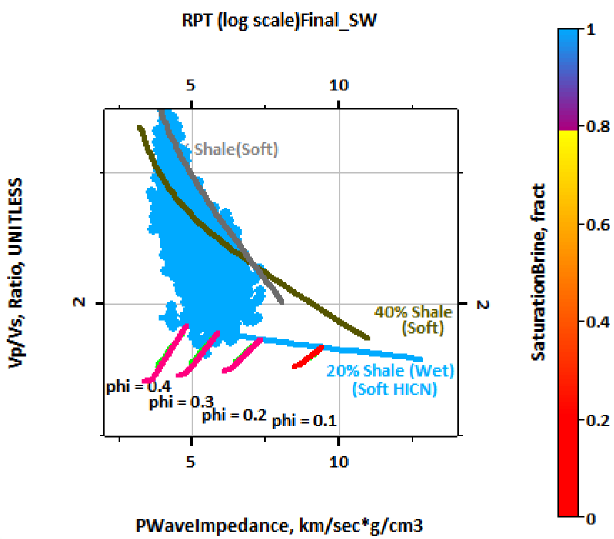
Sipadan-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

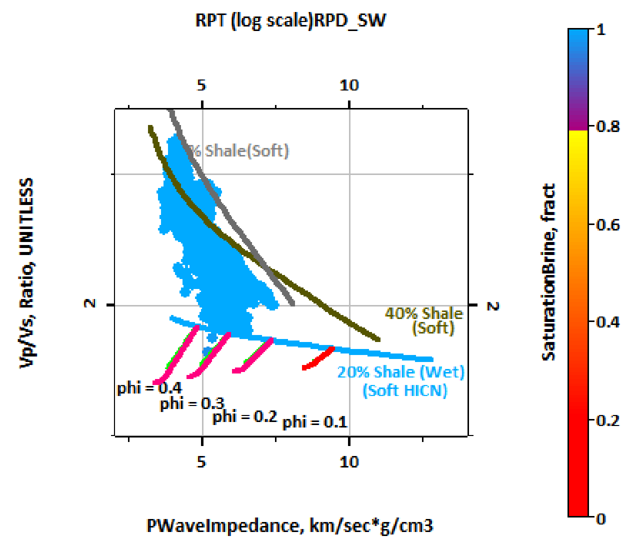
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

South Furious-1

South Furious-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality is poor especially the density and the sonic in some intervals but the data availability is fair. Client's petrophysical interpretation was not provided for this well.Full elastic logs except VS were available throughout the wellbore covering the interval (400m-T.D.)
- Shear wave velocity(VS)was fully modelled in the well using the RPD after the model was carefully calibrated based on the offset wells behaving elastically the same especially(Danum-1 nearby and Bilit-1 to the south) The resulted Vs matched in trend all the nearby wells especially the final modelled results for Bonanza-1(most closest well) and West Emerald especially when comparing same penetrated section(IVD stage).
- Due to the sever bad hole conditions density was completely replaced with the modeled one above 1400m and below 2000m since the original one was not honoring the density trend in the area when compared to many nearby wells with good measured data.
- Vp was also totally replaced with the modelled one in the interval(1030-1100 and 1190-1250m) after carefully calibrated the model with the good measured data present in the well and also in the offset wells.
- Elastic curves in the bad Vp and Density measurements intervals were filled using deep resistivity to predict Vp via Faust equation then density and Vs were estimated using the RPD.
- Other logs include Gamma, SP, Caliper, shallow and Deep resistivity, which all run for the full logging run to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Miocene marine sands found in the different stages(C and A)stages. These are a series of turbiditic fine to very fine soft sands.
- The well penetrated in stage IVC some good porosity sand but all were wet while in the IVA stage the sand characterized by very low porosity and permeability.

Volume of hydrocarbons:

- All the penetrated sand reservoirs were 100% brine saturated.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the clean wet sand(1040-1125m)yielded a formation water salinity of 23000 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.85 and Saturation exponent (n)=1.85 (assumed based on nearby wells' information).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to good measured data in the nearby reference wells and other wells on the same elastic trend.
- Elastic behavior for the well was carefully calibrated with the nearby wells and other wells honoring the same elastic trend for the well(P-Wave impedance depth trend) And concluded that the well elastically behaves similar to Danum-1 well and Bilit-1(even though it is far but elastically honoring South Furious-1 elastic trend) , so S-wave velocity completely modelled in the well based on the same model and parameters used in the offset wells which resulted in a matched trend with the calibrated nearby wells and very well behaved model when compared to the modelled results in the most nearby wells(Bonanza-1 and West Emerald-1).

Fluid properties:

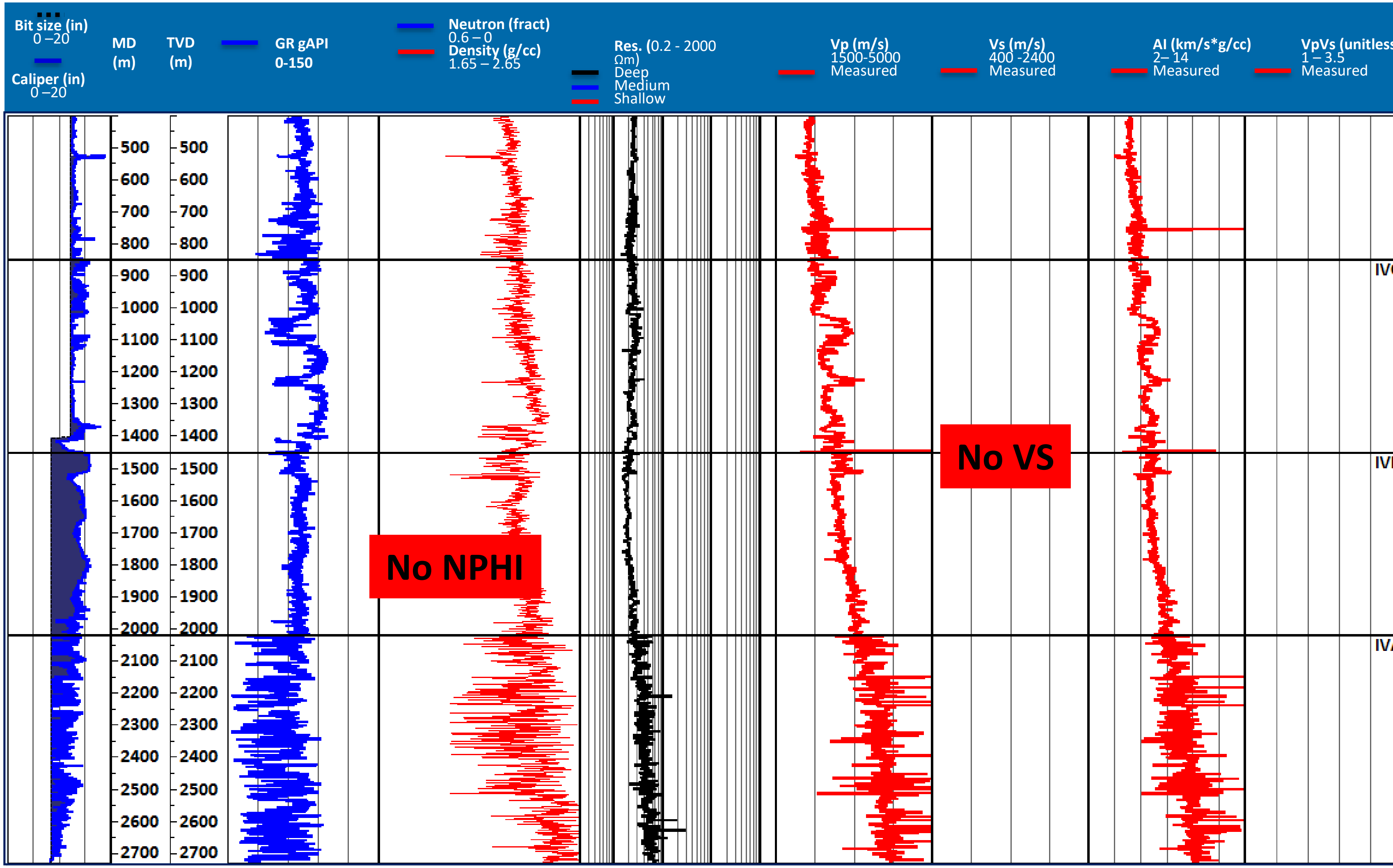
Fluid properties used in substitution have been taken from PVT report of nearby well Danum-1, Main parameters used in this modeling are:

- Brine salinity: 17500 ppm[Pickett plot]
- Gas gravity: 0.82[PVT analysis]
- Oil Gravity: 38.9 API[PVT analysis]
- Gas / Oil ratio: 500 (L/L) [PVT analysis]

Rock physics modelling (lithology, fluid and porosity):

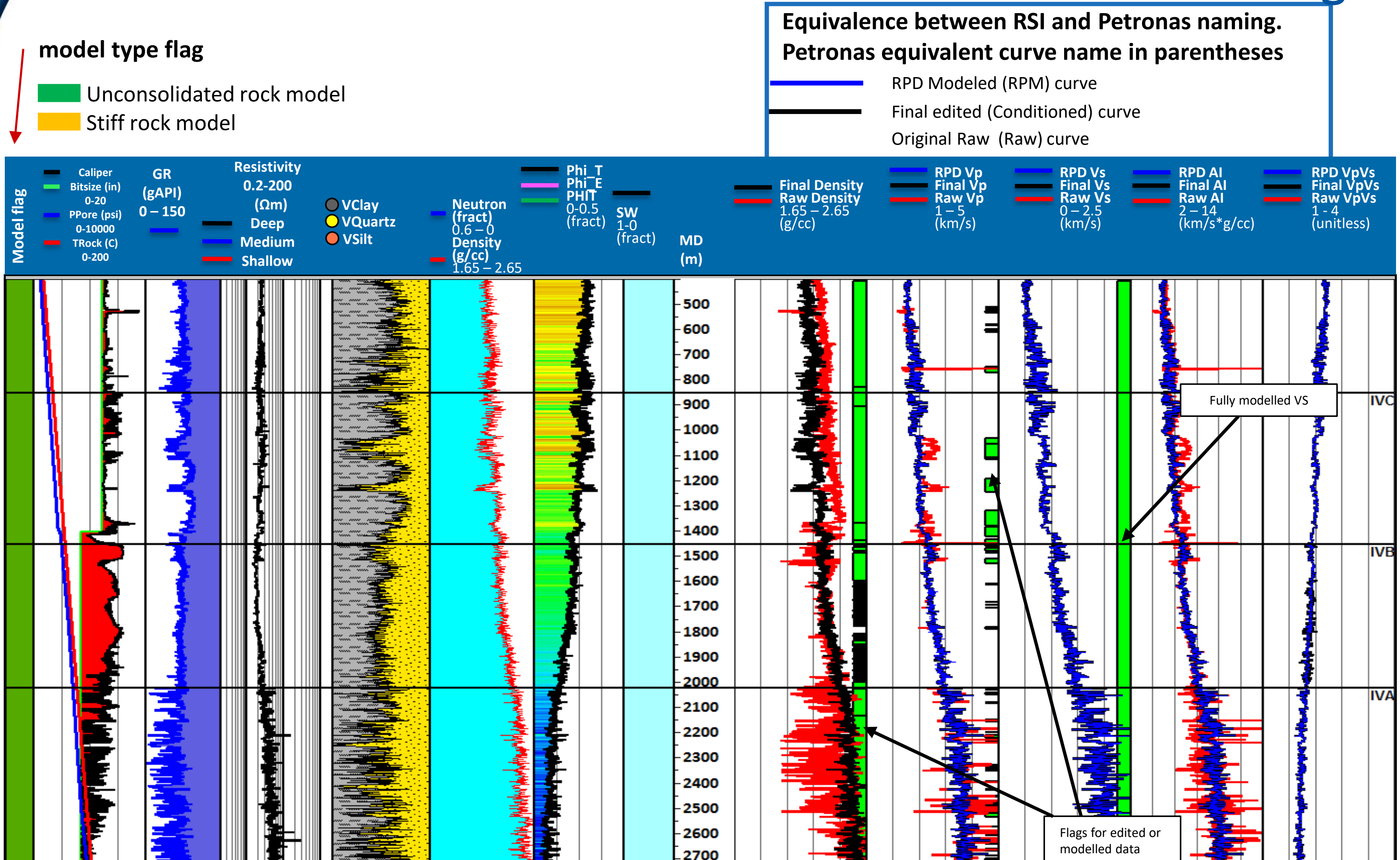
- Perturbational modelling was performed in the different Miocene sands of the IVD and IVC stages using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination with the brine sands.
- AVA class IV was observed near a good porosity sand(stage IVC) @ 1035m for all fluid cases at in situ reservoir conditions.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) no significant change for the AVA class could be noticed for all fluid scenarios.

South Furious-1 Input Logs



Additional data includes final geological report. No VS and NPHI(in most of the well interval) were found in the well.

South Furious-1 Geophysical Well Log Analysis (GWLA) – Interval from 400 to End of the logs

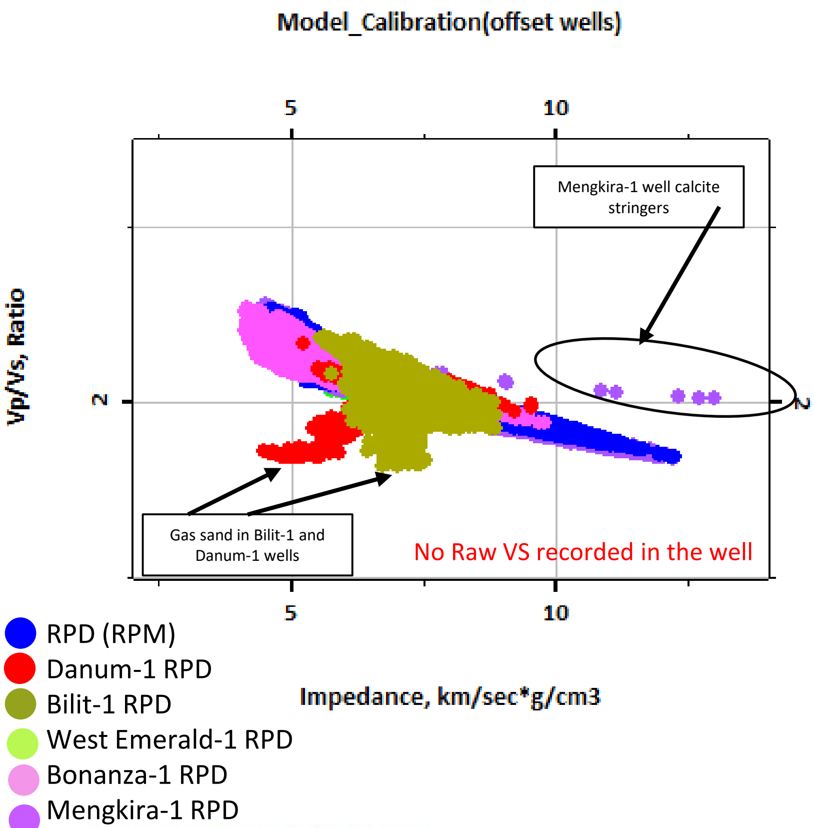


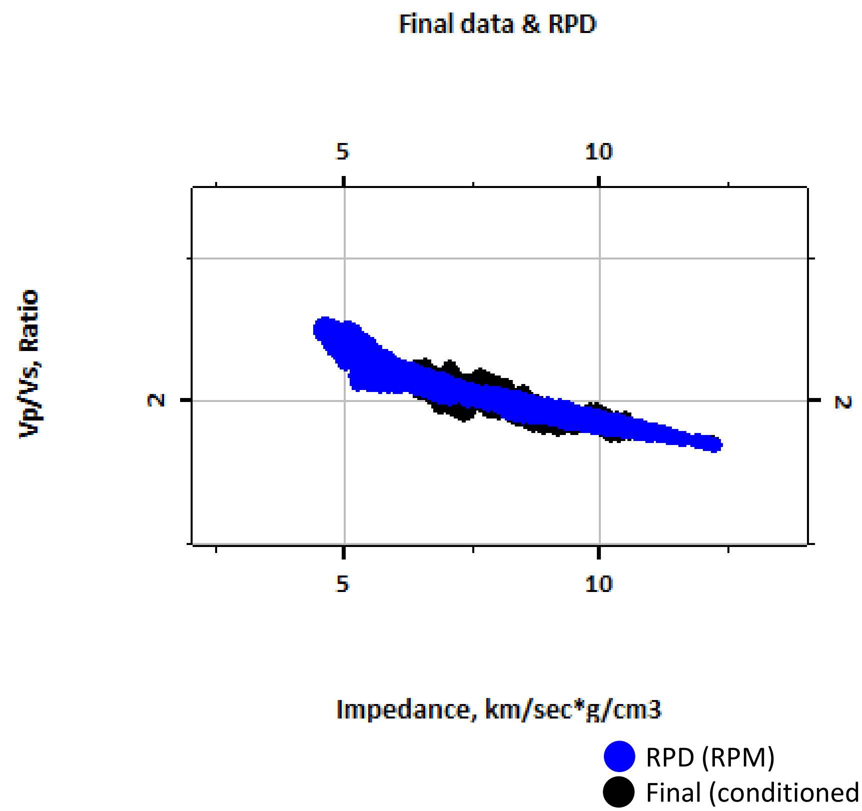
Many edits to the measured Density and model calibration is strong where measured data looks good and reliable. Granular media model (Soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) for both sand and clay rich intervals, with good correlation with the measured data in the well(VP and Rhob)and in the nearby wells. VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells.

South Furious-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the good calibration for the South Furious-1 well RPD with the nearby wells Danum-1, Bilit-1, West Emerald-1, Bonanza-1 well and Mengkira-1.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data(Rhob and Vp ere conditioned while VS is totally modelled).

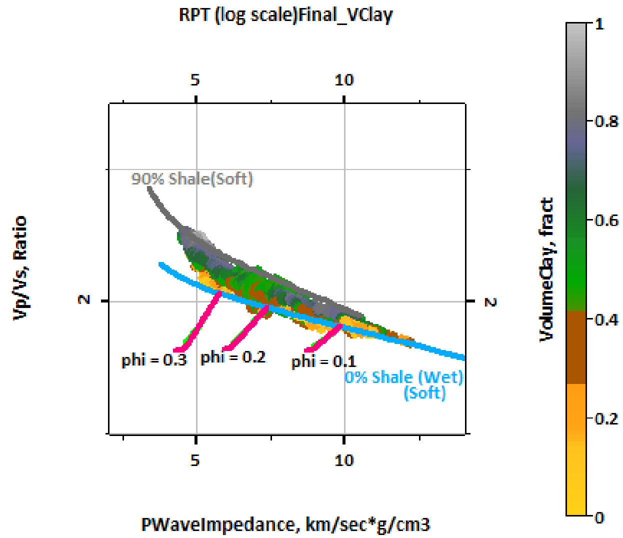


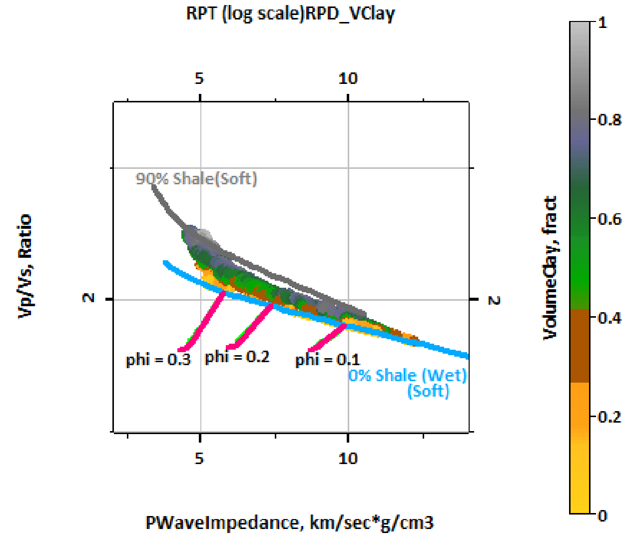


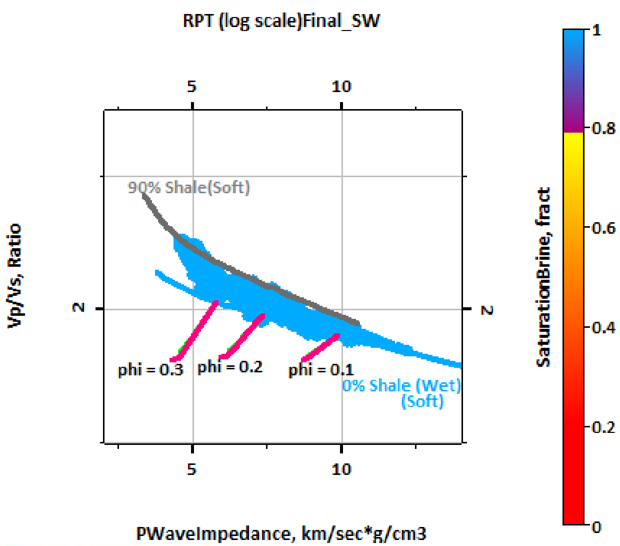
South Furious-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

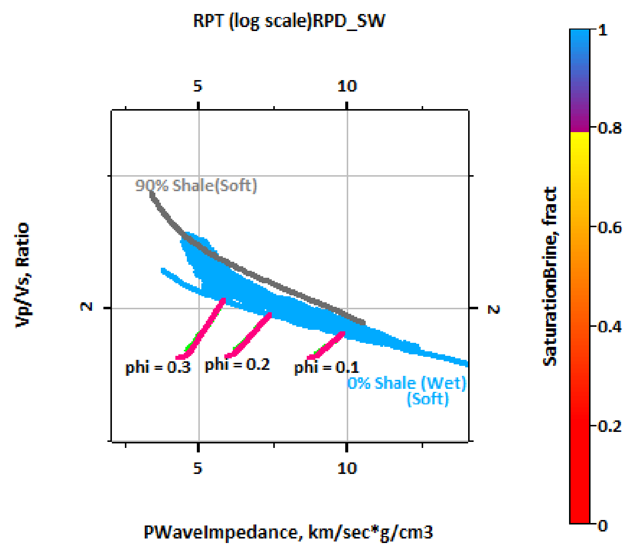
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Sukau Gaya-1

Sukau Gaya-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- A suite of elastic logs as well as GR and resistivity logs were provided from about 1070m to approximately 2170m.
- Data quality is in general good and wide gaps are absent. The compressional and shear velocity logs are of good quality in general although the shear velocity log show minor gaps at about 1850m. Elastic logs are in general good from 1050m to bottom of the well.
- Volumetric interpretation was provided from about 1070 to bottom of the well.

Clay volume (VClay):

- Volume of clay was calculated from gamma ray log and density-neutron suite. The mudlog from the report was used as a guideline to calibrate GR and density-neutron responses.

Reservoir characteristics:

- The IVC interval contains the highest percentage of sands with a high net to gross ratio. There are only two sands present in this interval. Sand2 is the more developed one with very low clay content and porosity reaching values of 32%. This interval is mainly interpreted as water wet.
- Sand1 in the same interval is much less developed, shows a slightly higher clay content and reaches porosity values of about 33%. This interval was also interpreted as water wet.

Volume of hydrocarbons:

- Sand1 and Sand2 interval sands were interpreted as water bearing.

Water saturation (Sw):

- Water saturation was estimated using Simandoux's equation. Parameters used for the calculation of water saturation were estimated from the Pickett Plot. Estimated parameters used for water calculation are a=1,m=1.8,n=2.0; Rw = 0.27 Ohmm @ 160 DegF. Conversion charts were used for water salinity estimation resulting in an approximated value of 10000ppm NaCl.

Sukau Gaya-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Rock physics diagnostics (RPD) and elastic log data editing:

- The rock physics diagnostics (RPD) was performed from top to bottom for this well. the Soft sediment model proved to be the best predictor for Clay intervals. In the sand interval a mixture of unconsolidated and cemented sands are present. In this case the unconsolidated and stiff models were used accordingly. These models have been used to edit the Vp, Rhob, and Vs data where necessary and to perturb the rock for changes to VClay and Phi_T at the Rock physics modelling (RPM) stage of the project.

Fluid properties:

Fluid properties used in substitution have been taken from main average values known in the area. Specific information for oil and gas parameters was not found in the reports. Salinity was estimated from Pickett Plot analysis . Main parameters used in this modeling are:

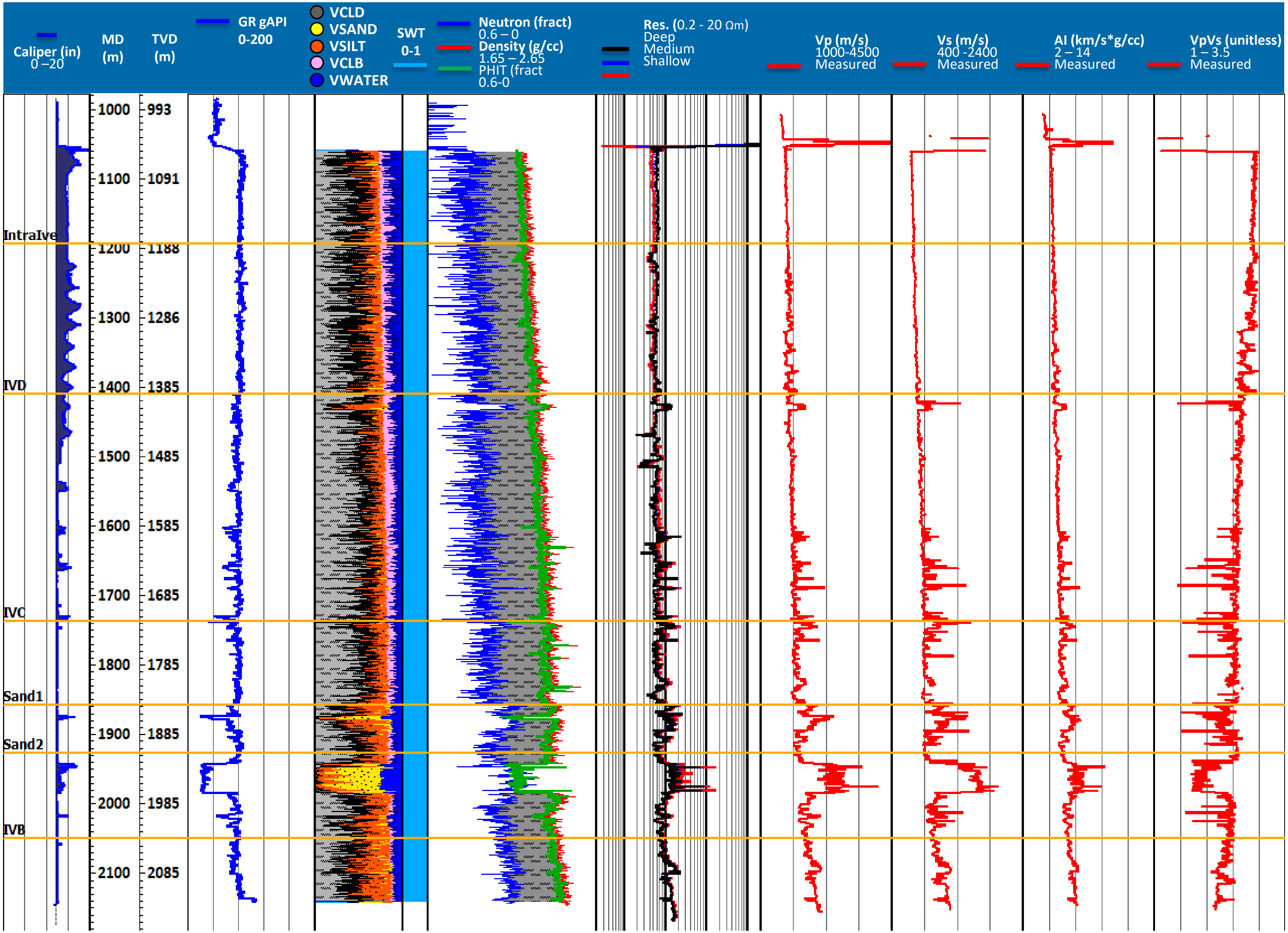
- Brine salinity: 10000 ppm (from Pickett plot analysis)
- Gas gravity: 0.7
- Oil Gravity: 44.4 API
- Gas / Oil ratio: 178 (L/L)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling can be performed in the Sand1 and Sand2 intervals. Perturbational modelling can calculate the effect in elastic properties with change of porosity, volume of clay, and fluid content of the rock. In general, gas saturated sands show lower Vp/Vs ratios and lower p-wave impedance (AI) values than wet sands at log scale. Fluid substitution is performed via Gassmann's model.

- Particular AVO responses will depend on the selected modeling interval, porosity and fluid content of the rock. As an example, the sand package at 1950m (Sand1 interval) was gas substitute allowing the Waster saturation to be reduced to 20%. Porosity was preserved for this exercise. This exercise showed much lower values for VpVs ratio and lower values for Acoustic Impedance compared to the wet case. Good separation of Gas and wet case was also observed in the upscaled data. AVO analysis at an interface defined at 1940m revealed a class II response somewhat well separated from the background trend, while the wet case showed higher intercept values leaving the points in the background trend.

Sukau Gaya-1 Input Logs



Sukau Gaya-1 Geophysical Well Log Analysis (GWLA)

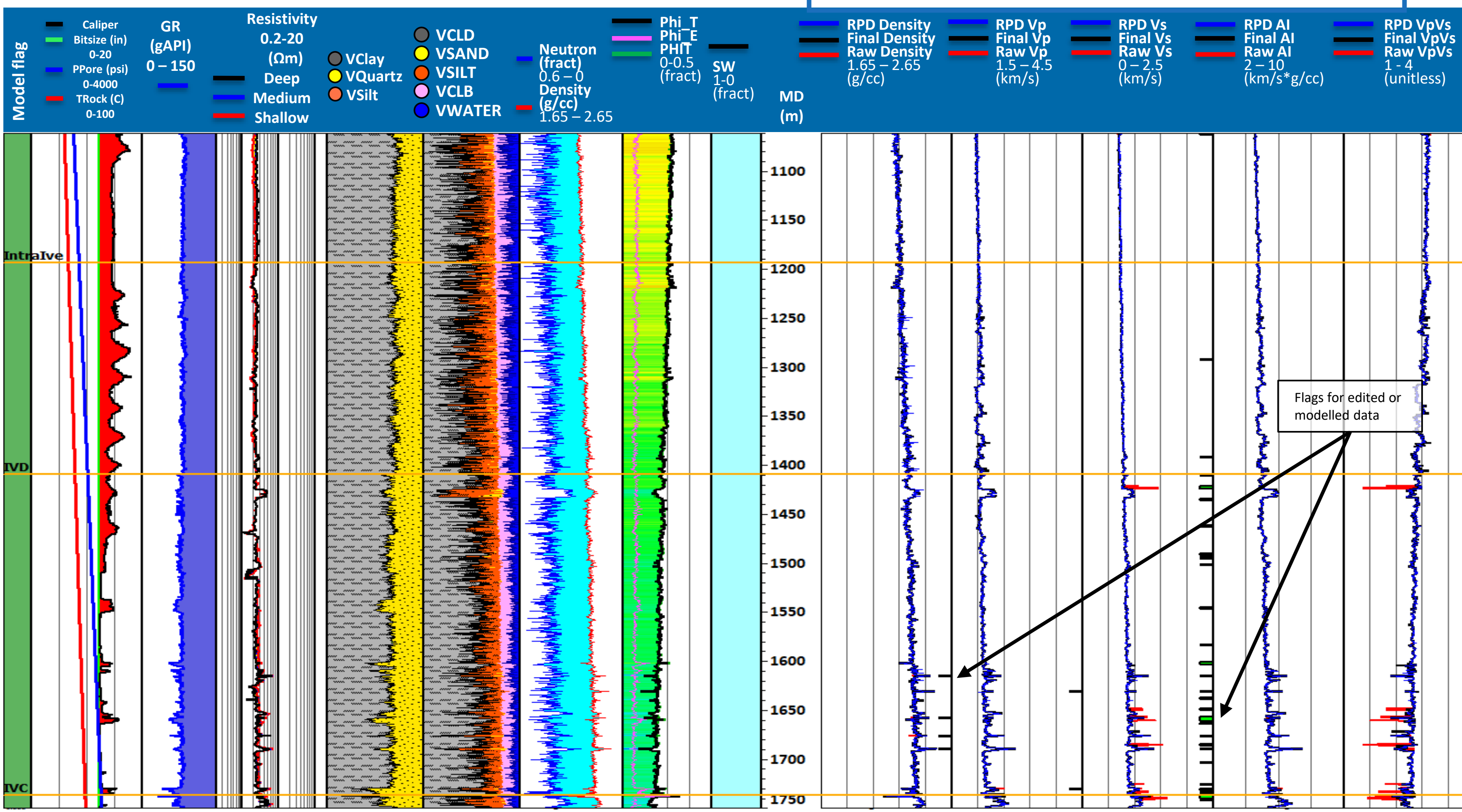
Interval from Top of logs (1708m) to 2160 m

model type flag

Unconsolidated rock model

Equivalence between RSI and Petronas naming.
Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve



Edits mainly performed in shear measurements to eliminate spikes. Data in general was of good quality.

Sukau Gaya-1 Geophysical Well Log Analysis (GWLA)
Interval from 2300 m to the bottom of the well

model type flag

Unconsolidated rock model

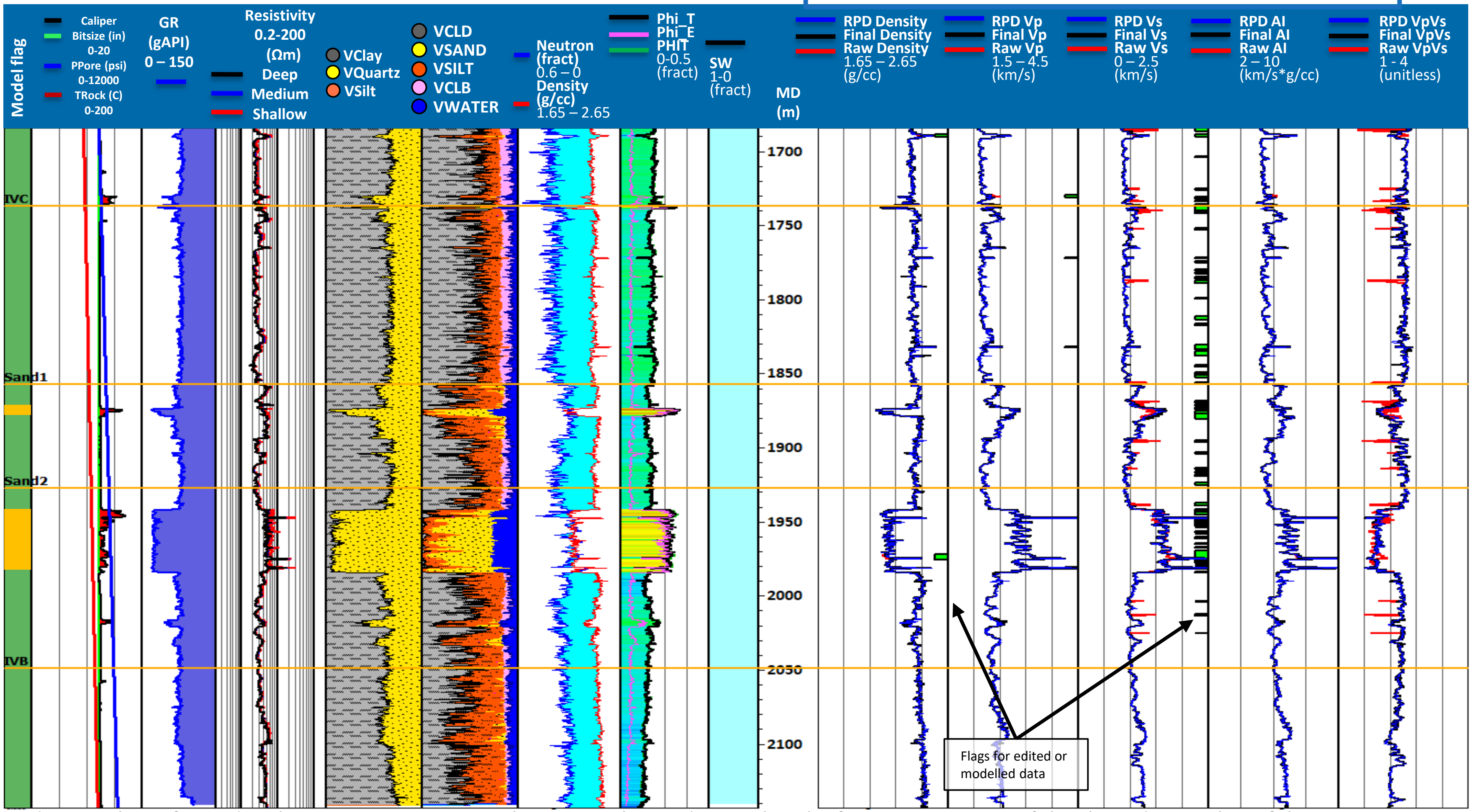
Stiff and unconsolidated rock models

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve

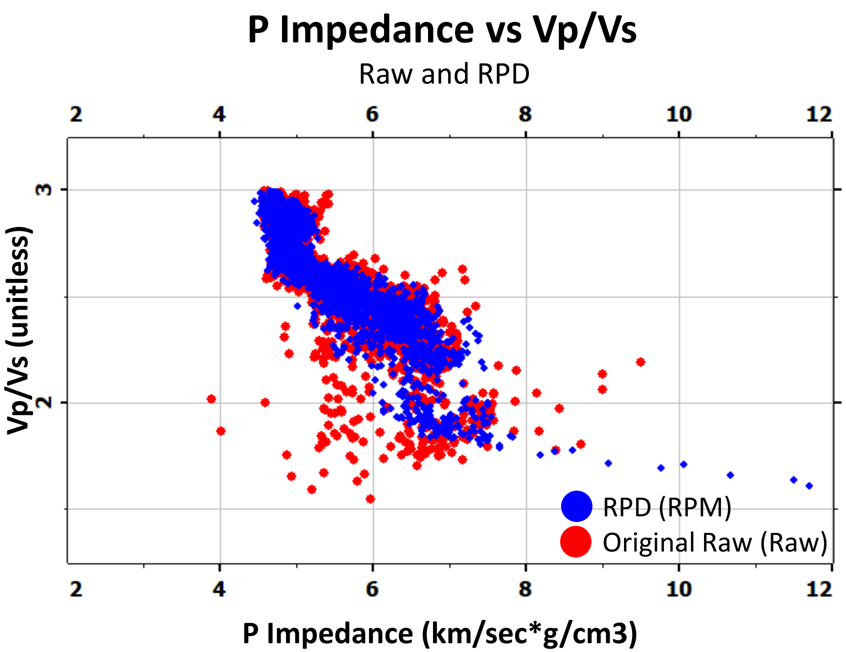


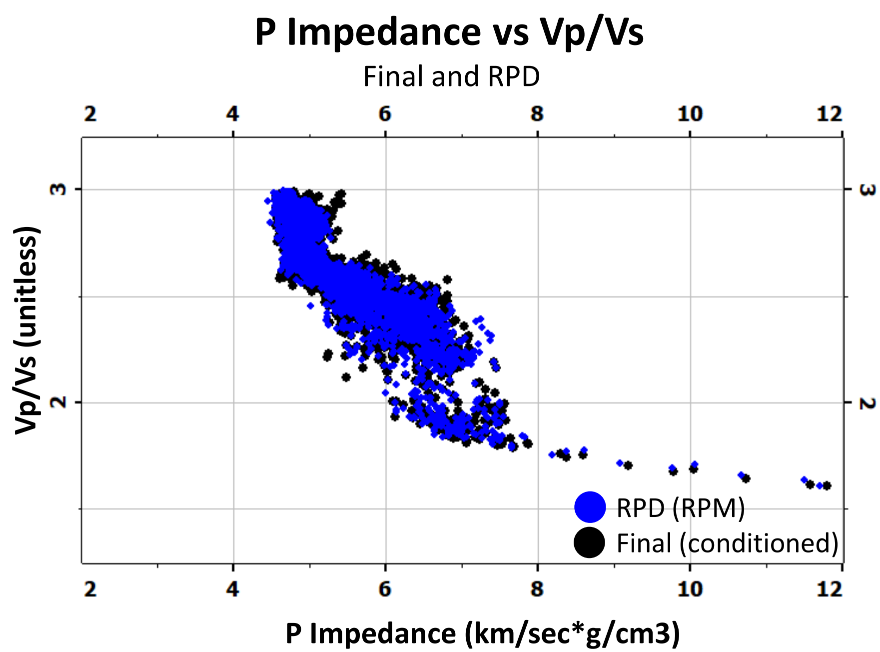
Edits mainly performed in shear measurements to eliminate spikes and normalize the frequency content of the shear data to that of the compressional measurements. Data in general was of good quality.

Sukau Gaya-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.



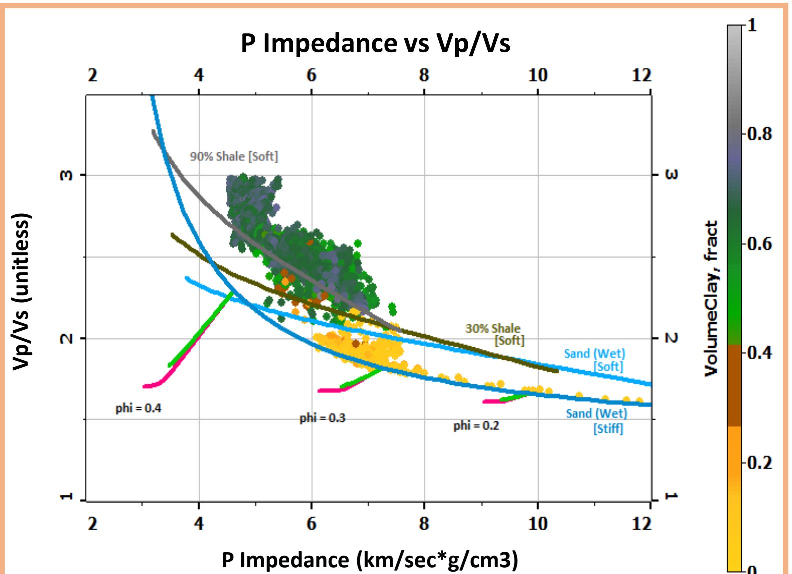


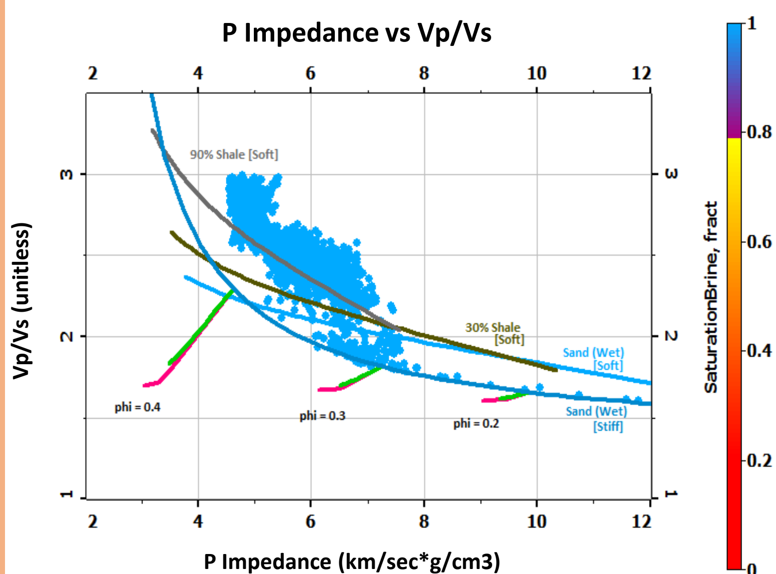
Open

Sukau Gaya-1,Rock Physics Diagnostics (RPD)
Rock Physics Models

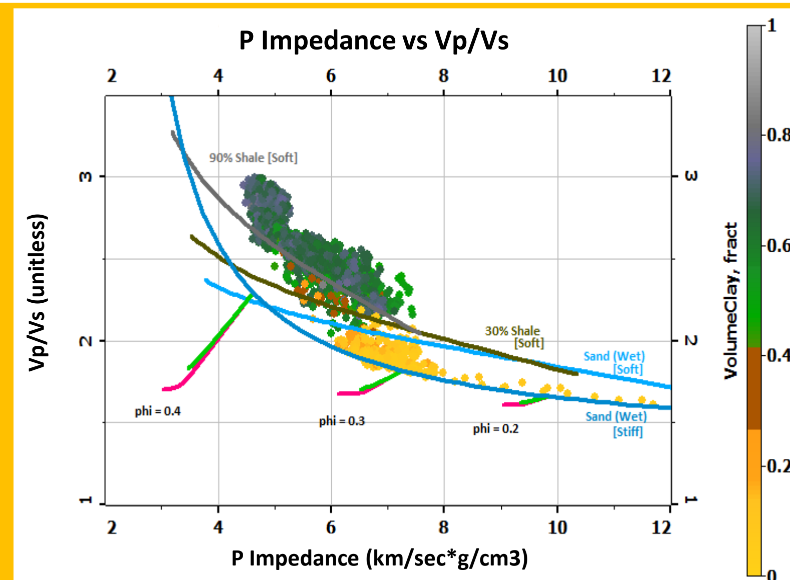
Cross plots Showing the Rock Physics Template lines, overlaid to both, the final (conditioned) elastic data to the left and the modelled data (RPM) to the right, color coded by clay volume (Top row) and water saturation (Bottom row).

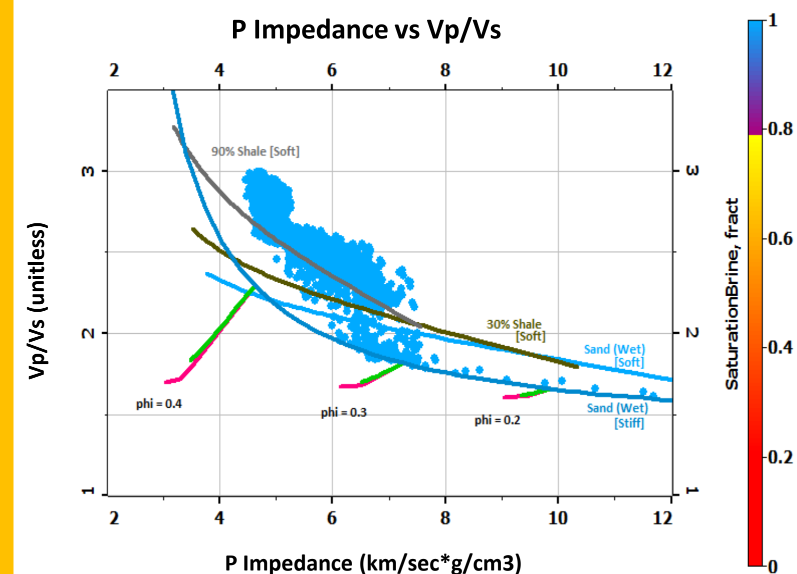
Final conditioned data





RPD (Modeled data)





Tekuyong-1

Tekuyong-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality is poor especially the density and the sonic in some intervals but the data availability is fair. Client's petrophysical interpretation was not provided for this well(except total porosity in some intervals). Full elastic logs except VS were available throughout the wellbore covering the interval (800m-T.D.)
- Shear wave velocity(VS)was fully modelled in the well using the RPD after the model was carefully calibrated based on the offset wells behaving elastically the same especially(Danum-1 nearby and Bilit-1 to the south) The resulted Vs matched in trend all the nearby wells especially the final modelled results for Bonanza-1(most closest well) and West Emerald especially when comparing same penetrated section(IVD stage).
- Due to the sever bad hole conditions density was completely replaced with the modeled one in the interval(2200-2400m)since the original one was not honoring the density trend in the area when compared to many nearby wells with good measured data.
- Vp was also totally replaced with the modelled one in the interval(1350-1750m) after carefully calibrated the model with the good measured data present in the well and also in the offset wells.
- Elastic curves in the bad Vp and Density measurements intervals were filled using deep resistivity to predict Vp via Faust equation then density and Vs were estimated using the RPD.
- Other logs include Gamma, SP, Caliper, shallow and Deep resistivity, which all run for the full logging run to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Miocene marine sands found in the different stages(D, C and A)stages. These are a series of turbiditic fine to very fine soft sands.
- The well penetrated very rare good sand layers in the main objective of the well(stage IVA) while in stage IVC the well penetrated about 2m of good porosity hydrocarbon sand.
- The logged interval of stage IVD especially in the section(880-1100m) characterized by many carbonate layers interbeded with sandstone beds.

Volume of hydrocarbons:

- The only hydrocarbon saturation calculated in the well was in Stage IVC good porosity sand layer with saturation of about 55% while all other sand reservoirs penetrated in the well were 100% brine saturated.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the clean wet sand(950-1025m)yielded a formation water salinity of 17500 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.85 and Saturation exponent (n)=1.85 (assumed based on nearby wells' information).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to good measured data in the nearby reference wells and other wells on the same elastic trend.
- Elastic behavior for the well was carefully calibrated with the nearby wells and other wells honoring the same elastic trend for the well(P-Wave impedance depth trend) And concluded that the well elastically behaves similar to Danum-1 well and Bilit-1(even though it is far but elastically honoring Tekuyong-1 elastic trend) , so S-wave velocity completely modelled in the well based on the same model and parameters used in the offset wells which resulted in a matched trend with the calibrated nearby wells and very well behaved model when compared to the modelled results in the most nearby wells(Bonanza-1 and West Emerald-1).

Fluid properties:

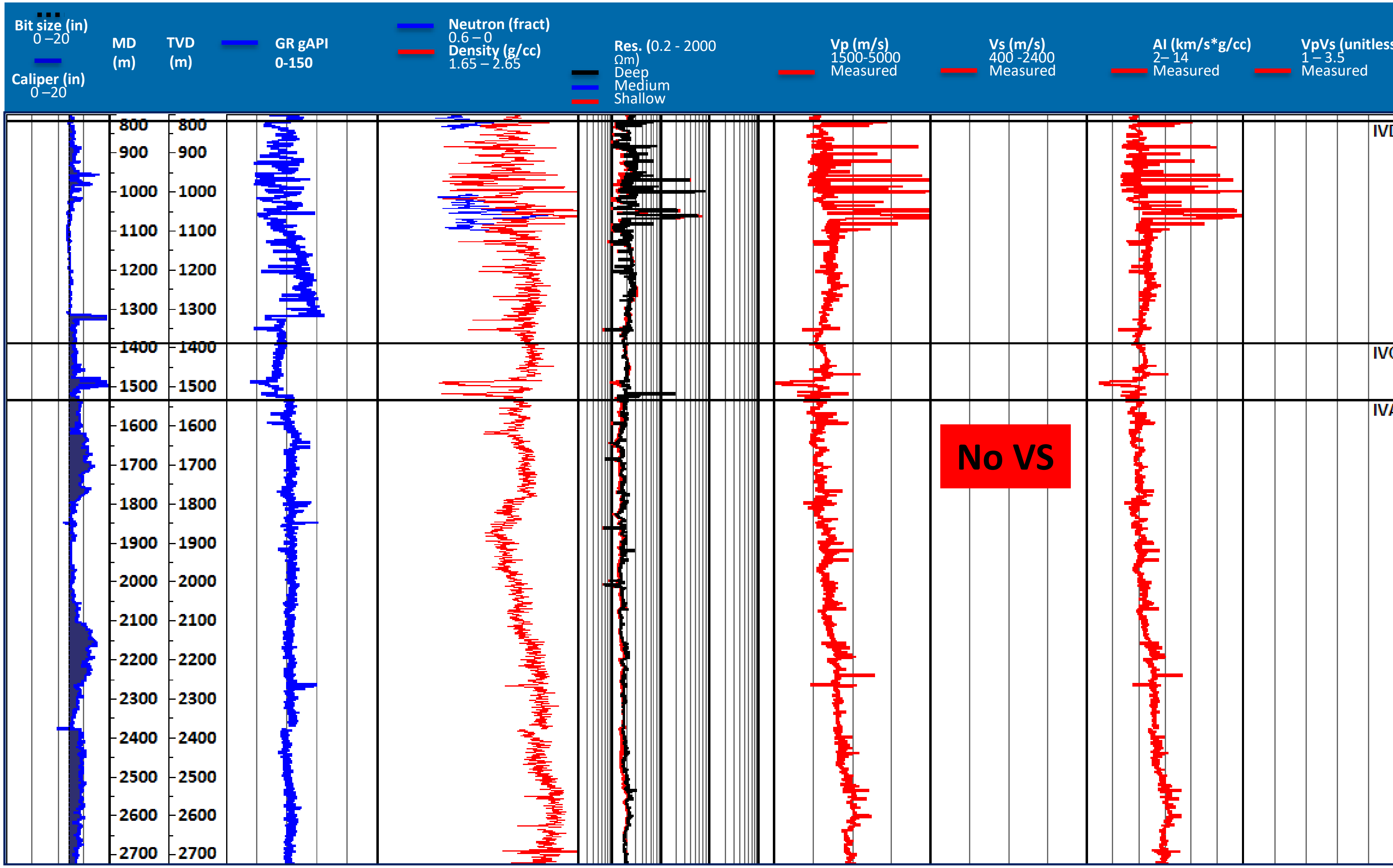
Fluid properties used in substitution have been taken from PVT report of nearby well Danum-1, Main parameters used in this modeling are:

- Brine salinity: 17500 ppm[Pickett plot]
- Gas gravity: 0.82[PVT analysis]
- Oil Gravity: 38.9 API[PVT analysis]
- Gas / Oil ratio: 500 (L/L) [PVT analysis]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the IVD and IVC stages using the final modelled elastic curves as an input.
- Gassmann’s fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination with the brine sands.
- AVA class IV was observed near a good porosity hydrocarbon sand(stage IVC) @ 1477m for all fluid cases at in situ reservoir conditions.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) no significant change for the AVA class could be noticed for all fluid.

Tekuyong-1 Input Logs



Additional data includes final geological report. No VS and NPHI(in most of the well interval) were found in the well.

Tekuyong-1 Geophysical Well Log Analysis (GWLA) – Interval from 800 to End of the logs

model type flag

Unconsolidated rock model

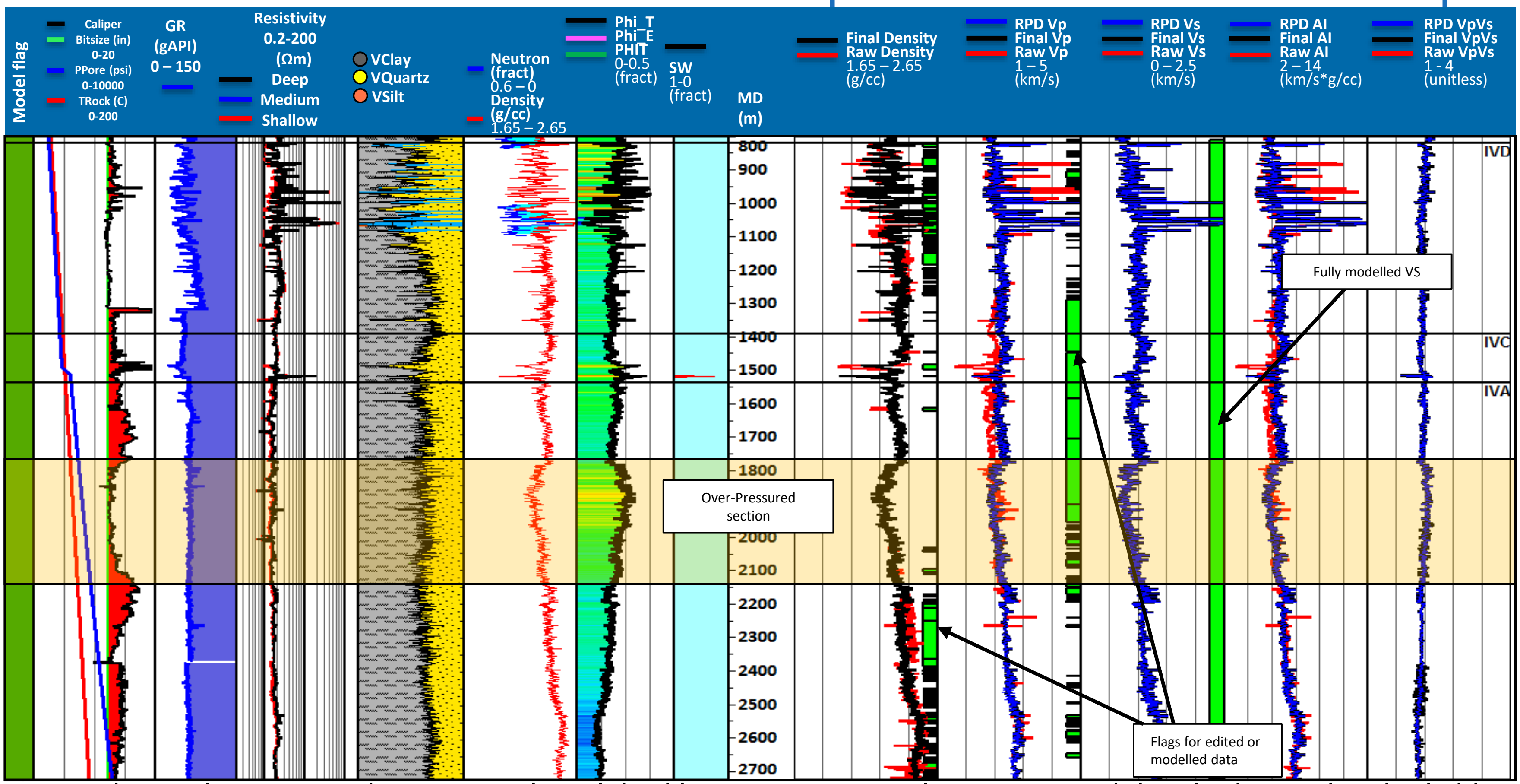
Stiff rock model

Equivalence between RSI and Petronas naming.
Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve

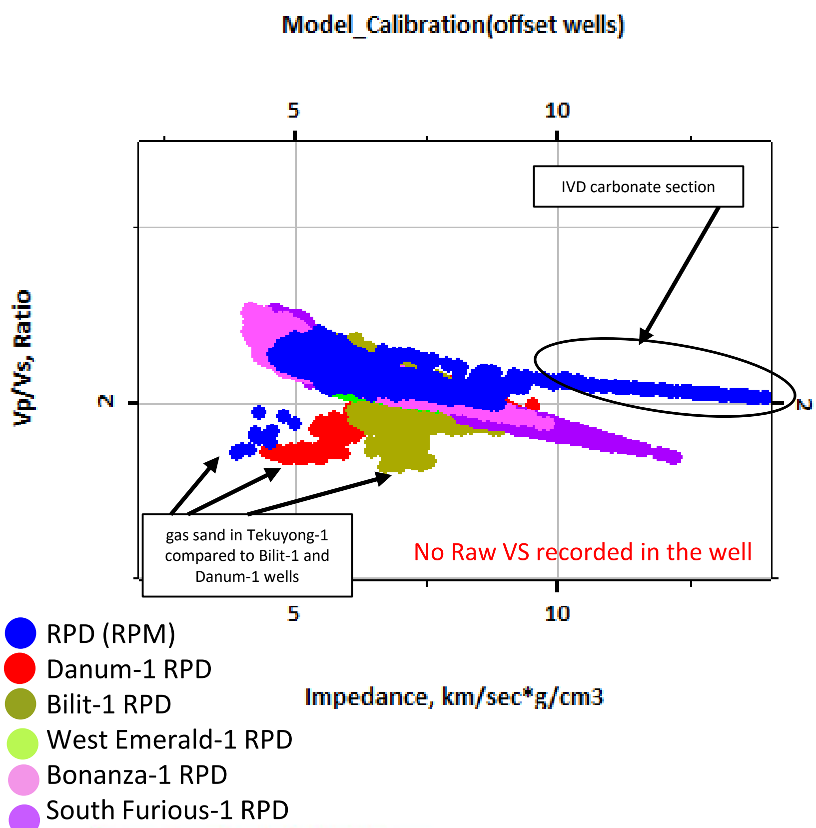


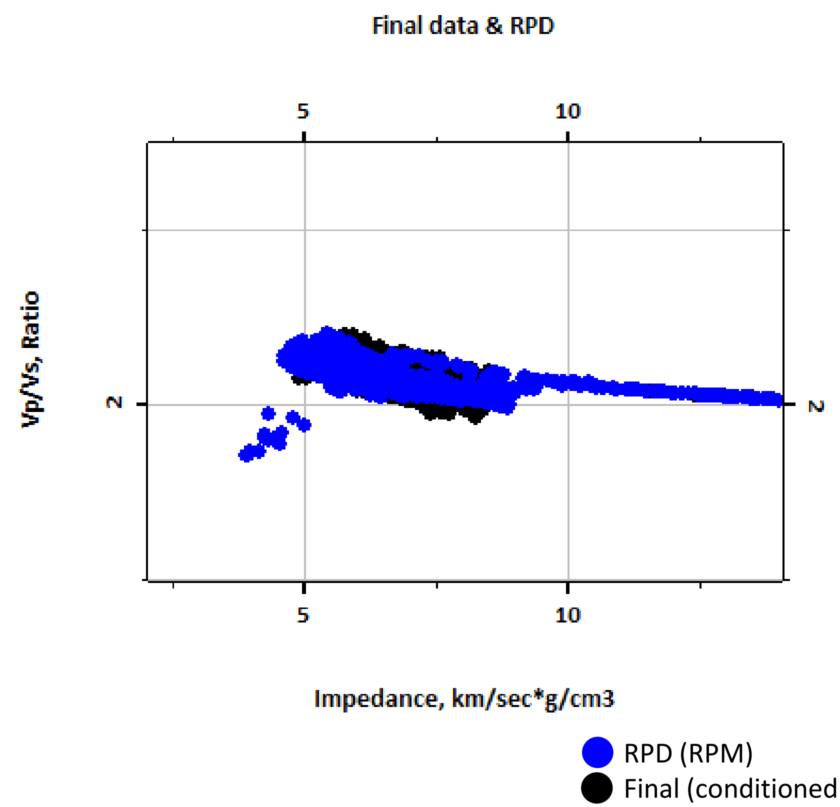
Many edits to the measured Density and model calibration is strong where measured data looks good and reliable. Granular media model (Soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) for both sand and clay rich intervals, with good correlation with the measured data in the well(VP and Rhob)and in the nearby wells. VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells.

Tekuyong-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the good calibration for the Tekuyong-1 well RPD with the nearby wells Danum-1, Bilit-1, West Emerald-1, Bonanza-1 well and South Furious-1.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data(Rhob and Vp ere conditioned while VS is totally modelled).

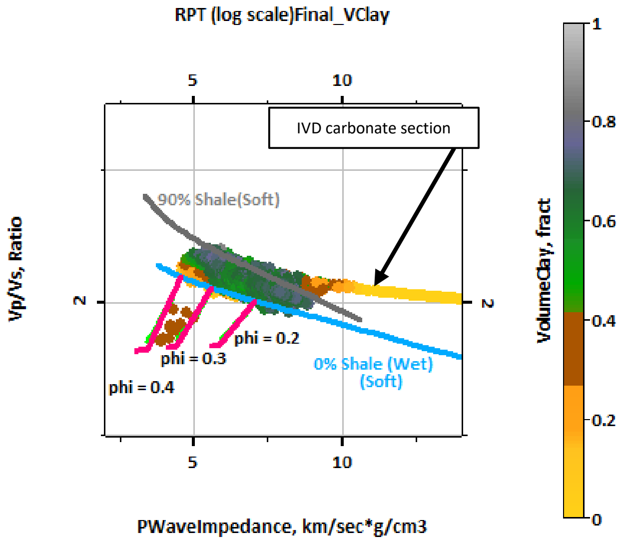


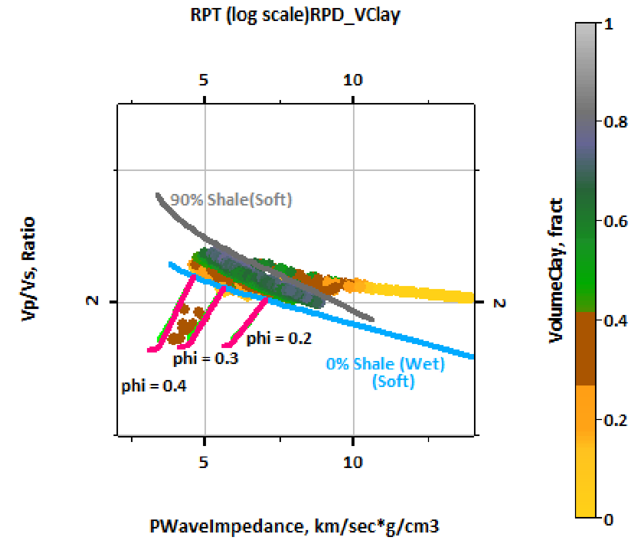


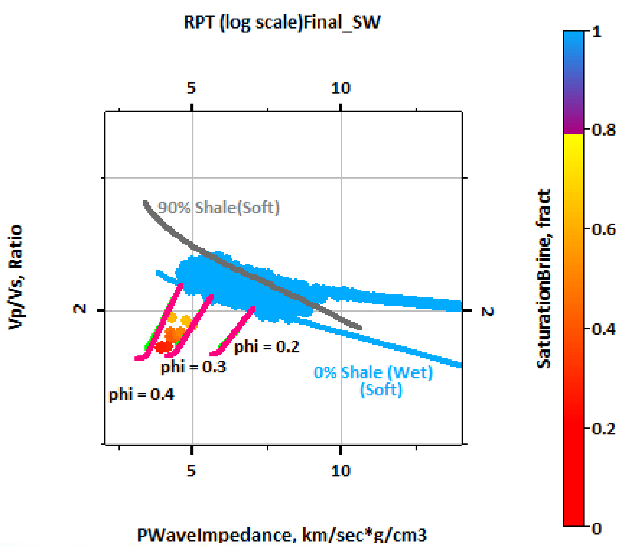
Tekuyong-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

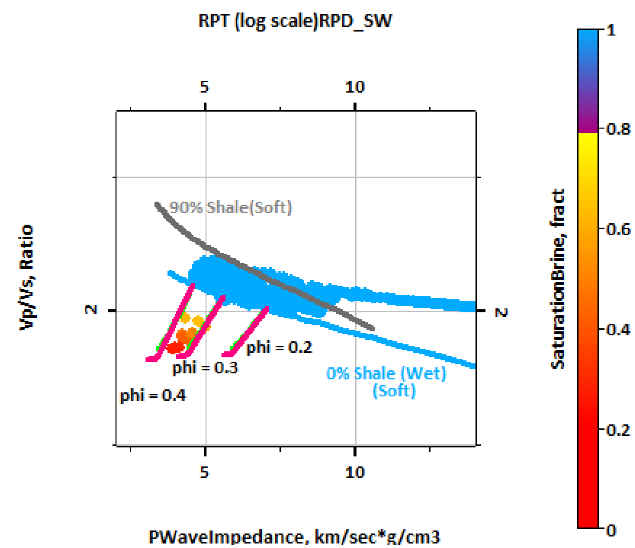
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Telus-1

Telus-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- Data was provided from 1300m to almost 2500m. Only GR, resistivity curve suite and compressional velocity were provided in this interval. Availability of other curves goes from 1700m to bottom of the well, except for the shear velocity data which is available from 2000m to bottom of the well.
- Elastic logs(VP and Rhob)were totally affected by the bad hole conditions above 1700m so no reliable response could be obtained to establish a rock physics model for that interval.
- Wide gaps are present in two sections of the provided logs. In this intervals the data is either not available or is not reliable. The density log is believed to be more reliable. The compressional and shear velocity logs show abnormal low and flat velocity values in most of the depth section that goes from 1700m to 2355m. The compressional velocity log is believed to be unusable above 1700m.
- Vp was predicted in many intervals where density was poor via Faust equation using deep resistivity as input.
- Volumetric interpretation was provided from about 1750 to bottom of the well as a reference. Interpretation is missing in the gap intervals.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- The Kinarut formation contains the highest percentage of sands with a high net to gross ratio. Sand packages in this interval are relatively thick and consistently developed. Porosities in this interval reaches values in the range from 27% to 38%. A compaction depth trend can be observed in the density log, causing the wide range of porosities in this interval. This interval is mainly interpreted as water wet.
- The Upper Kebabangan Formation shows a much lower net to gross ratio. Thinner sand packages appear at the middle section of the interval and more thick and somewhat better quality reservoir sands appear at the bottom of the interval, showing gas saturation of about 35%.
- Below the Base Upper Kebabangan geological marker there is no account of sand packages of reservoir quality.

Volume of hydrocarbons:

- Bottom sands of the Upper Kebabangan Formation, in the interval from 2335m to 2345m are the only sands with estimated volume of hydrocarbon, reaching values of about 30%.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Yielded a formation water salinity of 14000 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.93 and Saturation exponent (n)=1.95 (as in the final geological report).

Telus-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Rock physics diagnostics (RPD) and elastic log data editing:

- The well Telus-1 presented three sections that were edited independently. A bottom section going from 2355m to 2550m, a middle section going from 2031 to 2355m and the upper section going from 1400m to 2031m.

- The section from 1400m to 2100m presented intervals where measured P velocity values tend to lower and flatten out. This possibly can be associated to tool misreading of the compressional and shear first arrival time picks. Compressional velocity log was heavily edited in this interval. The soft sediment model provided the best adjustments in the intervals where the measured data was believed to be of good quality. In the gap interval present in this section, the compressional velocity was adjusted first by replacing the measured data with Faust model. In the intervals where there was not enough information to create modeled curves using rock physics methods, the compressional velocity log was linearly interpolated.
  Density was modeled from the soft sediment model in the gap section. Above the gap section the density log is believed to be more reliable. Minor editions were performed in the density in the interval above the gap. Shear velocity was totally estimated in this interval using the soft sediment model.

- The section from 2031m to 2355m presented intervals with the same issues as the interval above for compressional velocities, showing very low values and constant or flat response in wide intervals. Porosity at point 2187.5m is believed to be inaccurate due to bad borehole conditions that span from about 2171 m to 2189 m. Porosity in this interval was estimated to be approximately about 29% according to a regression analysis. In the interval 2316m-2333m the missing porosity data was filled by linear interpolation of the missing values. Elastic curves were recalculated accordingly. Vclay was readjusted in the interval from 2071m to 2310 m, although this readjustment did not change significantly the results. The editions were done using the soft sediment model. Coordination number value for this section and the above was 9.

- The section from 2355m to 2550m Measurements are believed to be good and more stable in this interval. Model was adjusted without any problems.

Fluid properties:

Fluid properties used in substitution have been taken from PVT well reports. Main parameters used in this modeling are:

- Brine salinity: 14000 ppm
- Gas gravity: 0.7
- Oil Gravity: 44.4 API
- Gas / Oil ratio: 178 (L/L)

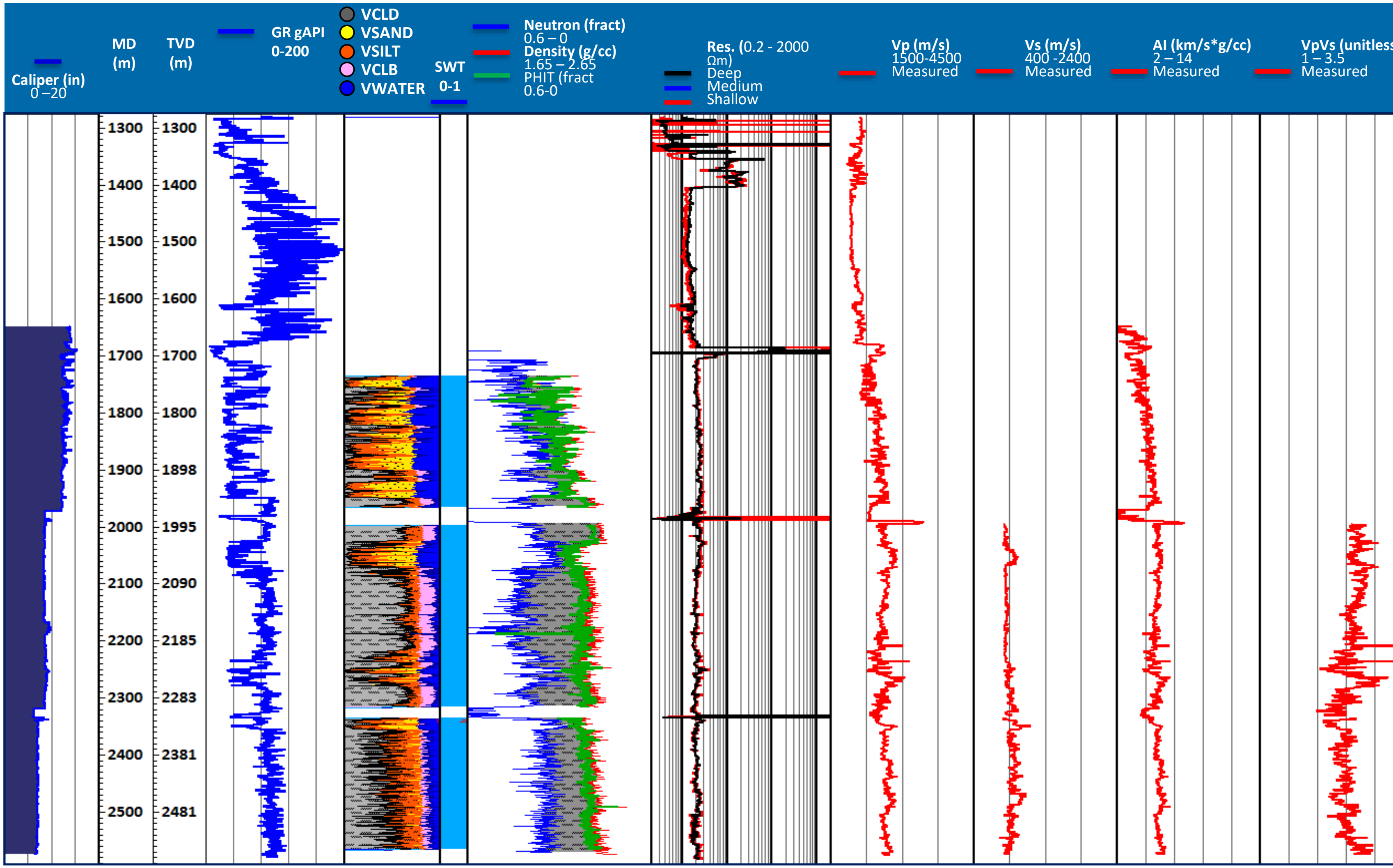
Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling can be performed from 1733m to the bottom of the well for Telus-1 using the final modelled curves as input. Perturbational modelling in this well can calculate the effect in elastic properties with change of porosity, volume of clay, and fluid content of the rock. In general, gas saturated sands show lower Vp/Vs ratios and lower p-wave impedance (AI) values than wet sands at log scale. Fluid substitution is performed via Gassmann's model.

- Particular AVO responses will depend on the selected modeling interval, porosity and fluid content of the rock. As an example, the sand package at 1920m (base of Kinarut Formation) was gas substitute allowing the Water saturation to be reduced to 20%. Porosity was preserved for this exercise. This exercise showed much lower values for VpVs ration and lower values for Acoustic Impedance compared to the wet case. Good separation of Gas and wet case was also observed in the upscaled data. AVO analysis at an interface defined at 1920m revealed a class III response for all the hydrocarbon cases well separated from the background trend, while the wet case showed intercept and gradient values close to zero.

- By downgrading the reservoir quality(decreasing porosity and increasing clay content) the hydrocarbon cases changed to be class II AVO response.

Telus-1 Input Logs



Additional data includes pressure, temperature data and cuttings descriptions (Final geological report).

Telus-1 Geophysical Well Log Analysis (GWLA) – Interval from 1700 m to the end of logs

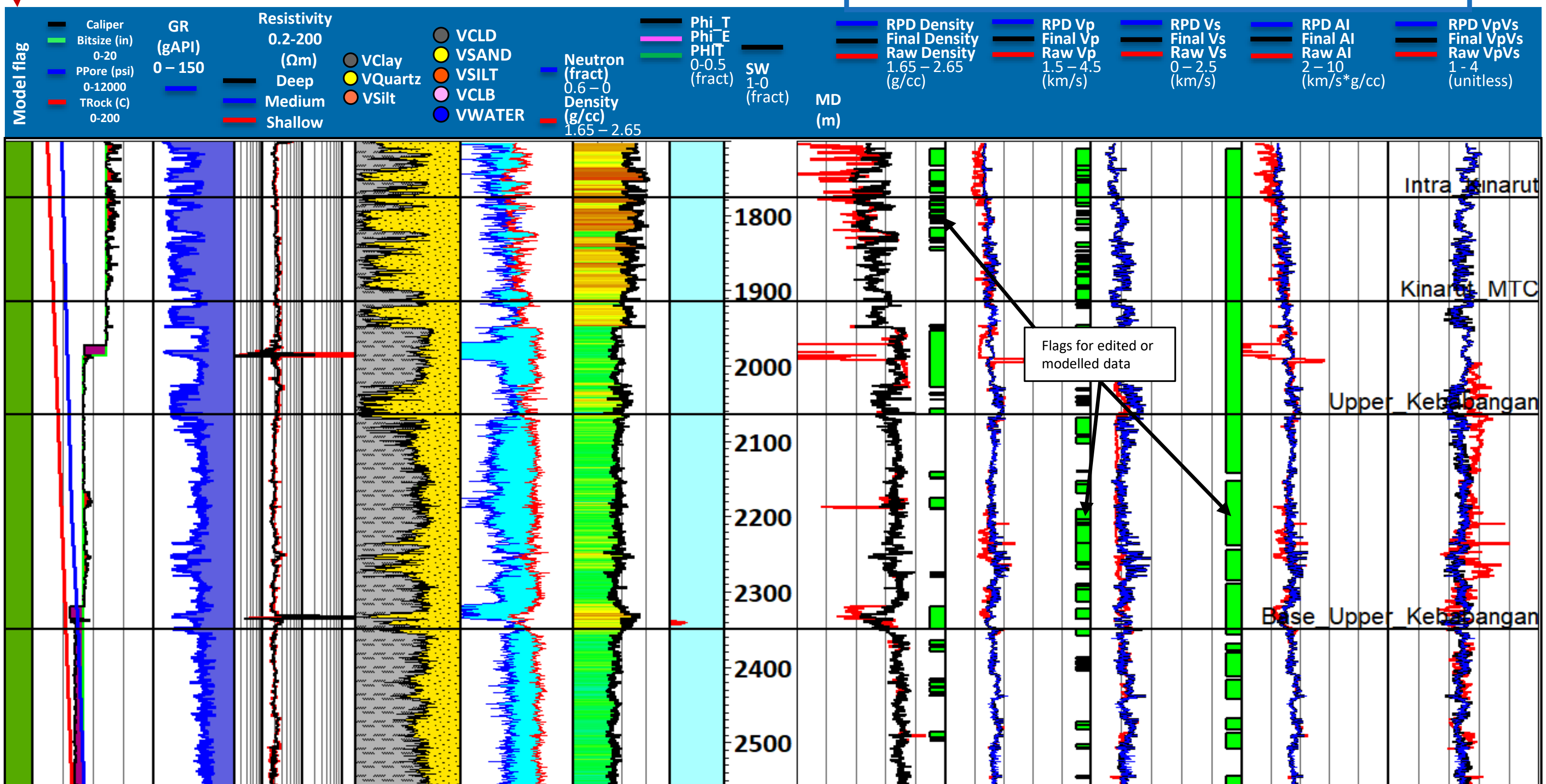
model type flag

- Unconsolidated rock model
- Stiff rock model

Above depth of 1700m(MD) no reliable logs were available to establish a rock physics model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

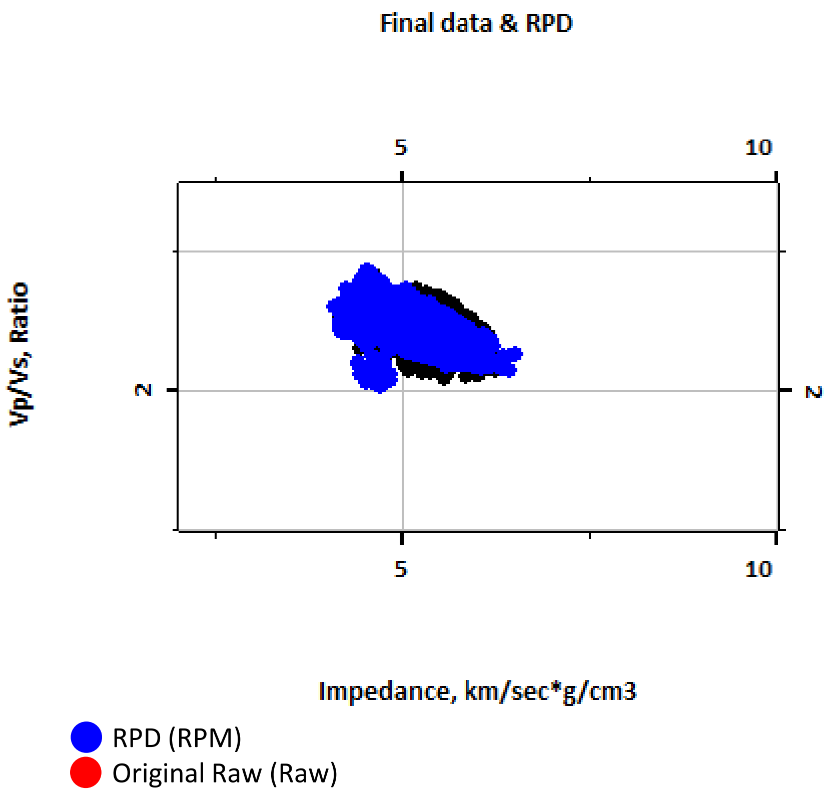


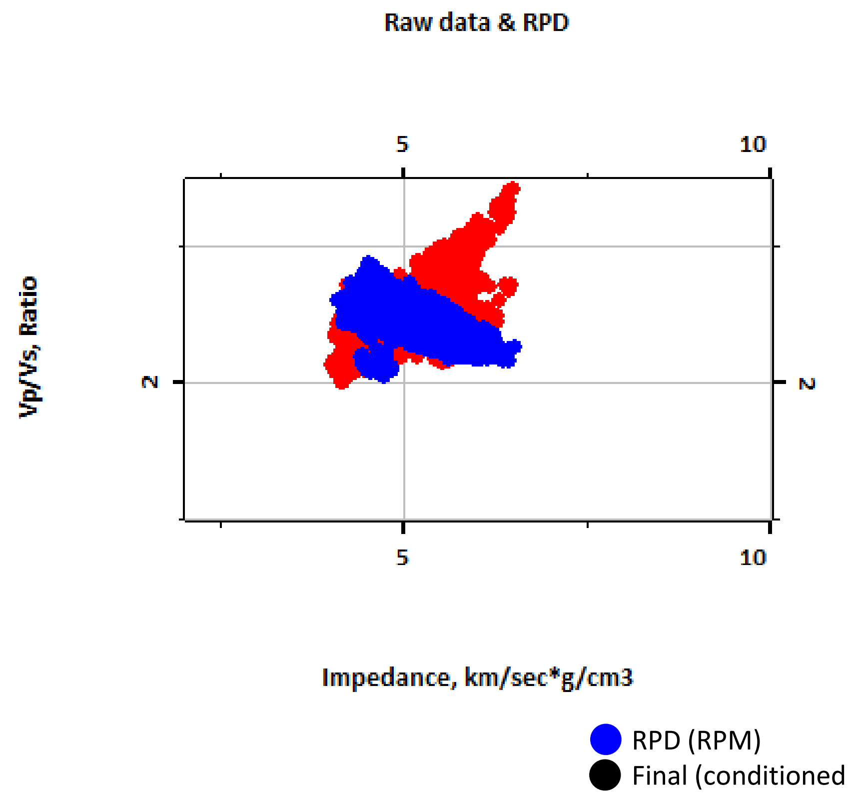
Some edits to the measured data and model calibration is strong. The casing gaps were filled from resistivity via Faust equation to predict Vp then density and Vs from RPD. Granular media model (soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) in the clean reservoir rocks and the clay rich intervals as well with good correlation with the measured data.

Telus-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

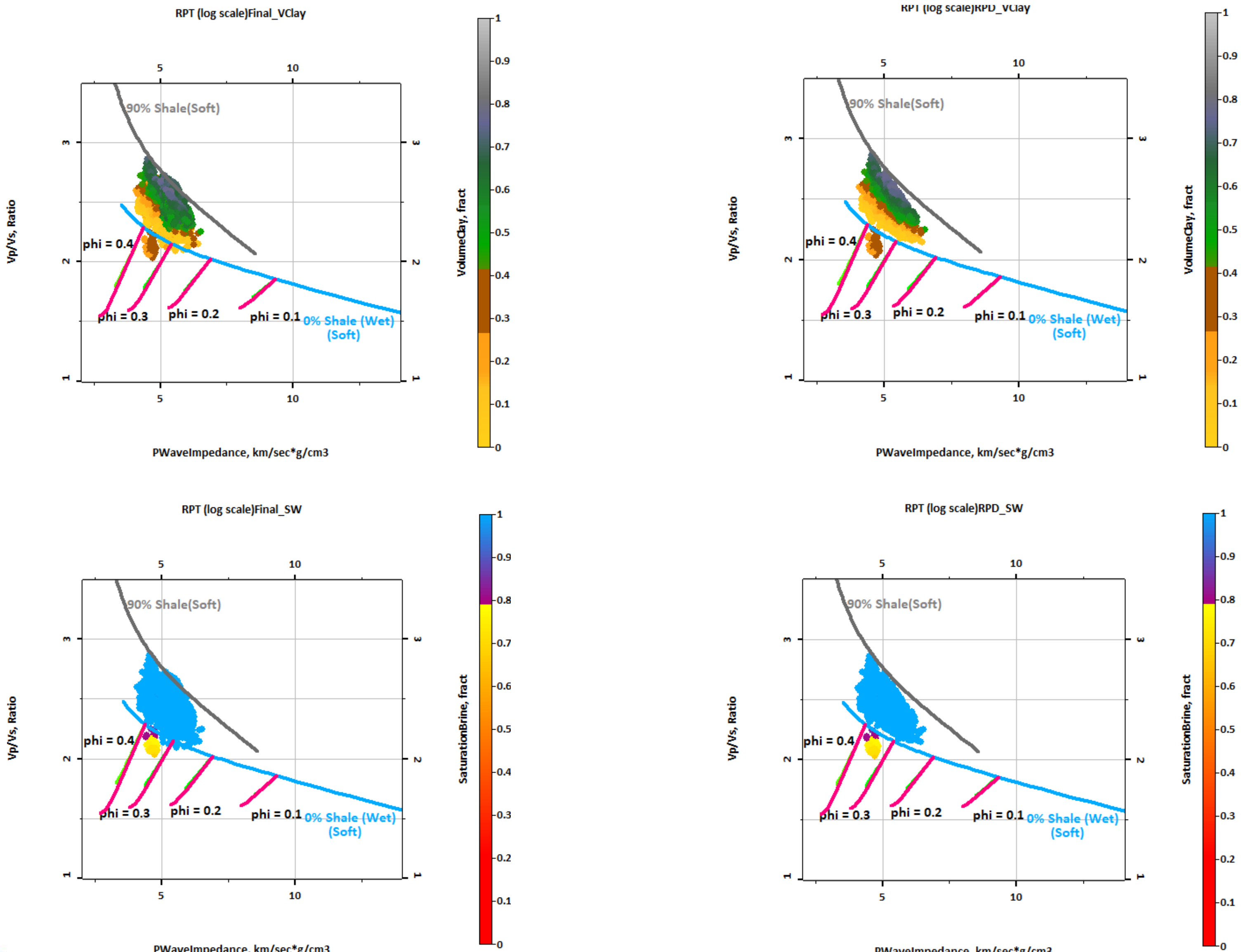




Telus-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data



RPD(Modelled)data

Tembungo-1

Tembungo-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality is fair but the density and the sonic in some intervals looks very poor and lazy especially the sonic in the gas sand intervals, but the data availability is good. Client's petrophysical interpretation was not provided for this well. Full elastic logs except VS were available throughout the wellbore covering the interval (600m-T.D.)
- Shear wave velocity(VS)was fully modelled in the well using the RPD after the model was carefully calibrated based on the offset wells behaving elastically the same especially(Danum-1 nearby and Bilit-1 to the south) The resulted Vs matched in trend all the nearby wells especially the final modelled results for Wset Emerald-1 and South Furious-1 wells especially when comparing same penetrated section(IVD stage).
- Due to the sever bad hole conditions density was completely replaced in many intervals of the well with the modeled one especially in the section 1250-1700m.
- Vp was also totally replaced with the modelled one in the interval gas reservoir section after carefully calibrated the model with the good measured data present in the well and also in the offset wells to honor the regional trend in the area.
- Other logs include Gamma, SP, Caliper, shallow and Deep resistivity, which all run for the full logging run to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Miocene marine sands . These are a series of turbiditic fine to very fine soft sands.
- The well penetrated ivery good porosity sand in the different intervals of the well but hydrocarbon started to appear at the deeper levels(below 1600m).

Volume of hydrocarbons:

- Gas saturation was calculated in the reservoir section and ranged(50-75%) .

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the clean wet sand(1880-1925m)yielded a formation water salinity of 24000 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.88 and Saturation exponent (n)=1.88 (assumed based on nearby wells' information).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to good measured data in the nearby reference wells and other wells on the same elastic trend.
- Elastic behavior for the well was carefully calibrated with the nearby wells and other wells honoring the same elastic trend for the well(P-Wave impedance depth trend) And concluded that the well elastically behaves similar to Danum-1 well and Bilit-1(even though it is far but elastically honoring Tembungo-1 elastic trend) , so S-wave velocity completely modelled in the well based on the same model and parameters used in the offset wells which resulted in a matched trend with the calibrated nearby wells and very well behaved model when compared to the modelled results in the most nearby wells(South Furious-1 and West Emerald-1).

Fluid properties:

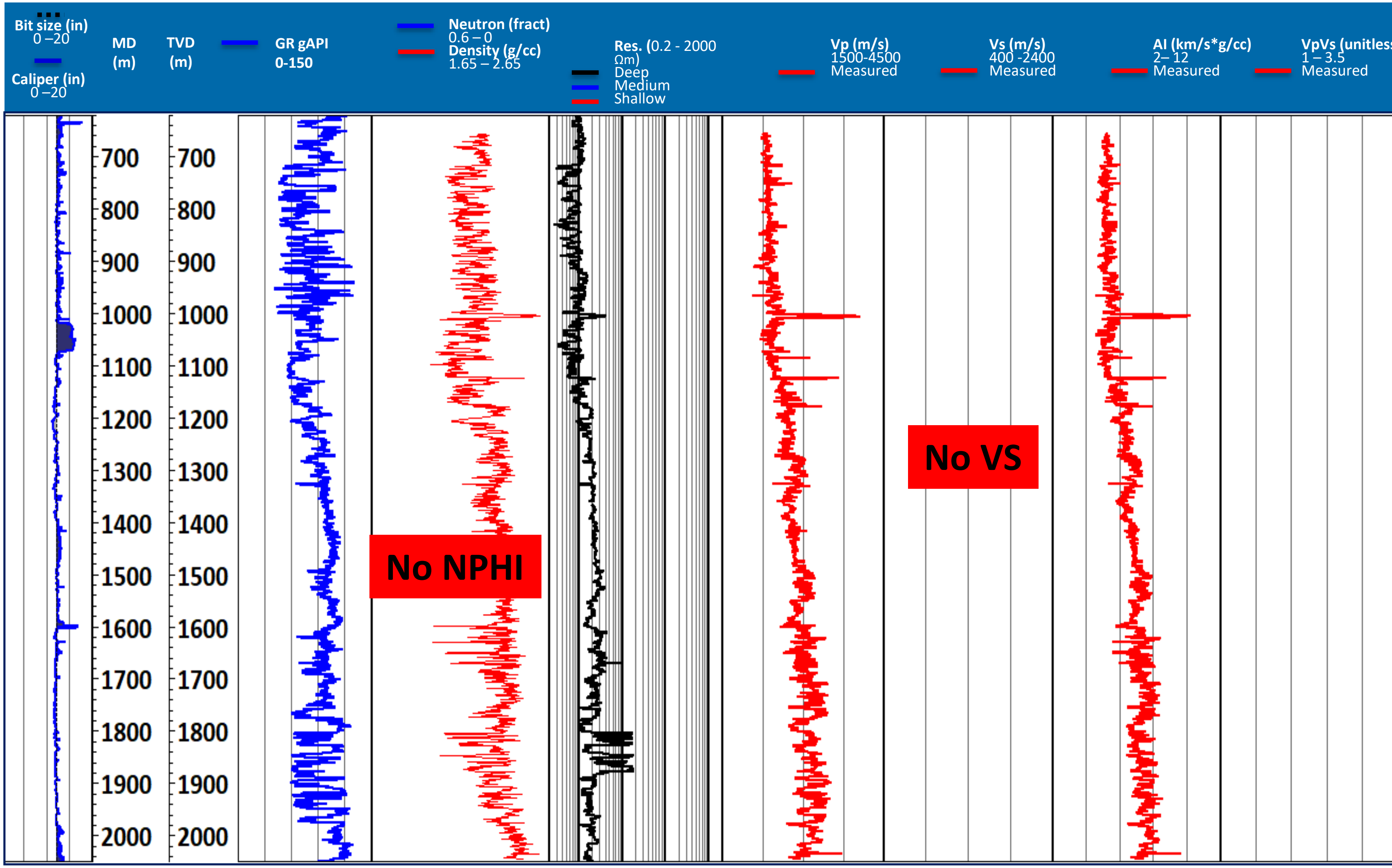
Fluid properties used in substitution have been taken from PVT report of nearby well Danum-1, Main parameters used in this modeling are:

- Brine salinity: 17500 ppm[Pickett plot]
- Gas gravity: 0.82[PVT analysis]
- Oil Gravity: 38.4 API[Well test]
- Gas / Oil ratio: 500 (L/L) [PVT analysis]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination with the brine sands.
- AVA class IV was observed near a good porosity gas sand @ 1799m for all hydrocarbon cases while class II for the brine case all at in situ reservoir conditions.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) the hydrocarbon cases started to behave as class IIP AVO response while the wet case class I.

Tembungo-1 Input Logs



Additional data includes final geological report. No VS or NPHI run were found in the well.

Tembungo-1 Geophysical Well Log Analysis (GWLA) – Interval from 650 to End of the logs

model type flag

Unconsolidated rock model

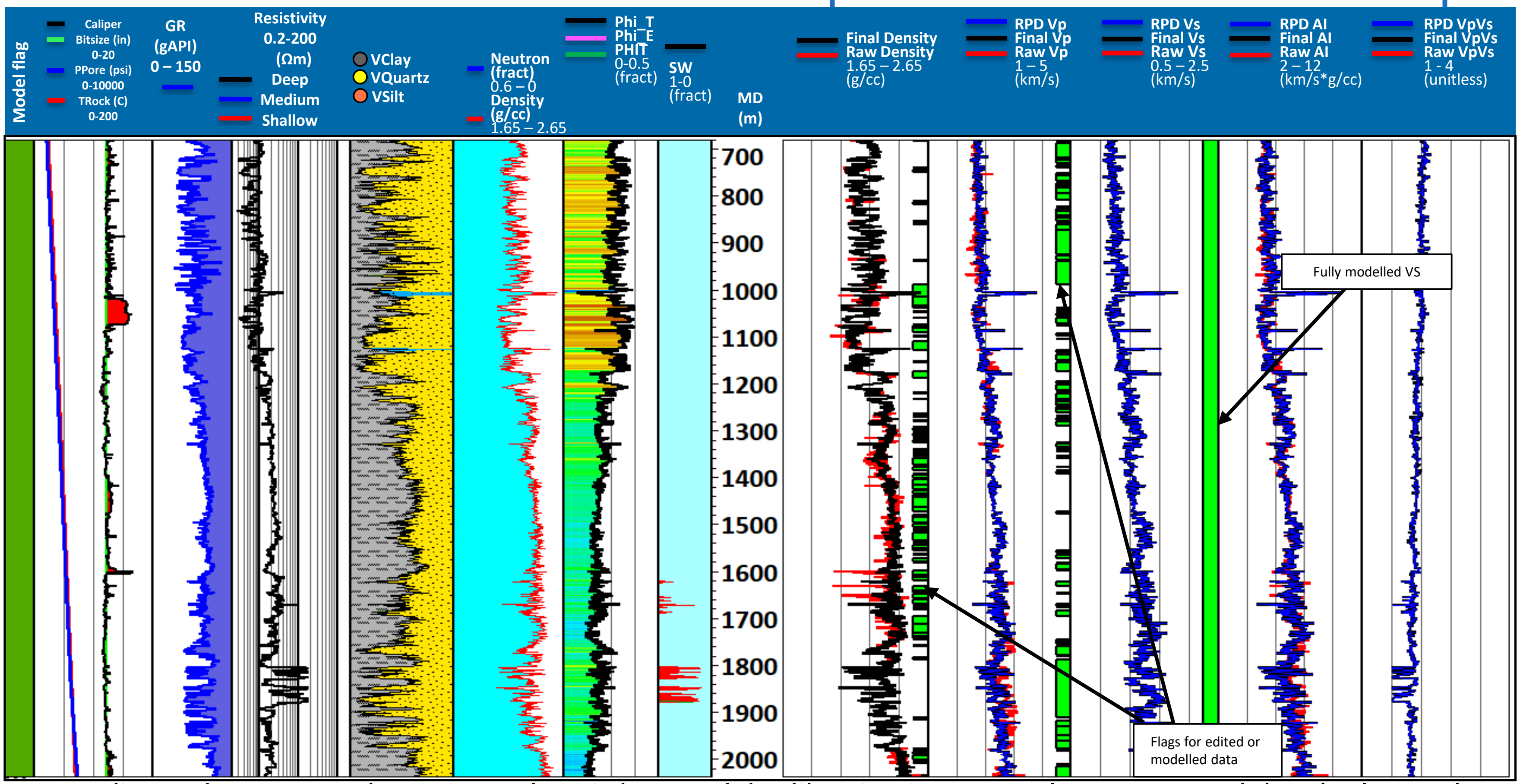
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

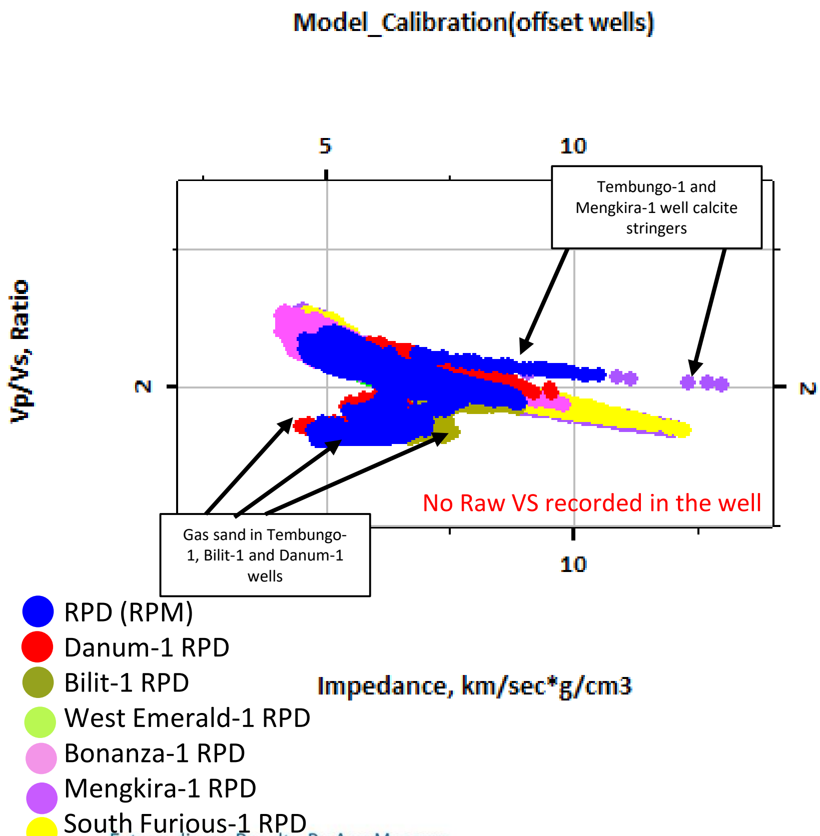
Original Raw (Raw) curve



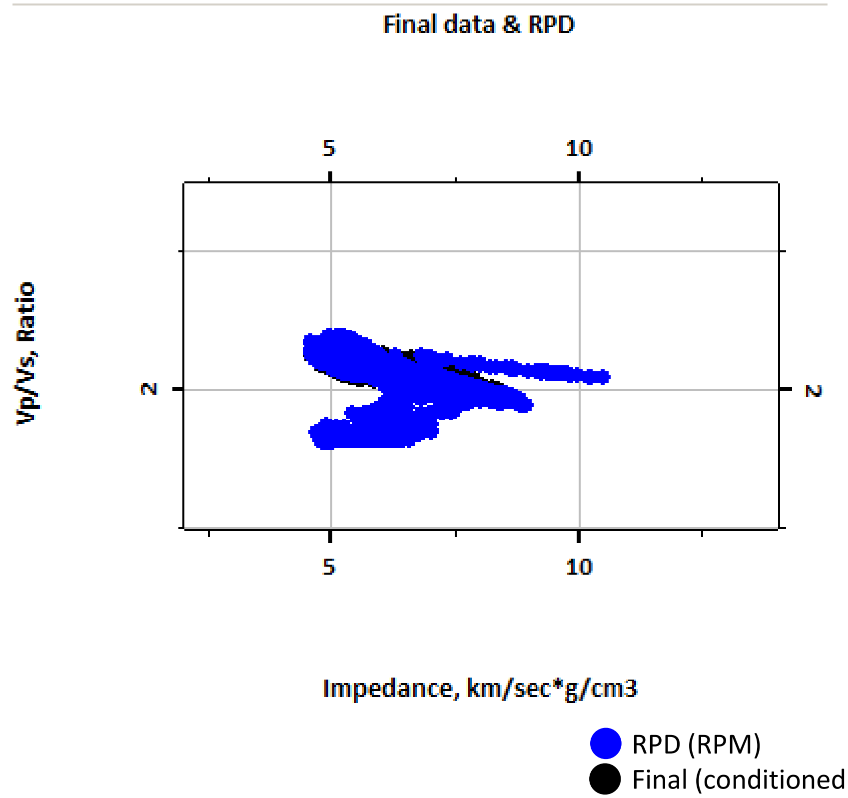
Many edits to the measured Density and sonic but model calibration is strong where measured data looks good and reliable. Granular media model (Soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) for both sand and clay rich intervals, with good correlation with the measured data in the well(VP and Rhob)and in the nearby wells.VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells.

Tembungo-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the good calibration for the Tembungo-1 well RPD with the nearby wells Danum-1, Bilit-1, West Emerald-1, Bonanza-1,Mengkira-1 and South Furious-1 wells.



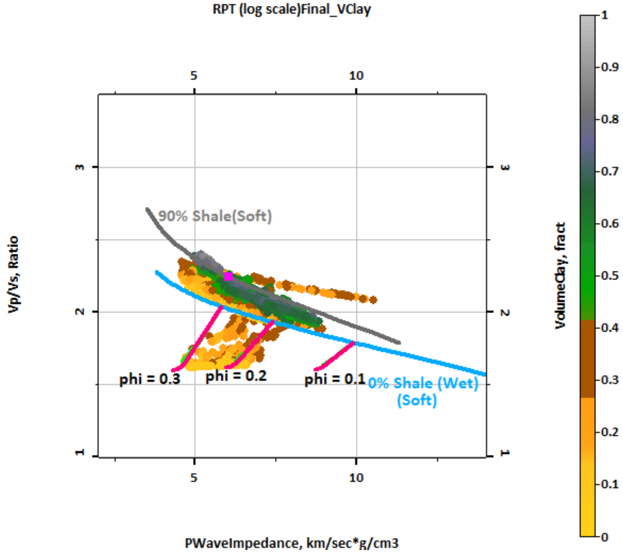
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data(Rhob and Vp ere conditioned while VS is totally modelled).

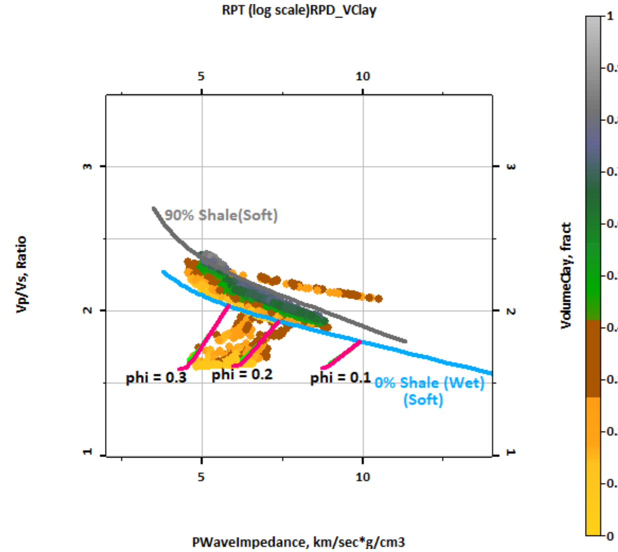


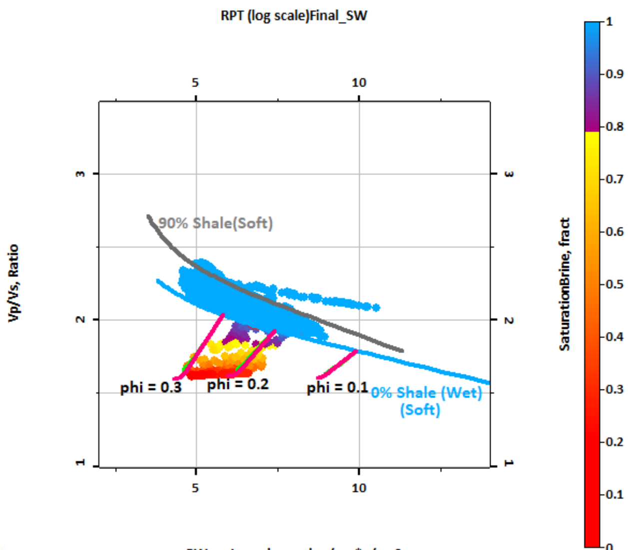
Tembungo-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

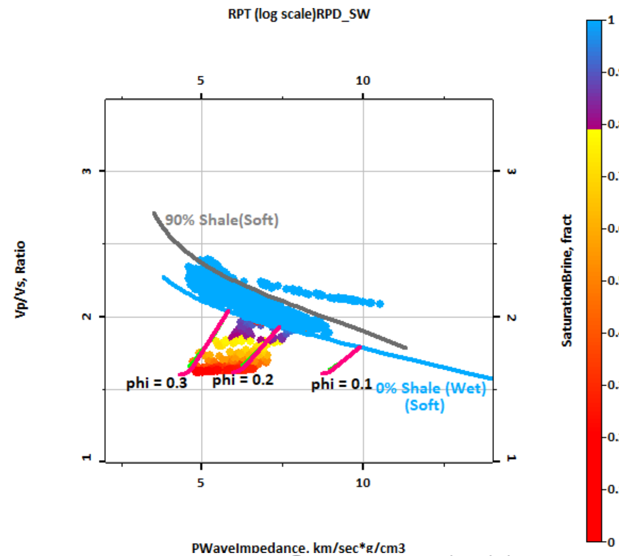
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Tinutudan-1

Tinutudan-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is poor especially the velocity measurements. Client's petrophysical interpretation was fully provided as a reference(except porosity).
- Density measurement was highly impacted by the bad hole conditions so it was edited using the RPD in many intervals as(1250-1350m, 1714-1770m and 2175-2200m).
- Vs was heavily edited using the RPD throughout the borehole especially starting from depth 1250 to the total depth. That poor Vs measurements created noisy VP/VS ratio .
- Vp was edited in some intervals to maintain consistency in the VpVs ratio in clay intervals(2100-2170m).
- Due to the lack of any elastic measurement in the interval(1250-1280m)Vp was fully modelled using deep resistivity via Faust equation then the rest of the elastic curves were predicted using the RPD.
- No logs run in the interval(2200-2225m)so no interpretation was made due to lack of information.
- Other logs include Gamma, Neutron, Caliper, Deep resistivity and SP which all run for the full logging run.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is the Kamunsu section. These are a series of turbiditic fine to very fine soft sands.
- The well penetrated only few clean sand intervals in the Kamunsu C interval , the upper sand body(2162-2178m) characterized by tight nature due to some calcareous cement presence while the other deeper sand interval(2200-2222m)could not be analyzed due to the lack of information(no logs run in this section due to drilling problems).

Volume of hydrocarbons:

- Only residual hydrocarbon saturation was interpreted in the Kamunsu sand while the sand section in the intervals(2200-2222m)could not be analyzed due to no logs run.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the section below 2230m yielded a formation water salinity of 12000 PPM. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=2 and Saturation exponent (n)=2 (as in the final geological report).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to the measured data and also when compared to good measured data in the nearby reference wells.

Fluid properties:

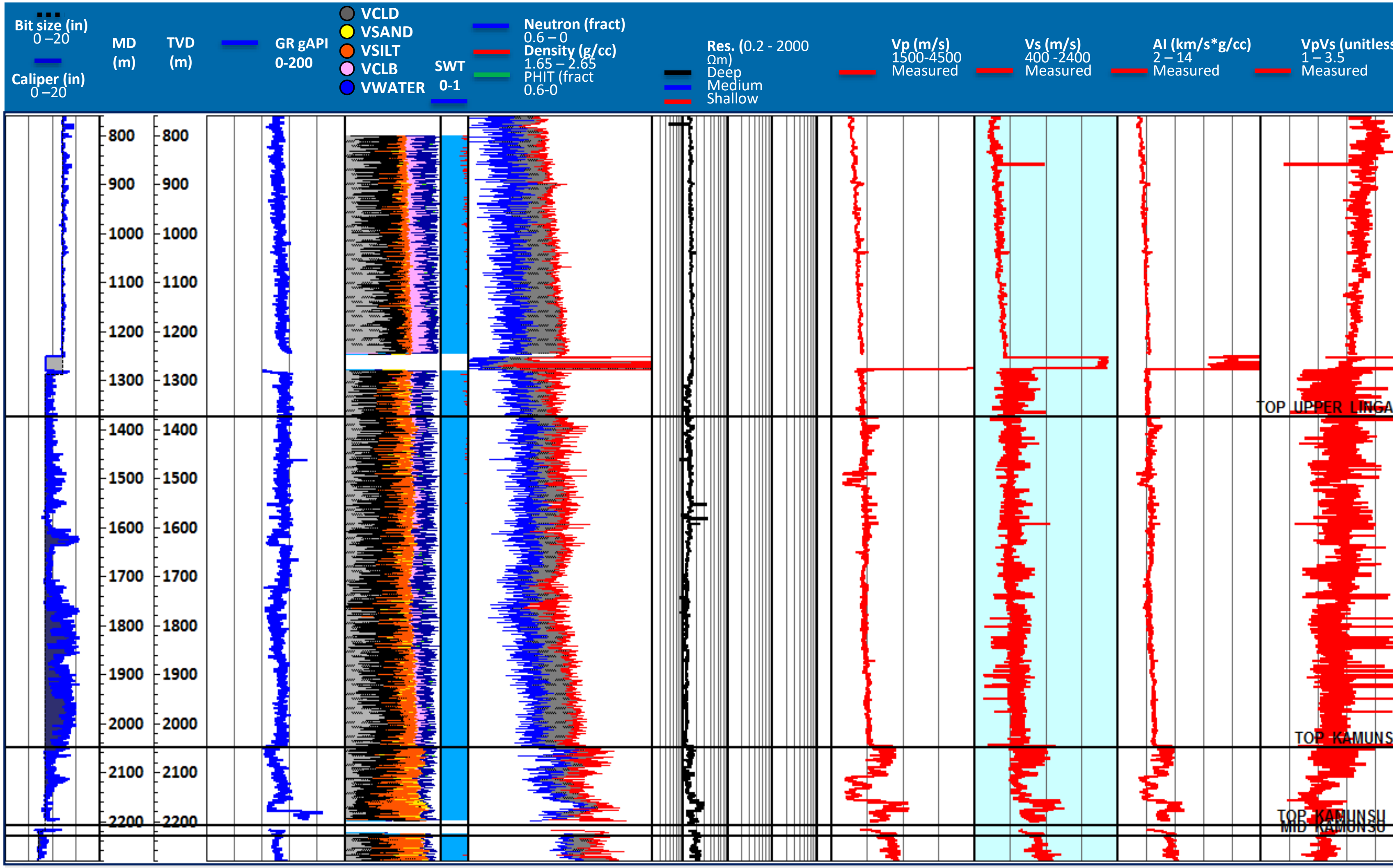
Fluid properties used in substitution have been taken from Azurit-1 well PVT report. Main parameters used in this modeling are:

- Brine salinity: 12000 ppm
- Gas gravity: 0.797[PVT analysis]
- Oil Gravity: 45.8 API[PVT analysis]
- Gas / Oil ratio: 200 (L/L) [Assumed based on area results]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different late Miocene sands(Kamunsu formation)using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with very good discrimination with the brine sands.
- AVA class II was observed near the Kamunsu sands @ 2050m for all hydrocarbon cases at in situ porosity compared to class I for the brine case.
- By decreasing the clay content the hydrocarbon cases(gas and oil) behave like class IIP AVA response while no change for the wet case.

Tinutudan-1 Input Logs



Additional data includes pressure, temperature data, cuttings descriptions and final geological report.

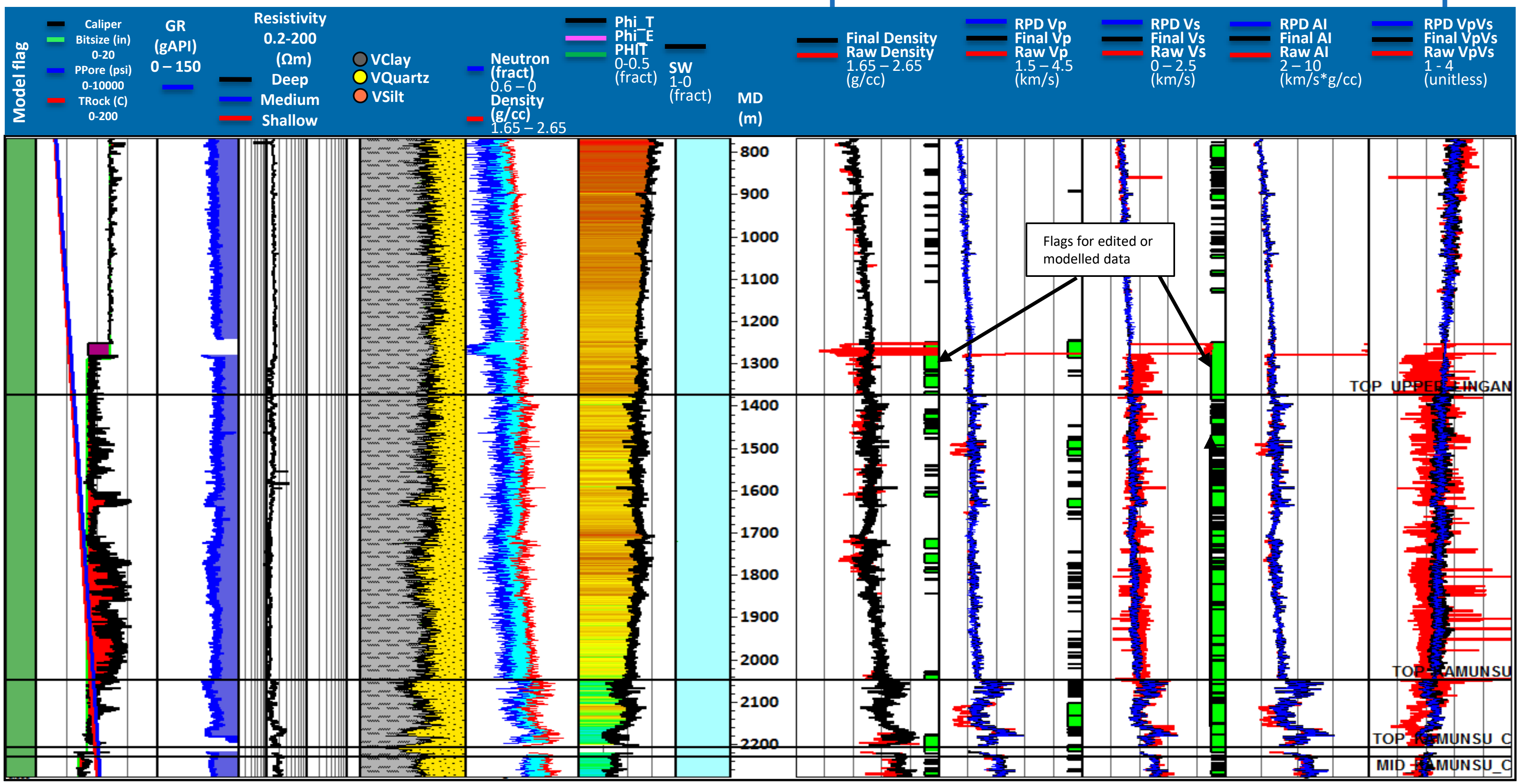
Tinutudan-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of Elastic logs to end of logs

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming.
Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

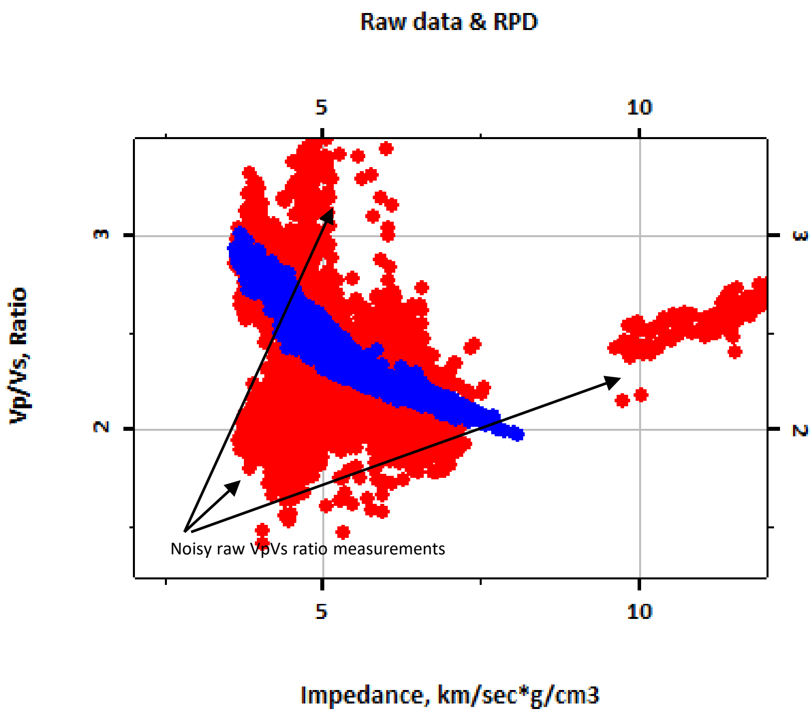


Major edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) with good correlation with the measured data and using Azurit-1 and Biris-1 wells as reference.

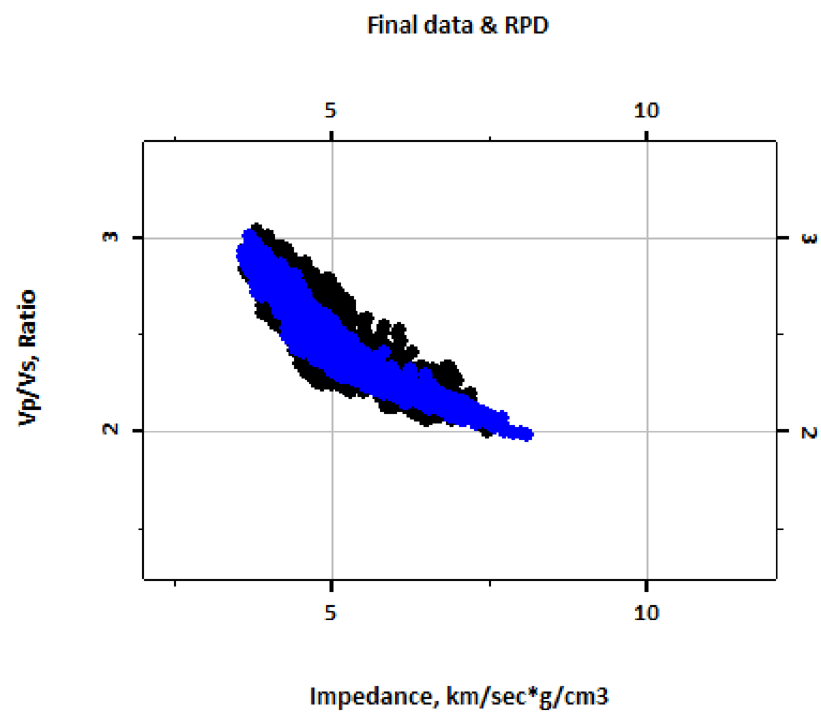
Tinutudan-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.



RPD (RPM)
Original Raw (Raw)

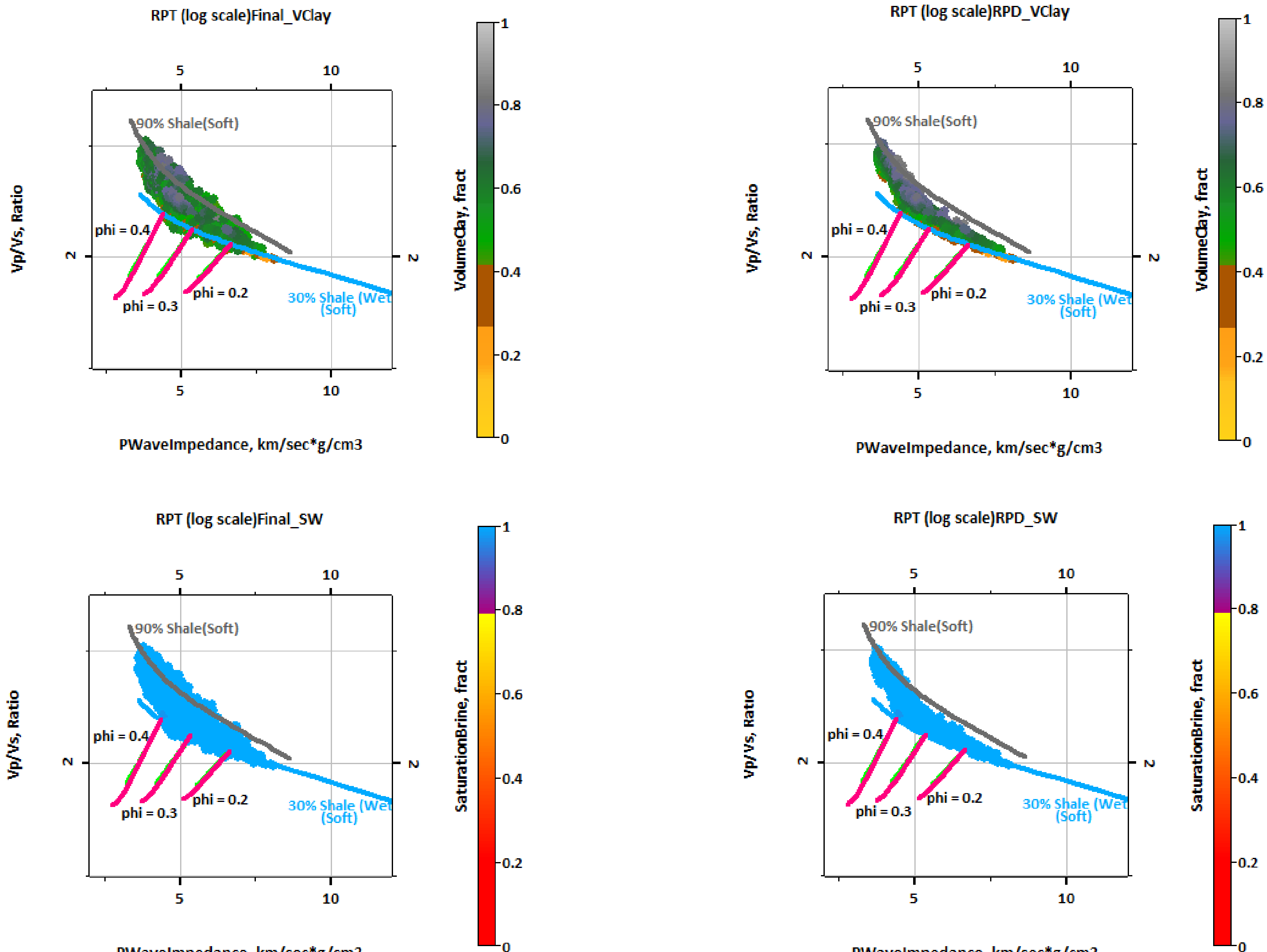


RPD (RPM)
Final (conditioned)

Tinutudan-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data



RPD(Modelled)data

Tomani-1

Tomani-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is good. Client's preliminary petrophysical interpretation was fully provided. In the 2610.3-2614.8 m gap section, the GR was used to estimate VClay while following the interpreted clay content trend of the underlying.
- RSI recalculated the well volumetrics(clay volume,, porosity and water saturation) to assure regional consistency between wells .
- In the 2609.5-2611.1 section close to the casing shoe, density values were sanitized via rock physics modelling.
- For the VP curve Depth shift remnants were observed locally in a few sections (e.g. 2782.5-2785 m 2765-2769 m, 2570-2573 m) and therefore shifted using density and gamma ray logs as references.
- For the VS curve Depth shift remnants were observed locally in a few sections (e.g. 2782.5-2785 m) and therefore shifted using density and gamma ray logs as references.
- Vp was fully modelled using the RPD in the interval 2590-2610 m.
- Vs was available in the entire well and some edits were performed due to inconsistency in the VpVs ratio results. A granular media model(soft sediment and stiff sand models) was used to predict the shear velocity.

Clay volume (VClay):

- This volume was derived from both linear Gamma Ray method and in some zones a combination of both Gamma Ray and Neutron/Density crossplot applied .

Reservoir characteristics:

- Perhaps the best reservoir properties in the well are encountered in the D50 – F section, particularly in the 2550-2914 m interval. There is a claystone sandstone laminae alternance in most of the section, but there are better developed sands with thicknesses up to 14 m towards the bottom of the section. Average porosities in these zones can be as high as 29%, but most of the reservoirs have been interpreted as water wet.

Volume of hydrocarbons:

- Interpreted gas saturation was best in the 2571-2573 m sand with values up to 70%. Additionally, some gas was interpreted in thin sands in F(2960-2962m and 3071-3073m)with an average of 35-40% gas saturation.

Water saturation (Sw):

- Salinity analysis from samples acquired in the wellbore yielded salinity values in the range of 8000-9000 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.9 and Saturation exponent (n)=1.9(as reported in the final geological report)

Tomani-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore, and indicated that from the mudline down to about 1800mBML the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both cleaner sand intervals and clay rich intervals while in the deeper horizons the stiff sand model proved to be the best elastic logs predictor in the clean sand intervals when compared to the measured data .

Fluid properties:

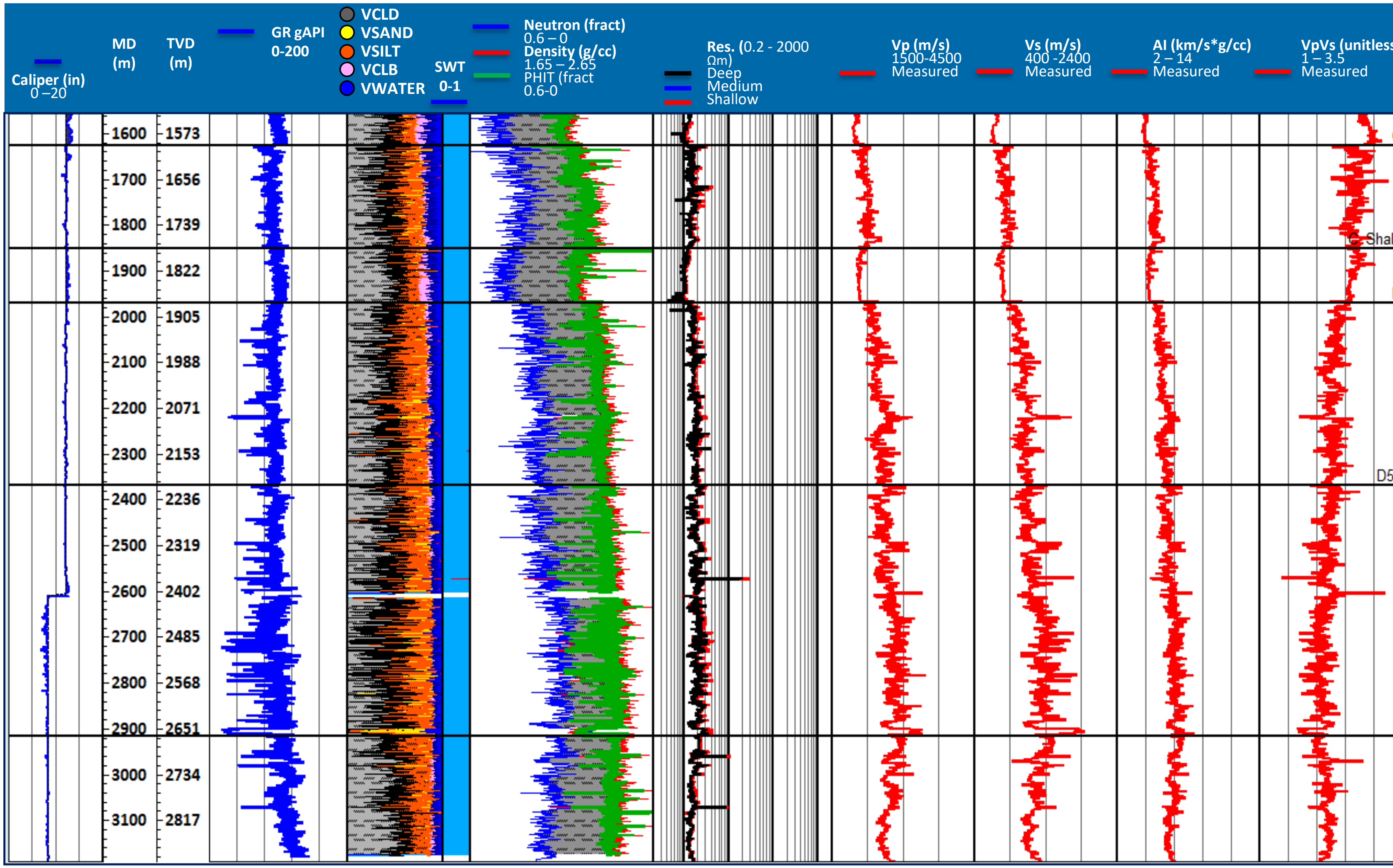
Fluid properties used in substitution have been taken from PVT well reports. Main parameters used in this modeling are:

- Brine salinity: 9000 ppm
- Gas gravity: 0.64
- Oil Gravity: 35 API [assumed]
- Gas / Oil ratio: 100 (L/L) [assumed]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in sands of C, D, D50 and F.
- Gassmann’s fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale.
- The top of D50 sand interval (2695m MD) does not exhibit any AVO response with the in-situ properties.
- By upgrading the reservoir quality(increasing the porosity anddecreasing the clay content) the discrimination between the different fluid cases will be hard on the AVA Xplot.

Tomani-1 Input Logs



Additional data includes pressure, temperature data and cuttings descriptions (Final geological report).

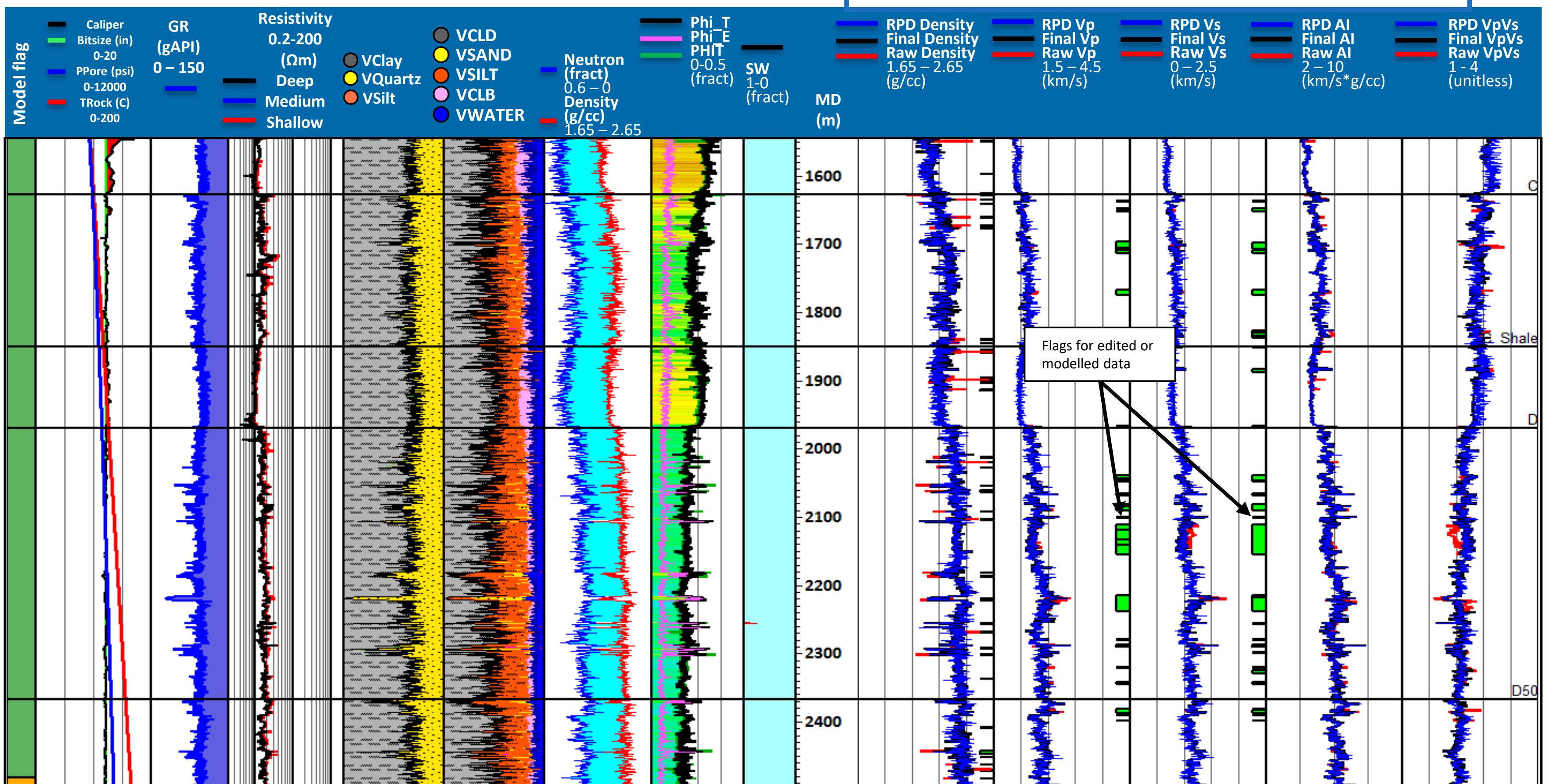
Tomani-1 Geophysical Well Log Analysis (GWLA) – Interval from Top of logs to 2500 m

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

model type flag

- Unconsolidated rock model
- Stiff rock model



Some edits to the measured data and model calibration is strong. The casing gap was filled via Faust from resistivity to Vp then density and Vs from RPD. Granular media model (soft sand with variable Coordination Number) was used for all elastic curves prediction (Rhob, Vp and VS) in the clean reservoir rocks and the clay rich intervals as well with good correlation with the measured data.

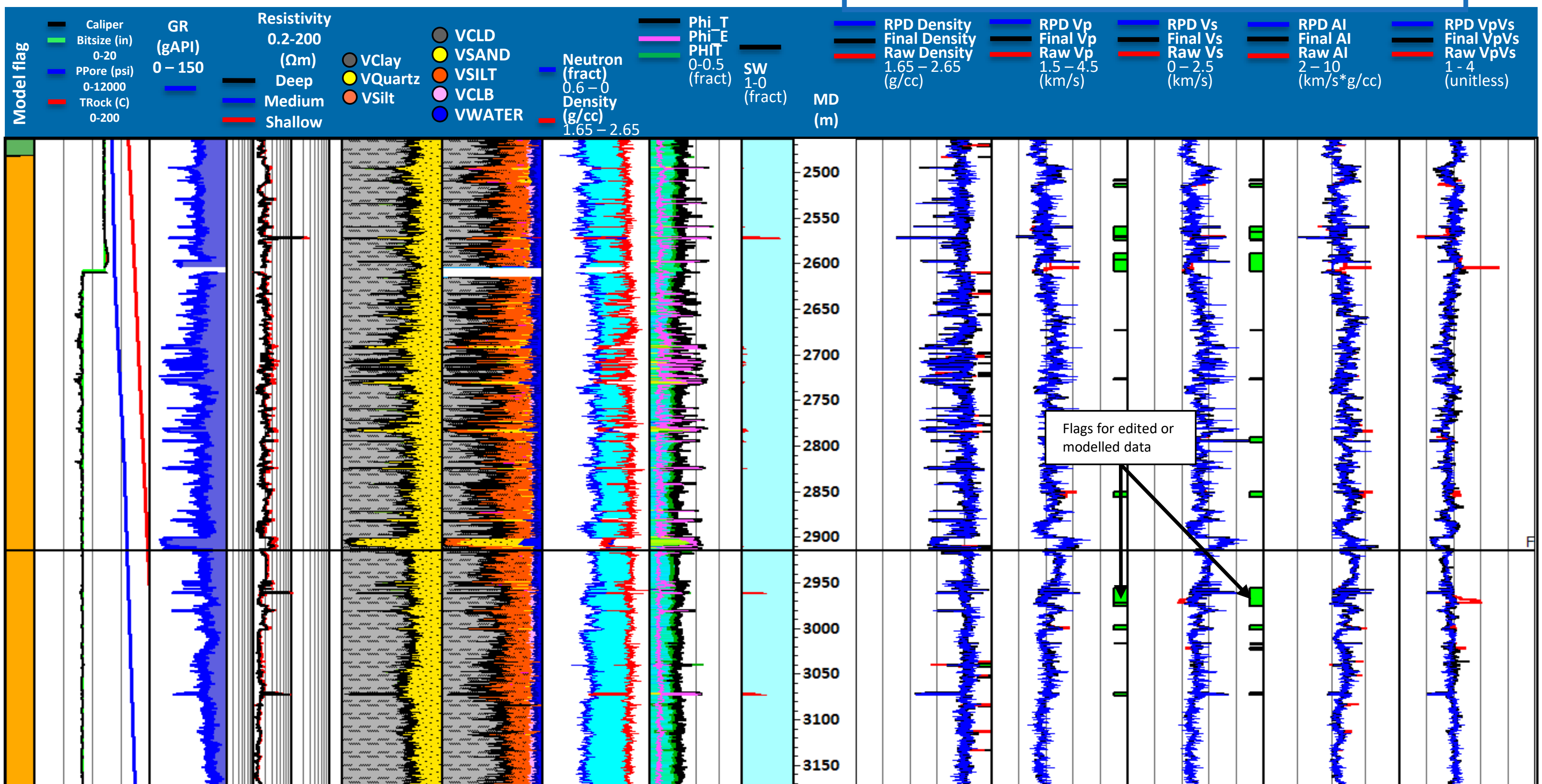
Tomani-1 Geophysical Well Log Analysis (GWLA) – Interval from 2470 m to the end of logs

model type flag

- Unconsolidated rock model
- Stiff rock model

Equivalence between RSI and Petronas naming.
Petronas equivalent curve name in parentheses

- RPD Modeled (RPM) curve
- Final edited (Conditioned) curve
- Original Raw (Raw) curve

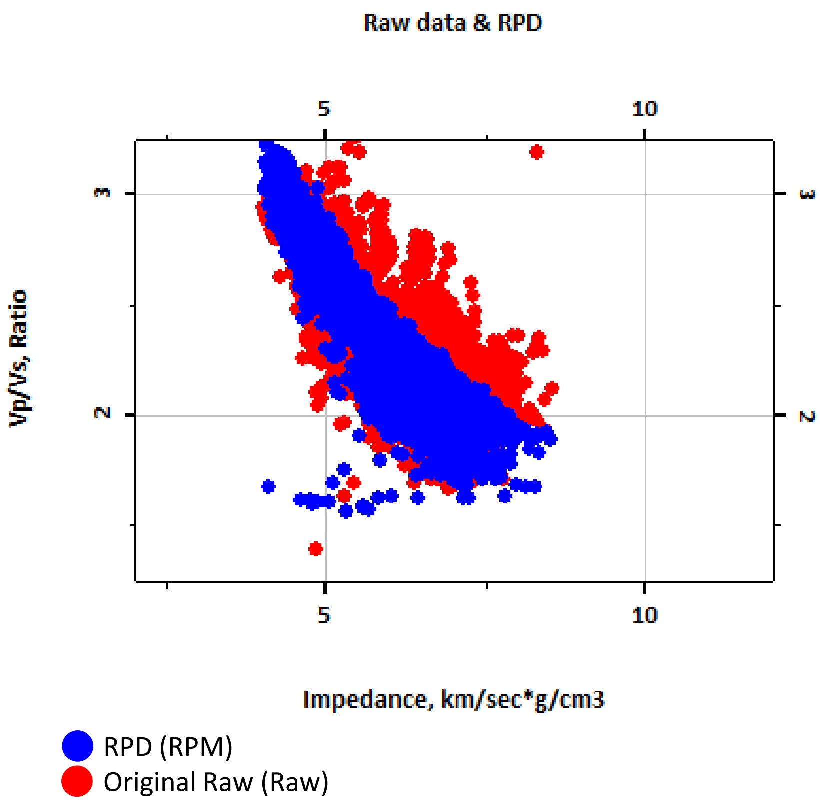


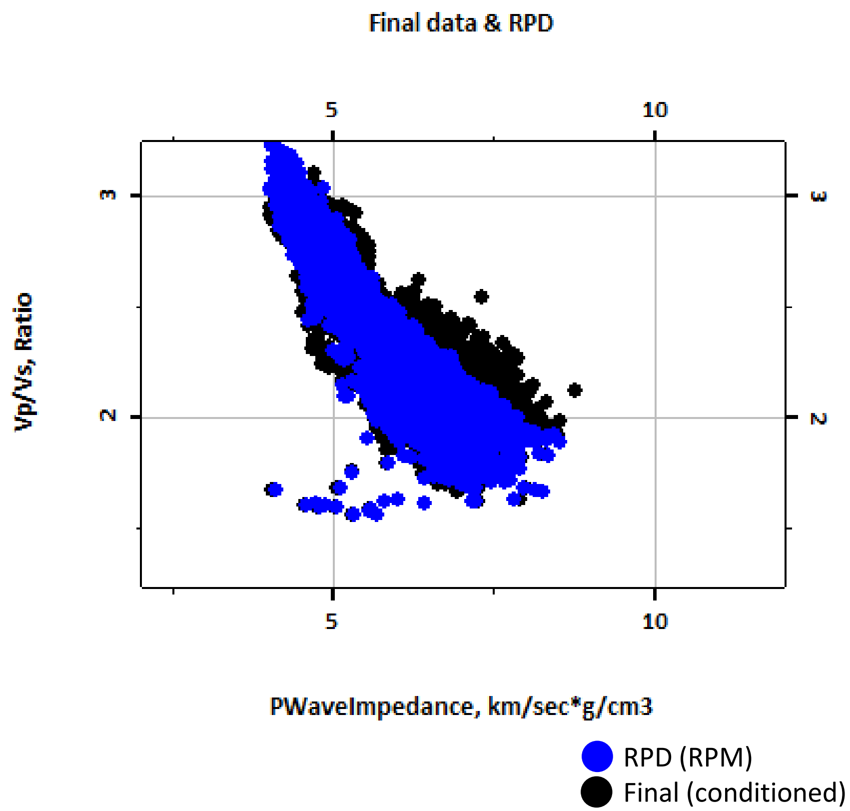
Some edits to the measured data and model calibration is strong. The casing gap was filled via Faust from resistivity to Vp then density and Vs from RPD. Granular media model (stiff sand) was used for all elastic curves prediction (Rhob, Vp and VS) in the clean reservoir rocks while soft sediment model was used in the clay rich rocks with good correlation with the measured data.

Tomani-1,Rock Physics Diagnostics (RPD)
Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the original un-edited measured data.

P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data.

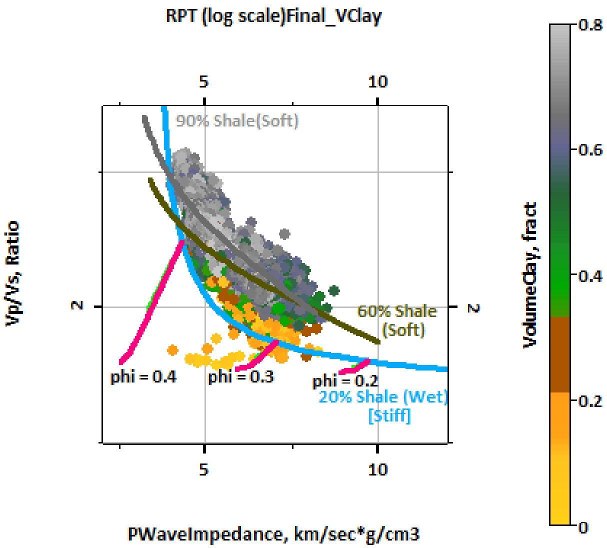


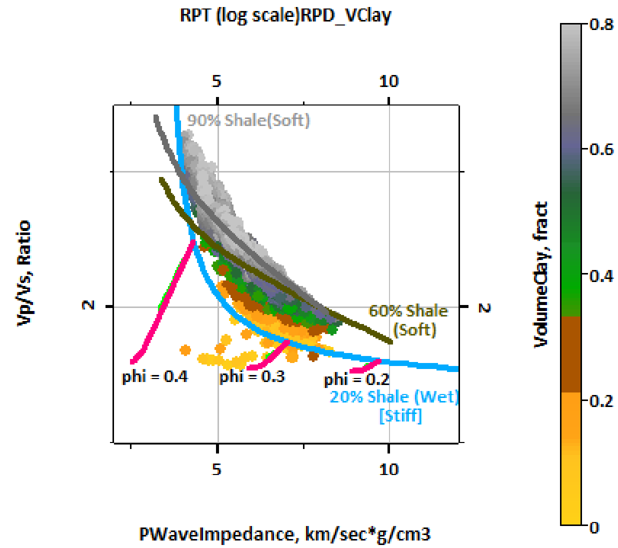


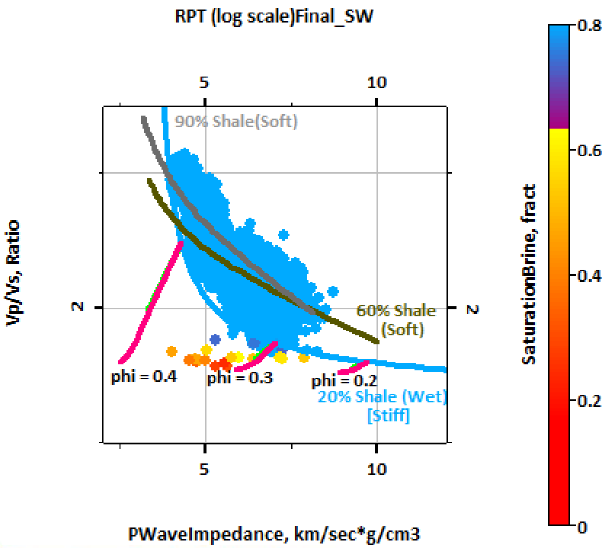
Tomani-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

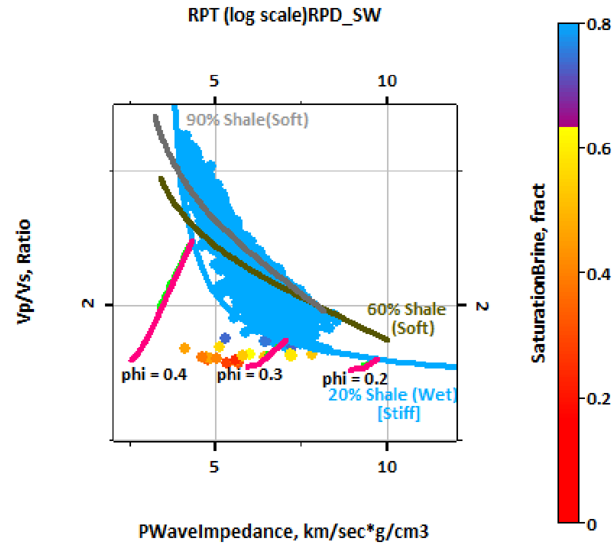
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model and stiff sand model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

Tulak-1

Tulak-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality and availability is poor. Client's petrophysical interpretation was not provided for this well(except for fast track SW and PHIT not for the whole well interval). Full Compressional wave velocity logs for the entire borehole while the density only runs in the interval(1030-1420m)
- No VS was run in the well, so it was fully modelled in the using the RPD after the model was carefully calibrated based on the nearby wells especially(Andalusit-1 and Haselfoot-1) The resulted Vs matched in trend all the nearby wells(Anadlusit-1, Haselfoot-1 and Samarang-1 wells).
- Vp was heavily by the bad hole conditions above 620m so no reliable response could be obtained to establish a rock physics model for that interval.
- Density was heavily edited in many intervals using the RPD due to the bad hole conditions
- Vp also was edited using the RPD in some intervals especially where the hole was affected by washouts as in the interval(1224-1280m).
- Elastic curves in the gap intervals was filled using a regression equation from Gamma ray to predict Vp then density and Vs was estimated using the RPD.
- Other logs include Gamma and Neutron which all run for the full logging run to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is the Miocene marine sands(no stages identified in the final geological report). These are a series of turbiditic fine to very fine sands intercalated with many claystone layers.
- The well penetrated many good sand layers especially above 800m and all were water saturated.
- No good quality sand was penetrated below 800m except few thin sand layers without any hydrocarbon saturation.

Volume of hydrocarbons:

- No resistivity log was available for the well to establish a detailed water saturation interpretation but the report indicated all the sands penetrated was water bearing.

Water saturation (Sw):

- Water sample obtained from nearby wells as Samarang-1 and Samarang-2 used in the well for reference as about 30000ppm. No water saturation was calculated since no resistivity was available for the well so the well was assumed to be dry as indicated in the final geological and completion report.

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that from the point where the elastic logs started down to the T.D. the Stiff sand model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for sand rich intervals while the soft sediment model honor more the elastic trend for the clay rich intervals.
- Elastic behavior for the well was carefully calibrated with the nearby wells and concluded that the well elastically behaves similar to Andalusit-1 and Haselfoot-1 wells , so S-wave velocity completely modelled in the well based on the same model and parameters used in the offset wells which resulted in a matched trend with the calibrated nearby wells.

Fluid properties:

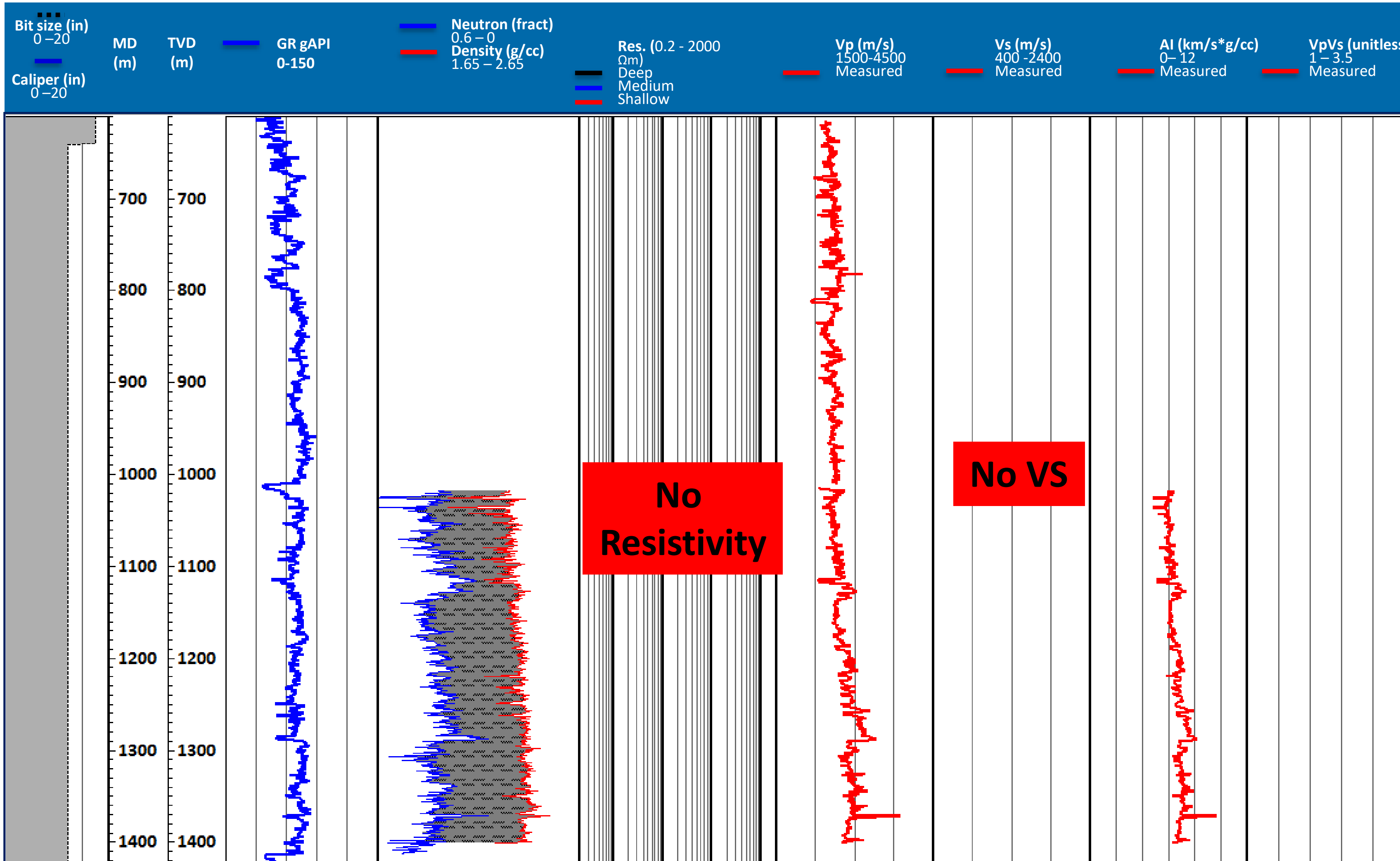
Fluid properties used in substitution have been taken from Samarang-1(DST). Main parameters used in this modeling are:

- Brine salinity: 30000ppm
- Gas gravity: 0.61
- Oil Gravity: 40.5 API
- Gas / Oil ratio: 615 (L/L)

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the different stages(IVE, IVD and IVC) using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with very good discrimination with the brine sands.
- Because of the poor quality sand no AVO response could be captured.

Tulak-1 Input Logs



Additional data includes final geological report. No VS recorded in the well.

Tulak-1 Geophysical Well Log Analysis (GWLA) – Interval from top of elastic logs to the end of the logs

model type flag

Unconsolidated rock model

Stiff rock model

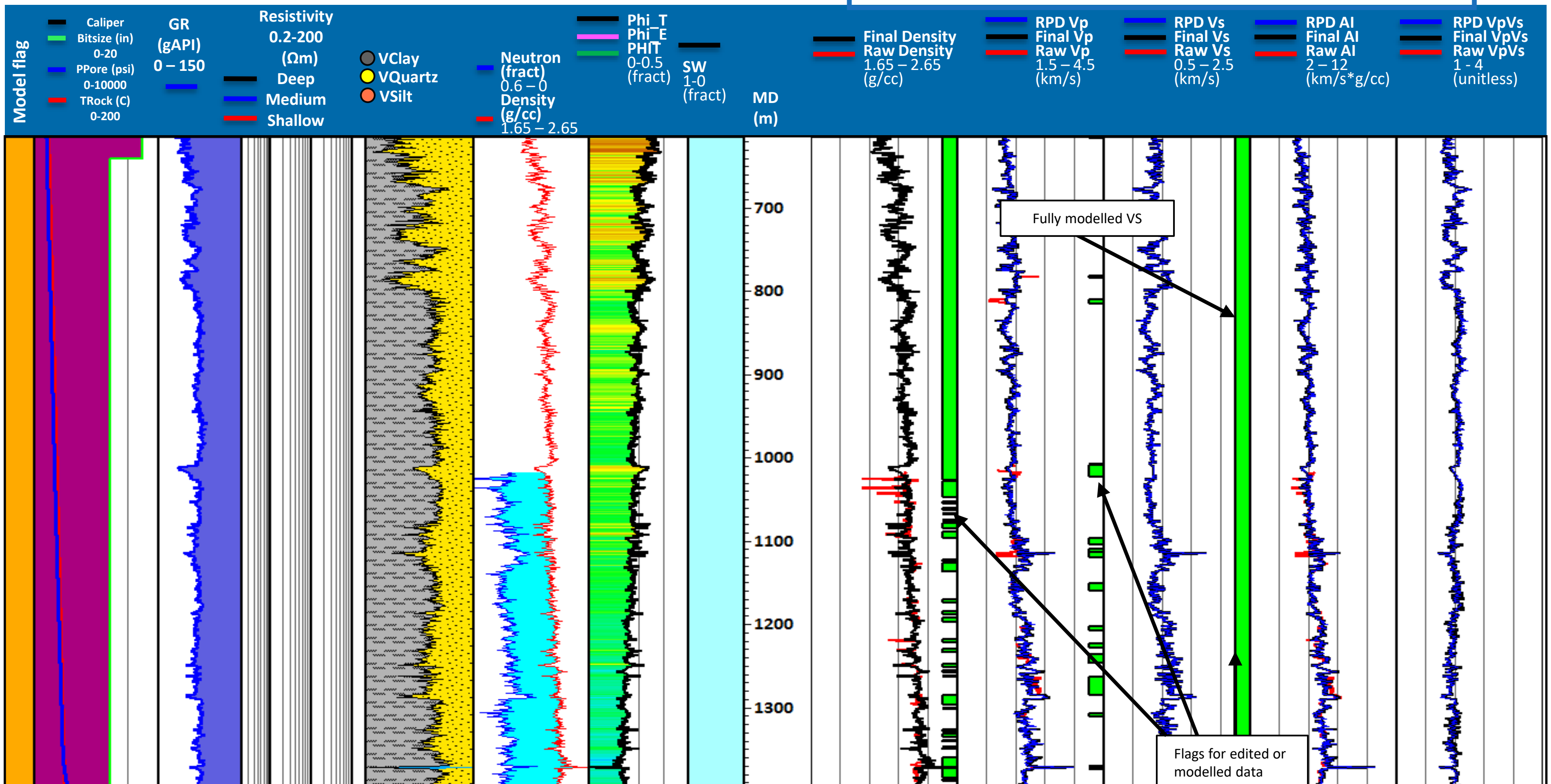
Above depth of 620m(MD) no reliable logs were available to establish a rock physics model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve



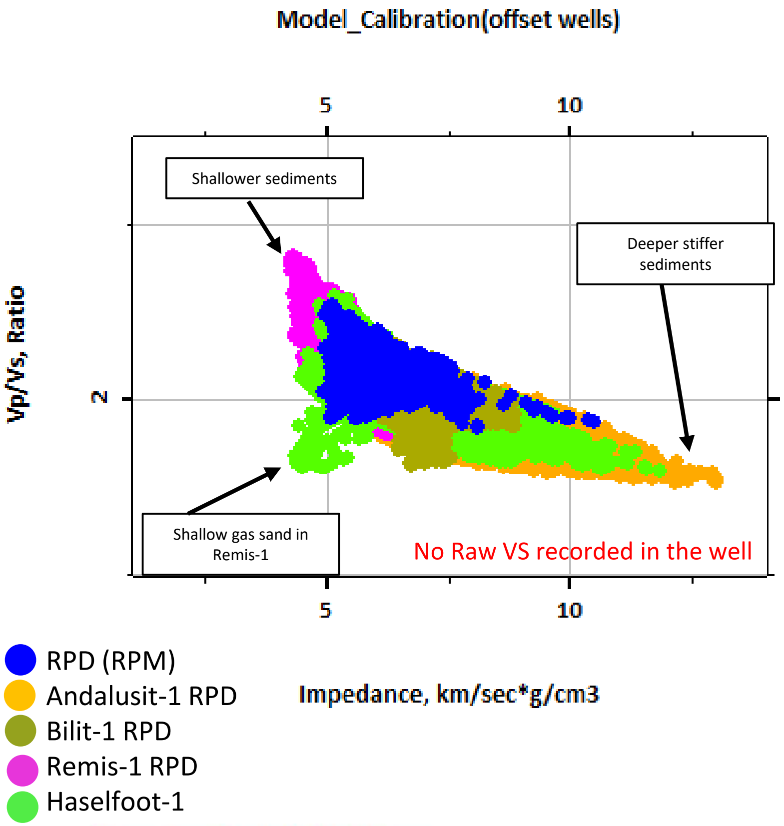
Many edits to the measured velocity and model calibration is strong where measured data looks good and reliable. Granular media model (Stiff sand) was used for all elastic curves prediction (Rhob, Vp and VS) for sand rich intervals and soft model for clay rich ones, with good correlation with the measured data and the nearby wells.

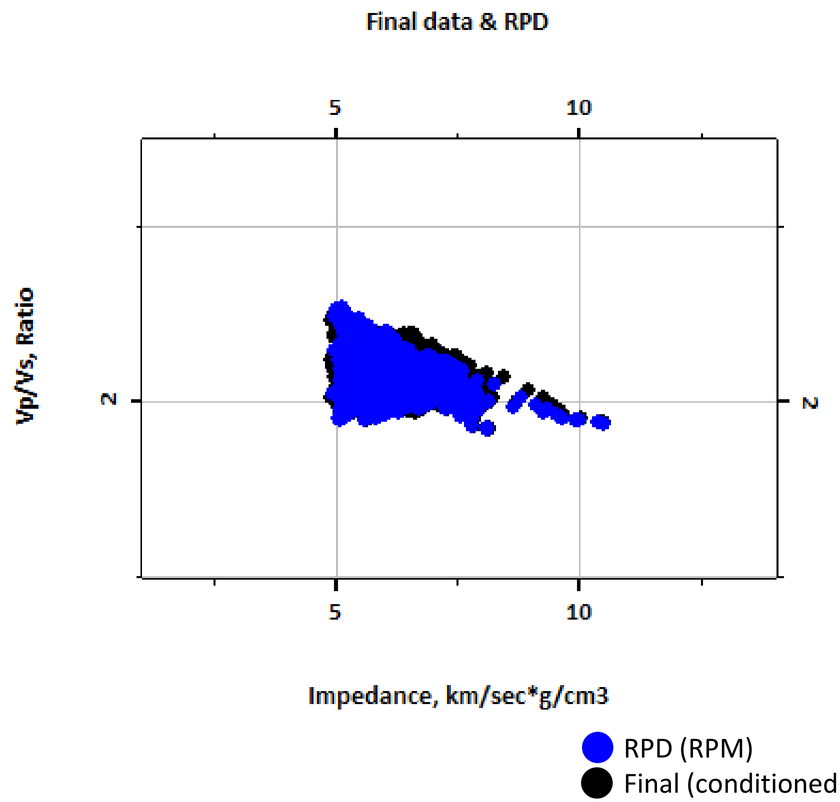
VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells

Tulak-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the good calibration for the Tulak-1 well RPD with the nearby wells Andalusit-1, Bilit-1, Remis-1 and Haselfoot-1.

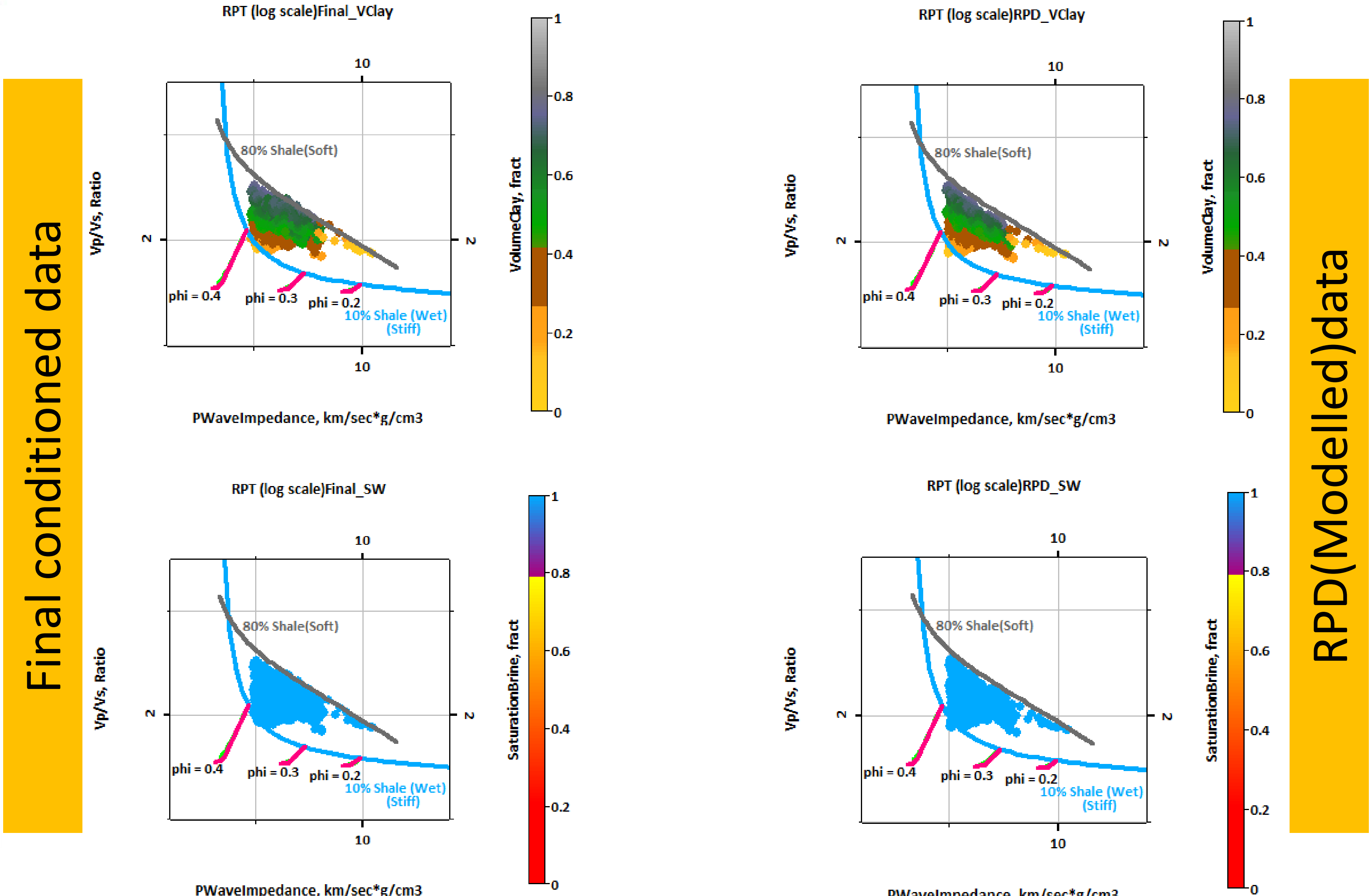
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data(Rhob and Vp ere conditioned while VS is totally modelled).





Tulak-1,Rock Physics Diagnostics (RPD) Rock Physics Models, Full Well

RPT cross plot shows the correlation between the rock physics model lines(soft/Stiff sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.



West Emerald-1

West Emerald-1 Geophysical Well Log Analysis and Rock Physics Modelling Summary

Log data availability and quality:

- In general, data quality is poor especially the density but the data availability is fair. Client's petrophysical interpretation was not provided for this. Full elastic logs except VS were available throughout the wellbore covering the interval (350m-T.D.)
- Elastic logs(VP and Rhob)were totally affected by the bad hole conditions above 380m so no reliable response could be obtained to establish a rock physics model for that interval.
- Shear wave velocity(VS)was fully modelled in the well using the RPD after the model was carefully calibrated based on the offset wells behaving elastically the same especially(Danum-1 nearby and Bilit-1 to the south) The resulted Vs matched in trend all the nearby wells especially the final modelled results for Bonanza-1(most closest well)
- Density was heavily edited in many intervals using the RPD due to the bad hole conditions especially above 700m and in the interval(1600-1900m)
- Vp also was edited using the RPD in some intervals especially where the hole was affected by washouts as in the interval(1000-1200m).
- Elastic curves in the bad Vp and Density measurements intervals were filled using deep resistivity(and Vclay where Resistivity is not reliable) to predict Vp via Faust equation then density and Vs were estimated using the RPD.
- Starting at depth about 1645m(MD) the well started to be impacted by over pressured causing sudden drop in the P-wave impedance records.
- Other logs include Gamma, SP, Caliper and Deep resistivity, which all run for the full logging run to the T.D.

Clay volume (VClay):

- This volume was derived from linear Gamma Ray method.

Reservoir characteristics:

- In terms of lithology the primary reservoir target is Miocene marine sands in the IVD stage. These are a series of turbiditic fine to very fine soft sands.
- The well penetrated many good sand layers in the IVD stage especially in the interval 700-1000 where total porosity reached up to 38% .

Volume of hydrocarbons:

- All sand reservoirs penetrated in the IVD sequence were 100% brine saturated.

Water saturation (Sw):

- Pickett plot analysis assisted in the Rw interpretation. Particularly, the clean wet sand(1100-1150m)yielded a formation water salinity of 18000 ppm. Water saturation was calculated using Simandoux's equation with constants used were (a)=1, Cementation exponent (m)=1.85 and Saturation exponent (n)=1.85 (assumed based on nearby wells' information).

Rock physics diagnostics (RPD):

- This was performed from top to bottom of the wellbore and indicated that the soft sediment model proved to be the best to predict the different elastic curves(RHOB, VP and VS) for both sand rich and clay rich intervals when compared to good measured data in the nearby reference wells and other wells on the same elastic trend.
- Elastic behavior for the well was carefully calibrated with the nearby wells and other wells honoring the same elastic trend for the well(P-Wave impedance depth trend) And concluded that the well elastically behaves similar to Danum-1 well and Bilit-1(even though it is far but elastically honoring West Emerald-1 elastic trend) , so S-wave velocity completely modelled in the well based on the same model and parameters used in the offset wells which resulted in a matched trend with the calibrated nearby wells and very well behaved model when compared to the modelled results in the most nearby well(Bonanza-1).

Fluid properties:

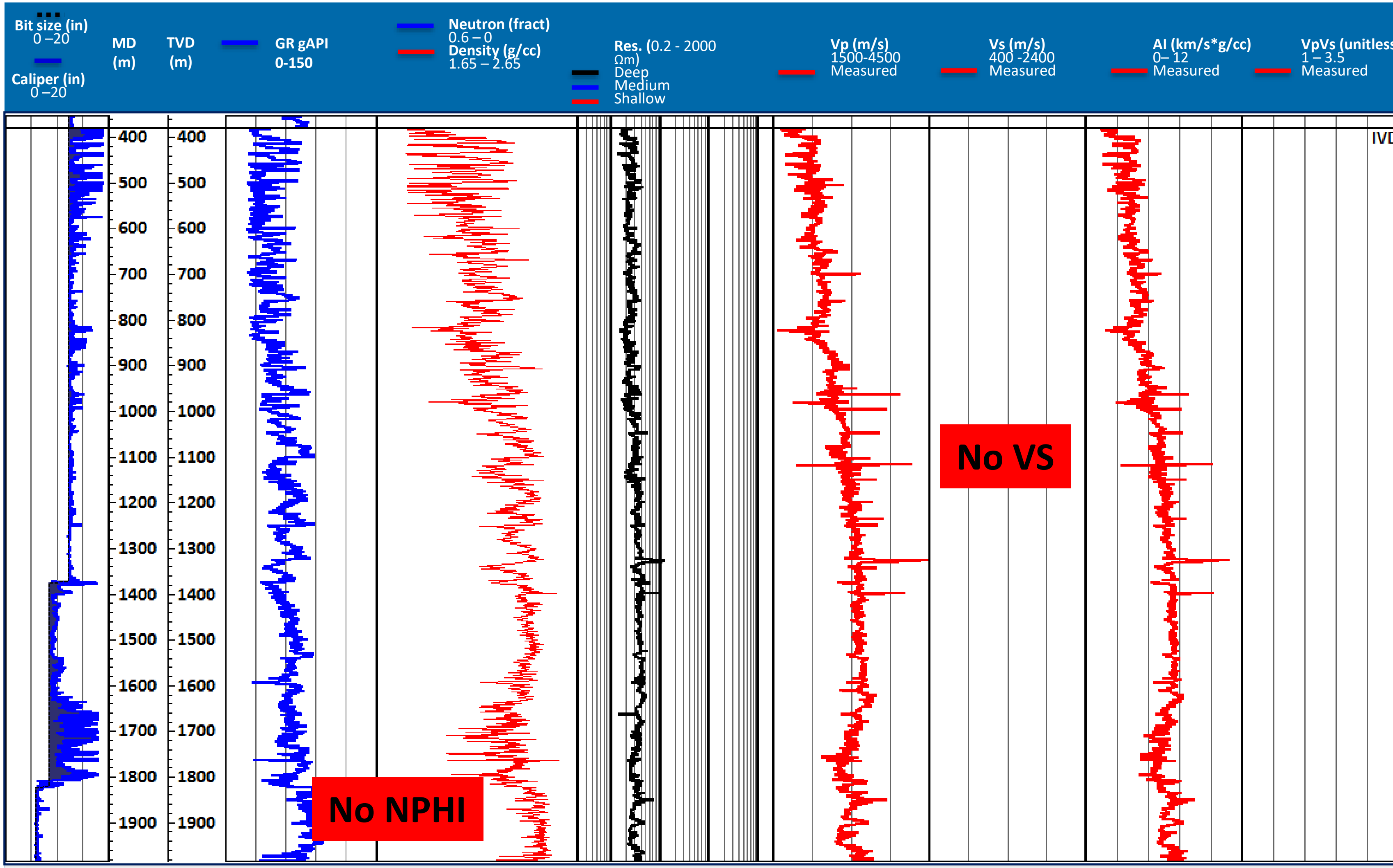
Fluid properties used in substitution have been taken from PVT report of nearby well Danum-1, Main parameters used in this modeling are:

- Brine salinity: 18000 ppm[Pickett plot]
- Gas gravity: 0.82[PVT analysis]
- Oil Gravity: 38.9 API[PVT analysis]
- Gas / Oil ratio: 500 (L/L) [PVT analysis]

Rock physics modelling (lithology, fluid and porosity):

- Perturbational modelling was performed in the different Miocene sands of the IVD stage using the final modelled elastic curves as an input.
- Gassmann's fluid substitution method was used to perturb the different Modeling scenarios
- Perturbational modelling showed the effect of changing porosity, volume clay, and fluid on the elastic properties. Gas saturated sands showed lower Vp/Vs ratio and lower p-wave impedance (AI) values than wet sands at log scale and upscaled domains with good discrimination with the brine sands.
- AVA class III was observed near a good porosity sand @ 1197m for all hydrocarbon cases at in situ reservoir conditions while the brine case following the background response.
- By downgrading the reservoir quality(decreasing porosity and increasing clay content) no significant change for the AVA class could be noticed except that the hydrocarbon cases tend to go towards class IIP response.

West Emerald-1 Input Logs



Additional data includes final geological report. No VS and Neutron logs recorded in the well.

West Emerald-1 Geophysical Well Log Analysis (GWLA) – Interval from 400 to 1100 m

model type flag

Unconsolidated rock model

Stiff rock model

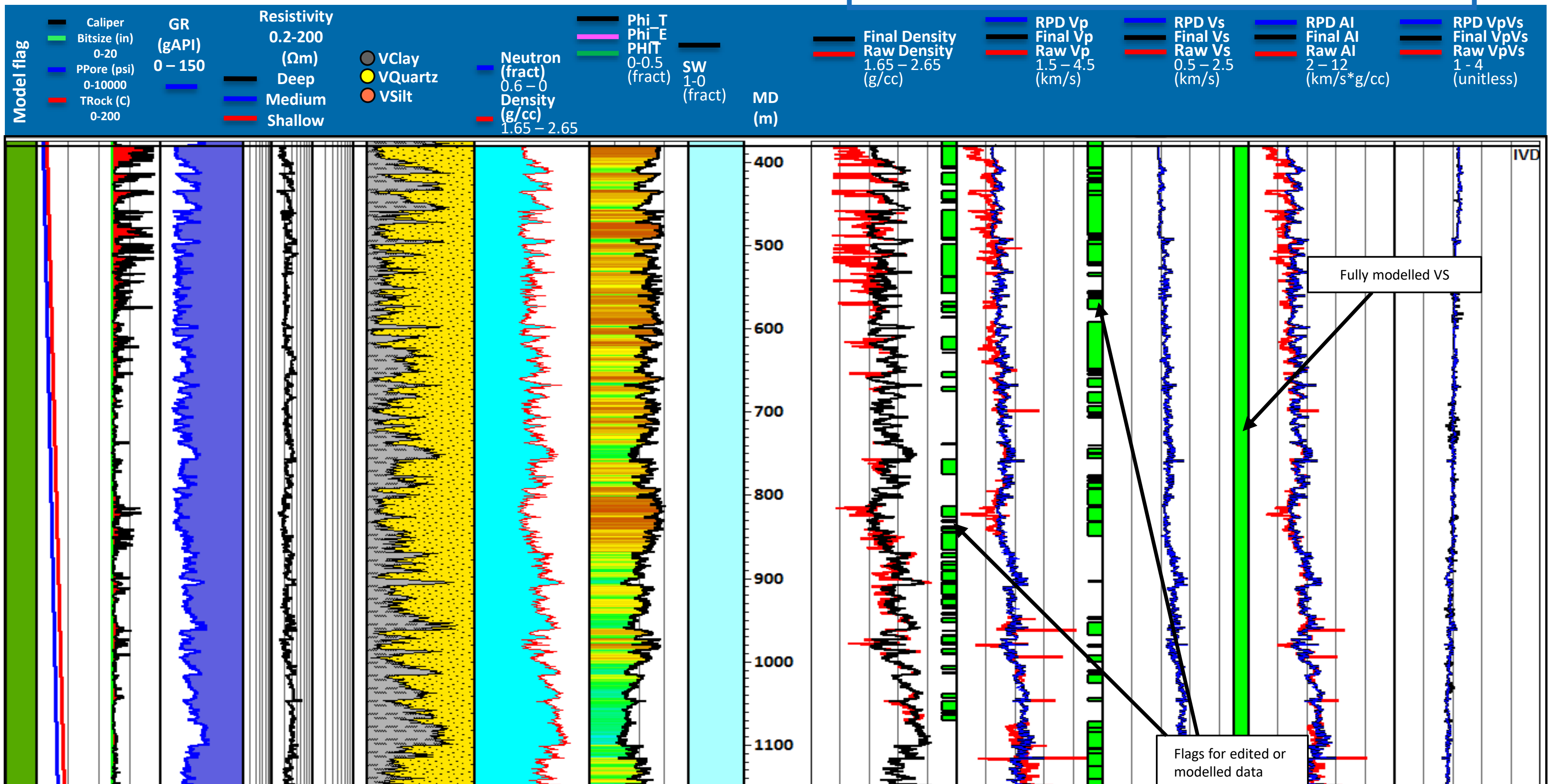
Above depth of 375m(MD) no reliable logs were available to establish a rock physics model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve

Final edited (Conditioned) curve

Original Raw (Raw) curve



Many edits to the measured Density and velocity and model calibration is strong where measured data looks good and reliable. Granular media model (Soft sand) was used for all elastic curves prediction (Rhob, Vp and VS) for both sand and clay rich intervals, with good correlation with the measured data in the well(VP and Rhob)and in the nearby wells.VS was totally modelled after elastic behaviour of the well was carefully calibrated with the nearby wells.

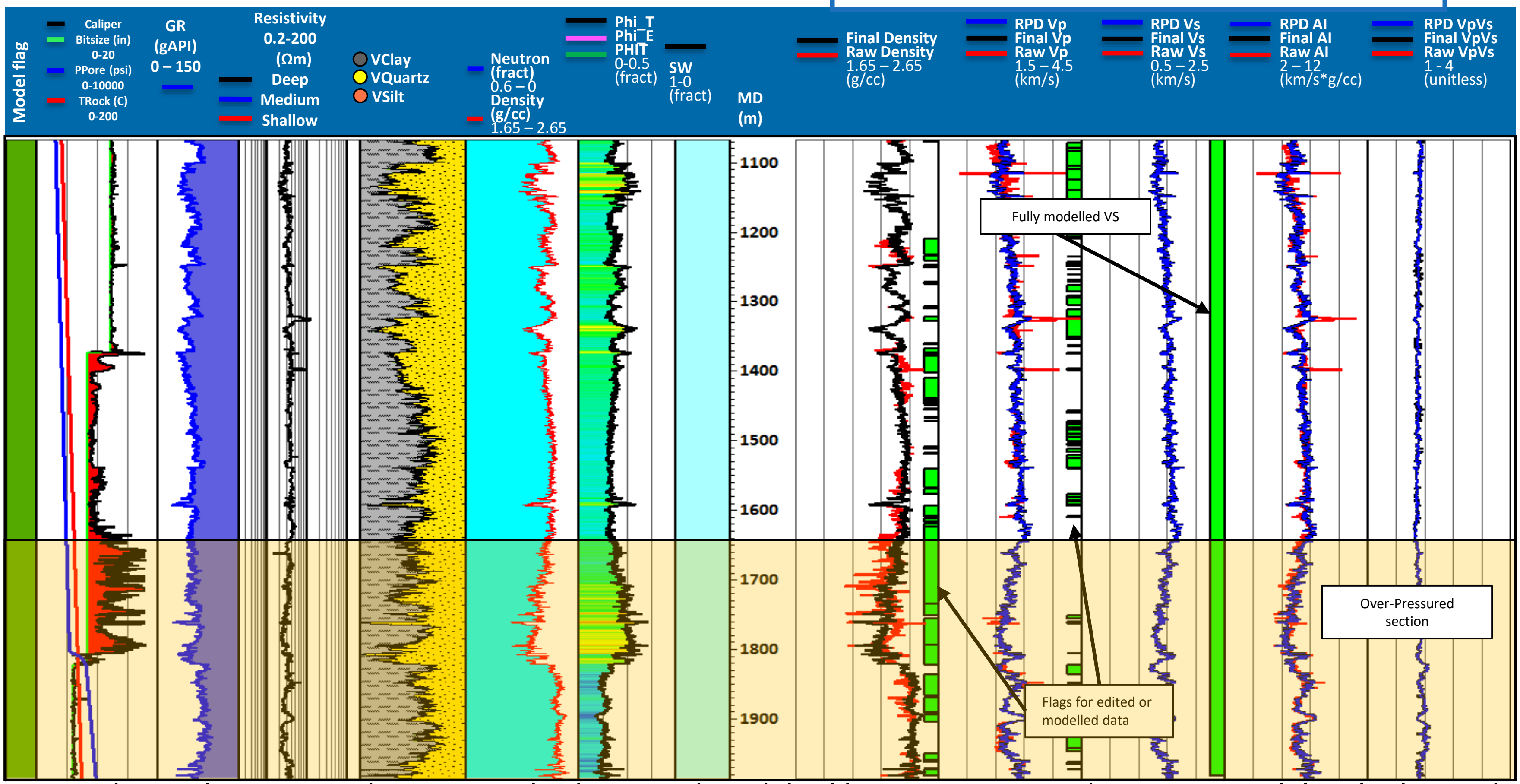
West Emerald-1 Geophysical Well Log Analysis (GWLA) – Interval from1100m to the end of logs

model type flag

Unconsolidated rock model
Stiff rock model

Equivalence between RSI and Petronas naming. Petronas equivalent curve name in parentheses

RPD Modeled (RPM) curve
Final edited (Conditioned) curve
Original Raw (Raw) curve



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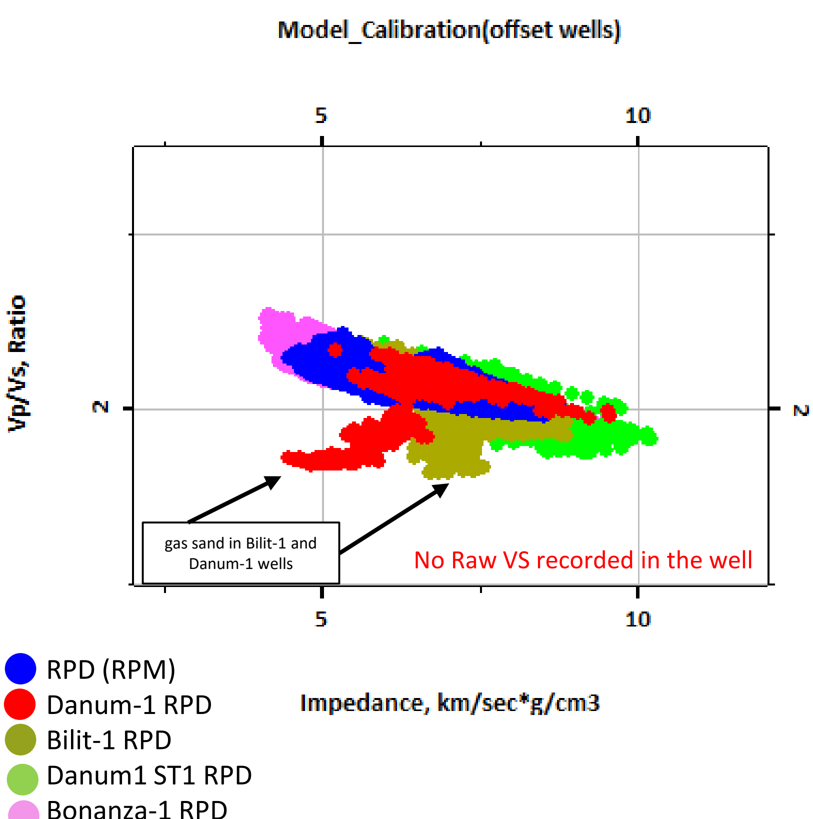
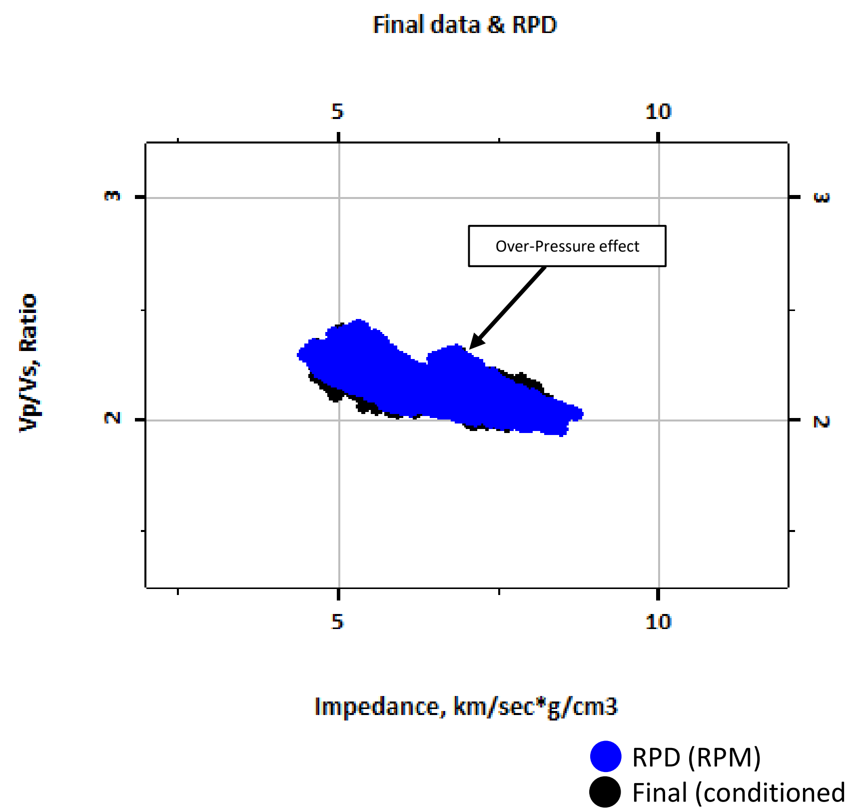
West Emerald-1,Rock Physics Diagnostics (RPD) Measured, conditioned and modelled data

P-Impedance vs. Vp/Vs plot showing the good calibration for the West Emerald-1 well RPD with the nearby wells Danum-1, Bilit-1, Danum-1 ST1 and Bonanza-1 well.



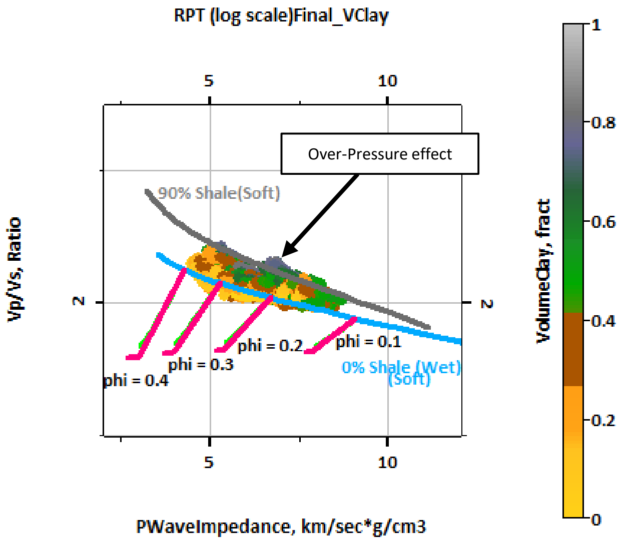
P-Impedance vs. Vp/Vs plot showing the overlay between the RPD model estimated elastic variables over the final conditioned data(Rhob and Vp ere conditioned while VS is totally modelled).

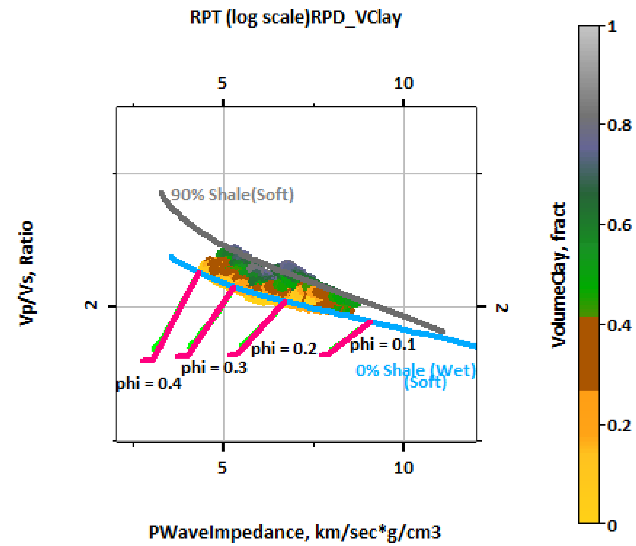


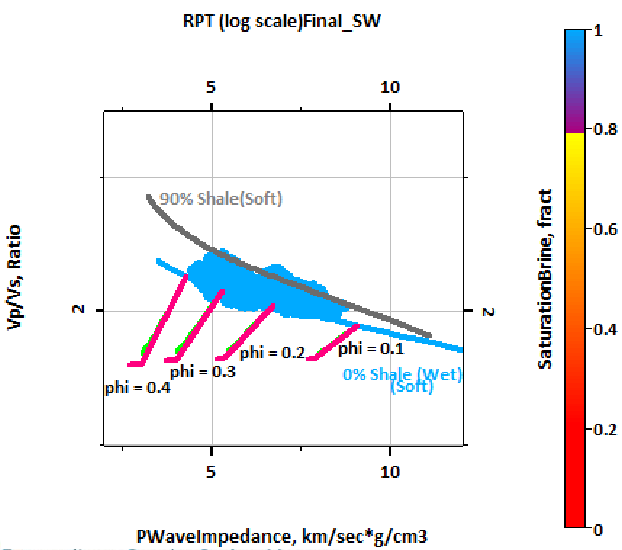
West Emerald-1,Rock Physics Diagnostics (RPD)
Rock Physics Models, Full Well

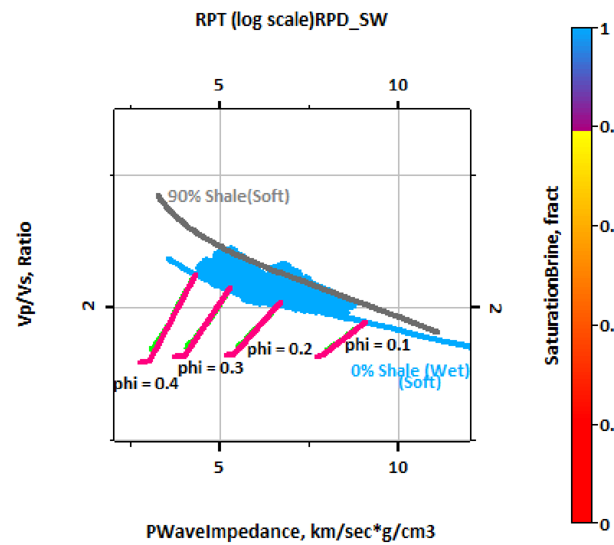
RPT cross plot shows the correlation between the rock physics model lines(soft sediment model) compared to both the final elastic data to the left and the modelled data to the right color coded by clay volume and water saturation.

Final conditioned data









RPD(Modelled)data

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