Click to View Poster

[EA]Impact of Shear Velocity Estimation on Wellbore Stability*

Charles Otoghile[1] and Chima Cyril Udeze[1]

Search and Discovery Article #42351 (2019)**
Posted February 4, 2019

*Adapted from extended abstract prepared in conjunction with poster presentation given at 2018 International Conference and Exhibition, Cape Town, South Africa, November 4-7, 2018
 DOI:10.1306/42351Otoghile2019

[1]Software Integrated Solutions, Schlumberger, Lagos, Lagos, Nigeria (cotoghile@slb.com)

Abstract

The main purpose of this study is to determine a shear velocity prediction scheme for deep offshore Niger Delta accurate enough for use in wellbore stability. There are few wells in the area that contain measured shear velocity data and these wells are located close to each other. Six (6) wells are utilized. The available logs were analyzed using Greenberg and Castagna and Mudrock line equations.

The aim is to determine how reliable the Greenberg and Castagna equation is in estimating shear velocity and to determine the locally calibration coefficients of the equation to use for similar lithologies in the Niger Delta. The results from the Greenberg and Castagna equation was further compared to the Mudrock line equation. The difference in the results further establish the importance of having locally calibrated coefficients when using the Greenberg and Castagna equation to estimate shear velocity.

Introduction

The Greenberg - Castagna method was used to predict the Vs in the study area using a control well with known sand and shale coefficients. New lithologies i.e. sand and shale (illite, kaolinite, muscovite mica, and chlorite) coefficient were derived using the data from the wells in the study area. This new calibration shows that the locally calibrated coefficient gave a better result in estimating shear velocity than the widely accepted Greenberg - Castagna coefficient. The local sand and shale trends are also closer than the controlled sand and shale trend. Note: The coefficients from Greenberg - Castagna equation were derived from a global data set including Gulf of Mexico samples.

The linear relationship between Vp and Vs used by Greenberg and Castagna is:

$$Vs = A0 + A1Vp \text{ for sand} \quad (1)$$
$$Vs = B0 + B1Vp \text{ for shale} \quad (2)$$

where A0=-0.85588, A1=0.80416, B0=-0.86735, and B1=0.76969.

Mudrock line equation is:

$$Vp = 1.16Vs + 1.36$$

Where Vp and Vs refers to P-wave velocity and S-wave velocity.

The wells in the study area are located in the range of 2,953 ft – 3,937 ft water depth and are referred to as Well #1, Well #2, Well #3, Well #4, Well #5, and Well #6. Crossplots of the Vp-Vs from Well #4 shows a linear relationship with some data points of the linear trend relationship. However, some data points outside the linear trend are due to the presence of hydrocarbon as shown in Figure 1.

Method

Petrophysical analysis was carried out in the study area and a robust lithologic model was developed. This model captures the volume of key minerals (quartz, illite, kaolinite, muscovite mica, and chlorite) in the study area. The Greenberg - Castagna Vp-Vs approach is lithology dependent.

A Gassmann fluid substitution of 100% brine saturation was performed on the key logs (Vp, Vs, density). Fluid properties were computed as this is a key component for fluid substitution (Figure 2, Figure 2a, and Figure 2b). Elastic properties (Poisson's Ratio, Young's Modulus, Bulk Modulus, and Vp/Vs) were also computed. The model was calibrated by adapting the constant/linear and quadratic factors of the Greenberg - Castagna equation for each of the minerals. Zones were defined for shales, hydrocarbon bearing sands, and wet sands. This was done to improve the calibration of the coefficient for each of the defined rock units/zones. These calibrated models were applied to other wells excluded from the calibration model to verify the accuracy of the prediction.

Results

The results of the study show the importance of having a locally calibrated coefficient for the Greenberg – Castagna equation (Figure 3). The results show a good match between the measured Vs and the modeled Vs (Figure 4, Figure 5, and Figure 6).

Discussion

From the analysis a good trend was observed between the measured Vs and the modeled Vs (Figure 7). This is an indication that the coefficient that was generated fit the shear velocity trend for computation of the Greenberg – Castagna equation locally i.e. Niger Delta. In addition, the Mudrock line equation was also used to compute shear velocity and this was compared to the result of the study. The result of the Mudrock line indicates an over estimation of the shear velocity as seen in Figure 8.

Conclusions

The locally calibrated coefficient shows a close match for Vs compared to the measured Vs. Even though these values are localized, they produce better Vs estimates in a test well. Shear slowness is a key component of the mechanical earth modeling because it is an important input when computing elastic parameters such as Young's Modulus and Poisson's Ratio. An over estimation or under estimation of shear slowness will have a huge impact on the final wellbore stability model.

Selected References

Henning, A., and G. Powers, 2000, Shear-Wave Velocity Estimation in the Deepwater Gulf of Mexico: 2000 SEG Annual Meeting, 6-11 August, Calgary, Alberta, SEG-2000-1723, 4 p.

Castagna, J.P., M.L. Batzle, and R.L. Eastwood, 1985, Relationships Between Compressional-Wave and Shear-Wave Velocities in Clastic Silicate Rocks: Geophysics, v. 50/4, p. 571-581.

Corredor, F., J.H. Shaw, and F. Bilotti, 2005, Structural Styles in the Deep-Water Fold and Thrust Belts of the Niger Delta: American Association of Petroleum Geologists Bulletin, v. 89/6, p. 753-780. doi:10.1306/02170504074

Onuoha, K.M., 1999, Structural Features of Nigeria's Coastal Margin: An Assessment Based on Age Data from Wells: Journal of African Earth Sciences, v. 29/3, p. 485-499. doi:10.1016/S0899-5362(99)00111-6

Tuttle, M.L.W., M.E. Brownfield, and R.R. Charpentier, 1999, Tertiary Niger Delta (Akata-Agbada) Petroleum System (No. 701901), Niger Delta Province, Nigeria, Cameroon, and Equatorial Guinea, Africa: U.S. Geological Survey, Open-File Report 99-50-H, 41 p.

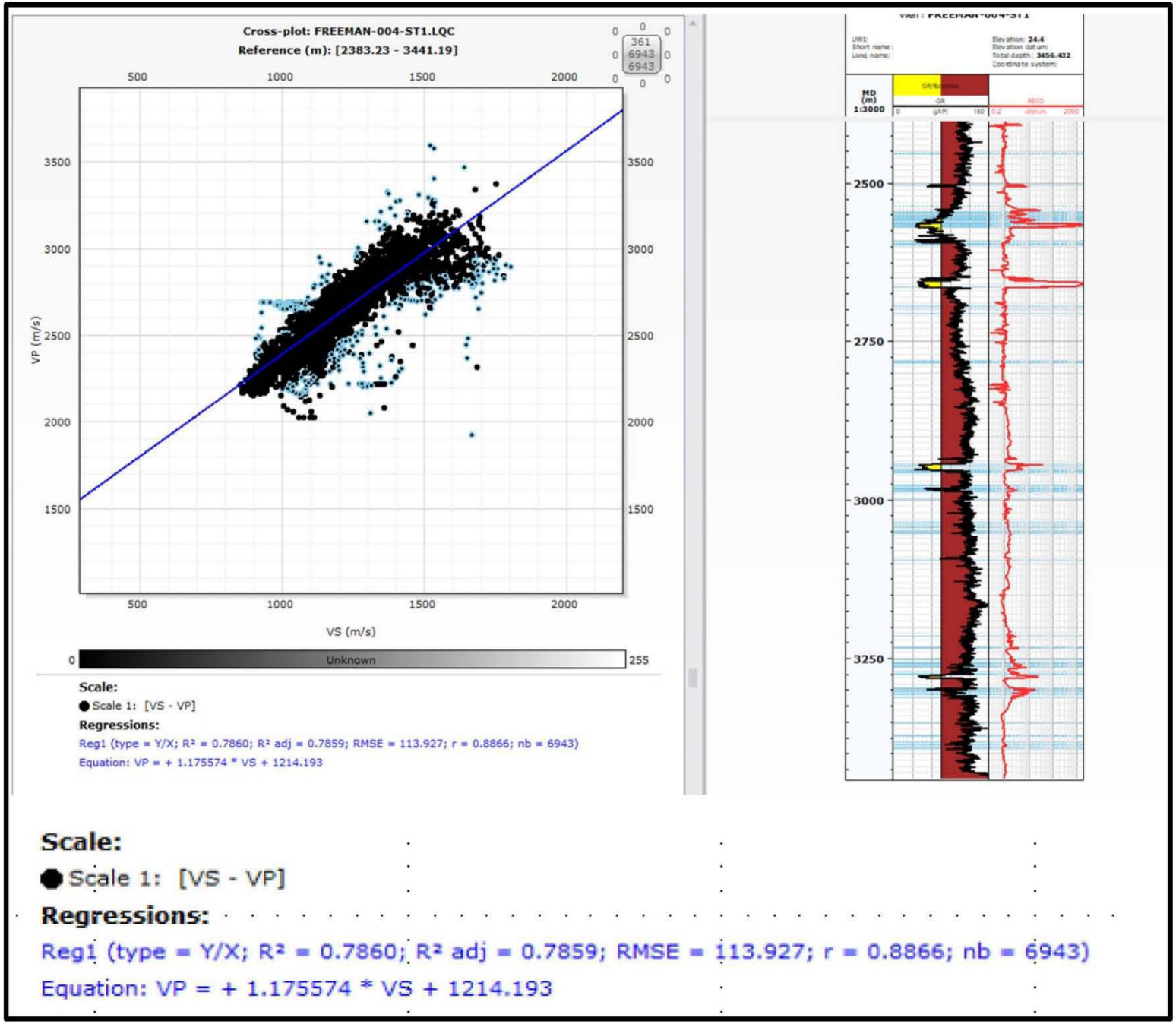

Figure 1. Showing crossplot of Vp – Vs relationship.

Method settings

Gassmann fluid substitution from logs | save and display

Inputs | Zonation | Cut-Off | Fluid Mixing | Mineralogy Mixing | Post-processing | Component specification

	1	2	3	4	5	6
Use	yes	yes	yes	yes	yes	yes
Group	2- main		2- main	2- main	2- main	2- main
Well	FREEMAN-001	FREEMAN-002	FREEMAN-003	FREEMAN-003-ST1	FREEMAN-005	FREEMAN-004-ST1
Dataset	LQC	LQC	LQC	LQC	LQC	LQC
Bulk Density	DEN	DENSITY	DENSITY	DENSITY	DENSITY	DENSITY
Total Porosity	PHIT_ND	PHIT_QE	PHIT_ND	PHIT_QE	PHIT_QE	PHIT_QE
Compressional Slowness	DT	DTC	DTC	DTC	DTC	DTC
Shear Slowness	DTS	DTS	DTS	DTS	DTS	DTS
Initial Water Saturation	SW_QE	SW_QE	SW_QE	SUWI_QE	SUWI_QE	SW_QE
Mineral Volume Fraction_Clay Volume Fraction	VCL_GEO_QE	VCL_GEO_QE	VCL_GEO_QE	VCL_GEO_QE	VCL_GEO_QE	VCL_GEO_QE
Mineral Volume Fraction_Chlorite Volume Fraction	Chlorite_QE	Chlorite_QE	Chlorite_QE	Chlorite_QE	Chlorite_QE	Chlorite_QE
Mineral Volume Fraction_Illite Volume Fraction	Illite_QE	Illite_QE	Illite_QE	Illite_QE	Illite_QE	Illite_QE
Mineral Volume Fraction_Kaolinite Volume Fraction	Kaolinite_QE	Kaolinite_QE	Kaolinite_QE	Kaolinite_QE	Kaolinite_QE	Kaolinite_QE
Mineral Volume Fraction_Muscovite Volume Fraction	Musc-Mica_QE	Musc-Mica_QE	Musc-Mica_QE	Musc-Mica_QE	Musc-Mica_QE	Musc-Mica_QE
Mineral Volume Fraction_Quartz Volume Fraction	Quartz_QE	Quartz_QE	Quartz_QE	Quartz_QE	Quartz_QE	Quartz_QE

Figure 2. Showing Gassmann fluid substitution of 100% brine.

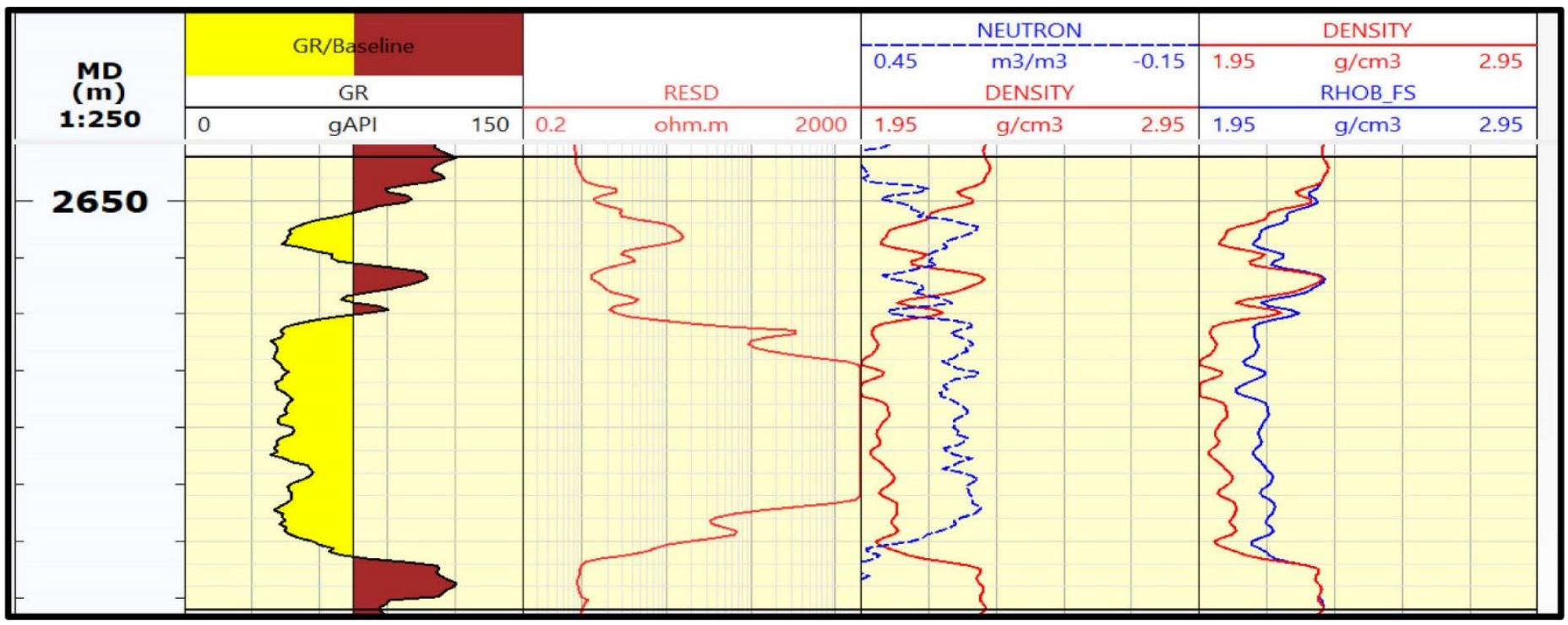

Figure 2a. Showing Gassmann fluid substitution of 100% brine.

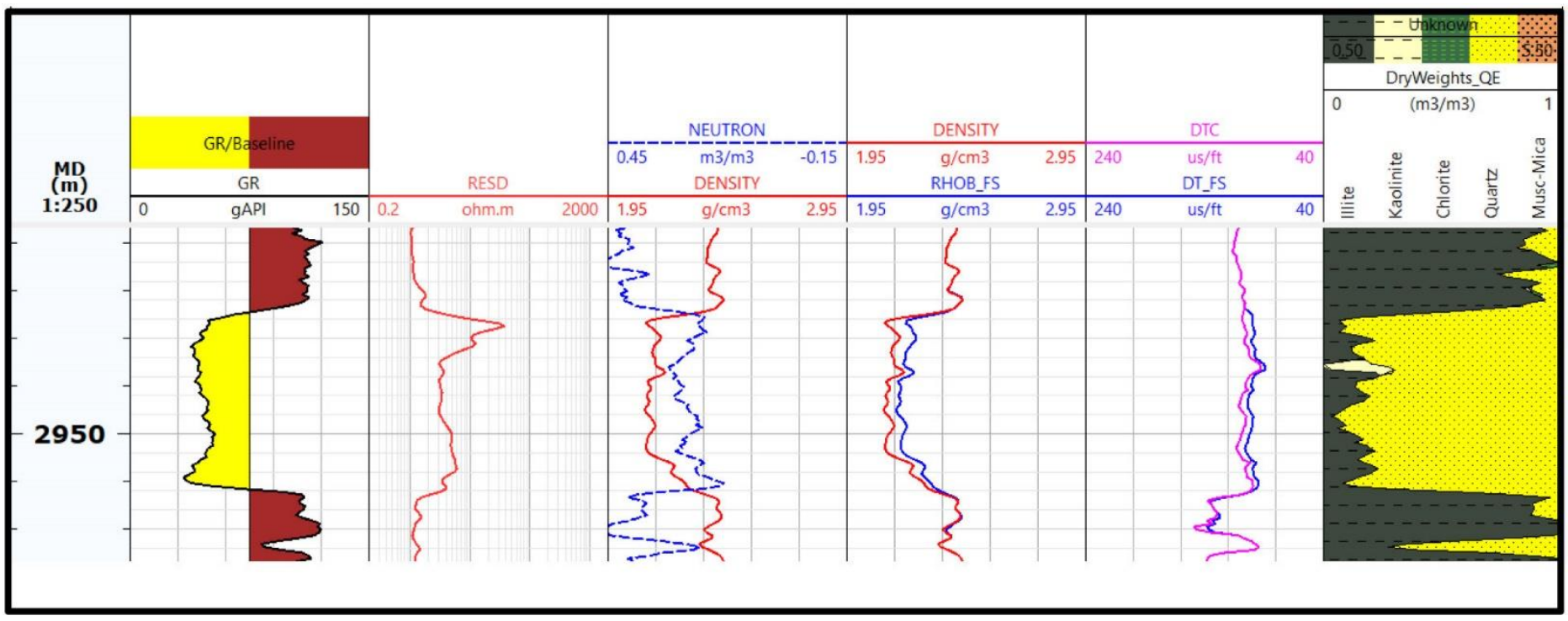

Figure 2b. Gassmann fluid substitution showing gas effect on the mineral.

	Well #1	Well #1	Well #1	Well #1	Well #1	Well #4	Well #4
Dataset	LQC	LQC	LQC	LQC	LQC	LQC	LQC
Zone	Shale 1	wet sand	Oil Sand	Shale 2	Shale 1	Oil Sand	Shale 2
Top	3099.89	1583.489	3602.284	3651.448	2393.605	2501.575	2593.238
Bottom	3407.165	2067.446	3651.448	4120.042	2501.575	2506.886	2648.046
Optimize	Quartz quadratic ...	Quartz quadr...	Quartz q...	Quartz q...	Quartz quadra...	Quartz quadra...	Quartz quadra...
Quartz quadratic coefficient	0.364117	0.250895	-0.158975	-0.139388	0.364117	-0.158975	-0.139388
Quartz linear coefficient	-1.00167	-1.21936	1.70757	1.7686	-1.00167	1.70757	1.7686
Quartz constant	1.2812	2.11182	-2.14303	-2.48821	1.2812	-2.14303	-2.48821
Shale quadratic coefficient	-0.235079	1.49698	-0.0596675	-0.084599	-0.235079	-0.0596675	-0.084599
Shale linear coefficient	1.88333	-5.19973	1.08327	1.16387	1.88333	1.08327	1.16387
Shale constant	-2.122	5.11545	-1.22976	-1.27943	-2.122	-1.22976	-1.27943
Calcite quadratic coefficient	-0.05508	-0.05508	-0.05508	-0.05508	-0.05508	-0.05508	-0.05508
Calcite linear coefficient	1.01677	1.01677	1.01677	1.01677	1.01677	1.01677	1.01677
Calcite constant	-1.03049	-1.03049	-1.03049	-1.03049	-1.03049	-1.03049	-1.03049
Dolomite quadratic coefficient	0	0	0	0	0	0	0
Dolomite linear coefficient	0.58321	0.58321	0.58321	0.58321	0.58321	0.58321	0.58321
Dolomite constant	-0.07775	-0.07775	-0.07775	-0.07775	-0.07775	-0.07775	-0.07775

Figure 3. Calibration of the Greenberg – Castagna coefficient.

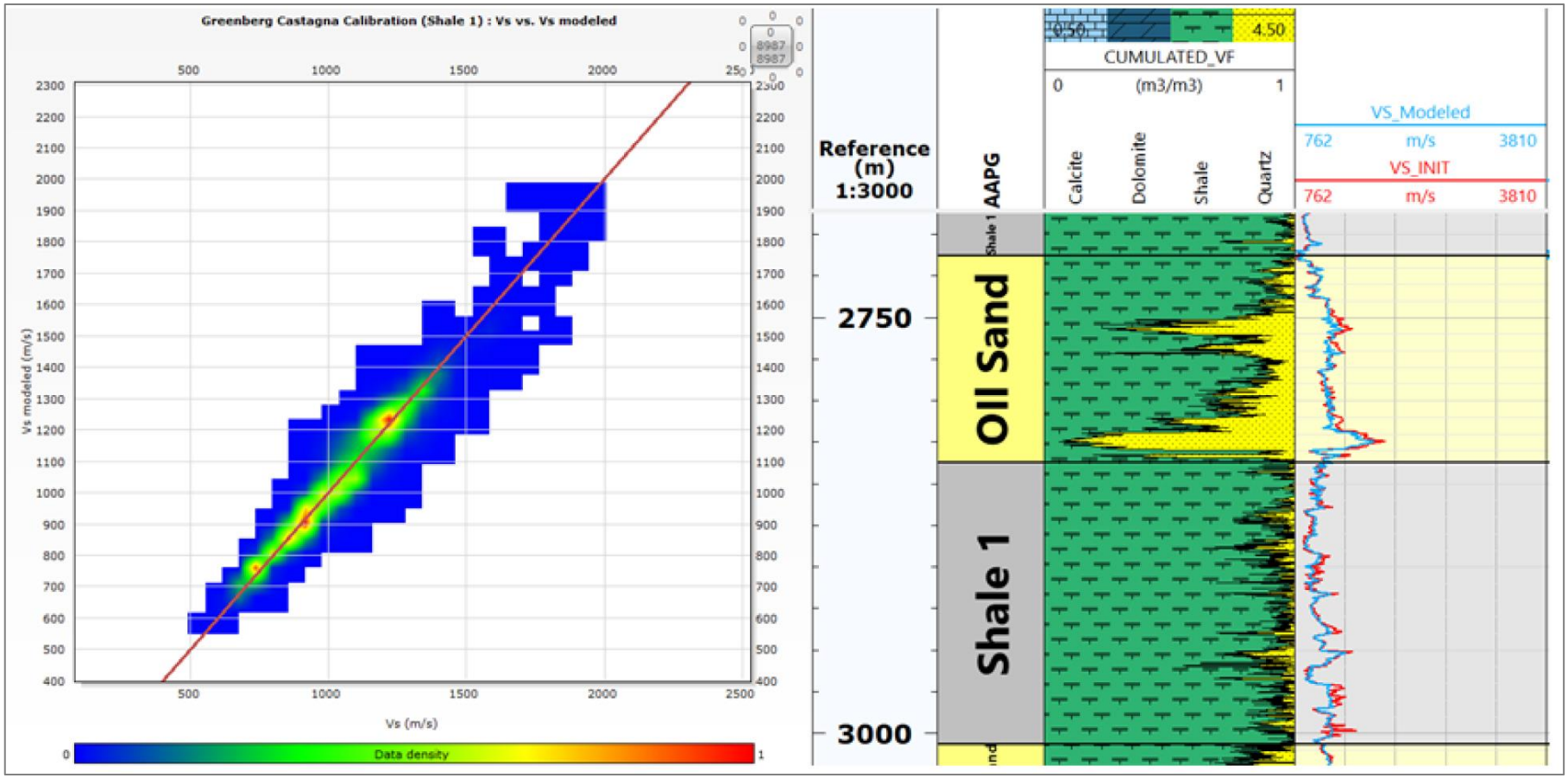

Figure 4. Crossplot of Vs modeled vs Vs measured for well #1.

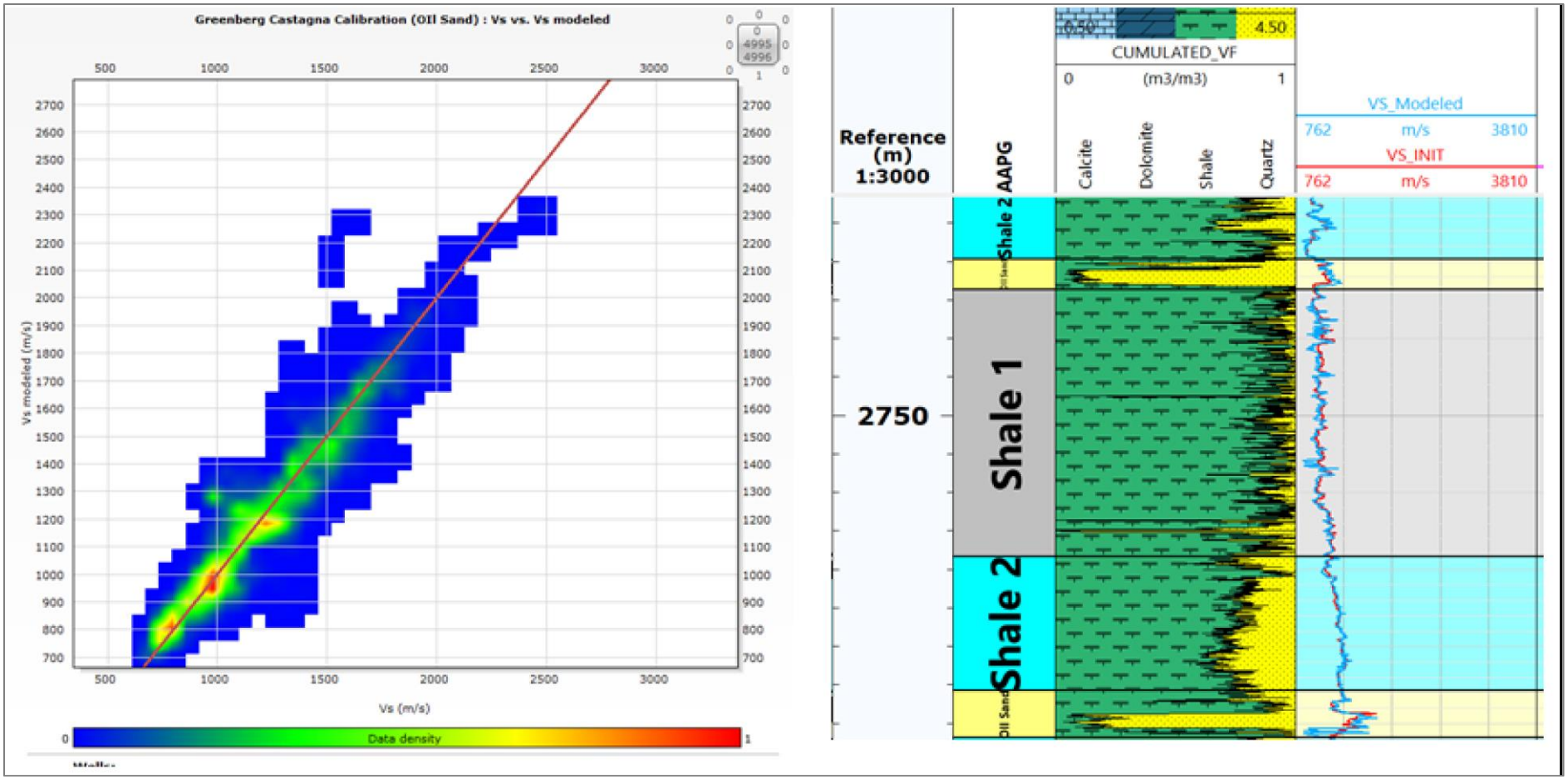

Figure 5. Showing a crossplot of Vs modelled vs Vs measured for well #4.

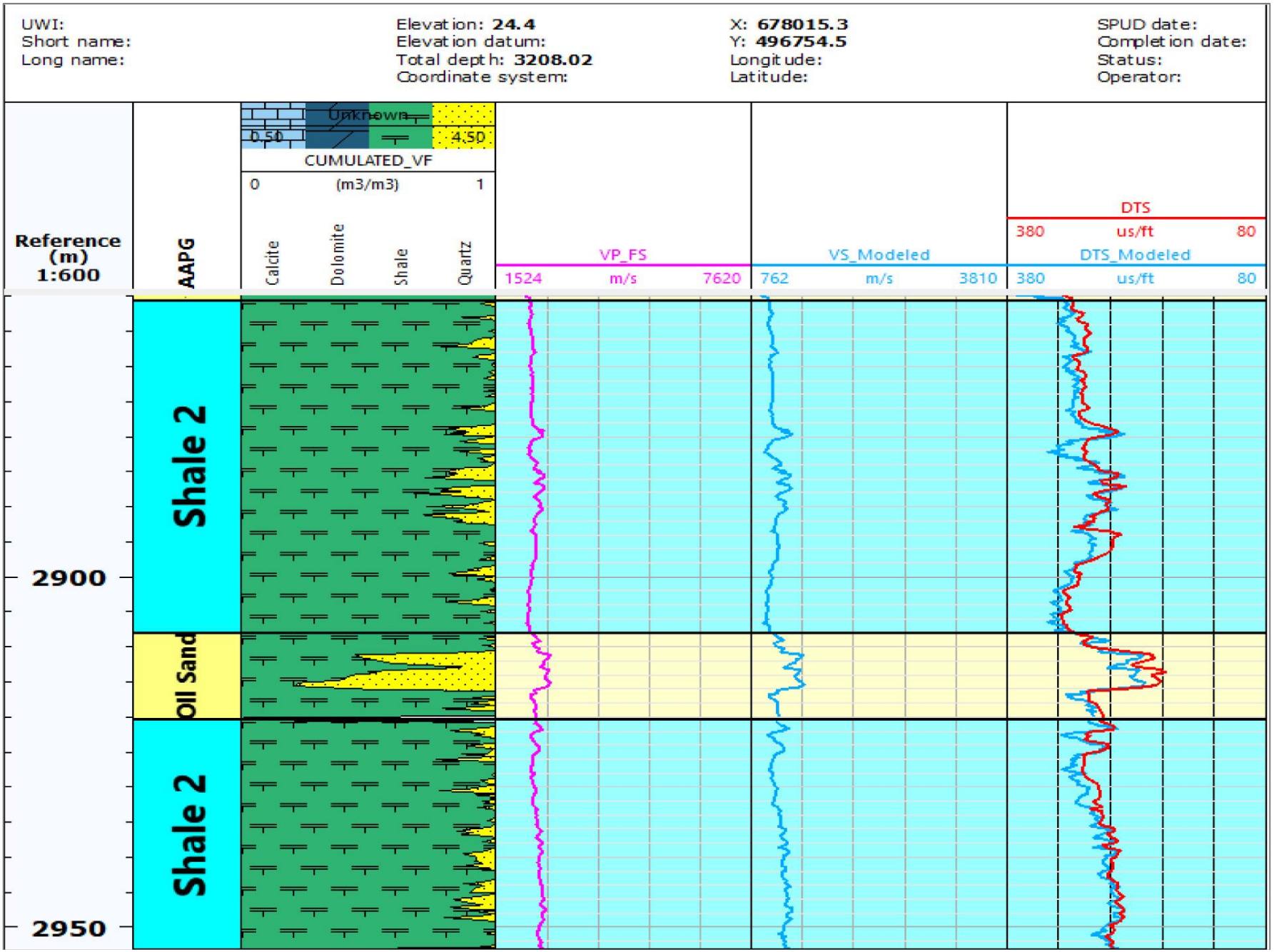

Figure 6. Showing application of the calibrated on Well #3. Note shows close match between the predicted DTS and measured DTS.

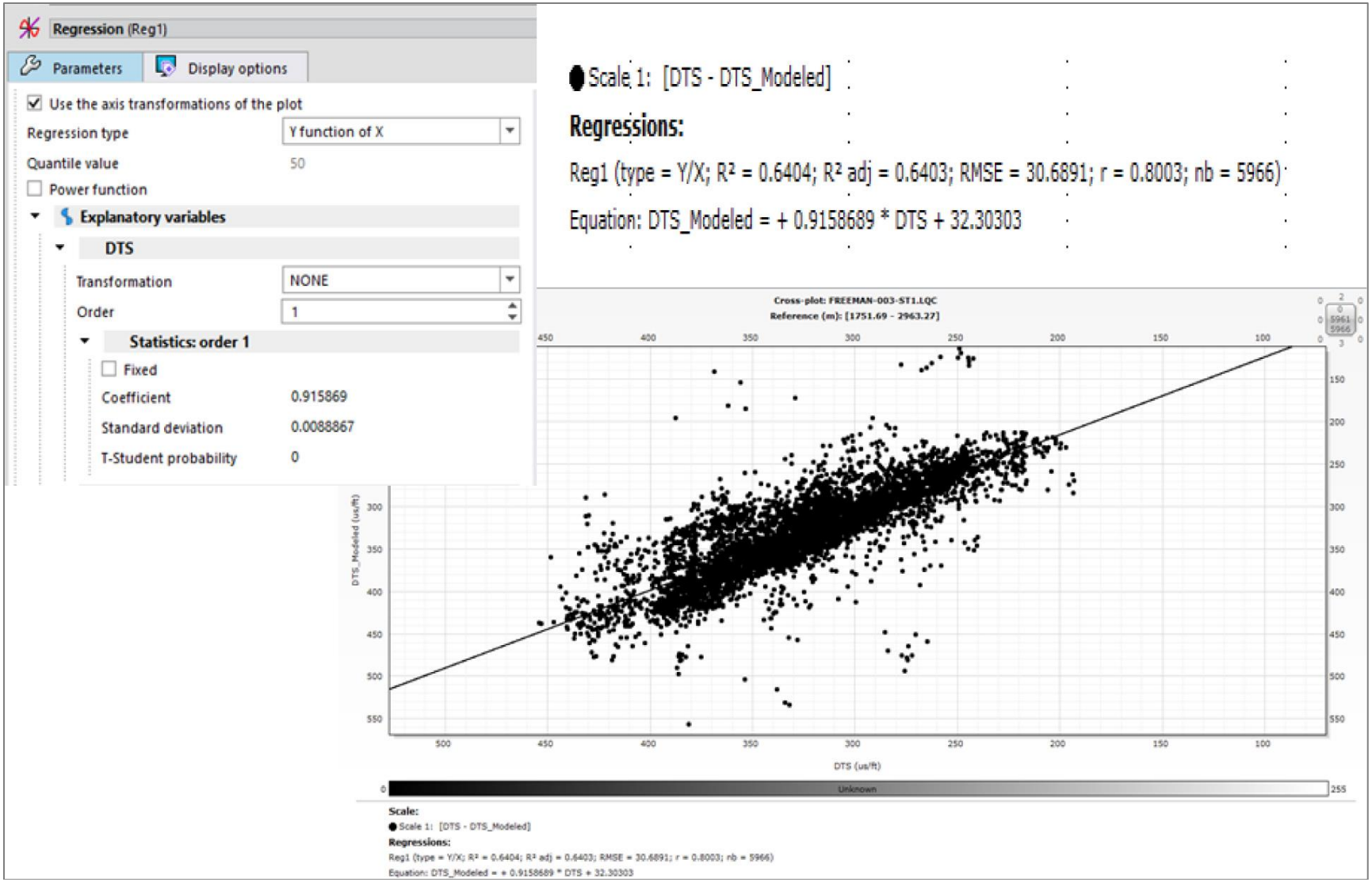

Figure 7. Showing the crossplot of the measured vs predicted.

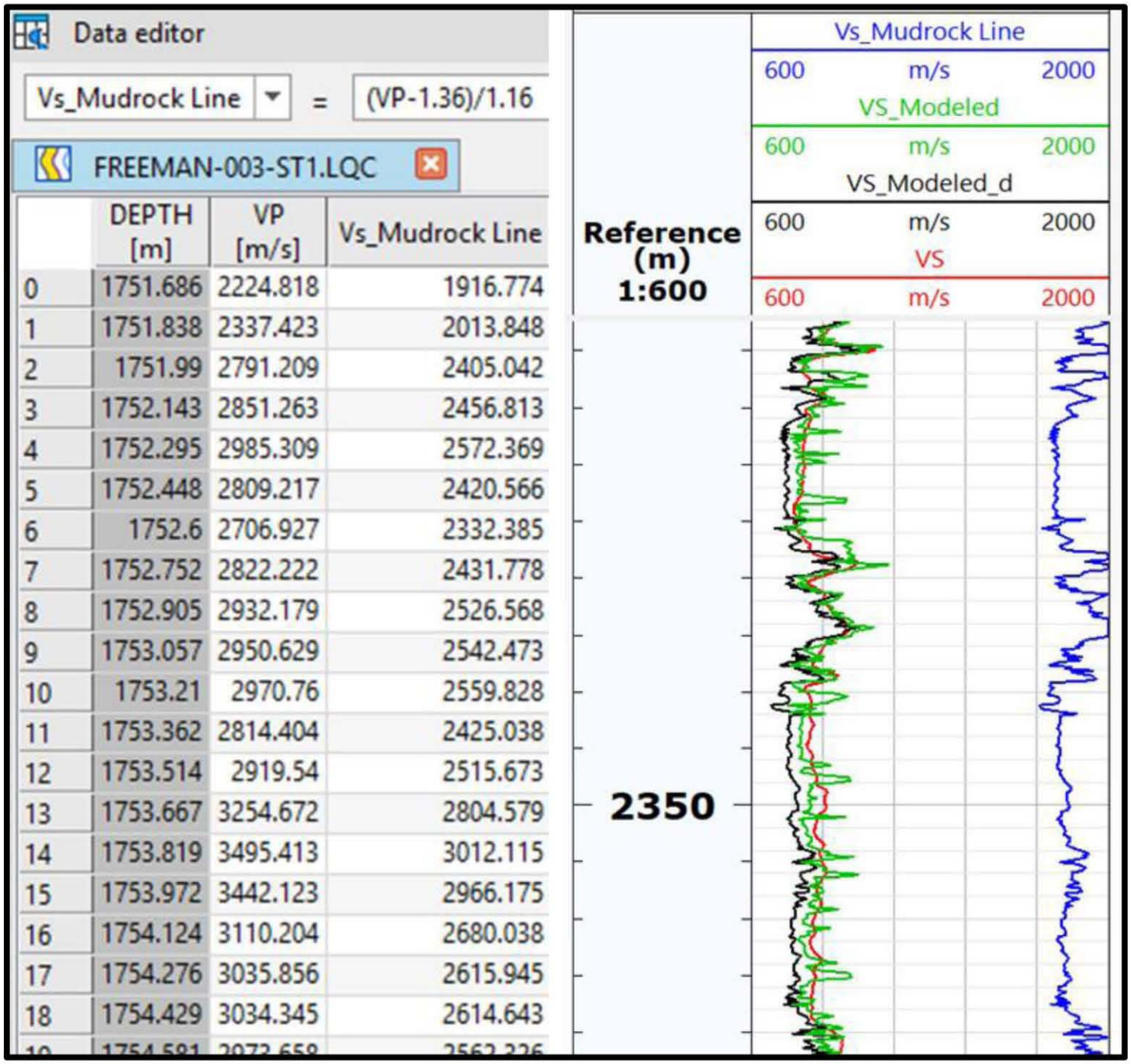

Figure 8. Mudrock line comparison with modeled Vs.