A Way of TOC Characterization on Barnett and Woodford Shale*

Sumit Verma[1] and Kurt Marfurt[2]

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[1]University of Oklahoma, Norman, OK (sumit.verma@ou.edu)
[2]University of Oklahoma, Norman, OK

Abstract

TOC is one of the most important parameter for a resource play characterization. TOC can be measured on the core data accurately or TOC can also be estimated on the logs with different methods. Passey's (1990) method of TOC calculation with well log data is one of the most popular methods. We believe that if core and log data both are available the multi-linear relation can also be generated to estimate the TOC on the non-cored wells. This technique can give a better result with in the area, as the relationship is generated for one in that area or that type of rock.

Here, we also tried to compare the results of TOC estimation by Passey's estimation and multi-linear regression. The results show that the multi-linear regression and Passey's method has the same trend in TOC curve but the absolute values are not the same. But, in reality we are more interested in the relative value of TOC rather than the absolute values of TOC. So, TOC calculation can be made by either method will be appropriate. With multi-linear regression and the neural network method the TOC calculated on the logs can extended to the volume with different seismic and seismic inversion attributes available.

Introduction

Barnett and Woodford shales are one of the most important shale plays in USA. The high TOC Mississippian-age Barnett Shale is an unconventional gas resource that keeps the Fort Worth Basin (FWB) in the limelight. The organic-rich, silty Woodford Shale in west-central Oklahoma is a prolific resource play producing both gas and liquid hydrocarbons. The sweet spots in the Barnett Shale and Woodford Shale are defined by two main factors, the high TOC and high brittleness.

Several authors including Passey et al., 1989; Fertl and Rieke 1980, and Schmoker 1981 have worked on finding TOC from well log data. Passey's method has been very popular in some recent years. Here, in this paper we have computed the multi-linear regression relation with which we can generate a regression relation for TOC log and the other available log on the well which has core data. We also tried to compare the results of Multi linear regression and Passey's method. TOC can be calculated over volume in the similar way as described by Verma et al., 2012 for GR.

Method and Results

We calculated the TOC with Passey's method (Figure 1) and multi-linear regression. Here, we will describe the Passey's method and show the result of Passey's method and the actual TOC. Then, we will show the multi-linear regression method result and compare it with the actual TOC. After that, we calculate the TOC over volume for Barnett Shale by multi-linear regression with the seismic attributes and TOC logs generated by Passey's method.

Passey's Method

Passey's method is also called "Delta log R" method. For calculating TOC, a resistivity log along with a porosity log (P-Sonic, Density or Neutron log) is required (Figure 2).

$\Delta logR = log (RTD / RTD\_Base) + 0.02 * (DT – DT\_base)$

$TOC = (\Delta logR * 10^{(0.297 – 0.1688 * LOM)})$

RTD = deep resistivity in any zone (ohm-m)
RTD_Base = deep resistivity baseline in non-source rock (ohm-m)
DT = compressional; sonic log reading in any zone (usec/ft)
DT_Base = sonic baseline in non-source rock (usec/ft)
LOM= Level of Maturity

Here, for finding the appropriate RTD base, we have tried several values and the base line, as the baseline is interpreter dependent. Here, the TOC comes from the core measurements and the log values come from the well logs. The final relation:

logR=log10(Resistivity_1/150)+(1/25)*(P_wave_1-70)
TOC=logR*10^(2.297-).1688*8)

Multi-linear Regression

The relation between the well logs and TOC log generated by the muti-linear regression can be used to calculate the TOC on the wells where there is no core TOC available (Figure 3).

Comparison of Passey's Method and Multi-linear Regression

Comparison of TOC generated by Passey's method and the multi-linear regression shows a shift of scale. So, the absolute values of TOC calculated by the two methods do not match but the trend of TOC curve remains the same (Figure 4).

3D - TOC Volume Generation

After generating the TOC over different wells based on the Passey's method, the approach of Neural Network (Verma et al., 2012) is applied. I have used the same workflow which was used for the GR prediction by Verma et al., 2012 (Figure 5). Then I used step wise multi-linear regression relation and neural network to compute the TOC. I used operator length of 14 and 6 attributes (Figure 6).

The generated volume was compared with the TOC well logs. Figure 7 shows the TOC volume section and the match between the generated TOC volume and well logs is good on the wells which were used in the neural network as well as the wells which were not used in the neural network analysis.

The computed TOC Map can be used to find the location of good TOC areas (Figure 8).

Conclusions

TOC can be measured on core as well as can be calculated by several methods. TOC calculated with different method shows that, although the values of TOC are not matching but the TOC trend is similar. TOC with multi-linear regression gives a very good tool to find the TOC on wells. The only condition here is that, we need to have a well inside the survey which has TOC estimated on the core. The volumetric estimation of TOC provides a good tool for well planning.

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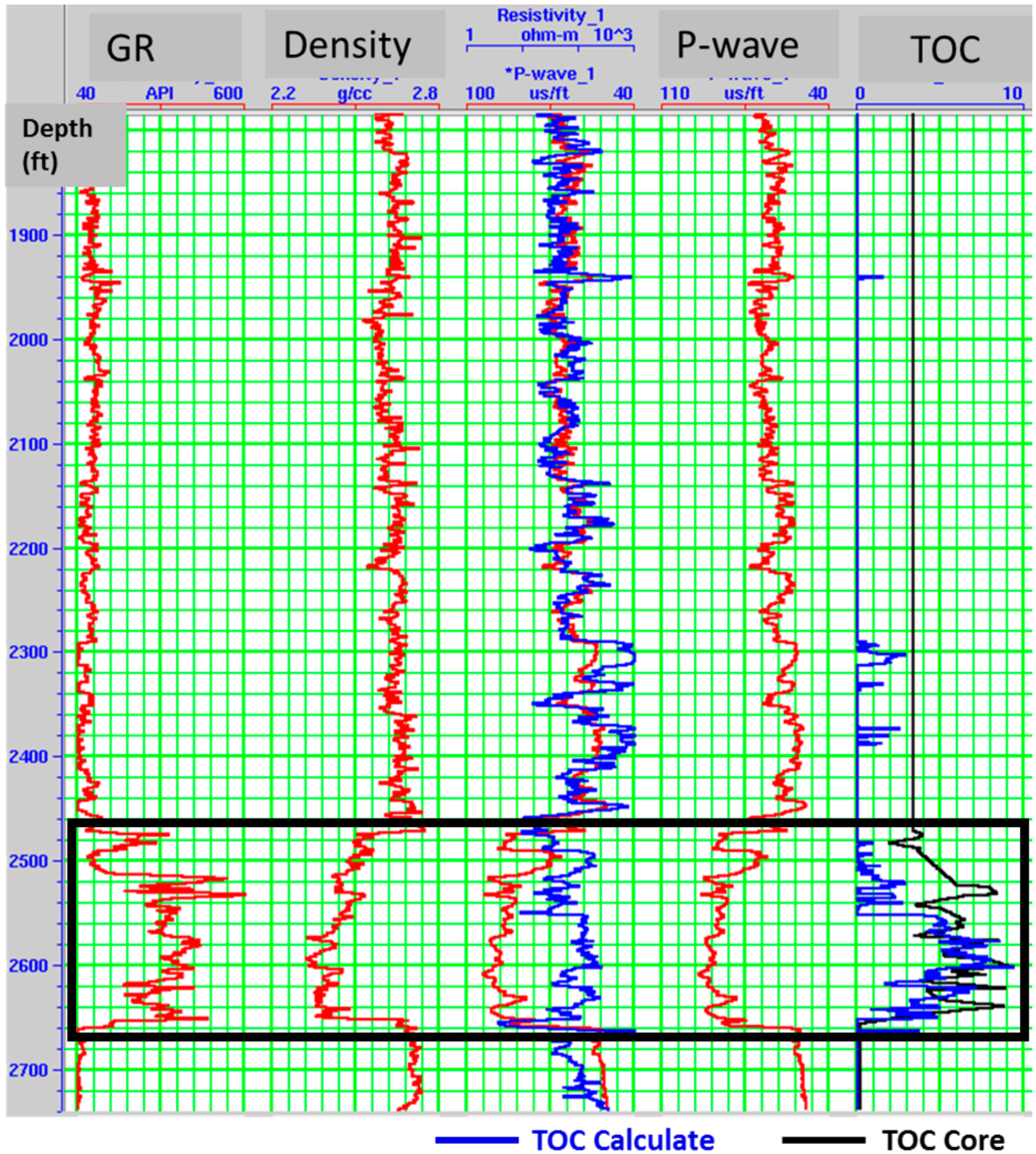

Figure 1. TOC log calculated by Passey's Method.

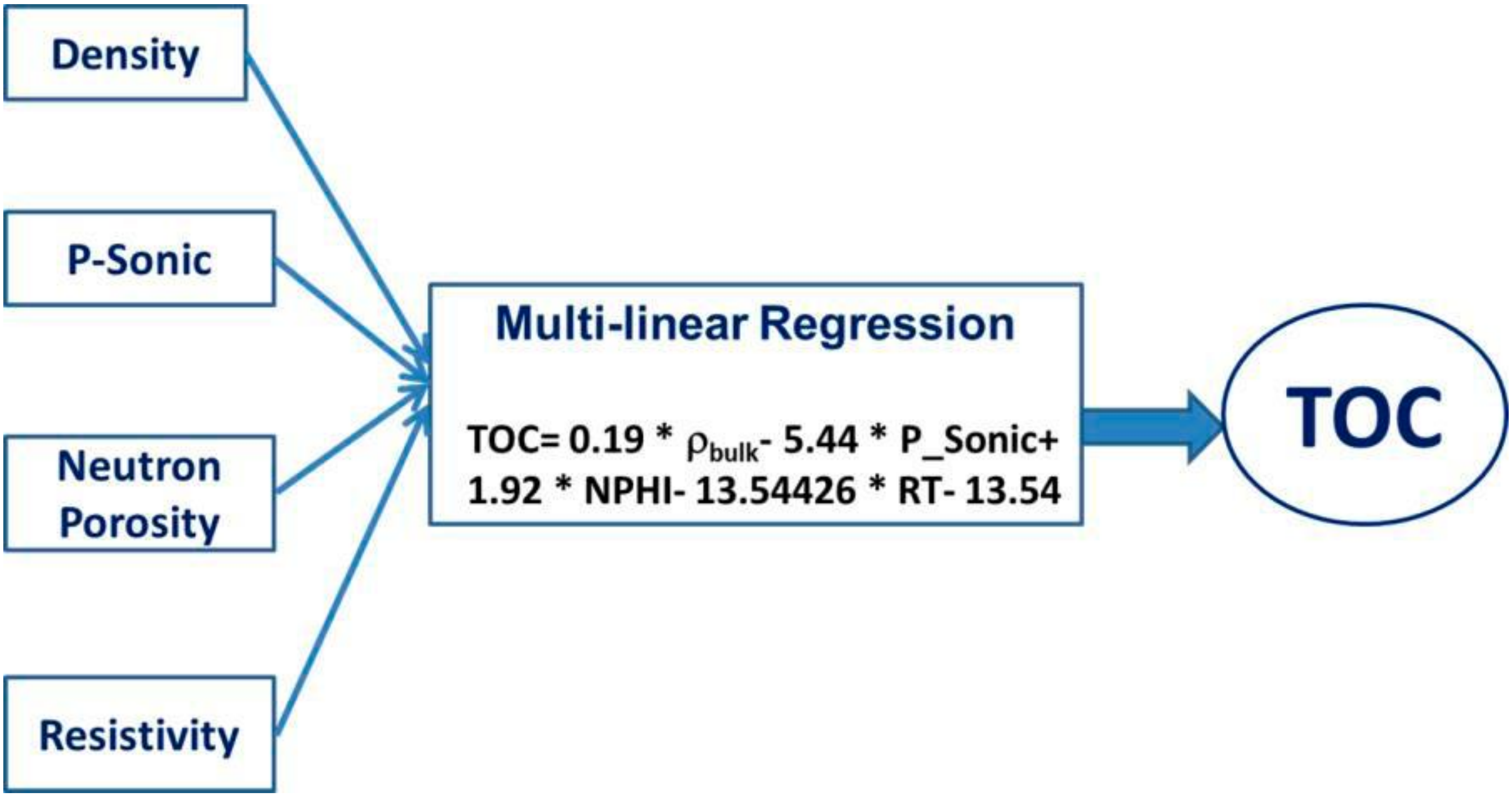

Figure 2. Multi-linear regression relation estimated on a cored well with Density, P-Sonic, Neutron Porosity and Resistivity logs and core measured TOC.

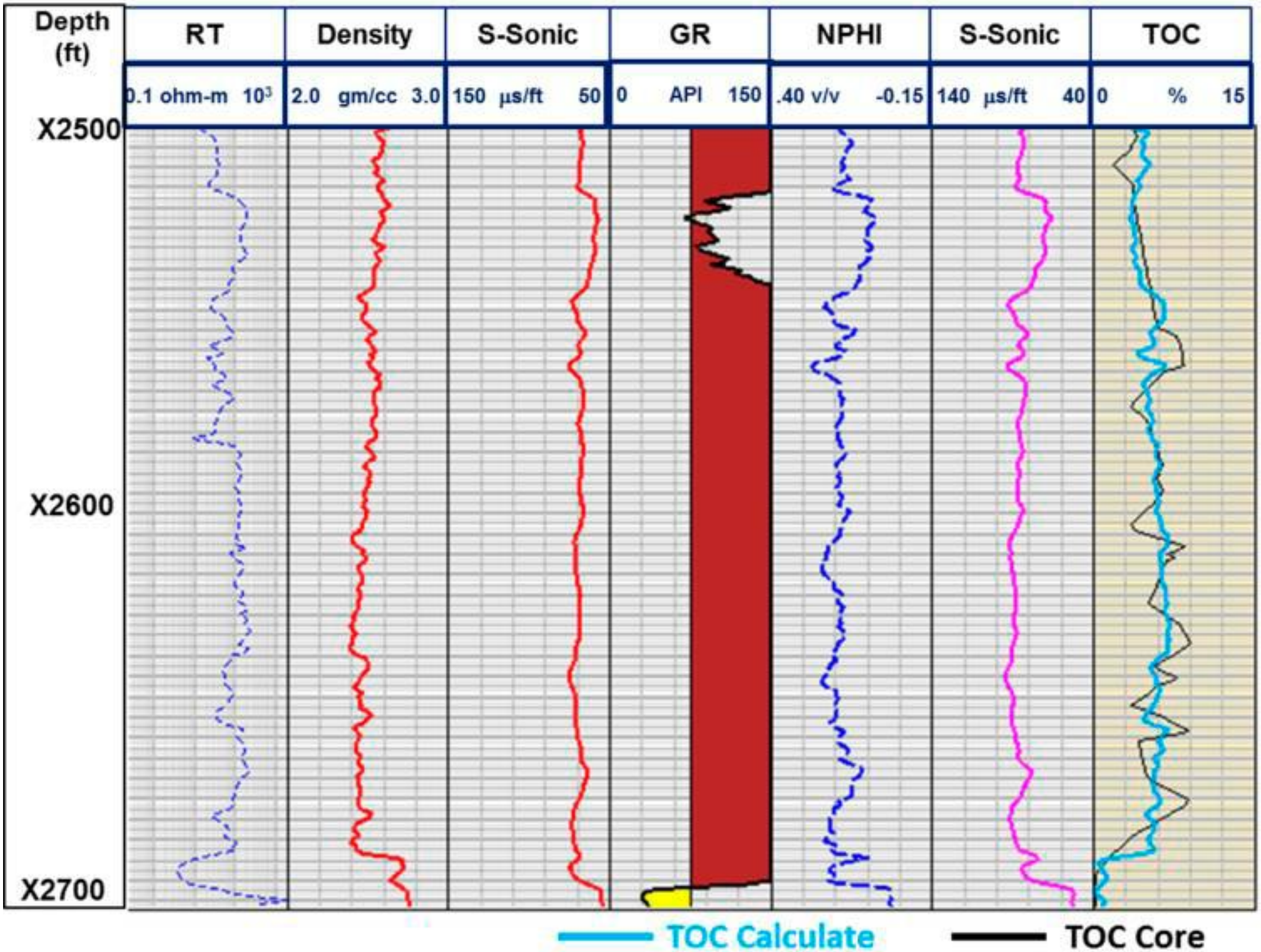

Figure 3. TOC log calculated by Multi-linear regression method.

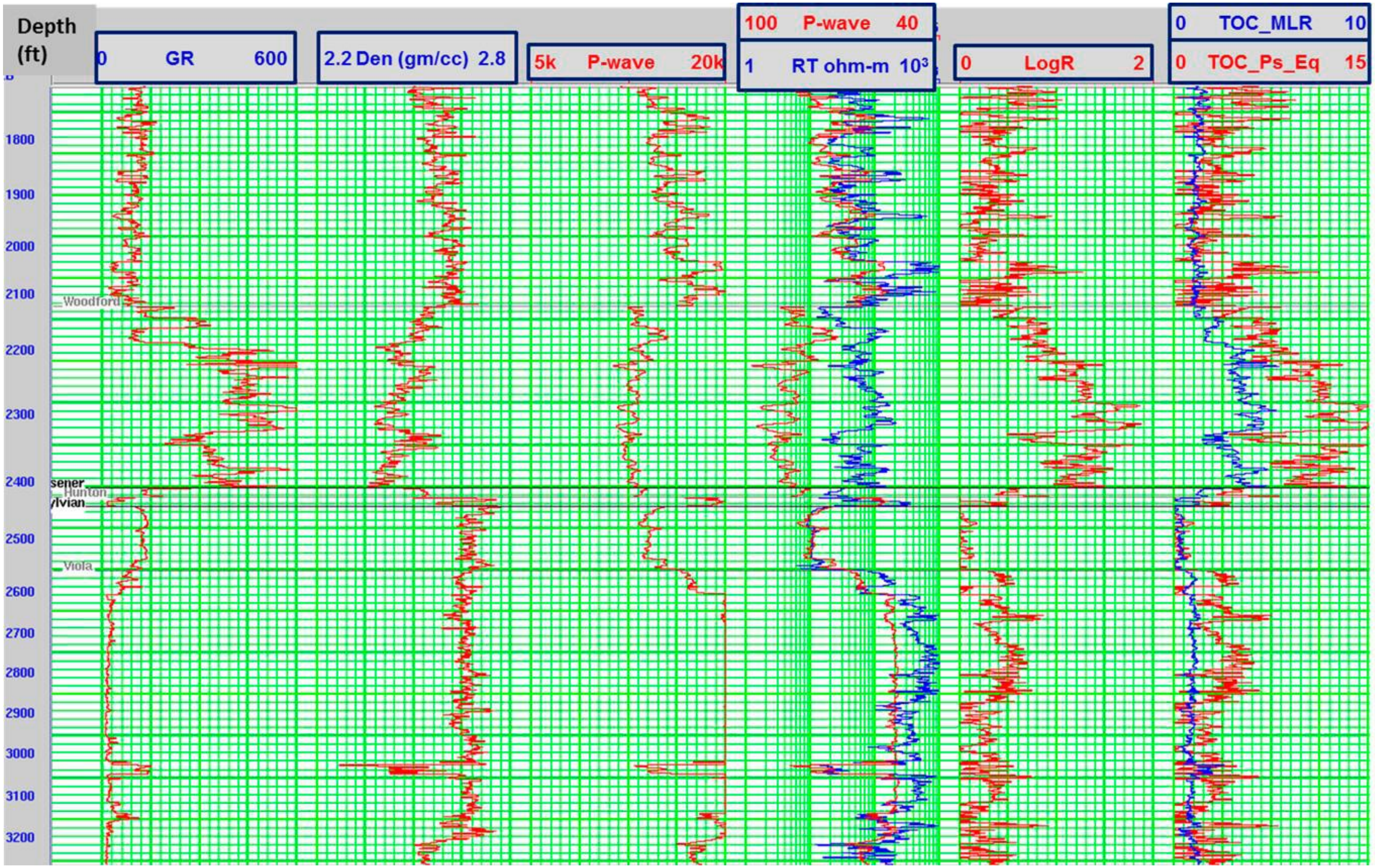

Figure 4. TOC log calculated by Passey's method and Multi-linear regression.

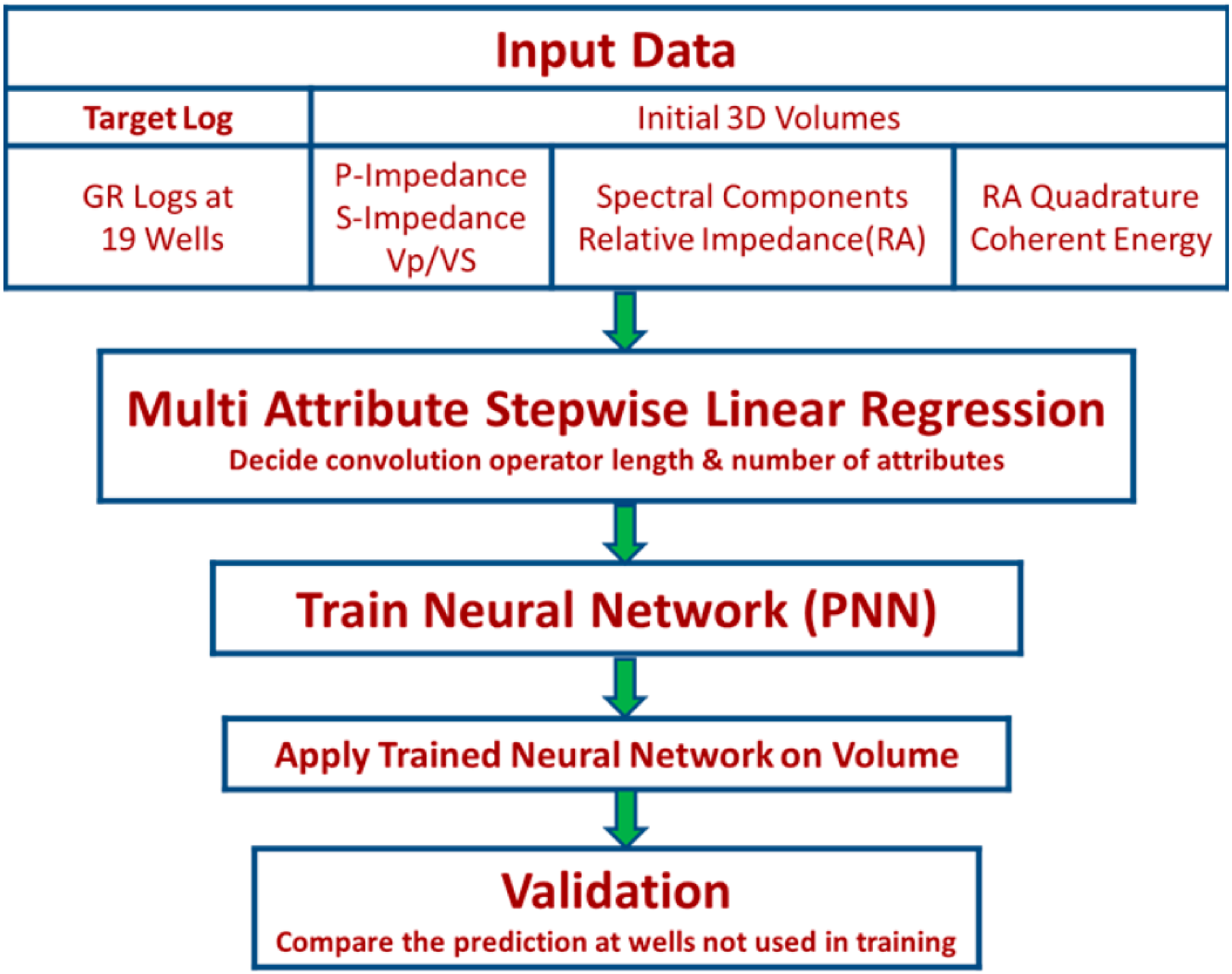

Figure 5. Probabalistic Neural Network work flow used to predict the gamma ray volume from seismic attributes (Verma et al., 2012).

Final Attribute	Training Error	Validation Error
(Lambdarho)**2	5.135546	5.173916
1 / (Zs)	4.915546	5.013536
Sqrt(Sweetness_Fairview)	4.728005	4.848704
Quadrature_Amp_Fairview	4.657984	4.810673
RAI_FairView	4.588311	4.751475
(spec_mag_3d_fairview_2__60)**2	4.512935	4.734096
(spec_mag_3d_fairview_2__10)**2	4.496637	4.765013

Figure 6. Table showing training and validation error; with operator length of 14 and 6 attributes the validation error is minimum.

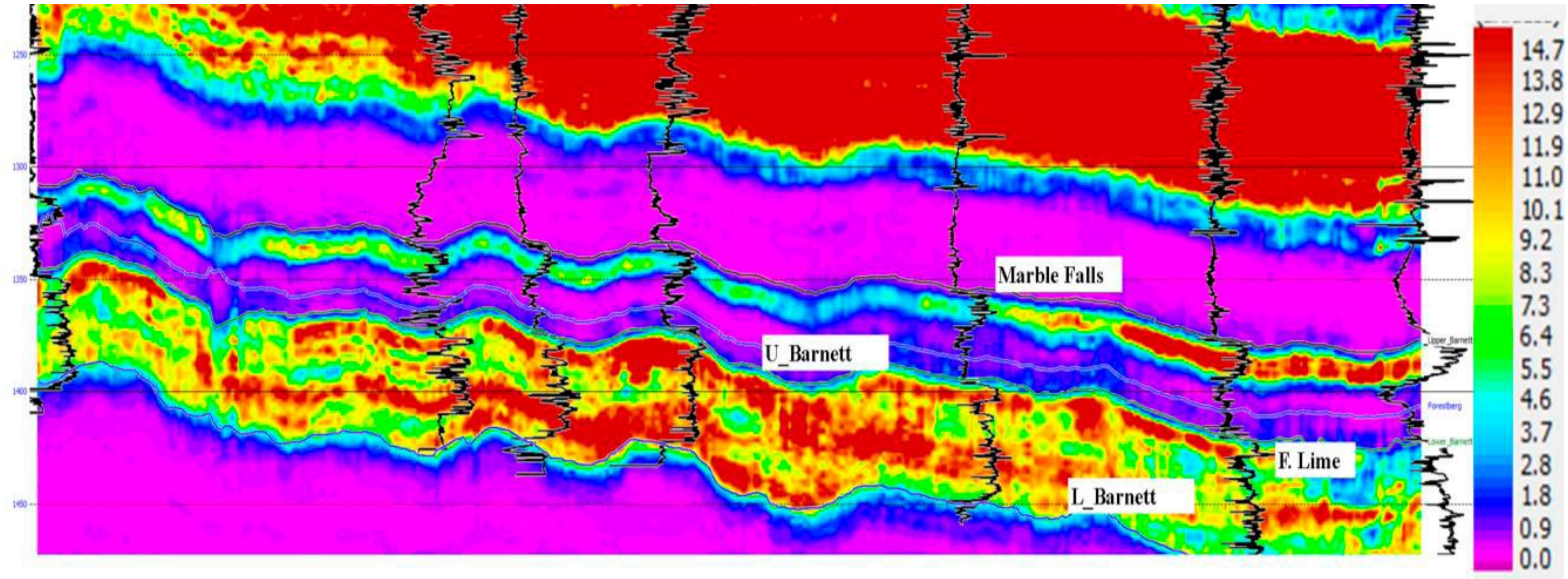

Figure 7. TOC volume generated with MLR, the TOC logs are over-laid. The well indicted by the yellow arrow was not included in the Multi-linear regression analysis at any stage.

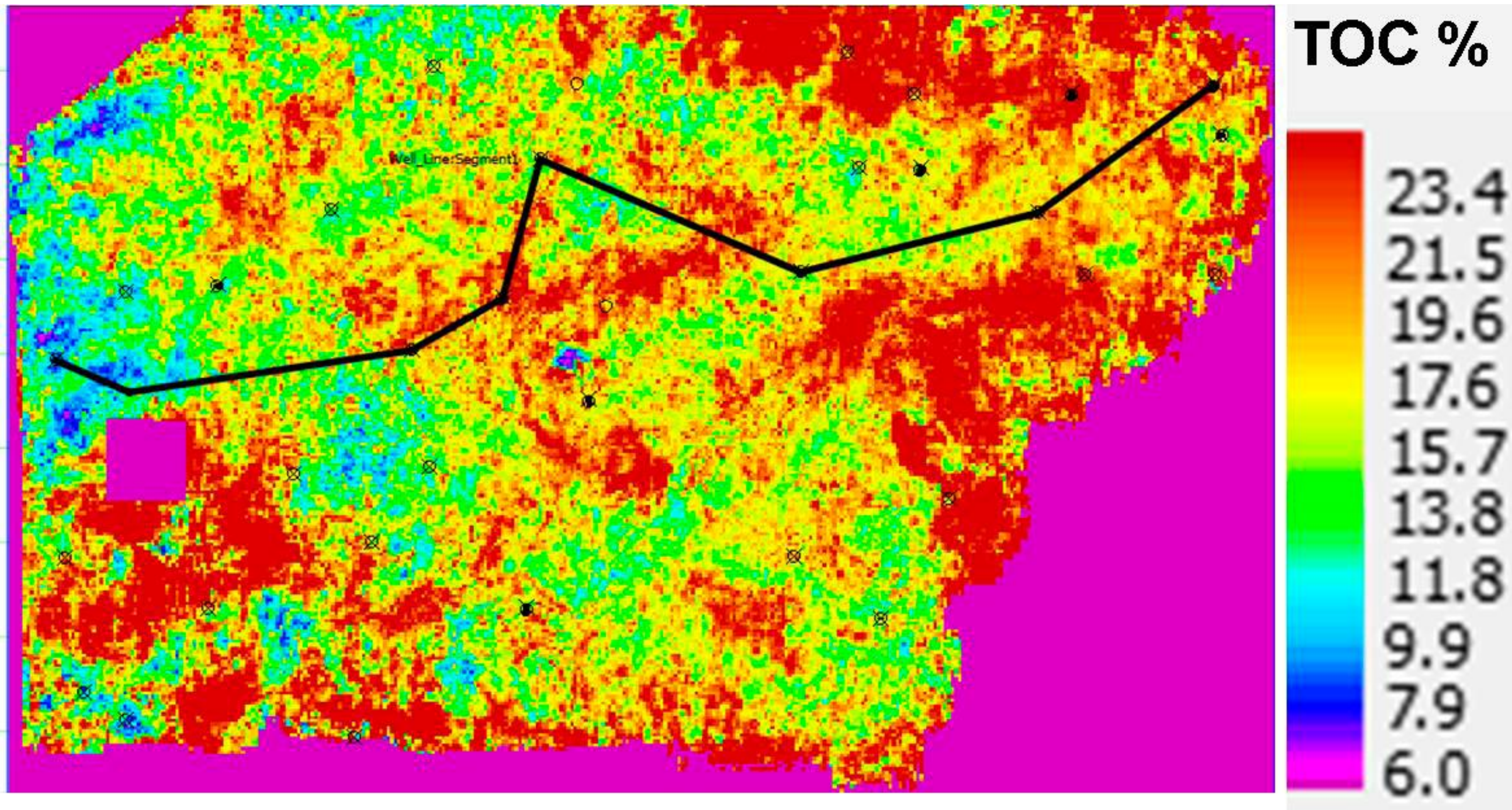

Figure 8. The TOC distribution Map at Lower Barnett bottom 20 ms interval.