Proceedings of the 18th Iranian Geophysical Conference, May 2018, pages 871-873

Application of Geophysical Strata Rating (GSR) in carbonate reservoir characterization

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ABSTRACT

The Geophysical Strata Rating (GSR), which is introduced in this study for carbonate reservoirs, is an empirical strength rating of rocks. It provides ratings from 10 to 100 where the lower values correspond to rocks such as shales which are weak from a borehole stability point of view and also the porous, permeable reservoir rocks. In comparison, the higher values of GSR are associated with intact rocks with few defects in the form of fractures and discontinuities and low porosity. In this study, GSR is calculated from petrophysical data using the equations developed in clastic rocks. The region investigated is the South Pars gas field where the Permo-Triassic Dalan and Kangan reservoirs host the largest accumulations of gas in the world. A 3D GSR model is then estimated from 3D post-stack seismic data of the South Pars gas field by using a probabilistic neural network model. Strong correlations between neural network predictions and actual GSR data at unseen borehole locations proved the validity of the intelligent model in GSR estimation. This 3D GSR cube can be utilized for construction of geomechanical models over the South Pars gas field.

Keywords: GSR, South Pars, well logs, Probabilistic Neural Network, geomechanical model

INTRODUCTION

As with soils, clastic sedimentary rocks, are amenable to characterization via a description of the grain size and type, amounts of pore space, the cements and moisture content. In massive carbonate rocks, however, it is more important to consider the effect of fractures instead of grain size and type. For clastic rocks, the Geophysical Strata Rating (GSR) has been introduced as an empirical scheme based on petrophysical logs, especially sonic velocity and porosity values, fractures and clay content (Hatherly et al., 2016). As with the RMR and CMRR, GSR scores rock quality over the range 0 to 100. As with these other methods the GSR considers the properties of the intact rock and also the defects within the rock mass. In this study we investigate the calculation of GSR in carbonate rocks from well logs and through seismic inversion.

The GSR is a new methodology for rock classification for the carbonate rocks common in the oil and gas bearing reservoir rocks in the Middle East. The results can be used in petroleum industry for evaluating reservoir rocks and identification of non-reservoir rocks. From a wellbore stability point of view, GSR data with lower values are related to weak rocks because these rocks are weak due to the high porosity and fracturing or the presence of softer shaly rocks. Higher values of GSR represent rocks with a greater strength with lower porosity and fewer fractures and discontinuities.

Methodology

GSR is designed primarily for clastic rocks and its determination involves the following components. The scores from each component are added to give the final GSR value for each depth point in the well.

1. A strength score which is linearly related to the sonic log P-wave velocity, Vp, with a value of zero when Vp is 2.25 km/s and 50 when Vp is 5.5 km/s. This score is intended to reflect the rock competency. Most sedimentary rocks have P-wave velocity in a range as 2.5 to 3.5 km/s in shales, up to 6 km/s in sandstones and 6.5 to 8 km/s in limestone and dolomites (Wyllie et al., 1956). If the velocity is smaller than 2.5 km/s, it is reset to 2.5. There is no upper limit to the velocity.
2. A porosity score between 0 and -15, with the value of -15 being assigned when the porosity is greater than 20% and the clay content is less than 25%. Rocks are generally less competent with increasing porosity.
3. A moisture score between 0 and -10 with the value of -10 being assigned when the clay content is greater than 75%, the porosity is greater than 7.5% and Vp is less than 3 km/s. Rocks with high clay content, high porosity and low velocity are adversely affected by moisture content.
4. A cohesion score between 0 and up to 25 when Vp is greater than 3.5 km/s and the sum of the porosity and clay content is less than 33%. Clastic rocks with low porosities and clay contents are assumed to be well cemented.
5. Defect scores between 0 and -20, with decreasing values indicating increased variability in the logs which is assumed to indicate increased bedding and fracturing.

A full description of the GSR and its calculation are provided in Hatherly et al. (2016). Of the component scores, the strength and cohesion scores are designed to be positive while the porosity, moisture and defect scores are negative and lower the overall GSR value. The GSR normally lies between 0 and 100 but in rocks with very high values of Vp, the GSR may exceed 100. **Figure 1** shows the location of studied wells on the seismic data and **Figure 2** illustrates the GSR calculated for wells A, B and C together with the porosity for these wells. The tops of the reservoir units are correlated and it can be seen that low values of GSR represent weak rocks which correspond to porous, fractured (permeable intervals) or shaly rocks (prone to washout during drilling). High values of GSR are associated with intact rocks which have poor reservoir quality and are of good quality from a wellbore stability point of view (Faraji et al., 2017). Model-based inversion was then conducted using a model geometry based on the interpretation of the seismic data. The acoustic impedance as the output of inversion along with other seismic attributes were then applied to estimate the GSR through a probabilistic neural network (Hampson et al., 2001). The results of the application of PNN for the estimation of GSR at the boreholes provided by cross-validation (i.e. the borehole has been utilized by the PNN) are displayed in **Figure 3**. As shown in this figure, the correlation between estimated and actual GSR is very high and it can, therefore, be concluded that PNN can successfully predict GSR. The PNN was then applied to the full 3D seismic cube to provide a 3D volume of GSR; the results shown in **Figure 4** are obtained.

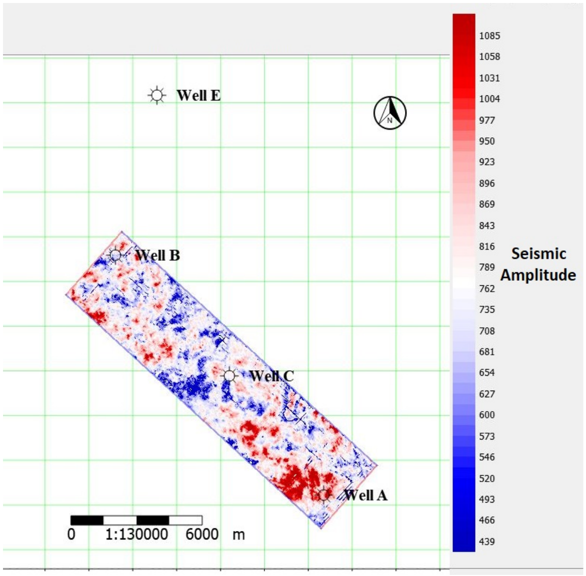

Figure 1. The location of studied wells on the seismic data.

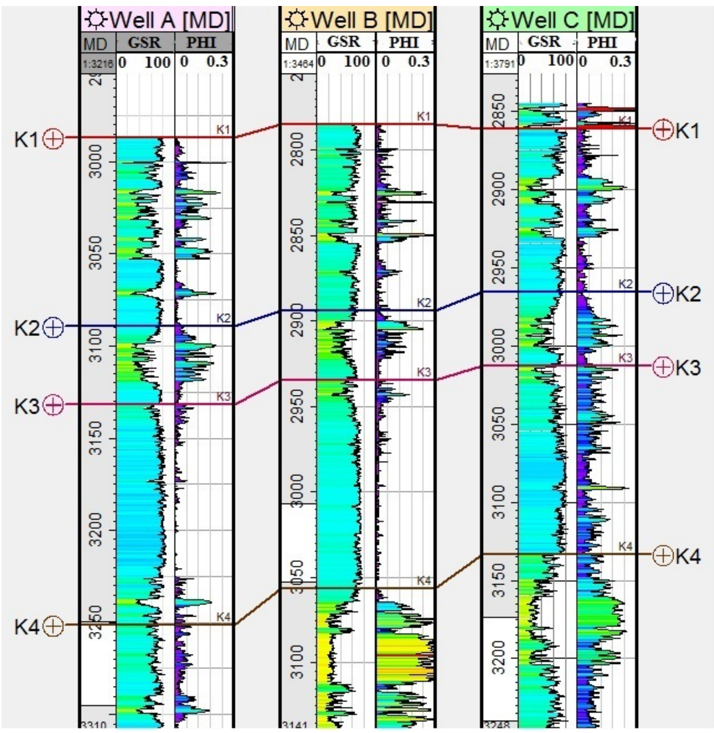

Figure 2. GSR and Porosity for wells A, B, C.

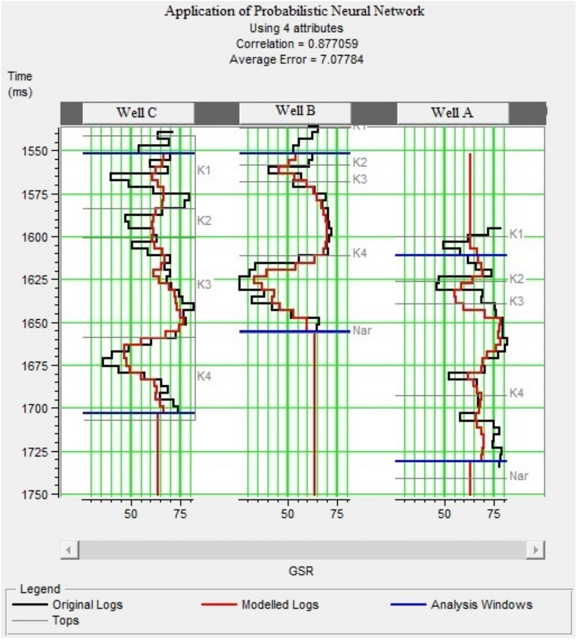

Figure 3. The application of PNN in estimation of GSR.

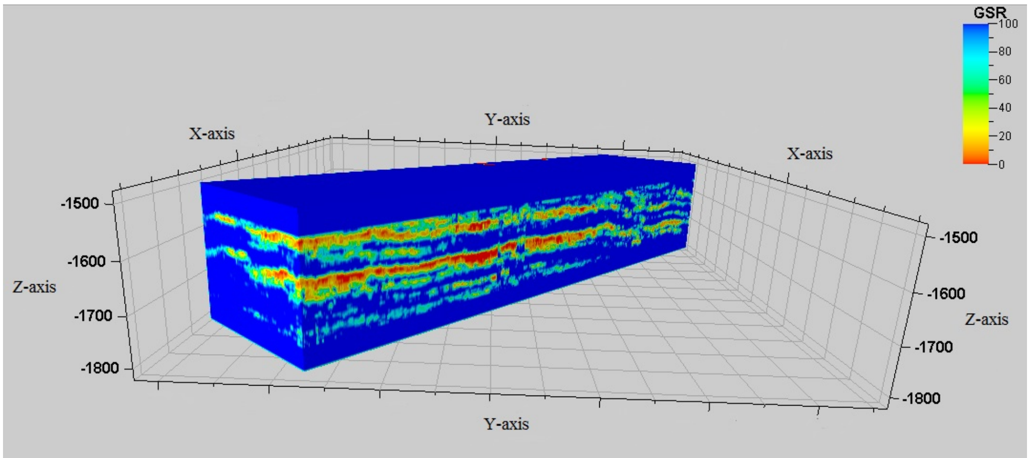

Figure 4. The final estimated cube of GSR.

CONCLUSION(S)

Although GSR was originally developed for clastic rocks, the results of this study show that it also works well in carbonates and follows the rock strength trends in carbonate rocks based on porosity and elastic properties. With regard to the huge costs of taking core samples for assessing reservoir quality, the GSR could be used as a cost-effective reservoir quality and rock mass parameter. The GSR logs can be utilized in drilling to investigate wellbore stability and in production to distinguish permeable and tight zones.

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