Fluid Detection in Tight Gas Sand from the Seismic Data

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Abstract: As the seismic attributes were affected by many factors at the same time, such as lithology, porosity, fluid property and so on, and different seismic attributes have different sensitive ability to geology factors. In the prospecting of lithology gas reservoir, it is very important to detect fluid with seismic data, so that we should prioritize the seismic attribute which is more sensitive to fluid. This paper is based on example of predicting tight gas reservoir, according to the experimental data, and then prioritize the rock physics model which is fit for tight sand rock physics modeling to assure the relationships between the rock physics parameters and lithology, porosity, gas saturation, and then filter best seismic attribute which is most sensitive to fluid. From the research result, Brie model is more suitable for tight gas sand rock physics modeling, it is feasible to detect the gas saturation in tight sand, and the gas saturation can be predicted by the P+G attribute.

Key words: tight sand, rock physics model, AVO attributes, prioritizing seismic attributes, detection of fluid

The technology of AVO was developed and widely used in the oil and gas prospecting and reservoir description, by analyzing the feature of amplitude versus offset or angle to predict the lithology and pore fluid. Because the prestack attributes were affected by the geology factor of lithology, porosity, fluid and so on, in the prospect of lithology reservoir, it is very important to detect the fluid by seismic attribute directly, so it is the first thing to optimize the most sensitive attribute to fluid, and then to predict the fluid by this attribute.

Base on the rock physic analysis, digging the law of elastic parameters affected by lithology, porosity and gas saturation, and then deduce the AVO attributes affected by lithology, porosity and gas saturation, combining with forward modeling

1 Rock physics analysis

In order to clarify the rule how reservoir parameters affect the seismic response, the first thing was building the link between the reservoir parameters and elastic parameters via rock physics model. There are a lot of rock physics models to apply to different condition, so the first thing was optimizing the model fitted for tight sand by the calibration of lab data. The Xu-white model[1] was applied widely in sandstone modeling, it concludes 4 steps, calculation of matrix elastic modulus, dry rock elastic modulus, mixed fluid elastic modulus, saturated rock elastic modulus. The calculation of mixed fluid elastic modulus will affect the calculation of effective rock modulus which affect the law of P-velocity and S-velocity. The models of Wood[2] and Brie[3] were applied in the calculation of mixed fluid elastic modulus, each of them can be applicable only under special fluid distribution pattern, the Wood model will be applicable when fluid distributed in homogeneous pattern, the Brie model will be applicable when fluid distributed in heterogeneous pattern. Because poisson’s ratio is a very important elastic parameter in the research of AVO. Figure 1 shows that the Brie model data can match better to lab data than Wood model data, and the lab data is measured from the low porosity core whose porosity is about 8%.

It also demonstrates that poisson’s ratio varied gradually with the gas saturation, different gas saturation has different poisson’s ratio. But Domenico [4] concluded that in unconsolidated sandstone, when the gas saturation get the 20%, the poisson’s ratio will be lowest, even the gas saturation get higher, the poisson’s ratio will keep a constant value, which imply AVO only can detect whether there is gas in the pore, but can not predict whether it is industrial gas reservoir. From this research, the gas saturation can be detected by AVO in tight sand resvoir.

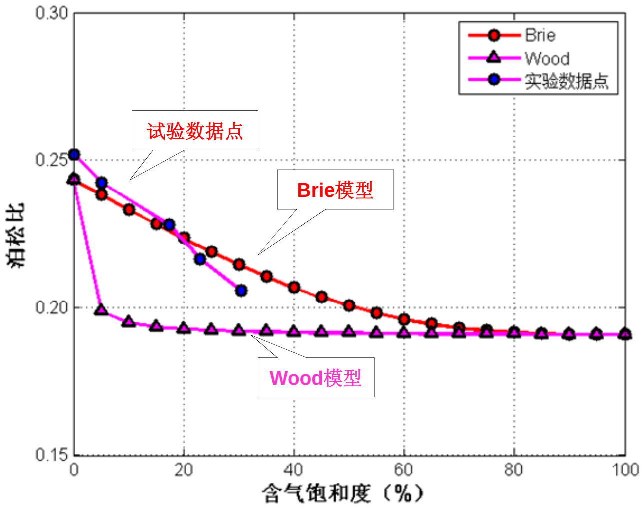

Fig. 1. Modeling data compared with lab data

2 Forward modeling analysis

Baed on the rule of elastic parameters which are affected by porosity and gas saturation, beginning with the forward modeling which will help to find the most senstive attribute, through the attribute analysis on the modeling data.

The widely applicated attributes is P, G, P+G, P*G, fluid factor and so on. P and G is derived from Shuey [5] fomula, given by

$$R_{PP} = P + G * \sin^2 \theta \qquad (1)$$

Where θ is the incident angle, P is intercept and the G is gradient, they are fitted by cdp gathers, the formula of each of the attributes is listed as bellow,

$$P = \frac{1}{2}\left(\frac{\Delta V_p}{V_p} + \frac{\Delta \rho}{\rho}\right) \qquad (2)$$

$$G = \frac{1}{2}\left(\frac{\Delta V_p}{V_p} - \frac{\Delta \rho}{\rho} - 2\frac{\Delta V_s}{V_s}\right) \qquad (3)$$

$$P + G = \frac{\Delta V_p}{V_p} - \frac{\Delta V_s}{V_s} \qquad (4)$$

$$P - G = \frac{1}{2}\left(\frac{\Delta V_s}{V_s} + \frac{\Delta \rho}{\rho}\right) \qquad (5)$$

The fluid factor ΔF was proposed by Castagna[6] in 1998, given by

$$\Delta F = \frac{\Delta V_p}{V_p} - b\frac{\Delta V_s}{V_p} \tag{6}$$

Where V_p 、 V_s 、 ρ is the average p-velocity, s-velocity, density of both sides of the medium, ΔV_p 、 ΔV_s 、 $\Delta\rho$ is the change of P-velocity, S-velocity, density, b is the adjusting factor depended on the geology, b is gotten by the p-velocity and s-velocity fitting whose data collected from the project in this case.

Prestack attributes are affected by fluid and porosity at the same time, from the figure 2, the X axis is the porosity, the Y axis is the gas saturation, the color represent the attribute value, by comparing, P+G can reflect the gas saturation, under the condition of higher porosity and gas saturation, it becomes larger accordingly.

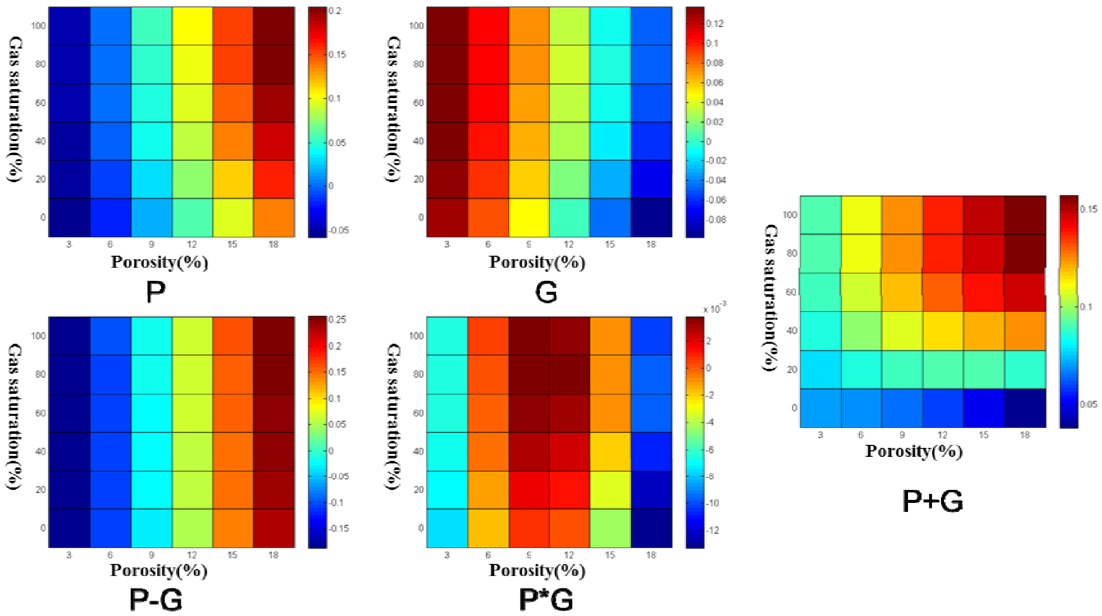

Fig. 2. Two variables forward modeling analysis

3 Application reusult

Figure 3 is the gas detection result in the Sulige gas field with P+G, the high value of P+G represent the higher gas saturation, the detection result is consistent with the drilled result.

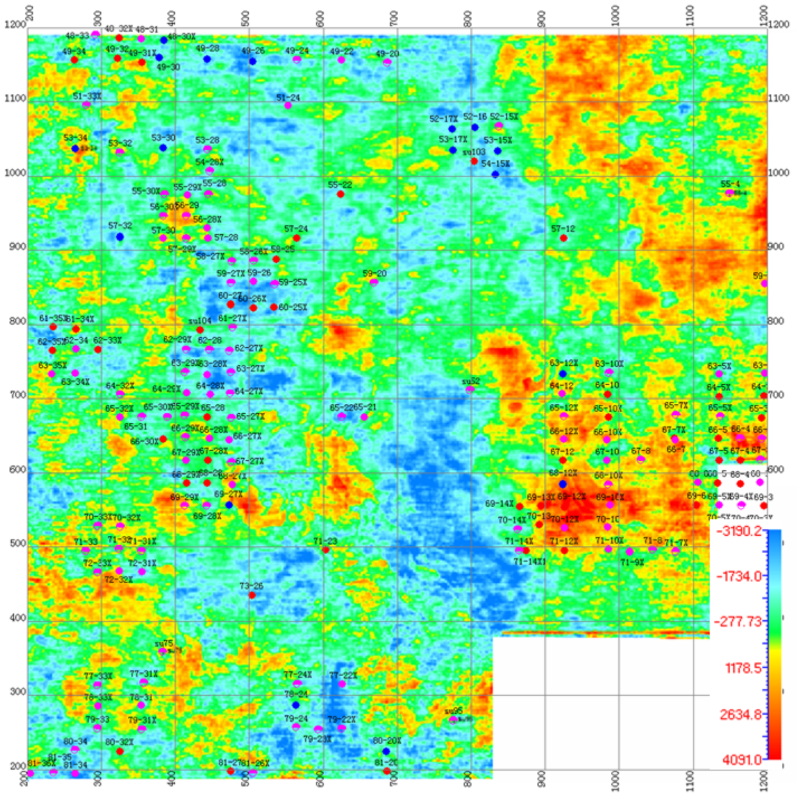

Fig. 3. Gas detection result by P+G

4 conclusion

Rock physics analysis and forward modeling are the key techniques of attribute optimizing, the rock physics model optimizing is vital, it will affect the result of attribute optimizing.

In tight sand reservoir, the Brie model is more suitable for rock physics modeling.

The most sensitive AVO attributes are P+G which can detect the fluid directly.

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