The prediction of Jurassic gas-sand with low water saturation using seismic-derived density property—a case study from Sichuan Basin

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Summary

Rock physics study shows that Jurassic gas-sand with low water saturation (Sw) is highly correlated to density properties. Moreover, density property of Jurassic gas-sand is much less than that of shale. Seismic-derived density property is used for the prediction of Jurassic gas-sand with low water saturation. Density contrast (reflectivity) is derived from 3D pre-stack time migrated CRP gather data and velocity data, and then density reflectivity are inverted to density volume. Two low density anomalies (including one new anomaly discovered) was drilled and proved to be gas-sand with low water saturation.

Introduction

It is commonly accepted that density may reveal important crucial information about fluid saturation. Roderick W. Van Koughnet. (2001, 2003) and Ezequiel F. Gonzalez (2003), proved that low density is the main behavior of gas-sand with low water saturation. Density had been extracted from P-wave AVO inversion successfully by Roderick W. Van Koughnet. (2003) and Jyoti Behura. (2010).

Block D is based on 12 exploratory wells over an area of approximately 200 square kilometers. Jurassic formation is composed of delta channel sand and shale. The porosity of sand reservoir ranges from 12% to 19%.

Several wells encountered gas-sand at Jurassic formation, but few wells encountered partially-saturated gas-sand (high water saturation). It is important to predict gas-sand using seismic-derived density property successfully.

In this paper, a seismic prediction study of gas-sand with low water saturation is presented where inversion-derived density property had been used to predict gas-sand with low water saturation in the Jurassic formation, Sichuan basin, China. The study begins with rock physics analysis, followed by pre-stack elastic inversion. Last, an interpretation of results was carried out using the available wells drilled, including new wells drilled.

Rock physics analysis

There is only one well (w20) with shear sonic log in study area. Density and other conventional logs are available at Jurassic formation. Among of all elastic parameters, for example, P-wave velocity or Poisson’s ratio, any elastic parameter can’t discriminate sand from shale fairly (Figure 1). Fortunately, density can differentiate gas-sand (low water saturation) from partially-saturated gas-sand (including shale). Figure 2 shows the difference of density between gas-sand and partially-saturated gas-sand. Samples in Figure 1 and Figure 2 are from eleven wells in study area. The density value of gas-sand is less than 2.350g/cc.

![Figure 1: Vp-Density Cross-plotting at Jurassic formation from eleven wells. There is much overlap of Vp between gas-sand and shale. Density can discriminate gas-sand from partially-saturated gas-sand (including shale).](image1)

![Figure 2: Poisson’s ratio-Density Cross-plotting at Jurassic formation from eleven wells. There is much overlap of Poisson’s ratio between gas-sand and partially-saturated gas-sand (including shale). Jurassic gas-sand is much less than that of shale and partially-saturated gas-sand.](image2)
Jurassic gas-sand with low water saturation is highly correlated to low density property in study area.

Figure 3: Density log vs Sw log. When porosity is fixed (12%), density does increase with with the increasing of Sw.

Pre-stack elastic (density) inversion

In this study, density contrast (reflectivity) is derived from 3D pre-stack time migrated CRP gather through robust three term AVO inversion algorithm (Aki & Rechards equation, 1980) using angles up to 31 degrees, and then density reflectivity are inverted to density volume.

Figure 4 shows that seismic-derived density property matches density log very well. Seismic-derived density property is reliable.

Figure 4: There is a good match between Density log and seismic-derived density property.

Results

In block D, there is no structure trap. Figure 5 shows the TWT map of top Jurassic gas-sand. Obviously, it is a slope which uplifts northward. The river channel sand is the main microfacies type of sedimentation.

Figure 6 shows the density map of Jurassic gas-sand. Figure 7 shows the stack amplitude map of Jurassic gas-sand.

There are four wells (w605, w105, w20, w1) which encountered gas-sand (Sw ranges from 30% to 35%) corresponding to low density (red) at target zone in Jurassic formation (Figure 6). There are two wells (w6, w9, w19, w112) which encountered partially-saturated gas-sand (Sw ranges from 40% to 55%) corresponding to high density (yellow) at target zone in Jurassic formation (Figure 6). There are three dry wells (w21, w621 and w9) at target zone in Jurassic formation (Figure 6).

Three low density anomalies on density map of Jurassic gas-sand indicate the absence of probable gas-sand. Anomaly A is located at structural low. Anomaly B is located at relatively structural high. Anomaly C is located at structural high. Among of three anomalies on density map, there are two anomalies (A and B) which exist on stack amplitude map. Anomaly C on stack amplitude map does not appear, that’s why anomaly C was not drilled before. W605-1H is a new well drilled on anomaly C which encountered gas-sand at target zone. W102H is also a new well drilled on anomaly B which encountered gas-sand at target zone.

W605-1H and W102H proved the prediction of gas-sand (low water saturation) based on pre-stack density inversion, especially anomaly C was proved to be gas-sand area. It is not possible to discover anomaly C with gas-sand based on stack amplitude map, because there is not any distinct amplitude anomaly on stack amplitude map.

Conclusions

Jurassic gas-sand with low water saturation is highly correlated to low density property in study area. Density can discriminate gas-sand (low water saturation) from partially-saturated gas-sand (including shale). It is possible to distinguish gas-sand from partially-saturated gas-sand (including shale) using density property derived from pre-stack elastic inversion.

The prediction of gas-sand (low water saturation) based on pre-stack density inversion was proved by two new wells (W605-1H and W102H).
The prediction of gas-sand using seismic-derived density property

Figure 5: The TWT map of top Jurassic gas-sand. There is no structure trap.

Figure 6: The density map of top Jurassic gas-sand. Four wells (w605, w105, w20, w1) encountered gas-sand (Sw is ranges from 30% to 35%) corresponding to low density (red). Three wells (w6, w9, w19 and w112) encountered partially-saturated gas-sand (Sw is ranges from 40% to 55%) corresponding to high density (yellow).

Figure 7: The stack amplitude map of top Jurassic gas-sand. There is not any distinct amplitude anomaly near well 605-1H.

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REFERENCES

Rodrick W. Van Koughnet. 2003, Prospecting with the density cube : The Leading Edge, 22(10):1038-1045
Jyoti Behura, Nurul Kabir. 2010, Density extraction from P wave AVO inversion: The Leading Edge, 22(10):772-777
EDITED REFERENCES
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REFERENCES


