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Shallow Water Flow Assessment from an Inverted Seismic Cube

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Introduction

A proprietary seismic process can identify potential drilling problems before costly after-the-fact drilling disasters are encountered. Considering the financial impact of a single unanticipated drilling problem, such as a shallow gas kick or an uncontrolled shallow water flow (SWF), well planning should include a petrophysical evaluation of the 3D seismic data to provide inexpensive insurance against those unwanted drilling trouble costs.

Transformed 3D seismic cubes can be used to assess the risk of encountering zones that may be capable of SWF. A recent geohazards study in the Gulf of Mexico (GOM) used exploration 3D seismic as its prime interpretive tool. High amplitudes indicative of a potential SWF zone were identified at a proposed location. Upon further investigation using these 3D cubes, the high amplitudes were found to lack appropriate reservoir indicators. Therefore, the SWF risk was downgraded, and the casing program proceeded as originally planned.

While there are many methods to transform seismic data, this process used proprietary algorithms based on prestack velocities, Vp/Vs ratios and long offsets on a 3D seismic cube. The transformed cubes displayed lithology, porosity and reservoir quality. Values associated with SWF zones were highlighted to emphasize location and magnitude prior to selecting a drill site.

Though the interpretation is constrained by seismic data quality, accuracy of velocity picks and assumptions used in converting seismic reflection characteristics to lithology; the technique adds value by providing another tool with which to assess shallow drilling risks. This can be particularly important since the shallow section of a well may be drilled riserless, in the case of deepwater wells, or drilled with only a diverter when using land, platform, or jackup rigs.

Shallow Water Flows

Shallow water flows are a serious drilling problem. They occur when the drill-bit penetrates an overpressured SWF zone at a shallow depth prior to cementing the initial casing string and installing the blowout preventer (BOP). Sand and water flow uncontrollably out of the borehole from the overpressured formation. Generally, SWF formations lie at relatively shallow depths below the seafloor within the top-hole range (0-3,000 feet below mud line) in water depths over 1,200 feet. They have been reported in 50 percent of deepwater wells in the Gulf of Mexico (Alberty, 2000) costing the industry millions of dollars due primarily to lost rig time. To reduce loss, it is essential that a detailed geohazards assessment be made prior to drilling and that it include SWF zone detection.

SWF zones occur primarily within overpressured, under-consolidated sands, deposited less than half a million years ago. Sand deposits produced during sea level lowstands become covered by fine-grained deposits during sea level highstands. Finer grains seal the coarser sand deposits, such as basin floor turbidites and channels. The combined rapid accumulation of thick sand-rich deposits topped by fine-grained seals creates an environment in which pressures from the overburden coupled with a thick, impermeable seal prevents the formation from expelling water and generates overpressured conditions. Where sands have high porosity and permeability, SWF zones are produced.

Integrating well logs, seismic attribute analysis, and seismic sequence stratigraphic methods commonly identifies coarse-grained, overpressured SWF deposits. In addition, seismic-based interpretation, using transformed seismic cubes can be used very objectively. While transformed seismic cubes are usually produced with targeted reservoir depths in mind, these cubes can also be used to decipher shallow formations prone to SWF.

Seismic Analysis Techniques

The Lithology, Porosity and Reservoir Quality (RQ) Cubes provided for this geohazards study were prepared by *e*Seis, Inc. The company uses an advanced seismic interpretation technique that converts seismic data into rock properties utilizing proprietary petrophysical algorithms. These techniques utilize compressional and estimated shear impedances to determine lithology, porosity, and the presence of compressible hydrocarbons. When offset well logs are available, a proprietary log analysis package is used to de-spike, smooth, and analyze the log curves. Using the edited logs, an error-correcting, multi-mineral analysis is performed and the logs are solved for lithology, effective porosity, and fluids. The results are forward modeled into corrected density and sonic logs. These two curves are used to create a synthetic seismic trace in depth and time. The main use of this log analysis is to check the phase of the seismic data, which impacts the values derived for the lithology and porosity cubes. The addition of a velocity derived low frequency porosity trend enhances the standard porosity volume generated by the process.

The resulting Lithology Cube can discriminate from pure shales (green) to dirty sands (brown) to clean sands (yellow-white) to sands with compressible fluids (red). Similarly, the Porosity Cube can discriminate various levels of porosity with higher porosities being displayed using brighter colors of red, orange, and yellow. It must also be noted that the porosity volume has a higher resolution and is often useful in the depiction of depositional environments and the imaging of reservoirs. Lastly, the RQ Cube is the product of the values from the Lithology Cube times the values from the Porosity Cube. Therefore, wherever there are good sands with good porosities, a "High" RQ can be expected. This makes the RQ Cube useful as an initial screening tool, one that is used in conjunction with the original datasets of lithology and porosity.

In addition to their usefulness in assessing the risk of SWF zones, these cubes can also be used to identify the possible presence of shallow gas. Since a compressible gas effect would be highly anomalous in the strata below the mudline, the Lithology Cube displaying a strong red discriminator would be a flag that gas may be trapped in shallow sand.

Case Study

While assessing drilling hazards for a proposed deepwater well located in a portion of the GOM known for high SWF risk, a shallow formation was designated a high-risk SWF zone (Figure 1). Interpretation was based strictly on a 3D seismic amplitude cube. A transformed seismic cube produced by *e*Seis, Inc. using their proprietary algorithm was loaded on a seismic workstation for viewing the derived Porosity, Lithology and Reservoir Quality Cubes (Figures 3-5). Subsurface areas of interest were correlated with each cube simply by clicking a mouse. The potential SWF zones previously mapped from both seismic stratigraphy and logs showed excellent correlation with high quality reservoir indicators on the cubes. The basin floor turbidites at the correlation well displayed high porosity, high sand lithology and high reservoir quality (Figure 2).

Looking at the proposed drill-site it became immediately apparent that high amplitudes with SWF characteristics at shallow depth did not display expected reservoir quality attributes typical of SWF zones (Figure 2). As a result the potential SWF zone at the proposed well site was degraded from moderate to low and the well drilled through the zone without complications. Following completion of the new well, the logs were displayed on the seismic and cubes to reveal that the zone had no SWF potential.

Conclusions

Based on post-drilling verification, well logs confirmed the value of seismic transformations to assess the risk of encountering potential SWF zones prior to drilling deepwater wells. Analysis of a prestack seismic cube can save time and money by allowing geohazards interpreters a more confident assessment of potential SWF zones.

A proprietary seismic process can identify potential drilling problems before costly after-the-fact drilling disasters are encountered. Considering the financial impact of a single unanticipated drilling problem (shallow gas kick and possible diverter failure and uncontrolled blow-out or an uncontrolled shallow-water-flow over a subsea development), well planning should include petrophysical evaluation of seismic data to provide inexpensive insurance against those unwanted drilling trouble costs.

Figures

1. Seismic amplitudes, line X
2. Seismic inversion: Porosities, line X
3. Seismic inversion: Lithology, line X
4. Seismic inversion: reservoir quality, line X

Acknowledgements

The authors thank

References

Alberty, M.W., 2000, Shallow Water Flows: A Problem Solved or a Problem Emerging. OTC Preprint No. 11971.