ASEG-PESA 2015

Geophysics and Geology together for Discovery

24th International Geophysical Conference and Exhibition
15–18 February 2015 Perth, Western Australia

Geopressure variations with the North West Shelf from well analysis and the regional hiQbe™ velocity model

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SUMMARY

A careful analysis of the geopressure regime in one hundred wells on the North West Shelf (NWS) is integrated with an analysis of apparent overpressure derived from the regional hiQbe™ velocity model. The well analysis is a traditional pressure interpretation, considering all available data and all types of overpressure. The hiQbe™ analysis is based on velocity data, and can therefore detect compaction disequilibrium overpressure. The calibration and integration of these two forms of analysis give new insight into the regional distribution of potentially overpressured rocks in the NWS, and provides a good basis and guidance for well planning.

Key words: overpressure; geopressure; velocity; North West Shelf.

INTRODUCTION

Careful well planning to avoid drilling incidents requires a prediction of the overpressure that is likely to be encountered during the drilling operation. The traditional approach is first to make a pore pressure interpretation of adjacent wells, and then to extrapolate that to the planned well location using seismic processing velocities. Our method is a supplement to that approach. After well interpretation we step out regionally with a pore pressure inversion of the hiQbe™ velocity model, in order to establish a spatially continuous understanding of the pore pressures in the basin. This provides us with two things: 1) a regional understanding of the pore pressure distribution in these basins, and 2) a numerical model for calibration of the seismic processing velocities that is used for the well prognosis. The latter is provided by the delta anisotropy model in the hiQbe™. This paper describes the development of such a regional pore pressure model for the North West Shelf of Australia. It has been built using the full 2014 hiQbe™ velocity model from Aker Solutions (now First Geo) and Searcher Seismic, and is calibrated to an analysis of the over-pressure indications in one hundred selected NWS wells.

METHOD

Well Analysis

An analysis of sixty wells in the Carnarvon Basin and forty wells in the Browse Basin was undertaken. Indications of drilling problems from all available well completion reports were noted, and these events, such as connection gas and trip gas, changes in mud weight, lost circulation and “stuck pipe” used to provide an understanding of the down-hole conditions. These events were also compared to data acquired from the petrophysical and mud logs.

Log Analysis

Available well logs for these 100 wells were edited and poor quality data removed. Initially, the overburden gradient (OBG) was calculated, and this requires the density over the complete range of depths. Often the density log is acquired only over the reservoir or deeper sections, so the density for the first few hundred metres below the mud-line was estimated by assuming a seabed density of 1.94g/cc and using a modified Miller’s algorithm. This was then compared to the average from relevant offset wells for quality control, and the OBG extended beyond TD for shallower wells. The resistivity and sonic log values from the shaley sections were filtered and the resulting log analysed against a “normal compaction shale line” derived for each well (see Fig. 1).

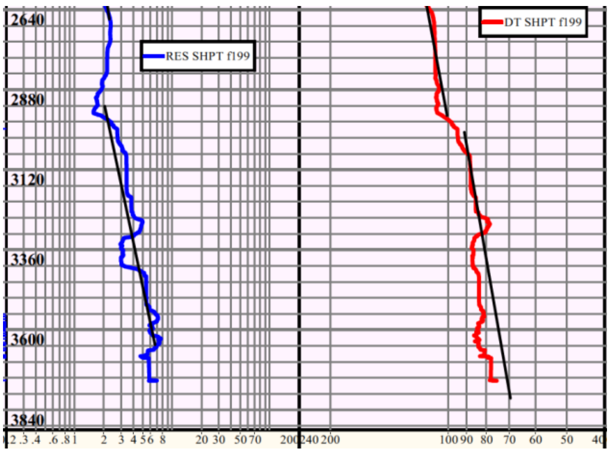

Figure 1. Filtered resistivity (blue) and sonic (red) log curves of the shale prone units are plotted, with the respective interpreted normal compaction trend line (NCT) in black. Portions of these filtered resistivity and sonic logs to the left of the NCT indicate possible zones of under-compaction.

Pore pressure was estimated by applying Eaton's equation to both the resistivity and sonic logs, taking into account the lithological effects. Well observations (cavings, mud weight) and indications (gas) were used to calibrate the pore pressure (PP) interpretation. The fracture gradient (FG) was then calculated from the OBG and the PP interpretation, and this result cross checked with the leak-off tests (LOT), formation integrity tests (FIT) and the mud weight to ensure self-consistency of the interpretation for each well.

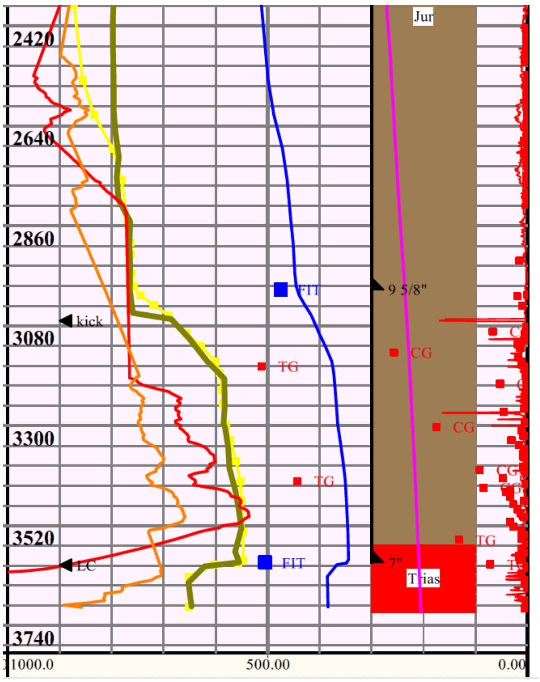

Figure 2. Geopressure analysis from resistivity (red) and sonic (orange) logs compared to the OBG (purple) and the FG (blue). Drilling gas has been plotted as red squares.

Geopressure from the regional hiQbe™ velocity model

The hiQbe™ regional velocity model was used to estimate overpressure due to undercompaction. The hiQbe™ model covers the offshore Carnarvon, Canning, Roebuck, Browse and Bonaparte basins, and has been generated with lateral grid dimensions of 2000 m x 2000 m laterally and 50 ms two-way time vertically down to 14 seconds below mean sea-level, using available open file well checkshot and seismic velocity data plus proprietary data from Searcher (Dheasuna et al., 2012). Although primarily designed for rapid depth conversion of time referenced data, the hiQbe™ model can also be inverted to provide useful indications of rock properties. The Velocity Inversion method is based on a regional Normal Compaction Trend (NCT) model for shales, sandstones and limestones, and produces porosity, lithology, pore pressure and uplift indicators. The inversion to apparent pore pressure in our study uses a regionally variable NCT line tied to the study wells. Well calibration is also provided by the hiQbe™, which has been tied to checkshots in over eight hundred wells. The hiQbe model includes delta anisotropy functions for well calibration of each of the component seismic processing velocity datasets. This allows each of these to be accurately matched to well velocities, which is a significant advantage in well planning, since pore pressure predictions depend on the difference from absolute velocity values and an NCT. An error in anisotropy leading to only a few percent error in velocity can significantly alter a pore pressure prediction.

CONCLUSIONS

The North West Shelf of Australia has a complex geological history, and overpressure occurs for reasons other than undercompaction. Our analysis of wells identifies all types of overpressure. The analysis of the hiQbe™ velocity model, which is based only on seismic velocity, has modelled areas where overpressure results from undercompaction. Our regional geopressure analysis method represents a supplement to the traditional method for pore pressure prediction during well planning, where we step out regionally after the initial well interpretation step. The regional model provides guidance with respect to which layers are prone to being overpressured, and through the hiQbe™ delta anisotropy model, this model can provide a numerical basis for more accurate pore pressure predictions in undercompacted layers. Compared to the traditional method, the numerical advantage comes from the superior delta anisotropy model in the hiQbe™, which is based on a calibration to hundreds of wells across the NWS.

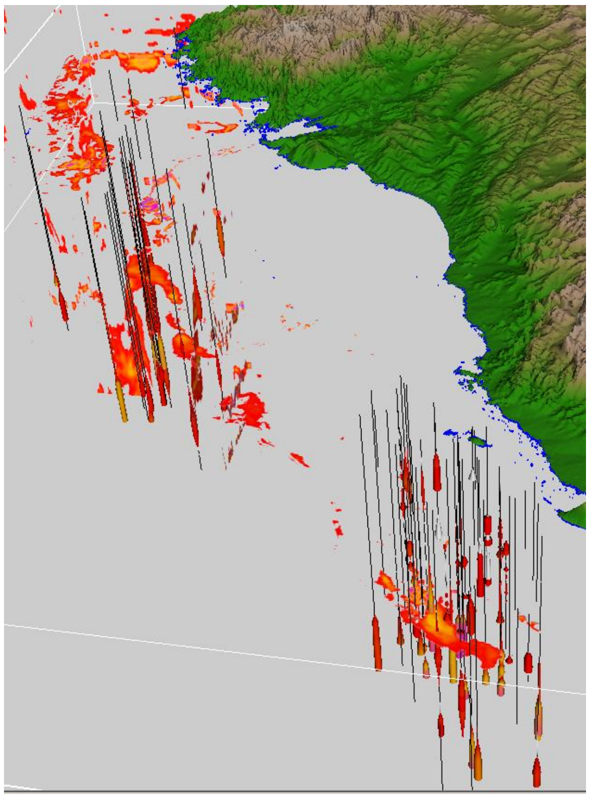

Figure 3. An oblique view of the Northwest Shelf, looking northeast, showing the location of the wells that have been analysed together with a horizontal slice through the pore pressure cube.

REFERENCES

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