Predicting Pore Pressure in Carbonates: A Review

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Abstract

Carbonate reservoirs are the target of many drilling programs in the Middle East. One of the challenges in developing these reservoirs is to mitigate the risk caused by potential abnormal pore pressure. There is a tendency in the industry to use seismic velocity data and porosity-based, shale-proven techniques to predict pore pressure in carbonates. This approach, at best, will only ever give a local, empirical fit, and in reality, the next well drilled may encounter very different pore pressures. The variation in encountered pore pressure is due to porosity varying by other processes such as fracturing and dissolution rather than simply stress; carbonates are stress-invariant.

This paper reaches the following conclusions about pore pressure in carbonates:

1. Carbonates differ substantially from shales in their diagenetic history and compaction, i.e. they have been chemically lithified. They compact via both mechanical and chemical processes such that there may be no basin-scale relationship between porosity and effective stress. Therefore, primary methods of predicting overpressure (and their detection) associated with shales do not work in carbonates.
2. Carbonates are not prone to generate overpressure internally.
3. Overpressured carbonates are those found in association with overpressured shales.
4. Isolation of the reservoir (i.e. where there is little or no lateral escape of pressure to the surface) preserves the overpressure in these carbonates.

The results of this paper suggest that currently the best approach to predicting the pore pressure within a carbonate is based on;

A. The use of seismic inversion to identify carbonates in the subsurface and their associated shales as accurately as possible,
B. Understanding the mechanisms of pressure generation in these shales and use shale techniques to establish the surrounding pore pressures,
C. Modelling the carbonate as a PTZ based on the best understanding of its internal geometry and porosity from the geological facies model (e.g. high energy vs. low energy deposition).
D. Careful thought on the type of carbonates present such as facies, and their abilities to either drain laterally or have elevated crest pressures due to seismically-visible, down-dip extension.

The integration of geopressure, rock physics and geomechanics may result in a way to accurately tie the pore pressure regime to the elastic properties of the carbonate in a way that will allow more accurate prediction of the pore pressure. A multi-stage and multi-disciplinary

approach is required, integrating the geological-pressure model described above with geomechanical and rock physics studies. Geomechanical modelling is supported by accurate pore pressure prediction but it can also provide a constraint to the pore pressure, i.e. the pore pressure predictions which may not be calibrated must also satisfy the geomechanical model which is constrained by laboratory measurements from cores and by image log analysis. Rock physics modelling would aim to build a relationship between the elastic logs (Vp, Vs & Rho) and empirical models linking the mineralogy of the carbonate to its porosity and its compressibility. The use of data types derived from seismic attributes, calibrated to the 1D well-based analysis, could allow for field/basin-scale models to be accurately built. The final output of this analysis would be a powerful basin model (or inputs to a basin model) that would have far reaching and major positive implications for pore pressure prediction in carbonates world-wide.