Basin Scale Modeling of Pore Pressure, Rock Stress and Failure: Method and Applications

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Abstract

Currently three methods are used for the prediction of pore pressure and rock stress before drilling: log analysis of analog wells, seismic attribute to pressure modeling and basin modeling techniques. Basin modeling has been used for pore pressure prediction for more than 20 years. : The coupling of pressure to rock stress formation, advanced models for rock failure and the introduction of organic and mineral rock diageneses and have significantly increased its value and applicability.

The main goal of the basin scale geomechanical modeling is the calculation of the 3D pore pressure and the horizontal stress cube in the study area. The modeling of pore pressure and rock stresses formation through geological time takes the following processes into account: (i) for pore pressure: background pressure variation in low permeable facies, centroid effects for high permeable facies, mineral diagenesis for smectite-illite transformation or cementation, aquathermal pressure and topographic driven pressure, hydrocarbon generation pressure and secondary organic porosity, petroleum column height pressure, fault permeability, (ii) for rock stress: Biot stress, tectonic stress, extensional and shear failure effects to permeability and stress.

It is an advantage of the basin modeling approach to investigate the magnitude of each effect separately as well as all together to understand the importance of the effect on all scales: basin, play, prospect or even at well-scale within the study area. The most important rock properties for this process modeling are the cubes of permeability and Poisson's ratio which can be taken from standard lithological data bases, derived from logs, sample measurements in laboratory tests or derived from seismic.

The final workflow for pore pressure prediction before drilling takes into account the following steps: (i) G&G data assembly to the dynamic geological model (ii) structural basin evolution (iii) assignment of rock mechanical properties (iv) pore pressure prediction (v) rock stress prediction.

The coupled rock stress to pore pressure solution is especially important in areas of non-uniform rock stress areas such as in the vicinity of salt, sections under compressional or extensional tectonics and deeply buried, highly compacted sediments. This is demonstrated with some example models and case studies. A Gulf of Mexico model from the Green Canyon area shows the influence to sub-salt pressure and rock stresses. Here, the resulting pressure, porosity, effective stress and temperature cubes were used in a rock physics model to calculate and calibrate a seismic velocity cube for improving the imaging in the sub-salt layers. In another Gulf of Mexico Study the level of predictability is discussed for the pre-drill well and mud weight design of a new exploration well. It is also shown how the original prediction is dynamically adjusted during drilling. The Shublik play in the Alaska North Slope area is shown as an example for an unconventional shale prospect evaluation. Finally, a 2D model from the Santa Barbara section in Venezuela is used to demonstrate the effects of tectonic stress in a compressional environment.