Latest Technical Developments in Petroleum Systems Modeling and their Applications for Pore Pressure Prediction

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ABSTRACT

Pore pressure prediction is critical for hydrocarbon trap evaluation, well planning, reducing drilling costs, improving drilling performance and operational safety while drilling. Basin and petroleum systems modeling is widely used as an alternative method to model pore pressure and timing of overpressure development through geologic time. Most of the processes that account for overpressure - such as compaction disequilibrium, mineral transformation, cementation, aquathermal pressure, primary and secondary hydrocarbon generation, and lateral pressure transfer effect - are considered at pressure calculations. Based on observations the primary factors affecting the overpressure development are the sedimentation rate, sediment compaction, facies distribution, fault properties and basin geometry.

Usually the numerical basin and petroleum systems modeling for pore pressure prediction is used to analyze the porosity evolution of the sediments for thermal and charge modeling, quality of the reservoirs during subsidence, hydrocarbon migration and containment. Most recently the basin and petroleum systems modeling has been incorporated in drilling programs as well in order to predict pore pressure where seismic based approaches or projections from well information may be challenging.

Commonly applied methods (wellbore or seismic) use the effects of overpressures such as undercompaction and the resulting changes of the present-day physical properties like porosities and velocities. Basin and petroleum systems modeling investigates the causes of overpressures as the result of the processes which occur through geologic time and are primarily due to the inability of pore fluids to escape from low-permeability sediments during burial. Process modeling has specific requirements as pore pressures are controlled by multi-dimensional hydrocarbon ‘plumbing systems’, and one- dimensional process modeling therefore only has very limited value. Two-dimensional modeling is an improvement if the geological cross sections are correctly located. However, only full three-dimensional process modeling enables the controlling factors and property distributions to be wholly taken into account, using fully coupled compaction and rock stress simulation through geologic time in order to deliver the best possible results.

There is no single ‘best methodology’ for pore pressure predictions. All methods provide valuable information, but all of them have limitations. The most meaningful approach is therefore to use the full suite of wellbore, seismic and geological process modeling tools in an integrated approach and with a multi-disciplinary expert team.

Pore pressure studies in restricted areas can be performed, but for conventional basin modeling approach their value will always be limited as the regional context needs to be fully investigated in order to better understand the possible causes of overpressure in a geologic system. This can in some cases even necessitate a complete basin-scale assessment to determine the causes of the overpressure before local conditions can be understood and predicted.

The presented basin modeling approaches and case studies demonstrate that pore pressure modeling coupled with basin-scale geomechanics enables areas and zones with higher fracture risks to be determined and improved pore pressure predictions to be made.