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Pore Pressure Prediction From Seismic Velocities: A Novel Approach Based on Skempton and Biot Theories

Bastien Dupuy[1], Mohamed A. Romdhane[1], Ane E. Lothe[1]

[1]Geophysics and Reservoir Technology, SINTEF Petroleum Research AS, Trondheim, Norway.

ABSTRACT

Conventional methods for pore pressure prediction from seismic velocities are usually based on empirical relations between effective stress and porosity trends. The basic concept is that undercompaction is the main driver of overpressure in shale layers. It relates to abnormal high porosity, which can easily be linked to P-wave velocity. However, the origin of overpressure is not limited to undercompaction and the porosity-velocity relations are not exclusive. Basin reconstruction analysis shows that multiple factors can contribute to abnormal pressures development. This includes the mix of depositional environments controlling the lithological properties and tectonic and geological processes (such as erosion, uplift or burial history) affecting porosities. Therefore, specific care in the choice of the appropriate relation (depending on the overpressure source) and extensive calibration is required when dealing with empirical relations for pore pressure prognosis. At the same time, quantitative seismic imaging methods are showing increasing levels of robustness and accuracy for deriving high-resolution velocity models that are foreseen to help pore pressure prediction at exploration stages. In this work, instead of using the conventional empirical relations, we derive the expression of the pore pressure with respect to the Skempton coefficient via the poroelastodynamic theory of Biot and end up with a physically-consistent equation to estimate pore pressure from velocities. The Biot-Gassmann theory allows estimating the Skempton coefficient with respect to fluid, mineral grains and rock frame moduli in addition to porosity. The pore pressure is then function of this coefficient and of the stress state. The poroelastic properties involved in the Skempton coefficient computation can be derived from seismic velocities via rock physics inversion, log data, or quantitative interpretation methods. Synthetic tests show that the pore pressure prediction derived with the new method is consistent with prediction based on Bowers relation. Th new method does not however require any extensive calibration, which is the main weakness of conventional empirical relations.