Abstract – Velocity and Density Considerations for Robust Overburden Stress Estimation in 3-D Geomechanical Earth Models

Overburden stress, also known as lithostatic pressure or total vertical stress, is a fundamental ingredient to pore pressure estimation and geomechanical modeling. It represents the pressure acting at a specific depth in the subsurface due to the weight of the overlying column of rock and fluids.

For onshore areas, simple overburden pressure gradient constants from surface topography are often assumed, usually 1.0 to 1.1 psi/ft. Offshore, similar approaches from below mudline or seafloor may also be adopted (0.85-0.9 psi/ft). While these methods might be useful for initial screening purposes, more rigor is usually needed.

To characterize overburden stress in more detail, bulk density log measurements should be utilized. However, the main challenge here is that density logs are usually absent over shallow intervals due to density tool hole size limitations. Therefore, shallow densities must be estimated, often using trends, to fill the data gaps. Furthermore, density log quality can be affected by wellbore enlargements so careful density log QC is also required. Once the density logs have been edited for bad hole and data gaps filled then overburden stress is calculated by vertical integration of the density model.

This 1-D focused approach can also encounter significant issues where highly deviated or horizontal wells traverse beneath a variable surface topography or sea floor, or where rapid lateral changes in density occur in the overburden (evaporite layers of variable thickness, for example).

To overcome these challenges, a 3-D velocity-density-overburden approach that integrates geophysics, geology and petrophysics should be applied where necessary. Seismic velocity models should be leveraged if available, transformed to interval velocity and calibrated to offset well velocities. Intervals of thick, anomalous velocity and density should be mapped (sea floor, evaporites, limestones, high net sand) and incorporated into the 3-D model. For mudstone dominated intervals, it is often necessary to utilize velocity-to-density transforms that account for smectite-illite clay mineral variations. One such model is from Alberty-McLean (2005). It incorporates thermal effects to robustly model density changes arising from smectite to illite transition. Calibrated seismic velocities can then be transformed to density and density integrated to overburden stress.

Using example deep wells from offshore Gulf of Mexico, I will highlight the approaches outlined above to demonstrate their effectiveness is overburden stress estimation. Model results will be compared to some common place methods to contrast the results.

Utilizing an integrated 3-D methodology yields robust estimates of overburden stress to front-end pore pressure and geomechanics workflows. The process can be applied efficiently on a field or semi-regional scale and resultant attributes extracted to all wellbores within the model area for further calculations, albeit 1-D or 3-D. This process often yields a more consistent interpretation than applying a well-by-well approach and accounts for spatial rock and fluid property variations that may not be present in offset wells.

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