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Impact of overpressures on subsurface exploration and reservoir management

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The presence of overpressures in the subsurface poses major problems for safety and cost efficient well design, but less well known is their importance for exploration and reservoir development. Overpressures reduce the vertical effective stress (VES, the difference between the vertical stress and fluid pressure) experienced by the sediment. As sediment compaction is primarily an irreversible function of VES, a reduction in VES will halt compaction. Similarly, a reduction in its rate of increase will reduce the rate of porosity loss. Porosity and other key rock properties will therefore reflect changes in vertical effective stress. Any measurement that senses porosity, or seismic velocity (e.g. sonic, density or resistivity logs) will provide a means of estimating overpressures. The reduction of porosity with vertical effective stress is exponential in nature. Consequently, overpressures generated early in the burial history, such as those generated by disequilibrium compaction, will have a greater impact on rock properties than those generated or emplaced during late burial. Indeed, late overpressuring, so-called inflation, may have little or no impact on rock properties and therefore methods for the prediction of overpressures from properties such as seismic velocity will not provide reliable pressure estimates.
In order for fluid pressures to rise in a basin, the pressures have to be contained by rocks with sufficiently low permeability. Overpressures are transient and gradually leak away when the generation mechanism ceases to operate. In some areas, such as in parts of the central North Sea and the Middle East, fluid pressures have built up until the failure envelope of the seal is reached, leading to a subsequent loss of the sealing capacity. The failure envelope is usually considered to be determined by the minimum horizontal stress. The failure pressure for the seal systematically increases with depth and this variation will control the maximum pressures possible within the subsurface.
An important matter is the prediction of the hydrocarbon phase distribution within overpressured reservoirs. In many areas, source rocks are also contained within the overpressured realm. Consequently these overpressures control the general presence of hydrocarbons and the distribution of their phases. Based on the PVT-data of the final products, modern modelling techniques allow the prediction of gas-/oil-ratios and distributions in reservoirs at different depths and pressure regimes. Field development and production within overpressured reservoirs are often hampered by the heterogeneous distribution of porosity and permeability which leads to low or inconsistent production rates. A widely know phenomenon is the general deterioration of reservoir properties by diagenetic processes. Another feature is the plugging of porosity by salt, bitumen and other movable phases by way of secondary processes.
Optimised strategies for future successful exploration campaigns, field development and production from overpressured fields can only be achieved by the integration of methods with the final aim of a dynamic reservoir model. This includes the amalgamation of various modelling techniques (thermal, chemical, reservoir, diagenetic, structural) combined with advanced 4-D (time lapse) seismic techniques.