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SDEM modelling of deformation associated with a listric fault system and associated fluid flow

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Numerical modelling of geological structures using FEM, DEM and SDEM methods as well as analogue modelling are widely used in order to achieve a better understanding of the kinematics and dynamics during deformation. The methods are furthermore the ultimate source for mapping (observing) the true geometry of geological structures as well as subsurface fluid flow phenomena in 3D seismic data developed for hydrocarbon exploration. Here we use 3D seismic data and SDEM modelling to suggest a dynamic-kinematic evolution of the deformation in the hangingwall of a listric fault overlying an active salt roller. We use the results to obtain a better understanding of the fluid flow in a complex deformed hangingwall.
The case study is focused at the D-1 fault trend in the western part of the Norwegian Danish Basin, at the northern slope of the Ringkøbing-Fyn High. The D-1 main fault detaches along the northern flank of a Zechstein salt roller which was active during the Cenozoic. The seismic analysis shows a system of secondary normal antithetic and synthetic faults dipping approximately 50-60dg within the hangingwall. Shallow gas is trapped in the hangingwall and the secondary faults often confine the accumulations i.e. indicating that the secondary faults are sealing. The modelling confirms that the geometry of the secondary faults is highly controlled by the rheology of different layers in the hangingwall but also on the intensity of the salt movement. The modelling also suggests the presence of vertical deformation zones; structures which are not directly observed on the seismic data. The vertical deformation zones are related to the differential vertical movement of the strata due to salt migration.
A neural network trained chimney probability cube shows high probabilities for the presence of minor vertical gas chimneys below the gas accumulations suggesting that vertical fluid migration in the hangingwall occurred in areas with significant vertical salt movements. The zones of high chimney probability coincide with the modelled vertical deformation zones. It cannot be excluded that the vertical deformation zones which have been inferred from the numerical modelling are responsible for or highly influence the high chimney probabilities observed in the chimney cube and thus that the interpretation of chimneys (and vertical fluid migration) is incorrect. However, since the chimney cube is also based on seed picks from areas without deformation, we suggest that the vertical deformation zones contributed to vertical fluid flow from the deeper succession into the shallow gas compartments. Thus the modelling demonstrates the capability of resolving sub-seismic deformation zones which appear to be critical for the facilitation of vertical fluid migration in the study area. Similar vertical deformation zones may therefore constitute the fluid migration routes in areas where such are only inferred but not imaged by the seismic data.