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Subseismic Deformation Analysis- A Prediction Tool for a Safe CO2- Reservoir Management

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SUMMARY

The evolution of a reservoir is mostly affected by deformation. Large-scale, subsurface structure and deformation is typically identified by seismic data, small-scale fractures by well data. However, faulting at the medium sub-seismic scale plays an important role, e.g. in gas or geothermal reservoirs: large individual reservoirs can be disrupted by faults enhancing fluid flow, or producing compartmentalized deposits due to cementation of fractures. Thus, between both scales, seismic and well data, we lack a deeper understanding of how deformation scales in the sub-seismic region. Bridging this gap will allow to make predictions about the future development of a reservoir, the generation of possible pathways due to changes in the stress regime, and thus to judge storage safety.

To start tackling this problem, a 3-D reflection seismic data set in the North German Basin was analysed with respect to structure and faults in great detail, calibrated by well data. This led to the determination of magnitude and distribution of deformation and its accumulation in space and time on the seismic scale. The structural interpretation unravels the kinematics in the North German Basin with extensional events during basin initiation and later inversion. For further quantitative deformation and fracture prediction on the sub-seismic scale, two different approaches are introduced. Increased resolution of subtle tectonic lineaments is achieved by coherency processing yielding together with geostatistic tools the distribution of low- and high-strain zones in the region. Independently, the distribution and quantification of the strain magnitude is predicted from 3-D retro-deformation of the identified structures. For the fault structure analysed, it shows major-strain magnitudes between 5-15% up to 1.5 km away from a fault trace, and variable deviations orientation of associated extensional fractures. The small scale is represented by FMI data from borehole measurements, showing main fault directions and densities. These well data allow the validation of our sub-seismic deformation analyses. In summary, the good correlation of results across the different scales makes the prediction of small-scale faults/fractures possible.

The suggested geomechanical workflow requires principally the 3-D coverage of a region. It yields in great detail both the tectonic history of a region as well as predictions for the genesis of structures below the resolution of reflection seismics.