3D fault integrity screening for Smeaheia CO_2 injection site

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Geological sequestration of CO_2 is steadily developed as a safe solution for mitigating global emissions. As a part of an ongoing Norwegian full-scale CCS demonstration project, the prospects for CO_2 storage are contained within a large fault block east of the Troll East gas field (Smeaheia) in the North Sea. Assessment of fault sealing and integrity related to the CO_2 injection process is an important task that requires detailed fault characterization and improvements in de-risking methodology. Several North Sea faults are found to provide excellent sealing properties supporting considerable hydrocarbon columns. Although some methods are proposed for evaluation of fault integrity during CO_2 injection (e.g. Chiaramonte et al., 2015), there is still high uncertainty associated with the determination of sealing versus non-sealing faults and their dynamic evolution in geologic time and at the scale of production and injection. Additionally, there is only limited experience of how fault integrity is influenced by increasing pore pressure due to CO_2 injection.

In this study, we apply the critically stressed fault model to the Smeaheia CO_2 storage site for screening of critically oriented faults. We use an analytical approach comparing the stresses acting on a fault surface with the frictional strength and including considerations of various failure mechanisms (i.e. tensile and shear failure criteria). The current work focuses on a detailed 3D fault mapping combined with addressing expected fault rock properties. The main reservoir unit considered for CO2 injection in the Smeaheia fault block is the Late Jurassic Sognefjord Formation of the Viking Group. The fault block is bounded by two approximately N-S striking faults, the Vette fault in the west, and the Øygarden fault in the east. The main top seal is the Draupne shale. Two main prospects termed Alpha and Beta are considered. The Alpha structure is a gentle 3D anticline possibly formed as footwall rebound along the Vette fault, whereas the Beta prospect is located next to the Øygarden fault and is a large roll-over anticline. The Øygarden fault juxtaposes the North Sea sedimentary succession towards the Norwegian basement rock.

The fault model aims to provide a first assessment of the stability of faults in a potential CO_2 storage site. The geometry of faults (strike and dip) is imported from a seismic interpretation /geomodel tool (e.g. Petrel). Knowledge about in-situ stress conditions (magnitude and orientation) and pore pressure allows the calculation of shear stress on fault surfaces and the mapping of allowable pore pressure increase before failure. The model can consider both shear and tensile failure and calculate the pressure limits comparing the two different pressure limitations. Preliminary results presented as allowable pore pressure on the faults are shown in Fig. 1. The results show that tensile failure (i.e. the grey area in Fig. 1b) is the likely failure mechanism at the crest of the Beta structure (Top reservoir 1304 m TVDMSL). At the crest, the difference in effective stress between the horizontal and vertical direction is small due to the shallow depth. This gives a small Mohr circle and hence the failure scenario is highly sensitive to the cohesion of the material. The results clearly show that consideration of tensile failure mechanism is as important as shear failure mechanism in the identification of critically oriented faults for this site. The model provides a useful tool for screening critical faults and evaluating sensitivity of the various parameters included in the model. Work in progress includes a more detailed assessment of fault rock material to be expected, the sensitivity in fault strength (friction and cohesion) as well as updating the fault geometry model with more details on the minor faults within the anticlines and along relay ramps.

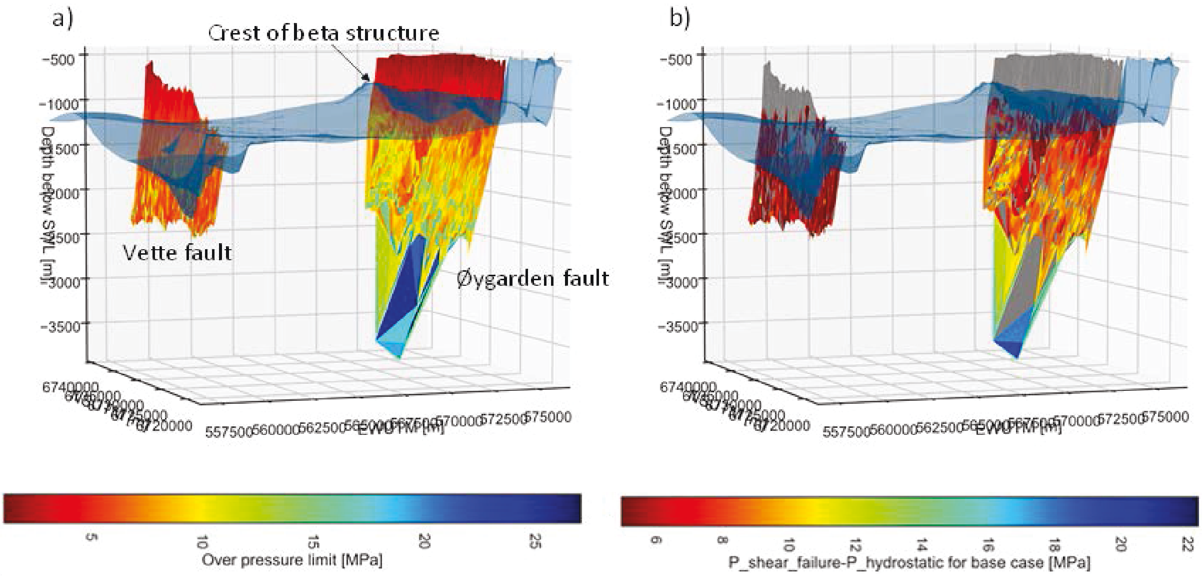

Fig 1 Example of calculated pore pressure limit for fault reactivation for the major faults together with the top reservoir horizon. a) the minimum value between shear and tensile failure limit are plotted, b) coloured areas have a shear failure limit, whereas grey faults show tensile failure limit. At the crest of beta structure, tensile failure could be the potential failure mechanism.

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