Experimental and Analytical Assessment of Draupne Shale Seal Integrity for CO_2 Storage Sites

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Introduction

Carbon dioxide (CO_2) capture and storage is one of the most important measures to reduce the atmospheric concentration of CO_2. To ensure safe storage, operations must be conducted in way that respects operational limitations. Furthermore, the operational limitations should be based on models appropriately accounting for relevant material properties and in-situ stress conditions. In this study, we combine various experimental approaches on the Draupne shale to get a more complete picture of the properties of intact and naturally fractured samples and to evaluate the feasibility of using passive seismic to monitor this North Sea caprock. The measured properties combined with in-situ stresses are used to calculate stresses acting on arbitrarily oriented fractures and associated stabilities using an in-house developed software.

Material and methods

The material used in this is the Upper Jurassic Draupne Formation from the Ling Depression in the North Sea. It is described as a low-permeable, homogeneously anisotropic black shale. All samples are sub-cored from 133 mm diameter cores retrieved from a depth of approximately 2580 meters below sea level. The 9-meter core section of high-quality shale provides a rare opportunity to comprehensively study both the intact and naturally fractured properties of an important North Sea caprock.

The intact strength and anisotropy of the core has been extensively studied through isotropically consolidated undrained (CIU) triaxial tests on samples sub-cored at different angles relative to layering (Skurtveit et al. 2015). Strength and frictional properties of a slickensided natural mode II fracture are investigated in the direct shear box. The fracture is characterized both before and after testing using, among other techniques, photogrammetry and Scanning Electron Microscopy (Smith et al. 2019). An elaborate test program is designed to examine the relationship between shear stress and increasing normal load, and to examine the shear stress response to increasing shear displacement rates. The latter can indicate whether the rock is expected to behave aseismically or not during slip. The expected aseismic behaviour is finally compared to triaxial test data on an undrained, isotopically consolidated sample, using simultaneous monitoring of acoustic emissions during shearing of the material. During this triaxial test, the failure plane is exposed to several re-activations at different effective horizontal stresses, relevant to different depths of this formation in the North Sea.

Main results and Conclusions

The experimental program performed enables an in-depth understanding of the mechanical properties of intact and fractured Draupne shale. The analytical software allows for calculation of stresses and stabilities acting on fractures with random orientations in a 3D stress field, informing on the stability of fractures in the sub-surface. In the current project, the input parameters from laboratory testing indicates that critically oriented fractures are already close to activation under the present stress conditions at Ling Depression. Hence, the main consequence of this study for CO2 storage is the increased precision in operational limitations, to avoid unwanted inelastic deformation. state.

References

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