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Assessment of seal quality for potential storage sites in the Norwegian North Sea from well log data

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Fluid migration through caprocks is a crucial process when it comes to evaluate their sealing capacity for underground CO_2 storage. Migration mechanisms such as flow through fault systems or along wells are quite easily identified by their relatively large size and because these features can be monitored by the use of reflection seismic data or well logs. However, microcracks in rocks, which can allegedly cause fluid migration through tight rocks, are difficult to detect from large scale observations and can only be deduced from thorough investigation. The objective of this work is to evaluate the likelihood of microfracture networks in potential seals (shales) through the analysis of well log data.

This study focuses on the Upper Jurassic and Lower Cretaceous shale succession in the Norwegian North Sea. The main target of the study is the Draupne Formation (upper Jurassic) found in the Horda Platform / Viking Graben area. It has been deposited syn-rift during the second episode of the Viking graben formation in the Upper Jurassic, and thus has a burial depth ranging from 914 to 4573 m. This formation is identified in well logs by its sharp decrease in ultrasonic velocity and density, and specifically high resistivity and gamma ray readings. Other studied shale formations include the rest of the Viking Group (Heather Formation), the Tyne Group in the Central Graben (Farsund, Haugesund and Mandal) and the Boknfjord Group in the Norwegian-Danish Basin (Egersund, Flekkefjord, Sauda and Tau).

Public well log data from 104 boreholes in the Norwegian sector of the North Sea have been analyzed and among them, 87 had a complete set of logs that are necessary for our analysis: ultrasonic velocities, gamma ray, density and resistivity.

This study illustrates that the first-order variation of the ultrasonic velocity for the Draupne Formation in the Norwegian North Sea is of course due to depth. Diagenesis, whether mechanical or chemical, stiffens the rock by strengthening the grain contacts and/or cementing them. This increases the ultrasonic velocity through the rock. The depth at which the transition between mechanical and chemical transition, together with the geothermal gradient study, help us to separate areas where these identified shales have a ductile rheology (softer rock, self healing low-conductivity cracks) from those where stiffening by secondary quartz cementation yields a brittle rheology (stronger rock, high-conductivity cracks).

Two other parameters are likely to influence the velocity, namely TOC and the presence of gas in the porous network of the rock. When taking into account the influence of both depth and TOC, around 80 % of the studied wells follow a distinct pattern. When taking into account gas as a pore fluid, around half of the other studied wells follow the same trend.