Rock-physics modelling of the North Sea greensand - DTU Orbit (04/10/2019)

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Greensands are composed of a mixture of stiff clastic quartz grains and soft glauconite grains. Glauconites are porous and composed of aggregates of iron-bearing clay. Greensands from the two formations in the Nini field of the North Sea were studied in this thesis. Hermod Formation is weakly cemented, whereas Ty Formation is characterized by microcrystalline quartz cement. A series of laboratory experiments including core analysis, capillary pressure measurements, NMR T2 measurements, acoustic velocity measurements, electrical properties measurements and CO2 injection experiments were done on greensand samples. Thin sections and BSE images are also available for this study. The objective of the first part of this study is to predict petrophysical properties from nuclear magnetic resonance (NMR) T2 distributions. NMR is a useful tool in reservoir evaluation. Estimated petrophysical properties from NMR measurements were correlated with measurements from core analysis. NMR underestimates the total porosity due to the presence of iron bearing clay minerals in greensand. Permeability may be predicted from NMR by using Kozeny’s equation when surface relativity is known. The surface area measured by the BET method is associated with the micro-porous glauconite grains. The effective specific surface area as calculated from Kozeny's equation is associated with macro-pores. Capillary pressure drainage curves may be predicted from NMR T2 distribution when pore size distribution within a sample is homogeneous.

The central part of this study is rock-physics modelling of greensand. The first of the models is a grain contact model of the North Sea Paleocene greensand. First a Hertz-Mindlin contact model is developed for a mixture of quartz and glauconite. Next step is to use the moduli predicted from this Hertz-Mindlin contact model of two types of grains as the initial moduli for a soft-sand model and a stiff-sand model. Results of rock-physics modelling and thin section observations indicate that variations in the elastic properties of greensand can be explained by two main diagenetic phases: silica cementation and berthierine cementation. Initially greensand is a mixture of mainly quartz and glauconite; when weakly cemented, it has relatively low elastic modulus and can be modeled by a Hertz-Mindlin contact model of two types of grains. Silica-cemented greensand has a relatively high elastic modulus and can be modeled by an intermediate-stiff-sand or a stiff-sand model. Berthierine cement has a different growth patterns in different part of the greensand, resulting in a soft-sand model and an intermediate-stiff-sand model. The second rock-physical model predicts Vp-Vs relations and AVO of a greensand shale interface. The relationship between Vp and Vs may be used to predict Vs where only Vp is known. Published work, focus is primarily on the Vp-Vs relationship of quartzitic sandstone. In order to broaden the picture Vp-Vs relationships of greensand were presented. A Vp-Vs relationship derived from modelling is compared with empirical Vp-Vs regressions from laboratory data. The quality of Vs prediction is quantified by statistical analysis. The Vp-Vs relationship derived from modelling works well for greensand shear-wave velocity prediction. AVO modelling shows that brine saturated glauconitic greensand may have similar seismic response to oil saturated quartzitic sandstone and that strongly cemented greensand with oil saturation can have similar AVO response to brine saturated weakly cemented greensand. The third rock-physical model predicts pore fluid effects on elastic properties of greensand. NMR studies were included to describe the fluid related dispersion in greensand. NMR studies show that Biot's flow should occur only in large pores in the greensand, while Biot's flow should not occur in micro-pores. Differences of fluid flow in macro-pores and micro-pores are described as high frequency squirt flow in greensand. The objective of the last part of this study is to investigate CO2 injection effects on physical properties of greensand. Laboratory results indicate that CO2 injection has no major effect on porosity, electrical properties and elastic properties of greensand. In contrast Klinkenberg permeability of greensand increased after CO2 injection. An NMR permeability modelling approach was tested to evaluate the effect on matrix permeability of CO2 injection. It appears that permeability after CO2 injection increased not due to fracturing but rather due to the increase of macro-pores in the greensand. The increase of macro-pores size is probably due to migration of fine pore-filling minerals. Rock-physics modelling indicates that the presence of CO2 in a greensand decreases Vp by 2%-41% relative to Vp of brine saturated greensand. CO2 flooding would at the same time increase Vs, typically 1%-2%, while decreasing density by 3%-5%.

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