Subjects for Bachelor and Master thesis from the ”Carbonate-Group,” Spring –07

Personnel involved in the work will be:

Engineer Kim A. N. Vorland
Dr. stud. Tina Puntervold
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Dr. stud. Victor Hegerland Havik
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IOR-studies

(Prof. Tor austad)

- *Wettability/EOR studies in chalk*: Supervisors Tina Puntervold and Skule Strand

  1. Impact of base number, BN, on the wettability of chalk at constant acid number (AN). Effects of temperature (90 and 110 ^oC). (Supervisor T. Puntervold)

  2. Optimization of injection fluid into chalk for oil recovery – Mixtures of seawater and produced water.

  Projects for at least 4 persons.

- *Wettability/EOR studies in limestone* (Thamama cores): Supervisors Tina Puntervold and Skule Strand

  1. Adsorption of potential determining ions on the surface
     a. SO_4^{2-}, Ca^{2+}, Mg^{2+}
     b. Effects of temperature.

  2. Possible substitution of Ca^{2+} by Mg^{2+} at the surface at high temperature.

Rock mechanics

(Ass. Prof. Merete V. Madland)

Supervisors: Ass. Prof. Merete V. Madland, Dr. stud. Reidar I. Korsnes, PhD. stud. Victor Hegerland Havik and PhD.stud. Edvard Omdal

We have listed subjects, which means that some of the following proposals could include several more than one bachelor -or master theses.

THE WATER WEAKENING PHENOMENON

Seawater is injected into the high temperature North Sea chalk reservoirs to improve oil recovery with great success. Increased compaction of the rock, which also is a significant contribution to the oil displacement, is observed in the water-flooded area. Recent laboratory studies at elevated temperatures (130, 90, 70 and 50ºC) have shown that seawater increased the water weakening effect of chalk, due to the presence of potential determining ions like Ca^{2+}, Mg^{2+}, and SO_4^{2-}. Substitutions of Ca^{2+} by Mg^{2+} at inter granular contacts when seawater contained SO_4^{2-} ions, is crucial in the water weakening mechanism.

1. *Optimization of the injected fluid in chalk reservoirs*

Reservoir compaction provides significant drive energy and greatly contributes to increased production and reserves. However, increased compaction by seawater is not only positive; it also leads to problems such as: seabed subsidence, loss of wells, numerous casing deformations and poses a notable challenge for well completion, significant pipeline concerns due to excess compressional or tensional strain and so on. Sulfate in seawater are important ions for wettability alteration of chalk, and should not be removed from the injection fluid. However, can we optimize the injection fluid by reducing the concentration of SO_4^{2-} ions, such that compaction is reduced, but still enough SO_4^{2-} ions for a wettability alteration to take place?

Series of mechanical tests on chalk cores should be performed at elevated temperatures. The chalk samples will be flooded with seawater containing varying sulphate concentrations. What is the minimum SO_4^{2-} concentration in seawater for enhanced water weakening in chalk to take place?

2. *The effect of water injection on low –and high porosity chalk*

The water weakening effect has been studied mainly on high porosity chalk (42-48 %). The porosity values for the chalk reservoir at the Ekofisk field vary within the range of 25 to 48%. The water weakening effect has been extensively studied on high porosity chalk; however, this water-weakening phenomenon should also be studied by use of lower porosity chalk.

a. *Static test series:*

Aging of chalk samples with different porosity (outcrop chalk from Stevns Klint and Kansas). The cores will be aged at 50, 90 and 130ºC for 4 to 6 weeks. Four aging fluids will be used: NaCl brine, distilled water (DW), synthetic seawater (SSW) and synthetic seawater without SO_4^{2-} (SSW-U). The different brine solutions will have the same ionic strength. After aging, the samples will be tested mechanically in a triaxial test cell.

b. *Dynamic test series:*

Perform creep tests at temperatures above 70ºC. Low -and high porosity chalk will be used and the tests should be performed with flooding of three types of brines: Synthetic seawater without SO_4^{2-} (SSW-U), synthetic seawater (SSW) and synthetic seawater without SO_4^{2-} and Mg^{2+} (SSW-U2). Start tests with SSW-U, but change the flooding fluid to SSW or SSW-U2 during the creep period. Can we observe any changes in compaction when the flooding fluids are changed? Which possible differences are observed between low and high porosity chalk?

c. *Dynamic test series:*

Perform creep tests with synthetic seawater (SSW) at different temperatures. Start the test at 50ºC before the temperature is increased stepwise to 90ºC and later to 130ºC. Can we observe temperature effects, such as increased compaction.

d. *Mechanical tests with pre-flooding*

Perform mechanical tests after different pre-flooding periods. The chalk samples (low and high porosity) will be pre-flooded for a certain period of time (1, 3 and 7 days of pre flooding) and different temperatures (70 and 130 ºC). The cores can be flooded with synthetic seawater (SSW) and synthetic seawater without SO_4^{2-} (SSW-U). Could we possibly observe any changes on mechanical strength after the various pre-flooding periods?

3. *Compaction of a carbonate reservoir rock from Vietnam and effects of water weakening*

Carbonate reservoirs can generally be classified as dolomite (>50% $CaMg(CO_3)_2$) or limestone (>50% $CaCO_3$). It would be of interest to investigate if the water weakening phenomenon observed for chalk, which is classified as a biogenic limestone, also takes place for other types of carbonates or not.

4. *Possible pore pressure build-up during water injection/water-weakening of chalk*

The pore pressure and compaction behaviour of collapsible materials, such as high porosity chalk, undergoing yield is dependent on the rate of fluid expulsion from the failing pore structure. In conventional experiments (unless imposed deformation rates are unrealistically fast) full drainage of the fluids occurs which gives a simple representation of the yield behaviour. This is not necessarily representative of the situation in a producing reservoir. In a reservoir undergoing production, the quantity of fluid leaving the pore structure of the reservoir rock is restricted to the net voidage rate. Under these conditions, particularly if the reservoir material exhibits a range of porosity's, then different parts of the reservoir may experience pore collapse under partially drained conditions and fluid pressures will not fall to the extent predicted by conventional engineering analysis for that particular voidage rate.

It is proposed that the following study should be undertaken to characterise the pore pressure response of chalks undergoing yield under partially drained conditions.

A limited experimental study in which chalks of different initial porosity are deformed to beyond pore collapse under conditions of partial drainage. Small volumes of fluid would be incrementally produced from the samples and their pore pressure and compaction would be monitored. The experiments will explore the impact of initial porosity, voidage rate and fluid compressibility on the pore pressure response.

5. *Water weakening due to pure dissolution*

In two previous studies at our laboratory (1. Risnes, R., Haghighi, H., Korsnes, R.I., Natvik, O., 2003 Chalk-fluid interactions with glycol and brines*. Tectonophysics 370, 213-226* and 2. Risnes, R., Madland, M.V., Hole, M., Kwabiah, N.K., Water weakening of chalk-Mechanical effects of water-glycol mixtures. *Journal of Petroleum Science and Engineering 48 (2005) 21-36*) chalk-fluid interactions with glycol and brines were discussed in terms of water activity. The different tests showed increasing strength with decreasing water activity, however, our latest results seem to show that these previous experiments could rather be explained due to pure dissolution of chalk in the actual fluid.

Within this present study one should saturate series of chalk with different water-glycol mixtures and further on, the series of samples should be aged for 4 to 6 weeks at different temperatures for instance 50, 80 and 130 oC. After aging, the samples will be mechanical tested and it would be of interest to investigate any differences in strength.

6. *Reservoir compaction behavior for reservoir simulation of Ula sandstones*

The water weakening effect observed for chalk may also take place for other types of rocks. Reservoir sandstone at Ula undergoes high effective stresses at high temperatures and how will compaction of this reservoir rock be affected by seawater injection? Creep (time dependent behaviour) and possible water weakening effects should be studied.

MECHANICAL PROPERTIES OF CHALKS

7. *Mechanical properties of low porosity chalk*

The mechanical properties of low porosity chalk should be further investigated. Series of compression tests, hydrostatic tests as well as tensile tests should be performed on dry -and water saturated chalk. From these tests, yield strength and complete yield curves, cohesion, friction –and failure angle, elastic parameters such as K-modulus (bulk modulus, E-modulus (Youngs modulus), Poissons forhold (ν) could then be determined.

8. *Variation in friction angle*

The friction angle is linked to the shear strength or the cohesion of the rock. From previous studies, in-house studies as well as others, the friction angle for chalk, seems to vary according to which stress path the samples have been exposed to. The friction angle seems, however, also to depend on the saturating fluid as well as the testing temperature. This study will include a systematical type of work. Series of chalk samples should be deformed to different stages of plastic deformation. At least 3 to 4 samples of tests are needed at each level of plastic strain. Also different types of saturating fluids should be tested. If time allows, one should also perform tests at different temperatures.