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The effect of aging, temperature and brine composition on the mechanical strength of chalk

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Chalk strength has been of great focus for several research communities since the 1980s when the Ekofisk subsidence problem was discovered. Sea water injection was initiated in 1987 to improve the oil production and to re-pressurize the reservoirs to halt the subsidence. The oil production was improved significantly, but the reservoir compaction in the water saturated regions continued, in contrast to the regions with no water breakthrough. This observation indicates a water weakening effect of the chalk.

Extensive studies have been performed during the last decades to enlighten how the brine chemistry alters the rock mechanical properties. These studies have shown that the elastic bulk modulus, yield strength, creep and the deformation rate at constant stress conditions depend on the pore fluid composition. In general, the injected brine is in non-equilibrium with the rock surface inducing alteration of the rock mineralogy.

In this study we examined two aspects of the mechanical strength, namely the bulk modulus and the onset of yield during hydrostatic stress loading with 0.7 MPa pore pressure. The test program consisted of aged and un-aged cores, ambient and 130°C test temperature, and four brine compositions: $MgCl_2$, NaCl, Na_2SO_4, and synthetic sea water (SSW) at ion strengths of 0.657 M. The aging was performed by submerging saturated cores in a closed container with the respective test brine for three weeks at 130°C. Un-aged cores were saturated the same day as they were tested. For each brine composition we present four test setups; (a) aged and tested at 130°C, (b) aged and tested at ambient temperature, (c) un-aged and tested at 130°C, and (d) un-aged and tested at ambient conditions.

The main results from our study are:

1. By using NaCl and $MgCl_2$ as saturating brines, neither the test temperature nor the aging procedure affected the yield stress and bulk modulus significantly.

2. Using Na_2SO_4, the yield point and bulk moduli were reduced if the core experienced 130°C either during the hydrostatic loading phase or during core aging. As such, weakening was observed also at ambient test temperature, given the plug experienced 130°C during aging. These results imply that the plug was permanently weakened by the aging. In addition, un-aged cores were weakened at 130°C, indicating that weakening by Na_2SO_4 at elevated temperatures is an immediate process which could be explained in terms of adsorption of surface active ions creating inter-granular disjoining pressures.

3. Using SSW, the bulk moduli and yield strength were reduced at 130°C independent of aging or no-aging. Aged and un-aged cores tested at ambient temperature show no alteration to the mechanical properties, with results similar to the ones obtained for the NaCl and $MgCl_2$ saturated cores. This observation indicates that, in these cases, the mechanical properties are in-sensitive to the brine chemistry.