EVALUATION OF LATE CAPROCK FAILURE ON HYDROCARBON MIGRATION USING A LINKED PRESSURE AND STRESS SIMULATOR

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Knowledge of timing and placement of hydraulic fracturing is essential to be able to evaluate hydrocarbon potential in overpressured sedimentary basins. Till now, the understanding of hydraulic fracturing and leakage has been limited due to lack of good exposures in nature and few cores from potential hydraulic fractured caprocks. One way to achieve new knowledge is to use a basin simulator that couple pressure and stress through time.

The initiation of tensile hydraulic fracture occurs when the pore pressure exceeds the sum of the minimum horizontal stress and the tensional strength of the rock. However, in cases where pre-existing fractures occur, the pore pressure only has to be larger than the minimum horizontal stress. Thus, the type of hydraulic fractures will depend on the burial depth (stress state) and pore pressure. Tensile failure will take place at shallow burial depths, while shear failure will occur at greater burial depths.
The fault pattern on top of the reservoir formation defines the extent of the pressure (Borge 2000) and stress compartments in a pressure and stress simulator. The overlying cap rocks are the top seals to the compartments. Depth-converted maps of the overlying sediments are used to construct a decompacted burial history through time. Pressure and stress results are reported for a series of time steps, which are correlated to the depositional ages of the stratigraphic horizons that are used to build the model. The porosity-depth relation in shales is used to model mechanical compaction and a kinetic model for quartz cementation is used for chemical compaction. The geo-mechanical properties for the caprock will vary through time with burial depths. The pressure modelling is calibrated to measurement from exploration wells in the study area.

Figure 1 shows a map of a case study, where hydraulic fracturing is simulated to occur in the dark shaded compartments. The grey scale represents the logarithmic cumulative leakage in the compartments through time. Studying two compartments in more detail (cell X and Y in Figure 1), the amount of leakage versus time is plotted for the two cells in Figure 2. As we can see in Figure 2 the leakage for both cells are instantaneous, with a marked pulse. The pulses are followed by a marked reduction in the flow-rates, and then a near constant leakage. This is illustrated by a near linear increase in the cumulative leakage for both cells (Figure 2).

In hydrocarbon exploration, the late hydraulic fracturing and following leakage, here simulated to occur at 0.82 Ma and at a depth of 3.9 km for compartment X would have a dramatic effect on the hydrocarbon potential of nearby traps. The most extreme case would be efficient drainage of the system resulting in a pressure drop in nearby traps as well. However, since the hydraulic fracturing is modelled to occur quite late for compartment X, compared to compartment Y, which is simulated to fail at 1.56 Ma, other scenarios should be evaluated. a) Leakage from the highest top point of the structure, but less or nor leakage from deeper points in the same structure. b) Leakage from the highest point of the structure, but with a certain time-delay that may imply a tilted oil-water contact. c) The pressure compartment can internally have minor fault zones that are controlling the internal fluid flow and would also influence on hydrocarbon drainage.

The leakage from one compartment will have an effect on possible leakage from neighbouring compartments. The pressure and stress history in the rest of the basin will influence the leakage pattern. One approach would therefore be to test many different cases systematically varying the input for the simulator. A quantification of the uncertainties and their importance for hydrocarbon potential in the reservoirs is thereby obtained.

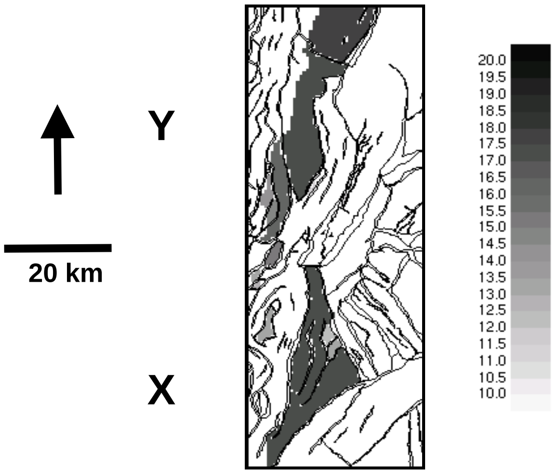

Figure 1Map showing logarithmic cumulative leakage (log m3) in the study area. Compartment X and Y are referred to in Figure 2.

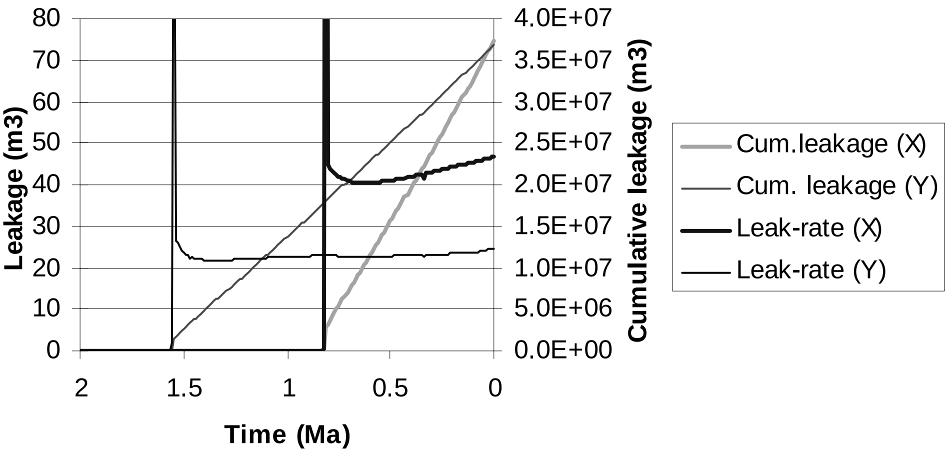

Figure 2The graph shows simulated cumulative leakage and leakage rate versus time, for the compartment X and Y marked in Figure 1. The timing of the hydraulic fracturing of the two compartments differs with 0.74 Ma.

Reference:

Borge, H. 2000: Fault controlled pressure modelling in sedimentary basins. PhD thesis, Department of Mathematical Sciences, the Norwegian University of Sciences and Technology, 156 p.