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Impact of fluid extraction on the creep behaviour of clay-rich formations enveloping Rotliegend sandstone reservoirs

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Introduction

Extraction of fluids, such as natural gas, from subsurface reservoirs can cause surface subsidence and induced seismicity, as seen in the Groningen area in the Netherlands. In the Groningen gas field, most compaction occurs in the porous Slochteren sandstone. However, the overlying Ten Boer claystone and the underlying Carboniferous shales, directly bounding the reservoir, will slowly equilibrate to the pore pressure of the reservoir rock. This causes additional deformation on top of the compaction of the Slochteren sandstone itself.

The reservoir-bounding formations have a very low permeability and a high clay content, meaning that the expected microscale deformation mechanisms are likely different from those in the Slochteren sandstone. Understanding the role of all formations in the stratigraphy of the Groningen gas field is key to make accurate predictions for the evolution of the Groningen gas field. In this project, the impact of fluid extraction on the creep behaviour of the Ten Boer claystone and the Carboniferous shales is investigated.

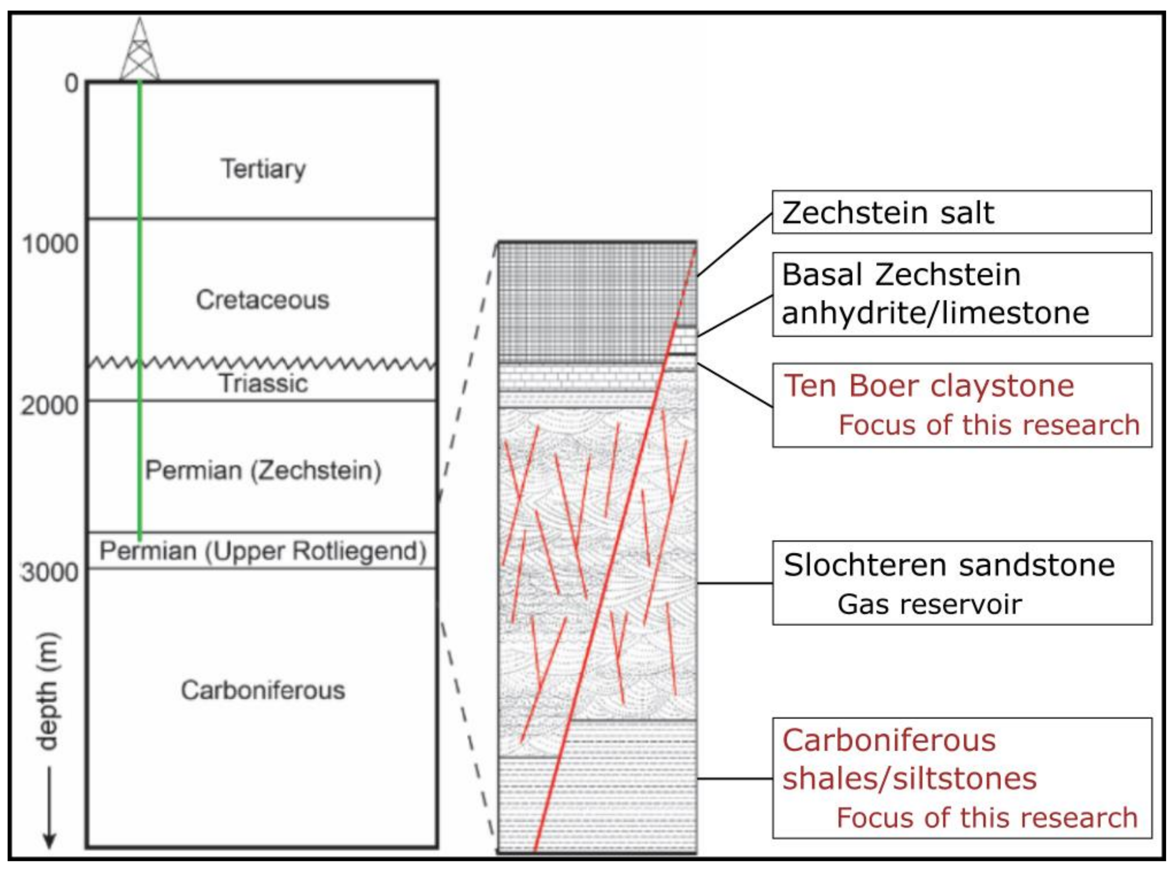


***Figure 1**: Schematic stratigraphy of the Groningen gas field (figure after Spiers et al. [2017]). The formations which are the focus of this research are indicated in red.*

Time-dependent deformation

One of the main goals of this project is to gain a better understanding of the time-dependent deformation in the clay-rich formations enveloping the Groningen reservoir. To achieve this, we perform triaxial stress-stepping experiments under in-situ conditions relevant for the Groningen gas field. With our experiments we can distinguish elastic from inelastic deformation, and time-dependent from time-independent deformation.

Figure 2 presents the results of an experiment on Opalinus claystone. The Opalinus claystone can be considered a good analogue for the Groningen shales. Results for the Groningen shales will later be compared to those of the Opalinus claystone.

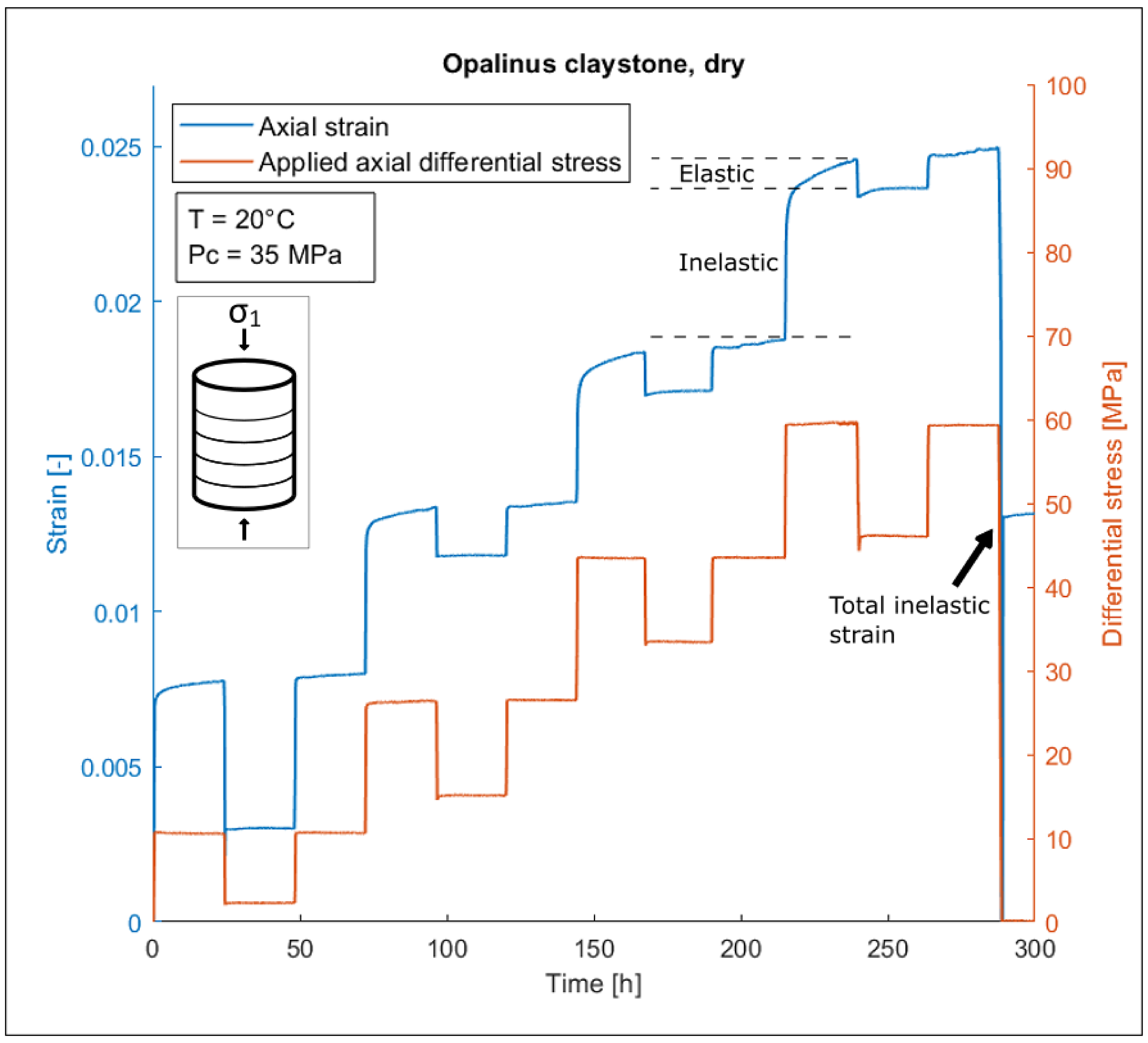


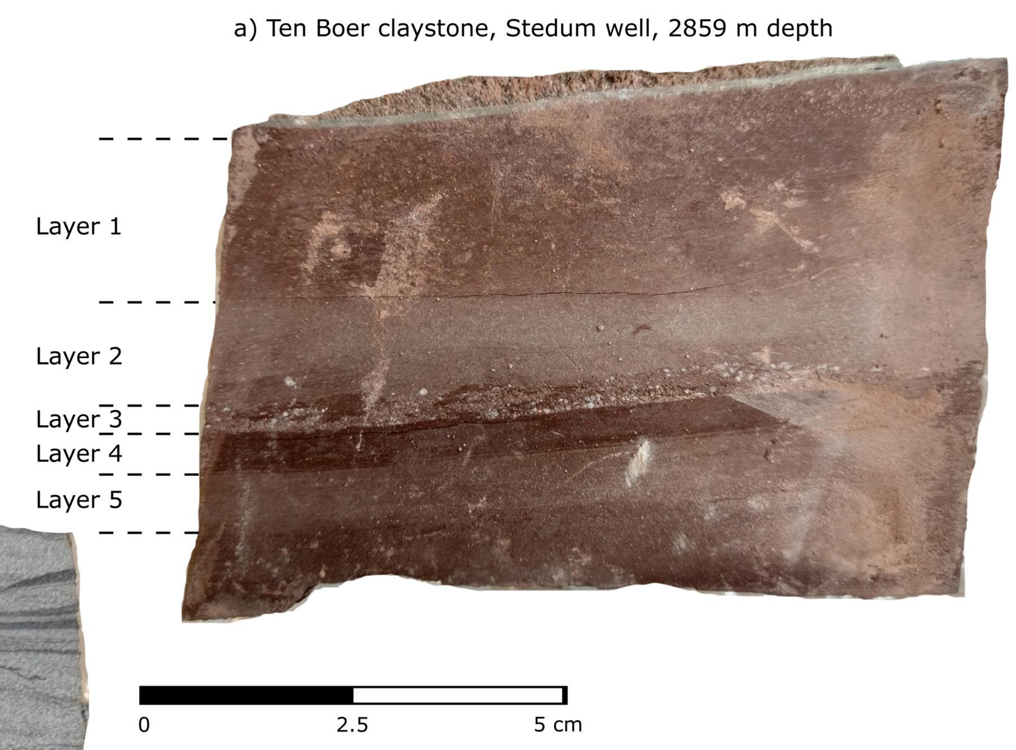
***Figure 2:** Results of a stress-stepping experiment in triaxial setting on Opalinus claystone. Axial stress σ_1 is perpendicular to bedding and is applied in a step-wise manner. The axial stress is applied in 15 minutes and held constant to allow creep for 24 hours. Experiment is performed at room temperature with a confining pressure of 35 MPa and without a pore fluid pressure. The sample was dried in an oven at 50°C for over two months. The total inelastic strain is 1.3%.*

Characterisation of Groningen claystones

To get a good understanding of the deformation in the Groningen claystones, we want to investigate which deformation mechanism is dominant. The way rocks deform correlates to some of their characteristics, such as the mineralogy and the permeability. We therefore aim to provide a detailed characterisation of the Groningen claystones, with a focus on the mineralogy and the small-scale heterogeneities therein.

We perform quantitative XRD analyses on a range of samples from the Ten Boer claystone and the Carboniferous shales from the Groningen field, covering all observable facies in these formations. For each sample (i.e., each facies) we measure the bulk mineralogy. Where possible, the individual layers in a sample are separated and analysed separately, to find small-scale differences in mineralogy (see figure 3).

In addition to these highly detailed, quantitative XRD analyses, we will investigate the microstructures to find how the different minerals are distributed throughout the formations. We will also determine the permeability of the samples in each formation. This set of analyses will provide a framework for our deformation experiments.



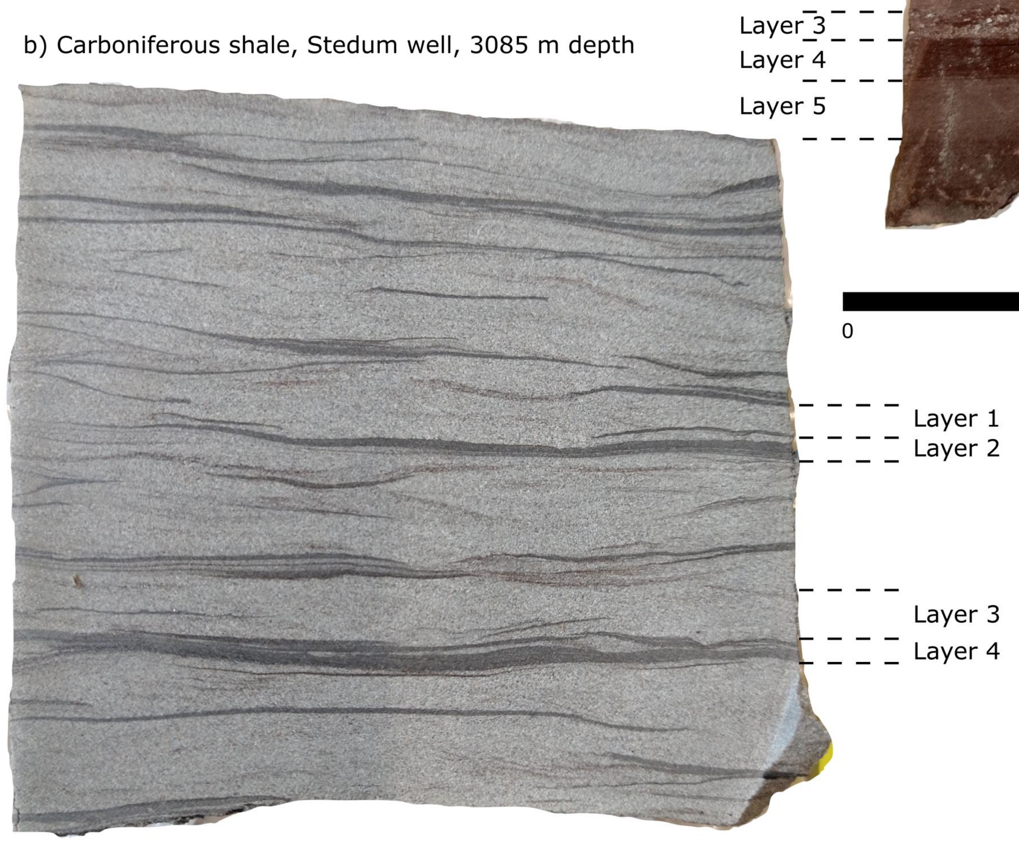


***Figure 3:** Two of the samples used for quantitative XRD analyses. The individual layers that are used for XRD analyses are indicated. a) Ten Boer claystone sample from the Stedum well, 2859 m depth. b) Carboniferous shale sample from the Stedum well, 3085 m depth.*

References

1. Spiers, C. J., S. J. T. Hangx, and A. R. Niemeijer (2017), New approaches in experimental research on rock and fault behaviour in the Groningen gas field, Netherlands Journal of Geosciences, 96(5).

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