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Modelling permeability and capillary pressure curves for Lower Cretaceous marly chalks

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Introduction

This study outlines a new approach for relating permeability and capillary pressure to specific surface and porosity in the clay rich chalk of the Lower Cretaceous in the Danish North Sea.

The low-permeability marly chalk reservoirs Sola and Tuxen (figure 1) found in the Danish North Sea are challenging to interpret in conventional ways. The varying clay content either situated as separating layers or mixed within the chalk affects the reservoir properties in terms of permeability and capillary forces. In this study we use existing porosity, Klinkenberg permeability and mercury injection capillary data to show how we can consistently model the permeability and capillary pressure from porosity and specific surface.

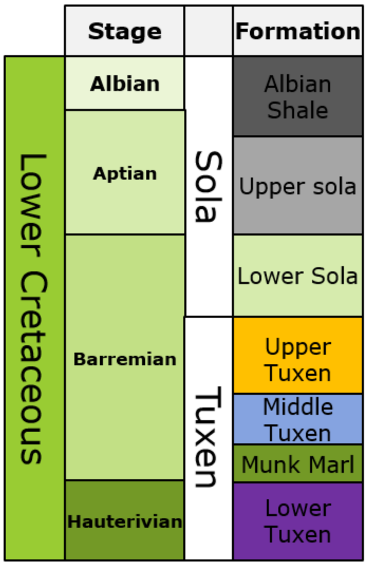

Figure 1: Lower Cretaceous stratigraphy.

Methodology

Permeability was modeled from specific surface and porosity using Kozeny`s equation (1) for laminar flow in a porous medium:

$$k = c\frac{\phi^3}{(S_g \rho_g (1-\phi))^2} \tag{1}$$

where k is the liquid (here approximated according to Klinkenberg) permeability, ϕ is porosity, ρ_g the grain density and S_g the specific surface of the grains with respect to grain mass, and c is Kozeny`s constant as estimated from porosity by the model of Mortensen et al. (1998). Capillary pressure was modeled from porosity and specific surface using the Laplace equation (2) by expressing the capillary radius as a function of porosity, specific surface, and grain density:

$$p_c = \frac{2\gamma\cos\theta}{r_c} \Rightarrow P_c = \frac{S_g \rho_g (1-\phi)}{\phi}\gamma\cos\theta \tag{2}$$

Where p_c is the capillary pressure, γ the interfacial tension, r_c the capillary radius, and θ the wetting angle between the liquid and the surface of the capillary.

Results

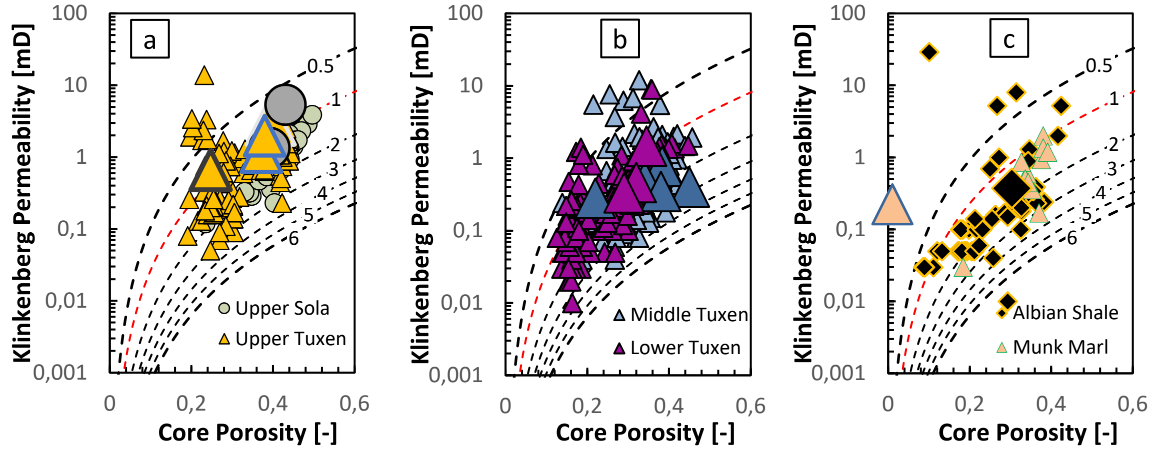

Figure 2: Modelled permeability curves from constant specific surface [m^2/g] and grain density of 2.71 [g/cm^3] as a function of porosity. For comparison Klinkenberg permeability and N_2-porosity data from (a) Upper sola and Upper Tuxen, (b): Middle Tuxen and Lower Tuxen, and (c): Albian Shale and Munk Marl.

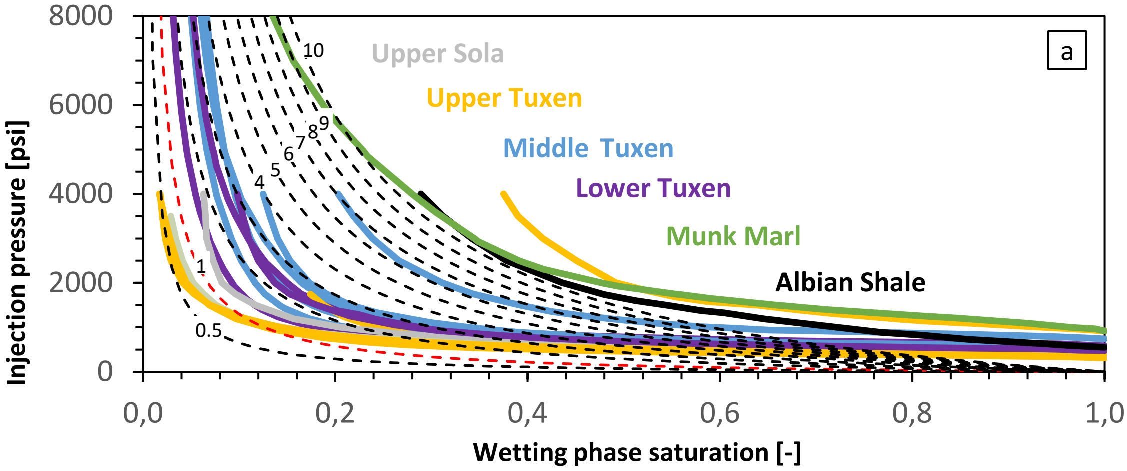

Figure 3: Modelled capillary pressure curves from constant specific surface [m^2/g] as a function of porosity. For comparison mercury injection capillary pressure curves from Upper Sola, Upper, Lower and Middle Tuxen, Albian shale and Munk Marl.

Conclusion

We show how permeability and capillary pressure of Lower Cretaceous marly chalk in the Danish North Sea can be modelled from porosity and specific surface. Data from Sola and Tuxen formations display a good consistency where the capillary pressure curves fall within the same specific surface region as the permeability. In contrast, no apparent consistency could be found for the Albian Shale and Munk Marl.

Acknowledgements

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