Quantitative Petrographic Characterization of Faulted Rotliegend Sandstones
Slochteren Reservoir, Groningen and Annerveen gas fields – The Netherlands
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Introduction and Research Objectives
Considerable research has focused on faults in the Groningen field either with the interest of predicting reservoir quality or due to production-induced seismicity. In situ characteristics (microstructures and fault related mineralization) play a key role in unravelling the internal processes and evolution of fault zones. Deformational features are quite rare in the Dutch Rotliegend cores (since faults are considered a drilling hazard) and thus many studies rely on outcrop analogues. However, core samples provide the only direct way of examining faults and fractures in the subsurface and in situ reservoir conditions.

1) Contribute to the existing knowledge of diagenesis along fault zones and the understand effect of inter-formational fluid flow on reservoir quality.

2) Exhibit microstructural characteristics of Rotliegend fault rocks.

![Figure 1](image1.png)
Figure 1: (A) E-W seismic cross section through the Annerveen-Veenland (ANV-1) well with major (texturally resolvable) faults drawn in red. (B) Top Rotliegend depth map with major fault trends demarcated by white dotted lines. The red dotted box indicates the section through which fig. A is taken. (C) Schematic diagram of a normal fault cutting the Carboniferous and Permian stratigraphy of the Groningen and Annerveen field. Note the expected inter-formational fluid exchange at zones of lithology juxtaposition. After Van den et al., 2018.

Core Samples

![Figure 2](image2.png)
Figure 2: Overview of samples used in the study and their corresponding depths.

Methodology

- 3D seismics
- Well log analysis
- Petrography
- Point counting

Authigenic Mineral Phases

- Results
- Deformation Features

![Figure 3](image3.png)
Figure 3: SEM-BSE images of (A) clay generations (red arrow) perpendicularly to a phyllosilicate grain (PA) and (C) hydroxylated fibrous dolomite (FD) overgrowth. (B) Siderite (S) enveloping dolomite (D) and kaolinite (K) appearing to be deformed due to contraction. Thin dispersed kaolinite (K2) also visible. (D) Optical (PP) micrograph of clay coats being sandwiched between sutured grains.

![Figure 4](image4.png)
Figure 4: SEM-BSE images of (A) Extensive siderite precipitation (bright in BSE image) along the clastic pore space. (B) Localised, thin calcarenitic band with intense grain crushing and quartz cementation. (C) Extensive anhydrite precipitation within a natural fracture. (D) BSE image exhibiting a clay smear consisting of fine rock debris. (E) Optical (PM) micrograph of parallel calcarenitic bands (red dotted lines) preserving porosity between the bands.

Key findings and Conclusion

1) In the Rotliegend, depositional facies control reservoir quality (Aeolian sands → highly porous and permeable). However, in the samples fault-controlled fluid flow enhanced diagenetic alteration and diminished reservoir properties (6-10% porosity).

2) Dolomite + siderite up to 48% and siderite alone up to 16%.

3) Porosity impairment by siderite (in addition to known dolomites) and permeability by kaolinite (up to 8%) should be considered during reservoir modelling.

4) Deformational features have occasionally operated as fluid pathways (e.g., localised anhydrite precipitation) but also as barriers under different circumstances (e.g., siderite alongside deformation bands but not within).

![Figure 5](image5.png)
Figure 5: Diagenetic evolution curve and burial history of the Rotliegend in the Netherlands (onshore). Depth and timing of burial are compiled from various basin evolution publications. Modified after Cheadle et al., 1987.

![Figure 6](image6.png)
Figure 6: Proposed paragenetic sequence.

![Figure 7](image7.png)
Figure 7: Point counting results. N=40.

References