DeepNL Stakeholder Meeting 2023

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.

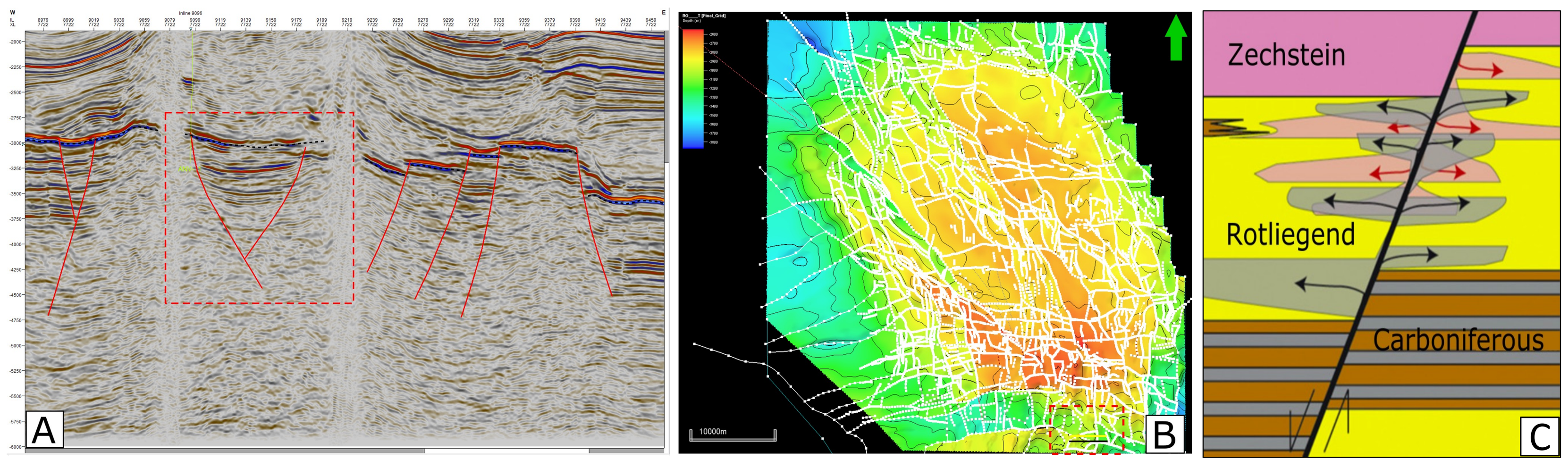


Figure 1: **(A)** E-W seismic cross section through the Annerveen-Veendam (ANV-1) well with major (seismically resolvable) faults drawn in red. **(B)** Top Rotliegend depth map with major fault trends demarcated by white dotted lines. The red dotted box indicates the section through which fig.A is taken. **(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 Vincent et al., 2018.

Core Samples

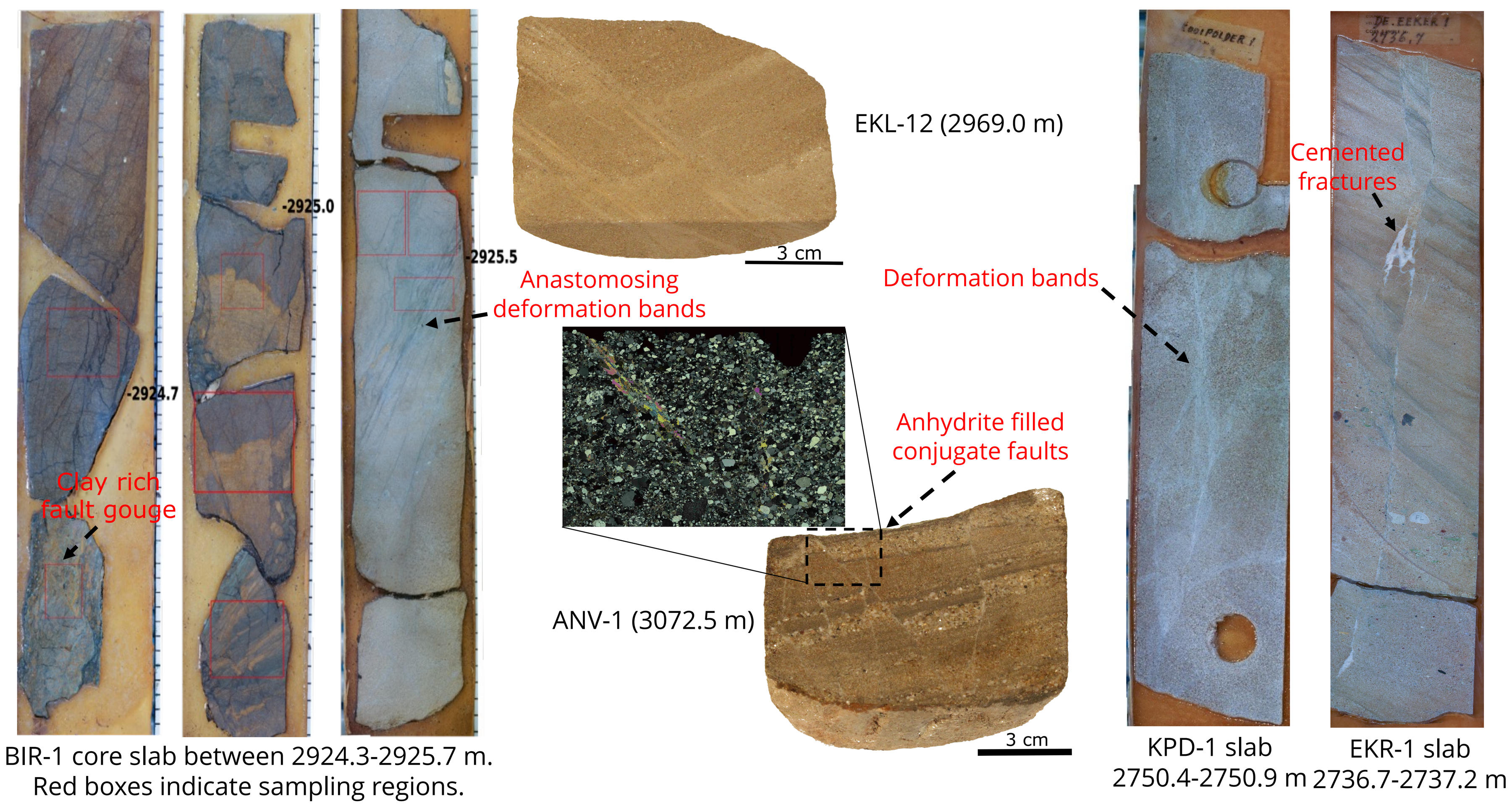
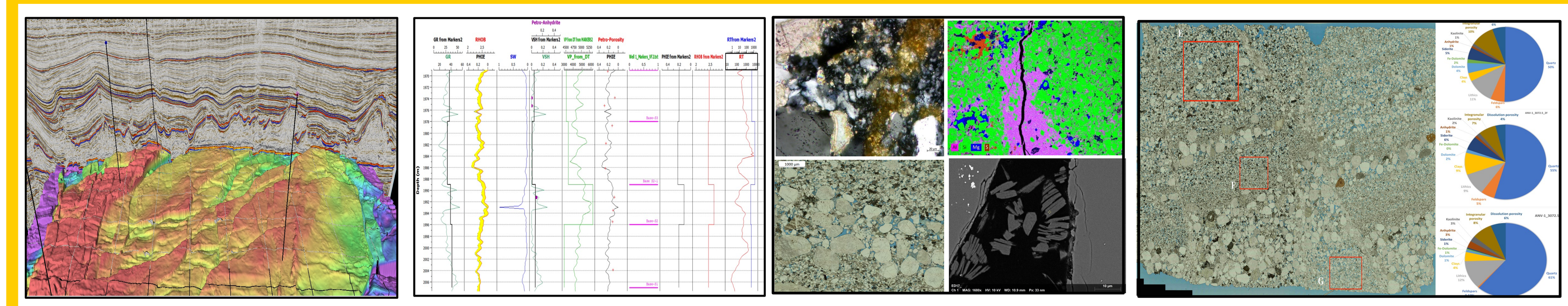


Figure 2: Overview of samples used in the study and their corresponding depths.

Methodology



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

Results

Authigenic Mineral Phases

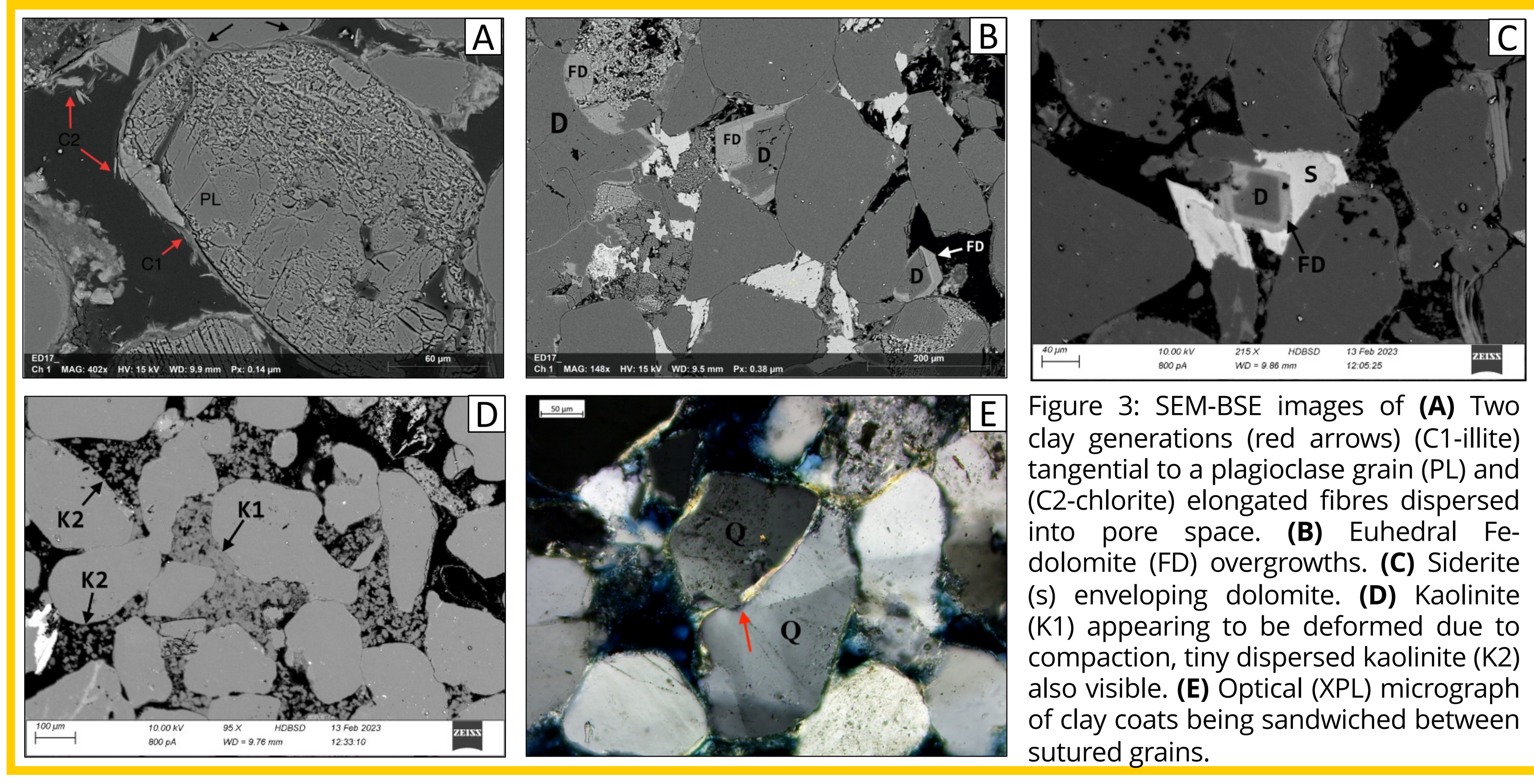


Figure 3: SEM-BSE images of **(A)** Two clay generations (red arrows) (C1-illite) tangential to a plagioclase grain (PL) and (C2-chlorite) elongated fibres dispersed into pore space. **(B)** Euhedral Fe-dolomite (FD) overgrowths. **(C)** Siderite (s) enveloping dolomite. **(D)** Kaolinite (K1) appearing to be deformed due to compaction, tiny dispersed kaolinite (K2) also visible. **(E)** Optical (XPL) micrograph of clay coats being sandwiched between sutured grains.

Deformation Features

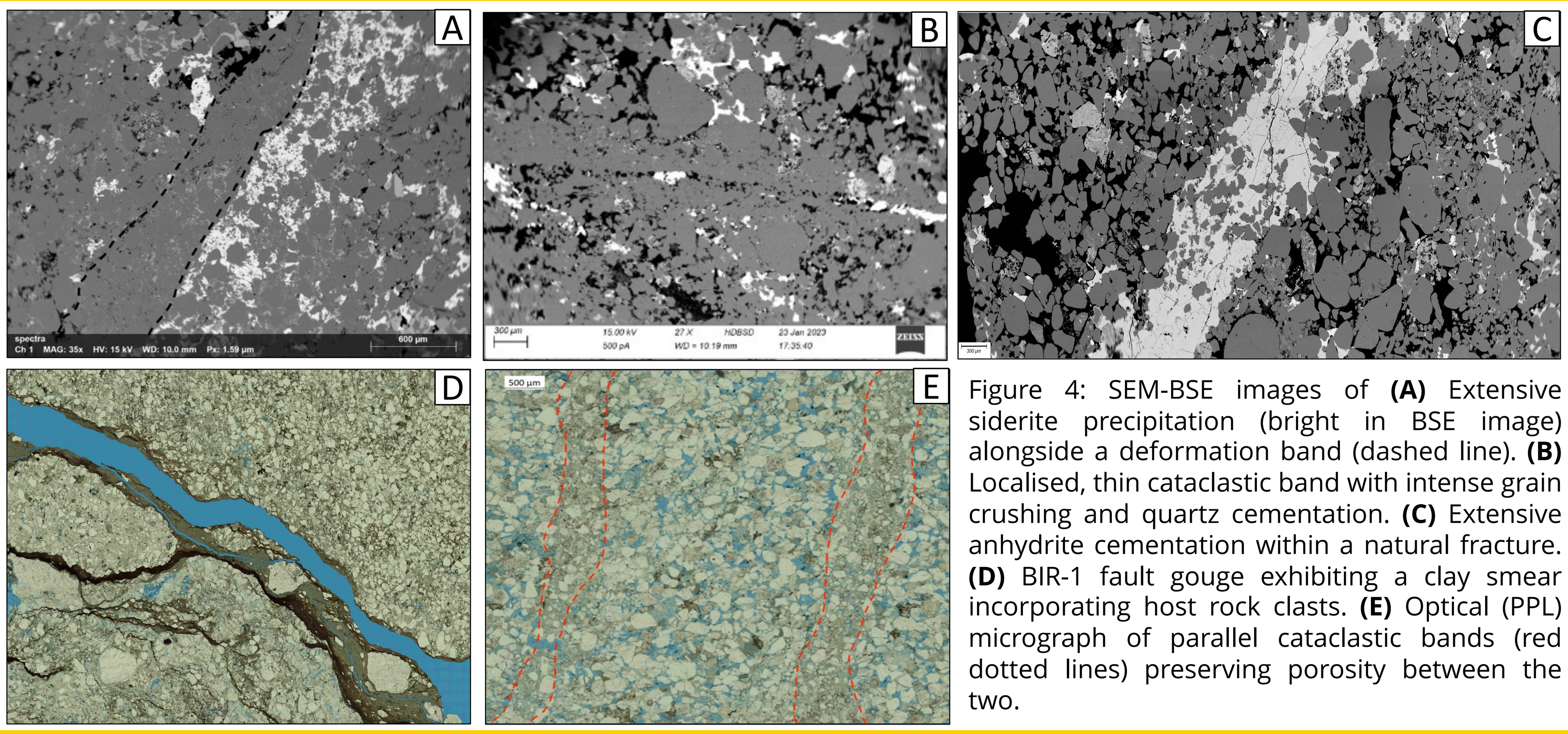


Figure 4: SEM-BSE images of **(A)** Extensive siderite precipitation (bright in BSE image) alongside a deformation band (dashed line). **(B)** Localised, thin cataclastic band with intense grain crushing and quartz cementation. **(C)** Extensive anhydrite cementation within a natural fracture. **(D)** BIR-1 fault gouge exhibiting a clay smear incorporating host rock clasts. **(E)** Optical (PPL) micrograph of parallel cataclastic bands (red dotted lines) preserving porosity between the two.

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).

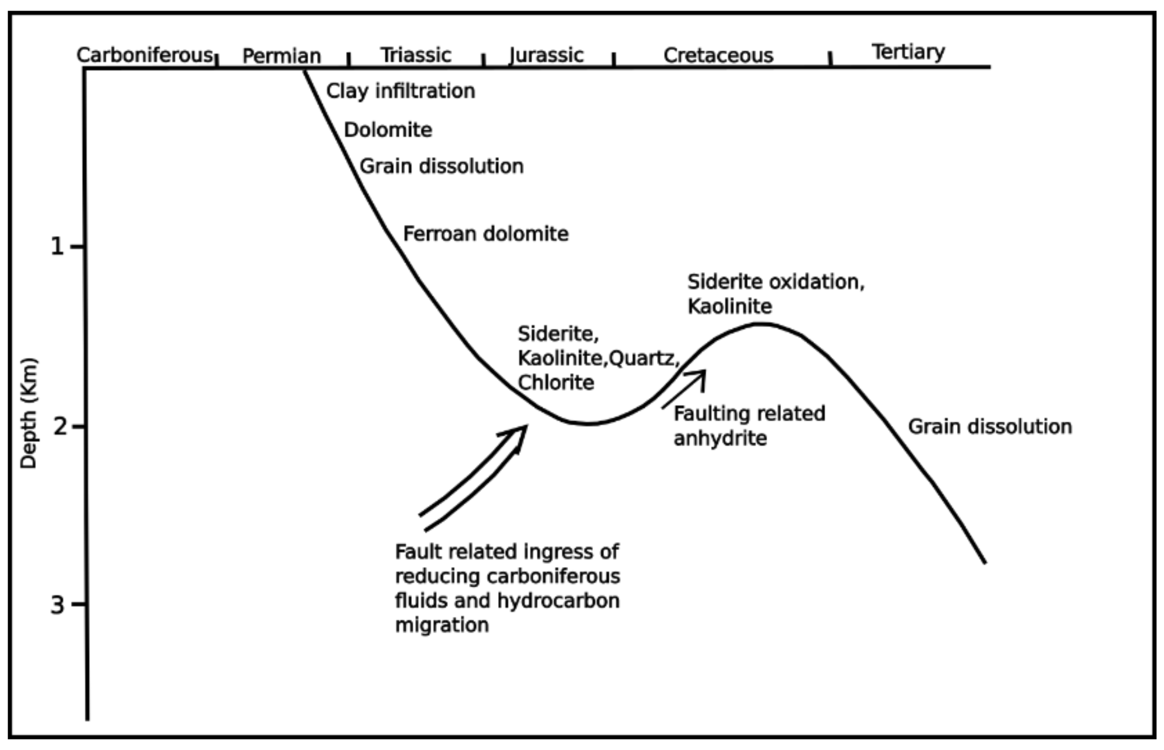


Figure 5: Diagenetic evolution curve and burial history of the Rotliegend in the Netherlands (onshore). Depth and timing of burial are compiled from various basin evolution publications. Modified after Clelland et al.,1987.

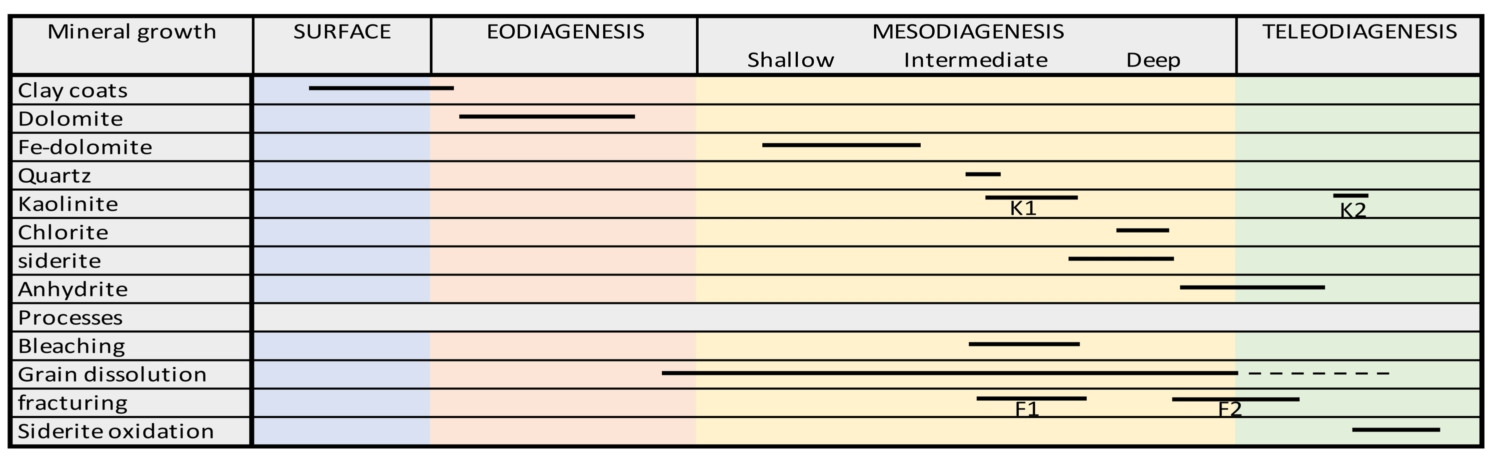


Figure 6: Proposed paragenetic sequence.

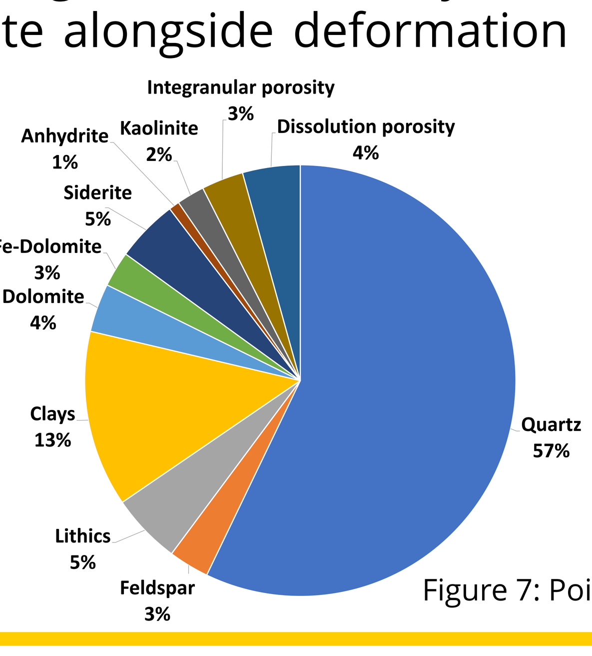


Figure 7: Point counting results. N=40.

References

1. Vincent, B., Waters, J., Witkowski, F., Daniau, G., Oxtoby, N., Crowley, S., & Ellam, R. (2018). Diagenesis of Rotliegend sandstone reservoirs (offshore Netherlands): The origin and impact of dolomite cements. Sedimentary Geology, 373, 272–291.
2. Clelland, W. D., Kantorowicz, J. D., & Nicholls, C. A. (1987). Pilot study into the diagenesis of the Northern Groningen wells STEDUM-1, UITHUIZERMEEDEN-1 and DELFZIJL-1, onshore Netherlands. (Restricted RKTR.87.282). NAM.