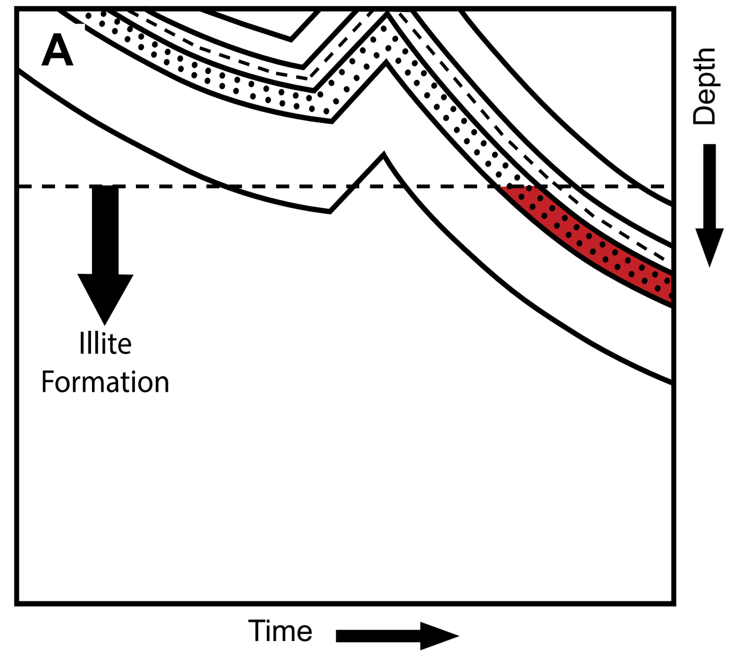
Conceptual Diagenetic Models for the Upper Rotliegend Sandstones

Synopsis

Porosity and permeability determine to a large extent the reservoir quality and the success of gas production. The growth of diagenetic minerals (cements) can lead to severe reservoir quality reduction locally. This study is aimed at the understanding of processes that influence cement diagenesis in relation to porosity and permeability loss in the Upper Rotliegend sandstones. Four main conceptual diagenetic models were established. The diagenetic models can be used to help predict locations of enhanced cementation of a particular cement or cement combination and the related porosity/permeability loss. The detailed study can be found in TNO report number R10166.

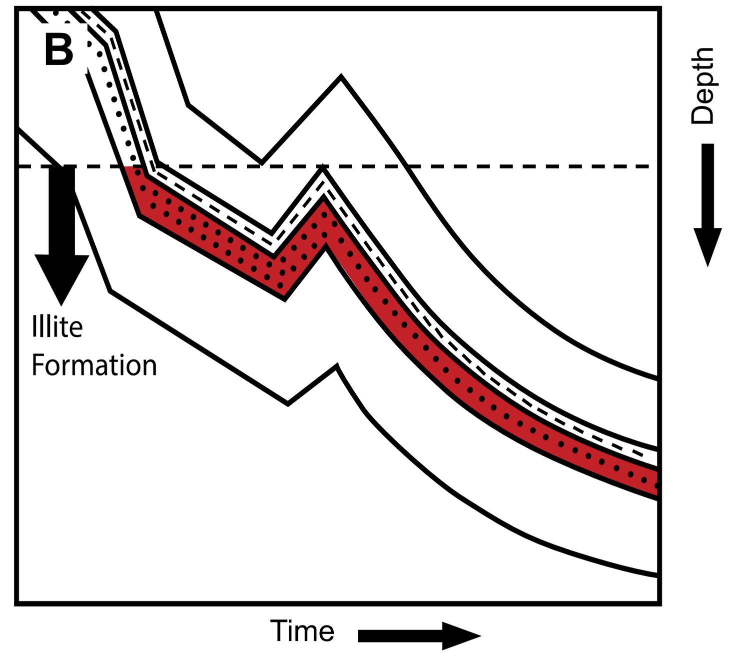
Workflow

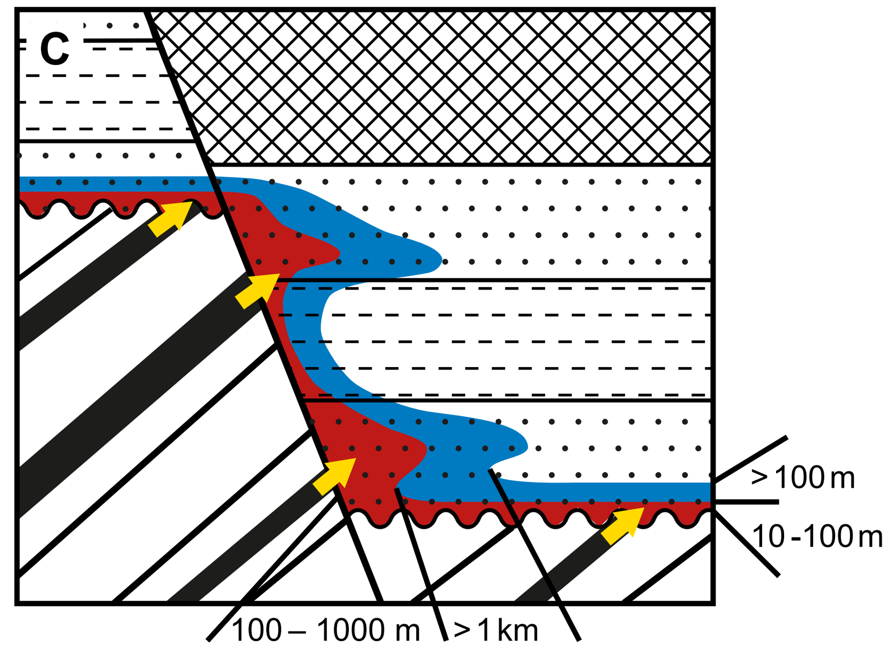
A detailed, quality controlled petrographic database builds the foundation for the study. The data was sourced from publicly available reports, literature and confidential reports and includes core analyses and environmental interpretation. Diagenesis and cementation was studied in detail and combined with 1D and 3D basin modelling and fault interpretation. Sources and causes of cementation were determined to achieve an understanding of cementational porosity and permeability reduction.



1. Prolonged deep burial

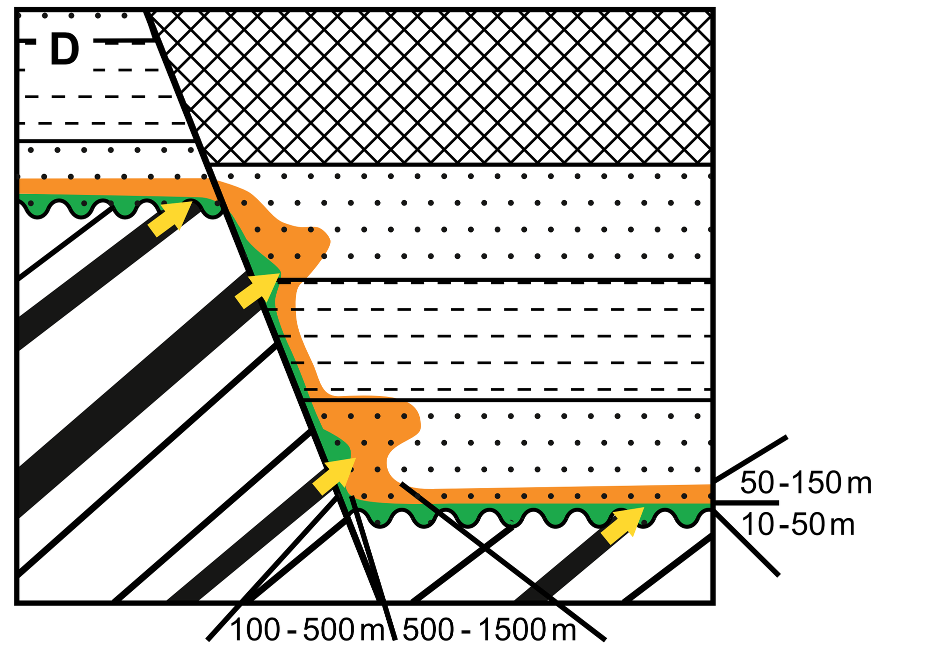
An important factor for high illite content is the duration of deep burial, which is found in deep basinal structural elements (Fig 1, Fig A, B). This is likely due to kinetically controlled illite formation during prolonged deep burial. Illite formation is preferred in fluvial environments, particularly in proximal alluvial unconfined and overbank deposits where high detrital clay contents could be converted to authigenic illite (Fig 2).

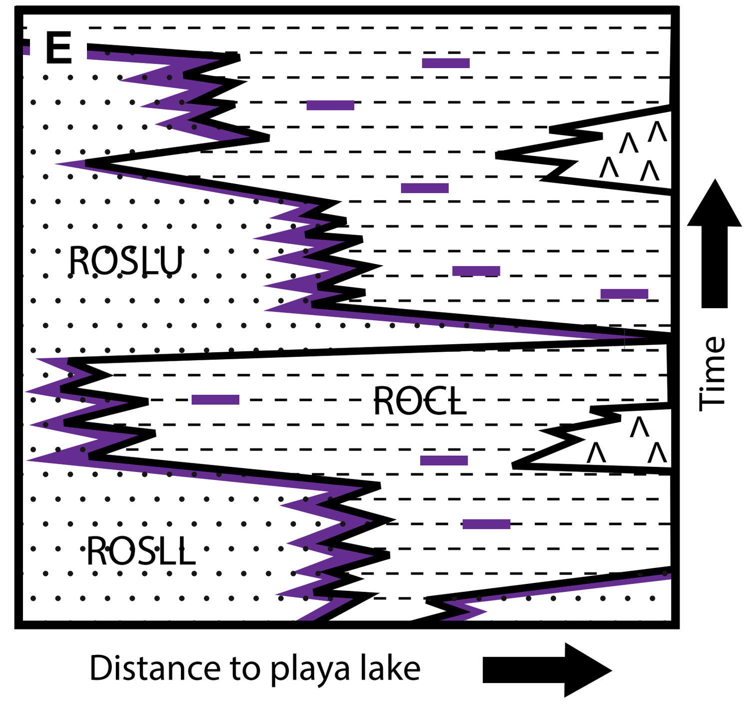




2. Influence of Carboniferous fluids

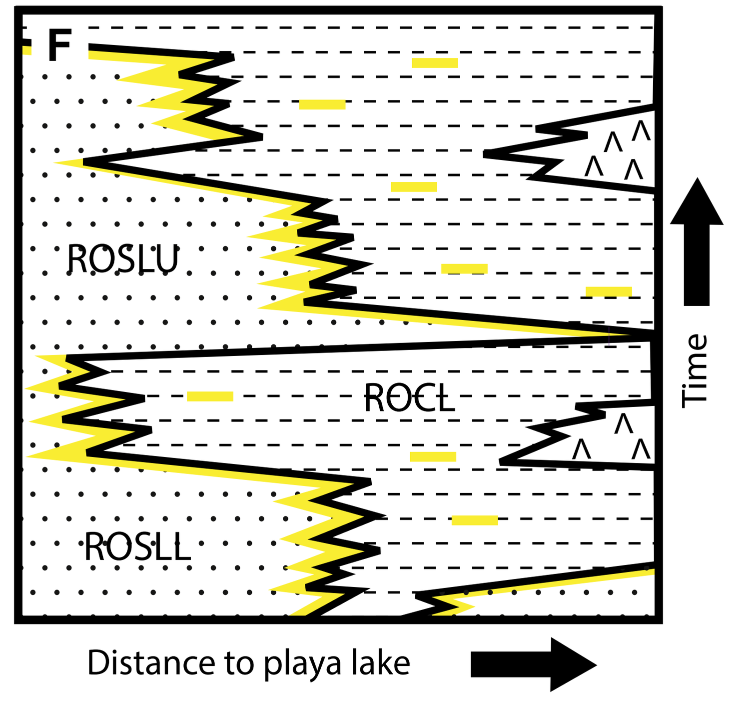
The acidic fluids from the coal-bearing Carboniferous strata are responsible for significant dissolution and precipitation of a variety of minerals, particularly in the presence of feldspar. The influx of the acidic Carboniferous fluids tends to cause a zonation in the authigenic mineralogy. A kaolinite zone (Fig C) is followed by an illite zone and an ankerite zone is followed by a dolomite zone (Fig D).

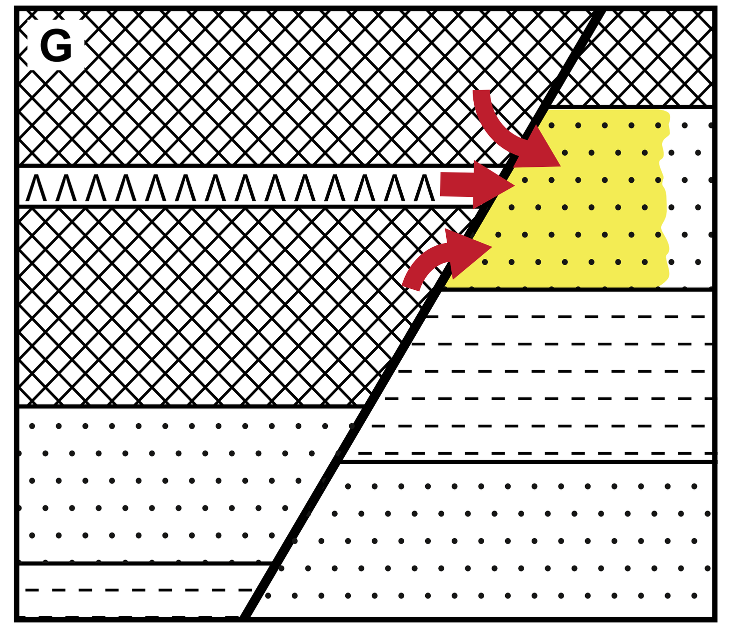




3. Evaporitic-environmental control

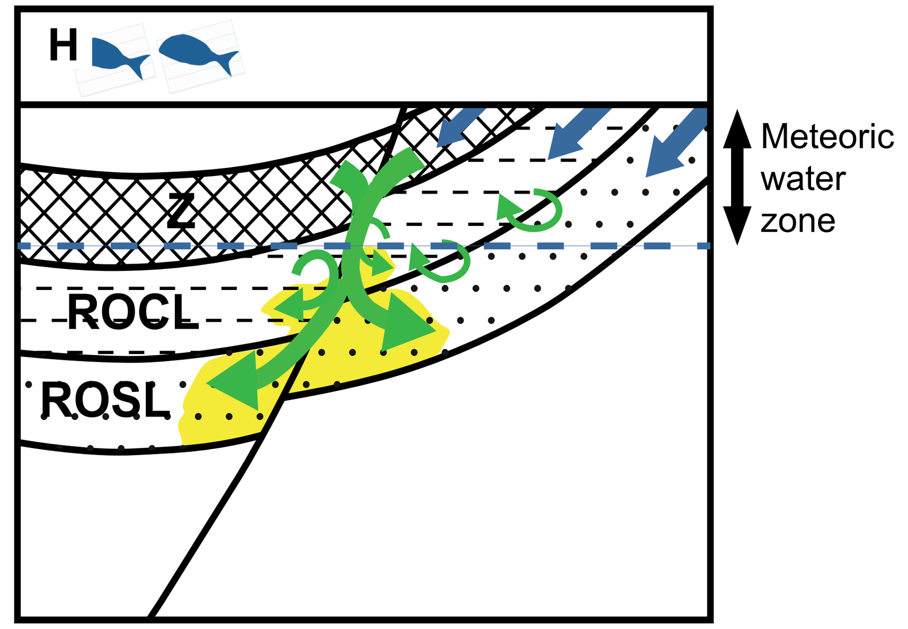
Evaporitic conditions towards the Silverpit and the Zechstein strata promoted the supersaturation and precipitation of sulphates and carbonates, initially deposited as gypcretes, calcretes and dolocretes (Fig 2, Fig E, F). The formation of these minerals was either synsedimentary or by fluid expulsion from the Silverpit playa lake towards the adjacent Slochteren sandstones during early burial. Upon further burial, P/T increase lead to conversion of gypsum to anhydrite and calcite to dolomite or ankerite.





4. Influence of Zechstein/Silverpit and meteoric fluids

The elevation of the Silverpit and Zechstein evaporites to the ground-water level (e.g. Late Jurassic inversion) leads to dissolution of sulphates via meteoric fluid interaction. Fluid transport to and precipitation of anhydrite in the Slochteren sandstones requires an existing fault/fracture network (Fig H). Tectonic juxtapositioning with Zechstein/Silverpit evaporites against the Rotliegend sandstone layers can also cause Zechstein brine flow into the Rotliegend sandstones and the precipitation of sulphate minerals (Fig. G).



Legend

Cements

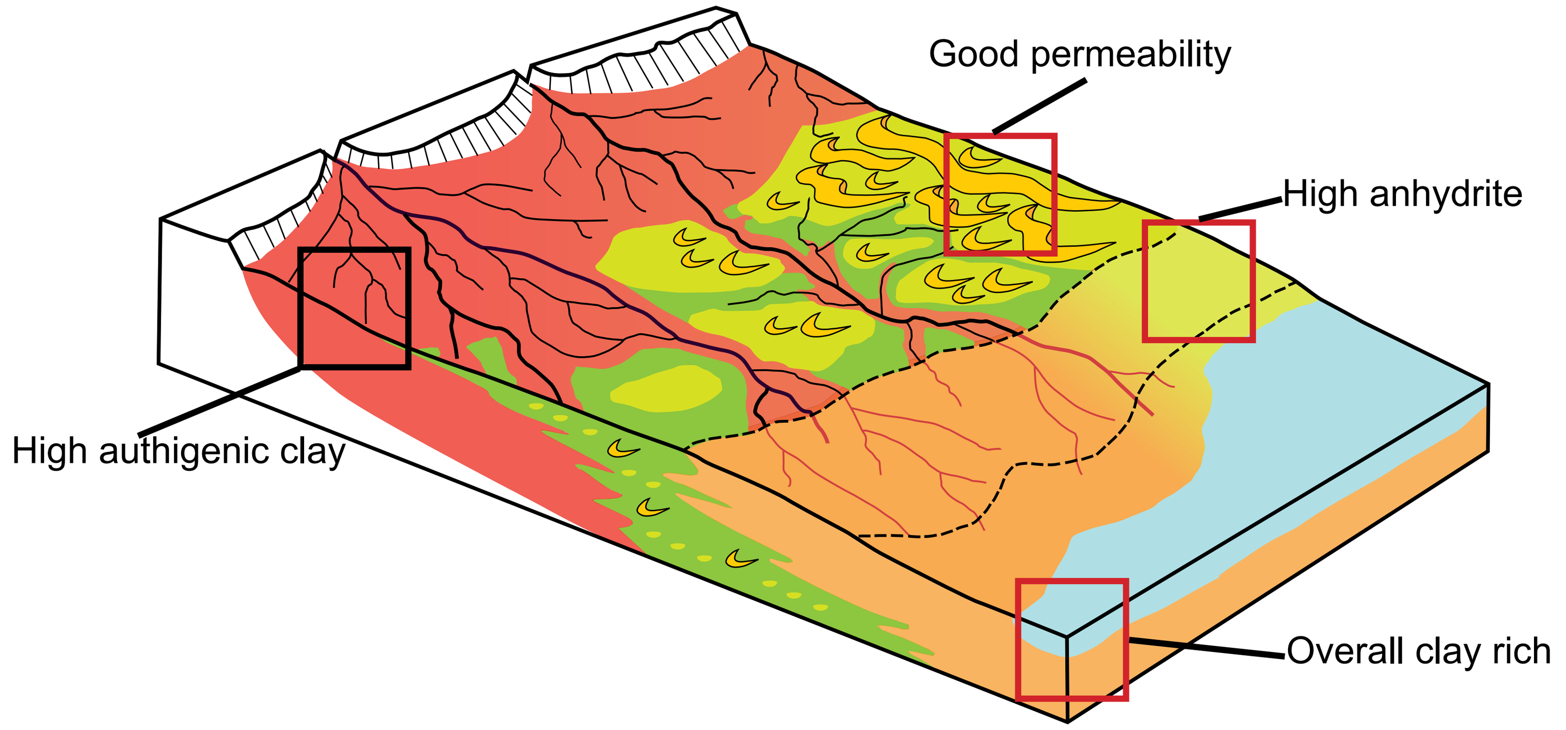
- Kaolinite
- Illite
- Carbonates
- Ankerite
- Dolomite
- Sulphates

Stratigraphy

- Zechstein Group
- Silverpit Formation
- Slochteren Formation
- Carboniferous (with coal layers)
- Anhydrite intercalations

Fluids

- Carboniferous fluids
- Zechstein Fluids
- Meteoric water
- Evaporitic dissolution



Legend

- fluvial (proximal alluvial - unconfined overbank)
- fluvial (proximal alluvial - channelized)
- aeolian dunes
- desert waterbodies
- aeolian interdunes
- aeolian sandsheets
- fluvial mudflat/alluvial sandflat
- sabkha/playa

Figure 2
A schematic model of the depositional environment (inspired by Lafont, 2000). Certain environments have higher contents of particular cements, such as clay, anhydrite and dolomite. The accumulations of the diagentic cements can often be linked to early cements, such as calcrete, dolocrete and gypcrete, and preferred detrital clay deposition in fluvial environments.

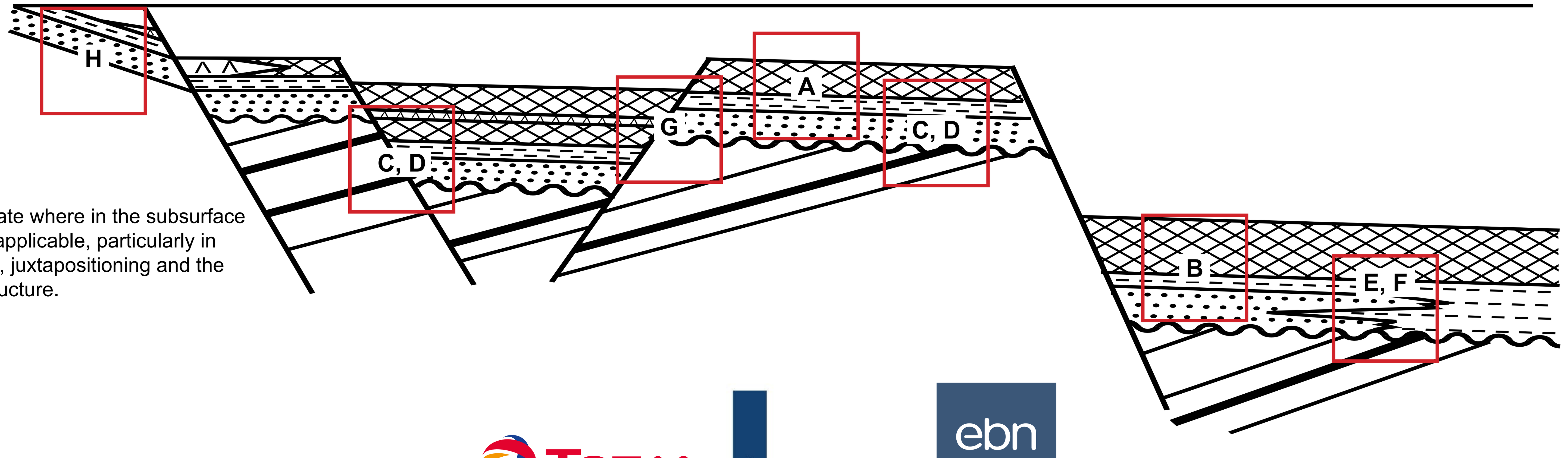


Figure 1
The boxes indicate where in the subsurface the models are applicable, particularly in relation to depth, juxtapositioning and the horst-graben structure.

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