LONG-TERM CO_2 INDUCED REACTIVITY

OBSERVATIONS ON A NATURAL CO_2 ANALOGUE AND GEOCHEMICAL MODEL PREDICTIONS

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ULTimate CO_2
SEVENTH FRAMEWORK PROGRAMME

CO_2 natural analogues provide a good opportunity to study the effect of CO_2 on reservoir and caprock. This will provide valuable insight in long-term geochemical processes concerning CO_2 storage. Moreover, natural analogues can help calibrate simulations of the long-term chemical effects of CO_2 storage.

We present an integrated approach of petrography (scanning electron microscopy), basin modelling (Petromod v11 of Schlumberger) and geochemical modelling (PHREEQC v3, THERMODDEM database). Our study is focused on the Werkendam natural analogue, a Dutch gas field containing > 70% CO_2.

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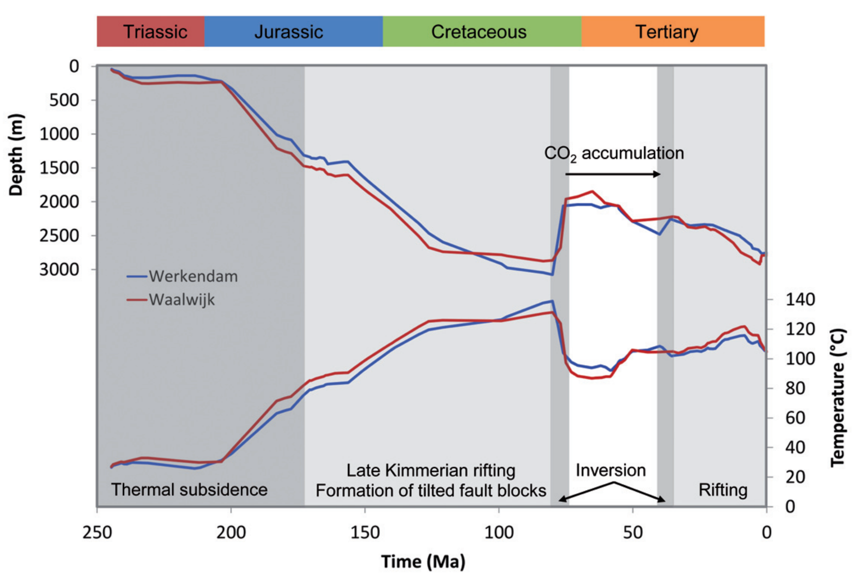
RESULTS

To distinguish reactions caused by CO_2 from 'ordinary' diagenetic reactions, the Werkendam (WED) samples are compared to samples of the Waalwijk (WWN) reservoir, a nearby CO_2 free gas field of the same formation. The WED samples have previously been compared to the CO_2 free gas field Barendrecht-Ziedewij. However, this field experienced a different temperature evolution than Werkendam (Koenen et al., 2013). Basin modelling showed that Waalwijk does have a comparable burial history as Werkendam (Figure 1).

Figure 1. Burial history (depth and temperature with time) for WED and WWN. CO_2 influx for WED.



The formation comprises mainly of sandstone and is of Triassic age. During the Late Cretaceous inversion took place, accompanied by major uplift, which is clearly reflected in the burial history of both fields (Figure 1). During this time, the CO_2, associated with Cretaceous volcanic activity (de Jager and Geluk, 2007), probably accumulated in WED.

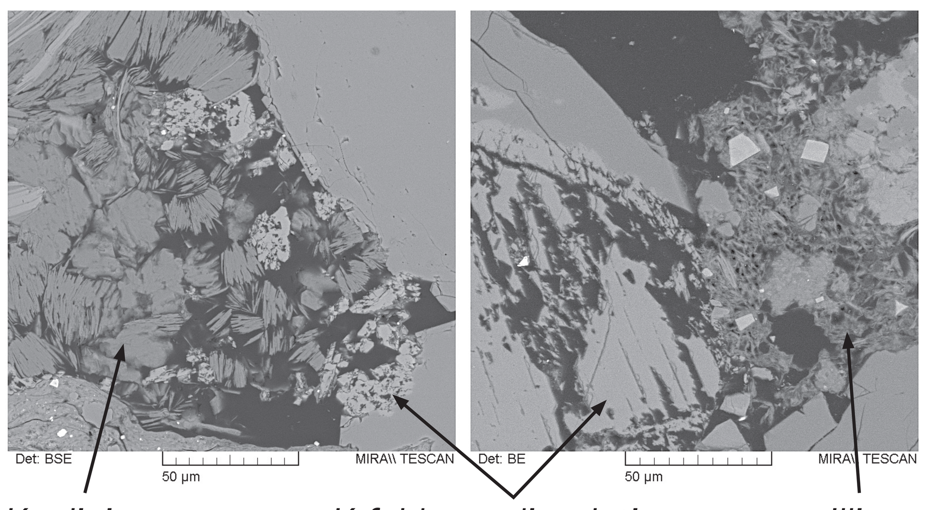
PETROGRAPHY

The comparison of the paragenetic sequences of WWN and WED samples shows distinct differences. Similar reactions are: dolomite formation, quartz overgrowth, feldspar dissolution and secondary clay formation. The differences are described below.

K-feldspar, illite and kaolinite

Both WWN and WED show major K-feldspar dissolution (Figure 2) and albitization. The WWN samples contain abundant kaolinite (Figure 2a), while the WED samples show a phase of major illitization (Figure 2b).

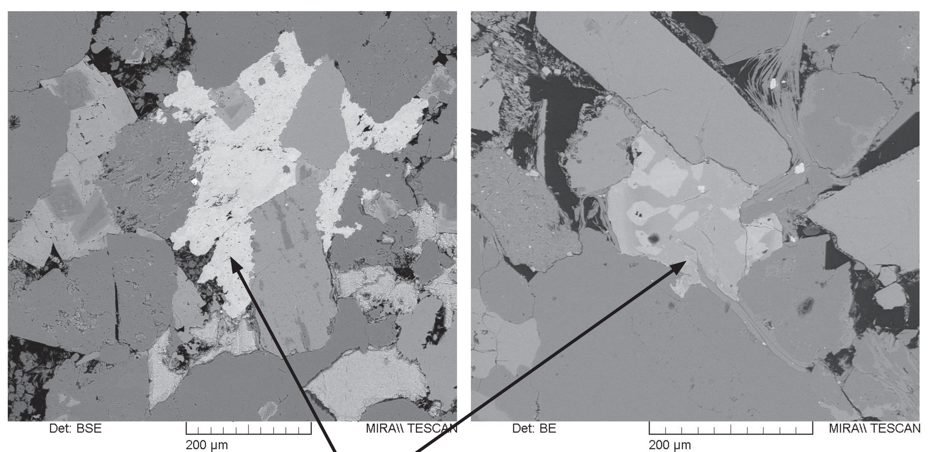
Figure 2a. Waalwijk *Figure 2b. Werkendam*



Siderite

Siderite as pore filling cement can be found in samples of WED and WWN (Figure 3). However, siderite is much more abundant in WED. In the WED samples, siderite is more variable in composition (spotted appearance in Figure 3b). EDX measurements indicated that siderite in WWN is more iron rich.

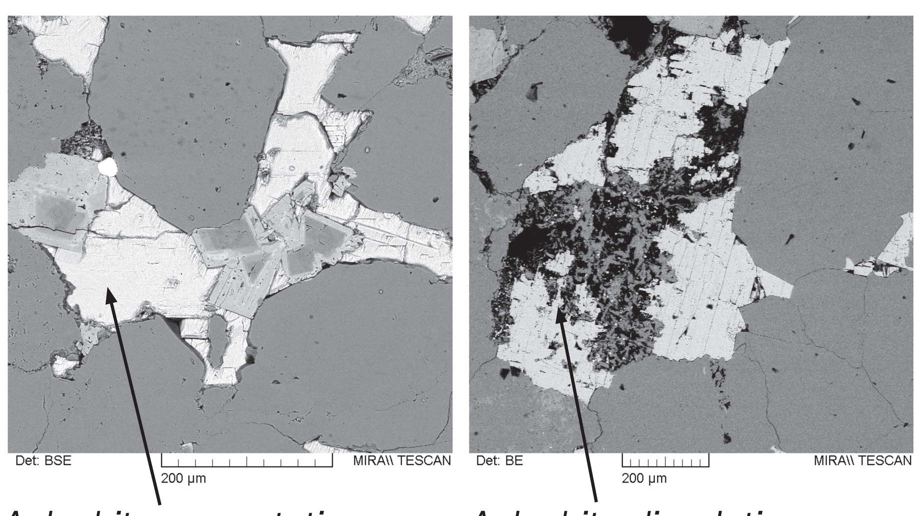
Figure 3a. Waalwijk *Figure 3b. Werkendam*



Anhydrite

Both fields show anhydrite cementation (Figure 4). The WED samples show a later phase of anhydrite re-dissolution (Figure 4b) which is not observed in the WWN samples.

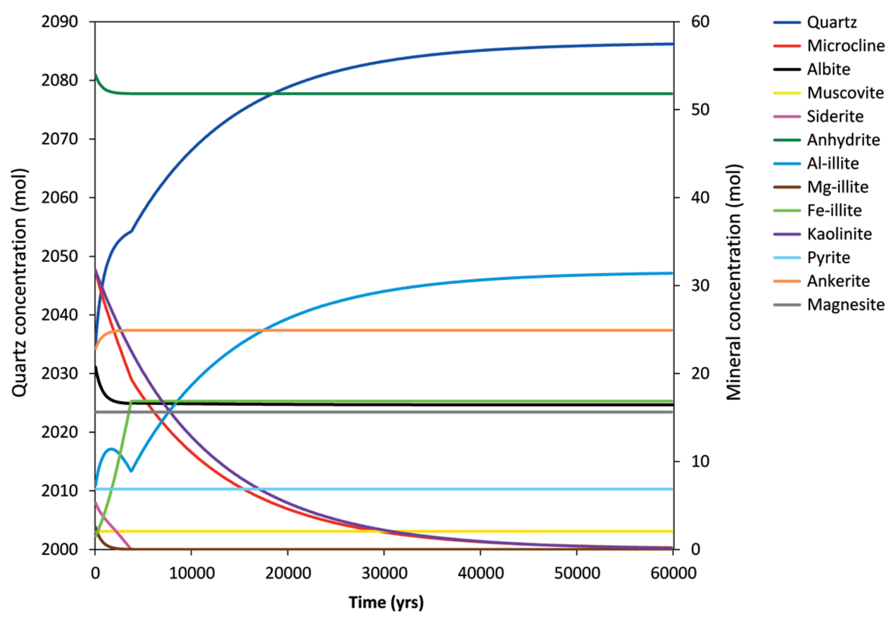
Figure 4a. Waalwijk *Figure 4b. Werkendam*



MODELLING

Geochemical modelling is performed to investigate the potential of modelling the observed reactions. The model results predict that dolomite and siderite quickly transform to ankerite and magnesite, and a small amount of anhydrite and albite dissolves (Figure 5). Calcite precipitation is minimal (dawsonite precipitation is not enabled). The reaction of kaolinite and microcline to Fe- and Al-illite is slow and equilibrium is reached after tens of thousands of years. A small amount of carbon mineralisation is predicted on the short-term, but it dissolves again after ~3000 years. At equilibrium, dissolution trapping is only 0.6% of the carbon and hence 99.4% is still present in the supercritical phase.
The predicted reactions are generally consistent with the petrographic observations. However, the reactions in WED are not as advanced.

Figure 5. Waalwijk mineralogy with time showing CO_2 induced reactions.



CONCLUSIONS

Microscopic analysis and comparison of samples from CO_2 and CH_4 fields indicate significant differences in secondary carbonate precipitation, mineral dissolution and clay occurrence.

Detailed mineralogical input and assessment of the burial history is required to calibrate geochemical models which will increase our knowledge on long-term geochemical processes considering CCUS. The next step is to further fine-tune and calibrate the model.

REFERENCES

Koenen M., Wasch L.J., van Zalinge M.E., Nelskamp S. (2013). Werkendam, the Dutch Natural Analogue for CO_2 Storage – Long-term Mineral Reactions. Energy Procedia (37): 3452–3460.

De Jager J. and Geluk M.C. (2007). Petroleum geology. In: Geology of the Netherlands. Royal Netherlands Academy of Arts and Sciences: 241-264.