

OBSERVED CO₂-INDUCED REACTIVITY IN WERKENDAM

The Dutch storage analogue

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INTRODUCTION

THE LONG-TERM INTEGRITY OF GEOLOGICAL CO₂ STORAGE BENEFITS FROM TRAPPING OF CO₂ IN CARBONATE MINERALS. MINERAL REACTIONS ARE VERY SLOW AND CHALLENGING TO SIMULATE IN LABORATORY EXPERIMENTS OR BY GEOCHEMICAL MODELLING. NATURAL CO₂ FIELDS PROVIDE A GREAT OPPORTUNITY TO STUDY THE GAS-WATER-ROCK INTERACTIONS ON LONG TIME SCALES IN COMPLEX GEOLOGICAL SYSTEMS.

THE WERKENDAM NATURAL GAS FIELD CONTAINS >70% CO₂, WHICH IS ASSOCIATED WITH JURASSIC VOLCANIC ACTIVITY. COMPARISON OF ROCK SAMPLES WITH CH₄-BEARING STRATIGRAPHIC EQUIVALENTS PROVIDES IMPROVED UNDERSTANDING OF CO₂ INDUCED REACTIVITY.



METHODOLOGY

Sandstone samples of the Werkendam CO₂ field (WED) and the CH₄-bearing stratigraphic equivalents Barendrecht-Ziedewij (BRTZ) and Waalwijk-Noord (WWN) were selected for a mineralogical and petrographic study. X-ray diffraction and Scanning Electron Microscopy were used to unravel the mineral reactions which occurred during the evolution of the reservoirs. Comparison of WED with BRTZ and WWN allows the distinction of reactions induced by the presence of CO₂ in WED.

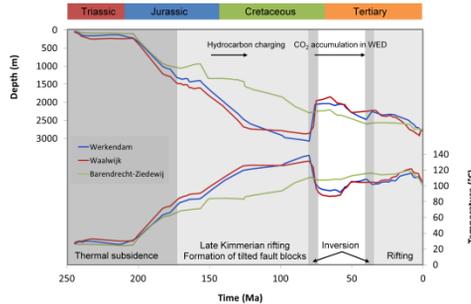
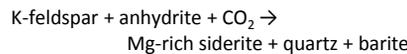


Fig 1: Burial history and corresponding temperature evolution for WED, WWN and BRTZ.

WED and WWN experienced very similar burial histories with fast subsidence, followed by major uplift during Late Cretaceous. BRTZ experienced slow but continuous burial (Fig. 1).

DIAGENETIC EVOLUTION

Fig. 2 summarizes the developed diagenetic evolutions. Similar early diagenetic reactions were observed. Some differences between the fields are caused by variations in primary mineralogy and formation water composition. Influx of CO₂ in WED probably occurred due to major uplift of the reservoir during Late Cretaceous (Fig 1). The following overall reaction was attributed to the presence of CO₂:



In BRTZ siderite is present as well, but it precipitated prior to anhydrite cementation (Fig. 3A) or is

Process/mineral	Eodiagenesis	Mesodiagenesis
Calcite	? Stabilising of grain framework?	? No sink for Ca from anhydrite dissolution
Dolomite/ankerite	Dolomite → Fe-rich dolomite/ankerite	After albite & kaolinite
Mg-rich siderite	Varying morphologies in BRTZ	No prove for timing in WWN
Fe-oxides	? Fe-oxides → Reduction of Fe ³⁺ and bleaching of sediment?	
Gypsum/Anhydrite	?	
Pyrite		
Barite		
APS		
Quartz		Only minor in WWN
K-feldspar	Authigenic overgrowth	
Albite	Albitisation	
Illite	Illitisation of Kfsp	
Kaolinite	Biotite → kaol + sid (+ Kfsp?) in BRTZ	Same event?
Fsp dissolution		After anhydrite
Anhy dissolution		After siderite
Carb dissolution		

CO₂ influx in WED ?

Fig. 2: Summary of the diagenetic evolution of WED (red), WWN (blue) and BRTZ (green). Processes observed in all three fields are in grey. Kfsp = K-feldspar, kaol = kaolinite, sid = siderite, anhy = anhydrite, carb = carbonate.

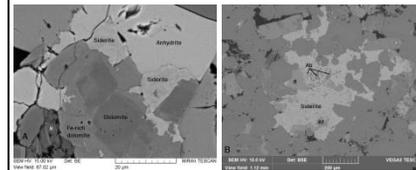


Fig 3: SEM BSE image of A) BRTZ showing kaolinite (k) and zoned dolomite enclosed by siderite, enclosed by anhydrite and B) WWN showing pore-filling siderite (rare) enclosing dolomite (d) and replacing K-feldspar (Kf) and albite (Ab).

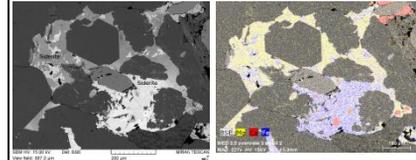


Fig 4: SEM BSE image and corresponding element map of a WED sample. Late stage siderite cement with varying Mg-concentration encloses anhydrite (A) remains.

associated with biotite alteration. In WWN siderite is rare and timing difficult (Fig. 3B). Biotite is not present as a primary mineral in WED, explaining the lack of early diagenetic siderite. The siderite in WED precipitated post anhydrite cementation (Fig. 4). We estimated that 20% to 58% of the CO₂ is sequestered in this carbonate mineral.

In the samples we did not find a sink for Ca,

Al and K from anhydrite and K-feldspar dissolution. It is unclear why Ca was not involved in carbonate formation. Also, the sources of Mg and Fe for siderite are currently unclear. We think that interaction with the clay-rich intervals in the sandstone formation, and migration of ions occurred.

CONCLUSIONS

By comparing rock samples from the Werkendam natural analogue with samples from two CO₂-free references, we were able to identify a set of mineral reactions caused by the presence of CO₂. A significant part of the CO₂ seems to be trapped in siderite. Sequestration in carbonates is highly beneficial for long-term containment of CO₂. The comparison did not allow the identification of required sources for Mg and Fe. Heterogeneities in the sandstone formation probably involved migration of ions into and out of the sandstone layers. Future research should investigate the effect of such heterogeneities on long-term geochemical interactions and mineral trapping.

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