

Impact of Dedolomitization on Reservoir Quality: Insights from Reactive Transport Simulations

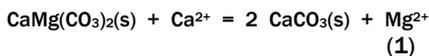
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INTRODUCTION.

It is commonly assumed that dolomites may be transformed to dedolomites by cold, low CO₂ pressure and Mg²⁺ concentration and rich Ca²⁺ waters (Eq. 1) through a slow process (Nader et al., 2008; Flügel, 2010).



Dedolomites normally have brown to redish color with syntaxial grain borders, calcite pseudomorphs and dolomite nuclei (Flügel, 2010). Dedolomitization may occur in different environments: a) early diagenesis, due to the instability of a Ca²⁺-rich dolomite; b) surficial, because of dolomite dissolution by meteoric waters and c) late diagenesis, caused by salinity variations in pore waters. The presence of calcium sulfate within the carbonates was suggested to promote calcite precipitation during dedolomitization because of gypsum/anhydrite dissolution (Raines and Dewers, 1997; Ayora et al. 1998).

Dedolomitization surfaces are used to mark subaerial exposure in the study of carbonate reservoirs. But dedolomitization processes may also be significant in reservoirs as they are responsible for modifying permeability and porosity. With the aim of establishing a systematic reference frame on this process, the present work quantifies the occurrence of dedolomitization under different conditions (temperature, rock and fluid composition) and provides results in terms of porosity changes of the replaced carbonate rock.

MATERIALS AND METHODS.

Water compositions from different environments were selected from literature data, prioritizing those with the

higher contrasting concentrations in Ca²⁺ and Mg²⁺ (Fig. 1). These waters were equilibrated with the carbonate rocks by means of the software PHREEQC (Parkhurst y Appello, 1999). The potential reactivity of these fluids was calculated at the reported temperature, and the influence of anhydrite dissolution to trigger or facilitate dedolomitization was tested.

Transient 2D numerical simulations were performed using kinetic data with the code RETRASO (Saaltink et al., 2004). A simple rectangular system of 200m x 5m was considered, where the dedolimitizing solution inflow from the left hand-side boundary. The initial carbonate considered had a porosity of 15% and a composition of 100% dolomite (Slider, 1976). The influence of anhydrite and other sulfates were evaluated.

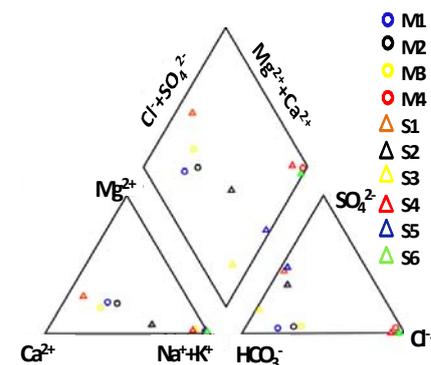


fig 1. Piper diagram showing the composition of fluids used for reactive transport simulations.

RESULTS AND DISCUSSION.

Equilibrium models in a closed system.

The geochemical calculations in close systems assuming water and rock equilibrium indicated that all meteoric waters had a dedolomitization capacity, as opposed to groundwaters and seawater. Besides, the dedolomitization

potential of meteoric waters was higher than that of the dolomitizing groundwaters. As expected, seawater is only able of dolomitizing, since this water is saturated with respect to dolomite at room temperature.

The most reactive fluids (for dedolomitization) happened to have low temperatures (25 to 50°) from a range of 4 to 150°C. These results concur with Nader et al. (2008) observations of dedolomitization being a surficial process.

Although all the waters considered had high pHs (from 6.2 to 9.4), their alkalinity did not seem to be directly related to the dedolomitization capacity of the fluid. Likewise, waters with similar calcium concentration had different dedolomitization potential, although the waters with the largest calcium concentrations showed the largest dedolomitization capacity.

Sulfate concentration of the incoming solution appeared to have an inverse correlation with dedolomitization potential, in agreement with Flügel (2010) conclusions.

Reactive transport simulations with kinetic rate laws.

Most simulations were performed with flow rates of 10 m/year, a value many authors have used (e.g. Withaker et al. 2004). Even though all the considered waters caused dedolomitization, not all of them induced an increase in porosity. Dedolomitization of the section was completed (100% dedolomitization or calcite) before 1 Ma of simulation time in systems at 25°C. In contrast, waters at higher temperatures reacted more slowly with the dolostone, reaching a maximum of 30% calcite in part of the dolostone after 1 Ma of simulation time (Fig. 2). This must be due to the faster

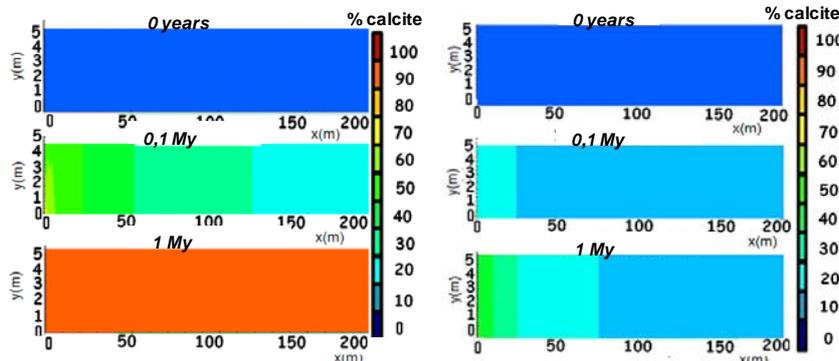


fig 2. Results of reactive transport models for dedolomitization: amount of calcite precipitated at different simulation times for groundwaters. a) Water from Chapelle (2005) at 25°C; b) water from Quin et al. (2005) at 50°C.

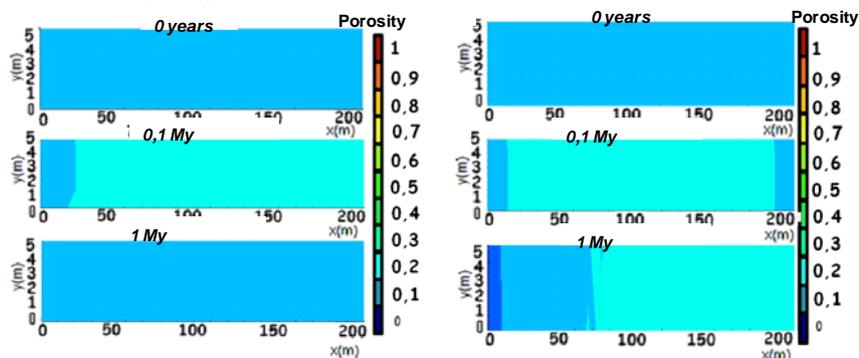


fig 3. Results of reactive transport models for dedolomitization: porosity evolution for groundwaters in a dolostone with anhydrite. a) water from Chapelle (2005) at 25°C; b) water from Quin et al. (2005) at 50°C.

carbonate dissolution kinetics in colder systems (Morse and Mackenzie, 1980).

Models of slow infiltration rates (fluid fluxes of 0.1m/year) resulted in a dedolomitization of 20% after 1 Ma of simulation time. Instead, models with fluid fluxes of 10m/year dedolomitized 100% of the rock in the same amount of time. Nevertheless, much larger fluxes (80m/year) diminished the dedolomitization capacity of the fluid. Several scenarios with anhydrite in different locations within the carbonate were tested. The presence of this mineral did induce a faster dedolomitization of the rock. Nevertheless, the only case that also caused an increase in porosity was the one where both anhydrite and calcite were initially in the dolostone. The maximum porosity increase was of 10% after 0.1 Ma of simulation time (Fig. 3). After this time porosity decreased again as calcite precipitation proceeded and finally occluded most of the rock porosity. The effect of calcic minerals is explained by the competing precipitation/dissolution kinetics between them and calcite. Anhydrite has

a faster kinetics, which resulted in the volume of precipitated calcite being smaller than the volume of dissolved dolomite. Simulations with warmer waters (50°C) produced a slower dedolomitizing front (Figs. 2 and 3). Therefore, the time gap where rock porosity is increased is longer for warmer fluids. This is the time period where a carbonate rock may become a reservoir. Most simulated scenarios turned out to occlude porosity with the precipitation of calcite. Therefore, such situations lead to barriers to flow, meaning these carbonates could be good reservoir seals.

CONCLUSIONS.

Geochemical simulations, both in closed systems under water-rock equilibrium conditions and solute transport with kinetic data, indicate that not only cold meteoric water can trigger dedolomitization. Warm fluids with composition of different groundwaters are also capable of dedolimitizing carbonates.

The numerical results indicate that the

following parameters enhance dedolomitization:

- The presence of calcic minerals with faster dissolution kinetics than calcite, such as anhydrite.
- Fluxes on the order of 10m/year. Too slow or too fast fluid fluxes do not allow the fluid reacting optimally with the rock.
- Reaction temperatures between 25 and 50°C.

Most of the dedolimitization scenarios simulated derived in a porosity loss of the carbonate rock. Only a dolostone with a minimal initial percentage of anhydrite resulted in a porosity gain of 10% after 100,000 years of simulation time using kinetics laws.

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