Origin and Timing of Stratabound Dolomitization in the Cretaceous Carbonate Ramp of Benicassim

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fig 1. Panoramic view of the field study area near Benicassim (NE Spain). Lighter layers are limestone and the darkest layers are sub-stratiform dolomite. The lateral field of view is ~ 4 km.

INTRODUCTION.

Hydrothermal dolomitization is one of the most important processes that may enhance or degrade carbonate porosity and permeability. Burial, high-temperature or hydrothermal dolomite forms due to the interaction of one or more solutions, mainly seawater-derived or deep brines, with limestone.

The Early Cretaceous Benicassim ramp (Maestrat Basin, E Spain) is an excellent outcrop analog for partially dolomitized petroleum reservoirs. In this area seismic-scale sub-stratiform dolomitized bodies extend for several kilometers, away from large-scale faults, in Aptian limestones (Fig. 1). In the present work the Benicassim ramp is used as a case study to characterize dolomite events and to evaluate controls on dolomitization via reactive transport simulations.

THE BENICASSIM DOLOMITES.

Benicassim is located in the eastern part of the Maestrat Basin, which is a Mesozoic extensional basin bounded by normal faults (Salas et al., 2001). During Aptian times extensional faults accommodated thick sequences of shallow marine limestone, which nowadays appear partially dolomitized along preferential layers (Fig. 1).

The geometric, geochemical, and petrographic characteristics of dolomites, limestone host rocks, and vein fillings are described by Martín-Martín et al. (2010) and Gomez-Rivas et al. (2010). These studies indicate that dolomite distribution conforms to a sub-stratiform pattern, where dolomite layers extend over several kilometres away from principal faults. Mississippi Valley-Type (MVT) ore deposits of Paleocene age (~62.6±0.7 Ma) have been documented in the area (Grandia, 2002); they are found spatially associated with the dolomitized bodies close to fault zones. Large-scale extensional faults most likely served as conduits for the circulation of reactive fluids, causing dolomitization as well as MVT deposition.

Petrographic studies of carbonates in the Benicassim area reveal that porosity was considerably reduced by early calcite cementation before the dolomitization-replacement stage. The grain-dominated carbonate facies appeared preferentially replaced by dolomite, while the mud-rich facies were rarely dolomitized. The dolomite paragenesis consists of two phases of replacive dolomite and a late phase of saddle dolomite. This is also found associated to MVT mineral deposits.

No evidence for low-temperature, shallow or early diagenetic dolomitization has been found in the Benicassim area. On the contrary, geochemical data (fluid inclusion microthermometry, C, O, and Sr isotopes) indicate that the main dolomitization event was produced by a high temperature (>80ºC) seawater-derived brine that had previously interacted with K-rich rocks, probably in the underlying Permian-Triassic strata and the Paleozoic basement. This information agrees with data of Nadal (2001) and Grandia (2002).

The dolomitized layers at Benicassim were buried to depths between 200 and 1100 m during the dolomitization stage, which must have occurred after deposition of Early Albian sediments (~112 Ma) but before precipitation of MVT deposits during Early Paleocene (~62.5 Ma) times.

REACTIVE TRANPORT SIMULATIONS FOR DOLOMITIZATION.

All simulations were performed with the reactive transport code RETRASO (Saaltink et al. 2004), using published kinetic rate laws. The mesh used in all cases had 861 nodes and 1600 triangular elements.

Two different scale models were designed for simulating various aspects of the Benicassim dolomites. On the one hand, outcrop-scale models (100 m X 20 m) served to compare reactivities of diverse fluids at distinct temperatures and contrasting flow rates and permeabilities. On the other hand, kilometric-scale models (1000 m X 300 m) served to calculate the dolomitization time. A darcian flux of 6 m/a was used in most simulations.

palabras clave: Dolomitización, Hidrotermal, Transporte Reactivo.	*key words:* Dolomitization, Hydrothermal, Reactive Transport

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The dolomitization capacity of four fluids (seawater, 2 brines selected from published data and a 5-times concentrated seawater) at different temperatures (from 25 to 150ºC) was tested with outcrop-scale simulations. Although all fluids were capable of dolomitization, the most reactive one turned out to be the 5-times concentrated seawater brine. The optimum temperature for dolomitization was 100ºC.

Models with two layers of different fluid flow and contrasting permeability simulated the Benicassim scenario, where dolomitization occurs mainly in layers with thicknesses of tens of meters with sharp contacts (Fig. 1). The results of a 5-times concentrated seawater at 100ºC indicated that a difference of two orders of magnitude in lateral flow rate is required in order to preferentially dolomitize certain layers (Fig. 2). As one mole of dolomite is assumed to replace two moles of calcite, the difference in molar volumes implies that a 13% increase in porosity is produced with the dolomitization reaction

At a kilometric scale, the Benicassim dolomitization is observed in two main sets of layers; the thicknesses of these sets are 200 m and 300 m, respectively. Large scale models were used to calculate the time it must have taken to dolomitize such carbonates. Evolved seawater at 100ºC with different lateral continuous flow rates (from 0.001 to 1 m/a) were used in these simulations. The results indicate that flow rates on the order of m/a would be required to originate a kilometer-scale dolomitization in a few million years time (Fig. 3).

CONCLUSIONS.

The stratabound dolomitization in the Early Cretaceous carbonates of Benicassim was caused by a seawater-derived brine at a temperature of more than 80ºC, according to microthermometric data of inclusion fluids. Dolomitization occurred between Late Aptian and Early Paleocene times.

Reactive transport simulations point out that the dolomitization process is optimized at temperature around 100ºC. Moreover, our results indicate that a permeability contrast of at least two-orders of magnitude is necessary in order to preferentially dolomitize certain layers of carbonates and to keep sharp dolomitization boundaries. With the conditions of our simulations and continuous fluid fluxes of meters per year, the kilometric-scale dolomitization of Benicassim would have formed in a few million years.

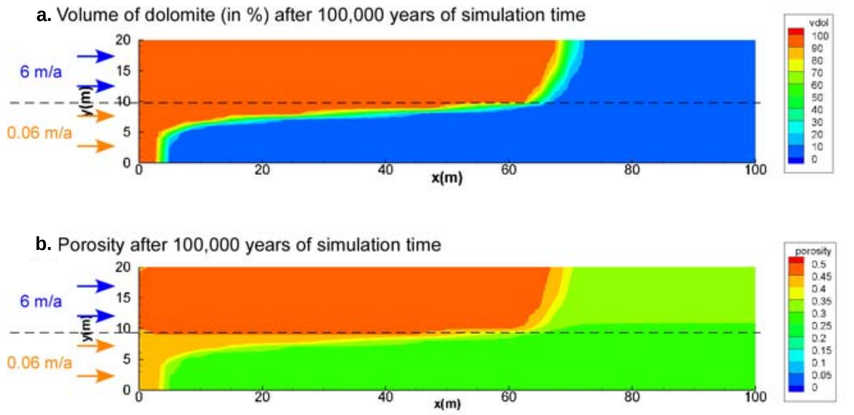

fig 2. Results of outcrop-scale simulations with 6 and 0.06 m/a flow rates through high and low permeability layers after 100,000 years of simulation time. a. Dolomite distribution (volume %). b. porosity distribution. Tthe simulations were performed using 5-times concentrated seawater at 100ºC.

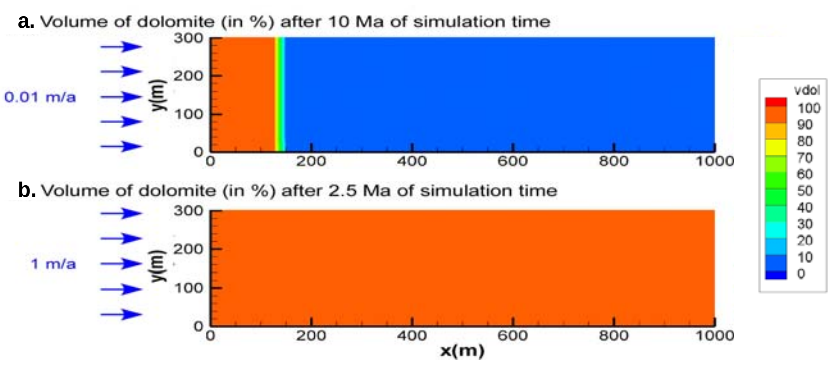

fig 3. Dolomite distribution (volume %) of a kilometer-scale simulation through a high permeability layer. a. Results after 10 Ma years of simulation time and a flow rate of 0.01 m/a. b. Results after 2.5 Ma years of simulation time and a flow rate of 1 m/a. The simulations were performed using 5-times concentrated seawater at 100ºC.

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