

Diagenetic Study Applied to Maruim Member (Riachuelo Formation), in the Onshore Part of the Sergipe Sub-Basin, Brazil*

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Search and Discovery Article #120086 (2012)*

Posted December 31, 2012

*Adapted from extended abstract prepared in conjunction with poster presentation at AAPG Hedberg Conference, Fundamental Controls on Flow in Carbonates, July 8-13, 2012, Saint-Cyr Sur Mer, Provence, France, AAPG©2012

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Abstract

The main objective of the study was the reconstruction of the diagenetic evolution of the carbonates within the upper portion of the Albian, Maruim Member in the Sergipe Sub-basin (northeastern, Brazil). Special emphasis was placed on the dolomitization, because the dolomites exhibit the best reservoir rock properties. Correlation of the outcrops and the integration of the petrographic, cathodoluminescence, SEM and geochemical (elemental and isotopic study) analyses allowed the reconstruction of the diagenetic history of the studied interval. Carbonates of the Maruim Member are affected by diagenetic processes of the eogenetic, mesogenetic and telogenetic phases ([Figure 1](#)).

Introduction

The upper portion of the Maruim Member (Riachuelo Formation), consist of shallowing upward depositional cycles. From outcrops study and petrographic analysis, the depositional environment was defined as a carbonate platform with a lagoon area and a high-energy region composed of carbonate banks. The lagoon area consists of packstone/grainstone with pellets, intraclasts and bioclasts. The high-energy banks consist of oolitic grainstone and grainstone with ooids and oncoids. The carbonate bank facies are characterized by the low content and variety of bioclasts. Dolomitization was one of the main diagenetic events of the eogenetic phase ([Figure 1](#)) and dolomite replaces all or part of the limestone of the Maruim Member. The dolomitization is concentrated at the top of

the depositional cycles and gradually decreases toward the base. The relationship between porous space and dolomitization was studied based on observations of the crystalline dolomite fabric from petrographic observations. A common feature of the dolomites is a planar fabric (euhedral to subhedral crystals) which is favored by low temperature conditions.

Discussion

Isotopic analysis of the dolomites indicate that the dolomitization process occurred during the reflux of brines in a slightly hypersaline environment (penesaline environment). The areas in closest proximity to the brine, which is the source of the dolomitizing fluids, exhibit lower porosity development. In these areas processes of super dolomitization (e.g. at Carapeba Quarry) have occurred. The carbon and oxygen isotopic signature associated with these processes is very positive ($\delta^{13}\text{C}$ between 2.37‰ and 4.83‰, $\delta^{18}\text{O}$ between 0.61‰ and 3.92‰), indicating that the late diagenetic processes have not altered the original isotopic signal greatly. The dolomites generated in the areas farthest from the brine source of the dolomitizing fluids (Massapé, Inorcal I, Inorcal II, Inhumas and San Antonio quarries), exhibit a greater development of porosity and have an isotopic composition of carbon and oxygen of more negative values ($\delta^{13}\text{C}$ between -5.66‰ and 2.61‰, $\delta^{18}\text{O}$ between -4.25‰ and 0.38‰). Moreover, in these quarries the isotopic signature of the dolomites is also further altered by processes of dedolomitization.

Diagenetic cements were also identified in the studied interval, nine stages of cementation were identified ([Figure 1](#)). These cements were precipitated during the eogenetic, mesogenetic and telogenetic phases and were responsible for the obliteration of the primary and secondary porosity of the Maruim Member limestones. Cements precipitated during the final stage of the eogenesis phase and the initial mesogenetic phase (shallow burial), are characterized by elemental concentrations and isotopic values associated with meteoric fluids. Cements precipitated during late mesogenetic phase (intermediate burial), have chemical characteristics associated with formation water modified in the burial environment. Further, the late diagenetic cements, calcitized the dolomite and partially closed its secondary porosity.

The interval studied comprises the upper portion of the Maruim Member and was deposited during the Albian. The rocks consist of shallow upward depositional cycles. The petrographic analysis allowed the definition of a carbonate platform with a lagoon area and a high-energy region composed of carbonate banks. The lagoon area consists of packstone/grainstone with pellets, intraclasts and bioclasts. These high-energy banks consist of grainstone with ooids and grainstone with oolites and oncoids. The carbonate banks facies are characterized by the low content and variety of bioclasts. The correlation of the outcrops and the integration of the petrographic, cathodoluminescence, SEM and geochemical (elemental and isotopic study) analyses allowed the reconstruction of the

diagenetic history of the studied interval. Carbonates of the Maruim Member are affected by diagenetic processes of the eogenetic, mesogenetic and telogenetic phases (Figure 1).

The main objective of the study was the reconstruction of the diagenetic evolution of the carbonates within the upper portion of the Albian, Marium Member in the Sergipe Sub-basin. Special emphasis was placed on the in dolomitization process, because the dolomites exhibit the best reservoir rock properties.

The dolomitization was one of the main diagenetic products of the eogenetic phase (Figure 1) and it replaces all or part of the limestone of the Maruim Member. The dolomitization is concentrated at the top of the depositional cycles and it gradually decreases towards their base. The relationships between porosity and dolomitization were studied with basis on the comparisons of the crystalline dolomite fabric through the petrographic observations. A common feature observed in the dolomites of the studied interval is the planar fabric (euhedral to subhedral crystals). The planar fabric is favored by low temperature conditions.

The isotopic results of the dolomites indicate that the dolomitization process occurred from the reflux of brines in a slightly hypersaline environment (penesaline environment). The areas closest to the contact with the brine, source of the dolomitizing fluids, exhibit lower porosity development because there would have occurred processes of super dolomitization (Carapeba Quarry). In these areas, the carbon and oxygen isotopic signature is very positive ($\delta^{13}\text{C}$ between 2.37‰ and 4.83‰, $\delta^{18}\text{O}$ between 0.61‰ and 3.92‰), indicating that the late diagenetic processes would not have altered much the original isotopic signal. The dolomites generated in the areas farthest from the brine source of the dolomitizing fluids (Massapé, Inorcal I, Inorcal II, Inhumas and San Antonio quarries), exhibit a greater development of porosity and have an isotopic composition of carbon and oxygen of more negative values ($\delta^{13}\text{C}$ between -5.66‰ and 2.61‰, $\delta^{18}\text{O}$ between -4.25‰ and 0.38‰). Moreover, in these quarries the isotopic signature of the dolomites is also altered by processes of dedolomitization.

Although we do not observe evaporitic units above the studied carbonates, it is believe that the restricted conditions caused by a proto-ocean, still in development, and an arid climate, created penesalines and/or hypersaline conditions. The penesaline diagenetic environment (between normal marine and hypersaline) may also explain the absence of evaporite minerals. Under these conditions the pore water is enriched with evaporates, but not to the level at which the gypsum and anhydrite may precipitate. The relatively high salinity conditions are evidenced by the limited quantity and variety of fauna, and would have been sufficient to generate dolomitization from reflux of brines saturated respect to dolomite.

Dissolution comprises one of the last diagenetic events identified in the studied interval (telogenesis phase, [Figure 1](#)). The dissolution affects all of the quarries studied and created secondary (vuggy porosity). This type of the pore space was observed in the cements of the mesogenetic phase and in the oolites. However, the percentage of the secondary porosity is generally very low, ranging between 5% and 8% in most microfacies. Other factors affecting the porosity primary and secondary are the mechanical and chemical compaction.

The dolomitic facies was also affected by processes of dissolution during the telogenetic phase. The dissolution generated vuggy porosity in the nucleus of the dolomite crystals. All dolomites in the studied area have nucleus characterized by high contents of Ca. The high concentration of calcium in the nucleus of dolomites can be caused by growth defects or the presence of inclusions. The selective dissolution in the dolomites with high concentrations of calcium in its nucleus can generate hollow dolomites. This feature is more common in the dolomites observed in Inorcal II, Inhumas and San Antonio quarries (dolomitized high-energy facies). The dolomites are also affected by processes associated to physical and chemical compaction. Finally, the silicification comprises the last diagenetic event identified in the study area (telogenesis phase, [Figure 1](#)). This process is associated to the input of siliciclastic material from the continent.

Conclusions

The key conclusions are:

- 1) The main microfacies observed in the studied interval were oolitic grainstone and oncolitic/oolitic grainstone deposited in high energy banks. The microfacies of low energy were deposited in lagoon area and are composed of packstone/grainstone with pellets, intraclast and bioclasts.
- 2) The top of the cycles of the carbonate banks of high energy with total dolomitization, exhibit the best reservoir properties.
- 3) The dolomites underwent two stages of porosity development; the first stage corresponds to intercrystalline porosity, developed during the dolomitization process (eogenesis phase). The second stage includes secondary porosity developed during the dissolution in the telogenesis phase (vuggy porosity creating hollow dolomites).
- 4) Overall the porosity of the carbonate sequence of the Maruim Member is greatly reduced by cementation and mechanical and chemical compaction.

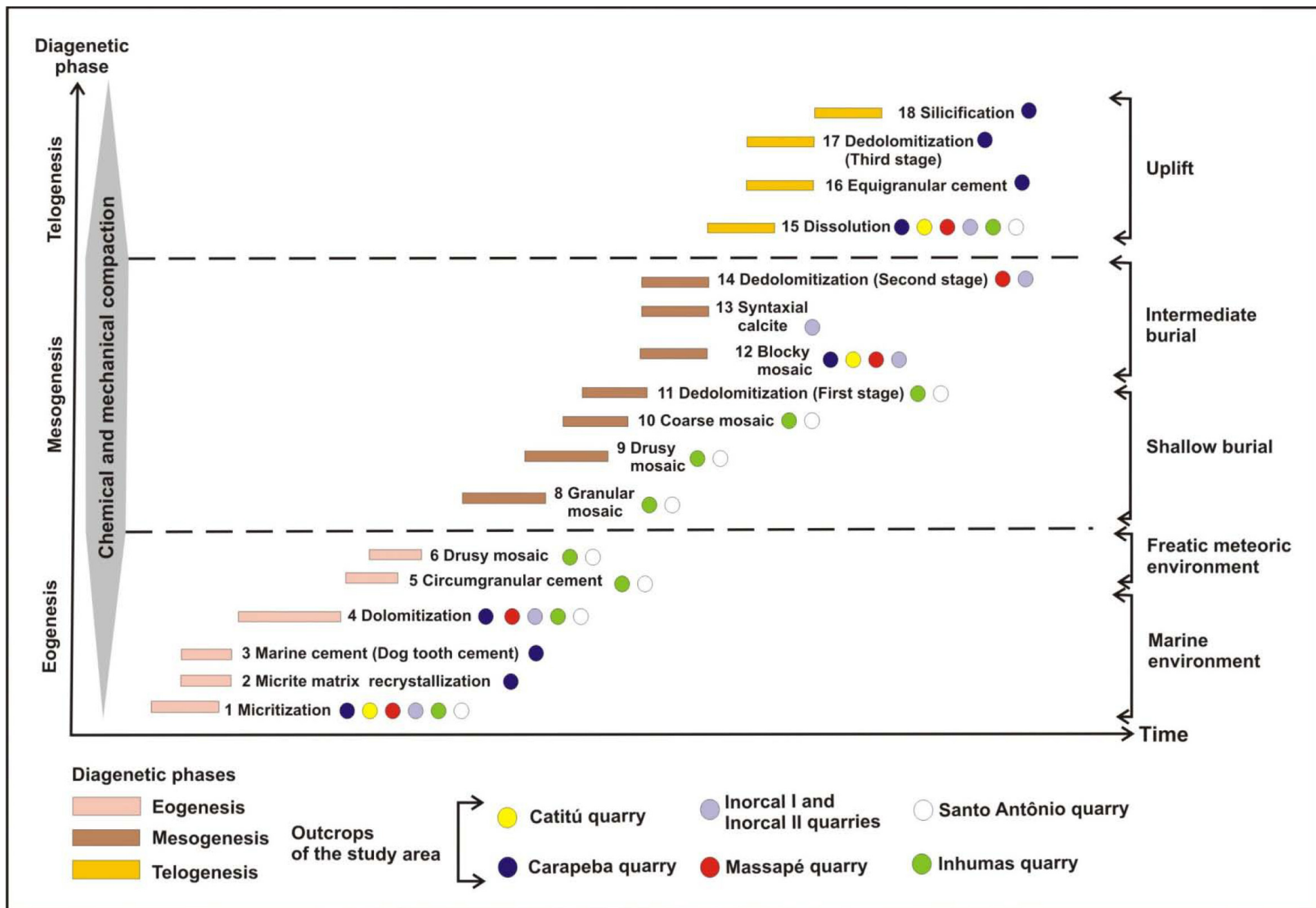


Figure 1. Illustration of the relative chronology of the diagenetic processes affecting the carbonates of the Maruim Member.