**Dedolomitization: Types, Mechanism and Its Relationship to Carbonate Reservoir Properties**

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**Abstract**

The dedolomitization is very common in the strata in China and abroad (Figure 1). But it is still in dispute about its formation environment, influencing factors, mechanisms, and the role in reservoir study and so on. We analyzed the recognition marks (Figure 2), and gave detailed classification on the dedolomitization from whether or not retaining the original rhomb shape, attitude and forming environment, and representation during different diagenetic stages. The dedolomitization of the sedimentary carbonate sequences are generally considered as the consequence under subaerial condition. But recent researches reveal that the dedolomitization can take place in different diagenetic conditions (Figure 3). The factors influencing the dedolomitization mainly are: the dolomites’ physical properties, degree of order, fluid characters (concentration of SO₄²⁻, Ca/Mg ratio, temperature, pH, and partial pressure of CO₂) and Fe content (Figure 4). We thoroughly analyzed the dedolomitization mechanism in different environments by cathodeluminescence and stable isotope data. The dedolomitization are obviously affected by the original dolomite texture, and the dedolomitization process can be divided into two steps: (1) dissolution of dolomite; and (2) the precipitation of calcite. Maybe only the first step occurs to form the rhomb-moldic pore. Maybe the two steps take place at the same time. Maybe firstly (1) occur and then (2). The dedolomitization mostly begin from the core of the dolomite or the interface between the core and the rim, which is because there are deficits during the growth process and have high Ca content. Some soluble inclusions promote the dedolomitization. The dedolomitization can be considered as a kind of process that the Mg²⁺ is gradually released. As an opposite process of dolomitization, the studies of formation condition of dedolomitization and calcite-dolomite-solution system can help to analyze the origin of dolomitization. The near-surface dedolomitization is generally relevant to the dissolution of gypsum and the meteoric water of vadose zone and phreatic zone. Prerequisites are a solution with high calcium and low magnesium content, low CO₂ partial pressure, and temperatures < 50°C. It is confirmed that the laterally continuous distribution of dedolomitization can indicate unconformity.

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The dedolomitization can reconstruct the pores. In Ordos Basin of China, it is very common that the leaching of dedolomitized calcite can increase porosity near the unconformity of the uppermost of Lower Ordovician (Figure 5). In the Huanglong Formation of Upper Carboniferous in Sichuan Basin of China, the dedolomitization is very universal. But the secondary limestones after dedolomitization have very low porosity (porosity of dolomite = 3.3-6%; porosity of dedolomitized limestone = 1-2%). The main reservoirs of Huanglong Formation are dolomite and calcareous dolomite (Figures 6, 7, 8). The dedolomitization not only resulted in the calcite replacing the dolomite, but also lead to the precipitation of calcite in the primary pores. So the porosity decreased after the dedolomitization. Generally speaking, the dedolomitization can enlarge the modic pore and inter-crystal pore. But there is close relationship between the increasing porosity of dedolomitization and latter eluviation. Without the latter leaching, maybe the dedolomitization relevant to calcite precipitation will destroy the primary pores.

Selected References


Dedolomitization: Types, Mechanism and Its Relationship to Carbonate Reservoir Properties

In the carbonate strata in China and abroad, especially in the place where gypsum/anhydrite is dissolved, the dedolomitization is very common (Fig. 1). Swiss geologist A. von Morlot first put forward the word “dedolomitized calcite” in 1947. He thought that the groundwater rich in Ca, S leaching the anhydrite evaporite can result in the calcitization of early stage dolomite. Dedolomitization — The product of diagenetic conversion of dolomite to another mineral (typically calcite), a process that occurs most commonly during the dissolution of associated calcium sulfates or at high temperatures. The term does not specify the end product of conversion; it is less definitive than terms such as “calcitized dolomite” - Peter A. Scholle. 2003

The calcitization (dedolomitization) of the sedimentary carbonate sequences are generally considered as the consequence under subsurface conditions. But recent researches reveal that the dedolomitization can take place in different diagenetic conditions.

\[ \text{CaMg}(CO_3)_{2} + \text{Ca} + \text{SO}_4^{2-} \rightarrow \text{Mg} + \text{SO}_4^{2-} + 2\text{CaCO}_3 \]  

Textual Criteria for Recognizing Dedolomitization

The dedolomitization has two meanings:

a) The dissolution of dolomite, forming rhombic crystal maldic pore;

b) Partially or wholly calcitization of dolomite (Fig. 2b).

For the 2nd dedolomitization, staining with Alizarin Red S shows the distribution of dolomite within the dolomite rhombus. However, besides there are some other symbols:

a. Brown and reddish rock colors: Liberation of Fe\(^{3+}\) from Fe-rich dolomite may form hematite occurring as thin coatings on the crystals or ferric iron precipitates (Fig. 2a).

b. Weathering along crystal faces of a calcitized dolomite may produce loose sandy sediment (Fig. 2c).

c. Calcite pseudomorphs after sucrosic xenomorphic, nonplanar dolomite (Fig. 2c).

d. Syntaxial calcite rims bordering rhombohedral crystals (Fig. 1).

e. Relicts of dissolved dolomites preserved inside the pseudomorphs or at their boundaries (Fig. 2b).

f. Association of dedolomite with evaporite minerals.

The dedolomitization phenomena in different diagenetic condition can be classified into 4 types:

1. Near-surface dedolomitization. Prerequisites for forming near-surface dedolomitized is a solution with high calcium and low magnesium, low CO₂, partial pressure, and temperatures > 50°C. Near-surface dedolomitization is often related to dissolution of gypsum and dolomite in vadose or phreatic meteoric waters.

2. The dedolomitization relevant to fracture have lower O iso value (-6.3 to -9.6), PDB and higher C iso value (1.0 to 2.6%), wide range of Mn content (290-540 ppm), medium Fe content (120-170ppm) and very low Sr content. It is shallow burial origin.

3. The dedolomitization relevant to stylolite have close relationship with hydrocarbon, and have very low O iso value (<-7.87%), lower C iso value (-1.37%), medium Fe, Mn content (Fe=450ppm, Mn=120 ppm), higher Sr content (940ppm). It is owing to deep-bury (Fig. 3).

4. The dedolomitization of the dolomite in the gypsum nodules.

The dedolomitization can be considered as a kind of process that the Mg\(^{2+}\) is gradually released. This is opposite to the dolomite forming process: firstly original dolomite precipitates, and then transforms to ideal dolomite in high Mg/Ca environment. That is to say, the ideal dolomite firstly releases the Mg\(^{2+}\) to become dolomite rich in Ca, then finally transforms to be calcite.

Fig. 1 Overseas dedolomitization examples (from Peter A. Scholle et al., 2003)

Fig. 2 a Weathering and dolomite alteration can accentuate zonal variation in the iron contents of dolomites through the formation of hematite or limonite alteration zones. b, Ellenvoor LS, Listro area, Texas: A stained example showing rhombic dolomite crystals in which cloudy, inclusion-rich cores were dissolved and the resultant pore spaces were filled by calcite cement (red). Glitterstone Gibeon Main, coastal South Atlantic; e, EPMA of microspar calcareous, O.J. Tarinn basin.

Fig. 3 The laser C.G.O isotope (up-right table) and EPMA spectrum (down table) result of medium-coarse crystal dolomite (up-left photo) in Pengalba formation, Lower Ordovician (O3) in SW Tarin basin. The up-left photo shows the dedolomitization in the centre of the dolomite. Stained, PPL, 40x.
The factors influencing the dolomitization mainly are:
1. The dolomites’ properties: The dolomite with good porosity is easily dolomitized. On the one hand, the Epsom salt (MgSO₄), which is the outgrowth of dolomitization, is easily dissolved, so the rock after dolomitization is porous with lower permeability; On the other hand, the dolomitized calcite is more easily dissolved than the original anhydrite, thus the permeability could become higher.
2. The degree of order of dolomite: The degree of order of dolomite has great influence on dolomitization velocity, but this influence tends to be lessened with the temperature increase.
3. The source of Calcium: Gypsum can provide the source of Ca for dolomitization, so a lot of gypsum can promote dolomitization.
4. The fluid properties: The fluid with high CaMg ratio easily leads to dolomitization. If the solution has higher CaMg ratio, the Mg²⁺ ions have higher releasing rate, and the dolomitization would be faster. The Ca/Mg ratio is controlled by the calcite-dolomite equilibrium of the fluids in the pore (Fig. 4) and the degree of order of dolomite.

In Ordos basin of China, there is an unconformity which can be correlated laterally in the uppermost of Lower Ordovician.

Dedolomitization developed between the unconformity surface and 100m downward, which has paragenesis relationship with dolomitized karst breccia (Fig. 5a, b, c, d).

It is very common that the leaching of dedolomitized calcite can increase porosity near the unconformity of the uppermost of Lower Ordovician in Ordos basin (Fig. 5b, c, d).

Significance of dedolomitization in carbonate diagenesis:
1. The dedolomitization is very important in recognizing exposure and unconformity. It is confirmed that the laterally continuous distribution of dolomitization can indicate unconformity (Fig. 5c, d).
2. The dedolomitization can reconstruct the pores. The distribution of the secondary pores associated with dolomitization in the hydrocarbon reservoir maybe more universal than that thought before.

Pursur (1985) considered that the dolomitization can enlarge the dissolved molybdenum pore and inter crystal space. After dolomite dissolved, subsequently the space is filled with latter cements, forming dolomite crystal mold. The crystal mold pore can indicate the exposure and the effect of meteoric water. There is this kind of dolomite in the Silurian dolomite in Kentucky of America. The reservoirs are fine grain dolomite and intrabrace dolomite, which have poor porosity. But the porosity can reach 9% in some area. There are two kind of pores: 50μm micropore and 5mm mullidic pore. The dedolomitized calcite has poikilitic texture, but it couldn’t increase the porosity by itself. The leaching of dedolomitized calcite produced the majority of pores.

References


Fig. 4 Calcite-Dolomite-Water system phase diagram, the isolems means the pressure value (after Yu et al., 2003)
But some researches indicated that the dedolomitization destroy the primary pore and resulted in the decrease of original rock.

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Table 1. The porosity correlation table of dolomite and limestone (including secondary limestone) in East Sichuan basin, China.

In the Huanglong formation of Upper Carboniferous in East Sichuan basin of China, the dedolomitization is very universal (Fig. 7a, b, c, d). But the secondary limestones after dedolomitization have very low porosity (porosity of dolomites 3.3-6%, porosity of dedolomitized limestone=1-2%).

Fig. 6 Lithological profile of C2h in East Sichuan basin, China

Fig. 7 Examples of C, h dedolomitization in East Sichuan basin, China

The main reservoirs of Huanglong formation are dolomite and calcareous dolomite (Fig. 8). The dedolomitization not only resulted in the calcite replacing the dolomite, but also lead to the precipitation of calcite in the primary pores. So the porosity decreased after the dedolomitization (Fig. 7a, b, c, d).

Fig. 8 Sedimentary facies of C2h in East Sichuan basin, China

There is close relationship between the increasing porosity of dedolomitization and latter eluviation. Without the latter leaching, maybe the dedolomitization relevant to calcite precipitation will destroy the primary pores. Of course the dissolution after the dedolomitization can form some pores (Fig. 7a).

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