

Mineralization of Dolomite

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Abstract

Worldwide carbonate rocks are occurring abundantly. These carbonate rocks are a major class of sedimentary rocks group. Carbonate are sedimentary rocks formed at (or near) the Earth surface by precipitation from solution at surface temperatures. The two broad categories are limestone, which is composed of calcite or aragonite (different crystal forms of CaCO_3) and dolostone, which is composed of the mineral dolomite ($\text{Ca Mg}(\text{CO}_3)_2$). Dolomite is not a simple mineral; it can have a variety of origin, can form as a primary precipitate, a diagenetic replacement, or as a hydrothermal/metamorphic phase, all that it requires is permeability, a mechanism that facilitates fluid flow, and a sufficient supply of magnesium. Dolomite can also form in lakes, on or beneath the shallow seafloor, in zones of brine reflux, and in early to late burial settings. It may form from seawater, from continental waters, from the mixing of basal brines, the mixing of hypersaline brine with seawater, or the mixing of seawater with meteoric water, or via the cooling of basal brines. Potential fluid sources are seawater and subsurface fluid of marine and/or meteoric origin: and addition Mg could be released from high-Mg calcite and smectite clays. The only abundant source of Mg^{2+} ions for early diagenetic surface and near-surface dolomitization is seawater. Dolomitization also creates new crystals, with new rhomb growth following the dissolution of less stable precursors. Dolomitization model and formation depend on the source dolomitization site and lastly, there must exist a favorable condition for a chemical reaction. One particular type of dolomite which may be a cement or a replacement is baroque dolomite, also called 'saddle' or 'white sparry' dolomite and known to mineral collectors as pearl spar. It is characterized by a warped crystal lattice.

Keywords: carbonates; dolomite; calcite; fluid source; dolomitization

Introduction

Carbonate rocks are a class of sedimentary rocks composed primarily of carbonate minerals. Carbonate are sedimentary rocks formed at (or near) the Earth surface by precipitation from solution at surface temperatures. The two major types are limestone, which is composed of calcite or aragonite (different crystal forms of CaCO_3) and dolostone, which is composed of the mineral dolomite ($\text{CaMg}(\text{CO}_3)_2$). Carbonate rocks are depositional most simple but diagenetically most complex rocks of the world. There are a number of carbonate minerals which are formed by combining of one or more ion with the CO_3^{2-} ion. Dolomite is an anhydrous carbonate mineral composed of calcium magnesium carbonate, ideally $\text{CaMg}(\text{CO}_3)_2$. The term is also used for a sedimentary carbonate rock composed mostly of the mineral dolomite. An alternative name sometimes used for the dolomitic rock type is dolostone. Dolomite is an unusual carbonate mineral. It is common in ancient platform

carbonates, yet it is rare in Holocene sediments Table 1 [1].

Table 1

Mineral name	Chemical formula
Calcite	CaCO_3
Aragonite	CaCO_3
Dolomite	$\text{CaMg}(\text{CO}_3)_2$
Ankerite	$\text{CaFe}(\text{CO}_3)_2$
Magnesite	MgCO_3
Siderite	FeCO_3

Table 1 Some important minerals the mineral dolomite is the main component of the sedimentary rock that is also called Dolomite. It is similar to the mineral calcite but contains magnesium as well as calcium. Just based on looks, the rock dolomite is often impossible to distinguish from limestone, which is composed mainly of calcite. Dolomite crystals are usually rhombic-shaped but, unlike most other minerals, the crystal faces typically are curved.

Chemical compound: calcium magnesium carbonate.

Chemical formula: $\text{CaMg}(\text{CO}_3)_2$ (Ca = calcium, Mg = magnesium, C = carbon, O = oxygen).

Color: white, gray, greenish, brown, pink.

Luster: often glassy.

Hardness: 3.5–4.

Specific gravity: 2.8.

Amount of transparency: transparent to translucent

Dolomite is a very common mineral, and is known for its saddle-shaped curved crystal aggregates. A unique, isolated Dolomite occurrence in Enugu, Spain has provided colorless transparent crystals that resemble the Iceland spar variety of calcite. The occurrence of Kolwezi, in the Congo, has produced some fascinating, cobalt-rich specimens that are a beautiful hot pink colour and highly popular.

Dolomite forms in a different crystal habit differing from the calcite group minerals. This can be noted by the fact that Dolomite generally forms more elongated crystals than those of the Calcite group. In addition, Dolomite never occurs in scalenohedral crystals, whereas minerals of the Calcite group do.



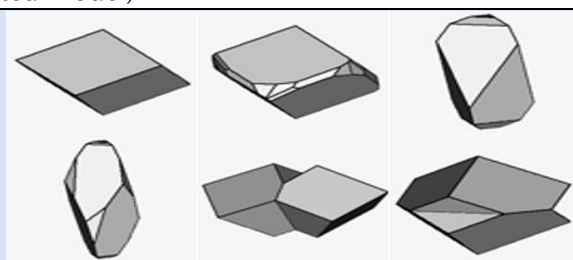
Dolomite

Table 1

Composition	Calcium magnesium carbonate. The amount of calcium and magnesium in most specimens is equal, but occasionally one element may have a slightly greater presence than the other. Small amounts of iron and manganese are sometimes also present.
Variable Formula	$(\text{Ca},\text{Mg})_2(\text{CO}_3)_2$ $(\text{Ca},\text{Mg},\text{Fe},\text{Mn})_2(\text{CO}_3)_2$
Color	Colorless, white, gray, peach, pink, yellow, and orange. Rarely yellow, green, red, and black.
Streak	White
Hardness	3.5 - 4

Crystal System

3D Crystal Atlas (Click for animated model)



Dolomite types



Iron bearing dolomite

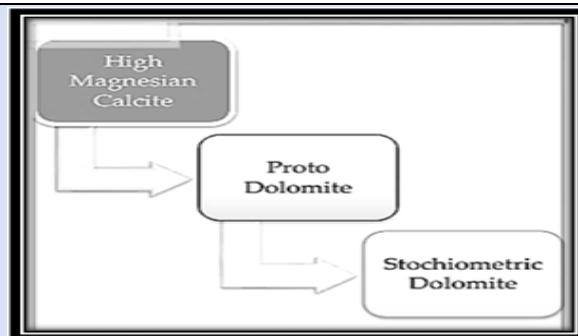


Figure 1: Showing the stages of dolomite formation.

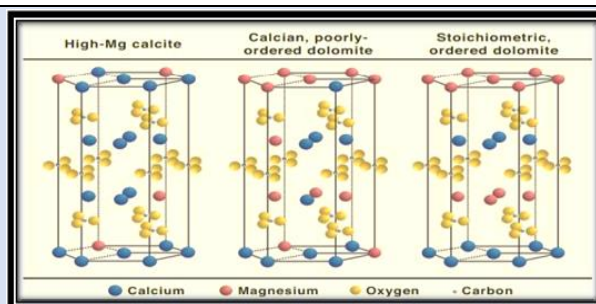


Figure 2: Showing the formation of high ordered dolomite from high-mg calcite.

Evaporation dolomite

Dolomite is in fact formed in high intertidal supratidal and sabkhas environment. Dolomitic that formed in the supratidal environment are precipitated from evaporated sea water. Early formation of gypsum and aragonite resulting to a sophisticated Mg/Ca proportion of pore water to enhance the formation of dolomite.

Seepage-reflux dolomitization

This process comprises the formation of dolomitizing solutions over vaporization of lagoon water or tidal flat pore water besides then the succession of these solutions into nearby carbonate rocks Figure 3.

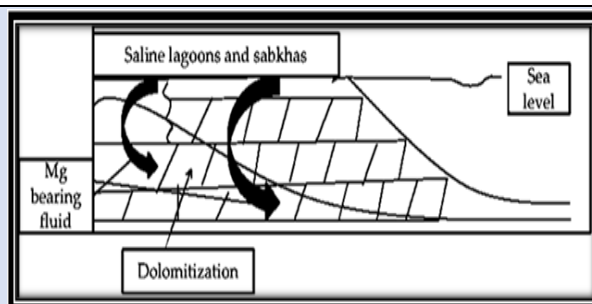


Figure 3: Figure showing dolomitizing fluid forming through evaporation.

Mixing zone dolomitization

This type of dolomite formed by the mixing of seawater with the fresh water. The source of water may be rainwater (Figure 4).

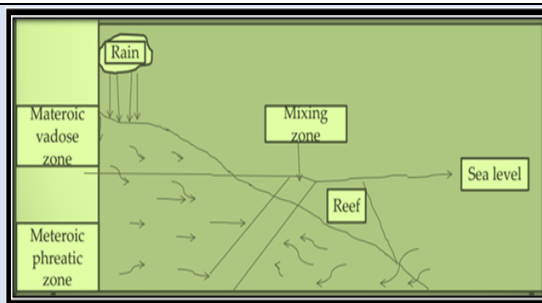


Figure 4: Figure showing water mixing zone.

Burial dolomitization

Burial dolomitization involves prime mechanism which is the dewatering of basal mud rocks due to compaction and removal of Mg-rich fluids into neighbouring shelf edge. Expulsion of water and changes of clay minerals with enlarged burial and increasing temperature suggest that it would liberate Mg ions along with Fe ion. The diagenesis of basal shales is generally organic-rich and the diagenesis would contribute to CO₃ ions [1].

Seawater dolomitization

Seawater itself can also be a source of dolomite because it contains the sufficient amount of Mg ions with little modification if a good pumping process exists.

Identification of dolomite

In the lab, it is best to identify by staining it with the Alizarin Red Sulphate Solution.

Result. The colour of calcite will turn into red-brown, whereas dolomite will not be affected. In the field, it

gives effervescence with 10% HCl in the powdered form.

Dedolomitization

Dedolomitization refers to the partial to the whole transformation of former dolomite rocks to a calcian rich rock. The dolomitization can be considered as a kind of process in which Mg is gradually released. The dedolomitization process can be divided into two steps,

Dissolution of Dolomite

The precipitation of Calcite.

Dolomitization is a geological process by which the carbonate mineral dolomite is formed when magnesium ions replace calcium ions in another carbonate mineral, calcite. It is common for this mineral alteration into dolomite to take place due to evaporation of water in the sabkhas area. Dolomitization involves a substantial amount of recrystallization. This process is described by the stoichiometric equation [7].



The conditions of dolomite formation are difficult to govern in the laboratory as up to yet no-one has been capable to form it at low temperatures from usual

H₂O. For undeviating result of dolomite formation, the equation is:



For complete dolomitization of a limestone sequence a large quantity of Mg²⁺ must be propelled over the formation. Beside existence of a favorable environment for chemical reaction, a Mg²⁺ source and effectual transportation structure are required.

Source of magnesium ion

Prospective fluid sources are seawater and underground water of oceanic and/or meteoric source: while addition of magnesium can be added from high magnesium calcite and clays. Sea water is thought to be the prime source of magnesium ion for early diagenetic surface and near-surface dolomitization. It consists 1290 part per million magnesium (0.052 moles l-l) and 411 ppm Ca (0.01

moles I^{-}), i.e., an Mg/Ca weight ratio of 3.14 or molar proportion of 5.2. Beside meteoric water generally inconstant possess low values of both; for example, normal river water has 15 ppm Ca and 4 ppm Mg depicting a molar Mg/Ca ratio of 0.44. Therefore, ocean water is usually thought to be the origin of the Mg^{2+} ions for maximum primary dolomitization but this water is generally altered in numerous dolomites forming models in trend [8].

Dolomitization model

Dolomite is one of the complex minerals and its artificial occurrence is difficult to study in lab experimentations. Though it is a very well-ordered mineral and demanding phase to precipitate, yet still dolomite synthesis at sedimentary temperatures using natural waters has not shown. Controlling chemical factors on dolomite formation from water is problematic to clarify and largely have been concluded from high-temperature experimentations [9]. Figure 5 Essential elements of any dolomitization model, supply of Mg and the supply of carbonate must be sufficient to form the observed amount of dolomite there must be a delivery mechanism commonly in the form of fluid flow adequate to deliver these ions to the dolomitization site and lastly

there must exist favourable condition for chemical reaction. For elucidation of primeval dolomite five extensive divisions of dolomitization model presently exists,

1. Evaporative
2. Seepage-reflux
3. Mixing-zone
4. Burial
5. Seawater models Figure 6 and 7.

Figure 7 Conceptual models for (a) dolomite precipitation and (b) dolomite replacement scenarios. (a) The thick black lines are the volume fraction of dolomite that is precipitation from the invading solution from the left. The dashed lines represent the dolomite precipitation rates t_1 and t_2 represent two different time slices. Dolomite precipitation front is moving towards the right as indicated by the open arrow. (b) The replacement front consists of two reaction zones namely zone A and zone B. In Zone A calcite chemically dissolves first releasing Ca^{+2} in the aqueous solution and producing secondary porosity. The Ca^{+2} thus released will eventually supersaturate the aqueous solution and precipitate dolomite that will pressure dissolve an equal amount of calcite in zone B. Again, t_1 and t_2 represents two different time slices. Dolomite precipitation front is moving towards the right as indicated by the open arrow [10].

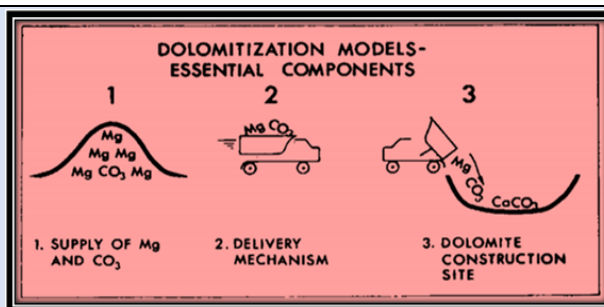


Figure 5: Essential elements of any dolomitization model.

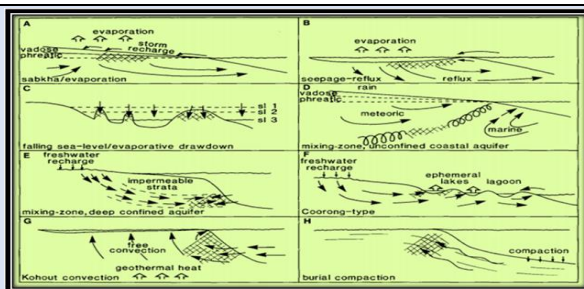


Figure 6: Models of dolomitization, illustrating the variety of mechanisms for moving dolomitizing fluids through the sediments [1].

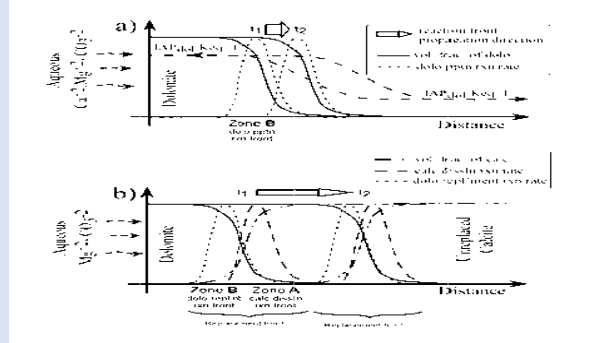


Figure 7: Conceptual models for (a) dolomite precipitation and (b) dolomite replacement scenarios.

Replacement dolomite

Formation of dolomite by replacement of $CaCO_3$ ranges from fabric damaging to retaining and from fabric selective to persistent. The important aspects now are grain mineralogy and crystal extent, the timing of dolomitization and natural

surroundings of dolomitizing liquids. Forms of dolomite crystals in replacement assortments differs from anhedral to euhedral shape, with the terminologies xenotropic and idiotypic denoting to the mosaics. Sibley [11] put stress on the origin of crystal boundary shapes, identifying non-planar, euhedral and subhedral categories Fig-8 and 9.

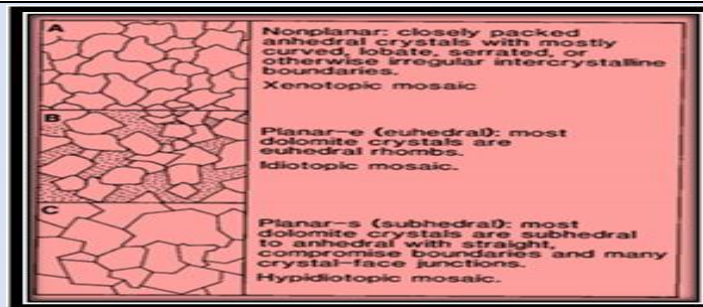


Figure 8: Three common dolomite textures; (A) Non-planar crystals in a xenotropic mosaic; (B) Planar-e crystals (e for euhedral) in an idiotypic mosaic; (C) Planar-s crystals (s for subhedral) in a hepatotropic mosaic.

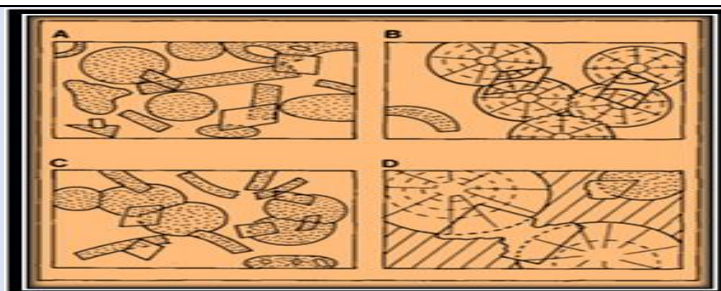


Figure 9: Common dolomite rhomb relationships in limestones; (A) Pre-compaction rhomb's, grains in point contact. (B) Compaction after rhomb precipitation so that ghost textures in rhomb's are displaced relative to grains; (C) Post-compaction rhomb's including fractured grains and stylolite's; (D) Pre-sprite rhomb's etched and replaced [1].

Dolomite cement

Though dolomite is mainly a replacement, cement of this mineral is common. In Pleo-Pleistocene dolomites of the Caribbean-Bahamas, dolomite cement generally formed amongst dolomitized grains and in the spaces. The dolomite can also be found as clear spur, straight analogous to calcite spar, although

usually cement is just a single layer of large rhomb's in between the spaces of grains. Crystals are too clear and thus they are known as limpid for their white look. Stress has been put on these, proposing they are a distinctive creation of mixing-zone dolomitization. In few cases, dolomite cement comprises regions of syntaxial calcite depicting fluctuation in pore water chemistry (Figure 10) [12].

Dolomite crystal size	Unimodal or polymodal
Dolomite crystal shape	Planar or non-planar
CaCO ₃ allochems	Unreplaced or replaced or moulds If replaced: partial or complete, mimic or non-mimic
CaCO ₃ matrix	
CaCO ₃ cement	
Void-filling dolomite	Limpid, rhombic, drusy, baroque

Figure 10: Terms for describing dolomite textures.

Arouse dolomite

This specific dolomite is also known as saddle or white sparry dolomite. Baroque dolomite is known to be forming as a result of replacement. In the minerals collecting community, it is known as pearl spar distinguished by a distorted crystal lattice it has bowed crystal looks, curved cleavage planes, having undulate extinction. Crystal of this dolomite which is larger than a millimetre is generally a compound of sub-crystals, resulting in stepped surface of the crystal. If the dolomite is of replacement origin fluid inclusions, and calcite relics will be present which provides the crystals a gloomy look in thin section and displays shining lustre in hand specimens. Baroque dolomite is calcium rich and usually having Fe content (up to 15 moles % FeCO₃). Dissimilarities in configuration of separate crystals are normally distinct, happening amongst dissimilar growing sheets giving a different zonation and inside the regions themselves. This dolomite takes place as together an opening fill and a replacement. In its cavity-fill approach, it typically consumes a xenotropic texture of asymmetrical crystal borders inside the assortment but bowed, scimitar-like ends into the void

Applications in Detail

Construction: Dolomite, in its crushed form, is used for producing concrete and cement. Its high hardness makes it a robust material for construction purposes.

Agriculture: Farmers use dolomite for agricultural pH control. The chemical industry uses the mineral dolomite in making magnesium salts.

Steel Industry: It serves as a flux for the smelting of iron and steel, helping to remove impurities and improve the quality and strength of the end product.

Ceramics: In ceramics, dolomite is used as a source of magnesia (MgO) and also in the creation of ceramics and glass.

Petroleum Industry: Dolomite rocks contain oil and natural gas reserves and serve as reservoir rocks in petroleum extraction.

Environmental Impact and Sustainability

While dolomite provides numerous benefits, its extraction and use come with environmental considerations. Open-pit mining can lead to habitat loss and air pollution. However, sustainable practices, such as phased recovery and reclamation of mined lands, are being implemented in many parts of the world to mitigate these impacts. Furthermore, dolomite can naturally capture carbon dioxide (CO₂), which contributes to climate change mitigation efforts.

Dolomite in Science and Research

Recent scientific research focuses on dolomite's potential in carbon sequestration. This involves using dolomite to capture and store carbon dioxide, offering a way to reduce greenhouse gas emissions. Dolomite's role in the carbon cycle and its potential contribution to reducing atmospheric CO₂ levels are currently under intense study, promising new avenues for combating climate change.

Conclusion

In conclusion, dolomite is a versatile and multifunctional material that plays a significant role in various industries worldwide. Its unique chemical and physical properties, combined with its global distribution, make it an indispensable resource. While its extraction and use have environmental impacts, the implementation of sustainable practices and its potential in climate change mitigation mark dolomite as a material of considerable interest in the future. It's not just a rock - it's a cornerstone of modern industry and could potentially be a significant part of the solution to our climate crisis. Dolomite is by formation a very complex which not only forms in the ocean by the simple addition of Mg but also forms as result of Vaporization and burial of magnesium-containing water upon reaction with limestone. Different dolomite types have their own history embedded within it. Baroque a specific category of dolomite which may be cement or a

replacement is, also called 'white sparry' dolomite and identified to mineral accumulators as pearl spar. The criteria for choosing between models are not definitive as could be desired and many of these criteria have been interpreted in more than one way. A considerable measure of work and research is anticipating to be completed identified with dolomite, its development and dolomitization process.

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