Dolomitization and its effect on the geochemistry of Lar Formation, South Behsahar (Iran)

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ABSTRACT

Petrographic studies indicate that dolomitization process affects the lower part of Lar formation in southern Highlands of Behshahr. In this research, dolomites are classified based on the size and fabric and then their geochemical characteristics and formation process has been studied. In subsurface sections, 5 dolomite types as Xenetopic-A, Idiotopic-S, Idiotopic-E, Idiotopic-C and Xenotopic-C were detected. Dolomite type 1 was formed in the effect of sea water pumping and is nearly syndepositional. The other dolomites were formed in shallow to deep burial environments based on crystal size. Dolomites are variety in this formation because dolomite fluid composition changes during initial to delay diagenesis. Based on elemental analysis, Ca and Sr values dropped from first to fifth types and Fe, Mn and Mg contents increased. Na concentration decrease in the early diagenetic dolomites, but increase in delayed diagenetic dolomite due to deep burial and probably basin brines.

KEYWORD

Dolomitization, Geochemistry, Lar formation, Behshahr

INTRODUCTION

Dolomite is a carbonate mineral that its formation mechanism is not yet fully understood in sedimentary environment [1, 2, 3]. Dolomites are formed under various temperatures between 300 ° C to 2 °C [4]. Lar Formation is part of an extensive carbonate platform that was established in the major part of the Alborz during the Late Jurassic. This formation can be subdivided into two main members. The lower part consists of thick-bedded, cliff-forming, grey dolomite with chert noduls. In the upper part alternations of Thin to medium and thick bedded, white limestones (mudstone to grainstone) occur. This Formation is overlain by yellow detrital sediments of Miocene units and underlain by siliciclastic Shemshak Formation disconformably. Dalichai formation doesn't found in this area. The age of Lar formation is considered to be Upper Jurassic (Titionian-Neocomian).

Due to soil covers and dense vegetation, there are very few outcrops of rock mass in the study area. Accordingly, some boreholes around the Gelevard dam site are selected to study Lar formation. The study boreholes (GV1, BH9 and BH10) are located at about 40 km south of Behshahr city in Mazandaran province (Iran), between 53°36′ and 53°37′ north latitude and 36°35′ and 36°36′ east longitude (Fig. 1). Dolomite thickness in these boreholes is respectively 85, 70 and 60 meters. In this research, petrographic and geochemical evidene is used to study dolomite types and their diagenetic process.

STUDY METHODS

For petrographic analysis, about 115 thin sections of Lar dolomite in three boreholes of Gelevard dam (GV1, BH9 and BH10) were prepared and studied with a polarizing microscope of transmitted light. All Thin sections were stained by alizarin-red to differentiate calcite from dolomite [5]. Also nineteen samples were analysed by X-Ray Florescence method (XRF) for Ca, Mg, Sr, Na, Mn and Fe in Kansaran Binalod laboratory.

PETROGRAPHY

The large part of Lar formation is highly dolomitized. Petrographic and geochemical studies indicate that multiple phases of dolomitization affected the Lar limestone. The dolomite classification [6] is used to determine the dolomite types. In this category, dolomite textures divided to Idiotopic and Xenotopic. Therefore Lar dolomites are
2.2. Dolomite type II (Idiotopic-S)

This type of dolomite has been mainly formed of dense and equal Subhedral to anhedral crystals with planar-S boundary between crystals. The crystal size varies and thus it can be divided into two categories. The first type consists of small, Subhedral to anhedral dolomite crystals, with a size of 35-100 microns which has disappeared the primary sedimentary features. This type can be called as dolomicrosparite (Fig.2b). Another type is containing of larger crystals (100-300 micron). Crystals often have cloudy center and clean rims (Fig. 2c).

Dolomite type II is equal to hypdiotopic texture [11] and planar [12]. According to Sibley and Gregg [6], subhedral planar-s fabric is the result of slow growth of crystals in the low temperature condition. So according to texture characteristics and the size of crystals, they're probably as replacement dolomites in shallow burial stage [13, 14].This type is the most abundant dolomite type in Lar Formation.

2.3. Dolomite type III (Idiotopic-E)

This dolomite is composed of relatively dense euhedral crystals with direct extinction (Fig. 2d). The crystal size is changed between 120 to 250 microns (mean 200 microns). This type can be described as dolosparite according to its size. More rhombohedrs have foggy surface with micrite inclusions surrounded by a clear rim. Dolomite Idiotopic-E is a replacement type, which is observed with the previous dolomite. It can be equal to Idiotopic fabric [11] and planar-p [12]. In some cases rhombohedrs are floated in calcite cement and provide a poikilotopic texture [11].

2.4. Dolomite type V (Xenotopic-C)

This type of dolomite is mainly dense, semi-transparent anhedral with non-planar boundaries (Fig. 2f). The crystals size is different (between 200 to 500 microns). The fifth dolomite is often composed of replacement coarse crystals that fill voids and fractures between previous dolomites as a dolomitic cement. These dolomites form at temperatures above 60 ° (between 60-150°C) in the depth of 1-3 kilometers [15]. Dolomite type V is equal to hipdiotopic [11] and subhedral nonplanar-s [12]. This dolomite is caused to damage the primary sedimentary texture so it is very difficult to identify the primary forms of sediment. This type of dolomite is formed in the late diagenetic stage therefore
cuts the first, second and third types of dolomite. The dolomite crystals sometimes show wavy extinction and this seems like a saddle dolomite [15]. It's possible to distinguish this dolomite from previous one by curved crystal faces and wavy extinction.

**Table 1:** The results of elemental analysis of Lar formation dolomite in southern Behshahr

<table>
<thead>
<tr>
<th>Dolomite type</th>
<th>Sample No.</th>
<th>Ca %</th>
<th>Mg ppm</th>
<th>Na ppm</th>
<th>Sr ppm</th>
<th>Fe ppm</th>
<th>Mn ppm</th>
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<tr>
<td>Xenotopic-A</td>
<td>GV1-16</td>
<td>26.41</td>
<td>8.95</td>
<td>518</td>
<td>169</td>
<td>910</td>
<td>15.5</td>
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<td></td>
<td>GV1-17</td>
<td>25.86</td>
<td>9.44</td>
<td>355</td>
<td>132</td>
<td>1100</td>
<td>13</td>
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<tr>
<td></td>
<td>GV1-20</td>
<td>26.12</td>
<td>9.52</td>
<td>296</td>
<td>150</td>
<td>2590</td>
<td>18</td>
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<tr>
<td></td>
<td>GV1-11</td>
<td>26.67</td>
<td>9.15</td>
<td>236</td>
<td>125</td>
<td>1500</td>
<td>24.5</td>
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<tr>
<td></td>
<td>GV1-12</td>
<td>26.16</td>
<td>9.50</td>
<td>230</td>
<td>115</td>
<td>1520</td>
<td>23</td>
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<tr>
<td></td>
<td>GV1-13</td>
<td>25.82</td>
<td>9.84</td>
<td>265</td>
<td>130</td>
<td>1450</td>
<td>15.5</td>
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<tr>
<td></td>
<td>GV1-15</td>
<td>25.15</td>
<td>10.32</td>
<td>414</td>
<td>154</td>
<td>1060</td>
<td>19</td>
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<td></td>
<td>GV1-18</td>
<td>25.47</td>
<td>10.17</td>
<td>158</td>
<td>121</td>
<td>3010</td>
<td>18.75</td>
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<tr>
<td></td>
<td>GV1-19</td>
<td>26.12</td>
<td>9.49</td>
<td>200</td>
<td>146</td>
<td>2980</td>
<td>20</td>
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<td></td>
<td>BH10-6</td>
<td>26.04</td>
<td>10.26</td>
<td>351</td>
<td>118</td>
<td>2150</td>
<td>19.5</td>
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<tr>
<td></td>
<td>BH10-8</td>
<td>25.32</td>
<td>9.13</td>
<td>283</td>
<td>135</td>
<td>2100</td>
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<tr>
<td>Xenotopic-B</td>
<td>GV1-14</td>
<td>24.80</td>
<td>10.30</td>
<td>252</td>
<td>154</td>
<td>1470</td>
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<td>BH9-4</td>
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<tr>
<td></td>
<td>BH10-5</td>
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<td>314</td>
<td>120</td>
<td>1661</td>
<td>15.5</td>
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<td>940</td>
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<td></td>
<td>BH9-7</td>
<td>24.68</td>
<td>10.81</td>
<td>715</td>
<td>110</td>
<td>4420</td>
<td>325</td>
</tr>
<tr>
<td></td>
<td>BH10-7</td>
<td>23.25</td>
<td>11.74</td>
<td>832</td>
<td>165</td>
<td>5140</td>
<td>418</td>
</tr>
</tbody>
</table>

**Fig 2:** Different types of Lar dolomite in the southern Behshahr (e in XPL, others in PPL). a: Dolomite Xenotopic-A include peloid ghost and clastic quartz. b: Dolomite Idiotopic-S. c: Dolomite Idiotopic-S with larger crystals. d: Dolomite Idiotopic-E with cloudy center and clear rim. e: Void filling dolomite (Idiotopic-C) around the cavities. f: Saddle dolomite (Xenotopic-C) which is observed within other dolomites.

**Geochemical Study**

Using geochemical data provides better understanding of dolomite origin, formation time, fluid composition, dolomitization model and diagenetic trend [16,17]. Researchers have done a lot of studies in this field to determine the origin of early and secondary dolomite, fluid composition, dolomitization time and dolomitization model [18]. Major elements are used in these studies include magnesium, strontium, sodium, iron and Manganese [17, 19, 20, 21]. Geochemical data obtained from testing dolomite samples in the study area (Table 1).

### 3.1. Magnesium

The amount of magnesium in pure dolomite is usually 13.8 percent while it ranges from 8.95 to 11.74 percent (average 10.04%) in study dolomites. The highest amount of magnesium is related to dolomite type 5. The lowest percent of magnesium is observed in dolomite type I. Ca values plotted against Mg shows that the amount of Mg increases along with dolomitization development and Ca level is reduced (Fig. 3a).

### 3.2. Strontium

Strontium is usually more important between trace elements in dolomite [22, 23]. The amount of strontium in study dolomites changes between 105 to 169 ppm (average 132 ppm). The amount of Sr in Lar dolomite is much lower than its value in the recent marine dolomite reported about 500-800 ppm [24] and also about 600-800 ppm [25]. It is probably because of neomorphic changes during next burial diagenesis [26].
Since most of the Lar formation dolomite has suffered severe recrystallization so decrease in the amount of Sr appears normal. The plot of Sr versus Mg indicates that strontium value in the Lar dolomites decreases with increasing magnesium (Fig. 3b). Sr value in dolomite type I is more than larger diagenesis dolomites [27]. Strontium level in dolomite type I, II and III is far more than dolomite type IV and V.

3.3. Sodium

Sodium is the most abundant cation in the sea water and its concentration in dolomites, will determine the main fluid salinity [27, 28]. The amount of sodium in recent dolomites changes from 1000-3000 ppm [29]. In Lar dolomites it varies between 158 to 940 ppm (average 376 ppm). Plot of Mg against Na indicates that Na value is reduced in dolomite type I, II and III along with increasing magnesium. But in the coarse crystal dolomite (Type V), sodium value is increased (Fig.3c). Sodium levels in the dolomites are difficult to interpret. The high concentration of sodium is probably due to the presence of NaCl liquid or solid inclusion or sodium-rich clay mineral alteration [30, 31]. The Na concentration in the dolomite type IV may be because of high salinity of dolomite fluids with Na value more than 230 ppm [32].

3.4. Manganese and Iron

Unlike sodium, iron and manganese are added to the rock during diagenesis [33] and are closely related to each other [34]. Mn content of Lar dolomite varies between 13 to 418 ppm (average 73.5 ppm). Also iron content varies from 910 to 5140 ppm (average 2171 ppm, Fig. 3d). Average values of Mn and Fe in Lar dolomite are more than the average amount of them in limestone (respectively 9.1 and 369 ppm). Since iron and manganese ions substitute for Mg so their abundance in dolomite could be due to this reason. Also, it seems that diagenesis and dolomitization has been little effect on Mn content in dolomitic type I, II and III compared to limestone (Fig. 3e). Significant increase in the amount of Mn and Fe in dolomite type V could be due to reduction conditions in the environment [35].

Fig. 3: Separation of different types of Lar dolomite by major and minor elements. a: variations of Ca versus Mg. calcium values are reduced along with increasing Magnesium in coarse crystal dolomites. b: Sr and Mg variations. Strontium levels also decreased with increasing magnesium. c: Chart Na versus Mg. In the first three dolomite types, sodium value is reduced with increasing magnesium, but in the dolomite type V, sodium increases suddenly. d: Variation of Fe versus Mg. Fe value increses along with dolomitization process and increasing Mg. e: Fe and Sr variations. Manganese has a direct relationship with Magnesium. Note the sudden increase in the amount of magnesium in dolomite type V. Not: T1:dolomite type I, T2: dolomite type II, T3: dolomite type III, T4:dolomite type IV and T5: dolomite type V.

DOLOMITIZATION MODEL

Lar Formation dolomites are formed in a variety of diagenetic environments so their textural, petrographic and geochemical characteristics are different. Generally dolomitization in lar formation carbonates in study area occurred as follows:

4.1. Marin dolomitization

According to petrographic evidence, such as very fine crystals, no fossils, dark color, presence of clastic quartz particles and also geochemical evidence like high values of Na and Sr and low Mn and Fe than other dolomites, the dolomite type I is considered to be syndepositional or early diagenesis dolomite. Therefore, it is composed under surface...
low temperature conditions in the upper intertidal to supra tidal environment (Fig. 4). In this model sea water or Mg-rich Intergranular fluids are cause of dolomitization [36, 22].

4.2. Shallow Burial Dolomitization

The second and third types of dolomite are probably made of the first dolomite recrystallization during shallow burial with a slight increase in temperature [22, 37, 38, 39, 10, 40, 26] (Fig.5). The patch of dolomite type I in the background of second and third type dolomite and also relatively high amounts of Sr, Na and low values of Mn and Fe are confirming this mater. The requirement magnesium is provided from dissolution of high Mg calcite [41, 42].

Facies study shows that some allochems and probably micrite in Lar formation are composed of aragonite and high Mg calcite that is converted to low-Mg calcite during diagenesis so they’re added magnesium to environment. The magnesium of this dolomite can also provide from marine pore water, fossil water and the magnesium in the clay mineral structures [43, 44].

Main mechanism affecting dolomitization in the burial environment is leaving water because of compaction and then exit of magnesium. Usually, stylolites, pressure dissolution and basin brines are sources of magnesium in the burial model [42, 43, 46, 47, 48].

4.3 Deep burial dolomitization

Dolomite type IV (Void fillings) and V (saddle) are probably formed in deep burial environment (Fig. 5). Usually saddle dolomites are formed by salty and hot fluids in the deep burial condition [49, 50]. Geochemical evidence like low Sr and Na values and significant increases in Fe and Mn content in these dolomites also support this claim. As the temperature increases underground, the kinetic and thermodynamic barriers of dolomitization disappears, so presence of magnesium ion constitute this process [44].

Probably during a warm and dry period after deposition of Lar formation, Mg-rich fluids derived from Shemshak shale units are located below, could rotate in the fracture of the lower part of this formation. Then coarse crystals of dolomite cement and void filling dolomites are created [51, 52].

In general we can say that reducing Sr and Na values and increasing Mn and Fe values from dolomicrite to fifth types and is because of high temperature diagenetic processes under reduction and burial (shallow and deep) conditions [53]. It seems that dolomitization in the Lar formation is started by sea water in the early stage and then is follow and complete by burial diagenesis.

CONCLUSIONS

Five different dolomite types were identified in the Lar Formation Based on petrographic studies. The first type is probably formed in the upper intertidal to supra tidal environment by pumping seawater. Therefore it considered to be nearly syndepositional. The dolomite type II is formed of calcium carbonate or primary dolomite replacement during shallow burial. The third type of dolomite is also the result of replacement or recrystallization of previous dolomites. Finally the dolomite type IV and V has been precipitated from dolomitization fluid in cavities and fractures during deep burial diagenesis.

The results of geochemical studies have shown that Sr and Ca values in the dolomite type I is more than next diagenetic dolomites. While the amount of Fe, Mn and Mg is increasing during dolomitization process. Elemental analysis also shows that Na value in medium and coarse crystalline dolomites (Idiotopic-S and E) is less than fine crystal dolomites (Zenotopic- A) due to the conditions of burial diagenesis and recrystallization. Significant increase in the amount of Na in saddle dolomite is probably because of basin brine affect. The crystal size and increasing Fe and Mn contents in coarse crystal dolomites than the medium crystals (Idiotopic- S) indicates that they are formed in more
reducing conditions and greater burial depth. Sea water is a source of magnesium in dolomite type I. The required magnesium of dolomite types II and III is probably supplied from intergranular waters. In the fourth and fifth type dolomite, magnesium has been supplied of Mg-rich fluids derived from shale units of Shemshak formation.

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