Diagenesis Processes in Yamama Formation in Tuba Oil Field, Southern Iraq

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Abstract
Yamama Formation (Late Berriasian–Valangenian) forms the most important Lower Cretaceous carbonate reservoir in the south of Iraq. The petrographic study by thin-section examination indicates that the Yamama Formation in Tuba Oil Field had been affected by nine diagenetic processes. These processes ruled the porosity system in this formation, these processes are; cementation, micritization, pyritization, silicification, dissolution, mechanical compaction, chemical compaction (stylolization), dolomitization, and neomorphism. The deposition of Yamama Formation was occurred during a regressive period within inner ramp, mid ramp, and outer ramp environments.

Key Words: Diagenesis, Lower Cretaceous, Yamama Formation, Tuba Oil Field, Iraq.

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Introduction
The main important reservoir of the Lower Cretaceous succession in Iraq is the Yamama Formation, (Sadooni, 1993). Only a few investigation data have been published about the Mesopotamian Basins. Sadooni and Aqrawi (2000) pointed out that the Cretaceous sediments of Mesopotamian Basins contain one of the richest petroleum reservoirs in the world, but unfortunately it had been poorly studied, particularly in the south of Iraq.

Generally this succession is a shallow marine carbonate, (Jamalian, 2011). The major lithologic constituent of Yamama formation is limestone, also shale and dolomitic limestone had been reported, (Sadooni, 1993).

The first definition for the studied formation was in 1952 by Steinke and Bramkamp where they described outcrops in Saudi Arabia, (Jassim and Goff, 2006). Bellen et. al, (1959) defined 257m intervals as the (Yamama- Sulaiy) Formation in Ratawi-1 Well in Iraq. Yamama Formation was represented by the upper 203m, (Sadooni, 1993).

Depending on the stratigraphic position the age of Yamama Formation, probably from Late Berriasian to Early Valangenian, (Jassim and Goff, 2006). This study was done by the examination of (80) thin sections under petrographic microscope. These 80 thin sections were prepared from (40) core samples that obtained from South Oil Company (S.O.C.). Each well represented by (20) cores and (40) thin sections that belong to Tuba-2 (Tu-2) Well and Tuba-3(Tu-3) Well.

The target of present study is to define the diagenesis processes in the Tuba Oil Field.

The Study Area
Tuba Oil Field locate in the Mesopotamian Zone within Zubair Sub Zone southern Iraq to about 40 Km at the south west of Basra Governorate and situated between western Zubair Oil Field and eastern Rumaila Oil Field, (Alrrawi, 2015), figures (1,4).

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**Tectonic Setting**

Tuba Oil Field is a dome structure and it is trending axis north north-west to south south -east, (Alrrawi, 2015). During the Yamama Formation deposition, the Mesopotamian Basin suffered from an active syntectonic sedimentation resulted in formation of large structures were seemingly instantly growing. These structures perhaps induced by warping of diapiric that triggered by the Infracambrian Hormuz Salt sediments, (Buday, 1980).

In the Cretaceous, the subduction of the Neo-Tethys crust produced compressional environment result in movement along the listric normal faults within passive margin. The compression phase produced dip-slip and strike-slip reverse movement on these faults and result in a stage of (block-folding) in the Mesopotamian Basin. The anticlockwise movement and the irregularity of the margins shapes of the colliding plates re-activate the old faults within basement rocks caused reshaping the topography of the sedimentary covers, (Numan, 2000).
Stratigraphy

Generally, the early Cretaceous was deposited in shallow-marine environment. The carbonate platform of early Cretaceous sloped slightly eastwards and created a ramp setting over the Jurassic sediments, (Al-Sharhan, 2003), figure (2). The deposition of the Yamama Formation was in the late Berriasian-Aptian Cycle. This cycle was represented from deep basin to shore by: Lower Balambo, Sarmord, Shuiaba, Yamama, Garagu, Ratawi and Zubair Formations. The regressive part of this carbonate cycle was represented by: Sulaiy, Yamama, Ratawi, and Zubair Formations and ended by the clastic of the Zubair fluvial deltaic facies, figure(4). The neritic lithofacies of this cycle was represented by the studied formation, (Buday, 1980).

The Sulaiy Formation conformably underlies the Yamama Formation, conformably overlies the Yamama Formation, (Sadooni, 1993). The thickness of Yamama Formation in Tuba-2 Oil Field is (351m) and in Tuba-3 Oil Field is (352m), (F.G.R,1977;1981), Table (1-1). The Fahliyan of Iran, Minagish of Kuwait, and Habshan of UAE Formations are equivalents to the Yamama Formation, (Alsharhan, 1986).

<table>
<thead>
<tr>
<th>Oil Field</th>
<th>Well Name</th>
<th>Easting</th>
<th>Northing</th>
<th>Yamama Top (m)</th>
<th>Sulaiy Top (m)</th>
<th>Thickness (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuba</td>
<td>a-2</td>
<td>734</td>
<td>3366</td>
<td>3789</td>
<td>414</td>
<td>351</td>
</tr>
<tr>
<td></td>
<td>a-3</td>
<td>739</td>
<td>3354</td>
<td>3847</td>
<td>419</td>
<td>352</td>
</tr>
</tbody>
</table>
Figure 3. Sub surface structural contour map of the Top Yamama, (0,E,C,2018)
Results

Diagenesis Process

Diagenesis is all the processes that happen to the sediments after deposition until the realms of incipient of metamorphism at elevated pressure and temperatures, (Tucker and Wright, 2001). These changes include shape, volume, size, chemical composition, crystalline structure of detrital or crystalline constituents after deposition, (Ahr, 2008).

The Figure (6) display the diagenetic sequence for the Yamama Formation in the studied wells. The figures (6, 7) show the distribution of diagenesis processes that developed in the studied wells involve the following processes:

1 – Micritization

It is a replacement process of the total carbonate grains or the margins grains by crypto- or microcrystalline carbonate crystals. The earlier diagenesis process is micritization which occur during and after deposition (lithification), (Boggs, 2009; Flugel, 2010). Micritization take place in the Yamama sediments by the activity of endolithic organisms which attacked carbonate grains, particularly benthic foraminifera and algae forming cortoids or complete micritized grains. Micritization process abundant in the Yamama Formation particularly micritized benthic foraminifera, Pl (1-1, 2-7).

2- Pyritization

Pyritization is an early diagenesis process that developed in reducing environments, (Flugel, 2010). Pyrite appears in the Yamama Formation as a framboidal (a microscopic spheroidal clusters of interlocking crystals), cubic crystal, or replacement within calcite, Pl (1-2, 1, 3).

3- Dissolution

Dissolution occurs in the carbonate sediments
when pore-fluids are under saturated conditions with respect to the carbonate mineralogy, (Tucker and Wright, 2002). Dissolution developed in deep burial, shallow near-surface environments, cold waters, and in the deep sea, (Flugel, 2010) and may lead to form karst, (Tucker, 2001). Dissolution is a very important process in the Yamama Formation because it enhanced the primary porosity of interparticle and/or intraparticle and form the secondary porosity such as channel, moldic and vuggy porosities. Dissolution made the Yamama Formation one of the best reservoir of the Lower Cretaceous southern Iraq, Pl (1-4, 1-5, 2-4, 2-8).

4 - Cementation
Cementation is a chemical precipitation from solutions, (Flugel, 2010), and consider the production of major diagenetic process forming a solid limestone from the loose deposits and grows in pores where the pore fluids in the state of super saturation conditions with respect to the cement mineral, (Tucker, 2001). There are many types of cement that recognized in the studied wells such as syntaxial rim, drusy, and blocky cements, Pl (1-6, 7, 8, 2-1, 2-8).

5 - Silicification
Silicification in carbonate rocks creates by the replacement of carbonate minerals with silica result in deposition of silica cement and filling the pores. Generally, the sources of silica are: (1) weathering solutions of silica that input by rivers, (2) siliceous tests, and (3) silica solution that brought by hydrothermal volcanic activity, (Flugel, 2010). In the Yamama Formation the major source of silica is the river input of silica in a shallow marine environment, Pl(1-6, 2-2).

6 - Mechanical Compaction
Mechanical compaction is a closer packing of the grains with increasing of burial, if the sediments are not already cemented, (Tucker and Wright, 2001). The original thickness of sediments may be decreased to one quarter, (Flugel, 2010). Mechanical compaction resulted in porosity reduction, Pl (1-7). This process was dominated in Tuba Oil Field at lower and middle parts of Yamama Formation.

7 - Chemical Compaction (Stylolitization)
After mechanical compaction, the elastic strain will increase with continued burial at individual grain contacts result in growing of potential for chemical reaction, revealed as an growth of solubility at the grain contact, and finally results in point dissolution at the contact. Soluble ions diffusing away and will have a tendency to precipitate on the unstrained sides of the grain surfaces, (Moore, 2001). Stylolites form thin surfaces of discontinuity within the rock, (Flugel 2010), but they can act as important conduits for fluid migration, (Tucker and Wright, 2002). In the studied formation, stylolite represents a late diagenesis process and was abundant at lower, middle, and upper parts, Pl(2-3).

8 - Dolomitization
Dolomitization is a process involve completely or partly converting of limestone or its precursor sediment to dolomite by the replacement of the original CaCO3 with magnesium carbonate, by the action of Mg bearing water,(Flugel, 2010). Although dolomitization enhance porosity, but the reservoir specifications has not affected by this process, propably because of the limited distribution of this process in the Yamama Formation, Pl (2-5).

9 - Neomorphism
Folk (1965) introduced this term to include the processes of recrystallization and inversion, (Boggs, 2009). Recrystallization is the changes in crystal size without any changing in mineralogy. Aggrading type is the most neomorphism process in the Yamama Formation resulting in a general increase in crystal size, and this occurs mainly in fine-grained limestones produce microsparite, (Tucker and Wright, 2002). Inversion (calcitization by Tucker and Wright, 2002) involve the transformation of aragonite and High-Mg calcite to Low-Mg calcite, (Flugel, 2010; Tucker and Wright, 2002). The transformation of aragonite to calcite increase the total rock volume of 8% result in decrease porosity to about 8%, (selley, 2000). In the studied formation, Inversion or calcitization could be diagnosed by the retaining the previous relict, Pl (2-6).
Figure 5. Diagenetic sequence for the Yamama Formation in Tuba-2 and Tuba-3 wells

Figure 6. Distribution of diagenesis processes in Tuba-2 Oil Field
Figure 7. Distribution of diagenesis processes in Tuba-3 Oil Field

Note: XPL = Cross-Polarized Light, X = Microscopic Magnified Power.

Plate (1)

1 - Micritization, Tu-2 Well, depth (3840.95m), X40, XPL.
2 - Cubic pyritization, Tuba-2 Well, depth (3806 m), X40, XPL.
3 - Framboidal pyritization, Tuba-2 Well, depth (3870 m), X40, XPL.
4 - Dissolution forms vuggy porosity, Tu-2 Well, depth (4088m), X40, XPL.
5 - Dissolution forms mold, vug, and interparticulate porosities, Tu-2 well, depth (3829 m), X40, XPL.
6 - Blocky cement, silicification, Tu-3 Well, depth (3940m), X100, XPL.
7 - Interparticle pores filled by spar calcite cement, mechanical compaction (red arrow) caused microfracture porosity (yellow arrow), Tu-3 Well, depth (3926m), X100, XPL.
8 - Syntaxial rim cement around echinoid fragment, Tu-3 Well, depth (3963m), X40, XPL.
Plate (1)
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Plate (2)

1- Chennal porosity filled by drusy cement, Tuba-2 well, depth (4042m), X100, XPL.
2- Silica replacement within bivalve shell, Tuba-3 Well, depth (3940m), X100, XPL.
3- Chemical compaction (stylolization), Tuba-3 well, depth (3926.95m), X40, XPL.
4- Dissilution forms channel porosity filled by organic matter, Tuba-3 Well, depth (3932.60 m), X40, XPL.
5 - Dolomitization, Tu-3 Well, depth (3930m), X100, XPL.
6 - Neomorphism, Tuba-2 Well, depth (3836.80m), X40, XPL.
7- Micritized benthic foraminifera, Tuba-3 Well, depth (3924.50m), X40, XPL.
8- Granular cement fill fractures, Tu-3 Well, depth (4859m), X40, XPL.
Conclusions
The aim of this paper is to diagnose the diagenesis processes in the Yamama Formation in Tuba Oil Field, illuminating the following conclusions:
1 – Carbonate rocks is the main constituent rocks forming Yamama Formation in addition to the occurrence of dolomite and shale.
2- The Top of Yamama Formation in Tu-3 Well is deeper than in Tu-2 Well
3-Nine diagenesis processes that effect on the Yamama Formation and ruled the porosity system in this formation, these processes are; micritization, pyritization, dissolution, silicification, cementation, mechanical compaction, chemical compaction (stylolites), dolomitization, and neomorphism.
4-The deposition of the studied formation was during a regressive period within inner ramp, mid ramp, and outer ramp environments.

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