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Facies-controlled dolomitization of the Lower Cretaceous Qamchuqa Formation, Kurdistan Region, Northern Iraq

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Summary

The Lower Cretaceous (Barremian – Albian) Qamchuqa Formation is a very thick lithostratigraphic unit in Northern Iraq and one of the prolific units that produce both oil and gas. Most of the formation is extensively dolomitized and it is this dolomitized succession that makes the best reservoirs of the formation. The dolomitization has obliterated most of the original textural facies properties but field observations and petrographic scrutiny shed some light on the pre-dolomitization lithofacies properties. These properties indicate that original textures included rudistic rudstone, and grainstone that accumulated in high energy carbonate shoals with possible rudistic reefs. The basin-ward facies of these carbonate shoals contained muddy facies of bioclastic floatsone, packstone and calci-mudstone. Most of these facies remained undolomitized. Farther landward of the shoal was a lagoonal depositional setting which accumulated muddy facies with interbeds of bioclastic (including rudists) rudstone to floatstone comparable to the shoal lithofacies. The lagoonal muddy facies is either non-dolomitized or contains fine-grained, most likely supratidal dolomudstone (possibly penecontemporaneous dolomite). The high energy rudistic and bioclasitic facies is highly dolomitized with medium to coarse-crystalline, idiotopic to hypidiotopic dolomite textures. The pathway of the dolomitizing fluids was most likely influenced by the porosity of the different facies of the formation. The carbonate facies being the one with the least mud content, coarsest grain size and significant inter- and intra-granular pores, dolomitizing fluids moved through the porous layers of the formation. The dolomitization process was most likely driven by hydrothermal fluids as suggested by the zebra nature and large, pervasive crystal sizes.

Introduction

Lower Cretaceous (Barremian – Albian) Qamchuqa Formation is one of the prolific reservoirs for oil and natural gas in northern Iraq. The formation is well-exposed in the mountainous region of Kurdistan-Iraq. Most of the exposed and subsurface rocks of the formation are well-dolomitized and highly porous, constituting the reservoir intervals that produce oil and gas in different fields, such as, Kirkuk, Khabbaz and Taq Taq (Fig.1) (Al Shddidi, et al., 1995; Al-Qayim, et al., 2010; Al-Qayim and Rashid, 2012; Ghafur and Hasan, 2017). Despite the high economic importance of these rocks, our knowledge on the dolomitization process, origin and nature of the reservoir properties, and stratigraphic and lateral distribution of the dolomitized zones needs further enrichment. For the purpose of understanding the vertical lithostratigraphic succession of the formation and the extension of its dolomitized zones, we have started to study the type section of the formation which occurs within Qamchuqa Village (Fig. 1). The logged section preserves a thickness of 730 meters for the formation. The latter is conformably underlain by the Early Cretaceous section of the Sarmord Formation and unconformably overlain by the Turonian section of Kometan Formation (Jassim and Goff, 2006; Al-Qayim and Rashid, 2012; Ameen and

Gharib, 2014). The section has been sampled based on lithofacies variations recognized in the field; the samples were then thin-sectioned for petrographic study.

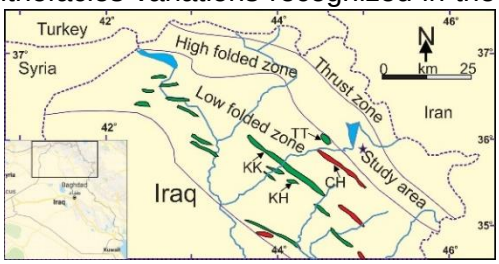

Fig. 1 Location map of Northern Iraq including the study area (star) and several oil (green) and gas (red) fields in the region. Re-drawn from Al-Qayim et al., 2010. KK = Kirkuk Oilfied, KH= Khabaz Oilfield, TT= Taq Taq Oilfied, CH= Chamchamal Gas field.

Lithostratigraphy and depositional facies

The type section of the formation preserves thick stratigraphic units and allows the subdivision of the formation into three informal members of lower, middle and upper. The lithofacies properties of the three members are described below.

Lower Qamchuqa member: The lower member is about 250m thick and dominated by various limestone lithofacies. The unit starts with thick to massively bedded limestone and dolostone layers. These are followed by thin- to medium-bedded limestone (Fig. 2). Four lithofacies have been recognized for the member and they include lime rudistic floatstone, dolostone, calcimudstone and bioclastic packstone. The rudistic floatstone is thick to massive bedded rocks with large rudistic fragments, bivalves and milliolids that are scattered within micritic mud. Partial dolomitization along the rudist fragments has been observed (Fig.3a).

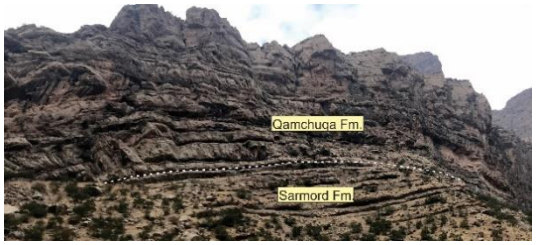

Fig. 2 Outcrop section showing the Sarmord-Qamchuqa formations and the thick beds of the lower member of the Qamchuqa Formation. Field of view is 200m.

This facies is poorly porous and most of the previously existing pore spaces are filled by calcite cement. The dolostone lithofacies is composed of thick to massive beds of medium crystalline, idiotopic to hypidiotopic dolomite textures. Presence of rudist fragments can be recognized. The intensive dolomitization has obliterated the original texture of the rocks, however, petrographic analysis (under white paper technique) shows existence of granular facies of most likely micritized or pelletized bioclastic grains. Porosity types associated with this unit are intercrystalline, vugy and fracture that are partially filled by cement. The calcimudstone lithofacies is composed of thin to medium bedded, burrowed limestone with miliolid, *Choffatella*, *Salpingoporella dinarica*, other types of green algae and rudist fragments. This lithofacies is nonporous and both intraparticle and fracture pores are filled by calcite cement. The bioclastic packstone lithofacies is composed of thin to medium bedded strata that contains green algae, *Choffatella*, *Salpingoporella dinarica,* miliolids, bivalves and gastropods (Figure 3b). Few porosity types are observed such as fracture and moldic porosity which is mainly filled with secondary calcite cement.

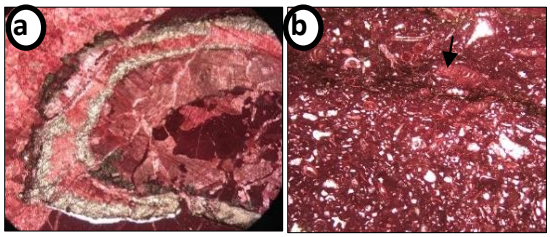

Fig. 3: a) Large rudist fragment partially replaced by dolomite. b) Biocalstic packstone with Choffatella grains (arrow). Field of view is about 8mm for both photos.

Middle Qamchuqa member: This member is about 325m of thick to massive bedded dolostone. The dolostone lithofacies is characterized by medium to coarse crystalline, idiotopic to hypidiotopic textures. Intensive dolomitization is destroyed most of the properties of the original textures. Detailed petrographic study shows that the rocks are dominated by granular texture with no or little matrix content (Fig. 4a). Some recognizable bioclasts include rudists, echinoids and foraminifera tests (such as milliods, biserial forams and *Orbitolina*) (Fig. 4b). The overall granular texture and presence of the bioclasts may indicate that original facies were porous rudstone to grainstone nature. Zebra structure is widely present in the middle member of the formation. Open intercrystalline, large vuggy and fracture porosity commonly occur in this member and forms the most attractive reservoir of the formation.

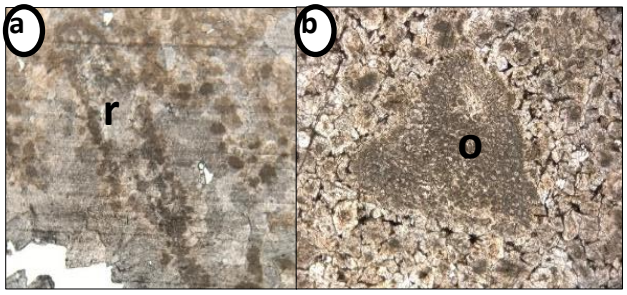

Fig. 4 a) Dolomitized and poorly-preserved rudistic (r) rudstone, b) Coarse-crystalline bioclastic grainstone with Orbitolina (o). Field of view is about 8 mm for both.

Upper Qamchuqa member: The upper member is about 155m and starts with 43m thick unit of thinly-bedded bioclastic calcimudstone with milliolids, *Cuneolina*, biserial forams and bivalves (Fig. 5). The dolostone facies is dominated by medium to coarse-crystalline bioclastic dolostone comparable with the dolomites of the middle member (Fig. 6a. 6b). The uppermost part of the member contains thick beds of fine crystalline dolostone most likely supratidal dolomudstone (possibly penecontemporaneous dolomite). This uppermost part contains some paleosol features such as cutans and chalcedonic glaebules suggesting an exposed surface (Salad Hersi et al., 2002) and development of the post-Qamchuqa unconformity.

Fig. 5 Qamchuqa – Kometan contact which is an unconformable contact where lagoonal and shallow marine carbonates are overlain by deep shelf carbonates full of planktonic foraminifera.

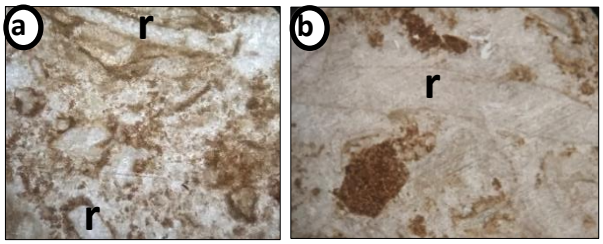

Fig. 6. Both figures are showing rudistic rudistone lithofacies that are highly dolomitized. The fossil outlines are recognized by using the white paper technique. R = rudist fragments. Field of view is about 8 mm for both photos.

Dolomitization pathway

The above sections of the paper demonstrate that the mud-containing lithofacies (e.g., lime mudstone, floatstone and packstone) were not dolomitized. These lithofacies occur mainly in the lower member of the formation and, subordinately, in the upper member. The latter also contains fine-crystalline dolomudstone interpreted as penecontemporaneous dolomite. Most of the middle member and a significant portion of the upper member are characterized by the granular lithofacies with micritized bioclasts and large rudistic fragments. These granular lithofacies constitute the most extensive dolomitization with medium to large crystalline textures. These members accumulated in a high energy subtidal environment with little or no presence of micritic mud. Thus, they contained a good amount of primary intergranular and intragranular (e.g., in the rudists) pores. It is envisaged here that the high primary porosity of the granular facies, both in the middle and upper members, formed the main pathway for the dolomitizing fluids. These fluids were most likely hydrothermal in nature and driven by the end-Cretaceous – early Neogene compressional tectonics of the region (Kareem et al., 2016). The initial vertical invasion of the hydrothermal fluids came along tectonically-induced faults but their lateral penetration was controlled by the rock permeability. Thus, the muddier facies were not affected by the dolomitization process whereas the coarser-grained lithofacies became the major recipients of the dolomtizing fluids. Extensive dissolution and dolomitization have produced different types of porosities (e..g., intercrystalline and vuggy) which make these rocks good reservoirs. Fracturing has also enhanced the overall porosity of the Qamchuqa Formation in both surface and subsurface regions of northern Iraq.

Conclusions

Lower Cretaceous Qamchuqa succession is divisible into three informal members. The lower limestone-dominated lithofacies is composed of around 250m thin-medium bedded limestone of rudist-bearing floatstone, packstone and calci-mudstone lithofacies with thick to massive bedded dolostone at the base. The middle member is about 325m thick and characterized by massive to poorly-bedded, medium to coarse-crystalline dolostone lithofacies. Although most of the primary textural properties are destroyed by the dolomitization process, detailed petrographic analysis shows that the member is dominated by granular texture with rudist, micritized bioclasts and different types of foraminiferal grains. The original depositional textures of the rocks that constitute this member were rudistic rudstone, bioclastic / peloidal grainstone with almost no micritic mud leading to relatively high primary pore content. This has allowed the dolomitizing fluids to invade the rocks and consequently produce highly dolomitized succession with extensive vuggy and intercrystalline porosity (i.e., good reservoir properties). The upper member is around 155m thick and dominated by thickly to medium-bedded, fine- to coarse-crystalline dolostone with subordinate thin bedded calci-mudstone interbeds. The dolomudstone layers are interpreted as early penecontemporaneous dolomite but the medium to coarse-crystalline dolostone are similar to those described in the middle member in all aspects.

Acknowledgements

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