Linking depositional environments and diagenetic processes to porosity evolution and destruction in the Arab Formation reservoirs, Offshore oilfields of Qatar

Faculty and PostDoc
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Abstract

Using a multi-proxy approach based on core analysis, thin sections and log data from the Jurassic Arab reservoirs in selected wells in the offshore area of Qatar, the reservoir has been divided into a set of distinctive petrophysical units. The Arab Formation consists of cyclic sediments of oolitic grainstone/packstone, foraminifera-bearing packstone-wackestone, lagoonal mudstone and dolomite, alternating with anhydrite. The sediments underwent a series of diagenetic processes such as leaching, micritization, cementation, dolomitization and fracturing. The impact of these diagenetic processes on the different depositional fabrics created a complex porosity system. So, in some cases there are preserved depositional porosity such as the intergranular porosity in the oolitic grainstone, but in other cases, diagenetic cementation blocked the same pores and eventually destroyed the pores. In other cases, diagenesis improved the texture of non-porous depositional texture such as mudstone through incipient dolomitization creating inter-crystalline porosity. Dissolution created vugs and void secondary porosity in otherwise non-porous foraminiferal wackestone and packstone. Therefore, creating a matrix of depositional fabrics versus diagenetic processes enabled the identification of different situation in which porosity where either created or destroyed. By correlating such petrographic data with logs, it will become possible to identify certain "facio-diagenetic" signatures on logs which will be very useful in both exploration and production studies.

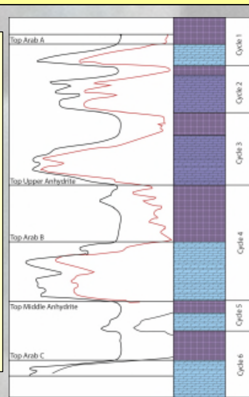
Depositional Fabrics	Dissolution Y	Dissolution N	Micritization and burrowings Y	Micritization and burrowings N	Cementation Y	Cementation N	Dolomitization Y	Dolomitization N	Fracturing Y	Fracturing N
Oolitic grst	Enhanced Intergranular	Intergranular	Intergranular Alteration porosity	Intergranular porosity	No Porosity	Intergranular	Inter-crystalline OR No porosity	Intergranular	Enhanced Intergranular Fracture Porosity	Intergranular
Foram algal pc/wc	Enhanced Intraparticle porosity Dissolution porosity	Intergranular porosity	Intergranular porosity Bioturbation porosity	Intergranular porosity	No Porosity	Intergranular porosity	Inter-crystalline OR No porosity	Intergranular porosity	Enhanced Intergranular porosity Fracture Porosity	Intergranular porosity
mudstone	Dissolution porosity	No porosity	Bioturbation porosity	No porosity	No porosity	No porosity	Inter-crystalline OR No porosity	No porosity	Fracture Porosity	No porosity
dolomite	Enhanced Inter-crystalline	Inter-crystalline	NA	Inter-crystalline	No Porosity	Inter-crystalline	NA	Inter-crystalline	Enhanced Inter-crystalline Fracture Porosity	Inter-crystalline
anhydrite	Dissolution porosity	No porosity	NA	No porosity	No porosity	No porosity	NA	No porosity	Fracture Porosity	No porosity

Porosity Creation | Porosity Destruction | No change | Non-Applicable

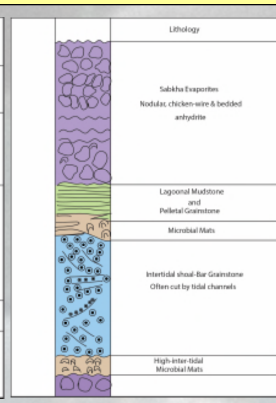
A **matrix** of the main **depositional fabrics** of the Arab Formation versus the main **diagenetic processes** that impacted its rocks appears in the table at the top.

The main rock types forming the Arab Formation are oolitic-peloidal grainstone-wackestone that formed persistent shoals all over the region, shallow-shelf carbonates formed of limestone and dolomitic limestone containing large benthonic foraminifera with green algae, mudstone with less than 10% of small dwarfed fossils which are believed to form in saline lagoons or restricted shelves, dolomite which represents a replaced texture some of them are difficult to recognize with beds of anhydrite. The main diagenetic processes include dissolution by meteoric water at exposure surfaces or after the final deposition of the formation, bioturbation that include micritization and burrows, cementation which was mainly meteoric blocky cement, dolomitization which may be selective or full dolomitization of the whole rock and fracturing as a result of tectonic activity.

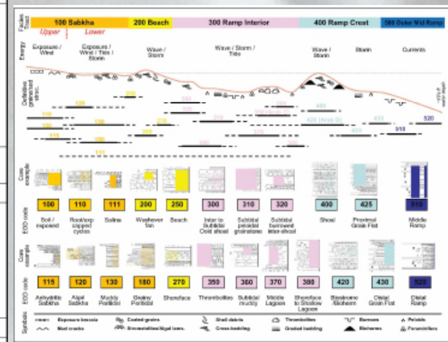
Plotting the two components versus each other led to the creation of a matrix that shows the best combination to create or destroy porosity as well as the cases where the original status is preserved. Clear from the table that diagenesis is creating more porosity than destroying it. This best example of this is the impact of dissolution that either enhance the intergranular, intragranular and inter-crystalline porosity or create news vugs and voids by dissolving the less stable components. Dolomitization and fracturing also either improve or create new porosity types. The destruction occurs only by cementation that may block primary or secondary porosity and also some interlocking dolomite that destroy the pores. So in general, diagenesis seems to improve the reservoir characteristics of the formation.



Depositional cycles of the Arab Formation



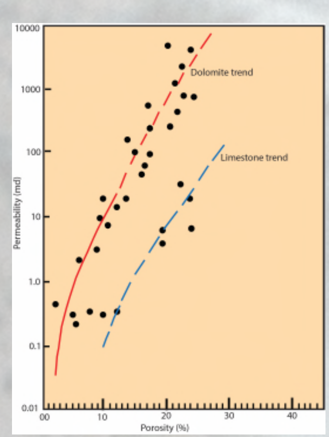
Typical lithologies of the Arab Formation

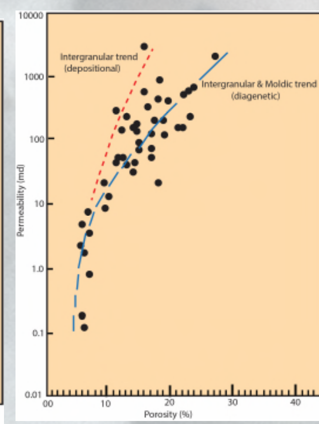


Depositional environments of the Arab Formation (Stephens et al., 2009)

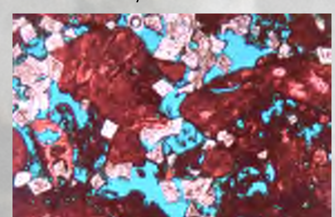
Porosity-Permeability relationship

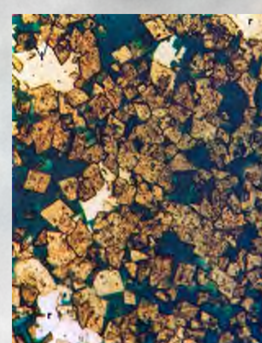
Plotting porosity versus permeability values provides a first-hand knowledge about both these two important reservoir parameters were created. For the Arab Formation, clearly there are two sets of data one for the limestone reservoirs and one for the dolomite. The second trend is that is a clear differentiation between primary and secondary porosity although this may be difficult to envisage due to the complex fabrics resulted from the act of different and successive diagenetic processes on different depositional textures with the presence or absence of biological components. In the limestone dominated reservoirs, the average porosity values range between 1-20% with relatively low permeability that does not exceed 100 MD. In the dolomite dominated reservoirs, this is much larger with porosity ranging between 3-30% and permeability within the range of 10000 MD. This variation is resulted from the nature of the dolomitization process, since dolomite increases porosity by around 13% during the early stages but then starts to block and destroy porosity and permeability as the dolomite crystals grow bigger and become interlocked. The same thing can be said about the difference between depositional and diagenetic porosity trends, where it is found that the values of the depositional porosity rarely exceeds 10% with permeability of around 5000 MD, while the diagenetic porosity trend shows much wider variations





Porosity Destruction



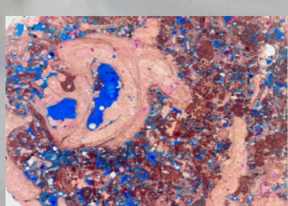


Top left: Oolitic grainstone which is a typical reservoir rock of the Arab Formation. In usual cases porosity of this rock type is around 26% but here the whole porosity is blocked by sparry calcite cement which may be of freshwater (meteoric) water origin.

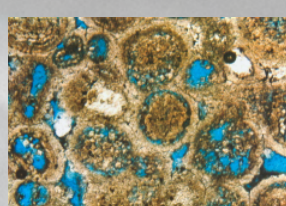
Middle: Peloidal bioclastic grainstone. The blue areas are pores, but large parts of these pores are blocked by medium-sized rhombs of dolomite. Usually dolomite improves porosity but not in this case.

Top right: Saccharoidal dolomite with well-developed inter-crystalline porosity (blue areas). However, some of these pores are blocked by anhydrite cement (white areas).

Porosity Creation



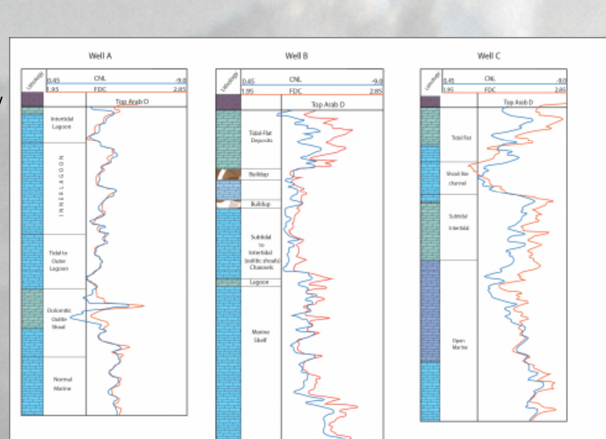
Intragranular porosity in bioclastic packstone enlarged by dissolution



Intergranular porosity in oolitic grainstone enlarged by dissolution and dissolving the nuclei of the ooliths

Inter-crystalline porosity created by dolomitization of otherwise impervious mudstone

Core piece formed of two contrasting micritic lime mudstone. Usually these rocks have no significant porosity, but fractures are well-developed and can be porosity and permeability channels at the same time



Correlation of the studied offshore wells shows a considerable variation in the depositional environments and the rock types of the Arab Formation. While the Well A and C show similar development of intertidal flats and lagoons, the Well B shows a more varied lithologies with the development of buildups formed of stromatoporoids and coral-algal association. Development of such buildups may be induced by the presence of some sub-marine highs resulted from the upward movement of the Hormuz Salt. This correlation on such a relatively small area gives indication about the scale of variation in both depositional environments and diagenetic process of the Formation.

Conclusions

1. **The Jurassic Arab Formation reservoirs in the offshore oilfields of Qatar shows a wide variation in the depositional environments in a relatively small area.**
2. **These rocks were subjected also to varied diagenetic processes that destructed partially or totally the original fabrics of the rocks and created new fabrics.**
3. **A matrix is developed between the depositional environments and diagenetic processes.**
4. **It is found that diagenesis was constructive in most of the time creating secondary porosity as it is the cases with bioturbation, dolomitization, and fracturing and destructive in the case of cementation.**
5. **By cross-plotting depositional fabric versus diagenesis facio-diagenetic units can be recognized.**
6. **These units can be imposed on logs and used for exploration and production purposes.**

Acknowledgment

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