# A Reservoir Scale Case Study: Facies Geometries, Cyclicity, and Depositional Environments of the Heterogeneous Oolitic Miocene Sequence, Wadi Al-Qattarah Formation, Cyrenaica Platform, Northeast Libya


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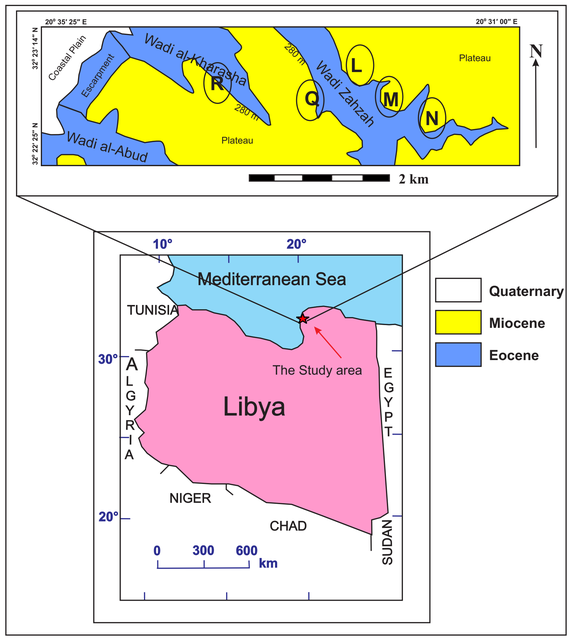


**Figure 1 Location and geological maps of the Miocene sequence, al-Qattarah Formation, Cyrenaica, NE Libya**



**Figure 4 Field photos for the small and large scale cross bedding in the oolitic grainstone of the Miocene sequence, al-Qattarah Formation, Cyrenaica, NE Libya**


## ABSTRACT

Five detailed field sections of 31 m maximum thickness, along 3.5 km distance were measured in the Middle to Late Miocene succession of Wadi al-Qattarah Formation. Five distinctive sedimentary facies associations were distinguished in the oolitic Miocene shallowing upward sequence. The facies associations are: 1) transgressive phase facies association, 2) Tidal shoal sand bar facies associations, 3) tidal shoal channels facies associations, 4) tidal spillover lobe sand-belt facies associations, and 5) interchannel 'bay' pond facies association. Moreover, interchannel flats or levees are regarded as subfacies and incorporated in tidal channels facies associations, and interchannel pond filling facies associations.

The transgressive phase facies associations form a fining upward cycle that is made up of skeletal conglomeratic-lime and limesand fragments of coralline red algae, gastropods, echinoids, and other shell fragments. It is graded, laminated and well bedded. This unit rests unconformably above the older Eocene rocks.
The tidal sand bar facies associations form a coarsening upward cycle of non-skeletal and skeletal limesand. It comprises ooids, composite ooids, pellets, fragmented coralline red algae, and gastropods. It is laminated, well bedded, and cross bedded, with imbrications structures at the base.
The tidal shoal channels facies associations form a fining upward cycle of skeletal and non-skeletal conglomeratic-lime, limesand, and pure limemud, and oncolitic-ooids. Gastropods, benthic forams and shell fragments are common in this unit. It is graded, laminated, cross laminate, well bedded, and burrowed at the top.
The tidal spillover lobe sand-belt facies associations form a uniform cycle of oolitic grainstone. It has a few echinoids shell fragments. The unit is graded, laminated, cross laminated, well bedded, and cross bedded, with lens shape channels that show soft sediment deformation and sharp basal surface. This sand waves and sand bars unit is characterized by a composite set of large planar and trough crosses bedding overlain by a small scale planar and trough cross bedding and then capped by wave-formed ripples.
The Interchannel 'bay' pond facies associations form a coarsening upward cycle of skeletal and non-skeletal limesand includes ooids and pellets. This unit contains bivalves, gastropods, and benthic forams. It is graded, laminated, cross laminated, and well bedded.

The heterogeneous oolitic Miocene shallowing upward sequence was deposited in the tidal environment as indicated by its facies associations and the herring-bone cross bedding. This outcrop case study covered a limited portion of the oolitic Miocene sequence that extends for more than 150 km along a dip profile and its excellent 3-D exposure makes it an analogue for ooid grainstone carbonate reservoirs in the subsurface within the Mediterranean region and globally.


## INTRODUCTION

The study area located in the western part of Al-Jabal Al-Khdar, 70 km northeast Benghazi city along the coastal escarpment. Its boundaries are defined by the longitudinal lines 20°35' 25' 'E and 20°31'00" E and the latitudinal lines 32°22'25"N and 32°23'14" N. The main objectives of this study are to define depositional facies and their environment, facies cyclcity, facies gemetries, facies heterogeneity, and to make stratigraphic correlations based on high resolution field measured sections in this carbonate ramp setting.

## METHODS

Five detailed bed-by-bed field sections measured in the al-Qattarah Formation. The measured data includes lithology, sedimentary structures, fossils identification and vertical variations, facies geometries and thickness variations, nature of bedding surfaces, facies vertical and lateral changes, and facies cyclicity.

## DISCUSSION

The W-E stratigraphic cross section delineated geometries of the facies associations and highlighted their vertical heterogeneity. The base of the tidal spillover lobe sand-belt facies was selected as datum for this high resolution stratigraphic correlation. The studied Cyrenaican Miocene carbonate ramp is made up of a shallowing upward sequence that comprise five facies associations. The facies associations are: 1) transgressive phase facies association, 2) Tidal shoal sand bar facies associations,3) tidal shoal channels facies associations, 4) tidal spillover lobe sand-belt facies associations, and 5) interchannel 'bay' pond facies association. Moreover, interchannel flats or levees are regarded as subfacies and incorporated in tidal channels facies associations, and interchannel pond filling facies associations. All facies associations in this study are separated from each other by sharp surfaces. The transgressive phase facies associations form a finning upward cycle of reworked bioclastic grainstone that includes fragmented red algae as dominant component and gastropods. This facies overlain by a coarsening upward cycles of shoal sand bars facies associations that made up of a mixture of ooid-bioclastic grainstone. It has two coarsening upward cycles dominated with ooids, composite ooids, and pellets with fragmented coralline red algae and gastropods. the next facies associations up in the section is the tidal shoal channels facies associations. It is made up of two finning upward cycles of channels fill that topped by tidal flats. The lower channel is made up of a finning upward ooid-bioclastic grainstone that has erosional, and burrowed base with bioclastic lags and topped by well bedded and rippled tidal flat deposits. The upper channel fill is laminated and rippled mudstone with some wackestone intervals and topped with well bedded and rippled tidal flat deposits. These channels are overalin by a roughly coarsening upward cycles of oolitic grainstone spillover lobes facies associations. The spillover lobes sand belts are very well bedded, laminated, cross laminated, and cross bedded. It has two cross bedding sets separated by a sharp surface. The lower set is made up of large scale planar cross bedding topped by large scale trough cross bedding, where the upper set is made up of small scale planner cross bedding contains herring bone cross bedding followed by small scale trough cross bedding and then topped by smaller scale bundle wave ripples. The upper facies association is intertidal shoal pond filling bio-oolitic grainstone, which characterized by a coarsening upward cycle within tidal flat facies. It is made up of a coarsening upward cycle that laminated in the lower part and become coarser and structureless at the top and then capped by well bedded and rippled tidal flat deposits.

## CONCLUSION

The al-Qattarha Formation of the Cyrenaican Miocene is made up of a heterogenous shallowing upward cycle that contains five facies associations. These facies associations deposited in a ramp setting in a high energy grainstone dominated tidal environment. This shallowing upward sequence shows a rapid facies change vertically. The depositional facies spacial distribution suggest an oolitic shoals overlain by tidal flats and dissected by tidal channels.

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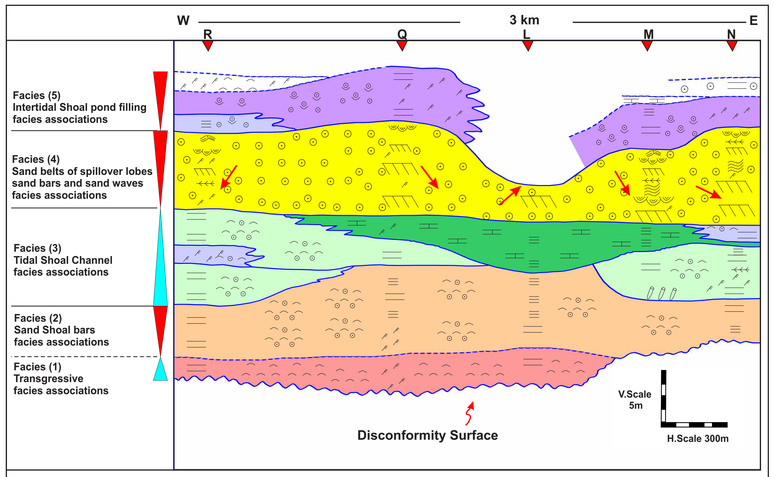


**Sedimentary Structures:**

Trough cross bedding (Large Scale, Small Scale)
Planar cross bedding
Herring bone X-bedding
Cross lamination
Puandle wave ripple cross bedding
Well bedding
Laminae
Soft sediment deformation
Inclined burrows
Palaeocurrents vector mean direction
Disconformity Surface
Mudstone and Wackestones
Cross Bedded Oolitic Grainstone
Bioclastic Grainstone
Ooid-Bioclastic Grainstone
Bioclastic-oolitic Grainstone

**Figure 2 The stratigraphic cross section of the Miocene sequence, al-Qattarah Formation, Cyrenaica, NE Libya**

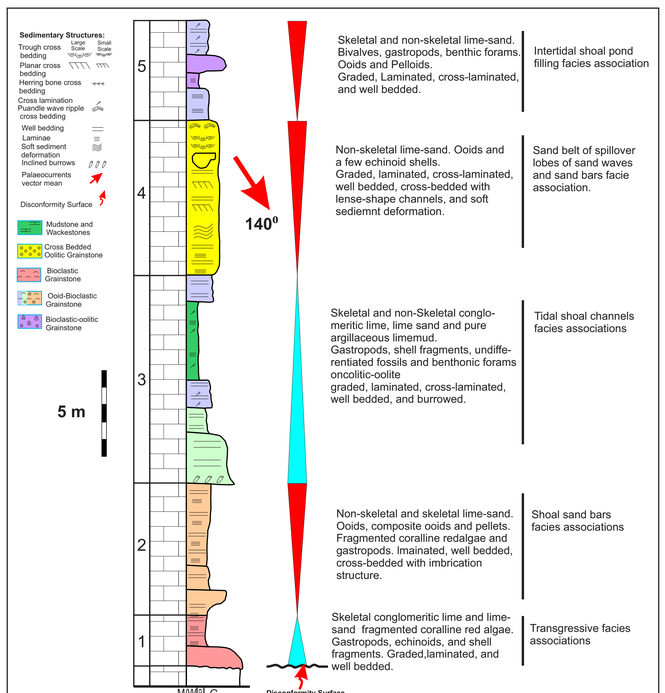


**Figure 3 The ideal carbonate Shallowing upward sequence of the Miocene al-Qattarah Formation, Cyrenaica, NE Libya**