Paleoshoreline and Prograding Clinoforms of Oolitic Grainstones of the Miocene Carbonate-Evaporitic Sequences of the Ar-Rajmah Group, Al-Jabal Al-Khdar Uplift and Soluq Trough, Cyrenaica, NE Libya

Khaled S. Amrouni1,2, Michael C. Pope1, Ahmed S. El-Hawat2, Adel A. Obeidi2, Aimen Amer2, Hassan S. El-Bargathi2, Mohamed SH. Abdalla El-Jahmi2, Ahmed M. A. Al-Alwani2, Essa A. Elbileikia1, and Khalid A. M. Mustafa2

1Department of Geology and Geophysics, Texas A&M University, MS 3115, College Station, Texas 77843
2Earth Sciences Department, Garyounis University, Benghazi, Cyrenaica 55555, Libyan Arab Jamahiriya

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ABSTRACT

This work focuses on the relationship between the unidirectional large scale clinoforms of oolitic grainstones and the paleoshoreline along 135 km in the Cyrenaican Miocene carbonate-evaporite ramp, NE Libya. Detailed regional facies relationships were determined from 29 measured stratigraphic sections, and 14 spectral gamma-ray profiles. Seven measurements of the progradation direction of oolitic clinoforms were taken at five different locations. The ramp oolitic grainstone facies was mapped and the azimuth of the unidirectional clinoforms measured data was plotted on the maps.

The Ar-Rajmah Group Miocene carbonate rocks record six 3rd order sequences. The Lower Miocene Benghazi Formation is up to 46 m thick, dominated by red algal reefs, bioclastic packstones, and contains some oolitic grainstone. The Middle and Upper Miocene Wadi Al-Qattarah Formation is up to 26 m and 25 m thick, respectively, dominated by continuous oolitic grainstones and microbialites associated with evaporites and siliciclastics.

The oolitic grainstone facies which is the focus of this study is spatially restricted between two parallel curved faults that run roughly north-south. These curved faults form the lower escarpment in the west (LE-fault) and upper escarpment in the east (UE-fault) and the spacing between them is 40 km in the south and 20 km in the north. The azimuths of the large scale unidirectional clinoforms of the oolitic grainstone facies between these two faults are in opposing directions to each other, but still parallel to the curved fault lines. In contrast, the azimuths of those clinoforms at or close to the west-
ern Lower Escarpment fault line (palaeoshoreline) are roughly perpendicular to the curved fault line and prograde to the east-southeast.

The clinoforms are always within a depositional sequence that starts with subtidal bioclastic wackestone/ grainstone sharply overlain by ramp crest oolitic grainstone, which may or may not be capped by microbial facies. The sedimentary structures of the oolitic grainstone facies are large clinoforms that change upward into either largescale trough cross-bedding or herringbone cross-bedding. The oolitic clinoforms are of 2–4.5 m thick and increase in thickness towards the north. The types of sedimentary structures and inconsistent direction of progradation indicate that the prograding oolitic grainstone clinoforms of the Cyrenaican Miocene were controlled by wave-tide depositional processes and tectonic fault lines running parallel to the paleoshoreline.
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Presented by
Dr. Khaled S. Amrouni


(1)Department of Geology and Geophysics, Texas A&M University, College Station, TX 77843, (2) Department of Earth Sciences, Garyounis University, Benghazi, Barga (Cyrenaica), Libya

amrouni@neo.tamu.edu/abcde_909@yahoo.com, mcpope@geo.tamu.edu, ashawat@lttnet.net, adelobeidi@yahoo.com, aamer@slb.com, Hasbargati@yahoo.co.uk, mohammed_eljahmi@yahoo.com, ahmedalalwani87@gmail.com, a.al3alwani@yahoo.com, essap2005@yahoo.com, geu.1987@yahoo.com

Session Title: CONVENTIONAL CLASTICS AND CARBONATES, Session Style: Technical-Talk
Bill Ambrose and Mike Bergsma, Session Chairs
Session Date: Tuesday-Sept 19, 2016- 4:05 PM
Session Location:
Measurements & Analysis:
(A) 29 detailed measured stratigraphic sections
(B) 14 gamma ray scintillometer profiles,
(C) 11 Depositional Facies, and
(D) 2 Structural elements (faults), and
(E) Azimuths of 7 prograding oolitic clinoforms,
(F) Anatomy of the prograding oolitic clinoforms sequences,

- Through time analysis, integration, and mapping of the sedimentological, stratigraphic, clinoforms progradation azimuths, and structural elements data sets to define the relationship between the oolitic grainstones unidirectional large scale clinoforms and the palaeo-shoreline along 135 km in the Cyrenaican Miocene carbonate-evaporite ramp of NE Libya
Location

Cyrenaican Miocene, Al-Jabal Al-Khdar Uplift and Soluq Trough, NE Libya

Central Mediterranean

- Base map and location map with measured sections annotations
Sedimentology and Sequence Stratigraphy

The Ar-Rajmah Group: nine carbonate facies and two siliciclastic facies, deposited in three environments on a gently sloping ramp.

- **The peritidal facies**: 1) evaporite, 2) microbialite (stromatolites, thrombolites, and laminite), 3) pelletal wackestone/packstone, 4) porites reefs and bioclastic packstone, 5) very fine to fine quartz sandstone, 6) green shale.

- **The ramp crest facies**: 1) oolitic grainstone.

- **The subtidal facies**: 1) bioclastic carbonate, 2) reworked bioclastic carbonate, 3) red algae reefs, 4) reworked red algae.
Ramp Depositional models, Ar-Rajmah Group

Legend:
- **Peritidal Facies:**
  - Evaporite (only Gypsum)
  - Microbialite Reef
  - Pellets
  - Siliciclastics
  - Mixed Carbonate-Siliciclastic

- **Ramp Crest:**
  - Oolitic Grainstone
  - Bioclastic Carbonate

- **Subtidal Facies:**
  - Red Algae Reef
Sigmoidal prograding oolitic clinoform, location C1
Tabular prograding oolitic clinoforms, location B1
Anatomy model diagram of the ideal vertical sequences of the sedimentary structures in the fossilized prograding oolitic clinoforms of the Cyrenaica Miocene, Ar-Rajmah Group, NE Libya (Amrouni, 2000).
Locations, azimuths, and facies of the prograding oolitic clinoforms.

<table>
<thead>
<tr>
<th>Log Name</th>
<th>360 Direction in Degrees</th>
<th>Number of Readings</th>
<th>Facies</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>90</td>
<td>1</td>
<td>Oolitic grainstone</td>
</tr>
<tr>
<td>B1</td>
<td>105</td>
<td>2</td>
<td>Oolitic grainstone</td>
</tr>
<tr>
<td>C1</td>
<td>340</td>
<td>1</td>
<td>Oolitic grainstone</td>
</tr>
<tr>
<td>D1</td>
<td>215</td>
<td>1</td>
<td>Oolitic grainstone</td>
</tr>
<tr>
<td>E1</td>
<td>135</td>
<td>1</td>
<td>Oolitic grainstone</td>
</tr>
<tr>
<td>H1-H2</td>
<td>0</td>
<td>1</td>
<td>Bio-Oolitic grainstone</td>
</tr>
<tr>
<td>H1-H2</td>
<td>10</td>
<td>1</td>
<td>Bio-Oolitic grainstone</td>
</tr>
</tbody>
</table>
## Locations, azimuths, sedimentary structures, facies, environments and geometries of the prograding oolitic clinoforms

<table>
<thead>
<tr>
<th>Clinoforms Location and proximity to the LE-Fault (paleoshoreline)</th>
<th>Oolitic Grainstone Packages</th>
<th>Prograding oolitic Clinoforms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D1</strong> Far from LE-fault</td>
<td>- Thickness: 15.5 m</td>
<td>- Thickness: 4 m</td>
</tr>
<tr>
<td></td>
<td>- Bottom Facies: bioclastic wackestone-packstone</td>
<td>- Bottom Facies: laminated oo-bioclastic grainstone</td>
</tr>
<tr>
<td></td>
<td>- Top Facies: bioclastic bioturbated pelletal-wackestone</td>
<td>- Top Facies: laminated bioclastic-oolitic grainstone</td>
</tr>
<tr>
<td></td>
<td>Sedimentary Structures: large scale planar x-bedding, small scale planar x-bedding, large scale herringbone x-bedding. Then another cycle laminae, LS planar x-bedding, LS festoon trough x-bedding. medium scale herring bone x-bedding.</td>
<td>Geometry, azimuth, and Environments: Sigmoidal composite sets 215-SSW Wave to Tide</td>
</tr>
<tr>
<td><strong>E1</strong> Close to LE-fault</td>
<td>- Thickness: 8.5 m</td>
<td>- Thickness: 3 m</td>
</tr>
<tr>
<td></td>
<td>- Bottom Facies: pelletal bioclastic wackestone-packstone</td>
<td>- Bottom Facies: laminated bioclastic-oolitic grainstone</td>
</tr>
<tr>
<td></td>
<td>- Top Facies: bioclastic packstone/grainstone</td>
<td>- Top Facies: laminated oo-bioclastic grainstone</td>
</tr>
<tr>
<td></td>
<td>Sedimentary Structures: The lower part: tabular large scale planar x-bedding, large scale trough x-bedding, lens-shaped channel with soft sediment deformation, cross lamination, and lamination. The upper part: small scale planar x-bedding, small scale trough x-bedding, chevron and bundle ripples, low angle x-bedding and includes channels with soft sediment deformation, herring bone x-bedding, reactivation surfaces, cross lamination, and lamination.</td>
<td>Geometry, azimuth, and Environments: Tabular Composite sets 135-SE Wave to Tide</td>
</tr>
<tr>
<td><strong>C1</strong> Far LE-fault</td>
<td>- Thickness: 8 m</td>
<td>- Thickness: 4.5 m</td>
</tr>
<tr>
<td></td>
<td>- Bottom Facies: bioclastic mudstone</td>
<td>- Bottom Facies: Laminated bioclastic mudstone</td>
</tr>
<tr>
<td></td>
<td>- Top Facies: bioclastic packstone</td>
<td>- Top Facies: Laminated bioclastic packstone</td>
</tr>
<tr>
<td></td>
<td>Sedimentary Structures: The lower 3 m part laminated bottom set, the fore set: large scale planar, lens-shaped channel with soft sediment deformation, and laminated top set then sharp surface followed by 1 m thick small scale planar x-bedding, then sharp surfaces and 0.5 m laminated ooids.</td>
<td>Geometry, azimuth, and Environments: Sigmoidal composite sets 340-NNW Wave to Tide</td>
</tr>
<tr>
<td><strong>B1</strong> Close to LE-fault</td>
<td>- Thickness: 12 m</td>
<td>- Thickness: 2.5-3 m</td>
</tr>
<tr>
<td></td>
<td>- Bottom Facies: bioclastic graminste</td>
<td>- Bottom Facies: laminated bioclastic-oolitic grainstone</td>
</tr>
<tr>
<td></td>
<td>- Top Facies: nodular mudstone/Wackestone</td>
<td>- Top Facies: laminated bioclastic-oolitic grainstone</td>
</tr>
<tr>
<td></td>
<td>Sedimentary Structures: large scale planar overlain by trough x-bedding and then fenestral laminae</td>
<td>Geometry, azimuth, and Environments: Tabular composite sets 90-105-E-SE Wave to Tide</td>
</tr>
<tr>
<td><strong>H1-H2</strong> Close to LE-fault</td>
<td>- Thickness: 5 m</td>
<td>- Thickness: 1.5 m</td>
</tr>
<tr>
<td></td>
<td>- Bottom Facies: oo-bioclastic grainstone</td>
<td>- Bottom Facies: laminated oo-bioclastic packstone</td>
</tr>
<tr>
<td></td>
<td>- Top Facies: bioclastic microbial boundstone</td>
<td>- Top Facies: laminated microbial-oolitic grainstone</td>
</tr>
<tr>
<td></td>
<td>Sedimentary Structures: tabular large scale planar overlain by laminae and then sharp mudcracke surface of microbial origin</td>
<td>Geometry, azimuth, and Environments: Tabular composite sets 0-10-N-NE Wave to Tide</td>
</tr>
</tbody>
</table>
Through time Analysis and Integration (Maps Analysis).

Data sets of sedimentological, stratigraphic, Prograding oolitic clinoforms azimuths, and structural elements
The paleogeographic map of the Early Miocene of Cyrenaica, Ar-Rajmah Group, NE Libya includes: oolitic grainstone facies distribution, the lower escarpment fault and the upper escarpment fault, locations of the visited outcrops.
The paleogeographic map of the Early Miocene of Cyrenaica, Ar-Rajmah Group, NE Libya includes: oolitic grainstone facies distribution, the lower escarpment fault and the upper escarpment fault, locations of the visited outcrops, and the palaeocurrents azimuths of the prograding oolitic clinoforms.
The paleogeographic map of the Middle Miocene of Cyrenaica, Ar-Rajmah Group, NE Libya includes: oolitic grainstone facies distribution, the lower escarpment fault and the upper escarpment fault, locations of the visited outcrops, and the palaeocurrents azimuths of the prograding oolitic clinoforms.
The paleogeographic map of the Late Miocene of Cyrenaica, Ar-Rajmah Group, NE Libya includes: oolitic grainstone facies distribution, the lower escarpment fault and the upper escarpment fault, locations of the visited outcrops, and the palaeocurrents azimuths of the fossilized prograding oolitic clinoforms.
Results

1- The studied oolitic grainstone facies is spatially restricted between two parallel curved faults that run roughly north-south.

2- Two 2\textsuperscript{nd}-order supersequences in the Ar-Rajmah Group Miocene carbonate rocks record comprise six 3\textsuperscript{rd}-order sequences and eleven shallow marine depositional facies.

3- The sedimentary structures in the oolitic clinoforms are produced by both tidal and wave processes and ideally arranged in two composite sets.

4- The clinoforms far away from the western LE-fault are bounded by mud supported bioclastic facies, sigmoidal in form, and have a western component in their progradation direction.

5- The clinoforms close to the western LE-fault are bounded by grain supported bioclastic packstone facies, Tabular in form, and have an eastern component in their progradation direction.

6- The clinoforms depositional sequence starts with subtidal bioclastic wackestone/grainstone that sharply overlain by ramp crest oolitic grainstone and then may or may not capped by microbial facies.
Conclusions

1- The Cyrenaican Miocene depositional ramp includes eleven facies arranged into six 3rd order sequences that form two 2nd order supersequences.

2- The Cyrenaican Miocene oolitic grainstone facies deposited in a fault controlled shallow subtidal landward basin.

3- The oolitic prograding clinoforms depositional facies, sedimentary structures, and direction of progradation indicate wave-tide depositional environments affected by fault controlled palaeoshoreline.

4- The prograding oolitic clinoforms experienced changes in thicknesses, geometries, sedimentary structures, and directions of progradation based on their proximity to the western fault line (LE-fault) that used to be the palaeoshoreline.

5- The oolitic clinoforms close or at the fault-controlled palaeoshoreline are tabular, perpendicular to the shoreline, contains both wave and tidal sedimentary structures.

6- The oolitic clinoforms formed basinward away from the fault line are sigmoidal, parallel to the shoreline, and contain wave dominated sedimentary structures.

7- The sigmoidal clinoforms are thicker than the tabular clinoforms.

8- The depositional sequence of the clinoforms was subtidal bioclastic wackestone/ grainstone that sharply overlain by ramp crest oolitic grainstone and then may or may not capped by microbial facies.
Thanks

Any Questions?!
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References Continued


