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

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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-

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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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GCAGS-Talk-2016-Corpus Christi, Texas, USA

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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**

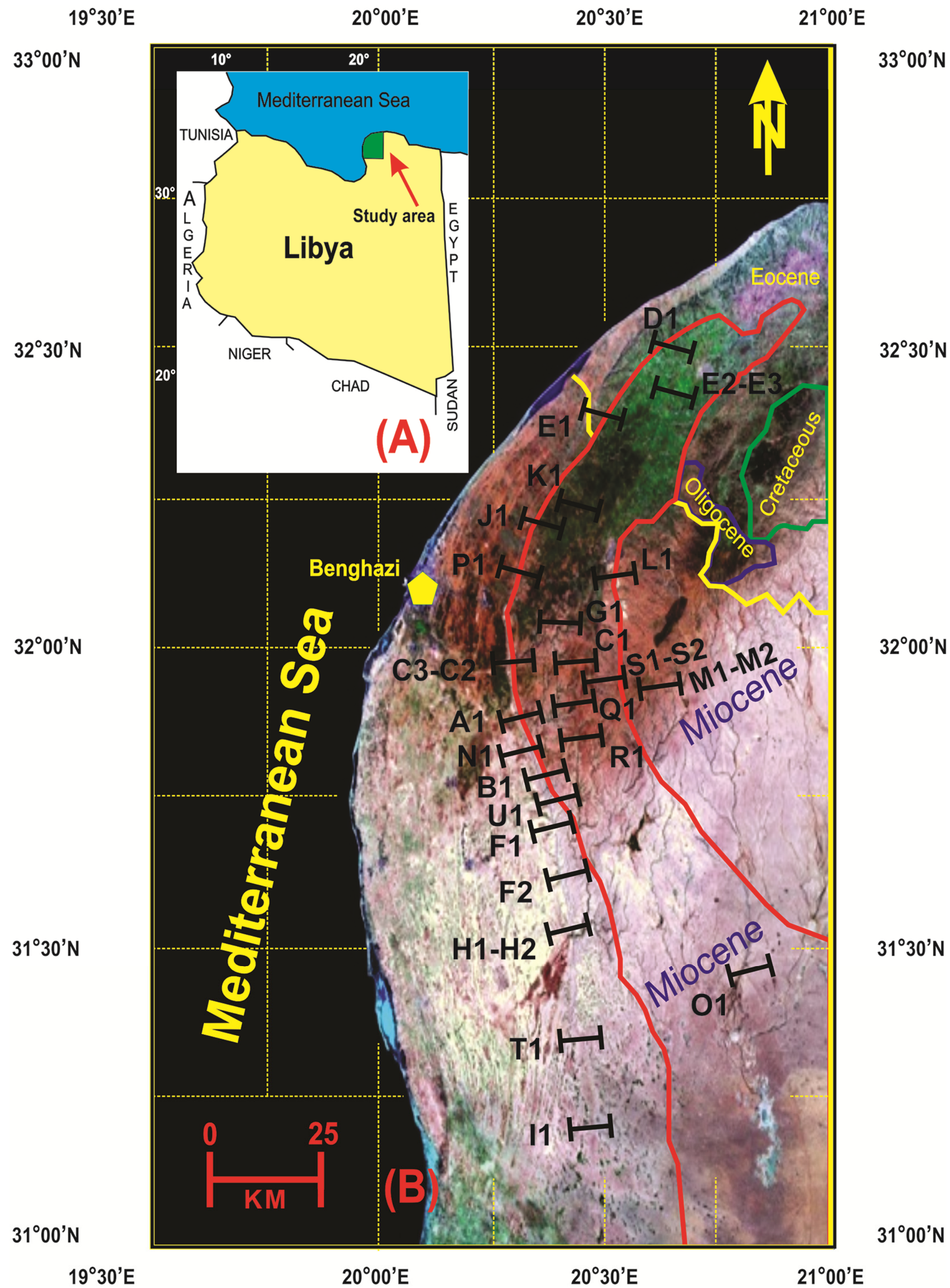
Location

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

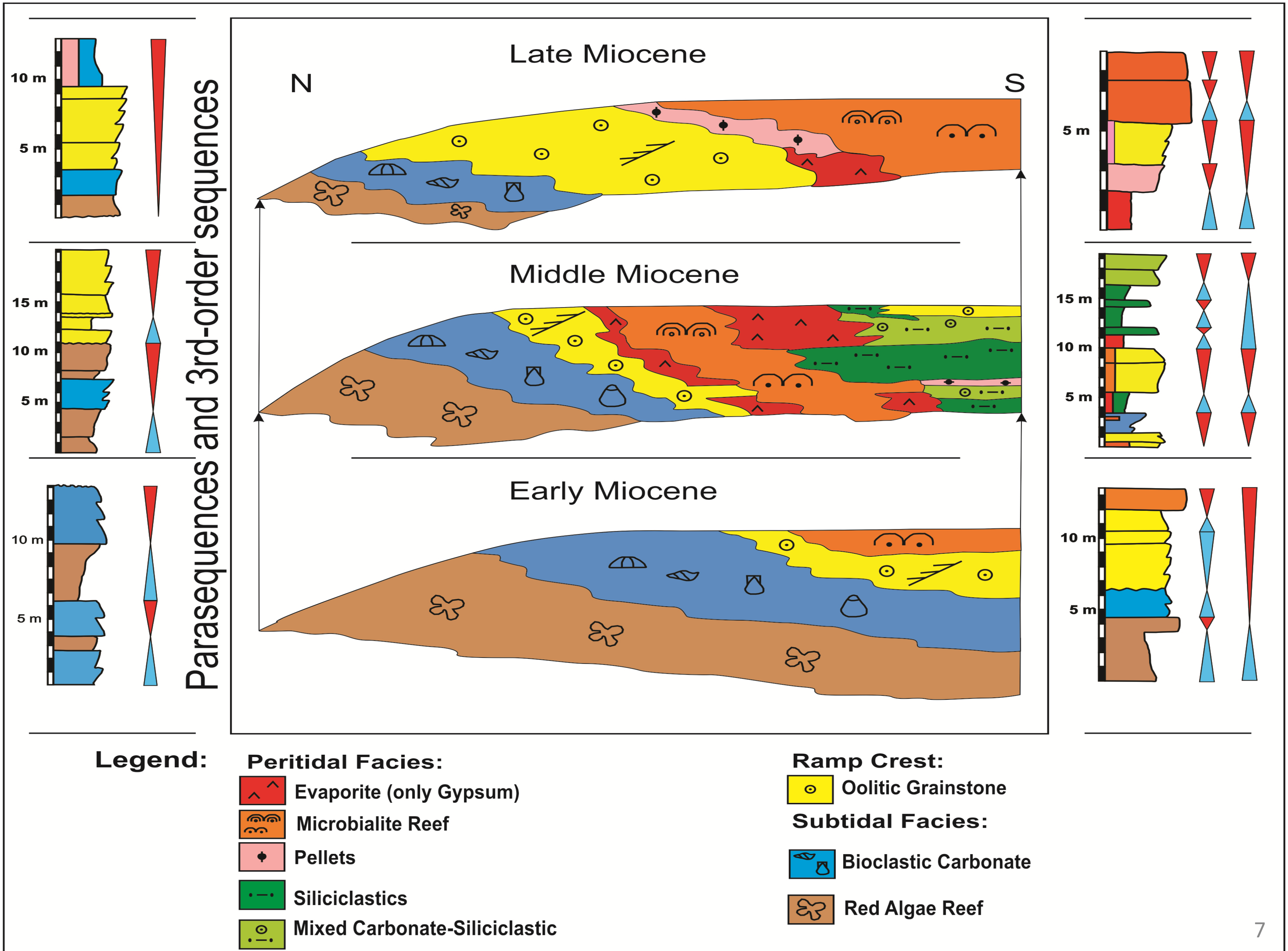
The Ar-Rajmah Group: nine **carbonate** facies and two **siliciclastic** facies, deposited in three environments on a gently sloping **ramp**.

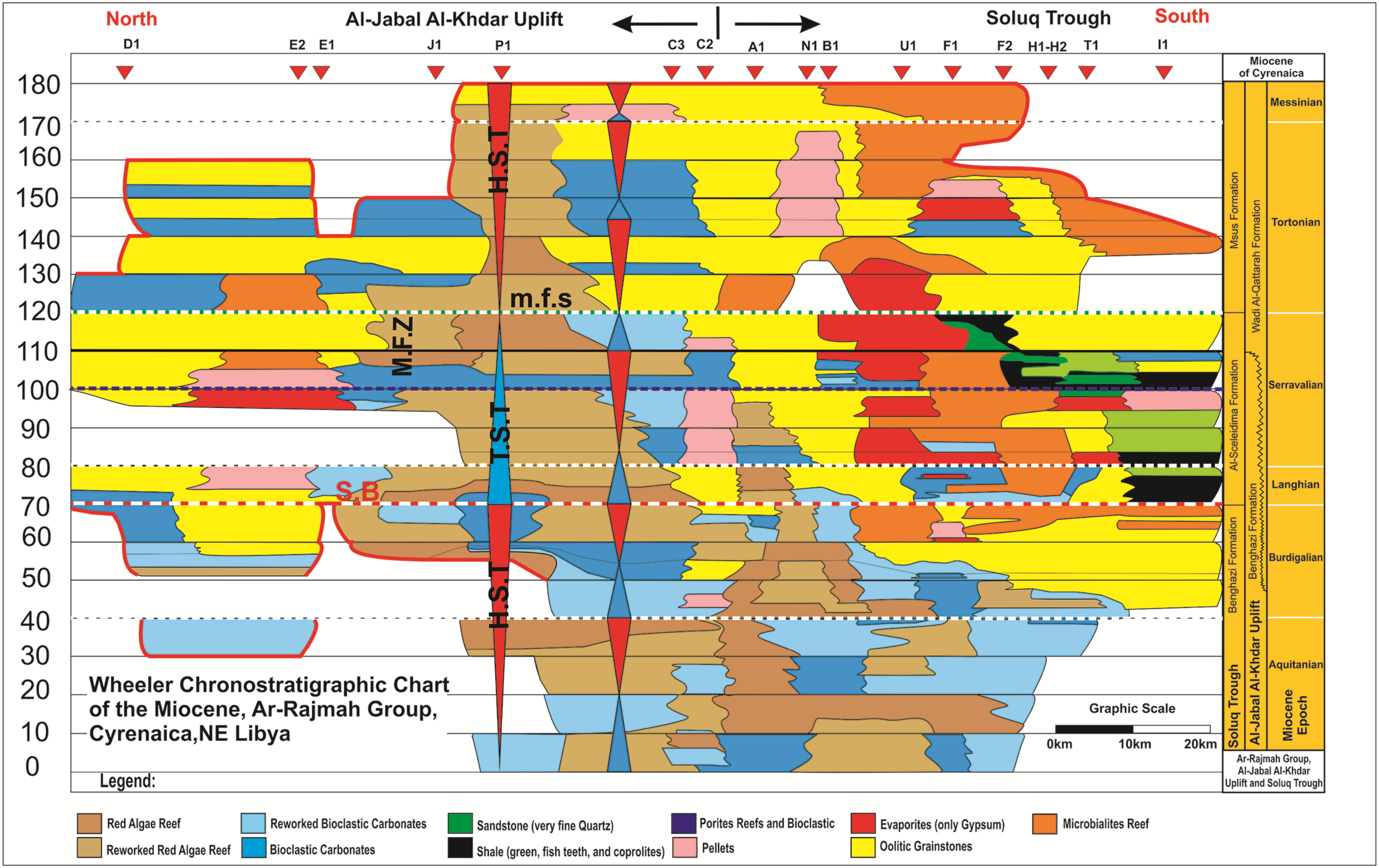
- **The peritidal facies** : 1) evaporite, 2) microbialite (stromatolites, thrombolites, and laminite), 3) pelletal wackestone/packstone, 4) porites reefs and bioclastic packstone, 5) very fine to fine quartz sandstone, 6) green shale.

- **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

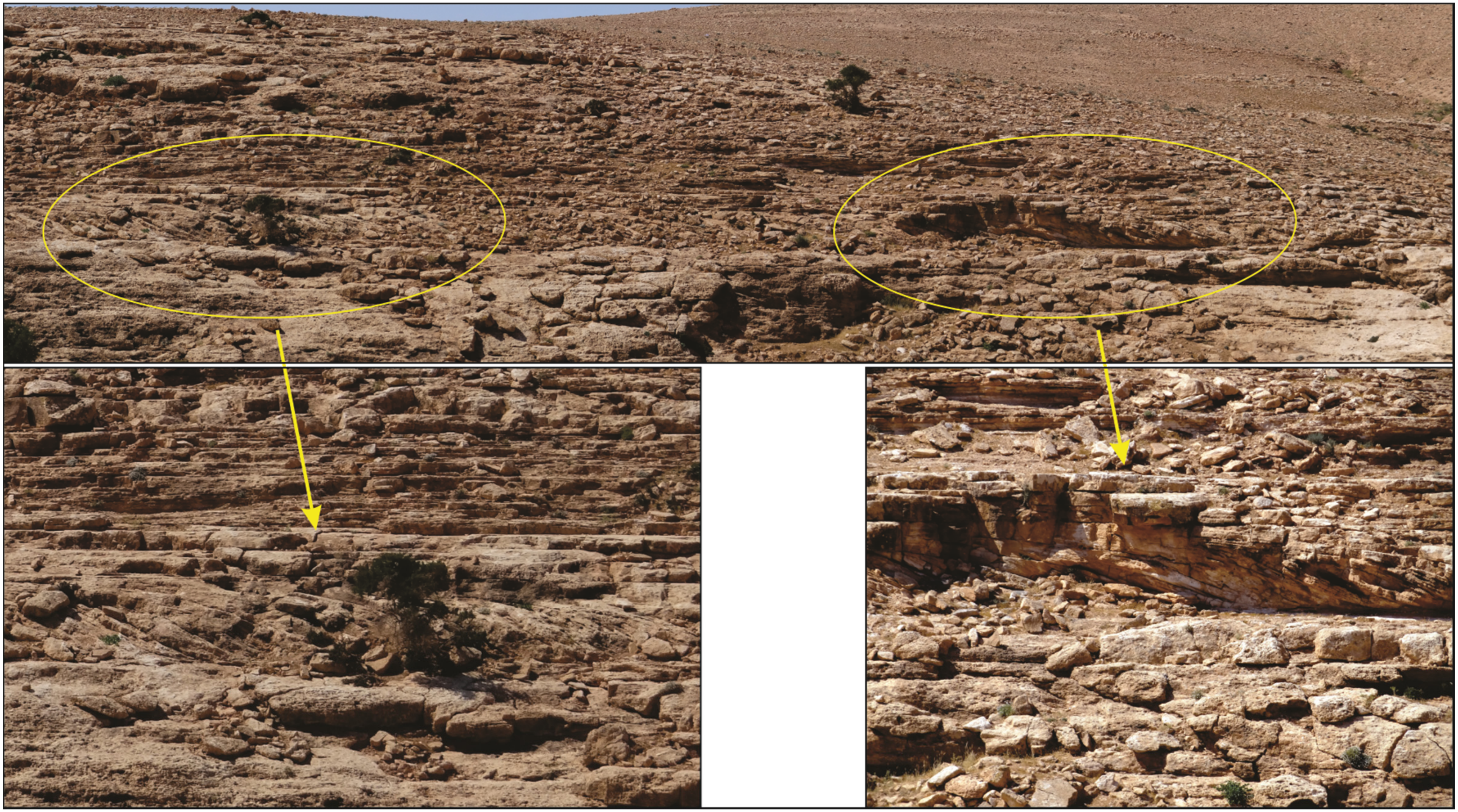




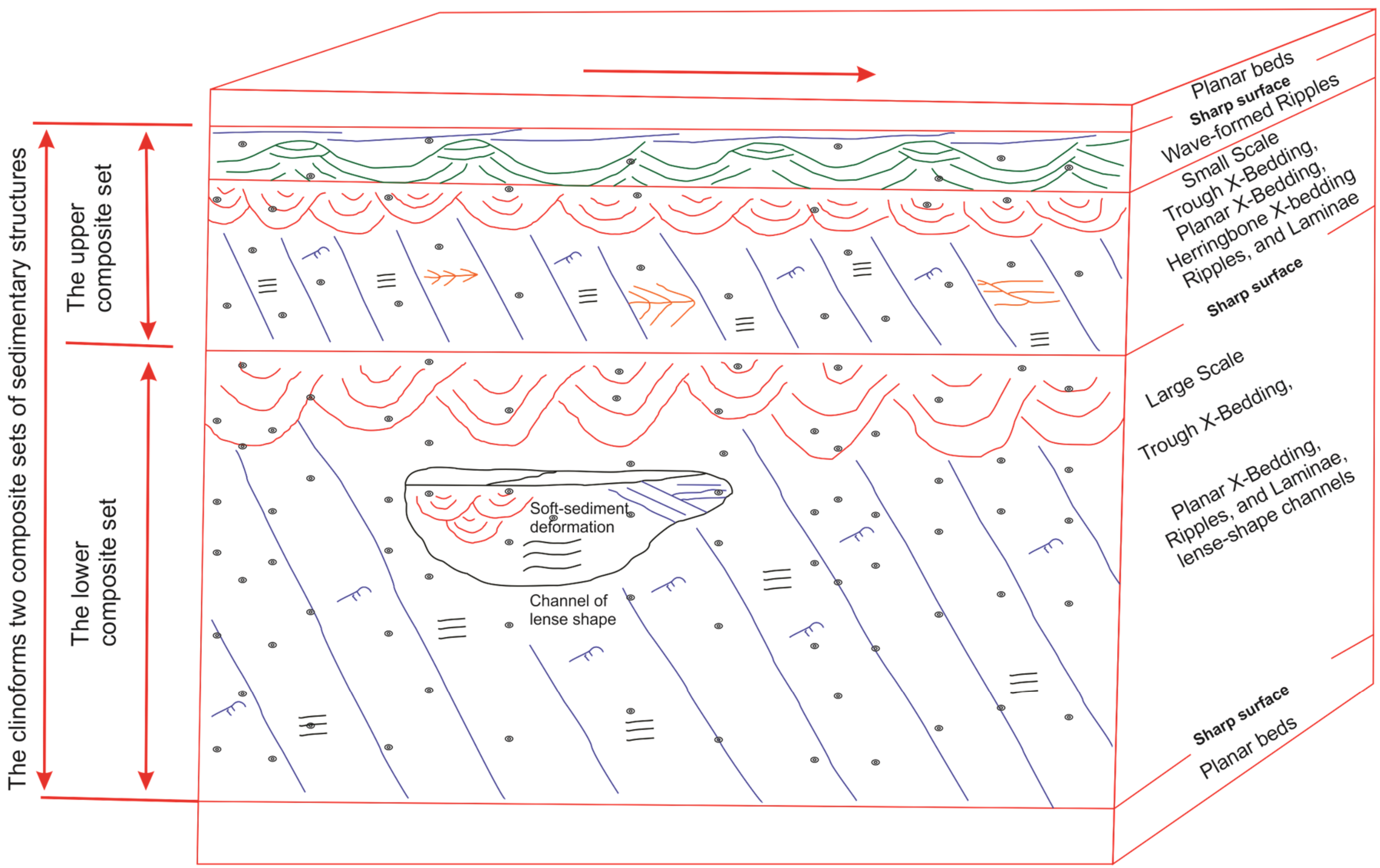
North
Al-Jabal Al-Khdar Uplift
Soluq Trough
South
D1
E2
E1
J1
P1
C3
C2
A1
N1
B1
U1
F1
F2
H1-H2
T1
I1
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
H.S.T
m.f.s
M.F.Z
T.S.T
S.B
H.S.T
Wheeler Chronostratigraphic Chart
of the Miocene, Ar-Rajmah Group,
Cyrenaica,NE Libya
Graphic Scale
0km
10km
20km
Miocene
of Cyrenaica
Messinian
Tortonian
Serravalian
Langhian
Burdigalian
Aquitanian
Miocene
Epoch
Msus Formation
Wadi Al-Qattarah Formation
Al-Sceleidima Formation
Benghazi Formation
Benghazi Formation
Soluq Trough
Al-Jabal Al-Khdar Uplift
Ar-Rajmah Group,
Al-Jabal Al-Khdar
Uplift and Soluq Trough
Legend:
Red Algae Reef
Reworked Red Algae Reef
Reworked Bioclastic Carbonates
Bioclastic Carbonates
Sandstone (very fine Quartz)
Shale (green, fish teeth, and coprolites)
Porites Reefs and Bioclastic
Pellets
Evaporites (only Gypsum)
Oolitic Grainstones
Microbialites 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.

Log Name	360 Direction in Degrees	Number of Readings	Facies
B1	90	1	Oolitic grainstone
B1	105	2	Oolitic grainstone
C1	340	1	Oolitic grainstone
D1	215	1	Oolitic grainstone
E1	135	1	Ooliticgrainstone
H1-H2	0	1	Bio-Oolitic grainstone
H1-H2	10	1	Bio-Oolitic grainstone

Locations, azimuths, sedimentary structures, facies, environments and geometries of the prograding oolitic clinoforms

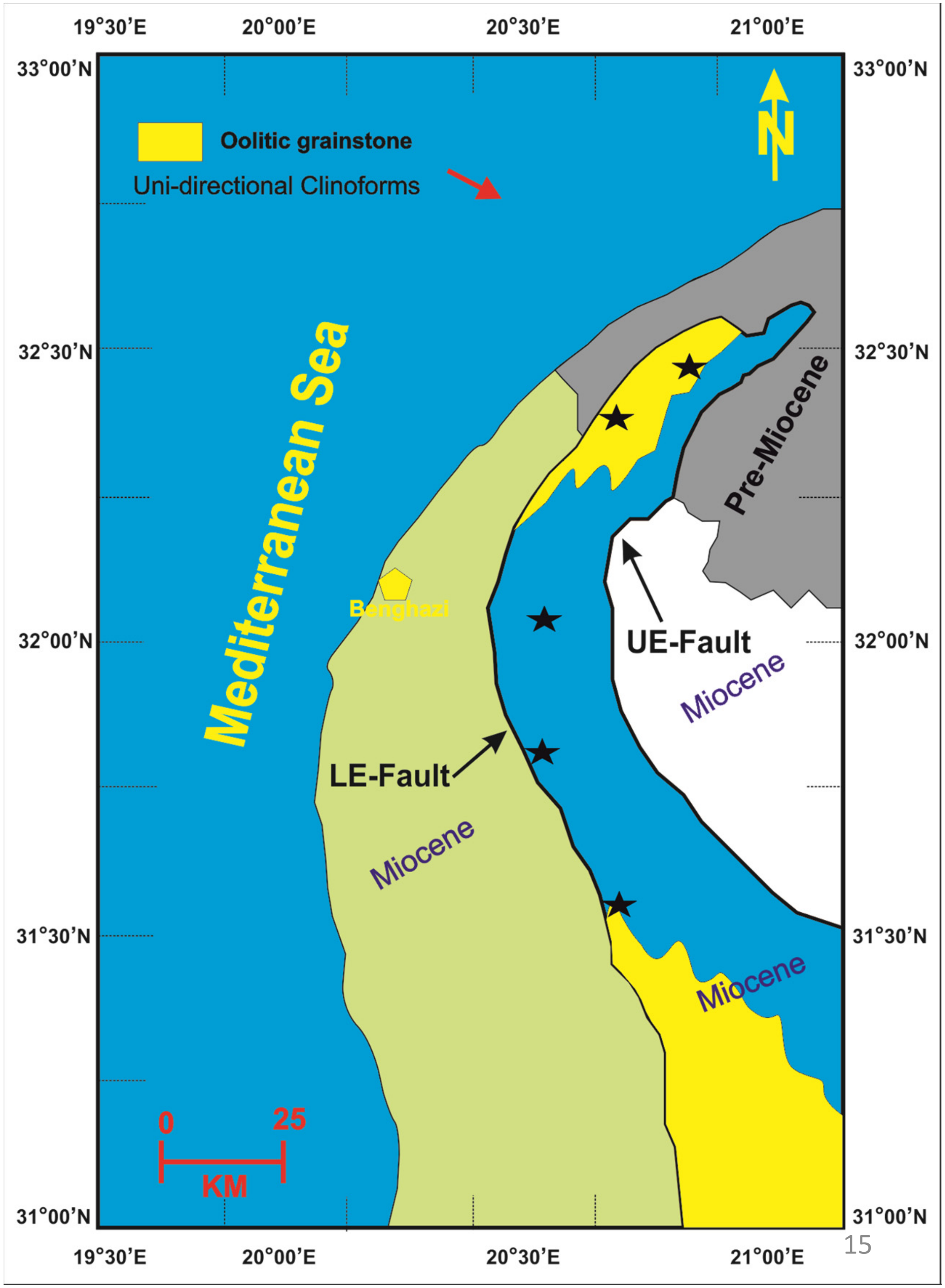
Clinoforms Location and proximity to the LE-Fault (paleoshoreline)	Oolitic Grainstone Packages		Prograding oolitic Clinoforms	
D1 **Far from LE-fault**	-Thickness: 15.5 m -Bottom Facies: bioclastic wackestone-packstone -Top Facies: bioclastic bioturbated pelletal-wackestone	Sedimentary Structures: large 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.	-Thickness: 4 m -Bottom Facies: laminated oo-bioclastic grainstone -Top Facies: laminated bioclastic-oolitic grainstone	Geometry, azimuth, and Environments: Sigmoidal composite sets 215-SSW Wave to Tide
E1 **Close to LE-fault**	-Thickness: 8.5 m -Bottom Facies: pelletal bioclastic wackestone-packstone -Top Facies: bioclastic packstone/grainstone	Sedimentary Structures: -The lower part: tabular large scale planar x-bedding, large scale trough x-bedding, lens-shaped channels 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.	-Thickness: 3 m -Bottom Facies: laminated bioclastic-oolitic grainstone -Top Facies: laminated oo-bioclastic grainstone	Geometry, azimuth, and Environments: Tabular Composite sets 135-SE Wave to Tide
C1 **Far LE-fault**	-Thickness: 8 m -Bottom Facies: bioclastic mudstone -Top Facies: bioclastic packstone	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.	-Thickness: 4.5 m -Bottom Facies: Laminated bioclastic mudstone -Top Facies: Laminated bioclastic packstone	Geometry, azimuth, and Environments: Sigmoidal composite sets 340-NNW Wave to Tide
B1 **Close to LE-fault**	-Thickness: 12 m -Bottom Facies: bioclastic grainstone -Top Facies: nodular mudstone/Wackestone	Sedimentary Structures: large scale planar overlain by trough x-bedding and then fenestral laminae	-Thickness: 2.5-3 m -Bottom Facies: laminated bioclastic-oolitic grainstone -Top Facies: laminated bioclastic-oolitic grainstone	Geometry, azimuth, and Environments: Tabular composite sets 90-105-E-SE Wave to Tide
H1-H2 **Close to LE-fault**	-Thickness: 5 m -Bottom Facies: oo-bioclastic grainstone -Top Facies: bioclastic microbial boundstone	Sedimentary Structures: tabular large scale planar overlain by laminae and then sharp mudcracked surface of microbial origin	-Thickness: 1.5 m -Bottom Facies: laminated oo-bioclastic packstone -Top Facies: laminated microbial-oolitic grainstone	Geometry, azimuth, and Environments: Tabular composite sets 0-10-N-NE Wave to Tide

Through time Analysis and Integration (Maps Analysis).

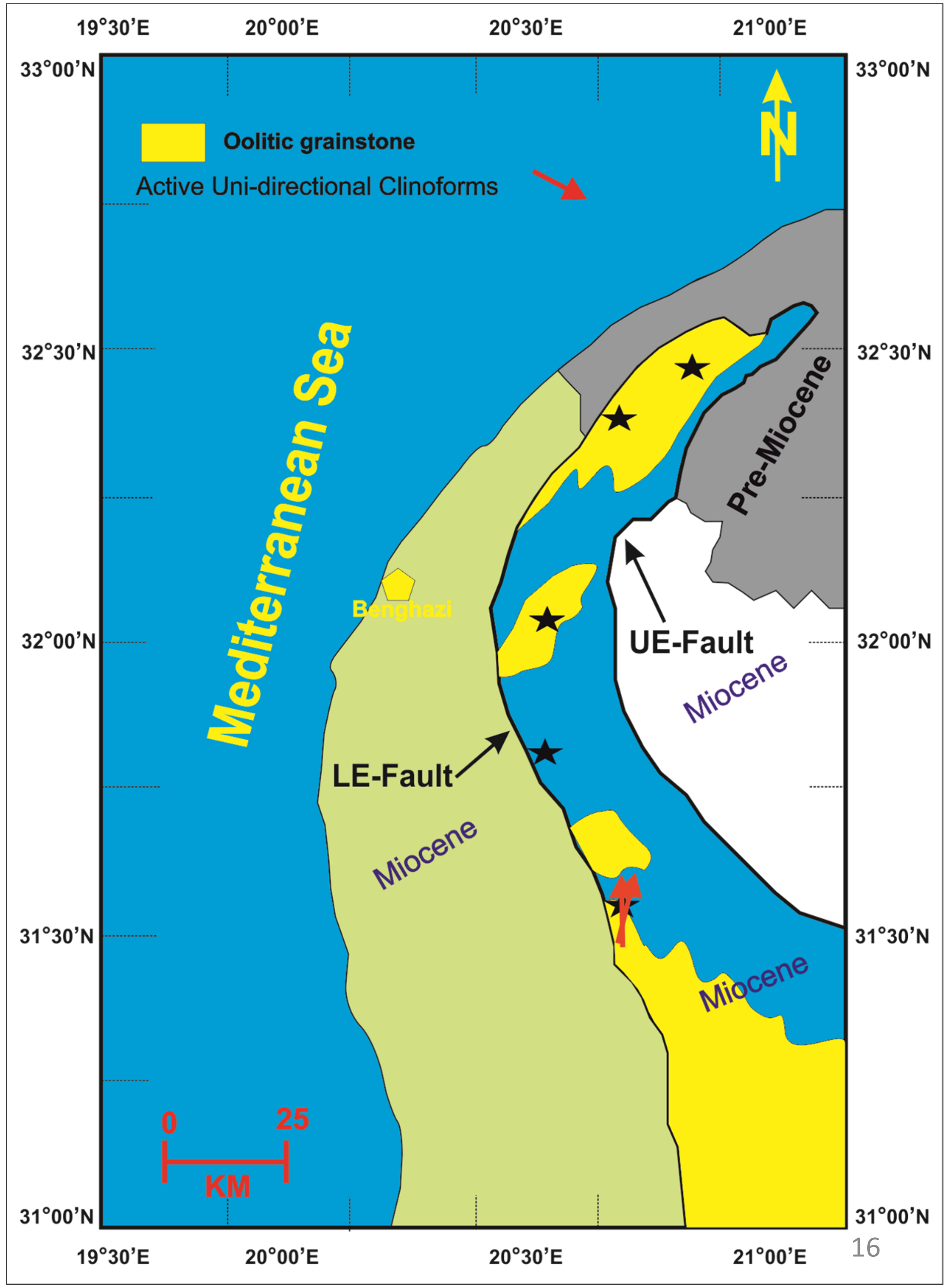
Data sets of

sedimentological, stratigraphic, Prograding oolitic clinoforms azimuths, and structural elements

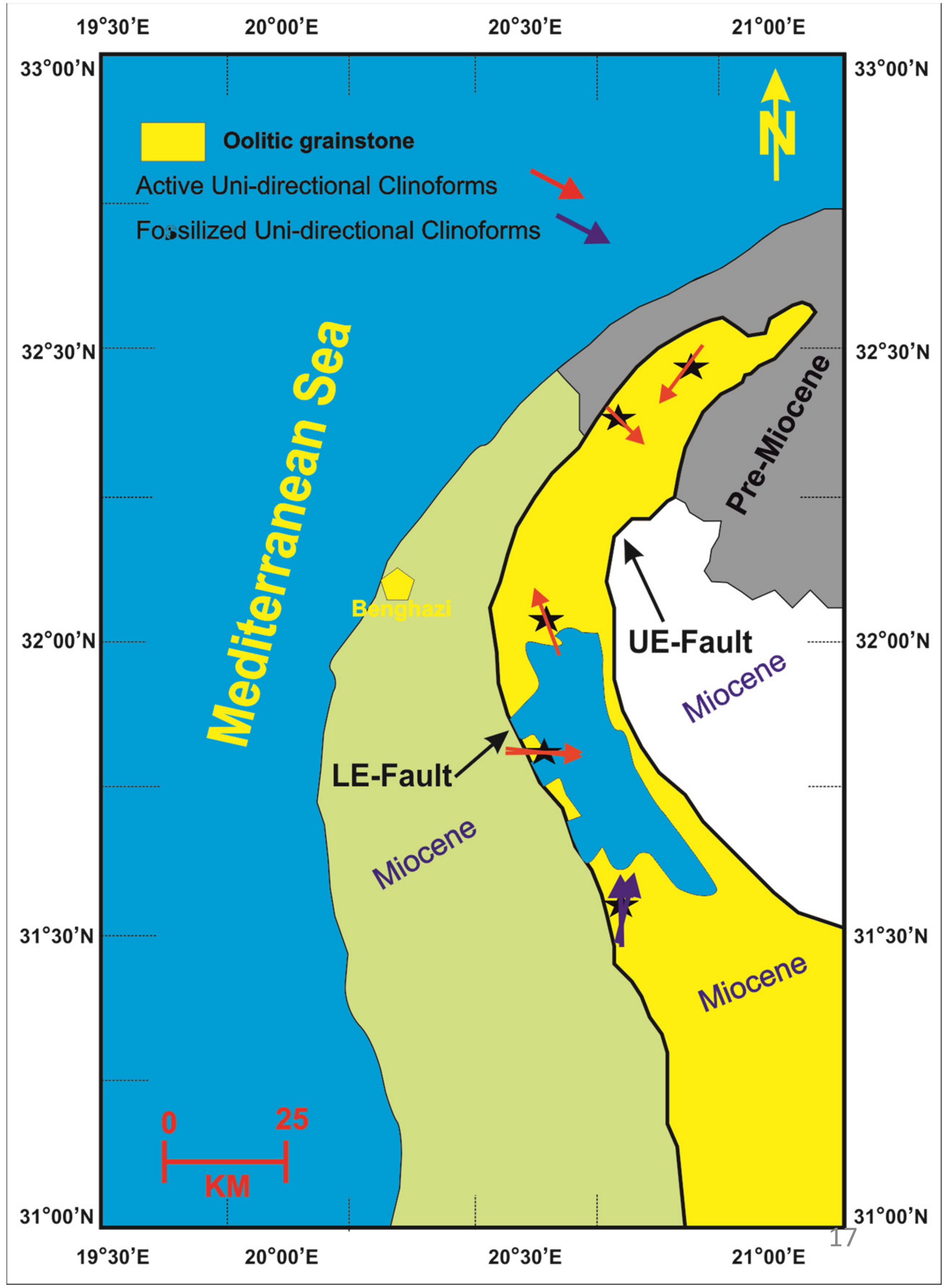
The **paleogeographic map** of the **Early Miocene of Cyrenaica**, Ar-Rajmah Group, NE Libya includes: oolitic grainstone facies distribution, the lower escarpment fault and the upper escarpment fault, locations of the visited outcrops.



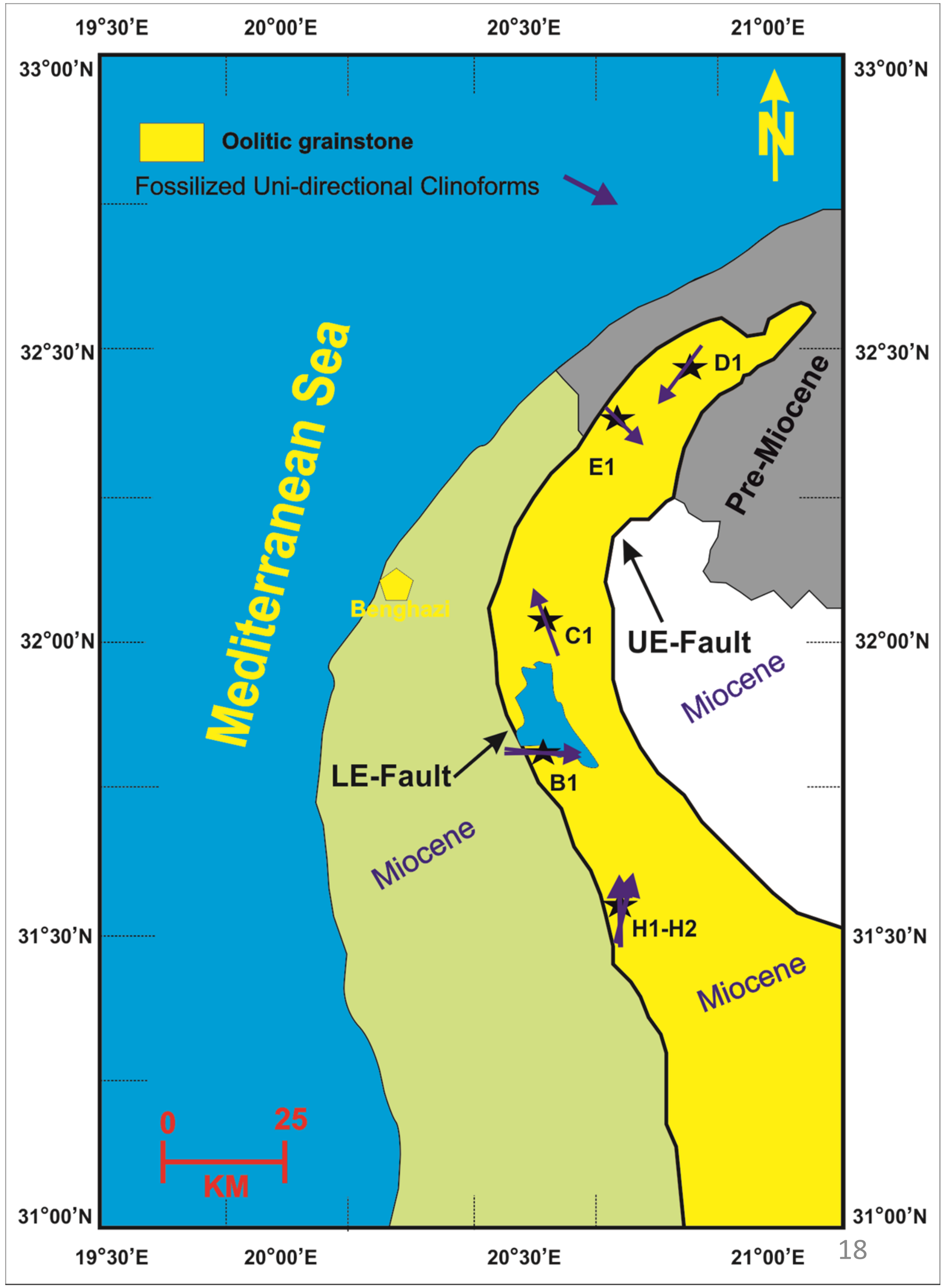
The **paleogeographic map** of the **Early Miocene of Cyrenaica**, Ar-Rajmah Group, NE Libya includes: oolitic grainstone facies distribution, the lower escarpment fault and the upper escarpment fault, locations of the visited outcrops, and the palaeocurrents azimuths of the prograding oolitic clinoforms.



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 2nd-order supersequences in the Ar-Rajmah Group Miocene carbonate rocks record comprise six 3rd-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.

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Thanks

Any Questions?!

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