PS Monterey Event in the Cyrenaican Miocene Carbonate Platform (Central Mediterranean), NE Libya*

Khaled S. Amrouni^{1,4}, Michael C. Pope², Ernest A. Mancini³, and Ahmed S. El-Hawat⁴

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Abstract

The focus of this field and lab integrated study is on the Cyrenaican Miocene 13C-isotope changes in the sequence stratigraphic, and diagenetic context. The field work included 29 measured stratigraphic sections along 135 km, 14 spectral gamma-ray profiles. The lab work includes petrographic and diagenetic studies of 501 hand samples, thin sections, and stable isotope (δ 18O and δ 13C) analyses. The sequence stratigraphic framework is based on the sedimentological analysis, correlation of stratigraphic time surfaces and vertical stratigraphic sections, oxygen and carbon stable isotope profiles, and gamma-ray logs. The Ar-Rajmah Group Miocene carbonate rocks record two 2nd order supersequences (97 m maximum thickness); containing six 3rd order sequences. The TST of the younger 2nd order sequence is separated by a sharp disconformity surface from the HST of the older 2nd order sequence, and by maximum flooding zone from the HST of the younger 2nd order sequence. The HST of the older 2nd sequence is the Early Miocene Benghazi Formation (46 m thick), and dominated by red algal reefs, and bioclastic packstones. The TST and HST of the younger 2nd order sequence occur in the Middle and Late Miocene Wadi Al-Oattarah Formation (26 m and 25m thick respectively), and dominated by continuous oolitic grainstones, microbialites that associated with evaporites, and siliciclastics. The 3rd order sequences range in thickness from 5 m to more than 15 m. The chemostratigraphic data shows that the Early Miocene is enriched in both δ 18O and δ 13C, the Middle Miocene is enriched in δ 13C but depleted in δ 18O, and the Late Miocene is depleted in both δ 18O and δ 13C. The Middle Miocene is characterized by a prominent positive increase in the δ 13C, Monterey event, which coincides with influx of siliciclastic facies that have high gamma ray zone, and evaporite deposits. In addition, this $\delta 13C$ enrichment event is roughly coinciding with major changes in facies lithologies, textures, and diagenetic patterns. The pre-Monterey event facies are dominated by silicified dedolomitized red algal and bioclastic packstones, where the syn-and-post-Monterey event facies are dominated by silicified and recrystallized oolitic grainstone, microbial-bioclastic-oolitic grainstone. The global Monterey event is preserved in the δ 13C record of the Cyrenaican Miocene carbonate platform in the Central Mediterranean, and associated with major sedimentological, stratigraphic, and diagenetic changes.

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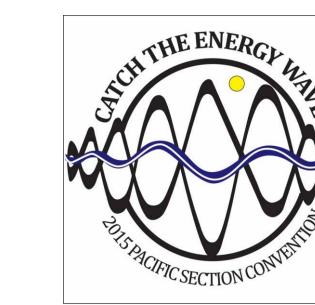
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Monterey event in the Cyrenaican Miocene carbonate platform (Central Mediterranean), NE Libya







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The focus of this field and lab integrated study is on the Cyrenaican Miocene 13C-isotope changes in the sequence stratigraphic, and diagenetic context. The field work included 29 measured stratigraphic sections along 135 km, 14 spectral gamma-ray profiles. The lab work includes petrographic and diagenetic studies of 501 hand samples, thin sections and stable isotope (δ 18O and δ 13C) analyses. The sequence stratigraphic framework is based on the sedimentological analysis, correlation of stratigraphic time surfaces and vertical stratigraphic sections, oxygen and carbon stable isotope profiles, and gamma-ray logs.

The Ar-Rajmah Group Miocene carbonate rocks record two 2nd order supersequences (97 m maximum thickness); containing six 3rd order sequences. The TST of the younger 2nd order sequence is separated by a sharp disconformity surface from the HST of the older 2nd order sequence, and by maximum flooding zone from the HST of the younger 2nd order sequence. The HST of the older 2nd sequence is the Early Miocene Benghazi Formation (46 m thick), and dominated by red algal reefs, and bioclastic packstones. The TST and HST of the younger 2nd order sequence occur in the Middle and Late Miocene Wadi Al-Qattarah Formation (26 m and 25m thick respectively), and dominated by continuous oolitic grainstones, microbialites that associated with evaporites and siliciclastics. The 3rd order sequences range in thickness from 5 m to more than 15 m.

The chemostratigraphic data shows that the Early Miocene is enriched in both δ18O and δ13C, the Middle Miocene is enriched in δ13C but depleted in δ18O, and the Late Miocene is depleted in both δ18O and δ13C. The Middle Miocene is characterized by a prominent positive increase in the δ13C, Monterey event, which coincides with influx of siliciclastic facies that have high gamma ray zone, and evaporite deposits. In addition, this δ13C enrichment event is roughly coinciding with major changes in facies lithologies, textures, and diagenetic patterns. The pre-Monterey event facies are dominated by silicified dedolomitized red algal and bioclastic packstones, where the syn-and-post-Monterey event facies are dominated by silicified and recrystallized oolitic grainstone, microbial-bioclastic-oolitic grainstone. The global Monterey event is preserved in the δ13C record of the Cyrenaican Miocene carbonate platform in the Central Mediterranean, and associated with major sedimentological, stratigraphic, and diagenetic changes.

1- Intended to establish the detailed sequence stratigraphy, sedimentology the Miocene rocks (Ar-Rajmah Group) of the Cyrenaica Platform, Libya that were deposited on a carbonate ramp.

2- To study the diagenetic events in Cyrenaican Miocene carbonate rocks, and establish their paragenetic sequence.

3-To study the 13C-isotope changes in the sequence stratigraphic, and diagenetic context.

4-To provide a valuable analogue for oolitic and Microbial carbonate subsurface reservoirs, where these rocks are superbly exposed for greater than 130 km in a dip direction.

-Detailed sedimentological and stratigraphic regional facies relationships from field and lab observations.

-The field work included measuring 29 stratigraphic sections bed-by-bed, 14 Spectral gamma-ray profiles constructed using a hand-held gamma-

ray scintillometer at 0.5 m intervals, and annotating panoramic digital photomosaics.

-The lab work includes petrographic and diagenetic studies of 501 hand samples, thin sections and stable isotope (δ 18O and δ 13C) analyses. -The sequence stratigraphic framework will be based on the sedimentological analysis, correlation of stratigraphic time surfaces and vertical

stratigraphic sections, oxygen and carbon stable isotope profiles, and gamma-ray logs.

-The 14 spectral gamma-ray profiles were constructed in the field, using a hand-held gamma-ray scintillometer at 0.5 m intervals. The Gamma Ray gathered field data are four different types K, Th, U, and total

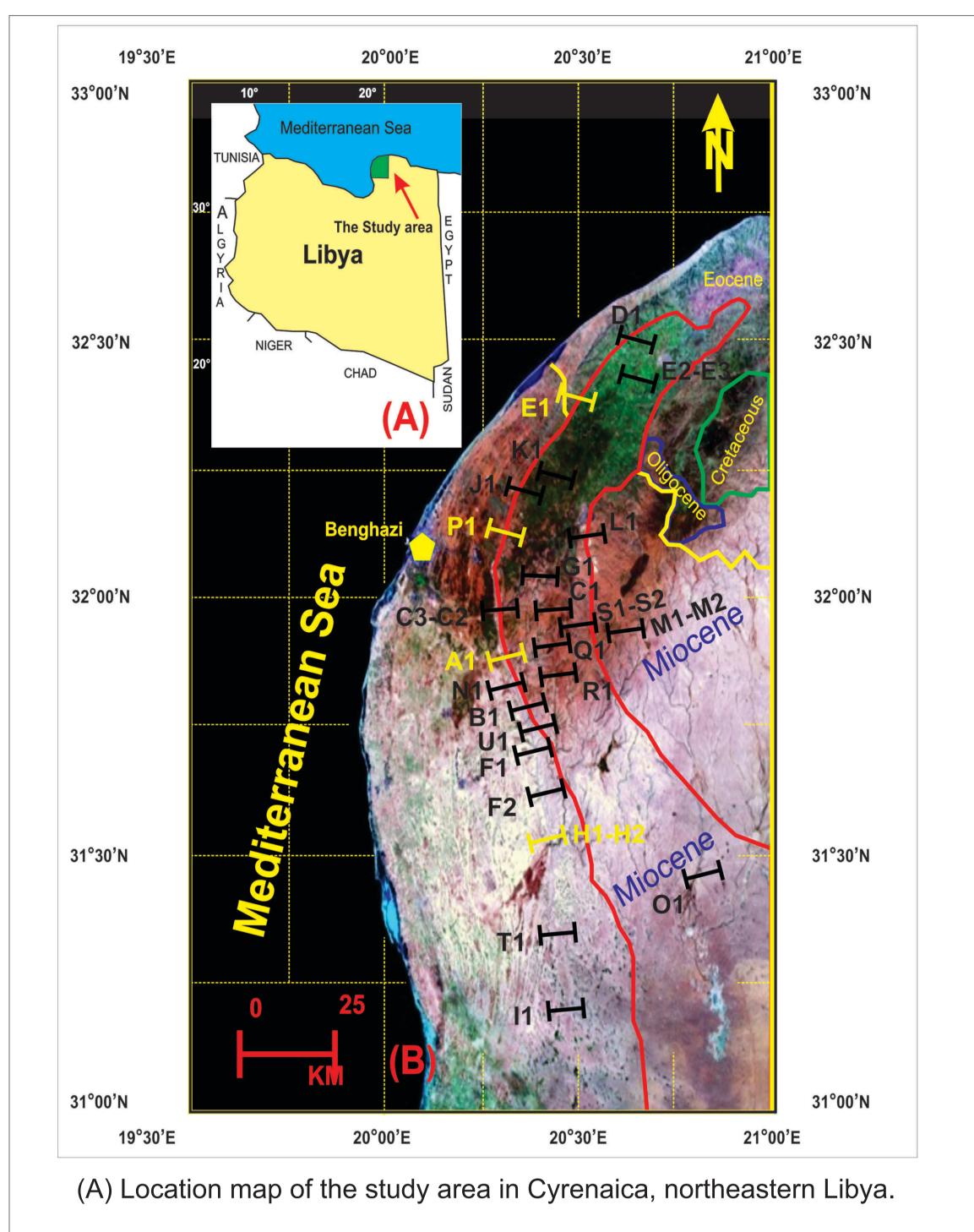
The 2-D tentative evolutionary depositional model(s) of this current study revealed the dominant depositional theme on the Cyrenaican -ramp system. It highlighted the dominant and laterally continuous bodies of oolitic grainstones, microbial carbonates, and red algae that are important targets as subsurface oil reservoirs. Also, it indicates the deposition of the siliciclastic facies in the southern part of the study area during the Middle Miocene.

The Ar-Rajmah Group Miocene carbonate rocks record two 2nd order supersequences (97 m maximum thickness); that include six 3rd order sequences. The TST of the younger 2nd order sequence is separated by a sharp disconformity surface from the HST of the older 2nd order sequence, and by maximum flooding zone from the HST of the younger 2nd order sequence. The HST of the older 2nd sequence is the Early Miocene Benghazi Formation (46 m thick), and dominated by red algal reefs, and bioclastic packstones, and changes laterally in the eastwards into bioclastic packstone Porites coral. The TST and HST of the younger 2nd order sequence occur in the Middle and Late Miocene Wadi Al-Qattarah Formation (26 m and 25m thick respectively). The Middle Miocene TST is dominated by continuous oolitic grainstones, microbialites that associated with evaporites and quartz snadstone, and coprolites and fish teeth bearing green shale. The Late Miocene TST is dominated by continuous oolitic grainstones, microbialites that associated with some selentic swallow-tail gypsum beds. The 3rd order sequences range in thickness from 3.5 m to more than 22.5 m. This outcrop study of the Ar-Rajmah Group extends for more than 130 km along a dip profile and its excellent 3-D exposure makes it an analogue for ooid grainstone and microbial carbonate reservoirs in the subsurface within the Mediterranean region and globally.

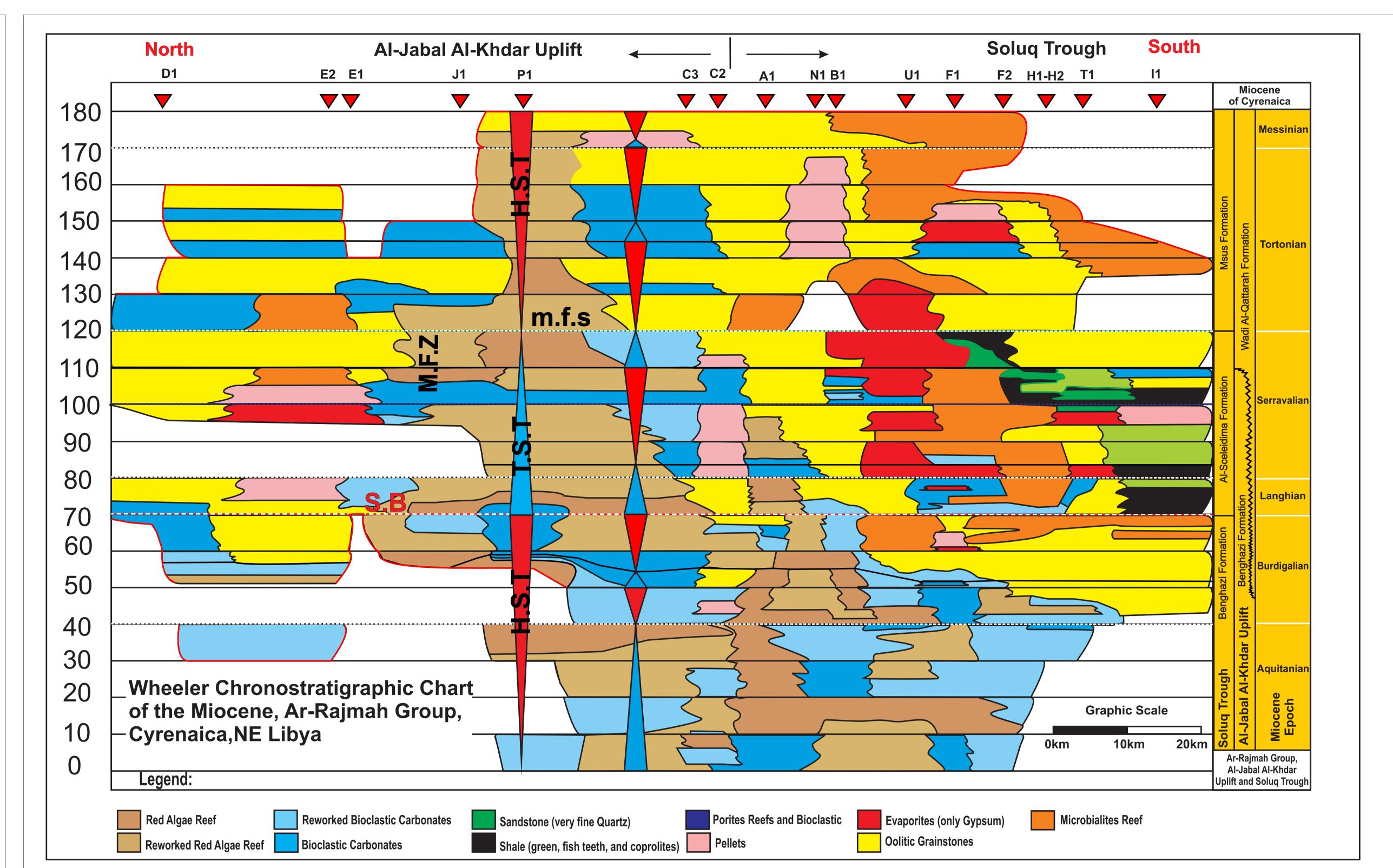
On a regional scale, the Miocene carbonate rocks of the Cyrenaica have different facies order and parasequences patterns than the rest of the Mediterranean region. The Cyrenaican Early Miocene is dominated by red algae with some local occurrences of porites and other coral types, while the Middle and Late Miocene is dominated by oolitic grainstone and microbialites with local evaporite occurrences. On the Mediterranean region, the Early Miocene is dominated by extensive carbonate platforms with barrier reefs "porites" and lagoons, the Middle Miocene rocks are coral reefs that change vertically into red algae, while the Late Miocene is evaporites and coral reefs (Franseen, 1996). In this study gamma ray, responses and patterns, is a very important tool to construct the detailed regional sequence stratigraphic framework besides the field measured lithostratigraphic sections and the field identified rock time surfaces. The gamma ray responses are always in agreement with the field measured lithological data, except for some occasions where some minor shifts due to human errors.

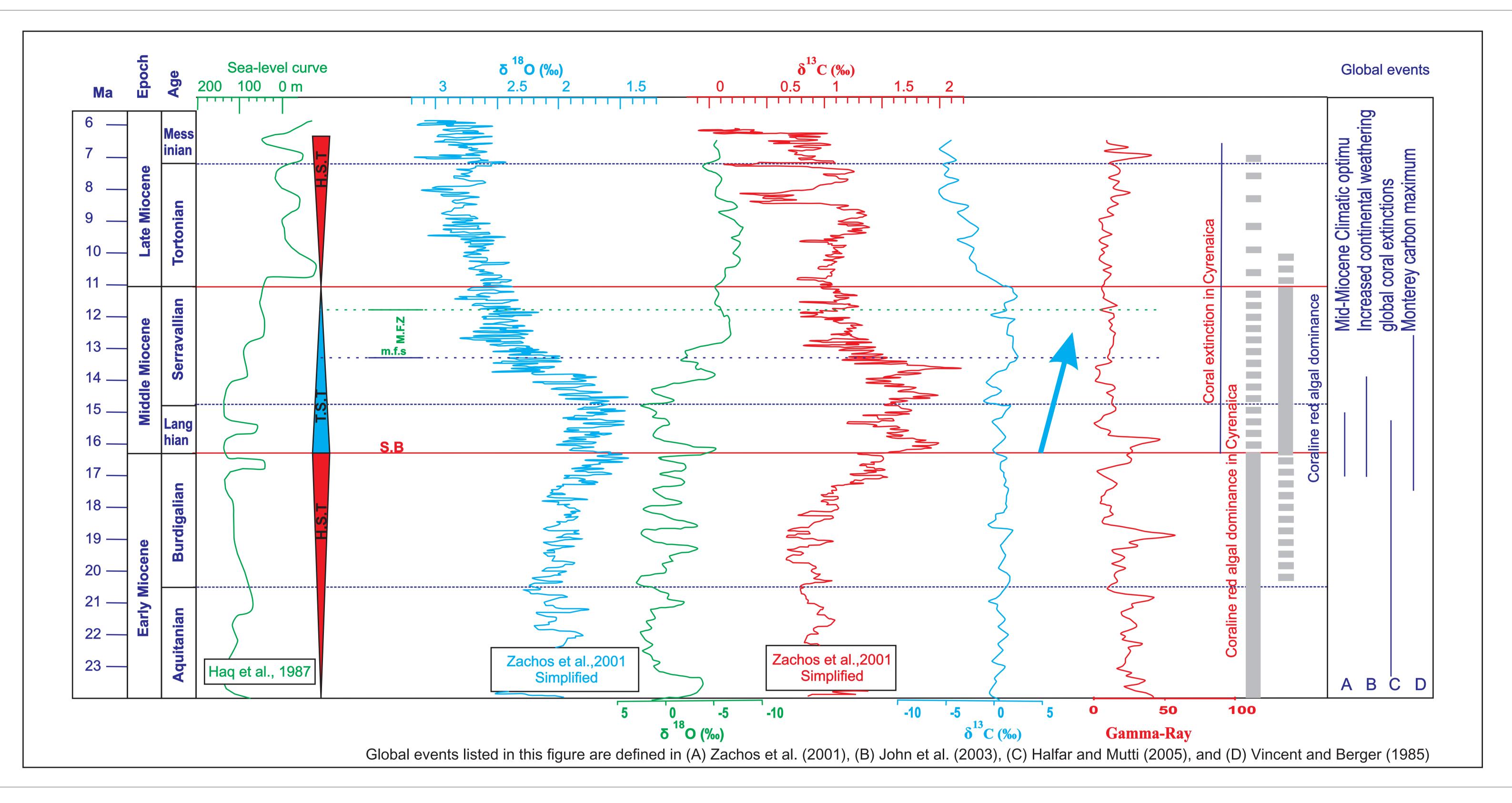
The stable isotopes chemostratigraphy and diagenesis is second step in this work. The stable isotope data helped us to have a better control over our sequence stratigraphic framework and to understand the ocean chemistry during the Miocene rocks in the Cyrenaica Platform. The stable isotopes chemostrationaphy helped us to determine the timelines for the Cyrenaican Miocene rocks, and to have a higher resolution tool to define more detailed parasequences. The δ13C curve of the Cyrenaican Miocene shows a positive enrichment in the Middle Miocene that corresponds to the global Monterey event by Vincent and Berger (1985). In addition, this Middle Miocene interval represents the TST of the younger 2nd-order supersequence, includes the maximum flooding zone, and it has siliciclastic influx of coprolites-fish-teeth bearing green shale that characterized by high gamma ray values.

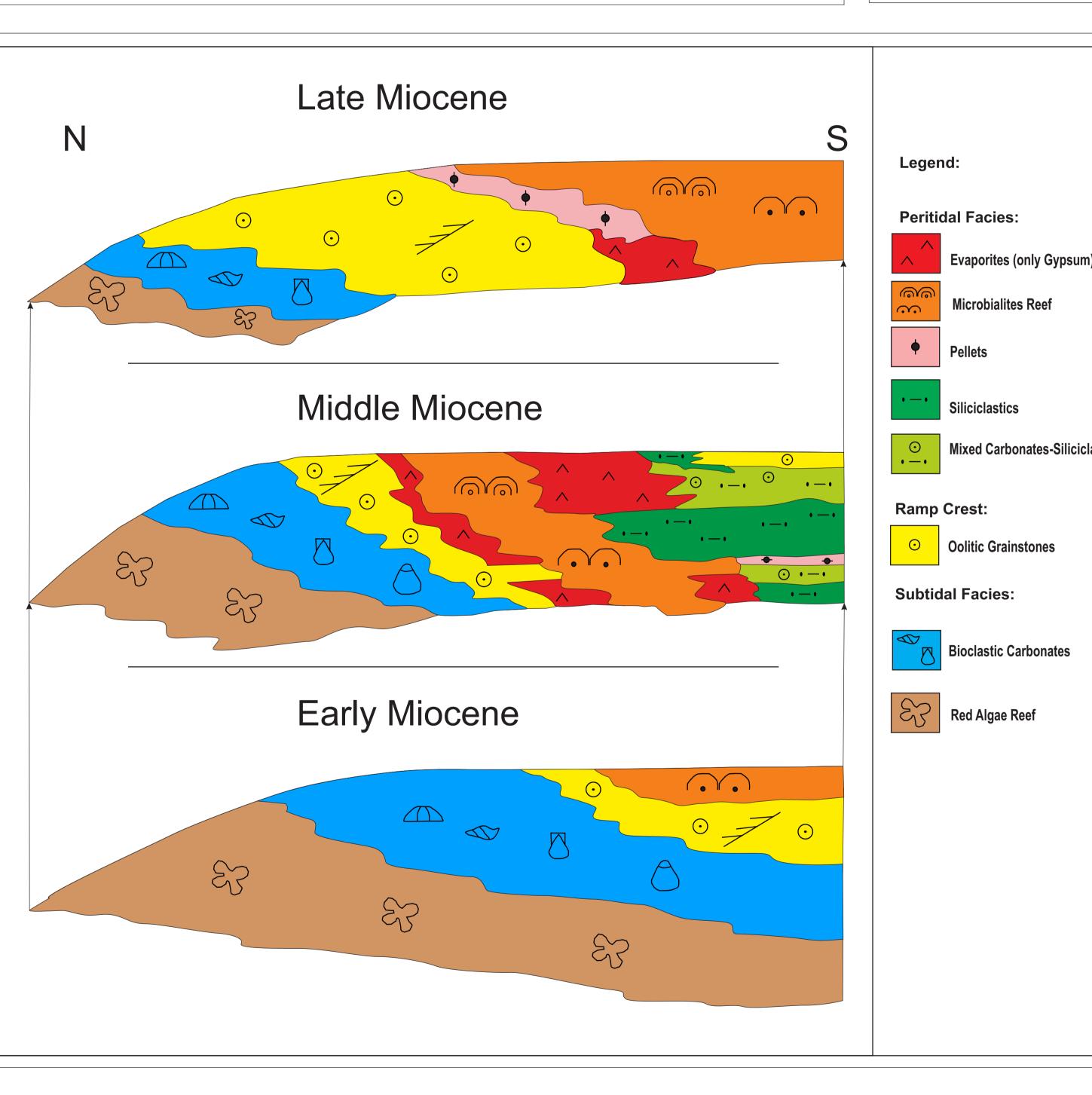
The petrographic work on the Cyrenaican Miocene carbonate platform of the Ar-Rajmah Group, NE Libya, reveals carbonate facies intercalated with a tongue of siliciclastic facies. The platform has been subject to many diagenetic processes that printed their diagenetic events on the rocks. There are eleven main depositional facies, and eighteen diagenetic events produced by six diagenetic processes. The petrographic analysis shows two distinct lithological, textural and paragenetic patterns above and below a sequence boundary corresponding roughly to the Middle Miocene Langhian-Serravallian boundary. The older Miocene interval (Langhian and older) is dominated by silicified dedolomitized bioclastic-rich bryozoan, and red algal packstone. The younger Miocene interval (Serravallian and younger) is dominated by silicified and recrystallized oolitic grainstone, microbial-bioclastic-oolitic grainstone.

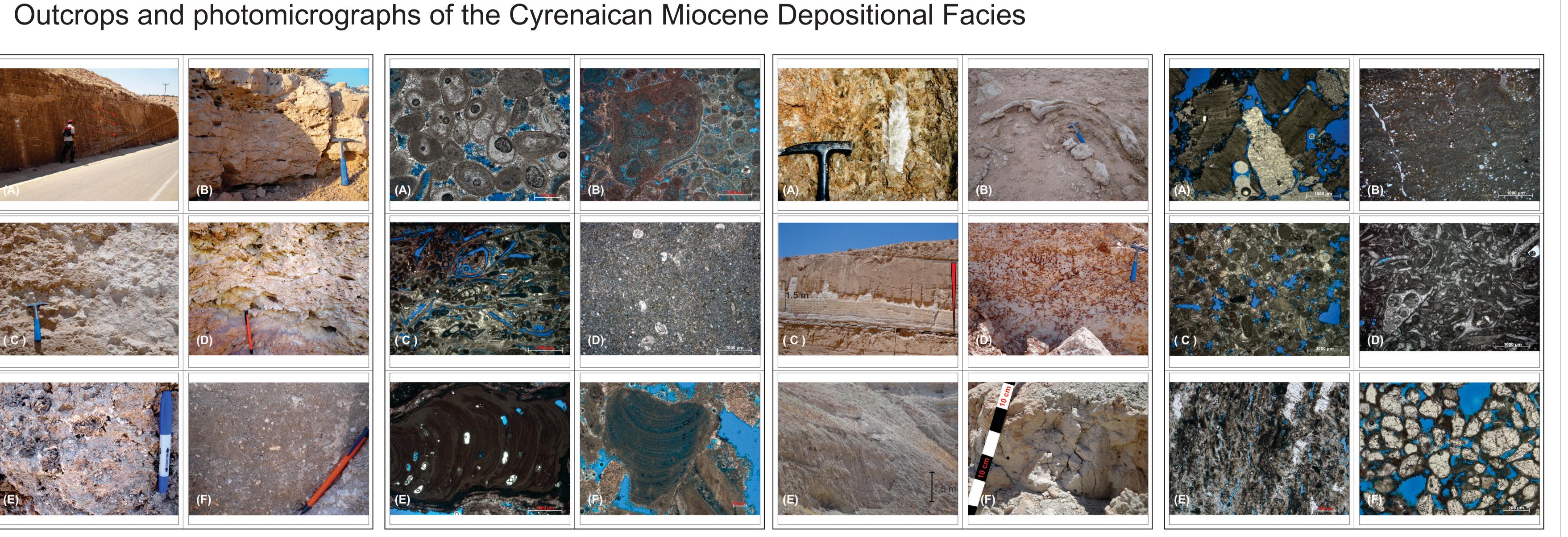


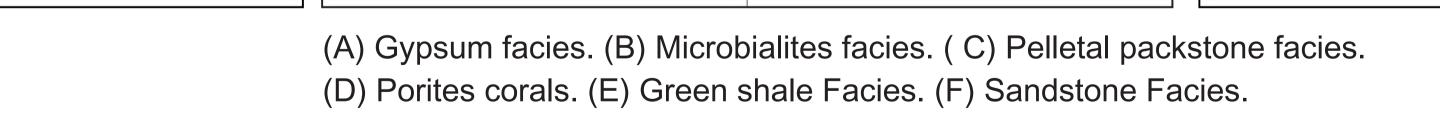
(B) Landsat image of NE Libya showing the geological boundaries of Cretaceous- Tertiary rocks. The geological boundaries are based on the IRCs sheet-Benghazi (Klen, 1974) and sheet-Soluq (Francis and Issawi, 1977) that were later modifed by (El-Hawat et al., 1987).

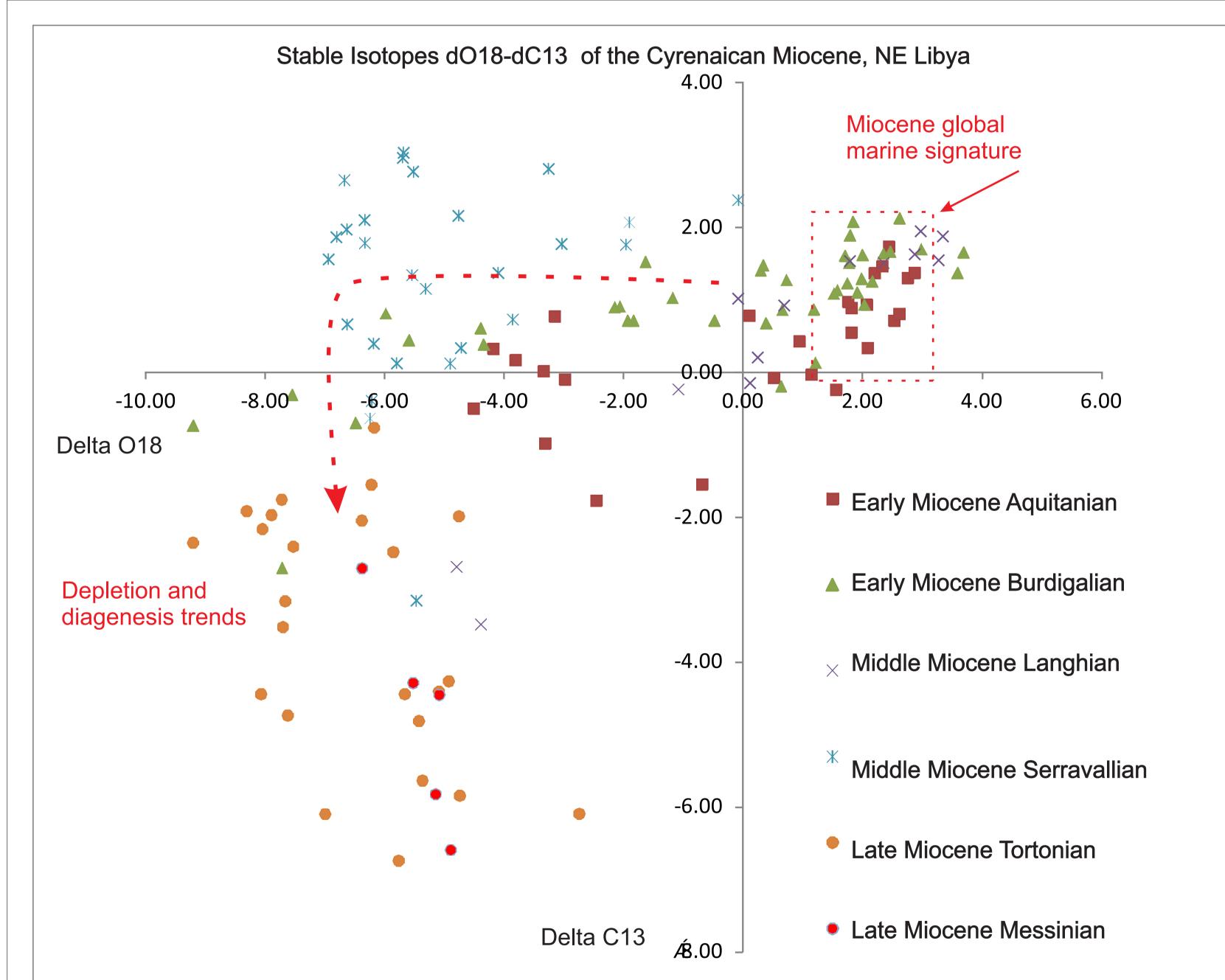












-The Ar-Rajmah Group of the Cyrenaican Platform is a ramp system with

irregular palaeotopography. -The platform has two major 2nd-order supersequences that separated by a

sharp unconformity surface. -The TST of the older 2nd-order supersequences represents the Benghazi

Formation of the Early Miocene. -The TST and HST of the younger 2nd-order supersequence represent the Al-Qattarah Formation and its lateral equivalents Al-Sceleidima Formation and

- The stable isotopes chemostratigraphy, petrography, diagenesis, and Gamma-Ray response profiles tie with and enhanced the resolution of the outcrop-based sequence stratigraphic framework. -The shallowing upward 3rd-order sequences range in thickness from 3.5 m to

more 22.5 m. -The Middle Miocene global Monterey event is exprsed in the Cyrenaican carbonate platform by 13C- isotope enrichment that associated with green shale influx, and major changes in the facies sedimentology, stratigraphy, and diagenetic patterens.

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(A) Oolitic grainstone Facies. (B) Composite oolitic gapestone. (C) Bioclastic packstone facies.

(D) Reworked bioclastic facies. (E) Red algal facies. (F) Reworked red algal packstone facies.

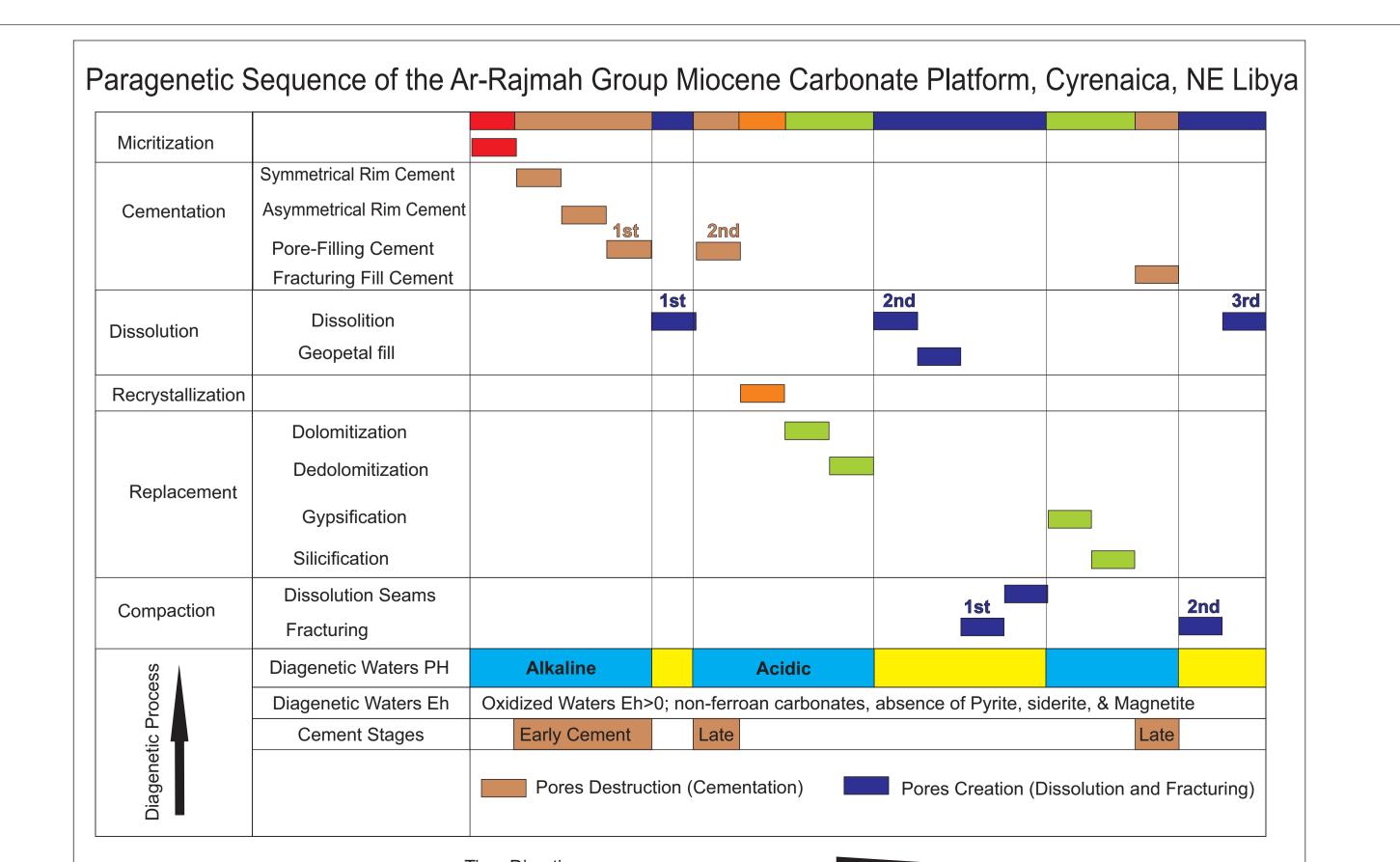
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