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Ahmed M. Muftah
University of Benghazi
Belkasim Khameiss
BelkasimKhameiss@outlook.com
William Hoyt
Muetaz A. Makhlouf

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Miocene Coral Diversity and their Paleobiogeographical Significance from Ar'Rahlah Member of the Maradah Formation in Jabal Zaltan, Sirt Basin, Libya

Ahmed M. Muftah [1], Belkasim Khameiss [1&2], William Hoyt [3], Muetaz A. Makhlouf [4],

[1]University of Benghazi, Faculty of Sciences, Department of Earth Sciences, Benghazi, Libya

[2]Oklahoma Geological Survey, Sarkeys Energy Center,100 E. Boyd St., Suite N131.Norman, OK 73019

[3]University of Northern Colorado, Department of Earth and Atmospheric Sciences,1100 22nd St. Greeley, CO 80639

[4]Mellitah Oil & Gas BV Libyan Branch, Department of Production, Tripoli, Libya

Corresponding Email, BelkasimKhameiss@outlook.com

Abstract

This study presents the first comprehensive documentation of Miocene corals from the Ar'Rahlah Member of Marádah Formation in the Jabal Zaltan area, Sirt Basin, Libya. The coral specimens were thin-sectioned using standard petrographic techniques. Three coral species have been recorded for the first time from Libya: *Favites neglecta*, *Tarbellastraea reussiana*, and *Dipsastraea speciosa*. The findings enhance our understanding of the paleobiogeographical distribution of these coral species. The three identified species indicate ages ranging from Aquitainian to Tortonian; therefore, the suggested age accordingly herein can be integrated as a Middle Miocene (Langhian) for this Marádah Formation in Libya.

The documented coral assemblages provide valuable insights into past climate conditions and environmental dynamics, paleobiogeography during the Miocene era. Coral reefs serve as indicators of marine environmental health and climate change, reflecting ecological interactions of that time.

Keywords: Coral, Favites neglecta, Marádahh, Sirt Basin, Libya

1 Introduction

The study of ancient coral ecosystems serves as a vital lens onto the past marine environments and climate conditions. Coral reefs, recognized as sensitive indicators of marine health, are essential for understanding ecological dynamics and environmental changes across geological time scales. By analyzing six coral samples collected from this region, this study enhances our understanding of biogeographical distribution. The implications of this paper extend far beyond paleobiogeography. The documented coral assemblages provide insights into the biodiversity of the Miocene era and the environmental conditions that prevailed at that time. Understanding the ancient coral ecosystems is crucial for contemporary oil exploration, as coral reefs significantly influence sedimentation patterns and reservoir characteristics. Furthermore, these findings have direct implications for hydrocarbon exploration in the Sirt Basin. Coral reefs not only act as indicators of past marine health but also play a critical role in shaping sediment deposition, affecting porosity and permeability, key factors in hydrocarbon reservoir quality. By investigating the ecological interactions of ancient corals, this study contributes to the optimization of resource management strategies in the Sirt Basin, ultimately aiding in the effective recovery of hydrocarbons. Thus, the interplay of paleontology and climatology sciences provides a multifaceted perspective on the significance of Miocene corals**.**

Location

This study presents the first comprehensive documentation of Miocene corals from the Ar'Rahlah Member of Marádah Formation in Jabal Zaltan area, Sirt Basin, Libya (Fig. 1).

Objectives

The objectives of this paper are to:

- Classify the collected coral specimens from the Marádah Formation at Al Sorra measured section in Jabal Zaltan, Sirt Basin.
- Interpret the paleoenvironmental setting of Marádah's coral-bearing rocks.

- Determine the palaeogeographical distribution of the identified corals worldwide.

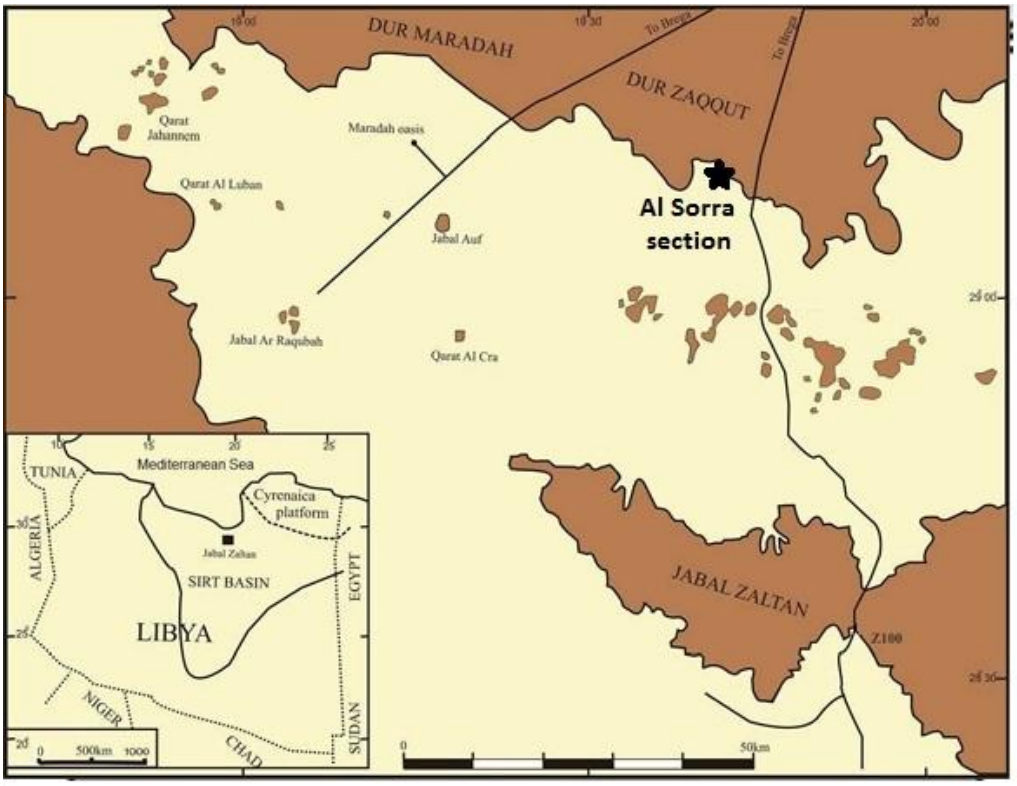


Fig. 1: Location map of part of Jabal Zaltan area showing the studied Al Sorra section of Ar'Rahlah Member of Marádah Formation (Muftah, 2013).

Material and Methods

Six coral samples have been collected from the Ar'Rahlah Member of Marádah Formation at Jabal Zaltan measured section. Selected coral specimens are subjected to thin sectioning according to Standard petrographic techniques of Jones et al, (2015) at the laboratory of the Sirt Oil Company in Al-Brega town, two thin sections are cut "transverse and longitudinal" for each specimen. A consultation with specialists in coral biology at University of Northern Colorado contributes to a thorough and accurate identification to species level. Twenty-nine rock samples and ten coral specimens were collected from Al Sorra measured in Jabal Zaltan locality (29° 08' 41.4"N and 19° 46" 49.3"E). Selected specimens are photographed using professional Digital

Camera. All coral specimens are housed at the Museum of the department of Earth Sciences in the university of Benghazi.

Stratigraphy

The distribution of stratigraphic rock units in Sirt Basin was controlled by structural paleo relief and tectonic development since the Late Jurassic to Early Cretaceous times. The stratigraphic architecture in Sirt Basin shows a lateral change from continental lithofacies at the basin margin to marine lithofacies at its central axis and offshore in the Mediterranean Sea.

Marádah Formation

The Miocene exposures of the Marádah Formation at Jabal Zaltan are characterized by intercalations of carbonate and siliciclastic lithofacies. In the Northern part the formation reaches 70m thick sequence, which consists of a series of alternating calcareous shales, marls and fossiliferous limestones (i.e. mainly bryozoans, oysterids, and corals) which show an upward increase of the carbonate thickness and a decrease of the shale content. Marádahh Formation is dated early Miocene by Magnier and de Blegiers (1959); and middle Miocene by Conant and Goudarzi (1970). Savage and White (1965) and Savage and Hamilton (1973) gave an early Burdigalian age to this Formation on the basis of the vertebrate remains and Foraminifera *Borelis melo crudica*. Mastera (1985) subdivided the Marádahh Formation into two members, the lower siliciclastic dominated Qarat Jahannam and the upper carbonate dominated Ar Rahlah Member with a gradational/ diacronous relationship (Maštera (1985). El Safori and Muftah (2019) described the different bryozan taxa retrieved from Al Rahla Member of Marádah Formation at Z138 in Jabal Zaltan from which two new species have been discovered namely, *Crisia spinosa* and *Thalamoporella zaltaniensis*.

Qarat Jahanam Member

At the type of section, this member attains a thickness of 123m thick and consists of cross bedded sandstones of fine to medium grained, alternating with calcareous siltstones and silty claystones which may contain gypsum in places, reflected in fining upward sequences.

Elsewhere interlaminated of sands and clays due to channel infill enriched with diverse ichnofossils and common cross bedding of bipolar paleocurrent readings (El Hawat, 1980), This Member contained numerous vertebrate remains and fossil wood (Mastera, 1985).

Ar'Rahlah Member

This member rests unconformable on the late Oligocene Bu Hashish Formation, which is exposed to the Southwest of As-Sabkha al Kabirah. The alternation of claystones, gypsiferous, mudstones, and cross bedded calcarenites in the Ar'Rahlah Member are associated with oyster banks referring to *Cubitostrea digitalina* (Fig. 3) and corals, which are often found in growth position such in case of *Favites neglecta* (Michelotti in d'Achiardi, 1868) (Fig. 4).

More recently, Ar'Rahla Member of Marádah Formation dated by Abdulsamad et al., (2021) as Langhian- Serravallian in the southwestern sectors on basis of total stratigraphic range of larger benthic foraminifera *Borelis melo melo* (Fichtel and Moll). However, in the northern sectors the fossiliferous facies in upper interval (i.e. NRF4-NRF7) dates as the Langhian – Serravallian. While the burrowed lower interval (i.e. NRF1-NRF3) dated as Aquitanian – Burdigalian).

Seven lithofacies are recognized by El Hawat (2008) in response to the interplay of steady eustatic sea level change overprinted by spasmodic tectonic activity of Sirt rift complex during Middle Miocene.

Lithology of the Studied Ar'Rahlah Section:

The section studied at the measured Al-Sorra locality is composed of several units. The upper six units made of a rhythmic pattern of limestones dominated lithotype intercalated with shales-clay, due to the fluctuation of sea level, whereas the lower three units of the measured section are made of sandstones and clays (Fig. 2).

Results

Coral identification involves systematic process utilizing a polarized light microscope to examine their internal structure (Smith, 2019). Examination of fossilized coral internal structure under petrographic microscope provides a translucent view of the transvers and longitudinal sections of the fossilized coral, enabling detailed investigation of their morphology and internal features (Brown, 2019).

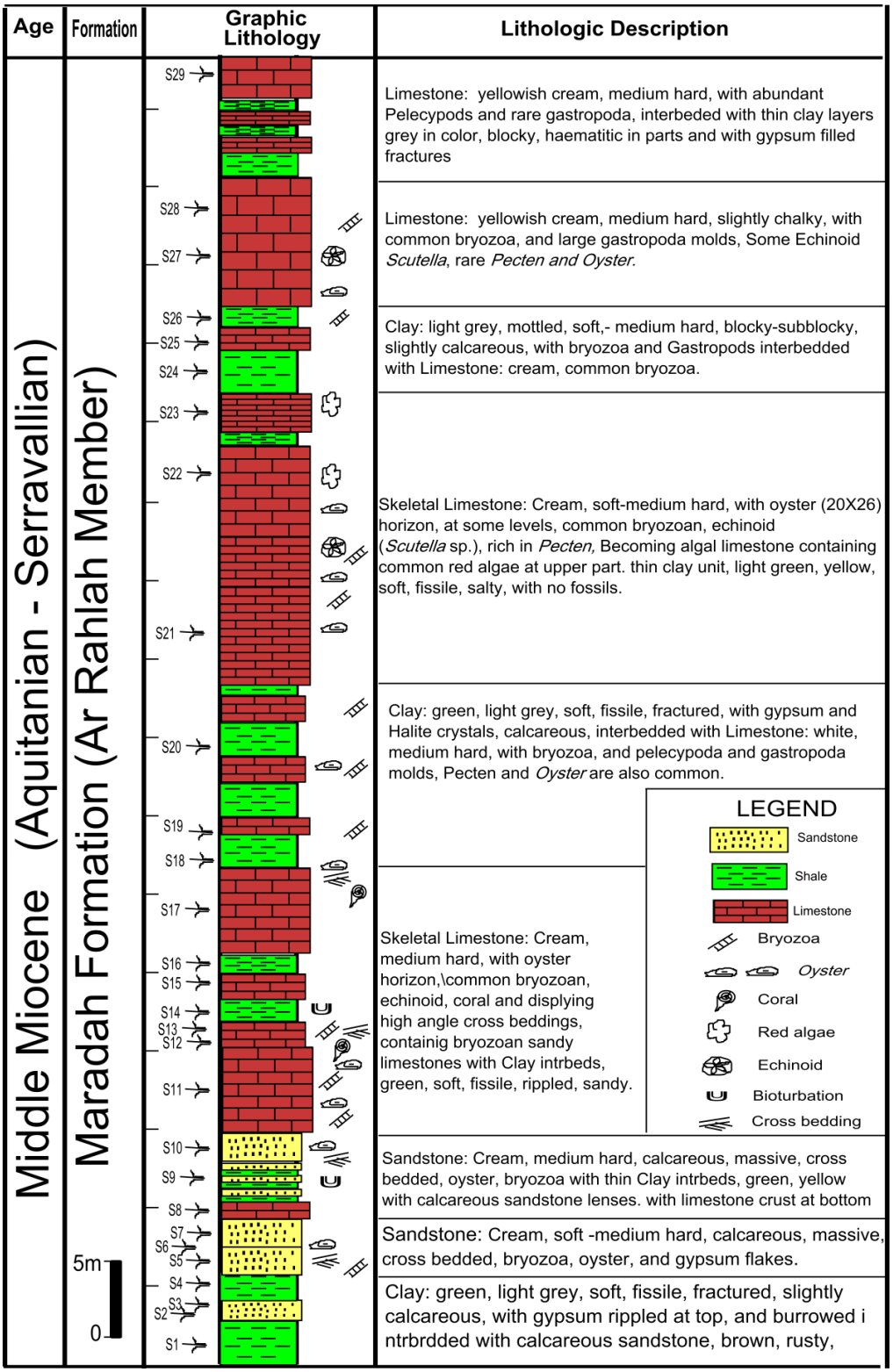


Fig. 2: Lithological column of Ar'Rahlah Member (Marádah Formation) at Assora in Jabal Zaltan area shows (Modified after El-Safori and Muftah, 2019).

To facilitate species identification, reference materials such as scientific literatures and databases are consulted to gain comprehensive descriptions and illustrations of coral thin sections (Johnson and Williams, 2020; Brown, 2019), furthermore, by comparing the observed features with reference and related studies in relation to taxonomical identification of the coral specimen can be accelerated (Smith, 2018). In this context, three coral species have been identified for the first time from Libya, these are *Favites neglecta*, *Tarbellastraea reussiana*, and *Dipsastraea speciosa.*



Fig. 3: Close view of shell concentration of *Cubitostrea digitalina* in Ar'Rahlah Member, Sirt Basin.



Fig. 4: Close view of *Favites neglecta* (Michelotti in d'Achiardi, 1868) in growth position from the lower coral level part of Ar'Rahlah Member of Marádah Formation

Taxonomical Notes

The key morphological criteria that are used in identifying the coral species are the arrangement and shape of individual polyps and the related septa, tabulae, and growth bands (Smith, 2018; Johnson and Williams, 2020). Moreover, trabeculae, dissepiments, and coenosteum are also considered for species variations and distinctive characteristics (Jones et al., 2015).

The following taxonomical information is summarized below:

Family: Merulinidae Milne Edwards and Haime, 1857

Genus: *Favites* Link, 1807

Species: *Favites neglecta* (Michelotti in d'Achiardi, 1868)

(Figs. 5a-c; 6a-c)

Age: Miocene "Aquitanian-Late Tortonian"

Material: 4 specimens from Ar'Rahlah Member of Marádah Formation, in Jabal Zaltan- Libya.

Neotype: The neotype from the Middle Miocene of Termofura near Turin is identified by Chevalier (1961) and is housed in the collection at the Laboratoire de Paléontologie of the National Museum of Natural History in Paris.

Description: The colony is enormous, cerioid, extra- or intratentacular, and has monocentric to tristomodeal calices. Corallites are not exerted, having 25 to 60 finely dentate septa, generally 35-50. 12 to 20 septa typically reach the well-developed trabecular columella. The corallites 265 have a diameter of 4.5 to 10 mm. Some specimens have uneven or extended calices. The septoor parathecal wall is often not thickened. There are vesicular endo dissepiments present.

Geographical Distribution: *Favites neglecta* is predominantly found in the tropical waters of the Indo-Pacific, the Indian Ocean, and the Western Pacific. Significant populations of this coral are present in countries such as Australia, Indonesia, the Philippines, and Japan, with a notable presence in the Great Barrier Reef, recognized for its rich coral diversity. Additionally, it thrives in the coral-dense waters of Southeast Asia, including Indonesia, Malaysia, and surrounding archipelagos, typically inhabiting shallow, clear waters on fringing reefs. Furthermore, it has been recorded in South Corsica (France) and South Sardinia (Italy) (Galloni et al., 2001), as well as in northeastern Esfahan, central Iran (Rahiminejad et al., 2016). The Red Sea, particularly in the northwest of Saudi Arabia, is another critical region where unique environmental conditions support its growth (El-Sorogy et al., 2020). The present records at Jabal Zaltan, in Sirt Basin of Libya, add a new geospatal record in North Africa (Fig. 9).

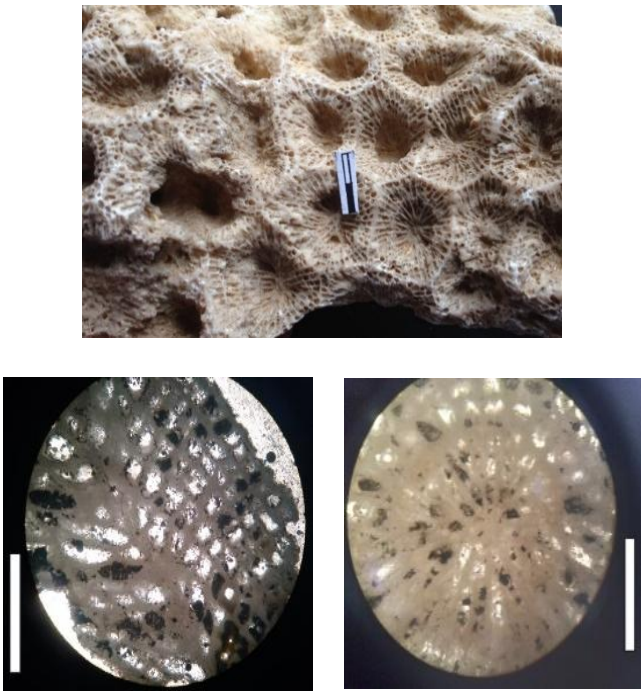


Fig. 5: A view of *Favites neglecta* (Michelotti in Achiardi, 1868), a) an external view (bar scale =10mm); b) transverse section; c) longitudinal section, scale bar = 5mm, PPL.

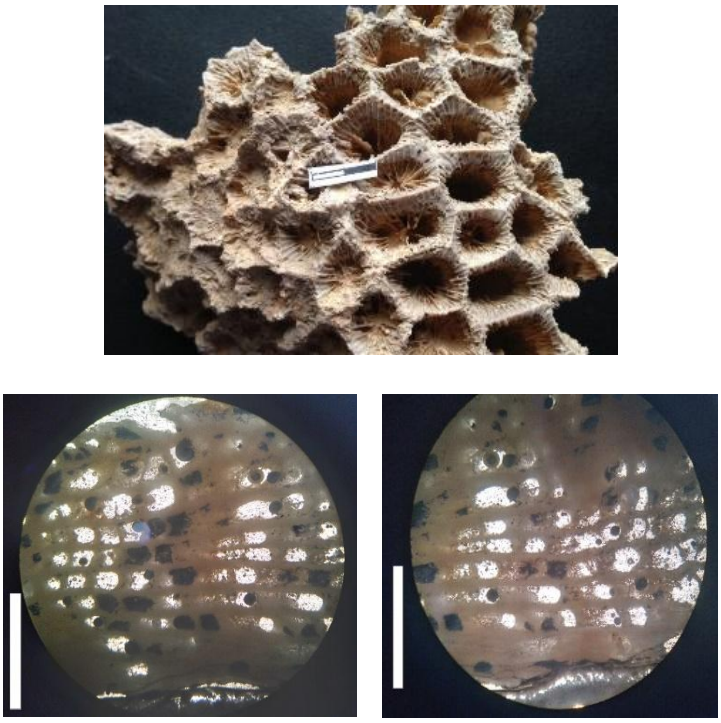


Fig. 6: A view of *Favites neglecta* (Michelotti in Achiardi, 1868), a) an external view (bar scale =10mm); b,c) transverse sections, scale bar = 5mm, PPL.

Family: Faviidae Gregory 1900

Genus: Tarbellastraea Alloiteau 1950

Species: *Tarbellastraea reussiana* Milne-Edwards and Haime 1850

(Fig. 7a-c)

Age: Miocene (Burdigalian -Late Messinian)

Material: 4 specimens from Ar'Rahlah Member of Marádah Formation, in Jabal Zaltan- Libya.

Description: Massive or branching colony with branches 15-30 mm in diameter. The corallites are plocoid and frequently exert with extratentacular budding. They are 1.0-3.2 mm in diameter, and generally oval, with 0.5-3.0 mm apart. In three cycles, there are typically 24 septa. (Fig. 6) A truncated fourth cycle of septa is present in some calices of some (typically branching) specimens. The first two cycles' septa reach the styliform columella. The columella is lacking in some calices. The costae are substantially developed, extending throughout the entire coenosteum surface, and opposing all septa. The septothecal wall is not thickened. The coenosteum is vesicular, with several exodissepiments that are thickened irregularly. Endodissepiments are present, although they are thinner and fewer in number (Fig. 6).

Geographical Distribution: *Tarbellastraea reussiana* is a fossil coral species commonly found in Miocene deposits throughout the Mediterranean and North Africa. It is recorded in countries such as Italy, Spain, Greece, and Malta, where it thrived in the warm, tropical waters of the ancient Tethys Sea. In North Africa, fossil remains of this species have been found in Egypt, and Tunisia, from extensive Miocene marine sediments. These regions once provided ideal conditions for coral reef development, reflecting the tropical marine environments of that era (El-Sorogy et al., 2020; Ekin and Tsaparas, 2023). The species has been known from the Middle Miocene of the entire Mediterranean region (Chevalier, 1961). The present records of *T. reussiian* at Jabal Zaltan, in Sirt Basin of Libya adds a new geospatal record in North Africa (Fig. 9).

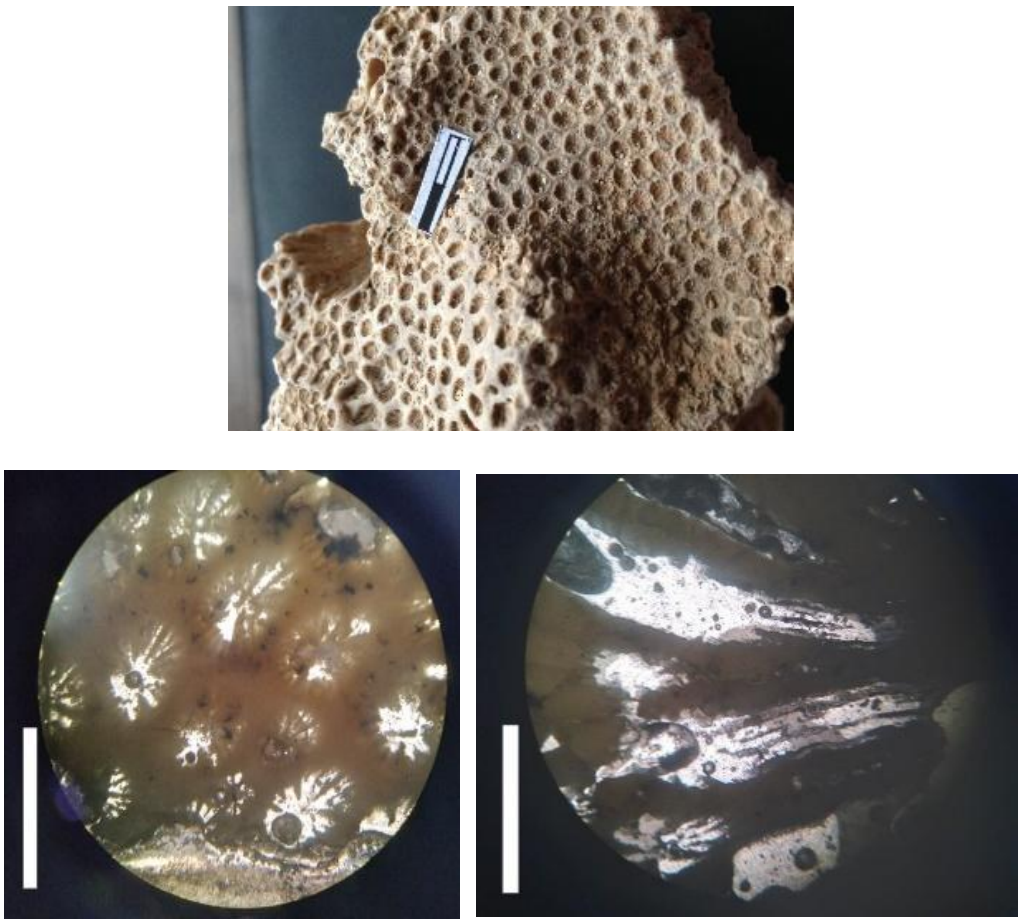


Fig. 7: A view of *Tarbellastraea reussiana* Alloiteau Milne-Edwards and Haime 1850, a) an external view (bar scale =10mm); b) transverse section; c) longitudinal section, scale bar = 5mm, PPL.

Family: Merulinidae Verrill 1866 (stony coral)

Genus: *Dipsastraea* de Blainville 1830 (stony coral)

Species: *Dipsastraea speciosa*) Dana, 1846)

(Fig.8a-e)

Age: Miocene "Langhian" to Holocene

Material: 4 specimens from Ar'Rahlah Member of Marádah Formation, in Jabal Zaltan- Libya.

Description: Corallites have shapes varying from very elongated to rounded, with sizes between 7 and 15 mm. Corallites range between 3 and 6 mm in size, is separated from the others by

substantial walls (Fig. 7). The presence of fine, numerous, and regularly spaced septa helps in the speciation of this species from the closely similar *Dipsastraea pallida*. The costae and septae have fine and evenly spaced teeth (Fig. 7). The colonies of *Dipsastraea speciosa* have enormous growth habits. Corallites have subcircular, grouped calices that can reach a diameter of 12 mm, with calices contrasting color range from light grey to green to brown. Large colonies of *Dipsastraea speciosa* have been observed by Veron, (1993) and Barnes, (1969).

Geographical Distribution: *Dipsastraea speciosa* is a coral species primarily found in the Indo-Pacific region. It thrives in tropical and subtropical reef environments, commonly occurring in shallow, warm waters. The distribution of *D. speciosa* spans across the Indian Ocean and Western Pacific, including countries like Australia, Indonesia, the Philippines, Malaysia, and parts of Japan. This coral species is often associated with fringing reefs, atolls, and lagoon environments, where it contributes to the overall reef structure and biodiversity. (Mihaljević, 2019, and Casazza, 2017). The present record of this species at Jabal Zaltan, in Sirt Basin of Libya, is the only record in the Mediterranean Sea (Fig. 9).

Conclusions

This study provides the first comprehensive documentation of corals from the Ar'Rahlah Member of the Marádah Formation in Jabal Zaltan, Sirt Basin, Libya. The identification of three coral species (*Favites neglecta, Tarbellastraea reussiana*, and *Dipsastraea speciosa*) not only enhances our understanding of the biodiversity present during the Miocene era but also confirms their geographical distribution within the Middle Miocene Mediterranean range (Fig. 9). The three identified coral species indicate ages ranging from Aquitanian to Tortonian; therefore, the suggested age is accordingly herein integrated as a Middle Miocene (Langhian) age for Marádah Formation based on the identified coral taxa from Libya. The presence of these corals suggests a warm, nutrient-rich marine environment conducive to reef development, which can inform our understanding of ancient sedimentary processes and depositional environments. The sedimentation rate during the Miocene, influenced by biological activity, water depth, and nutrient availability, is crucial for reconstructing paleoenvironmental conditions.



Fig. 8: A view of *Dipsastraea speciosa* (Dana, 1846), a) an external view (bar scale =10mm); b) transverse section; c) longitudinal section, scale bar = 5mm, PPL.

Moreover, the documented coral assemblages have significant implications for contemporary oil exploration in the Sirt Basin. The understanding of ancient coral ecosystems aids in recognizing sedimentation patterns and reservoir characteristics essential for optimizing hydrocarbon recovery. Coral reefs influence sediment deposition and the resulting porosity and permeability of sediments, which are critical factors in hydrocarbon reservoir quality.

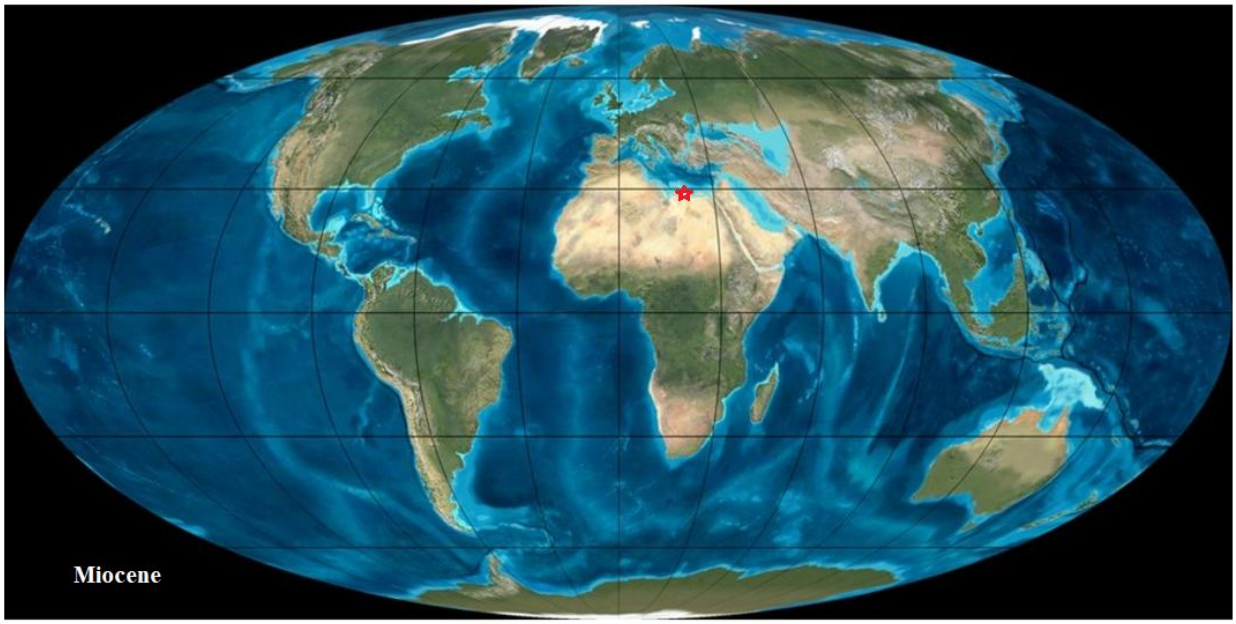


Fig. 9: A new introduced location of the Miocene corals (*Favites neglecta*, *Tarbellastraea reussiana* and *Dipsastraea speciosa*) in North Africa, Libya.

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Declarations

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Data availability: No datasets were generated or analyzed during the current study.

Declarations

Conflict of interest: The authors declare no competing interests.

Ethical approval: The manuscript does not report on or involve the use of any animal or human data.

Consent to participate: Not applicable.

Consent for publication. All authors have reviewed the manuscript and consented to its publication.

Coral samples were collected with permission from the relevant Libyan authorities, in accordance with local regulations governing geological fieldwork and sample collection.

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