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The effect of Mid-Miocene Climatic Optimum on Ostracod assemblages in the Fatha Formation from Banaman section- Erbil, Iraqi Kurdistan Region

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All praise is to ALLAH, who helped me in doing this scientific research.

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Abstract

The Middle Miocene Fatha Formation (previously Lower Fars Formation) in northern Iraq was deposited in a broad and shallow foreland basin adjacent to the Zagros and Taurus Mountains. It forms a transgressive-regressive sequence comprising numerous shallowing-upward cycles of alternating mud Rocks, limestones, gypsum and/or anhydrite and halite. These cycles reflect rapid changes in accommodation space in settings that ranged from open and restricted hypersaline marine to continental (sabkha and fluvio-deltaic). In the marginal parts of the basin, continental siliciclastic (red and variegated marls, silts and fine sandstones) represent either aeolian deposition or a combined lagoonal- and/or fluvial-dominated delta system. Eustasy, rather than tectonics, caused the high-frequency cyclicity in the Fatha Formation. Dolomitic limestones occur mostly in the lower part of the lower member of the formation, which was deposited in a barred lagoonal environment with high salinity. The presence of peloidal lime-wackestone with bioclasts, particularly in the upper part of the lower member of the formation, may reflect quiet, shallow-water marine conditions with moderate depths and low energy. The bioclastic-peloidal grainstone-packstone microfacies, with a common and diverse fossil assemblage, may reflect high to moderate energy, shallow-water environments. Evaporites comprise the main sediments of the Fatha Formation. Nodular gypsum is the dominant gypsum type, although laminated, thick-bedded, and secondary gypsum (selenite and satin spar) also occur. In the subsurface, anhydrite and halite are the principal minerals. We have the (14) sample in field work in Banaman section and do sieving and heating in laboratory and piking for microscope. The ostracod assemblages that have been studied indicate the shallow deposition of the current Formation. Having a well preserved and thick shelled carapaces with a minority of smooth and low ornamentation taxa also confirmed that.

1- Introduction:

The Neogene (Miocene & Pliocene, 23.03-2.58 Ma) can be informally subdivided into an early warm interval and late cool interval (Flower and Kennett, 1993). Superimposed on this long-term cooling is the Mid-Miocene climatic optimum (MMCO) between ~15-17 Ma, marking the warmest interval of the Neogene (Zachos et al., 2001). Cooling following the MMCO culminated at ~13-14 Ma in major growth of the East Antarctic Ice Sheet (EAIS). Further cooling coincided with increasing intensification of Antarctic deep-water formation and growth of the AIS and Greenland Ice Sheet (Flower and Kennett, 1993, 1994, 1995).

Profound palaeoclimatic and palaeoceanographic changes in the Neogene drove progressive and significant turnover of deep-sea benthic foraminiferal communities from the so-called Transitional fauna characterising the late Oligocene-early Miocene to the late Neogene fauna of the late Miocene, and finally the establishment of recognisably modern assemblages in the mid-Pleistocene (Jones, 1994, Kaiho, 1994). The first major transitional interval occurred in the early-middle Miocene, between ~13-17 Ma (Kaiho, 1994), spanning the onset of the MMCO and subsequent East Antarctic Ice Sheet growth, and associated changes in water mass character and upwelling intensity (Woodruff, 1985). Further changes in species abundance occur ~8-10 Ma, in the late Miocene. Finally, the last global extinction of benthic foraminifera (~20% of deep-sea genera) occurred in the late Pliocene-mid Pleistocene (Hayward et al., 2012) and is variously attributed to increasing ocean productivity and intensification of low oxygen zones, and changes in the food type and supply, due to the expansion of the Antarctic and later Northern Hemisphere ice sheets and global cooling (Hermoyian and Owen, 2001, Gupta et al., 2004, Smart et al., 2007). Water temperatures in the studied formation ranged from 24° to 32°C. Having a well preserved Cytherellids were found in the sediments of the Fatha Formation confirming the above recorded range of the temperature. This has also confirmed by Khalaf ad Kharofa (2020) during their study in the Hammam Al-Alil area. Khalaf ad Kharofa (2020) reported that the Ostracod assemblages give a shallow marine to restricted lagoon environment. Some of the species belongs to *Paijenborchellina* and *Keijella* genera have also been reported from the current study. The carapace colour of the current species are commonly white or light yellow which indicate the deposition in normal oxidation environment. This has also suggested by Khalaf ad Kharofa (2020). Having a high diversity and abundance of the miliolids especially in the sample S11 may give clue of deposition in a high salinity and more restricted environment (Khalaf ad Kharofa, 2020). Beside the tectonic setting of the area the global climate change may have been affected the current study biosystems as the interval between ~15-17 Ma, marking the warmest interval of the Neogene (Zachos et al., 2001).

2-Study area:

Fourteen samples are collected from the mid- Miocene successions of the Fatha Formation near the Banaman area. This formation situated in the south western limb of Pirmam anticline. The lithology is usually composed of mixed clastic and carbonate rocks. The previous works limited the depositional environment as a restricted lagoon and fluvial environment.

Figure 01: location map referred to the ***study area (Banaman area)***

3- Methodology:

Field work is the most important way to provide us so many useful data and excellent information to solving so many geological problems and ambiguities related to reconstruction of the depositional environments, sequence stratigraphic frameworks, and basin analysis. We gathered 14 samples from studied section during field work near Pirmam Anticline for stratigraphic succession. Describing rock descriptions, which consisting mainly of dolomitic limestone, marley limestone and dolomitized marly limestone with total thickness about 143m.

The collected samples will use to extract fossils by a sample preparation technique using hydrogen peroxide with a concentration nearly 3%. Later the sample treated by soda (Na_2CO_3) and boiled in water for more than three hours. The picked fossils will later identify under the stereoscopic microscope (Wild- category) in the College of Science (Salahaddin University) to species level and undergone several biostratigraphic analysis.

Figure 2: Test Vails of picked samples in laboratory of Fatha formation.

Figure 3: The microscope and sieves in laboratory for sample preparation and species identification.

4- The aim of the study:

The main objective of the current study is to examine the climatic changes and its impact on the fossil assemblages during the mid- Miocene. Using fossil as a proxy for climatic fluctuations still ambiguous and need more detailed investigations to answer all changes evidenced the Neo-Tethys during the Miocene in our region. The aim of our study can be summarized as follow: -

1- Gathering geological information on the middle Miocene Formations at the studied areas, especially relating to the stratigraphy and sedimentology such as bed forms, bed thickness and bed lithologic descriptions, in addition to showing boundary natures with underlying and overlying units.

2- Drawing geological columns to the selected sections and make a 2D stratigraphic correlation to showing lateral variations in bed thicknesses.

3- Collecting rock samples from studied sections to determining middle Miocene rocks and facies for discrimination the depositional environments of the middle Miocene Formation.

4- Detecting the effect of the MMCO on the current species beside the effect tectonic movements.

5- Stratigraphic setting:

The stratigraphy of Fatha formation succession is made up of a variety of mud rocks, limestones, and gypsum. It is divided into two distinct rock units. The Lower Member, which has a basal unit of organo-detrital limestone and anhydrite (or gypsum), green dolomitic marl and thin limestone, and cyclically interbedded gypsum, green marl, and limestone. The Upper Member is made up of cyclic red and green mudstones, gypsum, and thin grey limestone layers with calcarenite beds on top. According to the findings, the Fatha Formation may be classified into four major lithofacies based on the prevalent lithology.

6- Geology sitting:

Lower Fars (Fatha) Formation (Middle Miocene) Type locality: The type locality of the Lower Fars (Fatha) formation is in Iran From where the authors first described it (Bellen et al., 1959). Exposure Areas: The formation is exposed in Zakho, Dohuk, Shaqlawa, Salahaddin, Harir, Amadiya, Sar Sang, Mangesh, AinSifni, south and southwest of Sulaimaniyah, Kolosh anticline and around Derbandi Khan Lake. The formation has a very wide sub surface extensions toward south east of Iraq in Low Folded Zone, Al-Jazira and Mesopotamian plain (Sissakian and Al-Jiburi, 2014).

Thickness and lithology: A thickness of the formation is highly variable. It reaches up to 900 m in central parts of its depositional basin. In General, the lithology of the Lower Fars Formation in Iraq is composed of anhydrite, gypsum and salt, with limestone, marl and fine grained clastic inter beddings (Buday, 1980). Depositional environment: Agreed by all authors that it was closed lagoon or hyper saline condition (Sissakian and Al-Jiburi, 2014).

Lower boundary and underling formation: In a High Folded Zone the Lower Fars Formation is underlie unconformably by the Pila Spi Formation. However, locally in some areas Early Miocene rocks may underline the formation conformably (Buday, 1980).

Upper boundary and overlying formation: The upper contact is diachronous and gradational with Upper Fars Formation (Buday, 1980).

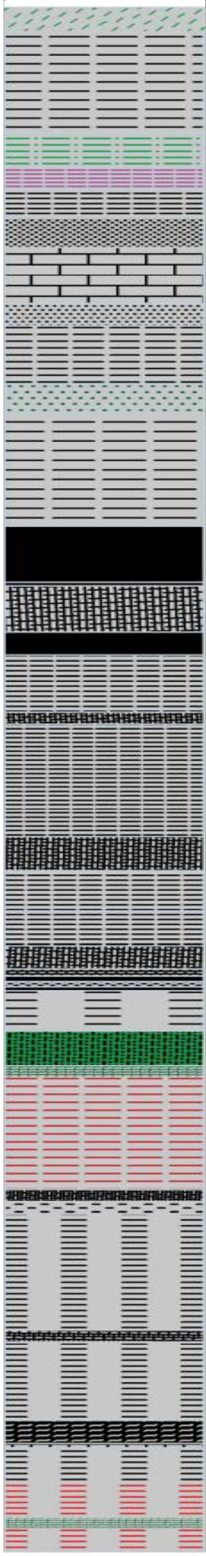
Lithology	Sample No.	Thickness	Description
	S14	14m	Light green siltstone and mudstone and green sandstone
	S13 S12	38.5m	Dolomitic limestone and mudstone and green sand and massive sand and pink clay and Interbedded between sand and mud
	S11	10cm	Marl and we have cover 5m
	S10 S9	26.5m	Marl with limestone and dolomitic limestone and more clay and 2m cover
	S8	5.5m	soft limestone and dolomitic limestone and clay
	S7, S6	80cm	Marl and silty marlstone
	S5	7.5m	Green marl and green dolomatic limstone and mud
	S4	12m	Siltstone and dolomatic limstone and red clay
	S3	11m	Dolomatic limstone and clay
	S2	9m	Marl and claystone
	S1	10m	Red clay and green marl and claystone

Figure 4: **The stratigraphic column of the study area, showng the thickess and description of the beds.**

7- Systematic description:

All the illustrated specimens are deposited in the collections of the Department of the Earth Sciences and Petroleum at the Salahaddin University (College of Science- Erbil). The Type locality of the specimens is located at the Banaman northern of the Erbil governorate. The coordinate is N 36° 21' 29.861477" E 44° 11' 10.616081".

Subclass **Ostracoda** Latreille, **1806**

Order **Podocopida** G. W. Miiller, **1894**

Suborder **Podocopina** Sars, **1866**

Family **Hemicytheridae** Puri, 1953

Subfamily **Campylocytherinae** Puri, **1960**
Tribe **Leguminocytherini** Howe, **1961**
Genus *Keijella* Ruggieri, **1967**
Keijella* cf. *fusa (van *den Bold,* **1966**)

Materials: About four (4) specimens in S2 sample in the Fatha Formation are picked. These specimens are of single valved adult carapace. One (1) single valved adult carapace is picked from the sample (S11) in the same Formation.

Remarks: In comparison with specimens described by van den Bold (1966) as *Thalmannia*? *fusa* from the Lower Miocene of Gabon, the specimens considered here appear to be less ornamented in their anterior area. They are distinctly sexually dimorphic. Remarks concerning generic assignment of that form are as those on *K. africana* El-Waer. It is worth to be noticed, that *Thalmannia*? *fusa* was compared by van den Bold (1966) to *Cythere hodgei* (*recte hodgi*) Brady, 1866. According to van den Bold (1.c.) species from Gabon differs from *C. hodgi* by lack of the posteroventral spine. In 1967 *C. hodgi* has become a type species of *Keijella*. a new genus erected by Ruggieri.

Subclass **Ostracoda** Latreille, **1806**

Order **Podocopida** G. W. Miiller, **1894**

Suborder **Podocopina** Sars, **1866**

Family **Hemicytheridae** Puri, 1953

Subfamily **Campylocytherinae** Puri, **1960**
Tribe **Leguminocytherini** Howe, **1961**
Genus *Keijella* Ruggieri, **1967**
Keijella cf. *fusa* (van *den Bold,* **1966**)

Figure 5: ***Keijella Ruggieri***

(All systematic descriptions have been cited in Szczechura & Abd-El-Shafi 1988)

Materials: About four (4) specimens in S2 sample in the Fatha Formation are picked. These specimens are of single valved adult carapace. One (1) single valved adult carapace is picked from the sample (S11) in the same Formation.

Remarks: The specimens considered here appear to be less ornamented in their anterior area if compared with specimens described by van den Bold (1966) (in Szczechura & Abd-El-Shafi 1988) as *Thalmannia*? *fusa* from the Lower Miocene of Gabon. They are distinctly sexually dimorphic. Remarks concerning generic assignment of that form are as those on *K. africana* El-Waer. It is important to be noticed, that *Thalmannia*? *fusa* was compared by van den Bold (1966) to *Cythere hodgei* (*recte hodgi*) Brady (1866). Van den Bold (1966) noticed that species from Gabon differs from *C. hodgi* by lack of the posteroventral spine. *C. hodgi* become a type species of *Keijella* in 1967 (Szczechura & Abd-El-Shafi 1988).

Family **Cytherettidae** Triebel, 1952
Genus *Cytheretta* G. W. Miiller,1894
Cytheretta cf. *rhenana rhenana* Triebel, 1952

Figure 6:Cytheretta

(All systematic descriptions have been cited in Szczechura & Abd-El-Shafi 1988).

Materials: The current species has reported only in the sample S3 (only 1 specimen in the lower part).

Remarks: Four adult carapaces and 1 adult valve have been reported from the Hommath Formation, western side of the Gulf of Suez (Egypt) and some specimens from the Marada Formation, Sirte Basin (Libya). Comparison with *Cytheretta rhenana rhencma* Triebel, known from the Oligocene and Miocene of Europe (Moyes 1965 in Szczechura & Abd-El-Shafi 1988).

Family **Candonidae** Kaufmann 1900
Subfamily **Cyclocypridinae** Kaufmann 1900
Genus *Cyclocypris* Brady & Norman 1889

Cyclocypris laevis (O.F. Müller 1776)

(All systematic descriptions have been cited in Pipík and Bodergat (2003)).

Materials: Only 1 specimen been recorded in each sample S11, S14 from the current study.

Remarks: The more robust specimens of *Cyclocypris cf. laevis* been recorded from the Pleistocene travertine near Weimar (Germany) is more robust. VM is convex, PDM more curved and AM higher (Pipík and Bodergat, 2003).

Occurrence: Recent species from the Holarctic region are found in the Pleistocene and Holocene as well in the Pannonian deposits (Upper Miocene) of Slovakia (Pipík and Bodergat, 2003).

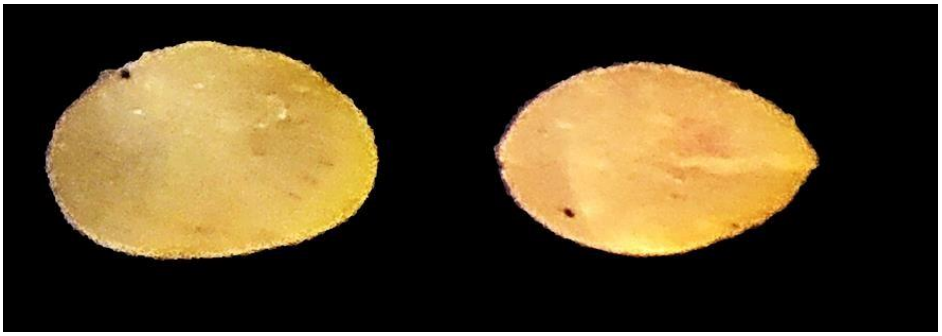


Figure 7:Cyclocypris

Family **Cytheridae** Baird, 1850b

Genus *Paijenborchellina Kusnetzova* in Mandelstam et al., 1957

Paijenborchellina prona (Lubimova and Guha in Lubimova et al., 1960)

(All systematic descriptions have been cited in Yasuhara et. al (2020)).

Figure 8:Paijenborchellina

Materials: Only 2 specimens of the current species have recorded in the lower part of the Fatha Formation in the sample S2.

Remarks*:* Well-preserved specimens of *Paijenborchellina prona* have been studied in southwestern India (Lubimova and Guha in Lubimova et al., 1960 both in Yasuhara et. al, 2020). High-resolution SEM images clearly showed that this species has both primary and secondary reticulation (Yasuhara et. al, 2020).

Occurrence: This species has been reported in different locality such as southwestern India (early Miocene) (Yasuhara et. al, 2020). Khalaf and Kharofa (2020) identified this species as a *Paijenborchellina* sp.1 in the Hammam Al-Alil area, northern Iraq. It considered to have a mid-Miocene range.

Suborder **Platycopa** Sars, 1866
Family **Cytherellidae** Sars, 1866
Genus *Cytherella* Jones, 1849

Cytherella vanttenboldi Sissingh, 1972

Figure 9:Cytherella

(All systematic descriptions have been cited in Dall'Antonia, and Bossio, 2001).

Materials: About 2 specimens in the sample S2 and another 2 specimens in the sample S11 have been picked in the present Formation in the both lower and the upper part.

Remarks: *C. vandenboldi* is close to *Cytherella salentina* n. sp.; their relationships are discussed under the latter species. The size of the puncta is somewhat variable, the ornament is less well developed all around the periphery. *C.* ? *vandenboldi* Illustrated by Barra & Bonaduce (2001) differs from current study material in disposition and size of the puncta on the lateral surface and is therefore, regarded as a different species. The current species is also closely compared with specimens been identified by Dall'Antonia, and Bossio (2001).

Occurrence: In the S. Caterina section: lower Langhian-middle Serravallian (*P. glomerosa sicana* Subzone-P. partimlabiata Zone); S. Maria al Bagno section: lower Langhian-lowermost Serravallian (*P. glomerosa sicana* Subzone-upper part of the *G. praemenardii-G. peripheroronda* Subzone) (Dall'Antonia, and Bossio, 2001). Also, this species been reported in the lower and the upper part of the current work.

Family **Cytheridae** Baird, 1850
Subfamily **Cytherinae** Baird, 1850
Tribe **Paijenborchellini** Deroo, 1960
Genus *Neomonoceratina* Kingma, 1948

Neomonoceratina ruggierii Szczechura

(All systematic descriptions have been cited in Szczechura & Abd-El-Shafi 1988).

Materials: About 81 specimens are picked in the sample S1, 6 specimens are picked in the sample S2 and 4 specimens in the sample S14 from the current Formation.

Remarks: The current species *Neomonoceratina ruggierii* closely related to recent Pacific species *N. entomon* (Brady, 1880) as figured by McKenzie (1986). They, however, differ from it, firstly, in being more spiny posteriorly, and secondly, in having two distinct ribs on ventral side. The specimens referred to *N. ruggierii* are less ovate in lateral outline, more spiny, more distinctly ribbed and their caudal process is shorter (Szczechura & Abd-El-Shafi 1988). **Occurrence**: The current species has also reported in Hommath Formation (? Middle Miocene), western side of the Gulf of Suez (Egypt), section XI and xz, and Marada Formation (? Middle Miocene), Sirte Basin (Libya) (Szczechura & Abd-El-Shafi 1988).

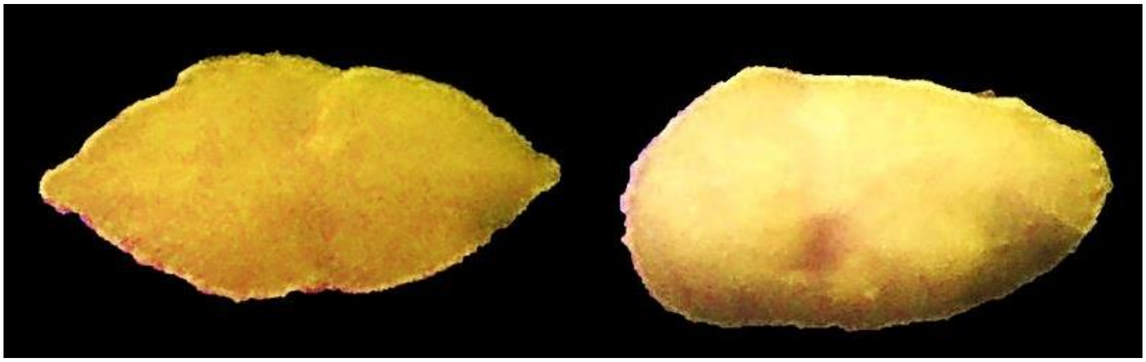


Figure 10:Neomonoceratina

Suborder **Podocopina** Sars, 1866

Family **Cytherideidae** Sars, 1925

Genus *Kotoracythere Ishizaki*, 1966

Kotoracythere sp.

(All systematic descriptions have been cited in Irizuki, 1994).

Materials: About 15 specimens are picked in S2 sample, 17 specimens in the sample S11 and specimens in the sample S3 in the current Formation). It does mean that the current species has long-range starting from lower part and ending to almost the upper part of the Fatha Formation.

Remarks: This species has been widely reported from the Plio-Pleistocene formations in northern Japan (Ishizaki & Matoba. 1985; Tabuki. 1986: Cronin & Ikeya, 1987) (Irizuki, 1994).

Family **Cushmanideidae** Puri, 1973

Genus *Pontocythere* Dubovsky, 1939

Pontocythere sp.

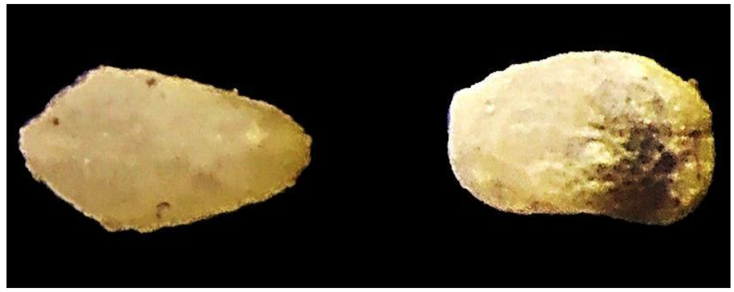


Figure 11:Pontocythere

(All systematic descriptions have been cited in Szczechura & Abd-El-Shafi 1988)

Materials: About four (4) specimens in S2 sample in the Fatha Formation are picked. These specimens are of double valved adult carapace.

Remarks: Specimens of *Pontocythere* sp. has parallel dorsal and ventral margins (the latter being somewhat incised in middle)**.** The common shape distinctly elongated, with length: height ratio about 3:1, especially in males, with almost parallel dorsal and ventral margins. It has lateral outline of the anterior and posterior margins; the anterior margin is only slightly more obliquely rounded than the posterior one.

Occurrence: The species has been recorded from the lower part of the current Formation. It has also recorded in Hommath Formation (? Middle Miocene), western side of the Gulf of Suez (Egypt), section X I, and Marada Formation (? Middle Miocene), Sirte Basin (Libya) (Szczechura & Abd-El-Shafi 1988).

Suborder Podocopina Sars, 1866

Family Cytherideidae Sars, 1925

Genus ***Kotoracythere*** Ishizaki, 1966

Kotoracythere sp.

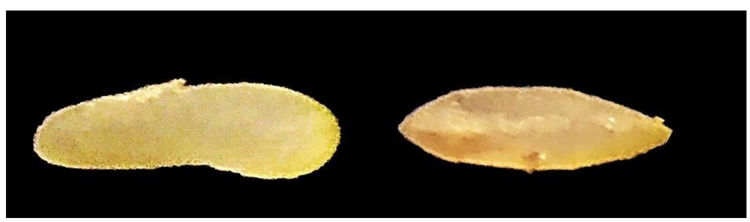


Figure 12: Kotoracythere

Remarks. This species has been widely reported from the Plio-Pleistocene formations in northern Japan (Ishizaki & Matoba. 1985; Tabuki. 1986: Cronin & Ikeya, 1987).

8- Result and Discussion:

1. Picked species of ostracoda belonging to (8) genera were recorded, in (14) sample

All curve for the sample change in abundance in sample (1,2,3,5,6).

2. In first and end samples fossil specimens are high abundance and in the middle of chart samples are low specimen abundance.
3. The studied section was divided into two life clustering ranges based on the stratification of the diagnosed species, which are as follows: -

A- Assemblages Biozone *Neomonoceratina ruggierii*.

B- Assemblages Biozone *Kotoracythere sp.*

4. The formation environment represents the environment of the shallow basin affected by tectonic movements that occurred during the Middle Miocene, which led to the formation of different normal, shallow and sometimes isolated lagoon and shallow marine environments, and this was inferred by changes in the shape of the diagnosed ostracoda genera and species Which reflects environmental factors as the degree of salinity fluctuates between high salinity - normal sea and mixed, warm temperature and rough bottom nature (Khalaf ad Kharofa, 2020).
5. Water temperatures in the studied formation ranged from 24° to 32°C. Having a well preserved Cytherellids were found in the sediments of the Fatha Formation confirming the above recorded range of the temperature. This has also confirmed by Khalaf ad Kharofa (2020) during their study in the Hammam Al-Alil area. Khalaf ad Kharofa (2020) reported that the Ostracod assemblages give a shallow marine to restricted lagoon environment.
6. Some of the species belongs to *Paijenborchellina* and *Keijella* genera have also been reported from the current study. The carapace colour of the current species are commonly white or light yellow which indicate the deposition in normal oxidation environment. This has also suggested by Khalaf ad Kharofa (2020). Having a high diversity and abundance of the miliolids especially in the sample S11 may give clue of deposition in a high salinity and more restricted environment (Khalaf ad Kharofa, 2020). Beside the tectonic setting of the area the global climate change may have been affected the current study biosystems as the interval between ~15-17 Ma, marking the warmest interval of the Neogene (Zachos et al., 2001).

sample number	*Neomonoceratina*	*Kotoracythere*	*Keijella*	*Pontocythere*	*Cytherella*	*Paijenborchellina*	SP7	SP8	total	diversity
S1	81						0	0	**81**	**1**
S2	6	15	4	4	2	2	0	0	**33**	**6**
S3	0	3	0	0	0	1	0	1	**5**	**2**
S4	0	0	0	0	0	0	0	0	**0**	**0**
S5	0	0	0	0	0	0	0	0	**0**	**0**
S6	0	0	0	0	0	0	0	0	**0**	**0**
S7	0	0	0	0	0	0	0	0	**0**	**0**
S8	0	0	0	0	0	0	0	0	**0**	**0**
S9	0	0	0	0	0	0	0	0	**0**	**0**
S10	0	0	0	0	0	0	0	0	**0**	**0**
S11	0	17	1	0	2	1	0	0	**21**	**4**
S14	4	0	0	0	0	1	0	0	**5**	**2**

Table 1 : Ostracod Species diversity and abundance.

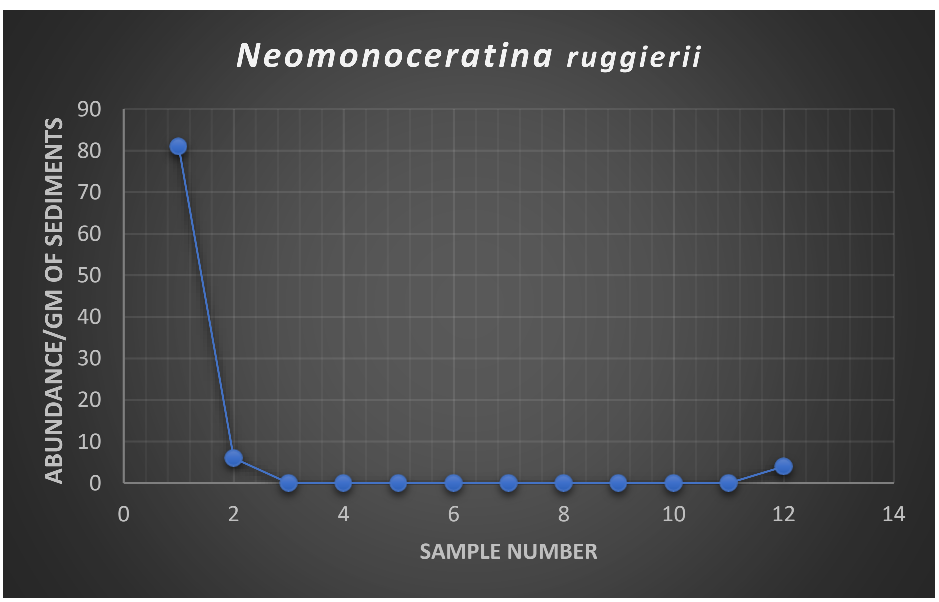


Figure 13: The abundance of *Neomonoceratina ruggierii*.

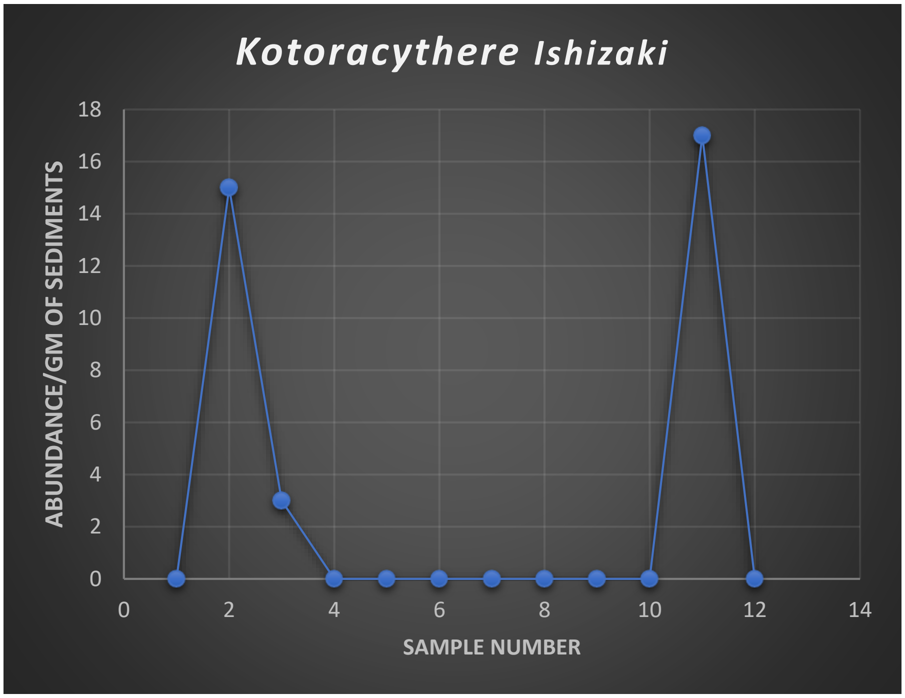


Figure 14: The abundance of *Kotoracythere* Ishizaki

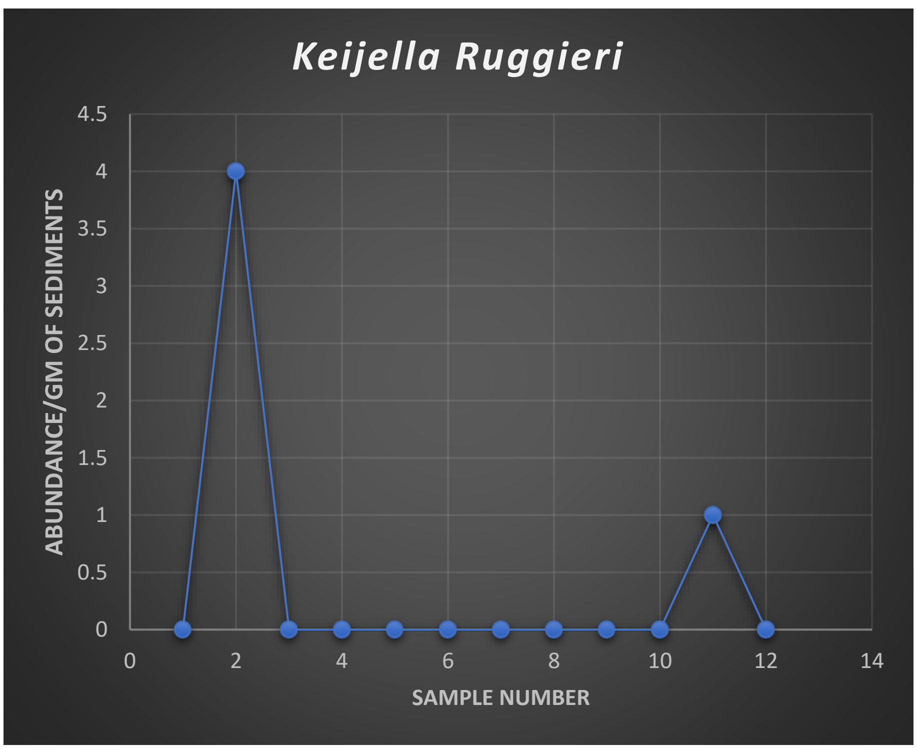


*Figure 15: The abundance of **Keijella Ruggieri***

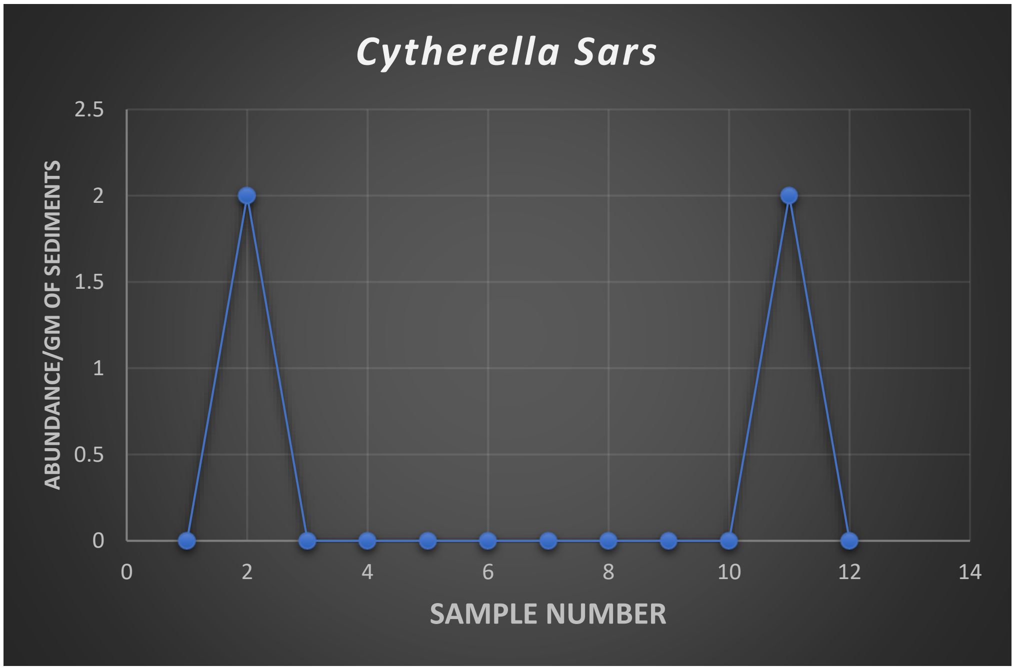


Figure 16: The abundance of ***Cytherella Jones***

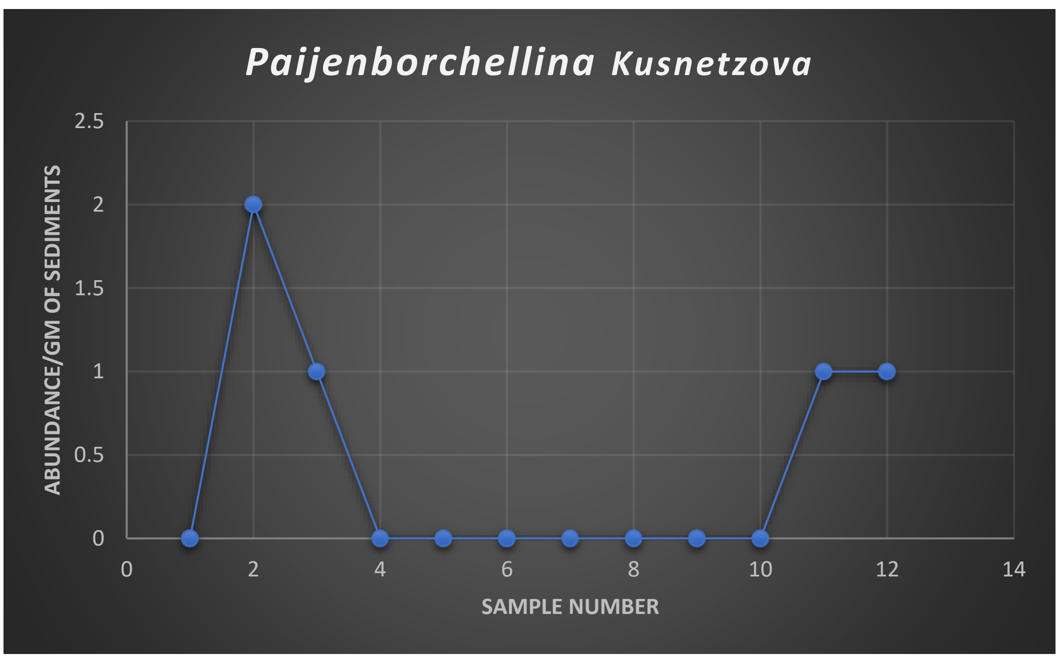


Figure 17 : The abundance of ***Paijenborchellina Kusnetzova***

sample number	specimens total	specimens richness
S1	81	675
S2	33	127
S3	4	4
S11	21	700
S14	5	3.1

Table 2: Total ostracod specimens and species richness/gm of sediments.

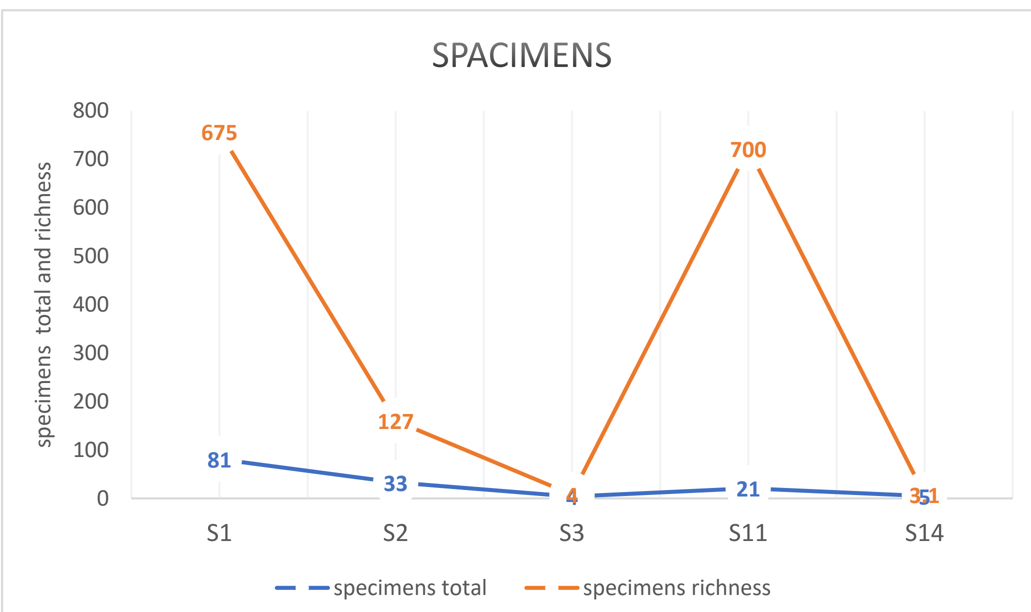


Figure 18: sample specimens for samples

9- Conclusion

1- At the end picked 8 genera of ostracoda in 14 samples .

2-at the first and end high fossil abundance but low at the middle.

3-represents the environment of the shallow basin affected by tectonic movements that occurred during the Middle Miocene.

4-Water temperatures in the studied formation ranged from 24° to 32°C.

5-the tectonic setting of the area the global climate change may have been affected the current study biosystems as the interval between ~15-17 Ma

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