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# Late Santonian - Campanian Ostracodes from Northwestern Jordan: Biostratigraphic and Paleobiogeographic Implications

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# Abstract

Nine ostracod species are described from the Late Santonian - Campanian of Wadi Al-Kharaj section, northwestern Jordan. These species provide valuable information for biostratigraphy and paleobiogeography of the southern Tethys realm. The nine species belong to the following genera: *Cytherella, Bythocypris, "Togoina", Brachycythere, Cythereis, "Veenia", Ventrocythereis,* and *Cristaeleberis.* These species confirmed that the top of the Wadi Ghudran Formation and the base of the Amman Formation span the Coniacian-Campanian boundary. *Brachycythere* provides valuable information on the palaebiogeography of the shallow marine ostracodes.

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# 1. Introduction

During most of the Late Cretaceous global transgression, Jordan was a part of an epicontinental sea where carbonate precipitation is associated with organic matter enrichment within the shallow marine setting (Bender, 1974; Powell, 1989). Ostracodes are tiny aquatic crustaceans that are common in shallow water and their shells are often abundant in fine sediments (e.g. Anadón et al., 2002; Rodriguez-Lazaro and Ruiz-Muõz, 2012). Previously published works on ostracods of the Jordanian Late Cretaceous of Jordan are scarce. The only available record for the Late Cretaceous (Senonian) ostracodes is represented by Bassiouni (1970) who worked on the Late Maastrichtian-Paleocene succession of Jordan.

The aspects of Late Cretaceous (Senonian) ostracodes and their paleogeographic distribution of the Middle East, and the North and the West African regions have been carried out by several authors. The studies in Jordan include Bassiouni (1970). In Egypt there are Bold (1964); Bassiouni & Luger (1990); Morsi (2000); Shahin & El-Nady (2001); Abdel-Shafy et al., (2002); Shahin (2005); El-Nady et al., (2008); Boukhary et al. (2013); Morsi et al., (2019, 2020) and Hewaidy et al., (2021). Reyment (1960, 1963). El-Sogher (1992) from Libya and Donze et al. (1982) from Tunisia, Bellion et al. (1973) and Damotte et al. (1987) from Algeria, Damotte (1995) from North Africa, Mali, and Congo. In Israel, Honigstein (1984); Honigstein et al. (1987), Honigstein et al (1993) and many others.

The paleogeographical distribution of the Mesozoic ostracodes has been one of the most useful tools in understanding the breakup of Gondwana land. The genus *Brachycythere* played a critical role in establishing a faunal connection among the Gondwana land continent.

To evaluate the paleogeographic and biostratigraphic

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significance of the ostracodes, a section between Al-Kharaj and Haufa villages (Figure 1) at the northern part of Jordan (32° 33′ 54″ N) and (35° 49′ 27″ E) was measured and sampled for the biostratigraphical study. The significance of this study comes from being the first on Senonian ostracodes record, originating from the Amman Formation of Jordan.

All specimens described in the present paper are obtained from the Amman Formation in the Wadi Al-Kharaj area. The rock samples and the ostracodes are deposited in the collection of the Department of Earth and Environmental Sciences, Yarmouk University, Irbid, Jordan, and has the number YUPOS KH where:.

Yu = Yarmouk University, POS= Palaeontology Ostracoda, KH = Wadi Kharaj.



Figure 1. Detailed location map of the study area from where the Late Creatceous Ostracode section was studied between Al-Kharaj and Haufa

## 2. Geological setting:

Sedimentation during the Mesozoic and Early Cenozoic was controlled by the configuration of Teyths Ocean in the north and northwest Jordan, which transgressed several times over parts or over the entire area of Jordan when the sea reached the southeastern part of the country. Regression of the sea in post-Eocene time was related to mountain-building events as the African-Arabian plate moved northward against the Euro-Asian plate (Bender, 1974; Powell, 1989).

During the Early and Middle Triassic, a transgression of the Tethys Ocean to the southeast was pronounced. The sea advanced from the west and northwest to the area just east of the Dead Sea, where Triassic littoral, lagoonal, and continental sedimentary rocks disconformably overlies Lower Paleozoic clastic rocks (Bandel and Khouri, 1981). After a regression during the Late Triassic and Early Jurassic, the Tethys advanced once again during Late Early Jurassic. Jurassic shorelines probably were just west of and approximately parallel to the borders of the Triassic transgression (Bandel, 1981).

Renewed epeirogenic uplift and erosion, and local volcanism, probably during the Late Jurassic, preceded Early Cretaceous sedimentation. Dominantly clastic rocks of the Early Cretaceous age, therefore, overlie the Palaeozoic, Triassic, or Jurassic formations with a regional angular unconformity. During the Early Cretaceous, a marine depositional environment dominated the northwest part of Jordan, and a transgression during the Albian reached the area east of the Jordan River. Farther east and to the south, clastic sediments of continental origin were deposited (Bender, 1974).

The shoreline lies off north Jordan during Early Cretaceous (Bandel & Mikbel, 1985). The sea advanced southwards during aseveraltransgressive episodes of short durations. In Late Albian to Early Cenomanian time, a major transgression occurred that led to the deposition of carbonate sediments in Jordan deposited on a broad platform extending to the southeastern part of the country. These facies are interfingering with fluvial siliciclastics in the south (Bender & Maedler, 1969).

The facies of Late Cretaceous in Jordan reflect a deposition on the slope and a very broad shelf, between the open Teyths Ocean to the west and northwest and the Arabian-Nubian Shield to the south, with environments controlled by the relief produced by Turonian-Coniacian incipient folding, tilt, and erosion and by Middle and Late Senonian synsedimentary folding of the Syrian Arc which led to the formation of intra-shelf and intra-slope basins and swells with differential subsidence and different rate of sedimentation, causing conspicuous variations in the thickness of the members of the Senonian sequence (Bender, 1968; Futyan, 1968; Reiss, 1988; Kolodny & Garrison, 1994). The sea-level changes, together with local tectonics, influenced bathymetry and effectiveness of basin-sills, as well as coupled with the intensity of upwelling and the resulting fertility of the photic zone, which ultimately affected the extent and degree of the oxygen minimum zone (Reiss, 1988).

A disconformity at the boundary between Ajlun and Belqa groups (Lewy, 1975; Al-Harithi, 1986) reflects non-deposition, or uplift and erosion of the platform in the Late Turonian (Bandel & Geys, 1985; Bandel & Mikbel, 1985). A renewed extensive transgression around Coniacian to Santonian reached the Saudi Arabia boundary. Sedimentation changed from platform carbonate facies to predominantly pelagic sediments deposited in the inner to mid-shelf environments. Gentle swells with phosphate, oyster beds, and chert layers and with basins of local euxinic environments led to thick accumulations of bituminous limestones and marls in the Campanian and Maastrichtian (Abed 1991 & 1994), Bandel (1981), Bandel & Mikbel (1985), Powell (1989), Nazzal & Mustafa (1993), Mustafa (2000), Bandel et al. (1999) and Mustafa (2000).

#### 3. Material and Method:

The bulk rock samples were collected from the studied section. Six marly limestone samples were examined and prepared for ostracode content. Each sample was heated, was soaked in diluted  $H_2O_2$  and heated till it was completely disaggregated. It was washed through 0.063 microns and dried and then stored. The ostracodes were picked under reflected stereo-microscope Specimens and then SEM-photographed using a scanning electron microscope-based in the Department of Earth and Environmental Science.

#### 4. Lithostratigraphy:

The studied section attains a thickness of about sixty five meters and belongs to the Coniacian - Campanian stages. It can be subdivided into the Wadi Ghudran and Amman formations in stratigraphic order and discussed as follows:

# 4.1.1. Wadi Ghudran Formation:

The studied part of this formation attains a thickness of about 13.5 m It consists of chalky marl intercalated with marls and marly limestones Figure 2. The chalky marls are whitish, soft, laminated, thick-bedded, and fossiliferous, especially with molluscan shells (i.e. *Dentalium* and *Exogyra*) that are scattered at the bottom of this part and intense at the top. The marls are rosy, hard, and dendenselycked by shells, many bivalve shells still articulated. The marly limestones are rosy, medium-hard to hard, and laminated. At the top of the formation, hard grey dolomitic limestone is encountered.

Brownish fossiliferous chert and beige marly limestone have marked the boundary between the Wadi Ghudran and the overlying Amman formations.

# 4.1.2. Amman Formation:

The studied part of this formation attains a thickness of about 51.5 m. It is composed of alternations of marly limestones, chert beds and nodules, phosphatic limestones, and phosphate at the top of the formation. The marly limestones are rosy, beige, grading to yellowish or whitish, medium to hard, and laminated. The chert and limestone concretions are partially located within the marly limestone layers. The marly limestones become fossiliferous with Dentalium, molluscans, gastropods, and bivalve shells in some layers. At the top of the section, the marly limestone becomes phosphatic and hard. The chert is brownish, greyish with preserved silicified fauna such as *Baculites*, gastropods, bivalves, scaphopods, and partially with coniqual veneer. Continuous lamination in the bottom and disturbed laminae in the top are observed in some chert layers at the top of the section. Light grey to brown, hard phosphatic layers lies at the top of the Al-Kharaj section Figure3.



Figure 2. Studied stratigraphic columnar section logged south of AL-Kharaj town.



Figure 3. Distribution chart of Late Cretaceous ostracod species obtained from the top of Ghudran Formation and the lower part of the Amman Formation section in Wadi Al-Kharaj (Northwest of Jordan). A: abundant, C: common.

# 5.1 Systematic Paleontology:

Nine ostracod species have been identified and described from the Late Santonian - Campanian interval of Al Kharaj section in north-western Jordan. These species belong to the following eight genera: *Cytherella, Bythocypris, "Togoina", Brachycythere, Cythereis, "Veenia", Ventrocythereis,* and *Cristaeleberis.* These genera belong to Cytherellidae Sars 1866, Bairdiidae Sars 1888, Trachyleberididae Sylvester-Bradley 1948 families. The generic assignment is based on Moore (1961) and later erected genera are treated as proposed by their authors.

Class Ostracoda Latreille 1806

Order Podocopida Mueller 1894 Suborder Platycopina Sars 1866 Family Cytherellidae Sars 1866 **Genus Cytherella Jones 1849 Type species**: *Cytherella ovata* Roemer 1840 **Cytherella aff. C. Elliott Holden 1964** Plate I, Figures 1-2

1964 *Cytherella eliotti* Holden pp.397-398, text-figs. 4a-c 1984 *Cytherella eliotti* Holden- Honigstein pp.5-7, pl.1, Figures 4-5

2002 Cytherella eliotti Holden- Abd-El Shafi et al. p.160, pl.1, Figures 13-14



# Plate I

Figs.1-2: Cytherella aff. C. Elliott Holden, 1964 Fig. LV, kh6. Fig.2: Dorsal view. Figs.3-5: Bythocypris windhami Butler and Jones, 1957 Fig.3: Male, LV, kh4 Fig.4: Female, RV, kh4 Fig.5: Female, RV, kh4 Fig.6-11: "Togoina"gerryi Honigstein, 1984 Fig.6: Female, RV, kh3. Fig.7: Female, RV, kh3.
Fig.8: Male, RV, kh4.
Fig.9: Dorsal view.
Fig.10: Male, LV, kh4.
Fig.11: Dorsal view.
Fig.12: The Brachycythere beershevaensis Honigstein, 1984
Fig.13: Dorsal view.
Fig.14: Female, LV, kh6.
Fig.15: Dorsal view.

#### Material: Twenty-five carapaces.

**Dimensions** (in mm):

Females: Length: 0.69-0.7 Height: 0.39-0.42 Width: 0.29

# Male: Length: 0.84 Height: 0.48 Width: 0.29

**Description**: The medium-sized carapace is elongated oval to subrectangular in the lateral view with a dorsal margin that is moderately convex in the left valve and convex to faintly concave behind the middle in the right valve. The anterior margin is broad, well rounded, and smoothly joined to the dorsal and ventral margins. The posterior margin is broadly rounded, slightly oblique, and somewhat angled in its upper part. The ventral margin is faintly convex. The greatest length is measured at the mid-height in the males, slightly below the mid-height in the females and the greatest height is measured at the mid-length of the valves. Numerous tiny pits cover the surface; otherwise, it is almost smooth.

The carapace inside the dorsal view is lens-shaped in the males to suboval in the females. A faintly developed anterior marginal rim becomes obvious only in the dorsal view.

The assumed males are longer, relatively lower, and thinner than the assumed females.

**Remarks**: Although the Jordanian specimens are larger; it is similar to Cytherella aff. C. Elliott described by Honigstein (1984).

**Occurrence**: Honigstein (1984) recorded this species from the Santonian and Lower Campanian of Israel. Abd Elshafi et al. (2002) reported this species from the Coniacian-Santonian of Wadi El Raha and Campanian of Wadi Boudra in the eastern side of Gulf of Sues, Egypt. Specimens related to this species are found among the investigated material from the Late Campanian in Wadi Al-Kharaj section, Kh5.

Suborder Podocopina Sars 1866

Superfamily Bairdioidea Sars 1888

Family Bairdiidae Sars 1888

# Genus Bythocypris Brady 1880

Type species: Bythocypris reniformis Brady 1880.

# Bythocypris windhami Butler & Jones 1957

# Plate I, Figures 3-5

1957 Bythocypris windhami Butler & Jones pp. 12-13, pl.1, Figures 8a-e

1965 *Bythocypris windhami* Butler & Jones- Crane p. 197, pl.1, Figure 1

1984 *Bythocypris windhami* Butler & Jones-Honigstein p.10, pl.3, Figures 1-3.

2001 *Bythocypris windhami* Butler & Jones- Shahin & El-Nady p.158, pl.1, Figures 1

2008 *Bythocypris windhami* Butler & Jones- El Nady et al. p.545, pl.II, Figures 4-9

Material: Fifteen carapaces.

**Dimensions** (in mm):

Females: Length: 0.77-0.81 Height: 0.35-0.37

Males: Length: 0.75 Height: 0.32

**Description**: The medium-sized carapace in lateral view is elongate-subtriangular that tapers posteriorly. The dorsal margin is convex with a faint angularity in the posterior part, where it grades into acutely rounded, and only slightly oblique in its upper part. The anterior margin is well rounded, slightly oblique in its upper part. The ventral margin is straight to faintly concave. The greatest length is close to the ventral margin and the greatest height is at about one-third of the length. The carapace is the dorsal view is almost perfectly lens-shaped with sharp end margins. The greatest width is at about mid-length. The surface is smooth. The internal features are not observed. The assumed males are lower than the assumed females.

**Remarks:** The Jordanian and Israeli specimens of Honigstein (1984) are similar in having a smooth surface with a complete absence of fine punctae.

**Occurrence:** Butler & Jones (1957) had described *Bythocypris windhami* from the Late Campanian deposits of Louisiana. Later, Crane (1965) described it from the Late Campanian of the Gulf Coast. Honigstein (1984) reported *B. windhami* from the Late Coniacian-Early Campanian of Israel. This species was also described from the Early Coniacian-Early Campanian rocks of northern Sinai (Shahin & El-Nadi 2001). Specimens of this species are present among the investigated material from the Late Campanian in Wadi Al-Kharaj section, Kh5.

Family Trachyleberididae Sylvester-Bradley 1948

Subfamily Buntoniinae Apostolescu 1961

#### Genus Togoina Apostolescu 1961

Type species: Togoina attitogoensis Apostolescu 1961

**Remarks**: The genus *Togoina* was originally described to comprise large species of Paleogene age with massive, strongly swollen, subovoid carapaces with a postulate, punctuate, or reticulate surfaces and without a subcentral tubercle by Apostolescu (1961). In the present material, which is attributed to the species *Togoina Gerry* Honigstein 1984 (and probably also in *Togoina gGerry*Honigstein itself (1984, pl. 4, Figure 6)), a very shallow, rounded subcentral tubercle can be observed in well-preserved specimens. The Late Cretaceous species *T. geGerry*therefore, can not be attributed to the genus *Togoina*. However, it might represent one of the possible ancestors of the otherwise Early Tertiary true *Togoina* species.

#### "Togoina" gerryi Honigstein 1984

Plate I, Figures 6-11

1984 *Togoina gerryi* n. sp. – Honigstein p. 15, pl. 4, Figures 6-10.

Material: Eighteen carapaces.

Dimensions (in mm):

Females: Length: 1.02 Height: 0.56

Males: Length: 1.01-1.2 Height: 0.52-0.6 Width: 0.45-0.5

Description: The large carapace in lateral view is

suboval in the assumed females, suboval to subrectangular in the assumed males. The dorsal margin is sinusoidal (more strongly developed in the larger left valve), with a short strongly convex part anteriorly above the well-developed eye spot, followed posteriorly by a deep concavity. Behind the middle, the dorsal margin is moderately convex and ends with a weak concavity before it is angularly joined to the posterior margin. The anterior margin is broadly rounded, slightly oblique in its upper part. The ventral margin is convex. The posterior margin is angularly rounded. The greatest length is at about the mid-height. The greatest height is at about onefourth of the length at the anterior cardinal angle. The ventral ridge is well developed, only slightly higher posteriorly. The ventral margin is convex and moderately to strongly overhanging. Coarse, deep pits cover the surface except for the end margins. At about mid-height and just in front of mid-length, a row of deep pits is arranged in a circle within a shallow depression, surrounding a small rounded, elevated, only weakly pitted shallow node, indicating the presence of a subcentral tubercle. The compressed anterior marginal area is covered by distinct, widely spaced radiating riblets and separated from the carapace inflation by a distinct row of deep rounded to almost rectangular pits. A well-developed depression is observed behind the eyespot and continues vertically down to the area of the subcentral tubercle to form a broad, shallow sulcus. Small blunt spines cover the anterior margin and posterior end in the well-preserved specimens.

In dorsal view, the carapace is oval with tapering, slightly set-off end. The greatest width is behind the midlength. The internal feature is not observed. The sexual dimorphism is distinct; the assumed males are longer and almost subrectangular in lateral outline, lower and less tumid than females.

**Occurrence**: The species was originally described from the Lower Campanian of Israel (Honigstein, 1984). In the present material, it occurs in samples Kh4 and Kh5 of the Late Campanian age.

Subfamily Brachycytherinae Puri 1954

#### Genus Brachycythere Alexander 1933

Type species: Cythere sphenoides Reuss 1854

# Brachycythere beershevaensis Honigstein 1984

# Plate I, Figures 12-15

1984 Brachycythere beershevaensis Honigstein pp. 16-17, pl.16, Figures 5-8.

1990 *Brachycythere beershevaensis* Honigstein- Bassiouni & Luger p.786, pl.9, Figures 6, 8.

2001 Brachycythere beershevaensis Honigstein- Shahin & El-Nady pp.161-162, pl.2, Figures 6-7

2008 Brachycythere beershevaensis Honigstein- El-Nady et al. pp.546, pl.II, Figure 16

Material: Thirty-two carapaces.

#### **Dimensions** (in mm):

Females: Length: 0.95-1.02 Height: 0.55-0.68 Width: 0.46-0.51

Males: Length: 0.95-1,15 Height: 0.58-0.65 Width: 0.46-0.56

Description: The large carapace in the lateral view is subtle oval. The dorsal margin is convex in the anterior part, where it is smoothly joined to the anterior margin, and almo, st sangulartraight in the strongly declining posterior part, where it is angularly joined to the posterior margin. The anterior margin is obliquely rounded in the upper part, well rounded in the lower part, and joined to the weakly convex ventral margin by a faint concavity. The posterior margin is angularly rounded. The posterior end and lower part of the anterior margin bear a few small denticles in some of the specimens. The greatest length is below the middle. The greatest height is below the well-developed eye spot in front of the middle at about one-third to one-fourth of length. The eyespot is posteriorly accompanied by a distinct short groove. The ventral ridge is posteriorly higher, distinctly overhanging the ventral margin only in the left valve. The surface of the carapace is covered by distinct round pits to be almost smooth.

The carapace is the dorsal view is oval with tapering end margins in males, suboval to pear-shaped with tapering anterior and compressed posterior margin in females. The greatest width is measured shortly behind the middle in the males, and a little more to the posterior in the females. The internal features are not observed. The sexual dimorphism is distinct in the dorsal view; the assumed females are more swollen and with a compressed posterior end rather than an oval with the tapering end in the assumed males.

**Occurrence:** This species was originally described from the upper part of the Early Campanian of Israel and is known from the Campanian and Maastrichtian of Sinai(Honigstein, 198the 4) and the Western Desert, Egypt (Bassiouni & Luger, 1990). It was also described from the Campanian of northeastern Sinai (Shahin & El-Nady, 2001) and eastern Sinai (El-Nady et al., 2008). The present material is from the Late Campanian sediments of Wadi Al-Kharaj section, Kh4, Kh5 & Kh6.

Subfamily Trachyleberidinae Sylvester-Bradley 1948

#### Genus Cythereis Jones 1849

# Type species: Cytherina Ciliata Reuss 1846

**Remarks**: The species described here under *Cythereis* Jones (1849) are probably not true *Cythereis* species nor can they be attributed to any other known genus. Therefore, they are treated here a ''*Cythereis*'' (See also discussion in Honigstein, 1984, p.18).

# "Cythereis" rosenfeldi cf. evoluta Honigstein 1984

Plate II, Figures 1-2



Fig.10: Dorsal view. Fig.11: Female, RV, kh4.

Fig.12: Dorsal view.

Fig.15:Dorsal view.

Fig.13: Male, LV, kh4.

Fig.14: Female, RV, kh2.

Fig.16: Female, LV, kh2.

#### Plate II

Figs.1-2: "Cythereis" rosenfeldi cf. evoluta Honigstein, 1984 Fig.1: RV, kh4. Fig.2: Dorsal view. Figs.:3-8: Cythereis aff. cretaria Bold, 1964 Fig.3: Male, LV, kh1. Fig.4: Dorsal view. Fig.5: Female, RV, kh1. Fig.6: Dorsal view. Fig.7: Female, RV, kh2. Fig.8: Female, LV, kh2.

Cf. 1984 *Cythereis rosenfeldi evoluta* n.sp., n.ssp. Honigstein. P.25, pl9, Figures 10-11

Material: Twenty-five carapaces.

#### Dimensions (in mm):

Length: 0.98-1.0 Height: 0.53-0.61 Thickness: 0.50-0.55

**Description**: The carapace is subrectangular in lateral view. The anterior margin is broadly rounded, passing into the straight to the slightly convex ventral margin by a minor concavity. The posterior margin is broadly rounded in the left valve, angularly rounded to slightly acute in the right

valve, where a small concavity is observed in the upper part. The posterior margin is smoothly joined to the gently rising ventral margin, and angularly connected to the straight dorsal margin. The dorsal margin joins the anterior margin through a well-developed convexity, which is formed by a welldeveloped hinge in the left valve. A similar structure can also be observed at the posterior cardinal angle. The dorsal and ventral margins are moderately converging posteriorly. The dorsal and ventral ribs are well developed; the dorsal rib is strongly overlapping the dorsal margin, while the ventral rib is only slightly overlapping the ventral margin. A third residual

Figs.14-16: Ventrocythereis sinaiensis Honigstein, 1984

rib may be indicated by an alignment of the nodes behind the well-developed subcentral tubercle, which is separated from it by a well-developed sinuous sulcus. The sulcus starts right behind the eye node, then bifurcates to surround the rounded subcentral tubercle and reunites beyond it, ending above the ventral rib. Irregularly spaced nodes cover the surface, and otherwise, it is smooth. Few small rounded nodes cover the only weakly developed anterior and posterior marginal ribs. The eyespot is small and rounded. The carapace is suboval in dorsal view, tapering anteriorly and set off at the posterior end. The maximum width is near the posterior end of the carapace inflation. The internal features were not observed. Due to the restricted number of specimens among the present material, a clear dimorphism can not be observed.

**Remarks**: The present material consists of mostly worn specimens, which are similar to *Cythereis Rosenfeld evoluta* Honigstein (1984). However, due to the poor preservation, the investigated material can only be compared with the subspecies of Honigstein.

**Occurrence**: Honigstein (1984) recorded the subspecies *C. Rosenfeld evoluta* from the Upper Santonian-Lower Campanian of northern and central Israel. The present material is from the Wadi Al-Kharaj section, Kh1, Kh2, and Kh3.

#### Cythereis aff. critaria Bold 1964

#### Plate II, Figures 3-8

aff. 1964 *Cythereis critaria* Bold pp.126-127, pl.15, Figures 3-4.

1972 Cytheris cf. critaria Bold – Damote & Saint Marc .281, pl.2, Figures 13.

1984 *Cythereis cretaria* Bold- Honigstein p.19, pl.17, Figures 1-5.

2001 *Cythereis critaria* Bold- Shahin & El-Nady pp.166-167, pl.3, Figures 11-12.

2008 *Cythereis critaria* Bold- El-Nady et al. p.551, pl.V, Figures 1-2

Material: Thirty carapaces.

Dimensions (in mm):

Females: Length: 0.86-0.93 Height: 0.44-0.50 Thickness: 0.33-0.41

Males: Length: 1.0 Height: 0.50 Thickness: 0.35

**Description**: The carapace is subrectangular in lateral view, with subparallel ventral and dorsal margins in the males and posteriorly converging lateral margins in the females. The anterior margin is well rounded, slightly oblique in its upper part. The ventral margin is straight to faintly convex, joined to the anterior margin by a small concavity in the right valve only. The posterior margin is subtriangular, slightly pointed in the right valve, where a weak concavity can be observed. The dorsal margin is straight unless a convexity in its anteriormost part, where it joins to the anterior margin. The hinged ear is well developed in the left valve. A small rounded eyespot is present and easily detectable. The dorsal

ridge is well developed, overreaching the dorsal margin, and separated from the eyespot by a small groove. The dorsal ridge starts a little below behind the eye-spot, rises rapidly above the dorsal margin, continues almost straight towards the posterior, and ends abruptly, truncated at the end of posterior carapace inflation. The ventral ridge is slightly convex and overreaches the ventral margin in its posterior two-thirds. A median ridge is only faintly developed. The anterior margin carries a strong rib on which numerous small denticles are present on its lower two-third. The subcentral tubercle is well developed, rounded, reticulated, surrounded by a small groove, and covered by small radiating reticules. In between the subcentral tubercle and the anterior margin, the otherwise irregular reticulation covering the entire carapace is arranged in concentric rows.

The carapace is the dorsal view is subrectangular, tapering anteriorly and abruptly set off at the posterior end. A small sulcus can be observed, formed by a narrow incision behind the subcentral tubercle. The maximum width is parallel to the carapace inflation. The internal features are not observed. The sexual dimorphism is distinct; the assumed males are with subparallel dorsal and ventral margins, while these margins are converging in the assumed females.

**Remarks**: The present specimens closely resemble *Cythereis cretaria* Bold as figured by Honigstein (1984) but smaller in size. However, they deviate from the smaller species of the originally described by Bold (1964) in the subrectangular outline in dorsal view, with almost parallel sides, rather than having undulating rectangular outline as figured by Bold (1964).

**Occurrence**: The species was originally described by Bold (1964) from the Campanian Abu Rawash, Egypt. The material from Israel as figured by Honigstein (1984), which is close to the described material here, was attributed to the Late Coniacian-Late Santonian. Shahin & El-Nady (2001) reported *Cythereis cretaria* from the Late Coniacian-Early Campanian of northeastern Sinai. The present material is from the Wadi Al-Kharaj section, Kh1, Kh2, Kh4, which are of the Late Santonian-Late Campanian age.

# Genus Veenia Butler & Jones 1957

Type species: Cythereis ozanana Israelesky 1929

**Remarks**: The genus *Veenia* has been erected by Butler & Jones (1957) for species with a smooth surface and welldeveloped longitudinal ridges. The hingement of *Veenia* species is an amphidont-heterodont type with smooth end teeth. In the present material, the outline resembles that of *Veenia*, also the hinge is amphidont/heterodont. Some of the present material resembles that of the species *fawwarensis dividua* Honigstein (1984) which has been placed in the genus *Veenia* by this author. It does not show a well-developed median ridge. Also, the shape of this species *fawwarensis* is more like in *Cythereis*. Therefore, it may be assumed that the species *fawwarensis* and the new species listed below do not represent true *Veenia* species and are only kept provisionally under this genus.

"Veenia" fawwarensis cf. dividua Honigstein 1984 Plate II, Figures 9-13 Cf. 1984 *Veenia fawwarensis dividua* n.sp. n.ssp. - Honigstein p.28, pl.11, Figures 1-7, pl.15, Figures 11-12

Material: Twelve carapaces.

#### Dimensions (in mm):

Female: Length: 0.91-0.98 Height: 0.57-0.61 Thickness: 0.49

Male: Length: 0.92-0.94 Height: 0.48-0.51 Thickness: 0.43

Description: The carapace is subrectangular in lateral view and about twice as long as high. The maximum height is about the median length of the shell. The anterior margin is broadly rounded, passing into the otherwise straight ventral margin by a minor concavity. The posterior margin is blunt to triangularly edged, bearing a clear concavity in its upper part. The straight dorsal margin is connected to the posterior margin by a sharp angular break, and by a well-developed hinge ear to the anterior margin. In the left valve, the dorsal and ventral margins are gently converging posteriorly. The ornamentation consists of well-developed dorsal and ventral ridges, overlapping the lateral margins. Remnants of a median ridge may be represented by a row of pustules. All ridges are covered by rounded to weakly spinose nodes. A nodose subcentral tubercle is developed right behind the eyespot at about median height. The swelling of the subcentral node is divided into four to five separate tubercles. Tubercles are often subdivided into one round prominent and one or two lower round tubercles with normal pores on their tops. A well-developed sinuous sulcus is running from behind the weakly developed eye spot, bordering the subcentral tubercle posteriorly and then running back again until the ventral rib. The otherwise smooth lateral surface carries several irregularly spaced nodes. A more prominent one of these is situated behind the sulcus at the lower part of the subcentral tubercle. A short line of more or less combined nodes is developed in the upper part of the valve, shortly behind the median length. Each of the anterior and posterior margins is marked by a well-developed rounded rib, carrying one row of widely spaced denticles at the posterior end and two rows of closely spaced fine denticles at the anterior end.

The carapace is the dorsal view is subrectangular with compressed posterior and anterior ends. The carapace inflation is gently rising from the anterior marginal zone, and steeply declining towards the posterior. The greatest width is at about one-third of the length at the protruding muscle node.

The internal features are not observed. The sexual dimorphism is distinct; the dorsal and ventral margins of the assumed females are more clearly converging posteriorly. Furthermore, they are higher and thicker than the assumed males.

**Remarks**: The present material deviates from *Veenia* fawwarensis dividua Honigstein (1984) in dorsal outline, which is more lense-shaped rather than subtriangular as in the present material. Therefore, the species can be conferred to "*Veenia*" fawwarensis dividua.

**Occurrence**: Veenia fawwarensis dividua was described from the Late Santonian-Early Campanian of Israel and

North Egypt (Sinai) by Honigstein (1984). The present material is of Late Campanian from the Wadi Karaj section, Kh4.

# Genus Ventrocythereis Honigstein 1984

**Type Species:** *Ventrocythereis sinaiensis* Honigstein 1984 from the Santonian-Early Campanian (upper part) of Israel.

Ventrocythereis sinaiensis Honigstein 1984

Plate II, Figures 14-16, and Plate III, figs.1-9

1984 Ventrocythereis sinaiensis Honigstein pp.29-30, pl.8, figs.7-11

Dimensions (in mm):

Females: Length: 0.97-1.03 Height: 0.5-0.60 Thickness: 0.5-0.55.

Males Length: 1.03-1.05 Height: 0.56-0.57 Thickness: 0.53

Description: The carapace in lateral view is subrectangular with an anterior margin that is rounded, slightly oblique in its upper part. The ventral margin is straight to slightly convex, joined with the anterior margin by a minor concavity. The posterior margin is obliquely rounded in the left valve, and broadly angular in the right valve, where it bears a small concavity in its upper part. The dorsal margin is straight, connected to the anterior margin by an only faintly developed hinge ear and by a sharp angularity to the posterior margin in the left valve. The maximum length is measured at about the median height or slightly above it. The maximum height is below the tiny rounded eye spot at about one-fourth to one-fifth of the length. The ornamentation consists of a distinct dorsal ridge overreaching the dorsal margin and a more weakly developed ventral ridge which may slightly overreach the ventral margin in its posterior part. The surface otherwise is covered by pustules and/or reticulation, and a distinct subcentral tubercle. A Conspicuous sinuous sulcus runs from just behind the eye node towards the anterior in the uppermost part of the valve, then sharply bends backward to border the well-developed muscle node and ends being bent forward again in front of the ventral margin. The dorsal and ventral ridges are covered by small rounded to spiny nodes. The only slightly elevated almost rounded subcentral tubercle is covered either by small nodes or reticules. Small pustules or reticulations otherwise cover the surface, which is only faintly developed to absent on the sulcus. The anterior margin is marked by a faintly to strongly developed marginal ridge bearing two rows of closely spaced spiny nodes. The posterior margin is bearing a well-developed marginal ridge with one row of widely to closely spaced tiny nodes. A short vertical riblet supporting the eye node is developed in most of the specimens.

The carapace is the dorsal view is suboval with moderately compressed end margins. The maximum width is just behind the middle. The hinge is amphidont/heterodont. The anterior tooth is elongated rounded, followed by a deep suboval socket in the right valve. The posterior tooth is elongated suboval. Other internal features are not observed. The sexual dimorphism is present; the assumed females show more strongly converging lateral margins.



Fig.3: Dorsal view. Fig.4: Female?, RV, internal features, kh3. Fig.5: Dorsal view. Fig.6: Female, RV, kh3.

**Occurrence**: *Ventrocythereis sinaiensis* was originally described by Honigstein (1984) from the Upper Santonianupper part of Lower Campanian of Israel. Specimens belonging to this species are found among the investigated material in the Late Campanian of North Jordan, from Wadi Al-Kharaj section, Kh3, Kh4, and Kh6.

#### Genus Cristaeleberis Bassiouni 1970

Type Species: Cristaeleberis reticulata Bassiouni 1970

# Cristaeleberis cf. C. fornicata Bassiouni 1970

Plate III, Figures 10-13

Cf.1970 Cristaeleberis fornicata Bassiouni, p. 29, pl. 3,

Figures 9-10

Fig.12: Male, LV, kh6.

Fig.13: Dorsal view.

1984 Cristaeleberis fornicata Bassiouni- Honigstein, p. 35, pl. 10, Figures 5-8

2008 Cristaeleberis fornicata Bassiouni- El-Nady et al., p.550, pl. IV, Figures 11- 12

Material: Twenty-eight carapaces.

**Dimensions** (in mm):

Females: Length: 0.85-1.02 Height: 0.46-0.59 Width: 0.46-0.51

Males: Length: 0.88-1.14 Height: 0.47-0.56 Width: 0.380.46

Description: The large carapace is subrectangular in

lateral view. The left valve is larger than the right valve, overreaching it at the anterior and posterior cardinal angles. The dorsal margin is strong to moderately convex at the anterior cardinal angle, faintly convex to straight behind it, and ending with a weak concavity before it joins the posterior margin with a blunt edge. The anterior margin is broadly rounded and smoothly joined to the moderately convex (in assumed females) and straight (in the assumed males) ventral margin, where a weak concavity may be developed at about one-fourth of length. The posterior margin is obliquely rounded in the left valve, bluntly subtriangular with a pointed end in the right valve. The greatest length is at about the mid-height. The greatest height is at about onefourth of the length below the anterior cardinal angle, where a small rounded eyespot is developed, which is posteriorly accompanied by a small groove. The anterior and posterior margins have numerous small denticles in the well-preserved specimens. The dorsal ridge is only weakly developed, faintly overreaching the dorsal margin behind the middle, or absent. The ventral ridge is only clearly developed in the right valve, where moderately convex and slightly overreaching the ventral margin, ending either in a blunt spine, or a node or a sharp edge, marking the posterior end of the ventral carapace inflation at about four-fifths of length. The surface of the valve is ornamented by sharp to smooth reticulation, being concentrically arranged in the anterior part of the valve, otherwise, it is irregularly spaced. The subcentral tubercle is absent.

The carapace is the dorsal view is suboval with compressed ends. The posterior end of carapace inflation is of unequal outline due to the strongly edged end of the ventral rib in the right valve. The greatest width is behind the middle. The internal features are not observed. The sexual dimorphism is present; the assumed males are relatively longer, lower, and less swollen than the assumed females.

**Remarks:** *Cristaeleberis fornicata* described by Bassiouni (1970) and Bassiouni & Luger (1990) and even described by Honigstein (1984) are smaller in size.

**Occurrence**: Bassiouni (1970) described *Cristaeleberis* fornicata from the Maastrichtian of Jordan. Honigstein (1984) reported the same species from a wider interval (Early Middle Santonian-Maastrichtian) in Israel. Records from the Maastrichtian include also Bassiouni & Luger (1990) and Shahin & El-Nady (2001) from Egypt. Specimens belonging to this species are found among the investigated material from the Late Campanian of North Jordan from the following horizons, Kh4, Kh5, and Kh6, from the Wadi Al-Kharaj section.

# 6. Discussion

# 6.1 Biostratigraphy:

The most comprehensive study on Late Cretaceous marine ostracodes from the neighbouring countries is that of Honigstein (1984), who gave a detailed description of the taxonomy and the biostratigraphic significance of species recorded in Israel. He established six ostracod assemblage zones, based on the first appearance of a diagnostic species; these zones are:

- Phyrocythere lata (S-1) Zone of Upper Coniacian (?Lower Santonian) age.
- Cythereis rosenfeldi rosenfeldi (S-2) Zone of Lower/ Middle Santonian age.
- Limburgina miarensis (S-3) Zone of Upper Santonian age.
- Leguminocythereis dorsocostatus (S-4) Zone of Lower Campanian age (lower part).
- Brachycythere beershevaensis (S-5) Zone of Lower Campanian (upper part)-Upper Campanian age.

The closeness of the studied area to the Israeli region makes some of the biozonations established by Honigstein (1984) are accepted here.

Comparing the recorded Jordanian association with the Israeli ones; the Jordanian association (Figure 3) can be referred to as the assemblage Zones S-3, Late S-4, and S-5. No species were observed belonging to the Lower Santonian. Although the zonal marker species Limburgina miarensis of the (S-3) (only Upper Santonian) Zone of Honigstein (1984) has not been observed in Kh1, the characteristic association of this zone is common. Cythereis cretaria, Cythereis rosenfeldi cf. evoluta, "Veenia" fawwarensis cf. dividua and Ventrocythereis sinaiensis have been recorded from these levels. Therefore, Upper Santonian can be attributed to the upper part of the Wadi Ghudran Formation and the lower part of the Amman Formation. This assignment is strongly supported by the findings of planktic foraminifera (Al-Rifay et. Al, 1993; Al- Harithi, 1986); ammonites (, Nazzal & Mustafa 1993), and shark teeth (Mustafa, 2000).

Honigstein (1984) found that *Togonia gerri* is only common to frequent in the assemblage zone (S-4) which has been attributed to the Early Campanian age. Here, abundant"*Togoina*" *gerri* has been observed in Kh4, and its presence extends to Kh5. Therefore, this interval can be compared with S-4 and belongs to the Early Campanian age.

This study shows that *Brachycythere beershevaensis* is an excellent marker fossil up to now in Jordan, Egypt, and Israel for Campanian age assignment. So, the samples Kh5 and Kh6 in the studied section correspond well to the S-5 Zone of the Late Campanian age. The associated *Baculites* and *Trachyscaphites* described from the same horizons by Nazzal & Mustafa (1993) support this assignment as well. The associated planktic foraminifera and ammonites in the studied section besides the closeness of the studied area to the Israeli region make some of the biozonations established by Honigstein (1984) are acceptable here.

A Late Santonian - Late Campanian age is assigned here to the studied material from the Al Kharaj section, which seems to be correlatable in part with the assemblage zones established by Honigstein (1984); *Cytheris rosenfeldi rosenfeldi* S-2 from the Late Santonian and *Brachcythere beershavaensis* S-5 from the Late Lower Campanian-Early Upper Campanian.

#### 6.2: Paleobiogeographic apects:

The paleobiogeographic implication of Tethyan Cretaceous ostracodes has been enhanced by many authors (Babinot & Colin, 1988, 1992; Dingle, 1988; Puckett, 2002; Luger, 2003; see also additional references in Luger, 2003). Babinot & Colin (1992) proposed four paleobioprovinces for the Teythyan Late Cretaceous ostracodes.

The Jordanian ostracod assemblages show a strong affinity to those of Israel since all the species recorded here were also recorded in the Senonian of Israel (Honigstein 1984). A similarity to species described from Egypt (North Africa) is confined by the common occurrence of these ostracods in both sites. Nearly all the recorded Jordanian species were recorded in Egypt (Bassiouni & Luger, 1990; Morsi et al., 2000; Shahin & El-Nady, 2001and many others ) ranging from the Early Coniacian-Early Campanian. Out of these ostracodes, Bythocypris windhami Butler & Jones 1957 was of common occurrence in the Santonian and Lower Campanian ranges in Egypt (Shahin & El-Nady, 2001) and northern, central, and southern Israel (Honigstein 1984 and Honigstein et al., 1987). Also, Cristaeleberis fornicata Bassiouni (1970) was originally described from the Late Maastrichtian of Jordan (Bassiouni, 1970) and was described later from the Maastrichtian of Egypt (Bassiouni & Luger, 1990; Shahin & El-Nady, 2001and many others). It ranges in Israel from the Santonian to Maastrichtian (Honigstein, 1984). This study showed that this species also occurs in a lower stratigraphic horizon in Jordan (Late Campanian). Regarding the Cytherella eliotti Holden 1964; it was described from the Santonian/Campanian-Lower Campanian in northern and southern Israel (Honigstein, 1984), and the Santonian-Campanian of southern Egypt (Abd-Elshafy et al., 2002). In the present work, it is reported from the Late Santonian- Late Campanian. This great similarity in the ostracod assemblage with the neighboring counties refers to a direct connection between them during that time.

The Santonian-Maastrichtian interval witnessed a great diversification of African brachycytherine ostracodes (Babinot & Colin, 1988; 1992); Puckett (2002); Luger (2003); Seeling et al. (2004). The group continued to be dominant constituents of the shallow marine deposits across Africa. Babinot and Colin (1988, 1992) recognized this provincialism and defined Tethyan and Australian paleobioprovinces, in which the studied brachycytherine ostracodes played an important role.

Brachycythere provides valuable information on the palaeoecology of shallow marine environments. The genus Brachycythere Alexander has been considered as one of the most important genera for understanding the routes and timing of ostracod migration through the Tethyan realm and West Africa (Figure 4). This species is taken into consideration because it has numerous records in Gondwanide localities (Reyment, 1980; Honigstein, 1984; Okosun, 1992; Shahin & El-Nady, 2001; Caus, et al. 2002; and the present work). They found that the dominance of the genus Brachycythere (with different species) is a common element in the Upper Cretaceous ostracods of North America, entire Africa, and northern part of southern America. Its extremely widespread distribution in these regions with its absence in the European Cretaceous provides an interesting insight into the development of the Atlantic Ocean and the role of the Tethys Ocean as an effective barrier to North-South faunal exchange (Caus, et al. 2002).

The recoded *Brachycythere beershevaensis* Honigstein 1984 was originally described from the Campanian of Israel (Honigstein, 1984) and extended to the Early Maastrichtian (Honigstein et al., 1987). It was also recorded from Egypt from the Early to Middle Maastrichtian of southern Egypt (Bassiouni & Luger (1990) and in northeast Sinai (Shahin & El-Nady, 2001) and from the Late Campanian of Jordan (present study). This great similarity with the neighboring countries refers to and confirms a direct connection between them during that time.



Figure 4. Reconstructed Tethyan Seaway map imposing the paleobiogeography of Brachycythere from Late Cretaceous (modified after Viviers et. al. 2000).

#### 7. Conclusions:

Nine ostracod species were identified and described from the Late Santonian - Early Campanian succession of northwestern Jordan. The nine species belong to the following genera: *Cytherella, Bythocypris, "Togoina", Brachycythere, Cythereis, "Veenia", Ventrocythereis,* and *Cristaeleberis.* These species were correlated with the assemblage Zones S-3 (upper Santonian), Late S-4 (lower Campanian), and S-5 (Lower to Upper Campanian) that were defined by Honigstein (1984) in Israel. They were also an addition to paleobiogeographic constructions of the southern Tethyan realm. This study shows that *Brachycythere beershevaensis* is an excellent marker fossil up to now in Jordan, Egypt, and Israel for the Campanian age assignment. *Brachycythere* provides valuable information on the palaeoecology of shallow marine environments.

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