## Combined ostracod and planktonic foraminiferal biozonation of the Late Coniacian – Early Maastrichtian in Israel

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**ABSTRACT**- The distribution and zonation of planktonic foraminifera and ostracods during the Late Coniacian – Early Maastrichtian succession in Israel was studied in detail from six surface sections. The combination of contemporaneous biozones led to a more accurate age determination of the local ostracod zones, according to the Tethyan planktonic foraminiferal zonation. The configuration of the biozones of both taxa presents more datum lines for stratigraphic correlation of the Senonian strata of Israel. Three new ostracod species were described from Campanian sediments: *Cytherelloidea zinensis, Loxoconcha hebraica* and *Cristaeleberis ordinata*.

## **INTRODUCTION**

Late Coniacian - Maastrichtian marine formations of the Mount Scopus Group (Flexer, 1968) are widely distributed in Israel. They are mostly composed of chalks, marls, cherts and phosphorites. A renewed interest in Senonian rocks of Israel was evoked after the micropaleontological studies of Moshkovitz (1984; calcareous nannofossils) and Honigstein (1983, 1984; ostracods). Additional biostratigraphic data on ostracods are recorded in Lipson-Benitah et al. (1985; combined with foraminifera) and in Lifshitz et al. (1985). Reiss et al. (1985) summarised multiple bio- and chronostratigraphic data from the Senonian of Israel, based on ranges of indicative species of megafossils (mainly ammonites), planktonic and benthic foraminifera, calcareous nannoplankton, and ostracods. A modified biostratigraphic chart, on the base of ranges of 54 Globotruncanidae species, was presented in Almogi-Labin et al. (1986) and the results were compared with the general European zonation of Robaszynski et al. (1984). In this study, the local ostracod zones are correlated with the more general planktonic foraminiferal zonation.

The combined biozonation is based on former results (Honigstein, 1983, Reiss *et al.*, 1985) and on six additional surface sections (Table 1, coordinates in Israel grid; Fig. 1). These profiles were chosen to be representative for a detailed bio-, litho- and chronos-tratigraphic study. Studies on other microfossil groups (from the same "type-" sections) are in preparation. Both planktonic foraminifera and ostracods were studied from the same samples, except those of the Ein Fawwar section (see Fig. 1). The distribution of the planktonic foraminifera and their ranges were determined here by Almogi–Labin and the ostracods by

Honigstein and Rosenfeld. The results are depicted in Figs. 3–12. Species with limited taxonomic and stratigraphic importance are omitted, such as *Arcaeoglobigerina cretacea* and *A. blowi* (foraminifera), and *Bythocrypris windhami*, *Cytherella* cf. *C. austinensis*, *Buntonia*? aff. *B. cretacea*, *Bairdoppilata pondera* and *Spinoleberis megiddoensis* (ostracods). The investigation of more than 400 samples led also to a modification of the general distribution chart of Senonian ostracods from Israel (Fig. 2). A calibrated scheme of ostracod versus planktonic foraminiferal zones is given in Fig. 13.

The samples from the studied sections, their washed residues, as well as the picked foraminifera, are deposited in the Micropaleontological Collection of the Geological Department of the Hebrew University, Jerusalem, catalogued with the Laboratory prefix HU-. The ostracod material is stored at the Micropaleontological Laboratory of the Geological Survey of Israel, Jerusalem.

#### TAXONOMIC NOTES Ostracoda

Most of the ostracod species and their ranges were described in Honigstein (1984). There, six ostracod assemblage zones were established within the Late Coniacian – Maastrichtian sequence in all parts of Israel. Each zone begins with the first appearance of diagnostic species (and assemblages) and is named after one of these indicative species. Five species were hitherto not recorded from the Senonian of Israel and are described in the present study, three of which are new species. The modified general distribution of the ostracod species during the Senonian is shown in Fig. 2. Genus Cytherelloidea Alexander, 1929

Cytherelloidea zinensis Honigstein & Rosenfeld sp. nov.

**Derivation of name.** From the type location, the Nahal Zin in southern Israel.

Holotype. Male carapace, HU-6837 (Pl. 1, fig. 3).

**Paratypes.** Two male and one female carapaces (Pl. 1, figs. 1, 2, 4).

Type locality and horizon. Nahal Zin, SMA 34, coord. 1538/0303. Mishash Formation.

Diagnosis. Cytherelloidea with entirely pitted surface.



Fig. 1. Location map.

#### Measurements (mm).

Length Height Width

0.87	0.41	0.31	Male	Holotype
0.79	0.43	0.29	Male	Paratype
0.81	0.45	0.28	Male	Paratype
0.82	0.46	0.34	Female	Paratype

**Description.** Medium sized carapace subovate. Anterior and posterior ends broadly rounded. Dorsal margin slightly concave with faint mid-dorsal sulcus; ventral margin nearly straight. Surface entirely covered with small, round pits in the central part and subrectangular pits in the peripheral areas. Females more tumid than males.

**Remarks.** Cytherelloidea zinensis sp. nov. is similar to C. besrineensis Bischoff, 1964 (p. 15, pl. 3, figs. 21–22; Rosenfeld & Rabb, 1984, p. 92, pl. 1, figs. 11–12; Aptian – Albian of Lebanon and Israel), but differs from the latter by its larger size and the finer type of reticulation. Cytherella cf. C. araucana Bertels, 1974 (Honigstein, 1984, p. 7, pl. 1, figs. 7–10; Campanian – Maastrichtian of Israel) possesses lower pits and lacks reticulation in the central area.

Material and distribution. About thirty carapaces from Nahal Zin.

Stratigraphic range. Late Campanian. Zone S-5\*.

Genus Krithe Brady, Crosskey & Robertson, 1844 Krithe echolsae Esker, 1968 (Pl. 1, figs. 5-6)

(Type No. 316)

- 1968 Krithe echolsae Esker; 330, Pl. 3, figs. 1-4.
- 1982 Krithe echolsae Esker; Boukhary et al.: Pl. 2, figs. 8-9.

1982 Krithe echolsae Esker; Donze et al.: 283.

Measurements (mm)

Length Height Width

0.80 0.39 0.34

0.85 0.38 0.37

**Remarks.** Krithe echolsae Esker, 1968 was formerly recorded from the Danian of Tunisia (Esker, 1968) and the Paleocene of Egypt (Boukhary *et al.*, 1982). It differs from K. solomoni Honigstein, 1984 (p. 11, pl. 3, figs. 9-12; Campanian of Israel) by its larger and angular posterior end.

Material and distribution. Four carapaces from Bar'am Stratigraphic range. (Early) Maastrichtian. Zone M.

Genus Cythereis Jones, 1849

Cythereis ornatissima (Reuss), 1846 (Pl. 2, figs. 5-10) (Type No. 319)

- 1846 Cytherina ornatissima Reuss: 104, Pl. 24, figs. 12-18.
- 1966 Cythereis ornatissima (Reuss); Herrig: 806, Pl. 24, figs. 3-4.

Cretaceous biostratigraphy of Israel

Location	Coordinates	Thickness [m]	No. of samples	Field Mark	Lithology by
Bar'am	1902/2723 1908/2726	105	107	BR	Reiss (in prep.)
Tarqumiya	1508/1974	53	72	PP1	Reiss (in prep).
Ein el Qilt	1850/1381	55	42	BL	Luz (1970)
Ein Fawwar	1831/1386	105	36 (foram.)	BL	Luz (1970)
		55	24 (ostr.)	AF	Flexer (unpubl.)
Nahal Zin	1538/0303	93	136	SMA	Reiss (in prep.)
Nahal Ya'alon	1602/9450	167	38	AVI	Lifshitz et al. (1985)

Table 1. Details of studied sections

1978 Cythereis ornatissima (Reuss); Neale (in Bate & Robinson): 366, pl. 17, figs. 10-12.

# Measurements (mm)

Length Height Width

- 0.93 0.52 0.50 Female "spinous form"
- 0.93 0.53 0.52 Female "spinous form"

1.16 0.56 0.49 Male "tuberculated form"

1.04 0.53 "tuberculated form" 0.55 ?Male Remarks. A complete synonomy for this species (up to 1966) is found in Herrig, 1966 (p. 806). Cythereis ornatissima (Reuss), 1846 occurs in Israel in two forms at different stratigraphic levels: The "spinous form" (Pl. 2, figs. 5-8) in the latest Campanian and the "tuberculated form (Pl. 2, figs. 9-10) in the Early Maastrichtian. Typical for the species are the subcentral tubercle with five distinct spines (Pl. 2, fig. 6) and the trifurcate spines at the peripheral zones (Pl. 2, fig. 7). Pokorny (1963) divided C. ornatissima into several subspecies, but Herrig (1966, p. 807) explained fine differences in ornamentation within the same species resulting from paleoecological changes. This species was recorded from different stratigraphic levels of several locations around the Tethys. Minor differences occur in shape and ornamentation, in our specimens the more convex ventral margin in females and the less strongly developed median rib (see also Neale, in Bate & Robinson, 1978, p. 367, pl. 17, fig. 11), and may be due to intraspecific variations in different palaeogeographic provinces. Our "spinous forms" are close to the subspecies ornatissima of Pokorny (1963, p. 8, pl. 1, fig. 1, pl. 3, fig. 3, pl. 4, figs. 1-7, pl. 6, figs. 1, 2, 5; Coniacian of Czechoslovakia) and the specimen figured by Herrig (1966, pl. 24, fig. 3; Maastrichtian of East Germany). The "tuberculated forms" resemble

the subspecies *adictyota* of Pokorny (1963, p. 20, pl. 1, fig. 2, pl. 4, fig 8; Turonian of Czechoslovakia) and the specimens illustrated by Neale (*in* Bate & Robinson, 1978, p. 366, pl. 17, figs 10–12; Campanian – Early Maastrichtian of England).

Material and distribution. Twelve carapaces from Bar'am, Nahal Zin and Tarqumiya.

Stratigraphic range. Latest Campanian – Early Maastrichtian. Zones S-5b, M (base).

Genus Cristaeleberis Bassiouni, 1971

Cristaeleberis ordinata Honigstein & Rosenfeld sp. nov. (Pl. 1, figs. 7-10)

(Type No. 317)

**Derivation of name.** Latin, *ordinatus*, meaning arranged, in order, from the relatively even reticulation of the carapace.

Holotype. Male carapace, HU-6172 (Pl. 1, fig. 9). **Paratypes.** One male and two female carapaces (Pl. 1, figs 7, 8, 10).

**Type locality and horizon.** Tarqumiya, PP1–13, coord. 1508/1074. Menuha Formation.

**Diagnosis.** *Cristaeleberis* with relatively even, net-like reticulation.

Measurements (mm).

Length Height Width

0.65	0.34	0.26	Male	Holotype
0.65	0.31	0.25	Male	Paratype
0.58	0.32	0.26	Female	Paratype
0.63	0.31	0.28	Female	Paratype

**Description.** Medium sized carapace, subrectangular. Anterior end broadly rounded, posterior end bluntly pointed subcentrally, with few denticules ventrally. Both ends compressed. Dorsal and ventral margins straight, rather parallel in males and slightly tapering posteriorly in females. Eye-spot relatively low. Subocular rib very faint, intersepted by the coarse reticulation meshes. Weak posterodorsal rib ends centrally. Surface covered by regularly arranged, round to polygonal reticulation meshes without nodes. Dorsal view subrectangular. Internal features as for the genus (Bassiouni, 1971, p. 24). Sexual dimorphism: males longer and less tumid than females.

**Remarks.** The subocular rib, one of the characteristic features of the mainly Paleocene species of the genus *Cristaeleberis* from Jordan (Bassiouni, 1971), is generally less developed in the Late Coniacian – Maastrichtian specimens from Israel (see also Honigstein, 1984). *Cristaeleberis ordinata* sp. nov. differs from *C. reticulata* Bassiouni, 1971 (p. 26, pl. 3, figs. 5–6; Paleocene of Jordan; Honigstein, 1984, p. 34, pl. 10, figs 1–4; Late Coniacian – Maastrichtian of Israel) and from *C. fornicata* Bassiouni, 1971 (p. 29, pl. 3, figs 9–10; Maastrichtian of Jordan; Honigstein, 1984, p. 35, pl. 10, figs. 5–8; Santonian – Maastrichtian of Israel) by its weaker eye-spot, the lack of nodes and the reticulation pattern.

Material and distribution. Fifteen carapaces and valves from Nahal Zin and Tarqumiya.

Stratigraphic range. Early – Late Campanian. Zones S-4, S-5a (base).

Genus Loxoconcha Sars, 1866 Loxoconcha hebraica Honigstein & Rosenfeld sp. nov. (Pl. 2, figs. 1-4) (Type No. 318) Derivation of name. Latin, hebraicus, meaning Hebrew, from its occurrence in Israel.

Holotype. Carapace, HU-6825 (Pl. 2, fig. 3).

Paratypes. Two carapaces (Pl. 2, figs. 1-2, 4).

Type locality and horizon. Nahal Zin, SMA 22, coord. 1538/0303. Mishash Formation.

**Diagnosis.** Loxoconcha with fine, subconcentric reticulation pattern.

Measurements (mm).

Length Height Width

0.69	0.37	0.27	Holotype
0.59	0.31	0.26	Paratype
0.65	0.34	0.27	Paratype

**Description.** Medium sized carapace, subrhomboidal. Anterior end broadly rounded, posterior end slightly pointed subcentrally. Both extremities sharply compressed. Dorsal margin straight; ventral margin sinusoidal, venter compressed, keel-like. Oval and low eye-spot. Polygonal, fine reticulation meshes arranged in more or less concentric rows; peripheral parts smooth. Dorsal view subovate. Valves nearly equal in size. Internal features not observed.

**Remarks.** Crane (1965, p. 229–232, pl. 8, figs. 8–20) described several species of *Loxoconcha* from the Senonian of the Gulf Coast, southern USA. They differ from *L. hebraica* sp. nov. mainly by their smaller size and the possession of longitudinal ridges. *L. striatopunctata* Veen, 1936 (see Herrig, 1966, p. 890, pl. 30, figs. 11–13; Maastrichtian of Netherlands and East Germany) is also smaller than our species and shows pronounced reticulation walls, parallel to the periphery.

Material and distribution. Eight carapaces from Nahal Zin.

Stratigraphic range. Late Campanian. Zone S-5\*.

## **Explanation of Plate 1**

Figs. 1-4. Cytherelloidea zinensis Honigstein & Rosenfeld sp. nov. (Late Campanian).

Fig. 1. Left valve, male carapace, paratype, Nahal Zin. SMA 22 (HU-6825), Zone S-5\* (× 104).

- Fig. 2. Right valve, female carapace, paratype, Nahal Zin, SMA 22 (HU-6825), Zone S-5\* (× 96).
- Fig. 3. Right valve, male carapace, holotype, Nahal Zin, SMA 34 (HU-6837), Zone S-5\* (× 104).
- Fig. 4. Dorsal view male carapace, paratype, Nahal Zin, SMA 21 (HU-6824), Zone S-5\* (× 114).

Figs. 5-6. Krithe echolsae Esker (Early Maastrichtian).

Fig. 5. Left valve, carapace, Bar'am, BR 75 (HU-6735), Zone M (× 109).

Fig. 6. Dorsal view, carapace, Bar'am, BR 75 (HU-6735), Zone M (× 109)..

Figs. 7-10. Cristaeleberis ordinata Honigstein & Rosenfeld sp. nov. (Late Campanian).

Fig. 7. Dorsal view, female carapace, paratype, Tarqumiya, PP1-17 (HU-6188), Zone S-5a (× 131).

Fig. 8. Dorsal view, male carapace, paratype, Tarqumiya, PP1-17 (HU-6188), Zone S-5a (× 147).

Fig. 9. Left valve, male carapace, holotype, Tarqumiya, PP1-13 (HU-6172), Zone S-5a (× 131).

Fig. 10. Right valve, female carapace, paratype, Tarqumiya, PP1-13 (HU-6172), Zone S-5a (× 136).



	AGE	CONIAC. Late	SANTONIA Early middle	IN SAN Late CAM	Early	MPANIAN	
	ASSEMBLACE	Phyrocythere	Cythereis rosenfeldi	Limburgina	Leguminocythereis	Brachycythere	Hazelina cl.
	frequent ZONES	lata	rosenfeldi	miarensis	dorsocostatus	beershevaensis	H. ordoniya
Type No.	SPECIES Symbol	S - 1	s - 2 a b-	s-3 a b	S - 4	S-5 a + b	W
283 265 269	Phyrocythere lata Cythereis negevensis Cythereis mesa centroreticulata			1			
288 49 251 299	Cythereis mesa centroleviata Cythereis cretaria Anticythereis judaensis Bythocvoris windhami						
51	Brachycythere angulata Crimoloporic resources					4 1 1 1	
261	Unistaeleberis retroulata Cythereis diversereticulata Curbondia of Countinuncia						
292	buntonia? all. B. cretacea						     
56 309	Bairdopillata pondera Paracypris sp.				       		T     
262	Acanthocythereis? massorensis Limburgina? santonia			11 11 11			
271	Cythereis rosenfeldi rosenfeldi			1 1 1			
290	Protobuntonia numidica Cythereis cretaria acuta						
281	Veenia fawwarensis fawwarensis	_			1 1 1		
302	Cytherelioidea israeliana Cristaeleheris fornicata						
273	Spinoleberis megiddoensis						
312 282	Pterygocythere? sp. Cythereis iordanensis			י ון ון ון ון	     		
280	Veenia fawwarensis dividua				     	1 1 1	
255 258	Limburgina miarensis Cythereis cretaria dorsocaudata				         	i 1 11 11	
284	Cythereis rosenfeldi evoluta			1	   		
286	Brachycythere ct. B. ekpo Cythereis mesa mesa	-			1   1   1	         	
259	Cythereis mesa ventroreticulata			1 1 1 1	     	     	
257	Ventrocythereis sinaiensis Oertliella? cf. 0.? rasbaalbekensis						     
298	Cytherella coryelli			1	1 1 1 1	, 1 1	
22	cytnerena aut. c. enotu Bythocypris aff. B. howchiniana			     	         	5 5 9 3 5 5 5 5 7 1	!
300	Krithe solomoni				1 1 1	1	
311	i ogoina gerryi Eucytherura tetracornis				1 1 1 1	1 1 1 1 1 1	
306	Phacorhabdotus cf. P. inaequicostata Rairdia? sn. R				         	• • • • • • • •	
266	Leguminocythereis dorsocostatus						
293	Protobuntonia campania			-			
301	Bythocypris hartuvensis						
307	Bairdia sp. A			_		1	
303	Cytherelloidea galileensis						
304	Cytherelloidea piscatoris					1 1 1 1 1	
256 256	Up viereitorucea uzariaria Ventrocythereis rotunda						
294	Brachycythere beershevaensis						
315	Loxoconcha hebraica Cytherelloidea zinensis					 ; ; ; ;	
285	Veeniacythereis tenyetensis					1	
319 316	Cythereis ornatissima Krithe echolsae					1	
268	Hazelina cf. H. ordoniya					-	T 1 1 1

# Fig. 2. General distribution chart of Senonian ostracods from Israel (modified after Honigstein, 1984).

## Planktonic foraminifera

The planktonic foraminiferal fauna which occurs in our material was discussed in detail in Reiss *et al.* (1985, 1986) and Almogi-Labin *et al.* (1986), where also Globotruncanidae species were figured. In the present study, species of Heterohelicidae of stratigraphical importance in the Santonian – Campanian were recorded in the distribution charts (Figs. 3, 5, 7, 11). These species are illustrated here for the first time from the Middle East, on Pl. 3: *Sigalia deflaensis* (Early – Middle Santonian, figs. 1–3); *Sigalia carpatica* (Middle Santonian, fig. 4–6; compare Lipson-Benitah *et al.*, 1985, fig. 6d); *Sigalia decoratissima* (Middle Santonian, Fig. 7); *Ventilabrella glabrata* (Late Santonian – Early Campanian, figs. 8–9) and *Ventilabrella eggeri* (Late Santonian – Early Campanian, figs. 10–12).

## CORRELATION USING PLANKTONIC FORAMINIFERAL AND OSTRACOD BIOZONATION

The distribution of the ostracods and planktonic foraminiferal assemblages within the six studied sections (Figs. 3-12), as well as from previous works (Honigstein, 1983; Reiss *et al.*, 1985), led to the following correlations of biozones, as presented in Fig. 13.

The *Phyrocythere lata* (S-1) assemblage zone of Late Coniacian age (Honigstein, 1984) was correlated in a northern Israel borehole section (Lipson-Benitah *et al.*, 1985) with the *Marginotruncana angusticarenata* zone (Lipson-Benitah, 1980). According to Lipson -Benitah (in press), at least the upper part of the S-1 zone, which was observed in Bar'am (Fig. 6), Nahal Ya'alon (Fig. 8) and Nahal Zin (Fig. 10), belong to the lower part of the *Dicarinella concavata* zone (Robas-zynski *et al.*, 1984). The planktonic foraminifera of this

SERIES CHRONOSTRATIGRAPHY STAGE CHRONOSTRATIGRAPHY	CROUP DRMATION LITHOSTRATIGRAPHY	ГТТНОГОСҮ	ГІТНОГОСҮ	OSTRACOD - ZONES	Globorrunanalla prashavananin	Sigalia carpatica	marginotruncana ununata Marginotruncana coronata	Dicarinella concavata	margimotruncana angusticarinata Dicarinella sp.	Marginotruncana pseudolinneiana	Dicarinella asymetrica Mardinotruncana sinuosa	Marginotruncana marginata	Globotruncana linneiana	Rosita fornicata	Marginotruncana tarfayaensis	Sigalia decoratissima Sidalia deflaensis	Marginotruncana sp. B	Ventilabrella eggeri	Rosita sp.	Ventilabrella glabrata	Globotruncana mariel	Globotruncanita elevata	Globotruncana arca	Globotruncanita stuartiformis	Globotruncana orientalis	Globotruncana rosetta	Kosita plummerae Globotrumcana hilli	Globotruncana insignis	Globotruncanita atlantica	Globotruncanita subspinosa	Globotruncana aegyptiaca	Globotruncana ventricosa	Hosita patellitormis Glohotruncanella havanensis	01 1
st MAAST.	. GHAREB F		EIN FAWWAR	ned G.	ta falsostuarti I																											╉┼		
Late late				not exami 6.	calcara																								-	_1				
EOUS CAMPANIAN	US MISHASE			B. beershevaensis S-5	G. rosetta																													
LATE CRETAC Early	MOUNT SCOR		$\begin{array}{c} \begin{array}{c} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	L. dorsoc S-4	G. elevata																							-						
middle SANTONIAN Late	MENUHA	EIN EL QILT		rosenteldi rosenteldi L. märensis S-2	D. asymetrica																								-ime Chalk Mari Shale Phose Phose Carbo Conce Mega Dolor Sond	e be be t be na c eian phati phati phor onato sforss mite	e e mino preccicio dula poncr te e soluta poncr te e e soluta poncr te e e e soluta poncr te e e e	t or ter		

Fig. 3. Distribution chart of planktonic foraminifera from Ein el Qilt and Ein Fawwar sections.

			LATE (	RETACEOUS				SERIES	
middle	SANTONIAN Late		Early		CAMPANIAN	Late latest	MAAST.	STAGE	
			MOU	NT SCOPUS				GROUP	VUA COLT CLOUDE
	MENUHA				MISHASI	ł		FORMATION	
		EIN EL C	I						гітногосү
	m - 50 - 25	)ILT							
							EIN FAW		гілногосу
		- 50		- 75	- 100	- 125	VAR		
rosenfeldi rosenfeldi S-2	i L. miarensis S-3		L. dersoc S-4		B. tsershevaensis S-5	not exani	ned	OSTRACOD	
D.	asymetrica		G. eleva	ta	G. rosetta	G. calcarata	G. falsostuarti	FORAMINIFE	RA-
								Phyrocythere	lata
								Cythereis neg	vensis
								Cythereis cret	sria
								Anticythereis	iudaensis
								Brachycythen	angulata
			Ī	)     				Cristaeleberis	reticulata
					1			Cythereis dive	rsereticulata
								Limburgina?	antonia
								Cythereis rose	nfeldi rosenfeldi
								Protobuntoni	numidica
1								Cythereis cret	aria acuta
1								Veenia fawwa	rensis fawwarensis
								Cythereis rose	nfeldi evoluta
		1	•					Cythereis jorc	anensis
				1				Cristaeleberis	fornicata
				1				Veenia fawwa	rensis dividua
			1					Limburgina n	iarensis
				1				Cythereis cret	aria dorsocaudata
				1				Brachycyther	cf. B. ekpo
				1				Ventrocyther	eis sinaiensis
			T					Cytherella aff	.C. eliotti
					1			Togoina gerry	
								Eucytherura t	etracornis
				1				Leguminocyti	ereis dorsocostatus
		- 4		1	3			Protobuntoni	ı campania
								Cytherella cf.	C. araucana
								Bythocypris I	artuvensis
								Cytherelloide	ı galileensis
								Ventrocyther	eis rotunda

Fig. 4. Distribution chart of ostracods from Ein el Quilt and Ein Fawwar sections.

SERIES CHRONOSTRATIGRAPHY STAGE	GROUP LITHOSTRATIGRAPHY FORMATION	гітногосу		OSTRACOD - ZONES	FORAMINIFERA-	Marginotruncana renzi	Marginotruncana sigali	Marginotruncana paraconcavata	Marginotruncana schneegansi Marginotruncana undulata	Marginotruncana tarfayaensis	Marginotruncana angusticarinata	Marginotruncana coronata	Dicarinella concevata	Dicarinella sp.	Dicarinella primitiva	Marginotruncana pseudounnetana Marginotruncana marginata	Globotruncanella praehavanensis	Sigalia decoratissima	Dicarinella asymetrica	Rosita fornicata	Usubot uncaria ininerana Vantilabrella dabrata	Vennadrena gladnata Ventilabrella eggeri	Rosita sp.	Globotruncana bulloides	Globotruncana orientalis	Globotruncanca mariei	Grouocruncana arca Marginotruncana sp. B	Globotruncanita elevata	Globotruncana cl. G. austinensis	Giobotruncanta stuartiformis	Hosita patelliformis	Globotruncanita auantica Globotruncanita subsomosa	Globotruncana ventricosa	Globotruncana hilli	Globotruncana rosetta	Globotruncana insignis	Hosita plummerae	Globotruncana rugosa	Globotruncana aegyptiaca	Globotruncanita calcarata	Globotruncanella havanensis	Globotruncana falsostuarti	Globotruncanella petaloidea	Gansserina wiedenmayeri	Globotruncanita pettersi	Rosita walfischensis	Rosita contusa	Ganssering gansseri
AAST.	HAREB		m	- <sub>M</sub> -	G. fals	sostu	arti	+	+-			$\dagger$													1	1				+		+	+-	+-			Γ	-				I	•	•	Ŧ	1	Ŧ	Γ.
atest		0-0 		S-5b	G. cal	carat	a	+	+	$\top$		+	Ŧ			Ŧ	F					+	$\left  \right $					-		Ħ				T						T				+	+	+	+	
Late 1			- 75	. beershevaensis S-5 a	G. rosetta																																											-
LATE CRETACEOUS Early CAMPANIAN	NOUNT SCOPUS		- 50	L. dorsocostatus B. S.4	G. elevata																												•															
		~							1-			1-			1							╈	Ľ	1	4					+	+	+						+							+	T	+	
SANTONIAN			- 29	2. ros. rosenfeldi miar. S-2 S-3	D. asymetrica			1												2																												
IAC	4A			S-1	ncavata		$\prod$				$\prod$	$\prod$		$\prod$																T			Ţ					T						1			1	-
L. CON	JUD 118				D. co																										T																T	•

Fig. 5. Distribution chart of planktonic foraminifera from Bar'am section. Distance to samples of the Gansserina gansseri zone not to scale.

time interval are rather well developed in size and relatively abundant, whereas ostracods are minute and scarce.

The Coniacian/Santonian boundary is problematic, but may be tentatively placed at the top of the S-1 zone. The Santonian succession is represented by high populations of ostracods and foraminifera. The *Dicarinella concavata* and *Dicarinella asymetrica* zones can be correlated with the *Cythereis rosenfeldi rosenfeldi* (S-2) and *Limburgina miarensis* (S-3) assemblage zones. Their biozone boundaries alternate (Ein el Qilt, Figs. 3-4; Bar'am, Fig. 5-6; Nahal Ya'alon, Figs. 7-8). The Santonian in the Nahal Zin section (Figs. 9-10) is reduced to about 5m; the *Dicarinella asymetrica* zone was probably therefore not observed because of the poor preservation of the foraminifera however, all ostracod zones were found.

The Santonian/Campanian boundary is defined by the common base of the Leguminocythereis dorsocostatus (S-4) and Globotruncanita elevata zones (Figs. 3-10). The Globotrunicanita elevata zone, indicative for the Early Campanian period, correlates to the S-4 zone and it its top, to the base of the Brachycythere beershevaensis (S-5) assemblage zone (Nahal Ya'alon, Fig. 8; Tarqumiya, Fig. 12). The diversity of planktonic foraminifera in the Tarqumiya section (Fig. 11) within the Early Campanian is much higher, the specimens are larger and contain a higher percentage of adults than in the Ein Fawwar exposure (Fig. 3). The ostracod diversity in these sections remains more or less constant, but the total ostracod content in the samples from Ein Fawwar is higher. These observations enhance the general W-E trend of planktonic foraminifera decrease and ostracod increase (Flexer & Honigstein, 1984).

The S-5 zone can be compared with the Late Campanian *Globotruncana rosetta* and the latest Campanian *Globotruncanita calcarata* zones (Figs. 3-12). Therefore, the former range of this ostracod zone, which can sometimes be subdivided into the subzones 5a and 5b (Honigstein, 1984: upper part of Early Campanian) must be extended into the Late and latest Campanian. The Late Campanian S-5\* subzone was recognised only from southern Israel (Honigstein, 1984; present paper: Nahal Ya'alon, Fig. 8; Nahal Zin,

Fig. 10). Two new ostracod species were found in the Nahal Zin section within this subzone, accompanying the usually rare and low diversity fauna. The S-5b subzone, contemporaneous with the *Globotruncanita calcarata* zone (Bar'am; Figs. 5-6; Tarqumiya, Figs. 11-12), can be differentiated from the S-5a subzone by the first occurrence of *Veeniacythereis tenyetensis* and *Cythereis ornatissima* (Fig. 2). Moreover, a higher ratio of pitted forms of *Brachycythere* and *Protobunto-nia* versus the reticulated specimens of *Ventrocythereis* is found in the S-5b subzone.

				LATE CRETACEOUS				SERIES	HRONOSTRATIGRAPHY
L. CONIAC	SANTONIA	N		Early CAMPA	NIAN Late	latest	MAAST.	STAGE	
JUDEA				MOUNT SC	COPUS			GROUP	ITHOSTRATIGRAPHY
BI'NA				YEN ZETIM			GHAREB	FORMATION	
		~ <u>-</u>				~~~~~		بر مربعہ ا	TTHOLOGY
•	- 15 - 10 - 5	- 25		- 50	- 75		m		
S-1	C. ros. rosenfeldi S-2	miar. S-3		L. dorsocostatus S-4	B. beershevaensis S-5 a	S-5b	_м_	OSTRACOD -	JONES
D. concavata	D. asymetric	e:		G. elevata	G. rosetta	G. calc	G. gan G. fals	FORAMINIFEI	tA-
			1			arai	ostu	Cythereis negev	ensis
		T	-			ta	iart.	Cythereis creta	ria
			Ħ				i	Brachycythere	angulata
			T	1				Cristaeleberis r	sticulata
		╢						Cythereis diver	sereticulata
		+	1					Limburgina? sa	ntonia
								Protobuntonia	numidica
		1	ſ					Cytherelloidea	israeliana
		╎╊╴				T		Cristaeleberis f	ornicata
		İ	1	1				Limburgina mi	arensis
		Ť					•	Cythereis creta	ria dorsocaudata
					1			Brachycythere	cf. B. ekpo
		İ						Cythereis mesa	mesa
			-					Cythereis mesa	ventroreticulata
								Ventrocythere	is sinaiensis
		İ	<b>/</b> *					Oertliella? cf. i	0.7 rasbaalbekensis
			Γ					Cytherella aff.	C. eliotti
		+	1				•	Bythocypris at	f. B. howchiniana
		-				-		Krithe solomo	ai
								Eucytherura te	tracornis
								Leguminocyth	ereis dorsocostatus
			•					Protobuntonia	campania
			Γ				,	Cytherella cf.	C. araucana
<u>+</u>			ţ_			+		Bythocypris h	artuvensis
			T					Ventrocythere	is rotunda
			T					Brachycythere	beershevaensis
		1						Veeniacythere	is tenyetensis
							L.	Krithe echolsa	e
								Cythereis orna	tissima

Fig. 6. Distribution chart of ostracods from Bar'am section.

				LATE CI	LETACEOUS		SERIES CHR	ONOSTRATIGRAPHY
L. CON- E:	arly	middle La	Ite SANTONIAN	Early	CAMPANIAN Late		STAGE	
				MOUNT	scopus		GROUP LITT	LOCTD ATICP ADHV
				SAY'Y.	ARIM	1	FORMATION	
		191911971914 191911971914 191911971914 191911971914					TITI	Аротон
- 5	- 25 - 20 - 15		- 50	- 75	-125	-150		
د 3-1	os. rosenfeldi S-2	L. mia S-	arensis -3	L. dorsocostatus B. b S-4	eershevaensis S-5	S-5*	OSTRACOD-	ZONEC
D.	concavata	D. asymetrica		G. elevata	G. rosetta		FORAMINIFERA	201453
							Dicarinella primi	tiva
							Marginotruncana	paraconcavata
							Marginotruncana	undulata
							Marginotruncana	pseudolinneiana
							Marginotruncana	coronata
		1					Marginotruncana	angusticarinata
							Marginotruncana	sinuosa
							Dicarinella conca	vata
				1			Marginotruncana	marginata
							Globotruncana li	nneiana
							Rosita fornicata	
							Marginotruncana	tarfayaensis
_							Marginotruncana	schneegansi
							Dicarinella asyme	trica
							Marginotruncana	sp. <b>B</b>
							Ventilabrella glab	vata
							Rosita sp.	
							Globotruncanita	elevata
							Globotruncana ai	ca
							Globotruncana m	ariei
							Globotruncanita.	stuartiformis
							Globotruncana b	ulloides
							Globotruncana o	rientalis
				•			Globotruncana h	illi -
				•			Globotruncana cl	. G. austinensis
				1 1 ?			Globotruncana ro	setta
				Ţ			Rosita patelliforn	nis
				_			Globotruncanita.	atlantica
_							Globotruncanita.	subspinosa

Fig. 7. Distribution chart of planktonic foraminifera from Nahal Ya'alon section.

L				LATE	CRETACEOUS				SERIES	
С Г	ON Early	middle Late	SANTONIAN	Early	C	AMPANIAN Lat	e		STAGE	HRONOSTRATIGRAPHY
				NOM	NT SCOPUS				GROUP ,	
				SA'	Y'YARIM				FORMATION	THUSTRATICKAPHY
~~~~~~		19, 2, 19, 19, 29, 21, 19, 19, 19, 19, 19, 19, 19, 19, 19, 1							1	АЭОТОНЦГ
L .	- 20 - 15 - 10	- 25	- 50	- 75		- 125	- 150	m		
L	C. ros. rosenfeldi	L. miarens S-3	ŝi	L. dorsocostatus S-4	B. beershevaensis S-5			S-5*	OSTRACOD -	
	D. concavata	D. asymetrica		G. elevata		G. rosetta			FORAMINIFE	KA-
									Phyrocythere	lata
	1								Cythereis nege	vensis
									Cythereis cret	ria
									Brachycythere	angulata
			       						Cristaeleberis I	eticulata
			1						Cythereis dive	sereticulata
									Limburgina? s	antonia
									Cythereis rosei	nfeldi rosenfeldi
			ון						Protobuntonia	numidica
									Cythereis creta	ria acuta
	1								Veenia fawwar	ensis fawwarensis
		-							Cristaeleberis f	ornicata
									Veenia fawwar	ensis dividua
		1							Limburgina mi	arensis
									Cythereis creta	ria dorsocaudata
									Brachycythere	cf. B. ekpo
									Ventrocythere	is sinaiensis
				1	·				Oertliella? cf. (	0.7 rasbaalbekensis
				T	1				Cytherella aff.	C. eliotti
				1					Bythocypris af	f. B. howchiniana
1					T			_	Togoina gerryi	
				T	1				Leguminocythe	ereis dorsocostatus
									Protobuntonia	campania
					1	1	1 1 1	T	Bythocypris ha	rtuvensis
									Cytherelloidea	piscatoris
_									Ventrocytherei	s rotunda

Fig. 8. Distribution chart of ostracods from Nahal Ya'alon section (modified after Lifshitz et al., 1985).

SERIES CURPONDER LEVEL AND	STAGE CHRUNUSI KAIIGKAPHY	GROUP	RMATION LUTHUST KATIGKAPHY	ГІТНОГОСҮ		STRACOD -	ZUNES BRAMINIFERA-	Dicarinella concavata	Dicarinella primitiva	farginotruncana angusticarinata	farginotruncana coronata	farginotruncana pseudolinneiana	Aarginotruncana schneegansi	Aarginotruncana sinuosa	Aarginotruncana tarfayaensis	farginotruncana undulata	farginotruncana renzi	farginotruncana paraconcavata	farginotruncana marginata	losita fornicata	licarinella sp.	farginotruncana sigali	ilobotruncanella praehavanensis	farginotruncana sp. B	lobotruncana arca	lobotruncana bulloides	Iobotruncana linneiana	lobotruncana orientalis	'osita sp.	osita patelliformis	lobotruncanita elevata	'osita plummerae	obotruncana hilli	lobotruncana cf. G. austinensis	lobotruncana rosetta	lobotruncanita atlantica	lobotruncanita stuartiformis	lobotruncana aegyptiaca	lobotruncana esnehensis
$\vdash$	ЧА.	╞	GI GI	HAREBA.		<u> </u>	G, fals	sost/	Jart	< ;	<	Y	Y		V	×	Y	<		`		Y		V				9	-	4	9	Y I	9	9	9	9	9	9	9
LATE CRETACEOUS	CAMPANIAN Late	MOUNT SCOPUS	MISHASH		- 73 - 50	evaensis \$													2																				
	rly (		IA		- 25 - 20 - 13	B. beerst S-S	G. rosetta																	-1-1					-1-				-		]	1	•		
	Ea		TENU		10 S-3	\$4	G. elev	ata																1	Ц		Ц		Ц	Ц	1	'	_			_			•
	SANT		Σ	±	- 0	<u>S-2</u> S-1	avata	Π	Π	П	1	1		Π	Π		Π	1	T	?	•	T	•																
	CON	JUDEA	NEZER				D. conc					-																											

Fig. 9. Distribution chart of planktonic foraminifera from Nahal Zin section.

The Campanian/Maastrichtian boundary is not clearly defined in the Israeli succession (Reiss et al., 1985, 1986) and cannot precisely be dated by planktonic foraminifera (disappearance of *Globotruncanita calcarata*) and the rare ostracod fauna. The Early Maastrichtian is determined in the present study with the common range of the *Globotruncana falsostuarti* and *Hazelina* cf. *H. ordoniya* (M) zones (Bar'am, Figs. 5–6; Nahal Zin, Figs. 9–10).

The combination of contemporaneous occurrences of ostracod and planktonic foraminiferal biozones enables us to date the local ostracod biostratigraphy according to the regional Tethyan planktonic foraminiferal zonation. The use of both taxa, ostracods and planktonic foraminifera, provides more datum lines and allows a finer resolution of the Senonian stratigraphy.

CHRONOSTRATIGRAPHY	VITE A TICE A BUN	LI TUUSI VALIAVALUI	Аротонци			RA-	angulata	reticulata	rsereticulata	israeliana	fornicata	iarensis	aria dorsocaudata	cf. B. ekpo	a mesa	is sinaiensis	0.? rasbaalbekensis	C. eliotti	ff. B. howchiniana		etracornis	ereis dorsocostatus	i campania	artuvensis	ordinata	ı galileensis	sis rotunda	t beershevaensis	tissima
SERIES	GROUP	FORMATION			OSTRACOD -	FORAMINIFE	Brachycythere	Cristaeleberis I	Cythereis dive	Cytherelloidea	Cristaeleberis 1	Limburgina m	Cythereis creta	Brachycythere	Cythereis mesa	Ventrocythere	<i>Oertliella?</i> cf.	Cytherella aff.	Bythocypris al	Togoina gerryi	Eucytherura te	Leguminocyth	Protobuntonia	Bythocypris h	Cristaeleberis o	Cytherelloidea	Ventrocythere	Brachycythere	Cythereis orna
LATE CRETACEOUS Early CAMPANIAN Late latest MAAST	MOUNT SCOPUS	MENUHA MISHASH - ZETIM		- 25 - 25 - 27 - 15 - 70 - 5 - 0	L. dorsocostatus B. beershevaensis S-5b Z	G. elevata G. rosetta 201	ata _																						

Fig. 10. Distribution chart of ostracods from Nahal Zin section.

#### **Explanation of Plate 2**

- Figs. 1-4. Loxoconcha hebraica Honigstein & Rosenfeld sp. nov.
- Fig. 1. Left valve, carapace, paratype, Nahal Zin, SMA 22 (HU-6825), Zone S-5\* (× 160).
- Fig. 2. Right valve, same carapace ( $\times$  137).
- Fig. 3. Left valve, carapace, holotype, Nahal Zin, SMA 22 (HU-6825), Zone S-5\* (× 127).
- Fig. 4. Dorsal view, carapace, paratype, Nahal Zin, SMA 33 (HU-6844), Zone S-5\* (× 137).
- Figs. 5-10. Cythereis ornatissima (Reuss) (latest Campanian Early Maastrichtian).
- Fig. 5. Left valve, female carapace, "spinous form", Bar'am, BR 71 (HU-6731), Zone S-5b (× 100).
- Fig. 6. Subcentral node of the same carapace with five distinctive, subdivided spines (scale bar = 100  $\mu$ m).
- Fig. 7. Trifurcated spines in the posteroventral area of the same carapace (scale bar =  $10 \ \mu m$ ).
- Fig. 8. Right valve, female carapace, "spinous form", Bar'am, BR 71 (HU-6731), Zone S-5b (× 91).
- Fig. 9. Left valve, male carapace, "tuberculated form", Nahal Zin, SMA 111 (HU-6896), Zone M (base) (× 75).
- Fig. 10. Right valve, ?male carapace, "tuberculated form", Nahal Zin, SMA 111 (HU-6896), Zone M (base) (× 85).



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#### **Explanation of Plate 3**

- Figs. 1-3. Sigalia deflaensis (Sigal) (Early Middle Santonian).
- Fig. 1. Ein el Qilt, BL 100 (HU-3376), D. asymetrica Zone (× 105).
- Fig. 2. Ein el Qilt, BL 100 (HU-3376), D. asymetrica Zone (× 110).
- Fig. 3. Ein el Qilt, BL 100 (HU-3376), D. asymetrica Zone (× 135).
- Figs. 4-6. Sigalia carpatica Salaj & Samuel (Middle Santonian).
- Fig. 4. Ein el Qilt, BL 100 (HU-3376), D. asymetrica Zone (× 125).
- Fig. 5. Ein el Qilt, BL 87 (HU-3363), D. asymetrica Zone ( $\times$  100).
- Fig. 6. Ein el Qilt, BL 87 (HU-3363), D. asymetrica Zone (× 180).
- Fig. 7. Sigalia decoratissima (de Klasz) (Middle Santonian). Ein el Qilt, BL 100 (HU-3376), D. asymetrica Zone (× 100).
- Figs. 8-9. Ventilabrella glabrata Cushman (Late Santonian Early Campanian).
- Fig. 8. Ein el Qilt, BL 156 (HU-3624), D. asymetrica Zone (× 110).
- Fig. 9. Ein el Qilt, BL 156 (HU-3624), D. asymetrica Zone (× 185).
- Figs. 10-12. Ventilabrella eggeri Cushman (Late Santonian Early Campanian).
- Fig. 10. Ein el Qilt, BL 144 (HU-3618), D. asymetrica Zone (× 100).
- Fig. 11. Ein el Qilt, BL 156 (HU-3624), D. asymetrica Zone (× 110).
- Fig. 12. Ein el Qilt, BL 156 (HU-3624), D. asymetrica Zone (× 155).



	LATE	CRETACEOUS		SERIES	HPONOSTRATIC RAPHY
	Early CAMPAN	IAN Late lates	t MAAST.	STAGE	
	MOUN	T SCOPUS		GROUP	ITHOSTRATICRAPHY
	MENUHA	MISHASH	SETIM I	ORMATION	
minim					гітногоду
["	- 20 - 15 - TO - 5	- 25	m - 50		
Ĺ.	dorsocostatus B. S.4	beershevaensis S-51 S-5a	IM II	OSTRACOD -	ZONIES
	G. elevata	G. rosetta	G.	FORAMINIFE	RA-
			ata	Ventilabrella g	labrata
				Dicarinella sp.	
				Rosita sp.	
				Marginotrunca	na sp. B
				Globotruncani	ta stuartiformis
				Globotruncana	a bulloides
				Rosita patellife	ormis
				Globotruncan	a linneiana
				Globotruncana	a mariei
			Ţ	Globotruncani	a orientalis
				Globotruncani	a arca
			T	Rosita fornica	ta
				Globotruncani	a cf. G. austinensis
				Marginotrunca	na marginata
				Globotruncani	ita elevata
	       			Globotruncan	ita subspinosa
	1			Globotruncana	a hilli
				Rosita plumm	erae
				Globotruncan	a rosetta
				Globotruncan	a rugosa
				Globotruncan	ita atlantica
				Globotruncan	a ventricosa
				Globotruncan	ita calcarata
			T	Globotruncan	a aegyptiaca

Fig. 11. Distribution chart of planktonic foraminifera from Tarqumiya section.

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- L - L - U	LATE	CRETACEOUS		SERIES CH	RONOSTRATIGRAPHY
VI.   Ear	IV CAMPANIAN	Late	YW ?	SIAUE	
	~	AOUNT SCOPUS		GROUP	THOSTR ATIGR APHY
MENCH	LA .	MISHASH	Gł	FORMATION -	
			AREBAY		Аротонд
- 10 - S-3-	- 25 - 20 - 15	- 30	m - 75		
S-4 S-2	B. beershevaensis S-5	S-5*	М	OSTRACOD -	
G. elev	G. rosetta		G. fals	FORAMINIFER	ZONES
ata			50sti	Phyrocythere lat	e.
			vart	Cythereis negeve	insis
Ŧ			1 7	Cythereis cretari	e
1				Brachycythere a	ngulata
				Cristaeleberis rei	ticulata
				Cythereis diverse	ereticulata
1				Limburgina? san	tonia
-				Cythereis rosenf	eldi rosenfeldi
				Cristaeleberis for	rnicata
	•			Veenia fawwarei	nsis dividua
				Cythereis cretari	a dorsocaudata
				Brachycythere c	f. B. ekpo
-				Ventrocythereis	sinaiensis
				Bythocypris aff.	B. howchiniana
				Togoina gerryi	
	9			Eucytherura tet	racorris
		-		Leguminocyther	eis dorsocostatus
				Protobuntonia c	ampania
				Cytherella cf. C.	araucana
-				Bythocypris har	tuvensis
	-			Cristaeleberis or	dinata
				Ventrocythereis	rotunda
	-			Brachycythere t	eershevaensis
				Loxoconcha het	naica
				Cytherelloidea z	inensis
			1	Cythereis ornati	ssima

Fig. 12. Distribution chart of ostracods from Tarqumiya section.

AGE	FORAMINIFERA- ZONE	OSTRACOD- ZONE						
MAASTRICHT. (Early)	Globotruncana falsostuarti	Hazelina cf. H. ordoniya M						
CAMPANIAN latest	Globotruncanita calcarata	ythere s S - 5 S - 2P						
CAMPANIAN Late	Globotruncana rosetta	Brachyc ershevaensi o 2-2 *						
CAMPANIAN Early	Globotruncanita elevata	Leguminocythereis dorsocostatus S - 4						
Late SANTONIAN middle	Dicarinella asymetrica	Limburgina miarensis S - 3 Cythereis rosenfeldi						
SANTONIAN Early CONIACIAN Late	Dicarinella concavata	rosenfeldi S - 2 Phyrocythere Iata S - 1						

Fig. 13. Correlation of planktonic foraminifera and ostracod biozonation during the Senonian of Israel.

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