

Santonian planktonic foraminiferal biostratigraphy of the northern Tunisia



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ABSTRACT

Planktonic foraminifera were quantitatively analyzed across the Santonian succession and their boundaries at the Jebel Ennahli and Ettout sections, northern Tunisia. The continuous sedimentary succession is dominated by hemipelagic facies, allowing a good biostratigraphic correlation for this time interval. Fifty-five planktonic foraminiferal species belonging to 13 genera have been identified. The distribution pattern of 17 heterohelicids and 38 trochospiral forms reveals the identification of 12 major bio-events and allows establishment of three zones based on heterohelicids and five zones based on trochospiral forms. Trochospiral based zones are from the base to the top: 1) *Dicarinella primitiva* Interval Zone, 2) *Dicarinella concavata* Interval Zone, 3) *Dicarinella asymetrica* Total Range Zone, 4) *Globotruncanita elevata*/*Globotruncana arca* Concurrent Range Zone, and 5) *Globotruncanita ventricosa* Interval Zone. The heterohelicid planktonic foraminiferal zones are: 1) *Pseudotextularia nuttalli* Interval Zone, 2) *Sigalia carpatica* Interval Zone, and 3) *Ventilabrella eggeri*/*Planoglobulina manuelensis* Concurrent Range Zone. The bio-events and planktonic foraminiferal zones were correlated with previously published works especially on Tunisia and other areas. The lowest occurrence (LO) of *Dicarinella asymetrica* is the only planktonic foraminiferal datum recorded across the Coniacian/Santonian boundary (CSB). It occurs slightly below the LO of the inoceramid *Platyceramus cycloides cycloides* representing a good proxy for the CSB. The Santonian/Campanian boundary in the studied sections is characterized by a major faunal turnover represented by the LO of *Ventilabrella* and *Planoglobulina* and the LO of *Globotruncana* and *Globotruncanita* slightly above. The boundary interval is also characterized by the highest occurrence (HO) of *Sigalia*, *Dicarinella*, and *Whiteinella*.

Keywords: Santonian, biostratigraphy, planktonic foraminiferal, bioevents, *Globotruncanidae*, *Heterohelicidae*, Tunisia.

1. INTRODUCTION

Northern Tunisia corresponds to a fold thrust belt linking the North Africa Atlas and the Sicilian Apennine chains, called the peri-Mediterranean orogenic arc (COWARD & RIES, 2003). It was formed during the Cenozoic following the collision between the African and European plates. Upper Cretaceous rocks in Tunisia are characterized by widely distributed, deep marine facies, which are extremely rich in microfauna as well as macrofauna especially ammonites and inoceramids. Therefore a considerable number of previ-

ous papers deal with the planktonic foraminiferal biostratigraphy of the Upper Cretaceous in Tunisia (e.g. PERVINQUIÈRE 1903, 1907; PINI, 1971; DALBIEZ, 1956; SALAJ, 1980; NEDERBRAGT, 1991; RAMI et al., 1997; ROBASYNSKI et al.; 2000; ROBASYNSKI & MZOUGH 2010; BEY et al., 2012). It is well-known that the Tethyan, or low latitude assemblages are characterized by abundant, highly diverse planktonic foraminiferal assemblages, whereas those from the Circum-Antarctic region are characterized by low diversity and usually long-ranging planktonic taxa of simple morphology (PETRIZZO, 2000). Many bio-

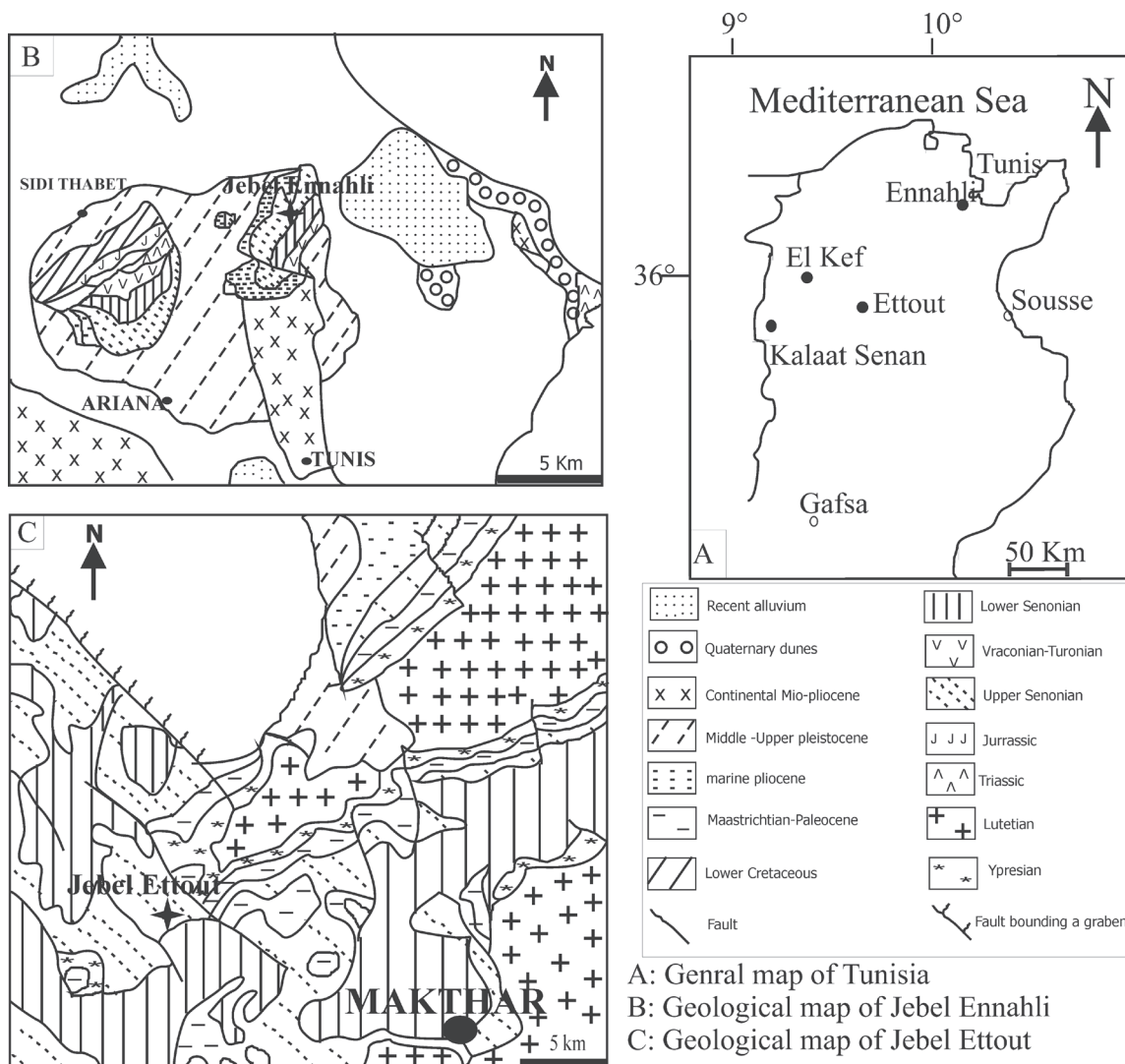


Figure 1: A) Location map of the studied sections. B & C) Geologic map after http://www.erlm.tn/lithotheque/IMG/pdf/carte_geologique_500_000.pdf

stratigraphic studies have been conducted on the Santonian deposits and their boundaries to define the global stratotype section and point (GSSP) but Comparison of the Santonian planktonic foraminiferal bioevents noted in the Tethyan province with other provinces has revealed variations in the stratigraphic ranges (FAROUK & FARIS, 2012).

The Olazagutia section (north Spain) was approved as the GSSP for the base of the Santonian by the Subcommittee on Cretaceous Stratigraphy, and submitted to the International Commission of Stratigraphy (ICS) in early 2012. The base of the Coniacian / Santonian boundary is placed at the lowest occurrence of the inoceramid bivalve *Cladoceras undulaticus* (LAMOLDA et al., 2007; LAMOLDA, 2013). This marker species has not been previously recorded in Tunisia. However, GRADSTEIN et al. (2012) noted that the Olazagutia section is not ideal the biostratigraphic record may be incomplete and the abandoned quarry wall might be unsuitable for future sampling. An alternative candidate is Ten Mile Creek, Dallas County, Texas (GALE et al., 2007), where portions of the record are composed of overlapping sections. Furthermore, the stratotype for the Santonian –

Campanian (S/C) boundary is still in the process of ratification. The S/C transition interval has been studied in many sections in Tunisia (e.g., NEDERBRAGT, 1991, 1993; SALAJ, 1980; ARZ, 1996; ROBASYNSKI, 1999; ROBASYNSKI et al., 2000; JARVIS et al., 2002). The geographic applicability of biostratigraphic zonation is influenced by palaeolatitudinally controlled temperature gradients and the niche preferences of marker species (BRALOWER, 1995). Integration of trochospiral and heterohelicid bioevents in the present study allows a high-resolution biozonation, and increased ability to correlate between deep and shallower basins, owing to the different life strategies of the various families (e.g., LI & KELLER, 1998; ARZ & MOLINA, 2002).

The main objectives of the present study are: 1) to define the major planktonic foraminiferal events; 2) to establish a high resolution planktonic foraminiferal biostratigraphic zonation based on the integration of trochospiral and heterohelicid forms; 3) to compare the planktonic foraminiferal bioevents from different palaeolatitudes; 4) to define the Coniacian-Santonian and Santonian-Campanian stage boundaries.

2. MATERIAL AND METHODS

151 rock samples were collected from the Kef Formation, sampled approximately every 50 cm from two exposed sections (Fig. 1). The first section named the Ettout section is located on the south eastern flank of the Ellès syncline in

central Tunisia (35°56'59"N and 9°6'2"E), while the second section named the Jebel Ennahli section, is located in north-eastern Tunisia in the Ariana area ~5 km from Tunis City towards the north (36° 54' 46" N 10° 09' 09" E). From both sections, the samples are washed following the classic micropalaeontological method. About 200 g of dry rock sam-

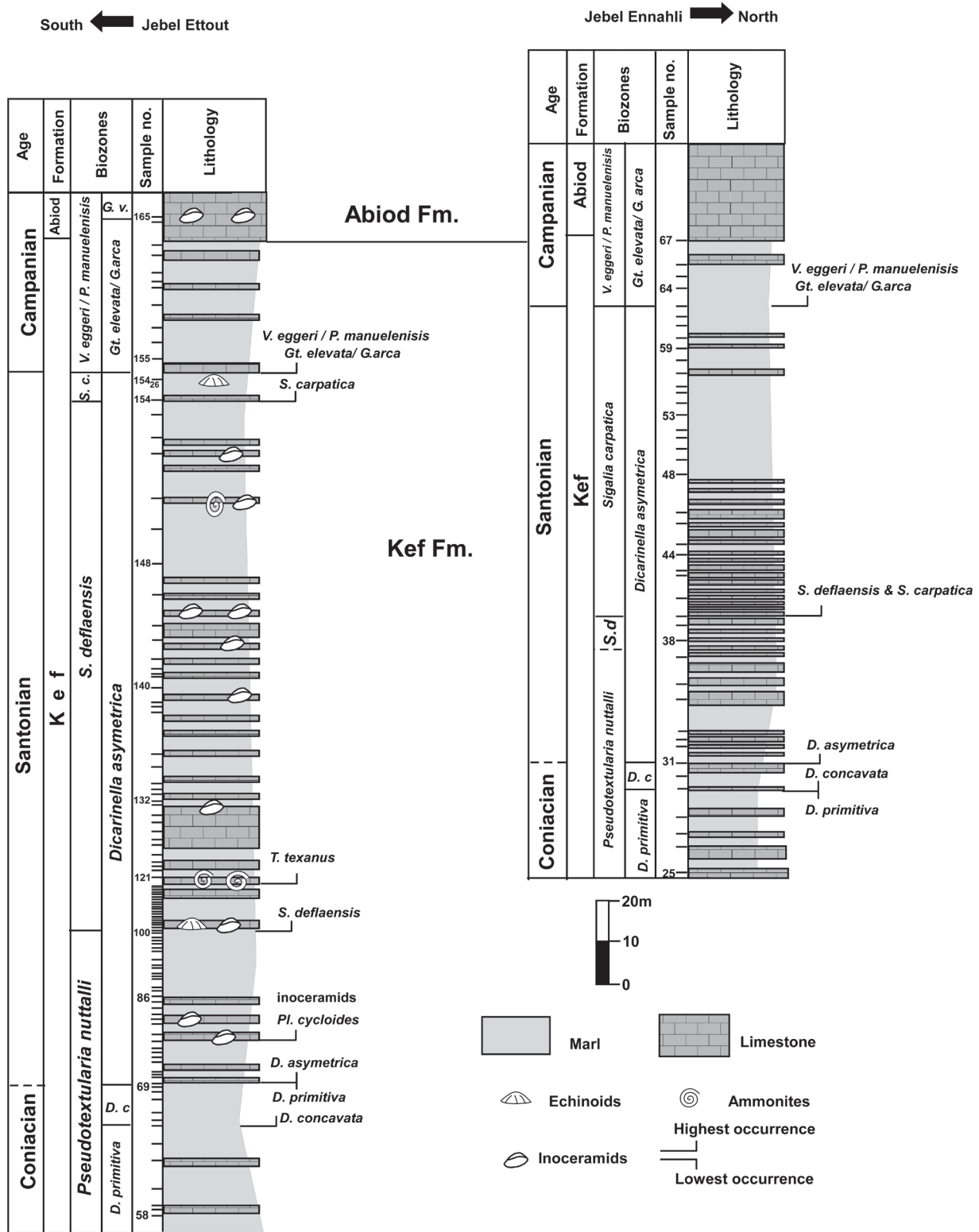


Figure 2: Stratigraphic correlation of the studied sections in the northern Tunisia, showing the (lowest and highest occurrence) of planktonic marker species.

Table 1. Relative percent abundances at Ettout section section, calculated for the > 63 µm fraction on 300-500 specimens.

Sample no.	ET58	ET61	ET62	ET67	ET68	ET69	ET71	ET73	ET75	ET77	ET79	ET82	ET84	ET85	ET88	ET90	ET95	ET97	ET100	ET108	ET115	ET128	ET132
<i>Heterohelix globulosa</i>	107	61	112	168	153	64	77	66	52	26	68	54	119	107	108	193	138	86	133	124	66	61	148
<i>Globigerinelloides ultramicrus</i>	31	16	54	30	50	64	87	43	52	176	45	69	72	75	126	44	56	63	37	45	33	31	88
<i>Heterohelix globians</i>	8	7	8	2	35	39	18	4	9	8	19	21	17	21	9	37	20	17	24	10	8	15	21
<i>Heterohelix reussi</i>	42	35	74	25	17	13	5	9	10	5	10	9	4	8	8	18	12	13	12	23	11	7	25
<i>Heterohelix pulchra</i>	46	90	41	51	36	49	192	163	87	25	104	81	89	66	60	59	91	105	61	70	42	22	105
<i>Archeoglobigerina cretacea</i>	6	3	0	1	4	10	2	7	2	0	7	1	0	4	6	7	1	2	5	7	8	13	6
<i>Archeoglobigerina blowi</i>	5	7	8	7	16	37	10	13	14	3	5	2	11	5	28	8	18	5	8	22	8	8	21
<i>Globotruncana ventricosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Heterohelix carinata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Globotruncana bulloides</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Costellagerina pillula</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	29
<i>Hedbergella flandini</i>	14	31	67	66	44	44	30	10	11	42	7	20	39	59	51	8	10	14	8	18	16	14	39
<i>Contusotruncana fomicata</i>	2	0	0	18	6	1	0	0	0	2	7	3	2	1	5	6	0	2	5	4	3	3	1
<i>Sigalia deflaensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	38	7	10	4	1	4
<i>Globotruncana linnei</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Globotruncana linnei</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Marginotruncana sinuosa</i>	0	0	0	3	3	1	1	0	1	2	3	6	0	5	3	3	0	1	0	6	4	11	3
<i>Heterohelix navarroensis</i>	2	9	8	5	10	17	13	6	5	6	11	5	3	8	9	8	0	6	2	6	5	0	3
<i>Globotruncana arca</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Globotruncana rosetta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sigalia sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Heterohelix moremani</i>	8	7	8	2	9	3	7	6	8	1	4	5	11	8	8	5	3	2	5	10	0	0	4
<i>Globotruncanella insignis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Globotruncana mariei</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Globotruncana caliciformis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pseudoglobulina austriana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Marginotruncana marginata</i>	1	0	3	3	10	6	0	1	1	1	2	1	0	6	9	7	7	14	4	4	4	1	1
<i>Dicarinella concavata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0	0
<i>Hedbergella Simplex</i>	0	0	3	4	22	9	6	0	1	5	0	3	5	8	17	7	2	2	0	10	2	1	6
<i>Marginotruncana undulata</i>	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2	0	0	0	3	2	3	0
<i>Ventilabrella globata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Marginotruncana coronata</i>	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	1	0	1	1
<i>Globotruncanella stuartiformis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ventilabrella eggeri</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Globotruncana orientalis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Globotruncanella elevata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pseudotextularia nuttalli</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Contusotruncana patelliformis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Heterohelix striata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Globotruncanella subspinosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ventilabrella alpina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Marginotruncana pseudolinnei</i>	1	0	0	0	2	2	2	0	1	8	1	1	1	2	2	4	3	2	3	4	1	2	0
<i>Marginotruncana tarfayensis</i>	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	3	2	1	0
<i>Marginotruncana renzi</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dicarinella asymetrica</i>	0	0	0	0	0	0	0	0	0	0	1	0	1	1	2	0	1	0	0	3	0	1	0
<i>Marginotruncana schneegansi</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sigalia carpatica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Marginotruncana paraconavata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	4	1	1	1	0	0
TOTAL	274	266	386	386	417	359	450	328	254	313	295	282	375	385	454	425	368	376	315	384	220	204	507

Table 1: continuation

Sample no.	ET134	ET139	ET141	ET145	ET146	ET147	ET148	ET149	ET150	ET151	ET152	ET155	ET156	ET157	ET158	ET159	ET160	ET161	ET162	ET163	ET164	ET166
<i>Heterohelix globulosa</i>	76	131	86	35	105	171	84	70	129	27	83	46	24	28	75	50	58	98	88	42	67	56
<i>Globigerinelloides ultramicrus</i>	38	39	46	36	30	65	47	61	55	64	58	56	67	59	58	52	51	50	52	77	72	56
<i>Heterohelix glabrans</i>	14	17	28	56	65	62	81	30	20	84	51	55	60	54	54	74	51	38	52	55	78	46
<i>Heterohelix reussi</i>	40	75	105	31	65	78	29	72	109	29	37	65	45	50	72	36	57	53	48	7	23	18
<i>Heterohelix pulchra</i>	7	9	2	0	8	12	23	13	2	3	12	26	18	9	17	14	17	17	10	1	9	10
<i>Archeoglobigerina cretacea</i>	6	7	12	0	7	22	17	8	13	3	20	16	16	17	30	52	19	26	35	3	7	7
<i>Archeoglobigerina blowi</i>	0	0	0	0	0	0	0	0	0	0	0	5	36	38	19	43	26	24	16	16	13	5
<i>Globotruncana ventricosa</i>	0	0	0	0	0	0	0	0	0	0	0	7	7	11	8	2	2	5	3	3	4	5
<i>Heterohelix carinata</i>	0	0	0	0	0	0	0	0	0	0	0	16	4	0	7	15	16	16	20	1	0	5
<i>Globotruncana bulloides</i>	6	21	13	2	12	10	1	0	2	4	13	16	4	0	2	2	18	16	20	3	4	5
<i>Costellagerina pillula</i>	17	12	27	16	16	30	32	20	33	22	28	38	30	25	29	36	7	21	33	3	6	4
<i>Hedbergella flandini</i>	2	5	2	5	4	7	5	2	1	7	0	5	3	7	2	3	2	1	4	14	3	3
<i>Contusotruncana fornicata</i>	3	4	4	2	16	9	36	22	11	11	9	20	11	15	1	2	6	5	3	5	6	3
<i>Sigalia deflaensis</i>	0	0	0	0	0	0	0	0	0	0	0	6	6	7	3	2	3	7	2	16	4	3
<i>Globotruncana linnei</i>	3	9	8	17	15	11	6	6	2	9	5	0	2	1	0	3	3	5	10	8	1	3
<i>Margino truncana sinuosa</i>	7	4	5	5	4	21	13	4	4	4	2	9	14	5	9	5	5	4	4	6	3	2
<i>Heterohelix navarroensis</i>	0	0	0	0	0	0	0	0	0	0	0	9	5	6	6	5	1	2	11	11	2	2
<i>Globotruncana arca</i>	0	0	0	0	0	0	0	0	0	0	0	4	3	1	0	0	1	0	2	17	1	2
<i>Globotruncana rosetta</i>	0	0	0	0	0	0	0	0	0	0	0	16	2	2	1	4	0	1	0	1	0	2
<i>Sigalia sp.</i>	5	10	1	0	5	4	1	4	2	1	0	8	0	0	1	5	9	10	6	1	0	1
<i>Heterohelix moremani</i>	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	1	1	2	1
<i>Globotruncana insignis</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	1	0	0	1
<i>Globotruncana mariei</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1
<i>Globotruncana californis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pseudoglobulina austriana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Margino truncana marginata</i>	5	4	1	28	9	11	17	17	5	10	2	1	0	0	0	0	0	1	3	1	4	0
<i>Dicarmella concavata</i>	0	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hedbergella Simplex</i>	2	0	3	2	2	3	0	3	1	3	1	0	4	2	0	6	1	2	0	0	0	0
<i>Margino truncana undulata</i>	4	1	1	2	2	2	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0
<i>Ventilabrella glabrata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Margino truncana coronata</i>	1	0	0	2	1	1	0	0	1	1	3	1	0	0	0	0	0	0	0	0	0	0
<i>Globotruncanita stuartiformis</i>	0	0	0	0	0	0	0	0	0	0	0	3	1	1	0	0	0	0	3	0	1	0
<i>Ventilabrella eggeri</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Globotruncana orientalis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
<i>Globotruncanella elevata</i>	0	0	0	0	0	0	0	0	0	0	0	7	7	1	0	2	0	5	4	4	2	0
<i>Pseudotextularia nuttalli</i>	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	1	1	2	4	0	0
<i>Contusotruncana patelliformis</i>	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	1	2	5	0	0	0
<i>Heterohelix striata</i>	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	1	0	0	0
<i>Globotruncanella subspinoso</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
<i>Ventilabrella alpina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0	1	0	0	0
<i>Margino truncana pseudolinnei</i>	6	8	8	19	6	3	1	6	3	5	12	0	0	0	0	0	0	0	0	0	0	0
<i>Margino truncana tarfayensis</i>	2	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Margino truncana renzi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dicarmella asymetrica</i>	5	4	2	0	6	3	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Margino truncana schneegansi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sigalia carpatica</i>	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
<i>Margino truncana paracavata</i>	1	0	0	3	1	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	262	377	366	281	391	546	425	361	412	303	373	465	426	383	422	449	358	408	437	307	315	255

ples were disaggregated were soaked in dilute hydrogen peroxide (H₂O₂), washed through a 63 µm sieve, and then dried. Population counts are based on random splits of 300-500 specimens in the size fraction larger than 63 µm. All specimens were picked, identified and mounted on microslides for permanent record. Results of the quantitative analyses for the Santonian succession and their boundaries at the Ettout section and the Santonian/ Campanian boundary at Jebel Ennahli section are listed in Tables 1 and 2 respectively. The most important foraminiferal specimens were digitally imaged under the Phillips XL30 Scanning Electron Microscope (SEM) in the laboratories of the Egyptian Mineral Resources Authority (E.M.R.A.), having been sputtering coated for 8 min with gold at 20–30 mA°. In addition, several thin sections were prepared of indurated carbonate samples to assist in microfacies analysis and foraminiferal species determination.

3. LITHOSTRATIGRAPHY

The present study deals mainly with the Kef Formation (FOURNIÉ, 1978) which overlies the Bahloul Formation and underlies the Abiod Formation. The age of the Kef Formation is Late Turonian to Early Campanian (ROBASZYNSKI et al., 2000; ROBASZYNSKI & MZOUGHJI 2010). It consists mainly of marl and limestone deposited in a pelagic or hemi-pelagic ramp setting. It is rich in inoceramids, e.g., *Endocostea ghadamensis* (TROGER & RÖHLICH) and in foraminifera, including *Globotruncana* and *Globotruncanita* representatives of Campanian age (BUROLLET, 1956; SALAJ, 1980; BELLIER, 1983; RAMI et al., 1997; ROBASZYNSKI et al., 2000).

At the Ettout section, the lower part of the Kef Formation (FOURNIÉ, 1978) is composed of marl with fossiliferous limestone and small pelecypods (*Nucula* sp.). The frequency of these limestone interbeds increases towards the middle part (SALAJ, 1980; BELLIER, 1983; MATMATI et al., 1991; RAMI et al., 1997; ELAMRI & ZAGHBIB-TURKI, 2005). The middle portion of the Kef Formation contains the inoceramid bivalve *Platyceramus cycloides* (WEGNER) and ammonite *Texanites texanus texanus* (ROMER). Towards, the upper parts of the Kef Formation, limestone beds are less frequent with very scarce macrofossils represented only by the echinoid species *Pleisaster peini* (COQUAND) in the Ettout section, followed by the predominantly white limestones of the Abiod Formation (BUROLLET, 1956). A similar succession is observed at the Jebel Ennahli section with an observed lack of megafossils in the whole measured section, suggesting that these variations in macrofaunal assemblages may be environmentally controlled (Fig. 2).

4. BIOSTRATIGRAPHY

The biostratigraphy of the Upper Coniacian – Lower Campanian succession in the study area is constructed with some modification based on the *Heterohelicidae* planktonic foraminiferal zonal scheme of NEDERBRAGT (1990) and the scheme of ROBASZYNSKI et al., (2000) for trochospiral forms. Four Tethyan trochospiral forms and three *Heterohelicidae* planktonic foraminiferal zones are identified in this study, based on the lowest and highest occurrence, (LOs, HOs) of the marker species. The biostratigraphic ranges of the identified planktonic foraminiferal species are given in Figs. 3 and 4. The most important planktonic foraminiferal taxa are illustrated in Plate 1. The established planktonic fo-

Table 2: Relative percent abundances around the Santonian / Campanian at Jebel Ennahli section, calculated for the > 63 µm fraction on 300-500 specimens.

<i>Constusotruncana fornicata</i>	20	12	50	5	31	12	60	75	30
<i>Marginotruncana undulata</i>	5	11	0	3	5	0	0	0	0
<i>Marginotruncana sigali</i>	1	0	4	1	0	0	0	0	0
<i>Heterohelix navarroensis</i>	1	23	30	12	20	30	15	0	0
<i>Ventilabrella decoratissima</i>	0	2	30	14	10	0	0	12	0
<i>Marginotruncana schneegansi</i>	0	1	0	0	0	0	0	0	0
<i>Ventilabrella eggeri</i>	0	1	1	14	50	6	0	0	0
<i>Globotruncana arca</i>	0	0	0	0	15	2	0	0	1
<i>Globotruncana linneiana</i>	0	0	0	0	7	18	15	0	25
<i>Globotruncana orientalis</i>	0	0	0	0	6	24	14	6	14
<i>Planoglobulina manuelensis</i>	0	0	0	0	10	0	0	0	0
<i>Ventilabrella glabrata</i>	0	0	0	0	0	12	0	0	0
<i>Heterohelix carinata</i>	0	0	0	0	0	36	6	0	62
<i>Globotruncanita elevata</i>	0	0	0	0	5	12	27	45	20
<i>Pseudotextularia nuttalli</i>	0	0	0	0	0	2	35	4	35
<i>Globotruncana bulloides</i>	0	0	0	0	0	0	6	5	16
<i>Globotruncana mariei</i>	0	0	0	0	0	0	0	20	30
Total	379	353	600	348	535	345	386	413	541

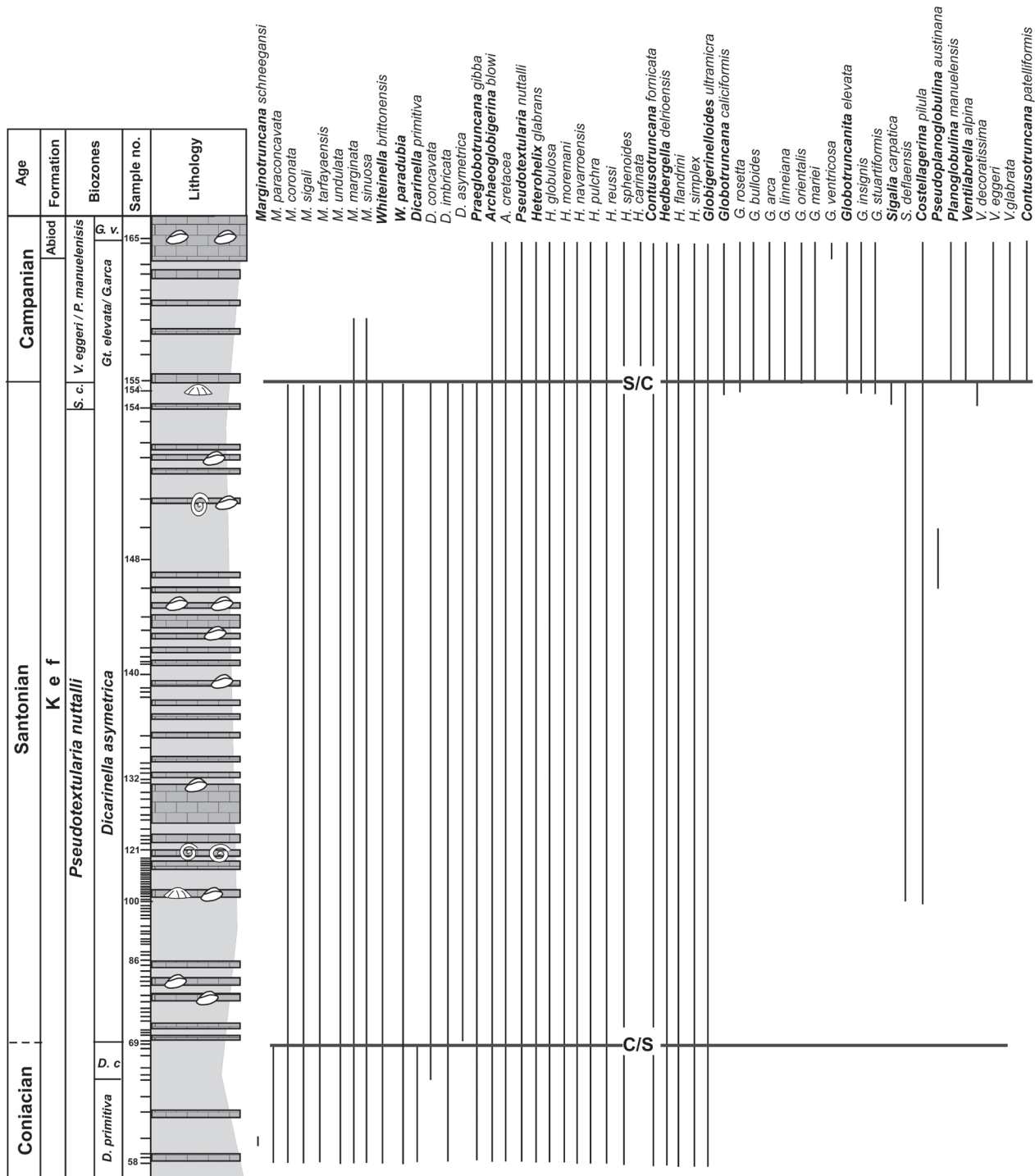


Figure 3: Lithology of the Coniacian – Campanian at Jebel Ettout section, with sample positions, range of planktonic foraminifera, and biostratigraphic zone; for symbol key see Fig. 2.

raminiferal bioevents and biozones arranged from older to younger are described below.

4.1. Globotruncanidae biozones

4.1.1. Dicarinella primitiva Zone

Definition: this zone covers the interval from the LO of *Dicarinella primitiva* to the LO of *Dicarinella concavata*.

Author: CARON (1978).

Age: Late Turonian-Early Coniacian. The present study deals only with the upper part of this zone.

Assemblage: The *Globotruncanidae* are predominantly recorded in this zone represented by *Dicarinella imbricata*, *Marginotruncana paraconcovata*, *M. schneegansi*, *M. sigali*, *M. renzi*, *M. coronata*, *M. undulata*, *M. pseudolinneiana* in addition to the less common occurrence of *Whiteinella paradubia*, *Whiteinella brittonensis* and *Præglobotruncana gibba*. For the complete assemblage see Figs. 3 & 4.

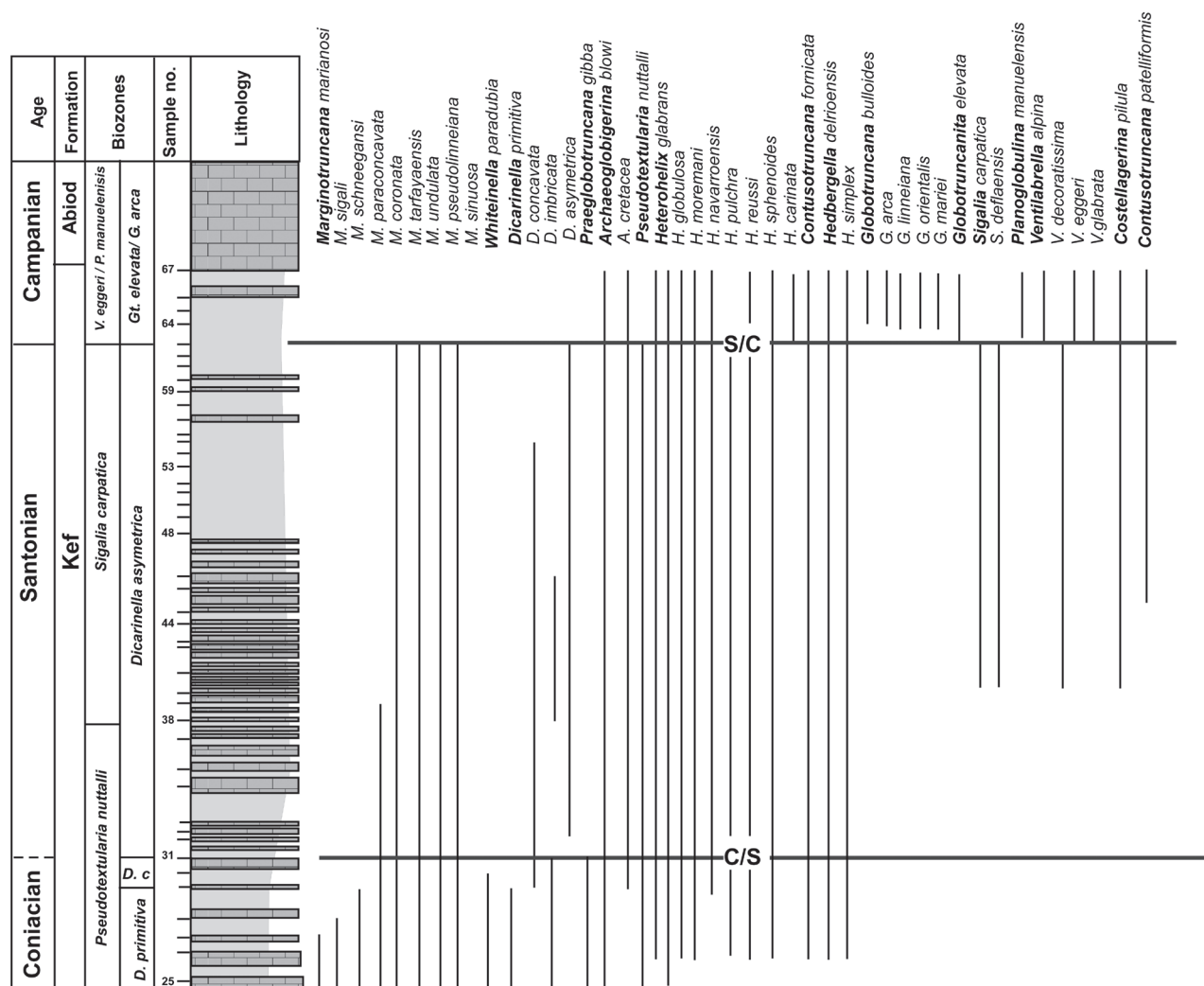


Figure 4: Lithology of the Coniacian – Campanian at Jebel Ennahli section, with sample positions, range of planktonic foraminifera, and biostratigraphic zone; for symbol key see Fig. 2.

Remarks: The stratigraphic range of *Dicarinella primitiva* differs from the two studied sections. The HO of *Dicarinella primitiva* at the Ettout section is placed at the C/S boundary directly below the LO of *Dicarinella asymetrica*. At Jebel Ennahli it is placed below the LO of *Dicarinella concavata* within the *Dicarinella primitiva* Zone (Figs. 3 & 4). This zone is attributed by different authors to the Early Coniacian (e.g., WONDERS, 1980; Caron, 1985; RAMI, 1998; ABDEL-KIREEM et al., 1995; ELAMRI & ZAGHBIB-TURKI, 2005), while it is dated as Late Turonian by other authors (PREMOLI-SILVA & SLITER, 1999). This biozone is considered to be of Late Turonian-Early Coniacian age in the Tunisian sections (NEDERBRAGHT, 1991).

4.1.2. *Dicarinella concavata* Zone

Definition: This zone covers the interval from the LO of *Dicarinella concavata* to the LO of *Dicarinella asymetrica*..

Author: SIGAL (1955).

Age: Late Coniacian

Assemblage: In this interval the assemblages are highly abundant and contain well preserved *Marginotruncana* and

Dicarinella spp. The zone is similar to that of the underlying *Dicarinella primitiva* zone with the extinction of *Marginotruncana marianosoi* (Figs. 3 and 4).

Remarks: The LO of *Dicarinella concavata* is dated as Late Turonian (PREMOLI SILVA & VERGA, 2004; ARDESTANI et al., 2011), while other authors attributed it to the Late Coniacian (SIGAL, 1955; BELLIER, 1983; ROBASZYNSKI et al., 1984; CARON, 1985; RAMI et al., 1997; ROBASZYNSKI, 1998; ROBASZYNSKI & CARON, 1995; PREMOLI SILVA & SLITER, 1999; ÖZKAN-ALTINER & ÖZCAN, 1999; ROBASZYNSKI et al., 2000; SARI, 2009; FAROUK AND FARIS, 2012; Figs 3 & 4). The present *Dicarinella concavata* Zone is approximately equivalent to the upper part of the *Dicarinella concavata* Zone of GRADSTEIN et al. (2012) and HAQ (2014), and coincides with the Late Coniacian CC14 nannofossil Zone (FAROUK & FARIS, 2012).

4.1.3 *Dicarinella asymetrica* Zone

Definition: Total range zone of the nominated taxon.

Age: Santonian

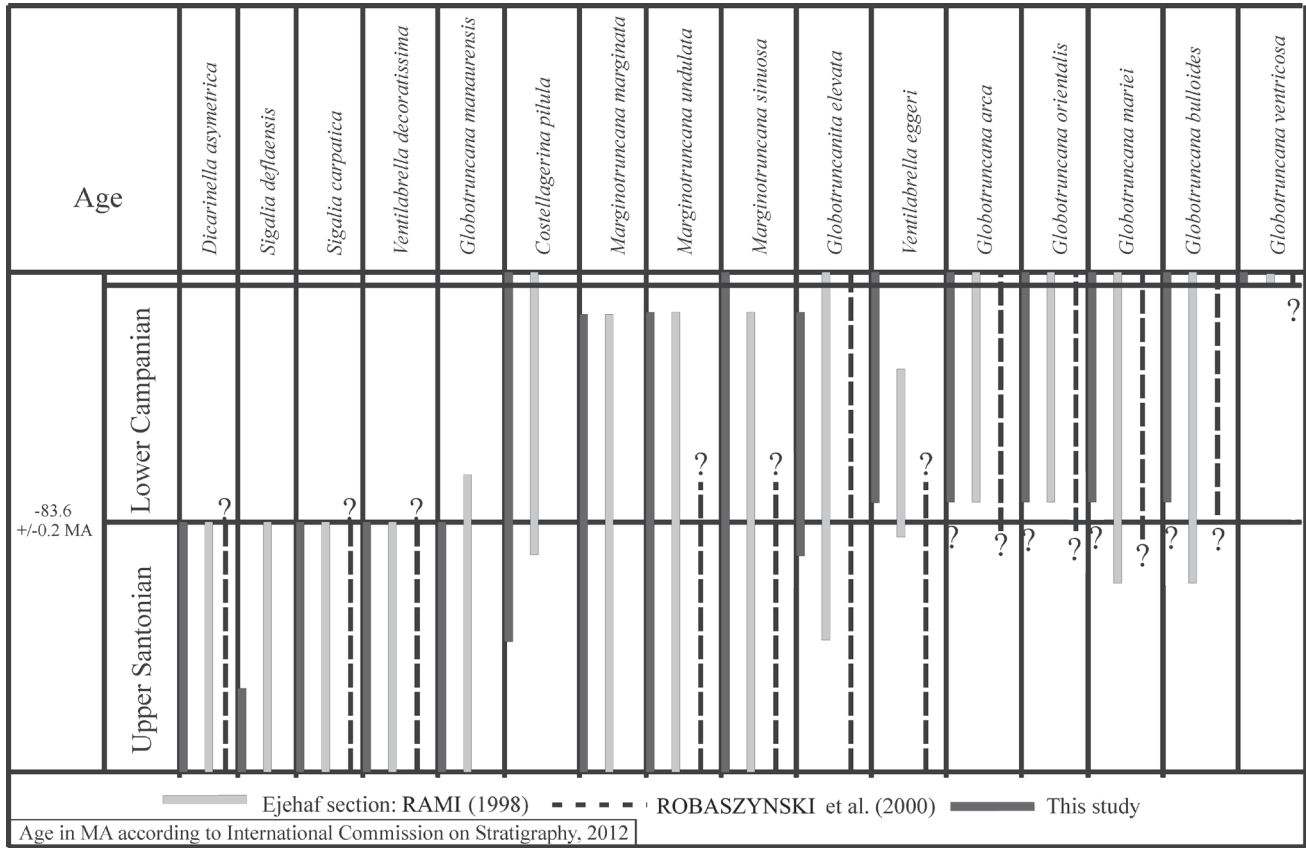


Figure 5: Comparison of different marker species distribution across the Santonian / Campanian boundary in Tunisia.

Author: POSTUMA (1971)

Assemblage: This biozone in both sections is characterized by the coexistence of predominant planktonic foraminiferal species belonging to the *Dicarinella* and *Marginotruncana*

cana genera. The marginotruncanids diminish in abundance and size toward the top of the *Dicarinella asymetrica* Zone. In this Zone, the LO of the genus *Sigalia* was observed in addition to *Ventilabrella decoratissima*, *Costellagerina pil-*

Age	Biozones Based upon trochospiral forms	Biozones Based upon heterohelicids	Major bioevents			
Campanian	<i>Globotruncana ventricosa</i>	<i>V. eggeri</i> / <i>P. manuelensis</i>	<i>G. ventricosa</i>	<i>G. arca</i>	<i>V. eggeri</i> / <i>P. manuelensis</i>	<i>Dicarinella</i>
	<i>Gt. elevata</i> / <i>G. arca</i>		<i>G. arca</i>			
Santonian	<i>Dicarinella asymetrica</i>	<i>Sigalia carpatica</i>	<i>G. elevata</i>	<i>D. asymetrica</i>	<i>S. carpatica</i>	<i>Whiteinella</i>
		<i>Pseudotextularia nuttalli</i>	<i>D. concavata</i>		<i>S. deflaensis</i>	
Coniacian	<i>Dicarinella concavata</i>	<i>Pseudotextularia nuttalli</i>	<i>D. concavata</i>	<i>D. primitiva</i>	<i>P. nuttalli</i>	<i>Marginostruncana</i>
	<i>Dicarinella primitiva</i>		<i>D. primitiva</i>			

Figure 6: Bioevents observed from the Coniacian to Campanian and proposed planktonic foraminiferal zones.

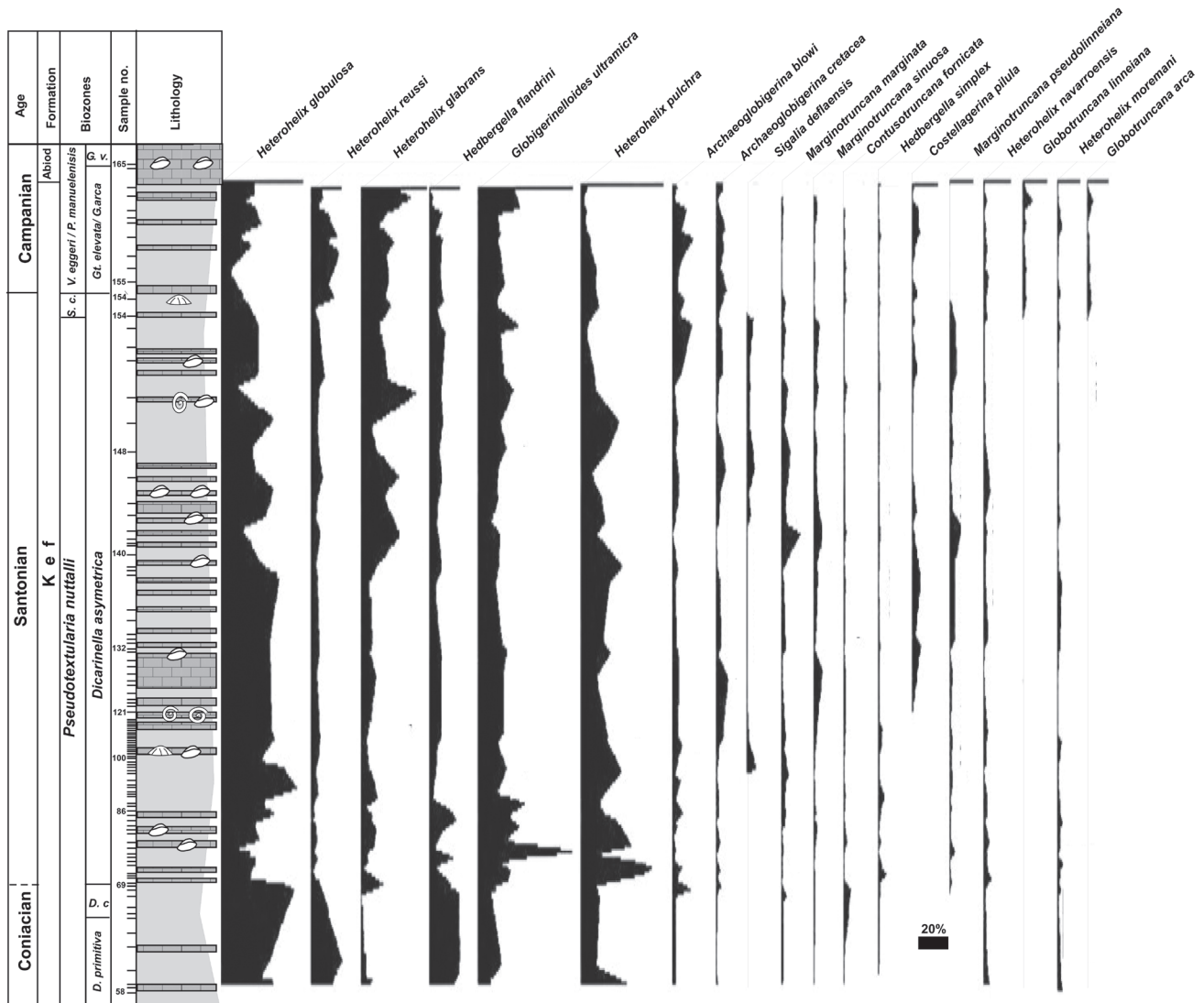


Figure 7: Relative abundance of the planktonic foraminiferal species correlates to the lithology and biozones at Jebel Ettout section; for symbol key see Fig. 2.

ula, *Contusotruncana patelliformis* and *Globotruncana manaurensensis*; for the complete assemblage see Figs. 3 and 4.

Remarks: The LO of *Dicarinella asymetrica* is more reliable for indicating the C/S boundary (e.g., MELINTE & LAMOLDA, 2002; GRADSTEIN et al., 2012). In Tunisian sections, according to ROBASYNSKI et al., (2000), the LO of *Dicarinella asymetrica* indicates the lowest Santonian and occurs within the calcareous nannofossil CC15 Zone and is placed slightly below the LO of *Platyceramus cycloides* (Figs 3 and 4). At the Ettout section, the LO of *Dicarinella asymetrica* is observed at ~7m below the LO of *Platyceramus cycloides*.

4.1.4. *Globotruncanita elevata*/*Globotruncana arca* Zone

Definition: Partial range zone from the HO of *D. asymetrica* to the LO of *Globotruncana ventricosa*.

Author: modified after DALBIEZ (1955).

Age: Early-Middle Campanian

Assemblage: Planktonic foraminiferal abundance is generally high and preservation is usually good. Common species include *Hedbergella flandrini*, *Globigerinelloides ultramicrus*, *Archaeoglobigerina blowi*, *A. cretacea*, *Contusotruncana fornicata* especially in the Ennahli section. Rare species include *Hedbergella simplex*, *Globotruncana linneiana*, *Costellagerina pilula*, *Marginotruncana sinusoa* and *M. undulata* are also recorded (Figs 6 & 7).

Remarks: The base of the Campanian is placed before the HO of *Dicarinella asymetrica* (considered to be a reliable bioevent to define the base of the Campanian), (PETRIZZO, 2000; WAGREICH et al. 2010). It is easily recognizable and widely distributed in different palaeolatitudes. In the Tunisian sections, the HO of *D. asymetrica* occurs at the Santonian/ Campanian boundary (e.g., RAMI, 1998; ROBASYNSKI et al. 2000; Fig. 5). At the Santonian-Campanian transition, many events are observed 1) the extinction of *Sigalia*, *Dicarinella* and *Whiteinella*; 2) the marginotruncanids suffered a gradual extinction; 3) an increase in the

relative abundance of flat biserial and multiserial Heterohelicids (*Ventilabrella* and *Planoglobulina*); 4) an increase in the relative abundance of *Globotruncana* and *Globotruncanita* genera (Figs. 7 & 8). The LO of *Globotruncanita elevata* and *G. arca* occurs slightly before the HO of *D. asymetrica* marker of the base of the Campanian stage (ROBAZSYNSKI et al., 2000; Figs 5 and 6). According to WAGREICH et al. (2010), the base of the Campanian is placed after the FO of *Globotruncanita elevata* as recorded in Tunisian sections. The upper part of the *Globotruncanita elevata* Zone is defined by the LO of *Globotruncana ventricosa*. Actually, this event is problematic as it shows considerable variation in the stratigraphic ranges between different latitudes (PETRIZZO, 2000; FAROUK & FARIS, 2012). On the north-western Australian margin, *Globotruncana ventricosa* ranges down into at least the Santonian *Dicarinella asymetrica* Zone, and cannot be used to mark the upper boundary of the *G. elevata* Zone. The LO of *G. ventricosa* occurs in the middle Campanian in Tethyan zonations and also in the present study (e.g., CARON, 1985; ROBASYNSKI & CARON, 1995; ROBASYNSKI et al., 2000; MANCINI & PUCKETT, 2005; FAROUK & FARIS, 2012).

4.2. Heterohelcid biozones

4.2.1. *Pseudotextularia nuttalli* Zone

Definition: Interval from the LO of *Pseudotextularia nuttalli* to the LO of *Sigalia carpatica*.

Age: Coniacian – Early Santonian.

Author: NEDERBRAGT (1990)

Assemblage: This interval is marked by a high diversity and abundance of heterohelcid foraminifera with good preservation (e.g., *Heterohelix reussi*, *H. globulosa*, *H. glabrans*, *H. sphenoides*, *H. moremani*, *H. pulchra* and *H. navarroensis*).

Remarks: The LO of *Pseudotextularia nuttalli* is placed within the lowermost Coniacian by a sporadic occurrence (e.g., NEDERBRAGT, 1990; RAMI, 1998; LAMOLDA et al., 2007). According to NEDERBRAGT (1990), the *Pseudotextularia nuttalli* Zone is attributed to the chronostratigraphic interval from the Coniacian to the Santonian. In the present study, it is attributed to the Coniacian – Early Santonian (Fig. 6).

4.2.2. *Sigalia carpatica* Zone

Definition: Interval from the LO of *Sigalia carpatica* to the LO of *Ventilabrella eggeri*.

Age: Late Santonian

Author: SALAJ & SAMUEL (1966)

Assemblage: This interval is marked by an abundance of Heterohelicids with good preservation (e.g. *Heterohelix reussi*, *H. globulosa*, *H. glabrans*, *H. sphenoides*, *H. moremani*, *H. pulchra*, *H. navarroensis*, *Sigalia deflaensis*, and *Ventilabrella decoratissima*). Rare large biserial and flat multiserial heterohelcid morphogroup including *Pseudotextularia*, *Planoglobulina*, *Sigalia* and *Ventilabrella* are observed in the middle and upper parts of the Santonian deposits. They do not exceed 10% at the Ettout section, increase to around 16% of the total assemblages at the Ennahli section.

Remarks: In the Tunisian sections, there is an absence of flat heterohelcid species, with limbate sutures such as *Sigalia deflaensis*, *S. carpatica*. Large multiserial heterohelicids *Ventilabrella decoratissima* are observed near the base of the Santonian which is also different (e.g., NEDERBRAGT, 1991; RAMI et al., 1997; ELAMRI & ZAGHBIB-TURKI, 2005 and the present study). ROBASYNSKI & CARON (1995) mentioned that *Sigalia carpatica* appears before the LO of *Sigalia deflaensis*. In the present study, the

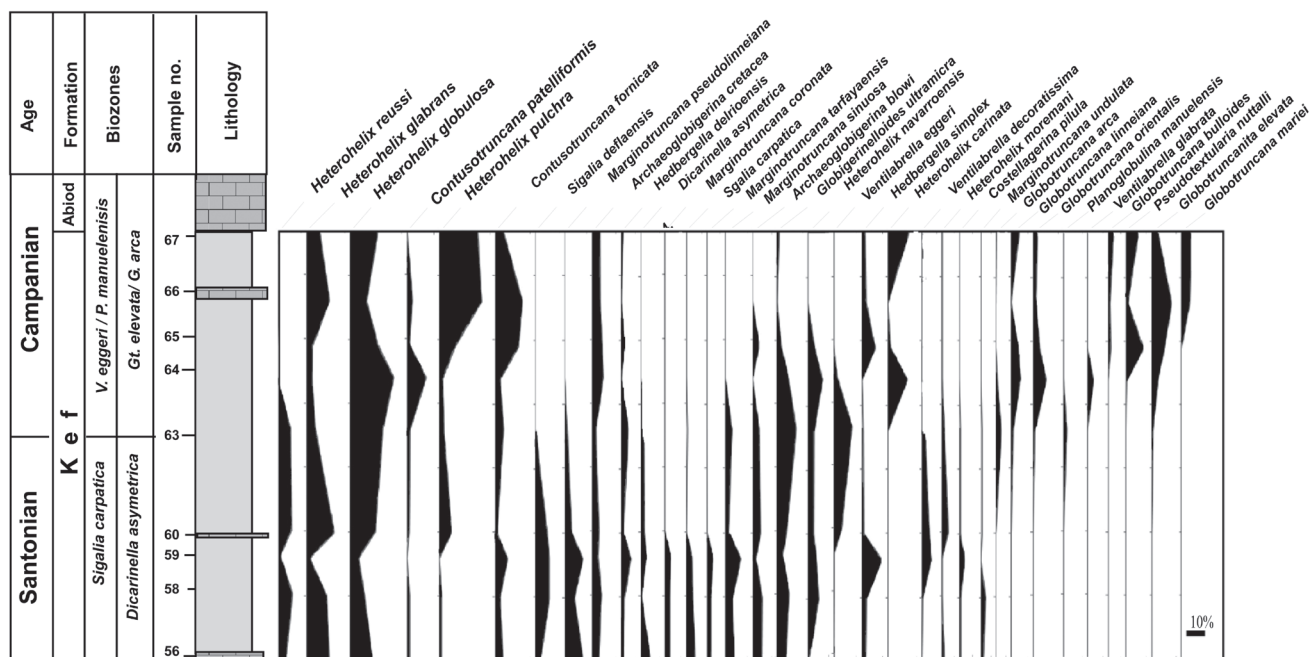


Figure 8: Relative abundance of the planktonic foraminiferal across the Santonian - Campanian boundary correlates to the lithology and biozones at the Ennahli section.

LO of *Sigalia deflaensis* appears earlier than *Sigalia carpat-ica* at the Ettout section while at the Jebel Ennahli section it appears together with *Sigalia carpat-ica* and *Ventilabrella decoratissima*. The LO of flat heterohelicids with limbate sutures such as *Sigalia carpat-ica* and *Ventilabrella decoratissima* is recorded above the LO of *Dicarinella asymetrica*. The LO of *Sigalia carpat-ica* is used as a second marker for the Coniacian/Santonian boundary in the proposed GSSP at the Olazagutia section (LAMOLDA, 2013). This event is problematic as it shows considerable variation in age due to its rarity and sporadic presence in Tunisian sections (RAMI et al., 1997), although it is easily recognized by its flat heterohelicids with limbate sutures. Many authors suggested the LO of *Dicarinella asymetrica* and *Sigalia carpat-ica* co-occur together (Salaj, 1980; ROBASZYNSKI AND CARON, 1995). Other authors noticed that the LO of *Sigalia carpat-ica* does not occur simultaneously with the LO of *Dicarinella asymetrica* (e.g., NEDERBRAGT, 1991; RAMI et al., 1997; Robaszynski et al., 2000; EL AMRI & ZAGHBIB-TURKI, 2005). In the present study, the LO of this taxon occurs higher in the Upper Santonian succession and does not coincide with the LO of *Dicarinella asymetrica* (Fig. 6). At the Jebel Ennahli section, the LO of *Sigalia deflaensis* occurs simultaneously with the LO of *Sigalia carpat-ica* and *Ventilabrella decoratissima*, while in the Ettout section, the LO of *Sigalia carpat-ica* appears higher, after the LO of *Sigalia deflaensis*.

4.2.3. *Ventilabrella eggeri/Planoglobulina manuelensis* Concurrent Range Zone

Definition: Interval from the HO of *Sigalia carpat-ica* to the LO of *Gublerina acuta*

Age: early Campanian

Author: modified after Nederbragt (1991)

Assemblage: *Ventilabrella aplina*, *V. eggeri*, *V. glabrata*, *Planoglobulina manuelensis*, and *Heterohelix carinata* are common in this zone, for the complete assemblage see Figs. 3 & 4.

Remarks: The LO of *Ventilabrella eggeri* was used as a good marker for the Santonian and Campanian boundary

(NEDERBRAGT, 1991; ROBASZYNSKI & CARON, 1995). It is associated with the HO of *Sigalia* spp. and *Dicarinella* spp, which marks the base of the Campanian. The LO of *Planoglobulina manuelensis* appears together with *Ventilabrella eggeri* simultaneously at the base of the *Globotruncanita elevata* Zone (Figs. 3 and 4). However, Arz (1996) adopts the LO of *Ventilabrella eggeri* to mark the terminal Santonian as recorded at the Jebel Ettout section, while at the Ennahli section, it is recorded near the base of the Campanian (Figs. 3 & 4). NEDERBRAGT (1991) gave a Late Santonian – Early Campanian age for the *V. eggeri* Zone. In the present study, this zone is approximately equivalent to the lower part of the *Globotruncanita elevata / Globotruncana arca* Zone. In both studied sections, only the lower part of the *Ventilabrella eggeri/Planoglobulina manuelensis* Zone was investigated.

5. PLANKTONIC FORAMINIFERAL RELATIVE ABUNDANCES

The distribution of planktonic foraminifers depends on sea surface water temperature and density. Diverse geometric tests were used to separate and distinguish the specimens found in particular depth ranges within the water column (ARDESTANI et al., 2013). Three groups of planktonic foraminifera were identified on the basis of different depth zones (PETRIZZO, 2002; ARDESTANI et al., 2013): shallow surface water forms (SWF), intermediate water foraminifera (IWF) and deep water forms (DWF) as follows:

Surface water foraminifera (SWF): This group is represented by simple morphotypes (*Heterohelix globulosa*, *H. moremani*, and *H. reussi*) or the non-keeled trochospiral morphotype group (*Whiteinella paradubia* and *W. brittonensis*).

Intermediate water foraminifera (IWF): This group is represented by *Preaglobotruncana gibba*, *Heterohelix pulchra*, *H. glabrans*, *H. carinata*, *Hedbergella delrieonsis*, *Hd. simplex*, *Globigerinelloides ultramicrus*, *Archaeoglobigerina blowi* and *Ar. cretacea*.

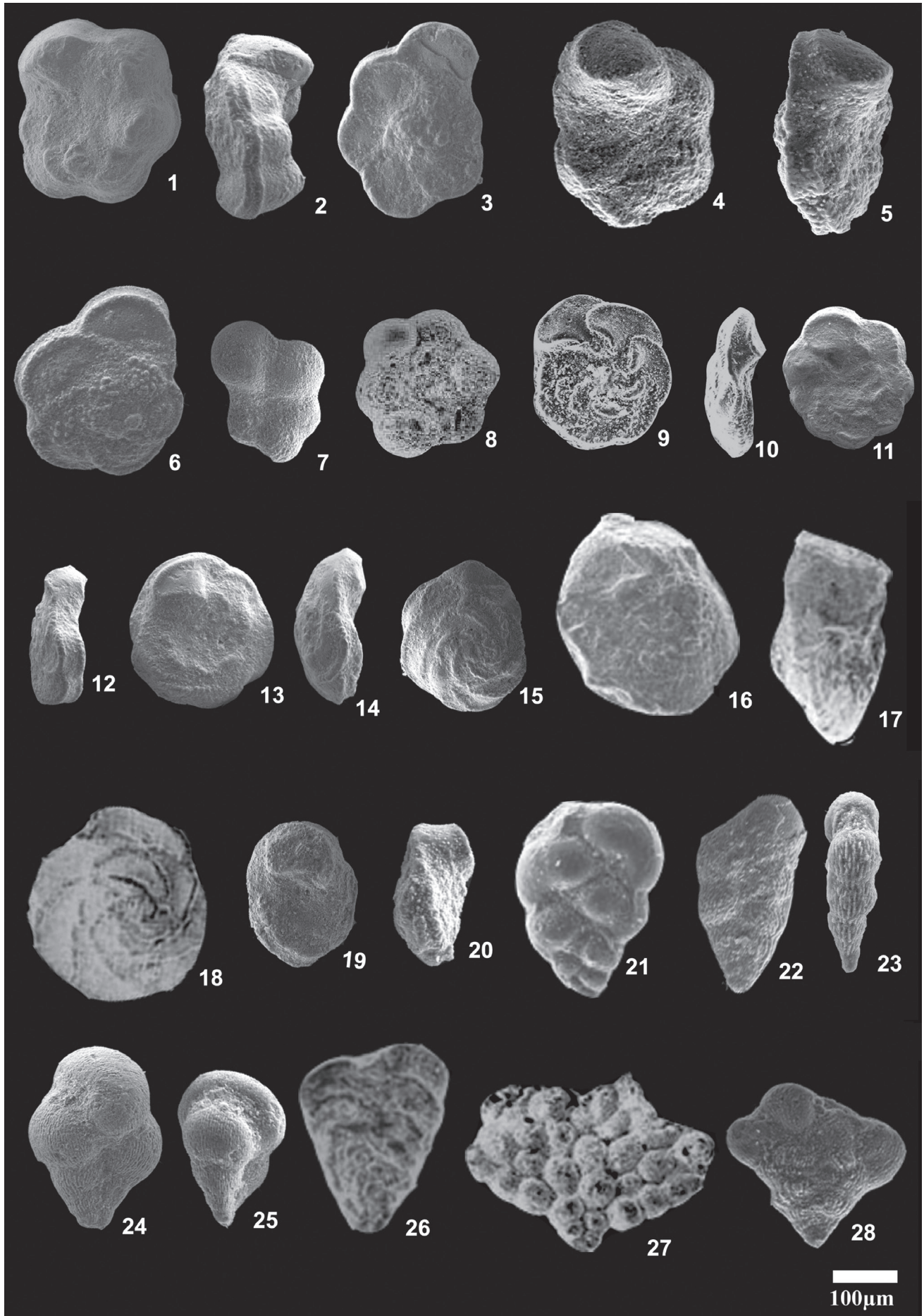
Deep water foraminifera (DWF): This group consists of ornamented and trochospiral forms of planktonic foraminifera.

Plate:

- 1-3 *Dicarinella asymetrica*; sample ET82.
- 4-6 *Dicarinella concavata*; sample ET69.
- 7 *Hedbergella simplex*; sample EN64.
- 8 *Whiteinella paradubia*; sample ET160.
- 9-10 *Marginotruncana tarfayaensis*; sample EN59.
- 11-12 *Marginotruncana pseudolinneiana*; sample EN64.
- 13-15 *Marginotruncana sinuosa*, sample EN64.
- 16-18 *Globotruncanita elevata*; sample ET160.
- 19-20 *Contusotruncana fornicata*; sample ET81.
- 21 *Heterohelix pulchra*; sample EN66.
- 22-23 *Heterohelix striata*; sample EN65.
- 24-25 *Pseudotextularia nuttalli*; sample EN56.
- 26 *Sigalia carpat-ica*; sample ET154.
- 27 *Planoglobulina manuelensis*; sample EN66.
- 28 *Ventilabrella eggeri*; sample EN66.

(EN=Ennahli section; ET= Jebel Ettout section)

Scale bar: 100µm



minifera including *Pseudotextularia nuttalli*, *Marginotruncana renzi*, *M. schneegansi*, *M. undulata*, *M. paraconcovata*, *M. coronata*, *M. tarfayaensis*, *M. sinuosa*, *M. marginata*, *M. pseudolinneiana*, *Contusotruncana fornicata*, *C. patelliformis*, *Globotruncanita elevata*, *Gt. insignis*, *Globotruncana arca*, *G. orientalis*, *G. mariei*, *G. bulloides*, *Sigalia carpatica*, *Ventilabrella decoratissima*, *V. eggeri*, *V. glabrata*, *V. alpina*, *Planoglobulina manuelensis*, *Dicarinella concovata*, *D. primitiva* and *D. asymetrica*.

The planktonic foraminiferal assemblages are dominated by the small heterohelid representatives mainly *H. globulosa* during the Coniacian of the *Dicarinella primitiva* Zone (Fig. 7). Other species of the Heterohelicidae group are less abundant and represented by *Heterohelix navarroensis* and *H. moremani*. Thus, at the Ettout section, the relative abundance of this species reaches 60 % of the total assemblage (Fig. 7). The *Heterohelix* spp. are associated with other cosmopolitan species belonging to *Hedbergella*, *Globigerinelloides* and *Archaeoglobigerina* genera that were considered as subsurface water dwellers. Their relative abundance does not exceed 30%.

At the Coniacian / Santonian boundary, a decrease in the abundance of the simple morphotype *Heterohelix globulosa* from 60 % to 20 % is followed by an increase in the abundance of keeled trochospiral morphogroup belonging to the genus *Marginotruncana*. The latter is considered as the most abundant and the most diversified group (Fig. 7). This turnover is related to an increase in water depth during the Santonian. The relative abundance of the total planktonic foraminifera in the two studied sections reaches 20 % of the total assemblage (>100 µm size fraction). The dominance of the Santonian assemblages by heterohelicids and unkeeled morphotypes such as representatives of *Globigerinelloides*, *Hedbergella* and *Archaeoglobigerina* and the presence of keeled trochospiral morphotypes belonging to *Dicarinella*, *Marginotruncana*, *Globotruncanita* and *Globotruncana* genera, does not exceed 20 % of the planktonic foraminiferal assemblage.

A major turnover in planktonic foraminifera occurred across the Santonian/Campanian (S/C) boundary associated with 1) the sharp extinction of *Dicarinella* and *Sigalia*; 2) the gradual extinction of *Marginotruncana*; and 3) an increase in the relative abundance of *Globotruncanita* and *Globotruncana* genera. This turnover could be related to an improvement in their ability for better adaptation to a deeper habitat of the photic water column (Figs. 7 & 8).

6. CONCLUSION

– Fifty-five planktonic foraminiferal taxa belonging to 17 heterohelid and 38 trochospiral forms are identified with moderate to good preservation and relatively high diversity.

– These microfossil assemblages allowed subdivision of the studied sections based on two different zonation schemes (Heterohelicidae and Globotruncanidae) to produce a higher resolution biostratigraphy and better correlation between deep and shallower basins.

– The base of the Santonian is marked by the LO of *Dicarinella asymetrica* associated with a decrease of the simple morphotypes and increase of keeled trochospiral morphogroup indicating a deepening phase.

– A major turnover in planktonic foraminifera occurred at the Santonian-Campanian transition. It is marked by the extinction of all *Dicarinella*, *Whiteinella*, *Sigalia* and *Marginotruncana* (except *Marginotruncana marginata* and *M. sinuosa*). After the extinctions, extremely well-preserved and diverse assemblages of *Globotruncanita*, *Globotruncana* and large heterohelicids such as *Ventilabrella* and *Planoglobulina* reflect a characteristic Campanian planktonic foraminiferal assemblage.

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18. *Globotruncana ventricosa* WHITE, 1928
19. *Globotruncanita elevata* (BROTZEN, 1934)
20. *Globotruncanita insignis* (GANDOLFI, 1955)
21. *Globotruncanita stuartiformis* (DALBIEZ, 1955)
22. *Globigerinelloides ultramicra* (SUBBOTINA, 1949)
23. *Hedbergella delrioensis* (CARSEY, 1926)
24. *Hedbergella flandrini* PORTHAULT, 1970
25. *Hedbergella simplex* (MORROW, 1934)
26. *Heterohelix glabrans* (CUSHMAN, 1938)
27. *Heterohelix globulosa* (EHERENBEG, 1840)
28. *Heterohelix moremani* (CUSHMAN, 1938)
29. *Heterohelix navarroensis* LOEBLICH, 1951
30. *Heterohelix pulchra* (BROTZEN, 1936)
31. *Heterohelix reussi* (CUSHMAN, 1938)
32. *Heterohelix sphenoides* MASTERS, 1976
33. *Heterohelix carinata* (CUSHMAN, 1938)
34. *Marginotruncana coronata* (BOLLI, 1945)
35. *Marginotruncana marginata* (REUSS, 1845)
36. *Marginotruncana marianosi* (DOUGLAS, 1969)
37. *Marginotruncana paraconcovata* PORTHAULT, 1970
38. *Marginotruncana pseudolinneiana* PESSAGNO, 1967
39. *Marginotruncana schneegansi* (SIGAL, 1952)
40. *Marginotruncana sigali* (REICHEL, 1949)
41. *Marginotruncana sinuosa* PORTHAULT, 1970
42. *Marginotruncana tarfayaensis* (LEHMANN, 1962)
43. *Marginotruncana undulata* (LEHMANN, 1963)
44. *Praeglobotruncana gibba* KLAUS, 1960
45. *Planoglobulina manuelensis* (MARTIN, 1972)
46. *Pseudoplanoglobulina austinana* LOEBLICH & TAPPAN, 1987
47. *Pseudotextularia nuttalli* (VOORWIJK, 1937)
48. *Sigalia carpatica* SALAJ & SAMUEL, 1963
49. *Sigalia deflaensis* (SIGAL, 1952)
50. *Ventilabrella alpina* DE KLASZ, 1953
51. *Ventilabrella decoratissima* (DE KLASZ, 1953)
52. *Ventilabrella eggeri* CUSHMAN, 1928
53. *Ventilabrella glabrata* CUSHMAN, 1938
54. *Whiteinella brittonensis* (LOEBLICH & TAPPAN, 1961)
55. *Whiteinella paradubia* (SIGAL, 1952)

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APPENDIX

List of species identified in this work, arranged alphabetically by genus with author attributions and dates.

1. *Archaeoglobigerina blowi* PESSAGNO, 1967
2. *Archaeoglobigerina cretacea* D'ORBIGNY, 1840
3. *Contusotruncana fornicata* (PLUMMER, 1931).
4. *Contusotruncana patelliformis* (GANDOLFI, 1955)
5. *Costellagerina pilula* BELFORD, 1960
6. *Dicarinella asymetrica* (SIGAL, 1952)
7. *Dicarinella concavata* (BROTZEN, 1934)
8. *Dicarinella imbricata* (MORNOD, 1949)
9. *Dicarinella primitiva* (DALBIEZ, 1955)
10. *Globotruncana arca* (CUSHMAN, 1926)
11. *Globotruncana mariei* BANNER & BLOW, 1960
12. *Globotruncana bulloides* (VOGLER, 1941)
13. *Globotruncana caliciformis* DE LAPPARENT, 1918
14. *Globotruncana linneiana* (D'ORBIGNY, 1839)
15. *Globotruncana manauensis* GANDOLFI, 1955
16. *Globotruncana orientalis* EL NAGGAR, 1966
17. *Globotruncana rosetta* (CARSEY, 1926)