Planktonic foraminiferal biostratigraphy and paleoecology of Upper Cretaceous deposits from the Palmyride Region, Syria

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1. INTRODUCTION

The Palmyride area is part of the northern Arabian platform (Fig. 1). The Arabian platform was located on the northern passive margin of Gondwana bordering the Tethys Ocean for most of the Phanerozoic. The Palmyride fold belt was established at the site of an inverted Mesozoic rift basin and
developed as a linear trough genetically related to the Levantine margin rift system (BREW, 2001). Ongoing extension produced a 6 km thick and 200 km laterally extensive Palaeozoic and Mesozoic sedimentary succession (BREW, 2001). Tectonic evolution of the area has been strongly influenced by geological activity along the Arabian plate boundaries: the Dead Sea transform fault to the west, the Bitlis suture and East Anatolian fault to the north, and the Zagros suture to the east (Fig. 1).

This study focuses on the Upper Cretaceous (upper Turonian–Maastrichtian) succession from two deep exploration wells Al Mahr-1 and Palmyra-1, and was aimed at age determination and correlation (litho- and biostratigraphic) of strata based on their microfossil assemblages (mainly planktonic and some benthic foraminifera). Planktonic foraminifera have been abundant in most oceanic environments since their appearance in the Middle Jurassic and are the most commonly used microfossil group for biostratigraphic zonation and reconstruction of past sea surface-water conditions and palaeoclimate (HEMLEBEN et al., 1989; MURRAY, 1991).

Many studies have focused on biostratigraphic evolution of Cretaceous planktonic foraminifera (e.g., ROBASZYNSKI et al., 1984; 2000; CARON, 1985; SLITER, 1989; ROBASZYNSKI & CARON, 1995; PETRIZZO, 2003; PELLO MO SILVA & VERGA, 2004; SARI, 2006, 2009; BABAZADEH et al., 2007; HUBER et al., 2008; PETRIZZO et al., 2011; GARDIN et al., 2012). Previous biostratigraphic investigations of the Upper Cretaceous deposits in the Palmyride area were undertaken on material from deep exploration wells by LUČIĆ (2001), STANKOVIĆ et al. (2003; 2005), and DACER et al. (2007), but not in a great detail.

The main purpose of this paper is to establish planktonic foraminiferal zonation of the upper Turonian–Maastrichtian succession of the Palmyride area based on the microfossil assemblages and/or index taxa present in order to improve palaeoenvironmental interpretations of deposition in the Palmyride basin during the late Cretaceous. The biostratigraphic zonation is compared with the regional Tethyan zo-

Figure 1: Map showing major tectonic zones in Syria and the surrounding areas (modified from LITAK et al., 1998) and the study area in the Palmyride region. A circle represents the approximate location of the Hayan block with the Al Mahr-1 (1) and Palmyra-1 (2) exploration wells; distance between the wells is about 50 km.
nation. Documenting variations in planktonic foraminiferal assemblages and any associated lithological changes are critical for making palaeoclimatic and palaeoceanographic interpretations. Santonian to early Campanian sediments rich in phosphate grains are examined here as an important indicator of specific geological and palaeoenvironmental conditions. The data obtained are compared to those from other coeval regional successions in order to establish the significance of the Palmyride strata, as part of the Arabian platform, for better understanding of the sedimentary evolution of the broader Tethyan region and its response to global environmental changes.

2. GEOLOGICAL SETTING

Regionally the investigated area is also known as the Hayan exploration block (Fig. 1), which is located in the Palmyride area, an intracontinental transpressive mountain range (LUČIĆ, 2001). The Palmyrides represent the most distinct tectonic and structural unit in central Syria as a zone of subdued topography that extends from the Dead Sea Fault Zone to the west, and disappears to the east at the Euphrates Graben or depression (Fig. 1). The Palmyrides are 400 km long and 100 km wide, stretching southwest–northeast across Syria with a maximum altitude of around 1300 m (LUČIĆ & FORŠEK, 2000; BREW, 2001; BREW et al., 2001; HERNITZ KUČENJAK et al., 2006; WOOD, 2011).

In the Palmyride area, Mesozoic deposits of Early Triassic to Late Cretaceous age were observed in all deep wells (LUČIĆ et al., 2002). Unlike the Upper Triassic and Jurassic deposits (maximum 700 m thick), which can either exhibit substantially reduced thickness (to 200 m minimum) or be absent in some places due to erosion or non-deposition, the Cretaceous strata are present throughout the region (approx. 800 m thick). The oldest deposits exposed on the surface are Upper Triassic evaporites interbedded with shales. Jurassic deposits are represented by different varieties of carbonate rocks, and Lower Cretaceous deposits consist of dolomites and limestones with rare interbeds of anhydrite and shale. In the Late Cretaceous there was a deepening of the depositional system, which resulted in the deposition of shales and marly limestones with a gradual increase in the amount of marl up-section (PONIKAROV, 1966a, b; LUČIĆ et al., 2002).

For the purpose of the Syrian Petroleum Company (SPC), the investigated Upper Cretaceous succession is subdivided into three lithostratigraphic units (Figs. 2, 3): 1) the upper part of the Judeau Formation (upper Turonian–lowermost Santonian); 2) the Soukhne Formation (Santonian–lower Campanian); and 3) the Shiranish Formation (upper Campanian–Maastrichtian); (MOUY & AL-MALEH, 1983). The Judeau Formation is represented by limestones and dolomitic limestones with thin intercalations of yellow to brownish yellow marl. The Soukhne Formation is characterized by calcareous horizons in the lower part, and by clayey limestones, marls and phosphatic deposits in the upper part. Argillaceous limestones, marls, chert and ovoid calcareous concretions (10–30 cm in diameter) are present in the Shiranish Formation.

3. MATERIAL AND METHODS

The foraminiferal study is based on analyses of 81 samples of Upper Cretaceous deposits obtained as drill cuttings from two deep exploration wells (Al Mahr-1 and Palmyra-1) drilled in the Hayan exploration block in the Palmyride area. Samples of drill cuttings from mud samples were collected every 5–10 metres. Most of the analyzed samples contain very well preserved planktonic and benthic foraminifera.

Samples for micropaleontological analyses were disaggregated in tap water and diluted with hydrogen peroxide, then washed through 63 μm, 125 μm, and 160 μm sieves, dried and examined on an Olympus SZX16 stereomicroscope. Representative aliquots of approximately 300 planktonic foraminiferal specimens were counted for quantitative planktonic foraminiferal analyses. The term “dominant” was used for species that constitute more than 10% of the planktonic foraminiferal assemblage, whereas the terms “common”, “few” and “rare” refer to species comprising 3–10%, 1–3%, and <1% of the assemblage, respectively. Plankton/benthic ratios were determined for each biozone on at least 300 specimens from the entire foraminiferal assemblages in >63 μm grain fraction and were used for palaeoecologic and palaeoenvironmental interpretations.

Micropaleontological thin-sections were made of 35 samples throughout the Upper Cretaceous interval for the purpose of lithological interpretation. Prepared petrographic thin-sections were stained with Alizarin red – S after the method of EVAMY & SHEARMAN (1962) in order to distinguish carbonate minerals. A detailed study of foraminiferal morphology was performed on a scanning electron microscope (SEM). The overall preservation of foraminifera is good although their original calcite shells have been recrystallized.

The micropaleontological investigation was focused on the vertical distribution, diversity and composition of mainly planktonic and less abundant benthic foraminiferal assemblages (Figs. 2–3) according to GAWOR-BIEDOWA (1984), LOEBLICH & TAPPAN (1988), ISMAIL (1992), BOLL et al. (1994), LY & KUHNT (1994), KAIHO (1998), PREMOLI SILVA & VERGA (2004), ISMAIL et al. (2007), HAMPTON et al. (2007), and GASINSKI & UCHMAN (2009). The presence of rich and diverse foraminiferal associations enabled biostratigraphic zonation of the Upper Turonian to Maastrichtian deposits based on documented index-taxa and/or the entire microfossil assemblages. Standard planktonic foraminiferal zonation after ROBASZYNSKI et al. (1984), CARON (1985), ROBASZYNSKI & CARON (1995), PREMOLI SILVA & SLITER (1994), ROBASZYNSKI et al. (2000), PREMOLI SILVA & VERGA (2004), SARI (2006, 2009), HUBER et al. (2008), OGG et al. (2008), PETRIZZI et al. (2011) and PÉREZ-RODRÍGUEZ et al. (2012) have been used. A zonal sheme which emphasizes the lowest (LO) and the highest occurrences (HO) of index taxa and/or selected species in microfossil associations has been applied.

Phosphatic grains of the Soukhne Formation deposits were also analyzed using SEM back-scattered electron imaging (BSE) and energy dispersive X-ray analysis (EDX). The semi-quantitative X-ray elemental mapping of P, F, Cl
Figure 2: Stratigraphic column of the Al Mahr-1 exploration well showing stratigraphic distribution of planktonic foraminifera (Formation names after SPC – Syrian Petroleum Company).

Biozones

I (Late Turonian–Early Santonian)
II (Middle–Late Santonian)
III (Early Campanian)
IV Globotruncana plummerae Zone (Early–Middle Campanian)
V (Late Campanian)
VI Globotruncanella havanensis Zone (Late Campanian)
VII Pseudoguembellina palpebra Zone (Late Campanian)
VIII Racemiguembelina fructicosa Zone (Late Campanian–Early Maastrichtian)
IX Abathomphalus mayaroensis Zone (Late Maastrichtian)
Figure 3: Stratigraphic column of the Palmyra-1 exploration well showing stratigraphic distribution of planktonic foraminifera (Formation names after SPC – Syrian Petroleum Company).

**Biozones**

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VII Pseudoguembelina palpebra Zone (Late Campanian)

VIII Racemiguembelina fructicosa Zone (Late Campanian–Early Maastrichtian)

IX Abathomphalus mayaroensis Zone (Late Maastrichtian)

**Species**

- Conotruncana formicata
- Muriobolbergerella holmdelensis
- Whiteiella barcia
- Whiteiella sp.
- Heterohelix moremani
- Dicarinella sp.
- Archaeoglobigerina cretacea
- Globigerinoides bulloides
- Heterohelix globoturbata
- Heterohelix spinata
- Marginotruncana sp.
- Muriobolbergerella flabelliformis
- Pseudotextularia nuttalli
- Globotruncana linneana
- Heterostegina carinata
- Heterohelix punctulata
- Heterohelix obtusa
- Globigerinoides praehelecris
- Globotruncanina acuta
- Globotruncanina bulloides
- Globotruncanina hiltoni
- Heterohelix plana
- Globigerinoides subcarnarius
- Muriobolbergerella sp.
- Globotruncanina stuartiformis
- Pseudoguembelina coquilhati
- Rugoglobigerina rugosa
- Conotruncana pummeae
- Heterohelix navarreiensis
- Leburoheterohelix gibba
- Muriobolbergerella moumoutheimensis
- Globotruncanella navarreiensis
- Globotruncanina stuarti
- Heterohelix labiosus
- Leburoheterohelix oculata
- Planoglobulina carinacea
- Pseudoguembelina exoletula
- Rugoglobigerina hexasclera
- Globotruncanella pochadnae
- Pseudoguembelina kempeniensis
- Pseudoguembelina paliopora
- Rhipocheilocalinella powelli
- Gansserina gansseri
- Abathomphalus intermedius
- Globotruncana minutula
- Globotruncanina peltieri
- Globotruncanina conica
- Planoglobulina australoides
- Pseudotextularia intermedia
- Pseudotextularia elegans
- Racemiguanella fructicosa
- Abathomphalus macrayensis
- Pseudoguembelina hanaensis

**Stratigraphic Column**

| Biozones | JUEEA | SOURINE | SHIRANISH | LATE TURONIAN - MAASTRICHTIAN |
|----------|-------|---------|-----------|-------------------------------|
| I        |       |         |           |                               |
| II       |       |         |           |                               |
| III      |       |         |           |                               |
| IV       |       |         |           |                               |
| V        |       |         |           |                               |
| VI       |       |         |           |                               |
| VII      |       |         |           |                               |
| VIII     |       |         |           |                               |
| IX       |       |         |           |                               |

**Formation (after SPC)**

| Age     | I | II | III | IV | V | VI | VII | VIII | IX |
|---------|---|----|-----|----|---|----|-----|------|----|
| Cret.   |   |    |     |    |   |    |     |      |    |

| Depth (m) | Samples |
|-----------|---------|
| 0-10      |         |
| 10-20     |         |
| 20-30     |         |
| 30-40     |         |
| 40-50     |         |

**Notes**

- SPC: Syrian Petroleum Company.
Figure 4: Correlation between the two exploration wells (Al Mahr-1, Palmyra-1) showing planktonic biozones and lithology.
and Ca was performed using a FEI Quanta 450 SEM with EDAX TEAM EDS at Smith College (Northampton, Massachusetts, USA).

4. BIOSTRATIGRAPHY

Biostratigraphic subdivision of the investigated Upper Cretaceous successions is based on planktonic foraminifera. Stratigraphic ranges of the identified microfossil assemblages indicate a late Turonian to Maastrichtian age. Stratigraphic relationships between the identified planktonic foraminiferal species are shown in Figs. 2 and 3, whereas the lithostratigraphic and biostratigraphic biozonation correlation between Al Mahr-1 and Palmyra-1 are presented in Fig. 4.

The upper Turonian to lowermost Santonian deposits contain planktonic and benthic foraminiferal assemblages characteristic of this stratigraphic range. These poorly diversified microfossil assemblages have equal proportions of small benthic and planktonic foraminifera. The Santonian to lower Campanian strata, on the other hand, are characterized by a moderately diversified microfossil assemblage with increased abundance and diversity of planktonic foraminifera, and the absence of nominal taxon/zonal markers. High diversity microfossil assemblages with a dominance of planktonic foraminifera and well-preserved index taxa are present in the upper Campanian to upper Maastrichtian deposits.

Previous studies of late Cretaceous planktonic foraminifera from the Palmyrides only generally indicated the age of the deposits (STANKOVIĆ et al., 2003, 2005; DACER et al., 2007). Biostratigraphy of the upper Turonian to Maastrichtian successions from the Al Mahr-1 and Palmyra-1 wells is correlated with the existing and well-established planktonic foraminiferal zonation for the Tethyan realm (ROBAZYNSKI & CARON, 1995; ROBAZYNSKI et al., 2000; PREMOLI SILVA & VERGA, 2004), Fig. 5. Since the zonal markers are very rare or absent, alternative planktonic foraminiferal assemblages as well as the whole planktonic foraminiferal association enable application of standard biozonation (ROBAZYNSKI et al., 1984; CARON, 1985; SLITER, 1989; PREMOLI SILVA & SLITER, 1994; ROBAZYNSKI & CARON, 1995; ROBAZYNSKI et al., 2000; PREMOLI SILVA & VERGA, 2004; CHACON et al., 2004; HUBER et al., 2008; SARI, 2009; PETRIZZO et al., 2011; PEREZ-RODRIGUEZ et al., 2012).

Nine biozones have been identified in the upper Turonian to Maastrichtian succession: Biozone I, Biozone II, Biozone III, IV Contusotruncana plummerae Zone, Biozone V, VI Globotruncanella havanensis Zone, VII Pseudogrammelina palpebra Zone, VIII Rasteemiguembelina fructicosa Zone, and IX Abathomphalus mayorensis Zone. A list of taxa together with author names and year of publication are provided in the Appendix. All of the diagnostic species and some additional taxa typical of the studied foraminiferal assemblages are illustrated in Figs. 6–9.

Biozone I (Figs. 6A–D)

*Age.* Late Turonian–Early Santonian

*Interval.* Al Mahr-1 (185–210 m, Figs. 2 and 4), Palmyra-1 (180–200 m, Figs. 3, 4)

Assemblage characteristics. As index taxa were not observed, the lowest occurrence (LO) of *Contusotruncanifor nicata* and *Globigerinelloides bollii* has been used to define the lower boundary of this Zone. This biozone may correspond to the *Dicarinella concavata* Zone (PREMOLI SILVA & SLITER, 1994; ROBAZYNSKI & CARON, 1995; ROBAZYNSKI et al., 2000; PREMOLI SILVA & VERGA, 2004; SARI, 2006, 2009).

The foraminiferal assemblage of this interval is composed of rare non-keeled planktonic foraminifera with a wide stratigraphic range: *Archaeoglobigerina blowi, A. cretacea* (Figs. 6C, D), *Whiteinella balthica, Whiteinella sp.*, *Dicarinella sp.* (Fig. 6A) and *Marginotruncanella sp.* (Fig. 6B). In the middle of the biozone *Muricochedbergella holmdelensis* and *Pseudotextularia nuttalli* have their lowest occurrence. The most abundant species in the assemblage are *Heterohelix reussii, H. moremani*, and *H. globulosa*, comprising 38% of the total planktonic association. Biozone I is also characterized by very common *Pseudotextularia nuttalli, Murico hedbergella holmdelensis, Murico hedbergella flandrinii*, marginotruncanids and whiteinellids. In addition, the following small calcareous benthic foraminifera are present and account for up to 50% of the total foraminiferal association: *Bulimina ovulum, Gyroidinoids globosus, Bulimina sp.*, *Gavellinela sp.* (Figs. 9A, B), *Lenticulina sp.*, and *Nodosaria sp.*

Lithology and palaeoenvironment. Brownish grey to grey limestone (mudstone/wackestone to foraminiferal wackestone), dolomitic limestone and marl with equal proportions of planktonic and calcareous benthic foraminifera indicate accumulation within outer shelf environments.

Biozone II (Figs. 6E–I)

*Age.* Middle–Late Santonian

*Interval.* Al Mahr-1 (150–185 m, Figs. 2 and 4), Palmyra-1 (140–180 m, Figs. 3, 4)

Assemblage characteristics. Because of the absence of a zonal marker, the lower boundary of this Zone is defined approximately by the LO of *Globotruncanina lineinea*, whereas the upper boundary coincides with the disappearance of all dicarinellids and whiteinellids. This biozone may correspond to the *Dicarinella asymetrica* Zone (PREMOLI SILVA & SLITER, 1994; ROBAZYNSKI & CARON, 1995; ROBAZYNSKI et al., 2000; PREMOLI SILVA & VERGA, 2004; SARI, 2006, 29).

The first half of Biozone II is characterized by the LO of several new taxa such as *Globotruncanina bulloides, G. hilli, G. arca, Hendersonites carinatus, Heterohelix striata, H. punctulata, H. planata, Globigerinelloides prairiehillensis* and *G. subcarinatus*. Dominant species in this Zone are *Heterohelix globulosa* and *H. reussi* (Fig. 6I), while *Pseudotextularia nuttalli* and *Heterohelix punctulata* are very common. The following planktonic foraminifera continue from the underlying zone: *Archaeoglobigerina blowi* (Figs. 6E, F), *A. cretacea, Contusotruncanifor nicata* (Figs. 6G, H), *Globigerinelloides bollii, Muricochedbergella holmdelensis* and *Marginotruncanella sp.* *Globotruncanina arca, G. bulloides*, and *G. lineinea* range throughout Biozone II but are
Figure 5: Proposed biozonation for the Upper Cretaceous succession and stratigraphic range of selected species of the Palmyride region compared with the zonal schemes for Tethys (ROBASZYNISKI and CARON, 1995; PREMOLI SILVA & VERGA, 2004). Timescale was adapted from OGG et al. (2008), and sea-level curve is from HAQ et al. (1987). Grey area indicates the presence of phosphate grains.

| AGE (Ma) | SEA-LEVEL CHANGE | THIS STUDY | BIOZONES | FORAMINIFERAL EVENTS |
|----------|------------------|------------|----------|---------------------|
| 65-90    |                  |            | IX       | Abathomphalus mayaroensis |
| 90-95    |                  |            | VIII R. fructicosa |
| 95-100   |                  |            | VII      | Pseudouguembelina palpebra |
| 100-110  |                  |            | VI       | G. havanaensis |
| 110-115  |                  |            | V        | |
| 115-120  |                  |            | IV       | G. havanensis |
| 120-130  |                  |            | III      | D. asymmetrica |
| 130-140  |                  |            | II       | D. asymmetrica |
| 140-150  |                  |            | I        | D. concavae |

Biozone II (Figs. 6J–N)

Age. Early Campanian

Interval. Al Mahr-1 (120–150 m, Figs. 2 and 4), Palmyra-1 (115–140 m, Figs. 3, 4)

Assemblage characteristics. The main characteristic of the microfossil assemblage is the disappearance of marganotricancids at the base of this biozone while Pseudouguembelina costulata has its lowest occurrence. Rugoglobigerina rugosa first occurs in the middle part of Biozone III, whereas Heterohelix reussi has its highest occurrence (HO). This bi-
Figure 6: SEM photomicrographs of selected planktonic foraminifera observed in Biozone I (A–D), Biozone II (E–I), Biozone III (J–N) and Contusotruncana plummerae Zone (Biozone O, P). A Dicarinella sp., Palmyra-1, interval 190–200 m. B Marginotruncana sp., Al Mahr-1, interval 190–200 m. C, D Archaeoglobigerina cretacea (C), and detail of the wall texture (D), Al Mahr-1, interval 185–190 m. E, F Archaeoglobigerina blowi (E), and detail of the wall texture (F), Palmyra-1, interval 160–170 m. G, H Contusotruncana fornicata, Al Mahr-1, interval 155–160 m. I Heterohelix reussi, Palmyra-1, interval 140–150 m. J Heterohelix globulosa, Palmyra-1, interval 130–140 m. K, L Muricohedbergella holmdelensis, Palmyra-1, interval 120–130 m. M, N Heterohelix striata (M), and detail of the wall texture (N), Al Mahr-1, interval 120–130 m. O, P Contusotruncana plummerae, Palmyra-1, interval 100–110 m.
ozone may correspond to the *Globotruncanita havanensis* Zone (CARON, 1985; SLITER, 1989; PREMOLI SILVA & SLITER, 1994; ROBASZYNSKI & CARON, 1995; ROBASZYNSKI et al., 2000; PREMOLI SILVA & VERGA, 2004; CHACON et al., 2004).

Dominant species in the planktonic foraminiferal assemblage are *Hendersonites carinatus*, Heterohelix striata, *H. punctulata* and *Pseudotextularia muttilli*, while Globigerinelloides bollii is very common. In addition, the microfossil assemblage contains the following planktonic foraminifera that persisted from the underlying Biozone II, and comprise up to 35% of the microfossil assemblage, include *Bulimina ovulum*, *Bulimina* sp. (Fig. 9E), Gyroidinoides globosus, Lenticulina rotulata, Lenticulina sp. (Fig. 9F), Gavelinella sp., Gyroidinoides sp., and Cibicidoides sp.

**Biozone IV: Contusotruncanana plummerae Zone (Figs. 6O, P, 7A, B)**

**Definition.** Stratigraphic interval from the LO of *Contusotruncanana plummerae* to the LO of *Radotruncanana calcarata* (PETRIZZO et al., 2011)

**Age.** Early to Middle Campanian

**Interval.** Al Mahr-1 (85–120 m, Figs. 2 and 4), Palmyra-1 (75–80 m, Figs. 3, 4)

**Assemblage characteristics.** Beside the LO of the zonal marker *Contusotruncanana plummerae* (Figs. 6O, P) the lower boundary of this biozone is also characterized by the LO of *Hendersonites carinatus* and by the first occurrence of *Laeviheterohelix* glabranus, *Muricohedbergella mounmouthensis*, and *Heterohelix navarroensis*.

The planktonic foraminiferal assemblage is similar to that in Biozone III. However, planktonic foraminifera are more abundant and the overall number of species increased. The dominant species include *Heterohelix striata*, *H. planata*, Pseudoguembelina costulata and *Pseudotextularia muttilli*. In addition, the assemblage is characterized by common Muricohedbergella holmdelensis, M. mounmouthensis, Globigerinelloides bollii (Fig. 7A), G. subcarinatus and *Heterohelix globulosa*. Other species in this Zone include: Archaeoglobigerina blowi (Fig. 7B), A. cretacea, *Contusotruncanana fornicata*, Globotruncanana arca, *G. bulloides*, *G. linneiana*, *G. hilli*, *Globotruncanana stuartiformis*, *Heterohelix punctulata*, Globigerinelloides prairiehilliensis, Muricohedbergella sp. and Rugoglobigerina rugosa. Representatives of the genus *Heterohelix* decrease in abundance to 32%, whereas pseudoglobulinids increase in diversity as well as in abundance and can account for up to 10.5% of the total assemblage.

The amount of calcareous benthic foraminifera decreases to 30% of the assemblage. The most common taxa include *Bulimina ovulum*, Gavelinella monterelensis (Fig. 9C), Gyroidinoides globosus, Lenticulina rotulata, *Lenticulina* sp. (Fig. 9F), Gavelinella sp., Gyroidinoides sp., and Cibicidoides sp.

**Biozone V (Figs. 7C–G)**

**Age.** Late Campanian

**Interval.** Al Mahr-1 (80–85 m, Figs. 2 and 4), Palmyra-1 (75–80 m, Figs. 3, 4)

**Assemblage characteristics.** Since the zonal marker is very rare and generally poorly preserved, the base of Biozone V is marked by the LO of *Laeviheterohelix* dentata, *Globotruncanana havanensis* and *Globotruncanana stuartarti*. This biozone may correspond to the *Radotruncanana calcarata* Zone (ROBASZYNSKI & CARON, 1995; PREMOLI SILVA & SLITER, 1994; ROBASZYNSKI et al., 2000; PREMOLI SILVA & VERGA, 2004; SARI, 2006, 2009; HUBER et al., 2008).

The species *Heterohelix labellosa* appears in the middle part of Biozone V. The planktonic foraminiferal assemblage of this Biozone is abundant and highly diversified. Most planktonic foraminifera persist from the underlying Biozone IV, including Archaeoglobigerina blowi, *A. cretacea*, *Contusotruncanana fornicata*, Globotruncanana arca (Figs. 7E, F), *G. bulloides*, *G. linneiana*, *G. hilli*, *Heterohelix* globulosa, *H. navarroensis*, *H. planata*, *H. punctulata*, *H. striata*, *Globigerinelloides bollii*, *G. prairiehilliensis* (Fig. 7G), *G. subcarinatus*, Laeviheterohelix glabranus, Muricohedbergella holmdelensis, M. mounmouthensis, Muricohedbergella sp., Pseudoguembelina costulata, *Pseudotextularia muttilli* (Fig. 7C), and Rugoglobigerina rugosa (Fig. 7D). The genus *Heterohelix* constitutes 38% of the assemblage and remains the most abundant group in the planktonic assemblage. In comparison with previous biozones, the diversity of Biozone V increases and the total number of planktonic foraminifera reaches 27 species.

Small benthic foraminifera comprise less than 20% of the assemblage and include Bolivina incrassatea, Gavelinella monterelensis, Gavelinella sp., Gyroidinoides globosus, Lenticulina rotulata, Lenticulina sp., Neoflabellina reticulata, Serovaina complanata, and Cibicidoides sp.

**Biozone VI: Globotruncanana havanensis Zone (Figs. 7H–J)**

**Definition.** Partial range Zone from the LO of *Globotruncanana havanensis* to the LO of *Pseudoguembelina palpebra* (HUBER et al., 2008)
Age. Late Campanian

Interval. Al Mahr-1 (70–80 m, Figs. 2 and 4), Palmyra-1 (65–75 m, Figs. 3, 4)

Assemblage characteristics. The zonal marker Globotruncanella havanensis (Fig. 7H) is relatively rare, while species Pseudoguembelina excolata, Planoglobulina carsevae and Rugoglobigerina hexacamerata have their lowest occurrence at the base of the Biozone IV.

The following planktonic foraminifera continue from the underlying Biozone V: Archaeoglobigerina blowi, A. cretacea, Contusotruncana fornicata, Globotruncanella arca, G. bulboides, G. linneiana, G. hili, Globotruncanita stuartiformis, G. stuarti, Heterohelix globulosa, H. navarroensis (Figs. 7L, 1), H. planata, H. punctulata, H. striata, Globigerinelloides bulbii, G. prairiehillsensis, G. subcarinatus, Laeviheterohelix glutinata, L. dentata, Muricodentoglobigerina holmdelensis, M. moomouthensis, Muricodentoglobigerina sp., Pseudoguembelina costulata, Pseudotextularia nutalli, and Rugoglobigerina rugosa. In the middle of the biozone Globotruncanella petaloidea, Rugoglobigerina macrocephala and Guembelitria turrita have their LO. Species of genus Heterohelix remain the most abundant group in the micro-fossil assemblage with 37.5% representation. Globotruncanids increase in diversity (8 species) and abundance (13.5%), and become an important component of the planktonic assemblage. In addition, small benthic foraminifera comprise 15% of the total fauna and include Bolivina incrassata, Gavelinella monterelensis, Gavelinella sp., Gyroidinoides globosus, Lenticulina rotulata, Lenticulina sp., Neoabathomphalus reticulata, Serovaina complanata, Cibicidoides sp. (Fig. 9H), and an agglutinated form Spiroplectammina sp. (Fig. 9G).

Lithology and palaeoenvironment. Marl and argillaceous limestone (mudstone/wackestone) with abundant planktonic foraminifera (85%) suggest outer shelf to upper bathyal depositional environments.

Biozone VII: Pseudoguembelina palpebra Zone (Figs. 7K–P, 8A)

Definition. Partial range Zone from the LO of Pseudoguembelina palpebra to the LO of Racemiguelinella fruticosa (HUBER et al., 2008)

Age. Late Campanian–Early Maastrichtian

Interval. Al Mahr-1 (35–70 m, Figs. 2 and 4), Palmyra-1 (30–65 m, Figs. 3, 4)

Assemblage characteristics. Pseudoguembelina palpebra (Fig. 7N) is consistently present in this biozone. The first occurrence of Globotruncanella pschadae, Pseudoguembelina kemensis and Racemiguelinella powelli is recorded in the lower part of this biozone. Gansserina gansseri (Figs. 7O, P) is present, but very rare, throughout this interval. Very common species in the assemblage include Heterohelix globulosa, Pseudoguembelina costulata (Fig. 7M), Heterohelix striata, and H. navarroensis. Common species include Heterohelix labellosa, Pseudoguembelina excolata, Pseudotextularia nutalli, and Rugoglobigerina rugosa (Figs. 7L, 8A). Other representative species are Archaeoglobigerina blowi, A. cretacea, Contusotruncana fornicata, Globotruncanarca, G. bulboides, G. linneiana, G. hili, Globotruncanella havanensis, G. petaloidea, Globotruncanita stuarti, G. stuartiformis, Guembelitria turrita, G. cretacea, Heterohelix planata, H. punctulata, Globigerinelloides bulbii, G. prairiehillsensis, G. subcarinatus, Laeviheterohelix dentata, L. glutinata, Muricohedbergella holmdelensis, M. moomouthensis, Muricohedbergella sp., Planoglobulina carsevae, Rugoglobigerina hexacamerata (Fig. 7K), and R. macrocephala. The middle part of Biozone VII is characterized by the lowest occurrence of Abathomphalus intermedius, Globotruncanita minuta and Globotruncanita petteri, while Globigerinelloides bulbii become extinct. The upper part of this Biozone is also characterized by the lowest occurrences of Pseudotextularia intermedia and Globotruncanita conica. In comparison with Biozone VI, biodiversity significantly increases throughout Biozone VII and reaches the maximum of 41 species. This increase is partly related to speciation of globotruncanids, (represented by 12 species). The genus Heterohelix remains the dominant group with 34% abundance, whereas pseudoguembelinids remarkably increase up to 17%. Globotruncanids, despite numerous species, represent 15% of the planktonic foraminiferal population.

Among calcareous benthic foraminifera the most common taxa are: Bolivina incrassata, Bolivinoides miliaris, Gavelinella monterelensis, Gavelinella sp., Gyroidinoides globosus, Lenticulina rotulata (Fig. 9J), Lenticulina sp., Neoabathomphalus reticulata (Fig. 9I), Oridorsalis umbonatus, Serovaina complanata, Cibicidoides sp., Nodosaria sp., and agglutinated Spiroplectammina sp. The proportion of small benthic foraminifera significantly decreases and they make up only 10% of the microfossil assemblage.

Lithology and palaeoenvironment. Marl and argillaceous limestone (mudstone/wackestone) with high proportions of planktonic species (up to 90%) imply continuous deepening of this marine realm and deposition in outer shelf to upper bathyal environments.

Biozone VIII: Racemiguelinella fruticosa Zone (Figs. 8B–E)

Definition. Partial range Zone from the LO of Racemiguelinella fruticosa to the LO of Abathomphalus maa­roensis (HUBER et al., 2008; PEREZ-RODRÍGUEZ et al., 2012)

Age. Early Maastrichtian

Interval. Al Mahr-1 (30–35 m, Figs. 2 and 4), Palmyra-1 (25–30 m, Figs. 3, 4)

Assemblage characteristics. Beside the nominate species Racemiguelinella fruticosa (Fig. 8E), Planoglobulina acervulinoides and Pseudotextularia elegans are also recorded for the first time in the lower part of this biozone. In the same horizons Contusotruncana fornicata and C. plum­merae have their HO. Dominant species in the assemblage are Heterohelix globulosa, H. striata and H. navarroensis. Common species include Rugoglobigerina rugosa and R. macrocephala. The planktonic foraminiferal assemblage is similar to that in Biozone VII (41 species) and consists of the following species: Abathomphalus intermedius, Archae-
Figure 7: SEM photomicrographs of selected planktonic foraminifera observed in Contusotruncana plummerae Zone (Biozone IV, A, B), Biozone V (C–G), Globotruncanella havanensis Zone (Biozone VI, H–J) and Pseudoguembelina palpebra (Biozone VII, K–P). A Globigerinelloides bollii, Al Mahr-1, interval 95–100 m. B Archaeoglobigerina blowi, Al Mahr-1, interval 85–90 m. C Pseudotextularia nuttalli, Al Mahr-1, interval 80–85 m. D Rugoglobigerina rugosa, Al Mahr-1, interval 80–85 m. E F Globotruncanella arca (E), and detail of the wall texture (F), Palmyra-1, interval 75–80 m. G Globigerinelloides prairiehillensis, Palmyra-1, interval 75–80 m. H Globotruncanella havanensis, Palmyra-1, interval 65–70 m. I J Heterohelix navarroensis (I), and detail of the wall texture (J), Palmyra-1, interval 60–65 m. K Rugoglobigerina hexacamerata, Al Mahr-1, interval 65–70 m. L Rugoglobigerina rugosa, Al Mahr-1, interval 65–70 m. M Pseudoguembelina costulata, Al Mahr-1, interval 60–65 m. N Pseudoguembelina palpebra, Palmyra-1, interval 50–60 m. O P Ansserina gansseri, Al Mahr-1, interval 45–50 m (O), and Palmyra-1, interval 40–50 m (P).
oglobigerina blowi, A. cretacea, Contusotruncana fornicata, Gansserina gansseri, Globotruncanella arca, G. bulloides, G. linneiana, G. hilli, Globotruncanella havanaensis, G. minuta, G. petaloidea (Fig. 8B), Globotruncanita conica, G. stuarti, G. stuartiformis (Figs. 8C, D), G. pettersi, Guembelitria turrita, G. cretacea, Heterohelix labellosa, H. planata, H. punctulata, Globigerinelloides bollii, G. prairieheliensis, G. subcarinatus, Laveihoeterhelix dentata, L. glabrans, Muricohedbergella holmdelensis, M. monmouthensis, Muricohedbergella sp., Planoglobulina carseyae, Pseudoguembelina costulata, P. exclolata, P. kempensis, P. palpebra, Pseudotextularia muttalli, P. intermedia, Rugoglobigerina hexacamerata, and Racemiguelbelina powelli. Representatives of the genus Heterohelix increase in abundance to 38%, and rugoglobigerinids are more common here than in the underlying biozones and make up to 14% of the planktonic foraminiferal association. Pseudoguembelians that reached a peak in the previous biozone drop in abundance to 8%, and globotruncanids also decrease in occurrence towards the top of Biozone VII.

Small benthic foraminifera comprise less than 10% of the assemblage and include Bolivina incrassata, Gavelinella monterevensis, Gavelinella sp., Gyroidinoidea globosus, Lenticulina rotulata, Lenticulina sp., Neoflabelinia reticulata, Stensioeina pommerana (Figs. 9K, L), Cibicidoides sp., and agglutinated species Gaudryina laevigata.

Lithology and palaeoenvironment. Marl and argillaceous limestone (mudstone/wackestone) contain a high proportion of rich and very well preserved planktonic foraminifera suggesting deposition in upper to middle bathyal environments.

Biozone IX: Abathomphalus mayaroensis Zone (Figs. 9F–P)

Definition. Interval Zone from the LO of the nominal taxa to the extinction of most of the Cretaceous planktonic foraminifera (PREMOLI SILVA & SLITER, 1994; ROBASZYNSKI & CARON, 1995; ROBASZYNSKI et al., 2000; PREMOLI SILVA & VERGA, 2004; CHACON et al., 2004)

Age. Late Maastrichtian

Interval. Al Mahr-1 (10–30 m, Figs. 2 and 4), Palmyra-1 (5–25 m, Figs. 3, 4)

Assemblage characteristics. The zonal marker Abathomphalus mayaroensis (Figs. 8F, M, N) is represented by a few specimens. Very common species in the planktonic foraminiferal assemblages include Heterohelix globulosa, H. striata, Rugoglobigerina rugosa, Heterohelix navarroensis, H. planata and Muricohedbergella monmouthensis, while common species include Heterohelix labellosa, Globotruncanella arca, Rugoglobigerina macrocephala and Muricohedbergella holmdelensis. This very well preserved and highly diverse assemblage also contains other species such as Globotruncanella hilli, Globotruncanella havanaensis, G. minuta, G. petaloidea, G. pschade, Globotruncanita conica (Fig. 8P), G. stuarti, G. stuartiformis (Figs. 8K, L), G. pettersi, Guembelitria cretacea, Heterohelix punctulata, Pseudoguembelina excolata (Figs. 8G, H), P. kempensis, P. palpebra, Pseudotextularia elegans (Figs. 81, J), P. intermedia, P. muttalli, Planoglobulina carseyae, and Rugoglobigerina hexacamerata.

A large overturn in planktonic fauna occurred within Biozone IX due to the extinction and disappearance of many species at the base of the biozone, including: Archaeoglobigerina blowi, A. cretacea, Globotruncanella bulloides and Globigerinelloides prairieheliensis. Furthermore, species such as Abathomphalus intermedius (Fig. 8O), Gansserina gansseri, Globotruncanella linneiana, Pseudoguembelina costulata and Racemiguelbelina powelli become rare and then disappear in the middle part of Biozone IX. Species of the genus Heterohelix remain the dominant group in the planktonic assemblage with the same abundance of 36%, whereas globotruncanids and rugoglobigerinids have almost the same abundance as in the underlying Biozone VIII. The very high overall diversity (40 species) of Biozone IX, although somewhat lower than in Biozone VIII, dramatically decreases at the end of the zone when most planktonic foraminiferal species become extinct. Only a few species such as Muricohedbergella holmdelensis, M. monmouthensis and Guembelitria cretacea cross the Cretaceous/Palaeogene boundary.

The calcareous benthic species Bolivinoides draco (Fig. 9P) is also characteristic of Abathomphalus mayaroensis Zone (GAWOR-BIEDOWA, 1984). In addition to this species, many other small benthic foraminifera also occur: Bolivina incrassata, Gyroidinoidea globosus (Fig. 9N), Lenticulina rotulata, L. münsteri, Neoflabelinia reticulata, Stensioeina pommerana, Cibicidoides sp. (Fig. 9M) as well as agglutinated forms Gaudryina laevigata (Fig. 9O) and Spiroplectammina sp.

Lithology and palaeoenvironment. Marl, argillaceous limestone (mudstone/wackestone) and slightly dolomitized limestone (foraminiferal wackestone) contain rich and very well preserved foraminiferal assemblages (plankton/benthos ratio is 94:6), suggesting a permanent open-marine influence and deposition in upper to middle bathyal environments.

5. INTERPRETATION AND DISCUSSION

This detailed study of the Late Turonian–Maastrichtian planktonic and benthic foraminiferal assemblages provides the basis for biostratigraphic and palaeoenvironmental interpretations of the successions examined. A total of 56 planktonic foraminiferal species belonging to 20 different genera have been identified. Abundant and moderately to highly diverse and generally well preserved planktonic foraminiferal assemblages enabled biozonation and identification of the following biozones: Biozone I, Biozone II, Biozone I, IV Contusotruncanana plummerae Zone, Biozone V, VI Globotruncanella havanaensis Zone, VII Pseudoguembelina palpebra Zone, VIII Racemiguelbelina fructicosa Zone and IX Abathomphalus mayaroensis Zone. Identification of possible stratigraphic gaps in the Upper Cretaceous successions examined here was very difficult because the drill cuttings were sampled every 5–10 metres. According to BREW (2001), the Upper Cretaceous strata succession of the Palmyride area is characterized by progressively deeper water environments. Evidence for some minor compression and uplift has been documented for the latest Cretaceous of this area, together with an associated minor sedimentary hiatus at the Creta-
Figure 8: SEM photomicrographs of selected planktonic foraminifera observed in the Pseudoguembelina palpebra Zone (Biozone VII, A) Racemiguembelina fructicosa Zone (Biozone VIII, B–E) and Abathomphalus mayaroensis Zone (Biozone IX, F–P). A Rugoglobigerina rugosa, Palmyra-1, interval 40–50 m. B Globotruncanella petaloidea, Al Mahr-1, interval 30–35 m. C, D Globotruncanita stuartiformis (C), and detail of the wall texture (D), Al Mahr-1, interval 30–35 m. E Racemiguembelina fructicosa, Palmyra-1, interval 25–30 m. F Abathomphalus mayaroensis, Al Mahr-1, interval 30–35 m. G Pseudoguembelina excolecta (G), and detail showing wall texture (H), Palmyra-1, interval 20–25 m. I J Pseudotextularia elegans (I), and detail showing wall texture (J), Palmyra-1, interval 20–25 m. K L Globotruncanita stuartiformis, Al Mahr-1, interval 20–25 m. M N Abathomphalus mayaroensis, Al Mahr-1, interval 15–20 m (M), and Palmyra-1, interval 10–20 m (N). O Abathomphalus intermedius, Palmyra-1, interval 10–20 m. P Globotruncanita conica, Palmyra-1, interval 10–20 m.
Figure 9: SEM photomicrographs of selected benthic foraminifera observed in the upper Turonian–Maastrichtian sequence of the Palmyride Region. A, B Gavelinella sp., Al Mahr-1, interval 185–190 m (A), and Palmyra-1, interval 180–190 m. C Gavelinella monterelensis, Al Mahr-1, interval 115–120 m. D Bulimina ovulum, Al Mahr-1, interval 150–155 m. E Bulimina sp., Palmyra-1, interval 130–140 m. F Lenticulina sp., Palmyra-1, interval 90–100 m. G Spiraplectammina sp., Al Mahr-1, interval 70–80 m. H Cibicidoides sp., Palmyra-1, interval 65–75 m. I Neoflabellina reticulata, Palmyra-1, interval 50–60 m. J Lenticulina rotulata, Al Mahr-1, interval 45–50 m. K L Stensioeina pommernana, Al Mahr-1, interval 25–30 m. M Cibicidoides sp., Palmyra-1, interval 15–25 m. N Gyroidinoides globosus, Palmyra-1, interval 15–25 m. O Gaudryna laevigata, Al Mahr-1, interval 15–20 m. P Bolivinoides draco, Palmyra-1, interval 10–20 m.
ceous/Palaeogene boundary (BREW, 2001). To the northeast of the Palmyride area, however, a widespread unconformity has been documented for the Turonian–Coniacian. According to BREW (2001), during the Campanian and early Maastrichtian in the Palmyride area of Syria, progressively deeper water carbonate facies and pelagic marly limestones of the Shiranish formation were deposited. A significant period of Late Cretaceous deformation in northeastern Syria began in the latest Campanian or earliest Maastrichtian (BREW, 2001). The boundary between the Soukhne (massive limestone) formation and the syn-extensional Shiranish formation is unconformable, suggesting a major pre-extensional stratigraphic hiatus in that area.

The foraminiferal assemblage of Biozone I (late Turonian–early Santonian, upper part of the Judea Formation; Figs. 2–5 and 10) is moderately preserved. This biozone may correspond to the Dicarinella concavata Zone, and is characterized by the LO of Gobigerinelloides bollii and Contusotruncana fornicata, as well as by abundant Heterohelix reussi, H. globulosa and H. moremani. Opportunistic (r-strategists) biserial taxa heterohelicids and globular archeoglobigerinids (PREMOLI SILVA & SLITER, 1999; PETRIZZO, 2002, 2003) are important components in this biozone. The dominant species Heterohelix globulosa inhabits subsurface levels in the water column (ABRAMOVICH et al., 2003). Domination of opportunistic biserial heterohelicids and other genera with simple morphology (Muricolederella, Pseudotextularia, Archeoglobigerina and Whiteinella), which comprise up to 87% of the total planktonic foraminiferal assemblage, indicate palaeoceanographic conditions favorable for opportunistic (r-strategist) organisms, such as a high productivity ocean with generally cooler but fluctuating climate, well developed oxygen minimum zone, common up-wellings and cyclic eutrophications of the surface water (BOERSMA & PREMOLI SILVA, 1989; NEDERBRAGT et al., 1998; PETRIZZO, 2002).

On the other hand, the occurrence of K-strategists (Dicarinella and Marginotruncana), although present in a smaller percentage in the planktonic assemblage, indicates warm stable episodes with oligotrophic oceanic conditions and well developed water column stratification, which are favourable for these two groups with more complex test architecture (PETRIZZO, 2002). Almost equal proportions of small benthic and planktonic foraminifera in limestones (mudstone/wackestone to foraminiferal wackestone) and marl suggest deposition in outer shelf environments (OLSSON & NYONG, 1984; BOERSMA, 1988; MURRAY, 1991; GRÄFE, 2005).

The most important characteristic of Biozone II (middle–late Santonian, the Soukhne Formation; Figs. 2–5 and 10) is the high level of speciation of planktonic foraminifera. This Biozone is determined by the first appearance of several new taxa including Globotruncanita lineicosta, G. arca, G. bulloides, G. hilli, Hendersonites carinatus, Heterohelix planata, H. punctulata, H. striata, Globigerinelloides praeriehliensis, and Globotruncanita Stuartiformis, which may suggest the Dicarinella asymetrica Zone. The foraminiferal assemblage is moderately diverse and better preserved relative to biozone I. Heterohelicids experienced speciation during this Biozone; their abundance increased to 46.5%, and they remained a dominant group until the end of the Cretaceous. As opportunistic planktonic foraminifera heterohelicids inhabit more nutrient-rich waters and are indicators of cooler and unstable environments (NEDERBRAGT, 1991; NEDERBRAGT et al., 1998; PETRIZZO, 2002). Their speciation is most likely induced by a somewhat cooler but variable climate and anoxic events during the middle Santonian. Beside heterohelicids, other small-sized forms with simple test-morphology, such as muricolederberellids, archeoglobigerinids and globigerinellids, are very common in the planktonic assemblage. All of these groups belong to opportunistic taxa that have a great reproductive potential in eutrophic and somewhat mesotrophic environments with a very well developed oxygen minimum layer (NEDERBRAGT, 1991). Small-sized heterohelicids indicate expansion of the oxygen minimum zone (OMZ) due to increased surface water productivity and depletion of oxygen in subsurface waters by oxidation of organic carbon (LECKIE, 1987; LECKIE et al., 1998; KELLER & PARDO, 2004; PARDO & KELLER, 2008; ASHCKENAZI-POLIVODA et al., 2011). Heterohelicidae were found to be very common in most of the OMZ suggesting high productivity and/or some tolerance to subsurface oxygen depletion (ASHCKENAZI-POLIVODA et al., 2011). In addition, abundant phosphate grains in the upper part of this zone, support the interpretation that Biozone II was characterized by high palaeoproductivity, relatively constant and high food supply and moderate increase in bottom water aeration. Very high productivity during this biozone was supported by a fluctuating climate and up-welling cycles, which brought nutrient-rich water into the environments inhabited by heterohelicids and upper-middle bathyal benthic foraminifera. At the upper boundary of Biozone II all dicarinellids and whiteinellids became extinct. The proportion of planktonic species increased and reached up to 60% of the microfossil assemblage present in foraminiferal mudstone/wackestone, marl and dolomitic limestones that represent an open marine, most probably outer shelf environments (OLSSON & NYONG, 1984; BOERSMA, 1988; MURRAY, 1991; GRÄFE, 2005).

Biozone III (early Campanian, the Soukhn Formation; Figs. 2–5 and 10) is marked by the disappearance of margi- notrunancids in its base and by the LO of Pseudoguembelina costulata and Ruglogibberina rugosa. This planktonic assem- blage may correspond to the Globotruncanita elevata Zone. Planktonic and benthic foraminiferal assemblages are rich and moderately to well preserved. The proportion of planktonic species reaches up to 65% and indicates further deepening of this realm (BOERSMA, 1988; MURRAY, 1991; GRÄFE, 2005; DARVISHZAD & ABDOLALIPOUR, 2009). The most common species are opportunistic (r-strategists) taxa: Hendersonites carinatus, Heterohelix punctuata, H. striata and Pseudotextularia nuttalli. Although characterized by different deposits, i.e., limestone (foraminiferal mudstone/wackestone) and calcareous marl, relative to Biozone II, the deposition of these strata continued within the same open marine, probably outer shelf settings.
Phosphate grains are very common in dolomitic limestones from the upper part of Biozone II in Al Mahr-1 (Figs. 2 and 4), and in the uppermost part of Biozone II and the lowermost part of Biozone III in Palmyra-1 (Figs. 3, 4). Abundant phosphate grains generally indicate some very specific geological and palaeoenvironmental conditions, such as oxygen deficiency, upwelling conditions, and transgressive intervals (HAQ et al., 1987; REISS, 1988; AL-MOGI-LABIN et al., 1993; WIDMARK & SPEIJER, 1997; JARVIS et al., 2002; PUFAIL et al., 2003; SOULDRE et al., 2006; ASHCENAZI­POLIVODA et al., 2011). It is possible that such palaeoenvironmental conditions, especially upwelling, increased food supply and primary production in the surface and subsurface marine environments, and thus also indirectly affected higher production and domination of opportunistic (r-strategists) planktonic foraminiferal species during Biozones II and III.

The lowest occurrence of Laeviheterohelix glabrans and Muricochedbergella momouthenensis and rare Contusotrunca­na plumeriae in the planktonic foraminiferal assemblage of Biozone IV (middle–late Campanian, the Shiranish Formation; Figs. 2–5 and 10) suggest the Contusotrunca­na plumeriae Zone. This biozone has been appointed by PETRIZZO et al. (2011) for the lower–middle Campanian of tropical and subtropical areas because of the difficulties in using the first occurrence datum of Globotruncana ven­tricosa in low latitude successions from the Tethyan Realm. Species of the genus Heterohelix dominated in the previous Biozone III but decrease to 32.5% in Biozone IV, whereas the abundance of two genera Muricochedbergella and Pseudoguembelina significantly increases up to 15% and 10.5%, respectively. Although the opportunistic (r-strategists) species are still dominant, the specialized taxa (K-strategists) such as globotruncanids (PREMOLI SILVA & SLITER, 1999; PETRIZZO, 2002; DUBICKA & PERYT, 2012) increase in the overall number of species and also slightly increase in abundance within this planktonic assemblage. This indicates mesotrophic to more oligotrophic environmental conditions that are favorable for keeled globotruncanids. The well-preserved foraminiferal assemblage and high proportion of planktonic foraminifera (70%) in the argillaceous limestones marl and calcareous marls of Biozone IV suggest an open marine, probably outer shelf to upper bathyal environment (BOERSMA, 1988; MURRAY, 1991; GRÄFE, 2005).

The lowest occurrence of planktonic foraminifera Laeviheterohelix dentata, Globotruncanella havanensis and Globotruncanita stuartii in Biozone V (late Campanian, the Shiranish Formation; Figs. 2–5 and 10) may suggest the Ra­dotruncanca calcarata Zone. The well-preserved foraminiferal assemblage is rich, diverse and has an increased number of K-strategists (keeled globotruncanids; PREMOLI SILVA & SLITER, 1999). Globotruncanids have a complex test morphology and usually inhabit the subsurface water column (PETRIZZO, 2002; ABRAMOVICH et al., 2003; DUBICKA & PERYT, 2012), which implies good stratification of the water column and a tropical to subtropical climate during the late Campanian (LECKIE, 1989; HUBER et al., 1995; DARVISHZAD & ABDOLALIPOUR, 2009). Deposits and sedimentary settings remain the same as for Biozone IV, i.e., deep-water marine environments.

The zonal marker Globotruncanella havanensis is relatively rare in Biozone VI (late Campanian, the Shiranish Formation; Figs. 2–5 and 10), and the base of this Biozone is indicated by the LO of Pseudoguembelina excolata, Pla­noglobulina careysae and Rugoglobigerina hexacamerata. The foraminiferal assemblage is rich and well preserved. Although the opportunistic group heterohelicids stay dominant in the planktonic assemblage with 37.5% abundance, K-strategists, such as keeled globotruncanids, become an important component in the planktonic foraminiferal assemblage with 9 species and 13.5% abundance. These point to stable environmental conditions, such as an oligotrophic ocean with a tropical to subtropical climate, well stratified water column, stable thermocline and other favourable palaeoenvironmental parameters for r/K and K-selected group of planktonic foraminifera (LECKIE, 1989; MURRAY, 1991; DARVISHZAD & ABDOLALIPOUR, 2009). Abundance of species from the genus Globigerinelloides and Mu­ricochedbergella (r-selected forms) show inverse trends in comparison with the previous biozones and decrease to 7.5% and 6%, respectively (Fig. 10). The proportion of planktonic species increased and reached up to 85% of the microfossil assemblage present in marl and argillaceous limestone (mudstone/wackestone) that represent an open marine, outer shelf to upper bathyal environments (OLSSON & NYONG, 1984; BOERSMA, 1988; MURRAY, 1991; GRÄFE, 2005).

The Pseudoguembelina palpebra Zone (Biozone VII, late Campanian–early Maastrichtian, the Shiranish Formation; Figs. 2–5 and 10) is characterized by the LO of P. palpebra, which is consistently found throughout the interval in moderate abundance. Also, the lowest occurrence of Glo­botruncanella pschadae, Pseudoguembelina kempensis and Racemiguelinella powelli is recorded in the lower part of this biozone. Gansserina gansseri is very rare and poorly preserved in the investigated samples, and therefore P. palpebra serves as a better zonal marker for the uppermost Cam­panian, as also reported by HUBER at al. (2008) from subtropical North Atlantic (Blake Nose). The planktonic foraminiferal assemblage of Biozone VII is rich, very well preserved and in comparison with Biozone VI, biodiversity throughout this interval significantly increases (to 41 species). Opportunistic representatives of the genus Heterohelix are still the dominant group in the planktonic assemblage with 34% abundance. Also, the genus Pseudoguembelina, known as a successful surface and subsurface dweller in tropical and subtropical open ocean (NEDERBRAGT, 1989; HUBER, 1992; ABRAMOVICH et al., 2003), significantly increased in abundance up to 17%. Species of the genus Pseudoguembelina are strongly photosymbiotic and their expansion is related to favourable palaeoecological conditions in the Late Cretaceous ocean, such as the presence of warm and oligotrophic surface ocean waters (D’HONDT & ZACHOS, 1998; ABRAMOVICH et al., 2003). The proportion of planktonic foraminifera accounts for up to 90% of the microfossil assemblages found in marl and argillaceous lime-
stone (mudstone/wackestone), which implies further deepening of this realm and deposition in outer shelf to upper bathyal environments (BOERSMA, 1988; MURRAY, 1991; GRAFE, 2005; DARVISHZAD & ABDOLALIPOUR, 2009).

The lowest occurrence of planktonic foraminifera _Plano- globulina acervulinaeoides and Pseudotextularia elegans_ in association with the rare zonal marker _Racemiguembelina frucitcosa_, is indicative of Biozone VIII (early–late Maastrichtian, the Shiranish Formation; Figs. 2–5 and 10). This biozone is characterized by a diverse and very well preserved planktonic foraminiferal assemblage with 41 species, similar to that from Biozone VII. Rugoglobigerinids increased in abundance and reached up to 14% of the assemblage, while representatives of the genus _Heterohelix_ still dominate the assemblage with 38%. Species of the genus _Rugoglobigerina_ inhabit surface and subsurface habitats (ABRAMOVICH et al., 2003), and are known as symbiotic organisms (D’HONDT & ZACHOS, 1998). Speciation of planktonic foraminifera in this biozone is likely supported by good water column stratification and opening of new niches favourable for all groups of planktonic foraminifera. Many subsurface dwellers, such as several species of the genus _Globotruncana_ acquired adaptation to the thermocline habitat (ABRAMOVICH et al., 2003). All of these changes correspond very well to the documented global sea level fluctuations and alternating cooler and warmer periods in the early to late Maastrichtian (HAQ et al., 1987; Fig. 5). During Zone VIII the sedimentary setting was a deep sea environment (upper bathyal), as a result of further deepening of this sedimentary realm.

The planktonic foraminiferal assemblage of the latest Cretaceous Abathomphalus mayaroensis Zone (Biozone IX, late Maastrichtian, the Shiranish Formation; Figs. 2–5 and 10) is very similar to those in Biozone VIII and is rich in the overall number of species (39) as well as in the number of individuals. An important characteristic of this biozone is the increased number of K-strategist species of globotruncanids (15.5%), and planoglobulinids (4%), whereas rugoglobigerinids retained their abundance (14%). Some opportunistic species of the genus _Muricohedbergella_ also show an increase and constitute 9% of the assemblage, while members of the genus _Globigerinelloides_ (2%) decrease in abundance (Fig. 10). Species of the genus _Heterohelix_ have an almost equal abundance (36%) compared to Biozone VIII.

Composition of the planktonic foraminiferal assemblage with a significantly higher percentage of K-strategist specialists, which inhabit subsurface and thermocline layers, indicates an oligotrophic ocean with a very well stratified water column supported by a stable thermocline (PREMOLI SILVA & SLITER, 1999; PEARSON et al., 2001; ABRAMOVICH et al., 2003). On the other hand, the symbioint-bearing taxa _Rugoglobigerina_, _Pseudoguembelina_ and _Heterohelix_ were very well adapted to surface and subsurface oligotrophic ocean water (D’HONDT & ZACHOS, 1998; PEARSON et al., 2001; ABRAMOVICH et al., 2003). In the upper part of Biozone IX, the decreased numbers of globotruncanid species indicate fluctuating climate, sea-level changes and up-welling cycles which could cause instability in the water column and unfavourable environmental conditions for K-strategists (ABRAMOVICH & KELLER, 2002; HAQ et al., 1987). This high diversity abruptly decreases at the end of the Biozone, when most planktonic foraminiferal species became extinct. Marl, argillaceous limestone (mudstone/wackestone), and slightly dolomitized limestone (foraminiferal wackestone) contain rich and very well preserved foraminiferal assemblages, whereas planktonic foraminifera reach over 90% of the entire community suggesting deposition in upper bathyal environments (BOERSMA, 1988; MURRAY, 1991; GRAFE, 2005; DARVISHZAD & ABDOLALIPOUR, 2009). All these facts indicate the Late Cretaceous as being a long, warm and relatively stable period with palaeoceanographic conditions favourable for all groups of planktonic foraminifera which inhabited different niches in a well stratified water column (LECKIE, 1989; HUBER et al., 1995; PREMOLI SILVA & SLITER, 1999; PETRIZZO, 2002, PEARSON et al., 2001; ABRAMOVICH et al., 2003; DUBICKA & PERYT, 2012).

The Soukhne Formation (Santonian–Early Campanian, Biozones II and III, Figs. 2–4) contains phosphate grains. Similar phosphate deposits are widespread in many parts of the Levant region (i.e., Israel, Jordan, Iraq, Turkey and Egypt; AL MALEH & MOUTY, 1994; PUFHAL et al., 2003; ABED et al., 2005; BAIJUMY & TADA, 2005; SOUDRY et al., 2006; ASHKENAZI-POLIVODA et al., 2011; SCHNEIDER-MOR et al., 2012). The phosphate deposits in Syria formed in response to a high-productivity upwelling regime that persisted on the southern margins of the Tethys during the Late Cretaceous (AL MALEH & MOUTY, 1994). The planktonic assemblages associated with phosphate grains in the Palmyride strata are characterized by domination of opportunistic (r-strategists) taxa such as the genus _Heterohelix_ (Biozone II and III, Figs. 2, 3), which indicates a highly productive photic zone (REISS, 1988; ALMOGI-LABIN et al., 1993; WIDMARK & SPEIJER, 1997; PUFHAL et al., 2003) and a low oxygen environment (ASHKENAZI-POLIVODA et al., 2011). The benthic assemblages found with phosphates have abundant specimens of the genus _Bulimina_, which are commonly documented from highly productive, low-oxygen settings from around the world, including for example South America, Morocco, Egypt, Jordan, Iraq and Israel (PUFHAL et al., 2003; ASHKENAZI-POLIVODA et al., 2011). An additional factor that contributed to the formation of phosphate was the enrichment in phosphorous from P-rich deep waters that upwelled in the Palmyrida Basin by currents flowing along the northern edge of the Arabian platform (SOUDRY et al., 2006). Warming of the upwelled water and the abundance of nutrients caused the proliferation of plankton, which assimilated, stored and concentrated phosphate. After the deposition of plankton, a large amount of phosphate dissolved and became concentrated in the sea-floor sediments (AL MALEH & MOUTY, 1994).

Such high primary productivity and sea floor phosphogenesis prevailed mainly on the southeastern Tethyan margins as a result of persistent upwelling circulation that recycled dissolved phosphorous from the intermediate-depth waters and distributed it to the photic zone (SOUDRY et al., 2006).
The phosphates developed during transgressive periods that promoted carbonate sediment starvation. Simple (internally homogenous) $P_2O_5$-enriched phosphate nodules probably replaced calcite nodule precursors in suboxic conditions as a result of processes that involved oceanic upwelling, exhumation and burial coupled with alternating oxic and suboxic conditions (MARSHALL-NEILL & RUFFELL, 2004). The presence of phosphate is an important indicator of oxygen deficiency, upwelling conditions, transgressive intervals, and omission surfaces (TRAPPE, 2001), and any future studies of this Cretaceous stratigraphic interval should also include detailed analyses of the associated phosphate grains.

6. CONCLUSIONS

The stratigraphic analysis of the Upper Cretaceous strata from the Palmyride area in Syria included a detailed micropalaeontological investigation of foraminiferal assemblages and rock types obtained from drill cuttings in two deep exploration wells (Al Mahr-1 and Palmyra-1).

Nine biozones have been identified in the upper Turonian to Maastrichtian succession: Biozone I, Biozone II, Biozone III, IV Contusotruncana plummerae Zone, Biozone V, VI Globotruncanella havanensis Zone, VII Pseudoguembelina palpebra Zone, VIII Raceemiguembelina fructicosa Zone, and IX Abathomphalus mayorensis Zone.

During the late Turonian to early Campanian (Biozone I to III) in the investigated Palmyrde strata, domination of opportunistic taxa (Heterohelix, Globigerinelloides, Archaeoglobigerina, and Muricoheadbergella) implies upwelling, low oxygen conditions and subtropical climate. On the other hand, the rich and highly diversified planktonic assemblages (Biozone IV to IX) with many K-selected taxa (i.e., ornamented keeled globotruncanids, rugoglobigerinids, planoglobulinids, pseudoguembelinids) indicate a tropical to subtropical climate and well-stratified water column during the late Campanian and into the Maastrichtian. In the upper part of Biozone IX, the decreased numbers of globotruncanid species indicate a less stratified water column and unfavourable environmental conditions for K-strategists. A dramatic faunal turnover at the end of this Biozone is marked by the extinction of most planktonic foraminifera, with only a few species (e.g., Muricoheadbergella holmdelensis, M. montmouthensis and Guembelitria cretacea) present across the Cretaceous/Paleogene boundary.

Phosphate grains are very common in dolomitic limestone of the upper part of Biozone II in Al Mahr-1 and in the uppermost part of Biozone II and lowermost part of Biozone III in Palmyra-1 (Soukhne Formation). The presence of phosphate in the study area indicates oceanic upwelling that caused increased food supply and influenced higher primary marine production, and thus indirectly affected higher production and domination of opportunistic planktonic foraminifera in Biozones II and III.

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APPENDIX 1

List of taxa cited in the text and figure explanations, in alphabetical order according to genus

Planktonic foraminifera
- Abathomphalus intermedius (BOLLI, 1951)
- Abathomphalus mayaroensis (BOLLI, 1951)
- Archaeoglobigerina blowi PESSAGNO, 1967
- Archaeoglobigerina cretacea (D’ORBIGNY, 1840)
- Contusotruncana fornicata (PLUMMER, 1931)
- Contusotruncana plummerae (GANDOLFI, 1955)
- Dicarinella sp.
- Gansserina gansseri (BOLLI, 1951)
- Globigerinelloides bollii (PESSAGNO, 1967)
- Globigerinelloides prairiehillensis (PESSAGNO, 1967)
- Globotruncana arca (CUSHMAN, 1926)
- Globotruncana bulloides (VOGLER, 1941)
- Globotruncana hilli (PESSAGNO, 1967)
- Globotruncana linneiana (D’ORBIGNY, 1839)
- Globotruncancella havanensis (VOORWIJK, 1937)
- Globotruncancella minuta (CARON & GONZALEZ DONOSO, 1984)
- Globotruncancella petaloidea (GANDOLFI, 1955)
- Globotruncancella pschadae (KELLER, 1946)
- Globotruncanita conica (WHITE, 1928)
- Globotruncanita pettersi (GANDOLFI, 1955)
- Globotruncanita stuarti (DE LAPPARENT, 1918)
- Guembelitria cretacea CUSHMAN, 1933
- Guembelitria turrita (NEDERBRAGT, 1990)
- Hendersonites carinatus (CUSHMAN, 1938)
- Heterohelix globulosa (EHRENBERG, 1840)
- Heterohelix labellosa (NEDERBRAGT, 1990)
- Heterohelix navarroensis LOEBLICH, 1951
- Heterohelix moremani (CUSHMAN, 1938)
- Heterohelix planata (CUSHMAN, 1938)
- Heterohelix punctulata (CUSHMAN, 1938)
- Heterohelix reussi (CUSHMAN, 1938)
- Heterohelix striata (EHRENBERG, 1840)
- Laeviheterohelix dentata (STENESTAD, 1968)
- Laeviheterohelix glabrans (CUSHMAN, 1938)
- Marginotruncana sp.
- Muricochedbergella flandrini (PORTHAULT, 1970)
- Muricochedbergella holmedens (OLSSON, 1964)
- Muricochedbergella mounmouthensis (OLSSON, 1960)
- Muricochedbergella sp.
- Planoglobulina casevae (PLUMMER, 1931)
- Planoglobulina acervulinoide (EGGER, 1899)
- Pseudoguembelina costulata (CUSHMAN, 1938)
- Pseudoguembelina excolata (CUSHMAN, 1926)
- Pseudoguembelina kempensis (ESKER, 1968)
- Pseudoguembelina palpebra (BRÖENNIMANN & BROWN, 1953)
- Pseudotextularia elegans (RZEHAK, 1891)
- Pseudotextularia intermedia (DE KLASZ, 1953)
- Pseudotextularia nutalli (VORWIJK, 1937)
- Racemiguembelina fructicosa (EGGER, 1902)
- Racemiguembelina powelli (SMITH & PESSAGNO, 1973)
- Rugoglobigerina macrocephala (BRÖENNIMANN, 1952)
- Rugoglobigerina hexacamerata (BRÖENNIMANN, 1952)
- Rugoglobigerina rugosa (PLUMMER, 1926)
- Whiteinella balthica (DOUGLAS & RANKIN, 1969)
- Whiteinella sp.
- Benthic foraminifera
- Bolivinoides draco (MARSSON, 1878)
- Bolivinoides miliaris (HILTERMANN & KOCH, 1950)
- Bolivina incrassata (REUSS, 1851)
- Bulimina ovulum (REUSS, 1844)
- Bulimina sp.
- Cibicidoides sp.
- Gaudryina laevigata (FRANKE, 1914)
- Gavelinella monterelensis (MARIE, 1941)
- Gavelinella sp.
- Gyroidinoides globosus (HAGENOW, 1842)
- Gyroidinoides sp.
- Lenticulina rotulata (LAMARCK, 1804)
- Lenticulina münsteri (ROEMER, 1839)
- Lenticulina sp.
- Neoflabellina reticulata (REUSS, 1851)
- Nodosaria sp.
- Oridorsalis umbonatus (REUSS, 1851)
- Oridorsalis sp.
- Praebulimina reussi (MORROW, 1934)
- Praebulimina kickapoensis (COLE, 1938)
- Serovaina complanata (CUSHMAN & STAINFORTH, 1945)
- Spiroplectammina sp.
- Stensioeina pommerana (BROENSTEN, 1936)
### APPENDIX 2

Distribution of Late Cretaceous genera of planktonic foraminiferal assemblage from Al Mahr-1 and Palmyra-1 wells.

| DEPTH (m) | 180-185 | 145-150 | 125-130 | 90-95 | 80-85 | 65-70 | 40-45 | 25-30 | 20-25 |
|-----------|---------|---------|---------|-------|-------|-------|-------|-------|-------|
| BIOZONE   | I       | II      | III     | IV    | V     | VI    | VII   | VIII  | IX    |
| SPECIES RICHNESS | 14 | 22 | 22 | 24 | 27 | 32 | 41 | 41 | 40 |
| Abathomphalus intermedius | 1 | 2 | 1 |
| Abathomphalus mayaroensis | 1 |
| Archaeoglobigerina blowi | 15 | 16 | 10 | 6 | 6 | 3 | 3 | 3 | 2 |
| Archaeoglobigerina cretacea | 12 | 11 | 5 | 2 | 3 | 2 | 2 | 1 |
| Cantuosotruncana fornicata | 17 | 14 | 5 | 6 | 7 | 4 | 2 |
| Cantuosotruncana plummerae | 2 | 6 | 2 | 3 |
| Dicarinella sp. | 9 | 5 |
| Gansserina gansseri | 2 | 1 | 2 |
| Globigerinelloides bolli | 11 | 17 | 27 | 19 | 15 | 8 |
| Globigerinelloides prattrellensis | 11 | 15 | 9 | 13 | 7 | 12 | 9 |
| Globigerinelloides subcarinatus | 9 | 8 | 14 | 9 | 9 | 8 | 6 | 7 |
| Globotruncanana arca | 4 | 4 | 5 | 4 | 9 | 6 | 8 | 14 |
| Globotruncanana bulloides | 3 | 3 | 3 | 4 | 2 | 2 | 1 |
| Globotruncanana hilli | 3 | 3 | 2 | 3 | 4 | 2 | 4 | 11 |
| Globotruncanana linneiana | 2 | 2 | 3 | 3 | 4 | 7 | 6 |
| Globotruncanella havanensis | 10 | 6 | 5 | 7 |
| Globotruncanella minuta | 1 | 1 | 3 |
| Globotruncanella petaloidea | 5 | 3 | 3 | 3 |
| Globotruncanella pschadace | 3 | 3 | 2 |
| Globotruncanita conica | 1 | 2 | 1 |
| Globotruncanita pettersi | 3 | 6 | 3 |
| Globotruncanita stuarti | 3 | 4 | 2 | 6 | 2 |
| Globotruncanita stuartiformis | 7 | 8 | 7 | 6 | 6 | 9 | 7 | 4 |
| Guembelitria cretacea | 1 | 1 |
| Hendersonites carinatus | 17 | 34 |
| Heterohelix globulosa | 38 | 33 | 19 | 14 | 32 | 30 | 29 | 34 | 29 |
| Heterohelix labellosa | 11 | 14 | 14 | 12 | 14 |
| Heterohelix morremi | 31 |
| Heterohelix navarroensis | 8 | 17 | 27 | 23 | 31 | 21 |
| Heterohelix pinnata | 14 | 14 | 32 | 8 | 7 | 6 | 12 | 17 |
| Heterohelix punctulata | 21 | 33 | 9 | 16 | 9 | 9 | 7 | 11 |
| Heterohelix reussi | 35 | 31 | 18 |
| Heterohelix striata | 19 | 35 | 34 | 29 | 32 | 25 | 32 | 27 |
| Laeviheterohelix dentata | 5 | 6 | 10 | 4 | 6 |
| Laeviheterohelix glabrans | 6 | 4 | 8 | 7 | 7 | 5 |
| Marginotruncana sp. | 11 | 4 |
| Muricochedbergella flandrini | 18 |
| Muricochedbergella halmdelensis | 25 | 19 | 9 | 21 | 18 | 8 | 13 | 7 | 12 |
| M. mounmouthensis | 17 | 15 | 7 | 4 | 11 | 17 |
| Muricochedbergella sp. | 7 | 6 | 7 | 5 | 4 |
| Planoglobulina caseyi | 7 | 6 | 5 | 8 |
| Pseudoguembelina costulata | 15 | 31 | 26 | 23 | 26 | 7 | 4 |
| Pseudoguembelina excolata | 6 | 9 | 8 | 7 |
| Pseudoguembelina kempensis | 3 | 4 | 6 |
| Pseudoguembelina palpebra | 13 | 7 | 7 |
| Pseudotextularia elegans | 11 | 11 |
| Pseudotextularia intermedias | 2 | 1 | 1 |
| Pseudotextularia nuttali | 30 | 23 | 33 | 30 | 16 | 21 | 14 | 6 | 4 |
| Racemiguembelina fruticosa | 1 | 1 |
| Racemiguembelina pavelli | 2 | 2 | 1 |
| Rugoglobigerina hexacamerata | 4 | 5 | 9 | 10 |
| Rugoglobigerina macrocephala | 5 | 15 | 12 |
| Rugoglobigerina nugosa | 16 | 11 | 17 | 21 | 12 | 24 | 26 |
| Whiteinella balthica | 11 |
| Whiteinella sp. | 9 |

| (%) PLANKT. FORAM. | 51.22 | 59.30 | 64.27 | 70.21 | 80.34 | 85.17 | 91.24 | 92.56 | 93.98 |
| (%) BENT. FORAM. | 48.78 | 40.67 | 35.72 | 29.79 | 19.66 | 15.05 | 8.76 | 7.44 | 6.02 |