Paleoenvironment of the Eastern Tethys in the Early Paleocene

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Paleoenvironmental conditions of the early Paleocene eastern Tethys have been inferred based on carbonate sedimentation, biostratigraphy, and planktic foraminiferal assemblages of five sections from the Negev of Israel. In the earliest Paleocene at least three intervals of erosion or nondeposition of sediments have been identified (K/T, P0/P1a, P1a/P1b boundaries) in addition to a black pyrite- and organic-rich clay layer about 1.5 to 3.0 m above the K/T boundary (Subzone P1b/P1c, upper Chron 29N). These hiatuses appear to be widespread and correlate with global sea level fluctuations.

*Danian planktic foraminiferal assemblages of the eastern Tethys are dominated by alternating abundance maxima between triserial (*Guembelitria*) and biserial (*Woodringina, Chiloguembelina*) species. Biogeographic distribution of these taxa indicates that both groups thrived in shallow continental shelf regions. Moreover, abundance maxima of triserial taxa seem to correspond to $\delta^{13}C$ depletion intervals, which indicate low surface productivity, whereas abundance maxima of biserial taxa correspond to enriched $\delta^{13}C$ intervals which imply high surface productivity. These paleoceanographic changes may be related to sea level high- and lowstands during the earliest Paleocene. Stable isotope analyses of Danian species will be necessary to confirm these observations and to reconstruct oceanic conditions in both open marine and continental shelf regions of the early Paleocene.*

INTRODUCTION

The Cretaceous-Tertiary (K/T) boundary mass extinction resulted in a nearly complete turnover in planktic foraminifera. The evolutionary radiation of species that began immediately after the extinction event eventually gave rise to new faunal assemblages which do not resemble Cretaceous species. The ancestor-descendant relationships of the evolving earliest Tertiary species are still relatively little understood. Equally little understood are the post-K/T boundary oceanographic conditions that spawned the evolution of the Tertiary fauna. Carbon-13 isotope studies indicate that a major negative excursion at or near the K/T boundary was associated with a decrease in the surface to deep $\delta^{13}C$ gradient. This implies dramatically reduced surface water productivity (Boersma and Shackleton, 1981; Perch-Nielsen et al., 1982; Hsu et al., 1982; Zachos and Arthur, 1986; Barrera and Keller, 1990) with recovery of the ecosystem believed to have been delayed between 200,000 years (Keller and Lindinger, 1989; Stott and Kennett, 1989) and 0.5 to 1.0 m.y. (Zachos and Arthur 1986). Disruption of the atmospheric CO_2 reservoir (Baur, 1988), or reduced photosynthesis as a result of darkness caused by an impact generated dust cloud (Alvarez et al., 1980), has been proposed as a likely cause for the crash in plankton productivity.

Planktic foraminifera are sensitive indicators of oceanic surface water conditions. Changes in the relative abundances of species record variations in environmental parameters, assuming that carbonate dissolution of foraminiferal calcite is not a factor biasing the assemblages. Unfortunately, we know little of individual fossil species' preferences for nutrient, oxygen, temperature and salinity levels. Our interpretations are restricted to observing the temporal and spacial relationships of faunal changes and noting their correlation with environmental parameters such as $\delta^{13}C$, $\delta^{18}O$, and $CaCO_3$. To date, however, very few studies have documented $\delta^{13}C$ and $\delta^{18}O$ values for individual planktic foraminiferal species in the early Paleocene (e.g., Boersma and Premoli-Silva, 1988; Barrera and Keller, 1990; Stott and Kennett, 1990). This is, in part, because planktic foraminifers in Danian sediments, including the five sections discussed here, are poorly preserved and recrystallized and therefore are unsuitable for stable isotope analysis. This report therefore focuses on faunal assemblage variations and carbonate deposition.

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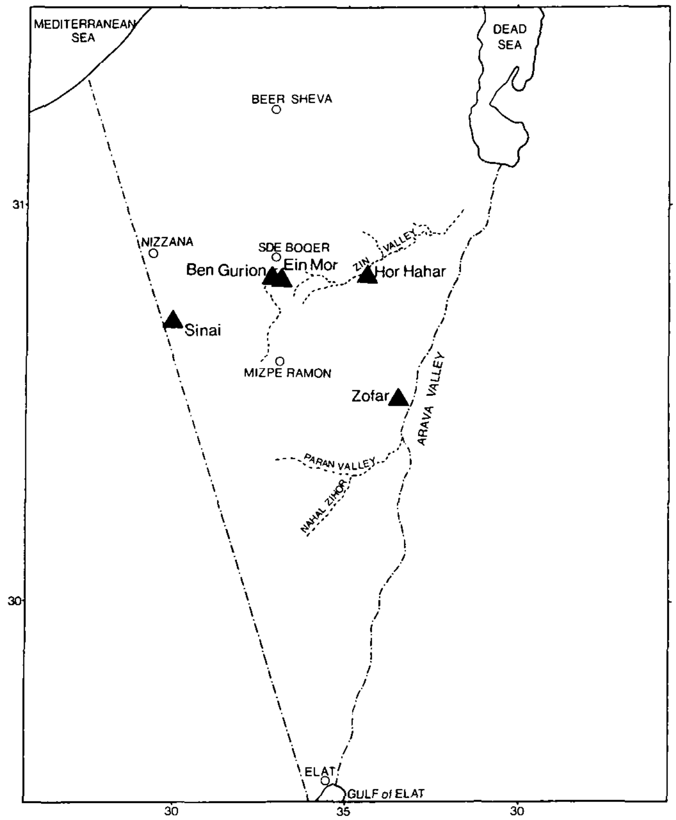

FIGURE 1—Location map of sections studied in the Negev, Israel; triangles represent site locations.

In this study we examine the early Paleocene record up to the reestablishment of stable oceanographic conditions. Our examination focuses on the correlation of major faunal turnovers, changes in carbonate deposition and hiatus formation. We have selected five stratigraphic sections from the Negev of Israel in an east-west and north-south transect (Fig. 1) in order to determine whether the observed faunal changes are of local or regional extent. We have found no significant variations between the faunal assemblages of the five localities which implies that these sections are representative of the eastern Tethys region. During Late Cretaceous to early Tertiary time these sections were located in upper slope to outer shelf depths, (Keller and Benjamini, unpubl.), in a more or less normal marine environment (with respect to salinity and temperature) associated with intermittent coastal upwelling as implied by oxygen isotope variations of Upper Cretaceous phosphorites from this region (Shemesh and Kolodny, 1988). A relatively open ocean marine environment is also implied by the similarity in faunal assemblages and relative species abundance variations in southeastern Spain (Canudo et al., 1991) and South Atlantic Site 528 (D'Hondt and Keller, 1991). The Negev sections may therefore be considered representative of the early Tertiary Tethyan outer shelf paleoenvironment.

METHODS

The outcrop sections were trenched to remove surface contamination and obtain fresh unweathered bedrock. Samples were collected at about 5 cm intervals across the K/T boundary and through a black clay layer about 1.5 m to 3 m above the boundary. Thereafter, sample spacing was gradually increased to 25 cm.

Samples were disaggregated according to standard micropaleontological techniques (Keller, 1985) and washed through a 63 micron screen. One section (Sinai border) was also analyzed for the $>105\ \mu m$ size fraction (Appendix 1a) in order to determine whether the larger size fraction significantly biases the biozonation and relative species abundances. It was found that nearly all species from the P0 to P1a interval are smaller than the $>105\ \mu m$ size fraction making it necessary to analyze the smaller size fraction. Quantitative foraminiferal analysis was therefore based on the $>63\ \mu m$ fraction. Samples were split into aliquots of about 300 specimens which were picked and mounted on microslides for a permanent record. The remainder of the sample was examined for rare species. All specimens were identified and relative percent abundances calculated and listed in Appendices 1–5. Percent carbonate analysis of bulk sediments was done with a Coulometric Carbonate analyzer with a precision of ±0.5%.

LITHOLOGY

All five early Paleocene sections examined from the Negev of Israel are very similar in lithology, stratigraphy and faunal turnover. Tan colored chalk and marl of the upper Maastrichtian Ghareb Formation are overlain by light grey colored shale and clay of the Paleocene Taqiye Formation. The K/T boundary contact between these two formations is bioturbated and shows reworking of tan colored Maastrichtian sediments into the grey Paleocene clay. (Stratigraphically the K/T boundary was recognized by the first appearance of Tertiary planktic foraminifers as discussed below.) This interval of mixed lithologies ranges between 20 to 50 cm in thickness. First and last appearances of species within this reworked interval may be biased. Uniform grey clay and shale succeed the interval of mixed tan and grey colored lithologies. Between 1.5 m and 3.0 m above the K/T boundary a thin 5 cm to 15 cm thick dark grey to black pyrite-rich clay horizon is present in all Negev sections examined. At its base there is a thin rust-red layer similar to the basal thin rust-red layer at the base of the K/T boundary clay in many of the most complete boundary sections (Keller, 1988a; Schmitz, 1988; Canudo et al., 1991). Above the clay horizon in the Negev sections, a light grey shale lithology resumes and becomes increasingly calcareous upsection.

BIOSTRATIGRAPHY AND FAUNAL ABUNDANCE

The ranges of planktic foraminifera are illustrated in Figures 2 and 3 for all five Negev sections examined and percent species abundances are listed in Appendices 1–5.

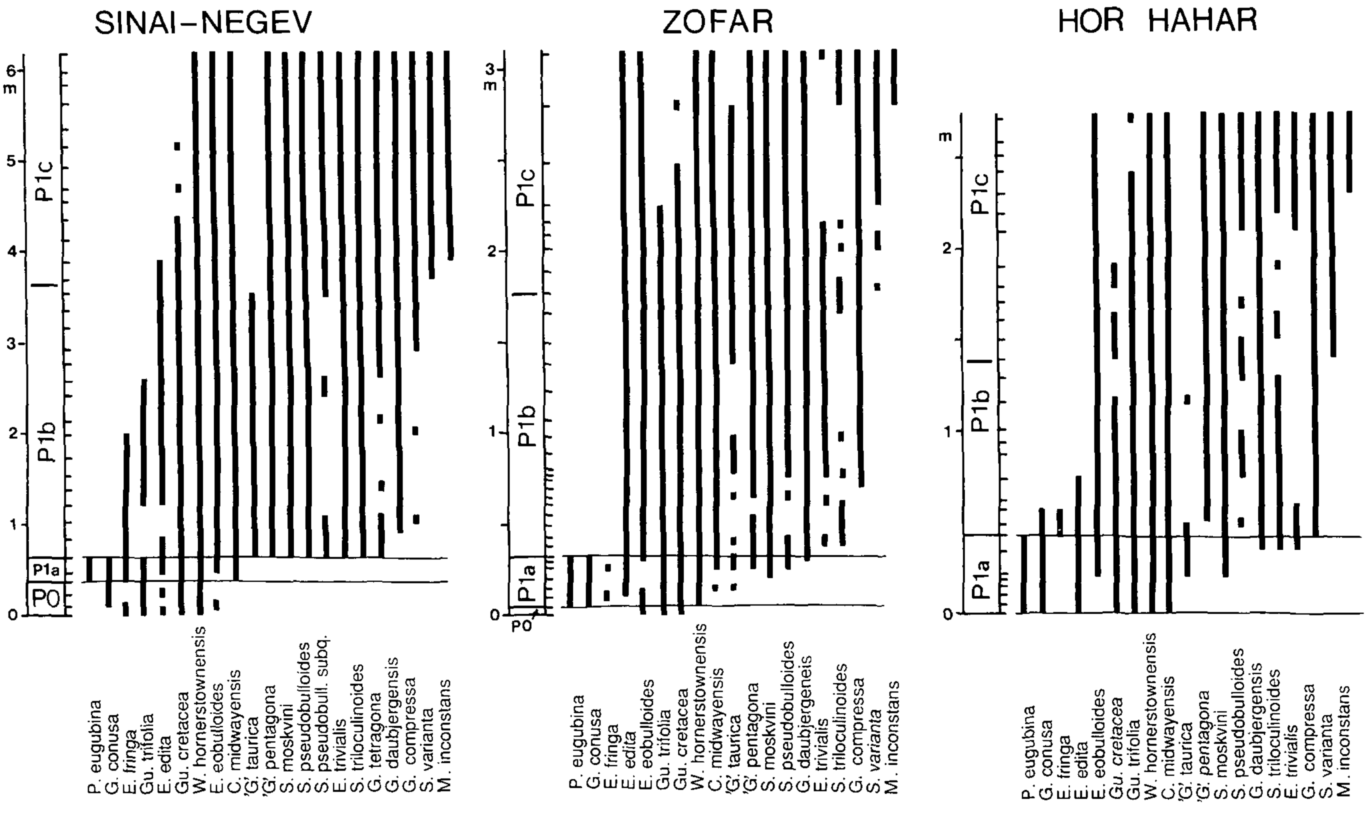

FIGURE 2—Species ranges of planktic foraminifera for the Sinai, Zofar and Hor HaHar sections.

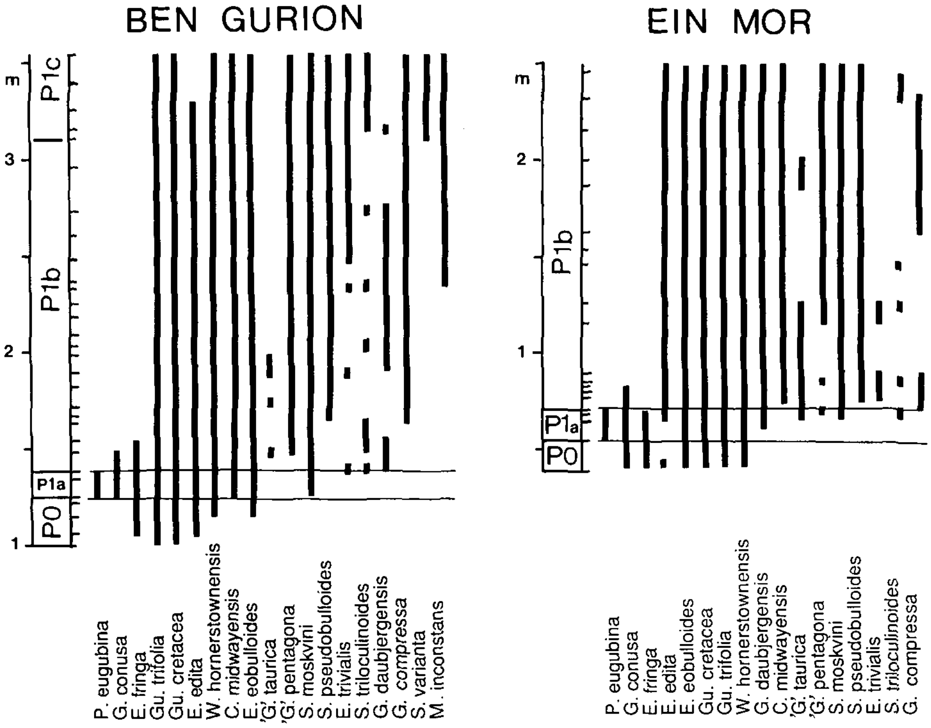

FIGURE 3—Species ranges of planktic foraminifera for the Ben Gurion and Ein Mor sections.

First and last appearances of some species differ between sections due to bioturbation, diachroneity, rare or sporadic occurrences and possibly an incomplete sedimentary record. Many of these problems are inherent in all sedimentary sequences. In contrast, relative species abundance patterns are less affected by these problems (except an incomplete sediment record) because patterns of relative abundance are generally responding to regional oceanographic conditions, which are compared from section to section. This method provides a potentially more rigorous method of local time correlation between comparable locations (i.e., shallow water marginal basins) and can provide a means of judging incompleteness of the sedimentary record. Hence, species range data, combined with relative species abundance data can provide optimum high resolution biostratigraphic correlation.

Phylogenies of Danian species are not well understood and generic and sometimes species assignments are in flux reflecting the current state of uncertainty. Studies now underway by the present authors, as well as others, will revise current taxonomy based on a significantly improved understanding of ancestor-descendant relationships among Danian species. However, these studies have so far produced no definitive generic division among the numerous taxa and we therefore prefer to use generic assignations that are most commonly used in the literature and discussed in Canudo et al. (1991). Our species concepts of the most common forms are illustrated in Figures 4 and 5.

K/T BOUNDARY—ZONE P0

Many biostratigraphers have failed to recognize a pre-*eugubina* zone Tertiary faunal interval, including Bolli (1957, 1966), Toumarkine and Luterbacher (1985), Blow (1979), Berggren (1978), and Berggren and Miller (1988). Smit (1977, 1982) discovered and defined this faunal interval Zone P0 (*G. cretacea*) and the concept was expanded and better defined by Keller (1988a) and Canudo et al. (1991). In stratigraphically complete K/T boundary sections Zone P0 is usually characterized by a dark grey to black clay layer. In the Negev sections no boundary clay was observed, rather the earliest Paleocene sediments are mixed and bioturbated with the underlying tan colored Maastrichtian marls. As a result, Cretaceous reworked foraminifera are abundant in earliest Paleocene sediments. Nevertheless, species of the earliest Paleocene Zone P0 (*Eoglobigerina fringa, Globastica conusa, Woodringina hornerstownensis,* Fig. 4, numbers 1, 9, 26–28) are present, although mixed with Cretaceous material, in an interval prior to the first appearance datum (FAD) of *Parvularugoglobigerina eugubina* in four out of five sections examined (Figs. 2, 3). The thickness of Zone P0 is variable ranging from 10 cm to 40 cm; this variability may be due to nondeposition, erosion, bioturbation and reworking of Cretaceous sediments. No relative species abundance data are provided for Zone P0 because of abundant reworked Cretaceous species in this interval as illustrated in Figures 6 to 10 (Appendices 1–5).

Subzone Pla

Subzone Pla was defined as a partial-range subzone from the first appearance (FAD) of *Parvularugoglobigerina eugubina* s.l. (which here includes *P. longiaperta*) to the first proliferation of *Eoglobigerina* spp. by Smit (1982) and Keller (1988a) and to the FAD of *Subbotina pseudobulloides* by Premoli-Silva and Bolli (1973) and Herm et al. (1981). Because of the diachronous first occurrence of *S. pseudobulloides,* and the local occurrence of the first *Eoglobigerina* spp. abundance peak, Canudo et al. (1991) proposed that the Pla Subzone interval include the total range of *P. longiapertura,* a species with a similar range as *P. eugubina,* but more easily identified and usually included in that group (Fig. 4, numbers 24, 25). We adopt this definition of Subzone Pla in this paper. This Pla Subzone differs from that of Berggren and Miller (1988) who characterized a higher stratigraphic interval ranging from the first appearance datum (FAD) of *S. pseudobulloides* to the FAD of *S. triloculinoides.* These taxa, however, have been shown to be diachronous by as much as 250,000 years (MacLeod and Keller, 1991b) as will be discussed below. In the Negev sections, the following species first appear within Subzone Pla: '*Globigerina*' (*Eoglobigerina?*) *taurica, S. moskvini, S. pseudobulloides, Chiloguembelina midwayensis* (Fig. 4, number 2, Fig. 5, numbers 1–3, 7–9, 10–12).

Relative abundances of dominant species provide a unique characterization of Subzone Pla in the eastern Tethys region. In all Negev sections examined, as well as in the El Kef section of Tunisia (Keller, 1988a), Pla is marked by abundant (20–40%) *P. eugubina* s.l. and *Guembelitria* (20–40%), common *Globastica conusa* and *Eoglobigerina edita* (not common at El Kef) (Figs. 4, 6–10). *Guembelitria* rapidly declines near the top of Pla. However, in all five Negev sections examined high abundances of *P. eugubina* s.l. appear and disappear abruptly suggesting truncation of its range. A similar pattern is observed by the high spired form of *Globastica conusa* except

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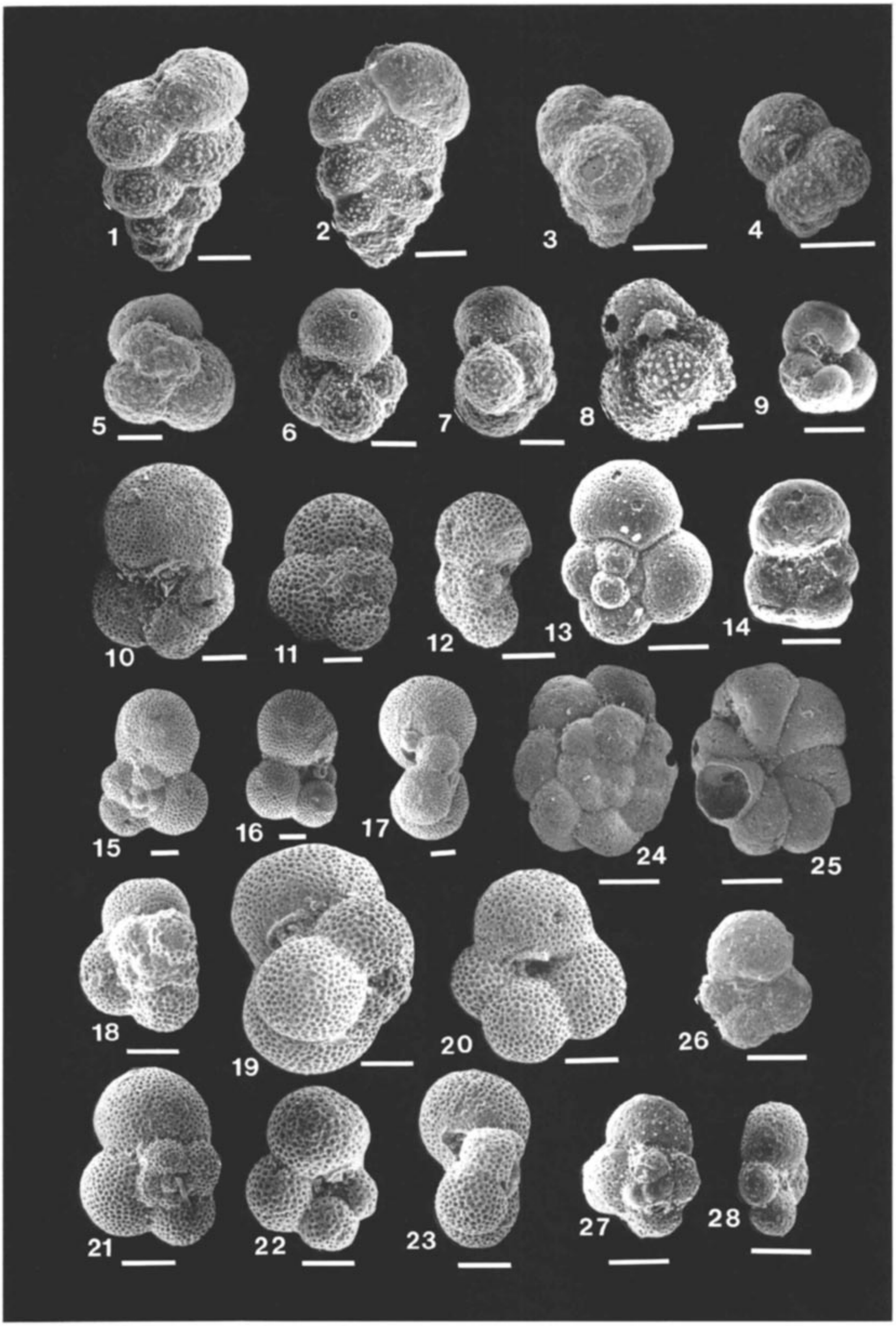
FIGURE 4—Serial and globigerinacean planktic foraminifera from the early Paleocene of the Negev, Israel. Bars = 50 μm. Nr. 1. *Woodringina hornerstownensis,* Zone P1c, Ben Gurion. Nr. 2. *Chiloguembelina midwayensis,* Zone P1c, Ben Gurion. Nr. 3. *Guembelitria cretacea,* Zone P1b, Zofar. Nr. 4. *Guembelitria trifolia,* Zone P1b, Zofar. Nr. 5–7. *Globastica daubjergensis,* Zone P1c, Ben Gurion. Nr. 8. *Globastica daubjergensis* (bullate form *G. kozlowskii* of Brotzen & Pozayska) Zone P1d, Ben Gurion. Nr. 9. *Globastica conusa,* Zone P0, Ein Mor. Nr. 10–12. *Eoglobigerina eobulloides,* Zone P1b, Zofar. Nr. 13–14. *Eoglobigerina eobulloides,* Zone P0, Ein Mor. Nr. 15–17. *Subbotina triangularis,* Zone P1c, Ben Gurion. Nr. 18–20. *Eoglobigerina trivialis,* Zone P1c, Ben Gurion. Nr. 21–23. *Subbotina varianta,* Zone P1c, Ben Gurion. Nr. 24–25. *Parvularugoglobigerina eugubina* (*P. longiapertura* sensu Blow), Zone P0, Sinai, Western Negev. Nr. 26–28. *Eoglobigerina fringa,* Zone P0, Ein Mor.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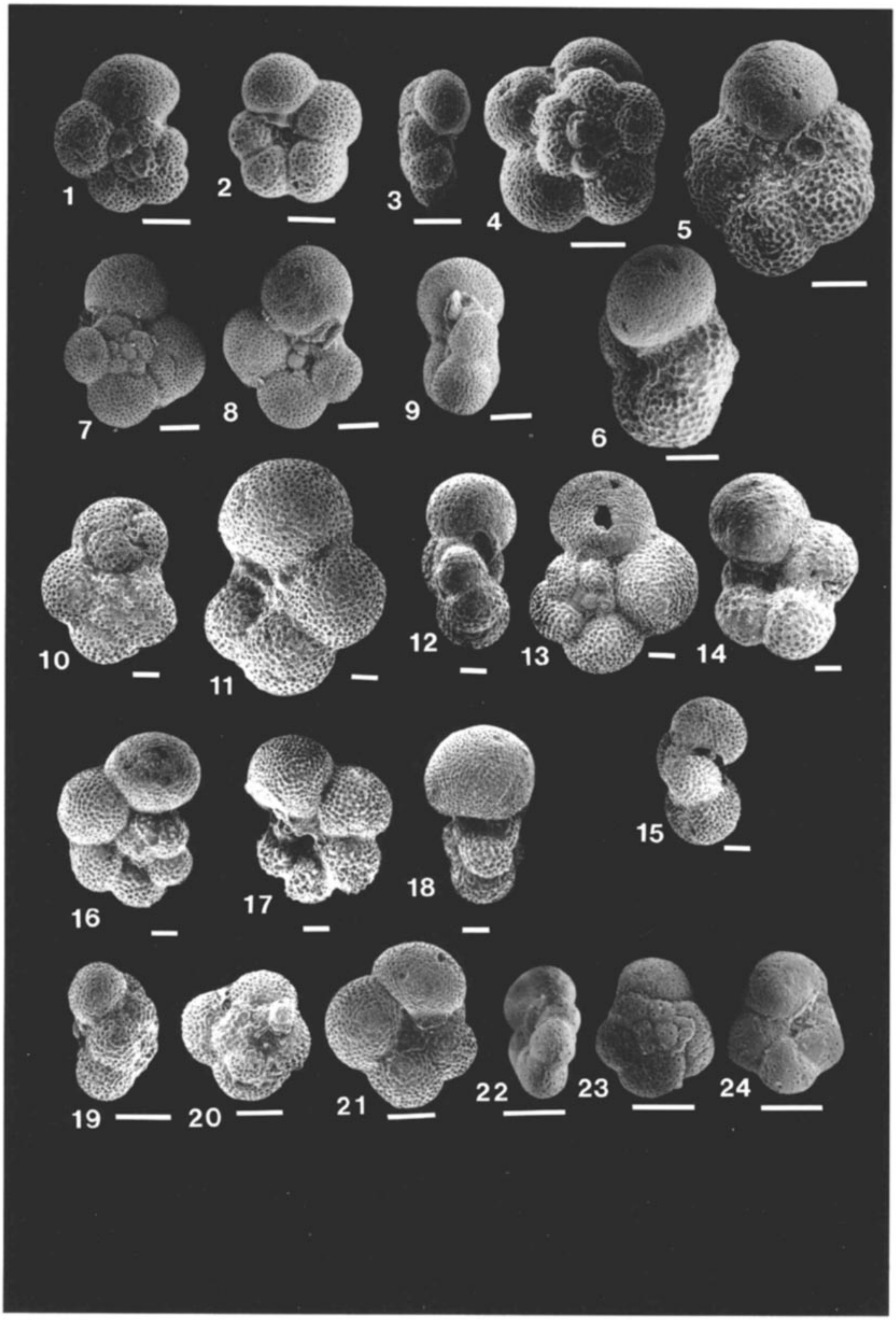
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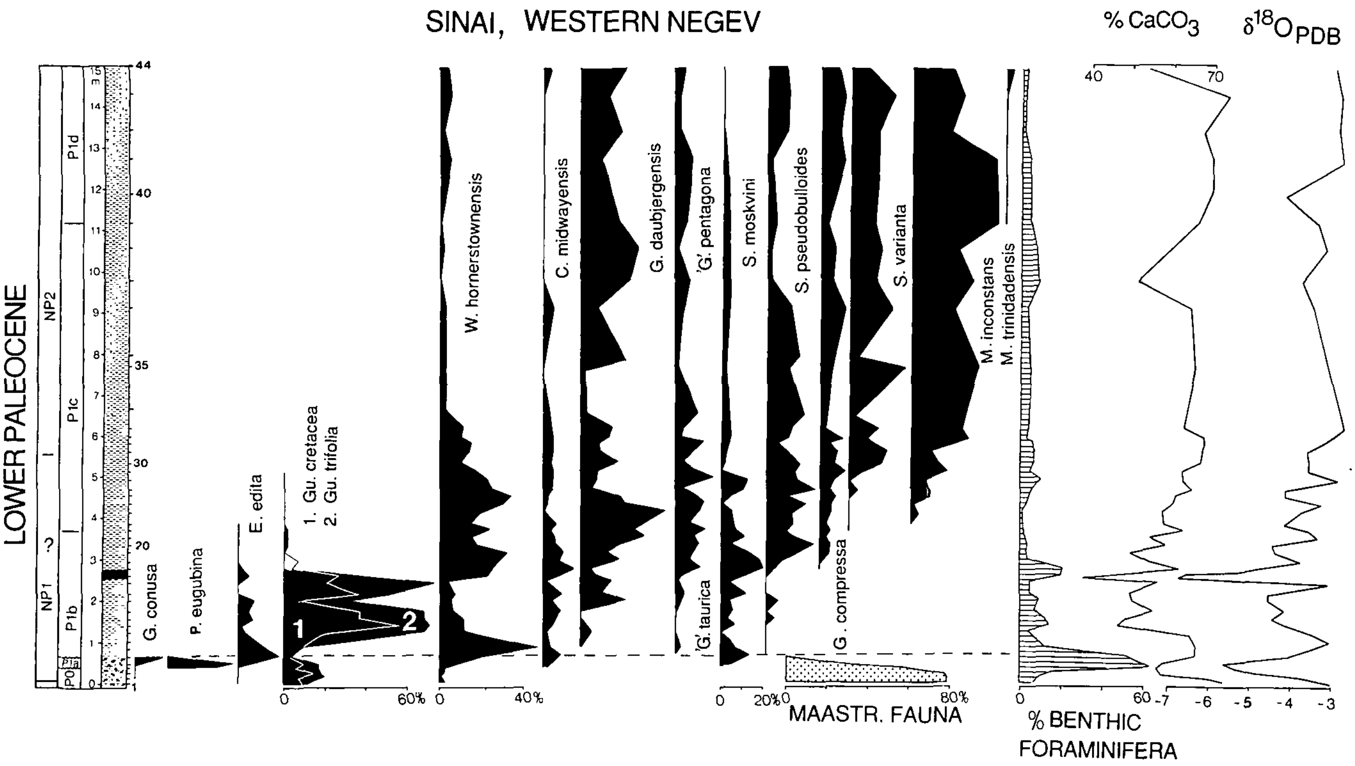

FIGURE 6—Planktic foraminiferal and nannofossil biozonation, dominant planktic foraminiferal species in the size fraction >63 μm, percent benthic foraminifera, percent Maastrichtian reworked species, %CaCO$_3$ and δ^{18}O values (bulk fine fraction carbonate, 32–63 μm), from the Western Sinai border section. Nannofossil biozonation from Keller et al. (1990). Lithology column indicates marls with mottled pattern at the base of the lithology column marking bioturbation and redeposition of Cretaceous sediment. Depth is in meters. Sample locations (tick marks) in section and sample numbers are marked in right hand column and Appendices 1-5.

in the Hor HaHar section. Such truncation of species abundance, along with the presence of reworked Cretaceous taxa, can be taken to imply an incomplete stratigraphic record due to a hiatus. The condensed or short Pla interval in all Negev sections combined with the truncation of species abundances at its upper and lower boundaries, strongly implies short hiatuses at the P0/Pla and Pla/Plb Subzone boundaries. In addition, significant reworking of Maastrichtian sediments ceases abruptly at the Pla/Plb boundary. Graphic correlation of microfossil datum events and relative abundance distribution of dominant species from the Negev sections with those of El Kef (Keller, 1988a), Spain (Canudo et al., 1991) and Brazos River, Texas (Keller, 1989a) corroborates the presence of hiatuses at these subzone boundaries (MacLeod and Keller, 1991a,b).

Subzone Plb

Keller (1988a) based the definition of the top of Subzone Plb on the last appearance datum (LAD) of '*Globigerina*' (*E.*) *taurica*. This datum appears diachronous in the Negev sections (Figs. 2, 3). Therefore, Subzone Plb is recognized in these sections as the interval between the *P. eugubina* s.l. LAD and the *Subbotina varianta* FAD. In all sections examined *S. varianta* first appears at or near a thin grey-black clay horizon which forms a prominent and presumably coeval stratigraphic marker. Near the Pla/Plb boundary a large number of species first appear in the Negev sections including *Globastica daubjergensis*, *Subbotina pseudobulloides*, *Globanomalina compressa*, '*Globigerina*' *pentagona*, *S. triloculinoides*, *E. trivialis* (Figs. 4, 5). Berggren and Miller (1988) defined a Subzone Plb

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FIGURE 5—Globorotaliform planktic foraminifera from the early Paleocene of the Negev. Bars = 50 μm. Nr. 1–3. '*Globigerina*' (*E.*) *taurica*, Zone P1c, Ben Gurion. Nr. 4–6. '*Globigerina*' *pentagona*, Zone P1b, Zofar. Nr. 7–9. *Subbotina moskvini*, Zone P1b, Zofar. Nr. 10–12. *Subbotina* cf. *pseudobulloides*, Zone P1b, Ben Gurion. Nr. 13–15. *Subbotina pseudobulloides*, Zone P1d, Ben Gurion. Nr. 16–18. *Morozovella trinidadensis*, Zone P1d, Ben Gurion. Nr. 19–21. *Eoglobigerina edita*, Zone P1b, Ben Gurion. Nr. 22–24. *Globanomalina planocompressa*, Zone P1b, Zofar.

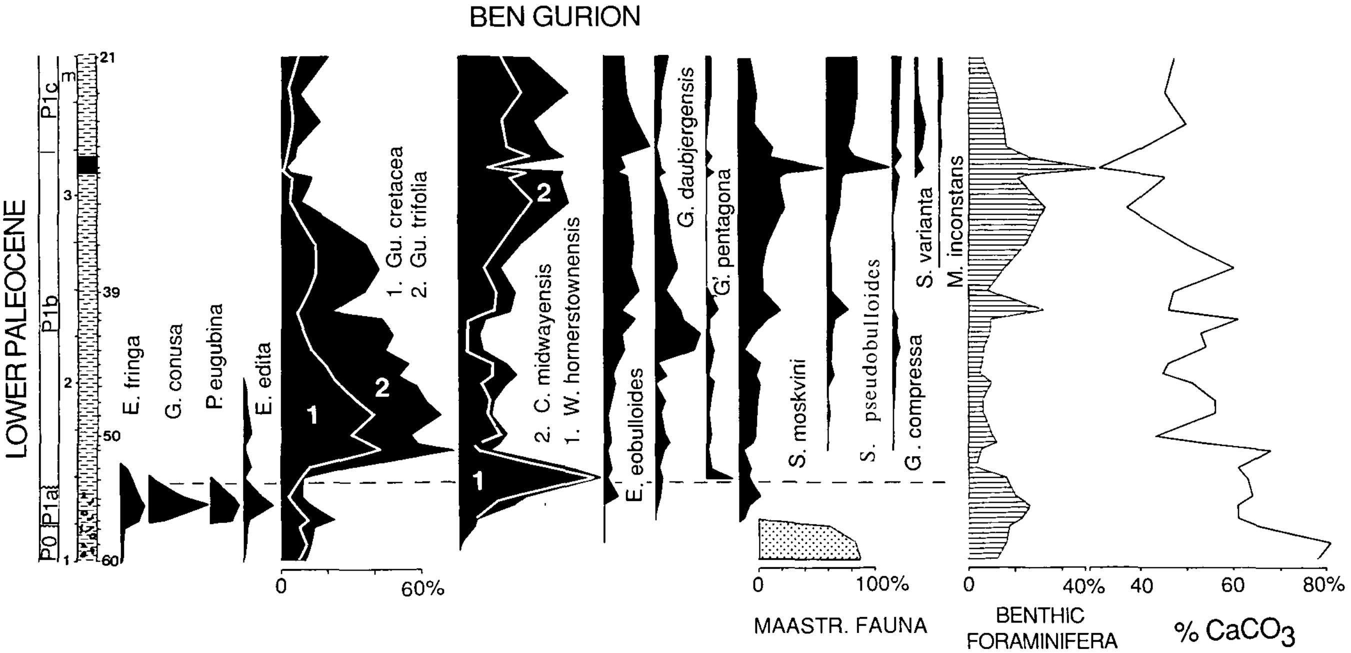

FIGURE 7—Planktic foraminiferal biozonation, relative population abundances of dominant species in the size fraction >63 μm, percent benthic foraminifera, percent Maastrichtian reworked species and %$CaCO_3$ data from the Ben Gurion section (data from D'Hondt and Keller, 1991). See Figure 6 for complete caption.

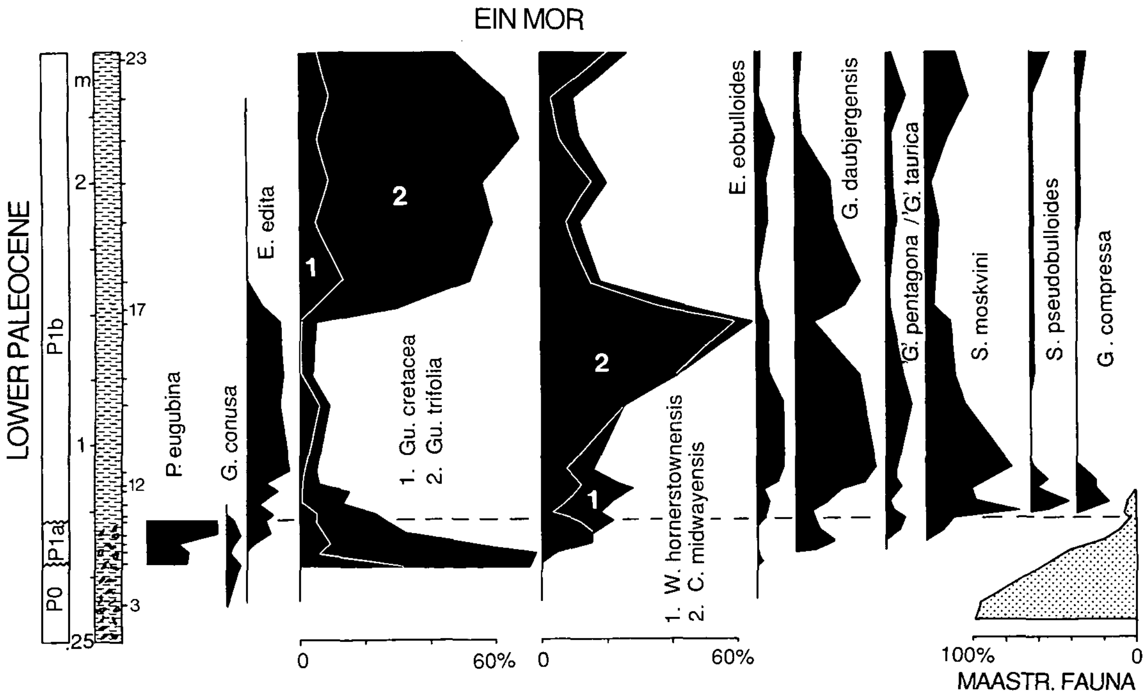

FIGURE 8—Planktic foraminiferal biozonation, relative population abundances of dominant species in the size fraction >63 μm and percent Maastrichtian reworked species from the Ein Mor section. See Figure 6 for complete caption.

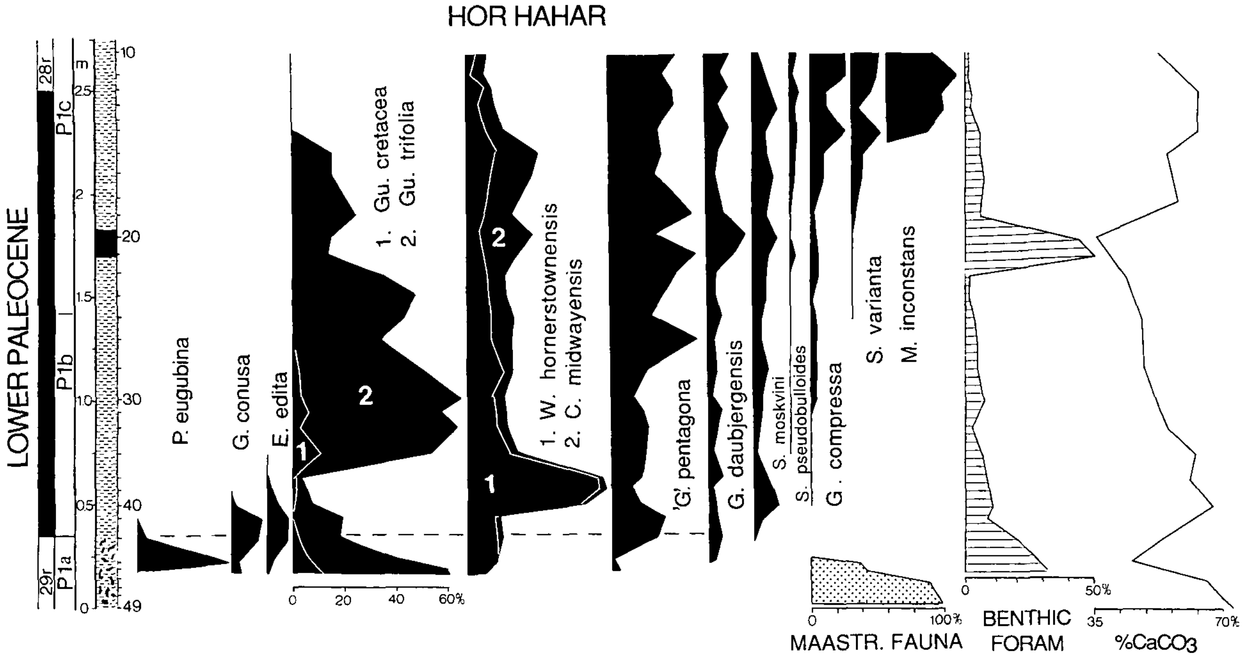

FIGURE 9—Planktic foraminiferal biozonation, magnetostratigraphy from Magaritz et al. (1985), relative population abundances of dominant species in the size fraction >63 μm, percent benthic foraminifera, percent Maastrichtian reworked species, and %CaCO$_3$ data from the Hor HaHar section. See Figure 6 for complete caption.

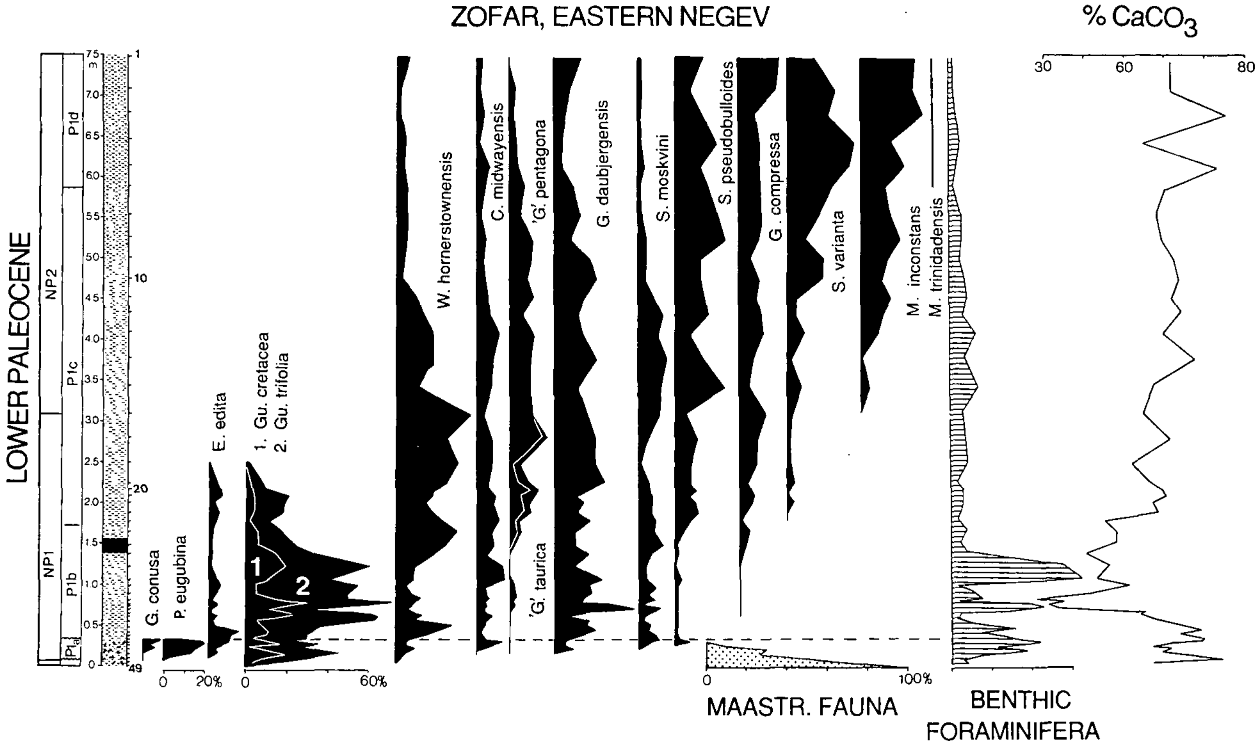

FIGURE 10—Planktic foraminiferal and nannofossil biozonation, relative population abundances of dominant species in the size fraction >63 μm, percent benthic foraminifera, percent Maastrichtian reworked species and %CaCO$_3$ data from the Zofar section. Nannofossil biozonation from Keller et al. (1990). See Figure 6 for complete caption.

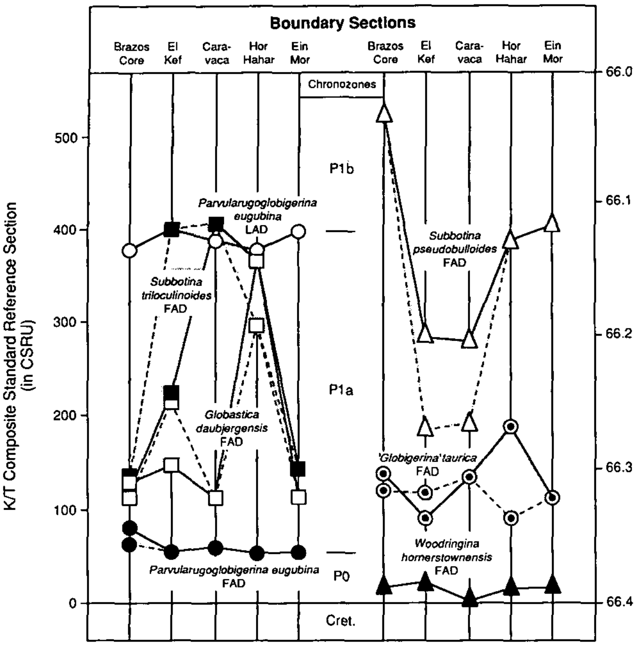

FIGURE 11—Estimated temporal positions of 7 lower Danian planktic foraminiferal datums in 5 K/T boundary sections. Stippled areas represent alternative placements of datum events based on 'best case' and 'worst case' correlation models. Age scale based on geochronologic calibration by Berggren et al. (1985) and MacLeod and Keller (1991a,b). Note the diachrony of some datums ranges up to 250,000 years among the sections examined.

between the first appearances of *S. triloculinoides* and *Morozovella trinidadensis* which spans Subzones P1b and P1c of this report. Their concept also differs from Berggren et al. (1985) and Blow (1979).

Subzone P1b is most easily characterized by the relative abundance changes of dominant species (Figs. 6–10). In all Negev sections, as well as El Kef, the lower part of P1b is marked by a dramatic but short-lived decline of the dominant triserial *Guembelitria* group to generally less than 20% and a concurrent increase in the biserial group to 40–65% (*Woodringina hornerstownensis* and *Chiloguembelina midwayensis*) to form the first abundance peak. Also common for the first time during this interval are *Eoglobigerina edita, S. moskvini* and *Globastica daubjergensis*. In the upper half of P1b the faunal assemblage rapidly reverts back to one dominated by *Guembelitria* (40–70%) and low abundance of the biserial group (<20%). The uppermost part of P1b, just below the pyrite-rich dark-grey clay horizon in the Negev sections, is characterized in all sections by the terminal decline in the triserial *Guembelitria* group and a concurrent increase in the biserial group. Quantitative foraminiferal studies of Agost and Caravaca, Spain (Canudo et al. 1991) and the South Atlantic DSDP Site 528 (D'Hondt and Keller, 1991) reveal similar and coeval faunal abundance changes providing evidence for open oceanic conditions in the eastern Tethys during the early Paleocene.

Subzone P1c

Smit (1982) and Keller (1988a) defined Subzone P1c from the last appearance of *'Globigerina'* (*Eoglobigerina?*) *taurica* to the first appearance of *Morozovella trinidadensis*. As *'G.'* (*E.*) *taurica* is rare in the Negev sections, we recognized the base of Subzone P1c by the first occurrence of *S. varianta*. The first appearance of *M. trinidadensis* defines the top of Subzone P1c.

A major faunal turnover characterizes the lower part of Subzone P1c as illustrated by the relative species abundance changes (Figs. 6–10). Most notable are the decline and eventual extinction of the *Guembelitria* group and *E. edita* followed by increasing abundances of the biserial group (*W. hornerstownensis, Chiloguembelina midwayensis*). *Subbotina pseudobulloides* and *Globastica daubjergensis* are common. The biserial group declines in relative abundance in the middle of Subzone P1c and is replaced by increased abundances of *S. varianta* and *Morozovella inconstans*.

TEMPORAL RELIABILITY OF STRATIGRAPHIC MARKER TAXA

Microfossil datum events (FAD's and LAD's) are routinely employed in stratigraphic studies to infer temporal completeness from biostratigraphic data. Unfortunately, datum events are often diachronous (Barron et al., 1985; Pisias et al., 1985; Hazel, 1989). Many early Paleocene (Danian) microfossil datum events have also been suspected of diachroneity although no comprehensive correlation scheme has been developed to evaluate the age difference in various regions. Recently, MacLeod and Keller (1991a,b) have used graphic correlation to evaluate 15 of the most complete early Paleocene (Danian) stratigraphic sequences. This graphic correlation method permits evaluation of the discrepancies in the chronostratigraphic occurrence of datum events between sections and geographic regions. Based on this study the occurrences of 7 commonly used Danian datum events in sections from Brazos River in Texas, El Kef in Tunisia, Caravaca in Spain and Hor HaHar and Ein Mor in the Negev, Israel, are illustrated in Figure 11 (MacLeod and Keller, 1991b). The time scale is based on Berggren et al. (1985). Stippled areas indicate alternative placements of datum events based on 'best case' and 'worst case' models of the graphic correlation scheme by MacLeod and Keller (1991b).

Figure 11 shows that the first (FAD) and last appearance (LAD) datums of *Parvularugoglobigerina eugubina* and *Woodringina hornerstownensis* FAD show little discrepancy in their chronostratigraphic occurrence in the five sections examined. The possible range between 'best case' and 'worst case' placements (stippled areas) indicate a maximum discrepancy of only a few thousand years. In contrast, the *'Globigerina' taurica* FAD is a less reliable datum event showing a discrepancy of tens of thousands of years even within the Negev region. Surprisingly, however, the index taxa *Subbotina pseudobulloides* FAD, *S. triloculinoides* FAD and *Globastica daubjergensis* FAD

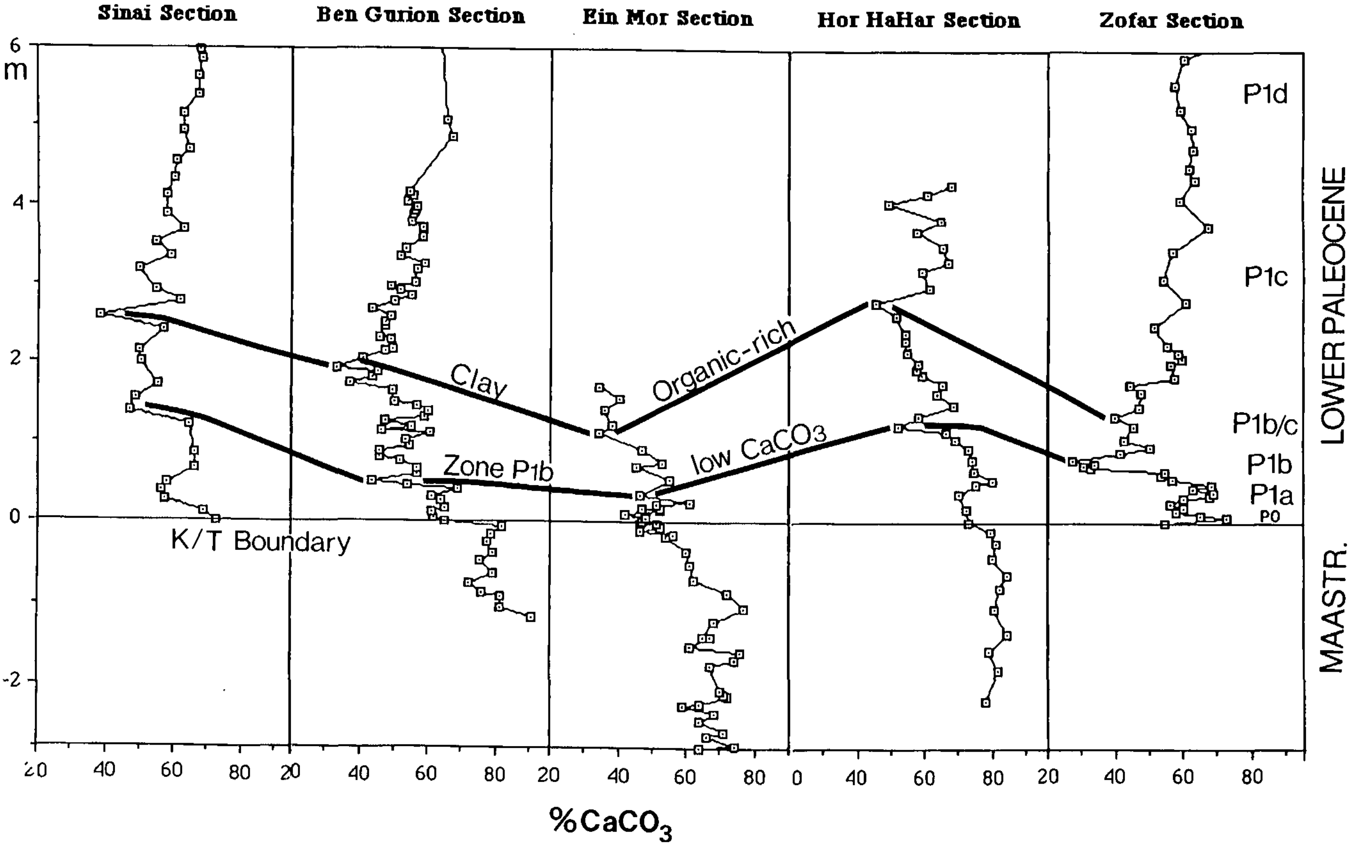

FIGURE 12—Percent $CaCO_3$ values of the Negev sections. Correlation lines mark negative $CaCO_3$ excursions at the K/T boundary, in Subzone P1b and at the dark grey-black pyrite and organic-rich clay layer near the Subzone P1b/P1c boundary.

show very large discrepancies between the five sections examined with intersequence diachroneity ranging up to 250,000 years. This large discrepancy in the FAD's is partly due to the difficulties in recognizing the evolutionary transitions from one species to another. Such evolutionary transitions are often not reliable stratigraphic markers and their use in biostratigraphic zonations should be reevaluated.

CARBONATE RECORDS AND FAUNAL TURNOVER

Sedimentary bulk $CaCO_3$ was analyzed for all Negev sections examined as illustrated in Figure 12 and individually in Figures 6, 7, 9 and 10. Percent $CaCO_3$ values in the five sections measured show considerable uniformity with values averaging 70–80% in the late Maastrichtian. A decline to lower %$CaCO_3$ values begins within the latest Maastrichtian prior to the K/T boundary as illustrated in the Ein Mor section (Fig. 12) and a similar trend may be indicated in the Hor HaHar and Ben Gurion sections although their records are incomplete. This decrease in carbonate values correlates with the latest Maastrichtian sea level regression (Haq et al., 1987; Brinkhuis and Zachariasse, 1988; Keller, 1988b; Peypouquet et al., 1986; Donovan et al., 1988).

Interpretation of earliest Tertiary %$CaCO_3$ data is complicated by low rates of sediment deposition as a result of short hiatuses at the K/T boundary and P0/P1a and P1a/P1b boundaries as well as reworking of Cretaceous sediments throughout this interval. Despite these difficulties three major negative excursions in %$CaCO_3$ can be recognized (K/T boundary, lower Zone P1b low $CaCO_3$, and organic-rich clay near P1b/P1c boundary, see Fig. 12). These negative carbonate excursions are associated with: 1) absence of terrigenous sediments, 2) absence of carbonate dissolution, 3) increased abundance of benthic foraminifers and 4) major changes in planktic foraminiferal assemblages which imply changes in marine productivity.

The first sudden drop in %$CaCO_3$ values occurs at the K/T boundary (Ein Mor, Hor HaHar, Ben Gurion, Fig. 12, see also Magaritz et al., 1985), but in some sections the signal is dampened due to reworked Maastrichtian sediments into basal Tertiary clays as discussed earlier. A sudden drop in %$CaCO_3$ at the K/T boundary has been observed in nearly all marine sections, associated with major species extinctions and a negative excursion in $\delta^{13}C$ values of plankton associated with a decrease in surface to deep gradients which is generally interpreted as a drop in marine plankton productivity (Hsu et al., 1982; Zachos and Arthur, 1986; Keller and Lindinger, 1989; Barrera and Keller, 1990). Most Cretaceous planktic foraminifera became extinct at or before this time leaving the small Cretaceous survivor, *Guembelitria cretacea,* to dominate (Smit, 1982; Keller, 1988a, 1989a, b; Brinkhuis and Zachariasse, 1988). However, the dominance of this species in the Sinai and Zofar sections is masked by the presence of abundant reworked Cretaceous species (Figs. 6–10). The Zone P0 to P1a transition is unclear in the Negev because of a short hiatus at this boundary. At El Kef, however, this interval is characterized by very low $CaCO_3$ values, dominance of *Guembelitria,* low productivity and a rapidly rising sea level (Brinkhius and Zachariasse, 1988; Keller, 1988a, b).

The second major negative excursion in $CaCO_3$ occurs in the lower half of Subzone P1b (Fig. 12) following a hiatus in the Negev sections. At this interval carbonate values drop by 20 to 40%. It is likely that the magnitude of this carbonate drop is exaggerated due to the fall-off of reworked carbonate-rich Cretaceous sediment common in the preceding Subzone P1a. A short peak in abundance of biserial species at this hiatus is followed by dominance in the triserial species *Guembelitria cretacea* and *G. trifolia.*

The third negative excursion in % $CaCO_3$ is accompanied by an ^{18}O depletion event (Fig. 6, Magaritz et al., in prep.) and an increase in benthic foraminifera which occurs in the pyrite- and organic-rich dark-grey clay layer that occurs near the planktic foraminiferal Subzone P1b/P1c boundary (Figs. 6–10). In this interval carbonate values generally drop from about 55–60% to about 40% in the Negev sections and $\delta^{18}O$ values drop to -5 to -7 permil (Fig. 6, Magaritz et al., in prep.). This negative excursion in $CaCO_3$ and fine fraction $\delta^{18}O$ is associated with a rapid and terminal decline in the triserial group (*G. cretacea, G. trifolia*) and an increase in the biserial group (Figs. 6–10). (The variable stratigraphic occurrence of this clay layer from within Subzone P1b to the lower part of P1c in the Negev sections is likely due to the diachronous first occurrence of *Subbotina varianta* which is tentatively used to mark the P1b/c boundary in this study.)

Although the increase in benthic foraminifera associated with organic-rich clay implies dissolution of fragile planktic species, no dissolution features were observed and fragile species are common. Moreover, the association of a large ^{18}O depletion and enrichment in organic matter has been interpreted to indicate times of sapropel formation and has been attributed to the creation of a low salinity surface layer in the Mediterranean Sea during the Neogene (Rossignol-Strick et al., 1982; Thunell et al., 1984). Magaritz et al. (in prep.) suggest that sapropelic environmental conditions may also have prevailed at times in the eastern Tethys during the early Tertiary. If so, then the absence of a contemporaneous dark organic-rich clay layer in Tunisia and Spain would imply that sapropelic environmental conditions would have been restricted to the eastern Tethys at this time.

Above the grey to black clay layer %$CaCO_3$ values gradually increase through the early part of Subzone P1c and stabilize between 60–70% during the remainder of Subzones P1c to P1d. Paleomagnetic data from the Hor HaHar section (Magaritz et al., 1985) indicates that carbonate values stabilize near the top of Chron 29N (Fig. 9). A major faunal turnover among planktic foraminiferal assemblages and the first mass occurrence of Tertiary nannofossils (Keller et al., 1990) occur during the interval of gradual increase in carbonate sedimentation as illustrated in Figures 6–10. Several planktonic foraminiferal species evolve at this time but do not establish stable populations until carbonate values reach a stable high level (*Globanomalina compressa, Morozovella inconstans, Subbotina varianta*). Other species thrive during the gradual rise but decline once carbonate sedimentation stabilizes (*Woodringina hornerstownensis, Globastica conusa, 'Globigerina' pentagona, S. moskvini, S. pseudobulloides*).

DISCUSSION

The results of our stratigraphic, faunal and sedimentary carbonate analyses are summarized in Figure 13. There appears to be a strong correlation between major faunal turnovers in marine plankton, major changes in carbonate deposition rates and hiatuses. Stratigraphic and faunal data indicate a period of intensified current activity and/or decreased sedimentation at the time of decreased marine productivity beginning at the K/T boundary and ending near the P1a/P1b boundary. In this short interval, three hiatuses or periods of non-deposition can be identified. The first hiatus coincides with the K/T boundary as also observed in numerous deep-sea sections (MacLeod and Keller, 1991a,b). Subsequently, tan colored Maastrichtian sediments were mixed into early Tertiary grey clays during P0 and P1a by current activity and bioturbation. Major mixing of sediments decreases rapidly near the P1a/P1b boundary as indicated by decreasing numbers of Maastrichtian foraminifers (Figs. 6–10, Appendices 1–5). Two short hiatuses or periods of non-deposition are recognized at the P0/P1a and P1a/P1b boundaries as implied by the abrupt truncation of abundant *P. eugubina* s.l. and *Globastica conusa* and by the very short sedimentary thickness of this interval as compared to El Kef, Brazos River (Keller, 1988a, 1989a, b), Agost and Caravaca sections (Canudo et al., 1991). These three short hiatuses or periods of non-deposition are correlative with changes in global oceanographic conditions. The first hiatus at the K/T boundary may be correlative with the latest Maastrichtian sea level regression (Haq et al., 1987; Brinkhuis and Zachariasse, 1988; Donovan et al., 1988) as well as the environmental changes associated with the K/T boundary event. The second and third hiatuses are correlative with coeval hiatuses or non-deposition at Brazos, Texas (Keller, 1989a), Agost and Caravaca in Spain (Canudo et al., 1991; MacLeod and Keller, 1991b). A generally rising sea level interrupted by two minor regressive phases at the top of Zone P0 and in Zone P1a have been identified by Brinkhuis and Zachariasse (1988) at El Kef based on dinoflagellate analysis (Fig. 13) and Haq et al. (1987) and Donovan et al. (1988) have identified a global sea level transgression

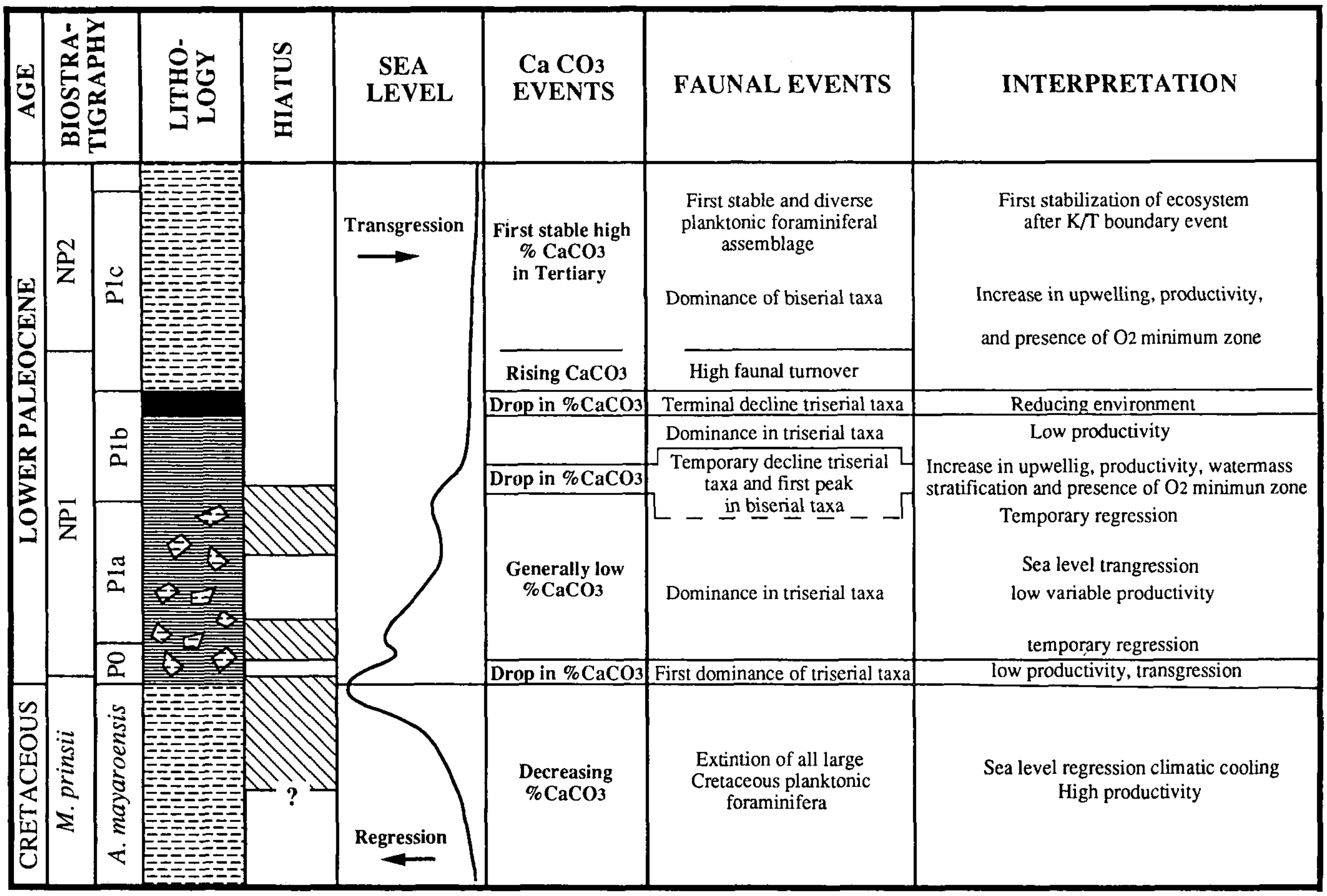

FIGURE 13—Summary of early Paleocene hiatuses or intervals of non-deposition, sea level fluctuations (Brinkhuis and Zachariasse, 1988), $CaCO_3$ and faunal events in the eastern Tethys. Paleomagnetic data from Magaritz et al. (1985) and stratigraphic correlation to the paleomagnetic time scale based on Berggren et al. (1985). Lithology: dashed intervals = high carbonate marls; horizontal lines = low carbonate marls with reworked Cretaceous marls; black interval = dark grey pyrite- and organic-rich clay.

during this time. Thus, the upper two hiatuses or non-deposition events may be due to sediment starvation during generally transgressive seas punctuated by two short regressive phases.

Planktic foraminifera are sensitive to environmental changes and can offer clues to the post-K/T environment. Although the biological needs of planktic foraminifera, their preferred water depth, oxygen, salinity, temperature and nutrient levels, are either unknown or only poorly understood at this time, some inferences regarding the early Tertiary environment can be made based on relative abundance changes of dominant species associated with changes in the oxygen and carbon isotope record. For instance, latest Maastrichtian planktic foraminiferal assemblages are dominated by the biserial genus *Heterohelix* (primarily *H. globulosa* and *H. navarroensis*) in shallow continental shelf sections. Species of this genus have been shown to survive the K/T boundary event although in dwarfed forms at El Kef and Brazos River sections (Keller, 1988a, 1989a; Barrera and Keller, 1990), but no determinations could be made in the Negev sections because of abundant reworking and bioturbation. At Brazos River, *H. globulosa* dominates for a short time after the K/T boundary event and then gradually declines simultaneously with a gradual depletion in $\delta^{13}C$ and $\delta^{18}O$ values of both this species and the benthic foraminifer *Lenticulina* sp. (Barrera and Keller, 1990). The $\delta^{13}C$ depletion, in association with a decreased surface to deep ^{13}C gradient in the deep sea, has been interpreted as a substantial reduction in surface water productivity (Boersma and Shackleton, 1981; Perch-Nielsen et al., 1982; Zachos and Arthur, 1986; Keller and Lindinger, 1989).

Barrera and Keller's (1990) study thus implies that *H. globulosa* thrived during the high productivity environment of the late Maastrichtian but declined in the Danian when productivity was reduced, possibly in association with a rise in temperature after the K/T boundary event. Oxygen isotope analysis of planktic foraminifers indicates that *Heterohelix globulosa* may have lived below the surface mixed layer (Boersma and Shackleton, 1981).

The decline of *Heterohelix* is followed by dominance of the triserial *Guembelitria* group in the earliest Tertiary, a genus which is present only in low abundances during the late Maastrichtian (Smit, 1982; Gerstel et al., 1987; Brinkhuis and Zachariasse, 1988; Keller, 1988a, 1989a, b). This genus (*Guembelitria cretacea, G. trifolia*) increased in relative abundance in Zone P0 coincident with the K/T boundary $\delta^{13}C$ depletion. In the Negev, as well as at El Kef (Keller, 1988a), Agost and Caravaca (Canudo et al., 1991) and DSDP Site 528 (D'Hondt and Keller, 1991), a dramatic temporary decrease in the abundance of *Guembelitria* near the P1a/P1b boundary occurs simultaneously with a major abundance increase in *W. hornerstownensis*. Similarly, the terminal decline of *Guembelitria* near the P1b/P1c boundary corresponds to an abundance increase in biserial taxa (*W. hornerstownensis, Chiloguembelina midwayensis*).

Guembelitria cretacea is well known in Maastrichtian shelf deposits, but generally rare in open marine sediments (McGowran and Beecroft, 1985; Keller, 1988a, 1989a, b; D'Hondt and Keller, 1991; Canudo et al., 1991). In early Danian sediments this species is generally common including in open marine sediments (e.g., Site 528, D'Hondt and Keller, 1991), and may constitute the bulk of the planktic foraminiferal fauna (Olsson, 1970; Hofker, 1978; Smit, 1977, 1982; Keller, 1988a, 1989a, b; Canudo et al., 1991). McGowan and Beecroft (1985) suggested that late Paleogene *Guembelitria* abundance peaks generally correspond to climatic cooling whereas *Chiloguembelina* peaks either precede or succeed these intervals. Kroon and Nederbragt (1990) studied the recent triserial species *Gallitellia vivans* and found its $\delta^{18}O$ values to be between that of the deep dwelling *Globorotalia menardii* and the surface dwelling *Globigerinoides trilobus*. From this data they inferred that *G. vivans* lives in the variable conditions of the outer shelf upwelling region. They then deduced, solely on the basis of this data, that the early Paleocene *Guembelitria cretacea* also thrived in high productivity upwelling regions characterized by unstable marine conditions. Since *G. cretacea* maximum abundances are associated with $\delta^{13}C$ depleted intervals (presumably low surface productivity), this conclusion is not supported by current faunal or isotopic data.

Kroon and Nederbragt's (1990) assumption that the Cretaceous to Danian species *Guembelitria cretacea* lived in a similar upwelling region as the living species *Gallitellia vivans* is based on overall morphological similarities—both taxa are triserial. This is analogous to the assumption that all keeled globorotalid foraminifers lived below the surface mixed layer. However, Shackleton et al. (1985) and Corfield (1987) have shown that this assumption is incorrect. Paleocene keeled morozovellids lived in the photic zone, whereas Neogene keeled globorotalids lived in deeper waters. Thus, it is necessary to evaluate the relative stable isotope ranking of *G. cretacea* within Danian planktic foraminiferal assemblages to determine the depth habitat of this species in the water column.

There is little isotopic data published on Danian *Guembelitria* and *Chiloguembelina* species and the available highly variable data precludes conclusions regarding their depth habitat or other environmental preferences. For instance, Boersma and Premoli-Silva (1987) measured $\delta^{18}O$ values of *Guembelitria cretacea* and *Chiloguembelina morsei* in three samples. At Site 356 (core 29-3) they found *G. cretacea* to be 0.79 permil lighter than *C. morsei*. But at Site 465 (cores 3-1, 3-3) they found *G. cretacea* to be nearly 2.0 permil and 0.22 permil heavier respectively than *C. morsei*. Clearly, a systematic analysis of Danian species is necessary before any conclusions can be reached regarding the depth habitat and environmental preferences of triserial and biserial species.

From faunal and isotopic data available to date, we can infer that Danian biserial taxa thrived in outer continental shelf regions within or just below the photic zone (surface mixed layer), at times of high productivity (Barrera and Keller, 1990) and possibly within a low oxygen layer (Boersma and Premoli-Silva, 1987). Danian triserial taxa (*G. cretacea*) also seem to thrive in shallow continental shelf regions, probably within the photic zone, and at times of low surface productivity ($\delta^{13}C$ depletion). The alternating triserial/biserial abundance peaks observed in the Negev sections, as well as in other Tethyan environments, strongly suggest that they do not share the habitat of biserial taxa at times of increased upwelling, high productivity and possibly low oxygen conditions. Rather, Danian *Guembelitria* species may be opportunistic taxa which flood continental shelf regions during stressful conditions (including low surface productivity) when most other species are unable to compete.

CONCLUSIONS

Faunal and carbonate data from the Negev, Israel, correlated with similar data from El Kef, Tunisia, and Agost and Caravaca, Spain, indicate at least three intervals of enhanced oceanic circulation leading to erosion or nondeposition of sediments (K/T boundary, P0/P1a, P1a/P1b). Percent carbonate data indicate major decreases in carbonate sedimentation at these times. These hiatuses are widespread (MacLeod and Keller, 1991a,b) and correlate with a global sea level regression during the latest Maastrichtian followed by a rapid transgression across the K/T boundary and into the early Tertiary (Haq et al., 1987; Donovan et al., 1988). Two short regressive pulses during the early Danian (Brinkhuis and Zachariasse, 1988) appear to correlate to the hiatuses at the P0/P1a and P1a/P1b boundaries (MacLeod and Keller, 1991a,b).

Danian sequences of the Tethyan region show alternating abundance maxima between triserial and biserial species. Preliminary faunal and stable isotopic analyses suggest that biserial taxa (*Heterohelix globulosa, Chiloguembelina, Woodringina*) thrived in shallow continental shelf regions, probably within the photic zone and at times of high surface productivity. Triserial taxa (*Guembelitria cretacea, G. trifolia*) also thrived in shallow continental shelf regions and probably below the photic zone. But in contrast to biserial taxa, their abundance maxima seem to correspond to $\delta^{13}C$ depletion intervals which indicate low surface productivity. Stable isotope analysis of Danian species will be necessary to confirm these observations and to reconstruct oceanic conditions in both open marine and continental shelf regions of the early Paleocene.

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ACCEPTED MAY 22, 1991

APPENDIX 1a

Relative percent abundance of planktonic foraminifera greater than 105 μm in the Negev-Sinai border section (sample number and depth in meters).

Species	Sample #—	1	2	3	4	5	6	7	*8	9	10	11	12	13	14	15	16
	Depth (m)—	0.00	0.12	0.26	0.39	0.47	0.66	0.86	1.03	1.22	1.40	1.56	1.73	2.00	2.16	2.42	2.59
Eoglobigerina fringa								x									
E. edita							14	13		x	x	x	x	5	4		
Parvularugoglobigerina eugubina																	
Subbotina moskvini							15	11	17	6	21	25	39	12	20	20	21
'Globigerina' pentagona							19	12	5	x	3	4	12	5	x	2	2
Eoglobigerina simplicissima							24	7	4	10	2	8	4	3	7	3	6
'Globigerina' (E.) taurica							x	x	30	x	x	x	x	x	x	x	7
'G.' tetragona											x				x		x
Subbotina triloculinoides							x	x	13	x	x	2	2	x	x	x	
Eoglobigerina trivialis							x	x	7	x	x	x	3	x	x	2	3
Subbotina varianta																	
Globanomalina compressa									2								
Morozovella inconstans																	
Globanomalina planocompressa									3								
Subbotina pseudobulloides							7		2	8	8	10	5	9	4	2	x
S. pseudobull. subquadratus							x	3								x	x
Morozovella trinidadensis																	
Globastica daubjergensis								x	x	3	x	x	x	16	8	2	4
Guembelitria cretacea							x	3	9	38	15	9	19	30	23	39	20
Guembelitria trifolia							x			x	x	x	x	7	8	4	x
Woodringina hornerstownensis							13	38	x	20	39	24	4	3	7	12	18
Chiloguembelina midwayensis							x	x	x	10	7	15	7	5	6	8	11
Globotruncanella caravacaensis																	
Juveniles: no identification								3									
Total number counted		0	0	0	0	0	115	205	314	322	288	277	301	315	237	341	273

Species	Sample #—	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	Depth (m)—	2.78	2.93	3.18	3.36	3.52	3.70	3.88	4.13	4.34	4.56	4.70	4.93	5.15	5.36	5.63
Eoglobigerina fringa																
E. edita																
Parvularugoglobigerina eugubina																
Subbotina moskvini		38	32	10	15	16	17	12	13	15	12	14	9	10	8	6
'Globigerina' pentagona		8	13	24	23	24	26	27	27	21	18	22	15	14	20	25
Eoglobigerina simplicissima		5	6	7	7	8	6	8	x	6	10	7	10	11	3	5
'Globigerina' (E.) taurica		x	x	x	x	x										
'G.' tetragona		3	2	x	x	x	2	3	3	x	x	x	3	3		x
Subbotina triloculinoides		x	x	x	x	2	x		x		3	x	5	2	2	4
Eoglobigerina trivialis		5	9	10	10	10	11	14	10	7	6	3	5	8	8	7
Subbotina varianta							x	6	2	2	3	2	5	4	24	21
Globanomalina compressa			x	x	x	x	2	x	x	x	x	3	5	x	x	x
Morozovella inconstans								x	x	2	x	x	10	11	x	5
Globanomalina planocompressa		x	x	x	x			x			4	x	x		x	
Subbotina pseudobulloides		13	4	18	17	10	9	15	8	22	16	24	19	20	6	10
S. pseudobull. subquadratus						4	2	x	3	x	x	3	2	x	5	3
Morozovella trinidadensis																
Globastica daubjergensis		x	9	2	x	4	4	x	5	3	x	x	x	x	x	x
Guembelitria cretacea		x	4	x	x	x	x	x	x	x		x		x		
Guembelitria trifolia					x	x		x								
Woodringina hornerstownensis		6	15	18	17	15	14	4	16	17	13	11	2	x	3	4
Chiloguembelina midwayensis		11	7	4	x	x	2	x	2	2	6	4	5	6	5	5
Globotruncanella caravacaensis																
Juveniles: no identification																
Total number counted		204	306	288	291	329	317	268	298	315	322	300	337	316	229	307

APPENDIX 1a

Continued.

Sample #—	32	33	34	34.5	35	35.5	36	37	38	39	*40	41	42	43	44
Species / Depth (m)—	5.84	5.97	6.20	6.61	7.72	7.95	9.13	9.81	10.60	11.20	11.92	12.74	13.46	14.31	15.00
Eoglobigerina fringa															
E. edita															
Parvularugoglobigerina eugubina															
Subbotina moskvini	6	9	7	9	5	15	4	3	3	2	10	x	2	x	
'Globigerina' pentagona	18	9	21	10	9	4	4	11	2	9	7	7	x	9	x
Eoglobigerina simplicissima	3	x	6	8	13	20	12	9	7	3	6	4	5	11	5
'Globigerina' (E.) taurica															
'G.' tetragona	2	x	2												
Subbotina triloculinoides	6	3	7	2	8	2	8	5	10	2	5	13	9	7	5
Eoglobigerina trivialis	6	9	5	14	9	4	10	7	5	3	6	4	2	5	5
Subbotina varianta	18	16	20	4	16	13	17	12	22	17	11	15	20	17	13
Globanomalina compressa	2	12	6	9	7	10	11	8	4	11	x	6	11	10	6
Morozovella inconstans	14	10	13	17	10	13	23	24	24	33	12	32	24	14	21
Globanomalina planocompressa									2			2	x	5	7
Subbotina pseudobulloides	8	6	5	20	5	14	5	x	8	3	10	6	5	2	5
S. pseudobull. subquadratus	6	6	2	x	10		x	x	x	3	x				
Morozovella trinidadensis										x		x	x	x	10
Globastica daubjergensis	x	x	x	2	x	x	x	6	9	6	2	2	9	5	17
Guembelitria cretacea											3	x			
Guembelitria trifolia											x				
Woodringina hornerstownensis	2	x	x	x	x		x	x	x	x	11	x		x	x
Chiloguembelina midwayensis	x	5	x	x	x	x	x	2	x	x	10	2	x	5	3
Globotruncanella caravacaensis															
Juveniles: no identification															
Total number counted	366	332	307	303	288	380	306	308	312	311	275	298	305	328	330

* Faunas in samples 8 and 40 appear anomalous and may have been mislabeled.

APPENDIX 1b

Relative percent abundance of planktonic foraminifera greater than 63 μm in the Negev-Sinai border section.

	Sample #—	1	2	3	4	5	6	7	*8	9	10	11	12	13	14	15	16
Species	Depth (m)—	0	0.12	0.26	0.39	0.47	0.66	0.86	1.03	1.22	1.40	1.56	1.73	2.00	2.16	2.42	2.59
Eoglobigerina fringa		2	x		x	6	14	7	5	x	x	x	x	x			
E. edita		x		x		6	20	14		3	2	7	5	8	x	x	6
Parvularugoglobigerina eugubina					23	32	3										
Subbotina moskvini							x	x	x	x	7	3	6	4	12	4	12
'Globigerina' pentagona							x	x	x	x	x	x	x	x	4	x	4
Eoglobigerina simplicissima			2			x	12	8	2	4	x	x	x	10	3	x	2
'Globigerina' (E.) taurica							x	2	58	x	x	x	x	2	x	x	x
'G.' tetragona							x	x	x		x				x		x
Subbotina triloculinoides							x	x	3	x	x	x	x	x	x	x	
Eoglobigerina trivialis							x	x	x	x	x	x	x	x	x	x	x
Subbotina varianta																	
'Globorotalia' archeocompressa						x	x										
Globanomalina compressa									x					x			
Morozovella inconstans																	
Globanomalina planocompressa									7								
Subbotina pseudobulloides							x	x	6	x		4	x	6	x	x	x
S. pseudobull. subquadratus							x	x	x							x	x
Morozovella trinidadensis																	
Globastica conusa			x	x	x	x	14										
Globastica daubjergensis								x	9	5	3	x	x	21	10	15	7
Guembelitria cretacea		9	7	14	6	10	3	8		20	57	37	37	6	37	21	27
G. trifolia		3	13	4	11	7	x			48	14	30	30	26	13	52	7
Woodringina hornerstownensis		2		2	2	10	20	47	2	11	11	11	6	5	7	4	23
Chiloguembelina midwayensis					2	4	8	3	0	2	4	5	8	4	9	x	8
Globotruncanella caravacaensis		x	x	x		x	x										
% Cretaceous (−*G. cretacea*)		80	77	78	54	21	0										
Juveniles: no identification		2		x	x			2	x	x	x						
Total number counted		305	371	298	315	277	307	344	391	393	253	332	252	248	310	342	306
% Benthic foraminifera		7	10	16	64	60	53	12	5	4	14	12	7	9	5	5	20

	Sample #—	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Species	Depth (m)—	2.78	2.93	3.18	3.36	3.52	3.70	3.88	4.13	4.34	4.56	4.70	4.93	5.15	5.36	5.63
Eoglobigerina fringa																
E. edita		2	x	x	x	x	x	x								
Parvularugoglobigerina eugubina																
Subbotina moskvini		20	19	13	4	11	7	6	5	x	5	11	13	7	2	2
'Globigerina' pentagona		12	7	9	11	9	15	7	12	14	12	3	19	9	4	11
Eoglobigerina simplicissima		6	x	x	x	x	2	x	x	x	x	x	2	2	2	x
'Globigerina' (E.) taurica		x	x	x	x	x										
'G.' tetragona		x	x	x	x	x	x	x	x	x	x	x	x	x		x
Subbotina triloculinoides		x	x	x	x	x	x		x		x	x	x	x	x	x
Eoglobigerina trivialis		x	x	3	3	2	2	3	x	x	x	x	x	x	3	2
Subbotina varianta							x	x	x	x	x	4	x	7	15	18
'Globorotalia' archeocompressa																
Globanomalina compressa			x	5	4	3	5	2	5	5	6	4	6	12	7	8
Morozovella inconstans								4	x	4	9	9	7	17	13	10
Globanomalina planocompressa		x	x	x	x			x			x	x	x		x	x
Subbotina pseudobulloides		5	7	15	23	13	10	13	12	19	10	24	15	14	16	10
S. pseudobull. subquadratus						2	x	x	x	x	x	x	2	x	x	x
Morozovella trinidadensis																
Globastica conusa																
Globastica daubjergensis		5	19	13	20	31	26	31	41	21	18	6	8	8	18	9
Guembelitria cretacea		4	7	x	2	2	2	x	x	x		x		x		
G. trifolia																
Woodringina hornerstownensis		25	28	32	17	15	24	14	19	30	34	25	22	17	10	14
Chiloguembelina midwayensis		15	7	10	6	5	3	6	x	2	2	4	5	5	4	5
Globotruncanella caravacaensis																

APPENDIX 1b

Continued.

% Cretaceous (−*G. cretacea*)															
Juveniles: no identification															
Total number counted	265	292	330	336	384	309	325	320	269	325	317	321	306	309	310
% Benthic foraminifera	21	4	3	4	2	2	2	1	3	4	5	10	5	7	7

Sample #—	32	33	34	34.5	35	35.5	36	37	38	39	*40	41	42	43	44
Species Depth (m)—	5.84	5.97	6.20	6.61	7.72	7.95	9.13	9.81	10.61	11.20	11.92	12.74	13.46	14.31	15.00
Eoglobigerina fringa															
E. edita															
Parvularugoglobigerina eugubina															
Subbotina moskvini	3	4	4	4	3	12	3	4	3	3	x	2	x	x	x
'Globigerina' pentagona	14	2	4	12	x	2	5	7	x	6	4	9	3	3	5
Eoglobigerina simplicissima	x	x	x	2	2	6	2	4	5	2	x	3	5	2	4
'Globigerina' (E.) taurica															
'G.' tetragona	x	x	x												
Subbotina triloculinoides	2	x	x	x	x		x	2	4	x	x	2	6	x	x
Eoglobigerina trivialis	x	x	x	2	3	2	2	x	2	2	2	x	x	x	x
Subbotina varianta	11	9	14	2	28	4	21	13	15	12	12	14	14	21	9
'Globorotalia' archeocompressa															
Globanomalina compressa	4	11	2	16	6	10	10	6	7	3	x	8	9	11	8
Morozovella inconstans	22	28	25	28	33	34	21	30	23	42	2	41	19	25	20
Globanomalina planocompressa				x		x			x			x	x	x	x
Subbotina pseudobulloides	5	10	12	21	10	19	11	2	2	4	2	2	9	10	9
S. pseudobull. subquadratus	x	x	x	x	3	x	2	x	2	x	x				
Morozovella trinidadensis										x		x	x	x	3
Globastica conusa															
Globastica daubjergensis	9	13	15	x	2	4	8	24	28	19	16	10	20	14	22
Guembelitria cretacea											11	x			
G. trifolia											15				
Woodringina hornerstownensis	15	10	11	3	3	2	3	x	2	x	26	5	2	5	3
Chiloguembelina midwayensis	5	5	4	x	x	5	5	x	x	x	2	x	x	x	4
Globotruncanella caravacaensis															
% Cretaceous (−*G. cretacea*)															
Juveniles: no identification															
Total number counted	359	361	282	274	338	304	269	300	317	315	338	318	255	304	283
% Benthic foraminifera	6	3	4	7	5	5	3	9	8	5	6	5	2	2	3

* Faunas in samples 8 and 40 appear anomalous and may have been mislabeled. These samples were not included in the relative abundance graphs.

APPENDIX 2

Relative percent abundance of planktonic foraminifera greater than 63 μm in the Ben Gurion section.

Sample #—	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45
Species Depth (m)—	1.05	1.14	1.22	1.26	1.35	1.38	1.48	1.54	1.64	1.67	1.73	1.83	1.9	1.98	2.03	2.1
Eoglobigerina fringa	x	x	x	9	10	8	5	2								
E. edita	x	x	x	2	13	8	x	2	x	2	3	2	x	x	x	
Parvularugoglobigerina eugubina	x			9	12	10										
P. cf. *Eugubina*				x			x									
Eoglobigerina eobulloides		2			x	7	x	4	2	3	3	x	3	5	5	6
Subbotina moskvini				2	5	9	4	6	3	6	7	7	7	9	8	9
'Globigerina' pentagona							7	2	x	x	x	x	x	2	x	2
Eoglobigerina simplicissima																
'Globigerina' (E.) taurica							4				x		x	x		
Eoglobigerina trivialis													x			
Subbotina triloculinoides						x		x	x	x	x				x	x
S. varianta																
Globanomalina compressa									x	x		x	x	x	x	x
Morozovella inconstans																
Subbotina pseudobulloides									x		x	x	x	x	4	2
S. pseudo. subquadratus							x			x						
Globastica conusa				7	25	15	2									
Globastica daubjergensis						x	x	x					x		x	x
Globastica sp.				x	x	x	3	x	4	6	4	3	4		6	x
Guembelitria cretacea	9	11	7	13	6	4	8	12	43	38	30	41	36	27	22	20
Gu. danica				x			x	2	x	x	x	x	x			x
Gu. trifolia	x	x	7	12	2	6	x	17	30	20	25	28	28	31	28	34
Woodringina hornerstownensis	x	x	4	3	15	24	59	44	8	10	19	12	13	10	14	14
Chiloguembelina midwayensis				x	8	2	x	4	4	7	2	2	2	10	9	5
Ch. morsei	x		2	4	x	x	x	x	x			x		x	x	x
% Cretaceous (−*Gu. cretacea*)	83	81	76	32	x											
Juveniles no. identification	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Total number counted	244	185	231	218	217	195	300	231	556	238	357	521	545	260	388	547
% Benthic foraminifera	12	16	17	23	26	20	10	3	6	12	10	6	6	10	5	6

Sample #—	44	43	42	41	39	37	35	33	34	30	29	28	27	25	23	21
Species Depth (m)—	2.17	2.25	2.34	2.37	2.48	2.61	2.74	2.96	3.11	3.13	3.15	3.2	3.27	3.4	3.55	3.74
Eoglobigerina fringa																
E. edita	x	x														
Parvularugoglobigerina eugubina																
P. cf. *eugubina*																
Eoglobigerina eobulloides	9	8	14	8	15	12	13	12	10	6	9	7	20	14	10	9
Subbotina moskvini	3	6	12	18	10	10	12	20	17	20	37	14	15	8	8	5
'Globigerina' pentagona	3	x	x	5	x	x			x	4		3		x	2	2
Eoglobigerina simplicissima																
'Globigerina' (E.) taurica																
Eoglobigerina trivialis			x		x		x		x	x		x	x	x		x
Subbotina triloculinoides				2			x			x	x	x	c	c	c	c
S. varianta										x	3	x	3	4	x	x
Globanomalina compressa	4	2	2			x	x	x	3	2		4	2	3	3	4
Morozovella inconstans			x	x	x	x	x	x	x	x	x	x	x	x	3	x
Subbotina pseudobulloides	3	2	3	9	2	2	x	5	6	8	27	12	9	12	13	13
S. pseudo. subquadratus		x											x	2		x
Globastica conusa																
Globastica daubjergensis	3		x	x	x						x			x		
Globastica sp.	15	20	11	10	5	10	7	5	2	5	3	3	x	4	3	6
Guembelitria cretacea	13	11	8	6	13	17	15	5	5	x	x	3	3	7	3	8
Gu. danica	2	x	x		2	x	x									x
Gu. trifolia	32	39	33	15	24	26	22	4	8	4	x	3	4	11	5	14
Woodringina hornerstownensis	4	4	5	14	16	11	17	30	21	27	12	28	20	16	26	18
Chiloguembelina midwayensis	6	5	7	7	8	7	9	16	22	15	3	14	18	13	19	12
Ch. morsei	x	x		x	x			x	x	3		3	x	2	x	x
% Cretaceous (−*Gu. cretacea*)																
Juveniles: no identification	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Total number counted	346	595	365	320	455	348	305	221	309	240	239	336	466	347	217	468
% Benthic foraminifera	7	9	9	32	8	15	24	32	21	27	54	25	16	15	12	6

APPENDIX 3

Relative percent abundance of planktonic foraminifera greater than 65 μm in the Ein Mor section.

Sample #—	3	4	5	6	7	8	9	10	11	12	13
Species Depth (m)—	0.39	0.55	0.59	0.63	0.66	0.72	0.74	0.77	0.83	0.85	0.90
Eoglobigerina edita	x			2	7	6	8	4	10	6	13
E. eobulloides	x	2	x	x	x	3	3	4	2	6	8
Parvularugoglobigerina eugubina		12	12	9	21	21					
P. cf. *eugubina*	x										
Eoglobigerina fringa	x	8	x	x	x	x					
Subbotina moskvini					5	8	29	15	14	18	26
'Globigerina' pentagona				x	x	x				2	
'Globigerina' (E.) taurica			x		3	4	2	x	4	x	3
Subbotina triloculinoides				x	x					2	
Eoglobigerina trivialis								6	x		x
Subbotina varianta											
'Globorotalia' archeocompressa					x						
Globanomalina compressa						x	4	10	6	6	
Subbotina pseudobulloides							5	11	2	5	x
Globastica conusa	x	4	x	2	4	2	x	x	x		
Globastica daubjergensis			6	11	7	6	5	10	14	21	24
Globastica sp.				x							
Globotruncanella caravacaensis			x					x			
Woodringina hornerstownensis	x	x	5	16	16	12	3	8	11	12	8
Chiloguembelina midwayensis						10	15	13	17	11	8
Guembelitria cretacea	x	31	6	9	7	5	5	x	x	x	2
Guembelitria trifolia	x	40	67	41	25	21	18	12	14	5	3
Juveniles: no identification		3	3	2	2	x	2	2	2	3	x
Total numbers counted	—	159	210	291	257	258	305	222	221	295	270
% Cretaceous (−*G. cretacea*)	98	50	42	24	11	3	6	5	1		

Sample #—	14	15	16	17	18	19	20	21	22	23
Species Depth (m)—	1.16	1.26	1.47	1.53	1.63	1.86	2.00	2.16	2.32	2.47
Eoglobigerina edita	10	11	10	5	x	x	x	x	x	2
E. eobulloides	8	4	4	2	x	4	3	6	x	
Parvularugoglobigerina eugubina										
P. cf. *eugubina*										
Eoglobigerina fringa										10
Subbotina moskvini	12	9	7	2	3	4	2	7	13	2
'Globigerina' pentagona	x	2	x	x	x		x	x	6	
'Globigerina' (E.) taurica	7	3	x			3	x			
Subbotina triloculinoides		x	x						x	
Eoglobigerina trivialis			x	x						
Subbotina varianta	x	x	x		x					x
'Globorotalia' archeocompressa										
Globanomalina compressa					x	x	x	x	3	
Subbotina pseudobulloides		x	x	x	x	x	x	x	x	6
Globastica conusa										
Globastica daubjergensis	21	20	6	15	20	12	11	2	x	2
Globastica sp.										
Globotruncanella caravacaensis										
Woodringina hornerstownensis	26	41	60	34	15	8	15	6	4	19
Chiloguembelina midwayensis	x	x	5	9	3	4	5	6	6	6
Guembelitria cretacea	6	x	5	4	13	5	9	6	9	6
Guembelitria trifolia	3	3	5	26	39	54	47	61	54	44
Juveniles: no identification	2	3	x	x	3	2	x	x	x	2
Total numbers counted	491	289	310	277	453	356	384	397	416	401

APPENDIX 4

Relative percent abundance of planktonic foraminifera greater than 65 μm in the Hor HaHar section.

Sample #—	49	48	47	46	45	44	42	41	40	39	38	36	34	32	30
Species Depth (m)—	0.00	0.06	0.10	0.14	0.18	0.22	0.34	0.43	0.49	0.57	0.63	0.74	0.87	0.94	1.01
Eoglobigerina edita	x	x	x	x	x	2	8	8	4	2	x	x			
Parvularugoglobigerina eugubina	x	x	x	x	7	35	3	x							
Eoglobigerina eobulloides					3	x	18	15	17	8	5	x	x	4	x
Eoglobigerina fringa			x	x	5										
Subbotina moskvini						3	5	5	3	2	6	2	4	5	2
'Globigerina' pentagona									4	10	8	2	2	3	3
Eoglobigerina simplicissima					x		x			2	3	x	x	x	2
'Globigerina' (E.) taurica						x	x	4	8						
Subbotina triloculinoides							x	x	x	x	6	2	2	x	x
Eoglobigerina trivialis							x	x	x	x					
Subbotina varianta															
Globanomalina compressa								x	3	x	x	x	x	x	x
Morozovella inconstans															
Subbotina pseudobulloides									x			x	x	x	x
S. pseudobull. subquadratus															
Globastica conusa	x	x	x	x	4	2	11	12	2	x					
Globastica daubjergensis							18	21	11	8	12	14	15	13	9
G. cf. *daubjergensis*					3	x									
Guembelitria cretacea					12	6	2	x	x	x	x	11	3	5	3
G. trifolia					53	35	16	19	7	3	2	43	53	51	62
Chiloguembelina midwayensis					x		x	2	x	2	x	3	4	4	4
Woodringina hornerstownensis	x	x	x	x	9	11	11	10	44	52	51	16	11	11	10
Juveniles: no identification					x	x	x	x	x	x	x	x	x	x	x
Total number counted	—	—	—	—	250	174	383	311	318	324	313	326	338	338	281
% Benthics	98	98	97	92	32	—	20	8	11	—	—	6	3	6	8
% Cretaceous (−*G. cretacea*)	42	39	0												

Sample #—	28	26	24	23	22	21	20	19	17	16	14	13	12	11	10
Species Depth (m)—	1.16	1.29	1.40	1.51	1.62	1.71	1.79	1.90	2.10	2.19	2.31	2.43	2.51	2.58	2.69
Eoglobigerina edita															
Parvularugoglobigerina eugubina															
Eoglobigerina eobulloides	2	x	5	x	7	7	8	5	11	5	x	5	2	x	x
Eoglobigerina fringa															
Subbotina moskvini	4	3	6	4	4	15	16	9	4	5	9	5	9	6	8
'Globigerina' pentagona	6	3	3	5	5	6	9	5	8	5	5	9	7	5	2
Eoglobigerina simplicissima	x		x		x		x	x		x					
'Globigerina' (E.) taurica	x														
Subbotina triloculinoides	x	2		x	x			x		x	x	x	x	x	
Eoglobigerina trivialis									x	x	x		x	x	x
Subbotina varianta			x	2	x	x	x	x	5	5	11	3	8	11	11
Globanomalina compressa	2	2	2	x	3		3	x	5	5	15	7	7	14	15
Morozovella inconstans											16	22	21	27	18
Subbotina pseudobulloides		x	x	x		2			2	2	3	2	4	x	5
S. pseudobull. subquadratus													x		
Globastica conusa															
Globastica daubjergensis	15	34	16	21	26	34	17	33	18	21	19	26	25	21	27
G. cf. *daubjergensis*															
Guembelitria cretacea	3		x	x	x		x	x							
G. trifolia	47	34	42	47	35	14	15	25	16	16	x	x			2
Chiloguembelina midwayensis	3	8	8	7	7	12	21	10	16	16	7	6	3	5	4
Woodringina hornerstownensis	14	9	10	8	8	7	5	8	12	14	7	5	7	2	4
Juveniles: no identification	x	x	x	x	x	x	x	x	x	x	x	4	x	x	x
Total number counted	355	335	322	302	268	106	130	306	325	317	342	267	290	241	265
% Benthics	4	5	5	2	2	50	12	6	7	6	6	2	3	1	2
% Cretaceous (−*G. cretacea*)															

APPENDIX 5

Relative percent abundance of planktonic foraminifera greater than 63 μm in the Zofar section.

Species / Sample #—	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33
Depth (m)—	0	0.05	0.10	0.15	0.21	0.26	0.29	0.32	0.38	0.43	0.49	0.55	0.61	0.64	0.69	0.74	0.76
Globigerinelloides aspera	10	9	4	x	x	x	x	x									
G. multispina	3																
G. volutus	x	x	4														
Globotruncanella subcarinatus	x	5	5	x	x		x										
G. caravacaensis						x	x										
Rugoglobigerina hexacamerata	x	x	x				x										
R. macrocephala	x	x															
R. rugosa	x	3	x	x	x												
R. scotti																	
Heterohelix americana	18	9	x	8	3		x										
H. globulosa	20	19	20	6	11	2	2	x									
H. navarroensis	3	7	6		4	x	x										
H. striata																	
H. pulchra	3	3	x		x												
Planoglobulina brazoensis		x															
P. carseyae s.l.	x	3	5	x	x												
Pseudoguembelina costulata	30	9	7	7	6	x	x										
P. kempensis	x			x	x		x										
P. palpebra																	
P. punctulata					x												
Pseudotextularia deformis	x																
P. elegans	x	x															
Eoglobigerina fringa			x			3											
E. edita			x	4	3	8	10	11	11	15	3	2	4	x	x	4	4
E. eobulloides	x	x	2	3				12	5	x							
Parvularugoglobigerina eugubina		x	3	14	15	20	19	6									
Subbotina moskvini					x	x	6	9	8	4	5	2	3	6	10	x	3
'Globigerina' pentagona						x		x	x	x	x	x		x	x	2	x
E. simplicissima				x		x			11	6	7	2	3	5	6	2	x
'Globigerina' taurica				x		x	x	2		x			x		x		x
'G.' (E.) tetragona																	
Subbotina triloculinoides									x	x	x	x	x				x
Eoglobigerina trivialis									2	x			x	x			x
Subbotina varianta																	
'Globorotalia' archeocompressa								x				x					
Globanomalina compressa															x		x
Morozovella inconstans																	
Subbotina pseudobulloides						x	8	2	x	x			x	x		x	x
S. pseudobull. subquadratus									x								
Morozovella trinidadensis																	
Guembelitria cretacea	5	6	12	19	x	17	10	4	10	11	8	6	21	23	11	21	31
Guembelitria trifolia		15	19	26	24	19	10	26	20	21	29	57	44	39	19	27	41
Woodringina hornerstownensis		x	3	4	9	5	5	7	15	20	27	8	13	9	5	7	9
Chiloguembelina midwayensis				x		7	12	4	2	x	3	3	7	3	3	4	3
Globastica conusa		x	x	x	6	2	6	8									
Globastica daubjergensis							5	6	13	20	15	17	5	16	39	28	13
G. cf. *daubjergensis*				x	9	5											
Total number counted	319	321	310	247	244	294	332	339	299	263	309	304	348	285	298	284	355
% Benthic foraminifera	8	6	16	38	23	44	35	28	15	32	11	3	5	29	44	38	4
% Cretaceous (−*G. cretacea*)	95	75	55	26	30	9	6	x		x							

APPENDIX 5

Sample #—	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17
Species Depth (m)—	0.80	0.88	0.97	1.06	1.23	1.38	1.48	1.65	1.77	1.88	2.01	2.08	2.16	2.24	2.49	2.80
Globigerinelloides aspera																
G. multispina																
G. volutus																
Globotruncanella subcarinatus																
G. caravacaensis																
Rugoglobigerina hexacamerata																
R. macrocephala																
R. rugosa																
R. scotti																
Heterohelix americana																
H. globulosa																
H. navarroensis																
H. striata																
H. pulchra																
Planoglobulina brazoensis																
P. carseyae s.l.																
Pseudoguembelina costulata																
P. kempensis																
P. palpebra																
P. punctulata																
Pseudotextularia deformis																
P. elegans																
Eoglobigerina fringa																
E. edita	x	4	6	4	x	2	x	2	3	5	2	6	5	4	x	
E. eobulloides																
Parvularugoglobigerina eugubina																
Subbotina moskvini	7	4	8	4	3	6	12	7	8	6	6	5	6	5	x	4
'Globigerina' pentagona	3	3	x			x	2	3	3	6	6	5	10	4	x	16
E. simplicissima	4	5	2	x		6	8	5	5	4	2	x	4	x	x	x
'Globigerina' taurica	x	x	2			x	x	2	x	3	4	7	3	6	4	3
'G.' (E.) tetragona							x	x			x	x				x
Subbotina triloculinoides			x					x	x		x		x			x
Eoglobigerina trivialis	x	x	x	x		2	3	4	5	3	2	2	3	x		
Subbotina varianta									x		3	x		3	2	x
'Globorotalia' archeocompressa																
Globanomalina compressa	x	x	x	x		2	3	5	x	3	6	7	6	4	9	9
Morozovella inconstans																?
Subbotina pseudobulloides	x	x	x	3		2	x	4	7	11	10	7	10	8	8	11
S. pseudobull. subquadratus	x										x				x	x
Morozovella trinidadensis																
Guembelitria cretacea	18	5	5	12	20	15	7	6	2	4	4	4	3	3		
Guembelitria trifolia	32	45	50	28	42	18	17	11	9	14	15	17	7	5	2	
Woodringina hornerstownensis	12	7	4	8	9	19	24	30	23	18	14	17	18	25	30	25
Chiloguembelina midwayensis	5	4	3	13	12	4	8	7	10	9	7	8	6	5	7	7
Globastica conusa																
Globastica daubjergensis	14	18	17	24	9	17	10	10	18	11	14	10	17	25	20	
G. cf. *daubjergensis*																20
Total number counted	322	313	367	258	290	373	313	297	324	344	291	351	337	343	276	319
% Benthic foraminifera	16	11	3	65	56	8	5	8	4	5	6	6	6	13	9	8
% Cretaceous (−*G. cretacea*)																

APPENDIX 5

Species	Sample #—	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	Depth (m)—	3.09	3.43	3.77	4.08	4.33	4.52	4.75	5.01	5.27	5.54	5.87	6.15	6.47	6.81	7.08	7.47
Globigerinelloides aspera																	
G. multispina																	
G. volutus																	
Globotruncanella subcarinatus																	
G. caravacaensis																	
Rugoglobigerina hexacamerata																	
R. macrocephala																	
R. rugosa																	
R. scotti																	
Heterohelix americana																	
H. globulosa																	
H. navarroensis																	
H. striata																	
H. pulchra																	
Planoglobulina brazoensis																	
P. carseyae s.l.																	
Pseudoguembelina costulata																	
P. kempensis																	
P. palpebra																	
P. punctulata																	
Pseudotextularia deformis																	
P. elegans																	
Eoglobigerina fringa																	
E. edita																	
E. eobulloides																	
Parvularugoglobigerina eugubina																	
Subbotina moskvini		10	11	14	9	12	7	3	4	2	x	3	x	x	2	x	2
'Globigerina' pentagona		11	10	10	12	6	10	9	11	11	5	8	4	3	2	3	
E. simplicissima		4	x	x	6	4	3	3	x	x	x	2	2	5	3	5	x
'Globigerina' taurica		?		?													
'G.' (E.) tetragona		x	x								x						x
Subbotina triloculinoides		x			3			2	x	x	x	x	x	x	x	x	x
Eoglobigerina trivialis		x		x		x		x	x	x		x	x	x	2		x
Subbotina varianta		2	7	2	8	3	5	17	18	9	16	22	30	33	20	24	13
'Globorotalia' archeocompressa																	
Globanomalina compressa		13	5	7	12	11	9	10	6	10	12	11	10	10	8	18	20
Morozovella inconstans		x	4	x	9	11	15	11	13	20	15	13	22	15	31	26	27
Subbotina pseudobulloides		6	25	14	8	17	15	13	13	26	22	17	13	20	14	8	13
S. pseudobull. subquadratus			x	x				x	2	x	x	x	x		x		
Morozovella trinidadensis												x	x		x	x	x
Guembelitria cretacea					x				x	x	x					x	
Guembelitria trifolia			x														
Woodringina hornerstownensis		36	11	18	18	13	10	3	4	5	5	5	3	4	2	2	6
Chiloguembelina midwayensis		3	7	7	11	6	6	4	3	4	2	4	6	x	4	2	3
Globastica conusa																	
Globastica daubjergensis		16	12	21	14	12	15	21	18	8	13	10	4	4	6	8	13
G. cf. *daubjergensis*																	
Total number counted		299	275	289	277	299	269	420	318	301	298	332	379	291	339	313	320
% Benthic foraminifera		6	14	8	13	7	9	8	5	6	6	2	3	5	3	2	2
% Cretaceous (−*G. cretacea*)																	