Latitudinal variation in the K/T event: inferences from planktic foraminifera

Alfonso Pardo

Dept. of Geological and Geophysical Sciences, Princeton University, Princeton, NJ 08544, U.S.A.

RESUMEN

Un análisis comparativo de diferentes secciones del límite Cretácico/Terciario (K/T) muestra una clara diferencia latitudinal en la sucesión de eventos paleoecológicos y paleoclimáticos durante el tránsito K/T. Así , se puede observar como la extinción masiva de foraminíferos planctónicos y los cambios de la productividad que se consideraban asociados al evento del límite son fenómenos restringidos a bajas latitudes, mientras que en altas latitudes la evolución de las asociaciones faunísticas es muy diferente, sin una extinción masiva en el límite K/T siquiera, contrariamente a lo postulado por la hipótesis de la extinción global causada por un impacto meteorítico. Este análisis comparativo preliminar sugiere un escenario más complejo, en el que sin descartar la posibilidad de un impacto, éste se superpondría a procesos de cambio paleoclimático de larga duración, cuyos efectos tendrían un claro control latitudinal e incluso longitudinal en cada hemisferio.

Key words: *Cretaceous, Tertiary, paleoecology, planktic foraminifera,latitudinal control*

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Introduction

The Cretaceous / Tertiary (K/T) boundary mass extinction event has been extensively studied in low latitudes, where high diverse planktic foraminiferal assemblages have been recorded, due to the mild and fertile paleohabitat. In these sections the highly specialized tropical-subtropical foraminiferal fauna of the Maastrichtian disappeared at or near the K/T boundary. Only cosmopolitan species ranged into the early Danian where some of them gave rise to the new Tertiary foraminiferal radiation (Keller, 1988, 1989 a, b; Canudo *et al.*, 1991; Pardo *et al.*, in press). If one considers only what occurred in the fertile and warm tropical-subtropical paleoenviroment, one could arrive at the conclusion that a sudden catastrophic event, such as a large bolide impact, wiped out almost every form of life as proposed by Alvarez *et al.* (1980). If this were the case, the atmospheric circulation belts would have homogenized and spread the dust shield across all latitudes within a few months. The predicted effects of such a global dust cloud would be the loss of sun radiation resulting in global cooling similar to a «nuclear winter», and the depletion of the trophic chain, due to cessation of photosynthesis (Alvarez *et al.*, 1980). The impact hypothesis postulates these adverse effects as the main causes of the K/T boundary mass extinction event. In this scenario, the mass extinction would have occurred at all latitudes at the same geological time interval. Thus, no latitudinal differences would be expected.

To test this hypothesis it is crucial to compare datasets from both low and high latitudes. Many low latitude Tethyan sections have already been studied, such as El Kef in Tunisia (Smit 1982; Keller, 1988; Li and Keller, in press), several sections in Israel (Keller and Benjamini, 1991) the Rotwandengraben section in Austria (Peryt *et al.*, 1993), Agost and Caravaca sections in southern Spain (Smit, 1982, 1990; Canudo *et al.*, 1991, Arz *et al.*, 1992; Pardo *et al.*, in press), Zumaya in northern Spain (Lamolda, 1988, 1990; Arz *et al.*, 1992); Brazos in Texas, U.S.A. (Smith and Pessagno, 1973; Keller, 1989 b), many sections in north-eastern Mexico (Smit *et al.*, 1992, Stin-nesbeck *et al.*, 1993, Keller *et al.*, 1994, Lopez Oliva and Keller, 1994) and the Poty section in Brazil (Stinnesbeck, 1989; Stinnesbeck and Keller, in press). In contrast, few high latitude sections are known with well-preserved microfossil records. K/T sections in the northern hemisphere include the Nye Kløv (Keller et al, 1993) and Stevns Klint (Schmitz *et al.*, 1992) sections in Denmark and the Koshak section in Kazakhstan (Sarkar *et al.*, 1992, Pardo *et al.*, 1995). In the southern high latitudes, only ODP Site 738 on Kerguelen Plateau in the Indian Antarctic Ocean contains a nearly continuous trans-K/T record (Keller, 1993). Nevertheless, these K/T transitions provide pole to equator latitudinal control on planktic foraminiferal extinctions and paleoclimatic events. This global dataset does not confirm the impact hypothesis and its prediction of a catastrophic and nearly instantaneous global mass extinction at the K/T boundary. Rather, it suggests that multiple environmental effects, including global cooling, sea level changes, volcanism and a bolide impact conspired to cause the K/T mass extinction over an extended period with its biotic effects largely restricted to low latitude.

Major latitudinal differences

Major latitudinal differences between the Tethys and boreal provinces are summarized below, in Table 1 and in Fig. 1.

1) SPECIES DIVERSITY: High latitude sections (Nye Kløv, Koshak and Site 738) show late Maastrichtian assemblages with low species richness, simple morphology and cosmopolitan distribution. In low latitudes, highly diversified

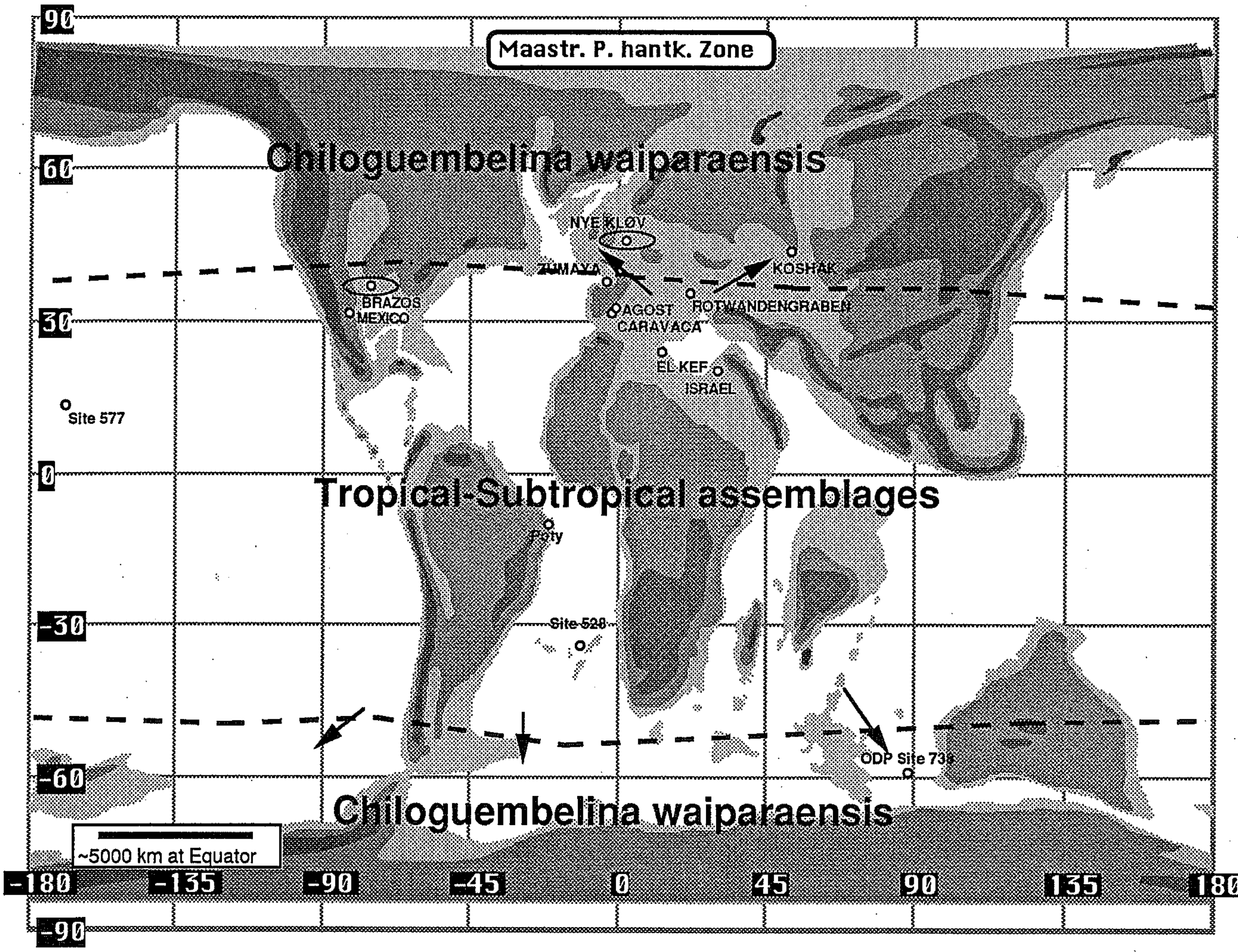

Fig 1.- Paleogeographic reconstruction of the planktic foraminiferal domains during the K/T transition.

Fig 1.- Reconstrucción paleogeográfica de los dominios de foraminíferos planctónicos durante la transición K/T.

and specialized late Maastrichtian assemblages are present with typically large and strongly ornamented species.

2) COSMOPOLITAN TAXA: High latitude faunas show a great abundance of biserial cosmopolitan species such as *C. waiparaensis* and *Zeauvigerina parri* in Maastrichtian and Danian sediments (e.g., ODP Site 738 and Koshak) whereas in low latitudes, these species are either absent or present in low abundance.

3) SPECIES ORIGINATION IN HIGH LATITUDES: *Chiloguembelina waiparaensis*, which has been considered as a Tertiary species and genus, is abundantly present in Maastrichtian sediments of high latitudes (ODP Site 738 and Koshak; Keller, 1993; Pardo *et al*, 1995), but absent in low latitudes (Canudo *et al.* 1991, Li and Keller, in press). This suggests that some species originated in high latitudes during the Maastrichtian and migrated into low latitudes after the K/T mass extinction when ecologic niches became available.

4) MASS EXTINCTION LATITUDINALLY CONTROLLED: In low latitudes, the K/T boundary mass extinction eliminated all tropical and subtropical species at or near the K/T boundary. In high latitudes no mass extinction occurred at the K/T boundary and virtually all species ranged into the Danian.

5) SURFACE PRODUCTIVITY: In low latitudes a decrease in surface water productivity ($\delta^{13}C$ shift of 2-3‰) occurred beginning at the K/T boundary (Keller and Lindinger, 1989; Barrera and Keller, 1994; Margaritz *et al.*, 1992). In high latitudes, surface water productivity remained nearly unchanged. For instance, at Stevns Klint, Nye Kløv and Koshak sections, $\delta^{13}C$ values show a decrease of only 0.5‰ (Keller *et al.*, 1993; Sarkar *et al.*, 1992; Schmitz *et al*, 1992), whereas at Site 738 in the southern high latitude there is no change (Barrera and Keller, 1994).

6) HIGH LATITUDE LATE DANIAN EVENT: A major $\delta^{13}C$ shift occurs in Zone P 1b in high latitudes (Barrera and Keller, 1994). No major change is observed in low latitudes at this time (see Table 1).

7) END-MAASTRICHTIAN GREENHOUSE EVENT: $\delta^{18}O$ analysis in high latitude sections shows climatic warming of sea water in the uppermost Maastrichtian (last 100 thousand years before the K/T boundary event), correlative with a temporary influx of tropical-subtropical species observed at ODP Site 738 and 690, Stevns Klint and Nye Kløv and the Koshak section (Schmitz *et al.*, 1992; Sakar *et al.*, 1992; Keller *et al.*, 1993; Barrera and Keller, 1994). This

HIGH LATITUDE			LOW LATITUDE					
Koshak	**Site738**	**Nye Kløv**	**Agost**	**Caravaca**	**El Kef**	**Israel**		
Low	Low	Low	High	High	High	High	Species richness	
from Maastrich. thru Danian	from Maastrich. thru Danian	Danian	No	No	No	No	C. waiparaensis pressence	
C. waiparaensis dominant	Hedbergellids, Heterolicids & Globigerinids	H. globulosa Guembelitria spp.	Subtropical fauna	Subtropical fauna	Subtropical fauna	Subtropical fauna	Upper Maastrichtian	DOMINANT FAUNA
C. waiparaensis	C. waiparaensis	H. globulosa, Guembelitria	Guembelitria spp.	Guembelitria spp.	Guembelitria spp.	Guembelitria spp.	P0	
C. waiparaensis	C. waiparaensis	H. globulosa Guembelitria	P. eugubina-longiapertura	P. eugubina-longiapertura	P. eugubina, Guembelitria spp.	P. eugubina, Guembelitria spp.	P1a	
C. waiparaensis	C. waiparaensis	C. waiparaensis E. danica	Guembelitria, Chiloguembel. & Woodringina	Guembelitria, Chiloguembel. & Woodringina	Guembelitria & Woodringina	Guembelitria, Chiloguembel. & Woodringina	P1b	
C. waiparaensis & diversif.	Diversification (S, P, G, M...)	Diversification (S, P, G, M...)	Guemb, Chilog & Woodringina diversification	Guemb, Chilog. & Woodringina diversification	?	Guemb, Chilog. Woodringina, diversification	P1c	
No change	No change	No change	Decrease	Decrease	Decrease	Increase	K/T boundary	
decrease (<1‰) P0 & P0/P1a	No change	decrease (<1‰) P0 & P0/ P1a	?	2-3‰ decrease	2-3‰ decrease	2-3‰ decrease	P0	PRODUCTIVITY
No change	No change	Remains low	?	Increase	No change	Decrease	P1a	
?	decrease in P1b	?	?	?	Increase	Remains low	P1b	
Warming at the end of Maastrichtian	Warming at the end of Maastrichtian	Warming at the top of Maastrichtian	?	No reliable	?	?	**TEMPERATURE CHANGES**	

Table 1.- Comparison of paleoecologic and paleogeographic events in high and low latitude sections during the K/T transition.

Tabla 1.- Comparativa de eventos paleoecológicos y paleoceanográficos en altas y bajas latitudes durante el tránsito K/T.

suggests major paleoclimatic changes preceding the K/T event possibly as a result of Deccan trap volcanism .

Northen hemisphere: east-west differences

In the Northern hemisphere the K/T extinction event has been studied in low to middle latitudes but very few high latitude sections are known. The Koshak section shows a typical high latitude or boreal foraminiferal assemblage (Pardo *et al.,* 1995). In contrast, the Zumaya section of Spain, which is at a similar latitude (43° N), shows a typical low latitude Tethyan assemblage. Without further data points, one might assume that the boundary between the Tethyan low latitude fauna and the boreal high latitude fauna is between 43° N and 45° N. This is probably wrong considering that these sections lie east and west, with the Koshak section geographically separated from the Tethys ocean by a mountain range as suggested by paleogeographic reconstruction. This geographic barrier presumably prevented the warm Tethys sea from reaching the Kazakhstan region at least during sea-level lowstand periods, such as in the late Maastrichtian. At these times, cooler arctic water and its boreal fauna was dominant in this region (i.e., Koshak). During the sea-level highstand and greenhouse warming at the end of the Maastrichtian, the influx of warmer Tethys water carried along the tropical-subtropical species observed in the assemblages of the Koshack section. The western Tethys sections of Agost, Caravaca and Zumaya show an essentially warm water fauna during the entire late Maastrichtian (Arz *et al.* 1992; Canudo et al, 1991; Pardo *et al.,* in press). The Danish sections at Nye Kløv and Stevns Klint at 55° N are similar to the Koshak section in that they also have a predominantly boreal fauna with a short Tethyan warm water incursion during the sea-level rise and greenhouse warming at the end of the Maastrichtian (Keller *et al.,* 1993; Schmitz *et al.,* 1992).

The boreal/Tehys faunal province boundaries of the Cretaceous/Tertiary transition have not been studied to date. In the northern hemisphere, it is particularly important to add data points at latitudes between 40° N and 30° N in order to confirm our preliminary observation of an east-west faunal change in the European Tethyan realm during the trans-K/T period.

Comparison between the Agost section as western representative and the Koshak section on the eastern side can yield valuable information on oceanic circulation and sea water fluxes of the northern Tethys basin.

1) Agost shows a typical Latest Maastrichtian subtropical planktic foraminiferal assemblage highly diversified, large size (>106 µm), strongly ornamented. Koshak shows low diversity assemblages, with very small specimens (106µm> size of specimens >38µm) characteristic of stress conditions and cold water (i.e., oligotaxic mode). Biserial species are dominant in the planktic foraminiferal fauna, including *Chiloguembe-*

lina waiparaensis, *Heterohelix spp*. and *Zeauvigerina parri*, which are typical of low O_2 environments.

2) The end Maastrichtian sea-level rise (Schmitz *et al.*, 1992; Keller *et al.*, 1993; Keller and Stinnesbeck, in press; Pardo *et al.*, in press) may be responsible for the warm water Tethyan influx that carried along various subtropical planktic foraminifera at Koshak and in the Danish sections. This sea-level rise can be tracked also at Agost by the change in the benthic foraminiferal assemblage, environmentally controlled morphologic traits, and the nature of associated fauna and sediments (Murray, 1991; Jackson, 1994; Buzas and Culver, 1994). Based on benthic foraminiferal assemblage changes and the paleomagnetic record (Groot *et al.*, 1989) at Agost, the late Maastrichtian sea-level lowstand reached a maximum about 300 thousand years before the K/T boundary. This sea-level lowstand has been identified based on benthic foraminifera from many sections worldwide, e.g.: Denmark (Hultberg and Malmgren, 1986; Schmitz *et al.*, 1992), Israel (Keller, 1992), Mexico (Keller *et al.*, 1994) and Brazil (Stinnesbeck and Keller, in press). At the end of the Maastrichtian (uppermost part of *P. hantkeninoides* Zone), about 1.5 meters below the K/T boundary at Agost, a sea-level rise is indicated by the increased abundance of bathyal species and decreased abundance of middle shelf species. This sea-level rise appears to be associated with an expansion of the oxygen minimum zone as indicated by the increase and dominance of the low oxygen tolerant outer shelf species *Buliminella carseyae* (Pardo *et al*, in press). Oxygen isotopic signals in the Agost sediment is distorted due to diagenesis, and therefore not reliable as climatic indicator.

3) The K/T extinction event is well represented at Agost with 57% of the species extinct at the boundary (Pardo *et al*, in press). At Koshak, just one species disappeared at the boundary, and two species disappear just below (5 cm) and just above (5 cm) the K/T boundary. There is no evidence of a sudden mass extinction at Koshak, but rather a gradual turnover in the planktic foraminiferal assemblage.

4) the decrease in the $CaCO_3$ productivity coincides with the K/T boundary at Agost, whereas at Koshak the first decrease is recorded at the Zone P0/P1a transition, in the early Danian.

These preliminary observations suggest the existence of a latitudinal control across the K/T boundary in the Tehtys region. Two distinct faunas are present: a typical «Tethyan» or subtropical fauna in low latitudes extending northward into the middle latitudes (43° N) in the western European Tethys. A boreal fauna characterizes high latitudes and extends southward at least to 45° N in the eastern Tethys.

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