Palynological study of the sediments across the K/T boundary in Texas, U.S.A.

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Three outcrop sections in Texas, U.S.A. having sediments across the K/T boundary were studied for their palynomorph assemblages. The change in the composition of palynomorphs across this boundary is conspicuous. There is a general decrease in the total diversity of palynomorphs from Maastrichtian to the base of Palaeocene. Even the common palynomorph taxa which occur across this boundary in Texas show a proportioal decrease at the base of Palaeocene. Such a change in the palynomorph assemblage across the K/T boundary is suggested to be more due to environmental changes than evolutionary changes. This is evident from the observation that late Palaeocene palynomorph assemblage has closer affinity to the Maastrichtian palynomorph assemblage than the early Palaeocene assemblage.

The difference in the composition of palynomorph assemblages between the Midway Group and the Wilcox Group is mainly due to facies change.

Key-words - Palynology, K/T boundary, Texas (U.S.A.).

INTRODUCTION

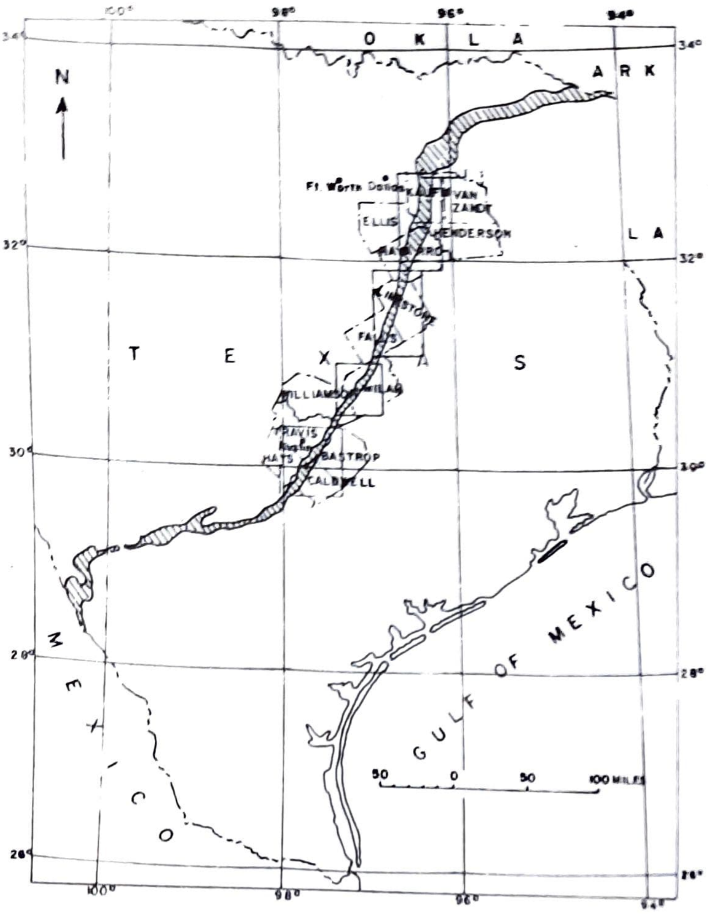
In Texas the uppermost Cretaceous is represented by the Navarro Group and the lowermost Tertiary by the Midway Group. The contact between the two is unconformable. Though the amount of time represented by this unconformity is unknown, there is sufficient evidence from sedimentology, invertebrate palaeontology, palaeobotany and palynology to support the interpretation that there is a time gap represented here between the Navarro and the Midway Groups.

Due to Larmide orogeny, the late Cretaceous time was marked by elevation of land and retreat of the sea in central Texas, but in the early Tertiary this area was inundated by a new transgression of the sea. The maximum extent of the retreat of the latest Cretaceous sea is not precisely known, but it is unlikely that the Taylor and the Navarro seas extended much farther inland than the position of the present Balcones fault zone (Sellards *et al.*, 1966).

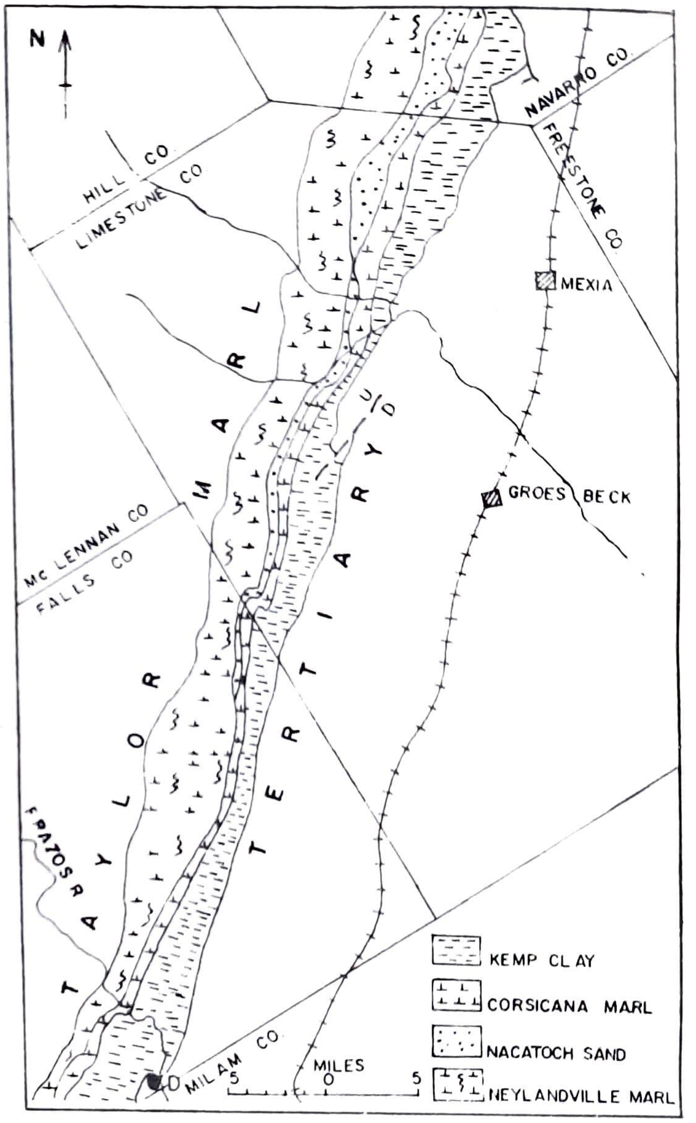
According to Adkins and Lozo (1951), Lozo and Stricklon (1956) and Murray (1955) these transgressive and regressive sequences are cyclic depositional sequences which coincided with widespread fluctuations of the sea level during the Mesozoic and Cenozoic eras. Primarily they appear to be the result of (a) major variations in locale or rate of sedimentation, or (b) regional warping related to epirogenic and isostatic adjustments.

The present paper describes the change in the composition of palynomorph assemblage across the K/T boundary sediments in Texas. This change is demonstrated both in terms of the diversity of palynomorphs, which decreases from Maastrichtian to the base of Palaeocene, and also the proportional representation of few common palynomorph species decrease from Maastrichtian to the base of Palaeocene. Such a change in the composition of the palynomorphs across this boundary is interpreted to be more due to ecological factors than evolutionary.

A discussion on the stratigraphic nature of the K/T boundary in Texas is provided and the available literature is surveyed to examine the changes in the composition of various other fossil groups. The change in the depositional environment across this boundary is discussed in the light of the movement of shoreline. Brief remark on the palaeoclimatic change is also made.



Text-figure 1. Map showing the belt of outcrop of the Navarro Group in Texas and index map showing the location of areas covered by a series of small maps (After Stephenson, 1941).



Text-figure 2. Outcrop of the Navarro Group in the Limestone and Falls counties. D. Brazos River Section (After Stephenson, 1941)

SECTIONS STUDIED

The upper Cretaceous-lower Tertiary outcrops, stratigraphy and important geological features of Texas are shown in text-figures7 . Three sections were studied, their locations are shown in text-figures 1,2,3 and 4. The Walker Creek section is located approximately 8 km northeast of Cameron and 3 Km east of U.S. Highway 77 in the Milam country (Text-figs 3, 6). This is number 6 in Smith's (1959) field trip guide book. Seven samples were collected here. The Brazos River section is stop number WA-18 in Pessagno's (1970) field trip guide book. This locality is 200 yards downstream from a bridge on the Brazos River, and 9 km northeast of Rosebud on the state highway 413 in the Falls county (Text-figs 2, 6). Five samples were collected from this locality. The Littig Pit locality is stop number A-24 in Pessagno's (1970) field trip guide book. This locality is about 3 km SSE of Littig, between Littig and

PLATE 1

(Kemp Clay Assemblage. All photographs magnified x 950)

1. *Wodehouseia fimbriata* Stanley 1961
2. *Biretisporites potoniaei* Delcourt & Sprumont 1955
3. *Stereisporites dakotaensis* (Stanley) Kumar 1992
4. *Camarozonosporites vermiculisporites* (Rouse) Krutzsch 1963
5. *Cycadopites giganteus* Stanley 1965
6. *Monocolpopollenites* sp.
7. *Cycadopites scabratus* Stanley 1965
8. *Todisporites* cf. *T. minor Couper* 1958
9. *Wodehouseia spinata* Stanley 1961
10. *Arecipites* cf. *A. columellus*, Leffingwell 1971
11. *Pterospermella* sp.
12. *Cycadopites* sp.
13. *? Deflandrea* sp.

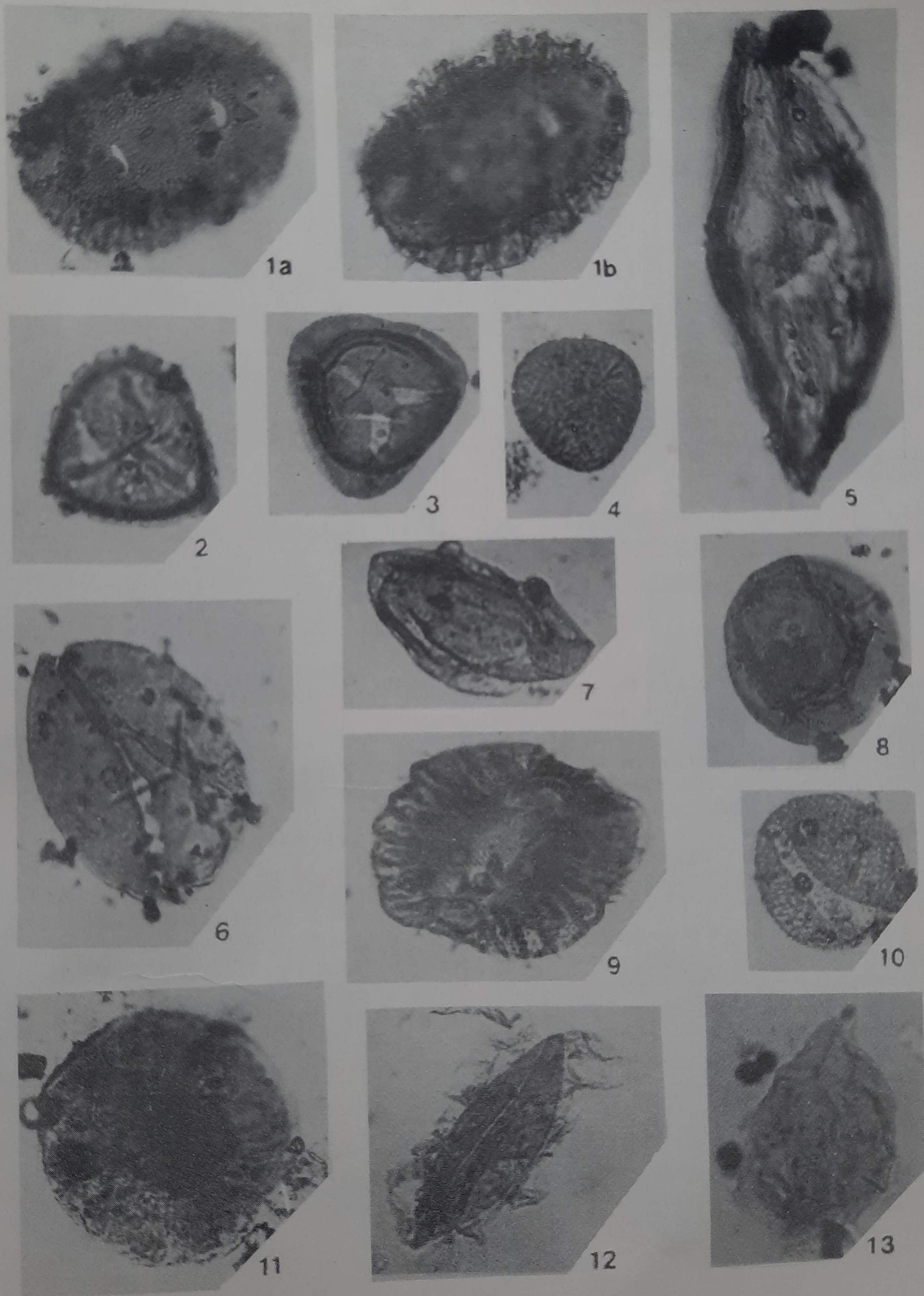
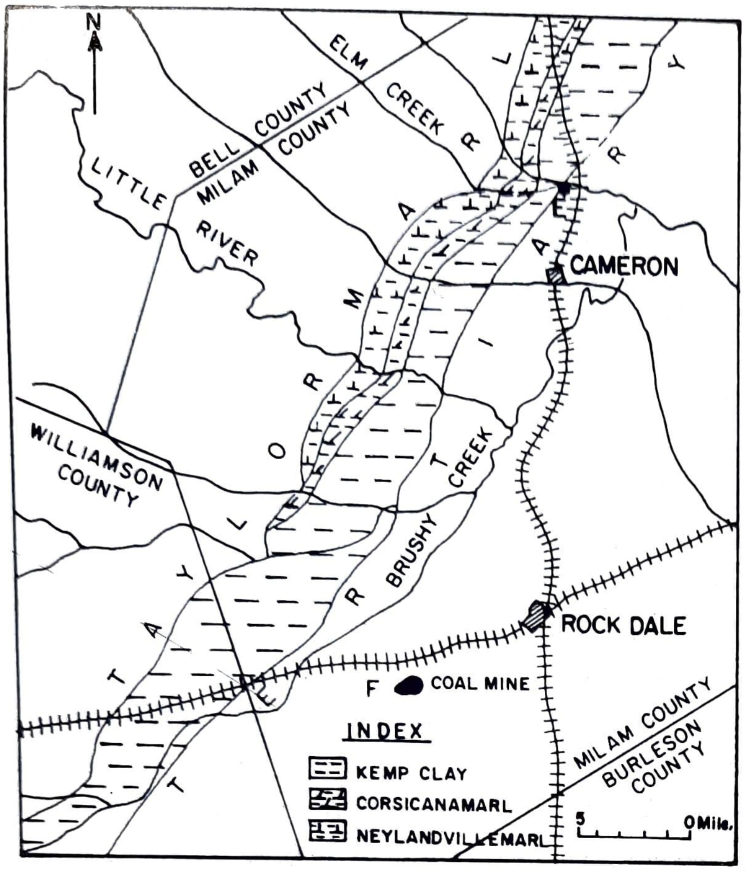
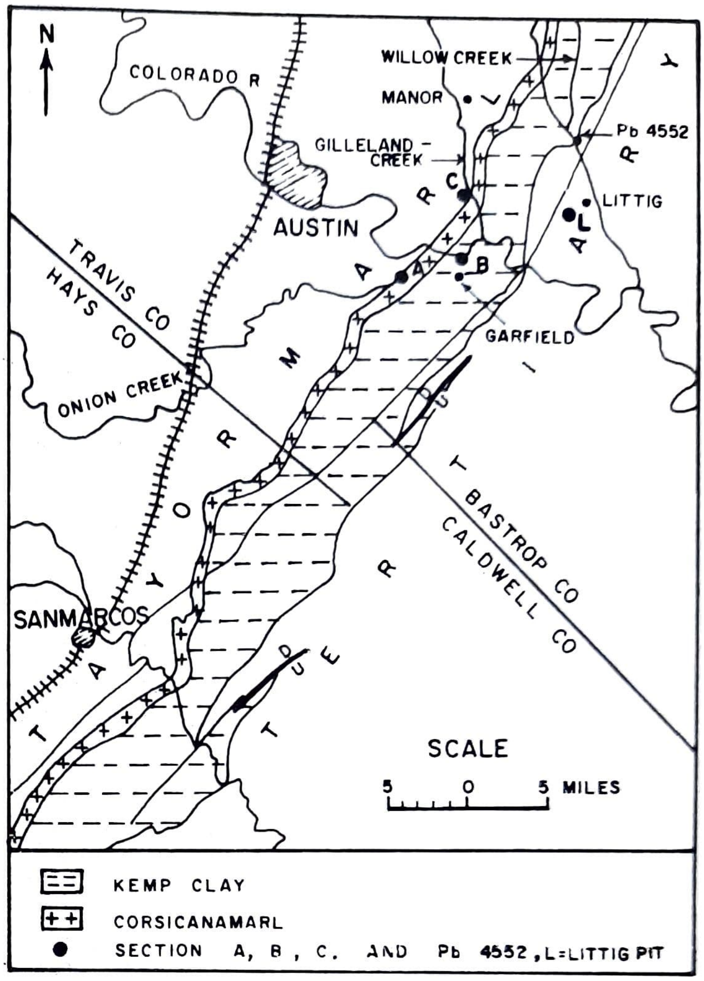


PLATE 1



Text-figure 3. Outcrop of the Navarro Group in the Milam and the Williamson counties. E. Walker Creek Section, F. Rockdale Section (After Stephenson, 1941)



Text-figure 4. Outcrop of the Navarro Group in Travis, Hays and Caldwell counties. L. Littig Section. (After Stephenson, 1941).

Elgin in Travis county (Text-figs 4 5). Ten samples were collected from this locality but all were barren of palynomorphs. Six samples of Rockdale Formation (Wilcox Group) were also studied to examine the change in the composition of palynomorphs from Palaeocene to lower Eocene. Text-figure 3 shows the locality of this section.

The top of the Navarro is not of the same age at all points due to the fact that the sea retreated earlier in some areas than in others. The basal part of the Midway also varies at different places between clay or limestone. This contact is marked in most places by a layer of glauconite, phosphatic nodules or a thin stratum of glauconitic sand containing polished pebbles and shark teeth. In east central Taxas, the lithologies of the Kemp Clay Formation (uppermost of the Navarro Group) and Kincaid Formation (lower Midway Group) are the same except for the glauconite layer at the base of the Kincaid Formation.

PALAEONTOLOGICAL EVIDENCE

According to Stephenson (1941), out of 192 genera of invertebrates which occur in the Navarro sediments, only 64 genera are known to range upward into Tertiary. Of the 99 species of molluscs in the Kemp Clay Formation, none except *Gryphaeostrea romer* is known to range up into Tertiary. Gardner (1935) states that out of 56 molluscan

PLATE 2

(Kemp Clay Assemblage. All photographs magnified x 950)

1. *Palmidites maximus* Couper 1953
2. *Ghoshispora* sp.
3. *Inaperturopollenites* sp.
4. Trisyncolpate pollen
5. *Extratriporopollenities* sp.
6. *Tricolpites* sp.
7. *Ghoshispora minor* (Norton) Srivastava 1978
8. *Momipites* cf. *M. quietus* (Potonie) 1973
9. *Tricolpites rugulatus* Brenner 1963
10. *Ghoshispora minor* (Norton) Srivastava 1978
11. *Ghoshispora* sp.

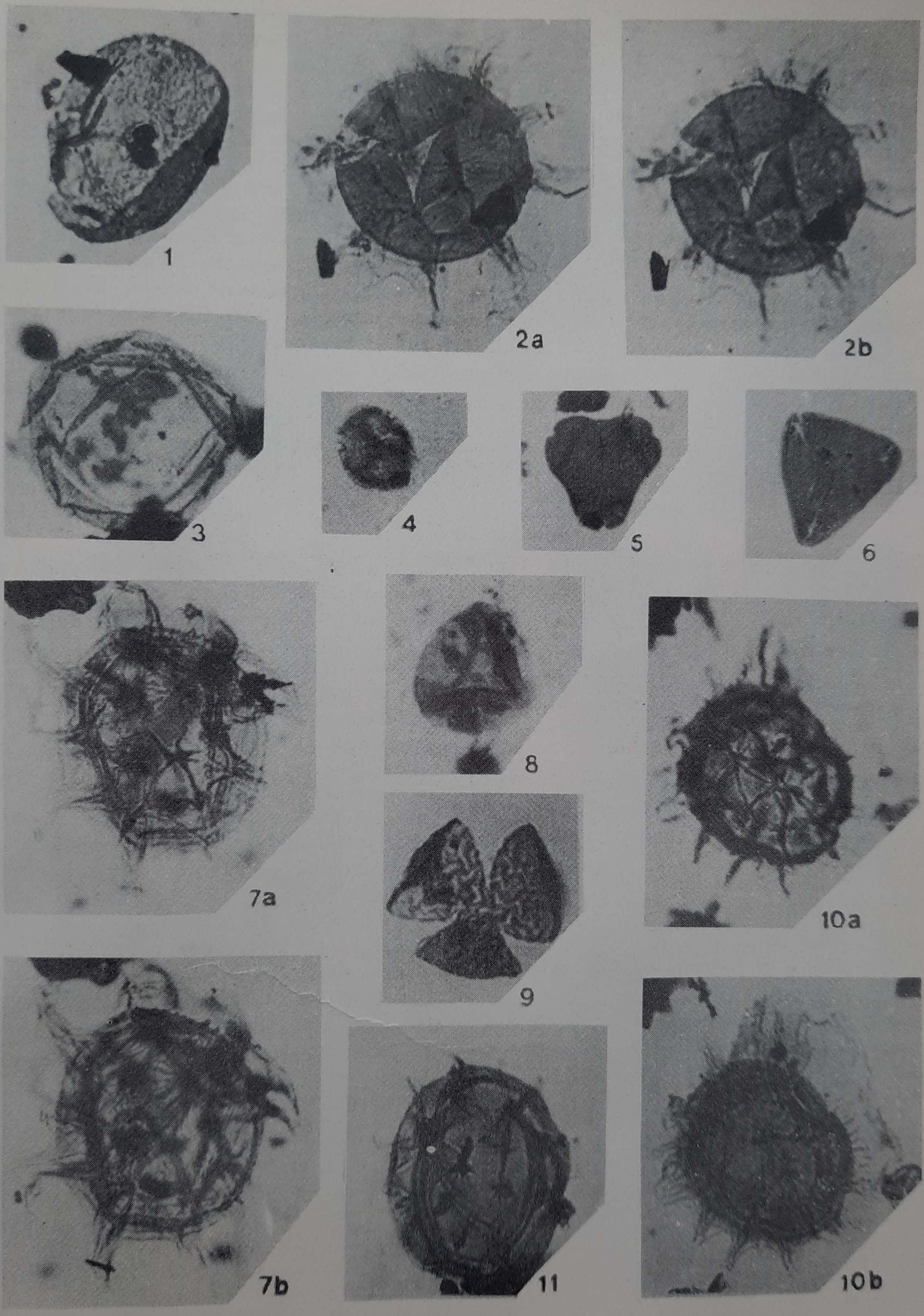
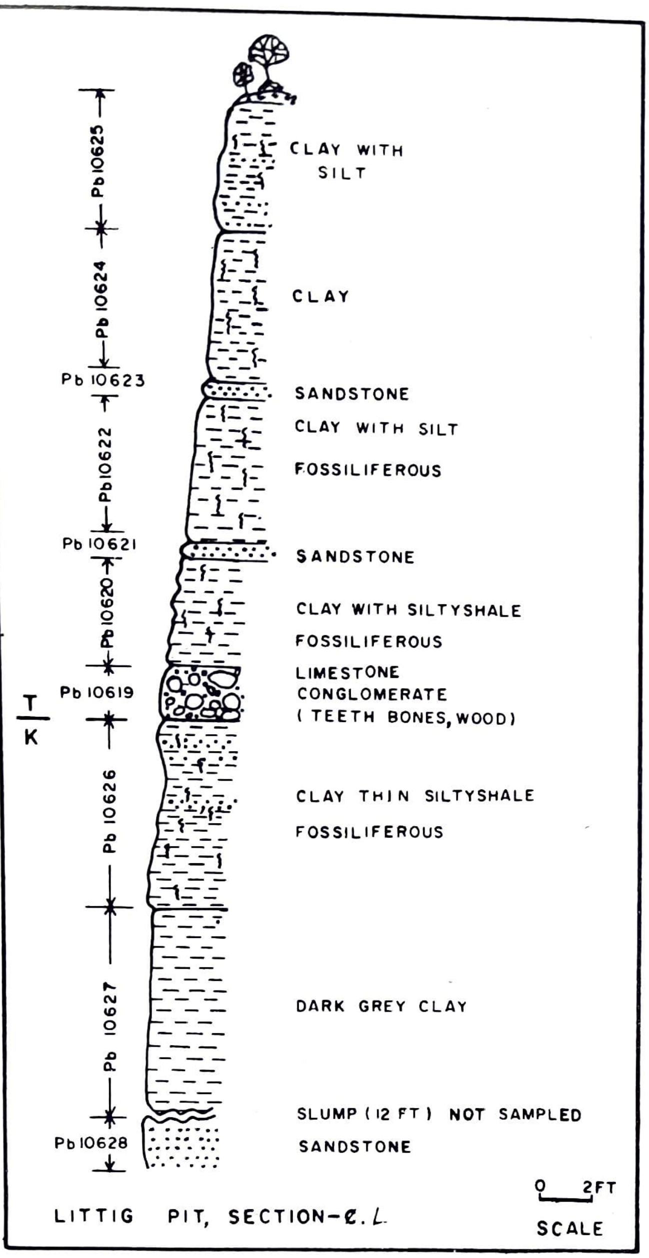


PLATE 2



Text-figure 5. Lithology and sample location of the Littig Section (L) across the K/T boundary

genera of the Midway Group only 21 are known from Cretaceous and 35 genera were new immigrants in early Tertiary seas of the Gulf Coast region. Stephenson (1915) gives a detailed account of the importance of the faunal change across the K/T boundary in the Gulf Coastal region.

Pessagno (1967) listed the following foraminiferal taxa which became extinct at the top of the Navarro : families Rotaliporidae, Abathomphalidae, Marginotruncanidae, and genera *Plummerina, Rugoglobigerina, Archaeolobigerina* and *Globotruncana* s.s. belonging to the family Globotruncanidae and genera *Globigerinelloides*, and *Biglobigerinella* belonging to the family Planomalinidae.

The family Heterohelicidae shows maximum diversity during the Navarro times and becomes much less diverse in the Midway. The following genera of this family became exinct at the top of the Navarro : *Racemiguembelina, Pseudotextularia, Pseudoguembellina, Heterhelix*, and *Planoglobulina*. Loeblich and Tappan (1957) listed the following genera of planktonic foraminifera characteristic of Cretaceous but not found in post Maastrichtian strata in the Gulf and Atlantic coastal deposits; *Globigerineloides, Planaomalina, Hestigerinoides, Schackonia, Praeglobotruncana (Hedbergella), Rotalipora. Globotruncana, Rugoglobigerna, Abathomphalus, Guembellitriella, Pseudotextularia, Gluberina, Planoglobulina*, and *Racemiembelina*. In addition *Heterohelix, Guembelitria*, and *Biglobigerinolla* although mostly occur in the Cretaceous but also range into Tertiary. After the extinction of many taxa of Cretaceous foraminifera a new expansion of planktonic foraminifera began in the Tertiary. The oldest Tertiary (Danian) is characterised by the genus *Chiloguembelina, Woodringina, Globigerina*, and non keeled species of *Globorotalia*.

Considering the conspicuous change in the faunal composition across the K/T boundary in Texas, it would appear that the time represented by this unconformity is fairly long. If it was an episode of shorter duration, it would seem theoretically probable that a considerable part of the Kemp Clay fauna might have survived under the presumably similar environmental and climatic conditions that existed in the Kincaid sea. Probably the Danian of the European section is not represented by synchronous sediments in the Atlantic and the Gulf coastal plains. Gardner (1935) following the generally accepted correlation, has concluded that the Midway Group is

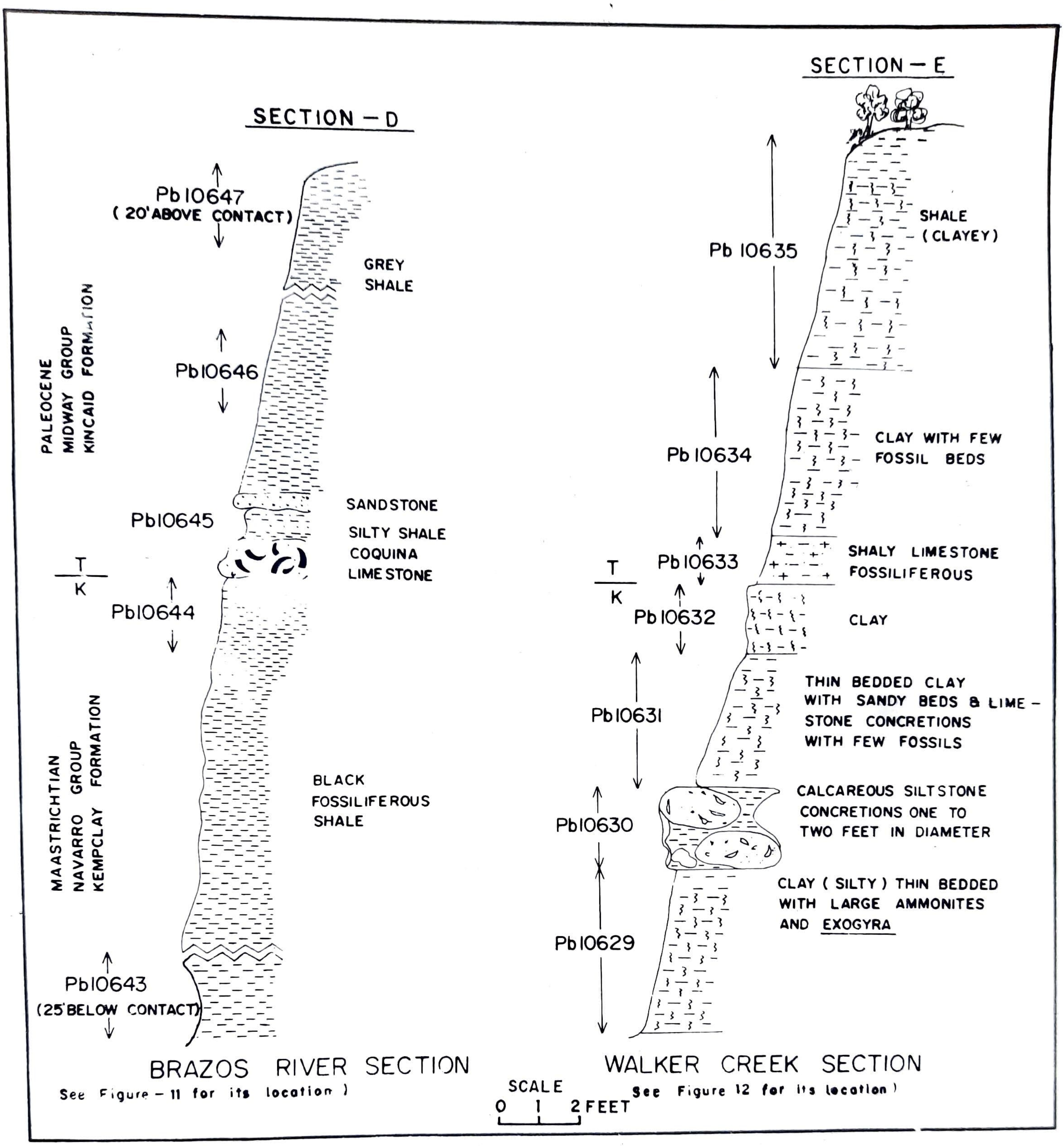
PLATE 3

(Midway and Wilcox Assemblage. All photographs magnified x 950)

1. *? Asteropollis* sp.
2. *Quadrapollenites vagus* (Stover) Elsik 1968
3. *Tricolpites reticulatus* Cookson 1947
4. *Striatocolporites* sp.
5. *Palmaepollenites* sp.
6. *Asteropollis asteroides* Hedlund & Norris 1968
7. Monoporate pollen
8. *Betulaepollenites claripitis* (Wodehouse) Kumar 1992
9. *Alnipollenites quadrapollenites* (Rouse) Srivastava 1966
10. *Cupuliferoidaepollenites liblarensis* Thomson in Potonie - *et al.* 1950
11. *Cyathidites australis* Couper 1953
12. Algal structure
13. *Monocolpopollenites* sp.
14. *Rhoipites* sp.
15. *Rhoipites* sp.
16. *Potamogetonacidites senonicus* Takahashi & Sugiyama 1990
17. *Liliacidites* sp.
18. *Arecipites* sp.
19. *Quadrapollenites vagus* (Stover) Elsik 1968
20. *Deltoidospora hallii* Miner 1935

PLATE 3

PLATE 4

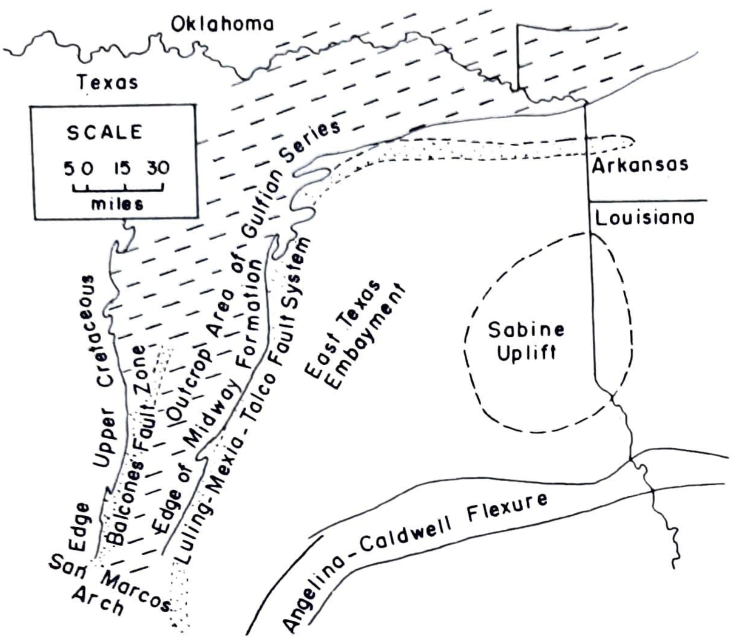


Text-figure 6. Lithology and sample location of the section across the K/T boundary in Texas. D. Brazos River Section, E. Walker Creek Section.

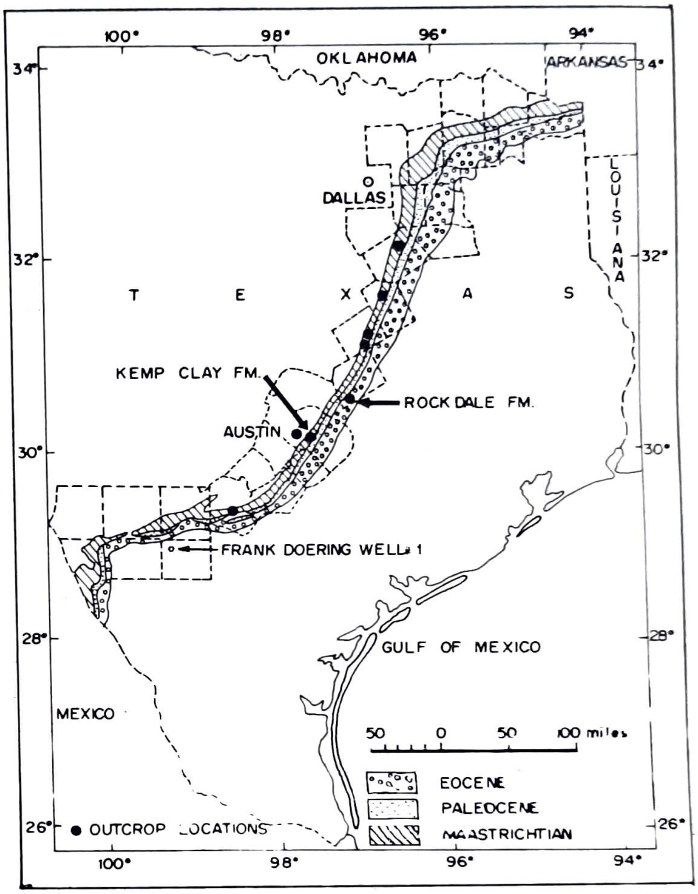
PLATE 4

(Wilcox Assemblage. All photographs magnified x 950 unless otherwise mentioned)

1. *Triatriopollenites bituitus* (Potonie) - Thomson & Pflug 1953
2. *Rhoipites* sp.
3,4. *Laevigatosporites* sp.
5,6. *Cupuliferoidaepollenites* sp.
7. *Rhoipites* sp.
8. *Inaperturopollenites dubius* (Potonie & Venitz) Thomson & Pflug 1953
9. *Laevigatosporites* sp.
10. Pollen tetrad
11,12,14,16. *Thomsonipollis magnificus* (Pflug & Thomson) Krutzsch 1960
13. cf. *Thomsonipollis* sp.
15. *Nyssapollenites pseudocruciatus* Fairchild 1966
17. *Palmidites maximus* Couper 1953 (x 400)
18. *Todisporites major* Couper 1958.
19. *Arecipites inaequalis* Elsik 1974
20. *Cupuliferoipollenites* sp.



Text-figure 7. Important geological features of Eastern Texas (After Stehli, 1972).



Text-figure 8. Uppermost Cretaceous and Lower Tertiary outcrops in Texas.(After Zaitzeff, 1967).

synchronous with the Palaeocene section of Europe which overlies the Danian. As Danian is itself bounded both below and above by erosional unconformities representing intervals of unknown length, the Navarro-Midway unconformity is an important time gap.

The sweeping changes in the composition of the fauna across the K/T boundary might not be adequately explained as an evolutionay phenomenon if the time interval was very short. The notable influx of new faunal elements present in the Midway Group could be due to two possibilities. Firstly it could be due to evolutionary change if we consider the time gap to be long enough, secondly it could also be due to a major environmental stress caused by drastically reduced area of shelf habitats during regression of the sea. Selective pressure on the organisms under such drastic environmental changes could bring out changes of such high magnitude. During transgression of the Midway sea, some of the older surviving forms may have acquired enough new characteristics that they are classed as different species. Alongwith such changes newer forms also came into the Midway sea by migration. Stephenson (1941) suggestd that the newer forms came from the south. Gardner (1935) believed that they may have spread westward from the old Tethyan sea.

In the past few years, several new papers have been published on the sedimentological, taphonomical, and on the extinction patterns across the K/T boundary in Texas (Hansen *et al.*, 1984). Jiang and Gartner (1986) have discussed the succession of calcareous nannofossil in Texas.

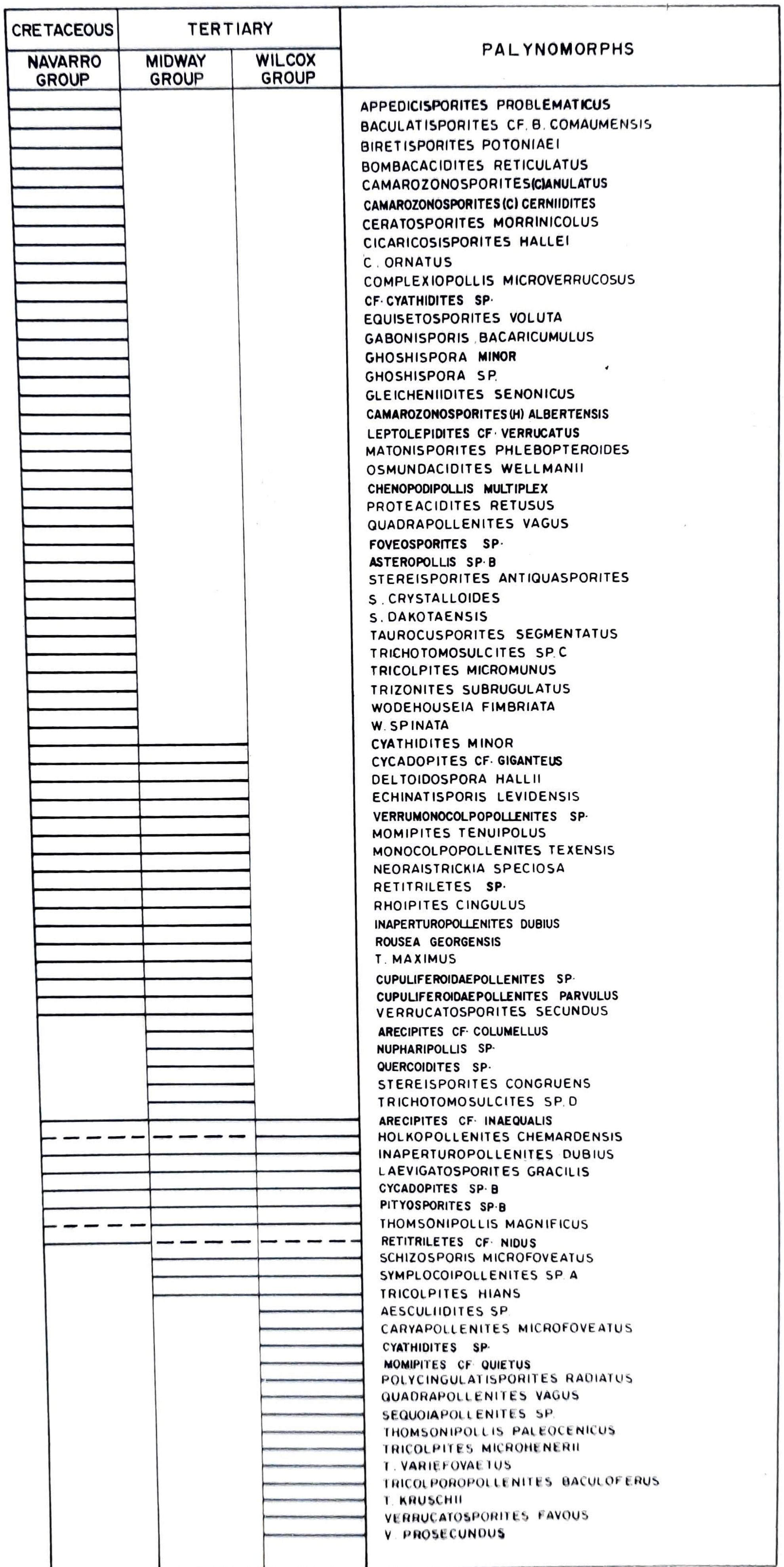
At Braggs in neighbouring Alabama, an almost complete section of shallow marine Maastrichtian and Danian sediments is exposed. These are mainly limestones and marls deposited during late Maastrichtian regression and subsequent Danain transgression. Zachos *et al.* (1989) studied geochemical and palaeoenvironmental variations across the K/T boundary and concluded that the shallow marine temperature along the Gulf Coast was around 19^{0}C during the K/T transition. A gradual cooling of 2^{0}C - 3^{0}C over 3 m.y. period beginning in late Maastrichtian was also suggested. Bryan and Jones (1989) provided a long list of fauna which became extinct across the K/T boundary in this section, and concluded that faunal decline across this interval was abrupt and severe with 50% of terminal Cretaceous species dropping out of record in Danian. Jarzen (1978) provided the data on the changes in the composition of terrestrial palynomorphs across the K/T boundary at Braggs. Donovan *et al.* (1988) studies sequence stratigraphy across this boundary at Breggs. The conclusions of these works on Braggs section provide a good basis for understanding the possible environments in Texas as well during the K/T transition.

SAMPLES / PALYNOMORPHS	WALKER CREEK SECTION							BRAZOS RIVER SECTION					ROCKDALE FORMATION (WILCOX GROUP)					
	Pb 10629(K)	Pb 10630(K)	Pb 10631(K)	Pb 10632(K)	Pb 10633(T)	Pb 10634(T)	Pb 10635(T)	Pb 10643(K)	Pb 10644(K)	Pb 10645(T)	Pb 10646(T)	Pb 10647(T)	WR-1(T)	WR-6(T)	WR-18(T)	WR-26(T)	WR-33(T)	WR-37(T)
DINOCYSTS AND ACRITARCHS																		
ACHOMOSPHAERA RAMULIFERA	C			R	F	F		C		A	R	R						
BALTISPHAERIDIUM SPP.			F		F	F												
CORDOSPHAERIDIUM SPP.	F			F	F		C	F		F	R	R						
CYCLONEPHELIUM SPP.	R				F		F	C		C	R	R						
CYMATIOSPHAERA SP.								F		F								
DEFLANDREA SPP.	C	B	C	F				C	R	A	R	R						
DINOGYMNIUM SP.				R		F				F								
GONYAULACYSTA SP.						F												
MICRHYSTRIDIUM SPP.					F	C												
PTEROSPERMOPSIS SP.			R	R														
SPINIFERITES SPP.	A		A	C	A	A	A	A	R	A	R	R						
SVALBARDELLA SP.	R			F				F	R									
TANYOSPHAERIDIUM SP.						F				F								
MISCELLANEOUS DINOCYSTS	F		C	F	C		F	F		F								
POLLEN AND SPORES																		
AESCULIDITES SP.														F				
ALNIPOLLENITES TRINA	F		F	R														
APPENDICISPORITES PROBLEMATICUS	R	A		F	F			F										
AQUILAPOLLENITES ECHINATUS	R			R														
ARECIPITES SP.	F			F									C					
BACULATISPORITES SP.								F										
BOMBACACIDITES RETICULATUS	R		F															
BIRETISPORITES ANTIQUASPORITES				R														
CAMAROZONOSPORITES ANNULATUS				R				F										
C. CERNIDITES	R			F														
CARYAPOLLENITES SIMPLEX														C	C	C	A	A
CICATRICOSISPORITES HALLEI	R							R										
C. ORNATUS	R		R	F				F										
CLASSOPOLLIS PARVUS	R	R	F	R	F	F	F	R										
C. TOROSUS	F		C	C	C	C	F	F									F	
COMLEXIOPOLLIS SP.	F																	
CONCAVISSIMISPORITES PARKINII								R										
CUPULIFEROIDAEPOLLENITES SP.	C		C	F	C	C	A											
CYCADOPITES GIGANTEUS	C		F	F	C	C	C	F										
CYATHIDITES MINOR	C			C		C	C	C		C								
DELTOIDOSPORA HALLII	R		F	F		F	F			F								
DIVISISPORITES ENORMIS													C					
ECHINATISPORIS LEVIDENSIS	R		R			F												
EQUISETOSPORITES VOLUTA	R	R																
ERDTMANIPOLLIS SP.								R										
GABONISPORIS BACARICUMULUS								R		R								
GLEICHENIIDITES SENONICUS				R														
HAMULATISPORIS ALBERTENSIS								F										
HOLKOPOLLENITES CHEMARDENSIS													C	A		C		C
INAPERTUROPOLLENITES DUBIUS	C		C	C	A	C	A	C	R	C				C	A	C	C	C
LAEVIGATOSPORITES GRACILIS	C		F	C	C		C	C						C			C	C
L. HARDTII						C			R	C	R	R	C			C		
LEPTOLEPIDITES TENUIS				F														
LILIACIDITES SP.	F		F	R	F	F	C											
MATONISPORITES PHLEBOPTEROIDES		E		F														
MOMIPITES QUIETUS													F		A	C	C	C
M. TENUIPOLUS	C		F	C	F	C	C	F	R							C	C	C
MONOCOLPOPOLLENITE SPP	R		C	C			C	C	R						A	C	C	C
M. TEXENSIS	F		F			F	F		R									
NEORAISTRICKIA SPECIOSA					F													
OSMUNDACIDITES WELLMANII				F				F										
PINUSPOLLENITES SP.	F		R	F		F	F	F		F			F	F				
POLYCINGULATISPORITES RADIATUS								R										
POLYPODIISPORITES INANGAHUENSIS				R				R										
POLYPORINA CRIBRARIA	F		F	R														
PROTEACIDITES RETUSUS	F	N	F	R		R		F										
QUADRAPOLLENITES VAGUS														F		F	F	
QUERCOIDITES SP.						F	F											
RETITRILETES AUSTROCLAVATIDITES						R		F										
RHOIPITES CINGULUS	F		C	F	F			F		F								
SCHIZOSPORIS SP.						F	F						C		C	A	C	C
SEQUOIAPOLLENITES SP.								F										
SESTROSPORITES PSEUDOALVEOLATUS				R														
SPARGANIACEAEPOLLENITES SP.	R							R										
STEREISPORITES ANTIQUASPORITES	R																	
S. CONGRUENS						F	F											
S. DAKOTAENSIS	F		R	C				F										
STYX MINOR								R										
SYMPLOCOIPOLLENITES SP.																F		C
TAXODIACEAPOLLENITES SP.	F		C	F	C	F	F	F										
THOMSONIPOLLIS MAGNIFICUS SP.							F						A	C		C	C	A
TRICHOTOMOSULCITS SP.				R		F		R										
TRIPOROPOLLENITES BITUITUS			F	F				R					C	F	A	A	A	A
TRICOLPITES GEORGENSIS	R		C	F	C	F		F		F								
T. HIANS													A	A	A	A	A	A
T. MICROMUNUS			C	F														
TRICOLPITES SPP	R		C	C	C		C											
TRICOLPOROPOLLENTES BACULOFERUS														A		C	C	
T. KARUTZSHII													C	F		F	C	
TRICOLPOPOLLENITES MICROHENERICII													C	C		C	C	C
TRIZONITES SUBRUGULATUS				R														
TILIAEPOLLENITES SP.						F												
VERRUCATOSPORITES FAVUS															F	F		
V. SECUNDUS						F		F										F
WODEGHOUSEIA SPINATA								R										
	28·0	BARREN	24·5	13·4	40·4	21·0	20·2	32·7	ALMOST BARREN	71·8	ALMOST BARREN	ALMOST BARREN						

ALL THE SAMPLES OF LITTIG PIT SECTION WERE BARREN OF PALYNOMORPHS

K = CRETACEOUS
T = TERTIARY
R = RARE (<1·0%)
F = FEW (1–3 %)
C = COMMON (3·1–10%)
A = ABUNDANT (>10%)

Text-figure 9. Distribution of palynomorphs in various samples across the K/T boundary in Texas.



Text-figure 10. Stratigraphic distribution of selected palynomorphs in the Upper Cretaceous and Lower Tertiary sediments in Texas.

PALAEOBOTANICAL EVIDENCE

E.W. Berry's comments (in September 1915) about floral changes between the upper Cretaceous and the Eocene in eastern Gulf Coast are quoted here : " with regard to upper Cretaceous and Eocene flora of the eastern Gulf region their differences are profound, and I believe the unconformity at the base of the Midway represents a very long interval. The last extensive floras of Cretaceous in the Gulf region are, of course, a good way from the end of the Cretaceous, but they are totally different form the plants collected near Earl, Texas in beds believed to belong to Midway Formation. Even when comparisons are made between these Midway (?) plants and the Wilcox flora of the Gulf and the late Cretaceous of the Rocky mountain province, the contrast is just as marked, unless you are prepared to call the Denver Formation Cretaceous. There are a number of plants of the Gulf Eocene, but I do not recall a single Larmie plant." While discussing the Cretaceous and Tertiary floras of eastern North America, Berry (1937) states, that forty per cent genera of the latest upper Cretaceous floras are unknown in the earliest Eocene and over twenty per cent are extinct. According to him this change was not sudden, older types of plants were dropping out and new ones were appearing either as a result of evolution or migration from the other centers of evolution. In the Gulf region the change in the composition of flora across the boundary is pronounced because of the considerable time gap between the latest Cretaceous and the lower Tertiary.

In the past few years several papers have been published on the extra terrestrial causes of mass extinction at the K/T boundary (Alvarez *et al.*, 1980, 1984) and how it effected the environment both on land and in the oceanic realm (Officer & Drake, 1985; Zachos & Arthur, 1986). The effect of such terrestrial environmental changes on the vegetation in North America has been the subject of extensive study by Upchurch (1989), Upchurch and Wolfe (1987), Wolfe and Upchurch (1986, 1987a, 1987b). All these studies provide insight on the changes in the terrestrial environments in Texas region during the K/T transition which led to significant extinction of flora in the Gulf coastal region.

PALYNOLOGICAL EVIDENCE

There are many publications from various parts of the world concerning palynological changes at the Cretaceous-Tertiary boundary. Several of the major contributions are : Couper (1953) in New Zealand, Zaklinskaya (1960) in the U.S.S.R., van der Hammen and Wymstra (1964) in Guyana, Van Hocken-Klinkenberg (1966) in Nigeria, Muller (1968) in Sarawak, Malaysia, Portniagina (1973) and Stover and Evans (1973) in Australia. The important North American publications are : Anderson (1960), Newman (1964), Stanley (1965), Drugg (1967), Norton and Hall (1967), Hall and Norton (1967), Snead (1969), Oltz (1969), Leffingwell (1970), Rouse *et al.* (1970), Rouse and Srivastava (1972), Tschudy (1970, 1973, 1976) Tschudy and Patterson (1975). More recently Tschudy (1984), Tschudy *et al.* (1984) and Tschudy and Tschudy (1986) are very significant studies.

Most of these publications provide a biostratigraphic characterisation of upper Cretaceous and lower Tertiary formations on the basis of palynomorph assemblages. Most of the papers dealing with North America are from the west coast and Rocky Mountain regions. Tschudy (1970), Tschudy and Patterson (1975) and Jarzen (1978) deal with the Gulf Coast and the Atlantic Coast. The general conclusions about floral change across the K/T boundary in North America can be stated as follows:

1. Palaeocene formations yield fewer palynomorphs than the underlying Creteaceous, but upper Palaeocene and Eocene rocks show an increase in number and diversity of species with a more or less modern aspect.

2. According to Tschudy (1970), Cretaceous and Palaeocene floras of the Mississippi Embayment exhibit closer similarities to the European flora than to those of the Rocky Mountain region. They suggested the cause of floral dissimilarity in the two floral provinces (Mississippi Embayment and Rocky Mountain) was due to the presence of a north-south trending epiric sea which was wide enough to inhibit migration between the two floral provinces.

3. In the Gulf Coastal region, floral change coincides with the lithologic boundary and may have been the result of environmental changes during the time represented by the unconformity. Most of the Cretaceous species died out leaving unfilled biological niches that were gradually filled by new species, either evolving from genera already there or migrating into the area from the outside.

4. Floral changes across this boundary might have been strongly influenced either by the depositional environments or by the climatic changes brought about by the uplift of the land area or by the transgression of the Gulf of Mexico sea.

5. The evidences from pollen and leaf floras do not suggest a profound climatic change during the K/T transition such as evidenced at the onset of the Pleistocene glaciation. Warmer climate existed during upper Cretaceous and Palaeocene, but later (mid Oligocene) changed to cooler climates (Dorf, 1969). The pollen and spore floras of the Mississippi Embayment region suggest a temperate to subtropical climate during the latest Cretaceous.

6. Jarzen (1978) studied the palaeocommunity structure during the K/T transition at Braggs, Alabama and found that these communities persist through the transition period with only minor changes in the generic composition.

CONCLUSION

The present study conclusively demonstrates the changes in the palynomorph assemblages across the K/T boundary in Texas. Text-figure 9 shows the ranges of allochthonous palynomorphs in the sediments across the K/T boundary in Brazos River and Walker Creek sections. Text-figure 10 shows the distribution of palynomorph species and their relative abundances.

The changes in pollen and spore flora across the K/T boundary in Texas is very pronounced. Out of 30 species of spores in the upper part of the Navarro, only 8 are found in the lower Midway, and only one is new. Only two of the Navarro species continue in the Wilcox. Among the angiosperm pollen, of the 23 species which are found in the Kemp Clay Formation only 12 are found in the Midway and 9 species are new. In the Wilcox Group four species of angiosperm pollen range upward from the Navarro and three species from the Midway are found, in addition to ten new arrivals. Among the gymnospermous pollen, seven species are found in the upper Navarro, six of which are represented in the Midway and two of which are present in the Wilcox Group. Although there is no new immigration of gymnospermous species in the early Tertiary, they form a conspicuous part of the flora because of their higher proportional representation.

Some of the species found in the Midway Group could be recycled specimens from the Navarro, but it is very difficult to state that a certain species is recycled or has a longer range. Evitt (1973) has pointed out this difficulty and he notes that this is due to the abundance of Cretaceous palynomorphs in the lower Tertiary.

The time gap between the Navarro and the Midway is quite long, which is evident from the significant differences in the pollen and spore assemblages in those two groups. It is not possible here to state the exact length of time of non-deposition between them. The changes in the composition of pollen and spore appears to be more due to the ecological reasons than evolutionary changes. This is suggested because several of the elements of the Maastrichtian assemblage are not found at the base of the Palaeocene, but several of them reappear later in the late Palaeocene and younger sediments. Thus there appears to be more similarity in the Maastrichtian and late Palaeocene palynomorph assemblages than Maastrichtian and early Palaeocene assemblages.

The floral change between the Midway Group and the Wilcox Group is mainly due to the facies changes. The Midway Group is predominantly marine whereas the Wilcox Group represents sediments deposited in the coastal swamp environments. Text-figure 10 shows the distribution pattern of palynomorphs in these two groups.

The composition of dinoflagellate cysts and acritarchs does not significantly vary across the K/T boundary in Texas, however, the diversity of pollen and spores decreases from Maastrichtian to the base of Palaeocene. Two significant pollen species, i.e., *Aquilapollenites echinatus* and *Wodehouseia spinata* mark the end of Cretaceous period in Texas.

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