

SEQUENCE ANALYSIS OF WESTERN VENEZUELAN CRETACEOUS TO EOCENE SEDIMENTS USING PALYNOLOGY: CHRONO-PALEOENVIRONMENTAL AND PALEOVEGETATIONAL APPROACHES

VALENTI RULL
MARA VEN
Exploration Department
Specialized Geological Services (Palynology)
P.O. Box 829
Caracas 1010-A
Venezuela

Abstract

Palynological evidence currently used to determine the global eustatic cycles of Haq et al. (1987) requires the existence of sediments from both continental and marine environments. The present work is a contribution to sequence analysis using sediments of continental nature. The boundaries of palynological zones help to locate and date sequence boundaries (SB) and maximum flooding surfaces (MFS); the SB is characterized by hiatuses and/or sudden floral changes (type 1 SB) and barren intervals with oxidized kerogen (type 2 SB), while the MFS may have a few brackish or marine water representatives. When marine fossils are absent, only paleovegetational criteria can be used. In this case, multivariate methods are used to find the most reliable pollen associations. Among them, the coastal and the more inshore associations are selected to compute an index that estimates the position of the tidal limit (TLI). The lateral movements of this tidal limit are recorded and correlated with corresponding sea level fluctuations, thus inferring the SB and MFS from paleovegetational data. The application of these methodologies to two wells from the Maracaibo Basin (western Venezuela) allowed determination of Maastrichtian to Eocene 3rd order cycles from the supercycle sets Upper Zuni A and Tejas A, as well as reconstruction of the local paleogeography of the coastal area.

INTRODUCTION

Several kinds of palynological evidence have been used to determine eustatic variations and to identify their cycles. The most frequent consist of the finding of maximum flooding surfaces (MFS) and sequence boundaries (SB) through the abundance of foraminiferal linings and

dinoflagellate cysts on the one hand, and pollen and spores on the other, which show an inverse relative frequency. Marine microfossils increase at the MFS and decrease or disappear in the SB, while terrigenous remains dominate during regressive phases. However, pollen and spores may be also absent at the SB due to oxidation by exposure to the air (Wall, 1965; Lister and Batten, 1988; Habib and Miller, 1989). Changes in the kerogen have been also used with success, since its quality varies if the sediments are either transgressive or regressive (Gorin and Stephen, 1989). Another approach consists of calculating salinity indexes, using freshwater and marine algae abundances, and correlating them with sea level oscillations (Rull, 1992a). These methods, however, require the occurrence of both terrigenous and marine environments, both of which containing fossils. This involves the presence of the main units of the sequence stratigraphy: highstand systems tracts (HST), transgressive systems tracts (TST) and lowstand systems tracts (LST).

However, in certain sequences practically all of the sediments are continental in origin, and only HSTs are present, with marine fossils scarce or absent. The present work is a palynological contribution to develop sequence analysis in these situations via two complementary methods, based on chronostratigraphy and paleovegetational analysis, respectively. Two examples from western Venezuela are presented in order to show the usefulness of these approaches; the first from well T-1 which has an Upper Cretaceous to Eocene sequence, and the second from well T-2 which has Paleocene sediments.

MATERIALS AND METHODS

Sample Analysis

Text-Figure 1 shows the location of the sections studied, which are parts of the oil wells T-1 and T-2. For this study, 160 samples were used - 102 from T-1 and 58 from T-2. The sample set consists of 88% core samples, 8% sidewall samples, and only 4% ditch cuttings. These samples were treated with HF and HCl, separated in a solution of zinc bromide, and mounted in glycerin jelly. Palynomorphs (pollen and archegoniate spores, fungal spores, freshwater algae, dinoflagellate cysts, foraminiferal linings) were counted until the saturation of diversity (Shannon-Weaver index), and a minimum of 200 pollen and spore counts were reached (Rull, 1987).

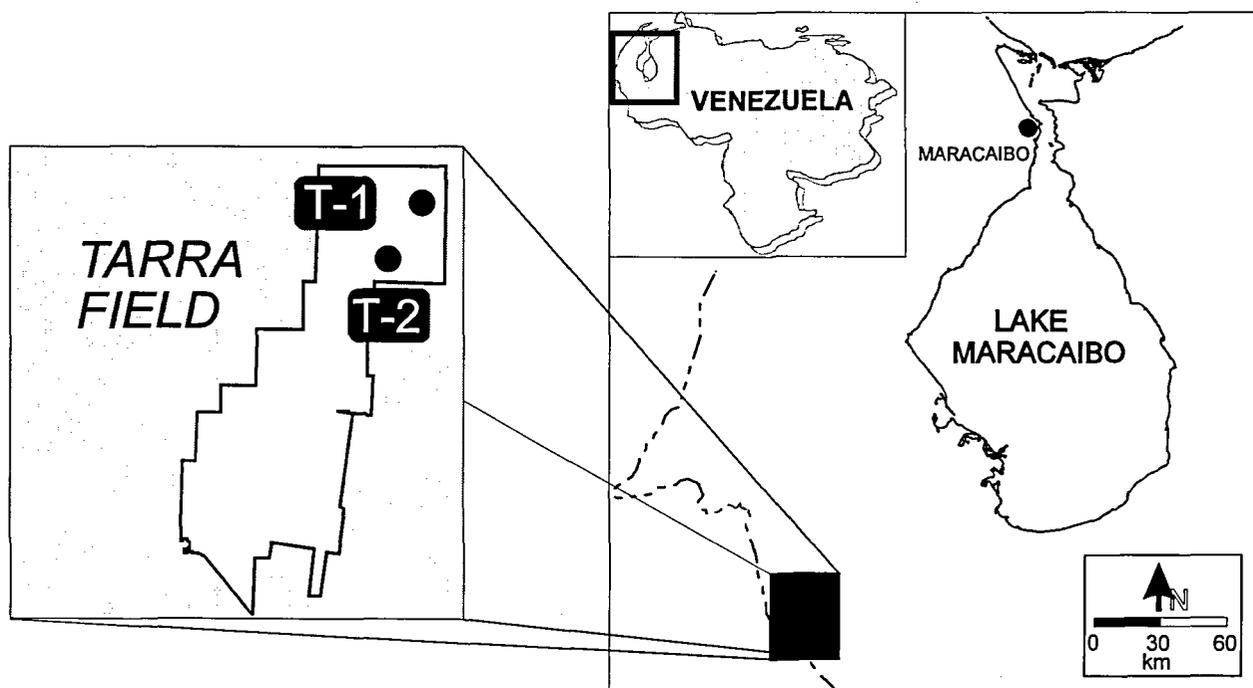
Scattered samples from both wells have been previously analyzed and stored in data bases, and some of these results had been used in MARAVEN internal reports as contributions to the establishment of a pollen zonation for the Maracaibo Basin. However, a continuous record was not available and the counts were not complete because only selected pollen grains and spores had been counted whilst marine microfossils, freshwater algae and fungal spores had not been considered. In the present work, these samples were chemically treated again and re-analyzed, recording all the palynomorphs present, and the sequences

were completed through the analysis of intermediate samples in order to obtain a thorough record. The palynological zonation of Muller et al. (1987) was used (Text-Figure 2). The eustatic framework chosen was the general Mesozoic-Cenozoic cycle chart of Haq et al. (1987).

Chrono-Paleoenvironmental Approach

The method described therein was applied to well T-1 because, although it mainly drilled continental sediments, there is some slight marine influence in several intervals. The steps of the method as follows:

1. Palynological zonation and comparison with the chronostratigraphic scale, in order to identify hiatuses, which represent the cycles or part of them that are not present in the section. Furthermore, the correlation between chronostratigraphical and pollen zonal boundaries dates them in million years (m.y.). Care must be taken to avoid those boundaries which are uncomformable or adjacent to a hiatus or a barren interval. The boundaries attached in this way are called attachment points (AP).
2. Detection of possible SBs, frequently characterized by uncomformities or barren intervals with oxidized kero-gen, as well as strong floral changes (synchronous local appearances or extinction of several taxa).



Text-Figure 1. Location map.

AGE		POLLEN ZONES		
E O C E N E	LATE	38.07	24- <i>Echiperiporites estelae</i>	
	MIDDLE	39.4	23- <i>Janmulleripollis pentaradiatus</i>	
		40.5	22- <i>Bombacacidites foveoreticulatus</i>	
			21- <i>Retitricolporites guianensis</i>	
			20- <i>Bombacacidites soleaformis</i>	
		42.5	19- <i>Retitricolporites magnus</i>	
		44.0	18- <i>Echitriporites trianguliformis</i>	
	EARLY	49.0	17- <i>Rugutricolporites felix</i>	
	PALEOCENE	LATE	54.0	16- <i>Foveotricolporites perforatus</i>
		EARLY	60.2	15- <i>Gemmastephanocolpites gemmatus</i>
			14- <i>Spinizonocolpites baculatus</i>	
MAASTRICHTIAN	66.5	13- <i>Proteacidites dehaani</i>		

Text-Figure 2. Palynological zonation of Muller et al. (1987) for the time interval studied. Ages of the chronostratigraphic boundaries (in m.y.) are from Haq et al. (1987).

3. Detection of possible MFSs, characterized by peaks in the abundance of marine microfossils. Since these remains are generally scarce, their presence/absence features may be also indicative.
4. Dating of the possible MFS and SB, through the integration of the three previous steps plus comparison with the eustatic framework used (in this case, the cycle chart of Haq et al., 1987). The most reliable procedure at this step is to correlate the AP with the probable SB and MFS found and those with the events of the Haq's cycle chart. Intermediate SB and MFS can then be deduced from this framework.
5. Naming of the 3rd order cycles, according to the SB and MFS found and dated previously.

Paleovegetational Approach

This approach was used in well T-2, because marine fossils show only sporadic occurrence and could not therefore be used as indicators of marine transgressions.

1. The first step is the same as in the chrono-paleovegetational method. Once the absent cycles and the AP are known, the following steps are done:

2. Group pollen into environmentally meaningful associations by means of multivariate statistical methods (in the present work, principal components analysis or PCA was used):
3. Choose the most representative associations, generally one from the lower coastal plain and the other from the alluvial plain, to compute indices reflecting the position of the tidal line (TLI). In the present work, the index is defined as:

$$TLI = (0.1+C)/(0.1+A)$$

where C is a variable containing the scaled PCA scores of the more coastal association, while A is that of scores from the most continental one. Thus, the higher the value of TLI, the nearer the sampling point to the coast. The value 0.1 is meaningless, and is used to avoid indeterminations. If there are values high enough to be considered outliers, the logarithm of TLI should be used. If outliers are occasional, they can be also removed, but after a careful evaluation of the influence of such procedure in the final result.

4. Construct the TLI curve for the section studied and note the most relevant maxima (M) and minima (m). Maxima are interpreted as higher sea levels and minima as lower ones.
5. Starting from the identified AP, try to correlate M with MFS and m with SB, in the same way as in step 4 for the chrono-paleoenvironmental method, and continue with step 5 which is identical.

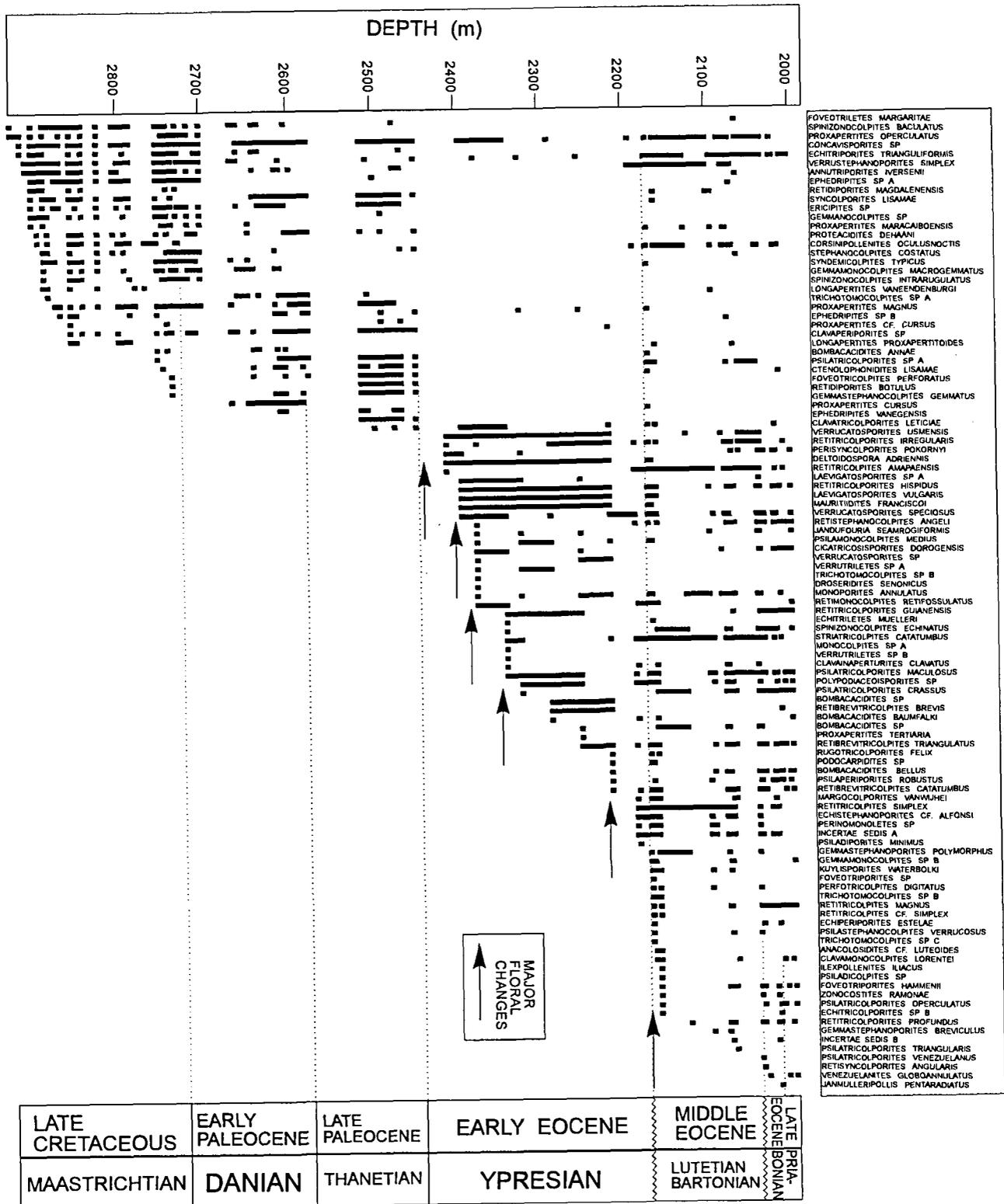
RESULTS AND INTERPRETATION

Well T-1

Text-Figure 3 shows the pollen record of this well, and the general chronostratigraphy deduced from the palynological zonation. Text-Figure 4 provides more detail and is the basis for the application of the chrono-paleoenvironmental method.

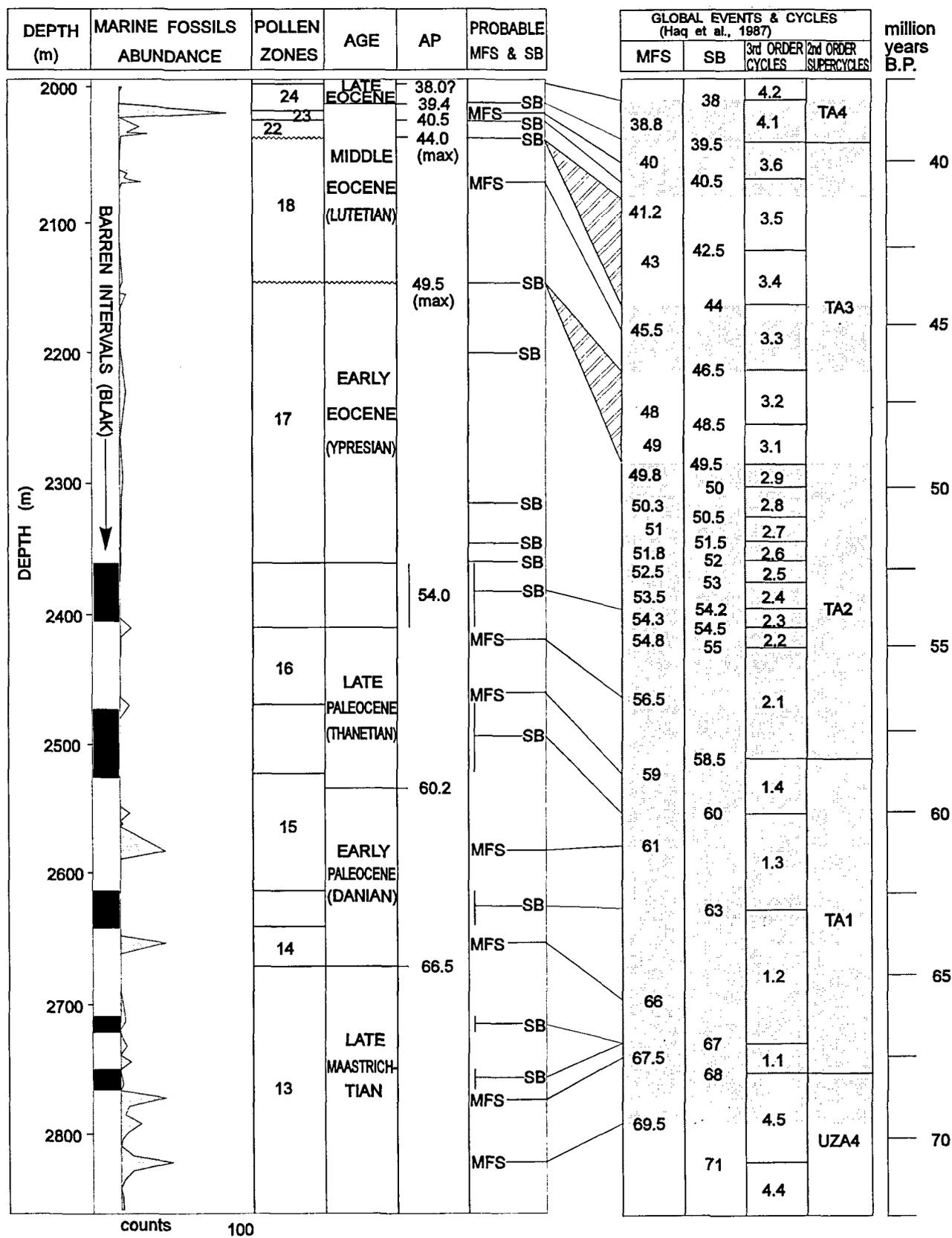
The hiatuses detected were the lack of the lower half of Subzone 18 (base of the Middle Eocene) and zones 19 to 21 (Middle Eocene), so several 3rd order cycles of Supercycle TA3 are absent. The AP found were the conformable points: boundary 13/14 (66.5 m.y.), intra 15 (60.2 m.y.), boundary 16/17 (54 m.y.), boundary 22/23 (40.5 m.y.), and two intra 24 (39.5 m.y. and 38.0 m.y.), though the last has not the same reliability as the others. Also, the hiatuses between 17-18 and 18-22 have maximum ages of around 49.0 and 44.0 m.y., respectively.

The probable SB were the mentioned hiatuses and the barren intervals near the boundaries: 14/15 (Early Pale-



Text-Figure 3. Distribution chart of well T-1, and the resulting palynologic and chronostratigraphic subdivisions. Arrows indicate the levels of major floral changes.

Downloaded by [Red de Bibliotecas del CSIC] at 21:53 25 April 2014



Text-Figure 4. Graphical synthesis of the chrono-paleoecological procedure in the well T-1, and correlations with the probable MFS and SB found with the global eustatic events. Cycles present in the sedimentary sequence are shaded.

ocene), 15/16 (Early-Late Paleocene), and 16/17 (Paleocene-Eocene). Furthermore, there are two intra-Maastrichtian barren intervals, that may be also significant. The stronger floral changes (Text-Figure 3) occur near the Paleocene/Eocene boundary, above a barren interval, and near the unconformable Early/Middle Eocene boundary. Several minor events of this type (at least 4) were also recorded during the Early Eocene, and are possible SB. The boundaries 22/23 and 24a/24b coincide in age with two minor SB, but it must be made clear that the pollen record did not provide evidence for these boundaries. The probable MFS are located in the Maastrichtian, Paleocene and Middle to Late Eocene, based on marine microfossil peaks (Text-Figure 4).

The correlation between the probable SB and MFS found with those of the global cycle chart (via dating through the attachment points) and the inferred age of the intermediate events is shown in Text-Figure 4. According to this scheme, the cycles absent are TA3-3.1, 3.2, 3.4 and 3.5. The Early Eocene cycles could not be correlated in detail, because only four probable SB were detected, and no clear evidence of MFS was found, because it is a continental sequence with high freshwater influence (high abundance of *Pediastrum*, *Botryococcus* and fungal spores). The more satisfactory results were achieved in the Late and Middle Eocene, and in the Paleocene. In the Late Maastrichtian the two barren intervals recorded probably correspond to the same SB.

A very interesting inference is possible from the nature of the sequence boundaries. Jervey (1992) pointed out that in areas with low subsidence rate, the SBs are of type 1, that is, with deeply incised valleys and significant hiatuses, whereas in other situations of high subsidence, SBs are conformable and represent little or no hiatuses (type 2). The two hiatuses in the upper part of the section are significant and might represent boundaries of type 1. The same is true for the four strong floral changes in the early Eocene, but a very different situation is present in the Paleocene and the Maastrichtian, where the SB are represented by barren zones, or probably boundaries of type 2. In these type of boundaries, sedimentation is not interrupted, but environments are subaerial; so oxidation and, therefore, absence of palynomorphs due to this fact is highly probable. As a result, there is a gradation from type 2 (base) to type 1 (top), with intermediate situation (little hiatuses as strong floral changes). Therefore, a progressive change in the subsidence rate from high (Maastrichtian to Paleocene) to intermediate (Early Eocene) and finally low (Middle and Late Eocene) might be postulated, on the basis of this evidence and the model of Jervey (1992). Estimated sedimentation rates support this statement, ranging from about 216 to 525 m/m.y. in

the Paleocene and Early Eocene, and 36 to 198 m/m.y. in the Middle and Late Eocene.

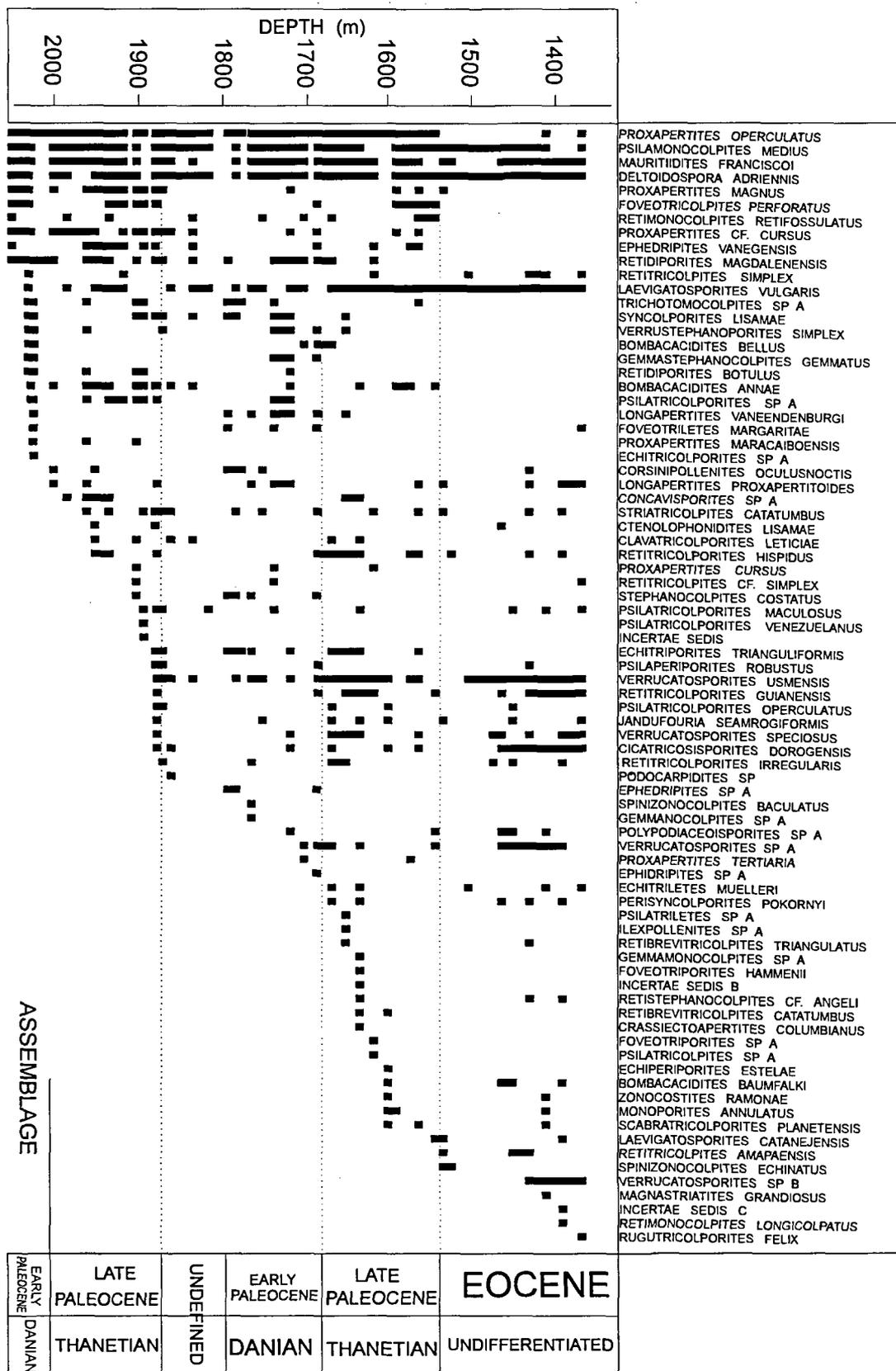
Well T-2

The palynological zonation of the Paleocene showed a repetition of the Danian-Thantian sequence (Text-Figure 5). An intermediate interval characterized by mixed Paleocene assemblages was found, at the same depth in which the eastern Tarra thrusting occurs. This indicates that the thrust determined the superposition of two blocks with the same chronological sequence, as well as the mixing of the floras in the friction zone.

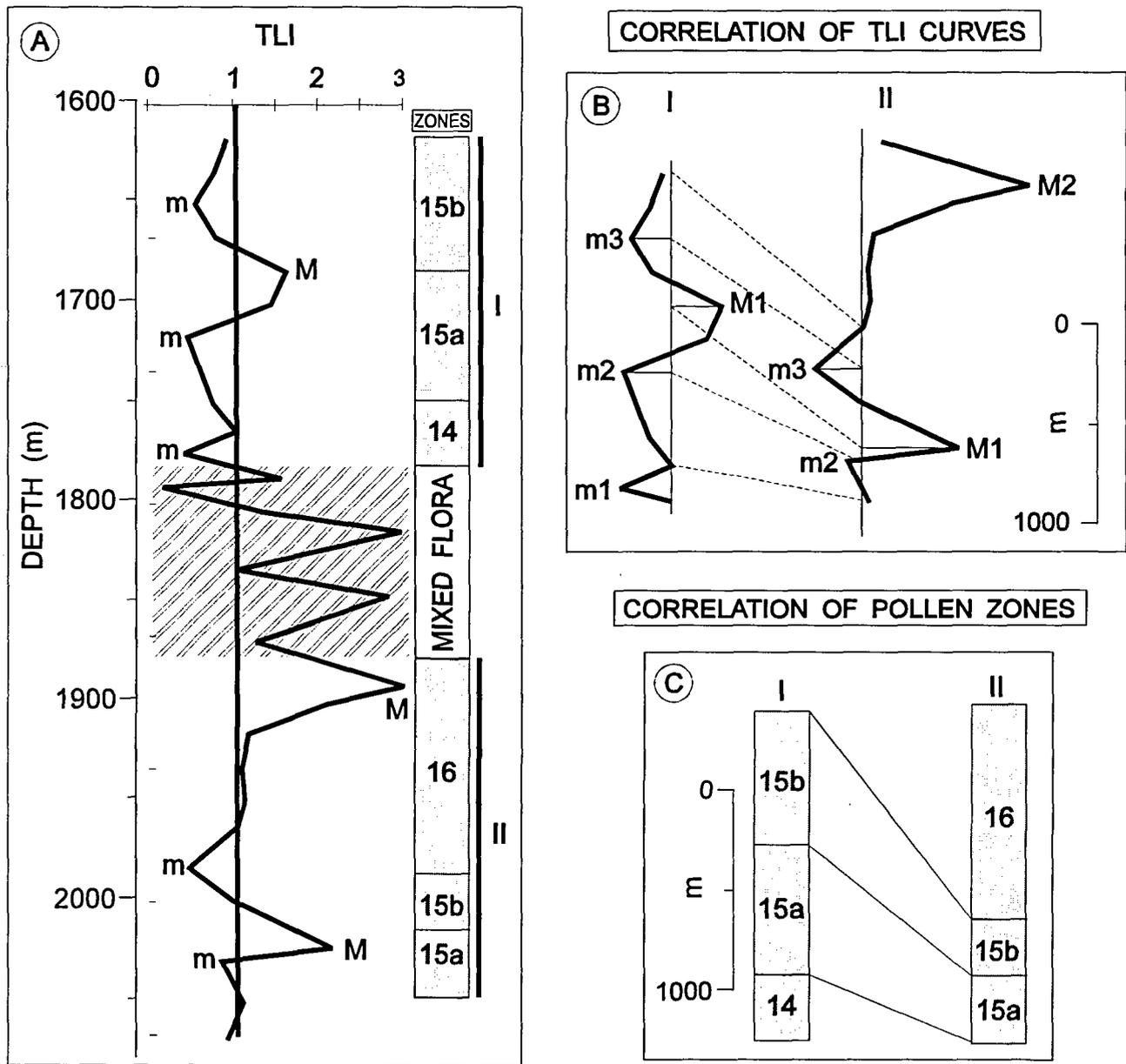
A large number of marker taxa occur at low frequencies, having very well-defined ranges and sharp limits, whereas environmentally influenced pollen types are abundant and present throughout the entire interval studied, showing only variations in abundance. In order to avoid possible artifacts in the statistical analysis, marker taxa were not considered (Birks, 1986). The Principal Components were obtained through diagonalization of the correlation matrix of the log-ratio transformed abundances (Kovach, 1989). The factor loadings and the cumulative variance can be seen in Table 1. Component 1 is positively related to *Proxapertites operculatus*, frequently found in both alluvial and coastal plain Paleocene sediments. Its corresponding living taxon is *Astrocaryum*, which comprises species of palms from both tropical rain forest and coastal swamps and marshes (Lorente, 1986; Schnee, 1984;

TABLE 1. Loadings and associated variance of the three first principal components

PALYNOMORPHS	1	2	3
<i>Proxapertites operculatus</i>	0.243	-0.044	-0.392
<i>Laevigatosporites vulgaris</i>	-0.025	0.214	0.186
<i>Deltoidospora adriennis</i>	0.046	0.408	0.058
<i>Mauritiidites franciscoi</i>	0.016	0.237	0.240
<i>Psilamonocolpites medius</i>	0.068	0.385	0.099
<i>Verrucatosporites speciosus</i>	-0.342	-0.084	0.061
<i>Bombacacidites annae</i>	-0.158	0.020	-0.278
<i>Clavaticolporites leticiae</i>	-0.477	-0.067	-0.185
<i>Retimonocolpites retifossulatus</i>	-0.261	0.069	-0.127
<i>Proxapertites tertiaria</i>	-0.410	-0.002	-0.191
<i>Pediastrum</i> spp.	0.038	-0.140	0.297
<i>Botryococcus</i> spp.	-0.043	0.147	0.251
dinoflagellates	-0.281	0.012	-0.070
foraminiferal linings	-0.147	0.171	0.001
fungal remains	0.150	-0.036	-0.087
Cumulative variance (%)	77.49	81.41	84.45



Text-Figure 5. Distribution chart of well T-2, and the palynological and chronostratigraphical zonation. The Early Paleocene part at the base of the sequence was deduced from the pollen assemblage, markers are absent.



Text-Figure 6. A) Curve of the Tidal Limit Index (TLI). B) Correlation of sections I and II of the TLI curve. C) Correlations of section I and II according to the pollen zonation.

Braun and Delascio, 1987; Van der Hammen, 1963). However, *P. operculatus* has been considered also to derive from a mangrove component (Frederiksen, 1985). Several other taxa are negatively associated with this component (Table 1), including dinoflagellates and components of the coastal and alluvial plains, thereby indicating some ambiguity in its interpretation. Furthermore, *P. operculatus* is the more abundant component in this section, and it can be considered that axis 1 is more related to differences in

abundance than in the stratigraphic arrangement of taxa. Therefore, Component 1 is not immediately useful for our purposes.

Component 2 is related to *Psilamonocolpites medius* and *Deltoidospora adriennis*. The first species represents palms which are frequent in the coastal swamps and marshes (Muller, 1959; van der Hammen, 1963), sometimes forming palm-dominated stands, associated with the tidal limit (Tissot et al., 1988). *D. adriennis* is related to the living

beach fern *Acrostichum aureum*, a well known mangrove component, especially in its inner or elevated parts, and also in disturbed areas and in the coastal palm stands with brackish water (Tissot et al., 1988; Ellison, 1989; Westgate and Gee, 1990). As a consequence, this component characterizes coastal, brackish water environments under tidal influence, mainly those in which palms are frequent.

Component 3 shows higher positive correlations with *Mauritiidites franciscoi* and the freshwater algae *Pediastrum* and *Botryococcus*. *M. franciscoi* is related to the palm *Mauritia flexuosa* that grows on lowland grasslands, swamps and gallery forests, and is intolerant to salinity (Lindeman, 1953; Muller, 1959; Van der Hammen, 1963; Lorente, 1986). Furthermore, its pollen is deposited locally due to its poor dispersion capacity (Rull, 1992b). Hence, this component is clearly representative of freshwater environments such as swamps or lakes, situated in alluvial plains far from the influence of tides.

The scaled scores of components 2 and 3 were used to compute the tidal line index (TLI); component 2 represents the more coastal factor (C), and component 3 the more inner one (A). The TLI curve is shown in Text-Figure 6. The central part of the curve was not considered, due to mixing. The maxima (M) and minima (m) of this curve were located and chronostratigraphically correlated using the pollen zones. The three Paleocene zones were present, but only the Zone 15 (*Gemmastephanocolpites gemmatus*) is repeated. Within this zone, one maximum (M1) and two minima (m2 and m3) were found, whereas one minimum (m1) and other maximum (M2) were present in zones 14 and 16, respectively. A tentative correlation with the global cycles was attempted (Text-Figure 7). Events within Zone 15 (Early/Late Paleocene) were the most reliable, because there are related to an attachment point (AP). The TLI absolute maximum M2 can be correlated either with MFS 59 or 56.5, but the second alternative is more probable, because MFS 56.5 is a major event and M2 is the absolute TLI maximum.

PALEOCENE CORRELATIONS: PALEOGEOGRAPHY

The two wells studied coincide in having an essentially complete Paleocene sequence, but their paleoenvironments are different, with well T-1 slightly more marine than T-2. Text-Figure 8 is an attempt to correlate the two wells in a chronological framework. The paleovegetational curve of well T-2 (TLI curve) was plotted in order to show a continuous trend. Its deformation and overlapping are based on the correlations from Text-Figures 6 and 7. The dinoflagellate peaks and barren zones in well T-1 were also placed in the

chronological scale according to the correlation of possible MFS and SB with global events (Text-Figure 4). This produced the fitting of peaks in brackish-water ecosystems (T-2) with plankton peaks in well T-1 (situation typical of a flooding surface event), and the peaks of inner communities with barren intervals, which most probably represent coastal sands (sequence boundaries). Text-Figure 8 also shows the paleogeography of the Maracaibo Basin during the Paleocene, according to González de Juana et al. (1980) and Zambrano et al. (1970). The paleoecological results and correlations of the present work show a good agreement with the trends that can be deduced from their position in this paleogeographical scenario. The location of the coast is tentative, but is the most consistent with the above paleoenvironmental results.

CONCLUSIONS

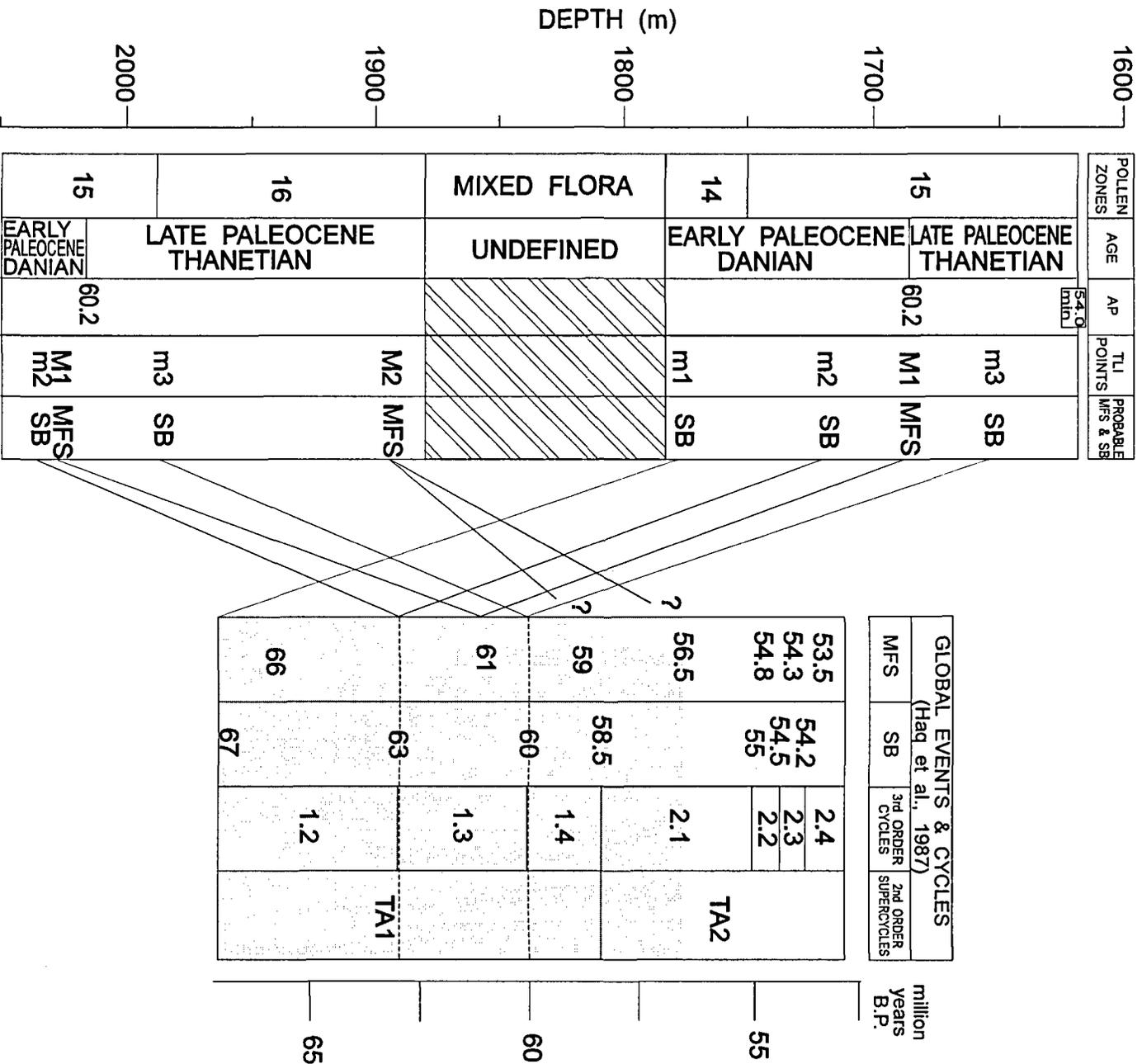
The palynological analysis of wells T-1 and T-2 from the Maracaibo Basin showed the contribution of palynology to the sequence analysis through chronological, paleoenvironmental and paleovegetational considerations. The results obtained must be reinforced with sedimentological analysis both to obtain a more complete picture and to increase the reliability of the conclusions.

In the well T-1, Maastrichtian, Paleocene and Eocene sediments were correlated with third order cycles of the supercycle sets Upper Zuni A and Tejas A. Cycles TA3.1, TA3.2, TA3.4 and TA3.5 are missing in the well. In T-2, the supercycle set Tejas A is represented by the cycles TA1.2 to TA2.1. The third order cycle TA1.3 is repeated due to thrusting. The correlation of Paleocene events in both wells are consistent with the accepted paleogeographical reconstruction of the Maracaibo Basin. Furthermore, the results of the present work help to place the coastal line.

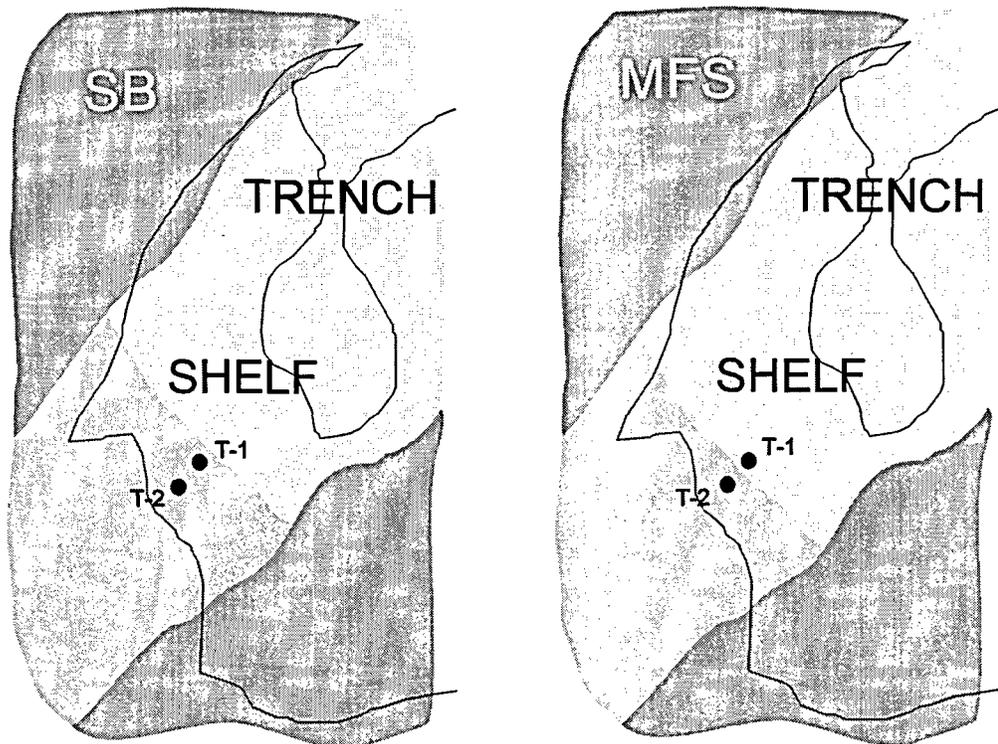
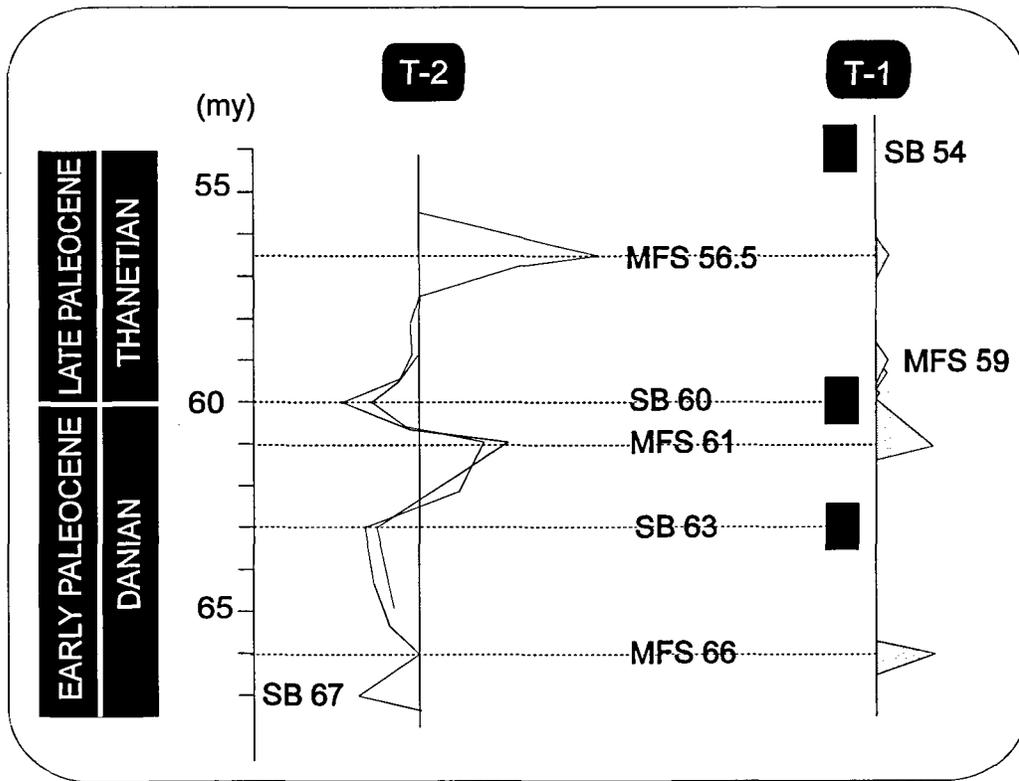
The chrono-paleoenvironmental and paleovegetational methods allowed determination of eustatic sequences in sediments of continental origin, where these type of studies seemed *a priori* difficult to carry out. The first approach is useful when marine microplankton is scarce, whereas the second one is necessary for these situations in which only terrigenous fossils are present.

ACKNOWLEDGMENTS

The author is grateful to N. Frederiksen, W. Kovach, M.A. Lorente and G. Norris for their revision, comments and suggestions, that contributed to the improvement of the manuscript, as well as to MARAVEN for permitting the publication and for editing facilities.



Text-Figure 7. Steps of the paleovegetational approach in well T-2, and correlations with the cycles present (shaded) in the sediments. The repeated interval is between the two dashed lines (cycle TA1.3).



Text-Figure 8. Correlation of the composed TLI curve (T-2) with the peaks of marine fossils (T-1), and paleogeographical reconstruction in transgressive (MFS) and regressive (SB) situations.

References Cited

- BIRKS, H.J.B.
1986 Numerical zonation, comparison and correlation of Quaternary pollen stratigraphical data. In: Berglund, B.E. (ed.), *Handbook of Holocene palaeoecology and palaeohydrology*. J. Wiley & Sons, New York, pp. 743-774.
- BRAUN, A., and DELASCIO, F.
1987 *Palmas autóctonas de Venezuela y de los países adyacentes*. N. Martínez Ediciones, Caracas. 156 pgs.
- ELLISON, J.C.
1989 Pollen analysis of mangrove sediments as a sea-level indicator: assessment from Tongapatu, Tonga. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 74: 327-341.
- FREDERIKSEN, N.O.
1985 Review of Early Tertiary sporomorph paleoecology. *American Association of Stratigraphic Palynologists Contributions Series*, 15. 92 pgs.
- GONZALEZ DE JUANA, C., ITURRALDE, J.M., and PICARD, X.
1980 *Geología de Venezuela y de sus cuencas petrolíferas*. Ediciones FONINVES, Caracas. 1031 pgs.
- GORIN, G.E., and STEFFEN, D.
1989 Organic facies as a tool for recording of eustatic variations in marine fine-grained carbonates—an example of the Berriasian stratotype at Berrias (Ardeche, SE France). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 85: 303-320.
- HABIB, D., and MILLER, J.A.
1989 Dinoflagellate species and organic facies evidence of marine transgression and regression in the Atlantic coastal plain. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 74: 23-47.
- HAQ, B.U., HANDERBOL, J., VAIL, P.R., WRIGHT, R.C., STOVER, L.E., BAUM, G., LOUTIT, T., GOMBOS, A., DAVIES, T., PFLUM, C., ROMINE, K., POSAMENTIER, H., and JAN DU CHENE, R.
1987 Mesozoic-Cenozoic cycle chart (version 3.1B). *Society of Economic Paleontologists and Mineralogists Special Publication*, 42 (in back pocket).
- JERVEY, M.T.
1992 Siliciclastic sequence development in foreland basins, with examples from the Western Canada foreland basin. *American Association of Petroleum Geologists Memoir*, 55: 47-80.
- KOVACH, W.L.
1989 Comparisons of multivariate analytical techniques for use in pre-Quaternary plant paleoecology. *Review of Palaeobotany and Palynology*, 60: 255-282.
- LINDEMAN, J.C.
1953 *The vegetation of the coastal region of Suriname*. Van Eedenfonds, Amsterdam. 135 pgs.
- LISTER, J.K., and BATTEN, D.J.
1988 Stratigraphic and paleoenvironmental distribution of Early Cretaceous dinoflagellate cysts in the Hurlands Farm borehole, West Sussex, England. *Palaeontographica*, Abteilung B, 210: 9-89.
- LORENTE, M.A.
1986 Palynology and palynofacies of the upper Tertiary in Venezuela. *Dissertationes Botanicae*, 99. 222 pgs.
- MULLER, J.
1959 Palynology of recent Orinoco delta and shelf sediments. *Micropaleontology*, 5: 1-32.
- MULLER, J., DIGIACOMO, E., and VAN ERVE, A.
1987 A palynological zonation for the Cretaceous, Tertiary and Quaternary of Northern South America. *American Association of Stratigraphic Palynologists, Contributions Series*, 19: 9-76.
- RULL, V.
1987 A note on pollen counting in palaeoecology. *Pollen et Spores*, 29: 471-480.
1992a Paleoeología y análisis secuencial de una sección deltaica terciaria de la cuenca de Maracaibo. *Boletín de la Sociedad Venezolana de Geólogos*, 46: 16-26.
1992b Successional patterns of the Gran Sabana (southeastern Venezuela) vegetation during the last 5000 years, and its responses to climatic fluctuations and fire. *Journal of Biogeography*, 19: 329-338.
- SCHNEE, L.
1984 *Plantas comunes de Venezuela*. Universidad Central de Venezuela, Ediciones de la Biblioteca, Caracas. 820 pgs.
- TISSOT, C., DJUWANSAH, M.R., and MARIUS, C.
1988 Evolution de la mangrove en Guyanne au cours de l'Holocène. Etude palynologique. *Institut français de Pondichéry, travaux de la section scientifique et technique*, 25: 125-137.
- VAN DER HAMMEN, T.
1963 A palynological study on the Quaternary of British Guiana. *Leidse Geologische Mededelingen*, 29: 125-180.
- WALL, D.
1965 Microplankton, pollen and spores from the Lower Jurassic in Britain. *Micropaleontology*, 11: 151-190.
- WESTGATE, J.W., and GEE, C.T.
1990 Paleoecology of a middle Eocene mangrove biota (vertebrates, plants and invertebrates) from southwest Texas. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 78: 163-177.
- ZAMBRANO, E., VASQUEZ, E., DUVAL, B., LATREILLE, M., and COFFINIERES, B.
1970 *Synthèse paléogéographique et pétrolière du Venezuela Occidental*. Editions TECHNIP, Paris. 72 pgs.