

Biostratigraphy and palaeoenvironmental analysis of subsurface Palaeogene sediments in western part of Ahmedabad Block, North Cambay Basin

M. SHANMUKHAPPA AND S.N. UNIYAL

Geology Laboratories, RGL, W O Basins, Oil and Natural Gas Corporation Ltd. Baroda.

(Received 06 August, 2007; revised version accepted 11 November, 2008)

ABSTRACT

Shanmukhappa M & Uniyal SN 2008. Biostratigraphy and palaeoenvironmental analysis of subsurface Palaeogene sediments in western part of Ahmedabad Block, North Cambay Basin. The Palaeobotanist 57(3): 465-477.

The western part of Ahmedabad Block is among the thrust areas for hydrocarbon exploration in Cambay Basin. Palynological studies of the Palaeogene sediments of Ahmedabad Block between Detroj and Wasnalava have been carried out to evaluate the palynostratigraphy and infer depositional environment to help in basin modelling for exploration of hydrocarbons. Based on palynofloral association three assemblage zones, viz. *Polybrevicolporites cephalus* Zone (Palynozone-I), *Proxapertites cursus- Polycopites flavatus* Zone (Palynozone-II) and *Palmaepollenites kutchensis* Zone (Palynozone-III) have been identified. These zones are dated Early, Middle and Late Eocene in age. The sediments corresponding to Olpad Formation (?Palaeocene) exhibited poor palynofloral contents.

The interpretation of depositional environment is based on the absolute pollen frequency and palynofloral associations. In Cambay and Kadi formations the coastal and back mangrove elements are common with sporadic occurrence of marine elements, suggestive of near shore environment of deposition. The overlying Kalol Formation has yielded rich back mangrove floral assemblage along with moderate occurrences of coastal elements and is suggestive of Littoral conditions. The dominance of marine phytoplankton in Tarapur Formation is indicative of shallow marine conditions of deposition.

Key-words—Biostratigraphy, Palaeoenvironmental, Palaeogene, Ahmedabad, North Cambay Basin.

अहमदाबाद खंड, उत्तरी कैंबे द्रोणी के पश्चिमी भाग में उपपृष्ठीय पैलियोजीन अवसादों का जैवस्तरक्रमविज्ञान एवं पुरापर्यावरणीय विश्लेषण

एम. शन्नमुखप्पा एवं एस.एन. उनियाल

सारांश

अहमदाबाद खंड का पश्चिमी भाग कैंबे द्रोणी में हाइड्रोकार्बन अन्वेषण हेतु विशिष्ट क्षेत्रों में से है। देतराज व वसनालवा के बीच अहमदाबाद खंड से प्राप्त पैलियोजीन अवसादों का परागाणविक अध्ययन हाइड्रोकार्बनों के अन्वेषण हेतु द्रोणी प्रतिरूपण में निक्षेपणीय पर्यावरण की व्याख्या की मदद में और परागाणुस्तरक्रमविज्ञान को मूल्यांकित करने के लिए पूर्ण किया गया है। परागाणुपुष्पी संघटन के आधार पर तीन समुच्चय मंडल अर्थात्-पॉलीब्रेविकोल्पोराइट्स सेफालस मंडल (परागाणुमंडल-प्रथम), प्रोक्सपर्टाइट्स कर्सस-पॉलीकाल्पाइट्स फ्लेवेटस मंडल (परागाणुमंडल-द्वितीय) तथा पामेपोलेनाइट्स कच्चेन्सिस मंडल (परागाणुमंडल-तृतीय) अभिनिर्धारित किए गए हैं। ये मंडल प्रारंभिक, मध्य एवं अंतिम आदिनूतन आयु निर्धारित करते हैं। ऑल्पेड शैलसमूह (? आदिनूतन) के संगत अवसादों ने अल्प परागाणुपुष्पी अंतर्वस्तुएं प्रस्तुत कीं।

निक्षेपणीय पर्यावरण की व्याख्या की सकारात्मक पराग आवृत्ति एवं परागाणुपुष्पी संघटनों पर आधारित है। कैंबे और कडी शैलसमूहों में समुद्री तत्वों की कदाचनिक प्राप्ति सहित तटीय व पश्च मैंग्रोव तत्व साधारण हैं निक्षेपण के समूह-तट के नजदीक पर्यावरण के संकेतक हैं। उपरिशायी कलोल शैलसमूह से तटीय तत्व की मध्यम प्राप्ति सहित प्रचुर पश्च मैंग्रोव पुष्पी समुच्चय मिली है तथा ये वेलांचली स्थितियों की सूचक है। तारापुर शैलसमूह में समुद्री पादपत्वक की प्रभुत्वता निक्षेपण की गाध समुद्री स्थितियों की द्योतक है।

मुख्य शब्द—जैवस्तरक्रमविज्ञान, पुरापर्यावरणीय, पैलियोजीन, अहमदाबाद, उत्तरी कैंबे द्रोणी।

INTRODUCTION

THE Cambay Basin (Fig. 1) is located in the western Indian state of Gujarat. The basin extends from north of Patan town through the Gulf of Cambay and then south beneath the Arabian Sea. The Cambay Basin is a graben with a width of 40 to 80 km and a depth of 5 to 7 km. It is a linear NNW-SSE trending rift, which is about 425 km long. The basin, including its flanks, covers an approximate area of 53,500 sq km of which 2,500 sq km lies in the Gulf of Cambay. It occupies part of the west-northwest margin of the Indian shield on the Indo-Arabian platform.

The basin is bounded on the west by the Saurashtra Peninsula, which is covered almost completely by Deccan Trap basalts, except in the northeastern corner where Mesozoic rocks crop out. The basin extends northward and connects with the shallower Barmer and Kutch basins (Mathur *et al.*, 1968). On its northeast flank, Aravalli-Delhi (Precambrian) rocks

crop out, just west of which is a thin fringe of Mesozoic outcrops. These outcrops bound the basin. The Aravalli Series-together with Deccan Trap outliers - define the eastern margin of the basin. Outcrops of the Deccan Trap along a line Rajpipla-

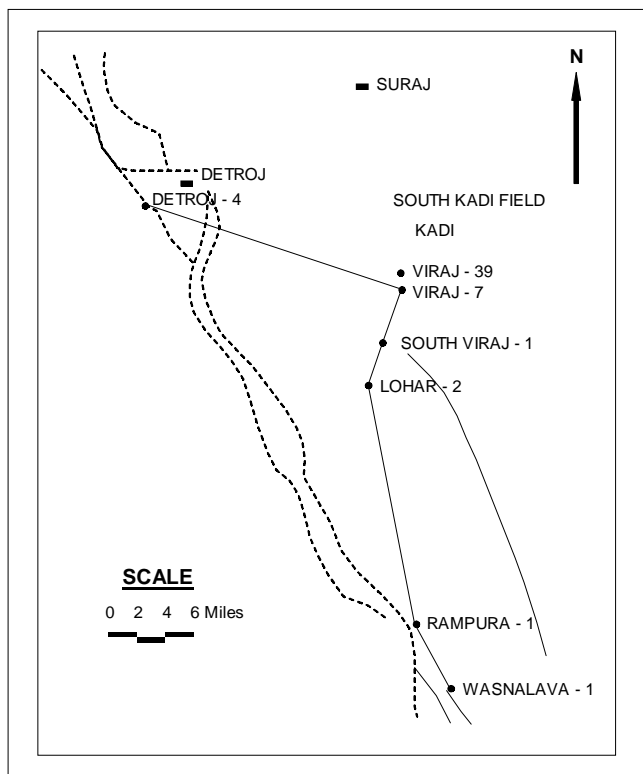


Fig. 1—Location Map of studied wells in Ahmedabad Block.

AGE	FORMATION	DEPTH IN MTS	LITHOLOGY	LITHOLOGICAL DESCRIPTION	THICKNESS IN MTS	PAL YNOZONES	PALEOENVIRONMENT
UP. E. EOCENE	TARAPUR	690		GREENISH GREY SHALE	20	III	SH. MARINE
MID. EOCENE	KALOL			SANDSTONE AND TRAPWASH	10	II	NEAR SHORE
	DECCAN TRAP	800-1500		TRAP BASALT WITH ASSOCIATED ANDESITE AND TRACHYTE	825		
MESOZOIC	VIRAMGAON	1600-1700		SANDSTONE, QUARTZITE, COARSE TO MEDIUM GRAINED TERRUGENOUS	725		POORLY FOSSILIFEROUS
	BASEMENT	1800-1900		GABRO DARK TO GREENISH GREY, HOLOCRYSTALLINE, OLIVINE IS ALSO PRESENT			

Fig. 2—Stratigraphy of a well at Detroj-D.

Navsari-Mumbai determine the southeastern limits of the basin. The basin extends southwards into the Gulf of Cambay, and farther offshore into the Mumbai Offshore Basin.

Another significant characteristic of the basin is that the basin filling was mostly longitudinal by a master river flowing along the basin with sediments mainly derived from Aravalli-Delhi highlands; sedimentary facies shows regular gradation along the basin axis, in sequences ranging in age from Eocene to Pliocene, from a sand-shale-coal sequence in the north to siltstone-shale sequence in the southern Cambay Basin to shale facies and finally carbonate facies in the Mumbai Offshore Basin. Some transverse basin filling, however, also took place by rivers originating to the east of the basin, and the Saurashtra craton to the west. A second source of sediment supply came into existence along the Narmada River and became an important source of coarse clastic sediments from Upper Eocene onwards following the removal of the Deccan Trap cover and exhumation of the underlying igneous and metamorphic rocks along the Narmada River.

The present work is confined to palynological studies of subsurface Palaeogene sequence of Detroj-D, Viraj-G, Viraj-CI,

AGE	FORMATION	DEPTH IN MTS	LITHOLOGY	THICKNESS IN MTS	PALYNOZONES	PALEOENVIRONMENT
MIDDLE EOCENE	TARAPIUR	1097 - 1200	SHALE WITH MINOR SILTSTONE AND SILTY SHALE	134	PALYNOZONE - II	SAMPLE NOT AVAILABLE
	KALOL	1200 - 1300	SHALE, SANDSTONE, SILTY SHALE, SILTSTONE AND COAL BAND	111		
LOWER EOCENE	YOUNGER CAMBAY SHALE / KADI / CHHATRAL / MEHSANA / MANDIALI	1300 - 1400	ALTERNATION OF SAND AND SHALE	150	PALYNOZONE - I	NEAR SHORE WITH MARINE INFLUENCE
		1400 - 1500	DARK GREY SHALE			NEAR SHORE
		1500 - 1600	ALTERNATION OF SAND AND SHALE	96		NEAR SHORE
		1600 - 1700	DARK GREY SHALE	12		
		1700 - 1800	ALTERNATION OF SAND SHALE	161		
		1800 - 2200	DARK GREY SHALE SHALE, SILTY SHALE, SILT AND MINOR SAND	26 / 371		

Fig. 3—Stratigraphy of a well at Viraj - CI.

AGE	FORMATION	DEPTH IN MTS	LITHOLOGY	THICKNESS IN MTS	PALYNOZONES	PALEOENVIRONMENT
MIDDLE EOCENE	TARAPIUR	1100 - 1200	GREENISH GREY SHALE	130	PALYNOZONE - II	SAMPLE NOT AVAILABLE
	KALOL	1200 - 1300	SHALE, SANDSTONE, COAL, SILTY SHALE & SILTY SANDSTONE	130		NEAR SHORE WITH MARINE INFLUENCE
LOWER EOCENE	YOUNGER CAMBAY SHALE / KADI / CHHATRAL / MEHSANA / MANDIALI	1300 - 1400	SAND, MEDIUM TO COARSE GRAINED WITH ALTERNATE LAYERS OF DARK GREY SHALE, SANDSTONE	150	PALYNOZONE - I	SHALLOW MARINE
		1400 - 1500	GREY TO DARK GREY SHALE, FISSILE & CARBONACEOUS	47		NEAR SHORE WITH MARINE INFLUENCE
		1500 - 1600	MEDIUM TO COARSE GRAINED SAND WITH ALTERNATE LAYER OF DARK GREY SHALE	73		
		1600 - 1700	GREY TO DARK GREY SHALE, FISSILE & CARBONACEOUS	47		
		1700 - 1800	MEDIUM TO COARSE GRAINED SAND WITH ALTERNATE LAYER OF DARK GREY SHALE	136		
		1800 - 1900	DARK GREY SHALE	34		
?	?	1900 - 2000	DARK GREY SHALE WITH SILTSTONE & SANDSTONE	260		POORLY FOSSILIFEROUS

Fig. 4—Stratigraphy of a well at Viraj - G.

South Viraj-A, Lohar-B, Rampura-A and Wasnalava-A. These wells are located in the western part of Ahmedabad Block (Fig. 1). The palynological studies have been carried out with an object to establish the lateral correlation of the sediments in the western part of Ahmedabad Block.

PALYNOSTRATIGRAPHY

Most of the wells taken up for palynological studies were terminated in lower Palaeogene sediments except Detroj-D. This well was drilled down upto 1772 m and terminated in the basement. The pre-Tertiary sequence (Viramgam Formation) encountered between 1545-1720 m is composed of terigenous, quartzitic and coarse- to medium-grained sandstone. Few palynofossils, viz. *Callialasporites trilobatus*, *Araucariacites* sp., *Classopollis* sp., *Staplinisporites* sp., and *Gleicheniidites* sp. are recorded between 1545-1600 m. These taxa have been reported from Jurassic to Cretaceous sediments from other basins.

AGE	FORMATION	DEPTH IN MTS	LITHOLOGY	LITHOLOGICAL DESCRIPTION	THICKNESS IN MTS	PALYNOZONES	PALEOENVIRONMENT
MIDDLE EOCENE	TARAPUR	1200		GREENISH GREY SHALE WITH OCCASIONAL SILT BAND	140		SAMPLE NOT AVAILABLE
	KALOL	1300		SANDSTONE, SILTY SHALE, SILTSTONE AND COAL	120	PALYNOZONE - II	LITTORAL
		1400		MEDIUM TO COARSE GRAINED SAND WITH ALTERNATE LAYER OF DARK GREY SHALE	170		SH. MARINE NEAR SHORE WITH MARINE INFLUENCE
LOWER EOCENE	YOUNGER CAMBAY SHALE / KADI MEHSANA	1500		DARK GREY SHALE	30	PALYNOZONE - I	NEAR SHORE
		1600		MEDIUM TO COARSE GRAINED SAND WITH ALTERNATE LAYER OF DARK GREY SHALE	100		NEAR SHORE WITH MARINE INFLUENCE
	1700		SHALE DARK GREY, FOSSILIFEROUS, LAMINATED AND CARBONACEOUS	130		NEAR SHORE	
	1800						
?	OLDER CAMBAY SHALE	2000		DARK GREY SHALE WITH SILT AND SANDS IN TRACES. SHALES, HARD, COMPACT AND LAMINATED, OCCASIONALLY CALCAREOUS AND CLAYEY	337	?	UNFOSSILIFEROUS
		2100					
		2200					

Fig. 5—Stratigraphy of a well at South Viraj - A.

The wells terminated in the Olpad Formation are Rampura-A, (1995 m T.D), and Wasnalava-A (1600 m T.D.), whereas wells Viraj-G (2100 m T.D.), Viraj-CI (2200 m T.D.), South Viraj-A (2200 m T.D.), and Lohar-B (1650 m T.D.) are terminated in the Cambay Shale Formation.

The Palaeogene subsurface sequences represented by Olpad, Cambay Shale, Kadi, Kalol and Tarapur formations are poor to richly fossiliferous. Based on palynological studies, three palynozones have been identified in the studied wells. The zonation is based on the concept of oppel zone (Assemblage zone characterized in term of range of numerous fossils) defined by Hedberg (1976). The upper and lower limit of oppel zone is delineated by the first down hole occurrence of certain characteristic taxa. The age of each zone is based on Thanikaimoni *et al.* (1984), Shanmukhappa (1990),

Shanmukhappa and Koshal (1991) and Mehrotra *et al.* (2005). The palaeoecology is interpreted by grouping the different plant communities as per their habitats (Venkatachala, 1977; Rawat *et al.*, 1977; Koshal, 1988; Mathur & Chaudhary, 1976). The well Wasnalava-A has been considered a standard for zonation as all the Palaeogene sequences are encountered in this well. (Figs 2-17).

PALYNOZONE—I

The first downhole appearance of *Pellicierioipollis langenheimii* marks the upper limit of this zone. This zone is characterized by the common occurrence of taxa *Proxapertites operculatus*, *Couperipollis kutchensis*, *Longapertites* spp.,

AGE	FORMATION	DEPTH IN MTS	LITHOLOGY	LITHOLOGICAL DESCRIPTION	THICKNESS IN MTS	PALYNOZONES	PALEOENVIRONMENT	
MIDDLE EOCENE	TARAPUR	1125		GREENISH GREY SHALES WITH OCCASIONAL BANDS OF SILT	150		SAMPLE NOT AVAILABLE	
		1200						
MIDDLE EOCENE	KALOL	1300		SANDSTONE, SILTY SHALES AND SILTSTONE	175	PALYNOZONE - II	LITTORAL	
		1400		MEDIUM TO COARSE GRAINED SAND WITH ALTERNATE LAYER OF DARK GREY SHALE			NEAR SHORE WITH MARINE INFLUENCE	
		1500		DARK GREY SHALES	40		NEAR SHORE	
?	YOUNGER CAMBAY SHALE / KADI MEHSANA	1600		MEDIUM TO COARSE GRAINED SAND WITH ALTERNATE DARK GREY SHALES	30	POORLY FOSSILIFEROUS		
		1650		DARK GREY SHALES	10			?

Fig. 6—Stratigraphy of a well at Lohar - B.

and *Arecipites* spp., The dominance of these taxa in microfloral assemblage is recorded in all the wells.

The other characteristic taxa are *Margocolporites tsukadai*, *Dicolpopollis* spp., *Rhoipites* sp., *Psilatricolporites* spp., *Retitricolporites* sp., *Meliapollis* sp., *Polycolpites flavatus*, *P. granulatus*, *Umbelliferoipollenites ovatus*, *Lakiapollis ovatus*, *Stephanocolpites* spp., *Myricipites* sp.,

AGE	FORMATION	DEPTH IN MTS	LITHOLOGY	LITHOLOGICAL DESCRIPTION	THICKNESS IN MTS	PALEOENVIRONMENT
? LOWER EOCENE	TARAPUR	900		GREEN TO DARK GREY SHALE WITH SANDSTONE	200	SAMPLE NOT AVAILABLE
		1000				
	KALOL	1100		SANDSTONE, SILTY SHALE AND SILTSTONE	95	
	YOUNGER CAMBAY SHALE	1200		DARK GREY TO BLACK, SHALE, FISSILE, PYRITIC, CARBONACEOUS AND RICH IN ORGANIC MATTER	215	NEAR SHORE
	1300					
	OLDER CAMBAY SHALE	1400		DARK GREY TO BLACK, SHALES WITH SILTSTONE	100	
		1500			200	POORLY FOSSILIFEROUS
	OLPAD	1600		CLAYSTONE, TRAPWASH, SANDSTONE, TRAP, CONGLOMERATE WITH CLAY MATRIX		
		1700				
		1800				
		1900				
		2000				

Fig. 7—Stratigraphy of a well at Rampur - A.

AGE	FORMATION	DEPTH IN MTS	LITHOLOGY	LITHOLOGICAL DESCRIPTION	THICKNESS IN MTS	PALYNOZONES	PALEOENVIRONMENT
?	TARAPUR	955-1000		GREENISH GREY AND DARK GREY SHALE, SANDY SHALE AND ARGILLACEOUS SANDSTONE	120	?	P.F.
UPPER EOCENE						PALYNO-ZONE III	SHALLOW MARINE
MIDDLE EOCENE	KALOL	1100		SANDSTONE, CALCAREOUS SILTY SHALE, SILTSTONE AND COAL	79	PALYNO-ZONE II	LITTORAL
	YOUNGER CAMBAY SHALE / KADI	1200		DARK GREY TO BLACK SHALE, FOSSILIFEROUS, PYRITIC, LAMINATED, CARBONACEOUS AND RICH IN ORGANIC MATTER WITH MINOR SANDSTONE	248	PALYNO-ZONE-I	NEAR SHORE WITH MARINE INFLUENCE
LOWER EOCENE		1300					NEAR SHORE
	OLPAD	1400-1600		VOLCANIC CONGLOMERATE, SANDSTONE, SILTS AND CLAYSTONE	197	?	POORLY FOSSILIFEROUS

Fig. 8—Stratigraphy of a well at Wasanalava - A.

Symplocoipollenites sp., *Iugopolls tetraporites*, *Marginipollis kutchensis*, *Cupanieidites* sp., *Dracaenopollis circularis*, *Polybrevicolporites cephalus*, *Pseudonothofagidites kutchensis*, *Striacolporites ovatus*, *Polypodiisporites* spp., *Laevigatosporites* spp., *Lygodiumsporites* spp., *Cleistophaeridium* spp., *Polysphaeridium* sp., *Polysphaeridium* sp., *Spiniferites* sp. and fungal spores.

The upper limit of this zone is marked at 1380 m, 1420 m and 1180 m in Viraj-G, South Viraj-A and Wasnalava-A, respectively. The top of this zone is not traceable in Viraj-CI, Lohar-B and Rampura-A.

The Palynozone-I of wells Viraj-G, South Viraj-A and Wasnalava-A corresponds to Cambay Shale Formation. The equivalent sequence of Cambay Shale Formation in Viraj-CI, Lohar-B and Rampura-A could not be zoned due to lack of diagnostic taxon *Pellicieropollis langenheimii*, otherwise characterized by similar general floral assemblage as recorded in Palynozone-I of wells Viraj-G, South Viraj-A and Wasnalava-A. As such these sediments between 1400-1600 m, 1440-1650 m and 1220-1500 m in Viraj-CI Lohar-B and Rampura-A are included in this zone for interpretation of palaeoecology and depositional environment.

Age—Based on stratigraphic range of taxon *Pellicieropollis langenheimii* (Thanikaimoni *et al.*, 1984) Palynozone-I is assigned Lower Eocene age. The taxa *Polybrevicolporites cephalus* (Lower Eocene) and *Striacolporites ovatus* (Palaeocene to Lower Eocene) are also recorded in this zone. This zone covers the sediments between 1380-2085 m, 1420-1780 m and 1180-1400 m in Viraj-G, South Viraj-A and Wasnalava-A, respectively.

Palaeoecology—Microfloral assemblage recorded in Palynozone-I shows combination of taxa from different habitats. For palaeoecological interpretation of the strata, the

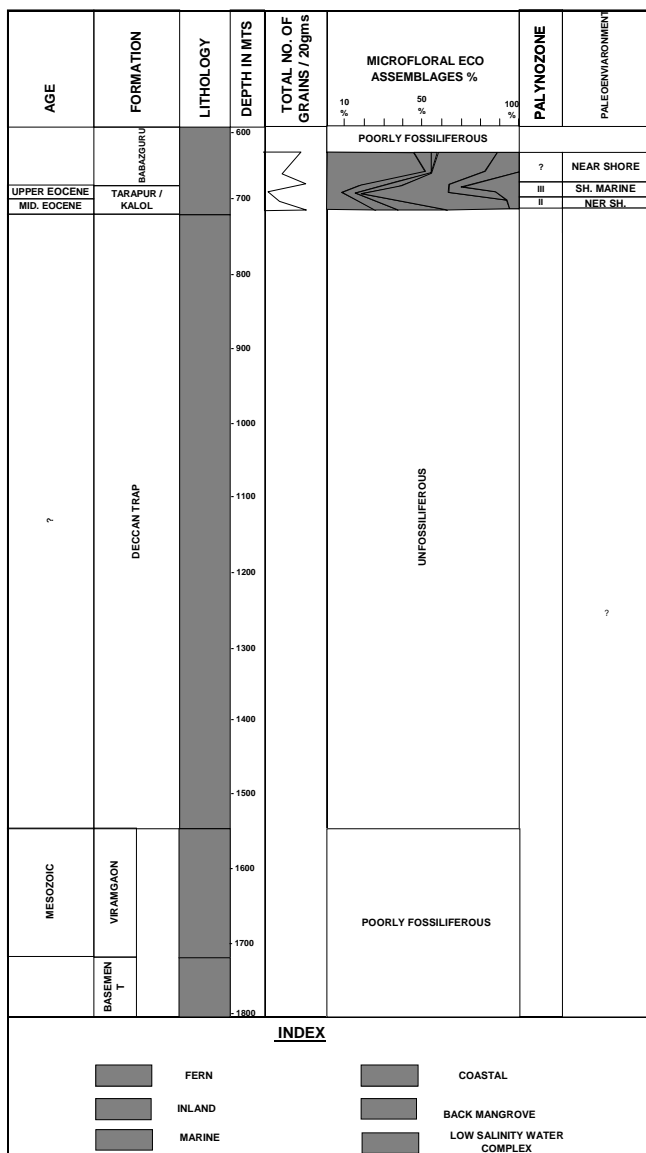


Fig. 9—Chart showing Microfloral Ecoassemblage and Paleoenvironment of a well at Detroj - D.

plant communities are grouped according to their habitats into marine, mangrove, coastal, inland and pteridophytic plant complexes.

The taxa *Cleistosphaeridium* spp. (Dinophyceae), *Polysphaeridium* spp., (Dinophyceae) and *Spiniferites* sp. (Dinophyceae) are the representative of marine complex. These taxa are recorded only at the top of this zone in Viraj-G and CI and otherwise rare throughout this zone in all the wells.

The mangrove complex is represented by tidal and back-mangrove elements in the floral assemblage. The taxa *Iugopollis tetraporites* (Sonneratiaceae) and *Marginipollis kutchensis* (Lecythidaceae) represents tidal complex in the floral assemblage. These tidal elements are rare in the floral

assemblage. The taxa related to back mangrove complex shows dominance throughout the zone in all the wells. The representatives of back mangrove complex are referred to taxa *Proxapertites operculatus* (Palmae), *Couperipollis kutchensis* (Palmae) *Proxapertites cursus* (Palmae) and *Arecipites* spp., (Palmae). These taxa show common occurrence in this zone.

The coastal complex restricted to sandy beaches are represented by taxa *Palmaepollenites* spp. (Palmae), *Longapertites* spp., (Palmae) and *Drecaenipollis circularis* (Palmae), are rare to common in this zone. These elements are common in this zone in Viraj-G and Viraj-CI.

The inland complex (fresh water) referred to taxa *Margocolporites tsukadii* (Caesalpiniaceae), *Psilatricolporites* spp. (Caesalpiniaceae), *Stephanocolpites* sp. (Labiatae), *Polycolpites flavatus* (Labiatae), *P. granulatus* (Labiatae) *Lakiapollis ovatus* (Bambacaceae), *Tricolpites* spp. (Cruciferae), *Symplocoipollenites* sp. (Symplocaceae) *Myricipites* sp. (Myricaceae), *Cupanieidites* sp. (Sapindaceae), *Pseudonothofagidites kutchensis* (Fagaceae), *Meliapollis* sp. (Meliaceae), *Polygalacidites clarus* (Polygalaceae), *Polybrevicolporites cephalus* and

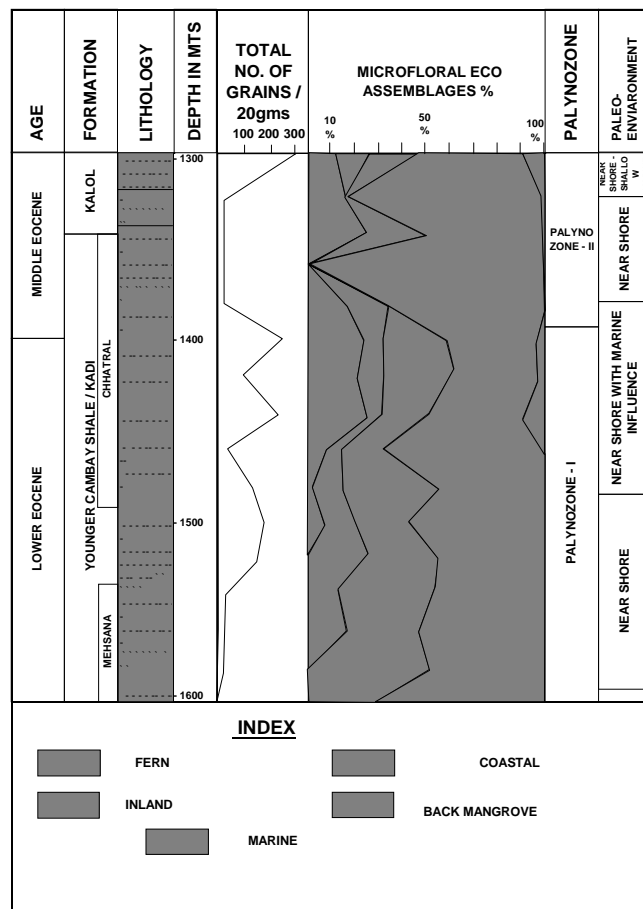


Fig. 10—Chart showing microfossil ecoassemblage and Palaeo-environment in a well at Viraj - CI.

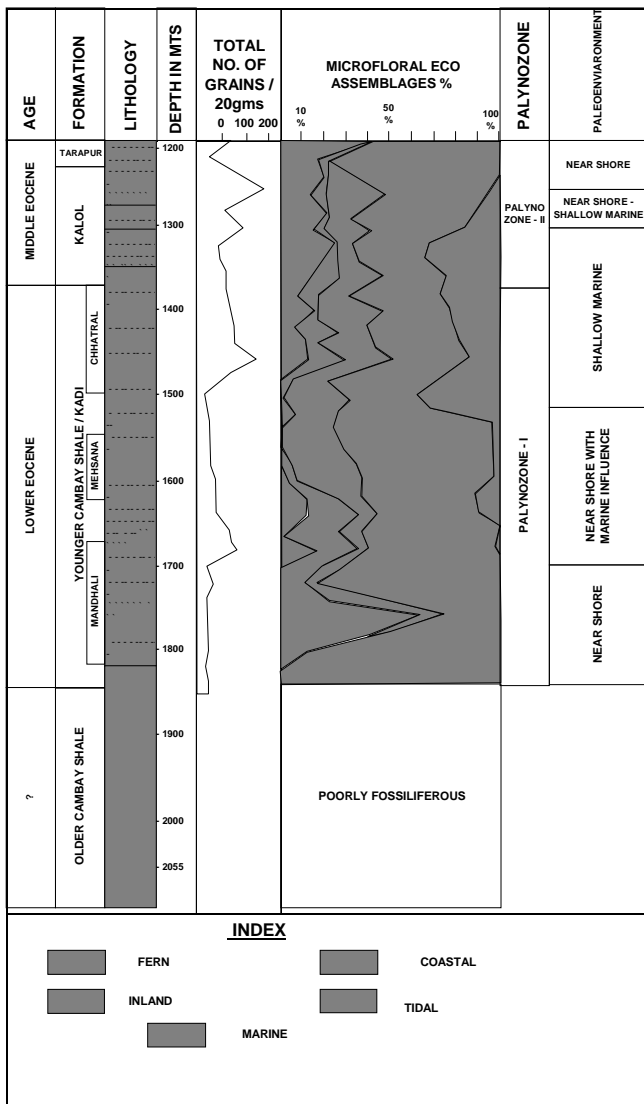


Fig. 11—Chart showing microfossil assemblage and palaeo-environment in a well at Viraj - G.

Striacolporites ovatus (Caesalpiaceae) are sparsely distributed in this zone.

The pteridophytic complex (fresh water) is represented by taxa *Polypodiisporites* spp. (Polypodiaceae), *Laevigatosporites* spp. (Polypodiaceae), and *Lygodium-sporites* spp. (Schizaeaceae) are rarely recorded in this zone.

The common occurrence of fungal spores and microthyraceous discs are also noticed in this zone. The fresh water algae *Pediastrum* spp., are also recorded at certain interval in Viraj-CI.

The analysis of different plant complexes indicates that main vegetation which contributed the flora grew in the proximity of shore line in tropical climate. Some of the vegetation also grew further inland in fresh water swamps and lowland areas on flat topography in tropical climate.

The rare presence of phytoplankton and tidal elements, the dominance of back mangrove, decrease in sandy beach, fern and inland complexes, common occurrence of fungal spores suggests that the sediments were deposited in near shore conditions. There was a little marine influence during the time of deposition of the sediments of the upper part of this zone in Viraj-G and CI.

From palaeoecological evidence it is deduced that the Cambay Shale was deposited in near shore conditions in Viraj-G, Viraj-CI, South Viraj-A, Lohar-B, Rampura-A and Wasnalava-A.

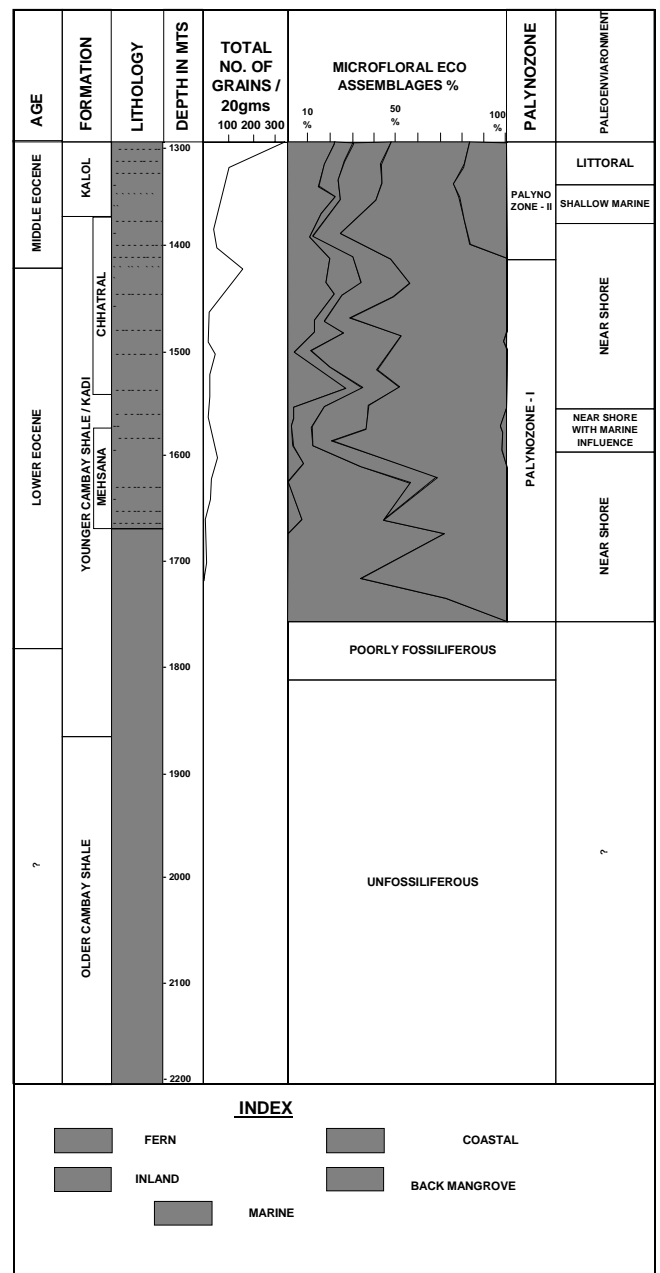


Fig. 12—Chart showing microfossil assemblage and palaeo-environment in a well at south Viraj - A.

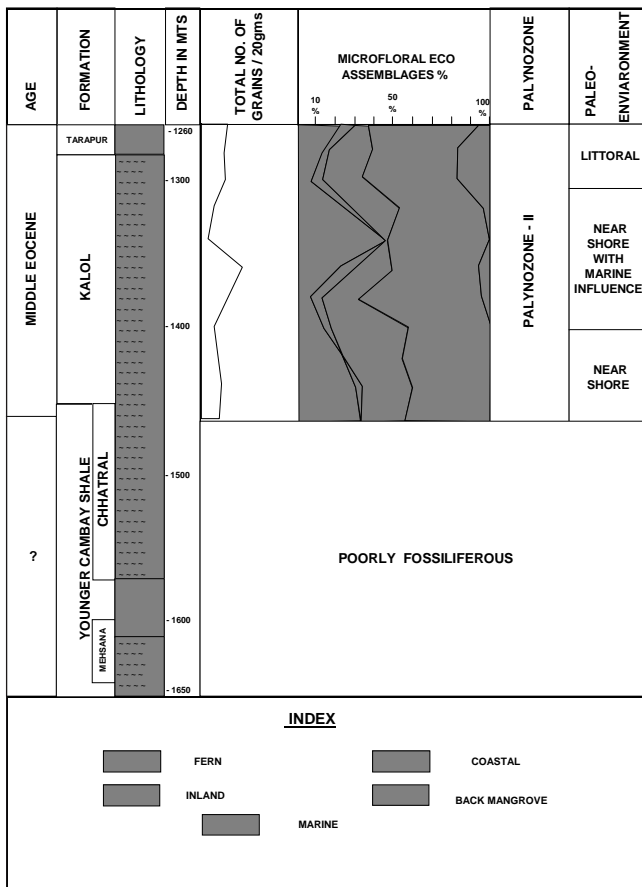


Fig. 13—Chart showing microfloral ecoassemblage and palaeo-environment in a well at Lohar - B.

PALYNOZONE-II

The first down hole appearance of taxon *Proxapertites cursus* marks the top of this zone. The associated dominant taxa are *Proxapertites cursus*, *Palmaepollenites kutchensis*, *Dracaenipollis circularis*, *Couperipollis kutchensis*, *Longapertites* spp., *Arecipites* spp., *Proxapertites operculatus* along with pteridophytic spores *Polypodiisporites* spp., *Laevigatosporites* spp., and *Lygodiumsporites* spp. The associated rare to common occurrence of *Marginipollis kutchensis*, *Iugopollis tetraporites*, *Rhoipites* sp., *Psilodiporites hammenii*, *Stephanocolpites* spp., *Polycolpites flavatus*, *Umbelliferoipollenites ovatus*, *Margocolporites tsukadai*, *Psilatricolporites* spp., *Retitricolporites* spp., *Dicolpopollis* spp., *Verrutricolporites* sp., *Circulisporites* sp., *Retistephanocolpites* sp., *Tricolpites* sp., *Myricipites* sp., *Pseudonothofagidites kutchensis*, *Cupanieidites* sp., *Myricaceoipollenites* sp., *Proteacidites* sp., *Cyathidites* spp., *Lycopodiumsporites* sp., *Cleistopshaeridium* spp., *Polysphaeridium* spp., *Spiniferites* sp. and *Homotrydium* sp. has also been recorded.

The top of this zone is marked at 710 m and 1040 m in Detroj-D and Wasnalava-A, respectively. In other wells, viz. Viraj-G, Viraj-CI, South Viraj-A, Lohar-B and Rampura-A, the samples were not available for study from the top of Palaeogene section. However, the studied sequence between

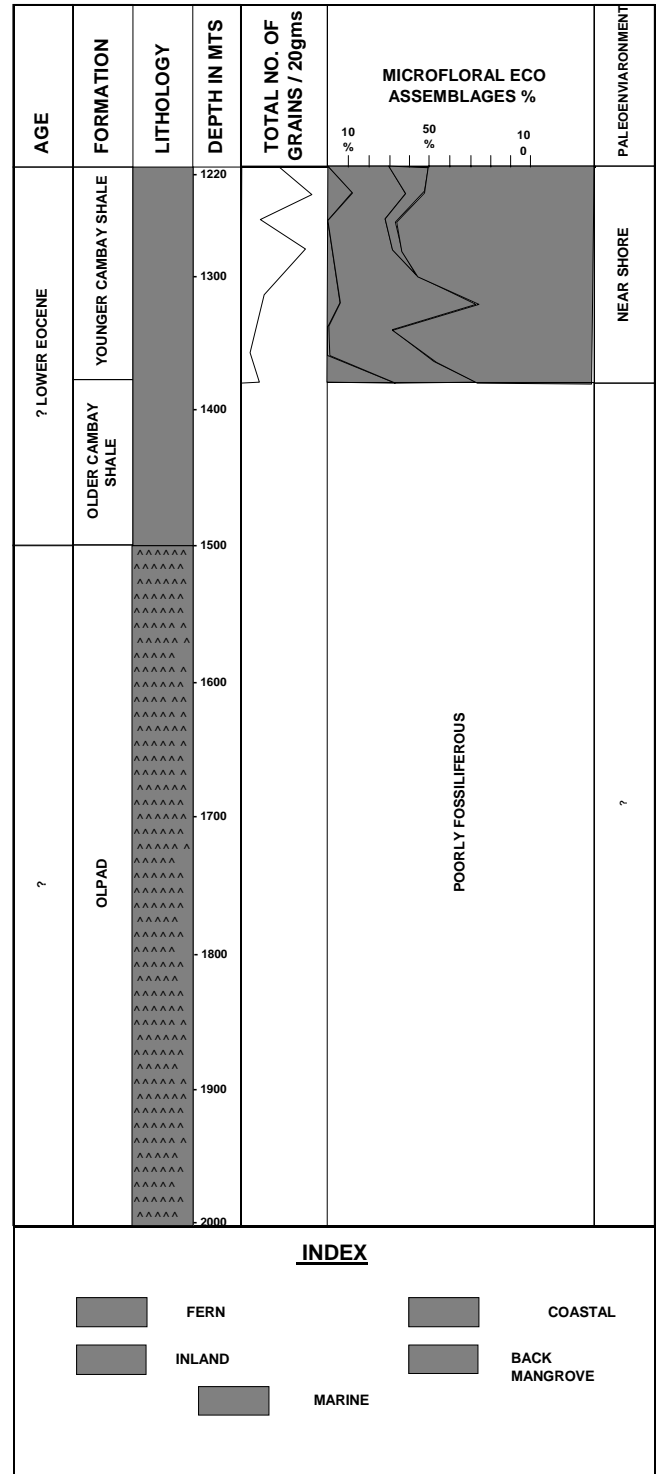


Fig. 14—Chart showing microfloral ecoassemblage and palaeo-environment in a well at Rampura - A.

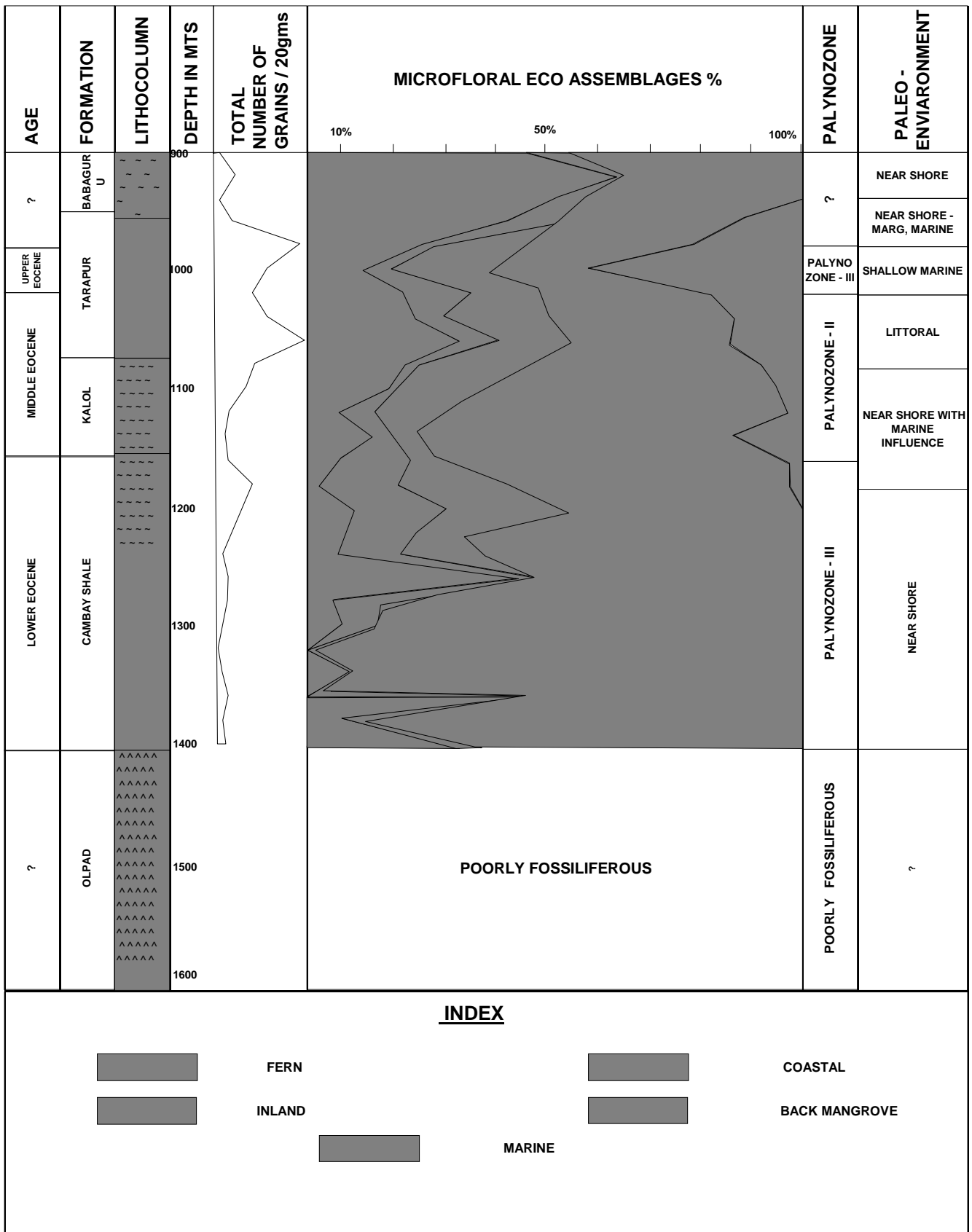


Fig. 15—Chart showing microfloral ecoassemblage and palaeo-environment in at Wasnalava - A at well.

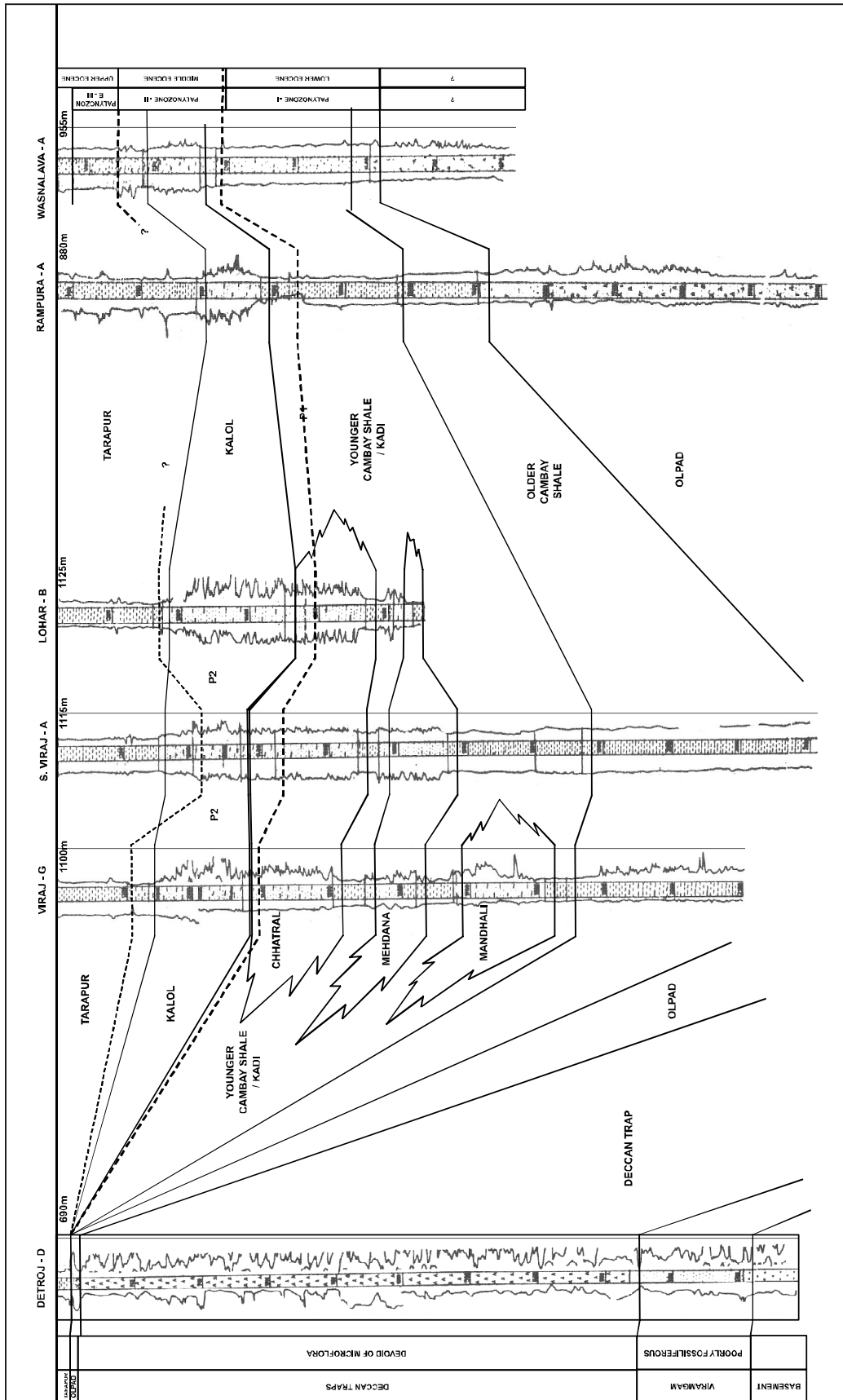


Fig. 16—Correlation chart showing stratigraphic units and palynozones in western margin of Ahmedabad Block.

1200-1380 m, 1300-1400 m, 1300-1420 m and 1260- 1460 m in Viraj-G, Viraj-CI, South Viraj-A and Lohar-B falls within this zone. The palynozone II corresponds to Kalol and lower part of Tarapur formations in Detroj-D and Wasnalava-A.

Age—The stratigraphic range of *Proxapertites cursus* in Palaeocene-Middle Eocene (Thanikaimoni *et. al*, 1984; Mathur & Chaudhary, 1976; Mathur, 1986). The taxon *Polycolpites flavatus* (Lower to Middle Eocene) also recorded in this zone. The underlying zone-I has already been assigned Lower Eocene age. Thus, on the basis of first down hole appearance of *Proxapertites cursus*, the palynozone-II is assigned Middle Eocene age. The upper and lower limit of this zone is marked in Detroj-D and Wasnalava-A only. Thus, the strata between 710-720 m in Detroj-D and 1040-1180 m in Wasnalava-A are assigned Middle Eocene age. The top of the zone-II corresponds to Middle Eocene age which could not be marked in wells Viraj-A, CI, South Viraj-A and Lohar-B due to non-availability of samples.

Palaeoecology—This zone is richly fossiliferous. The palaeoecological interpretation of sediments is based on microfloral ecoassemblages recorded in this zone. The microfloral assemblage is composed of marine, mangrove, coastal, inland and pteridophytic elements. The marine complex in the microflora is represented by taxa *Cleistosphaeridium*

spp., *Polysphaeridium* spp., *Spiniferites* sp. and *Homotryblium* sp.

The mangrove (tidal complex) is represented by taxa *Iugopollis tetraporites* (Sonneratiaceae) and *Marginipollis kutchensis* (Lecythidaceae) are very rare in the microfloral assemblage of this zone in all the wells. The back mangrove elements are referred to taxa *Proxapertites cursus*, *P. operculatus*, *Couperipollis kutchensis* and *Arecipites* spp., These taxa show affinity with palms of low salinity. The representatives of back mangrove complex are most common in all the wells except Detroj-D where they are rare.

The coastal (sandy beach) association of plants are represented by taxa *Palmaepollenites* spp., *Drecaenoipollis circularis* and *Longapertites* spp., are most common in Viraj-G, Viraj-CI and South Viraj-A. These elements are also common in Wasnalava-A and rare in Detroj-D.

The inland complex are common in this zone. They are referred to taxa *Margocolporites tsukadai* (Caesalpiniaceae), *Psilatricolporites* spp. (Caesalpiniaceae), *Ratitricolporites* spp. (Rubiaceae), *Rhoipites* sp. (Anacardiaceae), *Polycolpites flavatus* (Labiatae), *Umbelliferoipollenites ovatus* (Umbelliferae), *Retistephanocolpites* sp. (Labiatae), *Stephanocolpites* spp. (Labiatae), *Verrutricolporites* sp. (Verbenaceae), *Tricolpites* spp. (Caesalpiniaceae), *T.*

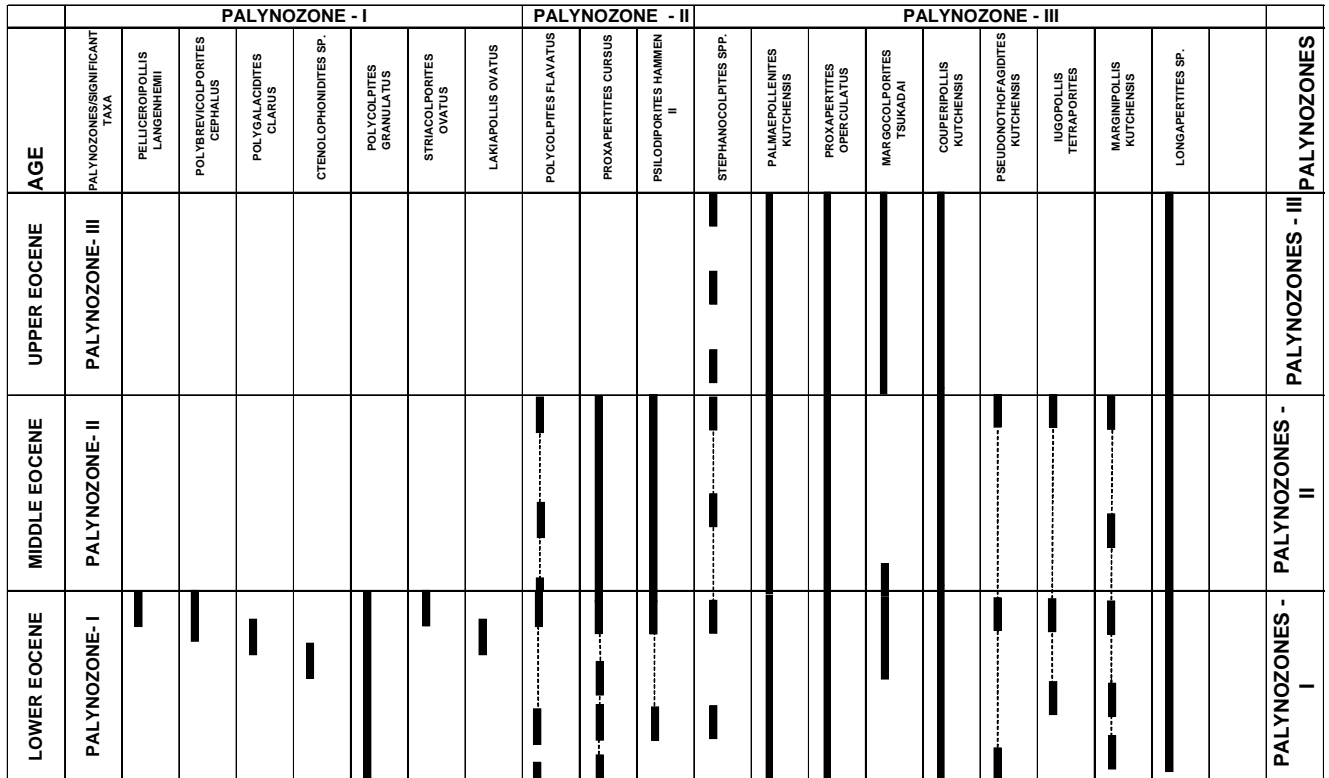


Fig. 17—Palynological zonation & distribution of significant palynofossils in subsurface palaeocene sequence of Detroj-4, Viraj-7, Viraj-39, South Viraj-1, Lohar-2, Rampura-1.

reticulatus (Cruciferae), *Cupaniedites* sp., (Sapindaceae), *Dicolpopollis* spp. (Palmae), *Myricipites* sp. (Myricaceae), *Myricaceoipollenites* sp. (Myricaceae), *Proteacidites* sp. (Proteaceae) and *Pseudonothofagidites kutchensis* (Fagaceae).

The fern complex is referred to taxa *Polypodiisporites* spp. (Polypodiaceae), *Laevigatosporites* spp. (Polypodiaceae), *Lygodiumsporites* spp. (Schizaeaceae), *Cyathidites* sp. (Cyathaceae), *Polypodiaceoisporites* sp. (Polypodiaceae) and *Lycopodiumsporites* sp. (Lycopodiaceae).

The fungal spores are common in the microfloral assemblage. The microfloral assemblage recorded in this zone suggests that the main vegetation grew in the vicinity of shore in tropical climate. The fern and inland complex indicate that the part of the vegetation also grew in fresh water swamps and lowland on flat topography in tropical climate near the area of deposition.

The dominance of palm, fern and back mangrove complexes and presence of fungal elements indicate that the sediments were deposited in near shore deltaic conditions. The marine influence has been marked in Lohar-B, South Viraj-A and Viraj-G and less pronounced in Viraj-CI, Wasnalava-A and Detroj-D during deposition of sediments.

From the above studies it is deduced that the sediments of Kalol and lower part of Tarapur formations were deposited in near shore environment under marginal marine influence. This marginal marine influence was not noticed in Detroj area during the deposition of lower part of Tarapur and Kalol formations.

PALYNOZONE-III

The first downhole occurrence of taxon *Palmaepollenites kutchensis* marks the upper limit of this zone. This zone is defined by the common occurrence of *Palmaepollenites kutchensis* along with *Dracaenoipollis circularis*, *Arecipites* spp., *Couperipollis kutchensis*, *Polypodiisporites* spp., *Laevigatosporites* spp., *Lygodiumsporites* spp., *Longapertites* sp., *Dicolpopollis* sp., *Proxapertites operculatus*, *Margocolporites tsukadai*, *Rhoipites* sp., *Psilatricolporites* spp., *Tricolpites* spp., *Stephanocolpites* sp., *Myricipites* sp., *Psilodiporites* sp., *Circulisporites* sp. and *Oudhkusmites* sp. the fungal spores are very rare in this zone. Marine elements are represented by *Cleistosphaeridium* spp., *Homotryblium* spp., *Polysphaeridium* spp., *Turbiosphaera* spp., *Spiniferites* spp. and Microforaminifera.

The upper limit of this zone is marked at 690 m in Detroj-D and 980 m in Wasnalava-A. In other wells, viz. Viraj-G, Viraj-CI, South Viraj-G, Lohar-B and Rampura-A, the top of this zone could not be marked due to non-availability of the samples. The zone-III corresponds to Tarapur Shale between 690-710 m in Detroj-D and 980-1040 m in Wasnalava-A.

Age—The stratigraphic range of *Palmaepollenites kutchensis* is Palaeocene to Upper Eocene (Thaniikaimoni *et al.*, 1984). Other taxa *Psilodiporites* sp. and *Margocolporites tsukadai* known to occur from Palaeocene to Upper Eocene, have also been recorded in this zone. On the basis of range of above taxa and the stratigraphic position the Palynozone-III is dated Upper Eocene in age.

Palaeoecology—Microfloral assemblage of palynozone-III is comprised of fern, inland, coastal, mangrove and marine complexes. The marine complexes are related to taxa *Cleistosphaeridium* spp., *Polysphaeridium* spp., *Homotryblium* spp. and *Turbiosphaera* spp. The microforaminiferal tests are also recorded in this zone. The marine floral complex shows dominant occurrence in this zone. The mangrove tidal complex is rare in this zone. The presence of back mangrove complex is shown by taxa *Proxapertites operculatus*, *Couperipollis kutchensis* and *Arecipites* spp. and are frequently noticed in this zone.

The coastal sandy beach complex is common and represented by the *Palmaepollenites* spp., *Dicolpopollis* spp., and *Longapertites* sp. The inland complex is in the floral assemblage is represented by taxa *Margocolporites tsukadai*, *Rhoipites* sp., *Psilatricolporites* spp., *Tricolpites* spp., *Stephanocolpites* sp., *Myricipites* sp., *Psilodiporites* sp., *Circulisporites* spp., and *Oudhkusmites* sp. The fern complex is represented by *Polypodiisporites* spp., *Laevigatosporites* spp., *Lygodiumsporites* spp. and *Cyathidites* sp.

The dominant occurrence of marine complex alongwith microforaminifera indicates that the sediments of Tarapur Shale were laid down under shallow marine condition.

CORRELATION

Palynological studies carried out in Palaeogene subsurface sequence have led to identify three correlatable levels in the western part of Ahmedabad Block (Fig. 16). The first level marked by the first occurrence of taxon *Pellicieripollis langenheimii*, corresponding to top of Lower Eocene has been traced at 1300 m, 1420 m and 1180 m, in wells Viraj-G, South Viraj-A and Wasnalava-A, respectively. The second level has been demarcated by first appearance of *Proxapertites cursus* which corresponds to upper limit of Middle Eocene and falls at 710 m in Detroj-D and 1040 m in Wasnalava-A. The third successive level has been identified by first occurrence of *Palmaepollenites kutchensis*. This level corresponds to top of Upper Eocene and marked at 690 m and 980 m in Detroj-D and Wasnalava-A.

SUMMARY

Three palynoassemblage zones—*Polybrevicolporites cephalus* (zone-I), *Proxapertites cursus-Polycolpites flavatus* (zone-II), *Palmaepollenites kutchensis* (zone-III) are assigned

Lower Eocene (at places inconclusive), Middle and Upper Eocene age, respectively. The common occurrence of back mangrove and coastal elements alongwith sporadic occurrences of phytoplankton in Cambay Shale and Kadi formations indicating nearshore conditions of deposition. The dominance of back mangrove alongwith moderate occurrence of coastal, swampy, inland elements and with fair presence of phytoplankton in Kalol Formation suggest littoral environment of deposition. An increase in overall percentage of marine phytoplankton in Tarapur shale inferred shallow marine environment of deposition.

Acknowledgements—*The authors are grateful to Shri D.P. Sahastrabudhe, GGM - Basin Manager, Western Onshore Basin, for his encouragement and permission to carry out this work. Sincere gratitude is expressed towards Shri R. Vijayrangan, DGM-Head, RGL for providing facilities to carry out this work and critical review of the manuscript.*

The views expressed in this paper are solely of the authors and not necessarily of the organization.

REFERENCES

- Hedberg 1976. International Stratigraphic Guide. Wiley Inter Science, New York, pp. 1-200.
- Koshal VN 1988. Palynofossils and palaeoenvironment of the Tertiary sub-surface sediments in Ahmedabad-Mehsana Block, Cambay Basin, western India. Proceedings of the Second Conference Vol. I Geology, Sea level changes Paleoclimatology and Paleobotany. Center of Asian studies, University Hong Kong.
- Mathur LP, Rao KLN & Chaube AN 1968. Tectonic framework of Cambay Basin, India. Bulletin Oil & Natural Gas Corporation 5: 7-28.
- Mathur YK 1986. Dinoflagellate cysts biostratigraphy and age of the Middle Eocene Kalol Formation in the Kalol 109 well, North Cambay Basin, western India. Review of Palaeobotany & Palynology 47: 193-202.
- Mathur YK & Chaudhary LR 1976. Palaeoecology of the Kalol Formation, Cambay Basin, India. *In*: Venkatachala BS & Sastri VV (Editors)—Proceedings IV Colloquium Indian Micropalaeontology and Stratigraphy: 164-178 Dehradun.
- Mehrotra NC, Venkatachala BS & Kapoor PN 2005. Palynology in Hydrocarbon Exploration. Memoir Geological Society of India 61: 1-128.
- Raju ATR 1968. Geological evolution of Assam and Cambay Tertiary basins of India. AAPG Bulletin 52: 2422-2437.
- Rawat MS, Mukherjee J & Venkatachala BS 1977. Palynology of the Kadi Formation, Cambay Basin, India. *In*: Venkatachala BS & Sastri VV (Editors)—Proceedings of the IV Colloquium Indian Micropalaeontology and Stratigraphy: 179-192. Dehradun.
- Shanmukhappa M 1990. Palynostratigraphy and palaeoenvironmental analysis of Gandhar area in Cambay Basin. Proceedings of the Conference on Integrated Exploration Research Achievements and Perspectives, Dehradun.
- Shanmukhappa M & Koshal VN 1991. Palynological investigations of Eocene sediments in Gandhar area, Broach depression, Cambay Basin. Proc. IInd Seminar, Petroliferous Basins of India.
- Thanikaimoni G, Caratini C, Venkatachala BS, Ramanujam CGK & Kar RK 1984. Selected angiosperm pollen from India and their relationship with African Tertiary pollens, Institute Francies, De Pondicherry Travanc de la Section Scientifique et tome XIX: 1-93.
- Venkatachala BS & Chaudhary LR 1977. Palaeoecology of the Kadi Formation, Cambay Basin, India. *In*: Venkatachala BS & Sastri VV (Editors)—Proceedings of the IV Colloquium Indian Micropalaeontology and Stratigraphy: 259-277. Dehradun.