JOURNAL OF THE PALAEONTOLOGICAL SOCIETY OF INDIA
VOLS. 23 & 24, 1980, pp. 156--165 (*For* 1978-79).

PALAEONTOLOGY, SEDIMENTATION AND PALAEOENVIRONMENT OF OLIGOCENE SEDIMENTS IN SOUTHWEST GUJARAT[1]

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ABSTRACT

A detailed correlation of the Oligocene-Miocene sediments between South Gujarat and Tarapur Offshore Well is attempted. Distribution pattern of sands in the Late Oligocene—Early Miocene, established after detailed correlations, is referable to that of a broad sand belt in a funnel shaped estuary., They were deposited between the seashore and the western limit of the then tidal energy. The same model has been extended down to the Middle Oligocene.

INTRODUCTION

A poorly fossiliferous sequence of strata, commonly referred to Early Miocene, is well known to occur in Gujarat subsurface between the marine fossiliferous beds of Paleogene and Neogene. Their low yield of fossils as well as of hydrocarbons rendered them less attractive for studying environmental parameters and sedimentation characteristics. A good chronostratigraphic correlation of these strata has been possible after drilling the wells of the Gujarat-Maharashtra coast. This, in turn, has helped to infer their sedimentation pattern. Details of correlation and environmental pattern, during sedimentation, have been discussed in this paper for the referred Early Miocene sediments between the fossil bearing Paleogene and Neogene sequences.

A detailed correlation of the Oligocene-Miocene sediments between South Gujarat and Tarapur Offshore well is attempted.

PROBLEMS AND APPROACH

A greater part of the sediments, conventionally referred to basal and lower Miocene in Gujarat subsurface, is either very sparsely fossiliferous or devoid of microfauna. Barrenness is mostly seen in the lower part of the sequence characterised by abundant globular bodies. Age attribution and precise correlation of these sediments —little studied earlier due to lack of microfauna—were the focal points for a systematised stratigraphic analysis. The paleoenvironmental studies, of this sequence had mainly to probe into the likely sedimentation distribution pattern during the period involved whereas the palaeoecologic work could provide an insight into general distribution of organic matter and vital parameters at depositional interface favouring, or otherwise, the accumulation of organic detritus.

For obtaining coherent but rapid results the studies were undertaken at two levels : intensive study of important well sections and general examination of other key sections. The intensive study of the samples, carried out in Aliabet Offshore-1 Bhandut, Bhatlai, Hazira, Pune wells involved microfaunal frequency and population variation. Weighted cutting samples ten grams each at every ten metre interval, were studied for the microfauna in all these wells. Some of these wells were also examined palynologically for demarcating the palynomorph boundary considered as Oligocene/Miocene boundary in Tarapur Offshore Well. Palynological studies on Aliabet, Bhandut, Bhatlai, and Hazira wells were carried out by Shri V. N. Koshal, Asstt. Palynologist.

MICROFAUNAL ASSEMBLAGE AND FREQUENCY

Two microfaunal horizons constitute definitive markers in the present study. The lower one—the top of the Eocene—Early Oligocene Rotaliid assemblage—connotes the widespread regression marking the end of the major Eocene transgression of Cambay basin. The upper horizon is the disappearance level of *Ammonia papillosus* which was believed to mark the Middle Miocene top by Guha and Pandey (1972) but has been subsequently revised, by the same authors (1974), as the top of Lower Miocene after the study of Bombay Offshore data.

Between the two biohorizons referred above, there lies an important third biohorizon of regional importance. This is the appearance level of Late Oligocene—Miocene assemblage. It is a definite horizon but very difficult to

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pinpoint in the well sections due to the contaminating microfauna in the cuttings of the barren zone between this horizons and the disappearance level of Paleogene Rotaliids. Vertical frequency distribution of Oligo—Mio Rotaliids helps to pick a thin zone, in most wells, where this boundary lies. A precise depth, however, remains elusive.

The studies of foraminiferal assemblage of the Oligo-Miocene sequence is rather monotonous and comprises of the species of *Rotalia*, *Ammonia*, *Elphidium*, *Florilus*, *Quinqueloculina*, *Triloculina* and few other smaller foraminifera. In the Miocene part *Archaias*, *Operculina*, *Miogypsina* and *Nephrolepidina* are represented by one or two species each. Nevertheless, these larger foraminifera—barring *Nephrolepidina*—are rare in most well sections. The planktonic foraminifera are noted only for their absence.

The foraminiferal frequency, as a whole, is poor and seldom exceeds more than fifty forms for ten grammes sample. Average yield of the samples is between ten and thirty forms.

CLASSIFICATION AND CORRELATION

In Gujarat subsurface the problem of a rational classification of the Oligocene—Lower Miocene sequence for near isochronous correlation of distant wells could not be solved till now. A greater part of the sequence is microfaunistically barren and even the latest microfloral study has not provided a definite zonation or correlation of zones in the sequence. To counter the inherent disadvantages of the sequence, a finer classification of the Oligocene in the Offshore well of Tarapur, based mainly of tectonoenvironmental parameters, was conceived; and, possibilities of correlating these finer divisions in the subsurface of Gujarat were examined considering that the two areas are parts of the same basin and, as the Walther's law (1893) emphasises, the vertical changes at any point in the basin extend for long distances. This approach seems to produce a tangible classification of Oligocene in South Gujarat conforming approximately with the chronostratigraphic class, for detailed correlation of Oligocene—Lower Miocene.

OLIGOCENE IN TARAPUR OFFSHORE

In the Tarapur Offshore Well, it was observed by Guha and Pandey (1974) that the top of Lower Miocene coincides, approximately, with the disappearance of *Ammonia papillosus*. The Neogene/Oligocene boundary was taken at *Miogypsina gunteri/tani* boundary and Oligocene/Eocene boundary was placed at the top of *Nummulites fabianii* s. l. (including *N. retiatus*). For the reasons being discussed in another report, the Focene/Oligocene boundary is now being revised to the level of disappearance of *Cribrohantkenina inflata*. The earlier boundary was placed at level of P-18/P-19 boundary in the zonation of Blow (1969) but now the boundary corresponds to P-16/P-17 boundary.

The Oligocene of the Standard Section—Tarapur Offshore, can be divided into a succession of five main tectonoenvironmental units. Each unit is possibly a continuous sedimentary sequence specific in an environmental framework and for the purposes of correlation with the subsurface of southern Gujarat recognised as a genetic sequence of strata (GSS). In Standard Section of Tarapur Offshore, the five genetic sequences of strata are named informally as OGSS I to V. Their order of superposition, thickness, lithological character and environmental parameters are as follows :

LOWER MIOCENE ASSEMBLAGE

	——Unconformity/Disconformity——	
OGSS—V (1725-1840 m;)	Mainly light to dark grey shales with some marls and limestone; smaller foraminifera common, Larger foraminifera less common.	Transgressive Shallow marine
OGSS—IV (1840 m.-1960)	Mainly light to dark grey shales some coals, silts and minor sands; 'globular bodies (spherulites) common. No microfauna/very poor microfauna.	Regressive mainly terrestrial, occasionally estuarine
OGSS—III. (1960-2175)	Light to dark or greenish grey shales and limestones. Flooded with larger foraminifera, particularly *N. fichteli* and *Lepidocyclina* Smaller foraminifera less common.	Transgressive shallow marine
OGSS—II (2175-2280 m.)	Poorly fossiliferous gray, silty shales Some impoverished Rotaliids. Larger Foraminifera absent ?	Regressive Eatuarine to ?Terrestrial
	——Unconformity/disconformity——	
OGSS—I (2280-2480 m.)	Dark grey, shales, some limestones in lowerpart, abundant planktonic foraminifera, Lagenids and Epistominids	Mainly Deeper basin facies.
	——Disappearance level of *Hautkenina*——	

LATE EOCENE ASSEMBLAGE

The five tectonoenvironmental units—OGSS I to V—may be referred to three marine cycles. The OGSS I. Transgressive and OGSS II Regressive constitute of the first marine cycle. Likewise the OGSS III and IV are the Transgressive and Regressive phases of the Second marine cycle of Oligocene. OGSS V is mainly transgressive and the regression at the end of the cycles, though wide spread, appears to be short lived. Regressive, estuarine or terrestrial sediments capping OGSS-V and comparable with the regressive phases in the two underlying cycles of Oligocene are too thin to be recognised as a distinct unit. The OGSS-V transgression itself, however, is much shallower development in comparison, to the other two transgressions and the bathymetric fluctuations in the deeper parts of basin, e.g. Tarapur Offshore area, could give rise in the marginal areas of the basin, like southern Gujarat subsurface an intertonguing of marine and nonmarine sediments.

For the purposes of formal classification, the three main transgressions of the Oligocene may be considered as main constituent units of this epoch. Accordingly the Oligocene of the Tarapur Offshore area is divided into Lower, Middle and Upper. In the zonation of Blow (1969), the Lower, Middle and/or Early, Middle and Late Oligocene of Tarapur Offshore correspond approximately to P17/18, P19/20 and P-21/P-22 respectively.

The Oligocene/Miocene disconformity is followed in the Early Miocene by a strong microfloral break—about 25 metres above the microfaunistically definea Oligocene top in Tarapur Offshore. The microfloral break seems to connote a major annhilation of the Oligocene coastal belt of vegetation, after the Neogene sea inundated, the then coastal land. Since the microfaunal and microfloral breaks are not far separated in the stratigraphic column and the latter is well defined in the subsurface of Gujarat, an useful palynological datum close to Oligocene/Miocene boundary is recognisable in Gujarat. This datum helps to draw approximate top of the OGSS-V in the subsurface of Gujarat.

The top of the Lower Miocene of Southern Gujarat is comparable to that of Tarapur Offshore since in both cases local disappearance level of *Ammonia papillosus* is homotaxial. Lower Miocene has been further classified in Tarapur Offshore by Guha and Pandey (1974) with the help of *Miogypsina*. Owing to paucity of larger foraminifera in the subsurface of South Gujarat, extending these subdivisions on foraminiferal control, to these areas seems less attractive.

CORRELATION BETWEEN GUJARAT SUBSURFACE AND TARAPUR OFFSHORE

A correlation between Tarapur Offshore and Southern Gujarat subsurface, for the Oligocene-Lower Miocene sediments, is possible on broad features associated with the tectonoenvironmental attributes assuming that the two areas were governed broadly by same tectonoenvironmental conditions during Oligo-Miocene. Although a good part of the Oligocene sequence is nonmarine in Gujarat, the tectonoenvironmental and microfossil of this sequence enable to recognise the informal units of Tarapur Offshore in the subsurface of Southern Gujarat. The correlation has been established primarily between Tarapur Offshore and the southernmost well of Gujarat, i.e. Dumas- and then extended to the other wells with the help of biostratigraphic and electrolog data. Aliabet offshore well has been taken up as a second example for correlation in this discussion.

OGSS-I : The control of foraminifera enables a definite correlation of this unit in Tarapur Offshore and Gujarat subsurface. The microfauna does show reduction in frequency and diversity when traced from Tarapur Offshore to Gujarat subsurface but the essential elements are common to the two areas.

In the subsurface of Southern Gujarat and Tarapur Offshore, the disappearance level of *Cribrohantkenina inflata* or equivalent horizons (within minor adjustments), e.g. those of *Pellatispira*, *Discocyclina* or *Turborotalia corrossulensis*, are nicely correlated and the base of OGSS-I is firmly established.

The disappearance level of microfauna at the boundary of OGSS-I and OGSS-II, suggesting a major regression, is a well correlatable datum in southern Gujarat and Tarapur Offshore Well. The contrast lies, however, between the disappearance of Rotaliids and benthonics in Gujarat and a rich assemblage of planktonics in Tarapur Offshore. OGSS-I is thus, microfaunistically best correlated segment of Oligocene in the two areas.

OGSS-II, III and IV : This sequence is essentially devoid of microfauna in Gujarat subsurface. However, the tectonoenvironmental features of the three successive units below the transgression of Late Oligocene corresponding to OGSS-V and above the OGSS-I regression seem to be broadly reflected by the gross succession of lithotypes. This case is vividly seen in Dumas-1 but could also be extended in other wells of the area.

The regression during OGSS-II, it appears, also initiated perceptable activation of provenance resulting into deposition of a sand sequence overlying the OGSS-I in Dumas. This sandstone unit, approximately homotaxial with the OGSS-II regression in Tarapur Offshore could be correlated in the north up to Aliabet Offshore.

The OGSS-III transgression of standard section, it seems, coincides with a regional increase in the argillaceous material in the well sections suggesting a subdued erosional activity in the provenance of the then southern Gujarat. The argillaceous development correlatable with OGSS-III of Tarapur Offshore is satisfactorily traced between Dumas and Aliabet.

The boundary between OGSS-III and IV is not very sharp. The frequency changes of foraminiferal population in the cutting samples help to pick up a thin zone where a sharp fall in frequency is noted. Within this thin zone lies the boundary between the OGSS-IV and OGSS-V.

OGSS-V : Not only the base of OGSS-V is slightly ambiguous its top also is difficult to recognise only on paleontological data. However, the palynological top of Oligocene, when correlated from Tarapur Offshore to Gujarat subsurface, helps to tie up this datum approximately in most wells. A sudden increase of *Ammonia annectens* above this level also helps to identify the top of

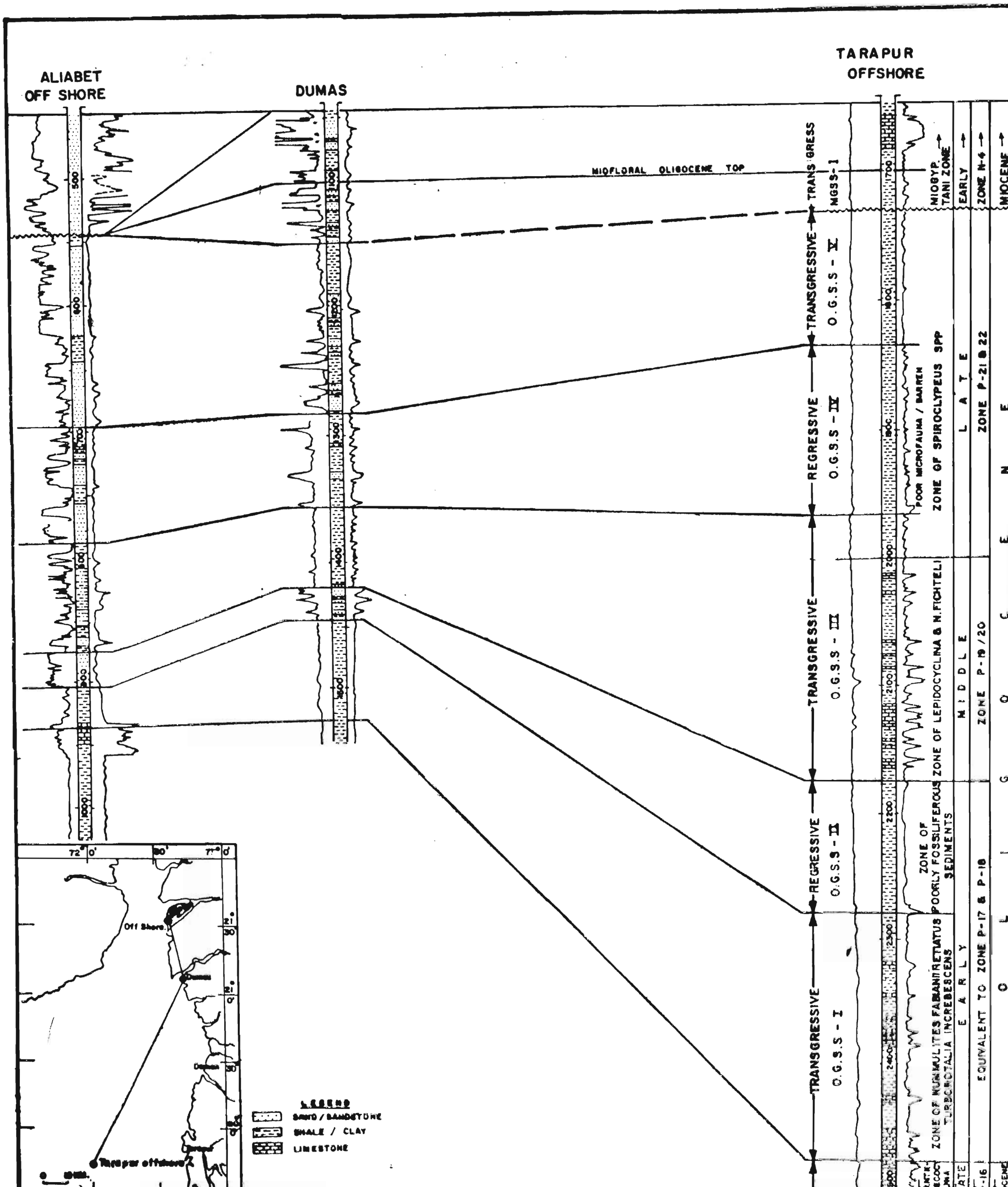


Fig. 1. Correlation of Oligocene strata: Gujarat subsurface & Tarapur offshore

OGSS-V. In some sections, e.g. Aliabet, the OGSS-V is nonmarine and Lower Miocene microfauna is absent and palynological control is the only viable criterion. Aliabet area, however, seems to be an exception in the present case and correlation of OGSS-V in various well sections offers only minor problems.

Lower Miocene : In southern Gujarat, correlation of Lower Miocene is less problematic if the sequence is to be correlated as a whole without splitting it into smaller units.

PALEOGEOGRAPHIC CONSIDERATIONS

At the end of OGSS-I phase, during the Oligocene, the areas of Gujarat subsurface witnessed a major regression and nonmarine sedimentation commenced. OGSS-II, III and IV are nonmarine. A shallow brackishwater body transgressed during the OGSS-V, at least in more coastal areas of Southern Gujarat subsurface. This transgression reduced its acme during Lower Miocene and was followed by a sharp regional regression.

The Lower Miocene shore line may be drawn with good control of drilled wells. This shoreline, as shown in Fig. 4, encircles considerable part of the areas being explored in the Cambay Basin. The area was inundated by a shallow body of water, probably less than fifty metres deep, containing foram assemblages with dominant *Ammonia* and infrequent *Florilus* and *Quinqueloculina*. In the area south of Narmada, however, this community is enriched by presence of larger foraminira like *Miogypsina* spp., *Nephrolepidina* spp., and occasional *Archaias* sp. and *Operculina* sp.

The distribution pattern of foraminifera, as stated above, implies likely changes in paleoenvironments south and north of Aliabet-Piram alignment. This change surmised in the areas lying north of Piram-Aliabet alignment, had salinties lower than needed for the sustainance of larger foraminifera, although they were higher than 5% below which *Ammonia* may not survive. Possible salinity range might have been 5 to 20 gms/litres in the areas north of Piram-Aliabet alignment but in the south, where larger foraminifera are encountered, salinities could reach around 30%. Even though the entire area between Ahmedabad and Dumas constituted a large estuarine body, a barrier, responsible for dilution of salinities in the north seems to be operative during the Lower Miocene. Some large islands, mainly submerged during strong tides and waves, were the probable barriers. It may be recalled, that Piram Island contains Lower Miocene vertebrates and in Aliabet Offshore, the Lower Miocene is devoid of marine microfauna. Possibility of these islands being a part of the extensive 'barrier system' during the Lower Miocene is supported by the Lower Miocene attributes in the two areas.

The extent to which the OGSS-III paleogeographic pattern simulated the basic conditions of Lower Miocene has a great significance for oil exploration since the basinal provenance and energy considerations during this period could lead to establishment of bigger reservoirs.

Assumption, have to be made for hypothesising the Middle Oligocene shore-line since it lay in Offshore areas west of Gujarat and there is no control point except Tarapur Offshore Well. In the reconstruction of Oligocene shore-line, however, the following considerations are helpful.

(a) The Oligocene sediments of coastal Gujarat subsurface contain a paludal and nearshore spore pollen assemblage. Rarely, the marine influx is also seen in the assemblage.

(b) The northern limit of the sea was south of Aliabet and most areas north of this island were nonmarine—though paludal swamps proliferated.

(c) The then Oligocene gulf with its possible coast line lies only slightly to the west of present coast line and terminating close to Aliabet-Piram alignment, received sediments from three major river systems within a distance of 50 kilometers leading to development of major estuarine features during this period.

DISTRIBUTION OF ORGANIC COMMUNITIES AND ORGANIC MATTER

Three main organic communities, temporarily separated from one another, are recognisable in the Oligocene-Lower Miocene of Southern Gujarat subsurface. These are : (a) the marine biota of OGSS-I unit; (b) the nonmarine, mostly paludal floral community during OGSS-II through OGSS-IV and (c) brackish shallow marine community during OGSS-V and Lower Miocene. The paleoecologic factors controlling the communities changed rather drastically from one to another community and not only affected the population density of organisms during sedimentation but also controlled the preservation of organic matter at the depositional interface.

The OGSS-I community of the Southern Gujarat subsurface thrived in practically the same conditions that prevailed during Late Eocene except in somewhat shallower conditions. In the marginal parts of the basin, devoid of clastic influence (e.g. Pune B and A), biogenic limestones were deposited in clear waters. In the axial parts like Hazira or Dumas, the basin tended to be deeper and with stronger tendencies of euxinic bottoms. Some Lagenids and pyritised planktonic foraminifera in the pyritic dark shales provide this information. The organic content of these shales-contributed mainly by phytoplankton debris subsiding to the bottom muds must

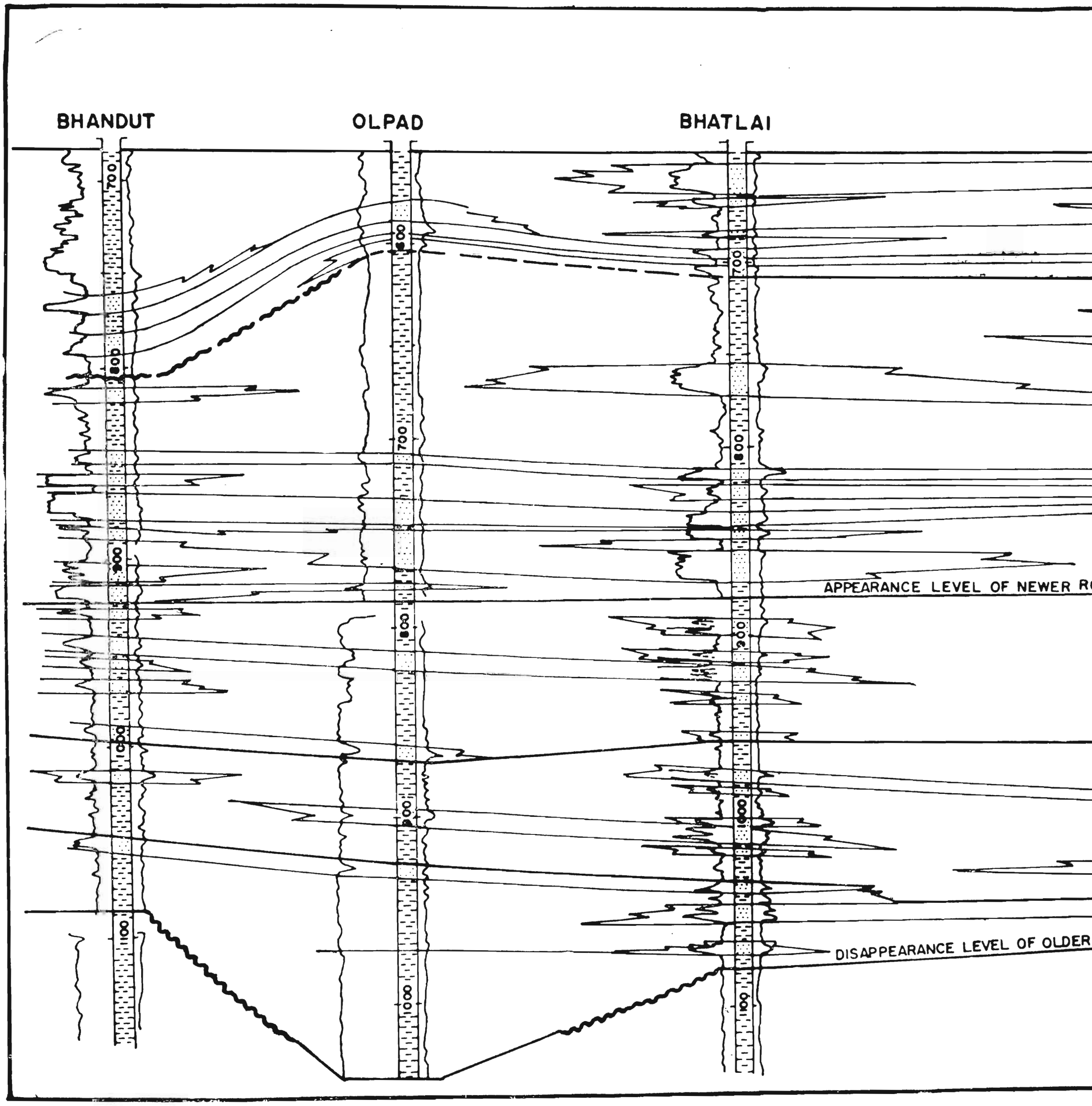
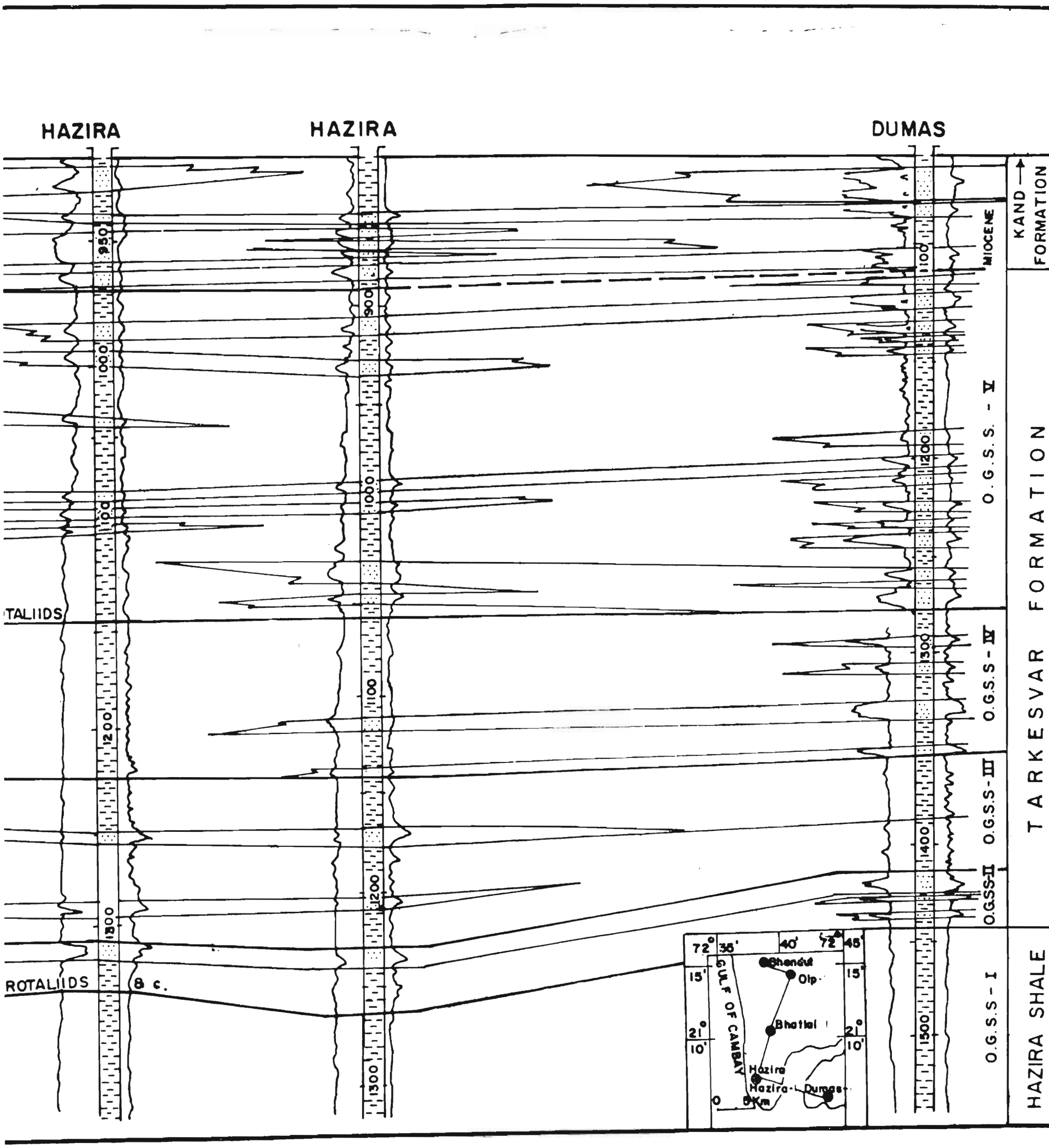


Fig. 2. Lateral behaviour of sandbodies in Oligocene-Lowe



r Miocene Section of Bhandut to Dumas Wells

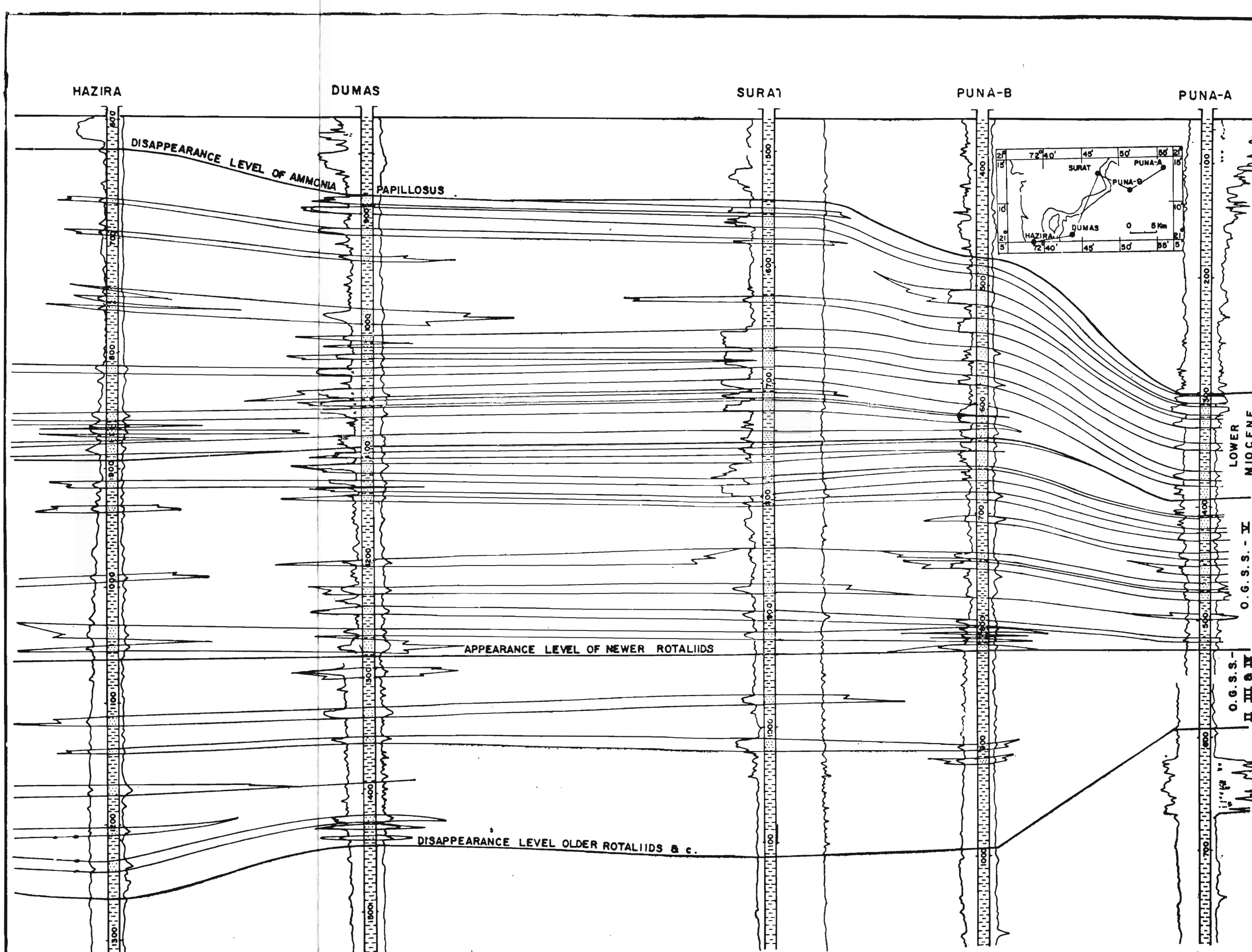


Fig. 3. Lateral behaviour of sandbodies in Oligocene-Lower Miocene Section of Hazira to Puna Wells

be pretty higher owing to nonoxidising, biocidal and euxinic bottoms.

The OGSS-II, III and IV sediments suggest that a terrestrial community of plants—mainly swampy flourished in the coastal area of southern Gujarat. The sediments contain some coaly matter too. Organic content, though chiefly continental, seems to have found preservation mainly due to its rapid burial, finer clastics being deposited in the flood plains of the then rivers and also in some of the swampy depressions.

Considering that OGSS-III is a well developed marine sequence in Tarapur Offshore, an environment similar to OGSS-II is visualised for this unit in those parts of the basin that were covered by OGSS-III transgression (Fig 4).

The OGSS-IV and the succeeding Lower Miocene comprise of a mainly shallow marine to estuarine environment. The luxuriant coastal vegetation, present during Oligocene, is apparently exterminated during the Neogene transgression cutting down the yield and diversity of spore-pollen in this part of the sequence. Microfaunistically too these sediments are poor. Neither the number nor the diversity of these forms are suggestive of a very congenial environment. Possibly the much agitated estuarine realm with well oxidised bottoms and a lower rate of terrestrial organic input from the adjoining provenance checked the abundance of benthonic life—including foraminifera. Oxidising and agitated conditions were also possibly responsible for post-depositional destruction of organic matter. As a result, Lower Miocene section neither contains pyritic shales nor other features associated with reducing bottoms. On the contrary, ferrugeneus matter in lower Miocene of Dumas has been recorded in the washed residues of this well.

MORPHOLOGY OF TERREGENOUS LITHOSOMES

The palaeogeographic and palaeoecologic parameters during the OGSS-III and OGSS-IV—Miocene are discussed at length in the preceding text. These are the main palaeogeologic tools to generalise the distribution pattern of the arenites and argillites in the Middle to Late Miocene of Southern Gujarat.

In the case of Lower Miocene and parts of OGSS-V the palaeoshoreline is demarcable satisfactorily and it may also be established that the drainage of the then Narmada and Tapti was the main source of sediment supply in southern Gujarat (Fig. 4). The modus operandi of subsequent distribution of the clastics, brought down in the basin by streams were possibly not very different from those of today. The usual intensity of tidal and wind energy—culminating into waves—played most vital role in segregation and distribution of the coarse and fine clastics on a widespread estuarine shallow submerged flat. Sedimentary features of large and small scale, like sand banks, sandwaves or tidal current ridges must have developed in suitable geographic locales and may be of interest in exploration of limited areas. These are presently left out as emphasis placed on the general distribution pattern of sand and shale lithosomes during Lower Miocene and OGSS-III.

For examining the lateral behaviour of the sandbodies and their general distribution a correlation profile of Hazira, Dumas, Surat, Puna-A and Puna-B was prepared in which the sand bodies were correlated precisely within two or more paleontological controls. Considerations about the Miocene position of the Tapti suggested it to be close to its present course and observations on the very large scale current bedding of the Neogene sandstones in Tapti River point out that its mouth was situated not far away from the present outcrops of Neogene in the Tapti River.

Keunen (1950, P. 317) has suggested "Where sand and lutite are transported together, the coarser grains will settle more easily. Generally the coarser fractions accumulate while the fine ones are still being carried away. Hence, sand and lutite tend to accumulate in different environments, or at different times in the same environment". (P. 318) "Bourcart and Francis-Boeuf (1942) have shown, however, that in estuaries the main mass of mud is deposited not where salinity commences but in localities where the mechanical action of tidal currents is favourable. This happens where the water is at rest for a sufficient lengths of time at each turn of the tide for settling to take place".

The object of examining the above profile has been three fold : (1) to infer the usual geometry of the sand-bodies ; (2) to measure the distance (from the coast) to which the tidal waves were actively distributing the sands of Tapti and Narmada Rivers ; and (3) map the areas covered by Tapti and Narmada sands with due considerations about the then paleogeographic and paleoecologic attributes.

The lateral behaviour of a sand member at the boundary OGSS-V and Lower Miocene appears as an exemplary case (Fig. 4) for suggesting the then sand distribution pattern. This sand member traced westerwards from Puna-A, differentiates in Puna-B, into sand-shale sequence with many sand bends separated by shale/clay beds. The change is introduced in about 7-8 km offshore with reference to Puna-A. About 8 km. further west, in Surat, most of the sand bands of Puna-B are traceable and invariably show a better defined SP than Puna-B. Apparently, the sands are cleaner than those of Puna-B and seemingly the sorting factor has improved. Again, the Surat area is also an area of maximum thickness (cumulative) in the sand member. The rate of burial and supply of sand grade material was optimum in this part. To the east there was an area of partial sediment by pass

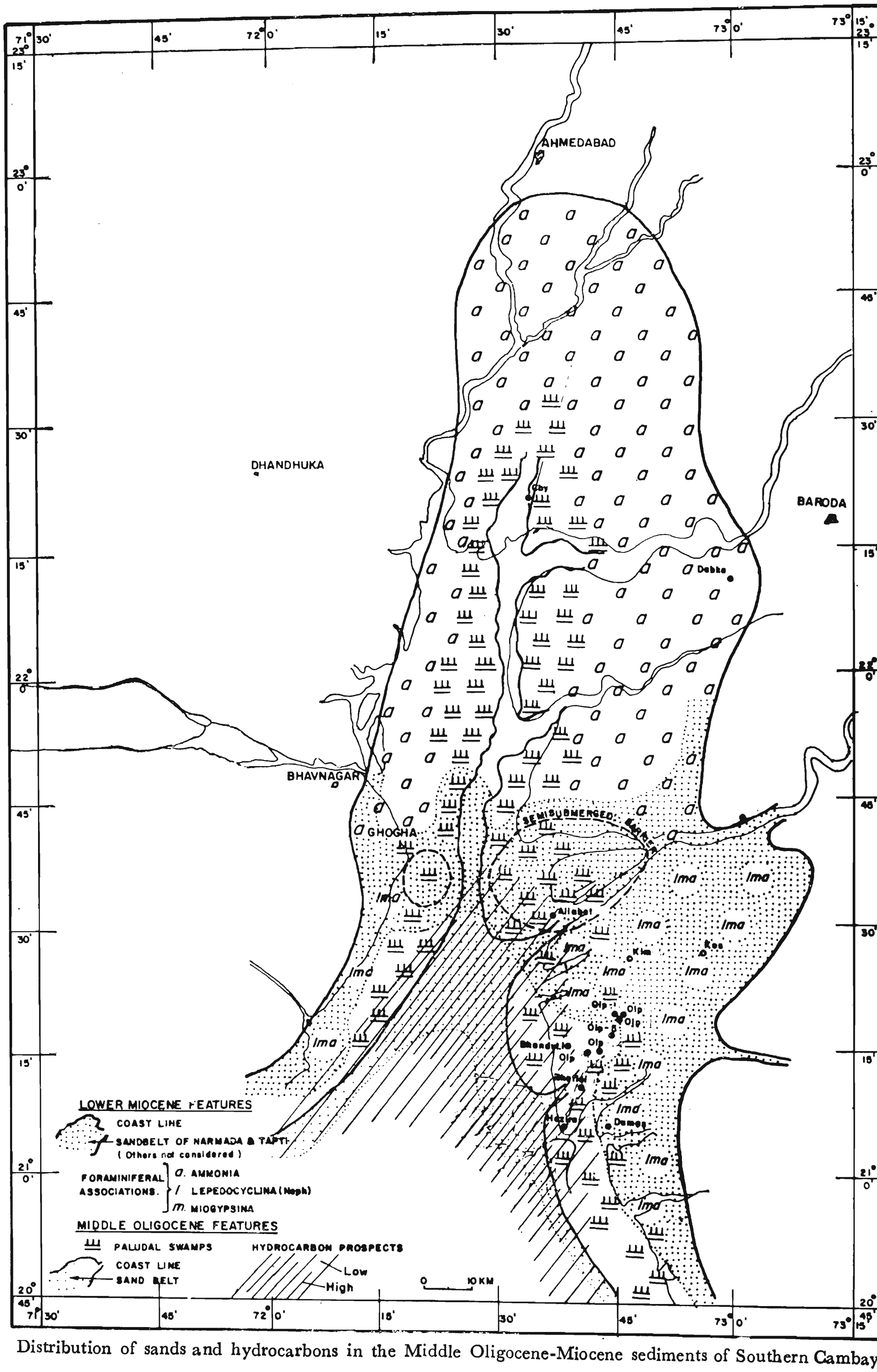


Fig. 4. Distribution of sands and hydrocarbons in the Middle Oligocene-Miocene sediments of Southern Cambay Basin

and higher energy (Washing out of finer clastics) that lead to thinner but more sandy sequence. To the west, e.g. in Dumas, net sediment accumulation is slightly reduced and the transporting energy (tidal and wind waves) also reduces. Most sand bands are traceable in the two wells but have reduced in thickness. Although north south separation between Surat and Dumas is nearly 20 km., the effective across—the platform separation work out at nearly 5 km. The thinning and fall in sand percentage between Surat and Dumas is also small (Dumas ; Thickness 145 m., sandstone 55% ; Surat ; Thickness—155 m, sandstone 65%).

A rapid shaling out of the sands of Dumas is accomplished in a distance of about ten kilometres when traced between Dumas and Hazira. Considering that in funnel shaped estuaries, to which southern Gujarat estuary simulated during Lower Miocene, the active tidal stirring could approach around 10 to 15 metres (Keunen, 1950) bands could be spread from shore to this depth. The shaling out phenomenon between Dumas and Hazira suggests a change between dominantly tidal to sparsely tidal part of the basin. Maybe, the probable bathymetric limit was around 20 m. for this change and the outer limit of the Lower Miocene sand belt of Tapti and Narmada as established by subsurface data in Southern Gujarat (Fig. 4) is more or less an isohypsometric depth contour circa 20 m.

Geometry of individual sand lithosomes of sand belt, evidenced by correlation of Puna though Dumas, was largely that of blankets—spreading widely on the submerged flat. Excellent continuity of the sand bands between Puna-B and Dumas may be explained by assuming them only as blanket sands. Minor irregularities are observed in sand bed correlation in the areas where Narmada and Tapti sands mix (e.g. Oplad) but for most other areas the blanket nature of the sands helps a good correlation. As evidenced by the miofloral assemblage and lithologic association, Aliabet, Bhandut and Hazira, areas constitute coastal swamps and the shale deposits in most of the wells were deposited possibly as coastal muds actively precipitated and caught by the coastal vegetation. The sands in this area were restricted merely to channels.

The distribution of sand and shales, during OGSS-III, could have followed the same pattern as Late Oligocene—Miocene in the Middle Oligocene offshore areas. Even if it is assumed that the provenance was subdued, the sand load brought by three main channel in southern Gujarat—southerly continuity of Saraswati-Mahi drawing, Narmada and Tapti—must have spread over wide areas and coalesced with each other to make a single belt spreading between Aliabet Island a little south of Dumas. Even with a modest assumption of 1/3rd river sand contribution during OGSS-III a considerable part of the then gulf is covered as a sand belt—nearly 700 sq. km. In the deeper parts this sand belt would pass into marine shales and on the land, as discussed earlier, a belt of coastal and mud plains.

ACKNOWLEDGEMENTS

The authors are indebted to Mr. C. K. R. Sastry, General Manager, Western Region, for according permission for publication and Dr. S. Ramanathan, Chief Geologist for encouragements.

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