PART : 5

CHAPTER : XI

DEPOSITIONAL ENVIRONMENTS

The various studies carried out in previous Chapters pertaining to the lithofacies and the ichnofacies association and perticularly the geomorphic implications ascertained by the author, accord a generalised fan-delta environment to the depositional sequence in Khadir Island. The commonly accepted definition of fan-delta [According to McPherson et al 1987] is that of alluvial fan prograding into a standing body of water. Fan-deltas are unusual but widespread in the geologic record and their facies execute the broad spectrum of primary structures and bed forms. However, biogenic sedimentary structures have been reported in only a very few fan-delta complexes and their treatment has been rather superficial. A main reason for the scarcity of fossils in fan-delta is that such a system consist mainly of rapidly deposited gravels and coarse-grained sediments resulting in unsuitable substrates for most burrowers and trace makers. The Khadir Island seems to be an exceptional locality where marine fan-delta system containing large amounts of very fine-grained sediments [siliciclastic - carbonate both] and a remarkably diverse and well displayed trace fossil assemblages represent several different ichnofacies characteristic of particular fan-delta environment can be observed.

Recently many good examples of fan-delta deposits have been reorted. Some of these are by Holmes [1965] and McGowen [1970], the Gum Hollow fan-delta; Surlyk, F [1978, 1984], Wollaston Forland Group, E. Greenland; Sneh [1979], Pleistocene fan-delta along theDead sea; Dutton and Hampton [1984], McPherson [1987] etc.

Three types of fan-delta have been distinguished by Ethridge and Wescott [1984] : [1] Shelf type systems where an alluvial fan builds into a continental shelf or epicontinental sea-floor; [2] Slope-type systems, comprising an alluvial fan, a narrow shelf and a muddy shelf with conglomeratic channels; and [3] Gilbert-type systems, characterized by gravelly forsets prograding into a shelf depth water body. Besides, Rust [1979], Hayword [1983] and Rust and Koster [1984] have suggested the term "Coastal Alluvial Fan" as a substitute name for fan-delta on the basis of the fluvial dominance of fan-delta systems.

As most of the authors agree the subaerial portion of the fan-delta does not differ and therefore forms a clastic alluvial fan in terms of overall morphology and facies association. However, transitional and subaerial fan-delta facies are controlled by many factors such as tectonic settings, depth of water body and hydrologic processes. Taking into account all these factors, Ethridge and Wescott [1984] proposed three fan-delta models : Slope, Shelf, and Gilbert type. In the first two, a delta front is dominated by marine littoral processes favouring a spreading of sands over relatively wide gently slopping areas. The Gilbert-type fan-delta is, by contrast, characterized by a progradation of large scale forsets. The Khadir Island fan-delta lacks typical large scale forsets of Gilbert-type fan-delta and also the typical shelf features associated with biogenic sedimentary structures but having quite distinctive morphologic features and facies association of a characteristic slope type of Ethridge and Wescott [1984].

In the successive paragraphs, the author following the above concepts, attempts to discuss and interpret the process of implacement and environments of deposition in the Khadir fan-delta system in light of the various facies association establishment.

As could be recalled there are in all eight members and ten lithofacies described by the author for the entire Khadir. As mentioned earlier, each of the facies deposited in a unique set of physical parameters can be interpreted on the basis of lithology, texture, primary sedimentary and biogenic structures, fossils content, stratigraphic position and geomorphic set up as part of the fan-delta system.

FACIES ASSOCIATION AND DEPOSITIONAL ENVIRONMENTS :

Four main depositional environments can now be identified for the entire depositional set-up in Khadir Island region. These include :

1 Alluvial fan - sub aerial;

2 Fan-delta front - transitional;

3 Mid fan-delta - sub aqueous;

4 Lower/Distal fan-delta - sub aqueous

I Sub Aerial Zone :

ALLUVIAL FAN : The alluvial fan are distinctive terrestrial subaerial portions dominated by fluvial processes and subordinately by mass flows consisting of water-laid sediments, debris flow deposits, or both [Bull 1972]. Two facies association are usually referred to as upper subaerial and lower subaerial are recognised. In this regard the internally chaotic, ungradded and non stratified clast-supported conglomerates of Chhariya Bet can be compared with the debris flow deposit discerned by Johnson, A [1970]; Hampton, M.A. [1972]; Walker, R.G. [1978]; Pierson [1981] and Ineson, J.R. [1989]. In the field the upward - projecting of clasts are the most conspicuous and diagnostic features which can be attributed to such debris flow. The Chhariya Bet conglomerate further varies from gravel to boulder which are set at random in fine-grained matrix and are bimodal or multimodal in their size distribution characterized textural property of subaerial debris flow as suggested in Johnson, 1970. Large size of the clasts suggest these deposits to have formed during periods of high discharge in fluvial channel debouching from the adjacent highlands [possibly, Nagar Parker - NE of Chhariya Bet; Meruda Takkar Hill, NE of Khadir, and Erinpura Granites of Aravalli Range in Rajasthan].

It is particularly interesting that the Chhariya Bet conglomerate display the multiple grading and absence of sharp erosional contact in conglomerate layers. This suggests that these deposits could be from individual surging flows. Such a flow style often reflects retrogressive slope failure or internal hetrogenetics with a sinuous confined flow. Again, similar subaerial debris flows as postulated by Hampton [1972] are ooften more sluggish and hence large clasts are concentrated at the front of a typical surge of debris flow and pushed along by the more fluvial material behind the front. Although the lower subaerial fan-delta sediments are rather conspicuous in Chhariya Bet, their counter parts in upper subaerial portions are rather difficult to be confirmed on account of the blanketing of the Rann sands over it. As expected all these conglomeratic horizons lack organic remains or biosedimentary structures.

II Transitional Zone :

The transitional zone incorporates a part of fan-delta which withstands with the subaerial and sub aqueous units and includes fan-delta front, mid-fan-delta and lower-fan-delta. As postulated by Wescott and Ethridge [1980], the transition zone composed of the foreshore and shoreface is the most significant environment in terms of recognizing ancient fan-delta. Facies landward of this zone are essentially alluvial-fan deposits and more seaward its marine facies incorporating marine-shelf and/or slope deposits.

FAN-DELTA FRONT : This is the area in which sediment ladden fluvial currents enter the basin and are dispersed whilst interacting with basinal processes. Basinal processes either assist in the dispersion and eventual deposition of sediment or rework and redistribute sediment deposited directly as a result of flow dispersion.

The delta front facies association in Khadir is generally represented by large scale coarsening and thickening upwards sequences [Facies HDM and HPM]. This records a passage from prodelta facies upwards into a shoreline which is usually sandstone dominated. All these sequences appears to have resulted from progradation of the delta front and may have been truncated by fluvio-dominated or tidal distributary channel sequences as progradation continued. Considertion of the processes operating in this subenvironment is usually crucial to a complete understanding of the ancient deltas as the interaction between sediment-ladden fluvial processes and basinal processes takes place in the delta front. Furthermore, fluvial dominated delta front sequences according to T. Elliott [1986] have been widely recognized in the geological record and exhibit considerable variety. Most ancient delta front sequences as postulated by him are mud-silt-sand systems developed at the margins of the marine sedimentary basins. In general they commence with a thick uniform interval of mudstones - siltstones deposited from suspension at the base of delta front. These facies in Khadir appear to be massive but more commonly exhibit diffuse banding defined by slight variations in grain size which reflect fluctuations in the supply of suspended sediment. Marine faunas occur, but faunal density and diversity are generally low due to the almost continuous fall out of sediment from suspension. Plant debris occur in this facies and is presumably an additional consequences of sediment input being direct from the distributaries. The intermediate parts of sequences comprise mudstone-siltstone background sediment in which coarser siltstone and sandstone beds are repeatedly intercalated. The coarser beds deposited have planer erosive bases and exhibit wanning flow sequences.

In light of the above discussion it will now be interesting to work out and assign the different members and their facies to the fan-delta front sequences of Khadir. The sandy intraformational limestone conglomerate lenses and wedges which appear in the beginning of Hadibhadang Dungar Member followed by the alternation of sandy micrite, cross-bedded micritic sandstone, gypseous shale, subarkosic micritic sandstone are quite significant. Again Hadibhadang Dungar Member closely match the description of the delta-front environment and can safely be assigned to the same. In these deposits the conspicuous **Corbula - Gervillia** bearing shelly sandy limestone and **Oyster** - bearing shelly sandy limestone needs explanation. These beds are typically intraclastic and have shells aligned parallel to bedding and have many infiltration structures such as cement filled shell voids. These beds vary in thickness and very often laterally pinchout. The **Corbula lyrata** beds following Kreisa [1981] could be recognized as the winnowed lag deposits of shells, perhaps little transported and may be worked out by storms. The Oyster - bearing shells on the other hand could be the features indicating minor periods of emergence. The subarkosic micritic sandstone facies often display deformation structures and could indicate submarine slumps resulting from lateral movement of unidirectional sediment by gravity or slopes or by sudden rapid current flow on a level surface. Such a characteristic is reported from steep slopes associated with delta front [Fig.10]. In such a physiographic province, erosional and depositional accretion are in delicate balance. Further as suggested by Stanley and Unrug [1972] the degree of crustal mobility, eustatic sea level changes and relative transgressions & regressions, rates of sedimentation, gradient, morphological relation to the shelf and break, sediment transport processes and resulting bioturbation are the critical controlling factors to be recognized.

In the middle massive portion of Hadibhadang Dungar Member the thickly bedded subarkosic sandstone display slump and cross-bedding structures. No ichnological activity is noticed. This may be due to high influx of subarkosic detrital sands over carborate mass and sediment accumulation with high pore water pressure conditions. The fining upward sequence can be interpreted as follow. The sands were apparently susceptible to liqueifaction within steep slopes and channels promoting evolution of liqueified flows from slumps failure and development of turbulence. Rapid sedimentation of the coarse liqueified detritus left deposits of coarse-grained, relatively clay-free sand deposits at the middle portion followed up by slow sedimentation at the top which is marked by the presence of micritic mudstone facies.

The Hadibhadang Pir Member is characterized by the presence of sandy intraformational conglomeratic limestone. This subfacies comprises poorly sorted matrix-supported ungradded and unorganized conglomerate containing clasts of rhomb-shaped felsite, granite, ironstone in sandy and calcareous matrix. This calcareous matrix comprises megascopically and microscopically distributed shell fragments. It is possible, storm-initiated sediment gravity flows may have been involved in the deposition of this conglomerate. Such types of conglomerate mostly form during high-energy storms when semi-lithified bottom sediments are eroded; currents are reinforced by the storm and eroded sediments are transported and later deposited under waning energy conditions [Markello and Read 1981]. The sedimentological characteristics of the conglomerate following McPherson et al [1987] can be interpreted to represent subaerial-subaqueous deposition of dilute debris flow. It's sandy matrix may indicate that the debris flows when moved through the water, they mixed with surrounding sands and became dilute, inducing shearing and allowed flatter clasts to become settle.

III Sub Aqueous :

MID-FAN-DELTA : The mid-fan-delta in Khadir can be distinguished by a depositional bulge that appears as a convexo-upward segment on a radial profile [Figs. 7 and 8]. This is characterized further by numerous unleveed distributary channels or channels remnants that developed as a result of rapid migration and deposition within the distributary system. Sands and even pebbles are present within channel remnants and over the central part of this mid-fan. In some cases sand lobes comprised of coarsening and thickening upward sequences are observed relatively free of channel development.

Three members : Ratnasar Calcareous Sandstone Member, Chamwa Wandh Fossiliferous Limestone Member and Gadhada Sandstone Member are assigned to the mid-fan-delta zone. Thick sedimentation is found in Gadhada Sandstone Member, while lower lying Chamwa Wandh

Fossiliferous Limestone Member show thinner sedimentation and occur in form of narrow band. Existence of micritic facies marks the repeatation of pulses of low-density currents where biogenic structure such as **Skolithos, Monocraterion, Cylindrichnus** etc. are developed. In vertical sequence this facies is interrupted by thick sedimentation of subarkosic micritic sandstone which is devoid of mega fossil or trace fossil. It perhaps marks the influx of non-marine sediment, more or less similar to that found initially in the Hadibhadang Dungar Member. It indicates restoration time, when the progradation once again become active. The overlying Chamwa Wandh Fossiliferous Limestone Member form the bottom as a result of which storm-generated pholadomiya-bearing sandy limestone deposits are found associated with ammonite bands and tiny gastropod shells. Before advent of this storm-wave condition presence of clay horizon in form of variegated clay sub-bentonitic clay and sandy calcareous shale marks sedimentation from quiet offshore setting and later on acquired diagenetic change. The association of shells in shallow waters reveals that suspension setting conditions were later on modified occasionally by the arrival of waters derived from shallower setting presumbaly under the influence of storm-surge reflexes. During the sedimentation of Gadhada Sandstone, different environmental conditions are observed from slow to moderate wave-energy, sandy non cohesive debris flow; low-density turbidity currents and both oscillatory and unidirectional high intensity currents. Here the deposition commenced with corbula-bearing sandy limestone facies and ended with wave-rippled sandy allochemic limestone facies. In between these two extremes micritic sandstone facies exhibit maximum sedimentation and represent several varieties in biogenic structures. This shows low density but high diversity except in trace fossils such as **Skolithos**, **Ophiomorpha** and **Phycodes** indicate high rate of bioturbation. This infact indicates mixtures of both low to high energy conditions. Association of hummocky cross-stratification with wave-rippled sandy allochemic limestone beds with underlying bioturbated **Ophiomorpha** and **Skolithos** bearing micritic sandstone beds form ideal sequence to suggest deposition from oscillatory and unidirectional high intensity currents.

LOWER FAN-DELTA : The lower fan-delta is the mere distal exposed part of a fan-delta system. Lower fan-delta sediments comprise most of the exposed fan-delta surface [McGowen, 1970]. It is characterized by the dominant horizontal surfaces, uniform parallel bedding sedimentary structures such as trough-fill cross strata and parallel laminae. On profiles, there is no evidence of channels. Distinct sand beds generally are fine-grained to medium grained, thin and wide spread.

The rocks of the Ganeshpur Calcareous Sandstone Member and Bambanka Member are interpreted to have deposited under this environment. Mixed siliciclastic-carborate deposits of six lithofacies of Ganeshpur Calcareous Sandstone Member marks the more marine influence as revealed from much micritic material as compared to detrital quartz. The beds show nearly parallel horizontal surfaces and no evidence of channels fill sedimentary structures are observed. The beds generally are fine to medium grained as compared to previously described Gadhada Sandstone Member.

The sedimentation of entire sequence of Ganeshpur Calcareous Sandstone Member a marked by changes in the depositional conditions. It is similar to Gadhada Sandstone Member in form of wave-rippled sandy allochemic limestone facies and indicate influence of both the oscillatory and the unidirectional high intensity currents. As in Gadhada Sandstone Member hummocky cross-stratification is not observed in Ganeshpur Calcareous Sandstone Member to have associated with the mega ripples having wave length of 83 cm and ammplitude 9 cm. In current rippled micritic sandstone/shale sequences, ripple marks indicate current direction towards SE.

In the overlying sequence of Ganeshpur Calcareous Sandstone Member few lithofacies of Bambanka Member are observed. They are SSL.Am, SM, FSM, KGCS. In most of these facies the transportation mechanism and development of relatively few sedimentary structures indicate deposition from dense highly turbulent to fluidized sedimentary gravel flows. Their rapid shift in composition from quartz rich to micritic rich beds suggest that the channel sands must have undergone mixing with unconsolidated mud-rich sediments from the sea margins.

TRACE FOSSIL ASSOCIATION AND DEPOSITIONAL ENVIRONMENTS :

The objectives of this section are : [1] to relate the distribution of specific ichnofacies to specific sedimentary facies; [2] to distinguish recurring association of trace fossil [so that assemblages of ichnocoenoses];

and [3] to consider the implications of trace fossils for paleoenvironmental interpretation.

The distribution and abundance of trace fossil within the six members is presented in Table : 8. As seen from the table, most of these trace fossil occurring in Khadir are facies restricted. Although the distribution may be interpreted as reflecting environmental control of the trace makers, preservational potential also are likely to have been an influence factor. As further could be accepted from the foregoing discussion in Chapters : IX and X trace fossil association have characterized the marine sedimentary facies of the fan-delta complex in Khadir. Proximal embayment facies and distributary channel facies contain practically no biogenic structures. On the other hand, all the other facies in fan-delta complex contain various types of burrows and traces of marine organisms. Considering various factors, recurrent association of trace fossil have been grouped into five ichnofacies namely **Glossigungites**, **Skolithos**, **Cruziana**, **Zoophycos** and **Nereites** and into eight ichnocoenoses including **Ophiomorpha**, **Skolithos**, **Phycodes**, **Rhizocorallium**, **Bergaueria**, **Planolites**, **Gyrochorte** and **Chondrites** ichnocoenoses. The possible environments as revealed by all these are briefly summarized as under.

The alluvial fan-delta is almost devoid of any trace fossil while the fan-delta front has developed **Glossifungites** ichnofacies indicating an omission surface representing an exposed semi consolidated substrate.

The **Skolithos** ichnofacies by far is the dominant ichnofacies found in SMS of Hadibhadang Dungar Member, SSL of Hadibhadang Pir Member, SM of Ratnasar Calcareous Sandstone Member, FSM and SM of Gadhada Sandstone Member, SM of Ganeshpur Calcareous Sandstone Member and FSM and SSL of Bambanka Member. It includes the monospecific vertical burrows of **Skolithos** that were constructed through the entire thickness of some sand layers. Their distribution in different members suggest that **Skolithos** pregenerators preferred life in sandy substrate and also in fine-grained substrate. A possible explanation of this ichnofacies is that it was attested to high energy sedimentation and possibly the major portion in the sand beds where these organism prevailed was deposited rapidly under high energy conditions and the intervening fair weather phases allowed the burrows to colonise the substrate from the top down.

The **Cruziana** ichnofacies in Khadir is characterized by predominently horizontal epifaunal and intra-stratal crawling traces as well as some vertical and steeply inclined burrows. Trace fossils in this zone exhibit high abundance and diversity and characteristically are produced by suspension and deposit feeders as well as by carnivores and scavengers. Alternatively, moderate to low energy are likely to be the environmental factors.

The **Zoophycos** and the **Nereites** ichnofacies in Khadir are difficult to be separated because only a rare occurrence of **Zoophycos** species is located in the Hadibhadang Pir Member. The **Nereites** on the other hand predominently found in Hadibhadang Pir Member and Gadhada Sandstone Member, include high dominance of endogenic feeding trails and surface trails. The abundance and diversity in these facies are due atleast in part to two factors : [1] The high preservational potential afforded by thinly interbedded lithology, and [2] Variation in ecologic condition [Primary Substrate and Energy Level] which resulted in variety of behavioural responses by the indegeneous benthos.

A few remarks on some of the ichnocoenoses are now necessary.

OPHIOMORPHA ICHNCOENOSES :

This monospecific trace fossil assemblage characterize the sandy micrite and shelly sandy limestone units in Gadhada Sandstone Member and Hadibhadang Pir Member or in other words it characterizes in Fan-delta front and mid-fan-delta deposits. Density of these burrows vary in different sections but maximum population can be observed in Gadhada Sandstone Member. It is interpreted to indicate the conditions of moderate to instantantial high sediment influx. Animals chiefly included are suspension feeders. The dense occurrence of this ichnocoenose with very closely spaced shafts resulting in lack of physical sedimentary structures found dominating the Gadhada Sandstone Member, may suggest low wave energy condition like those found today along the Georgia sea coast [Howard and Reineck 1972].

PHYCODES - ZOOPHYCOS :

These assemblages include **Phycodes** and **Planolites.** The specimens of these ichnogenera are generally restricted to current rippled micritic sandstone/shale in Gadhada Sandstone Member where the predominance of endogenetic activity may have been the result of stressful ecological conditions inducted by low oxygen, salinity variation and/or subaerial exposures. The **Phycodes** ichnocoenose may represent opportunistic ichnotaxa in that they are facies breaking, highly localized and typical of low diversity trace fossil association in state deposited under environmental extremes.

BERGAUERIA - ARENIÇOLITES - SPIROPHYCUS ASSOCIATION :

The occurrence of these ichnocoenoses are restricted to ferruginous sandy micrite of Ganeshpur Calcareous Sandstone Member and sandy micrite of Gadhada Sandstone Member. The association includes domichnia [dwelling structure of suspension feeding animals] represented by **Bergaueria - Arenicolites - Spirophyton.** Relatively high energy depositional condition prevailed in lower-fan-delta environments occurred during the deposition and formation of the said burrows.

PLANOLITES ICHNOCOENOSE :

This ichnocoenose generally dominates the current rippled micritic sandstone/shale in Gadhada Sandstone Member, the shelly sandy limestone in Hadibhadang Pir Member and sandy micrite in Ratnasar Calcareous Sandstone Member. The burrowing appear to be intense, and numerous generations of burrows [**Phycodes, Ophiomorpha**] are found superimposed upon one another. Because majority of the burrows appear to be simple unlined, horizontal and subhorizontal tunnels, their dominance can be explained by the abundance of food generated in the sandy beds possibly by the inter distributary channels.

GYROCHORTE ICHNOCOENOSE :

This high diversity assemblages is dominated by widely occurring trails of **Gyrochorte comosa, Curvolitus** and **Planolites** specimen. Their assemblages are restricted in sandy micrite of Gadhada Sandstone Member. The trails characterizes endogenic feeding habit of the trace makers. The abundance and diversity of the assemblage indicate high preservational potential afforded by the thinly-bedded lithology and variation in ecologic conditions.

CHONDRITES ICHNOCOENOSE :

This characteristically includes the **Chondrites** species and **Paleodictyon.** Their occurrences in Hadibhadang Dungar Member and Gadhada Sandstone Member suggest oxygen deficient environment and less circulation of water. May be indicative of deeper water and restricted zones in fan-delta front setting in Khadir basin.

In conclusion, the ichnofacies and ichnocoenoses within the fan-deltaic system of Khadir appears to be intimately linked with paleoenvironmental conditions because the salinity, interstitial oxygen, character of the sea floor and energy of the depositional environment, probably influenced the type of benthonic organisms and their burrowing habits which are adequately reflected in the biosedimentary record. It may further be stressed that the paleoenvironmental interpretation based on ichnofacies and ichnocoenose support in general and compliment sedimentologic interpretation drawn by the author.

FIG-42 STRATIGRAPHIC SECTION, LITHOFACIES AND DEPOSITIONAL ENVIRONMENT OF CHHARIYA BET BRECCIO-CONGLOMERATE

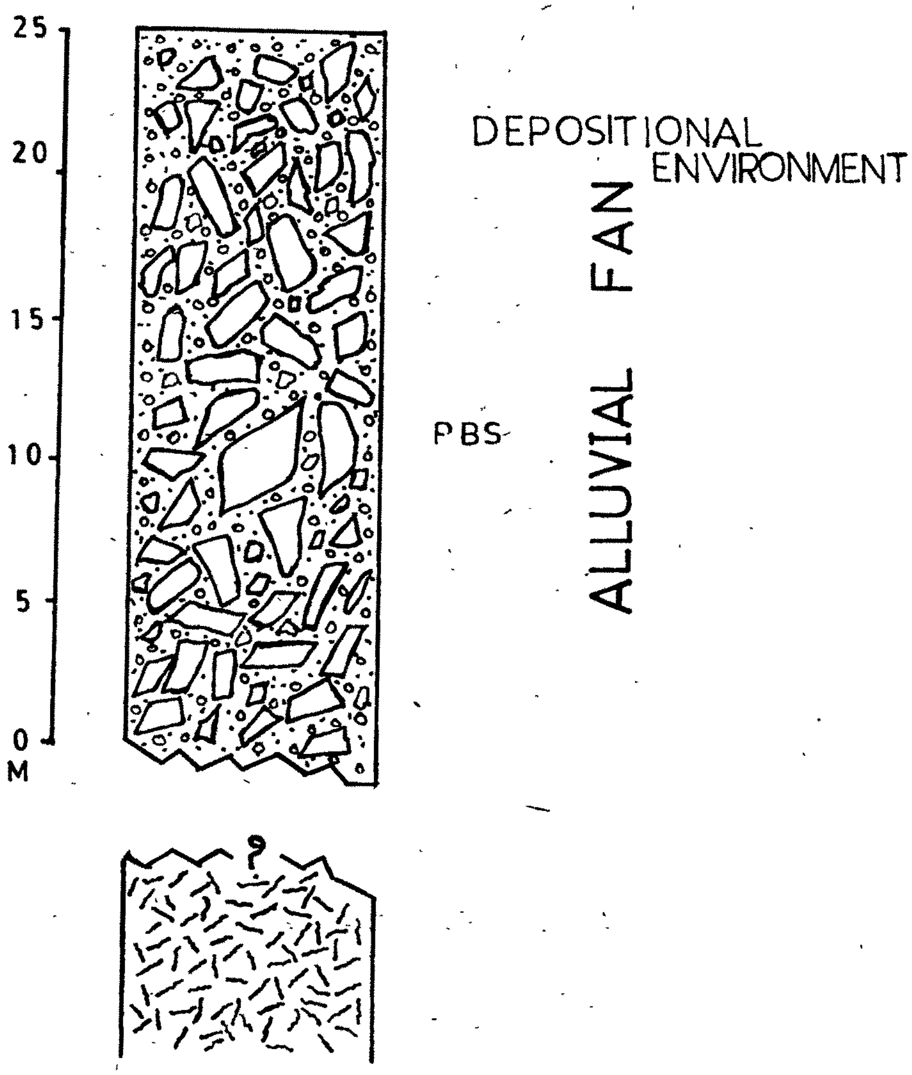


FIG 43 STRATIGRAPHIC SECTION, LITHOFACIES AND DEPOSITIONAL ENVIRONMENT OF HADIBHADANG DUNGAR MEMBER.

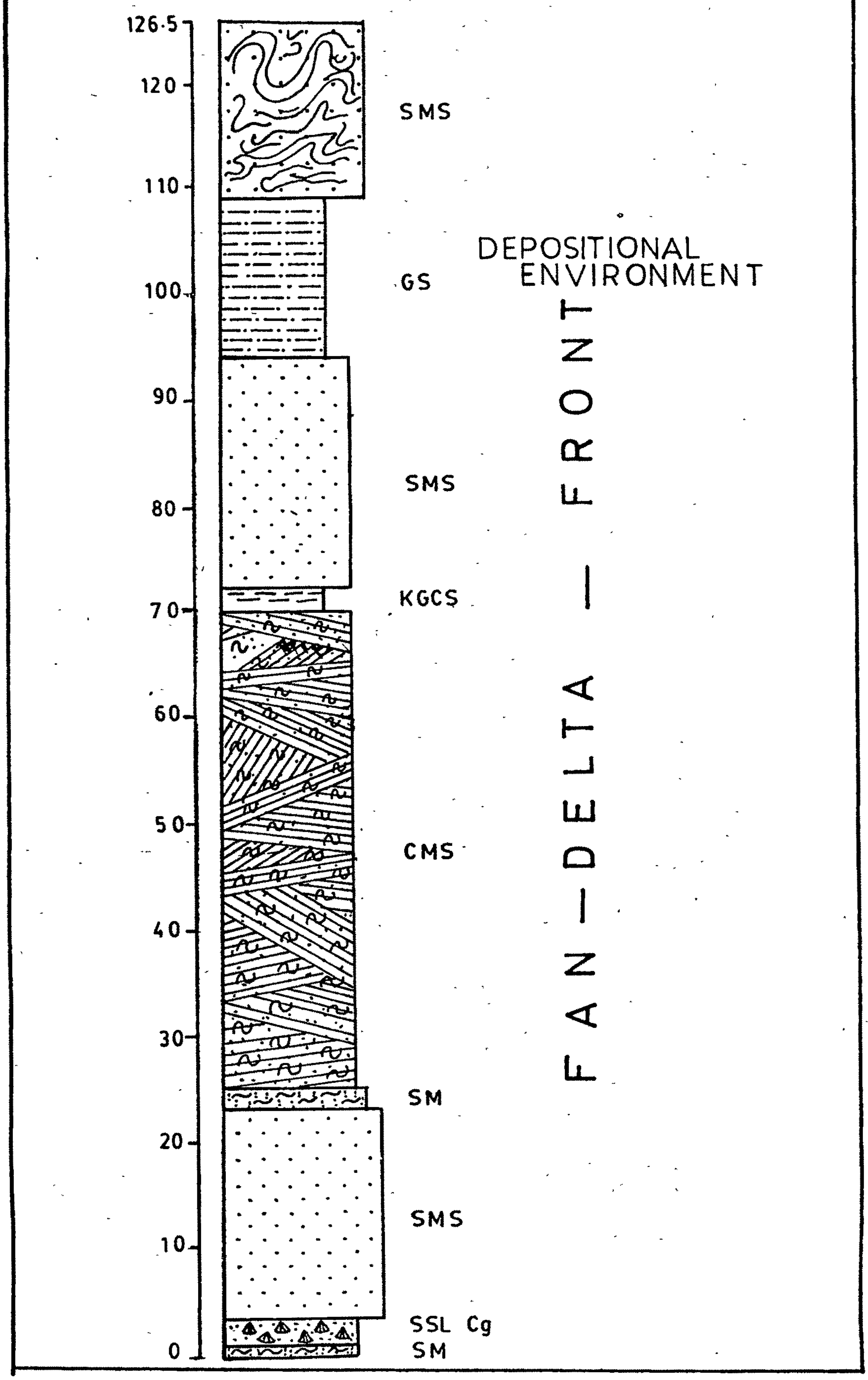


FIG-44 STRATIGRAPHIC SECTION, LITHOFACIES AND DEPOSITIONAL ENVIRONMENT OF HADIBHADANG PI-R MEMBER

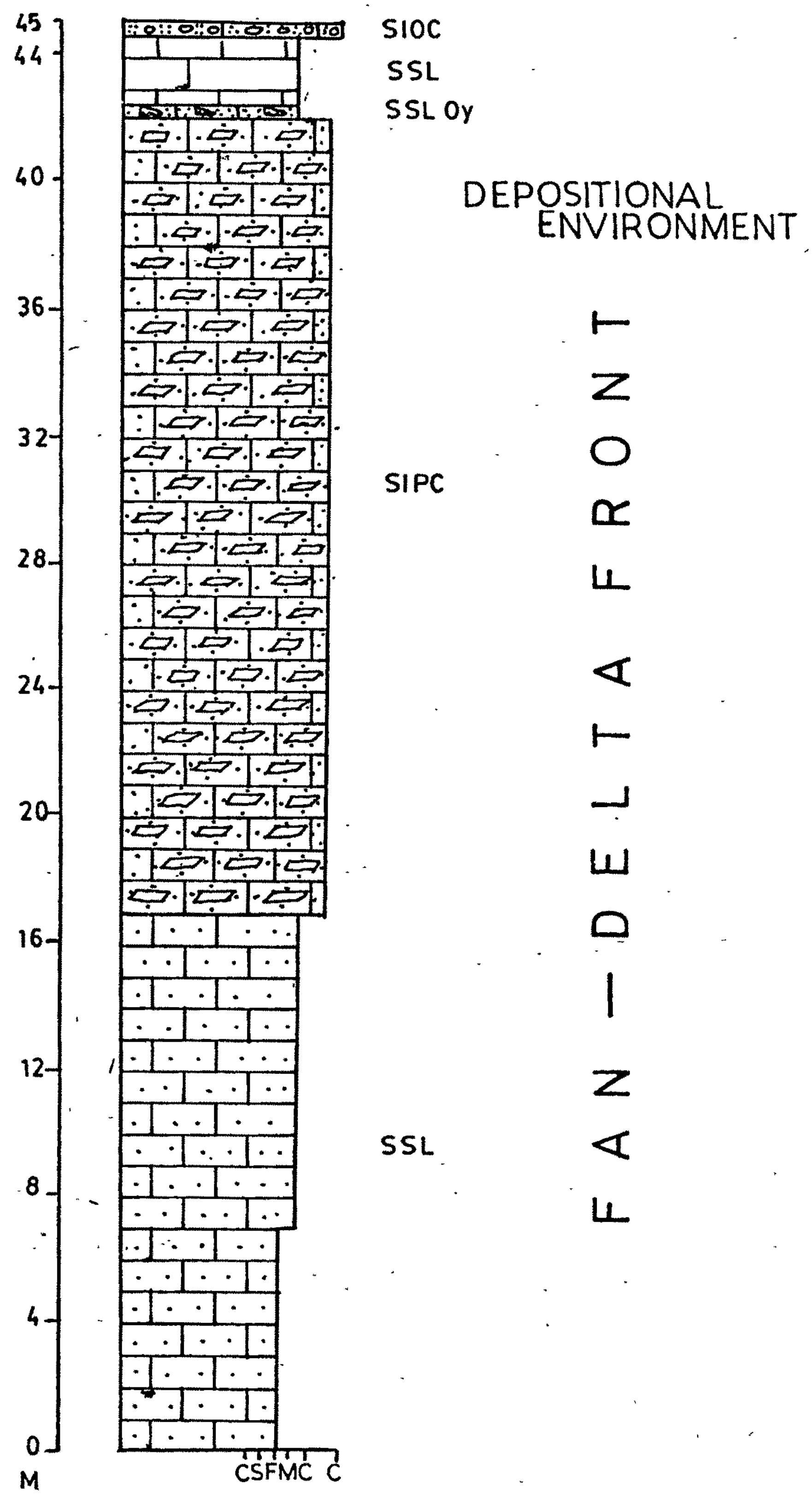
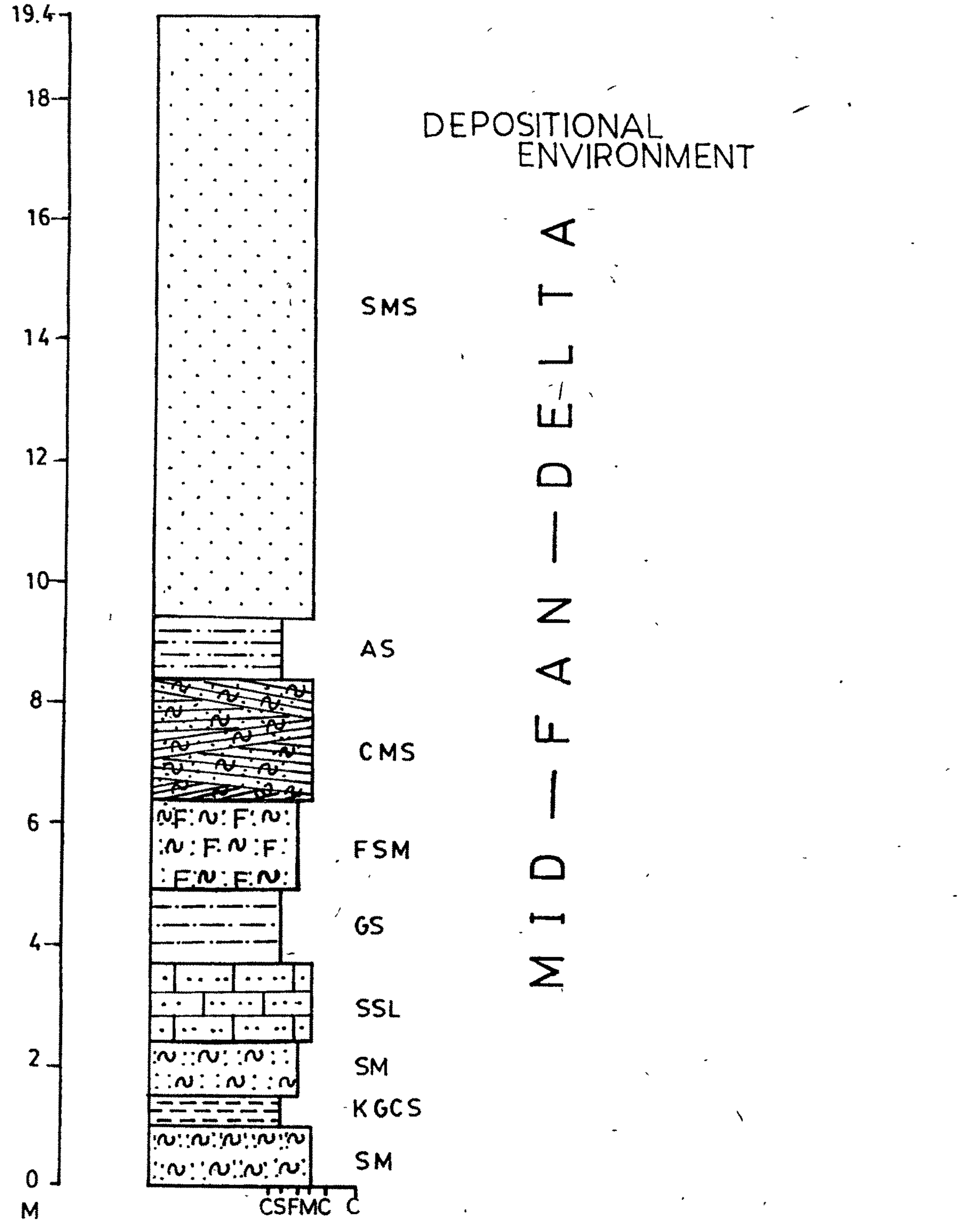


FIG - 45 STRATIGRAPHIC SECTION, LITHOFACIES AND DEPOSITIONAL ENVIRONMENT OF RATNASAR CALCAREOUS SANDSTONE MEMBER



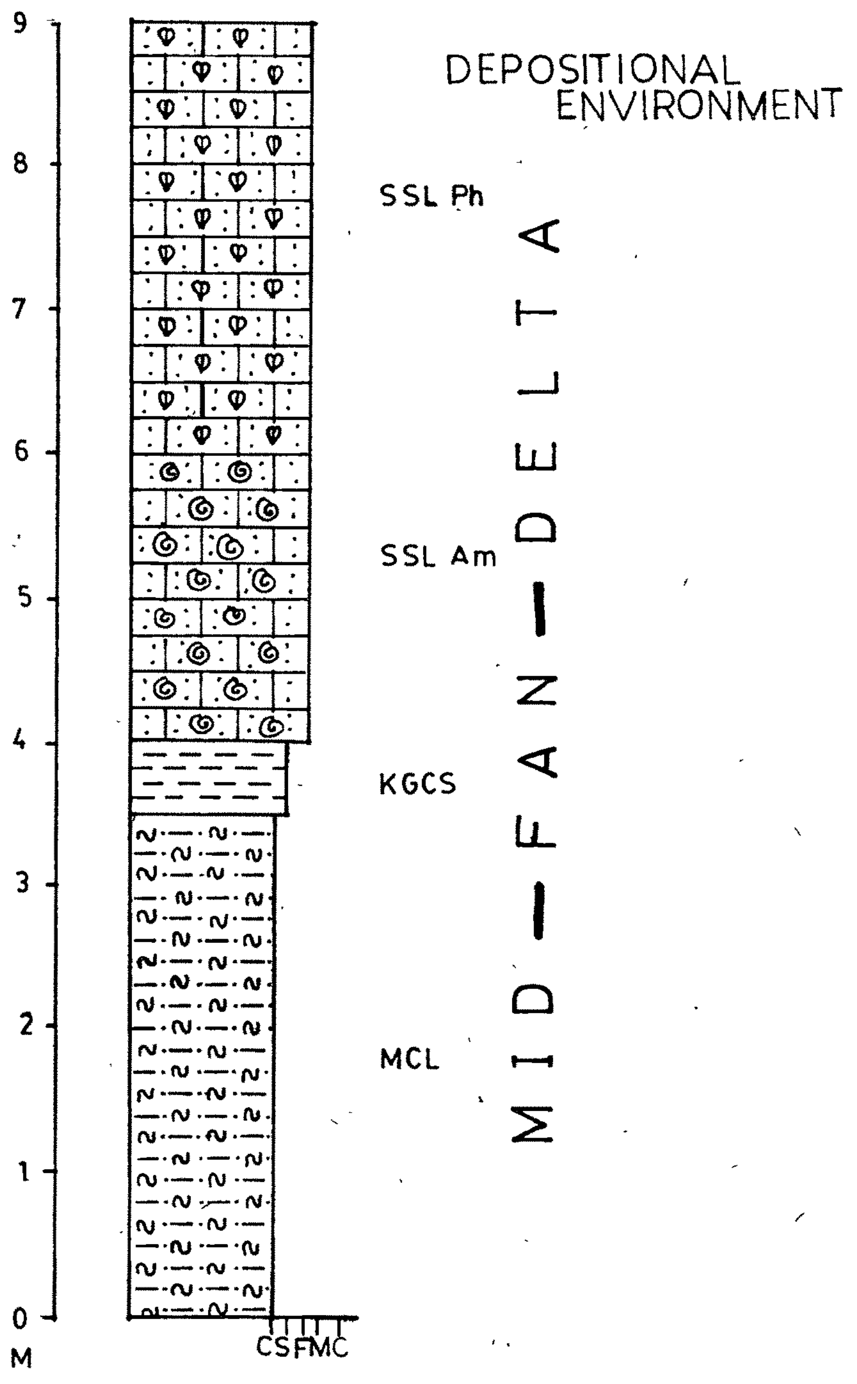


FIG - 46 STRATIGRAPHIC SECTION, LITHOFACIES AND DEPOSITIONAL ENVIRONMENT OF CHAMWA WANDH FOSSILIFEROUS LIMESTONE MEMBER.

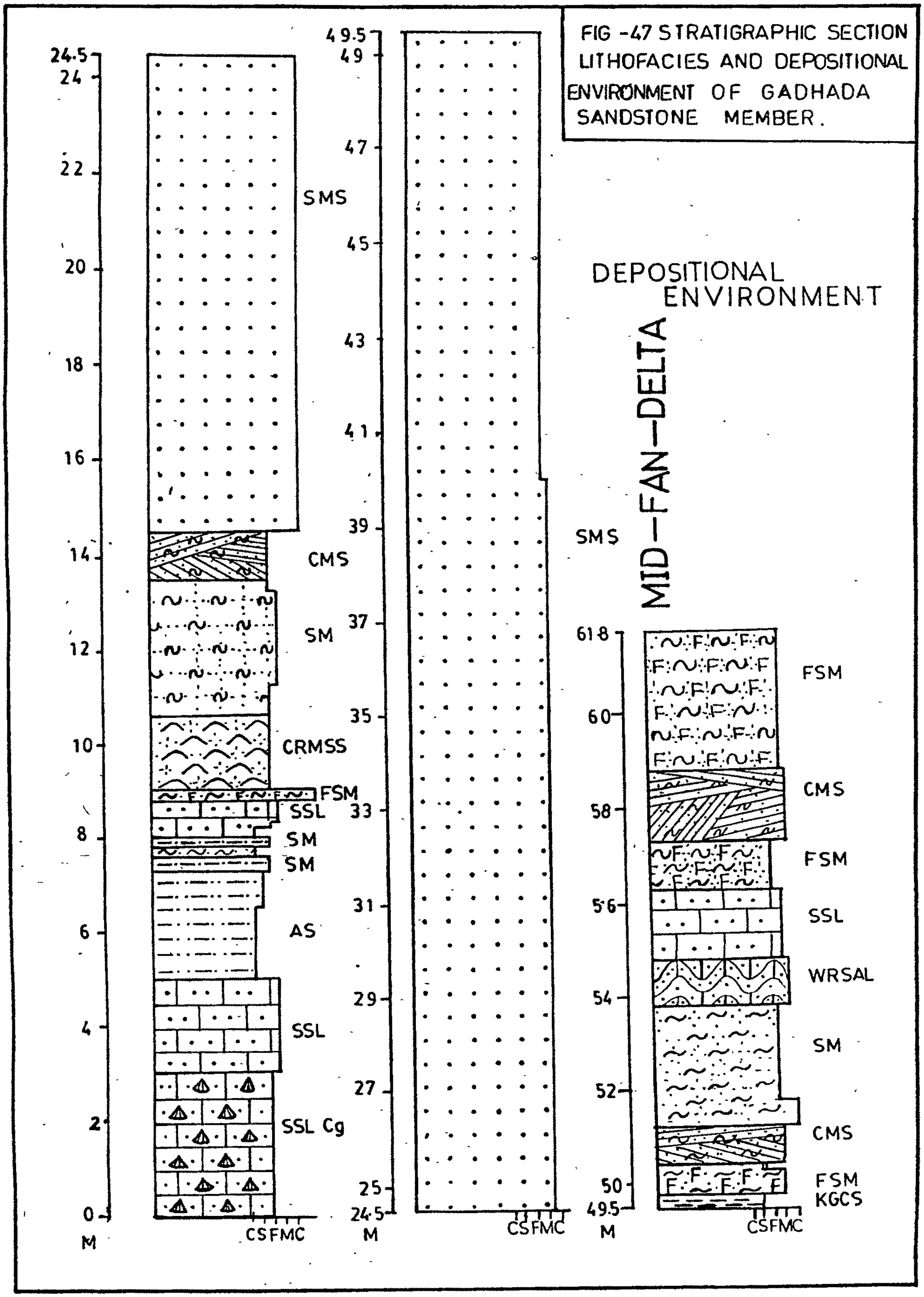


FIG -47 STRATIGRAPHIC SECTION LITHOFACIES AND DEPOSITIONAL ENVIRONMENT OF GADHADA SANDSTONE MEMBER.

FIG-48 STRATIGRPHIC SECTION LITHOFACIES AND DEPOSITIONAL ENVIRONMENT OF GANESHPUR CALCAREOUS SANDSTONE MEMBER.

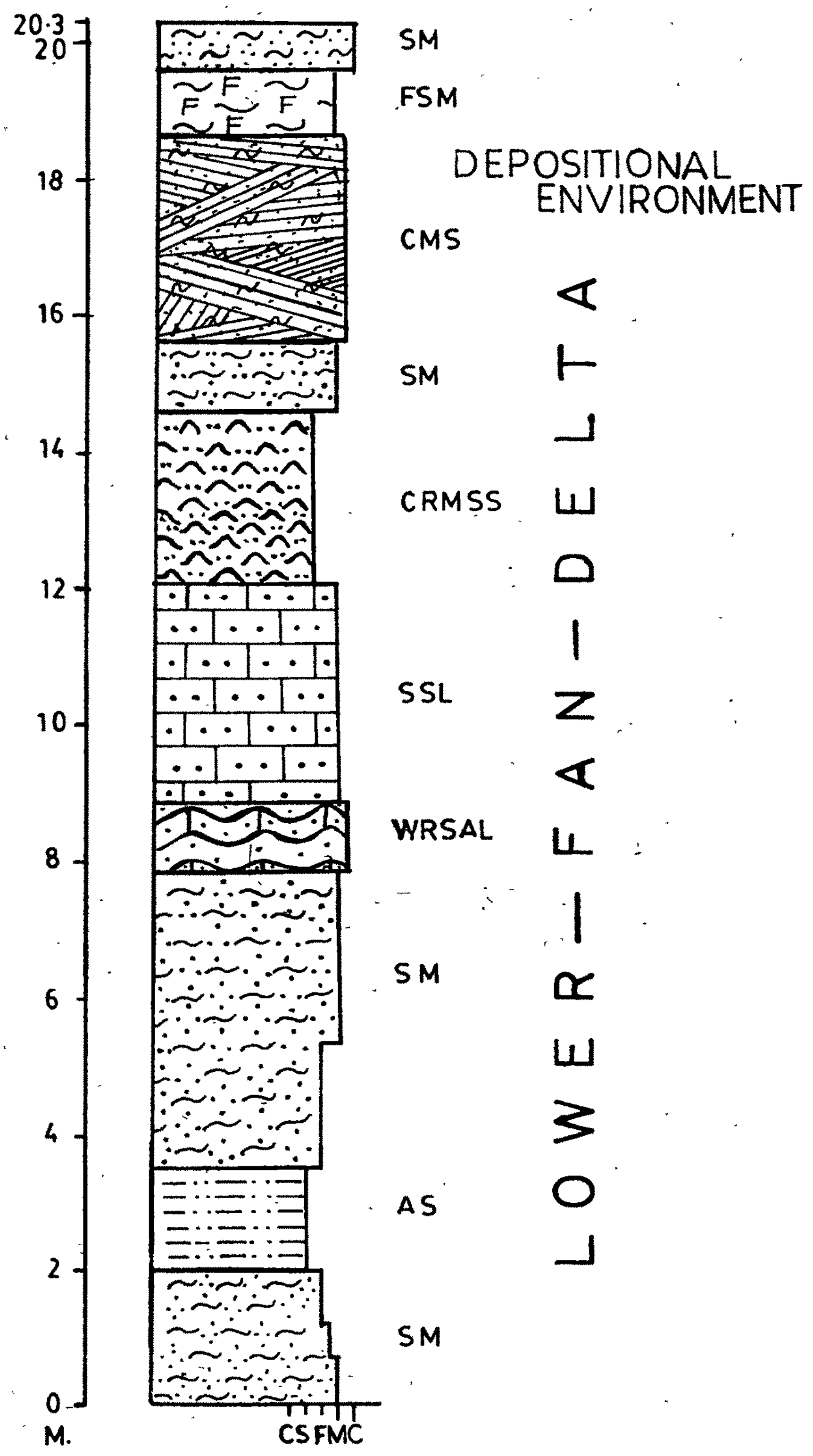
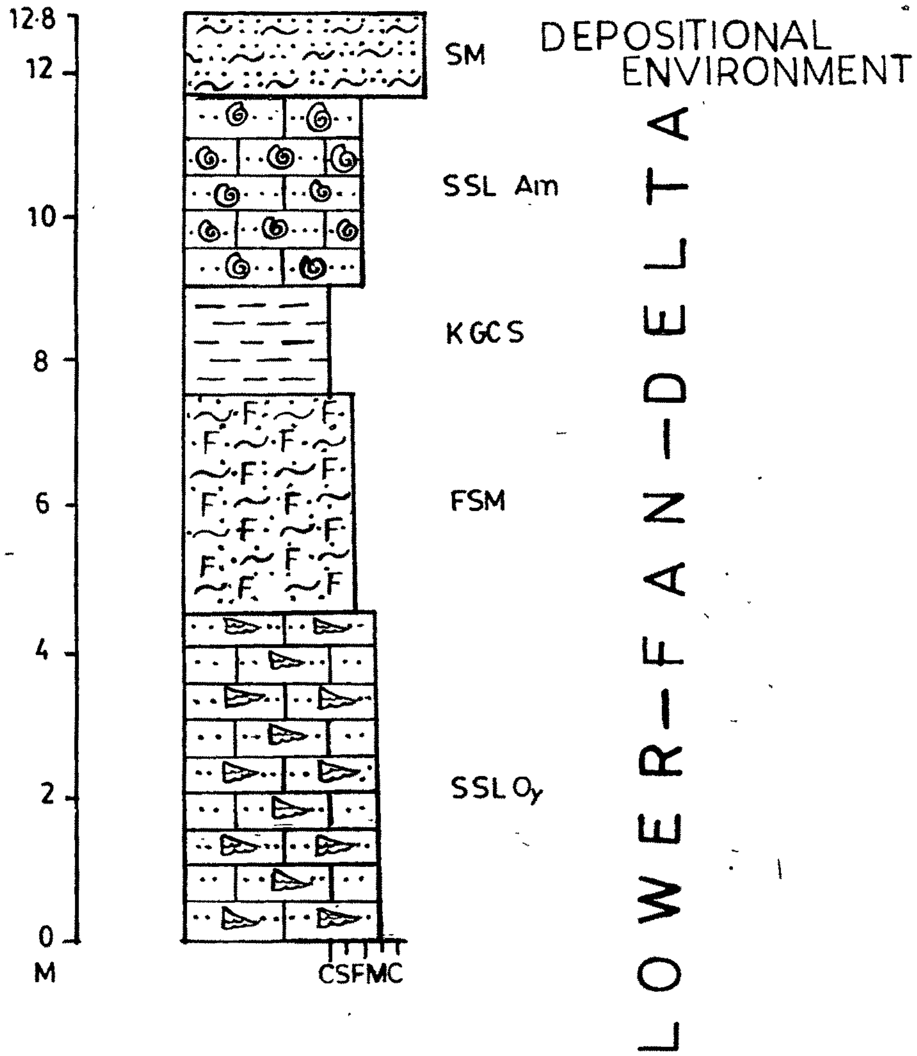


FIG-49 STRATIGRAPHIC SECTION LITHOFACIES AND DEPOSITIONAL ENVIRONMENT OF BAMBANKA MEMBER.



CHAPTER : XII

SEDIMENTARY MODEL

Schematically the evolution of the Khadir basin and ensuring sedimentary filling can be summarized as following [Fig. 50, 51 and 52].

During the first stage [L. Bathonian] a shallow fluvio-marine basin developed which was then filled up by coarse to fine clastic deposits with intercalation of marine facies [Bathonian-Callovian-Oxfordian time]. Successively, the basin underwent south westward tilting [Fig. 50]. As a consequence of this tectonic phase, the basin was enlarged, as a wider, very shallow and in turn incised by the channel. Further vertical tectonic movements and development of normal fault on the north, probably caused the extinction or the closure of the basin at the end of the Oxfordian.

Along the basin margin condition were suitable for the formation of fan-delta and alluvial fan deposits. The Khadir Island thus represents a marginal fan-delta portion of a major river system which was then active during the Middle Jurassic time in Kutch. In the proximity of such an area the deposits are characterized by coarse gravels with conglomeratic clasts and quartz-felspathic sand predominance. Distally in the subaqueous portion sands and micritic mud prevailed. The built up of the Khadir fan-delta appears to have occurred as a result of the discontinuous deposition of stacked conglomeratic, sandy and muddy micritic units probably related to episodic tectonic events. The distribution of conglomeratic fan sediments and their internal organization in fact can be attributed to a combination of tectonic & purely sedimentary processes.

The cyclic alternation of axial channel, marginal and interchannel deposits occurred in a cyclic manner. Similar megacycle in the Jurassic of Greenland have been suggested by Surlyk, F. [1978, 1984] to be tectonically controlled each basin wide coarse-grained incursion as in Khadir recording fault reactivation and uplift and regeneration of the source area.

The fan-delta documented in Khadir shows no features indicating strong long lasting climatic variations except some minor storm events recorded in sediments. The predominance of stream flow deposits suggest the fan-delta development under humid condition.

Three main depositional sub environments as identified by the Author include subaerial, transitional and subaqueous zones [Fig.51].

It is also possible that the slope sedimentation was probably controlled primarily by intrabasinal tectonism, pulses of resedimentation and local unconfirmity reflecting episodic local movement on basin margin faults. It is possible that such localized intrabasinal tectonism provided second order control on the fan delta development.

The subaerial portion in the study area of fan-delta is not different from a classic alluvial fan in terms of morphology and depositional processes. The adjacent highlands in the NE such as Kalinjar Hill [Nagar Parker - Pakistan]; Meruda Takkar Hill and Erinpura Granites of Aravalli Range [Rajasthan] probably supplied the coarse material at a very high rate. At the fan-apex a low sinousity stream with high gradient and coarse channel perhaps subjected to floods resulted in the coarse bed material that ultimately entrained as a whole and deposited itself as dump lobes by unconfined surges. Furthermore a down stream decline in gradient and reduction in bed material size may account for the development of braided channels in Khadir as commonly is observed in many fan sediments. The braided channels in turn migrated in the lower subaerial portion of the fan-delta giving rise to a broad belt of gravelly and sandy deposits in many parts of the Khadir.

As indicated by the basin configuration of the transition zone, a further decline in gradient and sediment load would result the distributary channels to transfer once again into a single low sinousity channel crossing the sandy mud flats interface between the alluvial areas and the sediments from the marine environments. The high sediment supply, the low gradient distal part of the fan-delta and the very shallow depth of the marine water body thus favoured the formation of mixed siliciclastic-carbonate sediments as mouth bar or lobes, instead of Gilbert-type forset beds.

Channel fill sediments of subaqueous area typically show a degree of oxidation which could have been achieved during the short periods of emergence or as indicated by the biological activity in these localities. Subsequently as more humid conditions were established, a rise in water level flooded the areas with fresh sediments deposition.

Evidences from shelly fossils benthic foraminifera and trace fossils described by the author give definite indications of relative energy levels, oxygenation and turbidity but provide no absolute limits for depth.

The trace fossil association in the Khadir fan delta complex has very well demarketed the response of infaunal benthic communities to numerous aspects of physical environments. The most important of this appear to be the salinity, interstitial oxygen, sediment composition and texture and hydrodynamic energy of depositional environments in terms of rates of sedimentation, frequency of erosional events and orientation of waves and currents. Substrate stability, water temperature and bathymetry were lesser important processes. The trace fossil association in the Khadir fan delta complex are therefore remarkable in their high diversity and in their excellent state of preservation.

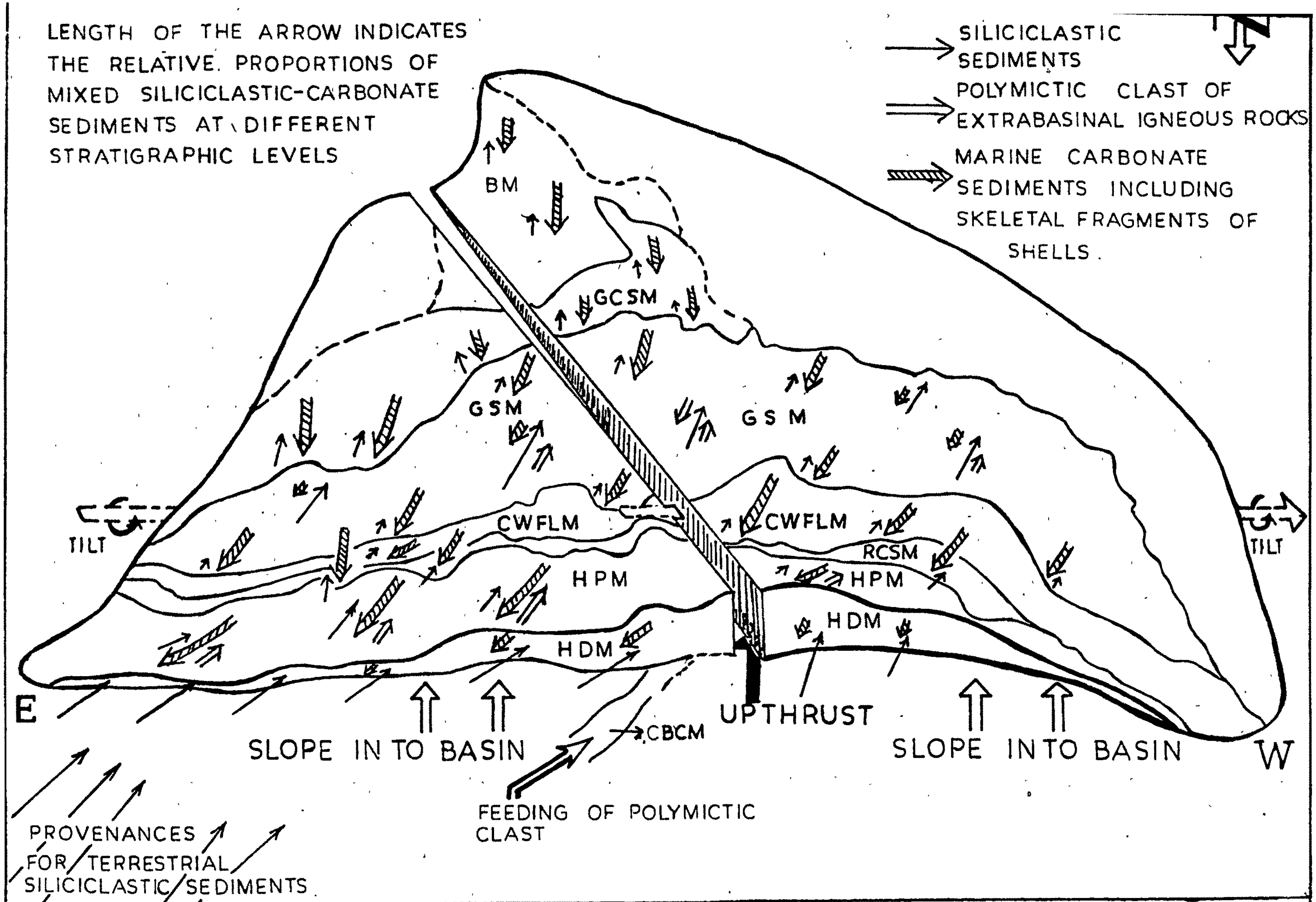


FIG 50 THREE DIMENSIONAL MODEL OF KHADIR ISLAND SHOWING COMBINATION OF BOTH PUNCTUATED AND INSITU MIXING OF SILICLASTIC - CARBONATE SEDIMENTS

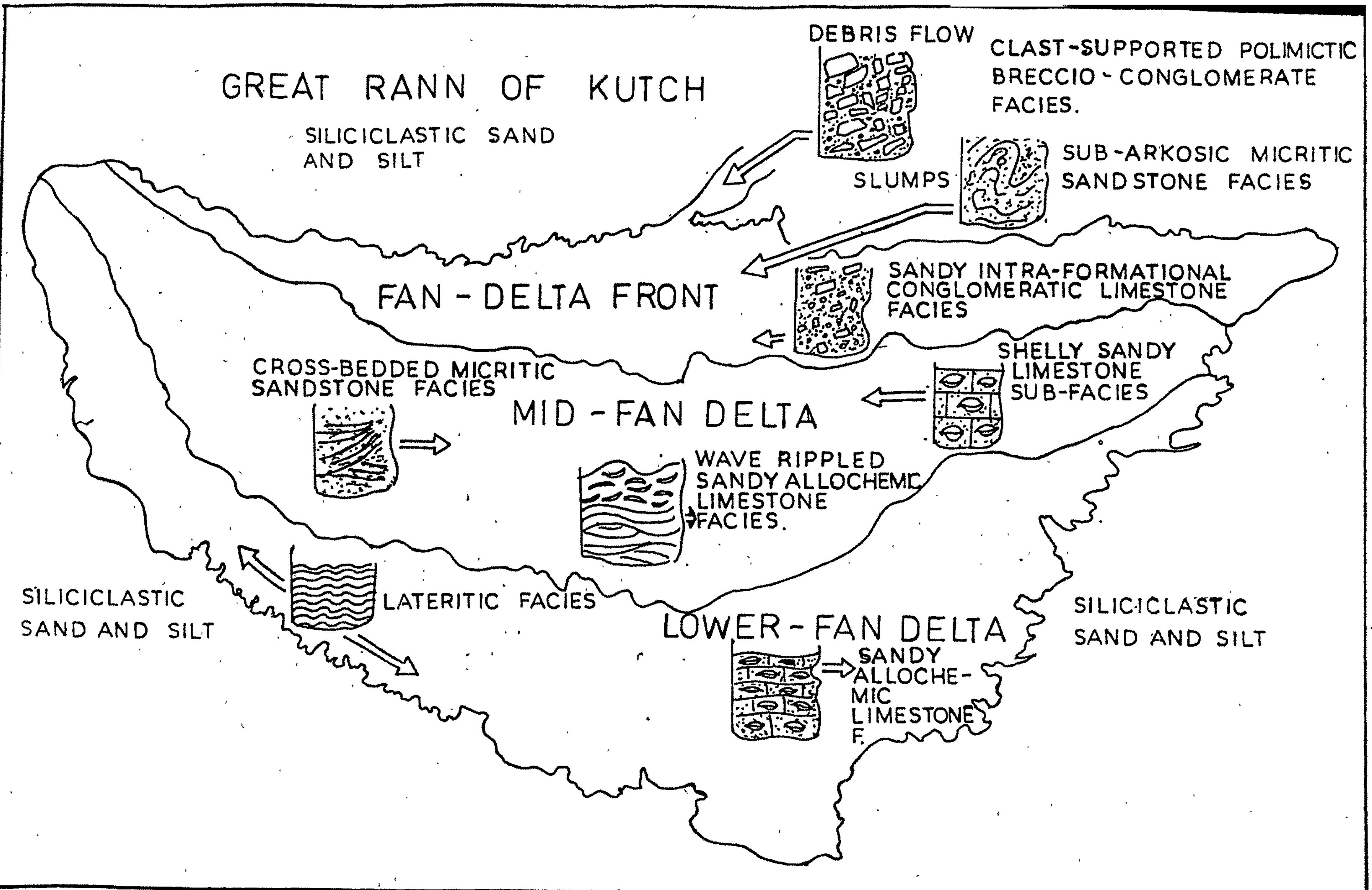


FIG-51. SCHEMATIC MODEL OF FAN-DELTAIC ENVIRONMENT OF KHADIR ISLAND RELATING RESPECTIVE PREDOMINENT FACIES.

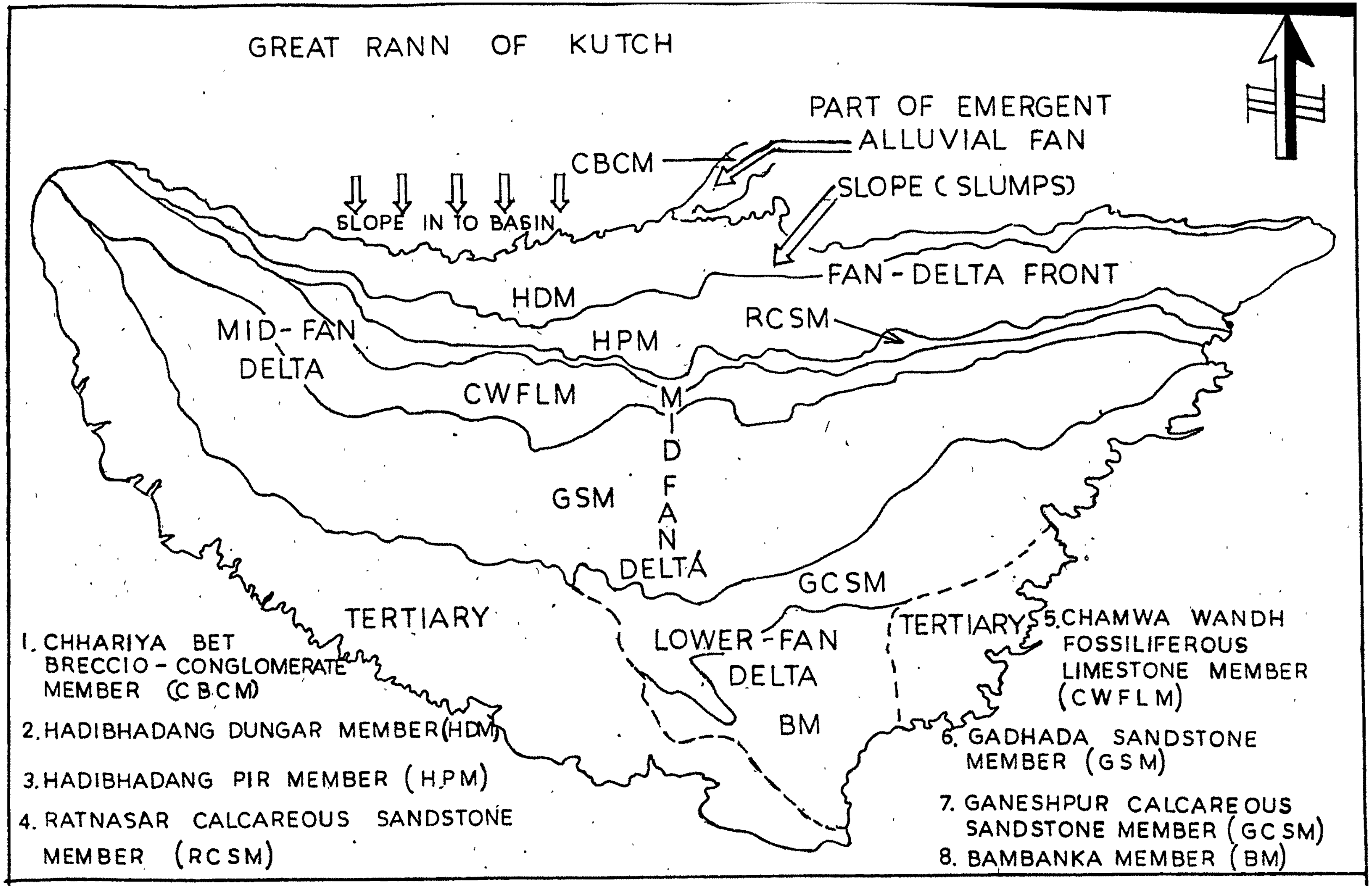


FIG52 SCHEMATIC REPRESENTATION OF MODEL OF FAN-DELTA DEPOSITION RELATING MEMBER AND DEPOSITIONAL ENVIRONMENT OF KHADIR ISLAND,