Chapter VI

FACIES AND DEPOSITIONAL ENVIRONMENTS

Sedimentological information on the Cretaceous Sedimentary rocks of the Narmada basin is scarce as very few relevent studies have been published (Raiyerman, 1975; Singh, 1981; Singh and Srivastava, 1981; Ahmad and Akhtar, 1990; Tandon et al., 1990; Akhtar and Ahmad, 1991). Despite paucity of sedimentological data, a broad framework of depositional model of the rocks can be reconstructed mainly on the basis of paleontological and paleoecological studies (Jain, 1966; Dassaram and Sinha, 1975; Guha and Ghosh, 1975; Chiplonkar et al., 1977; Singh and Dayal, 1979; Badve, 1987).

Detailed sedimentological studies of the Lower Cretaceous Nimar Sandstone in the western part of the basin suggested that the rocks were deposited in an essentially estuarine complex environment (Ahmad and Akhtar, 1990; Khan, 1990). The subenvironments of the complex included channels separated by terrigenous mud flats and carbonate mud flats.

The generalized depositional environments of the Karondia Limestone were interpreted mainly on paleoecological consideration by many workers (Jain, 1966; Guha and Ghosh, 1975; Chiplonkar et al., 1977; Badve and Ghare, 1977; Singh and Dayal, 1979; Singh and Srivastava, 1981). These studies suggested intertidal to subtidal environments.

In the present study an attempt has been made to integrate the petrographic and field data on the Nimar Sandstone and Karondia Limestone with a view to recognizing the various subenvironments and facies in Zeerabad-Jobat area of the Lower Narmada basin. The recognition of subenvironments and facies helped in constructing a depositional model for both, carbonate and clastic rocks of the study area. However, carbonate rocks have received greater attention and the thesis presents for the first time a detailed microfacies study of the Karondia Limestone. On the basis of microfacies and megafacies of carbonate rocks, a better understanding of their depositional environments have been arrived at.

DESCRIPTION OF CLASTIC FACIES

SHALE-SILTSTONE FACIES

This facies is thickest in the Bagh Cave section (10 m thick). In general this facies is better developed in the eastern part of the area, its thicknesses ranging from 1 to 7.75 m. In the western part, the thickness of the facies generally ranges between 2 to 4 m.

The facies comprises red shales and siltstones which are generally highly weathered and covered with red soil. However good exposures of the facies occur in some sections such as Sitapuri, Bagh Caves, Baria and Jamni.

The facies shows mottling, and highly irregular and disturbed bedding as a result of bioturbation in some sections, such as at Sitapuri.

In the Bagh Cave section the facies comprises 2 m thick variegated purple and yellow interbedded shales-siltstones showing soft sediment deformation. Soft sediment deformation is also shown by a 20 cm thick unit at Baria.

In many of the sections shales-siltstones are observed to laterally pass into a channel fill sequence. Moreover shales-siltstones also constitute uppermost part of a fining upward sequence.

LENTICULAR AND FLASER BEDDED SHALE -FINE SANDSTONE FACIES

This facies is developed in the eastern part of the area where it is upto 1.5 m thick. The facies comprises mainly purple shales which contain lenses of white calcareous sandstones. With increasing sand content, the facies passes into flaser bedded sandstones. This facies is 1.5 m thick in the West Zeerabad section. The facies is underlain by massive claystones and overlain by nodular bedded bioclastic wackestones. The facies is also developed in Baria and Bagh Cave sections.

RIPPLE CROSS BEDDED SANDSTONE FACIES

This facies is mainly developed in the Bagh Cave section where its average thickness is 1.5 m and occurs interbedded with flat bedded sandstones. Ripple marks and rib-and-furrow structures are seen on the bedding surfaces. Near Bagh a 12 cm thick tabular set of megaripple bedding passes laterally into ripple laminated sandstones. The bedding type in the facies varies from parallel ripple bedding to climbing ripple bedding.

This facies is developed on a smaller scale at Baria (30 cm thick), where it forms the middle part of a fining upward, 1.75 m thick, channel fill. In another 3 m thick channel fill at Baria, the very thin ripple bedded sandstone facies (bedding thickness 0.5 to 6 cm) overlies large scale cross bedded sandstone facies, and passes upward into flaser bedded white sandstone and purple shales.

CROSS-BEDDED PEBBLY SANDSTONE FACIES

This facies consist of coarse grained yellow brown purple and grey pebbly sandstones. This facies is developed at Ghursul, Sitapuri, Bagh Caves, Jamni and Karondia. Its thickness exceeds 2 m and ranges upto a maximum of 3.7 m at Sitapuri. It shows channelling and large-scale planar and trough cross-bedding with set thicknesses reaching upto 80 cm at Bagh Caves. The foresets of cross-bedding often show graded bedding. At Sitapuri the graded foresets comprise granule to coarse sand size detritus. Here, the facies is underlain by a basal conglomerate, with maximum pebble size of 4.5 cm. The pebbly sandstones sometimes show horizontal bedding, such as at Baria. The pebbles comprise white quartzite, red jasper and olive shales.

The facies generally forms the basal part of a channel fill. At Dhanora the pebbly sandstone facies occurs in 35 to 50 cm thick units and it is interbedded with 50 to 75 cm thick red siltstones.

CROSS BEDDED SANDSTONE FACIES

This facies comprises generally fine sandstones but may range upto medium or very fine size. It has various shades of colours such as white, pale yellow, yellow-brown and red. The sandstone is generally planar cross-bedded but trough cross bedding also occurs. The set thicknesses range upto 50 cm. At Jhaba this facies is interbedded with horizontal bedded and massive bedded sandstones.

HORIZONTAL BEDDED SANDSTONE FACIES

Only a few measured sections of the area show this facies. It comprises various shades of purple, white and yellow sandstones of varying sizes, ranging from fine to coarse grained. The thickness of the facies varies from 1.7 m to 5.5 m in different sections.. At Jhaba the facies occurs interbedded with cross-bedded sandstones and at Bagh the facies is associated with ripple laminated sandstones.

CLASTIC FACIES ASSOCIATION AND ENVIRONMENTS

Although the vertical arrangement of clastic facies is quite variable, a generalized facies sequence in the study area comprises an upward-fining sequence. The generalized sequence comprises, from base upward, pebbly, coarse, cross-bedded sandstones which are sometimes interbedded with horizontal bedded sandstones. In some localities a basal conglomerate is also present. The cross-bedded sandstones are overlain by ripple bedded and flaser bedded sandstones. With decreasing grain size and increasing shaly content, flaser bedded sandstones pass upward into shales-siltstones.

Scoured bases and geometry of the upward-fining sequences clearly demonstrate their channel fill origin. At some localities shales are found to laterally pass into such channel fills. The size of the channels is highly variable, for example, the channel sequence is 16.2 m thick at Sitapuri, 1 to 3 m thick at Baria and 1 to 2 m thick at Dhanora **(Fig. 28).**

The upward-fining sequence in the Rajpipla-Jobat area lying west of the study area were interpreted as deposits of subtidal and intertidal channels (Khan, 1990). In the study area the upward-fining clastic facies sequences are interpreted to be channel and interchannel deposits. The channels were generally small and shallow but deeper and larger channels were present at some localities, for example, at Sitapuri, Nandgaon and Bagh.

The vertical variation in grain size parameters of the channel fill at Sitapuri does reflect an upward fining sequence. But, at Baria the vertical variation in grain size parameters reflects increasing current and/or wave action as a result of switching of channel and increasing marine influence.

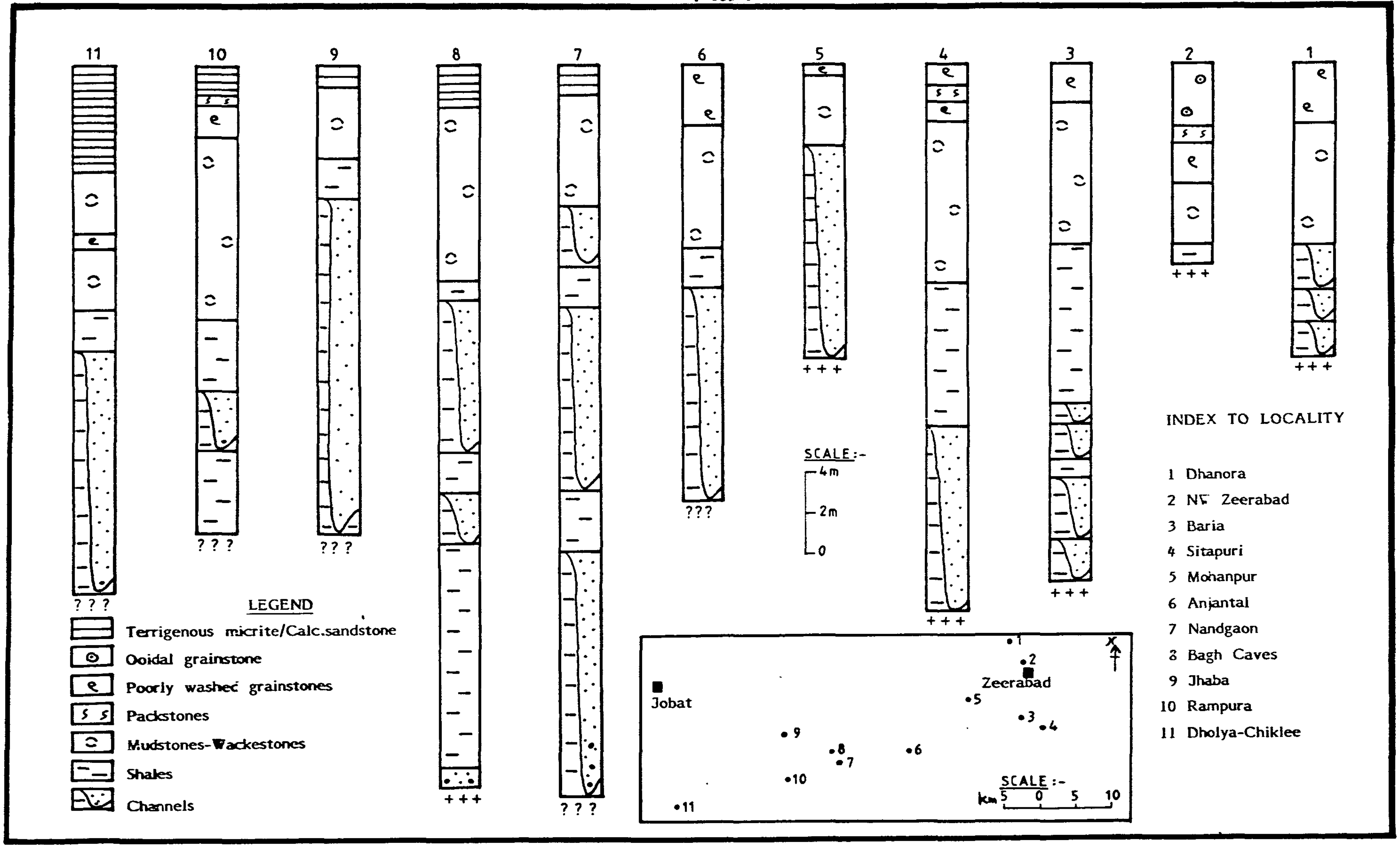

Fig : 28. GRAPHIC LOGS SHOWING VARIOUS FACIES ASSOCIATIONS, ZEERABAD - JOBAT AREA.

The tidal influence in channels of the study area is evidenced by bimodal-bipolar and quadrimodal cross-bedding and flaser bedding. Moreover the terrigenous clastic channel sequences directly overlain by marine carbonate rocks, in all probability represent deposits of nearshore environments.

The petrofacies studies and textural maturity of the sandstones suggest that their provenance consisted of fault bounded uplifts of continental basement rocks. The sands derived from the provenance, accumulated without much transport and reworking in the nearby incipient Narmada rift basin.

The sediment dispersal pattern and orientation of channels with respect to the basin axis suggests that the channels originated in the fault-bounded uplifts towards north.

CARBONATE FACIES AND ENVIRONMENTS

On the basis of field data and microfacies, described elsewhere, several natural lithological associations were identified in the Karondia Limestone for environmental analysis of the carbonate rocks. Five facies associations (FA) have been identified which are described below.

FA-1 : NODULAR BEDDED WACKESTONE-MUDSTONE

The facies association is persistantly developed in the study area ranging in thicknesses from 3.5 m to 10.3 m. It comprises white, grey-white, pale brown and purple carbonate mudstones and wackestones of various types, interbedded with thin olive shales. The bedding of the rocks is generally wavy and continuous in the lower part of the facies but acquires a definitely nodular character in the upper part with increasing percentage of shales. The bedding thicknesses range between 4 to 12 cm in different sections. Thallessenoid burrows are common, occasionally hemiaster and large ammonoids are seen. The facies association comprises four microfacies types which include lime mudstone, bioclastic wackestone, whole fossil gastropod wackestone and calcispheroidal bioclastic wackestone. The fossil content of the microfacies decreases in western part of the area with the increase in terrigenous content.

The abundance of micrite, poor sorting and angular nature of bioclasts and presence of whole fossils suggest low energy environment of deposition below wave base. The diversity of fauna indicates open marine conditions. Globigerinids, echinoderms and calcispheres suggest shallow marine to deep marine environment and normal salinity. Planktonic organisms, small amount of terrigenous quartz silt in the eastern part of the study area and absence of fenestral fabric confirm subtidal environment of deposition. However, an increasing terrigenous content with decreasing fossil content in the western part of the area indicates proximity to detrital source.

The mudstones and wackestones correspond to standard microfacies types 8 to 9 and belong to open marine shelf facies association (Wilson, 1975; Flugel, 1982).

FA-2 : HIGHLY BIOTURBATED PACKSTONE-WACKESTONE

The facies is developed only in a few sections of the study area which include Sitapuri, Northwest Zeerabad, Karondia and Rampura. The facies comprises red brown packstones, whole fossil wackestones which are highly bioturbated and show irregular and chaotic bedding. Occasionally whole fossils of hemiaster are seen. It contains considerable amount of glauconite pellets. All these characters suggest an interval of reduced rate of sedimentation or non-deposition during which the sediments were thoroughly burrowed and jumbled up.

FA-3 : CROSS-BEDDED, FLASER BEDDED AND RIPPLE BEDDED GRAINSTONE

The facies association is persistantly developed in the eastern part of the study area with a preserved thickness of 1.5 to 3.2 m. In the western part of the area the rocks laterally change into terrigenous micrite and calcareous sandstones. The facies comprises yellow-brown, large-scale planar and trough cross-bedded, ripple cross-bedded and flaser bedded grainstones, poorly washed grainstones and their variants, such as bryozoan bioclastic grainstone, brachiopod bioclastic grainstone, echinodermal bioclastic grainstone, intraclastic bioclastic grainstone and silicified bioclastic grainstone. Burrows and trace fossils, especially thallessenoids, are common. Interbedding of large scale cross-bedding and ripple cross bedding indicates fluctuating water energy conditions. This is also reflected in the incomplete winnowing of micrite. The generally abraded and rounded nature of bioclasts indicate their breakage by wave action and transportation. Geopetal fillings and umbrella effects suggest infiltration of micrite after deposition of lime sand. The appearance of intraclasts indicates shoaling as compared to the wackestones of the FA-1, which lack intraclasts. The fauna indicate shallow marine conditions of open circulation and normal salinity. The special varieties of poorly washed grainstones such as bryozoan variety with nearly 33 percent bryozoans, echinoderm variety with 28 percent echinoderms, and brachiopod variety with 23 percent brachiopods resembles standard microfacies 5. They appear to be a reef flank facies with bioclasts derived from adjacent reef or mounds. The concentration of bryozoans, echinoderms and brachiopods, geopetal fillings and umbrella effects are typical features of reef flank facies.

FA-4 : LARGE SCALE CROSS-BEDDED OOIDAL BIOCLASTIC GRAINSTONE

This lithological association is represented by a large scale planar cross-bedded unit in the field which comprises silicified ooidal bioclastic grainstone microfacies. The microfacies shows extensive replacement by silica but ooids can still be recognized and occur in abundance, forming 23 percent. The bioclasts are well sorted and well rounded. The presence of cross-bedding, ooids and well sorted and rounded bioclasts and remnant patches of sparry calcite indicate high energy environment of deposition and high degree of winnowing of micrite. This microfacies resembles the standard microfacies 15 and represent deposition on shoals, beaches and tidal bars where waves or tidal currents were high and relatively continuous.

Large scale cross-bedding in the facies association permitted its paleocurrent reconstruction. A total of 169 cross-bedding azimuths were measured at 5 localities, mostly from the eastern part of the area around Sitapuri and Zeerabad **(Appendix III)**. The cross bedding set thicknesses average 29 cm and inclination angle of foresets average 15 degrees. The rose diagrams constructed on the basis of large scale cross-bedding azimuths are mostly polymodal **(Fig. 27)**. The bipolar-bimodal nature of sediment dispersal patterns is indicative of reversing tidal currents. This is also clearly demonstrated by herringbone cross-bedding observed in the Northwest Zeerabad section **(Plate 1-C)**. The sediment dispersal is mainly westerly with occasional easterly dispersal.

FA-5 : LAMINATED TERRIGENOUS MICRITE/CALCAREOUS SANDSTONE

The facies association gains prominence in the western part of the area comprising sections measured near the villages of Nandgaon, Padlya, Jamni, Talawri, Mogra, Rampura and Dholya-Chiklee. The rocks range in thickness from 1.5 m to more than 5.25 m. They are grey, purple and yellow and are generally parallel laminated. Wavy bedding and cross-bedding occur occasionally. The lithological association comprises terrigenous micrite and calcareous sandstones. Terrigenous micrite is generally devoid of bioclasts which occur occasionally in traces.

DEPOSITIONAL MODEL OF CARBONATE ROCKS

During the Albian-Cenomanian marine transgression that proceeded along the Narmada basin from west, a carbonate platform came into existence. Several types of carbonate platforms have been recognized on the basis of studies of both ancient and recent carbonate sediments and much apparent diversity is obtained in platform morphology (Kendall and Schlager, 1981; Read, 1982; 1984; Hine and Mullins, 1983; James and Mountjoy, 1983). However, these apparently contradictory terminology and definitions can be resolved into two basic types : (i) Carbonate ramps, with gentle slopes leading from shallow water facies to deeper water low energy deposits and (ii) rimmed carbonate shelves with marked platform-to-basin transitions characterized by carbonate slope environments (Ahr, 1973; Ginsburg and James, 1974; Wilson, 1975; Read, 1982; 1984; James and Mountjoy, 1983; Mullins et al., 1984). These basic types are modified generally as a result of drowning or emergence and carbonate ramps may evolve into rimmed shelves or vice-versa.

The carbonate sequence of the study area was deposited on a ramp without a striking break in the slope of the ramp and where shelf margin was not developed.

The vertical arrangement of facies in the Karondia Limestone forms a shallowing upward sequence comprising nodular bedded mudstones and wackestones of subtidal open marine shelf followed upward by intertidal deposits comprising cross-bedded flaser bedded and ripple bedded grainstones. Within the intertidal deposits, presence of tidal channels is indicated by grainstone bodies with scoured bases and containing herringbone cross-bedding. Small scale local patch reefs were also developed in the intertidal zone.

The shallowing upward sequence resembles the model sequence described by James (1984), who ascribed it to rate of carbonate deposition exceeding the rate of platform subsidence or sea level rise. Consequently, carbonate acumulations buildup to sea level and above, resulting in a characteristic sequence of deposits in which each unit is deposited in progressively shallower water.

The Karondia Limestone sequence, however differs from a model sequence in two respects, firstly the basal unit recording the initial transgression has not been observed in the study area. Secondly the supratidal unit is also not discernible but there are are some evidences of processes typical of supratidal environment. For example in the Karondia section lineation caused by linear arrangement of small high spired gastropods seen on the bedding surfaces of grainstones **(Plate II-E)** perhaps reflects abnormal storm tides. Similarly the associated thick sets of planar cross-bedding (1 m thick) may also be the result of migration of large scale bed form during storms. Thus the grainstones appear to be intertidal-supratidal deposits. The absence of evaporties and dessication cracks is explained by the humid climate prevailing at that time.

The shallowing upward facies sequence of the study area is a small scale sequence, being only a few tens of metres thick. It shows much lateral variation and individual lithologies are not correlatable within short distances of only few kilometres **(Fig. 28).** The most likely explanation for the development of a variegated stratigraphic sequence is deposition on a platform dotted by a mosaic of exposed banks or islands separated by subtidal areas, with the whole complex shifting both laterally and vertically in response to hydrodynamic conditions through time.

The tidal island facies model was first envisaged by Laporte (1967) and later refined by James (1984) and Pratt and James (1986). This model took care of many shortcomings and objections to the conventional epeiric sea model. The refined model suggested that tides and superimposed storms are the most important processes controlling deposition, and that many shallowing upward cycles of the stratigraphic record of peritidal carbonate sediments have resulted from accreting islands during relatively continuous subsidence. Islands and banks, initiated as sand shoals by major storms, are later sculpted and modified by tides, waves and later storms to achieve equilibrium with ambient hydrographic conditions (e.g. Stoddart, 1962; Ball et al., 1967). The character of islands, such as shape, size and facies distribution would depend on distance from the open ocean, variation in tidal height, prevailing wind direction, location of storm and hurricane belts and so on. The spacing of islands would vary in a self limiting way so that they are not too close to overlie to restrict water circulation and the sediment generating capacity of subtidal areas.

Several hypotheses have been put forward to explain the origin of peritidal cycles. These can be broadly classified into two types of models : the eustatic model and the autocyclic model.

The accretion of symmetric peritidal cycles upto sea level occurs during times of static sea level that alternates with sea level rise by uniform subsidence (Tucker, 1977).

Asymmetric shallowing upward cycles have been related to fluctuating subsidence rate and termed 'punctuated aggradational cycles' by Anderson et al., 1984. The mechanism of eustatic sea level fluctuation has also long been suggested as a cause of small scale cyclicity in carbonate rocks (e.g. Fischer, 1964; Demicco, 1982). But, changes in the rate of relative sea level rise by subsidence or eustasy do not account for many small scale peritidal cycles because they are not correlatable on a regional or worldwide scale implying that no widespread event could have caused them (Pratt and James, 1986).

The autocyclic model implies an intrinsic control on the rate of sedimentation governed by source area (Ginsburg, 1971; Matti and McKee, 1976; Wilkinson, 1982).

All these hypotheses imply that, for each cycle, the entire platform grows to sea level, either all at once or diachronously as a prograding wedge, leading to a prolonged period of regional subaerial exposure. On the other hand, the tidal island facies model envisages that the entire platform is never exposed nor is it ever all submerged. The response of individual tidal flat island to variable local rates of sediment acumulation are reflected in the vertical succession of peritidal cycles. Islands accrete and migrate laterally with time. If islands are stable in their position simple vertical accretion occurs, but the rate of accretion of each island will inherently decrease when the depositional surface reaches the supratidal zone. Lateral progradation continues until it is prevented when neighbouring subtidal areas are in danger of becoming too reduced for sediment generation and for ambient hydrographic forces, such as tides, to operate.

The island model invokes an autoregulatory mechanism. A peritidal autocycle forms by building of an island until it reaches high tide level and also lateral progradation is prevented. At this stage the hydrographic forces shift the focus of sedimentation to a different but nearby area. This mechanism accounts for the variegated stratigraphic record that is observed in the study area as well as in many other peritidal sequences.

According to plaleogeographic setting of the Narmada basin, the basin was sloping and opening towards west. The gradual passage of intertidal grainstones westward into terrigenous micrite and calcareous sandstone facies association suggests that the western part of the basin received abundant terrigenous clastics which were also responsible for a reduction in biota. In the absence of directional structures in the terrigenous micrite-calcareous sandstones facies association, it is difficult to say that from what directions terrigenous clastics came to the basin. They were most likely delivered from the northern edge of the basin and represent proximity to larger channels.

RECONSTRUCTION OF BASIN DEVELOPMENT AND DEPOSITIONAL HISTORY

The Cretaceous Narmada basin forming part of an ancient lineament zone was initiated as an incipient rift on the Early Cretaceous peneplain, prior to breakup of Gondwana and large-scale effusion of basalt. The basal Nimar Sandstone was deposited in tidally influenced channels implying that the Albian-Cenomanian transgression had commenced in the basin. The channels dispersed sediments across the basin axis and brought the sediments from the fault bounded uplifts towards north and accumulated without much transport and reworking **(Fig. 29 A).**

With the cessation of clastic sedimentation and continued transgression, a carbonate platform came into existence on which the Karondia Limestone was deposited **(Fig. 29 B).** The carbonate sedimentation commenced with subtidal carbonate mudstones and wackestones. Storm processes created shoals, islands and banks which were later modified by tides, waves and later storms to achieve equilibrium with ambient hydrographic conditions. The islands accreted upward and migrated laterally resulting in a peritidal autocycle which displays a highly variegated stratigraphic record.

The top of Karondia Limestone in the study area is erosionally truncated by a regional unconformity over which lie the Deccan Traps of Maestrichtian age. There are some remnant patches of sandstones, belonging to the Lameta Group, occupying a position between the Karondia Limestone and the Deccan Trap.

Howmuch thickness of the Cretaceous sedimentary sequence was removed before the outpouring of Deccan Traps, is a matter of conjecture.

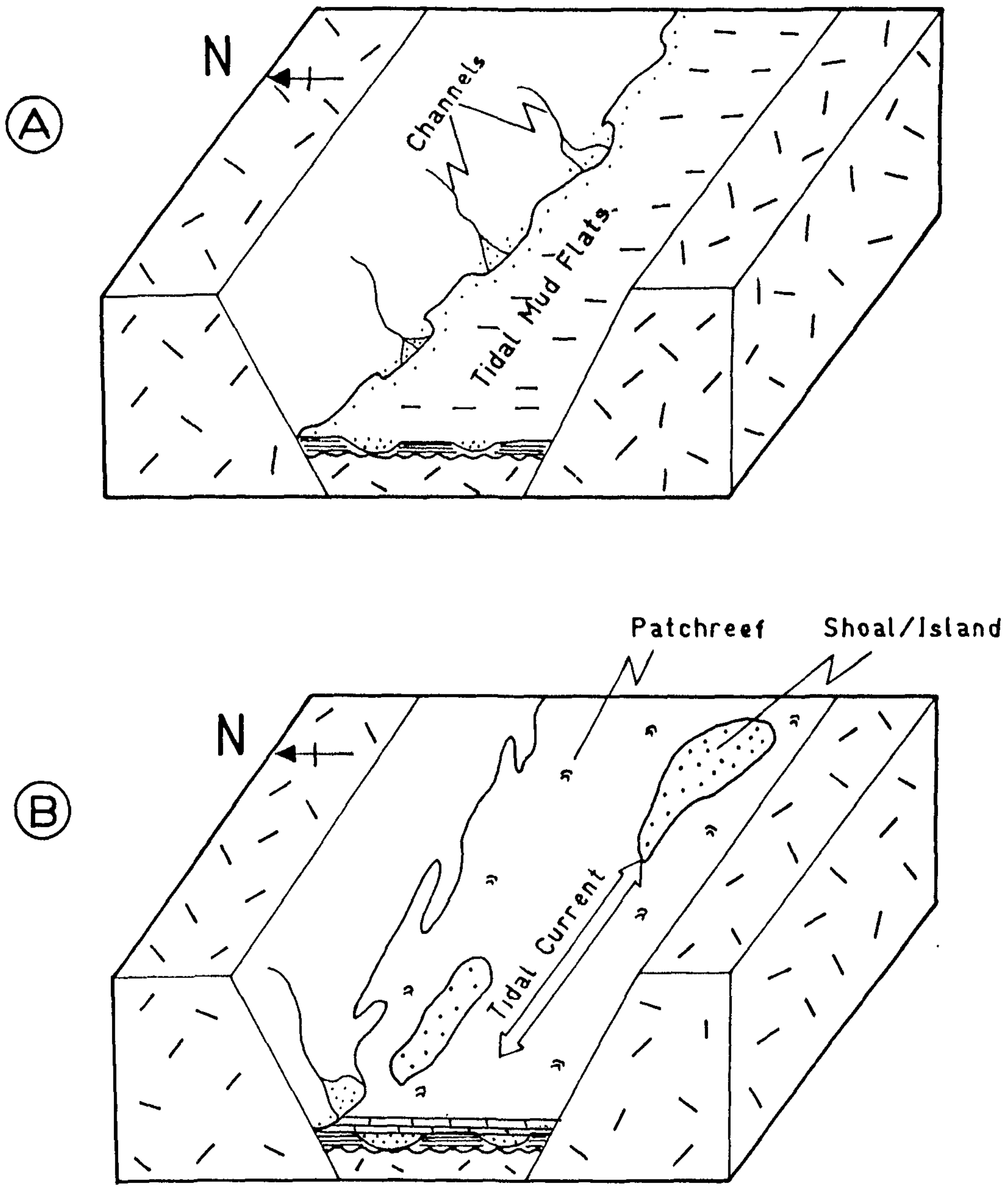

Fig. 29 : HYPOTHETICAL, THREE-DIMENSIONAL RECONSTRUCTION OF DEPOSITIONAL HISTORY OF THE BAGH GROUP IN THE LOWER NARMADA BASIN. (A) DEPOSITION OF THE NIMAR SANDSTONE AS TIDALLY INFLUENCED CHANNELS AND TIDAL MUD FLATS, (B) DEPOSITION OF THE KARONDIA LIMESTONE BY VERTICALLY ACCRETING AND LATERALLY MIGRATING SHOALS AND ISLANDS.

SUMMARY AND CONCLUSION

The siliciclastic-carbonate sequence of the Bagh Group (Albian-Cenomanian) outcropping in patches, extending from Zeerabad village in the east to Jobat town in the west in the Lower Narmada basin, was studied for the purpose of facies analysis and construction of depositional model, with special reference to carbonate rocks. A total of nineteen lithostratigraphic sections were measured in the Zeerabad - Jobat area. The Bagh Group unconformably overlies the Precambrian basement and is overlain by the Deccan Traps (Maestrichtian). The Bagh Group comprises two formations: the Nimar Sandstone overlain by the Karondia Limestone.

Petrography, petrofacies and dispersal patterns of the Nimar Sandstone were studied for the purpose of understanding the overall depositional milieu of the clastic roks. Thin sections of 57 sandstone samples were employed for grain size analysis. The sandstones are generally very fine to medium sand size, moderately sorted to moderately well sorted, near symmetrical to fine skewed, and dominantly mesokurtic. They are mostly texturally submature to immature.

The composition of the sandstones was determined in 54 thin sections. The average composition of the sandstones is quartz (75%), feldspar (5%), rock fragments (4%), micas (0.5%), heavy minerals (0.5%), clay matrix (4%) and cements (11%). The cements comprise carbonate, iron oxide and silica. According to Folk's classifications the sandstones are predominantly subarkoses (94%).

The petrofacies and provenance of the sandstones were studied according to Dickinson's scheme which involved calculation of detrital modes (Qt, Qm, F, L, Lt) and plotting them on Qt-F-L and Qm-F-Lt triangular diagrams. The samples lie dominantly in the craton interior field with few in quartzose recycled field. These results were examined in the light of textural and compositional maturity of the sediments and the ancient climate. The sandstones are texturally submature to immature and their low degree of textural maturity indicates their deposition without much reworking and abrasion in the nearby Narmada rift. They are compositionally mature and their high degree of compositional maturity is ascribed to prolonged weathering under humid tropical climate and long residence time in soil. The sandstones do not belong to the stable platform succession since they are texturally submature to immature. The provenance of sandstones is interpreted to be fault-bounded uplifts of continental basement rocks.

Sediment dispersal patterns of the sandstones were reconstructed on the basis of 123 azimuths collected on large-scale cross-bedding at different localities. The sands were dispersed mainly in southwest, south and westsouthwest directions, almost across the basin axis. Reversal of currents brought about dispersal in eastsoutheast and northeast directions. The sands were delivered to the basin from the northern uplifts.

Six terrigenous clastic facies were identified in the Nimar Sandstone and they are: shales-siltstones, lenticular and flaser bedded shales-fine sandstones, ripple cross-bedded sandstones, cross-bedded pebbly sandstones, large scale cross-bedded sandstones and horizontal bedded sandstones. The facies are generally arranged in upward-fining sequences that were deposited in channels of the different dimensions. The shales laterally passing into channel-fills represent interchannel deposits. The tidal influence in the channels and associated sediments is evidenced by bimodal-bipolar and quadrimodal cross-bedding and flaser bedding. A nearshore environment for terrigenous clastic channel sequence is also supported by their position directly below the Karondia Limestones containing marine fossils.

Textural constituents and microfacies of the Karondia Limestone were studied in 97 thin sections stained with Alizarin Red S to differentiate calcite and dolomite. The lower, nodular bedded part of the Karondia Limestone differs markedly from the upper cross-bedded/ flaser bedded part in the average percentage of various textural constituents.

13 types of carbonate microfacies were identified and grouped into five associations on the basis of their field and microscopic characters. The facies associations include: nodular bedded wackestones-mudstones; highly bioturbated packstones-wackestones; cross bedded, flaser bedded and ripple bedded grainstones; large scale cross-bedded ooidal bioclastic grainstones; laminated terrigenous micrite/ calcareous sandstones.

The carbonate facies-sequences in different sections are interpreted as shallowing upward sequences comprising nodular bedded mudstones and wackestones of open marine shelf, followed upward by intertidal deposits comprising cross-bedded, flaser bedded and ripple bedded grainstones. Within the intertidal deposits, tidal channels are represented by grainstone bodies with scoured bases and containing herringbone cross-bedding. Small patch reefs were also developed.

The carbonate rocks of the study area were deposited on a platform of ramp type which came into existence during the Albian-Cenomanian marine transgression. The platform was dotted by shoals, banks or islands, seperated by subtidal areas, the lateral and vertical shifting of the whole complex produced a highly variable shallowing upward sequence.

Earlier paleogeographic reconstructions of the Narmada basin suggest that it was sloping and opening towards west. The gradual passage of intertidal grainstones westward into terrigenous micrite and calcareous sandstone facies association suggests that the western part of the basin received locally abundant terrigenous clastics which were also responsible for a reduction in biota. The terrigenous clastics were most probably delivered to the basin from land on the northern edge of the basin.

The basin originated as an incipient rift on the Early Cretaceous peneplain. Deposition of the basal Nimar Sandstone in tidally influenced channels indicates the onset of Albian-Cenomanian transgression in the basin. With the cessation of clastic sedimentation and continued transgression, a carbonate platform was formed on which the upward shoaling sequence of the Karondia Limestone was deposited mainly by accretion and lateral migration of shoals and islands. The top of the Karondia Limestone in the study area is erosionally truncated by a regional unconformity over which lie the Deccan traps of Maestrichtian age.