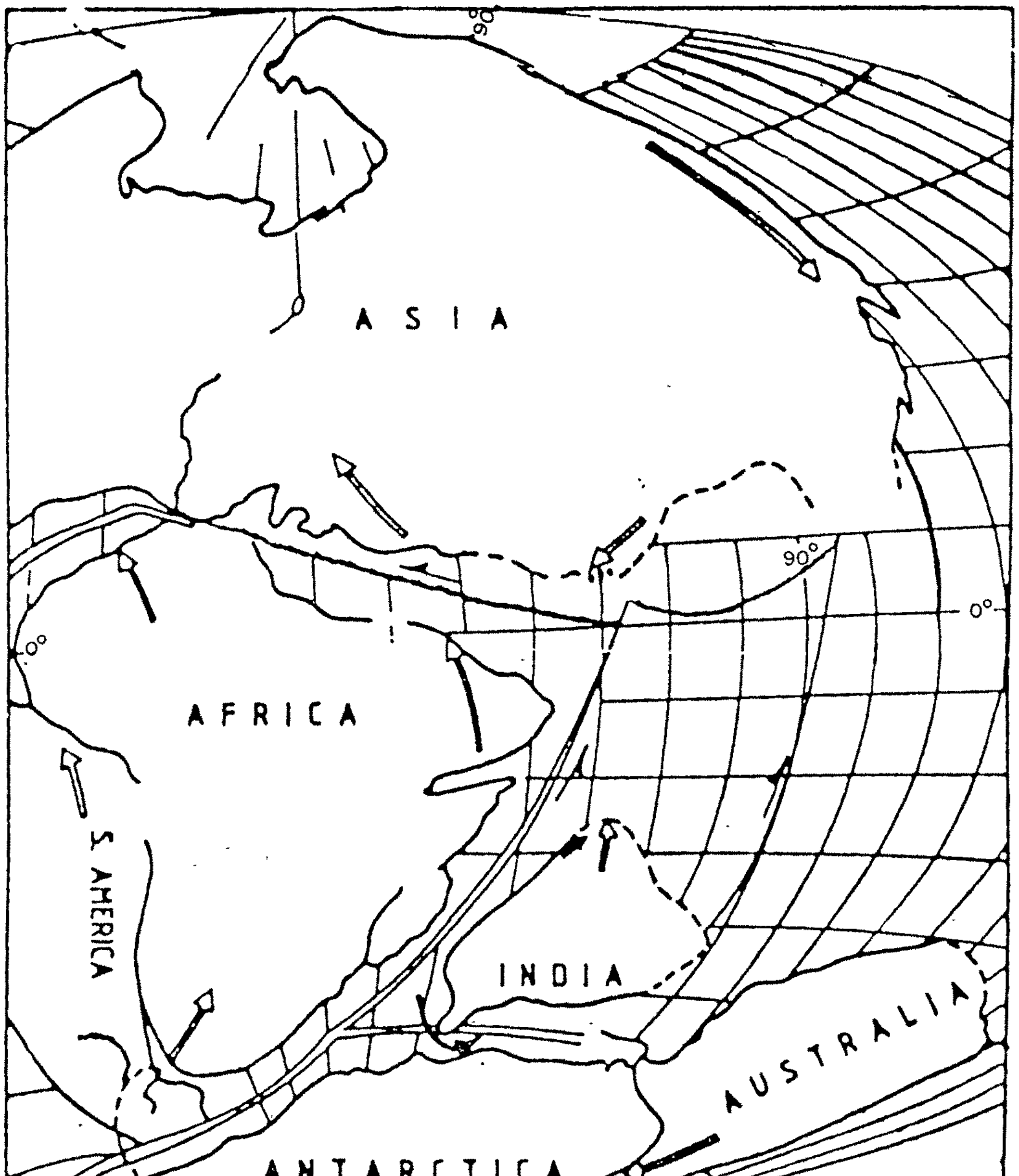
C H A P T E R - VIII

DEPOSITIONAL ENVIRONMENTS

Many parameters characterize depositional environments, and these can be recognized through their effect on accumulating sediments. Environmental reconstruction is based on the knowledge of environmental processes and their products, which build up the sedimentary sequence. Facies models are used as a basis for understanding depositional envirnoments and are constructed from real and theoretical studies, both of the rock record and of modern environments. The delineation of the depositional environments of Middle Jurassic carbonates of the study area is mainly based on lithofacies and microfacies identification and diagenetic history.

The rifting of Kutch basin was initiated during fragmentation of Gondwanaland in late Triassic with sinistral rotation (Fig. VIII.1). According to Biswas (1992-93), Kutch



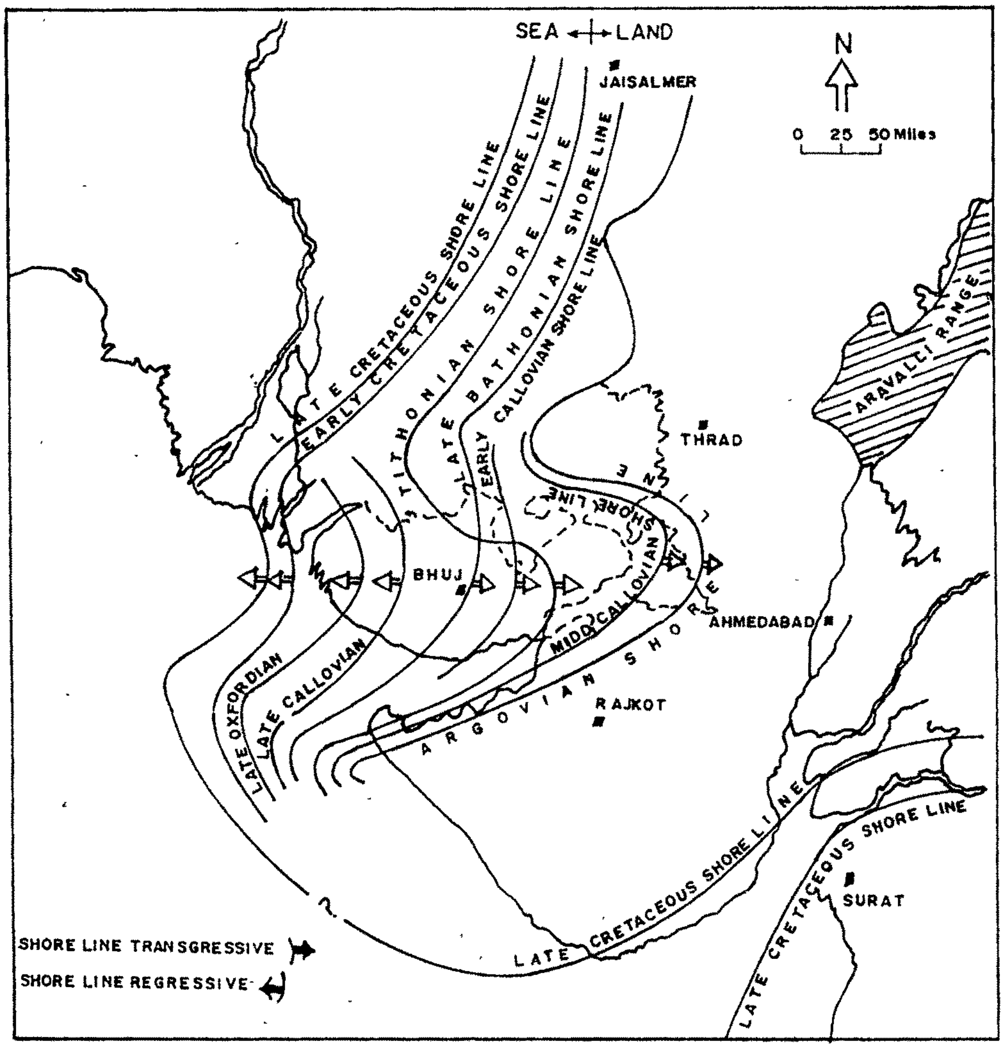
SPLIT OF SOUTHERN GONDWANALAND IN LATE TRIASSIC - EARLY JURASSIC. INDIA WAS SEPARATED FROM AFRICA AND ANTARCTICA BY A Y-SHAPED MEGASHEAR (AFTER DIETZ AND - - HOLDEN 1970)

FIG. VIII. I

basin is the earliest rift formed during breakup of India from Africa. It is mostly filled up by early rift stage Mesozoic sediments. Rifting failed by Late Cretaceous and the postrift stage tilt in Paleocene affected only the western part where the Tertiary sediments overlap.

Mesozoic sedimentation which took place in a tectonic environment of unstable shelf, comprise two major transgressive-regressive cycles. While exploring for hydrocarbon potential and based on regional stratigraphic correlation Biswas and Deshpande (1983) observed that the Kutch Mainland forms the depocentre of the basin while Patcham "island" and Eastern Kutch (Khadir, Bela, Chorar "island" and Wagad) form the northern and eastern margin of the basin.

The Middle Jurassic carbonate sequences were deposited in a major transgressive phase. On the basis of field study and scrutiny of lithofacies analyses, it is found that this transgressive cycle consists of smaller transgressive-regressive subcycles and microcycles of shorter duration. This cyclicity in sedimentary processes indicates unstable condition of the basin at the time of deposition of these sediments. While dealing with the palaeogeographic reconstruction, Biswas (1991) has identified the palaeo-shoreline positions in the basin (**Fig.VIII.2**). This shows clearly the shift of shorelines during different periods of time.



(AFTER BISWAS 1991)

PALAEO-SHORE LINE POSITION IN KUTCH BASIN

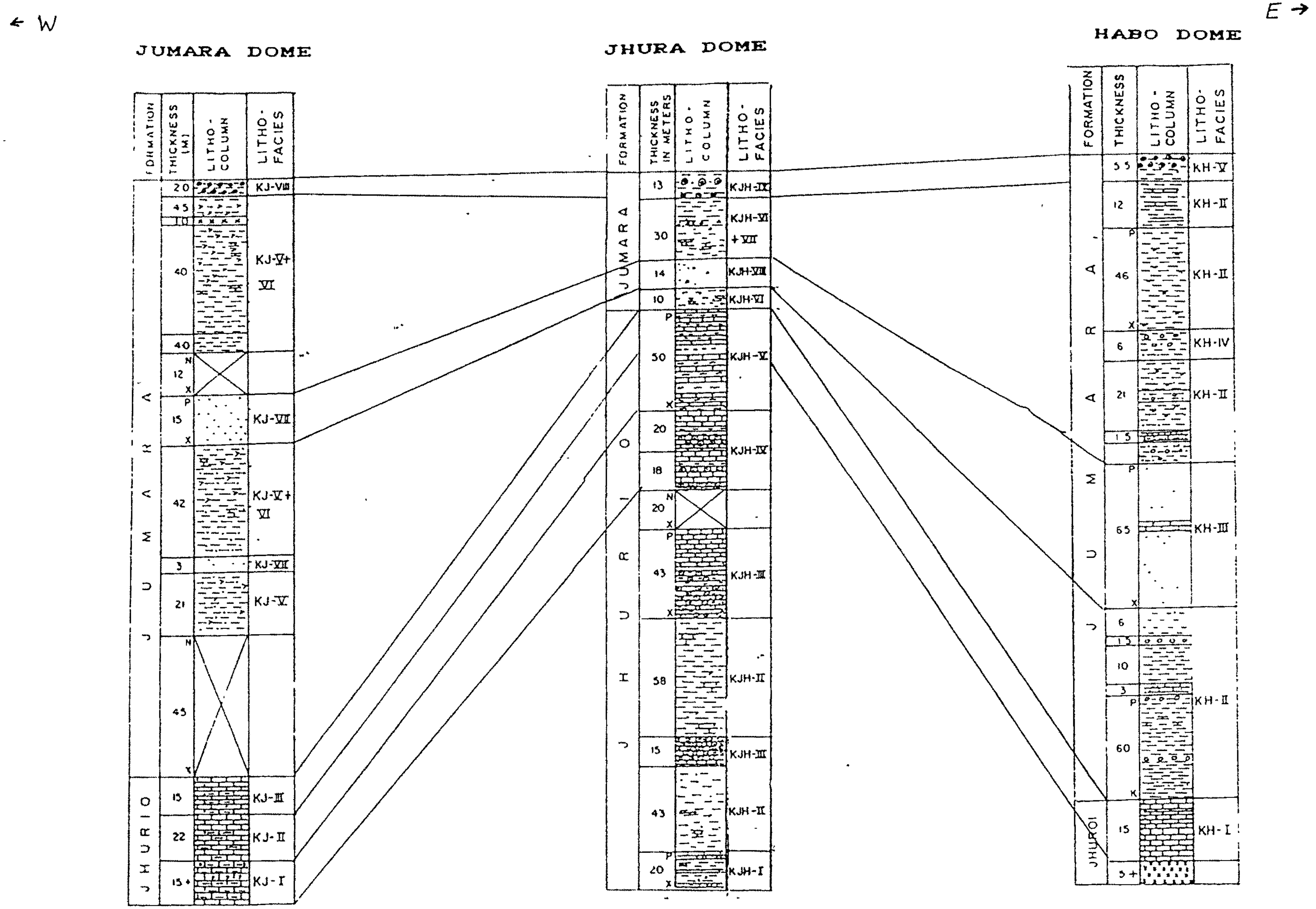
FIG.VIII. 2

As platform carbonates deposit at or very near to sea level, limestone facies types provide accurate gauges of sea level changes during the past. Worldwide changes in relative sea level (the sum of eustatic sea level changes, sedimentation and crustal movements) have occurred repeatedly and cyclically through geological time producing characteristic responses in carbonates.

CORRELATION AND PALEOENVIRONMENTS

As mentioned earlier, the Mesozoic carbonate sediments are exposed in the form of inliers in the study area. This is the result of post-depositional tectonic evolutionary processes in the basin.

Based on field studies, lithofacies and microfacies analyses a correlation of the rocks exposed in the study area has been attempted keeping in view the presence of a marker bed i.e. Dhosa oolite bed within all the three domes (**Fig.VIII.3**) and marking the top of the Jumara Formation. The interpretation of depositional environment of each lithofacies has been attempted after correlating the different lithofacies exposed from Jumara in the west to Habo in the east. The interpretation is based no several parameters like physical (bed geometry, primary structure), lithological (petrographic, mineralogic, textural and diagenetic), biological, chemical and stratigraphic relationship, together in a process to response model.



CORRELATION OF LITHO-COLUMN ALONG MAJOR TRAVERSES OF JUMARA, JHURA AND HABO DOME (NOT TO SCALE)

FIG. VIII-3

From the Figure VII.3, it can be seen that the Jhurio Formation is best exposed in the Jhura dome mainly because of the existence of Median High which came into existence towards the end of Oxfordian (Biswas, 1981). The Jumara Formation is well exposed in Jumara and Habo dome. However, the Jumara Formation in the Jhura dome is better developed in the eastern flank of the dome but poorly exposed along the line of traverse. The inter-domal correlation within the Jhurio Formation has been established as follows:

The coralline limestone lithofacies (KJ-I) of Jumara dome to the west is correlated with the limestone and golden oolite facies (KJH-IV) of Jhura dome. The same is not exposed in the Habo dome to the east. The limestone and marl facies (KJ-II) of Jumara dome is correlated with the lower part of bedded limestone facies (KJH-V) of Jhura dome and unexposed in Habo dome. The bedded limestone facies (KJ-III) of Jumara dome has been correlated with the upper part of bedded limestone facies (KJH-V),Jhura dome and bedded limestone facies (KH-I) of Habo dome.

The Jumara Formation is more or less uniformally exposed in all the three domes. The correlation of each lithofacies is as under:

The shales/ironstone facies (KJ-V) is correlated with the shales facies (KJH-V) of Jhura dome and shale facies (KH-II) of Habo dome. The calcareous sandstone facies (KJ-VII) of Jumara dome has been correlated with the ridge sandstone facies (KJH-VIII) of Jhura dome and calcareous sandstone facies (KH-III) of Habo dome. Being marker bed, the Dhosa oolite facies is easily recognized in the field and unifomally developed in all the three domes. However, it is best exposed in the south western portion of the Jumara dome. The exposures in Jhura and Habo dome are mostly eroded.

JHURIO FORMATION

Jumara dome

The sediments as well as the faunal assemblage clearly reveal a generally low energy marine shelf environment for the Jhurio Formation at Jumara dome. The coral bodies are mostly in their growth positions. Mud had evidently been trapped only between the bioclasts and within intraparticle pores. It seems likely that during these coral growths, the depositional substrate had been agitated atleast to a moderate extent. The interstitial mud, however, settled in the protected microenvironment between and within the organic bodies. The tabular geometry of the coral beds clearly reflects biostromal growth. Evidently reef formation was denied for these coral growths and these coral bodies had never been wave-resistant. That is evident also by the solitary nature of many corals lacking colonial integration. It can, however, be pointed out that the corals of the Jurassic age could not possibly adopt true reef building capabilities anywhere in the world (Clarkson, 1986). Abundance of corals and other fossil clasts whose primary aragonitic mineralogy is reflected in their selective dissolution strongly suggests that the sea was warm and tropical. The fossil assemblage clearly reflects Chlorozoan association (Lees, 1975; Lees and Bullar, 1972) and so does the abundance of pelloids. The abundance of corals in certain beds reflects that the salinity had been normal as for sea water. Local abundance of Terebratula also strongly supports this contention.

The limestone-marl alternations in the limestone and marl facies of Jumara dome with slight irregularity in bedding show striking resemblance to the shelf-sediments described by Wilson and Jordan (1983). The alternation is apparently due to variations in relative rates of organic proliferation and supply of argillaceous material from the land (Hallam, 1964; Arthur and Fischer, 1977; Schwarzacher and Fisher, 1982). These fluctuations in organic proliferation could be seasonal or of somewhat longer climatic cycles. The fine grained nature of the sediments in conjunction with total absence of any current or wave structures clearly reflects their deposition mostly, in low energy setting, below the wave base. The general lack of laminations in these muddy carbonate shelf sediments may, however, be due to extensive bioturbation. Abundance of very small burrows (diam 0.5 mm on an average) with ferruginous lining and common horizontal/subhorizontal orientation, supports this view. The general thinness of the shells possibly suggests depletion in oxygen circulation. The minute globular masses of goethite associated with the bioclasts presumably reflect pre-existence of pyrite, formed in the reducing microenvironment within the organic bodies. Despite this, faunal assemblages particularly abundant corals and brachiopods and also echinoids in certain levels clearly reflect an overall open marine environment. The deposition possibly took place on a low gradient carbonate ramp. While the fine carbonate mud accumulated on the shelf beneath the wave base, the stout coarser bioclasts were possibly indigenous, derived from nearby skeletal banks. The wave-agitated part of the shelf must have been shifted further landward and the present sequence represents the relatively distal/deeper part of the shelf.

The white limestone facies of Jumara dome shows a very good shallowing upward sequence of limestone and shale beds and resemble the shelf sediments. Similar to limestone and marl facies, it is of fine grained nature with total absence of any current or wave structures which clearly reflects deposition mostly, in low energy setting, below the wave base.

Jhura dome

The lithological association of the Jhurio Formation here is shales, limestone and golden oolite rocks. The sediments as also the faunal assemblage clearly indicate subtidal to intertidal open shelf environment of deposition. The limestone and shale facies (KJH-I) of Jhura dome consists of shales interbedded with limestone indicating nearshore deposition in a slowly transgressive sea under relatively stable conditions, when the rate of subsidence was slow and sea was encroaching gradually over the old land.

During the slow transgressive periods, the shales were deposited by reworking of the residual clays. The subsidence was intermittent and at times when the rate of subsidence was too low or the basin subsidence stopped for a short period, the depth of water was reduced and thick bed of golden oolite facies (KJH-III) were deposited under intertidal conditions. The occurrence of wave ripple marks on the golden oolite facies also suggests that strong waves were present during the deposition. The shale deposition followed again as the subsidence resumed.

The limestone and golden oolite facies (KJH-IV) above the shales points to their deposition under subtidal to intertidal conditions. Towards the end, the deposition of bedded limestone facies followed with deposition below the wave base in relatively calm conditions.

Thus, while the general environment of deposition of Jhurio Formation is stable shelf and subtidal, local variations of the environment produced variations in the sedimentation.

Habo dome

The Jhurio Formation is represented here by a bedded limestone facies (KH-I) resting on the top of an intrusive body. The lithological association of limestone with shales alongwith the paucity of faunal assemblage clearly indicates deposition in a shallow, nearshore environment connected with open sea such as lagoons.

The bedded limestone facies consists of bands of limestone alternating with finely laminated green shales devoid of any kind of current structures. They often contain glauconite. The presence of dolomite has been interpreted as of replacement type and may be the result of post depositional diagenetic effects. However, most of the modern occurrences of dolomite suggest intertidal-supratidal, often evaporative environment (Tucker, 1991). Thus, a supratidal environment cannot be ruled out for the dolomites of the Jhurio Formation of Habo dome.

JUMARA FORMATION

Jumara dome

The lithological association of Jumara Formation within Jumara, Jhura and Habo domes are well correlated and includes gypseous shales, sandstone with oolitic bed at the top characterizing deposition in a subtidal environment under stable conditions.

The shales/ironstone facies associated with white limestone facies indicate deposition in low energy states always below the wave base. The deposition was in a transgressive sea in slowly sinking basin (Biswas, 1981). The gypsum in the shales is either secondary or authigenic. It does not indicate any connection with the evaporite cycle. The hematite ironstones are indicative of an open oxidizing environment.

The calcareous sandstone facies seems to be anachronistic within the carbonate sequence. This could have formed due to sudden influx of sand from land during storms. However, their occurrence is very much restricted and does not indicate any form of cyclicity (fairweather-storm cycle) as expected in case of storm deposits. Further, when did such sand influxes occur, that took place in rapid successions resulting in formation of multistoreyed bodies warrannts explanation. Some episodic but apparently noncyclical mechanism had possibly been the prime reason for influx of these foreign materials. It is possible that this might have happened due to sudden tectonic tilting of the basin margin. Enhanced tilting of the sea margin is likely to result in influx of terrigenous materials. The sheet like geometry and the massiveness of the sand bodies are compatible with their presumed tectonic origin. The rapid consequtive influxes can be attributed to earthquakes and the aftershocks concomitant with tectonic tilting.

The depositional milieu of Dhosa oolite facies is unique. The association of ooids within micritic groundmass indicates deposition in very unstable shelf regime under fluctuating energy conditions in near shore environment. The textural composition suggests intermixing of materials from two contrasting depositional environments; the ooids are likely to be derived from high energy agitated water condition while the lime mud is a typical product of calm waters. It is significant that the average diameter of the ooids of this facies is distinctly smaller than that of golden oolite facies of Jhura dome (grainstone/packstone) which is otherwise constituted by similar ooids. The heterolithic lower part of this facies, as a whole, represents relatively quiet water depositional setting. The finely laminated shales is in all probability the indigenous sediment. In contrast, the oolitic wackestone reveals an intriguing admixture of high energy and low energy products which can be due to either of the following reasons.

1. Derivation of the ooids from oolite bars and their ultimate deposition in a low energy lime mud depositing environments during storms.
2. Derivation of materials from two contrasting environments and eventually accumulation of the admixture without sorting.

The second hypothesis also involves rapid sedimentation as expected from a rapidly waning episodic current such as those created by storms.

According to the first hypothesis, the lime mud has to be the indigenous sediment. In presence of close association of a more reliable indigenous sediment, namely shale, this interpretation seems unlikely. The second hypothesis is more tangible, implying that both the ooids and the lime muds along with the terrigenous materials together were extraneous and brought in the present site only during high energy events.

Jhura dome

The Jumara Formation here is represented by several coarsening upward sequences, starting from shales ending up with fine to medium grained sandstones or conglomerates. Deposition of shales is often interrupted by thin fossiliferous limestone beds. This also signifies cyclically transgressive deposits when mud supply was abundant with moderate sand supply during stillstands (Busch, 1974).

The ridge sandstone facies developed in the middle part of Jumara Formation represents a beach deposit above subtidal shales and also point to a regressive phase which culminated in a diastem as is evident from the upward passage to conglomerate. The pebbly grit facies also indicates a diastem.

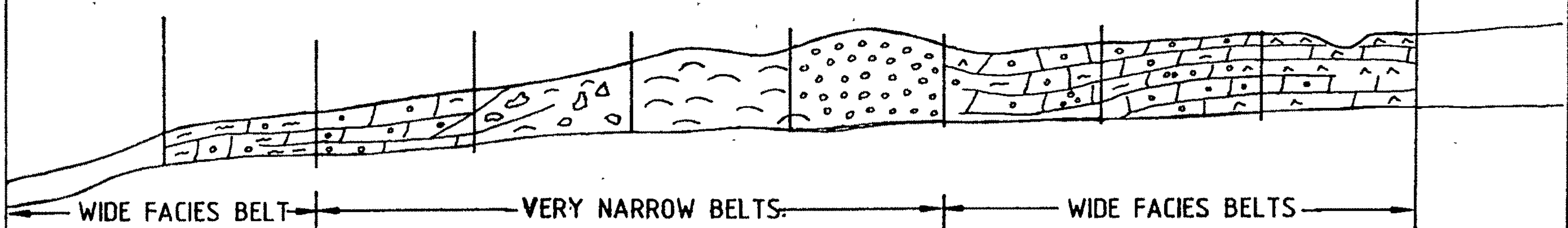
This regression is followed by a transgression depositing shales till the shallowing of the basin again towards the top of the formation (Oxfordian) as indicated by the Dhosa oolite facies deposited close to the wave base.

Habo dome

The depositional environment of Jumara Formation here follows the similar trend as discussed in case of Jhura dome. The calcareous sandstone facies which is correlatable with the ridge sandstone facies represents a beach environment. In Jhura dome, it is forming a narrow ridge surrounding island during deposition, whereas, these beaches prograde over subtidal deposits to build sheet like cross bedded accumulations. The cross bedding within the sandstone of Habo dome is supports this view. The Dhosa oolite facies is a transgressive condensation horizon (Singh, 1989) representing the Worldwide sea level rise during the Oxfordian time.

Stable conditions following a marine transgression over a gently seaward dipping slope (ramp) bring about the evolution from a simple pattern of nearshore sands and offshore muds into a mature carbonate platform with differentiated facies (**Fig.VIII.4**). According to Wilson (1975), not every carbonate province of the past will show all these facies belts side by side as represented in this idealized arrangement. The vertical arrangement of the facies that we see in geological sections help us to interpret the sequence of events and the major trends in tectonic, climatic

BASIN	OPEN SEA SHELF	DEEP SHELF MARGIN OR BASIN MARGIN	FORESLOPE	ORGANIC BUILD UP OR PLATFORM MARGIN	WINNOWED PLATFORM EDGE SANDS	OPEN PLATFORM (SHELF LAGOON)	RESTRICTED PLATFORM (SHELF & TIDAL FLATS)	PLATFORM EVAPORITES (SABKHA)	LAND
1	2	3	4	5	6	7	8	9	



1, 2, 3	2, 8, 9, 10	2, 3, 4	4, 5, 6	7, 11, 12	11, 12, 13, 14, 15	8, 9, 10, 16, 17, 18	16, 17, 18, 19, 20, 21, 22, 24	20, 23	SMF TYPES
DEEP MARINE	DEEP NERITIC MARINE SEDIMENT ATION	SEDIMENT ATION OF CARBONATE DETRITUS AND PELAGIC MATERIAL	INSTABLE SEDIMENTA-TION OF DEBRIS	ORGANIC REEFS	SHOALS, COASTAL AREAS OR TIDAL BARS EOLIAN DUNE SANDS ON ISLANDS	BAYS & OPEN LAGOONS BEHIND THE OUTER PLATFORM EDGE	CUT-OFF LAGOONS & COASTAL PONDS WITH RESTRICTED CIRCULATION	INTERMIT-TENTLY FLOODED SUPRATIDAL AREAS ARID CLIMATE	FACIES BELTS.

PENE-CONTEMPORANEOUS DEVELOPMENT OF CARBONATE FACIES BELTS (AFTER WILSON, 1975) : AND SEQUENCES OF THE STANDARD MICROFACIES TYPES.

FIG.VIII. 4

and sea level evolution of the area. The Wilson's model offers essentially a single model for prediction of geographic distribution of rock types.

Based on different sedimentological parameters, like depth, latitude, salinity, water movement, light penetration etc. that control the deposition in a marine environment, Wilson (1975) and Flugel (1972) have organized different microfacies into 24 standard microfacies types. They suggested grouping of these into nine standard facies belts of the generalized model as dicussed above. Such grouping is very useful while discussing the depositional environment of any ancient carbonate sequences.

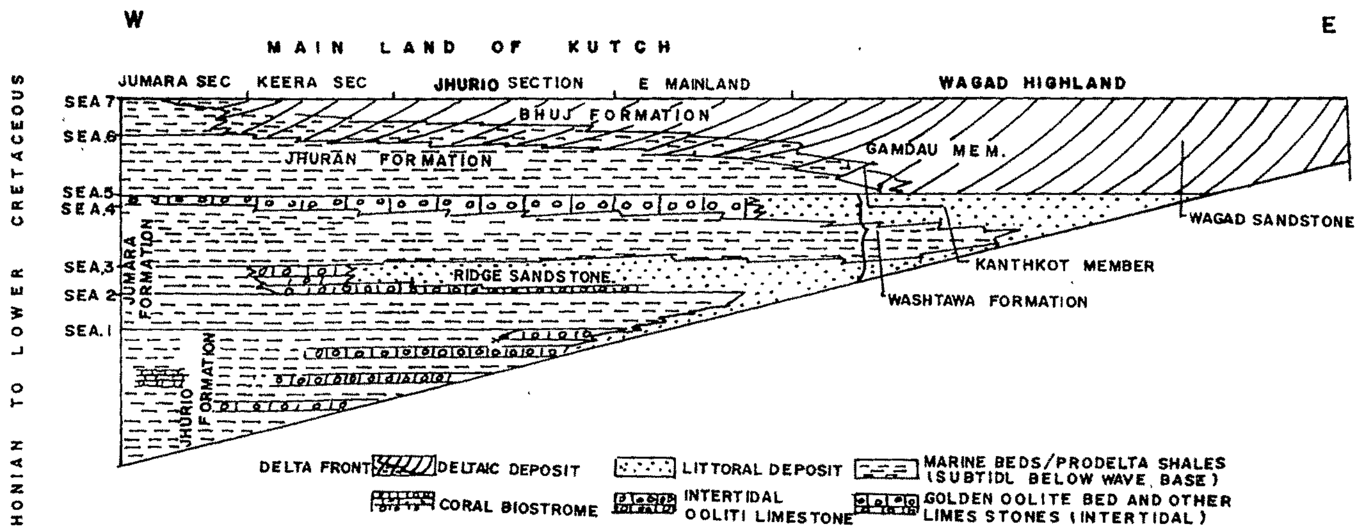
The author has in the present study made an attempt to correlate the microfacies observed under Jhurio and Jumara Formations with the Standard Microfacies type. It has been observed that the majority of microfacies under Jhurio Formation can be interpreted with the SMF Types 8, 9, 11, 15 and 16, whereas, the microfacies of Jumara Formation can be accomodated within SMF type 9, 10 and 24. These standard microfacies types represent a particular set of depositional environment as can be seen from Fig.VIII.4.

Biswas (1981), while discussing the depositional history of Kutch basin, has proposed a model of environmental reconstruction by stacking facies tracts of successive time slices and by correlating litho-units from different stratigraphic column (**Fig.VIII.5**). The field and laboratory studies carried out in the study area supports the model proposed by Biswas (1981).

Based on above, paleoenvironmental reconstruction indicates that a major transgressive marine cycle is responsible for the deposition of Jhurio and Jumara Formations. This transgressive megacycle consisted of transgressive-regressive microcycles which are correletable with the different lithofacies in a vertical column.

The depositional history began in Upper Bathonian. During this initial transgression, the sea advanced cyclically, and during still stands deposited interbedded shales and limestones of Jhurio Formation. The Jhurio Formation of Jumara dome is deposited in a subtidal open outer shelf marine environment, whereas carbonate sequences of Jhura and Habo dome are deposited in an intertidal shallow marine environment. Therefore, the corals of Jumara are coeval with the limestone and golden oolite facies of Jhura dome and formed in lower bathymetry.

The sea advanced further in Lower Callovian time when shales of Jumara Formation were deposited in a subtidal outer shelf environment. The subsequent regression in Upper Callovian was short and indicated by the ridge sandstone facies of Jhura dome and sandstone facies of Habo dome. The transgression that followed in Lower Oxfordian marks the



SEA-1 END OF BATHONIAN (TRANSGRESSIVE)
SEA-2 EARLY CALLOVIAN (TRANSGRESSIVE)
SEA-3 LATE CALLOVIAN (REGRESSIVE)
SEA-4 ARGOVIAN (PEAK OF TRANSGRESSION)
SEA-5 LATE OXFORDIAN (REGRESSIVE)
SEA-6 KIMMERIDGIAN-TITHONIAN (TRANSGRESSIVE)
SEA-7 EARLY CRETACEOUS (FINAL REGRESSION OF MESOZOIC SEA FROM THE BASIN)

SCHEMATIC EAST - WEST STRATIGRAPHIC SECTION OF THE KUTCH BASIN

(AFTER BISWAS, 1981)

(NOT ON SCALE)

FIG. VIII. 5

highest stand of the sea in Kutch basin when upper Jumara shales were deposited over shoreline deposits of previous cycle in Jhura and Habo domes. This was followed by a regression in Upper Oxfordian. This regression is marked by the deposition of silty oolitic limestone bed of Dhosa oolite facies. The unconformity above the Dhosa oolite facies marks a sharp environmental break in the vertical sequence. Huge thickness of clastics were deposited in Upper Jurassic onwards in marked contrast with the shale and carbonate of Middle Jurassic.