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STRATIGRAPHY AND SEDIMENTOLOGY OF THE MIDDLE JURASSIC (CALLOVO-OXFORDIAN) SEQUENCE OF HABO HILL, KUTCH (GUJARAT)

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Abstract

The Kutch Basin, a typical pericontinental embayed basin occupying a rifted graben, is filled with a thick Mesozoic succession of rocks which are exposed in the highlands. The study area, located to the northeast of Bhuj, is roughly elliptical in outline with its long axis trending approximately E-W. The Jurassic Sequence of rocks with varied lithologies exposed in the Habo Hill show quaquaversal dips. The older litho-units are disposed in the central region and are surrounded on all sides by younger ones. In all, five lithofacies associations (LFA 1 to 5) have been identified based on the lithological variations which corresponds to the five members of the Habo Formation as designated by Kanjilal (1978) indicating the fluctuating condition of the depositional basin. Two distinct sedimentary sequences are observed : (i) shale and carbonates, and (ii) coarse clastics. The first sequence includes a variety of light to dark coloured shales and limestone. The limestone is generally thin-bedded biomicrite consisting of mud-supported allochemical particles, while the shale is thin to thickly laminated comprised of a varied clay mineral assemblage. The second sequence comprises conglomerate and sandstone. The sandstone is relatively well-bedded quartz-arenite with ferrugenous and calcite cements. The stratigraphic variation of field observations, texture and mineralogical characters suggest an early regressive and later transgressive phase of the depositional environment.

General

The Kutch Basin, a typical continental margin (pericratonic) embayed basin occupying a rifted graben, exposes an impressive sequence of rocks ranging in age from the Middle Jurassic to the Late Cretaceous in six highland areas of Kutch (viz., Kutch Mainland, Wagad, Pachcham, Khadir, Bela and Chorar). The Tertiary strata crop out in the bordering plains which are covered at many places by Recent sediments.

The fabulous fossil wealth of Kutch, especially ammonites, has attracted the attention of many paleontologists and stratigraphers for over a hundred years and has been the subject matter of many memoirs/monographs and papers. Although there have been a number of publications on the palaeontology of the Kutch Mesozoic succession, comparatively very little has been published on the integrated stratigraphy and sedimentation history of the Jurassic sequence. Further, for a long time the geologic investigations in the Kutch Basin centered on the exposures that are palaeontologically important. Some of the important contributions on the Kutch Mesozoic include those of Rajnath (1932), Balagopal and Srivastava (1973), Biswas (1971, 1977, 1981, 1987), Agarwal (1978), Jaikrishna *et al.* (1983), Singh (1989)

and Pandey and Dave (1993). Though studied for more than a century, no attempt was made to undertake a systematic integrated study for understanding the sedimentation history of the Jurassic succession in the area. Therefore, the present work has been undertaken with the objective of providing additional information on the Jurassic sequence of the area and for filling gaps in the literature. In addition to the field and laboratory data gathered by authors, the published information of Kanjilal (1978) has been utilized for the interpretation of sedimentation history based on the lithofacies characteristics.

Geology and Stratigraphy

The Habo Hill, located approximately 20 km NE of Bhuj, is roughly elliptical in outline (15 km long and 6 km wide) with its longer axis trending approximately E-W (Fig. 1). The southern slopes are relatively gentler whereas the northern ones are steep. The Jurassic sequence exposed on these hills is popularly known as the Habo Formation (an equivalent to Chari/Jumara Formations of earlier works). The available faunal evidence from the literature suggests that the Habo Formation is Callovian-Oxfordian in age. Kanjilal (1978) has identified five members based on lithological variations, and the lithostratigraphic classification proposed by him is presented in Table 1. The area has been investigated along selected traverses (Fig. 1) to cover all the Jurassic outcrops and necessary rock samples and sedimentary structural data have been collected along these traverses. In all, about 100

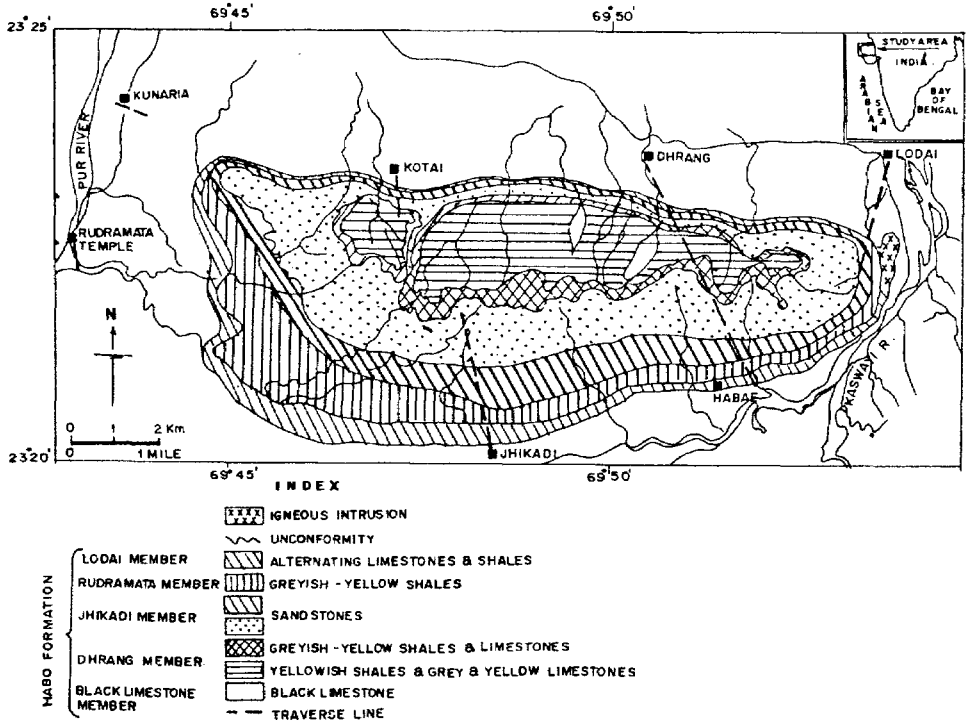

Fig. 1. Geological Map of the Habo Hill, District Kutch, Gujarat (after Kanjilal, 1978)

samples collected from the field have been subjected to mineralogic and textural studies. The five members of Kanjilal (1978) are described in the following paragraphs.

TABLE 1: THE MIDDLE JURASSIC STRATIGRAPHIC SUCCESSION OF HABO HILL

Formation	*Member*	*Lithology*	*Age*
		Gypsiferous shale and sandstone	Middle Kimmerdgian
		Disconformity	
	Lodai	Alternating beds of limestone and shale (limestone yellowish to light brown; shale greyish green to yellowish)	Oxfordian
	Rudramata	Yellowish shale overlain by ferrugenous sandstone	
Habo	Jhikdi	Ferrugenous and Calcareous sandstone with beds of shale and discontinuous conglomerate and coral bed on top sandstone exhibits cross-beddings and ripple marks	Callovian
	Dhrang	Yellowish to greyish yellow limestone and yellowish shale	
	Black Limestone	Black to greenish grey limestone	Bathonian
		Base not exposed	

Black Limestone Member

The oldest member of the formation is well exposed in the scarp section facing the Kalajar Nala, south of Dhrang village. The lithology of the member consists mainly of black to greyish black, hard, compact limestone, thick-bedded/massive in the lower part and thin-bedded in the upper part. Although the base of the limestone member is not exposed at many places, it has been observed that it directly overlies a basic igneous dyke rock. The allochemical constituents of the limestone include mainly pellets and a few superficial oolites set in a microsparitic matrix.

Dhrang Member

The typical section of this member is seen in several nala sections south of Dhrang village. Limestone, calcareous sandstone and subordinate shale form its dominant lithology. A number of narrow, laterally discontinuous conglomeratic horizons are encountered. There is an increased fossil and clastic content in the limestone of this member as compared to the Black Limestone member. Limestone is fossiliferous and sandstone is fine to medium grained, moderately sorted and belongs mainly to quartz-arenite to feldspathic-arenite categories. Kaolinite and chlorite form the important clay minerals of the shale.

Jhikdi Member

This member is well exposed to the north and northwest of Jhikdi village. The member is comprised mainly of sandstone with subordinate silty shale. The sandstone is mainly

ferrugenous with a few slightly calcareous variations. The sandstone is relatively coarse grained and better sorted than that of the underlying Dhrang Member. Cross-bedding of different types, such as herringbone cross stratification (Plate 1.1) and trough stratification are the common depositional structures observed. Large interference ripples (Plate 1.2) are also observed at some localities. Perfectly rounded nodules of ferrugenous quartzite resembling load ball structures are quite common in the sandstone.

Rudramata Member

Greyish to yellowish shale and limestone and subordinate sandstone constitute the main lithology of the Rudramata member exposed in the northwestern and western parts of the Habo Hills. Sandstone is ferrugenous, fine grained with abundant monocrystalline quartz. A fossiliferous intraformational conglomerate with flat marly pebbles set in a fine-grained matrix is the characteristic bed of this member. Shale is gypseous, and kaolinite and chlorite are the important clay minerals present in it. Limestone is very fine grained and belongs to mudstone to wackestone categories (Plate 2.1).

Lodai Member

This forms the youngest member of the formation and is well exposed in a nala section SW of Lodai village. Alternate shale and limestone intergradations constitute the main lithological component of the member. Atleast 15 transitions from shale to limestone have been observed. The limestone is yellowish brown in colour and protrudes as hard beds because of its resistance to weathering, whereas the shale is darker in colour and weathers easily. The thickness of the calcareous layers increases gradually towards the top. Limestone and shale are highly fossiliferous. An oolitic sandy limestone marks the top of the formation with a disconformble contact (Plate 1.3).

Lithofacies Association

A summary of the general lithologic observations including sedimentary structural data of the Middle Jurassic succession of the Habo Hills is presented in Table 2. The broad spectrum of lithologies and depositional textures represented in the Habo Formation have been grouped in the present study into lithofacies associations (LFA) on the basis of inferred genetic relationships.

1. *Quiet Water Subtidal Carbonate Association*

Rocks of this association belonging to the Black Limestone member consist predominantly of carbonate mudstone (burrowed) with rare to common interbeds of peloid, bioclastic wackestone-packstone (Plate 2.1). Beds are relatively thinner and vary from section to section. Laterally, these rocks vary into lime mudstone to wackestone to packstone. Compositionally, the limetsone consists mainly of pellets, a few superficial oolites set in fine grained calcitic cement. Strata of this association characterize a relatively low energy condition of the depositional environment below the wave base.

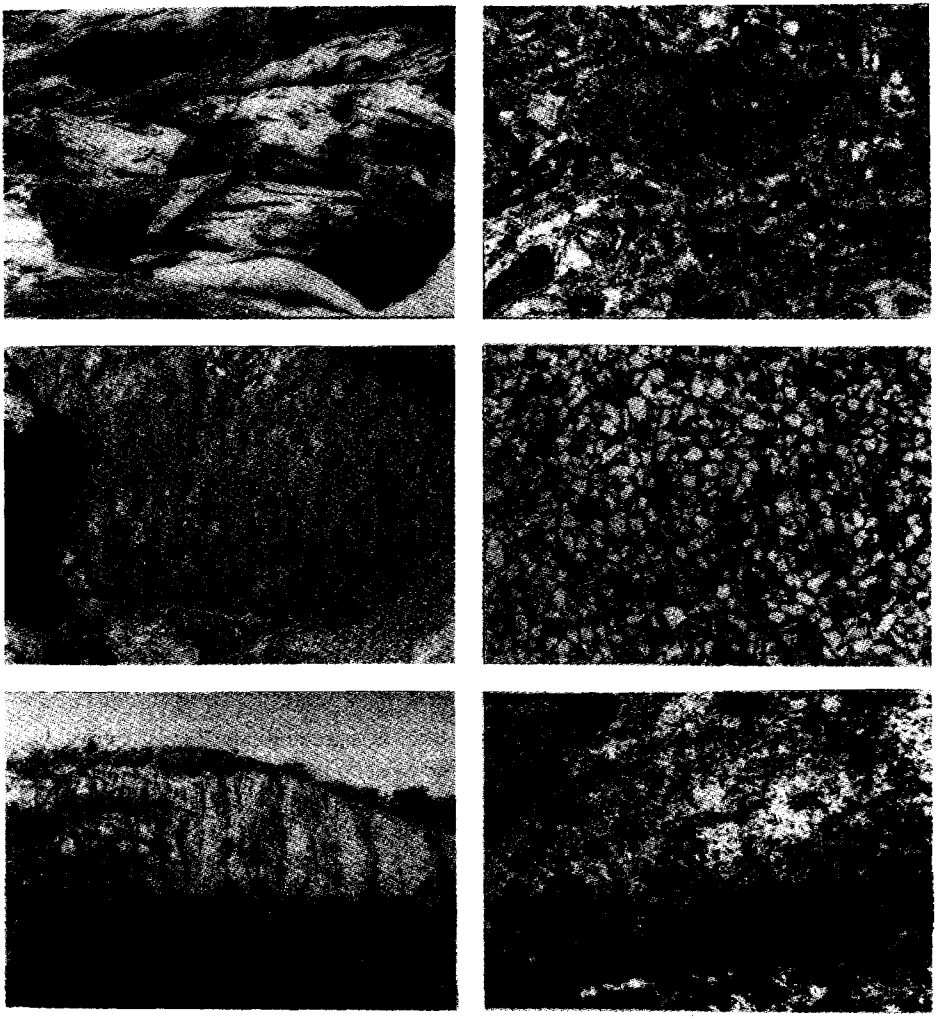

Plate 1. 1.1. A Section of Sandstone Exhibiting Herringbone Cross-bedding (Jhikdi Member, Habo Formation). **1.2.** Sandstone Exhibiting Large Scale Ripple Marks (Nala Section, NW of Jhikdi Village). **1.3.** The Disconformable Contact of the Lodai Member (LFA 5) with the Overlying Oolitic Limestone

Plate 2. 2.1. Photomicrograph of Algal Biomicrite (Bioclastic Wackestone). (LFA 1, Dhrang Member). **2.2.** Fine to Medium Grained Moderate to Well Sorted Sandstone Belonging to LFA 2. **2.3.** Photomicrograph of a Laminated Lime Mudstone

TABLE 2: LITHOLOGIC CHARACTERISTICS OF THE HABO FORMATION

Lithology	*Bedding*	*Texture*	*Composition*	*Petrographic Type*	*Remarks*
Sandstone	Well bedded Cross-bedded	Fine-medium grade subangular-subrounded moderately sorted	Qz, FS, mica ferrugenous and calcitic cements	Quartz arenite	Compositionally mature Texturally submature
Limestone	Thin bedded	Mud supported grain supported	Pellets, intraclasts oolites and fossils	Biomicrites	Relatively low energy conditions fluctuating
Shale	Thin to thick laminated lenticular	Preferred orientation and disturbed lamination	Clay minerals (kaolinite and chlorite) silt, pyrite	Light to dark coloured	Quiet water, episodic

2. *Mixed Siliciclastic Carbonate Shallow Marine Association*

A variety of lithofacies, including rippled, cross-stratified sandstone, burrowed sandstone, siltstone, peloid packstone, form this association which is about 15-20 m thick (Dhrang member). The burrows indicate that these rocks are deposited in a marine setting and this interpretation is supported by the presence of carbonate material either as detrital grains or interstitial material in sandstone. The sandstone (Plate 2.2) is fine to medium grained and moderately sorted and exhibits a relatively coarsening upward sequence. The relatively coarser size, presence of shallow water fauna, presence of much feldspar in sandstone and the sorting characterize a relatively shallow water at wave zone environment.

3. *Predominantly Terrigenous Valley-fill Association*

The rocks of this association (Jhikdi member) include a predominant sandstone followed by a few conglomerate and rare shale beds. The sandstone displays herring-bone cross-stratification, which may indicate a shoreface beach environment. The thickness of this strata varies from 68-130 m with an average value of 98 m.

4. *Quiet Water Lagoonal Shale—Carbonate Association*

The rocks of this formation include the shale and limestone of the Rudramata member. The shale is gypseous and is comprised of clay minerals chlorite and kaolinite. Limestone is mainly fossiliferous wackestone and is dolomitized. The strata of this association characterize a tidal flat lagoonal environment.

5. *Cyclic Shallow-water Peritidal Carbonate-shale Association*

Small scale succession of cycles are exposed near Lodai village NE of the Habo Hill (Lodai member). The cycle consists of shale at the base followed by laminated lime mudstone (Plate 2.3) or peloid packstone. Cycles are not regular and an increasing thickness of carbonate beds with decrease in associated shale thickness is observed. The strata have been interpreted as shallow water, tidally influenced cyclic deposit. The carbonate mud-rich facies was deposited under relatively low-energy conditions. Lack of much skeletal debris and limited bioturbation

in the laminated mud-rich carbonates suggest that deposition took place under conditions of restricted circulation.

This *Carbonate Shale Association* consisting mainly of oolitic limestone overlies the Habo Formation and indicates a high energy condition of the depositional basin.

Depositional Environments and Sedimentation History

The Kutch graben is the earliest rift basin which opened up during the beginning of the rifting of the Indian Plate from Gondwanaland in the Late Triassic times. Much of the Mesozoic sedimentation took place in the early-rift phase of the evolution of India's Western Continental Margin (Biswas, 1982).

The two megacycles, namely, the Early Mesozoic transgression and the Late Mesozoic regression, register the two major tectonic phases (i.e., early rift phase and its termination by failing of rifting processes (Biswas, 1982). The Jurassic sedimentation in the Kutch Basin corresponds to this early rift phase and represents a fluctuating transgressive sequence with small cycles of transgression and regression. Field and laboratory studies of the various rock types indicate fluctuating depositional conditions of the sedimentary basin through time. The Early to Middle Jurassic transgression (1st order) accompanied by carbonate and shale sedimentation continued till the mid-Callovian in a slowly, probably cyclically subsiding basin. During this time the lower two members (viz., Black Limestone and Dhrang members) corresponding to LFA 1 and LFA 2 were deposited in low-energy quiet water conditions of the depositional environment. The overlying thick sequence of sandstone and associated conglomerate (Jhikdi member - LFA 3) represent the shoreline regressive sands. Subsequent transgression in the Late Callovian-Oxfordian resulted in the deposition of the top two members (viz., Rudramata and Lodai) corresponding to LFA 4 and LFA 5.

TABLE 3: LITHOFACIES CHARACTERISTICS OF MIDDLE JURASSIC SUCCESSION OF THE HABO HILL

Member	*Bedding*	*Lithology*	*Biota*	*Clay Minerals*	*Texture*	*Environment*	*Sea Level* – 0 +	*Age*
Lodai (LFA 5)	Thin bedded	Limestone & shale	Abundant Diverse	Kaolinite Chlorite	Non-clastic	Sub-littoral		Oxfordian
Rudramata (LFA 4)	Bedded	Sandstone, shale & Limestone	Abundant	Kaolinite Chlorite	Fine, Moderately sorted, +ve	Sub-littoral		
Jhikdi (LFA 3)	Well bedded (cross-bedded)	Sandstone, shale & conglomerate	Few (molluscans)	Kaolinite	Medium, Well sorted + ve	Beach (Littoral)		Callovian
Dhrang (LFA 2)	Bedded	Shale, Limestone and Sandstone	Abundant	Kaolinite Chlorite	Fine, Moderately sorted, -ve	Wave zone		
Black Limestone (LFA 1)	Thin bedded	Limestone and shale	Few	Kaolinite, illite	Non-clastic	Quiet Water below wave zone		Bathonian

Sequences represent inter-relationships of several environments. The study of aerial variations in an environment and vertical facies relationship helps us to interpret the sedimentation history of the basin. As sedimentation proceeds with time, facial boundaries migrate laterally under the influence of transgression and regression and different facies are arranged in an orderly sequence so that those geographically contiguous will become stratigraphically successive in a vertical profile (Walther's Law). The order in which facies are arranged depends upon the nature of transgressive or regressive sea level. In the present study it has been attempted to arrange the lithologic characters and depositional facies in a vertical order in order to interpret the fluctuations of the sea level. Two distinct sedimentary sequences identified based on selected parameters (Table 3) are related to lower regressive and upper transgressive phases. The predominantly shale and limestone unit (Black Limestone and Dhrang members) passing upwards into quartz arenite and finally to a conglomerate indicates regression. The subsequent development of shale and finally carbonate shoal-oolitic limestone deposition close to the wave base indicate a transgressive phase.

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