CHAPTER 2

PREVIOUS INVESTIGATION

Kachchh basin, situated at the western margin of the Indian plate, is considered as one of the most important Jurassic localities of the Indo-East African marine faunal province, and is globally famed for its rich and stratigraphically significant ammonoids. This region has fascinated geologists and palaeonlogists since the middle of the nineteenth century for its abundant fossils, well exposed sedimentary sequence, and mineral deposits.

The maximum amount of work has been done on megafossils from Jurassic rocks of Kachchh, especially ammonoids. Among the microfossils, some work has been done on foraminifera and ostracods. On the other hand, little attention has been paid on sedimentological aspects of Jurassic rocks of Kachchh including microfacies, petrofacies and diagenetic evolution of these rocks. It is beyond the scope of the present study to review the work done by earlier workers in different branches of Geology on this area. Only those references which concern only foraminifera, microfacies, petrofacies and diagenesis of the Jurassic sediments of Kachchh have been mentioned in detail.

Tewari (1957) reported benthic foraminifera – *Aulotortus* from the Patchum series of Habo hill, central Kachchh and also recorded *Textularia, Bigenerina, Spiroplectammina* and *Gaudryina* from these rocks.

Subbotina *et al.* (1960) described and illustrated thirty five species of foraminifera from southeast of Lodai village on the eastern flank of Habo hill, Khawda (in Rann of Kachchh) and also from Jurassic exposures of Rajasthan. These authors also observed that out of thirty five foraminiferal species twelve were new. These foraminiferal assemblages were recorded from Chari ‘series’ of Kachchh and Jaisalmer Formation of Rajasthan and suggested an age ranging from Callovian to Oxfordian.
Agrawal and Singh (1961) recorded the following genera of foraminifera from near Habo hill: *Rhabdammina, Ammodiscus, Ammobaculites, Quinqueloculina, Triloculina, Robulus, Lenticulina, Nodosaria, Saracenaria, Vaginulina, Palmula, Nonion, Elphidium, Rotalia* and *Anomalina*. These authors (Agrawal and Singh, 1961) pointed out that the presence of *Elphidium*, essentially a Tertiary genus, is unusual in the Jurassic rocks but they did not give any explanation for this anomaly.

Balgopal and Srivastava (1975) studied the palaeocurrent and provenance of Jurassic rocks of central Kachchh around the city of Bhuj between the north latitudes of 23°11' and 23°28' and east longitudes of 69°32' and 69°56'. Their study was based on petrography, heavy mineral and palaeocurrent pattern of the various rock units of Chari, Katrol and Bhuj formations. The petrography and heavy mineral content were utilized in deciphering the probable composition of the provenance with respect to the study area. The location of the source area was deciphered by means of palaeocurrent study using various primary sedimentary structures, such as cross bedding, parting lineation and ripple marks.

On the basis of their study, they found that the Chari Formation had received the detritus from north of the study area which consisted of low to medium grade metamorphic rocks, acidic igneous rocks, pegmatites and some basic rocks. According to these authors (op. cit.) the Precambrian schists, granites and associated pegmatites and basic rocks that today lie buried under the Great Thar Desert, constituted the provenance for the clastic sediments of Chari Formation. These authors also observed that the Katrol sediments received the detritus from the south consisting of medium to high-grade metamorphic rocks. It is most likely that the Katrol provenance lay along the southwest extension of the belt of Aravalli and Delhi rocks, now covered partly below the post Jurassic rocks in Kathiawar and partly under the Arabian Sea. The Aravalli Group of rocks now underlying the northern Gujarat plains in the east were the parent rocks for Bhuj Formation.
Bhalla and Abbas (1975a,b,c; 1976a,b; 1978; 1984) carried out detailed study on foraminiferal systematics, depositional environment and stratigraphy of Jurassic sediments exposed at Habo hill, Kachchh and published a series of papers. Bhalla and Abbas (1975a; 1976a) reported sixty-five species of foraminifera. The foraminiferal assemblage being dominated by family Nodosariidae which is represented by forty species. Out of the total species, ten were new and some were indeterminate species which were recorded for the first time from Jurassic of Kachchh. Bhalla and Abbas (1975b) described and illustrated variation in *Lenticulina subalata* (Reuss) and concluded that this species like other Jurassic Nodosariids, exhibits a wide range of variation and caution must be taken while dealing with taxonomy of nodosariids. Bhalla and Abbas (1975c) also reported the post-Jurassic elements in Jurassic foraminiferal assemblage of Habo hill. This includes thirteen genera represented by a small number of specimens with obliterated morphological features, frosted surface and well rounded shapes. On the other hand, the Jurassic foraminifera were abundant, well preserved and show clear morphological features without any strain on their shape and abrasion of their surface. These authors (Bhalla and Abbas, 1975c) suggested the following reason for the presence of the Post-Jurassic elements in the Jurassic foraminiferal assemblages of Habo hill, Kachchh: as Kachchh basin is bounded by beaches on the western and southern margins and marine Tertiary rocks are well exposed in its northwestern part. It is most likely that during summer months when strong westerly winds and dust storms prevail in this arid region, the post-Jurassic foraminifera along with other material were blown from western and northwestern parts of Kachchh and sprayed over the Jurassic exposures present in the eastern sector. Thereafter, they impregnated the Jurassic sediments through percolating water during rainy season and got entombed in the sediments as 'leaked' material. Bhalla and Abbas (1976a, 1984) discussed the palaeoecology of these sediments by dividing the entire sequence of Habo hill into five palaeoecological unit and suggested the overall deposition of Kachchh Jurassic took place in a near-shore, shallow water, tectonically unstable marine basin which fluctuated considerably between lagoonal, neritic and littoral environment from time to time. Bhalla
and Abbas (1976a) suggested a Callovian to Oxfordian age for the studied section of Habo hill and stated that the Jurassic foraminiferal assemblages of Kachchh compares well with the Jurassic foraminiferal assemblages of Rajasthan, Iran, Egypt, Afghanistan and Somalia, showing Tethyan affinities. On this basis, these authors supported the view that during Middle and Upper Jurassic times, the entire Rajasthan and Kachchh region were covered by a gulf of the Tethys which emerged from near Iran and after covering Afghanistan, Baluchistan and east coast of Africa extended to Madagascar. Bhalla and Abbas (1978) finally published a detailed illustrated account of the Jurassic foraminifera of Habo hill, Kachchh giving a systematic account of sixty five species. The studied section of Habo hill comprises Patcham, Chari and Katrol ‘series’. The first two ‘series’ contain rich foraminiferal assemblages and third one is barren of indigenous foraminifera of Jurassic age.

Shringarpure and Desai (1975) reported nineteen species of foraminifera belonging to family Nodosariidae from Manfara dome section of Wagad hill block, Kachchh.

Shringarpure et al. (1976) revealed an interesting phenomenon of faunal mixing in the Mesozoic stratigraphic sequence exposed in the western Wagad region of the eastern Kachchh. They observed that the foraminiferal assemblages are mixed with minor amount of ostracoda, bryozoa and echinoderm spines, along with microscopic plant tissues and insect skeletons of Tertiary, sub-Recent and Recent age, associated with older mesozoic sediments of Jurassic and Cretaceous periods. These authors (op. cit.) suggested that natural agencies like storm wave, stream current, wind action, ice rafting or even the activities of birds were responsible for this mixing. They also observed that robust foraminiferal genera of Ammonia, Nonion, Quinqueloculina, Elphidium, Discorbis, Cibicides etc. have undergone two previous depositional cycles before reaching their present depositional site.

Singh (1977) described and illustrated five species of genus Epistomina from the subsurface sequence at Banni, Rann of Kachchh. He proposed two
biostratigraphic assemblage zones, *Epistomina stellicostata* - *E. alveolata* Assemblage-zone and *E. ventriosa*–*E. mosquensis* Assemblage -zone and suggested a Late-Jurassic age for the subsurface rocks.

In extension of his previous study, Singh (1979) proposed seven biostratigraphic zones for the subsurface Jurassic sequence of Banni, Rann of Kachchh, on the basis foraminifera, *Charites* spp., and ostracoda. These seven zones are as follows: Barren zone, *Charites-Otocythere* Assemblage-zone, *Lenticulina dilectaformis*–*L. carinocordatus* Assemblage-zone, *Epistomina stellicostata*–*E. alveolata* Assemblage-zone, *Eoguttulina liassica*–*Vaginulina cryptospira* Assemblage-zone, *Lenticulina–Nodosaria* Assemblage-zone, *Epistomina ventriosa* – *E. mosquensis* Assemblage-zone and *Lenticulina* zone. He also suggested that the beds of *Charites-Otocythere* Assemblage-zone were deposited in a brackish to marine environment whereas rest of the sequence was deposited in an inner-neritic environment.

Bhall and Talib (1978; 1980) reported nineteen foraminiferal species from a section of Chari ‘series’ near Badi village, central Kachchh. On the basis of foraminiferal assemblages combined with field observations, it was suggested that the overall deposition of Chari sequence near Badi was accomplished in a near-shore, shallow-water, marine environment which fluctuated between littoral to infraneritic conditions. These authors also assigned a Callovian-Oxfordian age to the studied sequence on the basis of foraminiferal assemblage. The Badi foraminiferal assemblage shows close affinities with those described from other regions of the Tethyan realm and supported the contention that during the Middle and Late Jurassic time, a gulf stretched from Tethys in the north to Madagascar in the south, which also covered the Kachchh region.

Deshpande and Merh (1980) proposed a sedimentary modal of Wagad hill in the eastern part of Kachchh, western India; comprising environment of deposition, basin geometry, lithic fill, lithic arrangement, directional structures and tectonic setting. The rocks exposed in studied area range in age from Middle Jurassic to Lower Cretaceous and are encircled by a thin and
narrow fringe of Tertiary sediments. These authors suggested that the area experienced a prograding delta system with gradual shift of stand line from east to west during the course of deposition.

Bhalla and Lal (1985) reported seventeen species of Jurassic foraminifera from Chari sequence, exposed in the northern flank of Kaiya hill, Kachchh. On the basis of filed and foraminiferal investigations, these authors suggested that the overall deposition of Chari sediments at Kaiya hill took place most probably in a near shore, shallow water, marine environment. The presence of Citharina hetropleura, Dentalina guembeli and Patellinella poddari indicates a Callovian to Oxfordian age for the studied section.

Bhalla and Talib (1985a, b, c; 1991) published a number of papers on the foraminiferal systematics, biostratigraphy and depositional environment of the Jurassic Sediments exposed at Jhurio hill, Kachchh. Bhalla and Talib (1985b, c) reported fifty-three species of Jurassic foraminifera from the Jhurio hill, Kachchh. Of these, only two were new and majority of them were described for the first time from the Indian region. The foraminiferal assemblage was dominated by the family Nodosariidae. The foraminiferal assemblage also included nine post-Jurassic foraminiferal species. The post-Jurassic foraminifera show sign of wind borne sediments and appear to have been brought in from the Tertiary sediments and Recent beach sands exposed in nearby western areas by strong westerly winds prevailing during summer months in the region and then getting entombed in the Jurassic sediments through percolating rain water during monsoon season. These authors (Bhalla and Talib, 1985c) suggested the depositional environment of the Jurassic sediments exposed at Jhurio hill, Kachchh, on the basis of foraminiferal assemblages combine with field observation and concluded that these sediments were deposited in a near-shore, shallow water, marine basin which was tectonically rather unstable as evidenced by occasional shifting of the shoreline. The present Jurassic foraminiferal assemblage exhibits close affinity with Jurassic assemblages from other regions belonging to Tethyan Realm, viz., Afghanistan, Iran, Egypt and Somalia. These authors also assigned a Callovian to Oxfordian age to the studied sequence on the basis of
foraminiferal evidence and demarcated, Callovian-Oxfordian boundary. Bhalla and Talib (1985a) carried out detailed variation study in *Lenticulina quenstedti* (Guembel) and concluded that this species like other Jurassic nodosariids, exhibit a wide range of variation in its morphology and commented that precaution must be taken while dealing with taxonomy of Jurassic nodosariids. In view of their previous study, Bhalla and Talib (1991) presented a detailed systematic account and illustrated the foraminiferal assemblage of the Jurassic sediments exposed at Jhurio hill, Kachchh.

Govindan *et al.* (1988) described and illustrated benthic foraminiferal species belonging to Epistominids, Lenticulinids and agglutinated genus *Dorothyia* across the Jurassic-Cretaceous boundary, from wells drilled in Kutch Mainland. These authors (Govindan *et al.*, 1988) marked the Early Cretaceous-Late Jurassic boundary between the extinction level of *Epistomina caracolla* and *Epistomina stelliscotata*. These authors (Govindan *et al.*, 1988) divided the entire sequence into six assemblage zones on the basis of highest occurrence level of zonal markers.

Bhalla and Gaur (1989) erected a new vaginulinid species from the Jurassic (Callovian) sediments of Jumara hill, central Kutch. The new species was designated as *Marginulina jumaraensis* and these authors (Bhalla and Gaur, 1989) inferred that it thrived in a wide range of environmental conditions from shallow, open marine to paralic, such as marsh or lagoon.

Mandwal and Singh (1989) described and illustrated thirteen index benthic foraminiferal species of genera *Garantella*, *Epistomina*, *Pseudomarssonella*, *Riyadhella*, *Singhamina* and *Tandonina*, for the first time from the Patcham – Chari sediments exposed in Jhurio hill, Kachchh. On the basis of these species, the authors (Mandwal and Singh, 1989) suggested a Bathonian age to the sequence exposed in the lower part of Jhurio hill and also demarcated Bathonian – Callovian boundary in the exposed sequence. These authors Mandwal and Singh (1993) reported new foraminiferal genus *Indomarssonella* with three species described from the Bathonian sediments of Jhurio hill, Kachchh. They placed the new genus into subfamily Paravalvulininae of the family Chrysalidinidae in view of its close resemblance with *Pseudomarssonella* Redmond in test morphology.
In their subsequent paper, Mandwal and Singh (1994) reported ninety-five species of foraminifera from Patcham and Chari formations of Jhurio hill (Jhura Dome), Kachchh, Western India. They assigned the species to 47 genera belonging to eighteen superfamilies. On the basis of the foraminiferal assemblage these authors also suggested a Bathonian – Oxfordian age for the Patcham and Chari formations of Jhurio hill and demarcated the Bathonian/Callovian as well as Callovian/Oxfordian boundaries in this area.

Pandey and Dave (1993) presented detailed systematics and illustrated account of the Jurassic benthic foraminifera of Kachchh. They selected six surface sections from western Kachchh, viz., Jhurio Dome, Jumara Dome, Habo Dome (Kalajar Nala), Mundhan Anticline, Umia river and Patcham Islands (Khavda Nala) and discussed each section with respect to its geological and stratigraphic setting, abundance and distribution of foraminifera, benthic foraminiferal zonation and chronostratigraphic units. They also made an attempt to define Jurassic- Cretaceous boundary on the basis of foraminiferal assemblages. These authors (op. cit.) also suggested Bathonian age to the lower part of Jhurio hill, on the basis of following foraminiferal species: *Epistomina khawdensis, E. regularis, E. coronata, E. ghoshi, Lenticulina bulla, L. diletcaformis, L. tricarinella, L. suturofusus, L. subalata, Vaginulina barnardi, Dorothia poddari, Spirillina polygyrata, Trocholina conosimilis, Garantella sp., Saracenaria triquetra and Marginulina haynesi*. However, their age assignment is either based on the forms which are long ranging or on the basis of species described from Kachchh basin only.

Dave (1996) introduced Dhosaian stage to the marine sediments comprising Dhosa Shale and Dhosa Oolite of Oxfordian stage. He reported rich benthic foraminiferal assemblages in the type section of Jumara Dome (Jumara formation). The common species include: *Epistomina majungaensis, Lenticulina quenstedti, L. bulla, Haplophragmoides bartensteini* and *Proteonina diffugiformis*. On the basis of foraminiferal assemblages the author identified two foraminiferal biozones viz., *Epistomina majungaensis* Range-zone and *E. majungaensis – L. bulla* Interbiohorizon (poorly
fossiliferous-zone and suggested the depositional environment of Dhosaian stage in shallow shelf, open marine environment.

Nandi and Desai (1997) made a detailed diagenetic study of the middle Jurassic carbonates exposed in Jumara, Jhura and Habo hills along the E-W axis of the depositional basin in Mainland of Kachchh. They described the various diagenetic features and interpreted the depositional environment of these sediments.

On the basis of their study, they revealed that the depositional and post-depositional changes took place mostly under the pheritic conditions in marine as well as fresh water environments. The evidences gathered by them also suggest diagenesis in a mixed-marine and fresh water as well as burial environment.

Bhalla et al. (1998) tried to reconstruct the depositional environment of Jurassic sediments of Chari Formation (Callovian-Oxfordation), exposed at Jhurio hill, Kachchh, on the basis of Carbonate microfacies and foraminiferal palaeoecology. These authors divided the studied sequence into five palaeoecological units, based on foraminiferal assemblages which accumulated in different depositional regimes. The limestones of the Chari sequence were employed to divide the entire sequence into four microfacies which suggested deposition in open beaches, shallow shelves, protected area and deeper part of the shelf. Overall study based on foraminiferal study suggested that the deposition of the Chari sequence exposed at Jhurio hill, Kachchh took place in a near shore, shallow marine basin which was tectonically unstable.

Dubey and Chatterjee (1999) broadly described the paleoclimate and depositional history of Mesozoic Basin of Kachchh, Gujarat and selected five consecutive domes from NW to SE, viz., Ghuneri, Sahera, Mundhan, Jara and Jumara for this purpose. In the studied area, oldest rocks are of Bathonian age, exposed in the centre of Jumara dome whereas the youngest rocks are of Late Cretaceous age are exposed on the southwest periphery (below laterites) in Ghuneri dome. During their study these authors (op. cit.) observed that the
Mesozoic sandstones of Kachchh basin contain detritals derived from coarsely crystalline parent rocks which were transported for relatively short distances before accumulating in coastal environments. The systematic variation in compositional maturity of Mesozoic sandstone suggested the change in paleoclimate of western India (arid/semiarid/semihumid/humid) from middle Jurassic to Late Cretaceous. The samples plotted on QFR ternary diagram exhibit clustering of samples in arid and humid fields. This suggested gradual removal of unstable minerals and rock fragments in humid climates. Petrography of sandstone reveals less dissolution of grains during diagenesis and lithification.

Bhalla et al. (2000) synthesized foraminiferal assemblage from Chari Formation (Callovian-Oxfordian), Jhuria hill, Kachchh with petrography and diagenetic study for interpreting the depositional environment, provenance and diagenetic pattern of the studied sequence. The dominance of nodosariids in assemblages indicates a shallow near shore, open marine environment of deposition. These authors observed that the different proportions of calcareous and arenaceous species at different levels in the sequence indicate occasional shifting of shoreline and also suggest the unstable nature of the basin in which Chari sediments were deposited. For the study of the provenance of the sandstone in light of plate tectonics, these authors employed the Qt-F-L and Qm-F-Lt triangular diagrams of Dickinson. These two plots of the samples from the Jhuria area suggested that the sandstones were derived from continental block orogenic provenance. These authors also made an attempt to study the diagenetic pattern of Jhuria hill sandstones that demonstrates a close relation to various phase of subsidence and uplift in the tectonically unstable sandstone from the time of deposition. Uplift of the area caused fresh water dissolution of carbonate and partial oxidation of iron.

Gaur and Singh (2000) described and illustrated a foraminiferal assemblage from Jurassic sequence of Kaiya hill, Kutch comprising forty-four species. Based on the foraminiferal assemblage, these authors (op. cit.) assigned a Callovian-Oxfordian age to the studied sequence and divided it into four biozones.
Gaur and Sisodia (2000) recorded forty-one foraminiferal species from Jurassic rocks of Keera hill, Kachchh. These authors *(op. cit.)* marked four benthic foraminiferal biozones within the studied sequence on the basis of the recovered assemblage.

Talib and Gaur (2005) discussed foraminiferal palaeoecology, microfacies and paleoenvironment of Middle-Upper Jurassic sequence of Jumara hills and divided the studies sequence into five palaeoecological units. They *(op. cit.)* interpreted that the Chari Formation exposed at Jumara hills were deposited in a tectonically unstable shelf zone, as indicated by fluctuations in the shoreline.

Talib and Bhalla (2006a) described the composition and discussed the age of the Chari Formation exposed at Jhurio hill, Kutch. Using few diagnostic foraminiferal species confined to or frequently recorded from Callovian-Oxfordian sequences of different parts of the world, these authors (Talib and Bhalla, 2006a) suggested a Callovian to Oxfordian age to the Chari Formation exposed at Jhurio hill, Kachchh. Callovian Oxfordian boundary was also marked by these authors *(op. cit.)* in the studied sequence. In a subsequent publication, Talib and Bhalla (2006b) discussed affinity and palaeobiogeography of the Middle to Upper Jurassic foraminiferal assemblage from Jhurio Hill, Kutch.

Talib and Faisal (2006) reported fifty-three species of foraminifera from Fakirwari Dome, Kutch including twenty-five species which were recorded for the first time from the Indian region. These authors *(op. cit.)* also briefly discussed the age, palaeoecology, and palaeobiogeography of the recovered foraminiferal assemblage. In a later publication, Talib and Faisal (2007) recorded forty species of foraminifera from the Jurassic sediments exposed at Ler Dome, Kutch. The foraminiferal assemblage included eighteen species recorded for the first time from the Indian region. These authors *(op. cit.)* also presented a brief account of the age, bathymetry and palaeobiogeography of the foraminiferal assemblage.

Talib *et al.* (2007) delineated the Callovian/Oxfordian boundary in two sections exposed in Jumara and Jhurio hills, Kutch on the basis of some characteristic foraminiferal species.
Talib and Gaur (2008) gave a detailed account of the affinities and palaeobiogeography of the Middle to Late Jurassic foraminifera recovered from Jhurio hill, Kutch.

Gaur and Talib (2009) described and illustrated a fairly rich foraminiferal assemblage including 51 species, having an overwhelming majority of the families Vaginulinidae and Nodosariidae, from the Chari Formation of Jumara hills, Kutch. These authors (Gaur and Talib, 2009) also suggested a Callovian to Oxfordin age for the studied sequence and also discussed palaeoecology and palaeobiogeography of the foraminiferal assemblage.

Ahmad et al. (2000; 2006; 2008) published a detailed account of the petrofacies and diagenetic aspects. The compositional study of sandstones suggested that the major source of the sediments were Purana schist, granites, associated pegmatites and basic rocks. The petrofacies plots of Qt-F-L, Qm-F-Lt and Qp-Lv-Ls suggested that the detritus were derived from continental block and recycled orogen provenance and were deposited in rifted basin setup. These authors also observed that the sandstones were cemented by iron-oxide, carbonate and silica cements and show good amount of existing porosity. This porosity evolution was mainly controlled by early cementation and mechanical compaction.