CHAPTER 3

STRATIGRAPHY OF THE STUDY AREA

3.1 INTRODUCTION

The study area, Jhura Dome (Jhurio hill) is a part of northern range and situated in the north-central part of the Kachchh Mainland. It is a large domal structure (Fig. 3.1) having deep incised seasonal channels showing radial drainage system. All the channels flow towards the periphery of the dome from the center (apex). The maximum reported elevation in the study area is about 324 meters. The only major river flowing just east of the study area is Kaila River.

The domal structure is formed due to convergent wrench movement and breaking up of the marginal flexures (Biswas 2005) of KMU. Most probably these are faulted closed anticlines. The original flexures have been modified in the last stage of compressive episode, therefore, some of these folds are highly faulted, e.g. Jhurio Dome at the northern edge of KMU, could be flower structures (Biswas 2005). Jhurio hill is an element of Northern flexure zone of Kachchh Mainland, the forelimb associated with the marginal fault (KMF). Moreover, the domal structure is in existence because the uplift zones have been intensively intruded by basic igneous rocks in form of Laccoliths. Laccoliths are seen only in the flexure zones of the Kachchh Mainland has produced many domical structures (Biswas et al. 1968 and 1973) like Jhura dome.

Owing to the domal structure, all the sequences are initially curved, banded and form a dome. Moreover in the process, entire sequence is badly faulted and shows almost vertical beds in the northern periphery and horizontal in the southern periphery. More or less all the beds show structural dips rather than stratigraphical. As mentioned above, even the core of the dome has shown the dips in all the direction. Intensive faulting and domal character will give compaction to the loose, friable, flaggy and soft sequences like shales and finally shows low thickness.

Broadly, it is a folding along the faulted margins (KMF) of the uplifts (KMU) showing similar style – asymmetric anticlines (Jhura dome) having a gently dipping long back limb draping the hanging wall and a short steep forelimb over the footwall often overturned or ruptured exposing the fault. Thus, these folds appear to be second-generation folds formed by modification of marginal flexures by later movements. The marginal flexures appear to be the first generation structures formed by vertical up-thrusting of rigid basement blocks during the first phase of uplift (Biswas 2005). All three measured sections in the area are along deeply dissected valleys or the seasonal streams in the Northern (Badi nala section), Eastern (Sodha camp section) and Southern (Kamaguna section) part of the dome. The valleys are mostly the fault valleys.

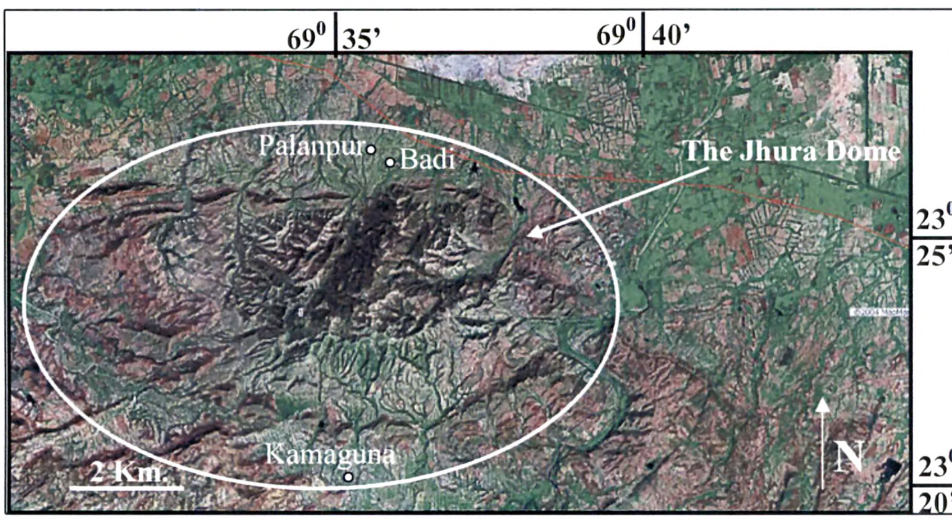

Fig. 3.1 Satellite Image of the Jhura dome (courtesy: Google earth)

Stratigraphically, the Jhura Dome consists of Mesozoic (Middle Jurassic) marine sediments. Maximum stratigraphic succession of the Jhurio Formation of Mainland Kachchh is exposed in Jhura dome. The sedimentological studies suggest a Jurassic syn-rift stage of sediment deposits.

3.2 LITHOSTRATIGRAPHY

The oldest rocks of Mainland Kachchh are well exposed as circular inliers at the cores of the Jhura dome (Fig. 3.2). The area consists of two Formations; namely, the older Jhurio Formation and younger Jumara Formation. The author has referred lithostratigraphic classification of Biswas (1977) for the present study. The boundary between two formations is very distinct, quite conformable and well marked by the contact of white well bedded limestones and greenish shale of Jhurio and Jumara Formations respectively in the various measured sections. Both the Formations are very well described and correlated in the other domal structures like Habo dome in the East and Jumara dome in the West by previous workers as well. Regionally, the lower part of the Jhurio Formation is correlatable with the upper part of the Kaladongar Formation and the upper part of the Jhurio Formation is correlatable with lower part of Goradongar Formation (Biswas 1977). The base of the Jumara Formation is exposed only in Jhurio, Jumara and Habo hills of the Northern range of Mainland Kachchh. Besides the base, the Formation is well exposed in Jara, Manjal (Kaya hill), Keera, Kas in Northern range and in Samatra-Bharaser, Walasar-Fakirwadi and Ler-Amundra anticlines of Charwar range (Biswas 1991).

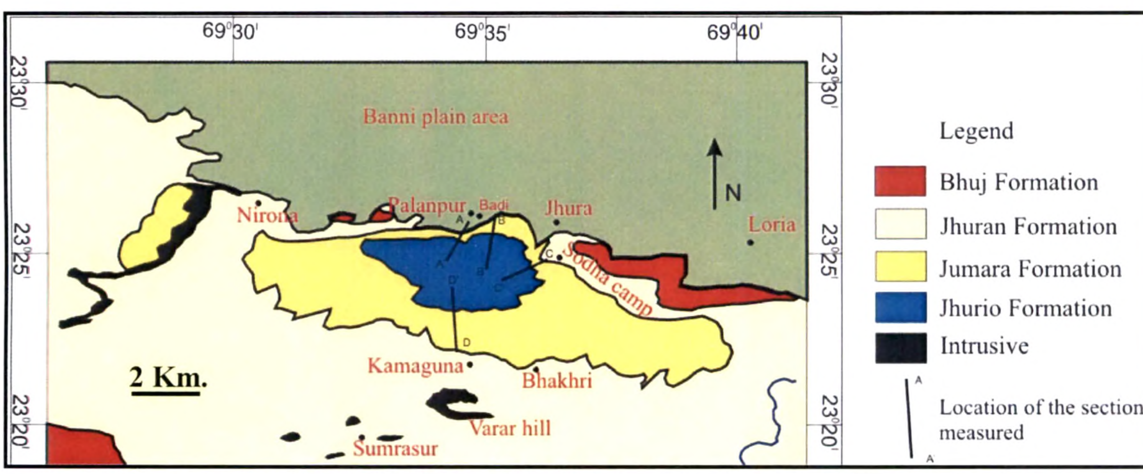

Fig. 3.2 Geological map of the Jhura dome (after Biswas and Deshpande 1970)

3.2.1 Jhurio Formation

Jhurio Formation is very well exposed along a big stream that flows from the center of the hill to the north. In fact, the entire hill is made up of Jhurio Formation and is considered to be a type section for the Jhurio Formation (Biswas 1977). The maximum thickness estimated in the type section is 290 meter. The major rock types are, white and grey limestone with fine to medium crystalline texture; pink to reddish coarse crystalline limestone with lenses of golden oolites; yellow calcareous golden-oolitic rocks, and grey quartzose shale. The rock types can be grouped according to different lithologic aspect into seven members. These members are, informally named as member A to G (Biswas 1977) from the oldest to the youngest (Table

3.1). The ferruginous ooids existed in the Bathonian and Callovian and are found interspersed between the Carbonates or Siliciclastic.

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Member	Description
Member G (72 meter)	Well bedded and jointed white, grey, cream colored limestone
Member F (20 meter)	Thick Golden oolite bands are intercalated with thinly bedded yellow limestone.
Member E (45 meter)	Golden oolite – thick beds
Member D (40 meter)	Khaki colored laminated calcareous shale with lenses of crystalline calcite
Member C (15 meter)	Golden oolite – thick beds on weathered brick red colored
Member B (25 meter)	Grey, Khaki colored, calcareous, laminated silty shales
Member A (19 meter)	Limestone and minor shale

Table 3.1 Classification of the Jhurio Formation (After Biswas 1977)

Member A: This member is exposed in the deep valley of the Jhurio hill and reveals radial dip (structural) in all the direction. Though, the base in not exposed it shows an average thickness of 19 meter. It consists of thick, well bedded limestone with locally inter-bedded thin layers of golden oolite and shale. The shales are greenish and grey, massive fine textured quartzose shale. The limestones are pale brown and grey, fine to medium textured silty sparite. Some limestones are oolitic with small golden ooliths and some are 'lump sparite' (Krumbien and sloss, 1963) containing streaks and lenticles of fine golden-oolite aggregate. Limestones and golden oolitic limestones are locally conglomeratic (limestone –pebble-conglomerate) in nature. Limestone is fossiliferous and consists of bioclast of bivalves, brachiopods, gastropods, ammonites and bryozoans. The limestone shows bioturbational structures at the top.

Member B: It encompasses khaki colored, laminated, calcareous, silty shales with lenses and tubes of crystalline calcite. It has an average thickness of about 25 meter. It is loose, fissile, laminated shale sequence, structurally disturbed and followed by intense weathering; the sequence has nott been very well preserved as compared to above and below members.

Member C: It consists of a massive bed of golden oolite with a thin bed of limestone bed at the base. The golden oolite rocks are quite famous for their beautiful golden color when freshly broken. The weathering of Golden oolite rocks of this Member gives a brick red colour which help in distinguishes from other Members. The average thickness is 15 meter and consists of fossiliferous oomicrites made up of large golden and brown ooliths, shell fragments and silt size quartz grains. The matrix is composed of micrite and clay material. It shows parallel lamination and a higher degree of bioturbation towards the top.

Member D: It is has a resemblance to the Member B and is about 40 meter thick. It shows grey, khaki colored hard, laminated silty calcareous shales with lenses of crystalline calcite and chert. This facies also consists of few belemnites and ammonite (*Macrocephalites)* species. The bioturbation structures are obscure due to presence of thin partings.

Member E: It is composed of banded brown and grey limestones with golden oolite rock in the lower part. The ooliths have concentric layers composed of chamosite which on oxidation give the golden yellow color. This is evident from the sub surface where no oxidizing condition exists, showing green color instead of golden yellow. The terrigenous material, mainly sand and silt grade quartz, is less than 10%. These beds of golden oolite stick out prominently as hard bands. This limestone band frequently consists of low angel trough cross bedding and top of the golden oolite bands often shows the presence of mega-ripple marks. The weathered surface gives a brownish-black appearance which is very typical of these rocks and help to distinguish these (Biswas 1977). The overall thickness of the Member E is 45 meters.

Member F: This member consists of 20 meter thick well bedded limestone. The limestones are yellow in color, finely crystalline, silty sparite, biosparites and biomicrites. About 6 meter thick golden oolite band occurs on the top followed by 2 to 3 such bands in thinly interbedded yellow limestone. Above the 6 meter golden oolite band occurs an olive green, coarsely crystalline, saccharoidal limestone (clayey sparite) which is very characteristic. The top limestone band frequently shows cross laminations and at towards the top of the golden oolite bands often shows the presence of mega-ripple marks as well. This member is highly fossiliferous and consists of abundant *Terebratula spp.* including *T. jumarensis, Rhynchonella spp.* includes *Rhynconella pseudo-inconstans, R. kutchensis,* and *Trigonia spp. Macrocephalitids* ammonites, Belemnites and Crinoid stems are more common in the upper limestone beds.

Member G: It is composed of white, grey, cream colored well bedded and jointed limestones with thin layers of calcareous shale. They are either micrite or sparite in composition with very little allochemical constituents and some terrigenous matter as silt and clay. Member G consists of about 72 meter thickness. The lower part is differentiated by white to grey and brownish grey, very finely crystalline clayey pelmicrite. The micrite is composed of pellets, clay, free calcite and few foraminiferal shells. This section is unique for its whitish appearance and brick like structure produced by the intersection of bedding plane and closely spaced vertical joints. The limestones are pelmicrite and biomicrite in composition. The upper part is flaggy and some limestone bands show nodular weathering. The upper part of the member is characterized by yellow to brownish yellow, fossiliferous silty sparites.

All the above described members are easily distinguishable in the field based on major lithological changes, their appearance and stratigraphical positions. Furthermore, geomorphic expression of the limestones forms high relief or shelf like extension as compared to shale which help in picking up the boundary.

The Jhurio Formation has not been devoid of fossil content. Some of the golden oolitic beds have shown the presence of corals. Brachiopods, Pelecypods and ammonites (Macrocephalites) are there in the entire sequence. This formation is mainly rich in fossils like Rhynchonella, Terebratula, Allectryonia, Ostrea, Astarte, Trigonia, Belemnites and ammonites. The age of the formation is from Bathonian (?Middle) to Lower Callovian.

The depositional environment of the rocks of the Jhurio Formation is sub-littoral under more or less stable shelf conditions. In the beginning, the sea was intruding gradually over the old land where the subsidence rate was more or less slow. Overall it appears as Transgression. The thick shale sequence was deposited in the comparatively deeper environment because the rate of subsidence is high which reflects as the transgressive period. Sequentially, when the rate of subsidence is very less, depth of the water was reduced abruptly and thick beds of golden oolites were deposited under littoral conditions. The occurrence of mega wave ripple marks on the golden oolite rock bands associated with sparite also suggest that the strong waves were present during the deposition. Presence of tiny Coral in golden oolite rocks also suggest that the organic reef is in further offshore areas and due to storm event they might be transported and dumped near shore. The shale deposition followed again which understand as starting up of subsidence simultaneously increase in water depths and produce deeper environments which overall taken as transgressive deposits. At the end, the thick deposition of Member F and Member G of carbonate indicate quieter conditions. If the micrites were deposited the conditions were below wave base and quite environment but if, presence of sparites were indicating high energy environment.

Overall, The Jhurio Formation consists mainly of shale, limestone with bands of golden oolites. Limestone bands are invariably bioturbated while golden oolitic bands are conglomeratic. The upper sequence comprises micritic and spar limestones. The spar limestone and golden oolite beds were deposited as time markers at time of still-stands (Busch, 1974) and shales were deposited during transgressive cycle where limited sand supply and abundant high mud supply.

3.2.2 Jumara Formation

A thick Jumara Formation predominantly consists of Shale - Silty Shale - Sandstone and Oolitic marlite overlying the white well bedded Limestone of Jhurio Formation (Plate 3.1).

Plate 3.1 Contact between Jhurio and Jumara Formation in the study area illustrated by drowning unconformity

It has been named after its type section in Jumara dome near the Great Rann, north of Jumara village, Kachchh Mainland. The Jumara Formation lies conformably over the Jhurio Formation without any possible break in the deposition (Biswas 1977). The formation is preserved and well exposed in two chains of inliers along the Northern range of Kachchh Mainland and Charwar Hills. In the Northern range it is exposed in Jara, Jumara, Manjal (kaya hill), Keera, Jhurio (Study area), Habo and Kas hill structures and in the Charwar range it is exposed in Samatra-Bharaser, Walasar-Fakirwadi and Ler-Amundra anticlines. The base of the formation is exposed in Jumara, Jhurio and Habo Domes. The type area of the formation is central part of the Jumara dome (Biswas 1977).The formation consists mainly of gypseous shales and quartzose shales with hard beds of fossiliferous marlites (sandy oomicrites) and calcareous quartzose sandstones. In the type section, this formation is sub divided informally into four members as described in the following Table 3.2.

Member	Lithology
IV (20 meter)	Dhosa Oolite Member: Green oolite marlite bands alternated by beds of green shale and topped by conglomeratic band.
III (106 meter)	Green, gypseous shale with fossiliferous marlite ferruginous and white marlite bands
II (50 meter)	Green, gypseous shale with fossiliferous white marlite and red ferruginous bands. Green, hard, sandy fossiliferous marlite
I (90 meter)	Thick greenish to yellow grey, laminated, gypseous, clayey shale with thin red nodular hematite bands and numerous grey marlite and yellowish white limestone bands

Table 3.2 Classification of the Jumara Formation, as per the type section (Biswas 1977)

Member I: This member is well developed, 90 meter thick and consists of thinly laminated calcareous shale and siltstone bands with occasional white to gray coloured marlite beds. The shale is greenish grey to olive green, weathering into khaki color, flaky to occasionally thinly laminated, clayey and highly gypseous. The gypsum also occurs as veins and thin laminations. The presences of larger salenite crystals are also common along with gypsite crystals. They are perhaps authigenic and secondary in origin. Thin limestone, green marlite, siltstone or sandstone partings are common within shale sequence. Occurrence of glauconite has given the green color to the outcrops. This member does represent some thin limestones as well as marlite beds with thin red nodular hematite bands and numerous grey marlite and yellowish white limestone bands.Calcareous shaly beds are thinly laminated and intercalated with rhythmic sequence of very thin, cream coloured calcareous siltstone or intergrades laterally and vertically and form massive, calcareous, fossiliferous siltstones and occasionally shows trough and planar cross- stratification and symmetrical to asymmetrical ripple marks on top. Bioturbation structures are also present in calcareous shales but owing to their fissile nature most of these structures are destroyed or show poor preservation.

Member II: The study area consists of thick sandstone beds at the base within the shale member II of the type section. The sandstones are hard, compact, bedded, poorly sorted, brown to greenish grey in colored and coarse grained. They are frequently pebbly, calcareous and quartzose in nature. They are highly bioturbated and usually show cross-laminations and current and mega (wave) ripple marks. The top of the bed is persistently conglomeratic having angular pebbles of limestone and marlite. There are three to four prominent sandstone beds marking the periphery of the dome and forming a steep hogback girdle called Ridge Sandstone. The Ridge Sandstone is occupying the stratigraphic position as Member II of type section. All these sandstones are richly fossiliferous and show structural dip of 30° to 65° towards the periphery of the dome.

Member III: This member is 106 meter thick and consists of greenish to yellowish colour gypseous shale with fossiliferous marlite ferruginous and white marlite bands. The shale highly gypseous and gypsums are occur as occurs as veins and thin laminations as well as varying shapes large crystal (salenite). The shale is intercalated by thin green glauconite and yellow limonitic layers, red ferruginous layers and few layers of calcareous concretions with sideritic nodules. The shale often contains silt-size quartz grains with glauconite and argillite and abundant leaf impressions and plant fragments. Body fossils are represented by fragments of scattered belemnites and ammonites.

Member IV: The green oolitic marlite bands, hard, medium to coarse grained and sandy alternated by beds of green shale is rather best developed in Kamaguna section of the study area and attains its maximum thickness of 20m. About 23 green, brown oolitic beds have been encountered within the shales. The oolite bands consist of green and brown ooliths of 0.5 mm to 1.00 mm in diameter. The top bed is locally conglomeratic and contains a good preservation of enormous, large ammonites and belemnites. This band and the underlying shale with alternation of similar oolitic marlite bands have been described as the Dhosa Oolite stage or member by earlier workers. Oolite limestone bands are form key horizon of the Dhosa Oolite member in the entire stratigraphy of Kachchh and taken up for regional lithostratigraphic correlation because it's very hard, prominent and easily distinguishable due to its typical color and weathering gaze. Even, its fossil assemblage is very unique, different and noticeable, seeing that it has considered as palaeontological marker horizon and used for biostratigraphic purposes.

This Formation is throughout very rich in its fossil content and called as a nature's museum of fossils. Most of wonderful, tremendous and large ammonite fauna of Kachchh have been found from this Jumara Formation. Apart from the ammonite fauna it is very much loaded with brachiopods, pelecypods and belemnites. The bio-facies of the formation remains unchanged in all the outcrops, except that they become progressively less fossiliferous to the East of the type area and also to the south in the Charwar Range outcrops (Biswas 1993). Giant forms of *Terebratula* and *Rhynchonella* are very common in the eastern flank of Jhurio dome. *Trigonia, Astarte Pecten, Ostrea* and *Lima* varieties of bivalves are very frequent in the sequence; associated with most common ammonites are: *Macrocephalites, Kamptokephalites, Indosphinctes, Encycloceras* and *Dhosaites* etc.

The Jumara Formation and Chari Series of the older classification are almost identical in stratigraphic unit (Biswas1991). Based on macro and micro fossils the age of the Chari Series is fixed Callovian to Oxfordian which is one of the same for the Jumara Formation.

The thick shale indicates deposition in low energy-deeper water conditions more precisely away from the littoral zone. The Jumara Formation includes several coarsening upward hemicycles, starting from shales ending up with fine to coarse grained sandstones or conglomerates (Howard and Singh, 1985). Deposition of shales is interrupted often by thin silty sandstone or fossiliferous limestones beds which are oolitic towards the top. All these above observations indicate transgressive deposits when the mud supply was copious with moderate sand supply during still-stands (Busch, 1974). As an entire sequence of the Jumara Formation express littoral– sub-littoral depositional environment.

Vertical environment profiles of lithologic sequences in Kachchh indicate two distinct mega-cycles: a transgressive followed by regressive cycle. These two cycles include several transgressive / regressive sub-cycles and micro cycles depending on the fluctuations of sea levels in unstable shelf condition. The transgressive mega-cycle starts with the initial transgression of the sea over Kachchh graben in Bajocian (Jai krishna, 1983) or even earlier (Lias) and continued cyclically till Oxfordian (Biswas 1991).