SEQUENCE STRATIGRAPHIC SIGNIFICANCE OF SEDIMENTARY CYCLES AND TRACE-FOSSILS IN JHURA DOME OF THE MAINLAND KACHCHH, WESTERN INDIA

A

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'SEQUENCE STRATIGRAPHIC SIGNIFICANCE OF SEDIMENTARY CYCLES AND TRACE-FOSSILS IN JHURA DOME OF THE MAINLAND KACHCHH, WESTERN INDIA'

Ichnofossils and Lithofacies were studied for the Jurassic sediments (Bajocian to Oxfordian) of the Jhura dome for Sequence Stratigraphic analysis and to determine different Sequence Stratigraphic surfaces, parasequences and system tracts. The study area is falls in the Survey of India Topographic Sheet No. 41 E/11 and it stretches from 23^0 30' to 23^0 40' N latitudes and 69^0 30' to 69^0 40' E longitudes and includes Jhura, Palanpur, Badi, Kamaguna, Bhakhri and Sodha-camp villages in the periphery of the dome.

Kachchh is an incredibly famous region amongst geologists for its rich fossil content and spectacular outcrops of Jurassic-Cretaceous-Tertiary sequences along various domes, highlands, streams and rivers. Amongst the domes of Mainland Kachchh, Jhura dome, comprising of oldest sediments exposed, provide vital information to understand stratigraphy, basin configuration and lateral facies change within the basin. Except structure, the area provides ideal sections to investigate facies and their related trace-fossils. The objective of the study is to apply sedimentological and ichnological data to analyze the Sequence stratigraphy and establish depositional environment for the mixed siliciclastic-carbonate sedimentary facies. The entire study is based on field observations and laboratory analysis. To achieve this goal author has carried out intensive fieldwork, measured the sections, and examined the rock sequences for trace fossils content. The author has discussed his observations, examination and outcome in eight chapters followed by conclusions.

Chapter one deals with introductory concept of sequence stratigraphy, significance of trace-fossils in sequence stratigraphy, approach, scope of work, aims and objectives, methodology, techniques in ichnology, observation and recording of trace-fossils, trace-fossils in clastic verses non-clastic sediments and overall information about study area.

The prime objectives of the study are sequence stratigraphic evaluation of mix siliciclastic-carbonate and carbonate sequences and demarcate different depositional environments using trace-fossils and physical sedimentology. To achieve the above objectives author has followed the methodology as under:

- Stratigraphic sequences have been measured at different places and mapped for their lateral and vertical continuity and lithologs have been prepared on the basis of correlatable conformities and rock types.

- Systematic stratigraphic sampling has been done; physical and biological sedimentary structures (trace fossils) have been observed, recorded and examined.

- Lithofacies have been analyzed based on field and laboratory studies.

- Rock samples have been analyzed petrographically for textural analysis and mineralogical study for each lithofacies.

- Qualitative and quantitative analysis of the trace fossils have been done (includes ichnotaxonomy, ethology, density and diversity, ichnoguilds, ichnoassemblages, ichnofacies, etc.).

- Various sequence stratigraphic surfaces; system tracts (genetic units); parasequences have been identified in context to sediment characteristics and substrate controlled ichnofacies.

- Ichnological, sedimentological and stratigraphical data have been integrated to reconstruct the depositional model for the Middle Jurassic rocks of Jhura Dome of Mainland Kachchh.

The second chapter deals with historical consideration and background geological information like physiography, geomorphology, previous work, Mesozoic stratigraphy, structure and tectonics of Kachchh rift basin. The details given in the previous work focus on the studies carried out related to the lithostratigraphy, trace-fossils and sequence stratigraphy.

Lithostratigraphy of the study area is dealt in detail in the third chapter. The Jhura dome area represents two Formations namely Jhurio (older) and Jumara (younger). In fact, Jhura dome is the only area where the oldest Mesozoic rocks of the Mainland Kachchh are exposed. Both

the formations are elaborately explained and sub divided into Members based on the classification by Biswas (1991).

The Sedimentological aspects of the Jhurio and Jumara Formations of study area are given in detail in the form of lithofacies in the fourth chapter of the thesis. Three measured sections displaying lithology, thickness, grainsize, sedimentary structures and associated ichnofossils have been illustrated. In all, six lithofacies and four subfacies [Limestone Lithofacies - LL, (Badi Limestone Subfacies - BLs, Nodular white well bedded Limestone Subfacies - NWWLs) Conglomerate Lithofacies - CL, Calcareous Silty Shale Lithofacies - CSSL, Oolitic Limestone Lithofacies – OLL (Golden Oolite Subfacies - GOs and Dhosa Oolite Subfacies - DOs), Rippled Marked Calcareous Sandstone Shale Lithofacies - RMCSSL and Greenish Grey Shale Lithofacies - GGSL) were identified on the basis of their lithologic association, sedimentary structures, texture, grainsize, thin-section study and the type of contact. All the identified lithofacies are described in detail with essential plates and photos including thinsection observations, list of associated trace-fossils and a brief of the depositional environment for particular lithofacies.. Trace fossils were observed in majority of the lithofacies but conglomerate lithofacies, greenish grey shale lithofacies, some part of the RMCSSL and DOs are found to be devoid of trace-fossils.

The fifth chapter includes an account of trace-fossils and functional interpretation of trace fossils. Principles and major strengths of ichnology are mentioned in the introductory part of the chapter. Ichnogenera and ichnospecies are named according to International Commission on Zoological Nomenclature (ICZN) norms and grouped on the basis of morphological affinity. Total thirty seven ichnogenera and seventy one ichnospecies are identified and Ichno-taxonomy is attempted. All identified ichnospecies have been tabulated and divided into different ethological and toponomic groups based on their behavioral and preservational patterns respectively. Further, in the chapter all the seventy one ichnospecies are described using systematic ichnology. Systematic ichnology includes name and reference of ichnogenus; diagnosis of ichnogenus; name and reference of ichnospecies; diagnosis of ichnospecies; description; remarks; occurrence and a representative field photo of the ichnospecies.

Analysis of the all identified ichnogenus and ichnospecies with respect to lithofacies is dealt with in the sixth chapter. The scheme proposed by Frey and Seilacher (1980) has been

adopted to classify these on their behavioral aspect (ethology) and group them as per their behavior against different lithofacies. Six ichnoassemblages are identified on the basis of their occurrence and association of other ichnotaxa within particular lithofacies. Distinctive eighteen ichnoguilds are recognized and described. Their description includes detailing on the substrate-behavior, level of tiering, diversity, density, degree of bioturbation, associated ichnotaxa, ichnofacies, lithofacies and probable depositional environment..Further, through the journey of the sixth chapter, three Seilacherian ichnofacies (*Skolithos*, *Cruziana*, and *Zoophycos*) are identified and explained. Idealized shoreface model of ichnofacies (modified after Pemberton et al. 1992a) and bathymetry scheme along with ichnofacies and related trace-fossils (Modified after Frey and Pemberton 1995) are mentioned for better understanding of various depositional environments corresponding to different ichnofacies. At the end, a table demonstrates the abundance of seventy one ichnospecies in the six different lithofacies (DOs, RMCSSL, NWWLs, GOs, CSSL and BLs).

Entire sequence stratigraphy concept and 3rd order sequence stratigraphic analysis of the Jurassic sediments of the study area is described and discussed in the following seventh chapter. On the basis of the trace-fossil data and sedimentary cycles (lithofacies information), drowning unconformities, correlative conformities, transgressive surfaces, regressive surfaces, flooding surfaces or transgressive ravinement surfaces and maximum regressive surfaces are identified and described. Transgressive lag deposits and maximum flooding surface towards the top have been also recognized and illustrated. Seven system tracts are documented in which four are transgressive system tracts and three are regressive system tracts (Fig. 1). All the seven system tracts along with the associated trace-fossils have been described in detail in this chapter.

Finally, all the information collected has been integrated in working out different depositional environments and a model for the sedimentary sequence of the Jhura dome. Existence of seven distinctive depositional environments that have come to be known are Shelfal below SWWB, Transition to Lower Shoreface, Upper Offshore to Lower Offshore, Lower Shoreface above FWWB, Lower Offshore to Shelf, Lower Shoreface to Middle Shoreface and Upper Offshore. Intensity of bioturbation, ichnodiversity, important ichnotaxa, tiering and ichnofacies are also mentioned for each and every depositional environment. Lastly,

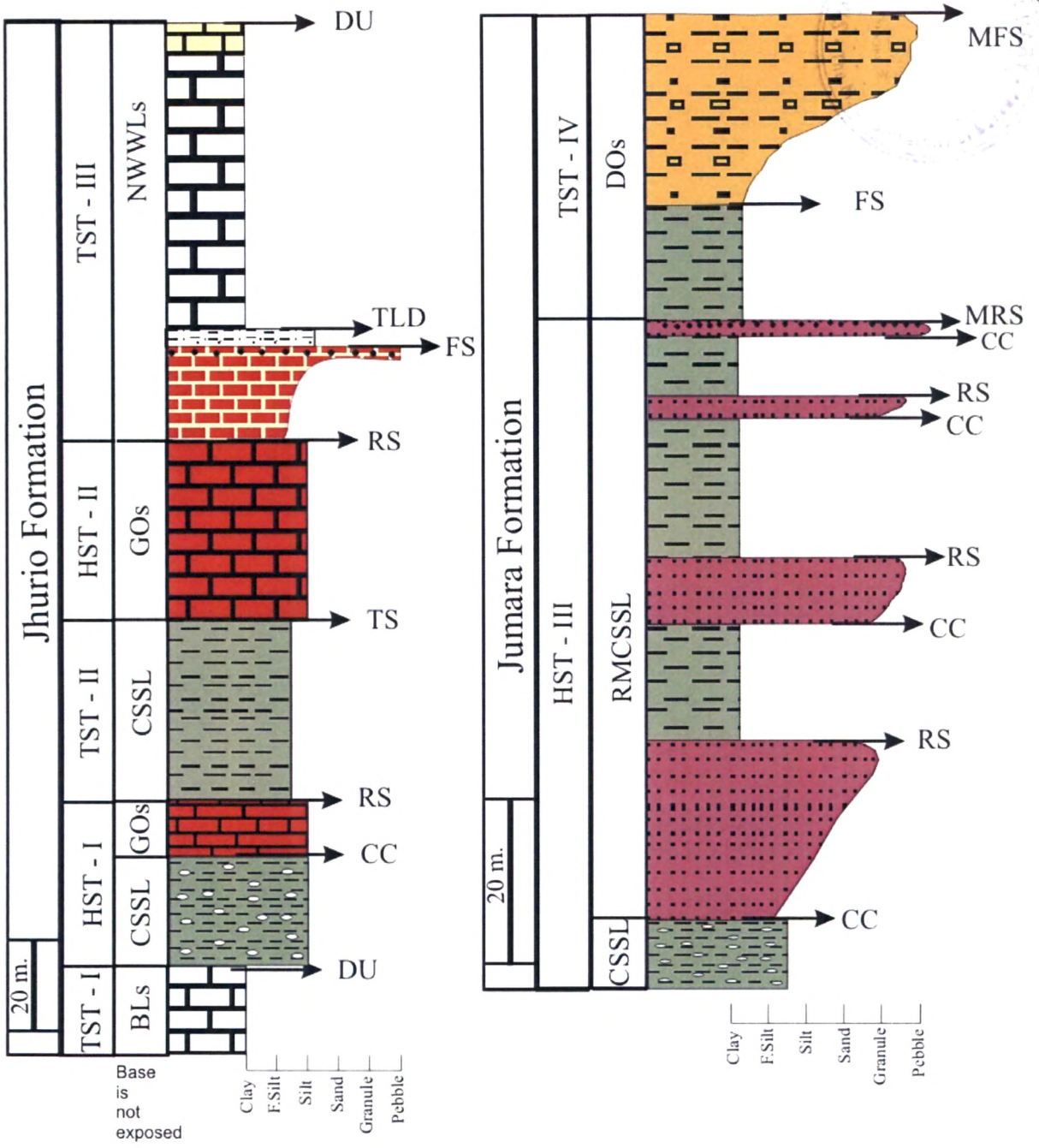

Fig. 1 - A composite section of the Jhura dome demonstrates sequence stratigraphic surfaces and system tracts.

the distribution of trace-fossils (as rare, moderate or abundant category) in distinct depositional environments of Jhurio and Jumara Formations in the study area is summarized in Table 1 and the sedimentary facies and their corresponding sedimentary structures, trace-fossils, body-fossils and depositional environment is given in Table 2 for better understanding of the relation of trace-fossil assemblages with the depositional environment.

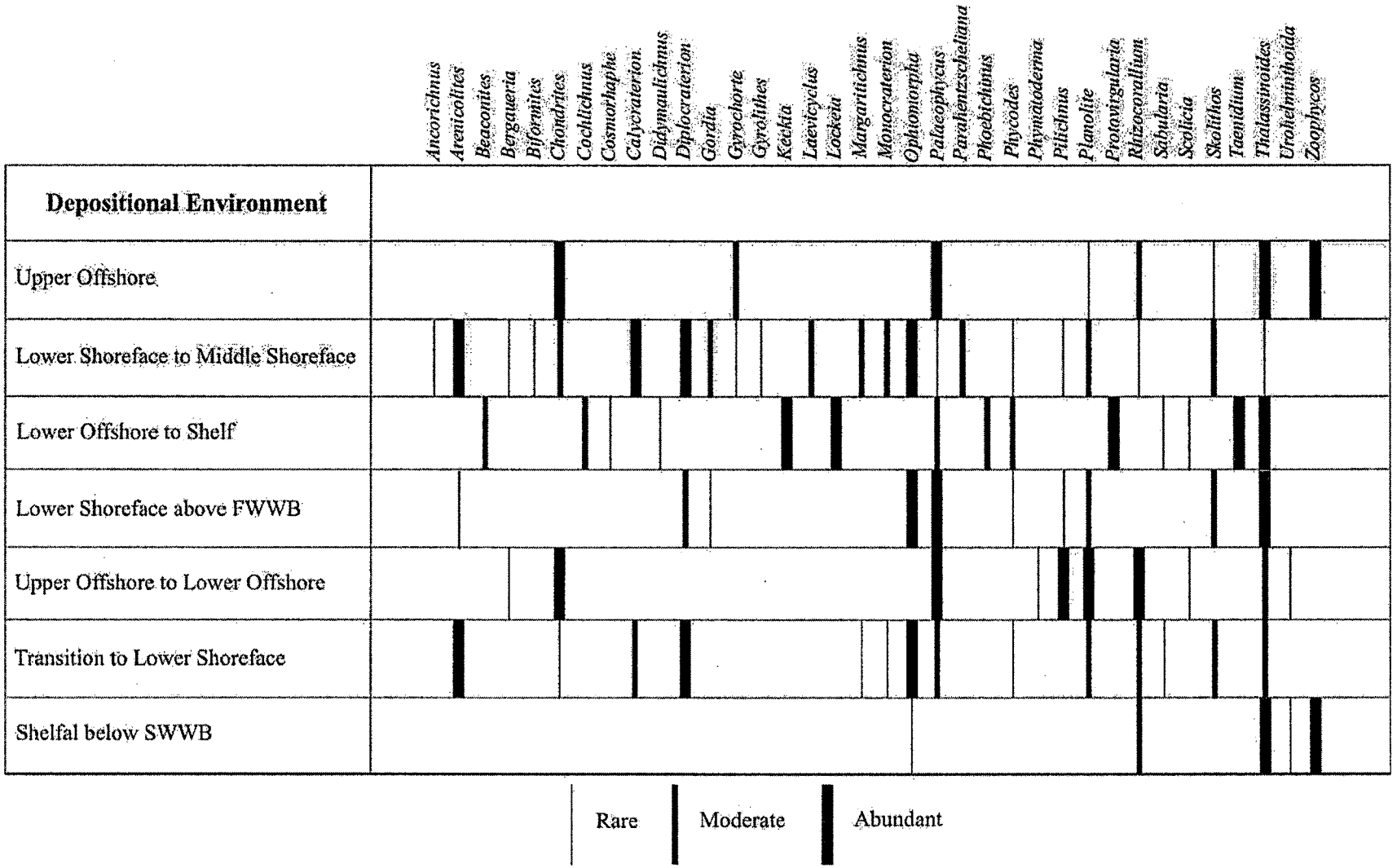

Table 8.2 Environmental distribution of Trace-fossils and their abundance.

Lithofacies	Physical sedimentary structures	Trace-fossils	Body fossils	Depositional Environment
DOs	Conglomeratic towards top; Oolites	Zo, Th, Pa, Ch, Sk, Rh, Gy, Pl	Highly fossiliferous; Ammonoids and Belemnites;	Upper Offshore
RMCSSL	Wave ripples; Cross stratification Coarse to granules and pebbles	Op, Th, Rh, Pl, Pi, Py, Pa, Par, Mo, Ma, Le, Gy, Gyl, Go, Di, Ca, Ch, Ar, An, Sk, Pa	Highly fossiliferous; Bivalvia; Brachiopods; Belemnites and Gastropods	Lower Shoreface to Middle Shoreface
NWWLs	Thin parallel lamination; Well bedded	An, Be, Ch, Co, Cos, Ke, Lo, Pa, Ph, Pr, Sc, Th, Zo	Bivalvia; Brachiopods; Belemnite and Crinoids	Lower Offshore to Shelf
GOs	Mega ripple marks; Low angle cross stratification; Parallel lamination Oolites; pebbly towards top	Ke, Ta, Op, Sk, Rh, Ch, Pl, Pa, Pi, Di, Dy, Go, Ar, Be, Sa, Ma, Mo, Py Th	Bivalvia; Brachiopods; Belemnite; Crinoids and Corals	Lower Shoreface above FWWB
CSSL	Parallel lamination;	Rh, Ur, Th, Sc, Sa, Pl, Pi, Py, Mo, Ma, Pa, Le, Gy, Di, Ca, Ch, Bi, Be, Ar	Belemnites and Ammonoids	Upper Offshore to Lower Offshore
BLs	Parallel lamination; Bedded	Zo, Ur, Th, Rh, Op	Bivalvia; Brachiopods; Gastropoda; small ammonoids and Bryozoans	Shelfal below SWWB

Table 2 Sedimentary facies and their corresponding sedimentary structures, trace-fossils, body-fossils and depositional environment

The significant observations made in the present study are as follows:

⇒ The Middle Jurassic rocks of the Jhura dome comprise of two Formations; the lower – Jhurio Formation and the upper Jumara Formation which are further divided in to seven and four members respectively.

⇒ Stratigraphic sequence of the Jhura dome consists of both, carbonate and mixed siliciclastic-carbonate sediments. The clastic (oolitic) carbonate rocks are present at four different stratigraphic levels in the sequence of the Jhura dome.

⇒ The entire sequence of the Jhura dome is subdivided into following eight informal lithofacies.

- Dhosa Oolite Subfacies (DOs)
- Greenish Grey Shale Lithofacies (GGSL)
- Rippled Marked Calcareous Sandstone Shale Lithofacies (RMCSSL)
- Nodular White Well Bedded Limestone Subfacies (NWWLs)
- Conglomerate Lithofacies (CL)
- Golden Oolite Subfacies (GOs)
- Calcareous Silty Shale Lithofacies (CSSL) and
- Badi Limestone Subfacies (BLs)

⇒ Presence of both intraformational and extraformational conglomerates indicate typical characteristic of storm generated facies

⇒ Oolitic facies (=clastic limestone) are very well developed. These in association with overlying and underlying siliciclastic as well as carbonate facies suggest extensive sediment reworking and slow net sediment accumulation rates in shallow marine (shoreface-offshore), agitated, moderate to high energy conditions and occasionally witnessed storms (wave ripples).

⇒ A sudden increase and decrease in terrigenous influx (siliciclastic sedimentation) is responsible for kick-off and drowning of non-clastic carbonate growth and subsequent development of carbonate facies.

⇒ Majority of the lithofacies are highly bioturbated and consist of abundant trace fossils. Conglomerate lithofacies and Greenish grey shale lithofacies are devoid of trace-fossils. Certain bands of various lithofacies like DOs, RMCSSL etc. are rich in Ammonites, Belemnites, Brachiopods and Bivalves.

⇒ Based on the trace fossils morphology author has been able to recognize five ethological groups including *Cubichnia, Repichnia, Pascichnia, Fodinichnia* and *Domichnia.*

⇒ 71 ichnospecies of 37 ichnogenera have been identified and systematically described from the Jhurio and Jumara Formations of the Jhura dome.

⇒ Trace-fossils genera such a *Rhizocorallium uraliense*, *Parahentzscheliana ardelia*, *Phoebichnus trochoides*, *Pilichnus dichotomus*, *Phymatoderma isp.*, *Cosmorhaphe carpathica*, *Chondrites recurvus* and number of *Zoophycos* species are reported for the first time from the sedimentary sequence of the Jhura dome.

⇒ *Zoophycos* trace fossil is the most conspicuous character of the Dhosa Oolite subfacies.

⇒ Six distinct ichnoassemblages (*Protovirgularia* IA; *Zoophycos – Chondrites* IA; *Rhizocorallium – Pilichnus* IA; *Ophiomorpha* IA; *Thalassinoides – Palaeophycus* IA and *Taenidium – Keckia* IA) are recognized and described. These ichnoassemblages have provided important information on palaeoenvironment, bathymetry, wave and current energy, food availability, oxygen conditions and substrate consistency.

⇒ 18 distinct ichnoguilds were reported, documented and described for the middle Jurassic sediments of the Jhura dome.

⇒ Following three ichnofacies have been identified and described.

- *Skolithos* Ichnofacies (Shoreface)
- *Cruziana* Ichnofacies (Lower shoreface – Offshore)
- *Zoophycos* Ichnofacies (Shelf)

⇒ Six identical sequence stratigraphic surfaces (Drowning unconformities, Correlative Conformities, Transgressive Surfaces, Regressive Surfaces, Flooding Surface or Transgressive ravinement surfaces and Maximum Regressive Surface) have been established and described together with a transgressive lag deposit and a condensed section for the entire sedimentary sequence of the Jhura dome.

⇒ The 3rd order Highstand – Transgressive system tracts identified and described in detail as TST-I, HST-I, TST-II, HST-II, TST-III, HST-III and TST-IV in chronological order, give cyclic tectono-sedimentary, Transgressive-Regressive (T-R

sequence) sedimentation pattern. Few 4th order parasequences are picked on the basis of flooding surfaces within transgressive system tract-III and IV.

⇒ The various depositional environments such as Shelfal below SWWB (BLs – TST-I), Transition to Lower Shoreface (GOs and CSSL - HST-I), Upper Offshore to Lower Offshore (CSSL – TST-II), Lower Shoreface above FWWB (GOs_- HST-II), Lower Offshore to Shelf (NWWLs and GOs – TST-III), Lower Shoreface to Middle Shoreface (CSSL and RMCSSL - HST-III) and Upper Offshore (DOs - TST-IV) are recognized.

⇒ Based on the sedimentological and ichnological data three dimensional depositional model of the shallow marine sequence of the Jhura dome sediments of the North Central Mainland Kachchh has been reconstructed.