SUMMARY AND CONCLUSION
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The Kachchh Basin is an ideal site for the study of marine history and operation of geological processes during the early phases of the opening of the Indian Ocean during Jurassic times. Kachchh Basin is situated at the southern edge of the Indus shelf at right angles to the southern edge of the Indus rift (Zaigham and Mallick, 2000). It is bounded by the Nargar Parkar fault in the north, Radhanpur-Barmer arch in the east and Kathiawar fault towards the south. The Basin extends between latitude 22° 30' and 24° 30'N and longitudes 68° and 72°E covering entire Kachchh district and western part of Banaskantha (Santalpur Taluka) districts of Gujarat state. It is an east-west oriented pericratonic embayment opening and deepening towards the sea in the west towards the Arabian Sea. The basin covers an area of about 16,500 sq.miles of which outcrop area include only 500 sq.miles. The basin is filled up with 5000 - 8000 ft. of Mesozoic sediments and 1800 ft. of tertiary sediments (Mishra and Tiwari, 2006). The sediment fills thicken from less than 500m in the north to over 4000m in the south and from 200m in the east to over 2500m in the west indicating a palaeoslope in the southwest (Biswas, 2002). Kachchh sedimentary basin is an E-W oriented peri-continental basin situated on the western margin of Indian plate representing the westerly dipping eastern flank of Indus shelf (Biswas, 1982). The basin is the earliest rift basin, which initiated as a result of north and north east drifting coupled with counter-clockwise rotation of the Indian plate after its detachment from the Gondwanaland during late Triassic (Biswas,1982) and experienced marine mixed siliciclastic - carbonate sedimentation from Middle Jurassic to Neogene time. The rifting took place within the mid-Proterozoic mobile belt that welded the northern Bundelkhand and Southern Deccan proto-cratons and was controlled by the Precambrian NE-SW trend of the Delhi fold belt that swing to E-W in Kachchh region (Radhakrishnan and Naqvi, 1986; Biswas, 1999).

The Mesozoic rocks in the Kachchh basin ranges from Middle Jurassic to Lower Cretaceous and are exposed extensively in the Kachchh Mainland, Wagad, the Islands of Patcham, Bela, Khadir and Chorar. Shallow marine Jurassic rocks are extensively spread in the Kachchh region ranging in age from Bajocian to Albian which rest unconformably on the Precambrian basement (Datta, 1983; Bardan and Datta, 1987;
Biswas et al, 1993). The mainland outcrops expose a continuous succession from Bathonian to Santonian and consist of most prominent ridge extending for about 193km from Habo in the east to Lakhpat in the west.

The Jhurio Dome of Kachchh basin was chosen for the study because of its proximity from Bhuj, Headquarters of Kachchh and good exposures of Middle to Upper Jurassic rocks along various Nala and River cuttings. In present study, an attempt has been made to emphasize the importance of microfacies, petrofacies and diagenetic studies to interpret the depositional environment, provenance and tectonic history of Kachchh basin as well as degree of compaction, cementation and depth of burial of the enclosed sediments.

The study area of Jhurio Dome of Kachchh basin is constituted of heterogeneous assemblage of sandstone, limestone, marl, shale and conglomerate. They are generally white, purple, brownish and yellow in color, fine to medium grained, soft to hard, friable to compact. There is vertical variation in the primary sedimentary structures. These are trough cross bedding, tabular cross bedding, herringbone cross bedding, laminations. In the present work, four lithostratigraphic sections are described. These sections were measured, analyzed in the field and ~400 representative sandstone and limestone samples were collected for their petrographic examination. Amongst which 270 samples were finally chosen for the study. The sandstone and limestone samples were cut into standard petrographic thin-sections. They were stained with cobaltinitrate for potassium feldspar recognition. 250 to 300 grains were counted per thin section. The traditional methods (Ingersoll et. al., 1984) were used to classify and tabulation of grain types. Standard petrological techniques using a polarizing microscope were employed to describe the thin sections. Authigenic components (cement and matrix replacement constituents) were counted separately. The heavy mineral separation was done following Carver (1971), and identification was undertaken following Krumbein and Pettijohn (1938) as well as Milner (1962). Taylor (1950) method was applied for the study of the nature of detrital grain contacts and for computation of contact index; the method of Pettijohn et. al., (1987) was used. The diagenetic process of sandstones and limestones was taken into account to check the modification of original detrital composition while attempting interpretation of provenance. Detrital mineralogy of the sandstones including lighter and heavy
minerals was studied for the purpose of petrographic classification of the sandstones and interpretation of their provenance. Classification scheme of Folk (1980) based on composition of detrital constituents and Dickinson (1985) scheme based on the tectonic setting of the provenance were used. The factors of climate and transport that influence the framework composition of sandstones were studied to evaluate their effects on the detrital modes of sandstone. Microfacies and lithofacies analysis of the limestone and sandstone were carried out respectively to interpret the depositional environment of the Jhurio Dome.

The statistical parameters of grain size analysis show that the sandstones are medium to fine grained, moderately to moderately well sorted, strongly fine skewed and platykurtic to mesokurtic. Most of the grains are subangular to subrounded and have low sphericity. Bivariant plots of various parameters has moderate inverse relationship between mean size versus sorting indicating decrease in grain size with increasing sorting, which reflects fluctuating hydrodynamic conditions during deposition. Mean size versus skewness has poor inverse relationship (except for Ridge sandstone member, which shows a very poor positive relationship). Mean size versus roundness has moderate inverse relationship indicating increase in roundness with decreasing grain size. Mean size versus sphericity shows poor negative relationship giving hint of decrease in sphericity with increase in grain size, roundness versus sorting has moderate positive relationship giving indication of increase in roundness with sorting and sphericity versus sorting has poor positive relationship giving hint of increase in sphericity. Overall textural maturity of the Jhurio Dome Sandstone Members can be considered as submature to mature.

According to Folk (1980) classification, the Jhurio Dome sandstones are mainly Quartzarenite and Subarkose. The framework grains are mainly quartz followed by feldspar, rock fragments, micas and heavy minerals. Most of the quartz grains are monocrystalline, rest being polycrystalline. The monocrystalline quartz generally shows undulatory extinction. Polycrystalline quartz grains possess both sharp and sutured intercrystalline boundaries. Feldspars include plagioclase and microcline, both fresh and altered varieties. Biotites as well as large flakes of muscovite mica are observed. Rock fragments include chert, shale, schist, phyllite etc. Average detrital mineralogy includes monocrystalline quartz (83.84 %), polycrystalline recrystallised...
metamorphic quartz (3.34 %), stretched metamorphic quartz (0.83 %), feldspar (6.94 %), rock fragments (2.65 %), mica (2.55 %) and heavy minerals. The detrital grains of the Jhurio Dome sandstones are in the sand size range.

Occurrence of zircon, tourmaline, and rutile suggest an origin from igneous (plutonic) source rocks. Presence of epidote, garnet and staurolite indicate a source of metamorphic rocks (Wanas et al., 2006). The opaque heavy minerals are dominant in the upper and middle sandstone members while the transparent heavy minerals are quiet appreciable in the middle and lower sandstone members. On this basis the sandstones can be distinguished in two distinct assemblages, i) garnet-staurolite-hornblende-epidote assemblage, ii) zircon-tourmaline-rutile assemblage. The assemblages indicate that the sediments were derived from two different lithological Precambrian terrain; one is dominated by metamorphic rock and other is igneous (acid and basic), besides a little contribution from sedimentary source. The Jhurio Dome sediments were derived from a variety of source rocks (mixed provenance) comprising granitic batholiths/igneous plutons, magmatic arc, granite-gneisses, pegmatite or schist, metaquartzite and quartz vein etc.

To interpret the depositional environment, facies analysis is categorized into two parts i.e. microfacies for the limestone units and lithofacies for the sandstone units of the study area. The temporal distribution of the microfacies assemblages reflect an inter-relationship of three sub-environment i.e., slope, carbonate shoal and lagoon representing cycles of coarsening upward or deepening - shallowing cycles. However, the change between successive sub-environments is both gradual as well as abrupt. The abrupt change may be attributed to quick transgressive - regressive events probably under the effect of local tectonics (uplift or subsidence due to faulting) or fluctuations of sea level. Two distinct lithofacies assemblages have been identified based on association of their textural characteristics and sedimentary structures with one another and their environment of deposition is interpreted as wave dominated inter tidal / sub tidal deposits and storm-wave dominated shoreline deposits. The depositional environment inferred on the basin of microfacies and lithofacies assemblages were later clubbed into one in order to construct a conceptual depositional model.
The Badi White Limestone Member is interpreted to be deposits of probably deep shelf margin below storm wave base or much below fair weather wave base and out of reach of storms. Badi Golden Oolite Member is interpreted to be deposited on the winnowed platform (carbonate shoal) thereby reflecting shallow of the basin. The deposition of Jhura Golden Oolite is interpreted starts in open to restricted platform (lagoon) and deposition took place at winnowed platform (carbonate shoal) thereby reflecting transgression phase. Goradongar Yellow Flagstone Member represents a mixed carbonate-siliciclastic environment in which the carbonates were deposited on the moderate to low energy outer carbonate ramp on the slope where the autochthonous carbonate content was diluted by silt and sand from terrigenous source and the siliciclastic material was reworked during subsequent transgression. The Jumara Coral Limestone Member is interpreted to represent deposits of the deep shelf margin or foreslope below fair weather wave base. The top of Jumara Coral Limestone Member is composed of lag deposits formed due to erosion by storm as the sea started regressing. The Purple Sandstone Member is interpreted to be deposit of storm-wave dominated shoreface in a regressive regime. The Sponge Limestone Member is interpreted to be deposited on the deep shelf margin or foreslope below fair weather wave base and is affected by occasional storm in the upper part of the unit and represents overall deepening of the basin. This unit contains beds of sandstone which are medium to coarse grained and are interpreted as storm wave dominated shoreface deposits based on lithofacies association. The Ridge Sandstone Member and the Athleta Sandstone Member are interpreted to be deposit of wave dominated inter tidal to sub tidal environment and represent regressive phase. Callovian-Oxfordian time was marked by a world-wide sea level rise, reaching its peak either in Oxfordian or Kimmeridgian (Vail and Todd, 1981: Hallam, 1984), causing major transgressions in many part of the world. Biswas (1981), Singh (1989) and Fursich (1991) consider Dhosa Oolite Member to mark the maximum transgression in Kachchh. Lithofacies assemblage suggest that the lower portion of Dhosa Oolite (Dhosa Oolite Sandstone Member) may have been deposited in storm-wave dominated shoreline environment, in the proximity of shore as suggested by presence of wave ripples deposited above the wave base. The deposition of upper part of Dhosa Oolite (carbonates) took place below the wave base and it can be best described as condensed horizon formed during a major regional transgressive event.
According to Fursich et. al., (1992), the deposition of Dhosa Oolite took place as a result of alternating phases of sedimentation, cementation and large scale bio-erosion in relation to uniform offshore setting well below fair weather wave base but still within the reach of singular storm.

In the present study, the detrital minerals of Jhurio Dome sandstones were studied for the purpose of interpreting their provenance. Triangular diagrams of Dickinson (1985); Qt-F-L, Qm-F-Lt, Qp-Lv-Ls, Qm-P-K were used. Both Qt-F-L and Qm-F-Lt plots show full grain populations, but with different emphasis. The Qp-Lv-Ls and Qm-P-K plots show only partial grains populations, but reveal the character of polycrystalline and monocrystalline components of the framework respectively.

The Qt-F-L diagram which emphasizes factors controlled by provenance, relief, weathering and transport mechanism is based on total quartzose, feldspar and lithic content. Plot of the recalculated values revealed that most of the samples of the Jhurio Dome sandstones lay in continental block provenance field suggesting contribution from the craton interior with basement uplift. One sample fall in the recycled orogen provenance suggesting their derivation from metasedimentary and sedimentary rocks those were originally deposited along former passive continental margins. The Qm-F-Lt plot shows that the samples fall in the continental block provenance with contribution from the recycled orogen provenance. The Qp-Lv-Ls plot, which is based on the rock fragments population, reveals the source in rifted continental margin and collision suture and fold thrust belt. In the Qm-P-K diagram, the data lie in the continental block provenance reflecting maturity of sediments and stability of source area.

The plots of Jhurio Dome sandstones on Qt-F-L and Qm-F-Lt diagram suggest that the detritus of the sandstones were derive from the granite-gneisses exhumed in the craton interior and low to high metamorphosed supracrustal forming recycled orogen provenance. The Qp-Lv-Ls plot reveals the source in rifted continental margin and collision suture and fold thrust belt. In the Qm-P-K diagram, the data lie in the continental block provenance reflecting maturity of sediments and stability of source area. The provenance for Jhurio Dome sandstones is believed to be weathered parts of the present day Aravalli Range situated northeast, east and southeast of the basin and Nagar Parkar massif situated north and northwest of the basin. The analysis of data
plotted on different diagrams, an attempt to reconstruct a plate tectonic for the
tectonic setting of Jhurio Dome sandstones within Kachchh basin. An incipient rift
develops during within Precambrian granite- gneiss and schist which formed the
basement. These rocks were weathered under relatively warm and humid climate,
which destroyed most of the feldspar and other labile constituents. Thus quartz rich
detritus were shed into the Kachchh rift. The relief of the provenance was low and
erosion processes were not strong enough to remove the cover rocks from the
basement.

The average percentage of different types of contacts is as follows: Floating grains
(56.73%), Point contact (27.34%), Long contact (12.14%), Concavo- convex contact
(3.15%) and Suture contact (0.65%). Values of type of contact are suggestive of
limited pressure solution activity in these sandstones. The average minus cement
porosity in the in the studied sandstones is 27.25%, 26.95%, 19.05% and 33.15%,
which may be due to less mechanical compaction during early stage of diagenesis.
The average contact index value of Dhosa sandstone, Athleta sandstone, Ridge
sandstone and Purple sandstone is 0.43, 1.23, 1.33 and 0.65 respectively. The low
contact index values are mainly found in sandstones with pervasive development of
calcite, Fe-calcite and silica cements, which probably precipitate at later stage.

Four types of cements are identified in the Jhurio Dome sandstones, viz; iron oxide,
carbonate, silica and clay cement. Silty to clayey matrix is present in varying
amounts. The existing original porosity (EOP) of the studied sandstones ranges from
16.9% and average is 2.74% and minus cement porosity values ranges from 14 to
41%, averaging 28.83%. As a whole, porosity loss due to compaction range from 8.43
to 37.43%, thereby indicating that compaction was not significant factor in primary
porosity reduction. Porosity loss due to cementation in the studied sandstone range
from 45.80 to 73.88%, thereby indicating that cement and matrix played a dominant
role in reducing depositional porosity. The average minus cement porosity plotted on
standard graphs suggests a depth of burial of about 777 to 2750 meters fit sandstones
of Jhurio Dome.

The diagenetic signatures of compaction, cementation, micritization, neomorphism
and resultant porosity and permeability observed within the limestone members of the
Jhurio Dome at different stratigraphic levels suggest early or syn-depositional
and post depositional changes in marine phreatic (all carbonate members), under-saturated freshwater phreatic (Jhura Golden Oolite, Goradongar Yellow Flagstone and Sponge Limestone members) and deep burial (Badi Lower Golden Oolite, Jhura Golden Oolite, Jumara Coral Limestone and Dhosa Oolite members) diagenetic environments.