**SYNOPSIS OF THE THESIS TO BE SUBMITTED TO
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LATE QUATERNARY GEOLOGICAL EVOLUTION OF SOUTHERN KACHCHH, WESTERN INDIA WITH SPECIAL REFERENCE TO MILIOLITE FORMATION

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Synopsis of the Ph.D. Thesis to be submitted by **Shri Rashmikant Talati**

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Introduction

The Quaternary sediments in Gujarat represent three depositional environments - marine, fluvial and aeolian. The interplay of paleoclimate and glacio-eustasy factors controlled the shaping of the landscape of Gujarat during Quaternary period. On the basis of landscape characteristics, sediments types and geological history, these are three geomorphologic units.

1. The Ranns of Kachchh.
2. Coastlines of Kachchh, Saurashtra and mainland Gujarat.
3. Alluvial plains of Central and North Gujarat

Late Quaternary geological history of the Gujarat state has been studied in detail with special emphasis on Mainland Gujarat (Merh & Chamyal, 1993; Chamyal & Juyal, 2005 and references therein). There are two principal areas in Kachchh, which have witnessed significant Quaternary sedimentation. One is the flat saline wasteland of the Ranns, which includes the Great Rann of Kachchh and the Little Rann of Kachchh, and the other area is the narrow E-W trending plains of southern Mainland Kachchh which are mainly formed by fluvial processes; however, some fluvial-marine interaction is indicated in the near-coastal areas. The region of Kachchh has received a special attention with reference to its seismicity and tectonic and coastal geomorphic evolution. (Biswas, 1971, Maurya et al., 2008, Bhatt et al., 2010). It has been realised by many that the bioclastic carbonates deposits (Miliolite Formation) are key in unravelling the contemporary geological processes and changing interface between the land and the sea during late Quaternary in coastal areas of Saurashtra and Kachchh (Bhatt, 2003). These deposits have been examined for their composition, mode of occurrence and depositional environment in much detail from Saurashtra and Kachchh (Bhatt, 1993, Allahabadi, 1987).

An attempt therefore is made in the present study to investigate the late Quaternary sequences of southern and southwestern region of Mainland Kachchh with reference to reconstruct the paleoenvironment & geological history during late Quaternary time. The Miliolite Formation of the region was given a special attention in understanding this complex history, as they represent an influence of change in sediment source during this time. The following objectives are dealt with in this study.

Objectives

- To evaluate the Miliolite Formation of Kachchh for its significance in late Quaternary history of the region.
- To reconstruct the late Quaternary paleoenvironment & geological history of southern Kachchh.

Methodology

To achieve the above objectives following methodology was adopted.

1. Literature review.
2. Geomorphological mapping using remote sensing data and SOI toposheets.
3. Reconstruction of lithostratigraphy through regional correlation and lateral mapping of late Quaternary sequences exposed in natural and artificial cuttings.
4. Collection field data and sampling.
5. Textural and compositional studies using standard sedimentological procedure.
6. Synthesis of the data to reconstruct geological evolution model of the study area.

Study Area

The Kachchh Peninsula, located between latitude 22°15' to 23°N and longitude 68°.10'-71°.80'E, (Fig.1), forms the western most part of India and constitutes the Kachchh district of Gujarat State. Occupying an area approx of 45,612 sq km, it has length and width extensions of 320 and 170 km, respectively through which passes the Tropic of Cancer. The delta land of Sindh (Pakistan), also known in the olden times by the name Sapta Sindhhu, or the seven distributaries of Indus River, borders it in the west. Its 352 km long southern margin is demarcated by the Gulf of Kachchh, which separates the peninsula from Saurashtra. Its northern margin makes the International border with Pakistan and the eastern abuts Gujarat Mainland. The district has a population of 1,526,321 people inhabiting 949 villages in ten Talukas, population density of 33-persons/sq km, and a total of 466,239 housing units

The Kachchh landmass is a central high plateau, which stands dissected in the north, west and east. Its physiographic features, comprising hill ranges, gently sloping peripheral coastal tract, dissected coastal erosional plain fringed successively by younger deltaic plains, tidal

flats, spits and marginal accretionary zones, can broadly be divided into four characteristic units, viz, Rann, Banni plains, Hilly tracts and Coastal plains.
The study area forms a window between latitude 22°.50’-23°.15’N and longitude 69.10°-69.50°E in the southern part of Kachchh (Fig. 1). Occupying an average area of 1000 sq km, it has length and width extensions of 40 and 25 km, respectively.

Geologically the Kachchh basin (Fig. 1) consists of the records of Juro-Cretaceous sediments in the form of the Jhurio, Jumara, Juran and Bhuj Formations non-conformably overlain by the magmatic rocks of the Deccan Trap Formation. The Cenozoic record is also equally fascinating that occupies north-western and southern parts of the Kachchh and is represented by the Madh, Berwali, Bar Moti, Khari and Kankavati Series. The Quaternary history is recorded in the Miliolite Formation and other Late Pleistocene-Holocene records of the coastal areas.

The Kachchh basin was originated as a pericratonic rift during the break up of Gondwanaland in Late Triassic. The basin evolved through three tectonic phases: (1) Rift phase, (2) Late rift divergent wrench phase, and (3) post rift convergent wrench phase.

These three phases correspond respectively to break up, drifting and collision of Indian plate. The rift was aborted in Late Cretaceous, following trailing edge uplift prior to collision with the Asian plate and later became a shear zone during inversion stage following collision. Post-collision compressive regime is responsible for present active neotectonic movements. The drift motion and the counter-clockwise rotation induced strike-slip movements. The rifting occurred within the weak zone of the Mid-Proterozoic mobile belt by reactivation of pre-existing faults. During wrench tectonics, the KMF became the principal right lateral strike-slip fault and active since then. Eastward KMF side steps sinistrally and continues as SWF. The two faults overstep each other, creating a convergent overlapping transfer zone between them. Epicenters of two big earthquakes including the major Bhuj earthquake are situated in this zone. All the aftershock hypocenters are located within this zone. The eastern part of the basin is highly strained between Radhanpur arch and Median High under the present NNE–SSW-directed compressive stress. The KMF-SWF overstep zone is the most strained part. This part is thus seismically active. Study of intrusive igneous rocks and seismic tomography data indicate the presence of a deep-seated magmatic body close to the mantle.

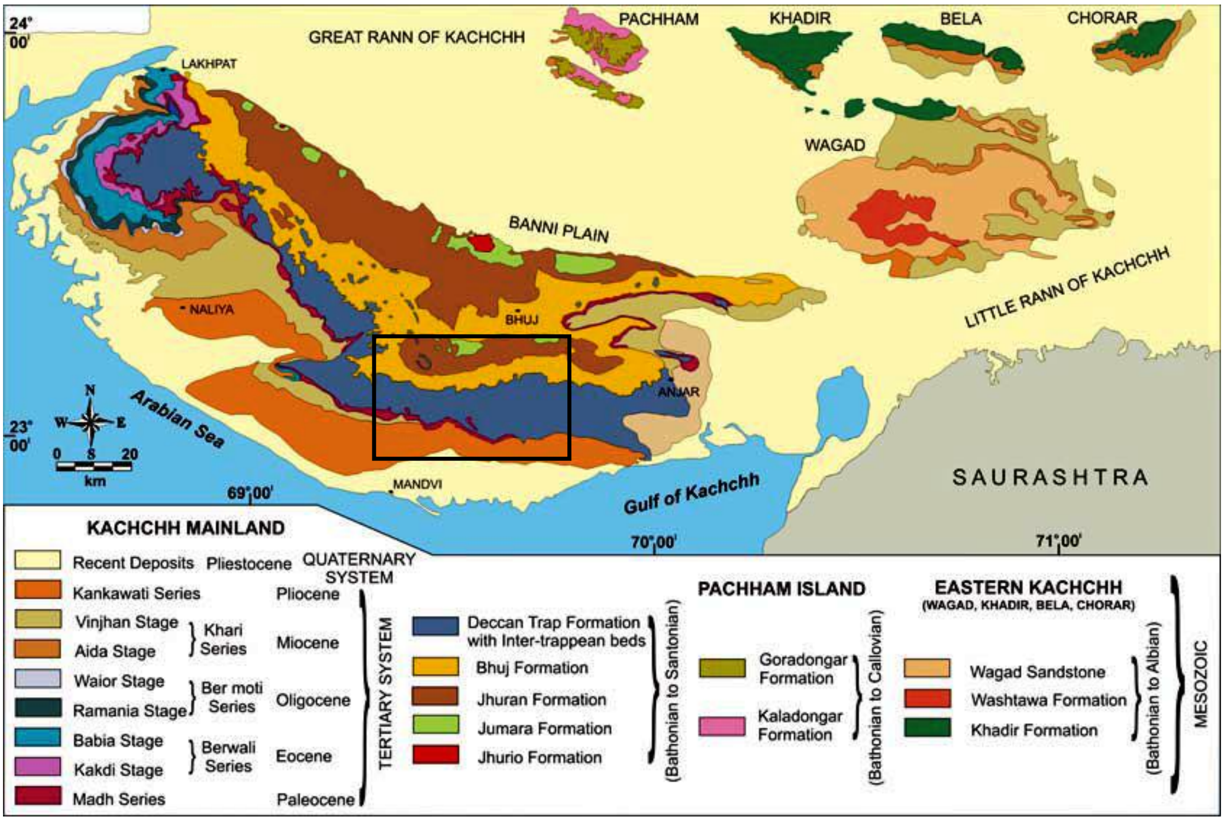
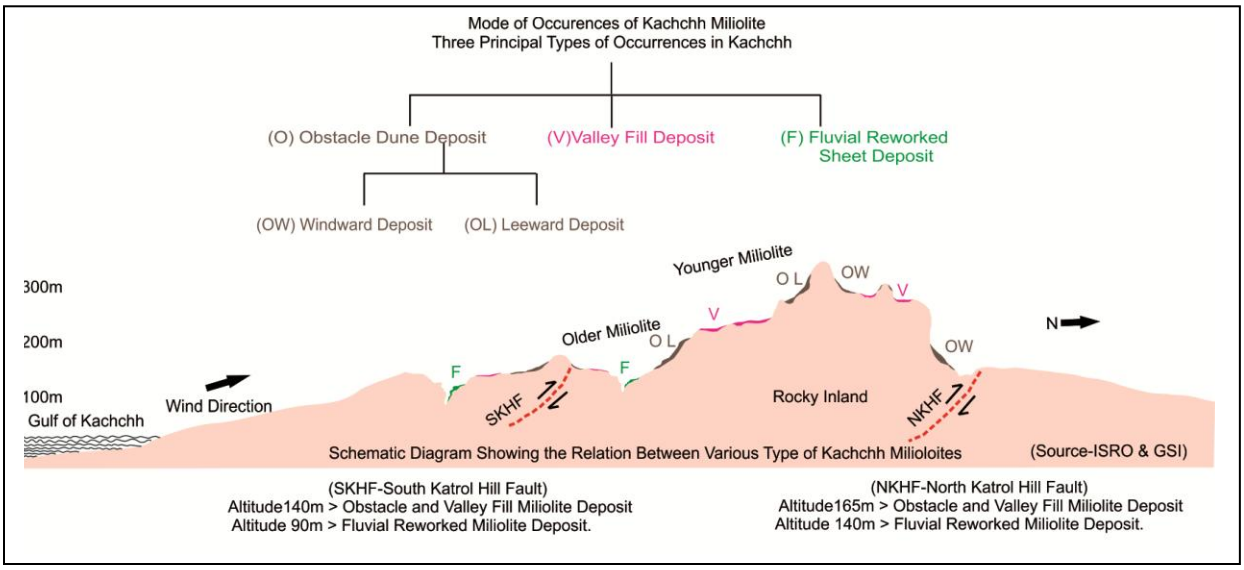


Fig. 1. Geological map of Kachchh showing major stratigraphic unit *(After Biswas and Deshpande, 1970).* Boxed area shows the area covered in the present study.

Mode of occurrences of miliolites in Kachchh

In the study area the occurrences of miliolitic limestone from a part of Katrol Hill Range, south of Bhuj we recognized and were classified based on their depositional characteristics in to three types; (I) Obstacle dune deposits, (II) Valley fill deposits and (III) Fluvial reworked sheet deposits (Fig. 2). These were documented from various localities from the Katrol Hill



range and further south in Kachchh. Figure 2 presents an example of these occurrences with reference to the topographic elevations.

Three principal types of occurrences in Kachchh were analysed for its field disposition as well laboratory studies for its textural and compositional characteristics. The miliolite deposits contain more than 40 to 63% $CaCO_3$ by weight in Type-I, and lesser than 45% to 25% in type-II and III. These occur in the upland area defined by the Katrol Hill Range hosting largely the obstacle dune deposits and valley fill deposits. In the ravines and alluvial plain fluvial reworked sheets of impure miliolites are found. Coastal area is devoid of miliolite unlike its counterpart in Saurashtra.

Laboratory Studies

Frequency Studies, Insoluble Residues Studies, Size variation measurements and Magnetic Susceptibility (MS) were carried out at the Geology Department of The Maharaja Sayajirao University of Baroda.

Frequency Studies: On the basis of petrographic study, three main components distinguished are allochemical constituents, detrital and cement. The detrials were found highest about 44% and above, peloids around 18% and bioclast around 14% whereas, remaining 24% were cement and pores**.** Orthochemical component is cement whish exhibits various ultra structures and is calcareous in nature. Cement type is granular to meniscus and gravitational, fibrous type also found. The fossils are foraminifers, bryozoans, brachiopods gastropods, bryozoans, etc. The texture of majority of miliolite is medium grained, sub angular to sub rounded showing point and long contact, well sorted and less compacted. It is seen that the first generation cement is mainly microsparite and second generation is of sparite. Higher amount of porosity indicate its less compaction and micro-sparite cement suggest that its diagenesis/cementation is mostly carried out by the meteoric water in vadose condition.

Insoluble Residues Studies: Miliolitic deposit contains 25 to 63 % CaCO3by weight and 36 to 75 % terrigenous material. This differentiate in terrigenous content is on account of the altitude of the site of deposition and type of the source rock available near the site of deposition of miliolitic sand. Also this acid insoluble non carbonate residues are observed in microscopes show mainly terrigenous contents like quartz, rock fragment of sand stone and trap, laterite, silt and clay.

Lower concentration of Residue percentage is observed towards southwest side i.e. in Kotda exposure block-III (High hill ranges) and Fakir wadi block-II area, while it's increased towards northeastern side at Gangeswar block-I area. Also extensive deposit of compact miliolite is more to SW side of the study area (i.e. 1km to 4 km width East West trend trap hill form the Kotda exposure), where several hills having heights higher than 260m to 433m provided first high obstacle hill range to south-westerly winds.

Grain Size Studies: It is observed that majority of these grains show size range from 0.5 phi to 3.0 phi, poorly sorted nature, fine skewed and platykurtic to mesokurtic distribution in type-I; and 0.5 phi to 4.0 phi medium to fine sand size, poorly sorted fine skewed to very fine skewed and platykurtic to mesokurtic nature in type-II & III. Size variation studies reveal that any aqueous role in deposition of miliolitic sand is ruled out by showing very little amount of silt and clay (up to 4%) within the miliolitic sand deposit and reveal addition criteria supporting windborne origin (Glennie, 1970).

Magnetic Susceptibility (MS): Obstacle deposits (Type-I), deposited and compacted in situ with high carbonate contain with low magnetic susceptibility lower than 660 (10 -6 SI/g) to 171 (10 -6 SI/g. Although more susceptibility range found i.e. 660 (10 -6 SI/g) and above up to 1517 (10 -6 SI/g) in some samples that must have derived detrital inputs from the mafic mineral containing source like basalt.

In valley fill miliolite (Type II), magnetic susceptibility lower range start with values more than that in the obstacle deposits i.e. from 357 (10 -6 SI/g) and higher up to 660 (10 -6 SI/g).

Fluvial reworked (Type-III) deposits have magnetic susceptibility ranging from 398 (10 -6 SI/g) and above up to 607(10 -6 SI/g).

No specific trend is observed in Magnetic Susceptibility (MS) study. MS-values [10^{-6} SI/g] Min 171 to max 1517 calculated in Kappa bridge. These all above reveal that the miliolite is quite younger and deposited in dryer climate condition. The reworked episode is not pronounced either by time span or drier to semi drier climate

Discussion

Unlike Saurashtra, coastal occurrences of miliolite deposits are not found in Kachchh. However, the high-resolution seismic reflection investigations (Machael et al., 2009) in the Gulf of Kachchh up to 10 to 50 m water depths have suggested that the sediments are mostly consisting of corals and coral sands and stratified upper sediment layers. This supports the earlier inference regarding local source for miliolitic sand (Allahabadi, 1987). The

Quaternary record of southern Kachchh is typically preserved in the form of locally derived colluviums at the base of hills that are partly covered by the reworked carbonate sand mixed with pebbles and gravels of the Mesozoic sedimentary rocks. At the same time on the slope of the hills typical aeolian deposits i.e. obstacle dunes of miliolite are conspicuous. The coastal area exposes 8 to 10 m thick alluvium (sandy gravel, sand and paleosols) in the coastal river bank sections that unconformably rest on the Tertiary sandstone/conglomerate. Overall thus, the Quaternary record in Kachchh indicate fluvial activities punctuated by the aeolian and again regaining of it under the control of climatic episodes, but the supply of sediment being much controlled by the tectonic activities in the Katrol Hill range. The transport of sediments through Dry Land Rivers must have remained very episodic.

According to different authors (Maurya et al., 2003 & 2017; Patidar, 2008; Chowksey et al., 2011) the Quaternary sediments appears in Katrol Hill range as discontinuous sediment cover and occur in the form of scarp-derived colluvium, alluvium, aeolian and valley-fill miliolites and boulder colluviums. Table 1 provides stratigraphic relations, lithological characters, mode of occurrence and possible age and depositional processes with reference to the tectonic environment of the Katrol Hill range.

Table.1. Quaternary stratigraphy, lithological characteristics, occurrence and age in Katrol Hill range.

Miliolite Phase	Quaternary Stratigraphy	Sediments Characteristics & Grain size	Occurrence	Age & Environment	Late Quaternary Faulting (F) and Geomorphic Surfaces (S)
Post Miliolite-Incision Phase	Scarp derived colluviums *Youngest Deposit*	Angular to sub angular pebbles and cobbles embedded in sandy to gravelly matrix. The deposit comprises of debris facies consists dominantly of class with subordinate matrix, whereas the wash facies is comprised of dominantly sandy matrix with dispersed clasts and occasional nested (embedded, surrounded and fixed) set in clasts.	At base of the front scarp. Scarp-derived colluviam is the youngest of the Quaternary deposits. At places overlies the alluvium whereas at other places it rest on directly on the fluvial miliolite.	<u>Late Holocene</u> The sediment characteristics suggest deposition in shallow braided stream channels under reduced level of neotectonic activity.	F3-3rd events < 2Ka. (Patidar et al. 2008) khari saction Fault F2<3.0Ka (Kundu et al. 2010). Uplift of S3- terraces faces during last and significant amount of incision of exposed Quaternary sequences by young streams.
	Alluvial deposits	Fine sand, silt and clay Scattered distributions Fine-grained channelized alluvium, These form 8 to 15m high cliffs along the river banks. Comprise fine to coarse sands with layers of cross-stratified gravels.	Sporadically along the various North flowing streams.	Incision3to5m. Erosion12to15 m deep gully <u>Early Holocene</u> Declining monsoon on set of aridity	F2-2nd in <u>Early Holocene</u> (Patidar et al. 2008)
	Reworked miliolite fluvial-Sheet	The horizontally stratified sandy sheet of miliolite deposits containing cobble and pebbles point to fluvial deposition. It include well-stratified sediments, presence of gravel rich layers, fluvial sedimentary structures such as small scour and fill, cross bedding and large clasts of Mesozoic rocks.	Extensively deposited along river valleys.	Initiating monsoon <u>LGM-Last Glaciations Maxima</u> Aeolian and fluvial	<20Ka S_2 Incision-erosion faces. >20KaVertical incision and lateral planation of Mesozoic and Tertiary.
Syn Miliolite phase (130 to 30 Ka)	Valley fill miliolite	Thick pile of loosely uncontaminated-clean in nature, full of miliolitic sandy sheet fine to medium sand size grains,buff dirty white yellowish to cream in colour.	Occupying Mesozoic depression along river valleys flood plain.	<u>Late</u> <u>to</u> <u>Middle Pleistocene</u> Dustier	F1-1st occurred sometime in <u>Late Pleistocene</u> (Patidar et al. 2008). within the vicinity of the KHF indicates post depositional upliftment of the area. khari saction Fault F1<30.Ka (Kundu et al. 2010).
	Obstacle miliolite wind ward & lee ward	Distinct internal large scale aeolian cross bedding and uniformly well sorted fine to medium sand grains size carbonate rich sand,friable, moderately cemented, upper surface became buff matt black.	Obstacle dunes, all higher evaluation on along the south slope of the hill range and at the base of the north facing front scarp.		
Pre-Miliolite phase Reactivation of KHF (Early then 130 Ka)	Boulder unsorted colluviam	Boulder-size fragment of Shale, thin bedded of sand stone and siltstones. Degradation of scarp. These deposits suggest pre-miliolite neotectonic activity along the KMF.	Colluviam at the base of range front scarps,and base of Quaternary. Its attributed to pre-miliolite reactivation of the KHF, which possibly occurred during the (middle Pleistocene) At places colluviam overlies the Mesozoic.	<u>Middle Pleistocene</u> Debris flows and sediment gravity flows, as small coalescing. Alluvial fans in front of the scarps. Geomorphic surfaces S1 (Course gravelly faces) is oldest featureless alluvial plain-gentle southward slope. Where S2(Incised faces) & S3(Terrace faces) are developed.	

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