Chapter 2

REGIONAL GEOLOGY

The Kachchh basin is an E-W trending palaeorift graben that is located on the western continental margin of India. The basin originated in the early Mesozoic and exposes a full sequence of rocks from the middle Jurassic till the present (Figure 2.1) The Mesozoic sedimentation took place during the rift phase of the basin that ended in the late Cretaceous. The basin was inverted at the end of the Cretaceous (Biswas and Khatri 2002). Since then, the basin suffered intermittent phases of uplift and flexure along the various E-W trending faults (Biswas and Khatri 2002). The Cenozoic sediments (Tertiary and Quaternary) were laid down in the geomorphic lows that resulted from the differential uplift of the basin along faults (Biswas 1993). The present landscape framework of Kachchh is therefore largely the result of the pre-Quaternary tectonic evolution of the basin (Biswas 1974). Continued tectonic instability of the basin and the active nature of various faults is evidenced by several large magnitude earthquakes in historic times including the 2001 earthquake that occurred in the region (Biswas and Khatri 2002).

The evolution of Kachchh, Narmada and Cambay rift grabens are related to the breakup of Gondwanaland in the Late Triassic/Early Jurassic and the subsequent spreading history of the Eastern Indian Ocean (Biswas, 1982; 1987). The Saurashtra block remained as a horst while the Kachchh, Cambay and Surat basins subsided around it for the deposition of Cenozoic sediments. The Kachchh rift was initiated in the Late Triassic along with the Delhi trend as evidenced by continental Rhaetic sediments in the northern part of the basin (Kosal, 1984). The Kachchh rift basin was formed by the subsidence of a block between the Nagarparkar Hills and the southwest extension of the Aravalli Range (Biswas, 1982, 1987). The Kachchh graben became a fully marine basin during the Middle Jurassic period (Biswas, 1981). In the Late Cretaceous, uplift of the Jurassic sediments took place in the Kachchh Basin. The major structural elements that have played a significant role in the post-Mesozoic geological and geomorphological evolution of southern Mainland Kachchh are shown in (Figure 2.1)

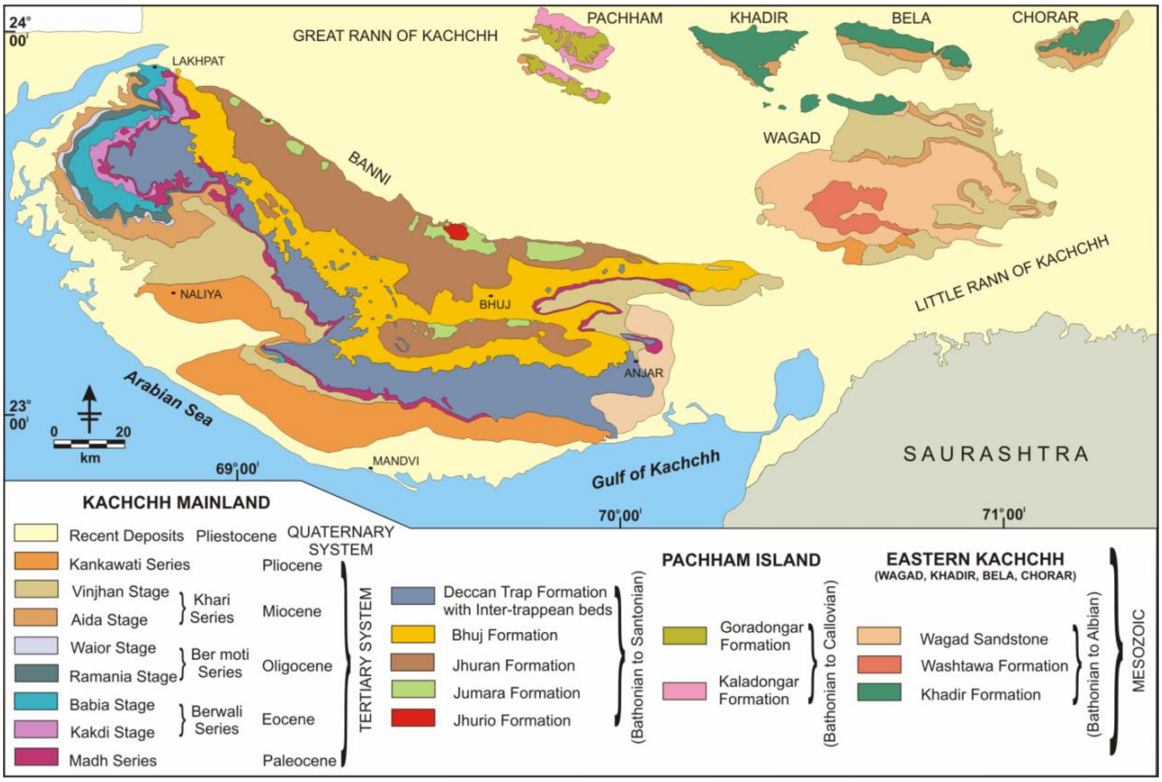

Figure 2.1 Geological map of the Kachchh basin (after Biswas, 1993). The map was redrawn by Patidar (2010).

STRUCTURE AND TECTONICS

The structural configuration of the Kachchh basin is characterized by highlands and plains, which are the uplifts and half grabens respectively. The E–W striking master faults are the primary faults (Figure 2.2), which control the structural evolution (Biswas, 2005). The structures of the Kachchh Basin are unique in itself as nowhere else in India similar structural style is seen (Biswas, 1982; Biswas 1987). The general structural features include a group of east-west trending along uplifts surrounded by residual depressions (The plains of the Great and Little Rann of Kachchh). Between the uplifts, the structural lows which are the extensions of the residual depressions occur as intervening basins (Biswas, 1982, 1987, 2005). The uplifts are 12 to 120 miles long and 5 to 45 miles wide. They are bounded on one side by faults or sharp monoclinal flexures and on the other side by peripheral plains, the sedimentary strata which dip gently into the surrounding basins (Biswas, 1987; Biswas 2016). Six major 8 uplifts occur within the basin along three sub-parallel lines trending generally from east to west in an echelon pattern (Biswas, 1993). Six major uplifts are Pachham, Khadir and Bela Island, Chorar Hill, Wagad Highland and the Mainland of Kachchh. Of these, the Mainland Kachchh is the biggest. The Wagad uplift is the second-largest and placed en-echelon with the chain of islands (Island-Belt) on the north and the

Mainland on the south. The Island-Belt consists of four individual uplifts along a line trending west to east Pachham, Khadir, Bela and Chorar (Biswas, 1982, 1987). These uplifts show an echelon arrangement with their position shifted progressively towards the north from west to east. This arrangement suggests that the individual uplifts are perhaps individually elevated parts of an east-west ridge. The Great Rann of Kachchh is the most extensive basin which separates the Nagar-Parkar uplift and the uplifts of the Island belt (Biswas, 1982).

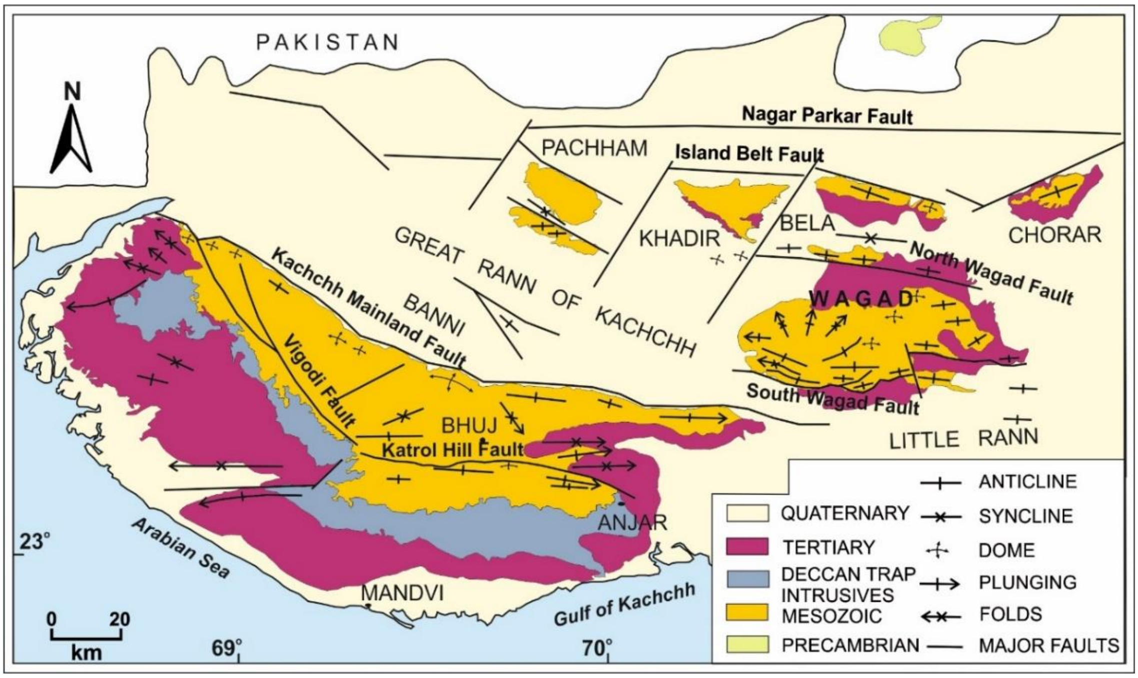

Figure 2.2 Structural map of Kachchh (after Biswas and Deshpade, 1970).

Thus, each uplift is characterised by a narrow linear flexure zone along its faulted-up margin. The flexure zones are often shifted across the strike by the cross-faults which cuts and displaces the marginal faults (Biswas, 1982; Biswas 1987). The development of the folds of the secondary orders is also seen along the subsidiary faults. In the eastern part of the Kachchh Basin, the Wagad uplift shows an orientation opposite to that in the western part. Its Southern margin is complicated by faulting and associated flexures. The Mainland Fault along its Northern Range Flexure zone.

MESOZOIC STRATIGRAPHY

Mesozoic rocks ranging in age from Middle Jurassic to Lower Cretaceous are exposed in six uplifted areas – Kachchh Mainland, Pachham Island, Khadir Island, Bela Island, Chorar Hills and Wagad Highland. The Lower Cretaceous rocks are represented by rocks of the Bathonian and Callovian ages. The Khadir, Bela and Chorar rocks represent the period between Bathonian to Oxfordian. The Wagad Stratigraphy comprises rocks of Oxfordian to Portlandian or perhaps Neocomian age. The generalised Mesozoic stratigraphy is given in Table 2.1.

Mesozoic rocks constitute more than three-fourths of the Mainland area of Kachchh. They are exposed to central hilly terrain and bordered by a narrow belt of Tertiary rocks along the coastal plain. These rocks are divided into four mappable rock-stratigraphic units. The following brief description of the various Mesozoic formations in Kachchh is based on (Biswas 1977; Biswas 1982; Biswas 1987; Biswas 1993; Biswas 2005).

Table 2.1 Litho-Stratigraphy of Mesozoic rocks of Kachchh Basin (after Biswas, 1977).

Mainland		**Pachham Island**		**Eastern-Kutch (Khadir-Bela-Wagad)**	
Formation	**Member**	**Formation**	**Member**	**Formation**	**Member**
Bhuj	Upper				
	Ukra				
	Ghuneri			Wagad Sandstone	Gamdau
Jhuran	Katesar				Kanthkot
	Upper				
	Middle				
	Lower				
Jhumara	Dhosa Oolite			Washtawa	Bhambhanka shale
	Middle				Gadhada
		Goradongar	Modar hill	Khadir (Khadir Island)	
	Lower		Raimalro		
Jhurio	Upper		Gadaputa		Hadibhadang
	Middle		Flagstone		
		Kaladongar	Kaladongar Sandstone		Cheriya bet
	Lower				
			Kuarbet		
				Precambrian	

Jhurio Formation

This formation is exposed as circular inliers at the cores of the hills of Habo, Jhurio and Jumara of the Northern Range along the northern margin of the Mainland. In Habo and

Jumara hills, only the upper part of this formation is exposed. It is very well exposed in the deep valleys of Jhurio hill. The typical section is seen along a big stream that flows to the north from the centre of the hill. In Jumara Dome these rocks are exposed at the core of the dome as a circular outcrop forming the central hill.
Age - Upper Bathonian to Callovian

Lithology - This formation is steadily identified in the field by its characteristic lithologic association of limestone, shale and golden oolite rock. This is the only formation where pure crystalline limestone is encountered (Biswas, 1987; Biswas 2016). The older shaly beds are exposed only is deeply dissected valleys.

Palaeontology - The Alectryonia – Rhynchonella assemblage is very common throughout the formation. This formation is very richly fossiliferous in the Jumara area. Among other fossils, the following may be present like Terebratulla spp. Including T.jumarensis, Rhynchonellapseudo-inconstant, R.kutchensis, Trigonal spp. and some Ammonites.

Depositional Environment - The lithological association of the formation is quartzose shale, limestone and golden oolite rock indicates nearshore deposition in the slow transgressive sea under relatively stable conditions. The limestones with clastic content show deposition away from the littoral zone and a gentle rate of subsidence when the rate of erosion was low. These suggest a shallow, open shelf deposition where free circulation and aeration predominated (Biswas, 1987; Biswas 2016). All these features characterize a sub-littoral deposition environment.

Jumara Formation

A thick argillaceous formation overlies Jhurio Formation. This formation is best developed and exposed in the central part of Jumara Dome which forms a hill adjacent to the Rann, to the south of Jumara village.

Age - Callovian to Oxfordian

Lithology - Jumara Formation consists mainly of quartzose shales and gypseous clayey shales with hard beds of marlites and calcareous quartzose sandstones.

Palaeontology - The Jumara Formation is highly fossiliferous throughout its thickness and extent. The fossils found are of ammonite, brachiopod and pelecypod fauna.

Depositional Environment - The typical clastic association of the formation is gypseous, glauconitic and quartzose shales, quartzose sandstones and oolitic marlites depict deposition in the sublittoral environment under stable conditions (Biswas, 1987; Biswas 2016). The abundance of shales indicates a transgressive sea in a slowly sinking basin.

Jhuran Formation

Jhuran Formation overlies the Jumara Formation and is exposed in the Northern Range of the mainland of Kachchh. The base of the formation is exposed in the Lothia Dam Dome and the top of the formation is exposed on the southern slopes of the Roha Hill (Biswas, 1987; Biswas, 2016).

Age - Agrovian to Neocomian

Lithology - The formation is characterized by thick shale beds alternated with hard sandstone beds present in ribbed topography with alternating valleys and cuestas.

Sedimentary Structures - A variety of sedimentary structures are noted in this formation that is current bedding, ripple marks, convolute bedding, load and groove casts, cut and fill and slump structures.

Paleontology - The formation is richly fossiliferous in the western part of the Mainland. The fossils that characterize this formation includes Ammonites, Belemnites and Lamellibranchs.

Depositional Environment - The appearance of younger beds towards the west below the surface of disconformity shows that the beds overlap in that direction. This is evidence of a regressive sea. The shales and sandstones of the Lower Member represent deeper water facies in continuation with the underlying shales of the sub-littoral environment (Biswas, 1987; Biswas 2016).

Bhuj Formation

The youngest Mesozoic formation of the Mainland of Kachchh is represented by non-marine rocks, very well exposed around the city of Bhuj and its neighbourhood.

Age - Pre-Aptian (Cretaceous)

Lithology - The lithology comprises felspathic sandstones, kaolinitic and sandy shales, ferruginous sandstone, pebbly laterite and ironstone.

Sedimentary Structures - Sedimentary structures include current bedding, ripple marks, load-casts, sole marks and convolute bedding.

Palaeontology - Bhuj Formation is barren of fauna but very rich in micro-fauna.

Depositional Environment - The prevalence of red sand sandstones, iron-oxide bands, presence of felspathic shales and claystones, absence of marine fossils, abundant plant fossils in carbonaceous shales, and poor degree of sorting all point towards a non-marine environment for deposition (Biswas, 1987; Biswas, 2016).

TERTIARY STRATIGRAPHY

The Tertiary sediments are most well developed in the western Kutch. A complete sequence of Paleocene to Pliocene sediments is about 900 m thick. Tertiary Stratigraphy classification is given in Table 2.2 (after Biswas, 1992).

Table 2.2 Stratigraphy of Tertiary sediments of Kachchh basin (after Biswas, 1992).

Age	Formation	Members
Pliocene	Sandhan	
Lower Miocene (Burdigalian)	Chhasra	Siltstone Claystone
Lower Miocene (Late Aquitanian)	Khari Nadi	
Oligocene	Maniyara Fort	Bermoti Coral Limestone Lumpy clay Basal member
Late Middle Eocene	Fulra Limestone	
Middle Eocene	Harudi	
Late Paleocene	Naredi	Ferr. Claystone Assilina Limestone Gypseous Shale
Upper Paleocene	Matanomadh	
Cretaceous–Lower Plaeocene	Deccan Trap	

The thickness of Neogene sediments suggests the basin subsidence took place during this time. Tertiaries are mainly exposed in narrow coastal plains of Kutch Mainland & in the peripheral plains of other highlands. They are nearly horizontal except near the Mesozoic structures where they show up warping. They are best developed in the coastal strips of southern and western parts of Kachchh Mainland. The lower Tertiary rocks overlie the Deccan Trap flows in Southern and Western Kachchh Mainland while in other areas they occur directly over the Mesozoic rocks. The Tertiary rocks range in age from Paleocene to Pliocene (Biswas, 1987; Biswas 2016). Most formation of this age over a Deccan trap follow Matanomadh, Naredi, Harudi, Fulra limestone, Maniyara fort, khari nadi, Chhasra, and Sandhan (Table 2.2). Biswas classified different members in various formations.

Matanomadh Formation

Overlying the Deccan Trap Formation occur a variety of rocks consisting of Trap derivate, pyroclastic and sedimentary clastic in various degrees of admixture. They form a conspicuous unit marking the base of the Tertiary sequence. Distinctive types of volcano-clastic rocks are deposited in continental to supra-littoral environments. The type section is exposed to Bhuj-Lakhpat road section east of Matanomadh. In the badlands around the village, in Madhwali and in the Nadi section to the south of the village.

Age - Paleocene to Lower Eocene

Lithology - Rocks found here are extremely irregular, soft and friable and hence readily form badlands. The common rock types are red laterite, bauxite, lateritic Trap-pebble conglomerate, Trap-wash/ wacke, variegated plastic bentonitic clays, red and yellow ferruginous clays, grey and white tuffaceous shales and red, current bedded, tuffaceous sandstones and occasional layers of lignite. The lithologic characteristics indicate that these volcanoclastic sediments were deposited during the waning phase of the Deccan volcanicity in different terrestrial environments. 16 Pyroclastic and ash ejected from various volcanic centres (Biswas and Deshpande, 1973) were carried by the wind.

Palaeontology - The rocks of the Matanomadh Formation have been found to be devoid of fauna and locally very rich in spores and pollens.

Depositional Environment - The lithological characteristics indicate that these volcanoclastic sediments were deposited during the waning phase of the Deccan volcanics in different environments (Biswas, 1987; Biswas 2016).

Naredi Formation

Naredi formation overlies Matanomadh formation. This Formation is named as Naredi formation after its stratotype in the cliffs of the Kakdi Nadi near the village of Naredi

(23°39'49": 68°40'38"). The type section is exposed in the cliffs along Kakdi Nadi south of Naredi and partly (upper part only) along Guvar stream NNW of Naredi. This formation is well developed only in Western Kachchh. It occurs in a narrow sinuous belt of outcrop from Lakhpat in the north to Jhulrai in the south (Biswas, 1993, 2016).

Age - Late Palaeocene to Early Eocene

Lithology - Lithology of this formation is distinctly divided into three members: Gypseous shale member, Assilina-limestone member, and Ferruginous claystone member. The lower and middle members locally develop black shale facies comprising black pyriteous shales and lignite beds.

Palaeontology - The Naredi Formation is rich in fossils. Assilinaspinosa, Lockhartia, sp., Nummulites sp., Globigerina sp., and Globorotalia sp., varieties of bivalves, gastropods and corals are seen.

Depositional Environment - The series consists of the various depositional environments due to its variety in lithology. The depositional environment includes a shallow water environment and a stable shelf tectonic environment in the sunlit photic zone of the sublittoral environment (Biswas, 1987; Biswas 2016).

Harudi Formation

This formation is named as the Harudi Formation after its type section near Harudi village (23°30'30"; 68°41'10"). The formation is very well exposed in an impressive escarpment to the west of Harudi village. The formation is very well exposed in an impressive escarpment to the west of Harudi village (Biswas, 1993).

Age - Middle Eocene age

Lithology - The formation consists of green and greenish-grey, splintery shale with yellow limonitic partings in the lower part and calcareous claystone and siltstone with occasional layers of gypsum and carbonaceous shale in the upper. This marker is 17 popularly referred as N. obtusus band.

Palaeontology - This series is highly fossiliferous with fossils like Truncorotaloides topilensis, Nummulites obtusus, N. acutus, Brarrudosphaera biglowi, Dictyoccites bisectus, Bolis and Xancus.

Depositional Environment – Littoral to lagoonal in the lower part and inner self in the upper part. Sediments represent a transgressive phase of deposition (Biswas, 1987; Biswas 2016).

Fulra Limestone

This formation has been named as the Fulra Limestone after its designated type section near Fulra village (23°42'30"; 68°47'12") in Western Kachchh. The type section of this formation is best exposed on the southern flank of babia hill near to Fulra village. This formation is well exposed only in the western part of Kachchh around Narayan Sarovar, Dedhadi, and Lakhpat noses in a 6.5 to 10 km wide belt of the outcrop (Biswas, 1987; Biswas 2016).

Age - Late Middle Eocene age

Lithology - The entire formation is made up of massive to thickly bedded, white, and buff coloured foraminiferal limestone. The limestones are fossiliferous micrites, biomicrites and biomicrosparites.

Palaeontology – Planktonic foraminifera like Orbulinoides beckmanni, Truncorotaloides rohri, Discocyclina sowerbyi, Fasciolites elliptica. Besides the microfossils, the formation is rich in megafossils like oysters, turritellids, Pecten, echinoids, and fossil carbs.

Depositional Environment – Foraminiferal assemblage and lithology are characteristics of low energy, clear waters probably under a marine-self environment (Biswas, 1987; Biswas 2016).

Maniyara Fort Formation

This formation is named after Maniyara Fort (23°28'05" 68°37'00"). The type section is continuously exposed along Bermoti Nadi (stream) flowing between Maniyara Fort and Bermoti village (23°25'00";68°35'00") from a locality 1.6km NNE of Bermoti to a locality about 450m SE of the village. Besides the type section, this formation is well exposed in Ramania stream, Waior stream, Berwali Nadi, Bermoti stream and also in the area around Lakhpat.

Age - Oligocene

Lithology - The basal member is about 14ft. thick and consists of alternating beds of foraminiferal, glauconitic, brownish to yellowish siltstone and calcareous, gypseous claystone (Biswas, 1993). The lumpy clay member is about 15 ft. thick and consists of cement colored to brownish calcareous, lumpy claystone, occasionally containing thin limestone and marlite beds. The Bermoti member is about 36 feet thick and is best developed in the stream SE of Bermoti and also NNE of Waior (23°05'002"; 68°41'45"). It is also well exposed on top of Maniyara Fort Hill (Biswas, 1987; Biswas 2016).

Palaeontology – The formation is richly fossiliferous with variety with variety of echinoids, pelecypods, gastropods, corals and carbs. Well preserved skeletons of reptiles, whales etc. are seen trapped between layers of foraminiferal limestone. Nummulites and Miogypsina are the characteristic foraminifera present.

Depositional Environment – Marginal marine, littoral to the shallow inner self. Marine transgressive, environment shifted from lagoonal to high energy open self-environment (Biswas, 1987; Biswas 2016).

Khari Nadi formation

This formation is named after Khari Nadi. The type section is exposed along cliffs and banks of Khari Nadi between its confluence with Sugandhi Nadi (locality: 23°25'45"; 68°49'40") near Goyela and the prominent elbow bend (23°23'00"; 68°48'00") about 2 km. North of Laiyari-Rampura cart-track. The maximum development of the formation is seen on the southern flank of the Narayan Sarovar nose between Waior and Jangadia. Good exposures are seen in the high cliffs of the Waior, Barkhan, and Khari streams (Biswas, 1987; Biswas 2016).

Age - early Miocene

Lithology - The lithology consists predominantly of laminated to very thin bedded red and yellowish mottled to variegated siltstone and very fine-grained sandstones with occasional grey and brown gypseous claystone. A bluish-grey claystone bed occurs consistently near the base in every section. Cross bedded, fine-grained, micaceous sandstone is present in the middle part, while a few thin fossiliferous marls and limestone beds are present in the middle and upper part of the type section.

Palaeontology –Foraminifera like Miogypsina tani, M. dehartti, Nephrolepidina and Austrotrillina. Plant fossils are common in the lower part. Turitella, Ostrea and echinoids are common mega fossils present (Biswas, 1987; Biswas 2016).

Depositional Environment – Tidal flat, littoral to shallow inner-self in a slowly transgressive sea over a stable shelf.

Chhasra Formation

This formation is named after Chhasra Village (23°21'20"; 68°46'40"). The type section is exposed along Khari Nadi from the top of Khari Nadi Formation near Laiyari to a locality 1 km south of Chhasra village.it is well exposed in Southern and Eastern Kachchh, also exposed as patchy outcrops in the low plains between the highlands. It also occurs as an outlier in the peripheral structural lows of the mainland and Wagad highland (Biswas, 1987; Biswas 2016).

Age – Early to middle Miocene

Lithology - A lower claystone member, consists of grey and khaki coloured, laminated to splintery, gypseous shales and claystones with alternations of thin, hard yellowish, highly fossiliferous argillaceous limestones. An upper siltstone member consists predominantly of alternating micaceous siltstone and laminated silty shales of monotonous khaki colour. The upper part is reddish.

Palaeontology – The formation is highly fossiliferous. Gastropods like Turritella, Murex, Natica, Cyprea, Physa, Conus. The formation also has an abundance of Arca, Pecten, Venus and echinoids.

Depositional Environment – Rich biota and lithology indicate deposition in the sublittoral environment during the highest stand of the sea. Foraminifera suggests fluctuating marginal marine to shallow inner-self conditions of deposition (Biswas, 1987; Biswas 2016).

Sandhan Formation

This formation is named after Sandhan village (23°01'15"; 68°59'35"). The type section is exposed along the Kankawati river from one km south of Vinjhan to south of Sandhan where it is overlain by Quaternary and Recent deposits.

Age - middle Miocene to early Pliocene

Lithology - The lower part of the formation consists of well-sorted, medium to coarse-grained, massive, micaceous sandstones, overlain by clayey, laminated siltstones and topped by thin yellow fossiliferous limestone beds. The middle part comprises conglomerates and coarse-grained sandstones with lenticular bodies of conglomerates. The upper part consists mainly of hard, calcareous grits, overlain by pink and grey mottled silty sandstone with calcareous nodules (Biswas, 1987; Biswas 2016).

Palaeontology – Foraminifera like Ammonia sp., Pararotalia sp., Elphidium sp., miliolids. Lenticular pockets of oyster debris and thin oyster bands are common in the upper conglomerate sandstone. This formation is also rich in vertebrate fossils like Anthracotheroids and suids (Biswas, 1987; Biswas 2016).

Depositional Environment – The basal conglomerate with fossil wood and channel fills over the underlying Vinjhan shales clearly suggest an erosional break in the deposition followed by fluvial sedimentation. The sandstone appears to be littoral sand of advancing sea after major regression. The depositional environment thus appears to be supra-littoral to the deltaic or foreshore environment (Biswas, 1987; Biswas 2016).

GREAT RANN OF KACHCHH BASIN (GRK)

The evolution of the Kachchh rift basin (KRB) materialized on account of periodic reactivation of the assorted basement related faults. During the Late Triassic or Early Jurassic, before India-Africa separation, the KRB rifted, which generated extensional stresses and experienced constant sedimentation until the Late Cretaceous (Biswas, 2016; Shaikh et al., 2020). The rift evolved within the Mid-Proterozoic Aravalli-Delhi fold belt by reactivation of pre-existing faults along with the NE–SW trend of the Delhi fold belt that swings to E–W in the Kachchh region (Biswas, 1977; 1987; 1993; 2005). The E-W striking major faults and other subsidiary faults were activated as normal faults on account of extensional stresses (Biswas, 2016). A series of half-grabens was formed on account of normal faulting successively from north to south (Biswas, 1987; 2005).

The rifting of the KRB was then aborted during Late Cretaceous (Biswas, 2016). Drift movement of the Indian plate started with counter-clockwise rotation from the Mid-Jurassic period onward after the break-up of the Gondwanaland and India-Africa separation (Biswas, 2016). In the KRB, this caused transtensional motion (Biswas, 2016). From Late Cretaceous to till now, the rifting of the KRB is followed by rift inversion, resulting in the formation of intra-basinal uplifts with associated structural lows due to reactivation of earlier normal major faults as reverse faults (Biswas and Khattri, 2002; Shaikh et al., 2020).

During the Neogene and Quaternary times, the lows were filled up by thick transgressive marine sediments (Biswas, 1993). During the post-Cretaceous inversion phase, the faults bordering the uplifts were periodically reactivated, thereby promoting the accumulation of Cenozoic sediments (Biswas, 1993).

The present structural sort of the KRB indicates large-scale, periodic lithospheric deformation because of varying regional stress fields and also, induced local anomalies within the regional stress pattern (Biswas, 2016). The basin is recognized united of the simplest samples of SCR (Stable Continental Region) earthquakes and has been compared with the New Madrid seismic zone (Bodin et al., 2001; Tuttle et al., 2002; Schweig, 2003). The KRB, which is the most earthquake-prone intra-plate region in India, falls within the highest seismic risk zone–V in the seismic hazard zonation map (BIS, 2002; Choudhury et al., 2018). The KRB is characterized by multiple seismic sources because it has witnessed several devastating, moderate-high magnitude intra-plate earthquakes attributed to periodic movement along the intra-basinal faults. A few examples are the 1819 Allah Bund earthquake (Mw 7.8; 15 km focal depth; Bilham, 1999; Rajendran and Rajendran, 2001), 1956 Anjar earthquake (Mw 6.1; 15 km focal depth; Chandra, 1977; Chung and Gao, 1995) and 2001 Bhuj earthquake (Mw 7.7; 23 km focal depth; Bendick et al., 2001). Therefore, an intensive understanding of the behaviour of the large-scale, regional stress pattern acting upon the KRB is important. However, the tectonic evolutionary history of those faults, particularly, in the Late Cenozoic and consequent landscape evolution isn't known. This has resulted in a very general lack of geological database on the fault zones that has precise fault maps, geomorphologic settings, and long-term and short-term slip rates. Tectono-geomorphic Studies are essential to resolve the above geological issues which are critical for seismic hazard estimation and mitigation within the KRB.

Neotectonic, tectono-geomorphic and paleoseismic aspects of the major E striking intra-basinal faults have been widely discussed in literature during the last two decades. Towards the south, these are – ABF (Rajendran and Rajendran, 2001; Padmalal et al., 2019), IBF (Bhattacharya et al., 2019), GF (Maurya et al., 2013), SWF (Kothyari et al., 2016; Maurya et al., 2017), KMF (Chowksey et al., 2011a, b; Shaikh et al., 2019) and KHF (Patidar et al., 2007; 2008). Probabilistic Seismic Hazard Assessment (PSHA) and Deterministic Seismic Hazard Assessment (DSHA) studies have estimated 1.0-1.1 g of maximum acceleration along the major faults in the KRB (Choudhury et al., 2018).

The KRB is in the hyper-arid belt of NW India that includes the Thar Desert to its north (Figure 2.2) resulting in a high rainfall deficit climatic regime (Machiwal et al., 2016). Therefore, various rivers show dry channels for the most part of the year with insignificant episodic water flows, lasting for a few days during monsoon season. Also, there are no historical records of extreme discharges or floods during historical times, however, several prolonged spells of drought have been common (Machiwal et al., 2016). This together with a long history of devastating earthquakes points to tectonics as the major geological factor in the geological evolution of the KRB.

The modern GRK is known for its unique annual inundation cycle through dragging of seawater into the basin for ~100 km inland and with less monsoon precipitation in this region baffled earth scientists for a long time to understand inundation pattern (Gleinne and Evans, 1976; Roy and Merh, 1981; Merh, 2005). The flat, gradient less surface of GRK and its slight elevation from sea allows extensive inundation from the Arabian Sea under the strong summer monsoon winds and through the rivers from the northeast by precipitation (Roy and Merh, 1981). The water does not percolate much into the subsurface and gets locked for several months into GRK until the increasing summer temperatures dry it up which leaves a thick salt crust across hundreds of square kilometres area (Gleinne and Evans, 1976). Overall, the alternate wet and dry condition in the Great Rann of Kachchh results in a unique and hostile terrain whose environmental condition fluctuates between extremes. There are several known zones where the slummy regions swallow large animals, vehicles and field parties which therefore warrants enough information to carry out field activities. Usually, local help is a prerequisite to visit before the interior parts. The GRK comprises overall vast, flat, monotonous terrain; however, there are rocky islands, small islets (locally called as bets), raised rann sediments and other peculiar geomorphic characteristics which clarify the overall geomorphic assemblage of the basin.

The GRK surface shows considerable variation in elevation from north to south and west to east which clearly gets reflected in its submergence pattern. Gleinne and Evans (1976) described modern GRK environments as coastal sabkha to supratidal environments. Roy and Merh (1981) described GRK into four zones based on the submergence pattern namely into- Bet Zone, Linear Trench Zone, Banni plain and Great Barren Zone. The rann (local, informal name for GRK and LRK) surface is dotted with several large to small islands such as Pachham, Khadir, Bela, Chorar and small rocky islands like the Bhanjada bet, Kuar bet, Mori bet and the Gainda bet (Figure 2.2). All these islands show rocky, hilly topography and expose Mesozoic and Tertiary rocks. In addition to this, there are several smaller islands rising up to 1-5 m above the rann surface, especially in the northern part of the Great Rann and consist of sediments similar to the rann surface raised to a higher level (Figure 2.2). The top cover of these islands is usually made up of aeolian sediment blown from the windswept surface of the rann that is underlined by rann sediments. The Rann is predominated by the saline landmass and the low-lying Rann surface is mainly associated with salt layers. Based on the inundation pattern and surface assemblage it is divisible in four E-W trending zone.

The western Indian continental margin of Gujarat state hosts several important marine marginal basins such as the Gulf of Khambhat, Gulf of Kachchh, Little and Great Rann of Kachchh where west-flowing rivers coming from the Himalayas, Aravalli hill ranges and local Kachchh mainland draining rivers debouch and emptied their sediment load (Tyagi et al., 2012; Mehar, 2005; Malik., 1999; Glennie and Evans, 1976; Roy and Merh, 1982; Oldham, 1893; Stein, 1942; Ghose et al., 1979). The sediment supply of these rivers to these marine marginal basins is not assessed well through time. Despite their significance for the palaeoclimatic/paleomonsoonal studies, these basins are least explored and studied based on the exposed sequences and/or short pits (Pant and Juyal, 1993; Chowksey et al., 2010; Maurya et al., 2008; Banerji et al. 2016). There are few studies from other neighbouring archives regions such as the Indus delta (Giosan et al., 2012), lacustrine sediments from the Thar Desert (Enzel et al., 1999; Sinha et al. 2006), mudflats of Saurashtra (Banerji et al., 2015) and Kachchh (Makwana et al., 2018) regions that discuss paleoclimatic variability records of the western Indian sector. Whereas there are very few records that cover the entire Holocene period extend beyond that for example lacustrine record of Nal Sarovar by Prasad et al. (1997). Therefore, studying the paleoclimatic/paleoenvironmental conditions throughout the Holocene period is one of the significant steps toward understanding the overall paleoclimatic/paleoenvironmental evolution of the presently arid Kachchh region (GRK basin). Additionally, studying these archives (GRK for example) for climate-tectonic coupling suits an opportunity to understand the relative dominance of these forcing mechanisms along with the landscape evolutionary stages of these basins.