Chapter - 1

Chapter 1

INTRODUCTION

Kachchh Peninsula in Western India has attracted workers from the field of earth sciences ranging from stratigraphy, tectonics to remote sensing and environmental geology as it forms an archetypal for investigation. The great 'Allah Bund Earthquake' of 1819 with an intensity of around X attracted earth scientists from all over the world. Subsequent recurrence of seismicity which included Anjar Earthquake of M_W 6.1 in 1956 and the Bhuj Earthquake of M_W 7.7 in 2001 prompted many workers to undertake seismological and tectonic studies in the region. The present author has chosen to undertake the structural and tectonic studies along the tectonically active eastern sector of the Kachchh Mainland Fault.

Geologically, Kachchh (also spelled as Kutch or Cutch) region forms an important peri-cratonic Mesozoic-Tertiary sedimentary basin located along the western continental margin of India (Biswas 2005) (Fig. 1.1). The E-W oriented rift is believed to be bounded by Nagar Parkar Uplift (NPU) to the north, Kathiawar Uplift (KU) to the south and by Radhanpur-Barmer Arc in the east (Fig. 1.2). The western margin of the rift extends in to Arabian Sea and is mostly covered by Indus River delta. Kachchh Basin includes the entire district of Kachchh and a part of Patan district of Gujarat State.

Kachchh is largest district of Gujarat State, extending from the southern border of Pakistan to the Gulf of Kachchh on the south and from the Arabian Sea on the west to the plains of Gujarat on the east. The district of Kachchh is well connected by all-weather roads.

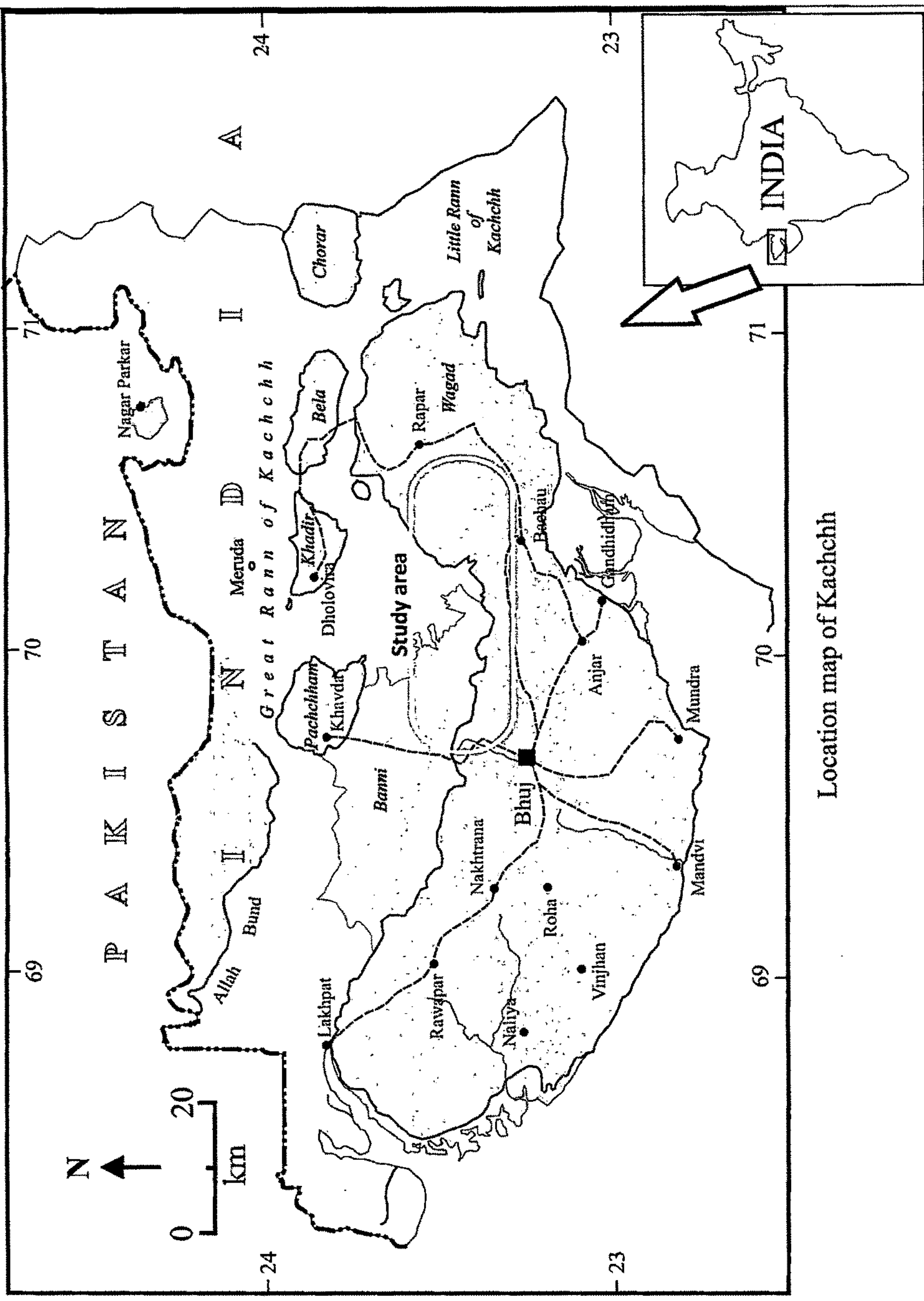

Fig. 1.1: Location map of Kachchh

Nearly half of the region constitutes inhospitable salt encrusted plain land lying barely 2-3 m above the Mean Sea Level (MSL), known as the Great and Little Ranns of Kachchh. During the rainy season and high tides the area is inundated by the knee-deep water (Fig. 1.3). Rest of the area remain dry during the rainy season well.

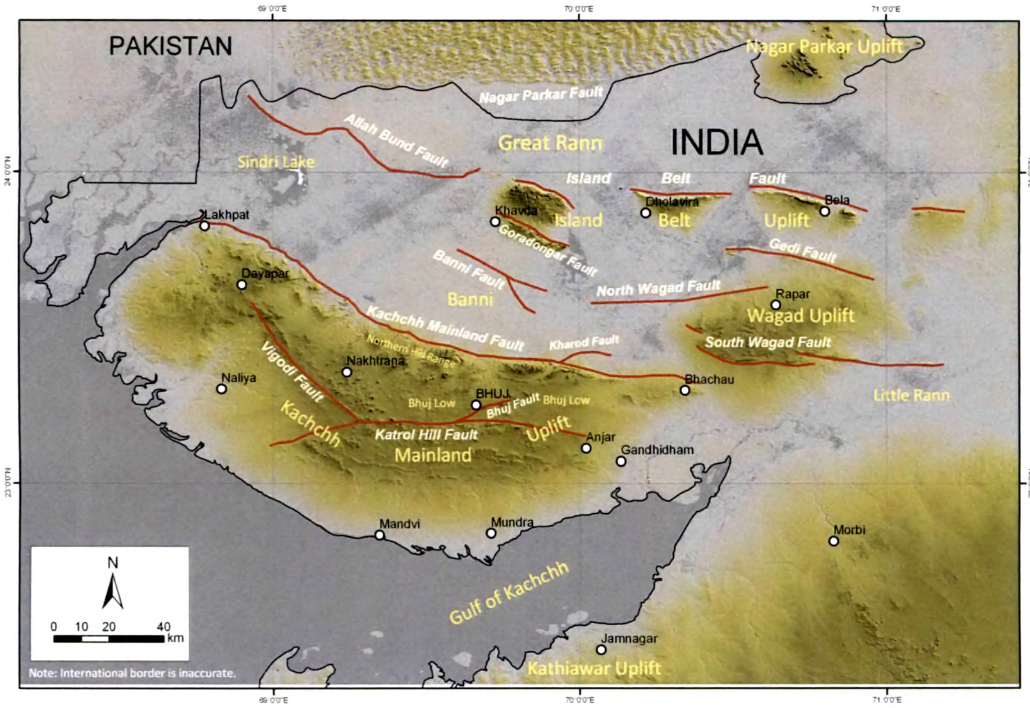

Fig. 1.2: Major faults and uplifts of Kachchh region. (incorporated from Bilham, 1999; Biswas and Deshpande, 1983; Mandal et al. 2004, Morino et al. 2008a, Malik et al. 2008b)

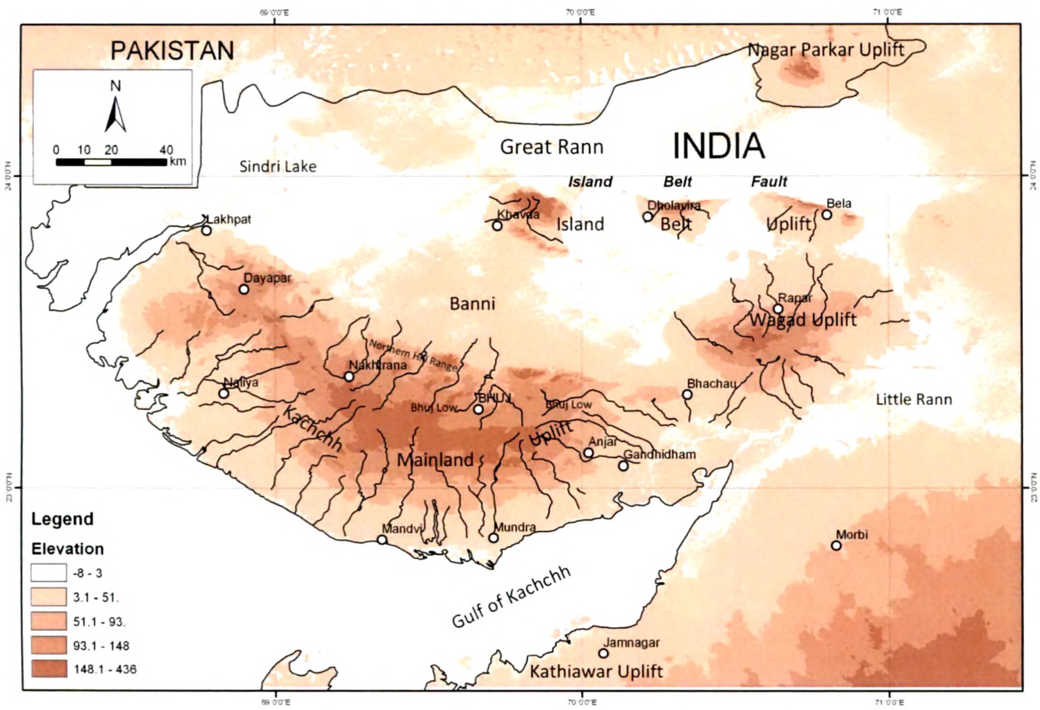

Fig. 1.3: Physiographic map of Kachchh.

GEOLOGICAL AND TECTONIC SETUP OF GUJARAT

Three major Precambrian marginal rift basins namely Kachchh (Kutch), Cambay (Anglicised form of 'Khambhat') and Narmada of western India control the structural setting of Gujarat. These basins are bounded by intersecting sets of faults. The Saurashtra peninsula occurs as a horst block between the rifts. These basins are formed at different times during Mesozoic Era. The Kachchh rifting took place in the Late Triassic-Early Jurassic, Cambay rifting in Early Cretaceous and Narmada rifting in Late Cretaceous time (Biswas, 1987). The three Precambrian orogenic trends - the NNW-SSE Dharwar trend, the NE-SW Aravalli trend and the ENE-WSW Satpura trend - dominate the structural fabric of Western India (Biswas, 1987). The Narmada -Son lineament along the Satpura trend is a major tectonic boundary (West, 1962) dividing the Indian Shield into a southern peninsular block and a northern foreland block. The Dharwar trend is parallel to the faulted west coast of India and a series of extension faults responsible for widening the western continental shelf (Mitra, 1983). Its northward extension into the western part of the Indian Shield across the Narmada rift gave rise to the Cambay graben. The third important tectonic trend is the NE-SW Aravalli trend, which, according to Biswas (1987 & 2005) splays out into three components at its south-western extremity. The main NE-SW trend continues across the Cambay graben into Saurashtra. The northern component of the Aravalli orogen which, is the trend of the Delhi fold belt, swings to E-W and continues into the Kachchh region across the Cambay graben (Fig. 1.4). The third component extends towards south, which can be traced in the eastern part of Gujarat. The western part of the Indian sub-continent is influenced by the Baluchistan orogen, Indus basin and the Indus shelf. The hinge zone of the Indus basin appears to be passing along the Jaisalmer-Kutch (Kachchh) meridian as indicated by the thickening of the sediments considerably to the west of it.

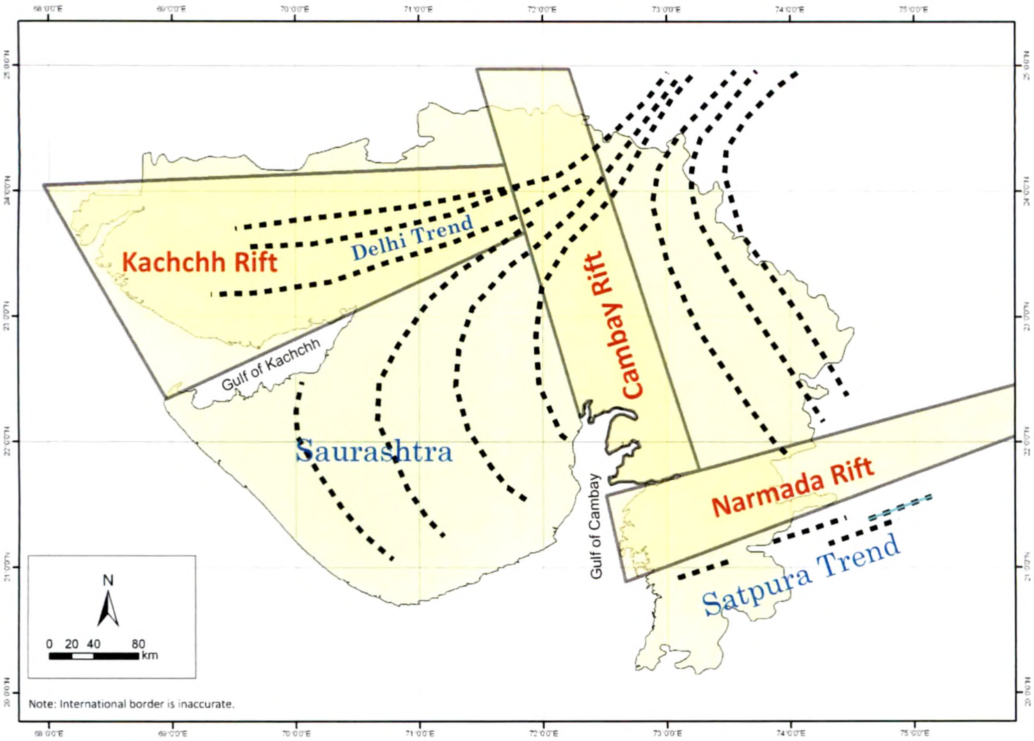

Fig. 1.4: Rift system of western India and Precambrian trends in Gujarat (after Biswas 2005).

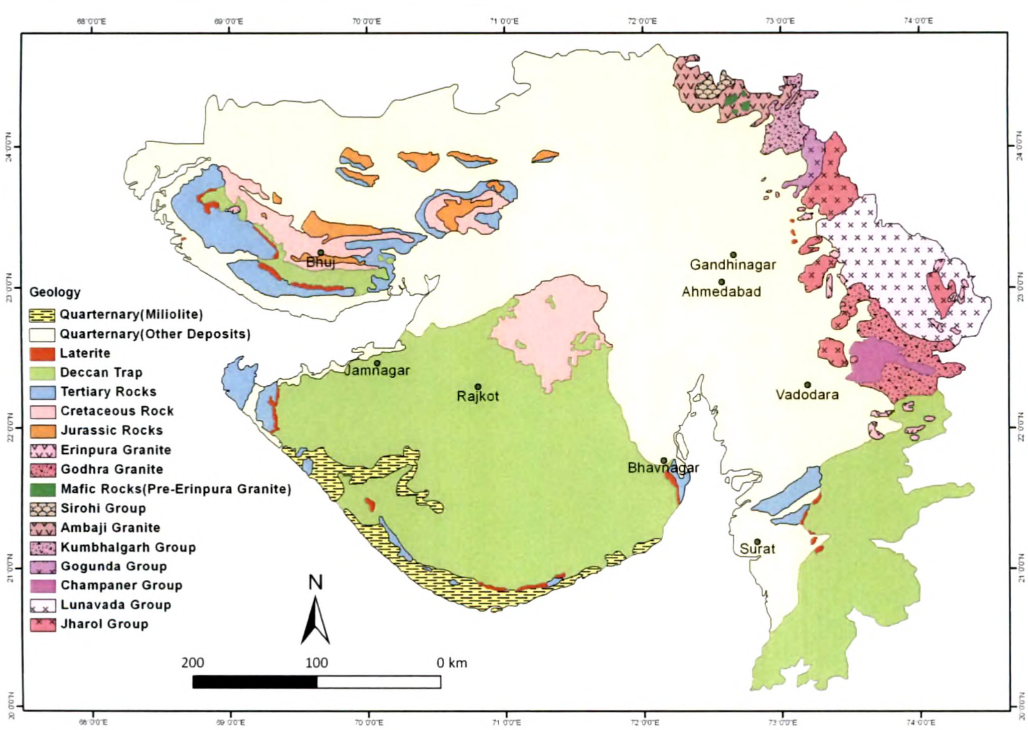

Fig. 1.5: Geological map of Gujarat (after Merh, 1995).

Rocks of Gujarat belong to formations ranging in age from the oldest Precambrian to the recent. The rocks of Aravalli series in north-eastern part are oldest rocks (about 2,500 my). Whereas the unconsolidated alluvial and beach material in its central and western parts are of Quaternary age. All the important lithological types, igneous, sedimentary and metamorphic occur within the State (Fig. 1.5). Stratigraphically however, the record is rather incomplete, as the rocks of Palaeozoic Era are absent in the state. The sedimentary and volcanic rocks resting over the south-westerly extended Proterozoic rocks of Rajasthan are post-Triassic in age. Therefore, major geological events of Gujarat are confined to Mesozoic and Cainozoic Eras. By and large the geological evaluation of Gujarat was initiated in Triassic with the breakup of Gondwanaland. The structural disposition and varying type of rock govern the physiography of the State.

PHYSIOGRAPHY OF GUJARAT

Physiographically, the State of Gujarat comprises of the three distinct zones.

1. Mainland Gujarat
2. Saurashtra and
3. Kachchh

MAINLAND GUJARAT

The mainland Gujarat is further divisible into two sub-zones.

1.1 the Eastern rocky Highlands

The Eastern Rocky Highlands are extensions of major mountains of West India- the Sahyadri, Satpura and the Aravalli. The topography shows strong structural control.

1.2 the Western Alluvial Plains

The Western Alluvial Plains comprise a thick pile of unconsolidated sediments deposited by a combination of fluvial and Aeolian agencies mainly during the Quaternary period.

SAURASHTRA

The peninsula of Saurashtra forms a rocky tableland fringed by coastal plains, a major portion of which is occupied by the Deccan Trap lava flow.

KACHCHH

Topographically, Kachchh region is made up of east-west trending hill ranges, which are separated by large tracts of low ground. All hill ranges and the intervening low ground run almost parallel to each other. The physiographic diversity in Kachchh region is apparent reflection of geologic and structural control on the topography (Fig. 1.2 *and* Fig. 1.3). Kachchh is divisible into four geomorphic zones:

3.1 The Rann,

3.2 The Banni Plains,

3.3 The hilly regions,

3.4 The southern coastal plains.

The Rann forms a unique salt-encrusted wasteland rising only around two to three metres above sea level extending E-W for about 250 km and over 50 km in the N-S direction. It is divided by the rocky highland into the Great Rann to the north and Little Rann to the east. Within the Great Rann lie four island-like landmasses known as Pachham, Khadir, Bela and Chorar. Collectively they are referred as 'Island belt'.

Banni Plains forms shrubby grassland area and is situated between Great Rann and the rocky mainland, it rises merely couple of metres above the Rann surface (Fig. 1.2 and

Fig. 1.3). To the north Island belt separates Banni Plains from the Great Rann. It is covered by recent to sub-recent alluvial deposits. Hitherto it was believed that Banni Plains are devoid of any rock exposure and therefore geologic information from this area was limited only to couple of drill holes sunk by O. N. G. C. (Koshal, 1975). However, during present study a few outcrops of Tertiary rocks are observed in south-eastern part of Banni Plains.

The hilly regions consist of three units, (a) Island belt, (b) Kachchh Mainland and (c) Wagad region. As mentioned earlier the Island belt consists of four rocky projections of Pachham, Khadir, Bela and Chorar rising above the Rann.

Rocky Mainland lies to the south of Banni and extends up to coastal plains. Northern boundary of Mainland is expressed by fault bounded hill range known as Northern Hill Range (NHR) (Fig. 1.2). The NHR rises abruptly from the Banni Plains.

Wagad Highlands lies to the northeast of the mainland and forms an isolated rocky landmass. The southern coastal plains border the mainland against the Gulf of Kachchh in the south and the Arabian Sea in the west.

The mainland forms largest hospitable tract in the district. Most of the areas in the mainland form a low-lying arable land, 30-50 m above the sea level.

SCOPE OF WORK

Kachchh region falls under seismic zone V outside the Himalaya, which has experienced several large to moderate magnitude earthquakes. The occurrence of three devastating seismic events 1819 M 7.8; 1956 Mw 6.1 and 2001 Mw 7.7 in the region within a span of 182 years and spectacular landscape changes caused by 1819 Allah Bund earthquake drew attention of many workers to undertake studies on (a) seismological and geophysical aspects to know the pattern of earthquakes occurrence In recent decades a few site specific studies emphasising towards identification of paleo-earthqukaes have been carried in the Allah Bund and Kachchh Mainland areas For nearly two centuries many workers are attracted to study its excellent Mesozoic-Tertiary stratigraphic succession, also towards its fossil treasure and to develop better understanding towards its complex structural framework.

Kachchh region offers an ample opportunity to study structural, seismic and tectonic aspects. The landscape of Kachchh region is largely a product of successive tectonic events. Kachchh region as a whole still continues to be a zone of active tectonics and obviously the frequent earthquakes that visit this area are the manifestation of the continuing movements.

Present study is an attempt to decipher the structural and tectonic features of eastern Kachchh Mainland and western Wagad region. The study area is characterized by the overstep zone between two major faults of Kachchh region Kachchh Mainland Fault and South Wagad Fault. This zone is described as one of the most vulnerable area for seismic hazard (Biswas 2005; Mathew et. al., 2006, Karanth and Gadhavi 2007, Morino et al. 2008b). Epicentre map of seismic events with magnitude 3.5 and above that visited the Kachchh region attests that the area is host of intense seismic activity (Fig. 1.6). Epicentres of two devastating earthquakes (1956 Anjar and 2001 Bhuj) that visited the region lie within this area.

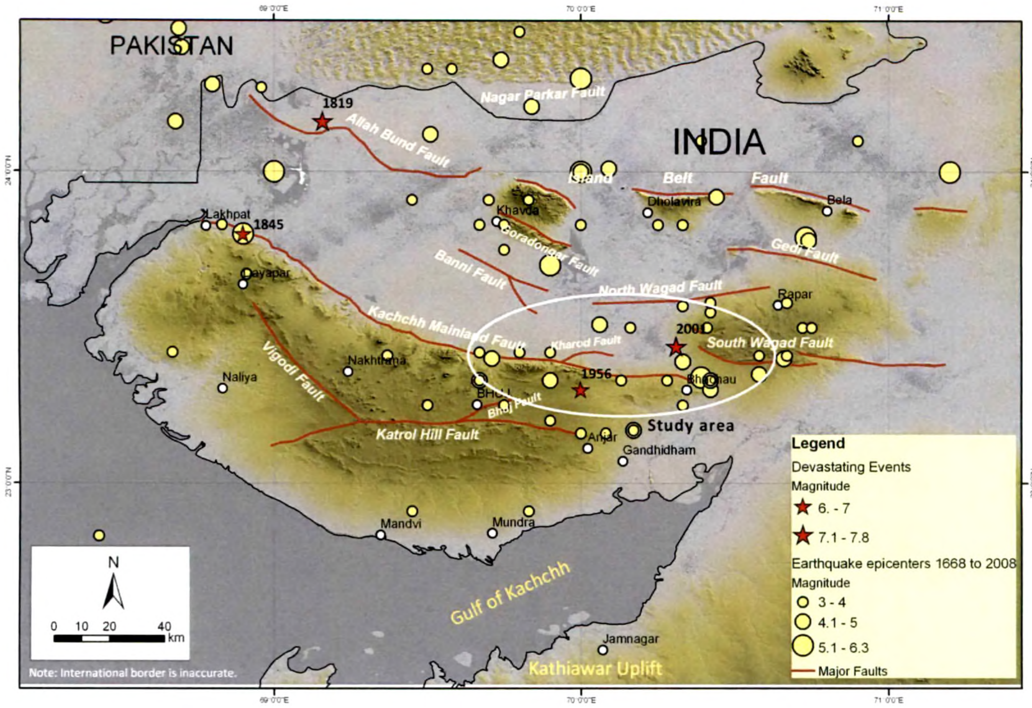

Fig. 1.6: Epicenters of historical (non-instrumental) and modern (instrumental) seismicity in Kachchh from 1668 to 2008; compiled from different sources (see table 5.1).

Study area consists of Mesozoic and Tertiary rocks along with Quaternary deposits. The lower part of Mesozoic rocks consist mainly of shale and oolitic limestone where as upper part consist of intercalated shale and sandstone layers; homogeneous sandstone of Cretaceous age becomes major litho-type in upper part. The Mesozoic rocks are observed folded into monoclinal flexures along Kachchh Mainland Fault and South Wagad Fault. Inclined Tertiary rocks, mainly consist of shale, limestone, clay stone and sandstone are seen on the periphery of folded Mesozoic rocks. Quaternary deposits include alluvial fan deposits and Rann Sediments. The landscape of the area is a unique product of tectonic activity

The present study was taken around eastern Kachchh Mainland and western Wagad with the aim to analyse nature and orientation of faults, and influence of tectonic activity on morphology to decipher structural style in the area. The scope of this study has been essentially tectonics and structure oriented. An attempt has been made to explain various aspects of study area emphasizing on the structure, seismicity, morphotectonics, active tectonics and paleoseismicity.

The studies are carried out with the following approaches:

1) Study of available geologic maps, toposheets (numbers 41-E/11,12,13,15,16; 41-I/3,4,6,7,8,10,11,12,15; 41-M/3) and satellite data (LISS-III FCC and PAN merged data, 7 band LANDSAT data, Google Earth TM, SRTM RADAR data, CORONA images) to identify areas for reconnaissance survey.

2) Detailed fieldwork carried out to record different structural elements.

3) Analysis of the field data to decipher the structural style.

4) Identification of geomorphic features using satellite data and toposheets to recognise sites of active deformation.

5) Field investigations to locate structures of active deformation and to locate suitable site for trenching.

6) Trench investigation at suitable sites to categorize Quaternary deformation and fault rupture.

Desk and field studies were carried out with aim of locating geomorphic features caused and/or influenced by tectonic activity. Drainage systems adapt to change in the surface slope and thus have the potential to record information about the evolution of folds and faults. In tectonically active regions topographic changes can be generated rapidly compared to the rates of erosion and deposition, so that the position of ridges and range fronts often offer a useful guide to locate active faults and folds. Longitudinal profiles and gradient indices for streams flowing through the area were obtained to locate areas of active deformation. Most streams in the Kachchh Mainland have either paired terraces or strath terraces. Even in relatively less active Bhuj Low strath terraces along with stream diversion and drainage reversal are observed. It is observed that the drainage and the topography of the region are under direct influence of ongoing tectonic activity. Deformed alluvial fans are found to be ideal locations in Kachchh region to locate active fault traces.

A record of different structural elements was made in the field. Well-exposed mesoscopic faults and folds were encountered in several parts of the study area. An attempt has been made to decipher structural style of major faults and their behaviour at depth. Based on his investigations the author has brought out fresh data on the region as listed below.

1. The egression of Northern Hill Range (NHR) is on account of fault-propagation folds with steeply north dipping fore-limbs and gently south dipping back-limbs.
2. The active Kachchh Mainland Fault (KMF) is situated 1-4 km north of topographic boundary between NHR and Banni area.
3. Eastern part of Kachchh Mainland Fault (KMF) is progressively emerging upward.
4. Low angle reverse faults are encountered together with asymmetric folds, bedding parallel slip, flat-ramp-flat structures and fault-propagation-folds at several places to the south of NHR. They implicate that the region is an example of fold-and-thrust tectonics instead of vertical tectonics as proposed earlier.
5. Horizontal compression related structures are observed in association with actively deforming synclinal fold have been identified about 8-10 km north of Bhuj.

6. The exposure of folded and gently north dipping tertiary rocks observed in Banni area is another appealing finding made during present study. This outcrop remained hitherto unnoticed by previous workers. The outcrop holds significant structural implication; it adds another dimension to structural, tectonic and active-fault modelling in the region.
7. Evidences of fold-and-thrust tectonics are detected in Wagad region as well, wherein, sub-vertical Jurassic rocks are observed resting over sub-horizontal Cretaceous sandstone.
8. An attempt has been made to throw light on origin of domal structures in Wagad region by examining their architecture. The origin of domes is correlated with slip-deficit subsurface reverse fault. The slip deficit in the fault plane is reflected as saddle between two domes.
9. Active tectonic features were identified along Kachchh Mainland Fault after comprehensive analysis of CORONA satellite photos, which were followed by trench investigations at suitable locations.
10. Existence of active faults was confirmed by folded and faulted Quaternary sediments observed in the trench.
11. Based on the stratigraphic cross-cutting relationship, variation in inclination of the units and angular unconformities observed in the trench at least three seismic events are inferred.

A careful scrutiny and appraisal of the landscape has led to some very interesting observations revealing active deformation led by compression. The study as a whole has enhanced existing database and perceptions regarding the structure and tectonics has in turn helped towards understanding possible seismic hazard encountered in the area.