CHATPER-2

GEODYNAMIC SETTING OF NSF

REGIONAL GEOLOGY

The rocks of study area range in age from Proterozoic to recent. However, there is a total absence of Paleozoic rocks and only uppermost rocks of the Mesozoic time period are found. The oldest strata that rest directly over the Precambrian belong to late Cretaceous. The outline of the stratigraphy of the rocks in the study area is given below:

Table 2.1 Stratigraphy of the study area (Merh, 1995).

Rock type	**Geological Time Period**
Continental sediments (fluvio-marine, fluvial and aeolian)	Quaternary
Marine and fluvio-marine sediments	Tertiary
Laterites	Paleocene
Basalts of the Deccan Traps with associated differentiates and intrusive bodies	Upper Cretaceous to Lower Eocene
Marine, fluvio-marine and fluvial rocks (Himatnagar, Bagh, Lameta)	Cretaceous
Crystalline rocks (metasediments with associated granitic, mafic and ultramafic rocks)	Precambrian (Proterozoic)

The rocks of Cretaceous and Tertiary ages, exposed in the study area include basaltic rocks of Deccan Trap formation, fluvio marine rocks of Bagh formation and, marine and fluvio-marine rocks of Tertiary. The Cretaceous rocks uncomformably overlie the Precambrian basement referred to as infra-trappean. The rocks of Bagh formation exposed as inliers along the river Narmada in the Rajpipala area (Merh, 1995). In Baroda and Bharuch district various exposures of Cretaceous rocks occur as inliers, within the basalt or outliers over the Proterozoic basement (Merh, 1995). Most of the outcrops are linearly aligned in WSW-ENE trend and hence, appear to be fault controlled. The Lameta formation is younger than the Bagh formation and occurs along the fringes of the Deccan Trap (Merh, 1995). The exposed Cretaceous rocks in the study area are comparable in age with the Himmatnagar sandstone, Songir sandstone, Nimar sandstone, Dhangdhra Formation and Bhuj formation (Merh, 1995).

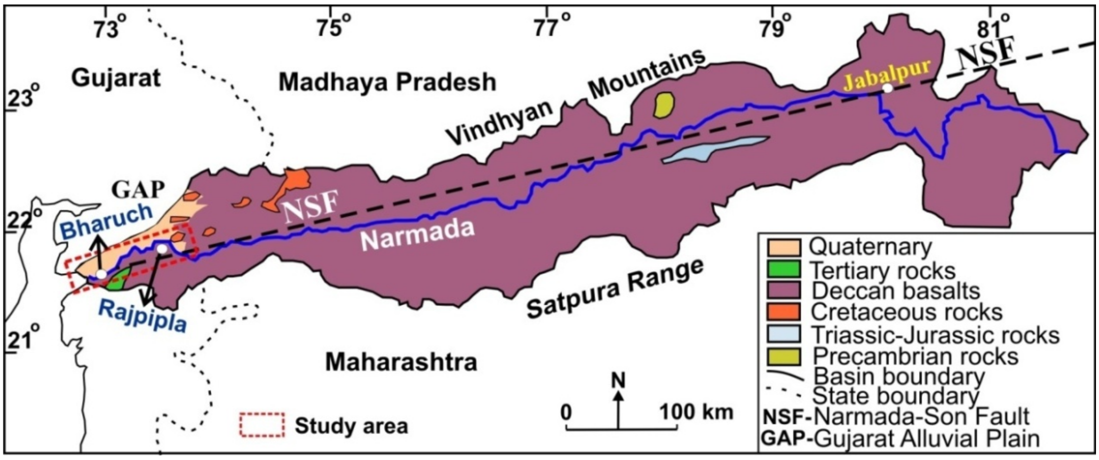

Figure 2.1 Map showing regional geology of the Narmada basin (after Biswas, 1987).

Major part of study area is covered by basaltic rocks of Deccan Trap Formation. Rifting of the western continental margin and reactivation of the Narmada geofracture during the close of the Cretaceous was the prime cause of the Deccan volcanism (Merh, 1995). Radiometric evidences has established that there is no significant difference in age between the stratigraphically oldest and youngest flows, and the lavas erupted rapidly within a short duration of Cretaceous-Tertiary boundary (Venkatesan et al. 1986; Merh, 1995). There is a general agreement that the Deccan Trap can be bracketed within an interval spanning the late Cretaceous to early Eocene, with a major peak in eruptive activity around 60-65 m.y. ago (Venkatesan et al. 1986). During this period, the Indian plate was migrating northward at a rapid rate (Biswas, 1987). The lava erupted mainly through two structural lineaments running N-S and E-W (Merh, 1995). Four magma types namely, tholeiite, rhyolite, carbonatic-alkalic magma and alkali-olivine-basalt magma, appear to have come as independent entities without any known genetic links existing between them, their root having been deep in the mantle (Merh, 1995). First magma, to erupt on a wider scale forming the major part of the Deccan Traps, was tholeiite followed successively by rhyolite in fairly large proportion, and an eruptive phase of minor quantities of the alkali-olivine-basalt magma and the carbonatite, alkali magma is found to be occurring as small plugs within the tholeiites (Merh, 1995). The final phase of volcanism is represented by numerous basic and ultrabasic dykes and showing two trends in ENE-WSW and NNW-SSE direction (Merh, 1995).

The terrain to the south of Narmada River around Rajpipala and highlands of Dang comprising trappean rocks is hilly and shows undulating topography characterized by E-W trending rows of hills that raises 200-300 amsl. The Rajpipala trap show an assemblage of basaltic differentiates and alkaline derivatives (Merh, 1995). The traps of neighborhood area of Rajpipala around Netrang, Dediapada and Navagam are made up of low potassic tholeiitic basalt flows overlain by potassic alkali basalt and cut by alkali dykes or plugs ranging basaltic to trachytic in composition (Merh, 1995). The basaltic rocks show enormous thickness rising to about 600 m above mean sea level (Pattnayak and Shrivastava, 1999) further east, main bulk of which consists of horizontal lave flows of 5-15 m thickness comprising both basaltic and alkaline derivatives (Merh, 1995). Hard massive basalts, porphyritic basalts, amygdaloidal basalts are encountered and quite often tuffaceous or agglomeratic layers are found to intervene the flows (Merh, 1995). An extensive jointing of the trappean rocks has facilitated weathering and erosion and also controlled the drainage pattern. The basaltic flows are traversed by many ENE-WSW trending dolerite dykes that vary in width from few meters to hundreds of meters (Krishnamacharlu, 1972). The basaltic flows in the study area show titling of 5-20° due south whereas they are found to be horizontal in the adjacent Deccan and Malwa regions (Blanford, 1869). Towards the north, the trappean rocks terminate at the north facing and ENE-WSW trending mountain front scarps that mark the surface trace of the NSF.

The Tertiary rocks are buried below the thick alluvium of Gujarat alluvial plains to the north of NSF which correspond to the Broach block of the Cambay graben, while they are exposed to the south of Narmada River which forms the Narmada block (Merh, 1995). A large part of Tertiary rocks lie within the Cambay basin. The outcropping Tertiary rocks occur between the Narmada and Tapi rivers forming two patches separated by the Kim River alluvium (Merh, 1995). The Tertiary rocks exposed between the Narmada and Kim Rivers are delimited by the ENE-WSW trending NSF in the north and the N-S trending Rajparadi Fault in the east (Agarwal, 1984). The exposed sequence comprises Dinod Formation (Late Eocene), Kand Formation and Jhagadia Formation of Miocene to Pliocene age (Agarwal, 1986). The rocks have been folded into several narrow anticlinal structures separated by synclinal lows which have geomorphological expression as well (Agarwal, 1986). The Quaternary sediments occur are represented by a variety of sediments pointing to diverse processes and environments. In Mainland Gujarat the Quaternary sediments occupy the structural depressions related to Narmada and Cambay graben and constitute thick layered sequence of sediments of fluvio-marine, fluvial and aeolian origins and are designated as Gujarat Alluvium (Merh, 1995).

STRUCTURAL SETUP

The Narmada Son Fault is related to one of the three rift system of western continental margin of India. The western continental margin of the Indian plate has evolved as a result of rifting along major Precambrian trends (Biswas, 1982) which gave rise to formation of three rift basins. During the Mesozoic time these basins opened one after another in a counter clockwise direction (Biswas, 1982). Their origin is attributed to the tension created by the northward drift of the Indian plate. After the drifting, the Kachchh basin was opened up first in Early Jurassic followed by Cambay basin in Early Cretaceous and Narmada basin in Late Cretaceous (Biswas, 1982). These three rift basins are bounded by intersecting sets of faults, whose trends follow the three important Precambrian tectonic trends viz. the Aravalli, Dharwad and Satpura trends. Of these, the Narmada rift basin is bounded by Narmada Son Fault which is parallel to the trend of Satpura orogenic belt, i.e. ENE-WSW. The NSF divided the Indian shield into two halves and demarcates a major tectonic boundary (West, 1962; Mathur et al. 1968; Choubey, 1971) between Vindhyan basin to the north and Gondwana basin to the south.

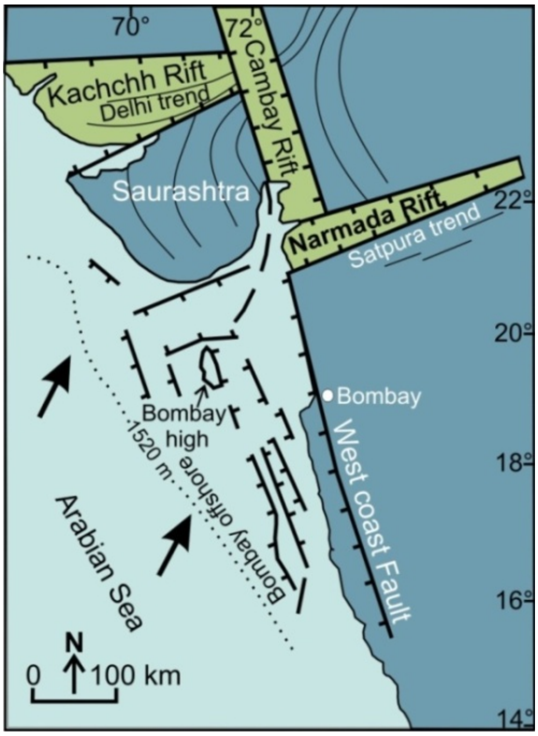

Figure 2.2 Map of western continental margin of India showing the rift systems (after Biswas, 1987).

Previous studies suggest that the NSF is a part of the composite, tectonically controlled zone in the middle of the Indian plate and it is termed as the SONATA zone (abbreviated form of Son-Narmada-Tapti Lineament zone; Ravi Shankar, 1991). Also the Narmada and Tapti Rivers all throughout their course follow this tectonic trend. The

Narmada, the Tapi and the west coast tectonic belts are characterized by positive gravity anomalies, high thermal gradients, high heat flow and seismic activity (Kailasam et al. 1972). The entire region is characterized by high heat flow, high geothermal gradient, thermal activities and occurrence of hot springs. The timing of lithosphere and consequent rise of asthenosphere (Royden at al. 1980) seems to be the cause of the heat flow in this region. The present high geothermal gradient indicates that the marginal rifting is still active and thermal equilibrium by cooling of the lithosphere has not yet been attained (Biswas, 1982). The thermal activity in the region indicates that the magma beneath the west coast chamber has not cooled completely which is manifesed in the form of hot springs (Murthy, 1981) in the area. The occurrence of hot spring is conspicuously associated with geological contacts, tectonic units and earthquakes (Chadha, 1992). It has been noticed that thermal springs occur either near the contacts of two geological units or along prominent tectonic units (Chadha, 1992). Presently, entire NSF zone is characterized by high gravity anomalies, high-temperature gradient and heat flow and anomalous geothermal regime (Ravishankar, 1991), which suggest that the zone is thermomechanically and seismically vulnerable to the contemporary tectonism (Bhattacharji et al.1996).

The NSF zone in Central India

In central India several Deep Seismic Sounding (DSS) studies have established existence of deep seated north Narmada Fault and south Narmada Fault (Kaila et al., 1981). Geophysical studies in the central part reveal this to be a zone of intense deep-seated faulting (Reddy et al., 1995). Also it has been indicated that the faults extends up to Moho and divide the crust into the blocks (Kaila et al. 1985). In the central India, south Narmada Fault is tectonically more active then the north Narmada Fault as majority of the seismicity is associated with south Narmada Fault. There are more than 30 earthquakes reported in the magnitude range 3.0 and 6.5 and are located along south Narmada Fault (Gupta et al., 1997). Specially, area around Jabalpur and in the vicinity of Satpura range have been identified to be prone to seismicity on the basis of various geophysical studies (Arora et al. 1995; Waghmare et al. 2008).

Geomagnetic Depth Sounding (GDS) experiments have provided evidence for the existence of an elongated high electrical conductivity zone south of Jabalpur beneath the Satpura ranges, due to the fluids in the crust known as Satpura Conductivity Anomaly-SCA (Waghmare et al. 2008). The lateral extent of the SCA is bounded between Jabalpur and Paraswada and its centre is located beneath Kalpi (Arora et al. 1995). Other geophysical studies carried out in the central India around north Narmada Fault and south Narmada Fault suggest that the tectonic activity along these faults is in form of vertical displacement which has not only played role in shaping the landscape but also controlled the sedimentation in the marginal basins. These faults mark the limit of the Vindhyan basin to the north and Gondwana basin to the south (Kaila et al. 1987).

Rai et al., (2005) have investigated crustal properties beneath the deep crustal (∼35 km) Jabalpur earthquake of 21 May 1997 in search of a possible cause of stress accumulation in the region. The results suggest that the presence of such an anomalous mass in the deep crust may lead to gravitationally induced stresses in the lower crust that contribute to the failure of rock along the pre-existing Narmada-Son fault leading to the earthquake in deep crust. Rai and Thiagrajan, (2006) have prepared a tentative 2D thermal model of central India across the Narmada-Son Lineament (NSL). This work deals with 2D thermal modeling in order to delineate the crustal thermal structure of central India along two Deep Seismic Sounding (DSS) profiles, namely Khajuriakalan–Pulgaon and Ujjan–Mahan, traversing the Narmada-Son-Lineament (NSL) in an almost north–south direction. It has been inferred that the variation in surface heat flow density values in these regions are caused by variation in the radioactive heat production and fluid circulation in the upper crustal layer.

Mandal (2010), has prepared three-dimensional modeling of intraplate stresses in the epicentral zone of the 21 May 1997 Jabalpur earthquake of M_w 5.8, central India. Results suggest that estimated large intraplate stresses associated with an inferred mafic intrusive in the presence of high pore pressure (resulted from the dehydration of the serpentinite minerals) and deep brittle/ductile transition may contribute to the failure of rock along the pre-existing weak south Narmada Fault leading to the earthquakes in the deep crust. It is proposed that the causal association of large intraplate stresses and the pre-existing deep crustal faults would control the future locales of earthquakes in the Narmada–Son lineament zone. Deshpande and Gupta (2013) have worked on the groundwater helium as an indicator of active tectonic regions along Narmada River in the central India. This survey was undertaken to identify active tectonic regions, based on locations of high helium concentrations, interpreted as indicative of upward migration of deep fluids. Results of a survey of dissolved helium, fluoride and electrical conductivity in groundwater from across the main stem of the Narmada River, between Bharuch in the west and Amarkantak in the east, are reported. This suggests a possible commonality between the causal factor of excess helium and higher fluoride in groundwater, which needs to be further investigated.

The NSF zone in Gujarat

The westward extension of the NSF zone into the lower Narmada valley exhibits a less complex structural setting. The lower Narmada basin is bounded by NSF in the south and it is expressed as a single deep seated fault confirmed by the Deep Seismic Sounding studies (Kaila et al., 1981). Seismic reflection studies have firmly established that the NSF is a normal fault in the subsurface and becomes markedly reverse near the surface with total displacement of about one kilometer within the Cenozoic section (Roy, 1990). In the extreme western part of Gujarat there is an overlapping of two rift systems, the Cambay and Narmada. The two major conjugate rift systems, the Cambay and Narmada rifts cross each other in the Gulf of Cambay region and together with the west coast fault, define an area which has been identified by many as a triple junction (Burke and Dewey, 1973; Bose, 1980). The deep seismic sounding study has indicated that the region from Surat to Bombay is Moho upwarp (Kaila, 1986; 1988). Deep seismic sounding data also indicates the depth of the mantle as 20-25 km near Surat north of Bombay (Kaila, 1986).

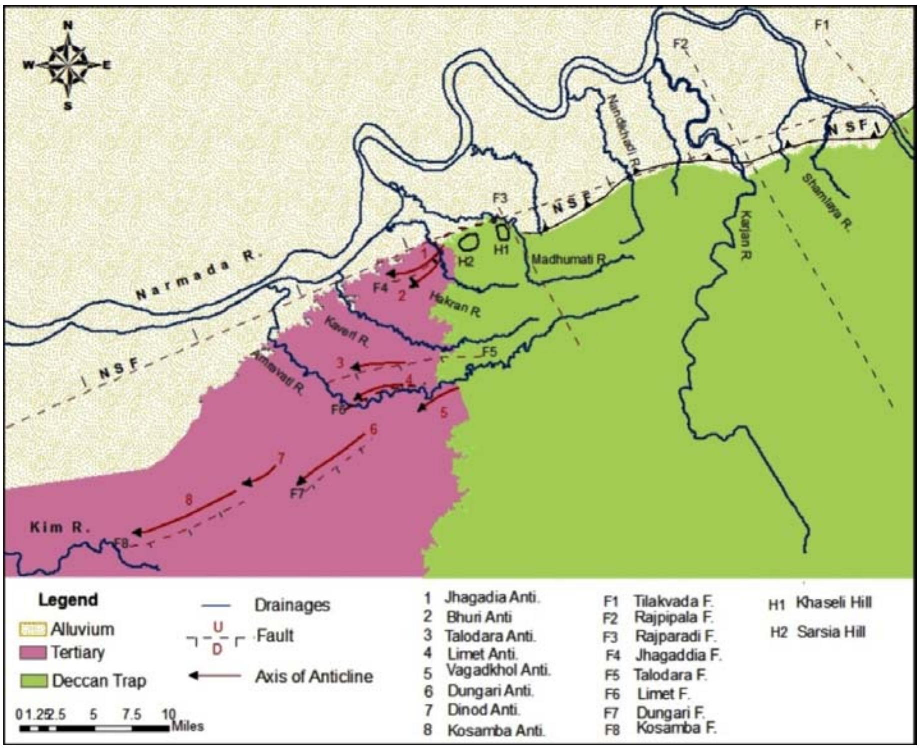

Figure 2.3 Geological and structural map of the study area (after Agarwal, 1984).

The basin has general tendency to subside which is punctuated by phases of structural and tectonic inversion (Roy, 1990). These phases of tectonic inversion are reported due to the N-S compressive stress which is related to the continuous northward movement of Indian plate. This has resulted into a reactivation of already existing faults dating back to Archaean times (Ravishankar, 1991). Reactivation of the fault in Late

Cretaceous led to the formation of a depositional basin in which marine Bagh beds were deposited (Biswas, 1987). The NSF remained tectonically active since then with continuous subsidence of the northern block, which accommodated 6–7-km thick Tertiary and Quaternary sediments (Biswas, 1987). After the deposition, the N-S directed compressive stresses during the Early Quaternary folded the Tertiary sediments into a broad syncline, the Broach syncline, in the rapidly subsiding northern block (Roy, 1990). This resulted in the development of several anticlines in the Tertiary rocks exposed in the western part of the lower Narmada basin. The major anticlines of Tertiary are Jhagdia anticline, Bhuri anticline, Talodara anticline, Limet anticline, Vagadkhol anticline, Dungari anticline, Dinod anticline and Kosamba anticline. These folds trend ENE, exhibiting invariably plunges towards WSW. The folds are invariably cut along their SSE limbs by reverse faults heading towards NNW (Agarwal, 1984). Deep Seismic Sounding studies suggest that these are deep seated faults cutting across Deccan Traps and Mesozoic sequence also (Kaila, 1981).

However, the movements along the NSF in Gujarat have not been unidirectional throughout and it is traversed by several transverse fault trending NW-SE to NNE-SSW. These transverse faults include Tilakvada fault, Karjan fault, Madhumati fault and Rajparadi fault. Along with the NSF, the transverse faults are equally active shaping the present landscape. Along with river Narmada, its major tributaries also follow the trend of transverse faults all along their path. Before turning to west, the Narmada River follows the trend of Rajparadi fault as it enters into the alluvial reach. All along its course, Karjan follows the trend of the Karjan fault. Likewise, Madhumati River flows in a straight course along the trend of the Madhumati fault before turning to west and meeting river Narmada. These faults have also displaced the terrain significantly and made tectonic contacts between different geological formations. Khaseli hill is the visible example of the displacement related to the tectonic movement along the Madhumati fault, while Rajparadi fault has made tectonic contact between Tertiary sedimentary rocks and basaltic rocks of Deccan trap formation.

REACTIVATION HISTORY AND SEISMICITY ALONG THE NSF

The tectonic nature of e NSF zone is reported to be very old dating back to around 2.5-2.2 Ga and 1.5-0.9 Ga when it witnessed large-scale tectonothermal events associated with large granitic intrusions (Acharyya and Roy, 2000). After this, possibly in the mid-Jurassic, latitudinal Narmada rift basin developed because of the tensional basement faults that had resulted by the counterclockwise rotation of the Indian plate. This has resulted in the deposition of Late Mesozoic sediments (Biswas, 1987). After the Cretaceous sedimentation in the Narmada rift basin through marine transgression and regression, depositing limestone, shales and sandstone, the basin was once again subjected to tensional tectonic activity along the pre-existing E-W trending basement faults (Auden, 1949).

During Late Cretaceous to Early Paleocene the reactivation occurred as the area experienced Deccan volcanic eruption. Because of this, the Late Mesozoic sediments that were deposited in the basin were covered by Deccan Trap basalts. The lava flows occurred along a large number of fissures and vents which were related to the tensional deep seated faults trending parallel to the Narmada rift basin (Agarwal, 1984, 1995). This phenomenon indicates rejuvenation of the pull-apart tectonic activity.

Another cycle of reactivation occurred during Paleocene soon after the volcanic eruption (Biswas, 1987). During this time the N-S trending Cambay rift system evolved and superimposed over the Narmada rift basin in the westernmost part. The N-S trending linear depression with parallel horst blocks accommodated the early Tertiary sediments in the depressions. Gradually the lows were leveled up and thereafter some of the horst blocks were also covered up with the trap wash sediments. After sedimentation, the Tertiary sediments were subjected to folding and faulting. This tectonic event could be correlated with the first collision of the Indian plate against the Asian plate resulting into the push of the of the fault blocks generating differential vertical fault block movement, folding, faulting and the upliftment of various rock sequences (Agarwal, 1984). During this period, the normal faults reactivated as reverse faults.

In the Late Cenozoic, during the final welding of the Indian plate with the Asian plate, the NSF again experienced tectonic activity due to the push of the southern Indian sub-plate against northern sub-plate. As a result, Tertiary sediments folded into narrow anticlinal folds and faults trending ENE-WSW to NE-SW (Agarwal, 1984). In the area of Narmada River and beyond sedimentation continued which resulted into the deposition of thick Quaternary sediments.

The area is still under compressive stress regime and tectonically active, which is indicated by the present day geomorphic set up of the landscape and recent seismicity along the NSF. More than 30 earthquakes in the magnitude range 3.0 and 6.5 are reported along the seismically active NSF (Gupta et al., 1997). Major earthquakes reported are, Son valley (1927, M = 6.5), Satpura (1938, M = 6.3), Balaghat (1957, M = 5.5), Broach (1971, M = 5.4) and Jabalpur (1997, M = 6.0). However, majority of seismicity is located in the area around

Jabalpur in Central India and around Bharuch in Gujarat. Also the focal mechanism is available only for the seismic activities occurred in these two regions.

Earthquakes of various magnitude that have occurred in the past with epicenters in and around Jabalpur, are 1846 (6.5 M), 1903 (4.7 M), 1973 (3.7 M), 1993 (3.8 M), 1997 (6.0 M) as reported by India Meteorological Department (1998). Of these, earthquake of magnitude 6.0 on the Richter scale occurred on May 22, 1997 was devastating and struck the Jabalpur area killing about 50 people and causing extensive damage to property. The main shock and aftershock studies of this earthquake revealed the depth of hypocenter section at a range of 35-40 km (Acharyya et al., 1998). The significant seismic event in Gujarat was Broach earthquake occurred on 23rd March, 1970. There is a very recent earthquake has been reported of M 3.6 on 21 January 2014. The epicenter location of this shock suggested by the focal point solution is about 38 km ESE from the Bharuch.

Focal mechanism solutions are available only for the Broach and Jabalpur earthquakes showing fault planes oriented in NE to ENE and NW to EW respectively (Rajendran and Rajendran, 1998). These are indications that faulting could occur along this plane with thrusting movement (Gupta et al., 1972; 1997; Chandra, 1977; Acharyya et al., 1998). Fissures that opened during the Broach earthquake were generally oriented in ENE–WSW direction (Chandra, 1977). Ground cracks associated with the Jabalpur earthquake were also oriented in ENE–WSW direction (Gupta, 1997). However, because of the poor distribution of recording stations in the NSF zone, the catalogue is short of full details, especially of lower magnitude earthquakes.

PREVIOUS WORK ON QUATERNARY GEOLOGY AND NEOTECTONICS

A lot of literature exists on the hard rock geology, hydrology and archeology of the area; however, very little information is available on the Quaternary geology, geomorphology, and neotectonics of the study area. Studies on the channel forms, fluvial processes and hydrological aspects carried out in detail by Kale et al. (1994), Rajguru et al. (1995), Gupta et al. (1999), but their studies were limited to the central Narmada valley.

It was Blanford (1869) who studied Quaternary deposits of Gujarat for the first time and reported the alluvial deposits of the Narmada and Tapi Rivers. In the book, ‘Geology of Baroda State’ Foote (1898) described the alluvial succession. Paleolithic industry was discovered by Sankalia (1946) near Sankheda on the banks of Orsang River, a major tributary of Narmada. Also he reported Paleolithic implements from the Karjan River deposits at Rajpipla.

A detailed account of the Quaternary deposits in a regional context was given by Zenuer (1950). He stressed on the changes in palaeoclimatic conditions in the deposition of the continental Quaternary sediments deposited during this period by the evaluation of the exposed Quaternary sediments of Sabarmati, Mahi and Orsang Rivers in particular and. He pointed out that the deposition of river deposits at the same height above the present water level in successive periods of aggradation, were separated by periods of erosion. He also stressed on two cycles of increasing aridity in Sabarmati separated by a fossil soil. A detailed account of the Pleistocene deposits in the lower Narmada basin and the role of sea level fluctuation during the Pleistocene period which is known to have occurred globally were given by Wainwright (1964).

The exposed terrace sequences of Narmada, Mahi and Sabarmati Rivers were studied by Allchin et al. (1978). The two main terraces identified by them broadly show similar records suggesting a characteristic phase of substantial aggradation followed by incision. They also dated Narmada alluvium through radiocarbon dating technique.

Geomorphology of the area around lower Narmada basin was investigated by Bedi and Vaidyanadhan (1982). They have emphasized morphogenesis of the landscape and the role palaeohydrological and neotectonic activity in shaping the landscape. In the central Narmada and neighbouring basins, Kale et al. (1993, 1994, and 1996) and Rajguru et al. (1995) have studied a lot of palaeo and modern flood data and related geomorphology. They have provided excellent records on Quaternary environments, Holocene flood deposits and variations in monsoon activity. In western India, the first post glacial wet phase was recorded around 12-8 ka interval. Marine records for past change from the Arabian Sea yield a similar record (Duplessy 1982; Prell, 1984; Prell et al. 1990: Siroko et al. 1991).

A good picture of the Quaternary fluvial sequences of Gujarat alluvial plain was given by Pant and Chamyal (1990), Chamyal and Merh (1992), Merh and Chamyal (1993), Chamyal (1990), Chamyal and Merh (1995), Maurya et al. (1995, 2000), Merh and Chamyal (1997), Chamyal et al. (1997; 2002; 2003), Raj et al. (1998a, 1999a, 2009), Jain et al. (1998). They have described the exposed Quaternary sediments of the various river sections of Sabarmati, Mahi and Narmada. Pant and Chamyal (1990) discussed about the bluish green (marine) clay, based on the field investigation and physical characteristics of the basal clay they identified them as marine clays. Merh (1993) suggested that these were deposited during Middle Pleistocene high seas. Chamyal and Merh (1992) described the Lithostratigraphy of the exposed Quaternary deposits of Gujarat alluvial plain. Merh and Chamyal (1997) describing the Quaternary geology of Gujarat alluvial plain provided the lithostratigraphy, depositional environment and sedimentary facies. They have correlated the sediments of Sabarmati, Mahi and Narmada Rivers.

Although so much geophysical and seismic studies exist for the neotectonics NSF zone in the central India, a very few research findings are there so far for the NSF zone in the Gujarat area. Agarwal (1984) studied the western part of the NSF zone where the Cambay and Narmada rift system overlap. In his study, he documented anticlinal folds and reverse faulting developed in the Tertiary sedimentary rocks. Also he established the existence of geomorphic highs that up-warped the Quaternary sediments and attributed it to the upliftment of the basement ridges. Chamyal et al. (1997, 2002) documented these as Late Pleistocene alluvial fan deposits.

Over all, in the late Quaternary time, two major phases of tectonic activity along the NSF are recorded (Chamyal et al., 2002). The first phase includes the Late Pleistocene during which slow syn-sedimentary subsidence of the basin took place along the NSF which allowed for uninterrupted sedimentation except for brief periods of pedogenesis of basal clays and the overbank sediments. Syn-sedimentary subsidence of the basin in a compressive tectonic setting is evidenced by the hindered alluvial fan sedimentation, thick overbank sediments and associated sediment deformation. The second phase includes the Holocene, which is marked by basin inversion due to differential uplift along the NSF (Maurya et al., 2000). In Holocene time three phases of tectonic uplift have been established in the lower Narmada basin (Bhandari et al., 2001; Chamyal et al., 2002; Raj and Yadav, 2009). Early Holocene uplift resulted in the development of ravine surface and deeply incised fluvial valley. Second phase of uplift took place after the deposition of mid-late Holocene sediment surface which resulted in the upliftment of this surface. The third phase of uplift was after 1950±90 to 1280±70 yrs BP which uplifted the late Holocene terraces (Raj and Yadav, 2009). The Holocene period is marked by inversion of the basin, which had earlier suffered subsidence which is due to a significant increase in compressive stresses along the NSF during the Early Holocene, resulting in differential uplift along the NSF (Maurya et al., 2000; Chamyal et al., 2002).