CHAPTER-9

NEOTECTONIC EVOLUTION OF THE NSF ZONE

The Narmada–Son Fault (NSF) is well known ENE–WSW trending seismically active fault in the peninsular India. The fault divides the Indian plate into two halves and has a long tectonic history dating back to the Archaean times (Ravishankar, 1991). The Narmada River emerges in the central India from the Amarkantak hills and draining east to west between the Satpura and Vindhyan ranges over a length of 1,312 km and debouches in Arabian Sea, throughout its course the river follows the NSF zone all. In the central India NSF zone as witnessed. The NSF zone has witnessed large-scale tectonothermal events associated with large granitic intrusions around 2.5 – 2.2 and 1.5 – 0.9 Ga (Acharyya and Roy, 2000). In the central India, this zone reveals to be a zone of intense deep-seated faulting which is confirmed by the geophysical studies (Reddy et al., 1995). In the present day the zone is thermomechanically and seismically vulnerable in the framework of contemporary tectonisim which suggested by high gravity anomalies, high-temperature gradient and heat flow and anomalous geothermal regime (Ravishankar, 1991, Bhattacharji et al., 1996).

In the Gujarat region, the NSF is a single deep-seated fault confirmed by the Deep Seismic Sounding studies (Kaila et al., 1981). It is a normal fault in the subsurface and becomes markedly reverse near the surface which indicated by Seismic reflection studies (Roy, 1990). The NSF reactivated in Late Cretaceous and resulted in the formation of depositional basin in which marine Bagh beds were deposited (Biswas, 1987). Since then the continuous subsidence of the northern block accommodated 6–7 km thick Tertiary and Quaternary sediments (Biswas, 1987). The total displacement along the NSF exceeds 1 km within the Cenozoic section (Roy, 1990). This general tendency of the basin to subside was punctuated by phases of structural and tectonic inversion in Early Quaternary due to N–S-directed compressive stresses which folded the Tertiary sediments into several anticlinal structures with steep reverse faults in the southern limb (Roy, 1990). Tectonic movement in the Late Quaternary time suggested by the Investigations on movements under compression during the late Quaternary the late Pleistocene alluvial sediments exposed along the cliff sections of the Narmada River have suggested (Maurya et al. 2000; Chamyal et al; 2002). Studies in the Kim river basin to the south of the NSF also point to reactivation of reverse faults within the Tertiary rocks during the late Quaternary (Mulchandani et al., 2007).

Geomorphologically, the fault is prominently expressed as north facing scarps throughout the study area. The scarps separate the alluvial terrain to the north and the rugged mountainous region to the south. The Narmada River flows westward in the alluvial zone to the north of the scarpline. The present study is confined to the narrow alluvial tract between the scarpline and the Narmada River which is drained by several north flowing rivers that traverse the NSF zone and meet the Narmada River. This linear alluvial tract bordering the scarpline is termed as the 'NSF zone' in the present study to distinguish it from the laterally extensive alluvial plain to the north of Narmada River and further beyond. The NSF zone is poorly constrained in terms of its geomorphic characteristics and neotectonic history.

MORPHOTECTONIC SEGMENTATION

The study area is divisible into two major geomorphological domains – the upland area to the south of the NSF and the alluvial plain to the north. The uplands comprise mountainous landscape over the south dipping basaltic flows and relatively gentler hummocky topography over the folded and faulted Tertiary rocks in the western part. The NSF is geomorphologically expressed as a linear series of ENE–WSW trending prominent north facing scarps. The scarps delimit the rugged mountainous terrain developed over south dipping basaltic flows of the Deccan Trap formation to the south and northward sloping alluvial terrain to the north. The scarps in the western part are ENE–WSW trending folds formed in the northern limbs comprising Neogene rocks. In the westernmost part, a continuous ENE–WSW trending straight scarp comprising late Pleistocene sediments occur, which has been described as the palaeobank of the Narmada River in its estuarine reach. The fault is therefore geomorphologically traceable up to the coastal zone in the west.

During the present study transverse faults which cut across the NSF in NNW–SSE direction were mapped in the upland area. These transverse faults presumably extend up to the NSF and possibly beyond. There are four transverse faults delineated in the study area viz, Tilakwada Fault, Karjan Fault, Madhumati Fault and Rajpardi Fault. The Tilakwada Fault is trending NW–SE and passes through the left bank of Narmada River. It appears that this fault has displaced the NSF scarp line by ~2.5 km. The Karjan Fault is trends in the NNW-SSE direction and is located on the right bank of the Karjan River. The Madhumati Fault is a NNW–SSE trending fault and shows a right lateral offset of the NSF for about 1 km. This is evidenced by the straight channel of the Madhumati River and the formation of a large deeply incised and compressed meander in alluvium as it emerges from the uplands. Also the slicken sides exposed along the fault plane, in basaltic rocks on the left bank of the river, suggests oblique slip movement. The Rajpardi Fault is trending in NNW-SSE direction located in the western part of the study area. It marks the tectonic contact between the basaltic flows and the Tertiary rocks. Based on these four transverse faults, the NSF zone subdivides into I to IV distinct segments area from east to west. Segment I is located between the Tilakwada Fault and Karjan Fault; segment II is between the Karjan Fault and Madhumati Fault, segment III is between the Madhumati Fault and the Rajpardi Fault; and beyond which lies segment IV.

Segment I

Segment I is occupied by three drainage basin including R1 (Shamlayakhadi River), R2 (unnamed river) and R3 (Karjan River). To know the youthfulness of the scarp mountain front, sinuosity was mapped along the mountain front of this segment. The calculated value of 1.04 indicates youthful nature of the mountain front scarp. It is the second lowest value observed in the other segments of study area. The river longitudinal profiles of the R1, R2 and R3 are characterized by steep gradients and several knickpoints in the upland area, and steep gradient in the alluvial reach. The hypsometric analysis was carried out to deduce the maturity level of the drainage basin. The hypsometric curves show S-shape in which convex up part coincides with area which is in the close vicinity of the NSF indicating relatively young stage due to neotectonic rejuvenation.

To know the active ground tilting which resulted in the asymmetrical drainage basin, the Asymmetrical Factor was calculated for R1, R2 and R3 basin. The resulted values suggest westward tilting of the surface in this segment. Stream Length gradient index (SL index) was mapped along the length of channel in their alluvial reach. There is a zone of high SL index values observed which is common in all three rivers of this segment. It occurs in the area of 60-50 m contour interval. The results plotted over the longitudinal profiles of the rivers to know the responsible factor among change in lithology and tectonic activity. The result suggest that the high SL value coincide with the convex and steep gradient of the profile in alluvial reach of the rivers, which verifies tectonic uplift as the responsible factor.

The GPR surveys were carried out in segment I at three locations near Gora colony, Umarwa and Chakva using 80 MHz and 200 MHz antenna. The survey lines were oriented across the NSF scarp in the N-S direction. The interpretation of the profiles suggest that NSF located within the trappean flows and show varying nature in terms of the deep and type of fault movemnet. The processed GPR profiles of Gora colony and Chakva suggests that the NSF is steep vertical fault at deeper level and it becomes southward dipping reverse fault near the surface. However, the processed profile of Umarwa suggests that the NSF is a steep vertical fault.

Segment II

Segment II is tectonically most active segment of the study area. It is occupied by R4 (unnamed river), R5 (Nandikhadi River) and R6 (unnamed river). The mountain front sinuosity calculated along the length of scarp in this segment show the value of 1.03 which is the lowest value among all the segments of study area. The river longitudinal profiles of this segment shows distinct convex up morphology in the alluvial reach. The convex up part of the longitudinal profile relates with the greatest depth of incision and highest altitude of the alluvial surface in this segment. The hypsometric curves of the drainage basin of this segment show concave shape upward and convex shape downward. In this segment, the mean value of hypsometric integral is highest which confirms the higher degree of tectonic activity.

The Asymmetrical Factor calculated to know the tilting direction of the surface in segment II suggest that the R4 drainage basin tilting eastward, whereas, R5 and R6 tilting westward. This change in the tilting direction of the surface correlates well with the physiographic setup of the alluvial surface shown in the lateral topographic profile. The results of the SL index vale suggested zone of higher SL value between 50-40 m contour intervals. The higher SL index values plotted over the longitudinal profiles of all three river of this segment which suggest that the values correlate with the steep gradient and convex up morphology of the alluvial surface. This indicates recent tectonic uplift of the surface which formed steep slope and higher SL index values.

The other significant evidence of the higher degree of tectonic activity in segment II is the sedimentation of bajada surface in this segment which suggests the major role of neotectonics in the late Quaternary sedimentation. This inference is supported by the present day altitude of the bajada surface which is higher than the alluvial surface of the other segments of study area. The good sections of bajada surface are exposed in the Nandikhadi River which is made up of matrix supported gravel, clast supported gravel, massive silty sand, soil, trough cross-bedded gravel, horizontally stratified gravels and massive brick red sand lithofacies. The composite litholog of the bajada sediments suggest two fining upward and three coarsening upward aggradation cycles on the scale of few tens of meters thick. These three cycles of coarsening upward suggest three pulses of tectonic activity along the NSF in this segment. During late Pleistocene time, initial uplift of the uplands in the south and slow subsidence of the basin in the north due to the reactivation of NSF facilitated the generation of huge amount of coarse clastic debris and provided space for the accommodation of sediments. The above discussed evidences indicate that the NSF in this segment is tectonically most active then the mountain front in the other segments.

In segment II, the GPR surveys were carried out near Sanedra, Jhuna Ghanta and Wali using 80 MHz and 200 MHz antenna. Due to the higher degree of tectonic activity the rock are sheared, weathered and chemically altered. The crushing of the rocks has formed clayey material which has resulted into the diffraction of radar wave energy. Because of this, the GPR profiles of this segment show distinct radar facies and low amplitude reflection than the profiles of the other segments. The processed GPR profiles of Sanedra and Jhuna Ghanta suggest that NSF is a vertical fault deep in the subsurface and becomes reverse as it approaches the surface. However, in the GPR profile of Wali, the NSF appears as a vertical fault.

Segment III

Segment III is the smallest segment of the study are occupied by the R7 (Madhumati River) basin. The combined mountain front sinuosity was mapped for segment III and IV. This has yield value of 1.17 which is a low enough to infer the youthful nature of the mountain front scarp in this segment. The longitudinal profile of the Madhumati River shows convex up morphology with several knick points in the upland and steep gradient in the alluvial reach which suggest the course of the river is throughout controlled by neotectonic activity. The hypsometric curve of the Madhumati River basin shows S-shape. The convex up part of the curve coincides with the alluvial plain indicating the neotectonic rejuvenation of the basin. The basin is highly asymmetrical and shows visible westward tilting which confirmed by the calculation of Asymmetry Factor of the basin. The zone of high SL index values observed between50-40 m contour interval. This zone coincides with the steep gradient of the alluvial plain in the vicinity of NSF scarp which suggests recent tectonic uplift in the segment III.

In the segment III, GPR survey carried out near Kapat using 200 MHz antenna.
In the processed GPR profile a zone comprises of complex pattern of low amplitude reflections identified in the middle part of the profile. This zone corresponds to the radar wave reflections from numerous fractures and sheared rocks which represent NSF fault zone. Within this zone, displacement of the reflection observed along the fault plane that demarcates NSF in the subsurface. It is inferred that the fault plane is vertical in the subsurface and steeply dips southward near the surface.

Segment IV

The segment IV forms the westernmost part of the study area and is drained by R8 (unnamed river), R9 (Kaveri river) and R10 (Amravati river) basin. For most of the part, the river longitudinal profiles shows convex up morphology. This convex part of the profiles fall within the deformed Tertiary rocks. The present day drainage pattern of this segment also shows structural control which is attributed to neotectonic rejuvenation of the terrain. The S-shaped hypsometric curves of the drainage basin support the influence neotectonic activity on the present day landscape. The drainage basins of the segment IV show anomalous tilt direction as they mostly flow in the complexly deformed Tertiary rocks. Asymmetry Factor values of these basins could not be interpreted because of the extremely short alluvial reach of these rivers. In this segment, zone of the highest SL values is in the 50-40 m contour interval. This area is close to the NSF scarp suggesting tectonic uplift along the NSF resulted in the steep gradient and higher SL index values in this zone.

In the segment IV, GPR survey conducted near Jhagadia and Karad using 200 MHz antenna. At Jhagadia, the NSF is expressed by ENE-WSW trending steep scarp developed in the northern limb of the Jhagadia anticline. In the processed GPR profile, changes in the radar facies and displacement of radar wave reflections are observed which represents NSF related tectonic movements. The type of the displacement observed through the pattern of the reflections suggests that the NSF is a steeply southward dipping reverse fault. Near Karad, GPR survey carried out across the palaeobank of Narmada River. In the processed GPR profile there is an abrupt contact between two different types of radar facies of very high and low amplitude. This represents the NSF in the subsurface. The behavior of the displaced reflections suggest that the NSF is south dipping reverse fault in this segment.

NEOTECTONIC EVOLUTION

In the study area, phases of neotectonic activity of Late Pleistocene to Late Holocene time, and related geomorphological and sedimentological changes studied through the geomorphic analyses and detailed investigation of sediments exposed in the incised cliffs. The late Quaternary sediments exposed in the cliff sections of north flowing tributaries of Narmada River that originate in the south from the upland and flow northward by crossing the NSF to meet the Narmada River in north. Investigations of the exposed sediments carried out and the lateral and vertical variations in the lithofacies were prepared to deduce the fluvial microenvironments based on sedimentary structures and to reconstruct the late Quaternary stratigraphy. The detailed study of the fabric and the spatial distribution of sediments suggest several phases of tectonic activity have evolved different sedimentation pattern in the different segments of the study area which is discussed below.

Late Pleistocene

In segment I, the fine Late Pleistocene sediments are overlain by coarse gravelly alluvial fan sediments. The Late Pleistocene sediments are exposed in the 21-22 m thick incised vertical cliffs of Karjan River at Nani-Limatvada. The lower part of the section represents the deposits of Late Pleistocene surface whereas the uppermost section made up of sediments of Early Holocene alluvial fan. The Late Pleistocene sediments made up of sandy gravel, horizontally stratified gravel, Vertisol (brown) and red soil (reddish brown) over which lie the sediments of alluvial fan surface. Stratigraphically the red soil is comparable to Late Pleistocene red soils of Narmada, Mahi and Sabarmati (Merh and Chamyal, 1997; Maurya et al., 2000). The deposition of fine grained alluvial plain sediments in segment I was because of the synsedimentary subsidence of the basin due to the differential uplift along the NSF.

In segment II, the sedimentation of group of fans, ‘bajada’ is documented (Joshi et al., 2013) in Late Pleistocene time. The extension of bajada sediments is confined by the NW-SE trending Karjan Fault on eastern side and Madhumati Fault on western side. The type section of the bajada surface is exposed in the 40 m thick incised cliff section in the Nandikhadi River near Jhuna Ghanta. The sediment succession comprises of massive gravels, matrix supported gravels, horizontally stratified sandy gravel, silty sand and soil. The middle part of the bajada succession exposed in the Nandikhadi River has yield OSL age of 25.1$\pm$1.8 ka BP which suggests that the sedimentation occurred during the later part of Late Pleistocene. The deposition of bajada strongly suggests the active nature of basin bounding mountain front.

In segment III, Late Pleistocene sediments are exposed in 35 m thick incised cliff section in Madhumati River near Tejpur. The sediments succession is a part of the western fringe of the bajada surface made up of massive gravel, horizontally stratified sandy gravel, weakly pedoginized sandy silt and massive sand capped by topsoil. The age of the succession inferred on the basis of occurrence volcanic ash layer in the middle of the Quaternary alluvial succession. This volcanic ash correlated with Youngest Toba tuff (Raj, 2008) of the Toba volcanic event which is one of the largest eruptions during the Quaternary (Schultz *et al* 2002) occurred in the Indonesian archipelago on northern Sumatra some 70,000 years ago. The deposition of coarse gravelly bajada sediments in the segment III indicates tectonically active nature of the NSF.

In segment IV, the Late Pleistocene sediments are exposed in the palaeobank of Narmada River. The sediment succession comprises of fine to medium grained massive sand and stratified silty sand enriched with calcite sheets and nodules. The deposition of fine alluvial plain sediments in the segment IV related to the synsedimentary subsidence of the basin due to tectonic activity took place along the NSF.

Overall, in the Late Pleistocene time, the fine alluvial plain sediments deposited in segment I and IV, while, in segment II and III coarse bajada sediments were deposited. This characteristic represent the differential uplift took place along the NSF in the Late Pleistocene time.

Early Holocene

In segment I, offset of late Pleistocene sediments is evidenced in the Karjan River basin. This was observed through the study of incised cliff sections exposed along the length of the Karjan River. In the upland zone of Karjan River near the Karjan dam incised section of the terrace surface is at the conspicuous height of 58 m from the present day channel. The sediments are mainly sand and silty sand deposits. OSL dating of the upper silty sand layer has yield date of 32.7±3.9 Ka. Few meters away in downstream direction at Nani-Limatvada village 21 - 22 m incised vertical cliffs are exposed. The lower part of the section represents the deposits of Late Pleistocene surface whereas the uppermost section made up of sediments of Early Holocene alluvial fan sediments. The Late Pleistocene sediments made up of sandy gravel, horizontally stratified gravel, Vertisol (brown) and red soil (reddish brown) over which lies the sediments of alluvial fan surface. On the basis of sediment fabric, grain size and lithofacies association, sediments exposed at Karjan Dam site are correlatble with the sediments occurring at Nani Limatwada site. However, there is a significant difference between the altitude at which sediments are exposed at both sites (i.e. Karjan Dam and Nani-Limatvada locations). On the basis of present day altitude of the sediments exposed near Karjan dam which is at height of 58 m from the present day channel bed, an uplift of about ~58 m is inferred. This indicates offset of ~58 m long the NSF during early Holocene.

In segment II, the influence of early Holocene tectonic uplift is deduced from the present day anomalous geomorphic characteristics. The altitude of the bajada surface is at higher level than the fan surface of the segment I. The drainages of this segment show anomalous incision pattern, tight meanders, frequent knick points and waterfalls. The rivers of segments II show maximum incision of up to 40 m near the scarps. This depth of incision decreases to 6–7 m in a straight distance of less than 3 km. This significant change in the depth of incision in a very short distance indicates the tectonically generated steep slope. The upland zone of Nandikhadi River is characterized by frequent occurrence of knick points, tight meanders and deeply incised channel. The height of the knick points range from 1 m to 16 m. In a very short distance of 1.5 km, the total fall of gradient related to knick points is of ~37 m which is These characteristics strongly indicate ongoing tectonic uplift that initiated in late Holocene time shaping the present day geomorphic setup.

In segment III, the tectonic activity shows strong control over the drainage pattern and incision pattern of Madhumati River. It represents contrasting characteristics of the trappean uplands and alluvial zone. In the upper reaches, the identified drainage pattern is trellis, whereas the lower reaches of the basin has a dendritic pattern. The straight river course suggests the major role of tectonic activity in shaping the present day drainage pattern. Overall, these characteristic observed in the Madhumati River basin suggests youthful nature of the upland due to the tectonic uplift of the NSF.

In segment IV, Early Holocene inversion phase is characterized by the development of palaeobank of Narmada River. The paleobank is marked by straight linear alluvial cliffs comprises of Late Pleistocene sediments. It represents abandoned left bank of the river when it was flowing further to the SE. The Narmada River has migrated to as much as 6 km to the NW due to tilting caused by upliftment of the Jhagadia-Ankleshwar area. The formation of paleobank is because of the tectonic activity along the NSF during Early Holocene which uplifted the Jhagadia-Ankleshwar area and shifted the Narmada River towards north (Agarwal, 1984). This has been verified by the previous seismic studies suggest presence of reverse fault along the paleobank with the downthrown side to the NW and the SE side as the upthrown side (Agarwal, 1984).

Middle to Late Holocene

In segment I, the present day drainage pattern shows strong structural control. This is clearly visible in the anomalous behavior of the Karjan River. The Karjan River flows in the N-S direction throughout the path, which shows the strong control of Karjan Fault. However, as the river enters in the alluvial plain, it forms tight meander by turning to left and flow along the trend of NSF for short distance, and again achieves the N-S flow direction. This shows that the active tectonic movements shaping the present day drainage pattern.

The other significant evidence is the sedimentation of group of small alluvial fans which were deposited during mid-late Holocene time (Bhandari et al., 2001). The tectonic uplift occurred in Early Holocene time has provided significant geomorphic contrasts which lead to the development of alluvial fan sediments. The alluvial fan sediments comprise coarse sandy gravels and colluvium deposits capped by massive sand sheet devoid of any internal stratification. The sediments have been incised by north flowing tributaries of Narmada River. This change from active fan aggradation to present state of dissection is attributed to Late Holocene uplift. The upper sand layer of sediment succession has yield age of ~ 6 ka (Chamyal et al., 2002) which verifies that differential tectonic uplift along the NSF have uplifted the alluvial fan surface to the present day altitude.

In segment II and III, the present day alluvial surface is deeply incised and thick vertical sediment succession is exposed. In these segments, the bajada surface is highly dissected by the alluvial rivers emerging from the uplands and flows towards north to meet the Narmada River. Specially, in the vicinity of the NSF scarp alluvial plain is deeply incised by deep and narrow gorge like rivers. The conspicuous geomorphic features observed in these segments and discussed in the above section are still preserved in the present day landscape of the study area which suggests youthful natures of the terrain. This cannot be explained by the present day ephemeral nature of the drainages and sub-humid climate prevailing in the study area. It is inferred that the present geomorphic set up is because of the neotectonic rejuvenation of the terrain.

In segment IV, the present day drainage pattern shows strong structural control. The major river basins of the segments are Kaveri and Amravati River basins. The drainage pattern of this segment ideally reveals its adoption to the change in the topographic expressions related to the late uplift of the Tertiary and Quaternary sequences. The Amravati River crosses the NSF to the north of Nawagam village where the NSF is expressed as the ENE-WSW trending line of incised cliffs marking the paleobank of Narmada River. Uplifted Late Holocene depositional terraces of 2-4 m height in the Madhumati, Amravati and Kaveri Rivers (Raj and Yadav, 2009) also support the active nature of NSF in this segment. These evidences suggest that late Holocene tectonic uplift is still ongoing.

NEOTECTONIC BEHAVIOR OF NSF AND CONTEMPORARY STRESS REGIME

Overall, the various landscape parameters and the deeply incised drainages point to uplift of the alluvial plain with prominent tilting of the alluvial surface away from the NSF. The tectonic uplift of the alluvial plain is evident by the N-S topographic profiles and river longitudinal profiles of the south to north flowing drainage of the study area. In the topographic profiles, the steep gradient observed in the alluvial plain area. This is confirmed by the river longitudinal profiles which characterized by concave gradient with frequent occurrence of knock points in uplands and, convex and steep slope in the alluvial reach. These characteristics suggesting major role of NSF related tectonic activity which resulted into the youthful nature of upland and neotectonic rejuvenation of the alluvial plain. This is attributed to differential uplift along the NSF whereby both, the southern block (upland) and the northern block (alluvium) an either side of the fault have been uplifted.

The other significant characteristic observed is the spatial variation of landscape parameters along the length of NSF in different segments. The results show that maximum uplift of the alluvial plain is in segment II followed by segments III, I and IV. This is evident by the altitude of present day bajada surface of segment II which is at the highest level among the alluvial surface of the other segments. This is clearly visible in the lateral profile of the alluvial plain drawn along the trend of NSF. Also the variation in the depth and pattern of fluvial incision observed in the vicinity of NSF scarp supports this inference. In segment I maximum depth of incision is ~6 m, in segment II it is of the order of ~40 m, in segment III the maximum incision is ~15 m while in segment IV the incision is ~8 m. This observation suggests that the maximum depth of incision is in the alluvial sediments of segment II, verifying the highest degree of tectonic activity in this segment. This characteristics suggesting major role of transverse faults related tectonic activity which resulted in the spatial change in the landscape parameters and variable magnitude of neotectonic activity along the NSF.

Thus, the steep slope of the alluvial plain and youthful nature of upland suggest vertical movements along the NSF, while spatial variation in the landscape parameter and development of distinct morphotectonic segments suggests oblique slip movements along the transverse faults. The results of the GPR survey and late Quaternary sedimentation in fan environment suggest the vertical movement along the NSF is of reverse nature. The reverse type of movement is attributed to the compressive stress regime which is in response to the inversion of the basin due to the northward movement of the Indian plate.

This inference is supported by the available models of neotectonic deformation of the Indian plate and its impact on the fault system of study area which indicates that the peninsular India has been undergoing high compressive stresses due to the sea floor spreading in the Indian Ocean and locking up of the Indian plate with the Eurasian plate in the north (Subramanya, 1996), because of this, a part of compressive stress being accumulated along the NSF as it is a major crustal scale discontinuity in the central part of the Indian plate which has resulted into the inversion of the basin in the late Quaternary time and transformation of previously subsiding basin into an uplifting one (Mulchandani et al., 2007).

Recent seismic event reported in the NSF zone confirms the ongoing tectonic activity. The responsible fault zone for these seismic activities and reverse type of fault movements are confirmed by the fault solution studies. This fault solution studies of the recent earthquakes of Broach (23 March 1970) and Jabalpur (22 May 1997) suggest a thrusting movement (Gupta et al., 1972, 1997; Chandra, 1977; Acharyya et al., 1998) along the fault planes oriented in NE to ENE and NW to EW respectively (Rajendran and Rajendran, 1997; Kayal, 2000; Mall et al., 2005). The focal mechanism solution of these earthquakes strongly suggests NSF related seismic event which is also supported by field evidences. The 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). Further, a very recent earthquake occurred (3.6 magnitude) on 21 June 2014. The epicenter location of this shock suggested by the focal point solution is about 38 km ESE from the Bharuch in the NSF zone. Occurrence of these earthquakes in a short period of time (~45 years) suggests ongoing coseismic tectonic movements along the NSF under compressive stress regime which is attributed to the continuing northward movement of the Indian plate.