CHAPTER-1

INTRODUCTION

PURPOSE AND SCOPE

The Narmada–Son Fault (NSF), which divides the Indian plate into two halves, has a long tectonic history dating back to the Archaean times. The NSF trends in ENE–WSW direction and is laterally traceable for more than 1000 km from central India to west coast of India. In the Gujarat state, the NSF is expressed as a single deep-seated fault confirmed by the Deep Seismic Sounding studies (Kaila et al., 1981). Reactivation of this 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. The total displacement along the NSF exceeds 1 km within the Cenozoic section. Investigations of the late Pleistocene alluvial sediments, exposed along the cliff sections of the Narmada River have suggested uplift during late Quaternary under compressional stress regime (Chamyal et al., 2002; Maurya et al., 2000). Studies in the Kim River basin to the south of the NSF also point towards reactivation of reverse faults during late Quaternary within the Tertiary rocks (Mulchandani et al., 2007). Historical and instrumental records indicate that the compressive stresses continue to accumulate along the NSF due to continued northward movement of the Indian plate as evidenced by the earthquakes at Broach (23 March 1970) and Jabalpur (22 May 1997). A very recent earthquake of M-3.6 has been reported on 21 June, 2014. The epicenter of this shock suggested by the focal point solution is about 38 km ESE of Bharuch. The present day occurrence of seismic activity along the NSF indicates the tectonically active nature of the fault.

However, the NSF is poorly constrained in terms of its geomorphic characteristics and neotectonic history. Geomorphologically, the fault is prominently expressed as north facing scarpment throughout the study area. The scarps (or scarp??) separate the alluvial terrain to the north and the rugged mountainous region to the south. The present day landscape of the study area shows strong control of the neotectonic activity suggested by conspicuous geomorphic features. The landscape of the NSF zone is characterized by various geomorphic features that indicate the rejuvenation of the surface which include presence of palaeobank in the Narmada River, rugged terrain, incising nature of drainages, anomalous drainage pattern, tight entrenched meanders, and straight linear river channel course with frequent occurrence of knick point and waterfalls. Such significant landscape features can be evaluated and converted into the data form to analyze and interpret the role of neotectonics in their formation. This is done by undertaking quantitative geomorphic analysis and by investigating exposed late Quaternary sediment successions. Further, to know the subsurface characteristics of the fault responsible for the neotectonic activity and development of anomalous geomorphic features, geophysical surveys were carried out.

Quantitative geomorphic analysis was carried out using remote sensing and GIS which is an effective way of deducing the pattern and spatial variation of neotectonic activity along poorly investigated active faults. There have been many successive attempts to systematically investigate geomorphic response to tectonism with the help of several geomorphic indices in various tectonically active areas or fault zones such as central European southern Rhine graben (Gimboni et al. 2004a, 2005), the Normandy intraplate area of NW France (Font et al. 2010), Central Italy (Troiani et al. 2008), southwestern USA (Bull and McFadden, 1977), the Pacific coast of Costa Rica (Wells et al., 1988), the Meditterranean coast of Spain (Silva et al., 2003), the Midcontinent of US (Adams, 1980), Ventura basin of southern California (Azor, 2002), Marrakech High Atlas (MHA) of Morocco (Delcaillau et al., 2010), Central Range Fault of Eastern Taiwan (Bruce et al., 2006).

Geophysical surveys were conducted using Ground Penetrating Radar (GPR) which is a qualitative geophysical technique to study the subsurface and it has been increasingly used for mapping of active faults or Quaternary faults (e.g. McClymont et al., 2010; Christie et al., 2009; Rashed et al., 2003; Demanet et al., 2001; Chow et al., 2001). Geological hazards associated with future ruptures are most likely to occur in the vicinity of already existing weak zones and so, getting an image of the shallow structures and subsurface strata in the vicinity of the fault zone can reduce the future damages of possible earthquake along that particular fault (Rashed et al., 2003). The advantage of GPR technique is that it is a cost-effective and easy to detect shallow subsurface, without damaging surrounding (like drilling and trenching). The present study was carried out to understand the neotectonic evolution of the seismically active Narmada Son Fault (NSF) in the Gujarat region using remote sensing, GIS techniques and Ground Penetrating Radar (GPR).

AIM AND OBJECTIVES

The present study is aimed at delineating the late Quaternary tectonic movements along the seismically active Narmada-Son Fault (NSF), a seismically active but poorly understood tectonic element in the Indian plate. In present study emphasis has been laid on application of detailed geomorphological, sedimentological and geophysical approach to understand the neotectonic behavior of the NSF in Gujarat region. The main objectives of the present study are as follows:

- Geomorphological evolution of the NSF zone in Gujarat as a consequence of neotectonic movements.
- Surface and shallow subsurface characterization of the NSF using remote sensing and Ground Penetrating Radar (GPR) data.
- Reconstruction of Quaternary tectonic history and landscape evolution along the NSF zone.

STUDY AREA

The study area is the lower Narmada basin which falls in the Gujarat state (Fig.1.1), enclosed by N latitude 21°30’ to 22°30’ and E longitude 72°30’ to 73°45’. The Narmada River is the third largest river of the India. It originates from the Maikala ranges at Amarkantak in the Madhya Pradesh and debouches in the Gulf of Cambay. In the Madhya Pradesh the river flows in the rocky terrain, where as in the Gujarat state it flows in the alluvial plain.

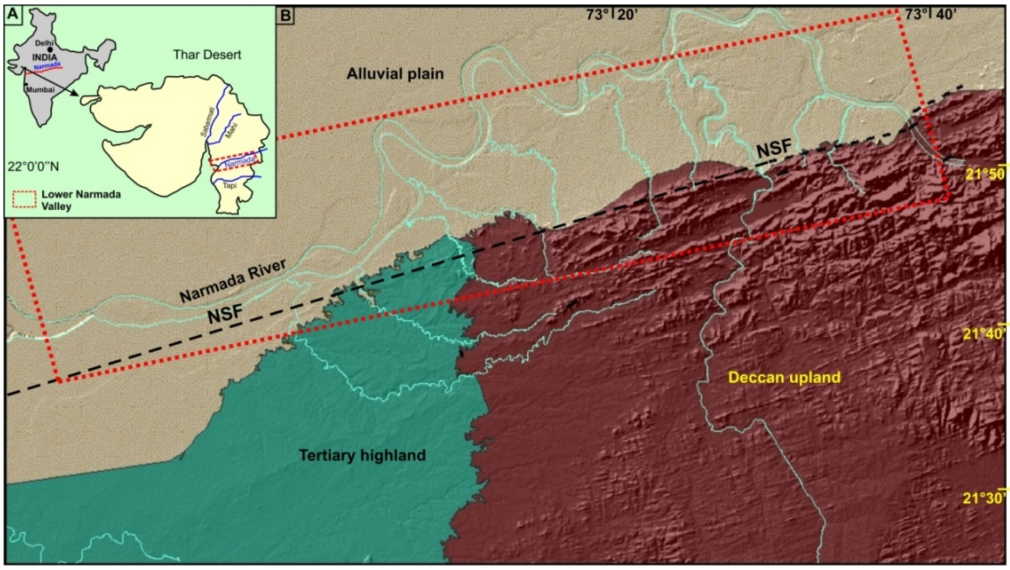

Figure 1.1 (A) Location map showing the lower Narmada valley. (B) Generalized geological map (after Biswas, 1987), showing the location of the study area enclosed in red dotted box.

Throughout its course, the river is controlled by the seismically active NSF. The river flows in the vicinity of fault following its trend, however as the river enters in its alluvial reach in the Gujarat state, it shifts north of the NSF. Hence, there is a narrow alluvial track formed and enclosed between the NSF and Narmada River. The present study is focused over this narrow alluvial zone which abuts again the ENE-WSW oriented mountain front in the south(Fig.1.1).The area of study includes parts of Narmada, Rajpipala and Bharuch districts. The area is well connected by the roads including National and state highways. A good network of metalled and non-metalled roads connects the towns and villages.

Climate

The state of Gujarat lies on the Tropic of Cancer and the study area falls in thesub-humid climate zone with hot summers and general dryness throughout the year barring the monsoon season. March to middle of June is the period of hot summer, followed by SW monsoon, which continues up to the end of September. October and November constitute post monsoon periods. December- February are cold months and after February there is rapid increase in temperature. May is the hottest month with mean daily maximum temperature 45^{O}C and mean daily minimum 26^{O}C. January is the coldest part of the year with mean daily maximum temperature at 30^{O}C and mean daily minimum at 12^{O}C.

Rainfall

The Gujarat state comes under the influence of SW Indian monsoon from June to September. The state receives precipitation over a period of four months starting in June. The regional rainfall isohyets decrease towards northwest. Mean annual rainfall is the highest in southeastern Gujarat. The average annual rainfall in the study area varies from 750 mm in the alluvial area to 1150 mm in the uplands. About 75 percent of the annual normal rainfall in the area is received during the monsoon months from June to September, July being the rainiest month.

Physiography and drainages

Physiographically, the study area is divisible in two broad zones- the rocky uplands and alluvial plain. The rocky upland shows an altitude range of 300 to 1100 m which is actually the extensions of the major mountains of western India – the Sahyadri, Satpura and Aravalli. The course of Narmada River is restricted between the Vindhyan range on the northht and Satpura hills towards the south until it reaches the Gujarat alluvial plains. The hilly terrain between the Narmada and Mahi rivers, are made up of Archaean metamorphics and granitic rocks. The Aravalli hills to the northwest fall within an altitude range of 300 to 600 m. The Rajpipla hills which are the terminal end of the Satpura and Sahyadri ranges are mostly Trappean hills placed in the southern part of Lower Narmada basin. The hilltops are flats and valleys are shallow and wide showing an altitude variation from 150 to 300 m. The alluvial plain comprises Quaternary continental and unconsolidated sediments falling within the altitude range of 25 to 75 m with a gradual southwestward slope. The Narmada River and its various tributaries flow across the alluvial plains.

The major drainages of the study area include the S-N flowing tributaries of Narmada River, viz., the Karjan, Shamlayakhadi, Nandikhadi, Kaveri, Amravati and Madhumati. These rivers emerge from the Trappean upland, while Kaveri and Amravati originate from the Tertiary highland.

Flora

The common trees found in the study area are Mangifera indica (Am), Cassia fistula (Amaltas), Sapindus lavrifolius (Aritha), Dalbergia latifolia (Sisam), Adina cordifolia (Hed), Mitragyna parvifolia (Kalam), Petrocarpus marsupuim (Biyo), Acacia catechu (Khair), Gmehna arboreau (Sewan), Grewia tiliaefolia (Dhaman), Ougeinenis (Tiwas), Madhuka indica (Mahua), Garuga pinnata (Kakad), Butea frandosa (Dhak), Ficus religiosa (Pipal), Lannea comandelica (Modal), Acacia nilotica (Deshi bawal), Zizyphus xylopora (Ghatbor), Santulum album (Chandan), Chlorosperma ciossypum (Girnar), Holorrihena antidysentrica (Dudhi), Bauhinia variegata (Kachnar), Salamahia malabarica (Semal), Dalbergia sissoo (Shisham), Anona squanosa (sitaphal), Ficus bengalansis (Bargad), Azadirachta indica (Neem), Calotropis procera (Ak), Butea monosperma (Khakra), Acacia arabica (Babool), Terminalia tomentosa (Sadar), Albizzia procera (Gurar), Dalbergia latifolia (Pai) and Saunea grandis (Gurjan).

Common herbs and shrubs of the study area are Calotropis procera (Ak), (Amarbel), Dhatura metal (Dhatura), Zizijphus nummalaria (Jharber), Lawsonia inernris (Mehendi), Carrisa spinarum (Karonda), Oeinun sanctum (Tulsi), where as the common climbers of the area are Cuccuta reflexa (Amerbel), Coccubnulus hirsutus (Bajarbel), Inchnocarpus frutesccus (Dudhi), Asparagus dumosus (Narkanta), Oxalis corniculata (Tripatti), malkangani, charmoi, chillati and vites.

Fauna

The main domestic animals of the study area are cow, buffalo, horse, goat, sheep, oxen, camel and ass. The representatives of dog family like wolf, jackal and fox also inhabit many forested part of the study area. The wild animal of cat family Panthera paradus is found. Besides this other carnivorous animals like hyena and tiger can be found in the protected forest areas. Sambar, Indian gazelle, black buck, nilgai, peacock, chital, antelope, sloth bear, chinkara, chital and black buck, etc. are found in the forested areas. Wild bores are also large in number.

The smaller animals are mongoose, langoor, wild cat, hare, civet cat, hedge-hog, porcupine, squirrel, rat etc. Common reptiles found are crocodile, python, vipers, krates, blind snake, cobra, water snakes, wolf snake, rat snake, marsh crocodile, monster lizard, chameleon etc. The important birds are crow, sparrow, parrot, parakeets, bulbul, magpie, robin, myna, weaver-bird, grey pigeon, white pigeon, wood-pecker, cuckoo, kingfisher, vulture, owl, grey jungle owl, red spur owl, teal, pea owl, partridge, crane, egret, flycatcher, jacana, tailor bird, grey partridge, grey shrike, black drongo, duck, vulture, kite, blue frock pigeon etc.

APPROACH AND METHODOLOGY

Comprehensive approaches involving morphotectonic, sedimentological and geophysical studies have been rarely utilized to investigate the complexity of processes and geologic events responsible for landscape evolution. In the present study emphasis is laid to understand the late Quaternary geology and resulting landscape in the seismically active NSF zone. The following is the brief methodology followed during the course of the present study:

1. Critical evaluation of the available data on the geomorphological, Quaternary stratigraphical, geophysical and seismotectonic aspects was carried out to understand the geologic setting of the lower Narmada basin in a regional perspective, satellite images, Survey of India topographical maps were studies to delineate the geomorphic set up of the study area.
2. Quantitative geomorphic studies with the help of remote sensing and Geographic Information System (GIS) was carried out to understand the drainage characteristics and, to identify the controls on the development of present landscape of the NSF zone.
3. Detailed field studies were carried out for the mapping of various geomorphic features and to identify the geomorphic signatures of neotectonic activity.
4. Quaternary sediments exposed along the incised cliffs of the north flowing drainages, traversing the NSF zone, were studied to delineate the tectonic controls on late Quaternary sedimentation. Vertical lithologs were prepared and various lithofacies were mapped to identify the depositional processes and to reconstruct the late Quaternary stratigraphy.
5. Geophysical surveys with the help of Ground Penetrating Radar (GPR) were carried out to precisely locate and to understand the shallow subsurface behavior of the NSF zone.
6. Integration of the data resulted from various studies and their interpretation was done to reconstruct neotectonic evolution of the NSF zone.