**Chapter**

# Intra-Plate Dynamics and Active Tectonic Zones of the Indian Plate

*Sanjib K. Biswas and Gaurav D. Chauhan*

**Abstract**

The tectonic framework of the Indian Plate started to evolve since the break-up of Gondwanaland in the Late Triassic. It evolved mainly during the time between its separation from the African plate in the Early-Cretaceous and its collision with the Eurasian plate on the north in Late-Middle Eocene and with the Burmese plate in the northeast in Late-Oligocene. Present active tectonic zones, responsible for earthquake generation, were created by the collision pattern and subsequent plate motion. Continued subduction and plate motion due to ridge push and slab pull are responsible for the activation of primordial faults in the inherent structural fabric of the craton depending on the related stress field. Major tectonic zones of the Indian continental plate are related to the collision fronts and the reactivated intra-cratonic faults along the resurgent paleo-sutures between the proto-cratons. Major Tectonic Zones (TZ) are Himalayan TZ, Assam-Arakan TZ, Baluchistan- Karakoram TZ, Andaman-Nicobar TZ, and Stable Continental Region (SCR) earthquake zone. The structure of the continental margins developed during the break-up of Gondwana continental fragments. Western margin evolved during the sequential separation of Africa, Madagascar, and Seychelles since the Late-Triassic to Late Cretaceous time. The Eastern margin structure evolved during the separation of Antarctica in Mid Cretaceous. The orogenic belt circumscribing the northern margin of Indian plate is highly tectonised as the subduction of the plate continues due to northerly push from the Carlsberg Ridge in the SW and slab-pull towards northeast and east along the orogenic and island arc fronts in the NE. This stress pattern induced an anticlockwise rotatory plate motion. The back thrust from the collision front in the direction opposite to the ridge push put the plate under an overall compressive stress. This stress pattern and the plate motion are responsible for the reactivation of the major intra-cratonic faults. While the tectonised orogenic belts are the zones for earthquake nucleation, the reactivated faults are also the strained mega shear zones across the plate for earthquake generation in SCR. These faults trending WNW-ESE are apparently the transform faults that extend across the continent from Carlsberg ridge in the west to the collision zones in the northeast. As such, they are described here as the 'trans-continental transform faults'. Three such major fault zones from north to south are (i) North Kathiawar fault - Great Boundary fault (along the Aravalli belt) zone, (ii) South Saurashtra fault (extension of Narmada fault) – SONATA-Dauki-Naga fault zone, and (iii) Tellichery-Cauvery-Eastern Ghat-T3-Hail Hakalula-Naga thrust zone. All these trans-continental faults, which are mega-shear zones, are traceable from western offshore to the northeastern orogenic belts along mega tectonic lineaments across the continent. The neotectonic movements along these faults, their relative motion, and displacement are the architect of the present geomorphic pattern and shape of the

Indian craton. The overall compressive stress is responsible for strain build-up within these fault zones and consequent earthquake nucleation. The mid-continental Sonata-Dauki shear zone follows the Central Indian Suture Zone between Bundelkhand Proto Continent (BPC) and Deccan Proto Continent (DPC). With the reactivation of this shear zone, the two proto-cratonic blocks are subjected to relative movement as the plate rotates anticlockwise. The kinematics of these movements and their implications are discussed here with a special reference to the recent 2001 Bhuj earthquake.

**Keywords:** active tectonic zones, intra-cratonic faults, trans-continental transform faults, Indian Plate

## 1. Introduction

Crustal plates are styled by the intra-plate stress depending on overall plate dynamics, i.e., break up by stretching, drifting by horizontal forces, and collision/subduction by convergence. The Indian plate is no exception to this. The structural framework of the Indian plate evolved since its break up from the African plate in Late Jurassic, subsequent northward drift and final collision with the Eurasian plate on the north in Middle Eocene and with Indo-Sinian plate on the northeast in Late Oligocene [1, 2]. Geodynamics of the plate created internal stress activating faults in the pre-existing structural fabric of the Precambrian-Archaean shield. During the break-up stage, when the Indo-African plate was undergoing far-field crustal distension, the intra-cratonic rift basins were formed in Late Jurassic-Early Cretaceous time. In Late Cretaceous post break up crustal rebound and slab-pull towards the north caused trailing edge uplift that aborted the rifting followed by basin uplifts. Drifting motion induced divergent trans-tensional stress on the reactivated faults. Collision and post-collision continued subduction generated compressive stress over the entire plate. This resulted in inversion of the rifted structures. In this paper, we discuss the development of the active tectonic zones (TZ; **Figure 1**) due to varying plate motion during different tectonic set-up and present neotectonic inversion stage.

## 2. Major plate events and related dynamics

### 2.1 Pre-break up stage

Before the initial break up in the Permo-Triassic pre-breakup stage, the Eastern Gondwana mega-plate was stretched by far-field crustal distension when the intra-cratonic rifted basins of Gondwana were formed. In the Indian craton, the rifting occurred mostly in the eastern part of the craton (**Figure 2**) as the extensional stress developed mostly between India and Australo-Antarctican plates [3].

### 2.2 Break up stage

The first break up between Africa and India took place in Late Jurassic and rifting was completed in Early Cretaceous with the separation of Africa and Madagascar-India. As a result, the related intra-cratonic rifting mostly happened in the western pericratonic region of the Indian plate [3]. This was followed by the early Late

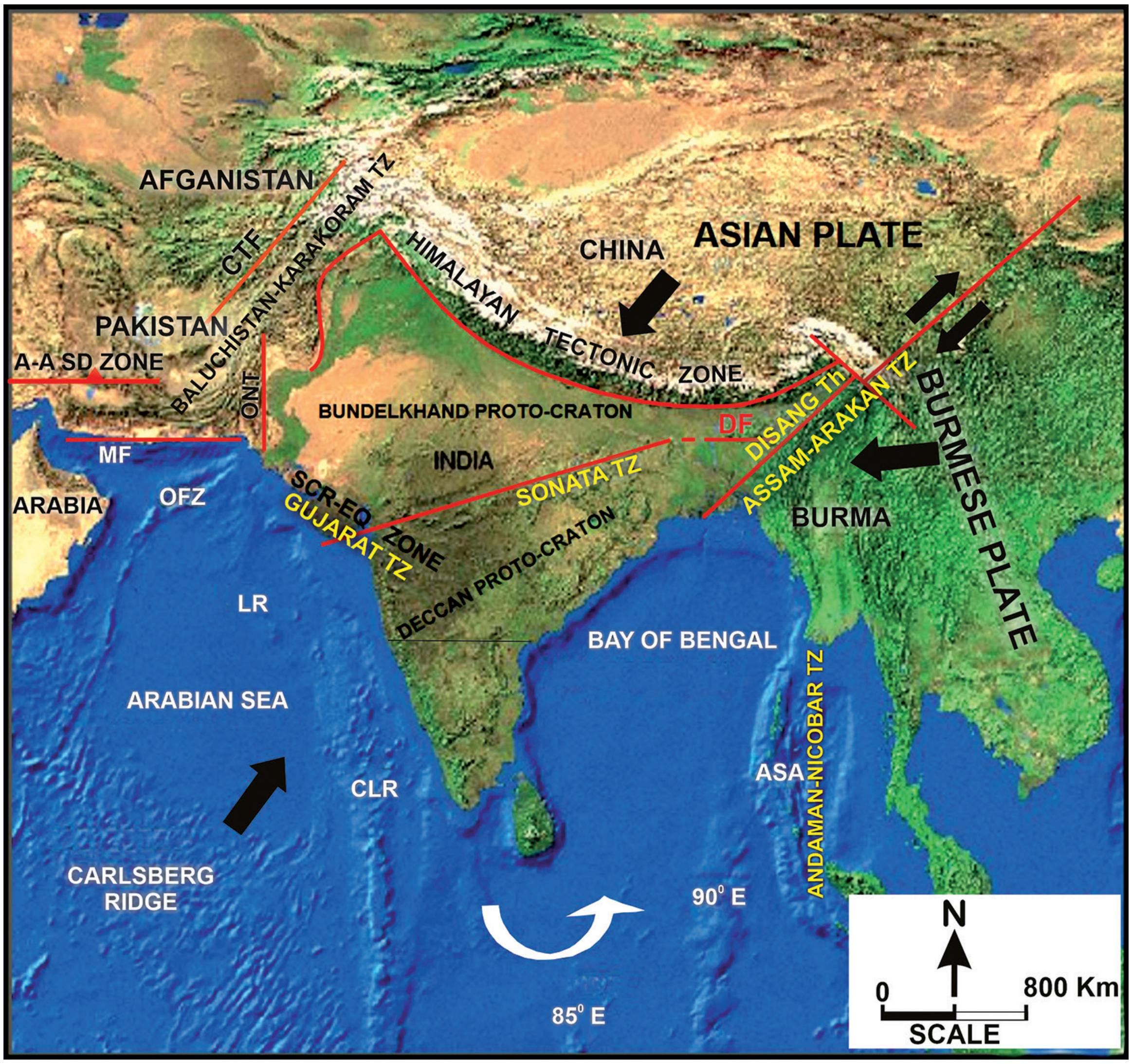


**Figure 1.**
*Present position of the Indian plate with major active tectonic zones (*TZ*). Black arrows indicate the direction of movement of plates and prevailing stress. The white arrow indicates the direction of plate rotation. Red lines mark major fault/thrust zones. (key:***A-A SD zone***- Afgan-Arabian Ocean subduction zone,* **CTF***- Chaman transcurrent fault,* **MF***-Makran fault,* **ONT***- Ornach Nai Transcurrent fault,* **OFZ***- Owen fracture zone,* **LR***- Laxmi ridge,* **CLR***- Chagos-Laccadive ridge,* **DF***- Dauki fault,* **ASA***- Andaman-Sumatran arc,* **SCR-EQ zone***- stable continental region earthquake zone,* **TZ***- tectonic zone,* **Th***- thrust).*

Cretaceous break up of India and Australia-Antarctica in the eastern part. Rifting of eastern pericratonic basins and a few Upper Gondwana intracratonic basins took place during this time.

### 2.3 Rift-drift transition

Rift drift transition occurred in the latest Cretaceous-Early Paleocene time, marked by a widespread unconformity in depositional sequences of both eastern and western pericratonic rift basins. This was a period of stress release and trailing edge uplift of the Indian plate due to the slab-pull from the Tethyan trench. This uplift is responsible for the aborting of the rifts and large-scale upthrusts along primordial faults boosting horst-graben structures along the evolved passive margins where the continents split.

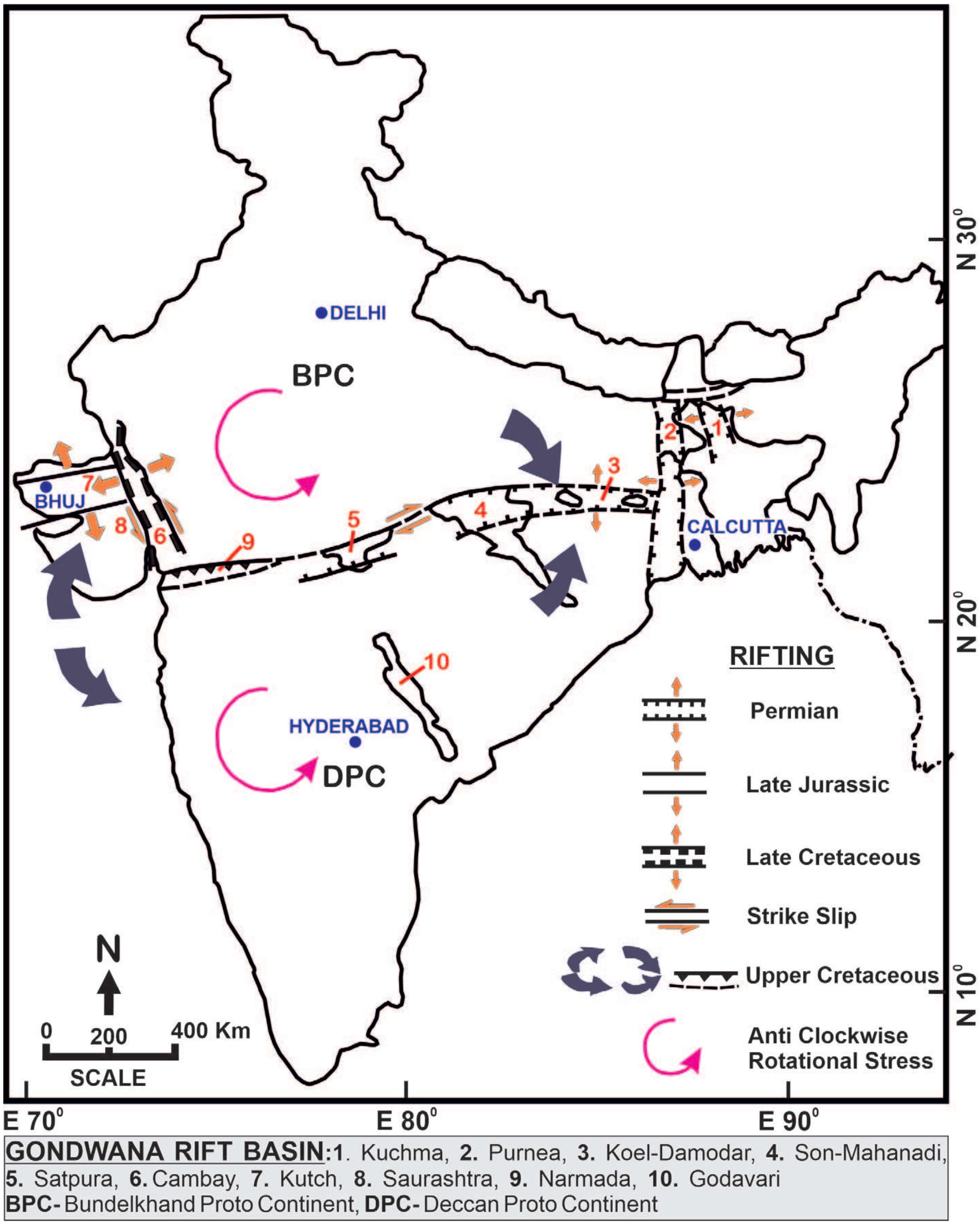


**Figure 2.**
*Map showing major Gondwana and Mesozoic-tertiary rift basins of India and mid-continental NSG. Arrows indicate intra-plate dynamics at different periods.*

### 2.4 Drift stage

As the Indian plate drifted northward with anticlockwise rotation along a curved path (**Figure 3**), the reactivated rift-faults were subjected to horizontal stress, inducing transtensional movements within the pericratonic rift basins. This is evident by the breaking of upthrust-related drape folds along the tilted-up edges of the uplifts (horsts) into small sub-order folds. The best example is seen in the structure of Kutch uplifts (**Figure 4**).

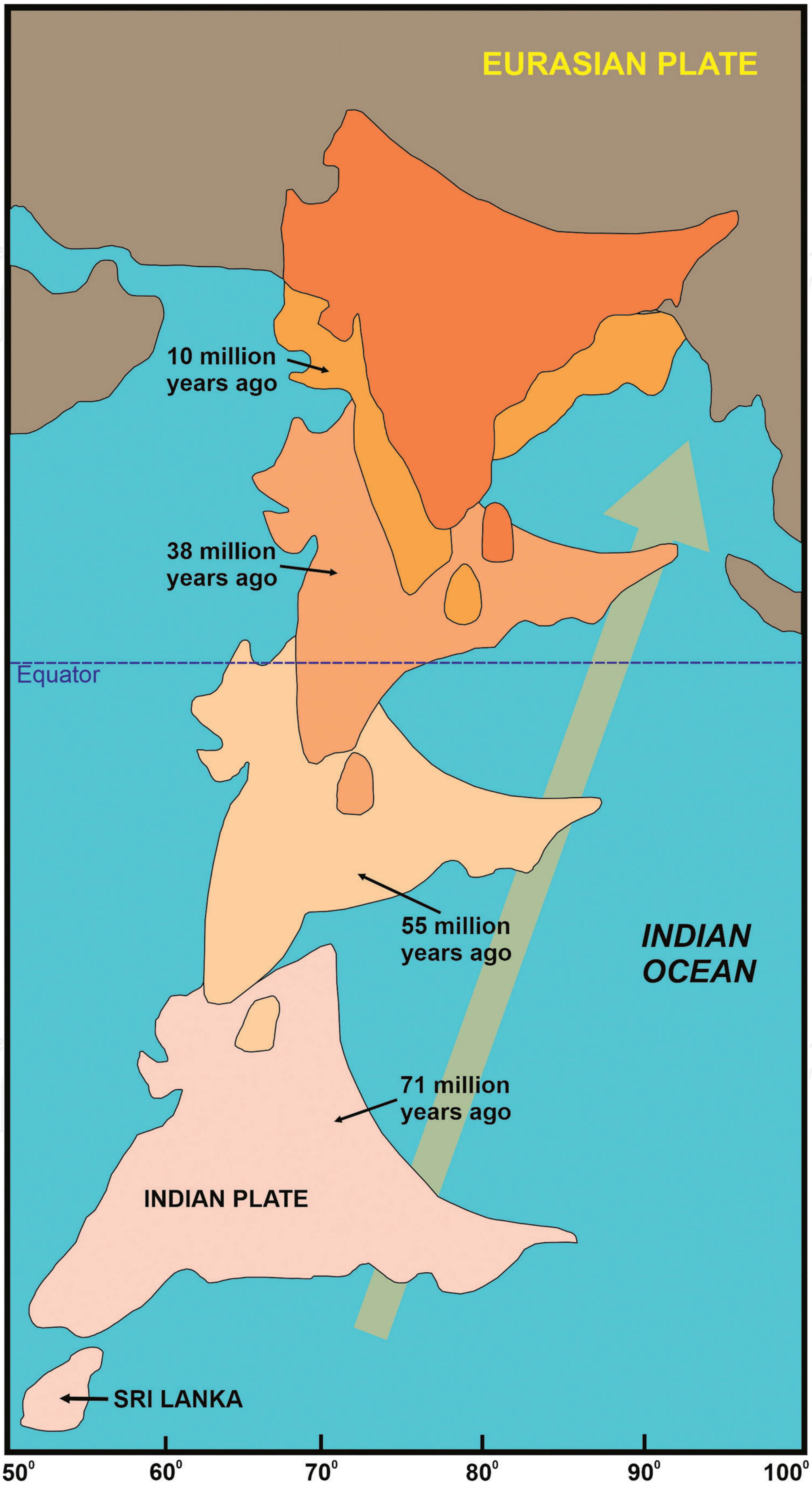


**Figure 3.**
*Path of post-cretaceous drifting of the Indian plate.*

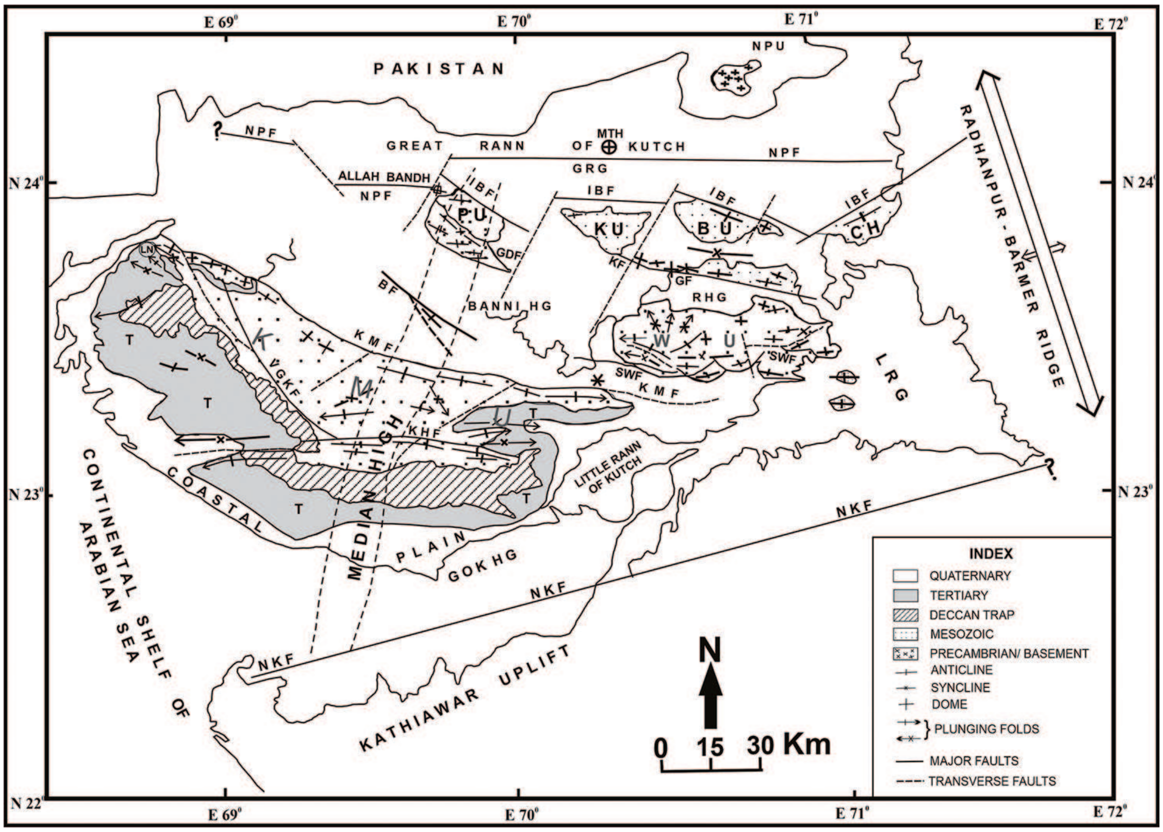


**Figure 4.**
*Tectonic map of Kutch rift basin, the zone of intensive seismic activity in SCR. The map shows major fault-bound tilted uplifts and intervening grabens/half-grabens. Evidence of strike-slip movement is indicated by the breakup of marginal drape fold over the tilted-up edges of the horst (indicated by fold symbols) and left step over of the KMF as SWF towards the east with en echelon shift of Kutch mainland and Wagad uplifts.*

## 2.5 Collision stage

India collided head on with the Eurasian plate in late Middle Eocene initiating uplift of the Himalayan orogenic belt in the north (**Figure 3**). In Late Oligocene Burmese plate collided obliquely with the Indian plate at its northeastern corner giving rise to Assam-Arakan orogenic belt (**Figures 1** and **5**). This stage is continuing as the northern and northeastern edges of the plate are continuing to subduct under the two converging plates. In the NE, due to oblique collision, the plates are still under the process of convergence with progressive southwestward closing of the intervening NE Indian remnant ocean basin, Bengal basin and Bay of Bengal [4] (**Figure 5**). Widespread compressive stress developed in the plate due to southerly backthrust from the collision front and northerly ridge-push from Carlsberg Ridge as the Arabian Sea continues to spread. This compressive regimen is continuing in the present neotectonic cycle. It is responsible for the initiation of inversion tectonic cycle in Eocene-Oligocene and its continuation in the current neotectonic cycle. This is quite evident from the inversion structures seen in all the intra-cratonic basins as well as in the offshore pericratonic basins. Morphotectonic features of India with predominance of the first-order topography also indicate active neo-tectonic cycle dominated by compressive stress.

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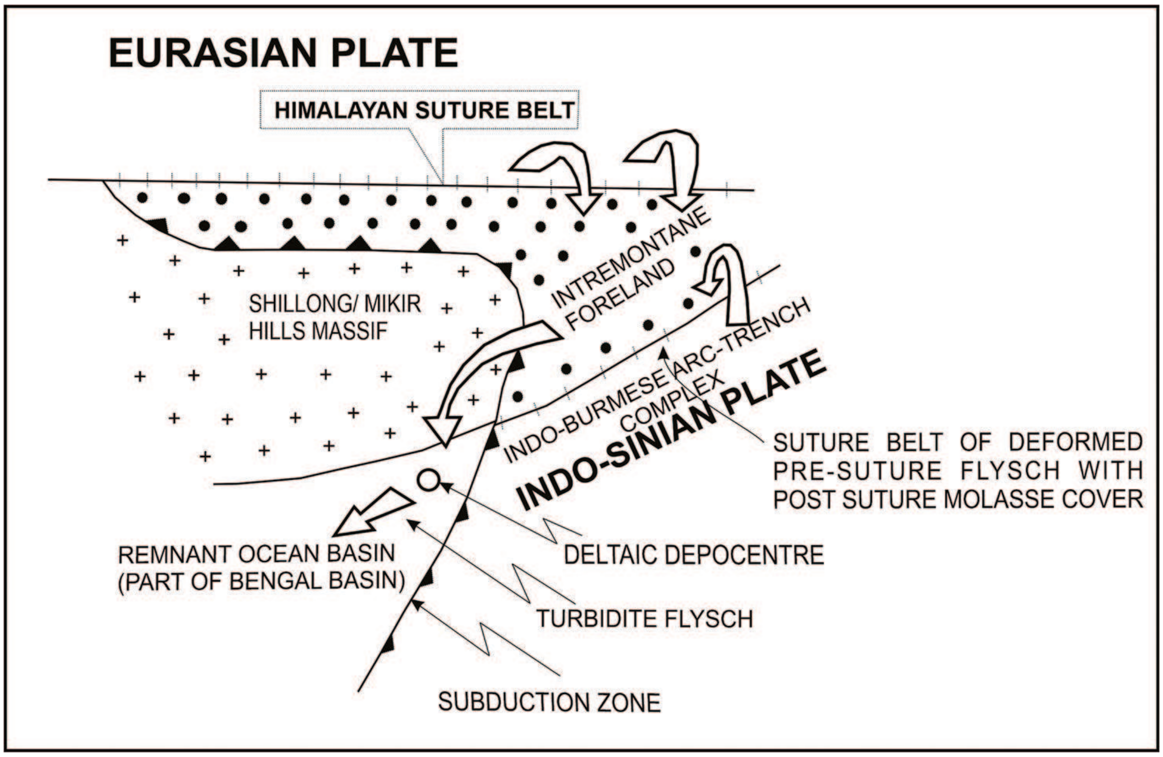


**Figure 5.**
*Plate collision dynamics of NE India – AATZ: The straight collision of Eurasian plate and oblique collision of Burmese plate at the NE corner of India, sutured part is Naga Schuppen belt, and open, the converging region, is the remnant basin of Bengal & bay of Bengal.*

## 3. Active tectonic zones

Several active tectonic zones (TZ) developed in the Indo-Pak Subcontinent (**Figure 1**) during the movement of the Indian plate through the tectonic stages discussed above. These zones are active under compressive stress. The Baluchistan-Karakoram TZ, Himalayan TZ, and Assam-Arakan TZ are present along the northern subduction front of the plate from west to east. A prominent midcontinental TZ, SONATA (Son-Narmada-Tapti) TZ along the NSG (Narmada-Son geofracture), occurs across the plate along a paleo-suture between northern Bundelkhand proto-continent (BPC) and southern Deccan proto-continent (DPC) (**Figure 2**). The tectonic reactivation is taking place due to differential rotating motion between the two proto-cratons along the SONATA TZ. The western pericratonic region covering parts of Maharashtra and entire Gujarat is another active TZ designated here as Gujarat TZ, as evident from the repeated earthquakes in this stable continental region (SCR). The Andaman-Nicobar Island arc is another active TZ as the oceanic plate of northeastern Indian Ocean (Bay of Bengal) is subducting under the arc. These TZs are briefly outlined below.

### 3.1 Baluchistan-Karakoram TZ

The Karakoram-Himalayan orogenic belt is the subduction complex along the northwestern periphery of the Indian plate (**Figure 1**). The northernmost projection of the leading edge of the plate in the region of Rawalpindi and Jammu had the first contact with the Eurasian plate. Subsequently, the subduction was affected by northward motion with simultaneous anticlockwise rotation of the plate. Thus, the northwestern part of the leading edge has a transformal relationship with the Afghan craton. The transpressional strike-slip relationship is marked by Chaman transcurrent (CT) and Ornach-Nai transcurrent faults (ONT). The Baluchistan arc marks the subduction complex of the Arabian Sea and the Afghan craton collision [5]. All these faults are presently active making this TZ a prime earthquake-prone zone.

### 3.2 Himalayan TZ

The Himalayan TZ marks the continent-continent collision zone with the ongoing thrusting of the Tibetan plate over the Indian plate. This zone, therefore, is highly vulnerable to earthquake generation. Epicentres of several disastrous earthquakes are located in this zone. The northward motion of the Indian plate is constrained by this collision front which is building up strain in this zone and also back thrust that is responsible for the compressive stress experienced in the sub-continent.

### 3.3 Assam-Arakan TZ

This is a zone of oblique collision where two colliding continents are still in the process of convergence with a remnant ocean between them [6]. The Burmese plate collided with the NE corner of the Indian plate near the present syntaxial bend of the mobile belt (**Figures 1** and **5**). The plate continues to rotate towards the northeastern edge of the Indian plate as suturing is progressing southwestward with the extension of the subduction complex of the mobile belt. As such, this zone is tectonically highly active in the present cycle. This is evident from the intense seismic activity and occurrence of many strong earthquakes.

### 3.4 SCR Earthquake zone (Gujarat TZ & SONATA TZ)

The SCR earthquake zone includes parts of central and western India covering parts of Madhya Pradesh, Maharashtra, and almost the whole of Gujarat (**Figure 1**). The rifted region of Kutch-Cambay, Saurashtra, and Narmada comprises the SCR EQ-zone. The Son-Narmada-Tapti tectonic lineament zone, SONATA, across the Indian shield is a part of this SCR EQ zone. This ENE-WSW trending SONATA zone is defined by Narmada-Son lineaments in the north and Tapti lineament in the south. The zone is reactivated along Precambrian Satpura-Bijawar mobile belt occupying the Central Indian Tectonic Zone (CITZ) [7]. The northern part of the CITZ is the suture zone between the BPC and DPC (Dharwar-Bastar-Singbhum) proto-cratons or sub-plates. The zone consists of a bunch of E-W striking faults parallel to the NSG, reactivated as right-lateral strike-slip faults in the neotectonic cycle. It is affected by NE-SW striking Burhanpur wrench fault [8] with a right-lateral shift. The active seismic zone around Jabalpur, Broach, and Surat is a part of this active tectonic zone. Gujarat TZ includes Saurashtra horst, Kutch, Cambay, and Narmada rifts with active faults. The most vulnerable area of strain build-up for earthquake generation is the Kutch rift (**Figures 4** and **6**).

### 3.5 Andaman-Nicobar TZ

This is an Island arc, a part of the Sumatran arc which is the collision front of the oceanic plate of the Indian Ocean and the Indochina-Malaysian continental

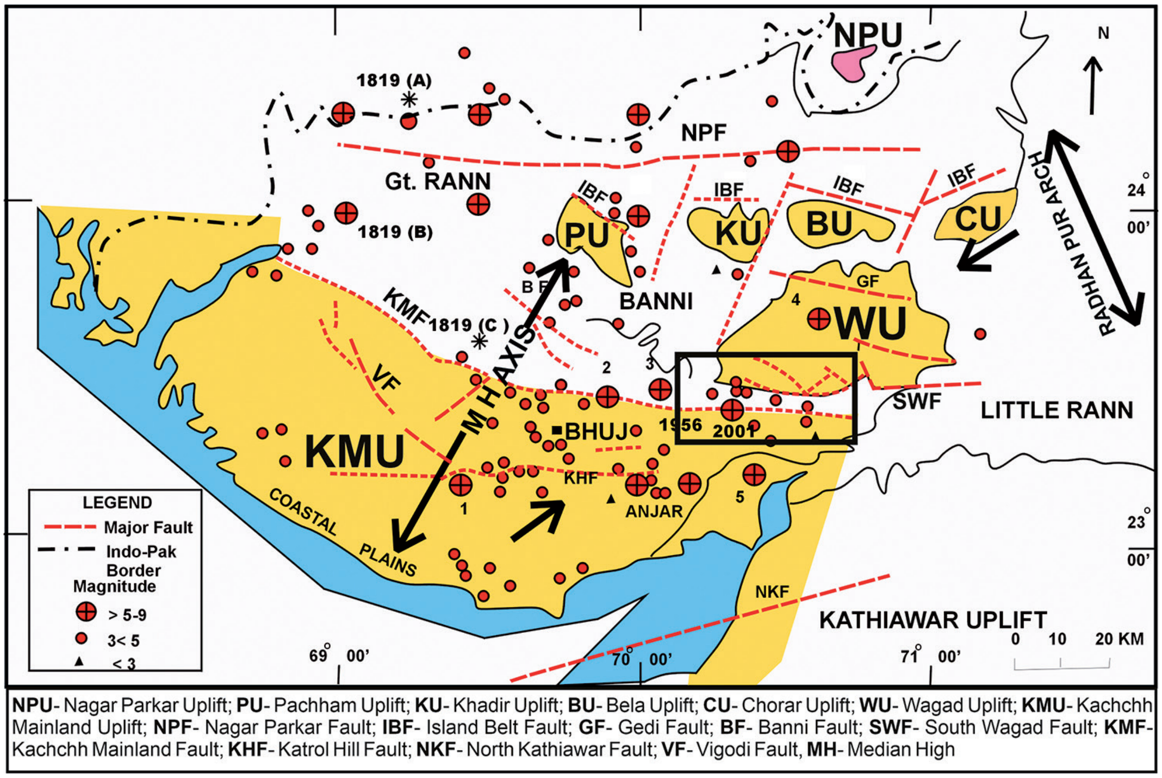


**Figure 6.**
*Tectonic map of Kutch showing major tectonic elements which are major stress barriers for strain build-up. Arrows indicate stress directions. Square marks the critical strain build-up zone in the fault step-over area. Stars and crossed circles within the critical zone are locations of major earthquake epicentres.*

plate (**Figure 1**). It extends northward into the Assam-Arakan orogenic belt where the oceanic plate has been consumed as the Burmese plate converged on the Indian plate. This Arc is very active seismic zone where the disastrous Tsunami of 2004 originated.

## 4. Transcontinental mega-shear zones (MSZ) and plate dynamics

Indian Plate is affected by five main ocean-to-continent transcurrent faults as indicated by the extension of important offshore transform/strike-slip faults across the continent. These are, from north to south, the North Kathiawar-Great Boundary fault, SONATA Zone, Alibag, Vengurla, and Tellichery-East Coast-HHL-Naga Hills faults (**Figure 7**) (HHL: Hail-Hakalula lineament). The trans-continental extension of these faults is traced by strong tectonic lineaments matching with mapped fault/shear zones and important Proterozoic tectonic trends. The matching strikes of North Kathiawar and Great Boundary Fault suggest a continuous trend of crustal shear between Trans Aravalli proto-craton (TAPC) and BPC. These extensive and active fault zones are considered here as mega shear zones (MSZ).

Presently the Indian plate is under compressive stress ([9]; **Figures 1** and **7**). The slab-pull from the Andaman trench is causing the anticlockwise rotation of the plate (**Figure 7**). The Indian plate is divided in the middle by the SONATA TZ which is a mega-shear zone (MSZ) reactivated in the present neotectonic cycle as a transcontinental transform fault (**Figure 7**). This MSZ extends from the Carlsberg Ridge to Upper Assam across the continent along NSG connecting the Dauki fault and Naga

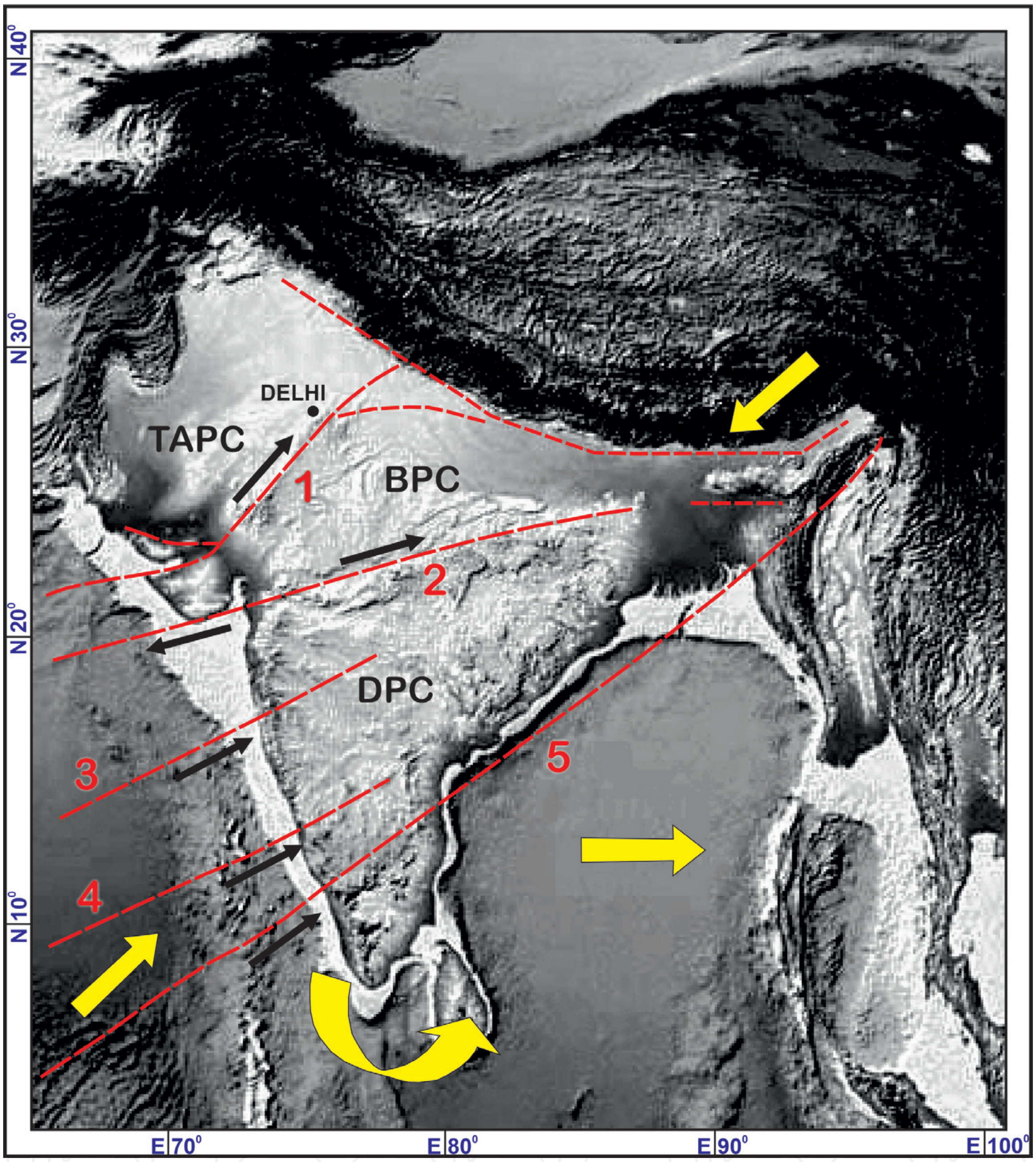


**Figure 7.**
*Red lines mark the major ocean-to-continent transcurrent faults (MSZs, numbered) across the Indian shield:* (1) *North Kathiawar – Great Boundary Fault,* (2) *Narmada-Son-Dauki-Naga Fault,* (3) *Alibag Fault,* (4) *Vengurla Fault,* (5) *Tellichery – E. coast-HHL-Naga Thrust. Stress/movement directions are shown by black arrows. Yellow arrows show prevailing regional stress directions following plate movement.*

thrust [9]. As a result, the two proto-cratons, BPC & DPC, are rotating with differential motion on either sides of this mid-continental shear zone (**Figure 2**) [3]. The motion of the northern protocraton is constrained by the collision front whereas the southern craton is moving relatively free in response to the anti-clockwise plate motion.
The Deccan sub-plate is affected by another mega-shear zone, the Tellichery fault, extending from Carlsberg Ridge in the offshore to Naga frontal thrust along the Naga Hills in AA TZ. This fault extends across the southern part of DPC through the Palghat gap, Kaveri shear zone, along the east coast (bordering Krishna- Godavari rift basin), and across the Bangladesh-Tripura fore-arc prism following Eastern Ghat Precambrian trend (**Figure 7**). This is defined here as Tellichery-Naga-Hills MSZ.

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Between SONATA MSZ and Tellichery-Naga Hills MSZ, two other offshore faults, Alibag and Vengurla faults, occur. These faults also appear to extend across the shield but the lineaments are obscured by the Deccan Trap cover. The relatively free rotation of the Deccan subplate is creating a tensional stress in the region of the Gulf of Cambay and Narmada (**Figure 2**). This is evident from the occurrence of pull-apart basins in this region [3, 9]. At the same time, in the central and eastern parts of this MSZ, transpressional stress is developed (**Figure 2**). This is evident from the uplift of the Gondwana rifts in the central and eastern parts of this MSZ. South of NSG, the three MSZs across the Deccan sub-plate divide the plate into slices which are slipping left-laterally relative to each other from north to south due to rotation of the plate. This progressive left lateral shift from north to south is apparently responsible for the convex outline of the present coastline.

The Tellichery-Naga MSZ is a resurgent shear zone playing an important role in the present-day plate dynamics. The identification of the mega shear extending from the Carlsberg ridge to the Indo-Burmese plate boundary adds a new dimension in the plate kinematics in the northern Indian Ocean as it appears to be a new or evolving transform plate boundary. Between Eastcoast and AA TZ this MSZ passes through an active zone of seismic activity (**Figure 8**) and it matches with the active TT3 and HHL tectonic lineament of Bangladesh [10] and Tripura-Naga Hills [11] respectively. This transform motion and the stress generated by active convergence of Indian and Burmese plates following oblique collision are responsible for the high degree of seismicity of the Assam-Arakan TZ.

The compressive stress due to continuing north and north-northeastward subduction of the Indian plate is responsible for the seismicity of the Himalayan TZ. The Baluchistan-Karakoram TZ (**Figure 1**) is also highly vulnerable to earthquakes. The recent 2005 Baluchistan earthquake is an example. This is caused by different plate motions along the AA-SD TZ in this northwestern border of the plate. The compression related to the continuing northward subduction of the plate along the Karakoram thrust, the transform motion between the Indian and Afghanistan plates along CT and ONT, and subduction of the Arabian Sea oceanic plate below the Afghan plate along the Makran Fault (MF) in AA-SD TZ, west of the transform boundary are causative forces.

In the SCR zone, the highly rifted Gujarat region is the most active seismic zone in peninsular India. The structural inversion of the rifted structures due to present compressive stress is responsible for the repeated generation of the large earthquakes $M > 7.0$, particularly in the Kutch rift where the confining stress is enhanced by the local structural framework as discussed below. The SONATA zone is another earthquake-prone linear zone. Several major strong earthquakes $M \sim 6.0$ occurred around Jabalpur in the past including the recent 1997 earthquake [12]. The focal depth of the 1997 Jabalpur earthquake is estimated at 35 km, at the crust–mantle boundary [13]. The dextral strike-slip motion and related kinematics associated with the parallel faults and their conjugate Riedel faults in the SONATA are the cause of repeated rift basin deep crustal earthquakes within this zone as noted in cases of the 1973 Broach and the 1997 Jabalpur earthquakes $M > 6.0$.

The Latur and Koyna earthquakes are apparently related to the Koyna-Kurduwadi rift (**Figure 9**) inversion with compressional stress [15]. These rifts are apparently related to Alibag MSZ passing south of the SONATA zone. These events are, however, shallow (depth < 10 km) upper crustal earthquakes.

### 4.1 The 2001 SCR (BHUJ) earthquake

January 26, 2001, Republic day EQ earthquake in Bhuj, Gujarat state, is a world example of a recent high magnitude Mw 7.7 earthquake in SCR. Several disastrous

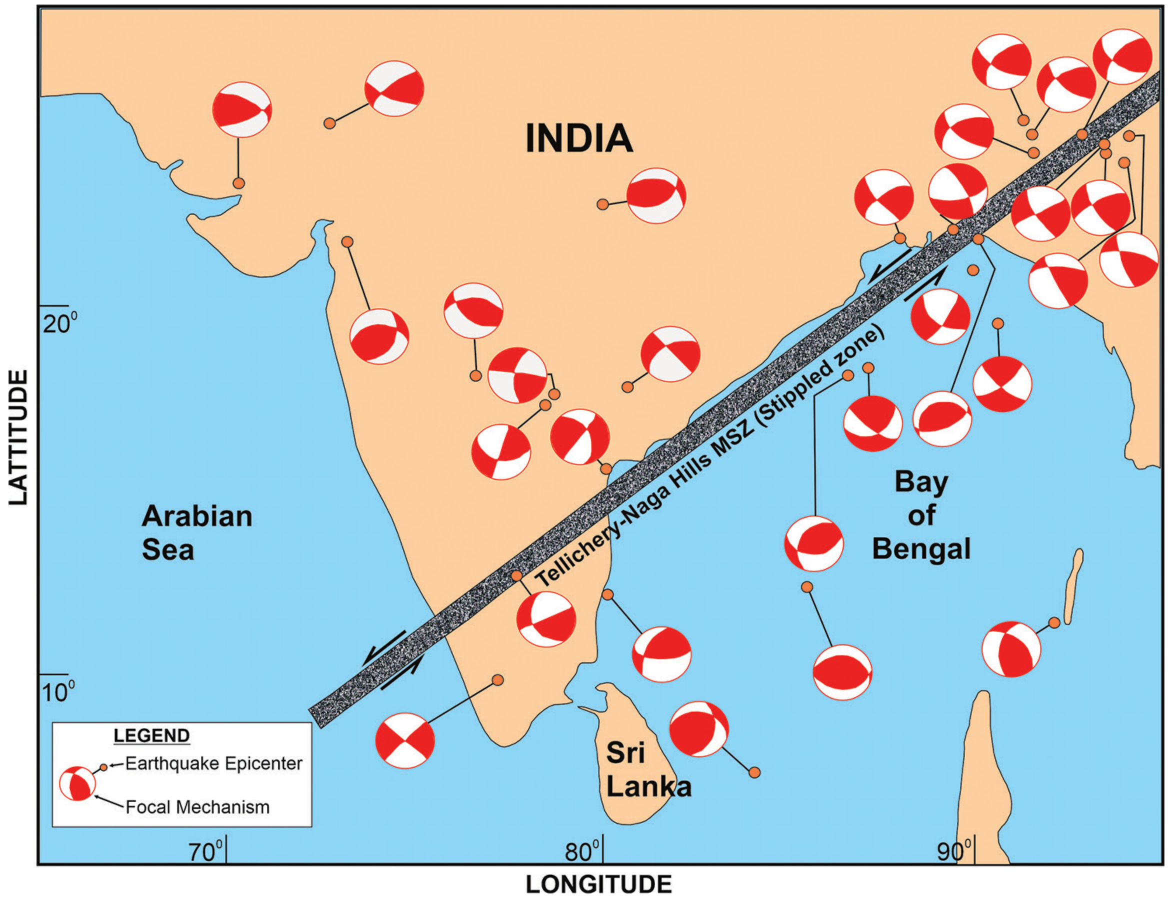


**Figure 8.**
*Map showing the focal mechanism of seismic events along Tellichery-Naga Hills MSZ (stippled zone). (Courtsey: Dr. C. Subrhamanyam, NGRI).*

earthquakes occurred in the Kutch rift since ancient times. Strain build-up at the E-W master faults due to intra-plate kinematics is the reason for repeated earthquake generation [16]. The Kutch Mainland Fault (KMF) in the middle of the rift is the main active fault for earthquake generation (**Figure 4**). This fault is currently experiencing dextral transpressional strike-slip movement. Towards the east, the fault tapers off and sidesteps to the left (i.e., shifts to the north) and continues eastward as South Wagad Fault with an approximately 50 km step-over zone (**Figures 4** and **6**).

Intense seismic activity within this step-over zone is indicated by crowding of earthquake epicentres including two major high-intensity earthquakes, the 1956 Anjar, and the 2001Bhuj (**Figure 6**) earthquake. This fault step-over zone is strained by the accumulation of regional compressional stress. Further, the occurrence of massive plutons and geophysical data indicate the presence of a deep-seated igneous body which appears to be syn-rift crustal melt in the deeper crust at 20–40 km depth (**Figure 10**). Seismic tomography study [17] in the Bhuj earthquake epicentre area clearly indicated fluid-filled rock matrix at this depth [18]. The E-W rift ends up against an NW-SE trending basement ridge, the Radhanpur-Barmer arch that separates this rift and the transversely oriented N-S Cambay rift (**Figures 4** and **6**). The easterly horizontal stress along KMF/SWF is constrained by this ridge, which acts as an effective stress barrier. This adds to the strain build-up due to compressive stress within the critical stepover zone. The resistance against the igneous body further

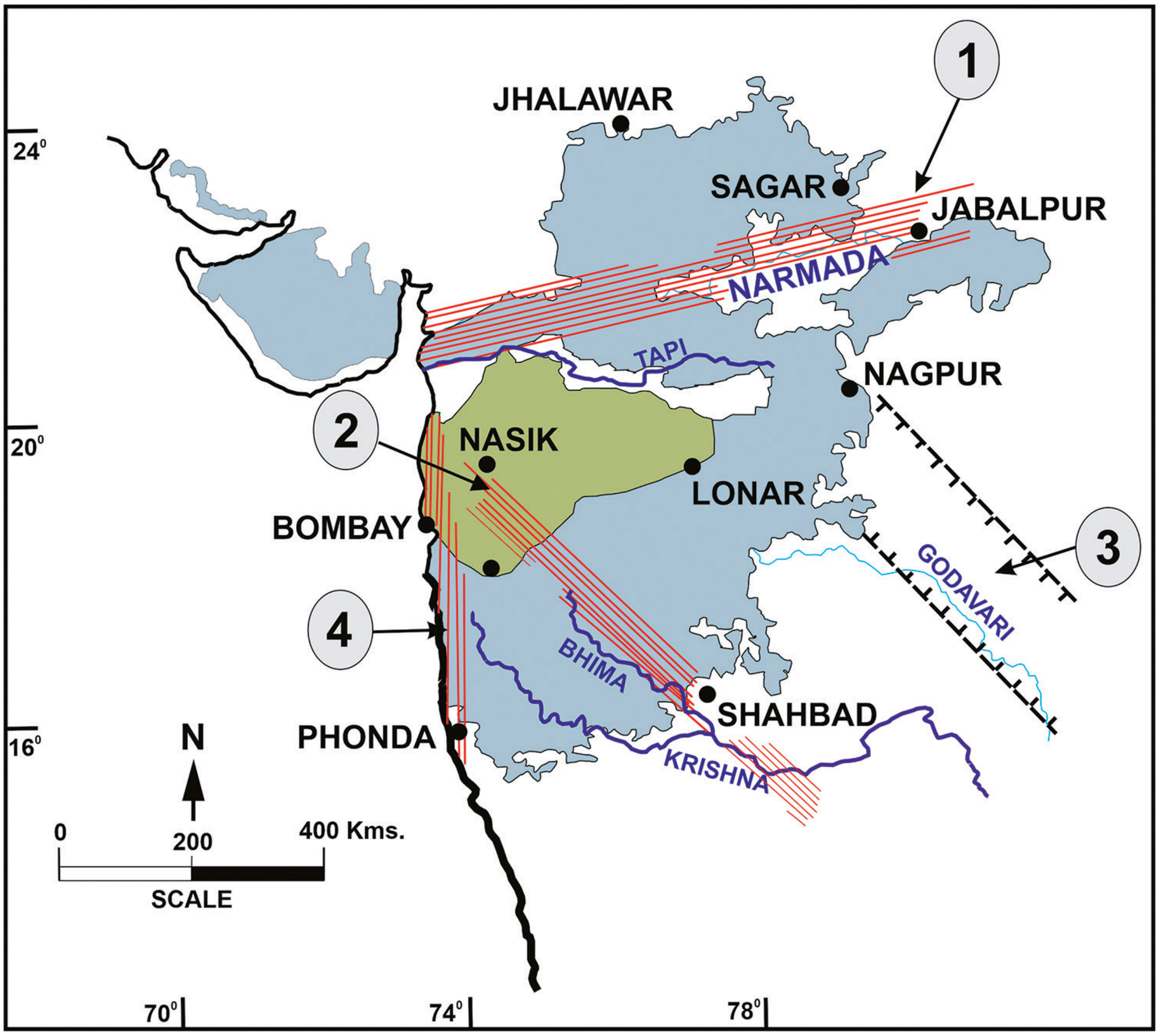


**Figure 9.**
*Major tectonic elements south of SONATA zone:* (1) *NSG;* (2) *Koyna-Kurduwadi rifts,* (3) *Godavari rift, and* (4) *west coast fault zone (after [14]).*

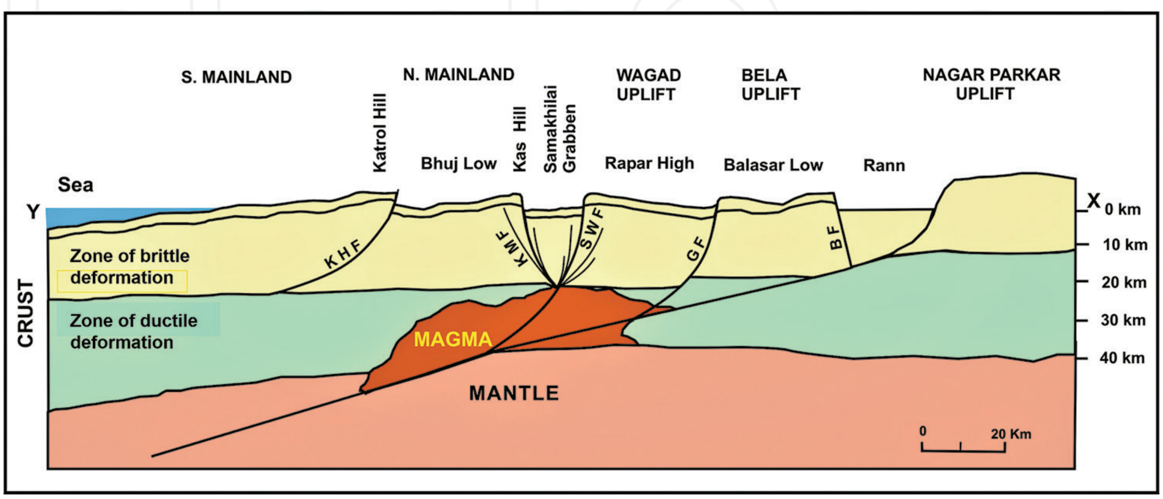


**Figure 10.**
*Conceptual rift model of Kutch showing causative fault, SWF, extending into the deeper crust causing mantle rupture and lithospheric melt. The igneous body formed by the melt forms the main stress barrier.*

adds to the strain build-up along a rift fault presumably passing over the flank of the igneous mass as shown in the conceptual model (**Figure 10**) drawn on the basis of the available geological and seismotectonic data [19]. The rift fault SWF that extends to the deeper crust is a sub-vertical planar fault bounding the basement domino block in the upper crust. It extends into the deeper crust becoming a low-angle rift fault in the semi-ductile layer of the deeper crust (**Figure 10**). This pattern of the fault along the flank of the igneous mass matches with the pattern of distribution of hypocentres of aftershocks. This indicates that the SWF is the causative fault for repeated earthquake generation [16, 19].

## 5. Conclusion

The neo-tectonic cycle is active on the Indian Plate due to present plate motion and related tectonic movements. It is manifested as structural inversion of the rifted structures, rejuvenation and modification of the existing structures by upthrust and transpressional forces, continued subduction at the collision fronts, and uplift of the crustal blocks in the exposed shield region. The structural stress is the compressive force being generated by the north-eastward ridge-push from the Carlsberg Ridge and the southwestward back-thrust from the collision front on the north.

The major plate motions are, north and northeastward underthrusting of the Indian plate below the Eurasian plate, transform movement with respect to Afghan and Burmese plates, and anti-clockwise rotation due to ridge-push from Carlsberg ridge and slab-pull from the Andaman-Sumatran trench (**Figures 1** and **5**). Intra-plate movements, mainly strike-slip in response to horizontal stress due to drift motion, are controlled by the three main ocean to continent mega-shear zones.

Several tectonic zones (**Figure 1**) were created by the above-mentioned plate dynamics along the periphery of the plate with varying stress kinematics – Himalayan TZ in the north, Baluchistan-Afghan TZ on the northwest, Assam-Arakan TZ on the NE, and Gujarat TZ in the west. Reactivation along the paleo-suture activated the mid-plate SONATA TZ. All these resurgent tectonic zones are presently active seismic zones and sites for several disastrous earthquakes. The Gujarat and SONATA TZs are more active seismic zones for the SCR earthquakes in India.

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## References


[1] Deitz RS, Holden JC. Reconstruction of Pangea, break up and dispersion of continents, Permian to Present. Journal of Geophysical Research. 1970;**75**:4939-4956

[2] Powell CM, Roots SR, Veevers JJ. Pre-break up continental extension in East Gondwanaland and the early opening of the eastern Indian Ocean. Tectonophysics. 1988;**155**:261-283

[3] Biswas SK. A Review on the evolution of rift basins in India during Gondwana with special reference to Western Indian basins and their hydrocarbon prospects. In: Sahni A, Loyal RS, editors. Gondwana Assembly: New issue and Perspectives. New Delhi: Ind. Nat. Sc., Acad; 1999. pp. 53-76

[4] Biswas SK, Bhasin AL, Ram J. Classification of Indian sedimentary basin in the framework of plate tectonics. In: Proc. Second Seminar on Petroliferous Basins of India, Dehradun. Vol. 1. 1993. pp. 1-46

[5] Zaighm NK, Malliick KA. Prospect of hydrocarbon associated with fossil rift structures of southern Indus basin, Pakistan. Bulletin of the American Association of Petroleum Geologists. 2000;**84**:1833-1848

[6] Biswas SK. The Upper Assam inter-orogenic peripheral foreland basin – A special type of peripheral foreland basin in Northeast India – An overview of tectono-sedimentary evolution, Souvenir vol. of National Seminar on Geodynamics, sedimentation and biotic response in the context of India-Asia collision, Mizoram University & Geol. Soc. Ind., 2009. pp. 77-90

[7] Acharyya SK, Roy A. Tectonothermal history of the Central Indian tectonic zone and reactivation of major faults/shear zones. Journal Geological Society of India. 2000;**55**(3):239-256

[8] Ravi S. Thermal and crustal structure of SONATA, a zone of mid-continental rifting in Indian shield. Journal Geological Society of India. 1991;**37**(3):211-220

[9] Biswas SK. Geodynamics of Indian plate and evolution of the Mesozoic-Cenozoic basins. Memoir Geological Society of India. 2008;**74**:247-260

[10] Khan AA, Chouhan RKS. The crustal dynamics and tectonic trends in Bengal basin. Journal of Geodynamics. 1996;**22**:267-286

[11] Khar BM, Ganju JL. Tectonics of Tripura folds - probable mechanics of folding and faulting. Petroleum Asia Journal. 1984;**1**:66-70

[12] Thakur VC, Sushil K, Phillip G. May 22, 1997, Jabalpur earthquake: reactivation of eastwest trending Jabalpur fault in the Narmada-Son lineament zone. Himalayan Geology. 1998;**19**(1):119-126

[13] Bhattacharya SN, Ghosh AK, Suresh G, Baidya PR, Saxena RC. Source parameters of Jabalpur earthquake of May 22, 1997. Current Science. 1997;**73**:855-863

[14] Kale VS, Kulkarni HS, Peshwa VV. Discussion on a geological map of the southern Deccan Traps, India and its structural implications. Journal of Geological Society. 1991;**148**:495-505

[15] Misra DC, Gupta SB, Rao V. Space and time distribution of gravity field in earthquake affected areas

of Maharashtra, India. Memoirs. 1994;**1994**:119-126

[16] Biswas SK, Khatri KN. A geological study of earthquakes in Kutch, Gujarat, India. Journal of Geological Society. 2002;**60**:131-142

[17] Mandal P, Rastogi BK, Satyanaraya HVS, Kousalya M, Vijayraghavan R, Satyamurty C, et al. Characterization of the causative fault system for the 2001 Bhuj earthquake of Mw 7.7. Tectonophysics. 2004;**378**:105-121

[18] Kayal JR, Zhao D, Mishra OP, De R, Singh OP. The 2001 Bhuj earthquake: Tomography evidence for fluids at hypocenter and its implications for rupture nucleation. Geophysical Research Letters. 2002;**29**(24):51-54

[19] Biswas SK. A review of structure and tectonics of Kutch Basin, Western India with special reference to earthquakes. Current Sciences. 2005;**88**(10):1592-1600