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# Quaternary Changes in the Indian Subcontinent: Implications on Neotectonics

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**Abstract:** *Several patches of Quaternary deposits occur in different parts of the Indian Subcontinent. Thick deposits of Quaternary formations occur the central part of India, mainly along the banks of Narmada and Tapti River Valleys, in the Bengal Basin, and in parts of Rajasthan and Gujarat. Stunning geomorphological changes are noted in different parts which have grossly altered the surface physical character of the Indian landmass, unknown in any other 'Shield' areas of the world. Gross physiographic character of the Indian Peninsula is considered a 'single-plateau' geomorphic entity, though there are significant diversities not only in its geological constitution but also in the physiographic types and character. There are also several mountain-like high linear ranges which occur traversing the entire Indian landmass. These mountain-like highlands do not seem to have evolved as fold-mountains. The flat-topped hills in the Deccan Plateau formed due to uplift of fault-bounded blocks during the late Quaternary period. The most noticeable feature in the development of remarkable physiographic diversity in the landscape of the Peninsular India was the outcome of sculpturing of the landscape mainly due to the lineament-controlled 'neotectonic' activities during the late Quaternary period.*

**Keywords:** Neotectonic

## I. Introduction

The Quaternary represents the youngest geological time phase of the Earth's evolutionary history that lasted from about 2,580,000 to 11,700 years (before present). It is conventionally divided into an older Pleistocene and younger Holocene Periods. Out of these, Pleistocene covers the major span of about 1.81 million years. The youngest Holocene that began about 10,000 years ago has an open-ended upper limit. The Indian Subcontinent is undergoing wide-ranging 'geomorphotectonic' changes during the post-Himalayan period, causing deposition of thick layers of sediments, reshaping of landmasses, and major alteration in the sub surface physical characters causing localized upliftment and reactivation. The scattered occurrences of Quaternary deposits are known from different parts fringing the entire Peninsular India, all along the western and eastern coastlines. Beyond the coastal regions, deposition of thick Quaternary formations took place in the central part of India especially along the Narmada and Tapti Valleys, in the Bengal Basin, and in parts of Rajasthan and Gujarat. In the Himalayas, the Quaternary formations constitute the newer parts of the youngest Siwalik Group. The outcrops of the Siwalik Group are continuously traceable south of the Main Boundary Thrust, almost all along the east-west stretch of the Himalayas.

The Quaternary geology is well accounted in literatures. The present discussion is intended to highlight the major geomorphological changes which grossly altered the surface physical character of the Indian landmass, unknown in any other 'Shield' areas of the world (Roy and Purohit, 2018). Significantly, the entire reshaping process was operative during the last phase of the Earth's history, more specifically during the Holocene that began about 10,000 years ago, and significantly much of these changes were presumably witnessed by 'Man' (Valdiya, 2010). According to Kale (2014), the Indian Subcontinent encompasses all the different geomorphic landscape features that are noted on the present-day Earth's surface. The geomorphic diversity shown in an East-West topographic section of the Indian Subcontinent appears quite remarkable (Fig. 1).

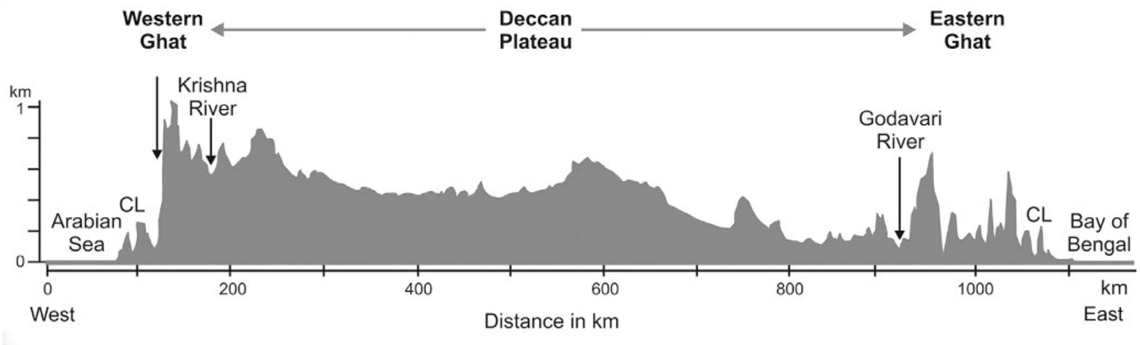


**Figure 1:** The geomorphic diversity shown in an East-West topographic section of the Indian Subcontinent appears quite remarkable.

## II. Evidence of Active Tectonics in Peninsular India

The gross physiographic character of the Indian Peninsula is considered a 'single-plateau' geomorphic entity, though there are significant diversities not only in its geological constitution but also in the physiographic types and character. There are several mountain ranges that cross-cut the Indian landmass(Fig. 2), which did not seem to have evolved simply as fold-mountains.

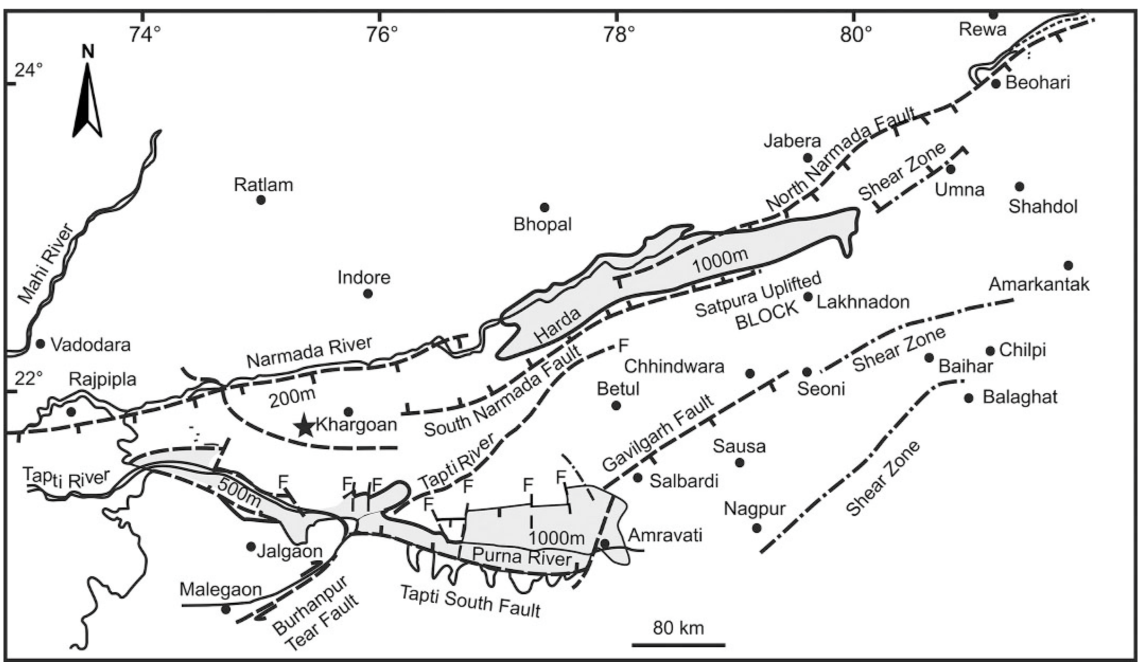


**Figure 2:** There are several mountain ranges that cross-cut the entire Indian landmass

which did not seem to have evolved simply as fold-mountains. There are several mountainous hills which appear to have retained thepristine horizontality of bedding or other depositional features even in those that show considerable vertical uplifts.

The only exception is the Aravalli Mountain that had a long Precambrian evolutionary history, and has undergone uplift related rejuvenation during late Quaternary (Roy and Jakhar, 2002). The topography of individual geomorphic entities is generally undulating with prominent granite hills having dome-like appearances in outlines. However, there are quite a few flat-topped hills having mountainous height but did not seem to have evolvedas 'orogenic' mountain. On the other hand, there are several precipitous hills which appear to have retained the pristine horizontality of bedding or other depositional features even in those that show considerable vertical uplifts. Added to these are several instances of sudden drops in surface topography leading to the development of water-falls especially when such faces cut across the river valleys and stream channels (Fig. 3). The features described above provide unmistakable evidence that the major landforms (valleys, high level surfaces, and lateritic landforms) could not have developed merely as the legacy of long history of prolonged weathering and erosion.

Figure 3

Figure 4

Figure 3. Invariable presence of scarp-topography and development of water-falls especially when such faces cut across the river valleys and stream channels. Fig. 4 The landscape around Munnar Hills (1450 mamsl) in Kerala lying on the western foot hill of the Anamudi Mountain in the southernmost part of the Indian Subcontinent is a classic example of a mountain formed in such way.

On the other hand, much of the mega- and the micro-scale geomorphic features can be attributed to the more-recent block uplift-type tectonic activities that affected the entire Indian Peninsula. The evidence of ancient gently rolling, almost featureless ‘peneplain’ surfaces marking the top of uplands areas like plateaus and mountains provide proofs of the prolonged period of denudation reaching the base level of erosion much before its elevation to the mountainous height. Heron (1953) while discussing the physiography of the Aravalli Mountains mentioned about the uplifted ‘Jurassic’ erosion surfaces. Presumably, the combination of two features resulted because of vertical uplift of much denuded peneplain surfaces. The landscape around Munnar Hills (1450m msl) in Keralalying on the western foot hill of the Anaimudi Mountain(Fig. 4)might have formed in that way. Thereare reasons to believe that the present-day physiographic characters of the Indian Peninsula provide examples of activetectonics. According to Kale and Shejwalkar (2008), the flat-topped hills in the Deccan Plateau evolved due to uplift of fault-bounded blocks during the late Quaternary period. Earlier, Radhakrishna (1993) had suggested that the most noticeable feature in the development of spectacular physiographic diversity in the landscape of the Peninsular India was the outcome of shaping of the landscape mainly due to the‘ neotectonic’ activities during the late Quaternary period.

Neotectonic changes during the Quaternary began during the waning phase of the Siwalik sedimentation and came to an end with the most recent upheaval of the Himalayas. The depositional sites had by then shifted to their subsiding southern parts, which ultimately evolved as the Indo-Gangetic Alluvial Plains. Geo-morphologically, the vast Indo-Gangetic Alluvial Plain includes both the narrow basin of theBrahmaputra River in the east, and the Thar Desert (in western Rajasthan and the Gujarat Plain) in the west. The average thickness of the alluvial deposits over the entire Indo-Gangetic Alluvial Plains ranges between 400and 800 m, with a maximum thickness of about 6 km along the edge of the Himalayas. The belt is divided into a number of sub-basins separated by several submerged ridges (basement highs) lying across it.

The Quaternary sediments outside the Indo-Gangetic Alluvial Plains occur along the Narmada and Tapti Basins in Peninsular India, and along the coastlines of the entire landmass. Thick laterite formations (some of which contain rich bauxite deposits) were produced at this time in parts of the central India, in the Eastern Ghats, and along the Konkan coasts in the Western Ghats.

The Thar Desert in the east of the Indus Basin show evidence of a fluvial prehistory. This is linked with the establishment of monsoon system over the Subcontinent during the mid-Pleistocene, simultaneously with the rise of Aravalli Mountains producing rain-shadow zone to its west. Theseries of saline lakes that dot the entire desert land were formed by the segmentation and blocking of river channels due to Quaternary (neotectonic movements (Roy and Jakhar, 2001).

The Quaternary neotectonic movements caused spectacular geomorphic changes in the entire Subcontinent, primarily through movements along fault-bounded blocks. The Rann of Kachchh in northern Gujarat is a classic example of regional uplift and down faulting during historical times (Roy et al., 2013, 2014). The development of the Ganges-Brahmaputra-Meghna Delta Complex (the Sundarban Delta, the largest delta system in the world) constitutes a very important geological landform feature that evolved in three stages (Roy and Chatterjee, 2015) of tectonically influenced delta sedimentation processes during the late Pleistocene.

Some classic examples of Quaternary landform changes in the Indian Subcontinent are described below:

**(A) Several lines of geological evidence confirm the existence of a high-energy fluvial regime in western**

Rajasthan during the late Quaternary period. The geomorphic description of the extinct river system matches well with the 'Saraswati River', vividly described in the Rig Vedic literatures (Roy and Jakhar, 2001).The Vedic River that presumably flowed parallel to the Aravalli Mountains during its initial stages, had migrated westward during the late Quaternary (Holocene) uplift of the Aravalli Mountains. The Quaternary movements, which brought about down-sagging of the northern part of the Aravalli Mountains, also forced the Yamuna River to swap its original course to flow eastward across the flattened 'mountain range'. The river presumably pirated the Saraswati waters while it drifted eastward joining the River Ganga (Roy and Jakhar, 2001).

**(B) Narmada Graben and associated Geotectonic features**

Geomorphic data combined with stratigraphic studies provide significant information constraining the timing and the extent of fault movements along the lower parts of the Narmada-SonTectonic Belt. The varying nature and degree of tectonic movements during the late Pleistocene-Holocene period have produced four geomorphic surfaces in the lower Narmada Valley. Two major phases of tectonic movements are recorded along the Narmada-Son Fault, which caused slow syn-sedimentary subsidence of the basin during late Pleistocene due to differential movement along zone of tectonicdis location (Chamyalet al., 2002). This was followed by inversion of the basin during the Holocene, marked by differential uplift along the Narmada-Son Fault. The present landscape of the lower Narmada Valley comprises four geomorphic surfaces and has evolved mainly due to tectonic activity long the Narmada-Son Fault in a compressive stress regime (Chamyal et al., 2002). The Holocene period is also marked by basin-inversion, which had earlier undergone subsidence. The inversion of basin is due to a significant increase in compressive stresses along the Narmada-Son Fault during the early Holocene, resulting in differential uplift of the lower Narmada Valley (Chamyal et al., 2002).

Increase of river gradient index in two places in and around Jabalpur indicates vertical uplift due to the north-south compression along the Narmada-Son Fault zone. The geomorphometric character and satellite data interpretation clearly suggest that the Narmada-Son South Fault was active during the Quaternary. Various tectonically induced landforms were formed all along the Narmada River. These include shifting of river channel (near Amarkantak) and the occurrence of waterfalls, formation of gorge with nearly vertical wall in and around Bheda-ghat near Jabalpur. The development of riverterraces is the common landform features that had formed due to movement along the Narmada-SonFault.

The morphotectonic indices and geomorphological observations in the Narmada River suggest the role of active tectonic in the evolution of fluvial landform in the region. The Narmada River basin is occupied by the rocks belonging to the Vindhya and Satpura mountains towards upper reaches, as also from the Deccan Trap region. The river system is controlled by two parallel faults, The Narmada–Son North Fault and Narmada-Son South Fault. Multiple of roughly north-south trending tear faults offset the Tapti and Narmada Grabens. Recent tectonic activity on these faults is evident from the abrupt eastward swerving forshort distances of the northerly flowing tributary river and streams joining the Narmada River.

The Narmada Rift is defined by a pair of parallel normal faults that are marked by a series of hot springs. Towards the upper reaches, the river shows southwest migration, while in the lower reaches it shows north-northwest migration of the river, which can be assigned either to the low resistance of the bedrock or due to tectonic uplift along the Narmada-Son Fault. The Satpura Horst shows evidence of uplift to the tune of about 1000 m during Quaternary). Matching with the rise, the river valleys are getting deeper and narrower, with simultaneous filling of the river beds by the loads of sediments brought from the eroded river banks. All the different features indicate that the terrain is tectonically active.

**(C) Western Ghats Mountain Belt**

The Peninsular India, conventionally thought as a 'Stable Continental Region', has well-preserved records of physiographicdiversity and youthful character of the mountain ranges, as significant as those in the Himalayas. This is especially so with the mountain ranges bordering the western margin known as the Western Ghats (also described as the Sahyadri Mountains, Radhakrishna, 1993). The Western Ghats, which run parallel to the West Coast, constitutes the most prominent physiographic feature of the Peninsular India. It is a greatescarpment that can be traced for more than 1500 km in the form of a formidable 'wall' extending from near theTapti River in the north to Kanyakumari in the southernmost tip of the Peninsula. Lithologically, the Western Ghats include three different rock types: the flat-lying Deccan Traps in the north, the Dharwar schists and Peninsular Gneisses in the middle, and the granulites and charnockites in the south.

The physiography of the Western Ghats Mountain is as magnificent and awe-inspiring as the Himalayas. Though, the two mountains evolved in two different tectonic regimes. While the Himalayas evolved entirely during the continental collision–related orogeny, the Western Ghats on the other hand evolved essentially due to epeirogenic tectonics associated with vertical movements of the continental blocks bounded between tectonic blocks. The 'straight line' aspect of the West Coast and that of the Western Ghats scarp are very striking. The abrupt termination of the outcrops of the Deccan Trap along the line of the Western Ghats is a clear indication of much younger (post Deccan Trapuplift-related movements along the fault surfaces (Radhakrishna, 1993). The evidence for this comes from the occurrence of long line of thermal springs that occur along the west edge of the Western Ghats scarp. The occurrence of north-south running linear array of thermal springs is an indication of recent faulting.

**(D) Bengal Basin**

The Bengal Basin evolved as a rift-controlled extensional basin along the NNE–SSW trending Basin Margin Fault coevally with the development of 85° East Ridge in the Bay of Bengal during the short-lived hotspot activity south of Bhubaneswar. The basin opening post-dated the Kereguelen Plume magmatism (at ~116 Ma), but predated the phase of continental collision that triggered the rise of the Himalaya in the north. Supply of sediments in the initial stages of basin opening was from the west, mainly through the denudation and erosion of the uplifted Precambrian Shield. Following virtually similar tectonic and depositional pattern in the entire basin, an abrupt change in depositional pattern was recorded during the Oligocene with the emergence of easterly source of sediments derived from the uplifting of Indo-Myanmarese Ranges. Between the Oligocene and Late Pleistocene different parts of the Sylhet Trough *(the best-studied region in the deeper part of the Bengal Basin*) received huge volumes of sediments, which resulted in the deposition of sediments measuring between 10 km and over 17 km in thickness. This was followed by an equally sudden drop in the sediment supply from the east due to the basin inversion concurrently with the westward advance of the Indo-Myanmar Mountain front during early and mid-Pleistocene. Followed by a short hiatus, the depositional scenario changed completely with the arrival of thick volumes of sediment during the late Pleistocene–Holocene, which covered the entire Bengal basin with the sediments brought by the Ganga and Brahmaputra from the Himalayan sources(Fig. 5).

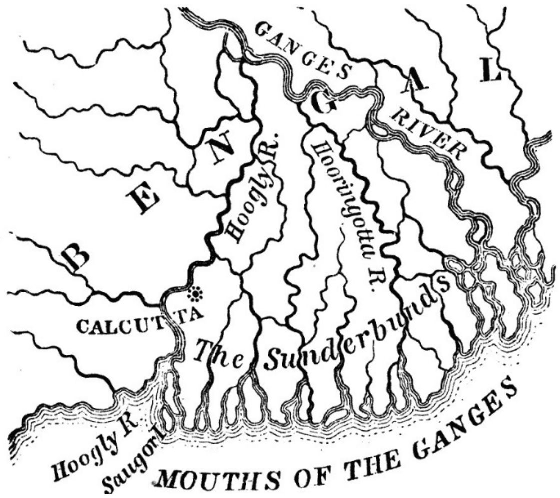


**Fig. 5.** The Bengal basin morphology due to sediments brought by the Ganga and Brahmaputra from the Himalayan sources

**(E) Dauki Fault and Uplift of Shillong Plateau**

Shillong Plateau is an important geomorphotectonic feature in the northeast part of Indian Subcontinent. This rectangular-shaped block of the highland is a fault-bounded horst. The east-west trending Dauki Fault borders the Shillong Plateau in the south. The Dauki Fault is a major tectonic feature in the region along which the Shillong Plateau has been lifted up by about 2 km, amsl. In fact, the Dauki Fault forms the east-west running line of the triple-point junction southeast of the Shillong Plateau (Roy and Chatterjee, 2015) (Fig. 6). The east-west trending subvertical Dauki Fault marks the southern wall-like boundary of the rectangular horst of the Shillong Plateau, thought as a giant 'pop-up' structure (Bilhgam and England, 2001). Studies have indicated that the Dauki Fault originated during the Kerguelen Plume outburst at c.117–118 Ma (Roy and Chatterjee, 2015).

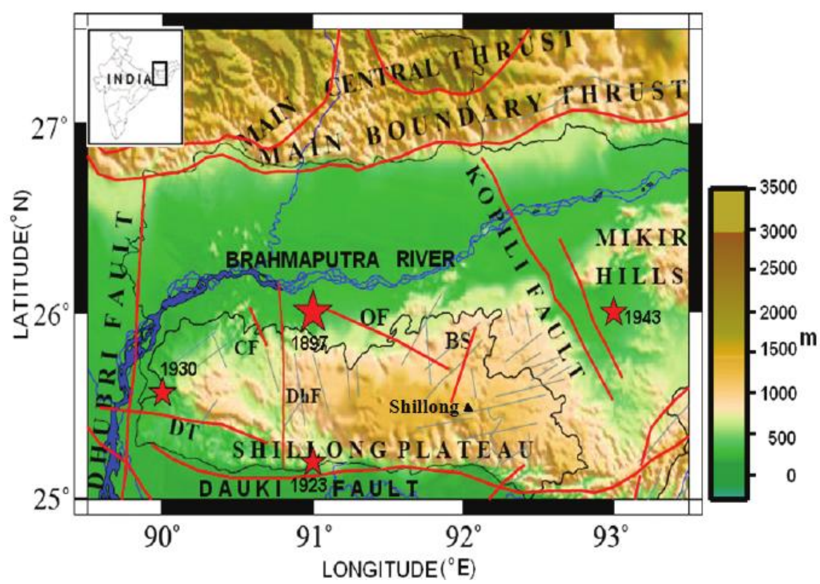


**Fig. 6.** The east-west trending subvertical Dauki Fault marks the southern wall-like boundary of the rectangular horst of the Shillong Plateau, thought as a giant 'pop-up' structure originated during the Kerguelen Plume outburst at c.117–118 Ma

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Tectonically, a triple-point intersection of lineaments/fractures develops because of local doming up of the Crust during upwelling of the Mantle Plume. The age of the Dauki Fault together with the 3He/4He ratios of the flood basalt help to correlate these with the upwelling of the Kerguelen Plume (Basu et al. 2001). Besides the evidence of Plume-related magma upwelling, the secondary proof of Plume outburstin the region comes from the coincidence of the north-south trending Jamuna Faulting roughly the Ninety East Ridge, considered the path of the Kerguelen Plume in the Bay of Bengal (Roy et al., 2013, 2014).

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