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Geomorphological evolution of Konkan Coastal Belt and adjoining Sahyadri Uplands with reference to Quaternary uplift

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The western part of the Deccan Volcanic Province comprises two geomorphic divisions—the Sahyadri Uplands and the Konkan Coastal Belt—which are separated by the Western Ghats Scarp. They exhibit different drainage characteristics and landforms as a result of altitudinal and climatic differences. Various lines of evidence suggest that the region has undergone episodic cymatogenic uplift particularly during the Quaternary.

Introduction

At the Cretaceous–Tertiary (K–T) boundary (~65 m. y. ago) the Indian plate was the site of intense intra-plate volcanism which resulted in the formation of the proto-Deccan Volcanic Province. Various lines of evidence suggest that this volcanism was the end-product of a series of related tectonic events and processes, namely, the northward movement of the Indian plate, plume activity related to the Reunion Hotspot resulting in the generation of basalt magma, the rise of this magma into the lithosphere with consequent crustal arching, and finally the rifting related to development of the Cambay tectonic junction[1–3]. Post-magmatic tectonism was responsible for the submergence under the Arabian Sea of part of the proto-province lying to the west of the West Coast Fault[4] and for the development of horsts and grabens (Figure 1). The sedimentary record preserved in the easternmost graben (the West Indian Depression) suggests that submergence was initiated in the Palaeocene-Early Eocene times and has continued spasmodically to the present[5]. The adjacent land area, forming the westernmost part of the present-day Deccan Volcanic Province, has had a related though much less vigorous tectonic history including phases of cymatogenic uplift[4,6]. Though the influence of structural elements on the development of geomorphological features is evident[7–10], the available data do not permit a definitive reconstruction of the history of vertical movements. An attempt is nevertheless made here to adduce evidence to substantiate vertical uplift in the marginal areas of the Deccan Volcanic Province and to tentatively date different phases of uplift.

Geomorphic setting

The westernmost part of the present-day Deccan Volcanic Province constitutes a passive, Atlantic-type

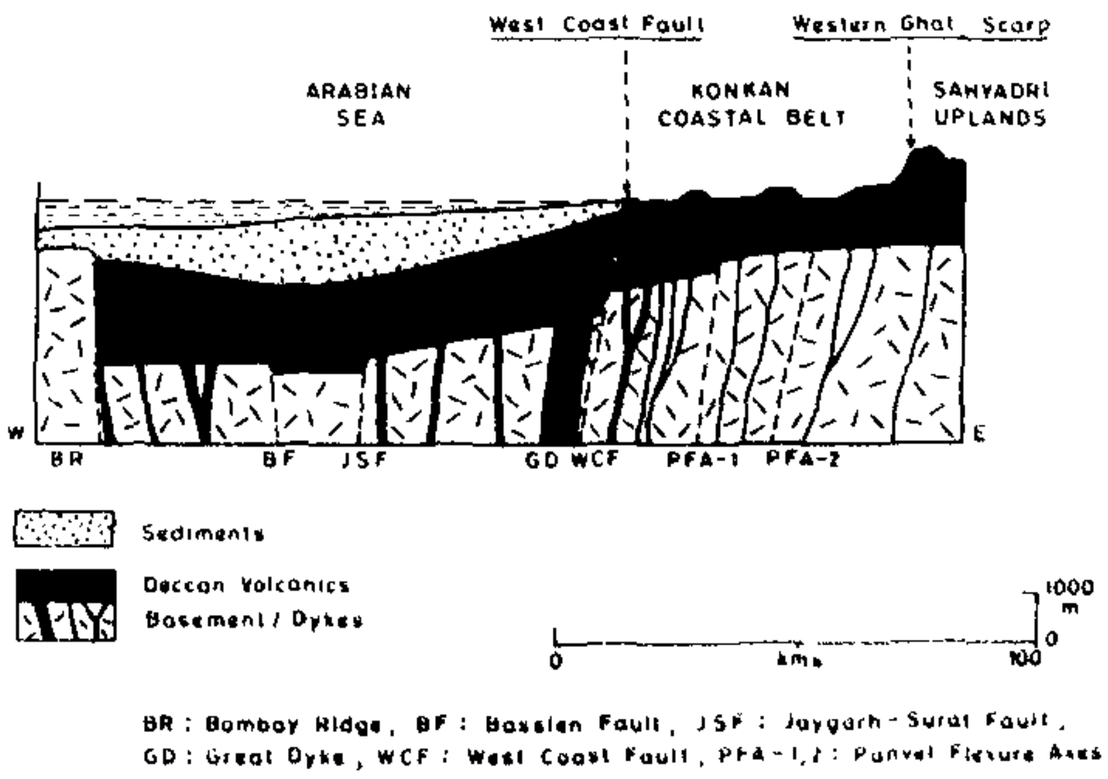

Figure 1. Idealized cross-section along the Latitude 19° N.

continental margin on the trailing edge of the Indian plate. It comprises a narrow coastal belt (referred to in Maharashtra as the Konkan), which is separated from the Sahyadri Uplands on the western edge of the Deccan Plateau, by the spectacular Western Ghat Scarp (Figure 2). These two geomorphic divisions (the Sahyadri Uplands and the Konkan Coastal Belt) have appreciable altitudinal and climatic differences, as a result of which two distinct types of drainage systems have evolved[11]. The drainage network of the Uplands is characterized by a parallel pattern on larger scale, and dendritic pattern on a smaller scale. In the Sahyadri Uplands the streams originate in the elevated (750–1400 m ASL) high rainfall zone of the Western Ghat and flow east to southeastwards, over the semi-arid Deccan Plateau, discharging into the Bay of Bengal. The valleys in the upper reaches have broad, box-like forms, flattening eastwards. The streams of the Konkan Coastal Belt display a subdendritic pattern characterized by sharp, nearly right-angled bends. They are short and flow westwards over a humid tropical landscape at 100–280 m ASL, along narrow to broad V-shaped valleys. The values for various hydrogeomorphic parameters like absolute relief at stream source, relative relief, catchment area, channel length, channel slope, valley-floor slope and basin circularity emphasize the differences between the two geomorphic divisions[11]. There are, however, many common features. The rivers in both the regions display high sinuosity marked by incised meanders, they have major inflection points, alluvial terraces occur on one or both banks, and presently all of them are in the incision phase. Planar surfaces and laterites are observed in both the divisions. The landforms observed in the Sahyadri Uplands are the result of fluvial processes while those developed in the Konkan Coastal Belt are the result of fluvial, marine and aeolian activities. Significantly, in the northern part of the Konkan Belt, amongst the marine landforms, those related to submergence dominate, while in the southern part the landforms are indicative of emergence. This suggests rotational movements on an E-W pivot centred in the region of the Alibag, between the Amba and Kundalika rivers[7].

Altimetric analysis, substantiated by field investigations, reveal the presence of a number of planar surfaces, both in the Sahyadri Uplands and in the Konkan Coast. In the Uplands the surfaces occur at 1320–1340 m ASL (Panchgani), 1200–1250 m ASL (Mahabaleshwar), 980–1020 m ASL (Pokhari), 900–940 m ASL (Dhangarwadi) and 580–620 m ASL (Pune, Kolhapur). These have been grouped into 3 prominent levels of planation at 1200 ± 100 m ASL (Mahabaleshwar), 1000 ± 100 m (Bhimashanker) and 700 ± 100 m ASL (Saswad-Parner). In the intermediate sub-Ghat section of the Konkan Belt narrow flats occur at 750 ± 50 m ASL (≡Saswad-Parner) and 300 + 50 m ASL. In the Konkan Coastal Belt proper, planar surfaces occur at 180–260 m ASL, 100–130 m ASL, 60–75 m ASL and 3–15 m ASL; the last being of marine origin with its eastern limit delineating the Flandrian strandline[12,13]. Laterites and latesols occur at different levels in both the geomorphic divisions. They are well developed on the Mahabaleshwar and Bhimashankar surfaces of the Uplands, and on the Lanza-Math (100–130 m ASL) surface of the Konkan Belt.

The Western Ghat Scarp, which separates the coastal plains of western Peninsular India from the Sahyadri Uplands, is spectacularly developed in the Deccan Volcanics. At places, like the western sides of the Mahabaleshwar and Bhimashankar plateaus, it is represented by vertical faces, locally 600 m high. The crest of the escarpment corresponds more or less with the continental watershed. This scarp originated, in all probability, during the Palaeocene as a fault scarp corresponding to the simple chasmic fault at the edge of the continental shelf, and has since retreated to its present position[14].

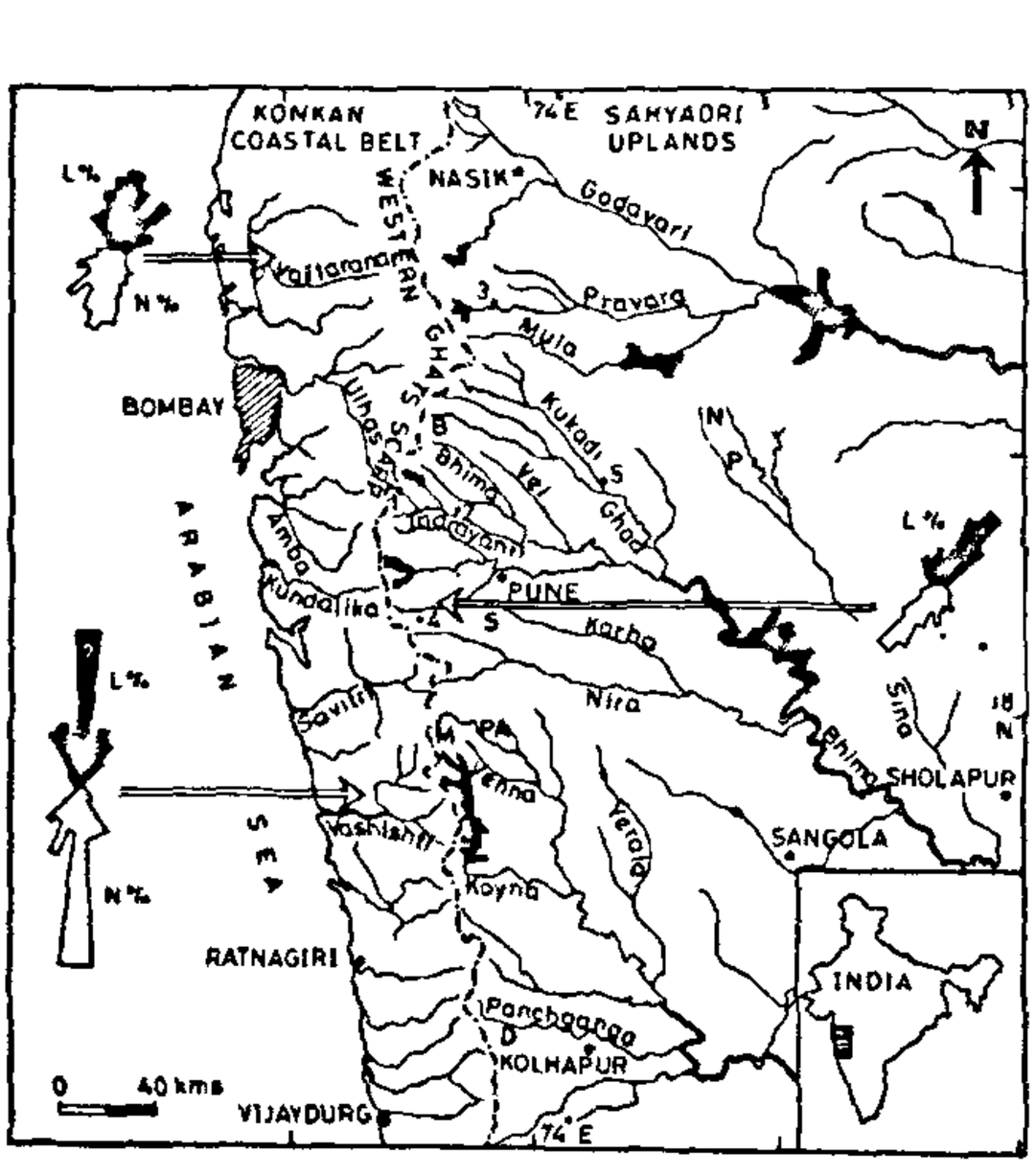

Figure 2. Index map showing drainage in the Konkan Coastal Belt and Sahyadri Uplands in Western Maharashtra. Location of townships: 1-Khandala, 2-Shelarwadi, 3-Ranadha, 4-Baneshwar, 5-Nighoj. Location of townships on planar surfaces: B–Bhimashankar, N–Nagar, P–Parner, S–Saswad, PA–Pachghani, M–Mahabaleshwar, D–Dhangarwadi. Also shown are Azimuth Frequency Patterns for lineaments. L%: Length percentage and N%: Number percentage.

Evidence of uplift

It has been postulated[2,15,16] that in the aftermath of the effusion of the Deccan basalts the whole Peninsular

Indian shield was subjected to episodic uplift. Various lines of evidence, which substantiate Cenozoic uplift in the western part of the Deccan Volcanic Province are briefly described below.

Geophysical data

Geophysical data collected in recent years have helped in establishing the structure of the Indian lithosphere. DSS studies indicate that the Mohorovicics discontinuity, which is at a depth of 37–42 km[17] below the Deccan plateau, rises to about 30 km along the West Coast[18] and then to 13–14 km below the continental shelf of the Arabian Sea[5]. This conclusion is also reflected in the MAGSAT scalar anomaly map prepared by Mishra and Venkatraydu[19]. The crustal thinning reflects hot-spot epeirogeny[20], a characteristic feature of which is isostatic uplift. Regional gravity surveys have revealed the presence of gravity 'highs' (Nasik, Sangola) and 'lows' (Koyna, Kurduwadi) in the western part of the Deccan Volcanic Province. These are suggestive of marked uplifts or subsidences involving the crust[15,21].

Lineament fabric

In earlier studies[4,6–8,10,22], the lineament fabric of the Deccan Volcanic Province, as traced from satellite imagery and aerial photographs, has been documented. The length and number azimuth frequency diagrams for the Konkan Coastal Belt are characterized by a strong concentration of lineaments in an approximately N–S direction. The lineament patterns, are characteristic of vertical uplift[23]. The pattern for the Sahyadri Uplands is similar, though the orientation is NE-SW, and suggestive of regional uplift. Additional conjugate systems indicate that compressive stresses were also operative. According to Powar and Patil[6] the lineament patterns reflect the joint role of compression (resulting from the collision of the Indian plate and its subsequent subduction, beginning Middle Eocene, below the Eurasian plate) and vertical uplift due to isostatic adjustment.

Knick points and incised meanders

The rivers of the Sahyadri Uplands exhibit prominent knick points in the zone 580–680 m ASL[11]. The knick points on the Pravara (at Ranadha), Kukadi (Nighoj), Indrayani (Shelarwadi) and Shivaganga (Baneshwar) are particularly striking. Most rivers in the Sahyadri Uplands show meanders in their source regions and spectacular incised meanders are observed along the Pravara, Mula (Nagar) and Pushpawati. The incision in bedrock is as much as 35 m. A very intense state of over-grade condition is evident, and this can be attributed only to vertical uplift, as base-level changes or climatic changes cannot revive river energy to the required extent[24].

Valley-fill deposits

Valley-fill deposits occur along the courses of many rivers of the Uplands, the best development being in the northern part, in the Godavari, Pushpavati, Pravara and Kas valleys. In the case of the Pravara and Kas valleys, the deposits of gravelly nature are locally more than 25 m thick and exhibit graded and cross-bedding. These deposits are considered to be 'anamolous geomorphic situations' suggestive of tectonic uplift in Late-to-Middle Pleistocene to 50,000 yr B.P.[24]. In the Konkan Coast, siliceous gravel beds occur at about 20 m ASL near Ratnagiri and Vijaydurg[11] indicating uplift.

Indrayani-Ulhas continuity

A remarkable feature of the study area is the apparent continuity of alignment displayed by the initially southeast-flowing Indrayani and the northwest-flowing Ulhas rivers in their source region near Khandala. Both occupy broad U-shaped valleys, with the continental divide being so inconspicuous that it is difficult to decide in which catchment a particular place is situated. The only explanation is tl at the alignment represents a pre-Tertiary valley once occupied by the ancestral, east-flowing Indrayani river, which was subsequently uplifted and warped; the portion of the valley to the west of the warp-axis being reversed to become the headwaters of the Ulhas[14].

Elevated lignite beds

Lignite beds, formed in warm and humid, estuarine environment, have been recorded at several places along the Konkan Coast. They have also been reported further inland at altitudes of 43–50 m ASL[25] and 168 m ASL[26]. The deposits are considered to be of Neogene age, and their elevated occurrence suggests post-Neogene uplift.

Planar surfaces and laterites

The occurrence of planar surfaces at various levels is suggestive of polycyclic evolution of the landscape. The surface at 3–15 m ASL in the Konkan Coastal Belt almost certainly represents an uplifted marine platform[13]. The other surfaces of the Konkan could possibly represent uplifted surfaces. It has been suggested that

the planar surfaces of the Sahyadri Uplands are denudational pediplain surfaces formed as a result of pulses of uplift[27]. If we accept Valenton's view[28] that the Upland laterites were developed at sea level and subsequently uplifted to their present elevation, then cymatogenetic uplift of the order of more than 1300 m will have to be visualized.

Geomorphological evolution

The geomorphological evolution of the Peninsular India commenced with the separation of India from Madagascar during Maestrichian (70 m.y. ago)[29]. Erosion and scarp retreat from the new continental margin created a coastal belt backed by an escarpment[16]. Subsequent volcanism at the K-T boundary resulted in the formation of the Deccan Volcanic Province. Rifting and floundering in its western part and its subsidence in the Arabian Sea during Palaeocene was followed by the establishment of an east-flowing drainage system. The Eocene to Early Oligocene period probably was a stable period during which the high-level laterites were formed[11]. The central part of the Peninsular shield sagged accompanied by upturning of the edges so that the top of the escarpment became the watershed. Two distinct geomorphological divisions were thus established. During Miocene and Pliocene there were periodic uplifts as a consequence of isostatic adjustments that followed the impingement of the Indian plate with the Eurasian plate during Early Miocene[30]. The end of Pliocene to Early Pleistocene witnessed another stable phase when the low-level laterites were formed[11].

The Pleistocene and Holocene times are characterized by alternate phases of alluviation and incision[11] which are attributed mainly to climatic changes[24]. The aggradational episodes are considered to be associated with semi-arid conditions and the incision with heavy rainfall. Only the intense fluvial erosion that took place between Late Middle Pleistocene and 50,000 yrs. B.P. was related to tectonic uplift[24]. According to Ruddiman and Kutzbach[31] climatic changes during the last 15 million years are related to plateau uplifts—the increase in elevations significantly affecting atmospheric circulation. A warm India became wetter as a result of the uplift. If this is so then, the Quaternary must be taken as a period of episodic cymatogenic uplift.

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