# RIVER RESPONSE TO CONTINUING MOVEMENTS AND THE SCARP DEVELOPMENT IN CENTRAL SAHYADRI AND ADJOINING COASTAL BELT by K.S. Valdiya, Jour. Geol. Soc. India, v.57, pp.15-30, 2000.

(1)

**K.R. Subrahmanya**, Department of Marine Geology, Mangalore University, Mangalagangotri - 574 199 comments:

I read with great interest the beautifully illustrated article. I had the privilege of being involved with the work during various stages in the past. However, there are one or two points, where I am not in agreement with the author, for example with his views on the evolution of the Western Ghat escarpment.

Valdiya summarises the prevalent postulations on the evolution of escarpment under three categories and explains why these are not acceptable propositions. According to him, the NNW-SSE trending horsts when pushed northward following oblique-slip movements on faults gave rise to linear tectonic blocks. There is no mention as to how these horsts originated in the first place. Although, I also would agree that the third postulate (upwarping due to passing over hotspots) is not convincing, at least for the central and southern *Sahyadri*, the first and second postulates have their own merit, when their order is changed. There are sufficient examples to substantiate the argument that break-up of a continent will result in scarps facing each other. Evidences from areas which represent different stages of break-up like (i) the African rift valleys, (ii) the land on either side of the Red Sea, and (iii) the scarps to the west and east of India and Madagascar respectively, bear testimony to this. It is also true that the break-up takes place along pre-existing planes of weakness, which in the present case corresponds to NNW trend of the Dharwar. The rift valley itself will have several step faults on either limb and hence there will not be a single fault but a system of faults. There has to be a recession of the Western Ghat as well, more due to marine processes than fluvial, as the sea-level has fluctuated considerably in the past, going up by about 200 m during Cretaceous and lowering by about 100 m during Quaternary. The near-flat gradient of the west-flowing rivers below the Western Ghat (Fig.11, Valdiya, 2001) and a remarkably similar gradient of the coastal plain and the shelf (about 0°7'; Subrahmanya, 1987) amply demonstrate that coastal plain and continental shelf have exchanged places in the past.

Another aspect where I would disagree with Valdiya is on the relation between NNW-SSE trending *en echelon* faults, and ESE/E-WSW/W trending shear zones. Valdiya has correctly recognized the existence of both NNW-SSE and ESE/E-WSW/W trending lineaments which are active. My own work in this region ascribes the near E-W trending lineaments to buckling of the landmass near 13°N (Mulki-Pulicat Lake axis; Subrahmanya, 1996), which is a younger event than the Precambrian trend (NNW-SSE). Keeping aside the matter of relative ages, let us see whether there is indeed a sinistral offset of E-W faults due to movement along NNW-SSE trending faults. The evidences for this in the Western Ghat region, according to him, are straight western scarp faces and steep slope break at their western edges. There can be no dispute about west-facing scarps. However, it is not true that there are steep slope breaks only at their northern edges. The steep break in the northern edge south of Mangalore is because of the arcuate nature of the junction between the granulite and the greenstone terranes. South of Kudremukh is a steep slope break which is as prominent as its northern break. The satellite image also does not bring out any *en echelon* pattern in areas further north. If indeed there were oblique-slip *en echelon* movements, these would have been apparent in the disposition of the Dharwar too (e.g. Shimoga schist belt). Notwithstanding these comments, I wish to congratulate Valdiya for demonstrating that the 'stable' Indian peninsula is almost as active as the Himalaya.

**K.S. Valdiya**, Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, Bangalore -560 064 replies:

I deeply appreciate the comments of K.R. Subrahmanya on my paper. I wholly subscribe to the view that India broke from Madagascar following rifting of the continent. This does imply existence of a scarp – albeit low scarp – facing the spreading sea. However, I do not believe that the present configuration of the Western Ghat escarpment evolved due to the recession of that original scarp along the coast. I have given four good reasons for my believing that the 45 to 90 km wide and 40 to 120 m high coastal belt *characterized by a thick mantle of laterite* represents the fault-defined block that failed to rise beyond 40 to 120 m above sea level when neotectonic resurgence overwhelmed the western part of the Dharwar craton, particularly the *Sahyadri* domain, which also has a cap of laterite. If it had been just the marine action at work, the situation would have been different. The near flatness of both the river-

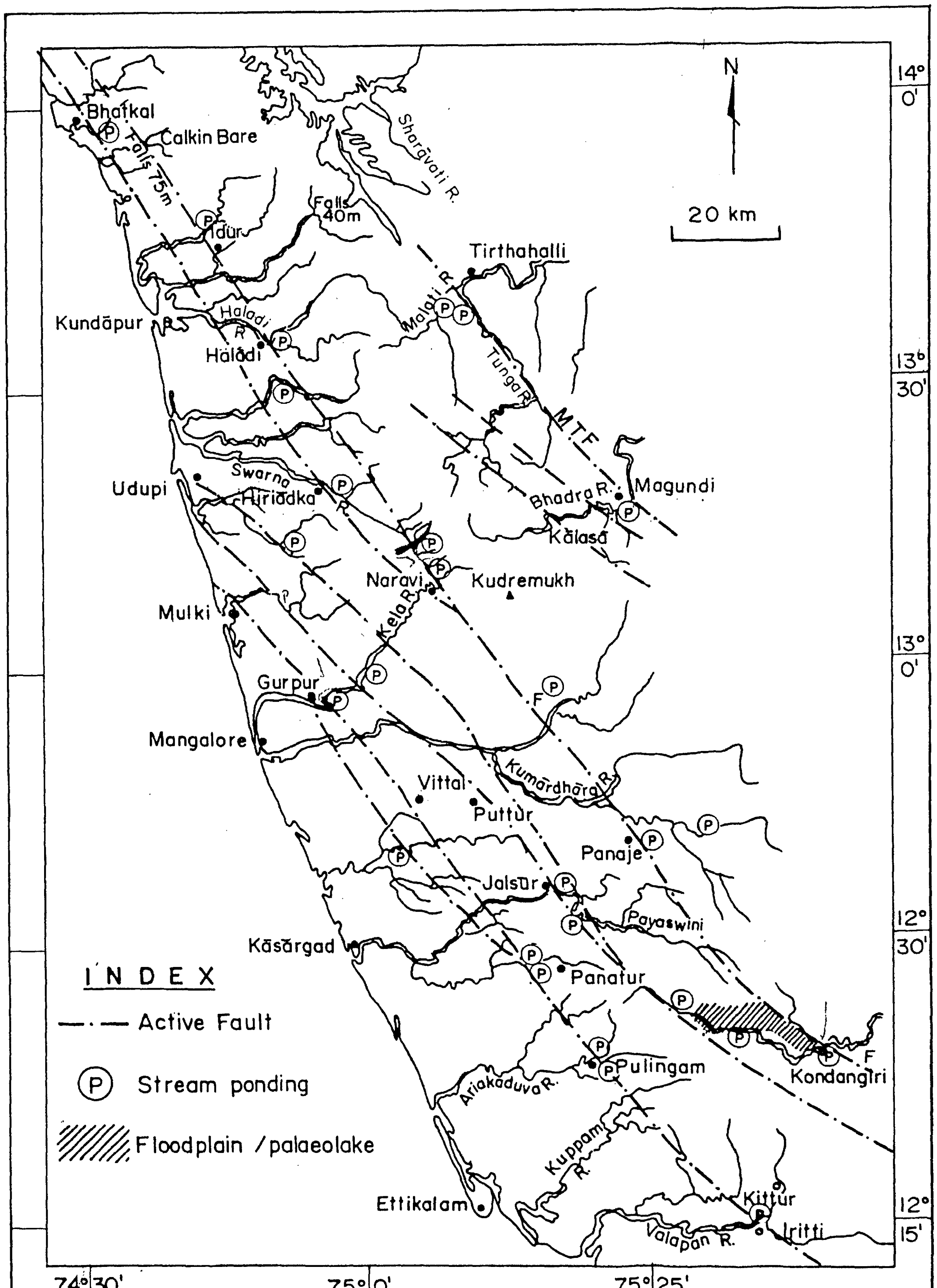


**Fig.1.** Sketch map shows only those active faults that have been discussed in the paper for having consistently caused conspicuous deflection of streams, are associated with palaeolakes (representing past impoundments), and with present-day stream ponding. Not only the main rivers but also their tributary streams evince upstream stagnation of water at the points of crossing of the faults – all along their long extensions.

gradient and coastal terrain only goes to support my viewpoint.

Recent detection of mid-crustal low velocity layer in the Western Ghat domain and in the Southern Granulite Terrane (Reddy and Vijay Rao, 1999) allows not only to invoke buckling of the Indian crust under compressive stresses – such as Subrahmanya has effectively demonstrated – but also the uplift of the whole Mysore Plateau. The deformation must have started after the reactivation of the ancient shear zones as the aftermath of India-Asia collision. It would be of interest to note that the Indian Ocean crust experiences events of deformation at 7.5 Ma, 4.0 Ma and 0.8 Ma (Krishna et al. 1988). The spurts of episodic uplift in the Southern Indian Shield were probably synchronous with the oceanic deformation.

The NNW-SSE trending faults (Fig.1) are of Precambrian antiquity, their pattern and disposition governed by the tectonics of that time. Later reactivation of these faults and fractures gave rise to linear hills of differential altitude, culminating in the evolution of a horst of sorts – the *Sahyadri.*

(2)

**U. Raval**, National Geophysical Research Institute, Uppal Road, Hyderabad - 500 007 comments:

In a valuable article K.S. Valdiya (Jour. Geol. Soc. India, v.57, pp.13-30, 2001) has drawn attention to the drainage pattern, morphotectonics and evolution of the central *Sahyadri*. The latter (or Western Ghat, as more commonly termed; Avasthi, 2000) is indeed one of the most important uplifted terrains, and the causes of its development as emerges from the insightful analysis by Valdiya, remain somewhat enigmatic. More specifically the article deals with:

(i) finding the nature and extent of NNW-SSE trending faults which predominate the central *Sahyadri*,
(ii) identifying active faults, if any, and their role in shaping the landform, and
(iii) understanding the uplift mechanism.

Evidently, the processes involved have different space-time scales and exploration of coupling (or linkage) between them, as done in the article, is probably first of its kind. The following few points are submitted which, hopefully, will supplement the analysis of the uplift mechanism for the *Sahyadri* mountain, particularly with regard to deeper thermal influxing of the Indian continental lithosphere.

Of the various mechanisms considered by Valdiya, it seems that the mechanical response of the Indian shield to ongoing compression (due to ridge-push and India-Eurasia collision) has been preferred, which may imply that plate (or horizontal) tectonics alone contributes to the uplift. The role of other geodynamic processes like mantle upwelling during either passive (continental break up) or active (mantle plume) asthenospheric upwelling does not find favour on the grounds that the 'subsidence' expected after cooling of the causative thermal source(s), is not evidenced. However, such a consideration presumes a very restrictive and narrow role for the interaction between asthenospheric upwelling and continental lithosphere, which could affect the lithosphere in more than one way.

Several factors/processes such as lithospheric thinning, magmatic underplating, volatile activity and gabbro-eclogite transition contribute to uplift and act on time scales of 50-100 m.y. and hence in addition to 'heating' and 'cooling' effects, other processes induced by mantle (or plume) upwelling also need to be considered.

If compressional forces alone act over a rigid and cold Archaean craton like the Western Dharwar as is the case for central *Sahyadri* (see Fig.2a), then its uplift may take quite long time ≥100 m.y., which perhaps does not match with the temporal history of recent geodynamics. But if, the deeper parts of the crust-lithosphere column develop 'extra ductility' following thermal inputs from mantle upwelling, then the time for uplift may reduce to smaller time scales. This implies that the observed uplift of *Sahyádri* could be due to combined effect of (1) the ongoing compression that represents a plate tectonic model, and (2) the deep thermal inputs due to mantle upwelling that caused lithospheric breakups (at ~130, 90, 64 Ma) along the eastern and western margins, and plume tectonics (Marion/Reunion plumes at ~89 and 66-57 Ma; *see* Fig.3).

Many Precambrian shields of the world have been significantly uplifted in Recent geological time e.g. Kaapavaal craton in South Africa lies at ~2.5 km above msl and this uplift has been attributed to 'warm asthenosphere' due to Recent and/or nascent plume activity (Artyushkov and Hoffman, 2000).

In the light of deep seated thermal inputs along the western margin and consequent uplifts, the morphotectonics of the *Sahyadri* needs to be assessed as a whole, in addition to its sector-wise development. For example, from north to south, the *Sahyadri* (or Western Ghat) crosses different crust-lithospheric columns which would have varying structures (including geophysical), Moho depth, lithosphere thickness and rheologies.

The region on the western side of *Sahyadri* forms the eastern half of the continental breakup (or rift) and in this sense, *Sahyadri* may represent a shoulder-uplift, the other shoulder being the eastern margin of Madagascar.

The seismicity along the Western Ghat (Fig.4 of Valdiya, 2001) apparently follows the high gravity and topographic gradients. Particularly, it may concentrate in the vicinity of along-the-strike heterogeneities of these gradient lineaments. This seismicity seems to be affected by this gravity gradient. Actually, gravity and topographic gradients manifest as relatively higher seismicity all along the western margin. The thermal inputs have significantly changed the deep rheology, making it vulnerable to earthquake activity from Kutch to Idukki.

Since the western margin represents a line of large thermal influxing near the lithospheric base from Kutch to Kerala, relatively more ductibility will develop beneath it. Under the load of Western Ghat (*Sahyadri*) uplift, this ductile lower crust could flow sideways. Such a process may significantly contribute to the formation of tablelands.

The thermal inputs at the base of lithosphere are maximum in the southernmost part (*see* Fig.3), implying greater positive (upward buoyancy) and thinner lithosphere, and consequently higher uplifts in the southern part. It follows that the uplift would be less in the 15°-20° N sector i.e. central *Sahyadri,* because it is underlain by the Western Dharwar craton where the Indian continental lithosphere is supposed to be thickest (≥220 km; *see* Fig.5).

The time difference of ~50 m.y. in the thermal inputs beneath the eastern (~130 Ma) and western margins (65-55 Ma) and consequent differential uplift/subsidence (and hence the drainage pattern) would contribute to the apparent W-to-E tilt of the Peninsular India (Cox, 1990; Kent, 1991).

The points in the foregoing discussion obviously emphasise the significance and evidence of the deeper thermal inputs in shaping the probably *Sahyadri* trend. For understanding the development of *Sahyadri* region – as impressed by Radhakrishna (2000) – it is necessary to constrain (a) the lithospheric rheologies of different regions along the *Sahyadri*, (b) the differential uplifts and their timings, and (c) the southern limit of the original Deccan Trap cover over the Southern Indian shield, since its continued shrinking due to erosion would also give rise to uplifts, as in the case of Scandinavian ice cap. This may also provide some insight into the level of erosion and crustal growth around the Western Dharwar nucleus.

**K.S. Valdiya**, Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, Bangalore -560 064 replies:

Raval postulates the force of upwelling currents and mantle plumes beneath the Indian shield causing its uplift. There are, however, many difficulties. I have already pointed out one of them.

The Western Dharwar craton is quite thick with a lower average velocity, the Moho being at the depth of 40 km (Reddy et al. 2000). This is contrary to what the invoking of the upwelling current requires. There is no thinning of the crust in the *Sahyadri*-Western Ghat Domain, no evidence for rifting apart of the crust and no signs of volcanic activity and high heat flow which the upwelling current would have produced. There is also no record of phase transition (eclogite to gabbro) beneath the lithosphere in this part of Peninsular India.

The uplift of the Southern Indian shield received impetus after the reactivation of the Precambrian shear zones and faults following collision of India with mainland Asia about 65 Ma. I did not suggest that the uplift took place within the span of the Quaternary period as has been made out. However, the pace of uplift accelerated at 7.5 Ma, 4.0 Ma and 0.8 Ma when the crust of the Central Indian Ocean was deformed by cyclic events (Krishnan et al. 1998).

I am not aware of any evidence for the Reunion-II hotspot causing uplift of the Mysore (Karnataka) Plateau, and influencing the Nilgiri terrane. I have not come across surface manifestation of "large thermal influx near the lithosphere base from Kutch to Kerala", and am unaware of the evidence for "relatively more ductility developing beneath it" and for "this ductile lower crust flowing sideways".

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