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Basin asymmetry and associated tectonics: A case study of Achankovil river basin, Kerala

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Abstract

Tectonic geomorphology has proven to be a useful tool for identifying and quantifying active and geologically recent tectonic deformation. Some of these techniques have been used in Achankovil river basin in order to decipher the basin tilting and asymmetry. Achankovil river of southern Kerala flows though a confined elongated structural valley and the river course is not uniform. Asymmetry Factor (AF) and Transverse Topography Symmetry Factor (TTSF) have been worked out for different segments and sub watersheds considering the course orientation. It is found that basin have experienced differential tilting. SE migration of river course in upper segment and NW migration of river course in the down segment is observed. Geologic events like Western Ghats uplift, base level changes and strike slip movements have influenced the drainage development and modified the basin asymmetry.

Key words: *Achankovil river basin, Basin asymmetry, Asymmetry Factor, Transverse Topographic Symmetry Factor.*

Introduction

Tectonic activity plays an important role in developing drainage pattern and controlling river behaviour (Holbrook and Schumm, 1999, Sinha Roy, 2001; Valdiya and Narayana, 2007) that can be described both qualitatively and quantitatively (Hare and Gardner 1985, Keller and Pinter 2002). Various geomorphic indices are commonly used as reconnaissance tool in tectonic geomorphology to describe the interplay of tectonics and drainage basin morphologies (Bull and Mc Fadden, 1977; Burbank and Anderson, 2001). Among these geomorphic indices Asymmetry Factor (AF) and Transverse Topographic Symmetry Factor (TTSF) are significant to identify the basin asymmetry which is an important indicator of tectonic activities in an active tectonic area. Present study is an attempt to decipher the role of active tectonics in modifying the basin symmetry of Achankovil river basin.

Achankovil River in south Kerala located between 76^0 24’ to 77^0 18’ E longitude and 9^0 2’ to 9^0 19’ N latitude (Fig.1) is different from the other adjoining rivers in basin shape and channel geometry. The course of the river is not uniform and appears to be passing through several structural blocks of various dimensions. Lateral shifting of drainage lines from the basin mid line is visible in most of sub watersheds as well as in the main stream. This study is expected to address differential tilting of river basin in detail with the aid of AF and TTSF.

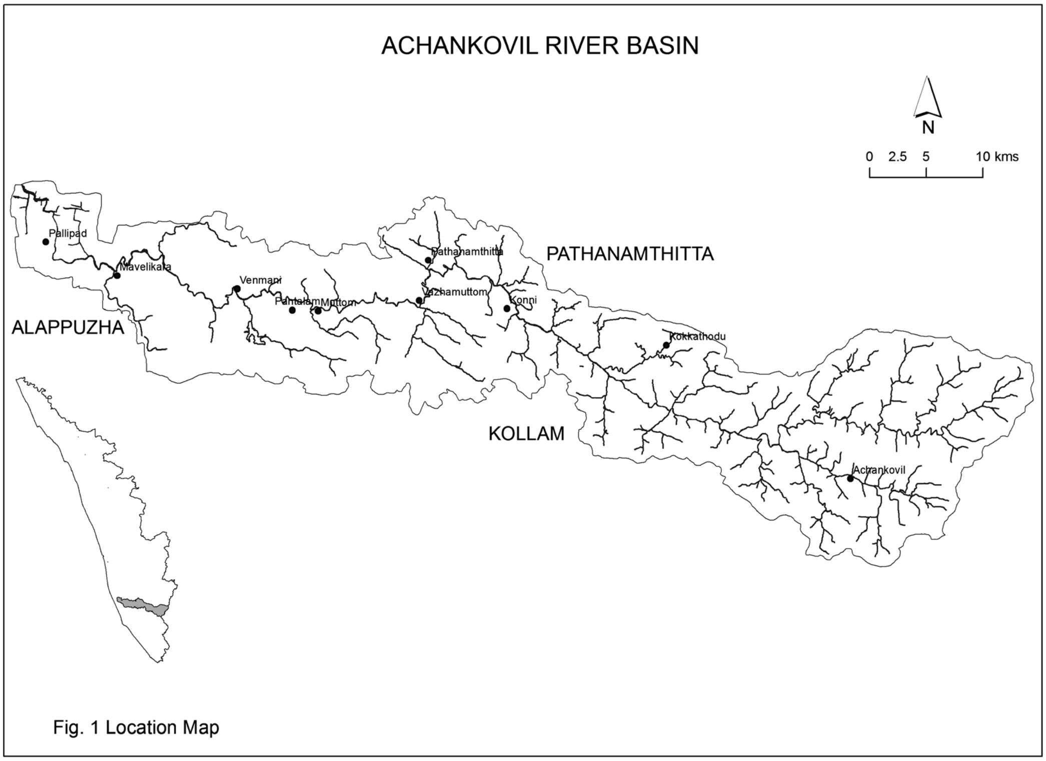

Fig. 1 Location Map

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Materials and methods

The study is based on analysis of topographic maps of Survey of India in 1:50,000 scale and maps are prepared by using Arch GIS software. Asymmetry Factor and Transverse Topographic Asymmetry Factor have been worked out for selected sub watersheds and for different segments of main stream considering the course orientation. Available literatures were reviewed to obtain a broad idea about the origin of Achankovil river.

The calculation of both AF and TTSF is a quantitatively rapid method of identifying ground tilting (Hare and Gardner 1985, Cox 1994, Keller and Pinter 2002).The asymmetry factor was developed to detect tectonic tilting transverse to flow at drainage-basin or larger scales.

The Asymmetry Factor (AF) is determined by the formula:

$$AF = 100\ (Ar / At)$$

Where, Ar is the area of the basin to the right of the trunk stream while facing downstream and At is the total area of the drainage basin.

For a stream network, that developed and continues to flow in a stable setting and uniform lithology, asymmetry factor should be equal to about 50, whereas unstable setting would give a deflection from normal value either < 50 or > 50 (Keller and Pinter, 1996). AF is close to 50 if there is no or little tilting perpendicular to the direction of the master stream.

Transverse Topographic Symmetry Factor can detect areas of lateral tilting. Topographic Symmetry Factor (T) is defined as:

$$T = Da / Dd$$

Where, Da represents the distance from the midline of the drainage basin to the midline of the active meander belt, and Dd corresponds to the distance from the basin midline to the basin divide.

Thus, the Transverse Topographic Symmetry Factor is a vector that has direction and magnitude ranging from zero to one (T = 0 to 1), which reflects a perfect asymmetric basin or a tilted one respectively (Burbank and Anderson 2001, Cox 1994, Keller and Pinter 2002). High values indicating areas of potential tilting influence on drainage pattern. In a set of vectors, the most dominant direction can be found by calculating the resultant vector. The direction of the resultant vector is the mean direction of all the calculated vectors. The length of the resultant vector divided by the number of the calculated vectors gives the mean resultant length, which is a measure of dispersion. The mean resultant vector length ranges from zero to one, values near one indicate small dispersion of the observation, while values near zero indicate that the vectors are widely dispersed. Like all geomorphic indices, single values of TTSF have no significance, but broad areas with similar values indicate a possible tectonic signature on the drainage pattern.

Regional Geological Settings

Descending from western front of the Western Ghats, the Achankovil roughly follows the WNW-ESE trending Achankovil Shear Zone (ASZ) to the deltaic plains of the Pamba. The 10-20 km wide and more than 100 km long Achankovil shear belt in southern India is a prominent lineament that has been interpreted as a major shear zone (Drury et al. 1984). It is a high strain zone dominated by flattening of structures, with a component of reverse top-to-the-north displacement (Cenki and Kreigsman, 2005). It is characterised by the change in rock types to the north and south, and by the sharp change from NE-trending structures north of the belt to NW-trending structures within and south to it (Drury et. al., 1984). Rocks north of the Achankovil shear belt are essentially massif charnockites (Chacko et al. 1992) and rocks to the south are called khondalites and leptynites. Rocks within the shear belt include quartzofeldspathic garnet biotite gneiss, granite, charnockite, cordierite gneiss with associated migmatites. Charnockite appears massive in fresh exposures, but gneissic layering is visible where it is weathered (Sacks et. al., 1997)

The region hosts a remarkable en-echelon pattern of valleys and faults (Rajesh et. al., 2007). The mountain slope of Western Ghats overlooking the valley is characterized by high scarps and triangular facets, waterfalls and gullies that descend into the river (Valdiya and Narayana; 2007). Structurally this area is dominated by asymmetric valleys and faults and WNW-ESE trending lineaments which are the oldest and subdued sets (Nair, 1990) and coincide with the strike of metamorphic foliation in the region (Rajesh et. al., 2007). Uplift of Western Ghats together with episodic regression and transgression phases has highly modified the drainage basin morphology. Part of basin is characterised by dextral strike slip fault well evident from the surface drainage pattern.

Drainage and Basin Characteristics

Achankovil is a 7^{th} order basin which traverses through highland, mid land and low land. It is flanked by the Pamba in the North, Kallada in south, Western Ghats in the east and Arabian sea in west. This river basin is elongated in east west direction and the river follows a straight line course there by manifesting tectonic control on the stream development. The Achankovil river has two sixth order tributaries, 10 fifth order tributaries and 41 forth order tributaries. The drainage pattern is sub dendritic to sub parallel, in general, and the higher order streams, in particular, show more or less trellis drainage pattern. Most of the higher and medium order streams follow general structural trend which indicates structural control. The tributaries are oriented in the WNW-ESE, NW-SE, NNE-SSW, NE-SW and ENE-WSW directions and most of the tributaries are short in length and align perpendicular to the main stream. The basin is confined and has restricted north-south development. In general right bank of the basin is more elevated than the left bank and right bank receives more tributaries than the left bank. Elevation of study area varies between 20 m and 1920 above MSL.

Results and Discussion

The whole basin has been segmented into six blocks aligned in North-South direction considering course orientation to identify the nature of general tilting of the basin (Fig.2). The AF value for these segments varied between 33.1 in segment S2 and 68.27 in S1 (Table. 1). The segments of S2, S3 and S4 show southward tilt and S1, S5 and S6 show northward tilt. These variations in tilt of adjoining segments indicate that Achankovil river is passing through different structural blocks although lithology is more or less same. Movements of these structural blocks may not be uniform.

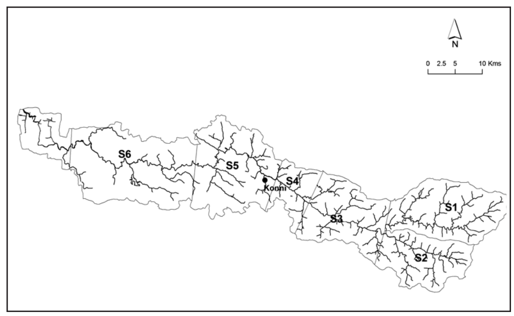

Fig. 2 Basin Segments

Table 1 : Segment-wise AF values

Segments	Asymmetry Factor
S1	68.27
S2	33.11
S3	55.66
S4	55.29
S5	40.73
S6	39.65

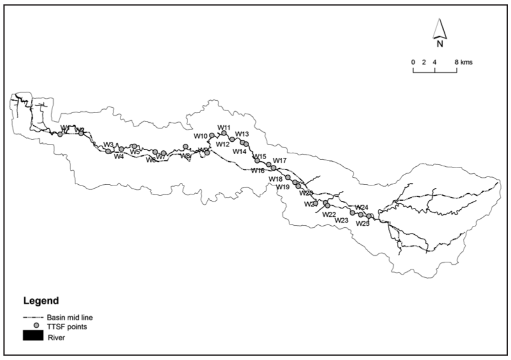

Fig. 3 Distribution of TTSF points

The Transverse Topographic Symmetry Factor method was applied to the main river. Altogether 26 points were taken to calculate the T values (Fig. 3). These points were taken considering the confluence points of all major tributaries of the river which connects the basin ridge with its valley. The Achankovil drainage basin is characterized by NW and SE migration of its principal stream, as suggested by the mean direction of the resultant vectors (Fig. 4, Table 2).

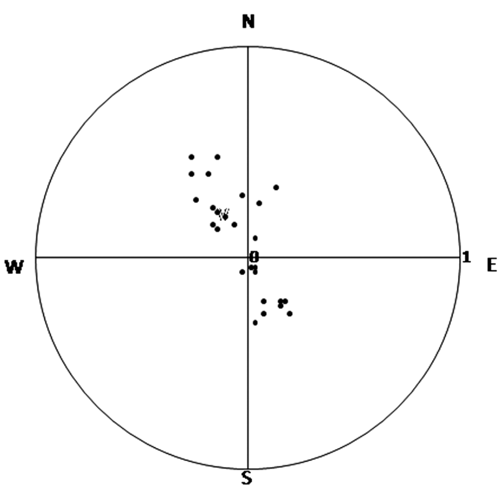

Fig. 4 Distribution of T vectors

Table 2 : Transverse Topographic Symmetry Factor

Sl no	Points	TTSF	Bearing in ^{0}
1	P1	0.11	176
2	P2	0.27	330
3	P3	0.03	147
4	P4	0.11	2
5	P5	0.29	328
6	P6	0.19	349
7	P7	0.25	6
8	P8	0.39	19
9	P9	0.05	173
10	P10	0.32	355
11	P11	0.52	344
12	P12	0.44	336
13	P13	0.47	327
14	P14	0.55	328
15	P15	0.39	315
16	P16	0.23	336
17	P17	0.2	318
18	P18	0.34	136
19	P19	0.25	137
20	P20	0.25	132
21	P21	0.29	171
22	P22	0.27	163
23	P23	0.26	134
24	P24	0.22	164
25	P25	0.03	194

Whereas few points in low land (P4, P7 and P8) display NE oriented T-vectors which is an exception of the general trend of the basin mean direction. The data are concentrated in the northeast and southwest quadrant of the polar plot and agree with the NW and SE migration suggested by the asymmetry of the principal river basin. The AF values calculated for different segments also corroborate with this observation. The mean T value obtained for the basin is 0.27 shows medium dispersion of values which indicate though the principal stream has migrated from the mid line the amount of shifting is less. Broadly the basin can be divided into two. East of Konni, characterised by the migration of channel towards SE from its main course and West of Konni, where the channel has shifted laterally to NW. Maximum shifting has been observed at West of Konni, where the channel has swiftly deviated from the main course taking a near circular course (Fig. 5). It appears that the basin has experienced differential movement.

It is observed that in the higher reaches the right bank is more elevated than the left bank and most of the tributaries have longer channel length (Table. 3) than the left bank and are directly debouching into the main stream. Whereas, in the lower reaches, left bank is more elevated than the right bank and the left bank tributaries are longer than those in the right bank. Any drainage basin with a flowing trunk stream that was subjected to a tectonic movement will most likely have an effect on the tributaries' lengths. Assuming the tectonic activity caused a left dipping to the drainage basin, the tributaries to the left of the main stream will be shorter compared to the ones to the right side of the stream with an asymmetry factor greater than 50, and vice versa (Hare and Gardner 1985, Keller and Pinter 2002).

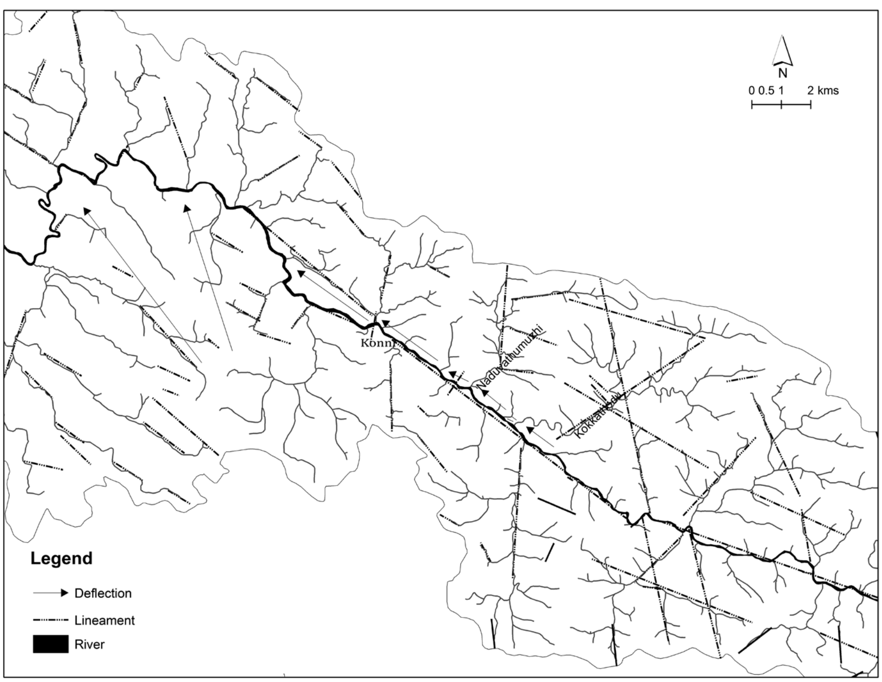

Fig. 5 Deflection of drainage lines

Table 3 : Channel length of selected tributaries

Right Bank tributaries			Left Bank tributaries		
Sl No.	Name	Channel Length	Sl No.	Name	Channel Length
1	W1	12.80	1	W60	9.76
2	W2	5.46	2	W58	4.60
3	W4	6.80	3	W57	6.90
4	W5	6.50	4	W56	8.80
5	W7	7.40	5	W55	4.97
6	W8	5.01	6	W50	8.30
7	W9	5.10	7	W48	13.80
8	W10	6.80	8	W43	12.97
9	W11	5.60	9	W39	15.10
10	W14	5.40	10	W35	7.01
11	W18	9.60	11	W32	15.44
12	W20	12.90			
13	W25	11.37			
14	W29	12.80			

The Asymmetry Factor calculated for 60 sub watersheds irrespective of drainage order (Table 4) gives further inferences on basin tilting. Sub watersheds were labelled from W1 to W60. It is observed that most of the sub basins are highly asymmetrical in nature. The AF values of right bank varied between 23.6 (W2) and 81.8 (W6) and the values of left bank ranges between 21.45 (W39) and 72.69 (W45). (Fig. 6) Prominent directions of sub basin tilting are NW, SE and E. Connecting the directions of tilting of adjacent sub basins can give the main tilting direction of the basin. It can be observed from the Fig. 5, that East of Konni southern margin of river basin is tilted towards NE and the western margin towards SE. It is significant to note that general slope of the basin is from East to West and the highland basin margins tilted towards East. This tilting can be possibly linked to the Western Ghats uplift. The Achankovil basin is a structural trough (Fig. 7) with elevated basin margins. Whereas, the smaller sub basins in Kokkathode-Naduvathumuzhi region marks a NW tilting which coincides with the NW

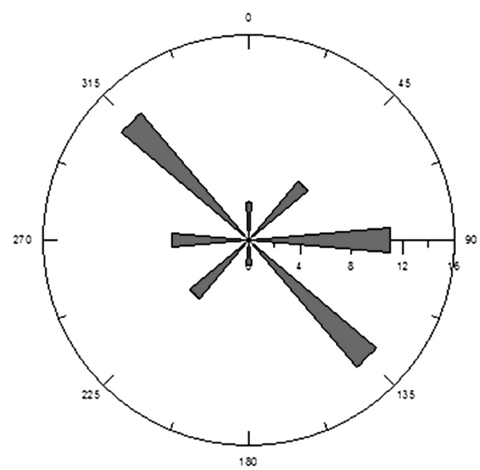

Fig. 6 Asymmetry of sub basins

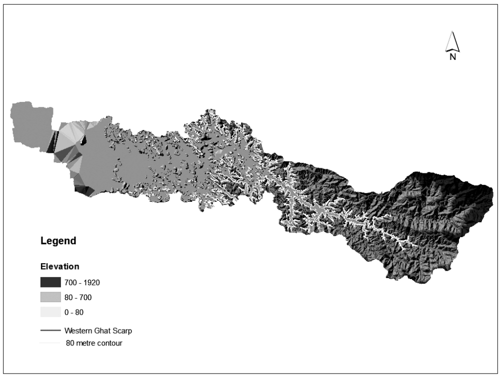

Fig. 7 Digital Elevation Model, Achankovil

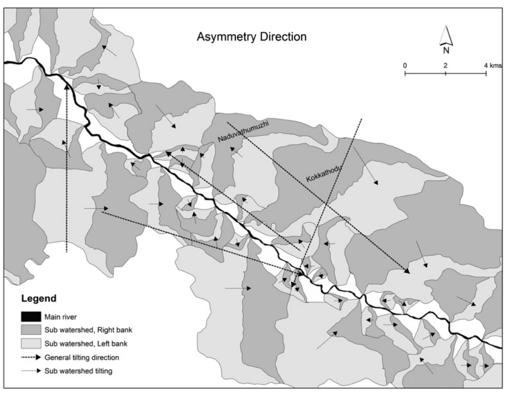

Fig. 8 General tilting directions of basin

strike-slip fault direction of this segment (Fig. 8). West of Konni, though the segment marked with NW deflection of channel from the main course, tilting directions of sub-basins shows variety of directions (Fig.9). In the right bank sub watersheds tilted towards NW, W and SW, whereas, in left bank basins are in the direction of NE and SW. In low land few sub watersheds show tilting towards basin margin.

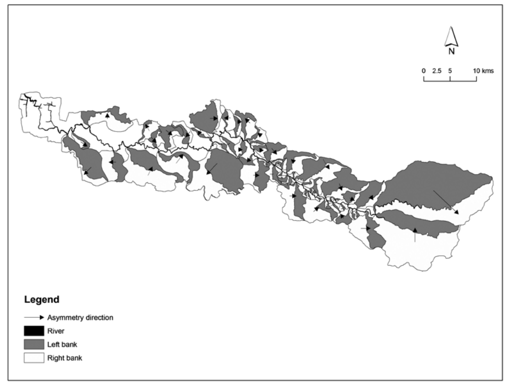

Fig. 9 Tilting direction of sub basins, Achankovil basin

Conclusion

Tilting direction of the river basin changes with segment implies periodic neotectonic activities in Achankovil river basin. The transverse topography symmetry factor method shows SE migration of river course in upper segment and NW migration of river course in the down segment. Though the basin tilting has influence the lateral shifting of the principal stream, the amount of shifting is restricted by the confined and trough like nature of the basin. Geologic events like Western Ghats uplift, base level changes and strike slip movements have modified the basin asymmetry.

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Reference

Bull, W. and McFadden, L. (1977): Tectonic geomorphology north and south of the Garlock Fault, California, Geomorphology in Arid regions, D.O., Doehring, ed., Publications in Geomorphology, State University of New York at Bingamton, 115–138

Burbank, D.W. and Anderson, R.S. (2001): Tectonic Geomorphology. Blackwell Scientific, Oxford. 270 pp

Cenki, B. and Kreigsman, L. M. (2005): Tectonics of the Neoproterozoic Southern Granulite Terrain, South India.Precambrian Res., V.138, pp.37-56

Chacko, T. Ravindra Kumar, G. R. Meen, J. K. And Rogers, J. J. R. (1992): Geochemistry of high-grade supra-crustal rocks from the Kerala khondalite belt and adjacent massif charnockites, south India: Precamb. Res., V. 55, pp.469-489

Cox, R.T. (1994): Analysis of drainage basin symmetry as a rapid technique to identify areas of possible Quaternary tilt-block tectonics: an example from the Mississipi Embayment. Geol. Soc. Am. Bull. 106, pp.571–581

Drury, S. A. Harris, N. B. W. Holt, R. W. Revees-Smith, G. J. and Wightman, R. T. (1984): Precambrian tectonics and crustal evolution in south India: Jour. Geology, v.92, pp.3-20

Hare, P.H. and Gardner, T. W. (1985): Geomorphic indicators of vertical neotectonism along converging plate margins, Nicoya Peninsula, Costa Rica. In: Morisawa M., Hack J.T. (Eds.), Tectonic Geomorphology, Allen and Unwin, Boston, pp. 75–104

Holbrook John, and Schumm, S. A. (1999): Geomorphic and sedimentary response of rivers to tectonic deformation: a brief and critique of a tool for recognizing subtle epeirogenic deformation in modern and ancient settings, Tectonophysics, 305, pp. 287-306

Keller, E.A. and Pinter, N. (2002): Active Tectonics: Earthquakes, Uplift and Landscape. Prentice Hall, New Jersey

Nair, M.M. (1990): Structural trend line patterns and lineaments of the Western Ghats, south of 13º latitude. Journ. Geol. Soc. India, V.35, pp. 99-105

Rajesh Guru, K. Vara Prasad, G. S. and Chetty, T. R. K. (2007): Structurally controlled drainage pattern in Precambrian mountainous terrain: A study from the southern Sahyadri, India, Journ. Geol. Soc. India, v.70, pp.499-519

Sacks, P. E. Nambiar, C. G. and Walters, L. J. (1997): Dextral Pan-African shear along the south western edge of the Achankovil shear belt, south India: Constraints on Gondwana reconstructions, Jour. Geol., v.105, pp.275-284

Sinha-Roy, S. (2001): Neotectonic significance of longitudinal river profiles: An example from the Banas drainage basin, Rajasthan, Jour. Geol. Soc. India, v.58, pp.143-156

Valdiya, K. S. and Narayana, A. C. (2007): River response to neotectonic activity: Example from Kerala, India, Jour. Geol. Soc. India, v.70, pp.427-443

Schumm, S.A. Dumont, J.F. and Holbrook, J.M. (2000): Active tectonics and alluvial rivers, Cambridge University Press, Cambridge, p.401

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