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ACKNOWLEDGEMENTS. We thank the Wadia Institute of Himalayan Geology, Dehradun, for providing the necessary facilities to carry out this study; and the Ministry of Earth Sciences, New Delhi, for providing funds to run the MPGO station through sponsored project (MoES/P.O.(Seismo)/NPEP/15/2009). D.D.K. thanks the Department of Science and Technology (DST), New Delhi for providing financial support. A.K.G. thanks DST, New Delhi for the financial support under J.C. Bose Fellowship. We also thank the entire team of MPGO and staff working at the remote site, Ghuttu for collecting valuable data. The TRMM-derived rainfall data analyses and visualizations used in this study were produced with the Giovanni on-line data system, developed and maintained by the NASA's Goddard Earth Sciences Data and Information Services Center.

Received 29 March 2014; revised accepted 27 November 2014

Drainage development in Achankovil Shear Zone, South India

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The WNW–ESE trending Achankovil Shear Zone (ASZ) in southern India is a major crustal discontinuity of Proterozoic age which separates Kerala Khondalite Belt (KKB) in the south from the Charnockite massif in the north. The Achankovil river drains this structural valley. Although the river bears imprints of various geologic events, including neotectonic activities, it could maintain a straight course even in the lowland indicating its antecedent nature. The present communication is an attempt to study structural controls on drainage development and evolution within ASZ based mostly on geomorphological evidences and also on some geological indicators.

Keywords: Antecedent river, palaeo strand lines, shear zone, structural valley.

DRAINAGE development and valley configuration in a region largely depend on the topography, geology, structure

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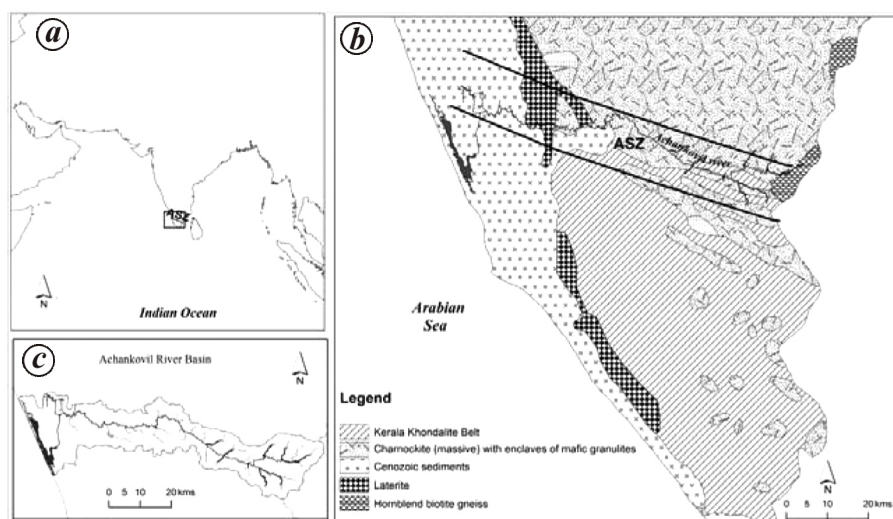


Figure 1. *a*, A general map showing location of Achankovil Shear Zone (ASZ). *b*, Simplified geology map of southern Kerala (compiled from GSI map) showing the coarse of ASZ. *c*, Map of Achankovil river basin.

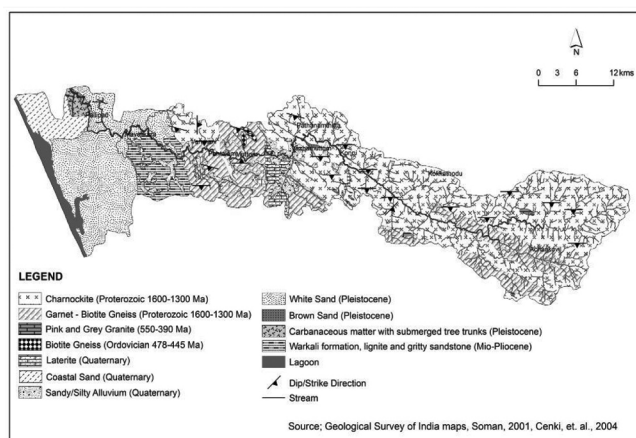


Figure 2. Map showing lithology with dip/strike direction.

and tectonic activities. At the broadest scale, geological controls, including lithology, tectonic history and rates of landscape dissection and denudation dictate the shape and other characteristics of a valley¹. Structural controls on drainage development and the interactions between tectonic activities and fluvial morphology are widely documented. This communication deals with a case of Achankovil Shear Zone (ASZ) in South India.

ASZ is a weak zone of Proterozoic age with pan-African traces². This zone has a lateral extension of 120 km and its width varies within 10–20 km and passes through the states of Kerala and Tamil Nadu in a WNW–ESE direction. A long straight section of the Achankovil river, in south Kerala roughly coincides with the northeastern boundary of the Kerala Khondalite Belt³. Descending from the western front of the Western Ghats, the Achankovil river roughly drains this structural valley within a confined basin (Figure 1).

There are various interpretations proposed regarding kinematics and tectonic evolution of ASZ^{3–5}, as to whether it is a shear zone³, a zone of high strain⁶ or a simple geomorphic expression⁷.

Major lithological units in the ASZ include garnet–biotite gneiss, granite, charnockite and cordierite gneiss with associated migmatites (Figure 2). Rocks within the Achankovil Shear Belt are layered and locally migmatitic biotite gneiss, cordierite gneiss, granite, and both massive and patchy charnockite⁴. Numerous small granitic and pegmatitic veins cut these gneisses. These rocks preserve evidence for polyphase deformation and metamorphism^{5,8,9}.

The Survey of India (SoI) toposheets, IRS-P6-LISS-III imagery, SRTM and ASTER elevation datasets and geological maps of the Geological Survey of India provided the principal dataset. Detailed field work was conducted to verify the maps and collect field evidences in support of the argument presented here. The Achankovil River Basin and drainage network was derived from 1 : 50,000 scale SoI topographic sheets. Lineaments were identified from images. Rose diagrams have been prepared to decipher structural influence on drainage network. For the detailed study, the basin has been divided into four segments based on topographical characteristics and course orientation. Transverse cross-profiles were constructed for selected locations across the river basin connecting water divides. Longitudinal profiles were prepared for the main river and two major sixth-order tributaries. Hypsometric indices and selected morphometric indices were worked out for geomorphological analysis.

The Achankovil, a seventh-order stream, exhibits a unique elongated shape with restricted north–south spread. The drainage in general exhibits sub-dendritic to sub-parallel pattern, but the higher order streams in

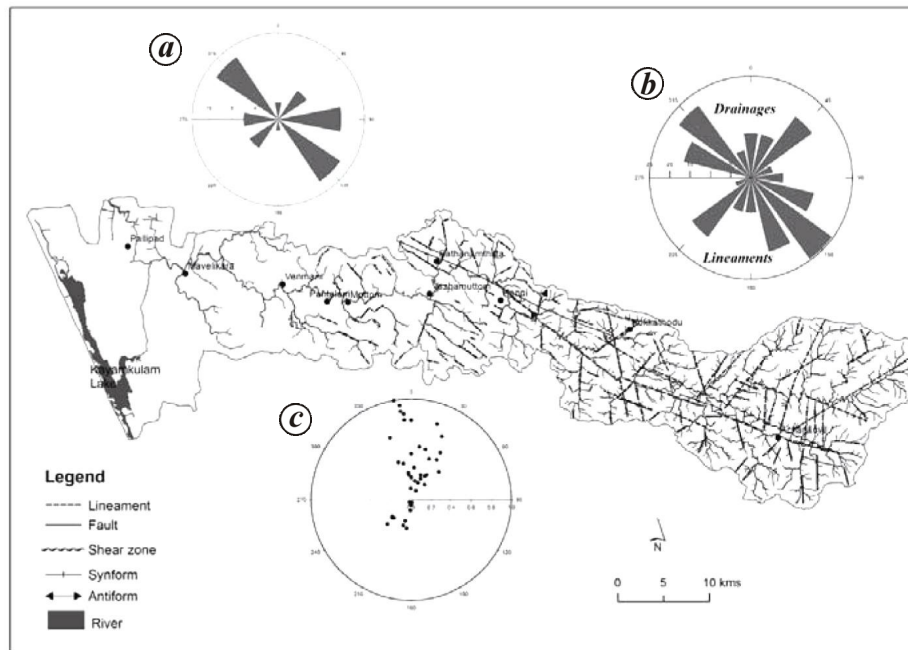


Figure 3. General map showing major structural features in the Achankovil basin. *a*, Rose diagram showing direction of sub waterhead tilting. *b*, Rose diagram showing orientation of drainage lines and lineaments. *c*, Polar plot of transverse topographic symmetry factor at centre magnitude = 0 and at margin magnitude = 1.

particular, show more or less trellis drainage pattern. Structural control on drainage pattern is clearly evident (rose diagrams in Figure 3). Comparing drainage layout with that of lineament distribution (Figure 3), it may be observed that most of the channel courses, including deflection in the channels are structurally controlled. In the southeastern part, a few lineaments trending ENE–WSW to E–W cut across the general NW–SE foliation trend and may represent brittle joints/faults. In the north-western part, these can be seen trending NNW–SSE to N–S. In the central part of the block, the lineaments trend in NE–SW direction. In general for the whole basin, the NW–SE trending lineaments predominate (Figure 3). The other directions of lineaments in the order of prominence are NE–SW and WNW–ESE. The main stream maintains a general NW–SE direction throughout its course. The tributaries are short in length and oriented in the WNW–ESE, NW–SE, NNE–SSW, NE–SW and ENE–WSW directions.

Relatively young drainage basins in tectonically active areas tend to be elongated in shape. With continued evolution or less active tectonic processes, the elongated shape tends to evolve to a more circular one¹⁰. The Achankovil River Basin is elongated in a trough-like set-up and perhaps the basin shape is broadly maintained since its evolution is connected with ASZ. This area hosts a remarkable en-echelon pattern of faults giving rise to linear valleys and ridges¹¹. The highest elevation reaches 1920 m amsl. The right bank of the basin is relatively elevated than the left bank as evident from the six cross-

sections drawn across the basin from ridge to ridge using ASTER DEM (Figure 4).

Valley of Kallar, a sixth-order tributary of Achankovil, is V-shaped with steep valley wall in contrast to the Achankovil river valley, which is broad and open with evidences of terrace formation. The profile *C–D* across the main Achankovil river shows wide asymmetrical valley. Relief amplitude reduces in the *C–D* profile. The valley configuration and thalweg character (Figure 5*a*) indicate that the Achankovil river valley has almost reached late mature stage. The relief of lowland segments has almost reached base level.

The Achankovil basin can be broadly divided into four segments (Figure 5). The first segment, i.e. the initial course of the river drains (roughly follows) the garnet–biotite gneiss terrain; the second segment is partly controlled by transverse strike–slip fault; the third segment is characterized by an abrupt deflection of drainage course from the mid-line, and the lowland segment follows a straight course through recent coastal sediments. Detailed characteristics of these four segments are discussed below: The criteria used for demarcating the four segments are: lithology, structure, drainage pattern and orientation of main drainage course of the Achankovil river. These elements are discussed while deliberating on each segment.

In segment 1, the main tributary of Achankovil follows the structural valley composed of garnet–biotite gneiss with limited lateral (N–S) spread of its catchment, and confluences with Kallar (sixth-order stream) at an elevation of 72 m to form the main river. Kallar has a wider

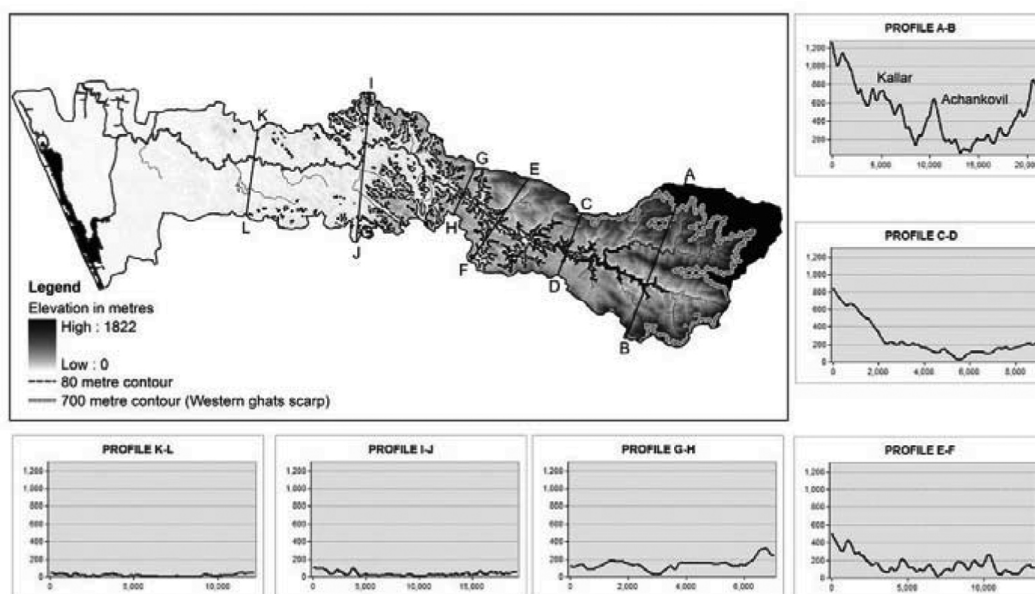


Figure 4. Map showing the Western Ghats scarp, Achankovil trough and selected cross-sections.

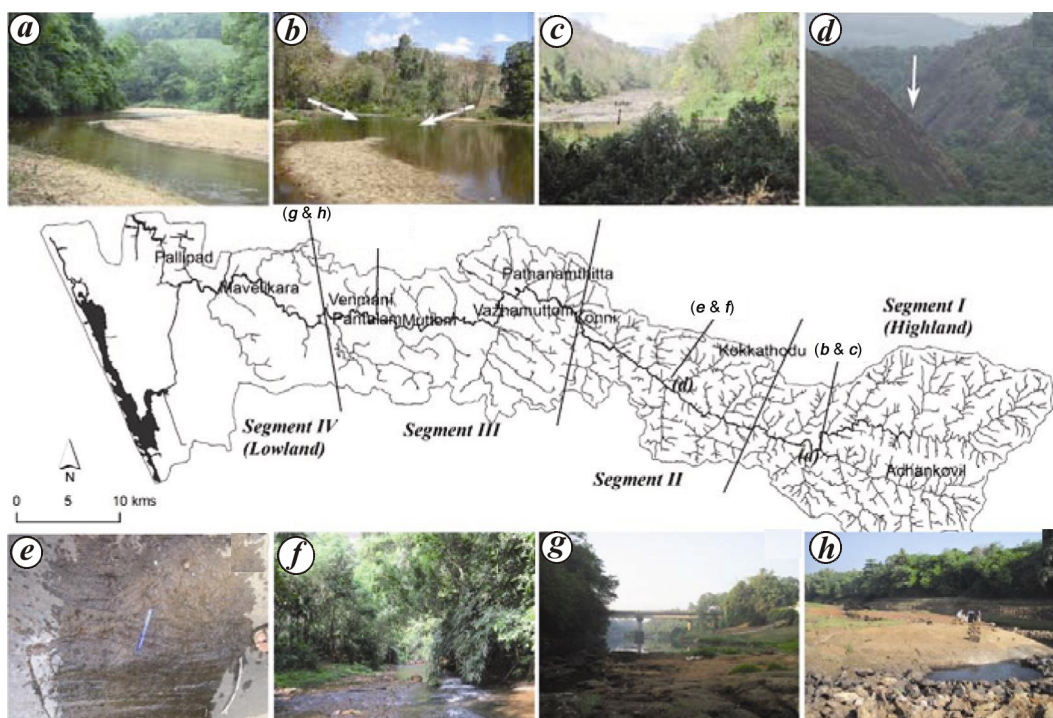


Figure 5. Four segments and marked with locations of photographs. *a*, Late mature characteristics in the upper catchment. *b*, Confluence of Kallar and Achankovil. *c*, View of Kallar; note the rocky bed. *d*, Deep incised gorge in massive charnockite at Kokkathodu. *e*, Signatures of stress in exposed rocks at Kokkathodu. *f*, Bed material consisting of cobbles and pebbles at Kokkathodu. *g*, Dyke exposure in the main stream at Pandalam. *h*, Exposure of granitic dome in the main stream at Pandalam.

catchment area developed over charnockite terrain with high internal relief (1780 m) compared to Achankovil (1160 m). Both tributaries show abrupt fall in elevation within a short distance with several knick points (Figure

6 *b* and *c*). In Kallar, a fall in gradient from 1900 to 1000 m within 1.9 km is observed. While in the case of the Achankovil tributary a sudden fall of 660 m is observed within 2.6 km from the source with a knick point

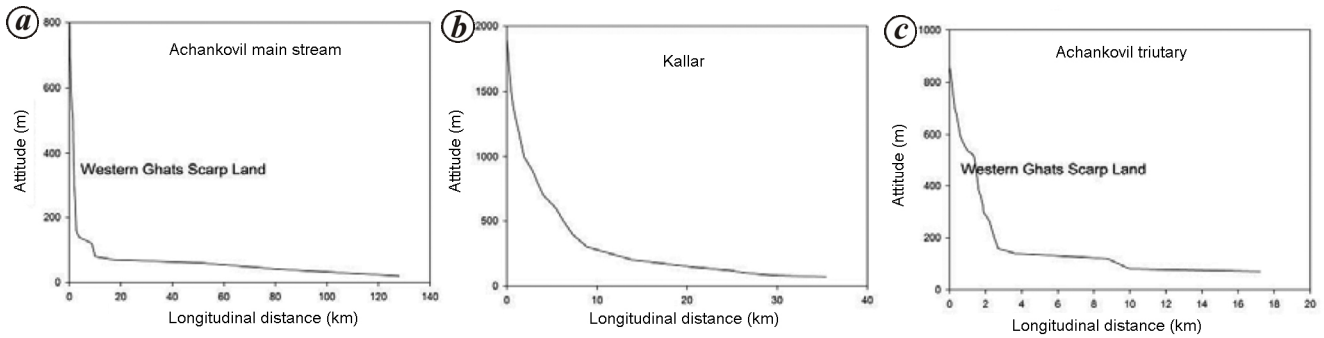


Figure 6. Longitudinal profiles of the main river and its two major tributaries. Note the scarp land of the Western Ghats with precipitous slope and the knick zones.

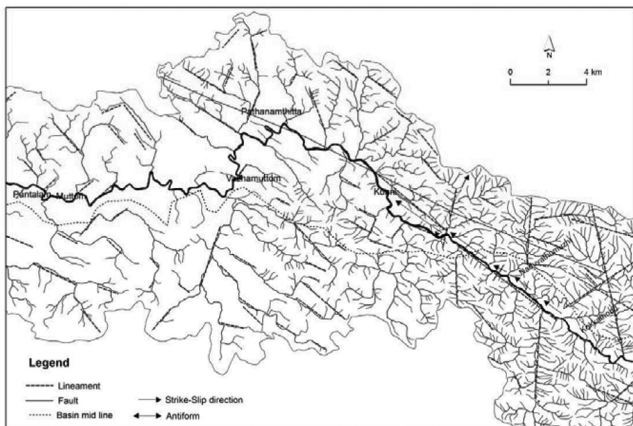


Figure 7. Abrupt deflection of the main river from the channel mid-line. The direction of strike-slip movement is also shown.

at 520 m and another fall of 100 m within 6.7 km with a knick point at 120 m. The channel gradient of Kallar is seven times steeper than Achankovil.

Kallar, is young and active compared to Achankovil. Hypsometric indices of Kallar and Achankovil show variation. Kallar has a higher toe value h (0.8) of 0.14 compared to Achankovil (0.04). Higher toe value indicates catchment widening through lateral drainage branching¹², hence Kallar has higher lateral drainage branching compared to Achankovil. Kallar has a higher hypsometric integral value of 0.32 than Achankovil (0.18). The Kallar river bed is rocky with youthful nature and lies at an elevated level than that of the Achankovil river, which has a sandy bed with mature to late mature characteristics (Figure 5 *b* and *c*).

In the case of segment 2, the ASZ has been described as a belt of strike-slip displacement due to strike-slip reactivation of E–W to NW–SE trending shear zones¹³. Geomorphic and drainage signatures indicate that NW–SE trending dextral strike-slip displacement has occurred within a short distance between Kokkathodu and Konni (Figure 7). The offsetting of tributaries as well as the ridge lines in this segment is mainly caused by the strike-slip fault. East of Konni, a long curved stretch of the

Achankovil is ponded interruptedly for more than 5 km (ref. 14), probably due to the activities along the fault. It can be observed from Figure 7 that the tributaries crossing the fault line near Konni also take the NW deflection. Structural control over the drainages is evident in this segment also, as most of the channels follow the lineaments.

The Kokkathodu, a fifth-order tributary of the Achankovil is deeply entrenched cutting a deep gorge through a huge resistant block of charnockite (Figure 5 *d*). It also creates incised meanders and terraces downstream flowing through extensive flood plains, which are unlikely to have been developed by the small tributary of the Kokkathodu catchment. In the later course of this tributary before joining the main river, it takes a 45° deflection towards NW, which can be attributed to the strike-slip deflection of the basement. Bed materials, mainly consisting of cobbles, pebbles and gravel (Figure 5 *f*) indicate high erosive nature of the stream.

Segment 3 starts from Konni and extends up to Pantaalam. Deviation of the main stream from the mid-line of the basin is observed near Pathanamthitta (Figure 7), from where the river follows an antiformal hinge zone. Dip direction (S, SW) is uniform in midland as well as in lowland; however, it changes after Panthalam (Figure 2). This segment is remarkable with instances of ponding formed due to blockage of the main stream at many places caused by exposed bedrock dykes within the channel, which can be linked to neotectonic activities¹⁴ (Figure 5 *g*). It also can be observed that the river continues to flow cutting across these ridges, which is a characteristic feature of an antecedent river. Occurrence of a granitic dome (Figure 5 *h*) at the river bed is also noticed near Panthalam. The tendency of the river to cut across an antiform is also an important geomorphic expression of an antecedent drainage. The Achankovil swerves in the SSW direction from its consistently WNW course near Vazhamuttam, making a distorted box-like loop, probably a result of an oblique-slip movement on the NNE–SSW trending fault associated with the uplift of the western block¹⁴. This observation is further supported by P – T data on charnockites from Kumbazha region in Pathanamthitta district¹⁵. The 6 m knick point observed at Vyazhi thodu,

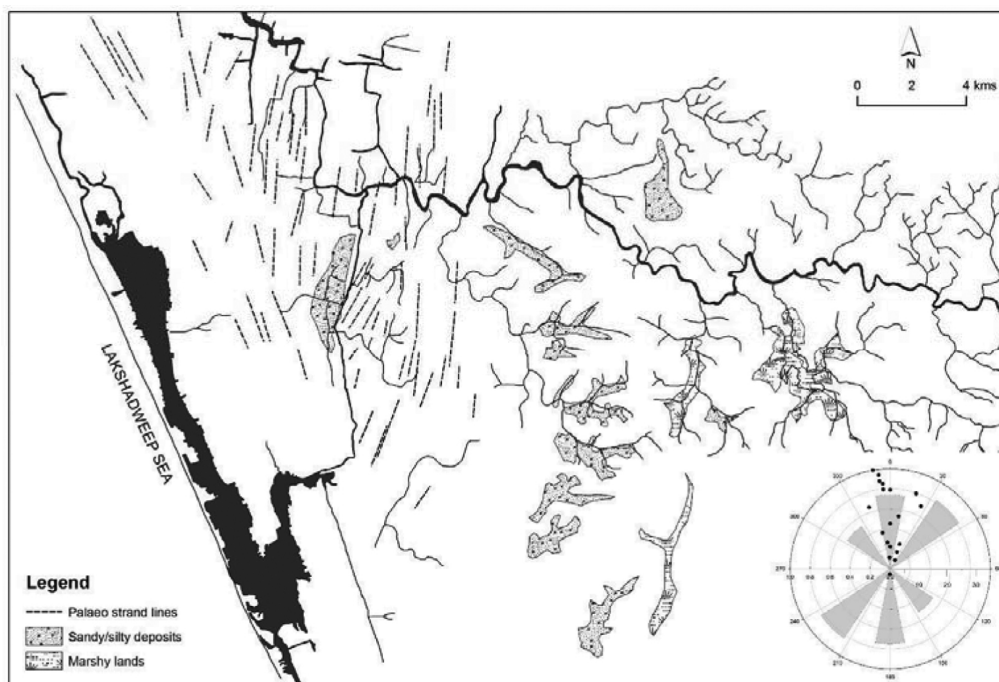


Figure 8. Straight channel course cutting the palaeo strand lines in the lowland. In the polar chart bars represent the direction of strand lines and the coastal line and the vector points represent the shifting of main river from the basin mid line. (Note the alignment of *T* vectors largely coincides with the direction of N–S strand lines.)

a third-order stream which joins with Achankovil near Pathanamthitta, may be the result of an uplift event.

Hypsometric integral of a fifth-order sub-watershed Chandanapally located in this area, shows higher value (0.36) compared to other fifth-order sub-watersheds of the left bank within the highland and midland, which could be due to rejuvenation of this region.

The lowland segment, i.e. segment 4 of the Achankovil basin is composed of coastal sands and fluvio-marine sediments. The main river takes a northward deflection in the lower reaches, joins the Pamba river and debouches into the Vembanad Lake. This segment forms a part of the Southern Kerala Sedimentary Basin (SKSB). Geologically, this area has developed under the influence of marine, fluvio-marine/estuarine and fluvial processes¹⁶. The sediments of this basin reported along the coast are of Tertiary age and mostly exhibit NNW–SSE strike¹⁷. There are positive indications of subsidence along ENE–WSW/E–W trends. During Pleistocene from ca. 20 ky BP to the Last Glacial Maximum, the sea level was possibly 80–100 m below the present and the coast was >30 km to the west¹⁸. Uplift to the tune of 50–100 m of this area could be one of the reasons to bring SKSB to the present level. That the SKSB has experienced northwesterly tilt is evident from the flow direction of the Achankovil and Pamba rivers¹⁹. In the lower reaches, the Achankovil river cuts the palaeo sand ridges and then takes a turn of 90° towards right, which is in a direction perpendicular to the main course. The polar chart (Figure 8) shows the frequency of direction of palaeo strand lines together with transverse topographic symmetry factors (*T*-vectors) in

the lower course, indicating the northward lateral shifting of the main river course from the middle line of the river basin. It can be deciphered from the diagram that the prominent direction of lateral shift in the main course coincides with the direction of palaeo strand lines and the coastal line. The coastline in Kerala is structurally controlled. The straight line deflection of the channel in the lower reaches flowing through recent sediments is mostly structurally controlled.

Thus the main river course of the Achankovil flowing through the shear zone shows near maturity symptoms up to the foot of the Western Ghats scarp. It is quite possible that post-ASZ tectonic activities have caused minor deflections, but the broad SEly alignment is well maintained. Segment-wise analysis indicates that the basin is not uniform and is subjected to differential structural deformation. The Achankovil river is of antecedent nature and a part of it could be due to superposition and re-establishment.

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ACKNOWLEDGEMENTS. The research was conducted at NCESS and funded by UGC. We are grateful to the Director, NCESS for providing the necessary facilities. We thank Dr Srikumar Chattopadhyay for his encouragement constructive discussions, Dr Mahamaya Chattopadhyay for her valuable suggestions, and Lijith P. Nair, S. Rajappan, Nikhil Kannothe, Indu P. Nair and N. P. Ragi for support during the field work.

High fat simple carbohydrate-fed male Wistar rats: a useful model to study metabolic syndrome

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Metabolic syndrome represents a combination of cardiovascular risk determinants and lipid abnormalities. The syndrome is associated with a five-fold higher risk of developing type-II diabetes and two to three-fold higher risk of cardiovascular disease. The etiology of the syndrome at the molecular level is not yet understood. Therefore, there is a need to study the syndrome in an animal model. In the present study, the effect of high fat simple carbohydrate (HFSC) diet on male Wistar rats was investigated. The rats were fed HFSC diet for a period of five months. Anthropometric parameters were measured and serum triglycerides, total cholesterol, HDL and LDL were analysed. Glucose intolerance was studied using oral glucose tolerance test. The formulated (HFSC) diet succeeded in developing an animal model for metabolic syndrome within 17 weeks characterized by obesity, hypertriglyceridemia, impaired glucose tolerance, fatty liver and abnormal cardiac histology.

Keywords: High fat simple carbohydrate diet, metabolic syndrome, oral glucose tolerance test.

METABOLIC syndrome (MetS) represents a combination of cardiovascular risk determinants such as obesity, insulin resistance, hypertension and lipid abnormalities. This syndrome has reached epidemic proportions worldwide. It affects one in five people and prevalence increases with age. According to the population studies, from the age of 20 to 25 years and upwards, the prevalence of metabolic syndrome varies from 8% (India) to 24% (the United States) in men and from 7% (France) to 46% (India) in women¹. Metabolic syndrome is a major public health burden² and contributes to cardiovascular disorders, cognitive decline and reduces the expected lifespan by an average of 15 years in the aged. Besides morbidity and mortality, these disorders impact the socio-economic status of individuals as well as the state³.

Metabolic syndrome seems to have three potential etiological categories: obesity and disorders of adipose tissue, insulin resistance and a constellation of independent factors (e.g. molecules of hepatic, vascular and

Received 27 March 2014; revised accepted 28 November 2014

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