International Journal of Current Research and Modern Education (IJCRME)
Impact Factor: 6.725, ISSN (Online): 2455 - 5428
(www.rdmodernresearch.com) Volume 2, Issue 2, 2017

MORPHOTECTONIC STUDY OF BRINGI STREAM RIGHT BANK TRIBUTARY OF RIVER JHELUM, SE OF KASHMIR VALLEY, NORTH WEST HIMALAYAS

Arshid Ahmad Dar*, Dr. Bikram Singh Bali & Tariq Ah Tahir*****
Department of Earth Sciences, University of Kashmir, Srinagar, Jammu and Kashmir

Cite This Article: Arshid Ahmad Dar, Dr. Bikram Singh Bali & Tariq Ah Tahir, "Morphotectonic Study of Bringi Stream Right Bank Tributary of River Jhelum, Se of Kashmir Valley, North West Himalayas", International Journal of Current Research and Modern Education, Volume 2, Issue 2, Page Number 318-329, 2017.

Abstract:

The Bringi watershed of Kashmir Valley has been studied to understand its morpho- tectonic evolution on the basis of Morphotectonic and geomorphic indices complemented and validated with extensive field observations, as rivers are one of the most important landforms on the ground that are extremely sensitive to tectonic movements and also they are the fundamental units of fluvial landscape. The geomorphic indices has been calculated by the use of topographic maps, digital elevation model, satellite images and aerial photographs. The landform study analysis us to determine the impact of tectonics in the development of lineaments, erosion processes and consequent drainage development. The analysis and calculation of Morphotectonic parameters viz Mountain front sinuosity (Smf), Sinuosity index (Si), Hypsometric integral (Hi), Drainage basin asymmetry or Asymmetric factor (AF), Stream length gradient index (SL), River profile (H), Transverse topography symmetry, and Valley-floor width to Valley height ratio (Vf) along with field observations shows that the Bringi watershed is strongly elongated and is tectonically active. The derived values show that the overall assessment of the geomorphic indices revealed that the tectonic uplift, lithology and climate forcing played a significant role in the landscape evolution of the Bringi stream and the area has experienced differential uplift and erosion rates from time to time in the geological past.

Key Words: Active Tectonics, Geomorphic Indices, Drainage Basin, Digital Elevation Model, Satellite Imageries & Aerial Photography.

Introduction:

Tectonic geomorphology is a wonderfully integrative field that presents stimulating challenges to anyone trying to extract information from deforming landscapes. It is now possible to quantify at the scale of millimeters how rapidly a given site is moving with respect to another and how those rates of relative convergence or divergence are partitioned among various faults and folds. Similarly, we can now quantify how rapidly rivers and glaciers are incising into bedrock and the rates at which landslides are stripping mountain slopes. Clearly, the merger of such data sets can underpin a new understanding of the balance between the rates at which crustal material is added at a given site and the rates at which this material is eroded away. Defining this balance and interpreting the landscape that results from this competition represents a major component of modern tectonic geomorphology.

Geomorphic indices of active tectonics have been developed with the objective of establishing relative tectonic activity, and identifying those locations where more detailed work may yield valuable information concerning rates of tectonic processes and recurrence intervals for seismic events. This endeavor was pioneered in the 1970s by William Bull at the University of Arizona, who developed several important indices including 'mountain-front sinuosity' and 'ratio of valley-floor width to valley height'. The former is defined as the ratio of the length of a mountain front at piedmont, as measured from an aerial photograph or topographic map, to the straight-line length along the mountain front. Mountain-front sinuosity therefore reflects a balance between the tendency of erosional processes to produce an irregular or sinuous mountain front and the effect of vertical active tectonic movement on steeply dipping, range-bounding faults, which tends to produce a relatively straight front. Low values of the indices thus correlate with relatively high rates of uplift along faults bounding mountain ranges, compared to others with greater sinuosity and lower rates of tectonic activity.

Measurement of deformation is relatively easy. Stream channels may be offset, marine terraces may be faulted, uplifted, tilted, or folded, and alluvial fans may likewise be faulted, tilted, or folded; and deformation can be measured in the field or from topographic maps. What is most difficult in tectonic geomorphological studies is to establish the late Pleistocene–Holocene chronology. In order to complete a successful study of this type, the rates of the processes should be calculated (or estimated). If no chronology has been established, then it is impossible to estimate rates. Relative chronology is not sufficient, and so we must look to a variety of other methods, including such techniques as dendrochronology and numerical dating, utilizing radioactive isotopes.

An important aspect of tectonic geomorphological evaluation is the construction of process–response models in conjunction with rates of active tectonics. These models are broadly defined so as to include the integrative investigation of deformation of Earth materials and landforms with the late Pleistocene–Holocene chronology. When this is accomplished, it is possible to predict future changes of the landscape and derive rates of tectonic processes, such as rates of tilting, uplift, or displacement caused by faulting. One of the most successful process–response models has been the evaluation of fault-scarp morphology as an indicator of active tectonics. When faulting ruptures the ground and produces a scarp in alluvial material, the scarp (i.e. steep slope) changes with time as the crest becomes more rounded by erosion and the toe is buried by deposits. The changes following the faulting event have been quantified mathematically, and so it is possible to estimate the time since faulting took place by examining the geomorphology of the fault scarp and knowing something about the climate of the region. Other process–response models have been developed for evaluating offset stream channels along strike-slip faulting. This work has been pioneered by Kerry Sieh at the California Institute of Technology. Careful evaluation of the stream channel deposits that have been displaced by strike-slip faulting, coupled to numerical dating (by the carbon-14 method) have yielded rates of slip along the San Andreas Fault in California. As a final example of process–response models, consider the study of uplifted marine terraces. Palaeo-shoreline angles delineate past sea levels. Coupling of the geomorphology of dated marine terraces and elevation of shoreline angles to paleo-sea-level curves allows rates of surface uplift in coastal areas to be estimated.

Study Area:

The study area that is one of the main upland catchments of River Jhelum, lies towards the SE of Kashmir Valley in Western Himalayas between lat. 33^{0}20'N and 33^{0}45'N and long. 75^{0}10'E and 75^{0}30'E of district Anantnag, covering an area of about 675 sq. km. The elevation of this mountainous catchment ranges from 1650m above mean sea level at Achabal town to more than 4000m above mean sea level near Sinthan top. The Bringi watershed is drained by the Bringi stream which is fed by a number of tributaries, of which the important ones are east Bringi and west Bringi. The streams are mostly fed by seasonal snow melt which generally lasts up to August and September. Bringi stream joins River Jhelum at Anantnag. Three major springs occur in the Bringi watershed, namely Achabalnag, Kokernag and Kongamnag. At Achabalnag, water comes out from the base of Sosanwar hills from two sites that are 150 m apart, with one major outlet carrying 75% of the total discharge. At Kokernag, water comes out from several places along a 50m front at the base of a limestone hill and is channelled through a garden. At Kongamnag, water issues out from Karewas in the form of a pool, at the base of a limestone hill and is channelled through the surrounding villages. The stream is showing dendritic to sub dendritic pattern in upper reaches of catchment and more or less uneven drainage pattern in the lower portions.

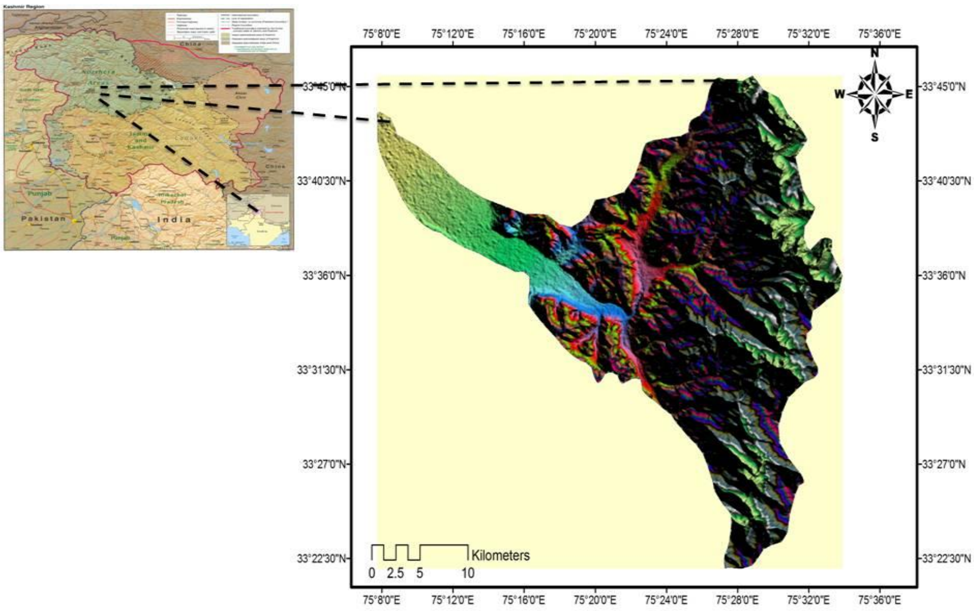


Figure 1: Showing Study area

Lithology of the Study Area:

The study area has a diverse rock types ranging in age from Archean to recent. In the study area the oldest formation comprises the Salkhala series which are found in the upper reaches in which dynamic high grade metamorphism is evident. The Salkhala group consists of slates, phyllite and schist with interbedded crystalline limestone and flaggy quartzite. Salkhala group are followed by Muth Quartzites and Panjal volcanics which are extensively found in the study area. The Panjal volcanic are of Carboniferous age in which the agglomeratic slate series is overlain often intermixed with a thick succession of andesitic and basaltic traps. The panjal volcanics are followed by Triassic-Jurassic limestone. The rocks are of light blue or grey tint compact and homogenous and sometimes heterogeneous in composition. They are then bedded in the lower part of the system with frequent interstratifications of black sandy and calcareous shales, but towards the top they become one monotonously uniform group of thickly bedded limestone with high coloration of their outcrops. The grain size ranges from fine to medium.

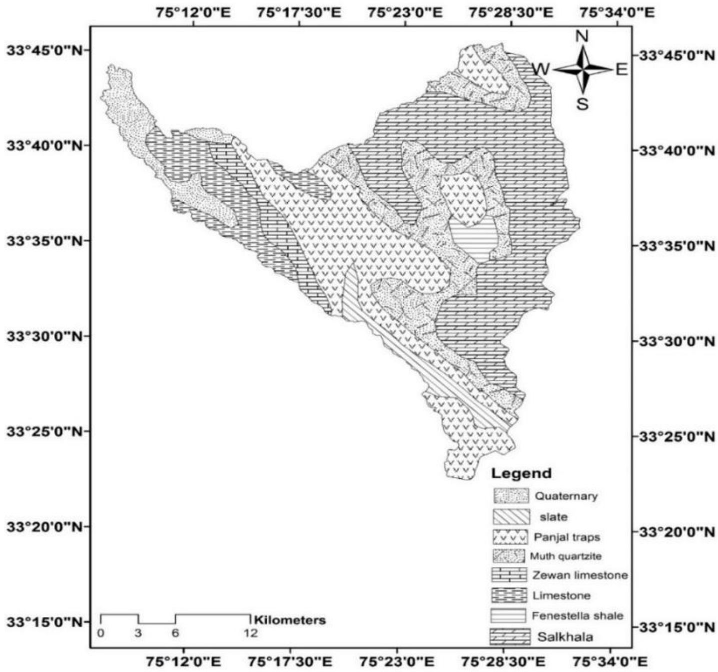


Figure 2: Showing lithological map of the study area

Lower part of the study area consists of Plio-Pleistocene deposits and recent alluvium. The Plio-Pleistocene of Kashmir comprises the Karewa Formation that contains lacustrine and fluvial sediments intercalated with glacial tills. Large amount of material is brought about by water and deposited in lower parts of the area. Lithologically, the alluvium consists of blue grey sand, silts and varved clays, shales and sands of various hues, textures and structures. The size of grains ranges from fine, medium to coarse. The colour of the alluvium varies from dark brown, reddish to flesh red.

Material and Methods:

The Morphotectonic analysis by the use of geomorphic indices has been developed as a basic reconnaissance tools to identify areas experiencing rapid tectonic deformation (Bull, W.B and McFadden L.D.1977, Keller and Pinter 1996). With the help of quantitative measurement of landscape shape of drainage watershed it becomes easy to compare different landforms to calculate less straightforward geomorphic indices/Morphotectonic parameters that may be useful for identifying a particular characteristic e.g., level of tectonic activity of an area, (keller and Pinter ;1996). The geomorphic indices that are most widely used to understand the active tectonics of a region are:

Mountain Front Sinuosity (SMF):

The geomorphology of mountain fronts reveals vital information regarding the current and past tectonic activity occurring along them. Mountain fronts are defined as major fault-bounded topographic escarpments with measurable relief exceeding the contour interval of 20 m (Wells et al., 1988). The degree of erosional modification of tectonic structures and landform development is measured by the mountain front sinuosity index (Smf) (Bull, 1977, 1978; Bull and McFadden, 1977; Keller and Pinter, 2002; Rockwell et al., 1985). The index (Smf) is defined as the ratio between (Lmf) the length of the mountain front along its base at the distinct break in slope and (Ls) the straight line length of the whole mountain front (Fig. 5.2). The index is based on the premise that tectonically active mountain fronts are often more straight than mountain fronts in regions where erosion dominates over tectonics. It is obtained using the equation:

$$Smf = Lmf / Ls$$

Where Smf = mountain front sinuosity index, Lmf = straight line distance along a contour line, Ls = true distance along the same contour line. Most active mountain fronts have Smf values ranging between 1.0 and 1.6, whereas less active and inactive mountain fronts have Smf values ranging between 1.4–3.0 and >3.0, respectively (Bull and McFadden, 1977). In the study area, the mountain front sinuosity is measured in eight segments and the results are given in Table 5.4. It is concluded from below table that the study area has most active mountain fronts which illustrates that tectonic forces dominate over erosion.

Segment	Lmf (m)	Ls (m)	Smf (m)= Lmf/LS	Inference
1	1467	1204	1.21	Tectonically Active
2	973	781	1.24	Tectonically Active
3	692	590	1.17	Tectonically Active
4	705	616	1.14	Tectonically Active
5	909.63	810	1.12	Tectonically Active
6	663.94	600	1.1	Tectonically Active
7	892	846	1.0	Tectonically Active
8	785	604	1.3	Tectonically Active

Table 1: Showing calculated Smf values.

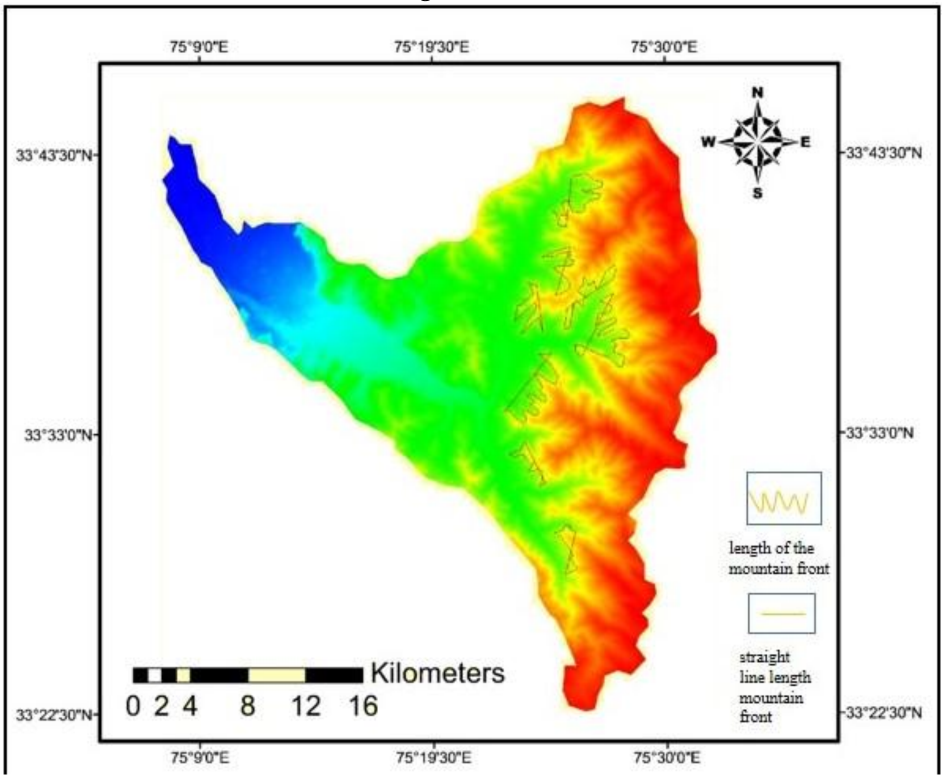


Figure 3: Showing calculation of mountain front sinuosity of Bringi watershed.

Sinuosity Index (SI):

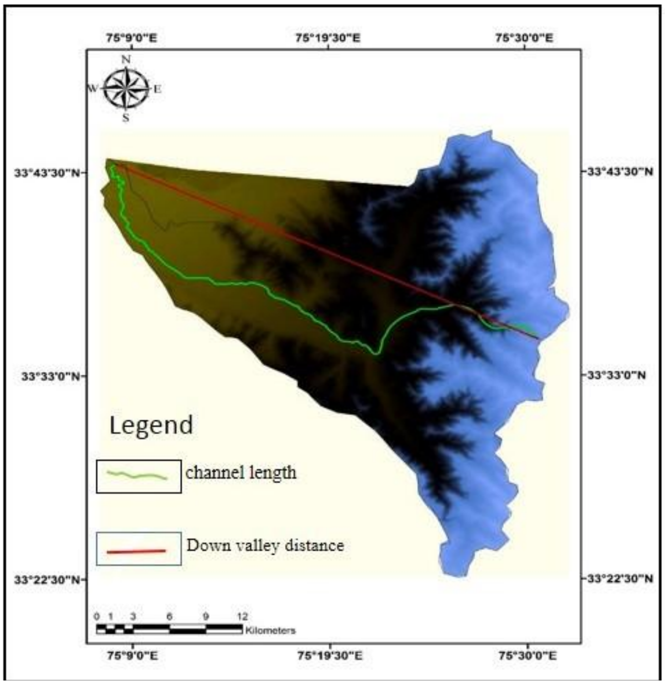


Figure 4: Showing sinuosity index of Bringi stream

Sinuosity has been defined as the ratio of channel length to down valley distance. Sinuosity deals with the pattern of channel of a drainage basin. In general, its value varies from 1 to 4 or more. Rivers having a sinuosity of 1.5 are called sinuous, and above 1.5 are called meandering (Wolman et al. 1964). It is a significant quantitative index for interpreting the significance of streams in the evolution of landscapes and beneficial for Geomorphologists. Rivers meander in order to maintain a channel slope in equilibrium with discharge and sediment load. A river meanders when the straight line slope of the valley is too steep for equilibrium-the sinuous path of the meanders reduces the slope of the channel. Any tectonic deformation that changes the slope of a river valley results in a corresponding change in sinuosity to maintain the equilibrium channel slope. A secondary effect of this adjustment is that, as river switches from one sinuosity to another, the rates of meander migration and floodplain reworking accelerate accordingly; this secondary effect has proved to be a diagnostic tool in identifying area of active tectonics. Bringi watershed has a sinuosity index value of 1.3 as calculated from fig 5.3 which reflects that the study area is tectonically active.

Hypsometric Integral (Hi) and Hypsometric Curve:

Area elevation analysis or hypsometry is a powerful tool for differentiating tectonically active regions from inactive ones. The hypsometric integral (Hi) is a quantitative measure of the degree of dissection of a drainage sub-watershed (Strahler, 1952). Its values are important elements in the analysis of landscape.

Hypsometric integral (Strahler, 1952) can be easily obtained from topographic maps or by using Digital Elevation Models (DEM) (Pike and Wilson 1972). High values of hypsometric integral indicate that most of the topography is high relative to the mean, such as smooth upland surface cut by deeply incised streams. Intermediate to low value of the integral, reflect exposure of the terrain to extended erosion, are associated with more evenly dissected drainage basins. The hypsometric integral is calculated as;

Mean Elevation – Minimum elevation / Maximum Elevation – Minimum Elevation

The calculated hypsometric integral value (Fig 5.4) for the study area is 0.46, which is on the higher side indicating that the area is in youthful stage, high topography and incised streams thus suggesting that the area is tectonically controlled.

The hypsometric curve describes the distribution of elevations across an area of land. The curve is created by plotting the proportion of total basin height (relative height) against the proportion of total basin area (relative area) (Figure 5.5) the drainage basin spans eight contour lines. The total surface area of the basin (A) is the sum of the area between each pair of adjacent contour lines. The area (a) is the surface area within the basin above a given line of elevation (h). The value of relative area (a/A) always varies from 1.0 at the lowest point in the basin (h/H=0.0) to 0.0 at the highest point in the basin (h/H=1.0).

A useful attribute of the hypsometric curve is that drainage basins of different sizes can be compared with each other because area and elevation are plotted as functions of total area and total elevation. As long as the topographic maps being used are of a sufficiently large scale to accurately characterize the basins being measured.

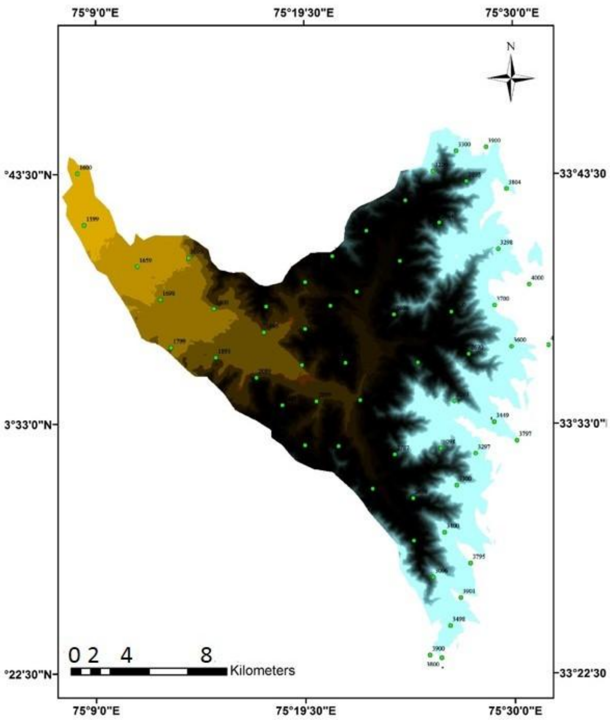


Figure 5: Showing random sampling for elevation data

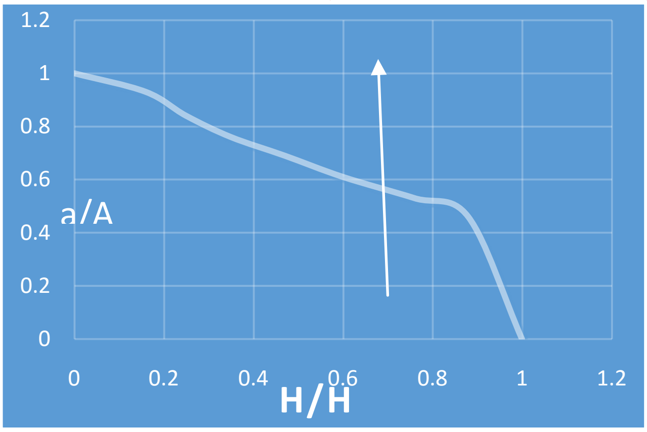


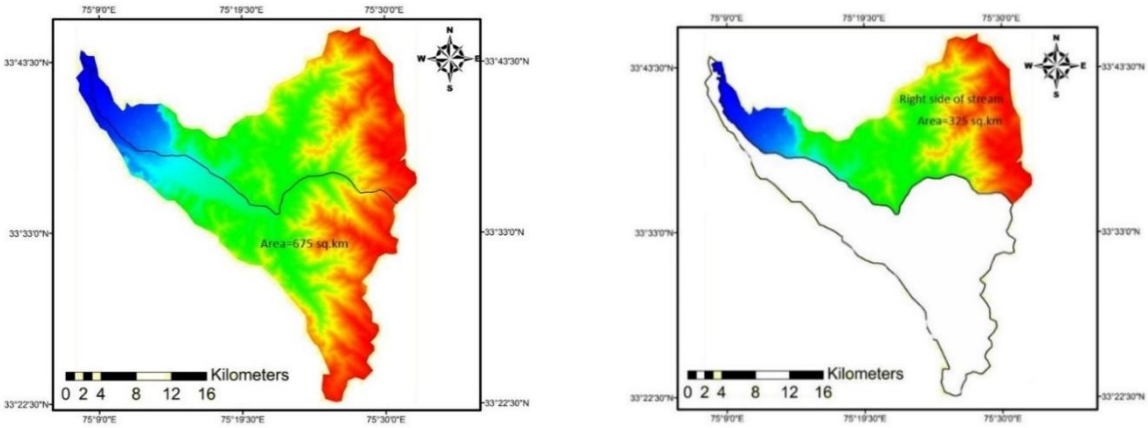
Figure 6: Showing several values a/A and h/H plotted toobtain a hypsometric curve.

Drainage Basin Asymmetry (AF):

The analysis of drainage system provides reliable information on the long-term evolution of the landscape. Drainage basin development is mostly effected by the tectonic activity which can be described both quantitatively and qualitatively by studying the pattern and geometry of the drainage network. The drainage basin asymmetry factor (AF) is widely used to detect tectonic tilting transverse to flow at basin level (Keller and Pinter, 2002). It is determined by the formula:

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

Where ‘Ar’ is the area of the basin to the right of the trunk stream facing downstream and ‘At’ is the total area of the drainage basin. The asymmetry factor is very much sensitive to tectonic activity. The factor is close to 50 if there is little tilting perpendicular to the direction of the master stream as is evident from the AF values of the Bringi watershed (AF= 48),(Fig 5.7 showing tilt). However, AF significantly greater or smaller than 50 indicates the effects of active tectonics or strong lithological control. Like most geomorphic indices, the AF works best where each drainage basin is underlain by the same rock type. The method also assumes that neither lithological controls (such as dipping sedimentary layers) nor localized climate (such as vegetation differences) causes asymmetry. Fig 5.6 (A, B) shows total area and right side area of Bringi watershed.



A B

Figure 7: A and B showing total area and right side area of Bringi watershed respectively.

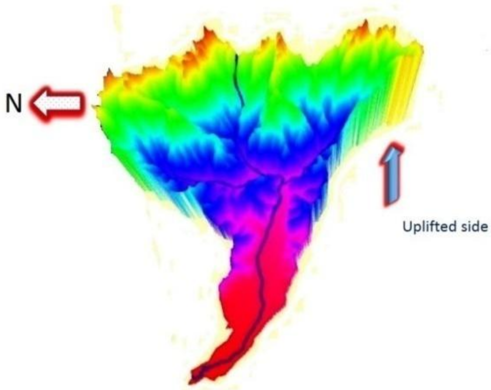


Figure 8: Showing tilt of Bringi watershed

Stream Length Gradient Index:

The SL index is a useful tool for the quantitative characterization of stream gradient conditions and the evaluation of relationship between potential tectonic activity, rock resistance, topography, and length of the stream (Keller and Pinter, 2002; Zhang et al., 2011). In landscape evolution, it is assumed that stream profiles adjust quite rapidly to the rock resistance. Commonly, the high SL index values are present where rivers cross hard rocks and reflect relatively high tectonic activity. While as the low SL index values indicate relatively low tectonic activity and suggest less-resistant and softer underlying rock types (Hack, 1973; Keller and Pinter, 2002). SL index is calculated using the following formula:

$$SL = (\Delta H / \Delta L)\ L$$

Where SL is the Stream Length-Gradient Index, L is the total channel length from the midpoint of the reach upstream where the index is calculated to the highest point on the channel, $\Delta H/\Delta L$ is the channel slope or gradient of the reach, where ΔH represents the change in elevation for a particular channel of the reach with respect to ΔL that symbolizes the length of the reach. The SL index is calculated using the parameters obtained from analogue or digital topographic data (Hack, 1973; Keller and Pinter, 2002).

In this study, the SL values were calculated along the Bringi stream for six segments namely a, b, c, d, e, f, with SL values 858, 1134, 1170, 2068, 1100 and 904 respectively by using a DEM in GIS environment (Fig. 5.8). Our observations show that the Bringi stream has high SL values, which corroborate with the major rivers across the Himalayan mountain range indicating high tectonic activity in the study area.

The sensitivity of channel gradient to rock-uplift is also evident from knick points developed along the studied stream. The development of knick points cause erosion and bring about changes in the drainage pattern, which is also suggestive of tectonic and lithological control on the landform development in the area.

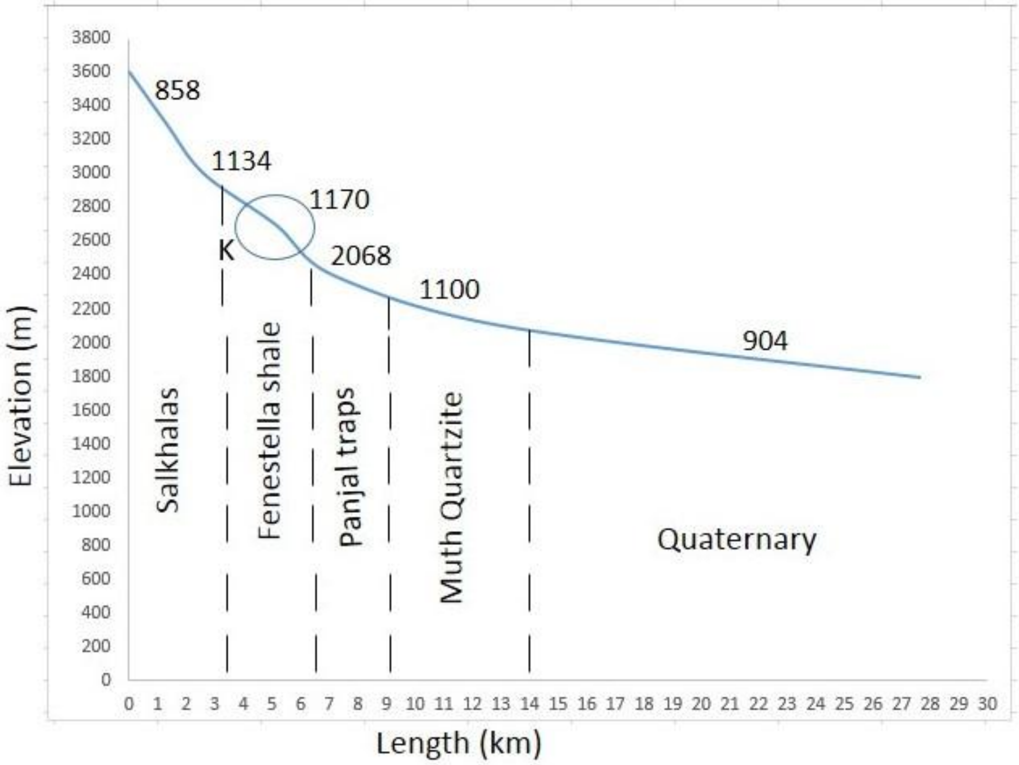


Figure 9: Longitudinal river profile of Bringi stream and plot of SL values.

River Profile:

Rivers have to accommodate periods of tectonic uplift, climate change and watershed development. Longitudinal river profiles provide useful data to make relevant conclusions about the geological setup, structure and the tectonic deformations of an area. Singh and Awasthi (2010) and Hovius (2000) observed that the longitudinal river profiles have the following characteristic features:

- ✓ They decrease in gradient monotonically,
- ✓ They are concave-up with occasional local convexities and
- ✓ Except for Knick points they have smooth curve over length scales of kilometers.

Under static equilibrium conditions, a river profile shows no degradation or aggradation and can be ideally described as a straight line on a semi logarithmic graph (Hack, 1973). However, practically rivers do not follow this theoretical postulation because the river longitudinal profile is inclined to actively respond to tectonic uplift through adjustments in slope (Synder et al., 2000; Seong et al., 2009). Moreover, the pattern of deviation, which is evaluated by gradient index (k), provides vital information on a variety of factors including riverbed lithology and drainage basin tectonics.

Using a digital elevation model (DEM), the channel profile for ~54 km stretch of Bringi stream was derived at a spatial resolution of 30m.The longitudinal profile of Bringi stream is shown in Fig. 5.9 which deviates from a simple concave-up form. The most marked feature of the profile is convex-up segment or knick zone developed at about 2600m. At this location the lithology is homogeneous, suggesting that lithology has no active role in developing the Knick zone. The other only explanation to this phenomenon is the influence of tectonics on Bringi stream.

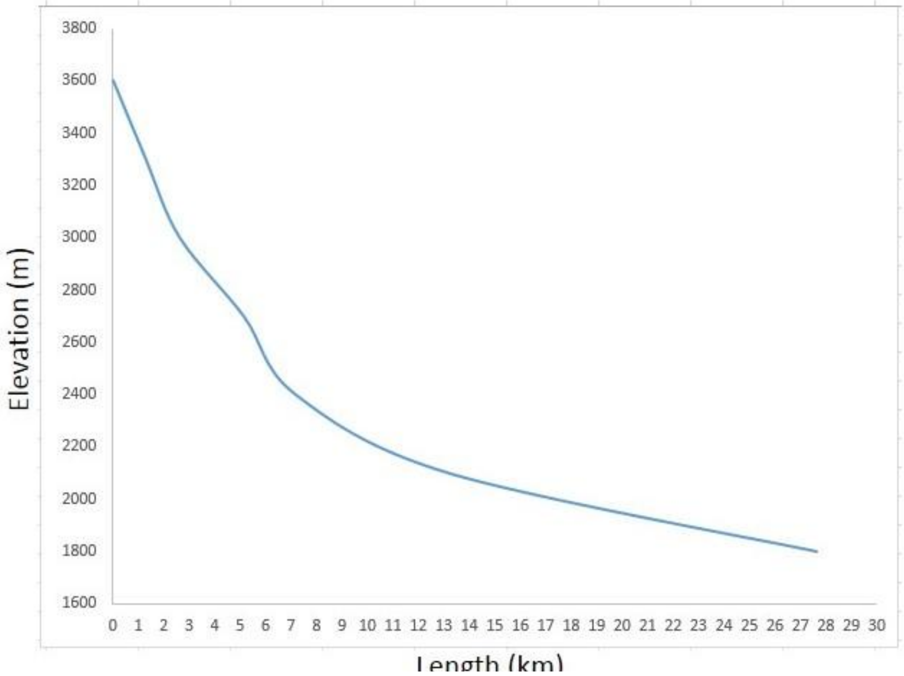


Figure 10: Longitudinal profile of Bringi stream

Valley-Floor Width to Valley Height Ratio:

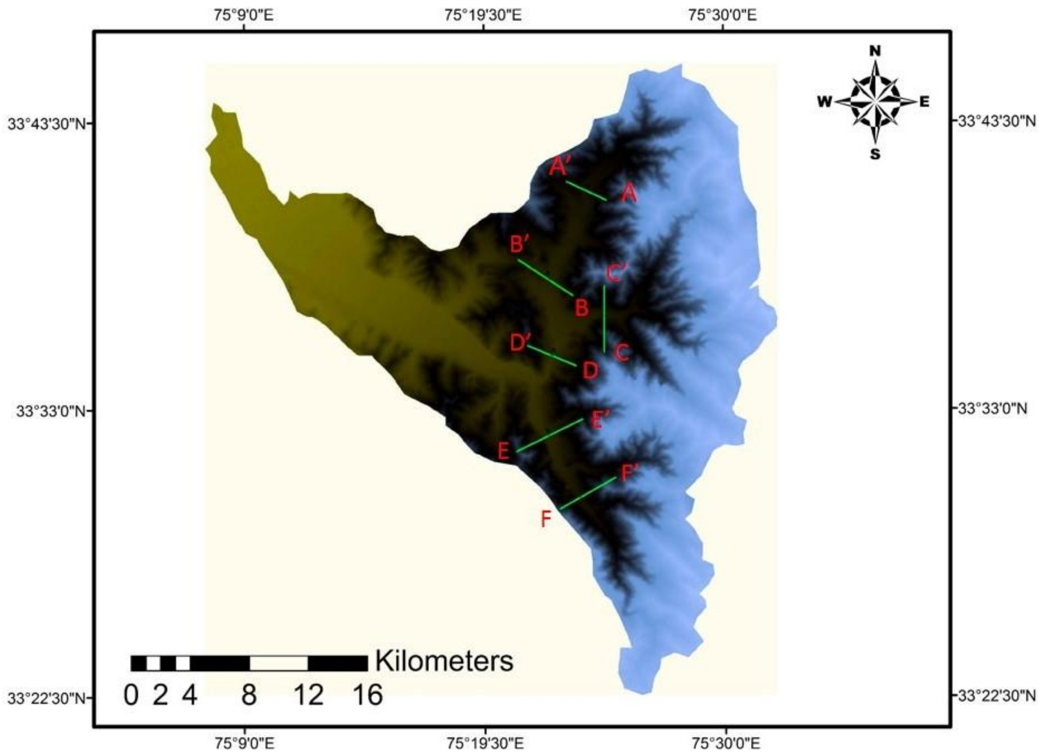


Fig.11. Showing how the ratio of valley-floor width to valley height for Bringi watershed has been calculated.

The ratio of valley floor width to valley height (Vf) may be expressed as:

$$Vf = 2Vfw / [(Eld-Esc) + (Erd-Esc)]$$

Where Vf is the valley-floor width to height ratio, Vfw is the width of valley floor, Eld and Erd are elevations of the left and right valley divides respectively, and Esc is the elevation of valley floor. This index differentiates between broad-floored canyons, with relatively high values of Vf and V-shaped valleys with relatively low values. Vf values <1.0 can be classified as V-shaped valleys with streams that are actively incising, commonly associated with uplift and Vf values between 1.0 and 1.5 indicates moderately active tectonics and Vf values >1.5 are classified as U-shaped valleys subjected to major lateral erosion (Bull &Mc Fadden).

The Vf values for the Bringi watershed has been calculated for six section lines namely AA', BB', CC', DD', EE', FF' (Fig. 5.10). The calculated values are 0.193, 0.501, 0.120, 0.290, 0.279, and 0.207 respectively. The left and right side of watershed is determined by looking downstream. The calculated values and profiles (Fig. 5.11) shows that majority of the basin is V-shaped, deeply incised, associated with upliftment which in turn reflects that basin is tectonically active.

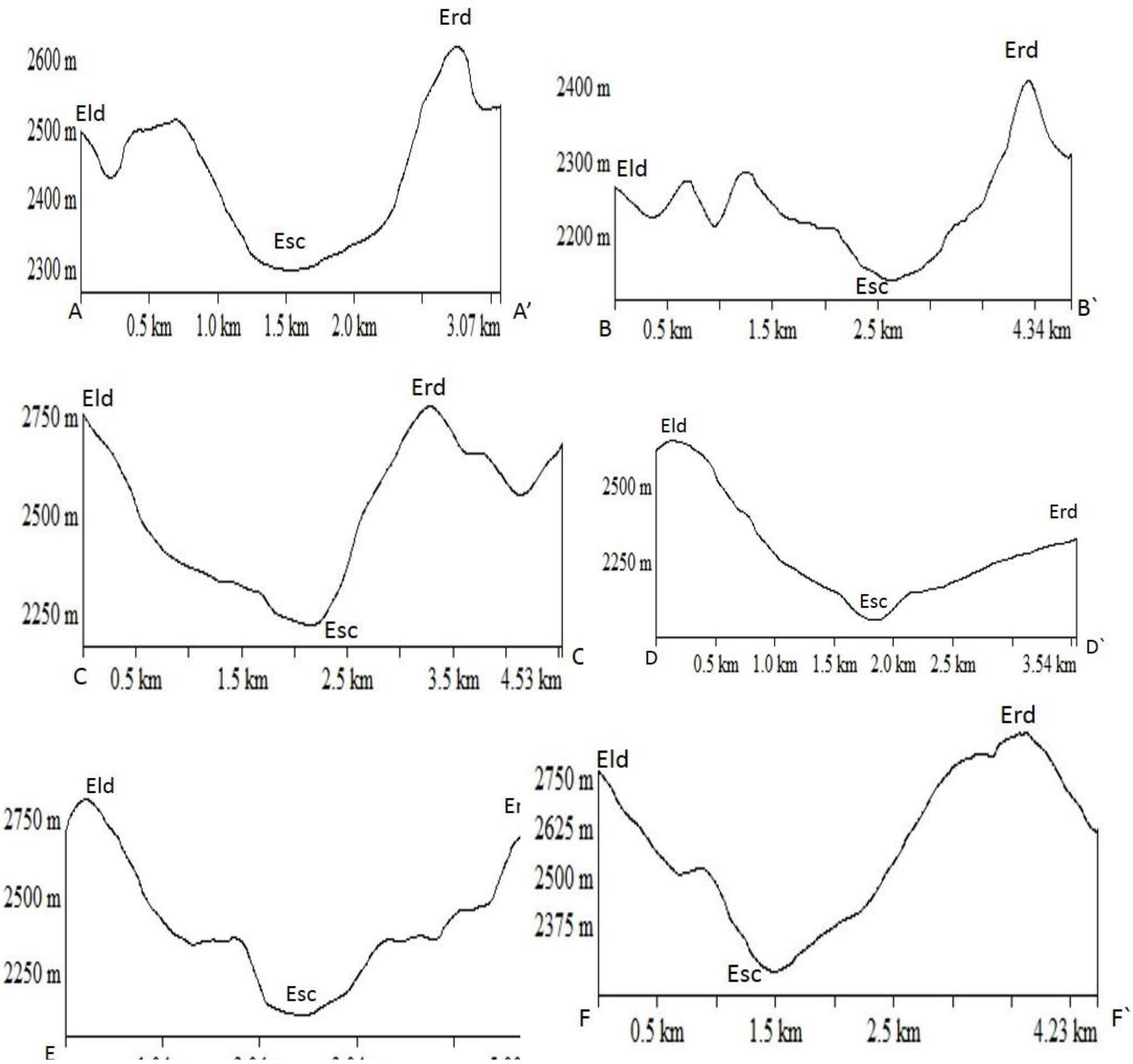


Figure 12: Cross section for transverse profiles (AA'- FF')

Transverse Topographic Symmetry Factor:

This is another quantitative index to evaluate basin asymmetry (T) and is given by:

$$T = D_a / D_d$$

Where D_a is the distance from the midline of the drainage basin to the midline of the active meander belt, and D_d is the distance from the basin midline to the basin divide. For a perfectly symmetric basin, T = 0. As asymmetry increases, T increases and approaches a value of 1. The transverse topographic symmetry factor (T) for the Bringi watershed has been calculated for fifteen locations (Fig.5.12). The calculated values are : 0.37, 0.24, 0.14, 0.27, 0.15, 0.11, 0.24, 0.25, 0.32, 0.13, 0.66, 0.53, 0.86, 0.16, 0.42 for locations a, b, c, d, e, f, g, h, I, j, k, l, m, n, o, respectively. So it is evident from the majority of values which ranges between 0.24to0.66 that the area shows asymmetry.

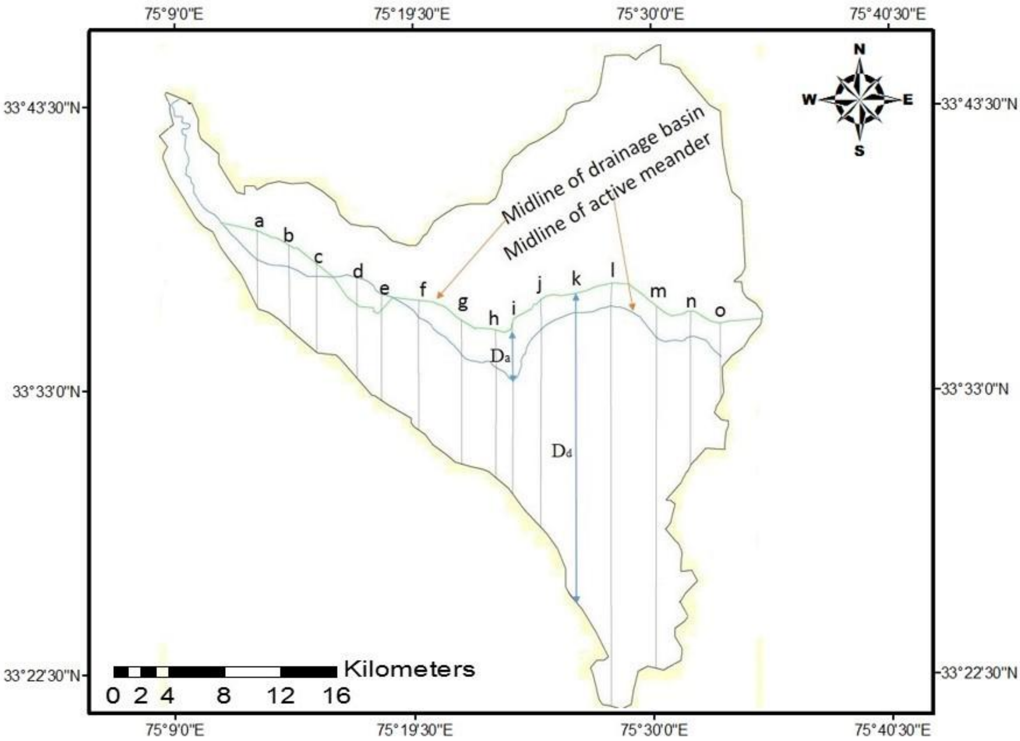


Figure 13: Showing calculation of Transverse topographic symmetry.

Conclusion:

The Bringi watershed of Kashmir Valley has been studied to understand its morpho- tectonic evolution on the basis of Morphotectonic and geomorphic indices complemented and validated with extensive field observations, as rivers are one of the most important landforms on the ground that are extremely sensitive to tectonic movements and also they are the fundamental units of fluvial landscape. The geomorphic indices has been calculated by the use of topographic maps, digital elevation model, satellite images and aerial photographs. The landform study analysis us to determine the impact of tectonics in the development of lineaments, erosion processes and consequent drainage development. The analysis and calculation of Morphotectonic and Morphometric parameters viz Mountain front sinuosity (Smf), Sinuosity index (Si), Hypsometric integral (Hi), Drainage basin asymmetry or Asymmetric factor (AF), Stream length gradient index (SL), River profile (H), Transverse topography symmetry, and Valley-floor width to Valley height ratio (Vf) , Circulatory ratio (Rc), Elongation ratio (Re), Bifurcation ratio (Rb) along with field observations shows that the Bringi watershed is strongly elongated and is tectonically active. The results of bifurcation ratio show that basin has experienced less structural complexity and differential uplift rates associated with tectonic uplift. The low Mountain front sinuosity value and high Stream length gradient index values and the presence of Knick point at the SL value of 1170 on the longitudinal profile of stream which is developed not because of lithology change as the lithology at that area is same but has developed because of tectonics which shows that the watershed has steep slopes and its formation is controlled largely by tectonic activity rather than erosion. The observed values of AF in the area shows widespread drainage basin asymmetry related to tectonic tilting. Area elevation analysis or hypsometry is a powerful tool for differentiating tectonically active regions from inactive ones. Hypsometric integral is related to the degree of dissection of a landscape. The calculated hypsometric integral value for the study area is 0.46, which is on the higher side indicating that the area is in youthful stage with high topography and incised streams thus suggesting that the area is tectonically controlled.

Overall assessment of the morphometric and Morphotectonic analysis revealed that the tectonic uplift, lithology and climate forcing played a significant role in the landscape evolution of the Bringi stream and the area has experienced differential uplift and erosion rates from time to time in the geological past.

References:

1. Abrahams, A. 1984. Channel networks, a geomorphologic perspective.
2. Agarwal, C.S. 1998. Study of drainage pattern through aerial data in Naugarh area of Varanasi district, U.P, Journal of Indian Society of Remote Sensing, 26, 169-175.
3. Agarwal, D.P. Dodia, R. Kotlia, B, S. Razdan and H.A. Sahni, 1989. The Plio- Pleistocene Geologic and Climate record of the Kashmir Valley.

4. Bhat, D. K. 1989. Lithostratigraphy of the Karewa Group, Kashmir Valley.
5. Bhat, D. K. 2003. Stratigraphy of Kashmir Valley basin-implication for Quaternary Glaciation in the Himalaya.
6. Bhatt D. K. Jamwal K. S. 1973. Geology of the parts of the Pir Panjal Range between Kousar Nag Nala and Riambiara River, Anantnag, distt. Jammu and Kashmir State. Progress Report for Field Season. pp 1-10.
7. Bhatt D. K. 1975. On the Quaternary geology of the Kashmir Valley with special reference to stratigraphy and sedimentation. Geological Survey of India, Miscellaneous Publications 24: 188-204.
8. Bhat, M. I. and Zain Uddin, S. M. 1978. Geochemistry of the Panjal traps of Mount Koyal, Lidderwat, Pahalgam, Kashmir.
9. Bhat, M. I. 1982. Thermal and tectonic evolution of Kashmir basin vis-à-vis petroleum prospects.
10. Bloom, A. L. 1979.Geomorphology.
11. Bull, W.B. 1977. Tectonic geomorphology of the Mojave Desert: Mentopark, California, U.S.
12. Bull, W.B. 1978. Geotectonic activity classes of the south front of the San Gabriel Mountains, California.
13. Bull, W.B. and McFadden, L.D. 1977. Tectonic geomorphology north and south of Garlock Fault, California.
14. Burbank, D.W. and Johnson, G.D. 1982. Intermontane-basin development in the past 4 Myr in the north-west Himalaya.
15. Burbank, D.W. 1983. The chronology of intermontane-basin development in the northwest Himalaya and the evolution of the Northwest Syntaxis.
16. Burbank, D.W. and Anderson, R.S. 2001. Tectonic Geomorphology.
17. Burnett, A.W. and Schumm, S.A. 1983. Alluvial river response to neotectonic deformation in Louisiana and Mississippi.
18. Cuong, N.Q and Zuchiewicz, W.A. 2001. Morphotectonic properties of the Lo River Fault near Tam Dao in North Vietnam.
19. Dar, A. Reyaz, R. Chandra and S. A. Romshoo, 2013. Morphotectonic and Lithostratigraphic Analysis of Intermontane Karewa Basin of Kashmir Himalayas, India
20. Dar, G. M. 1990. Morphometric studies of Sukhnag Drainage basin, M. Phil Dissertation (unpub.), Kashmir University, Srinagar.
21. Datta, N. K. 1983. Geology, Evolution and Hydrocarbon prospects of Kashmir Valley.
22. Demoulin, A. 1998. Testing the tectonic significance of some parameters of longitudinal profiles.
23. Duvall, A., Kerby, E. and Burbank, W. 2004. Tectonic and lithologic controls on bedrock channel profiles and processes in coastal California.
24. Gardner, T. W., Bullard, T. F., et. al. 1987. Geomorphic systems of North America.
25. Geological Survey of India 1989. Stratigraphic sequence of rocks exposed in Kashmir.
26. Gregory KJ, and Walling DE. 1973. Drainage basin form and process a geomorphological approach. Arnold, London.
27. Gupta, V. j. 1973. Indian Paleozoic stratigraphy.
28. Hack, J.T. 1957. Studies of Longitudinal profiles in Virginia and Maryland U.S. Geological Survey Professional Paper, 294 (B), 45-97.
29. Hack, J.T. 1973. Stream profile analysis and stream- gradient index.
30. Hare, P. W., and Gardner, T. W., 1985. Geomorphic indicators of vertical neotectonism along converging plate margins, Nicoya Peninsula Costa Rica.
31. Holbrook, J. and Schumm, S. A. 1999. Geomorphic and sedimentary response of rivers to tectonic deformation.
32. Horton, R. E. 1932. Drainage basin characteristics, Trans. Aer. Geophy. Union, 13, pp 35036 http: //www.gisdevelopement.net.
33. Horton, R.E. 1945, Erosional development of streams and their drainage basins.
34. Hovius, N. 2000. Macro scale process systems of mountain belt erosion, Geomorphology and Global Tectonics.
35. Hussain, M. 2006. Geography of Jammu and Kashmir.
36. Kaul, M.N. 1994. Late Quaternary Glacial and Climatic history of the Lidder valley, Kashmir Himalaya.
37. Keller, E.A. 1977. Adjustment of drainage to bedrock in regions of Contrasting Tectonic framework.
38. Keller, E.A. 1986. Investigation of active tectonics: use of surficial earth processes.
39. Keller, E.A. and Pinter, N. 1996. Active tectonics: Earthquakes, uplift and Landscape.
40. Keller, E.A. and Pinter, N. 2002. Active tectonics: Earthquakes, uplift and Landscape (second edition).
41. Krishnan, M. S. 1982. Geology of India and Burma.

42. Leopold, L. B. and Maddock, Jr. T. 1953. The hydraulic geometry of stream channels and some physiographic implications.
43. Mackin, J.H. 1948, Concept of the graded river.
44. Malik, M. I; Bhat, M. S and Kuchay, N. A: Watershed based drainage morphometric analysis of Lidder catchment in Kashmir Valley using GIS.
45. McCalpin, J. P. 1996. Paleo seismology.
46. McMohan, C. A. 1877. The Blaini Group and Central Gneiss in the Simla Himalaya.
47. Meher-Homji, V.M. 1971. The climate of Srinagar and its variability.
48. Melton MA (1958) A derivation of Strahler's Channel-ordering system. Jour. Geol.67:345-346
49. Middlemiss, C.S. 1896. The Geology of Hazara and Black mountains.
50. Middlemiss, C.S. 1910. A revise of the Silurian-Triassic sequence in Kashmir.
51. Pidwirny, M. 2006. Stream Morphometry. Fundamentals of Physical Geography, 2nd Edition.
52. Pike, R.J. and Wilson, S.E. 1971. Elevation relief ratio, hypsometric integral and geomorphic area-altitude analysis.
53. Pinter, N. 2005. Applications of tectonic geomorphology for deciphering active deformation in the Pannonian Basin, Hungsry.
54. Raina. 1971. Geography of Jammu and Kashmir.
55. Raza, M; Ahmad, A. and Mohammad, A. 1978.The Valley of Kashmir.
56. R. T. 1994. Analysis of drainage basin asymmetry as a rapid technique to identify areas of possible Quaternary tilt-block tectonics: an example from the Mississippi embayment. Geological Society of American Bulletin, 106: 571-581.
57. Schumm, S.A. 1956. Evolution of drainage systems and slopes badlands at Perth Amboy.
58. Schumm, S.A. 1977. The Fluvial System.
59. Seeber, L. and Gornitz, V. M. 1983. River profiles along the Himalayan are as indicators of active tectonics.
60. Singh, N. (1990). Geomorphology of Himalayan rivers (a case study of Tawi basin), Jay Kay Book House, Jammu Tawi.
61. Singh S and Singh MC. 1997. Morphomertric Analysis of Kanhar River Basin. National Geographical Jour. of India 43 (1):31-43
62. Strahler, A. N. 1952. Hypsometric (area-altitude) analysis of erosional topography.
63. Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology, Transactions- American Geophysical Union, 38, 913-920.
64. Strahler, A.N.1958. Dimentional analysis applied to fluvial eroded landforms.
65. Strahler, A. N. 1964. Quantitative geomorphology of drainage basins and channel networks, Handbook of Applied Hydrology, 39-76.
66. Sukumar B, Ahalya Sukumar 2013. Morphometric and Terrain analysis of Payaswani River Basin of Kerala and Karnataka States using GIS. International journal of geomatics and geosciences Volume 4, No 2, 2013.
67. Wadia, D. N. 1931. The syntaxis of the north-west Himalaya. Its rocks, tectonics and orogeny.
68. Wadia, D. N. 1941. Pleistocene Ice age deposits of Kashmir.
69. Wadia, D. N. 1961. The geology of India.
70. Wells, S., Bullard, T.et. al. 1988. Regional variations in tectonic geomorphology along segmented convergent plate boundary.