Morphometric Analysis for the Neotectonic Evaluation of the Pein River Basin, Lower Subansiri district, Arunachal Pradesh, India

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Abstract

The Pein River, in the Lesser Himalaya of Arunachal Pradesh, is a sixth order stream indicating strong tectonic control. The morphometric analysis of the Pein River basin (PRB) has been carried out using IRS ID-LISS III and PAN images and topographical maps of the area. Slope and relief aspects of the area have been studied by Digital Elevation Models using ARC VIEW 3.2 and ERDAS 8.5 softwares. The morphometric analyses of the basin points out that the drainage configuration is conspicuously controlled by tectonic design of the region.

The study indicates that elongated shape of the basin, high bifurcation ratio, parallel drainage and high drainage textures are the result of geomorphic adjustment of river channels in response to ongoing tectonic activity along the thrusts and faults of the area. The drainage also shows straight stream segments, right angle offsetting, triangular facets and asymmetrical terraces indicating evidences of neotectonic activities. Lineament analysis indicates the three prominent trends viz. NW-SE, E-W and ENE-WSW. It is postulated that the active tectonics in the region is related to its close proximity to the NE Himalayan Syntaxial bend.

Introduction

The study area forms an E-W elongated basin of the Pein River in Lower Subansiri district of Arunachal Pradesh. The confluence of the Pein river with the Kamla river is at Tamen which is located approximately - 50 km Northeast of the Ziro. The Major part of the basin is constituted of the lesser Himalayan rocks. Based on distribution of annual rainfall, three distinct climatic divisions have been identified in the Arunachal Himalaya. The Upper Himalayas near the Tibetan border comes under an Alpine or Tundra type climate, the Middle Himalaya comes under temperate type climates, areas at the Sub Himalaya experience a humid sub-tropical climate, with hot summers and mild winters. The state receives a heavy rainfall during the months of May to September. The mean annual rainfall is 2000 mm to 4000 mm. The Pein river basin (PRB), covering an area of about 387 km^2 falls in Survey of India toposheet (SOI) nos. 83E/10, 83E/14, 83F/01 and 83F/02. In turn, it is constituted of two tributary basins known as the Pein Tributary Basin (PnTB) and Pingo Tributary Basin (PgTB) having an area of around 213 and 130 km^2. Morphometric analysis of the Pein River Basin (PRB) has been carried out using SOI toposheets and IRS ID - LISS-III and PAN data (Path/Row 112/52 and 113/52).

The drainage network of the basin has been digitized and quantitative analysis of the morphometric parameters of the basin viz. stream number, stream length, basin area, perimeter, basin length etc. have been determined using ARC VIEW 3.2 software.

Morphometric parameters

The development of a drainage network depends upon the underlying geology, precipitation, exogenic and endogenic forces operating in the area. For each tributary

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basin, the different morphometric parameters have been calculated and divided into three categories i.e. - the linear, areal and shape parameters. The PnTB and PgTB have further been divided into 18 sub-basins and 16 sub-basins respectively for the purpose of morphometric analysis. Accordingly, these have been referred as Pein sub-basin 1, 2, 3, ... and Pingo sub-basin 1, 2, 3, ...

Linear Parameters

A number of linear parameters have been evaluated

Stream order

All the streams of the sixth order PRB have been ranked according to the Strahler's (1964) stream ordering system and the number of streams of each segment (Nu) is presented in Table 1 & 2. The stream order analysis shows that the PnTB and the PgTB are fifth and sixth order basins respectively.

Stream Length

Horton's law (Horton, 1932) of stream lengths supports the theory that geometrical similarity is preserved generally in the basins of increasing order (Strahler, 1964). The stream length depends up on the number of lower order stream and basin length. In the PnTB, the sub-basins 1, 2 and 3 have a higher number of first order streams than the other sub-basins so the total stream length within these sub-basins is higher. Similar conditions are noticed in the PgTB, the sub-basins 1, 2 and 3 have a higher number of first order streams (Table 1 & 2).

Stream Length Ratio (Rl)

The stream length ratios of the drainage basin of the study area have been calculated (Horton, 1945). The values of length ratio for the sub-basins of PnTB vary from 1.26 to 5.27 and for the sub-basins of PgTB, it ranges from 0.94 to 2.96 (Table 1 & 2). Rl between

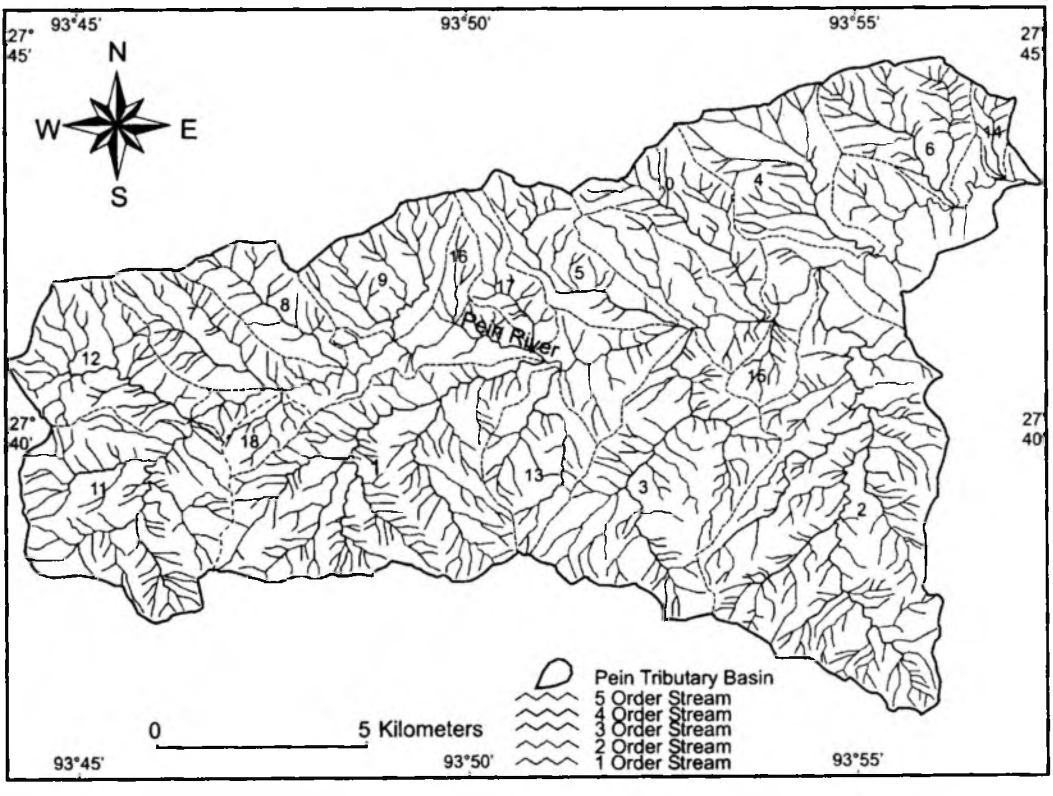

Fig. 1: Sub-basins in Pein river, Arunachal Pradesh

Table 1: Linear aspects of the Pein Tributary Basin (PnTB)

S. no.	Stream order					Total no. of Stream (Nu)	Bifurcation Ratio				Stream Length (Km)					Length Ratio				Mean Rb	Mean Rl	RHO Rl/Rb
	N_1	N_2	N_3	N_4	N_5		N_1/N_2	N_2/N_3	N_3/N_4	N_4/N_5	L_1	L_2	L_3	L_4	L_5	L_2/L_1	L_3/L_2	L_4/L_3	L_5/L_4			
1	129	28	5	1		163	4.60	5.6	5		60.63	20.20	11.68	6.51		1.53	3.23	2.79		5.06	2.51	0.49
2	164	31	8	1		204	5.29	3.87	8		81.83	24.68	13.11	12.6		1.61	2.06	7.73		5.72	3.8	0.66
3	77	20	3	1		101	3.85	6.66	3		42.04	13.38	4.94	4.98		1.22	2.48	3.03		4.50	2.24	0.49
4	26	8	3	1		38	3.25	2.66	3		14.56	8.23	3.26	2.81		1.82	1.05	2.60		2.97	1.82	0.61
5	22	6	1			29	3.66	6			11.84	3.37	5.32			1.05	9.5			4.83	5.27	1.09
6	42	7	2	1		52	6	3.5	2		20.08	4.93	4.90	0.57		1.48	3.5	0.23		3.83	1.73	0.45
7	26	5	1			32	5.2	5			12.90	5.16	2.73			2.10	2.65			5.1	2.37	0.46
8	19	4	1			24	4.75	4			10.65	1.97	3.14			0.87	6.40			4.37	3.63	0.83
9	25	7	2	1		35	3.57	3.5	2		13.71	8.28	3.15	0.51		2.18	1.33	0.32		3.02	1.27	0.42
10	29	5	1			35	5.8	5			16.77	4.15	4.21			1.45	5.07			5.4	3.26	0.60
11	74	18	5	2	1	100	4.11	3.6	2.5	2	46.15	9.39	4.63	4.00	1.53	0.83	1.76	2.17	0.76	3.05	4.95	1.62
12	38	11	3	1		53	3.45	3.66	3		18.97	8.62	1.29	3.61		1.59	0.55	8.39		3.37	3.51	1.04
13	21	4	2	1		28	5.25	2	2		10.88	2.82	3.89	1.29		1.37	2.77	0.66		3.08	1.60	0.51
14	8	2	1			11	4	2			3.59	0.53	1.66			0.59	6.38			3	3.48	1.16
15	8	2	1			11	4	2			4.20	0.98	0.78			0.94	1.59			3	1.26	0.42
16	5	2	1			8	2.5	2			2.91	1.05	0.95			0.89	1.82			2.25	1.35	0.60
17	13	3	1			17	4.33	3			6.88	1.99	1.39			1.26	2.10			3.66	1.68	0.45
18	9	3	1			13	3	3			3.89	2.05	0.77			1.58	1.13			3	1.35	0.45

Table 2: Linear aspects of the Pingo Tributary Basin (PgTB)

S. no.	Stream order					Total no. of Stream (Nu)	Bifurcation Ratio				Stream Length (Km)					Length Ratio				Mean Rb	Mean Rl	RHO Rl/Rb
	N_1	N_2	N_3	N_4	N_5		N_1/N_2	N_2/N_3	N_3/N_4	N_4/N_5	L_1	L_2	L_3	L_4	L_5	L_2/L_1	L_3/L_2	L_4/L_3	L_5/L_4			
1	98	19	5	1		123	5.15	3.8	5		47.12	13.23	8.16	6.22		1.43	2.36	3.81		4.65	2.53	0.54
2	65	12	3	1		81	5.41	4	3		32.51	6.95	5.05	2.83		1.14	2.94	1.68		4.13	1.92	0.46
3	132	29	10	2	1	174	4.55	2.9	5	2	62.83	18.41	9.45	3.88	5.52	1.34	1.49	2.06	2.84	3.61	1.93	0.53
4	18	5	2	1		26	3.6	2.5	2		10.67	3.43	1.87	1.93		1.15	1.36	2.07		2.7	1.52	0.56
5	34	7	2	1		44	4.85	3.5	2		18.80	5.53	5.22	0.97		1.43	3.30	0.37		3.45	1.7	0.49
6	15	4	1			20	3.75	4			8.57	2.74	2.24			1.19	3.29			3.87	2.24	0.57
7	49	10	3	1		63	4.9	3.33	3		21.57	6.11	3.81	1.67		6.01	2.08	1.31		3.74	1.59	0.42
8	17	3	1			21	5.66	3			7.60	2.09	1.22			1.56	1.76			4.33	1.66	0.38
9	9	3	1			13	3	3			4.44	2.58	2.43			1.75	2.82			3	2.28	0.76
10	11	3	1			15	3.66	3			6.70	1.52	0.72			0.83	1.44			3.3	1.13	0.34
11	9	2	1			12	4.5	2			4.83	1.48	0.37			1.39	0.50			3.25	0.94	0.28
12	16	3	1			20	5.33	3			7.66	2.83	1.32			2	1.40			4.16	1.70	0.40
13	11	2	1			14	5.5	2			5.99	1.65	0.51			1.51	0.62			3.75	1.06	0.28
14	9	3	1			13	3	3			3.51	1.87	2.70			1.58	4.35			3	2.96	0.98
15	6	2	1			9	3	2			3.10	2.59	0.28			2.52	0.21			2.5	1.36	0.54
16	8	2	1			11	4	2			3.90	2.05	0.32			2.12	0.31			3	1.21	0.40

successive stream orders varies due to differences in slope and topographic conditions, and has an important relationship with the surface flow discharge and erosional stage of the basin.

Bifurcation Ratio (Rb)

This parameter expresses the ratio of the number of streams of any given order (N_1, N_2) to the number in the next order (N_1+1, N_2+1) (Horton, 1945). In the PnTB, the mean Rb of the sub-basins varies from 2.25 to 5.72. The mean Rb of the PnTB is 5.76 and for the PgTB is 4.26. Lower Rb with in the sub-basins 4, 9, 11, 13, 14, 15, 16, and 18 sub-basins of the PnTB and, sub-basins 4, 9, 14, 15 and 16 of PgTB are attributed to the characteristics of less structural disturbances which, in fact, has not distorted the drainage pattern. Whereas the higher Rb values within the sub-basins 1, 2, 3, 5, 7 and 10 of the PnTB and the sub-basins 1, 8 and 12 of the PgTB indicate high structural complexity and low permeability of the sub-surface strata.

RHO coefficient

This parameter defined by Horton (1945) as the ratio between the Stream length ratio (Rl) and the Bifurcation ratio (Rb); RHO = Rl / Rb. It is an important parameter that determines the relationship between the drainage density and the physiographic development of the basin, and allows the evaluation of storage capacity of the drainage network (Horton, 1945). It is influenced by climatic, geologic, biologic, geomorphologic and anthropogenic factors (Mesa, 2006). The RHO of the sub-basins of the PnTB is ranging from 0.42 to 1.62 (Table 1) and for the sub-basins of the PgTB varies from 0.28 to 0.98 (Table 2). The value of the RHO (> 0.67) is higher, so it will have higher hydric storage during flood periods and it attenuates the erosion effects during elevated discharge (Mesa, 2006).

Areal parameters

The area of the Pein River Basin (PRB) is

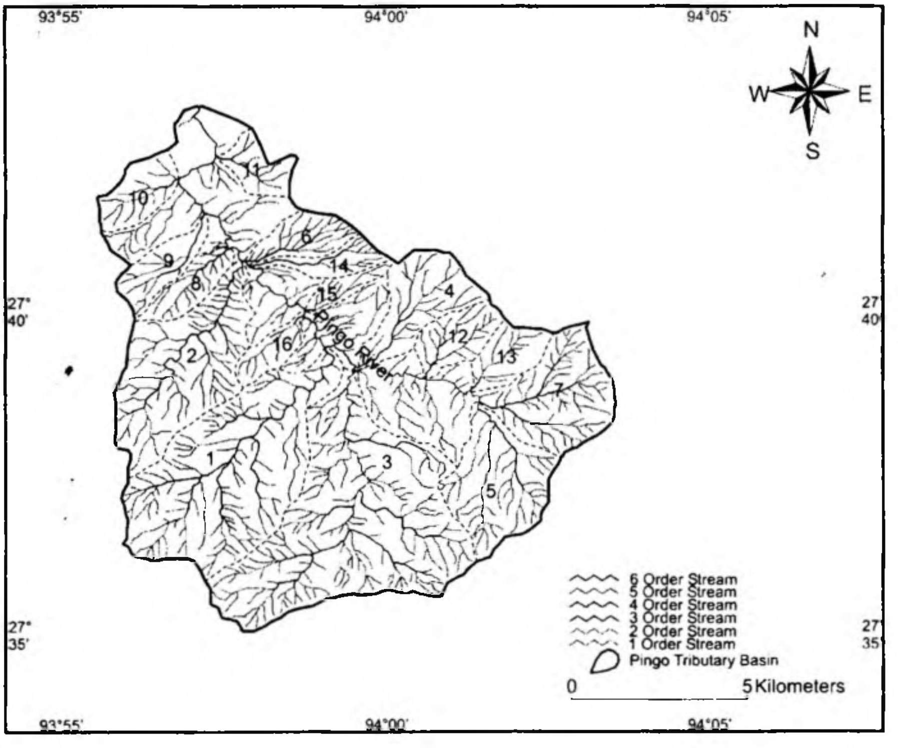

Fig. 2: Sub-basins in Pingo river, Arunachal Pradesh

386.53 km^2. The largest and the smallest sub-basin with in the PnTB are sub basin 2 (36.04 km^2) and sub-basin 14 (1.47 km^2) respectively. Similarly in PgTB, sub-basins 3 (26.64 km^2) and 15 (1.25 km^2) are the largest and smallest sub-basins respectively. The perimeter of the Pein River basin (PRB) is 100.69 km. Perimeter of the PnTB is 75.54 km and 62.06 km of the PgTB. The basin length corresponds to the maximum length of the basin and sub-basins measure parallel to the main drainage line. The basin length of the PnTB and PgTB is 24.28 km and 16.05 km respectively.

Drainage density (Dd)

The drainage density (Dd) is defined as the length of Streams per unit area divided by the area of the drainage basins. It is expressed as $Dd = Lu / A$, where, Lu = Lengths of all the ordered channels, A = Area of the Basin (Horton, 1932). Low drainage density exits in 4, 5, 8, 13, 16 and 17 sub-basins of the PnTB and 10, 11 and 13 sub-basins of the PgTB, having highly permeable sub-surface material and are under dense vegetation cover and low relief (Table 3 & 4). In contrast, high drainage density values are observed in 1, 2, 6, 11 and 14 sub-basins of the PnTB and 6, 8 and 15 sub-basins of the PgTB. This may be due to the presence of impermeable sub-surface material, sparse vegetation and high relief.

Drainage texture (T)

The drainage texture (T) depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development (Smith 1950). It is expressed by the equation $T = Dd \times Fs$, where, Dd = Drainage density, Fs = Stream frequency. Smith (1950) has classified Drainage Texture into:

Coarse	($T \leq 4.0$)
Intermediate	($T > 4.0 < 10.0$)
Fine	($T > 10.0$)
Ultra fine	($T > 15.0$)

In the PnTB, the sub-basin 4, 5, 8, 9, 13 and 17 show fine texture while, other remaining sub-basins shows the ultra fine (bad land topography) texture. In the PgTB, the 3 sub-basins (4, 10 and 13) show fine texture while, remaining 15 sub-basins show ultra fine (bad land topography) texture. The soft or weak rocks unprotected by vegetation produce a fine texture, whereas massive and resistant rocks cause coarse texture. The drainage texture has a maximum value of 29.39 for the PnTB while it is 38.13 for the PgTB. These indicate ultrafine texture and thus dominant neotectonic activity in the area.

The significance of a stream network has been recognized based on Dd, Fs and T, which are sensitive parameters that provide the link between the form attributes of the basin and processes operating along the stream course. These parameters serve as valuable indices, which reflect the topographic, lithological, pedological and vegetational controls (Sreedevi et al., 2005).

Shape parameters

Elongation ratio (Re)

Elongation ratio (Re) was defined by Schumm (1956) as the ratio between the diameter of a circle of the same area as the basin (D) and basin length (L). The Re is calculated by using $Re = D / L = 1.128 \sqrt{A / L}$. The elongation ratio of the PnTB and PgTB is 0.67 and 0.80 respectively. These values show that the PnTB basin is much elongated as compared to PgTB, highlighting structural control (Table 3 & 4).

Circularity index (Rc)

The circularity ratio (Miller, 1953; Strahler, 1964) is expressed as the ratio of the basin area (A) and the area of a circle with the same perimeter as that of the basin (P); $Rc = 4\pi A / P^2$, where, Rc = Basin circularity, P = Basin perimeter, A = Area of the basin and 4 is constant. The value of circularity index of the

Table 3: Areal and Shape aspects of the Pein Tributary Basin (PnTB)

S. No.	Area A (Km^2)	Total stream length (Lt. in Km)	Stream frequency Fs=Nu/A (Km^{-2})	Drainage density Dd=Lt/A (Km^{-1})	Texture T=Dd . Fs (Km^{-3})	Basin Length (Km.)	Form Factor A/L^2	Perimeter (km)	Elongation Ratio $Re=1.128\sqrt{A}/L$	Circularity index $Rc=4\pi A/P^2$
1	26.56	99.02	6.13	3.72	22.80	9.24	0.31	24.53	0.62	0.55
2	36.04	132.22	5.66	3.66	20.71	11.34	0.28	29.39	0.59	0.52
3	19.90	65.34	5.07	3.28	16.62	7.34	0.36	21.04	0.68	0.56
4	9.70	28.86	3.91	2.97	11.61	5.44	0.32	15.25	0.64	0.52
5	7.09	20.53	4.09	2.89	11.82	5.70	0.21	13.95	0.52	0.45
6	8.31	30.48	6.25	3.66	22.87	4.31	0.44	11.99	0.75	0.72
7	6.17	20.79	5.18	3.36	17.40	4.41	0.31	10.45	0.63	0.70
8	5.60	15.76	4.28	2.81	12.02	4.38	0.29	10.85	0.60	0.59
9	7.91	25.65	4.42	3.24	14.32	3.92	0.51	11.96	0.80	0.69
10	7.38	25.13	4.74	3.40	16.11	5.74	0.22	15.13	0.53	0.40
11	18.16	65.70	5.50	3.61	19.85	5.09	0.70	17.48	0.44	0.74
12	9.89	32.49	5.35	3.28	17.54	4.38	0.51	13.97	0.80	0.63
13	6.66	18.88	4.20	2.83	11.88	4.69	0.30	11.58	0.62	0.62
14	1.47	5.78	7.48	3.93	29.39	2.58	0.22	6.01	0.53	0.51
15	1.98	5.96	5.55	3.01	16.70	2.17	0.42	5.84	0.73	0.72
16	2.19	4.91	3.65	2.24	8.17	2.77	0.28	8.12	0.60	0.41
17	3.71	10.26	4.58	2.76	12.64	4.33	0.19	10.70	0.50	0.40
18	2.11	6.71	6.16	3.18	19.58	2.41	0.36	6.21	0.67	0.68

Table 4: Areal and Shape aspects of the Ping Tributary Basin (PgTB)

S. No.	Area A (Km^2)	Total stream length (Lt. in Km)	Stream frequency Fs=Nu /A (Km^{-2})	Drainage density Dd=Lt/A (Km^{-1})	Texture T=Dd . Fs (Km^{-3})	Basin Length (Km.)	Form Factor A/L^2	Perimeter (km)	Elongation Ratio $Re=1.128\sqrt{A}/L$	Circularity Index $Rc=4\pi A/P^2$
1	20.59	74.73	5.97	3.62	21.61	8.03	0.31	20.61	0.63	0.60
2	12.47	47.34	6.49	3.79	24.59	7.11	0.24	17.13	0.56	0.53
3	26.64	100.09	6.53	3.76	23.11	8.41	0.37	26.64	0.69	0.47
4	5.70	17.90	4.56	3.14	14.31	4.23	0.31	11.36	0.63	0.55
5	8.15	30.52	5.39	3.74	20.15	4.75	0.36	12.60	0.67	0.64
6	2.78	13.55	7.19	4.87	35.01	3.12	0.28	7.27	0.60	0.66
7	8.01	33.16	7.86	4.13	32.46	3.62	0.61	11.80	0.88	0.72
8	2.45	10.91	8.57	4.45	38.13	3.26	0.23	7.57	0.54	0.53
9	2.82	9.45	4.60	3.35	15.41	3.68	0.20	8.42	0.51	0.49
10	3.07	8.94	4.88	2.91	14.20	2.63	0.44	7.27	0.75	0.72
11	2.23	6.68	5.38	2.99	16.08	2.30	0.42	7.01	0.73	0.56
12	3.14	11.81	6.36	3.76	23.91	2.94	0.36	7.41	0.67	0.71
13	2.77	8.15	5.05	2.94	14.84	2.90	0.32	7.54	0.64	0.61
14	1.99	8.08	6.53	4.06	26.51	3.72	0.14	8.45	0.42	0.35
15	1.25	5.97	7.2	4.77	34.34	2.78	0.16	6.14	0.45	0.41
16	1.79	6.27	6.14	3.50	21.49	2.71	0.24	6.41	0.55	0.54

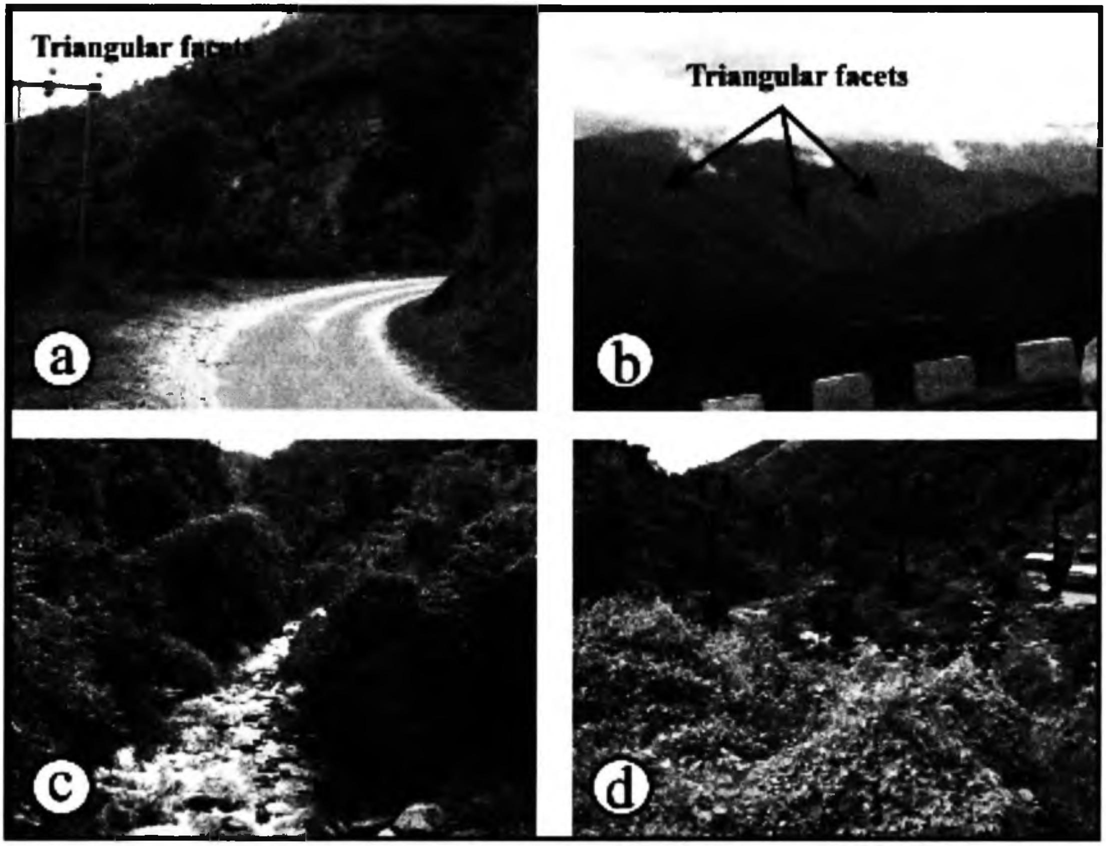

Fig. 3: a. Triangular facets, b. Series of triangular facets, d. Pingo River valley narrow near the confluence with Pein River and d. Asymmetrical Pein river terraces.

PnTB and PgTB is 0.46 and 0.61 respectively (Table 3 & 4).

Conclusions

It is observed that the PnTB is constituted of 735 first order streams, 166 second order streams and 42 third order streams. The bifurcation ratio between the first and second order and second and third order comes out to be 4.43 and 3.95 respectively. Similarly, the PgTB is constituted of 507 first order streams, 109 second order streams and 35 third order streams. For this, the bifurcation ratio between the first and second order and second and third order comes out to be 4.65 and 3.11 respectively. These values suggest the formation of higher number of lower order streams during recent geologic times, which in turn is attributed to the neotectonic activity in the area (Agarwal et al., 2007, 2008). Also, amongst the two tributary basins, the PgTB shows relatively higher bifurcation ratio values. High bifurcation ratio shows the area is neotectonically active.

Although the basin area of PgTB is less than the PnTB, however, the former is a sixth order drainage basin as compared to the fifth order of the latter. This shows that the Pein tributary basin PnTB is highly asymmetric. Similarly, the elongated Pein tributary basin with the trellis pattern stream reveals that the basin is highly faulted and thrusted. The dominance of ultrafine drainage texture within the PgTB as compared to PnTB suggests relatively higher neotectonic activity in the former tributary basin. This is also supported by the higher elongation ratio and circularity index for the PgTB. Offsetting in the Pingo river, its right angle turn and entrenchment of the river suggests a good structurally controlled river features attributed to neotectonism within the basin. Similarly, the presence of other geomorphic features viz. T1 and T2 terraces exposed along the left bank of Pein river, entrenchment of Pingo river and presence of triangular facets on the right bank of Pein river (Fig. 3) shows dominant neotectonic activity in the area.

Besides morphometric analysis, study of Lineament distribution pattern suggests the distribution of recent stress fields (Valdiya, 1986; Jain, 1987; Sharma, 1991). In the present area, the Pein River Basin (PRB) shows the dominance of three sets of lineaments trending NW-SE, E-W and ENE-WSW. The first two sets seem to have developed due to the NE-SW and N-S directed stresses. After the comparison of morphometric parameters and observing the lineament pattern, it seems that the area is structurally controlled and is possibly related to proximity of the basins to the prominent north eastern Himalayan Syntaxial bend.

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