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Drainage Basin Morphometric Analysis; A Case Study of Bhagirathi Valley between Maneri and Gangnani Area, District Uttarkashi, Garhwal Himalaaya, Uttarakhand, India

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Abstract

The area of investigation lies in central and lesser Himalayan block of Garhwal Himalaya along Bhagirathi river between Maneri and Gangnani area. Main Cnetral Thrust is the major tectonic unit separate rocks of Garhwal group from central crystallines. MCT passes near Sainj along Kumaltigad. Garhwal group comprises by quartzites, epidiorites, while central crystallines by scisht, gneisses, and amphibolites. For the purpose of drainage basin morphometric analysis 100 IIIrd order drainage basins were marked. The area was divided into three morphogenetic units viz. Central crystalline, Thrust zone and Garhwal group. Sixteen morphometric parameters of all drainage basins were measured and calculated.There average value and range for three morphogeneic regions were calculated. Drainage basin morphometric analysis of three zones was compared. For slope morphometry longitudinal profile of 8 major streams were drawn. Mean channel slope and slope ratio were calculated for streams of Central crystalline and Garhwal group. There values were compared. Although the valley side slope were modified by erosion, depositional process and by anthropogenic causes.

Keywords: Drainage Basin Moprphometric Parameters, Slope Morphometry, Central Crystallines, Thrust Zone, Garhwal Group, Longitudinal Profile, IIIrd Order Bifurcation ratio Basin shape.

Introduction

The study area is located between Maneri to Gangnani area along Bhagirathi river. Rishikesh to Gangotri highway connecting number of pilgrims center. Bhagirathi is the main River which originates from Gangotri glacier near Gaumukh. It flows NE-SW direction from Gangnani to Bhatwari and N-S from Bhatwari to Malla and again follow NE-SW direction up to Uttarkashi. It has carved out deep gorges at Bhukki. Large numbers of tributaries join Bhagirathi as Helgu gad, Din gad, Saundhar Gad, Kamar gad, Jalang gad, Andri gad, Paper gad, Nahar gad, Pilang gad and Maneri gad. The topographically the area is highly rugged with steep escarpment, high ridges and high relief which make it difficult terrain. The main ridges are Kalanti ki dhar, Amlo ki dhar, Goidhar, Lingu dhar, Kothidhar which act as water divider. The valley is v shape near Bhukki but at MCT it is U shape. Four hot springs are also located along NE-SW direction and their temperature increases towards NE direction. Due to climatic variation then water increases in river and as well as in channels which causes loss of property and life by toe erosion. Drainage pattern is mainly dendritic type because most of the tributaries join Bhagirathi at acute angles while other at right angle give rise trellis pattern Radial pattern observed at summit surfaces and parallel in at higher altitudes.

Aim of Study

The qualitative and quantitative analysis of Bhagirathi river drainage basin and the slope morphometry. The litho-structural control on morphometric parameters.The study is very useful for waterset management in the area

Methodology

Base map were prepared with the help of toposheet survey of India. Various lithological units identified and plotted on base map.Total 100 IIIrd order drainage basins were marked on topographic map for morphometric analysis. Linear measurements were measured with the help of rotameter and area by planimeter. The area was divided into three morphogenetic units based on lithology and structure...The area was divided into Central crystalline, Garhwal group and Thrust zone. Sixteen drainage basin morphometric parameters were calculated for 100 basins some morphometric parameters were measured directly like Number of Ist, IInd, IIIrd order streams.length of streams while others are calculated like basin shape, drainage density, length ratio. All the parameters were calculated as suggested by Horton (1913, 1945) and Doornkamp and King (1971). For slope morphometry longitudinal profile of 8 major streams were drawn and six breaks in the slope profile at different altitudes shows litho-structural control.All the morphometric parameters shows variation, suggest the litho- tectonic control on parameter.

Geological Setting of the Area

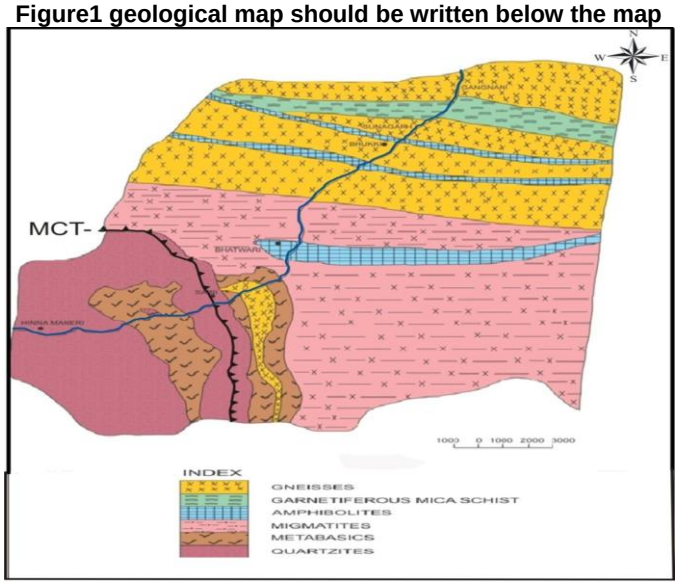
Geologically the study area lies in Geo-tectonic block of lesser and central part of Garhwal Himalaya. The Main Central Thrust is main structural feature passes near Sainj along Kumalti gad and Dgadda gad ie 20 kms from Uttarkashi along Uttarkashi-Gangotri road. It is dipping 50 to 60 degree N and follow NW-SE trend. Main Central Thrust separates the rocks of Garhwal group in south from the Central Crystalline in north. The rocks of Garhwal group mainly comprises of Quartzites, Limestones, Slates, Epidiorites, Mylonitic Quartzites and schistose quartzites while Central crystallines by Migmatites, Biotite schist, Garnetiferous Mica Schists and Amphibolites. Several Geologist worked on this part of Himalaya. Giesbach (1891) took the traverses in upper Bhagirathi valley. Heim & Ganser (1939) used the term Central crystallines. Jain (1971) Agarwal and Kumar(1973) worked on the lesser Himalayan region of the Uttarkashi area. Dave & Gupta (1982) worked on Petrology of Upper Bhagirathi valley. Saklani & Nainwal (1986) studied the migmatites of the Sainj area. Purohit& Thakur (1988) made attempt on geo-chemistry of upper Bhagirathi valley. Naithani (1992) studied the Quaternary sediments of Bhagirathi valley between Maneri and Gangnani area. Naithani and Bhatt (2011) made some observation on geo-hazards of Uttarkashi area. Litho Tectonic succession is shown in table-1, and geological map depicted in fig-1.

Table-1

Litho-Tectonic Succession of the Area.(After Jain(1971), Dave & Gupta (1982) and Naithani (1992)

CENTRAL CRYSTALLINES	Garnetiferous Mica Schists Amphibolites Banded Gneisses Augen Gneissess Foliated Gneisses Augen Gneisses Migmatites Mylonitic Migmatites Quartz Muscovite Schist Biotite Schist Quartz Chlorite schist Chlorite Schist
M—A—I—N---------C—E—N	T – R-- A – L--- T—H—R—U—S—T----------
GARHWAL GROUP	Schistose Quartzites Mylonitic Quartzites Epidiorite Gamri Quartzites

Figure1 geological map should be written below the map



Drainage Basin Morphometric Analysis

Drainage basin morphometry is the quantitative study of the drainage basin. A drainage basin is the area, which contribute water to the particular channels or set of channels. Third order drainage basins were marked as depicted in fig-2.The morphometric parameters their range and average value were measured and calculated as shown in table-2.

Table—2

Range and Average Value of Morphometric Parameters In Morphogenetic Regions

S.No.	Morphometric Parameter	Central Range	Crystalline Average	Thrust Range	Zone Average	Garhwal Range	Group Average
1	No of Ist order stream	4-44	11.2	5-29	13.6	4-33	16.4
2	No of IInd order streams	2-9	2.9	2-8	3.64	2-6	3.8
3	Basin Area (Sq Kms)	.56-15.1	2.68	1.1 -17.3	5.1	2.6-10.2	5.7
4	Length of Ist order stream Km	1.1-17	4.23	2.2-14.9	6.0	3.1-16.7	8.5
5	Length of IInd order stream Kms	.17-6.7	1.66	.7-3.67	1.76	.9-3.57	2.6
6	Basin Length Km	1.6-5.5	2.22	1.3-6.4	2.98	2.3-5.1	3.26
7	Basin Altitude Kms	2200-3800	3100	1900-2700	2200	1600-3200	1900
8	Basin Shape	.12-.96	.53	.14-.76	.38	.19-.40	.32
9	Bifurcation Ratio	2-6.6	3.68	2.5-8	4.09	2.2-6.6	4.09
10	Stream Frequency	.9=40.1	7.71	2.1-8.9	4.75	2.7-5.9	3.63
11	Stream Density	1.5-9.9	3.05	1.3-4.6	2.49	5.9-2.7	2.20
12	Drainage Texture	2.9-160.4	29	2.8-40.9	13.60	4.7- 16.4	8.51
13	Ruggedness Number	.1-6.8	1.65	.13-3.5	1.1	.27-.68	.42
14	Length Ratio	.7-5.8	2.7	1.7-5.8	3.65	2.6-4.4	3.28
15	Texture Ratio	.2-7.6	3.49	1.2-5.4	2.76	1.5-2.5	2.04
16	Relief Ratio	.12-1.2	.43	.28-.53	.39	.27-.43	.31

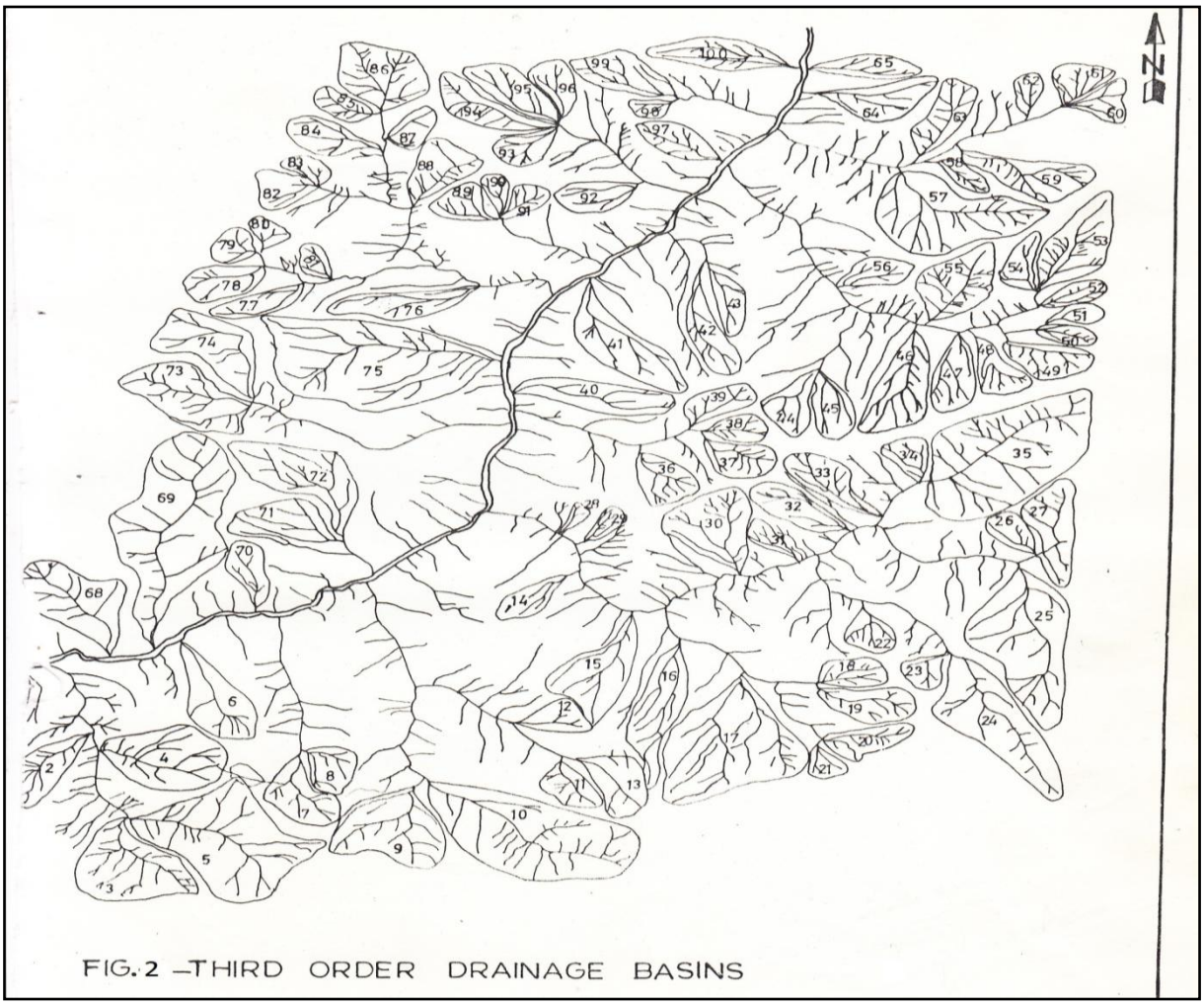


FIG. 2 –THIRD ORDER DRAINAGE BASINS

Measured Parameters

Frequency of first order is (44) in a basin is maximum in central crystallines zone as it receive maximum precipitation but average value is maximum in Garhwal Group followed by Thrust zone and Central crystallines. Larger basin is present in thrust zone but average value is high in Garhwal group followed by Thrust zone and Central crystallines. Longest Ist order stream is located in Central crystallines, but average value of length of first order stream is more in Garhwal Group followed by Thrust zone and Central crystallines. Longest IInd order stream is present in Central crystallines but average value is maximum in Thrust zone followed by Garhwal Group and Thrust zone and Central crystallines.

Calculated Parameters

Basin Shape is mainly influenced by lithology and structure and also altitude. Basin shape indicates that basins of Central crystallines are wider and thrust zone are elongated. The bifurcation ratio value is maximum in Thrust zone followed by Garhwal Group and Central crystallines. Variation in bifurcation ratio in central crystallines (2-6.6) is due to the structural and tectonic activities. It is due to the Main Central Thrust, Bhatwari fault and Gangori-Jamak fault. Stream frequency is the number of stream segment per unit area. Stream frequency is maximum in Central crystallines suggest high precipitation and snow fall in the area.

The value of stream density is higher in Central crystalline basin and average stream density is also maximum in Central crystallines the basins were fed by glaciated area. Higher value of stream density suggests fine texture. Ruggedness number which is a product of relief and drainage density. The average value of ruggedness number is maximum in Central crystallines followed by Thrust zone and Garhwal group. The average value of length ratio is maximum in Thrust zone followed by Garhwal group and Central crystallines. The average value of Texture ratio and Relief ratio is maximum in Central crystallines followed by Thrust zone and Garhwal group.

Slope Morphometry

The slope or inclination of a terrain in a fluvial landscape is the function of geology, structure and climate. The slope forms were also studied on the basis of field observation and the longitudinal profiles of various streams as suggested by Strahler (1964), various slope element were delineated as proposed by Doornkamp and King (1971).The longitudinal profile of 8 major streams were as shown in Fig3-5 and break of slope and their altitude has been shown in table -3

Table-3 Streams Altitudes and Break of Slope

Name of Stream	I--B	II--B	III--B	IV--B	V--B	VI--B
Maneri Gad	--	3000	2800	2400	==	1800
Kamar Gad	--	--	2800	--	--	1800
Dogadda Gada	--	3000	2800	--	2200	1600
Pilang Gad	--	3000	2800	2600	2200	1800
Kola Gad	3400	3000	--	2600	2200	--
Din Gad	3600	3000	2800	2400	--	--
Saundhar Gad	3600	3000	2800	2400	2000	----
Helgu Gad	3600	3000	2800	2400	2200	----

1. The first break in slope profile was found at an altitude of 3600 mtrs observed in Saundhar Gad, Kola Gad and Din Gad. Straight and steep slope indicate constant intensity of erosion.
2. The second break in the slope profile was found at 3000 to3200 mtrs in Saundhar Gad, Kola Gad, Helgu Gad, Dogadda Gad, Maneri Gad and Pilang Gad. In case of Kola Gad and Saundhar Gad the slope is concave while in case of Pilang Gad and Helgu Gad the slope is convex. This may be due to variable rate of erosion and morainic deposits.
3. Third break observed at an altitude 2800 mts. The slope is straight as in the case of Kamar gad, Maneri gad, Din gad and Dogadda gad. The slope is covex in the Helgu gad ansd straight concave in the case of Saundhar gad. The concave slope may be due to the declining intensity of erosion.
4. The fourth break is present in all the stream at an altitude of 2600 mts to 2400 mts. Slope is straight in the case of Dogadda gad, Mneri gad and Kamar gad this is due to the uniform rate of erosion.The slope approaching to concave in the case of Saundhar gad, Din gad, Kola gad, Helgu gad and Pilang gad due to the deposition of alluvial material.
5. The fifth break was at an altitude of 2200 mts in all the stream of Central crystallines. This may be due to tectonic disturbance .The slope is straight in the case of Din gad, Pilang gad and is convex in Saundhar gad, Kola gad and Helgu gad. Convex represents an uplift unconsumed summits.(Cunningh and Griba 1973).
6. The last break was found at an altitudes of 1600 to 1800 mtrs in Maneri ga, Dogadda gad and Kamar gad which is straight suggesting accumulation of scree material at low reaches.From all longitudinal profile it is clear that all the stream are steep and straight in the upper part and showing convexity in the summit surface then straight convex and concave in the lower reaches.

Channel Slope and Slope Ratio

For slope morphometry the slope profile or longitudinal profiles of 8 major streams were divided into segments of Ist, IInd, IIIrd, IVth Vth and VIth order. The average value of Channel slope and Slope ratio for the segments calculated as suggested by Strahler (1964) given in table -4.

Table-4 Channel Slope of Various Order of Major Streams

S.No.	Name of Stream	Stream Order					
		S-1	S-2	S-3	S-4	S-5	S-6
1.	Maneri gad	.72	.46	.22			
2.	Kamar gad	.57	.43	.26	.16	-	-
3.	Dogadda gad	1	.93	.4	.23	.16	
4.	Pilang gad	1	.72	.54	.10	.70	.64
5.	Kola gad	1.25	.83	.25	.20		
6.	Din gad	1.3	.4	.42	.22	.14	
7.	Saundhar gad	.67	.4	.26	.13	.13	.13
8.	Helgu gad	.49	.31	.47	.26	-	-

Table-5 Mean Channel Slope and Slope Ratio of Two Unit Stream

Stream Order	Central Mean Channel Slope	Crystallines Slope Ratio	Garhwal Group Meanchannel slope	sloperatio
S-1	.94	--	.76	---
S-2	.53	.56	.60	.86
S-3	.39	.66	.36	.60
S-4	.18	.46	.19	.52
S-5	.11	.61	.16	.84
S-6	.14	1.2	-	-

Out of 8 streams 5 falls in Central crystallines and 3 in Garhwal group. The value shows mean channel slope for Ist and IInd order stream is higher in Central crystallines while IIIrd,IVth and Vth order stream have higher value in Garhwal group .Channel and valley side slope provide gradient for water flow and debris transport in fluvial system. For valley side slope Crest slope ranges value between 3-5 degree. At crest the main process seen to be surface wash creep and removal by soil water. The mid slope is characterized by steep slope and rapid movement. The slope is of repose type. The steeper

part appears to be maximum slope segment of Young (cited by King1960). Foot

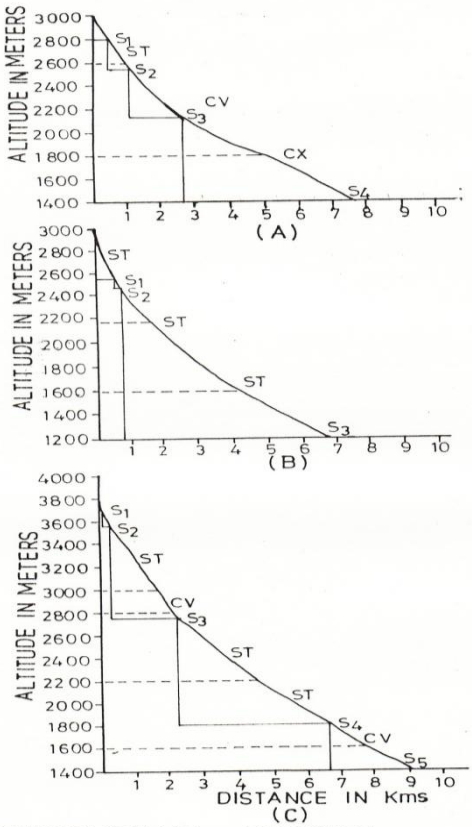


FIG. 3 -LONGITUDINAL PROFILE
(A) KAMAR GAD (B) MANERI GAD (C) DOGADDA GAD
(ST- STRAIGHT CX – CONVEX CV- CONCAVE)
S_1 – I ORDER STREAM, S_2 – II ORDER STREAM, S_3 – III ORDER STREAM,
S_4 – IV ORDER STREAM, S_5 – V ORDER STREAM.

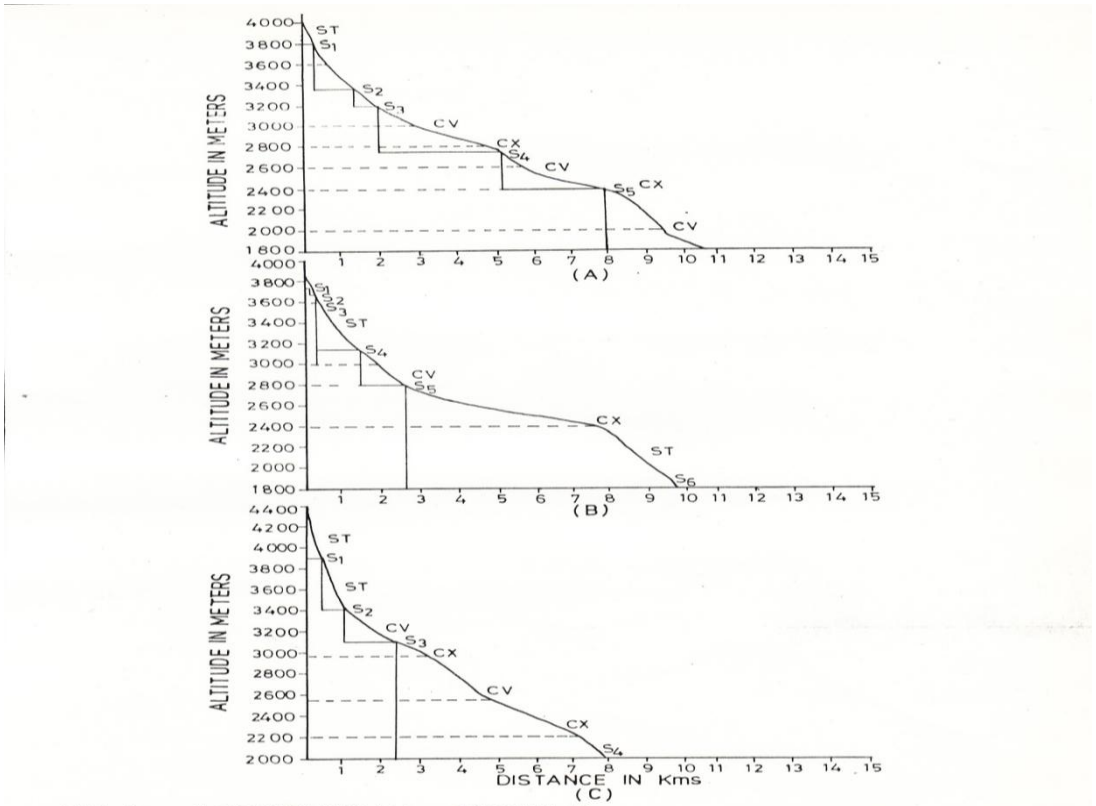


FIG. 4 – LONGITUDINAL PROFILE
(A) SOUNDHAR GAD, (B) DIN GAD, (C) KOLA GAD,
(ST – STRAIGHT, CX – CONVEX, CV – CONCAVE)
S_1 – I ORDER STREAM S_2 – II ORDER STREAM S_3 – III ORDER STREAM
S_4 – IV ORDER STREAM S_5 – V ORDER STREAM S_6 – VI ORDER STREAM

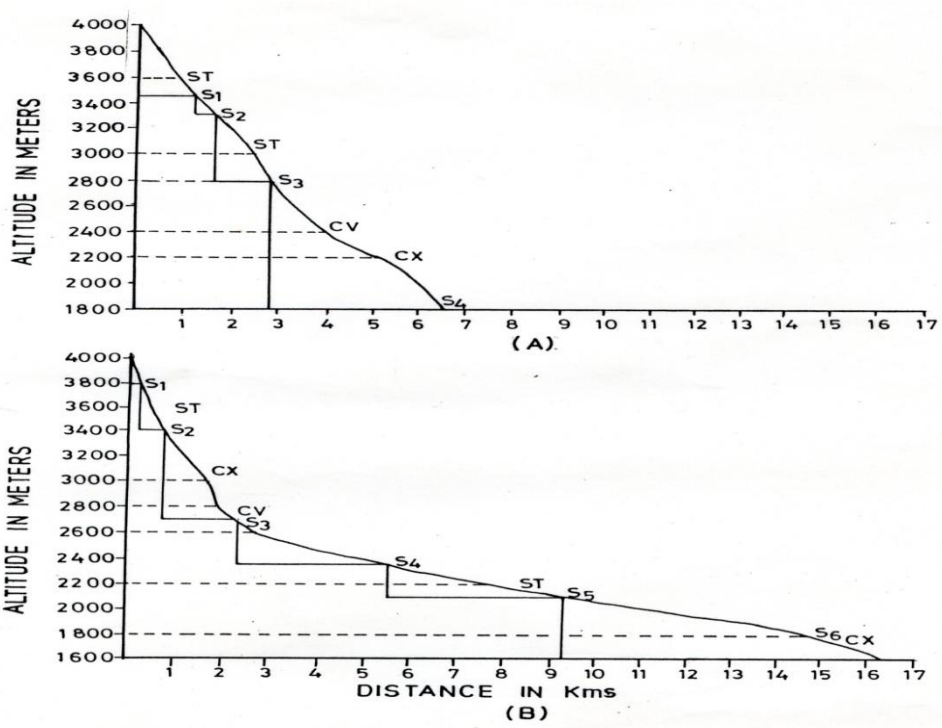


FIG. 5 –LONGITUDINAL PROFILE OF(A) HELGU-GAD,(B) PILANG-GAD
(ST – STRAIGHT, CV – CONCAVE, CX – CONVEX)
S_1 – I ORDER STREAM, S_2 – II ORDER STREAM, S_3 – III ORDER STREAM,
S_4 – IV ORDER STREAM, S_5 – V ORDER STREAM, S_6 – VI ORDER STREAM

Slope is generally concave appear to be accumulation of scree material and alluvial material.

Discussion and Conclusion

The presence of Ist order streams indicate newly emergent surfaces (Prasad1977). Nmbers of Ist order streams are maximum in Central crystalline .As area is fed by glacier and having higher altitudes. High stream frequency in Central crystallines indicate glacial activity in the area. (Selvan et al, 2011). The shape of the basin indicate condition of newly emergent surface surfaces. Wider basins are located at higher altitudes in Central crystallines while narrow and elongated basins are near Thrust zone suggesting the presence of subsequent surfaces along Thrust zone. Narrow and elongated basin in the Thrust zone is also due to Main central Thrust. Stream density is also higher at central crystallines suggest highly dissected with rapid hydrological character response to rainfall activity. The study conclude that Central crystalline zone is characterized by maximum number of Ist and IInd order stream, wider basins, high stream frequency, high ruggedness number high drainage texture. Thrust zone indicate elongated basin high bifurcation ratio and length ratio. Garhwal group drainage basin shows low stream frequency, low drainage texture and less rugged topography.

The slope morphometry indicates the presence of six breaks in most of trtibutaries. There is a major break at 2800 mts which suggests the presence of escarpment at Main Central Thrust .Study of slope analysis indicate the presence of cliff type slope in central crystalline area whereas in areas of Garhwal group the middle slope are of repose type, which suggest greater erosion and deposition in the south of Main central thrust.

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