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EMERGENCE OF REVERSE TREND IN DOON VALLEY

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The Bench Marks falling in the profile from Saharanpur to Mussoorie have been periodically observed since 1991, by first order levelling by N3 level with a view to know the seismo-tectonic status of Main Boundary Thrust (MBT) and Foot Hill Thrust in the vicinity of Dehra Dun, Garhwal Himalaya. The levelling data for the epochs (1861-62, 1903-04), 1905-07, 1926-28, 1974-77, 1991, 1992 and 1993-94 have been taken for this profile to analyse the stress pattern. The results of variations in levelled heights for these epochs are reported here. It is seen from the results that the process of release of stress started probably just before the Uttarkashi earthquake of 20th October 1991 and continued till 1992. However, stress is increasing again at alarming rate after release of energy in Mussoorie block of compressional regime between MBT and Main Central Thrust. The variations in levelled heights from Fatehpur (Saharanpur) to Rajpur (Dehra Dun) is not as large as in the domain of the Lesser Himalaya from MBT to Mussoorie. This shows that the stress is building up somewhere near Rajpur around MBT. During peak time this area might turn out to be a potential hazard in near future.

Key Words: Doon Valley; Bench Marks; Main Boundary Thrust; Foot Hill Thrust; Main Central Thrust; Lesser Himalaya; Earthquakes—Kangra and Uttarkashi

Introduction

The continued North North East (NNE) convergence of Indian plate under Eurasian (Tibet block) plate is seen from the geologically determined current Himalayan convergence rate of less than 2 cm per year and also confirmed recently from 1991-92 GPS observations across the Nepal Himalaya[1]. This continued movement and convergence generate stresses in the lithosphere. Building up of these stresses can be determined by studying the scientific data obtained through precise techniques. First Order Precision Levelling Technique has been utilised here to study the seismotectonic process in Doon Valley, Garhwal Himalaya (Fig. 1). This type of study also enhances the importance of earthquake risk mitigations programme in the mountains and in its contiguous plains.

Observations

Doon Valley is located south of Main Boundary Thrust (MBT) in Garhwal Himalaya as shown in Fig. 2. This figure also shows tectonic feature in and around Doon Valley. Major Central portion of Doon Valley is occupied by Doon gravels, north portion beyond MBT upto Main Central Thrust (MCT) by Lower Himalayan rocks and south portion by Shiwalik rocks.

A precise level line from Saharanpur to Mussoorie across two faults—one Foot Hill Thrust (FHT) and the other—MBT, has been repeated a number of

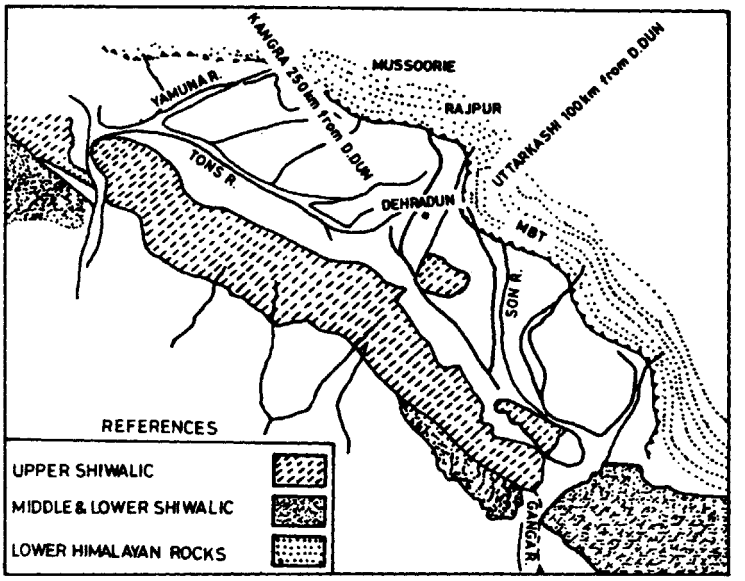

Fig 1 Tectonic map of Dehradun Valley (After Nakata 1972)

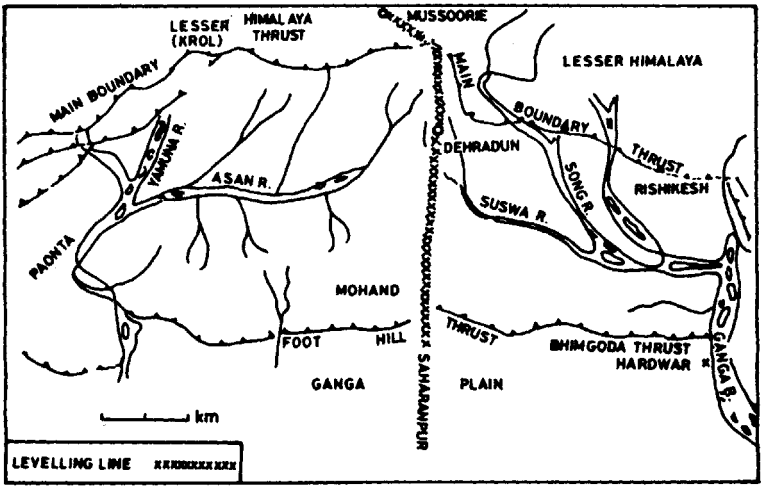

Fig 2 Tectonic features in and around Doon Valley

times since 1861. First 71 km of levelling was carried out in the year 1861-62 from Saharanpur to Dehra Dun which was further extended by about 40 km up to Mussoorie in the year 1903-04.

The entire line from Saharanpur to Mussoorie was relevelled during 1905-07 after Kangra earthquake of 4th April 1905 and there after during 1926-28, 1974-77, 1991 and again after Uttarkashi earthquake of 20th Oct., 1991, during 1992 and 1993-94 field seasons. However, it is a point of interest that the

repeat levelling operation in 1991 was completed just before the occurrence of Uttarkashi earthquake.

Deformation after Kangra and Uttarkashi Earthquakes

Kangra earthquake of magnitude 8 on Richter scale took place on the early morning of 4th April, 1905 which caused some destruction between Dehra Dun and Mussoorie also. An earthquake of magnitude 6.6 on Richter scale occurred at Uttarkashi on 20th October 1991 which also affected Doon Valley but only partially. Cracks in some of the buildings at Dehra Dun were observed.

Table I shows the variations in heights at different locations at different epochs i.e. (1905-07), (1926-28), (1974-77), 1991, 1992 and (1993-94) with respect to (1861-62, 1903-04) as base epoch. This base epoch, having spread over such a large time span may not be taken too rigorously but certainly gives some idea of the tectonic processes taking place in the area.

Table II shows the variations in heights at different locations at epochs 1991, 1992 and (1993-94) with respect to (1974-77) as base epoch. This table also includes the height variations in additional levelling length of about 4 km in Mussoorie hills carried out during (1974-77).

Similarly Table III shows height variation at epochs 1992 and (1993-94) with respect to 1991 as base epoch. These height variations shown in Tables I, II & III are depicted graphically in Figs 3, 4 & 5 respectively. The change in

Table I

Variations in heights with base epoch (1861-62, 1903-04)

Sl. No.	Description	Distance Km	(1905-06)-(1861-62, 1903-04) cm	(1926-27)-(1861-62), 1903-04) cm	(1974-77)-(1861-62, 1903-04) cm
1	SBM Saharanpur	0.000	0.00	0.00	0.00
2	Stone BM Mohand	44.271	10.27	10.60	14.99
3	BOM on stone Mohabawala	60.878	11.37	13.23	14.94
4	Gravity Stn. Mussoorie	108.810	1.83	5.79	19.31

Sl. No.	Description	Distance km	(1991)-(1861-62, 1903-04) cm	(1992)-(1861-62, 1903-04) cm	(1993-94)-(1861-62, 1903-04) cm
1	SBM Saharanpur	0.000	0.00	0.00	0.00
2	Stone BM Mohand	44.271	10.69	10.68	11.91
3	BOM on Stone Mohabawala	60.878	8.66	8.10	9.84
4	Gravity Stn. Mussoorie	108.810	16.68	10.73	22.67

Table II

Variations in heights with (1974-77) *as base epoch*

Sl. No.	Description	Distance km	(1991)-(1974-77) cm	(1992)-(1974-77) cm	(1993-94)-(1974-77) cm
1	SBM Saharanpur	0.000	0.00	0.00	0.00
2	Type D Fatehpur	24.372	−3.85	−3.47	−3.85
3	Stone BM Mohand	44.271	−4.30	−4.31	−3.08
4	BOM on rock *in situ*	51.601	−4.09	−4.19	−2.38
5	BOM on Mohabawala	60.878	−6.28	−6.84	−5.10
6	Type P at Dehra Dun	73.656	−5.89	−6.48	−4.26
7	SBM at Dehra Dun	74.036	−5.79	−6.44	−4.18
8	BOM on Rock	85.878	−4.49	−6.22	−2.48
9	Q on Rock	94.058	−3.67	−6.74	−0.34
10	BOM on rock	101.375	-4.05	−8.22	+0.74
11	Gravity Stn. Mussoorie	108.810	−2.63	−8.59	+3.36
12	BOM on Rock	111.15	−2.27	−8.97	+0.16
13	Type P at Mussoorie	112.834	−4.40	−11.04	+1.12

Table III

Variations in heights with 1991 *as base epoch*

Sl. No.	Description	Distances km	(1992-1991) cm	(1993-94)-(1991) cm
1	SBM Saharanpur	0.000	0.00	0.00
2	Type D Fatehpur	24.409	+0.38	0.00
3	Stone BOM Mohand	44.271	−0.01	+1.22
4	BOM on rock	51.601	−0.10	+1.71
5	BOM on Mohabawala	60.878	−0.56	+1.18
6	Type P at Dehra Dun	73.656	−0.59	+1.63
7	SBM at Dehra Dun	74.036	−0.65	+1.61
8	BOM on Rock	85.878	−1.73	+2.01
9	Q on Rock	94.058	−3.27	+3.33
10	BOM on Rock	101.375	−4.16	+4.79
11	Gravity Stn. Mussoorie	108.810	−5.95	+5.99
12	BOM on Rock	111.157	−6.70	+6.43
13	Type P at Mussoorie	112.834	−6.64	+5.52

topographic profile from Saharanpur to Mussoorie during the period from 1991 and (1993-94) is shown in Fig. 6. From Fig. 3 it can be seen that after the Kangra earthquake of 1905, the area in general had been rising from Mohand to Mussoorie ranging from 5 to 17 cm approximately at the rate of about 1 mm per year. The maximum variation of 17 cm is seen near Mussoorie.

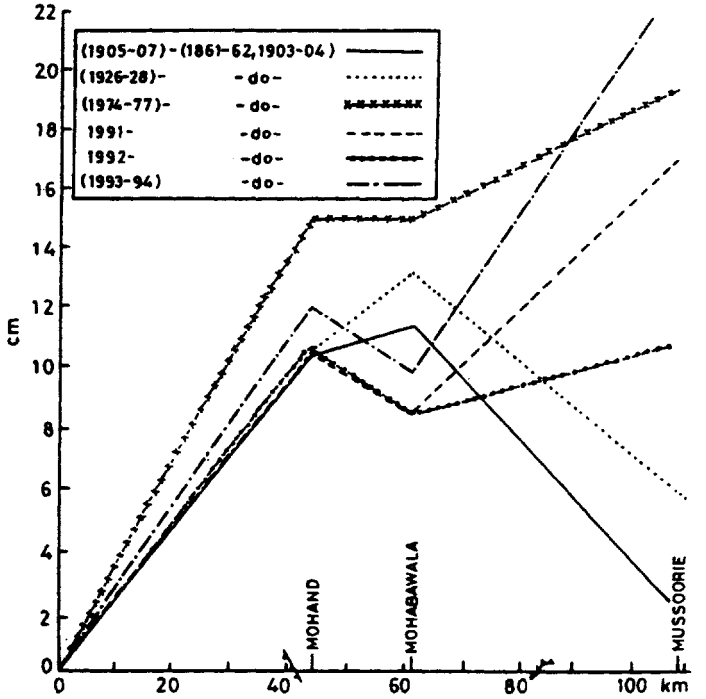

Fig 3 Variations in elevations with base (1861-62, 1903-04) as base epoch

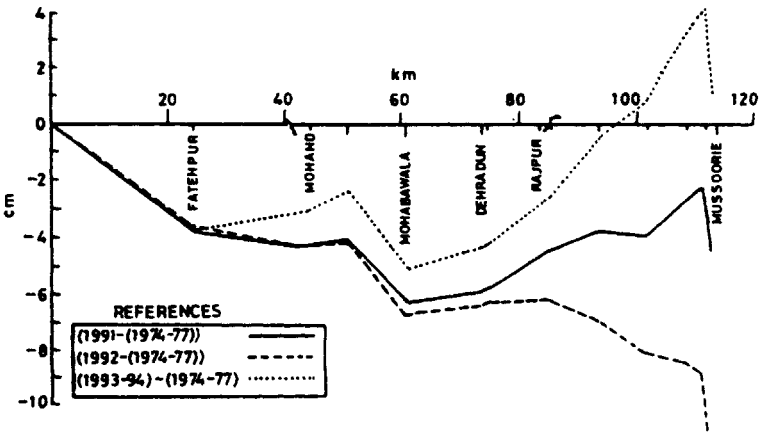

Fig 4 Variations in elevations with base (1974-77) as base epoch

Another important phenomenon seen from Fig. 3 is that the variation in heights are significant at Mohand, Mohabawala and Mussoorie. Figs 4 and 5 show the behaviour more clearly. The process of release of energy started probably just before the earthquake of Uttarkashi of 1991 because the entire area in general shows subsidence with respect to 1974-77 base epoch. The process of subsidence continued in 1992 also from near Mohabawala to Mussoorie

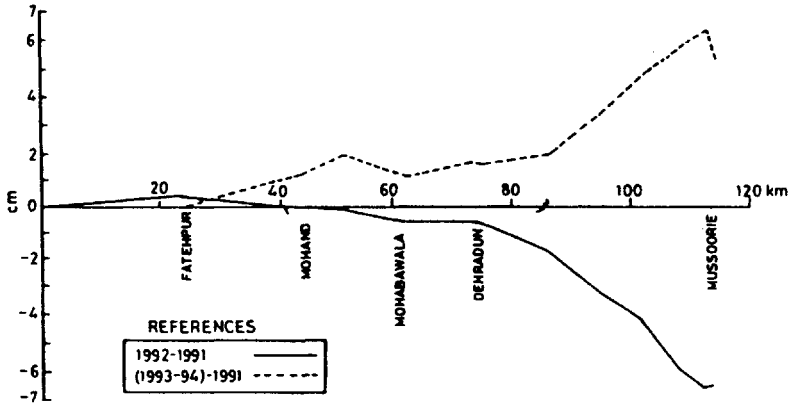

Fig 5 Variations in elevations with base 1991

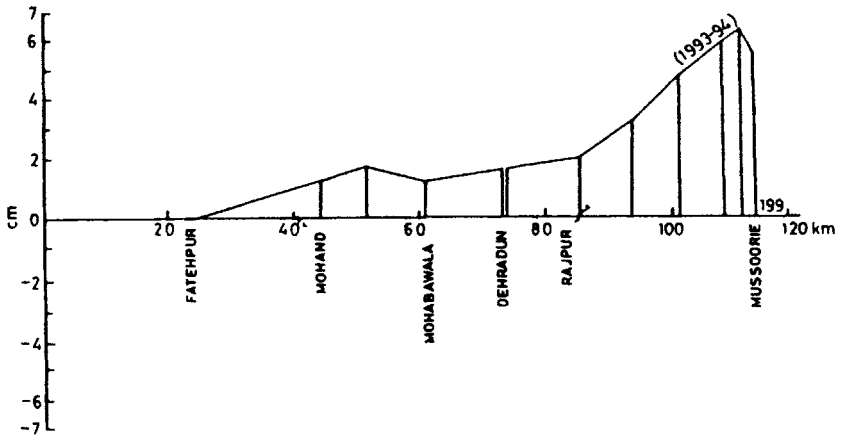

Fig 6 Changes in topography after 1991

with increasing quantum ranging from 0.5 cm to 6.6 cm (Figs. 4 & 5). Fig. 5 shows gradual upliftment of the entire area in general. The maximum upliftment taking place at Mussoorie to the range of about 13 cm within one year. This variation seems to be significant with fulcrum being somewhere near Rajpur.

Analysis of Levelling Data

From Table I and Fig. 3 it is revealed that the area from Saharanpur to Mussoorie was rising more rapidly towards Mussoorie than close to Saharanpur between the epochs (1861-62, 1903-04) and (1974-77). During this period in 113 years, the rise of Mussoorie with respect to Saharanpur was 19.31 cm in a distance of about 109 km at the rate of about 2 mm per year.

Earthquake of magnitude 6.6 on Richter scale took place on 20th October 1991 at Uttarkashi which is about 100 km north east of Mussoorie. But the re-

lease of energy started probably just before this earthquake as the levelling data indicate. Between the epochs (1974-77) and 1991, this area started subsiding with maximum subsidence of about 6.3 cm taking place at intermediate point of Mohabawala (Table II and Fig. 4). Mussoorie was subsided only by about 4.4 cm during this period.

The process of subsidence continued beyond Mohabawala during the period 1991 and 1992 with maximum subsidence of about 6.6 cm taking place at Mussoorie within one year of occurrence of Uttarkashi earthquake (Table III and Fig. 5). However, the trend reversed within a year. It can be seen that entire area started rising with Fatehpur as main fulcrum and Rajpur as sub-fulcrum within next one year period from 1992 to (1993-94) with maximum upliftment of about 13.1 cm taking place at Mussoorie.

The Uttarkashi earthquake of 1991 has been termed by geologists as thrust (compression) earthquake whereas sequential levelling data require more analytical explanation. The subsidence of Mussoorie block (from MBT to probably upto MCT) just before, during and after (upto one year) the earthquake suggests release of strain. The rebound (rise) of this Mussoorie block to the tune of about 13 cm during the subsequent year (1993-94) is phenomenal.

Conclusion

From the above discussion of sequential levelling data in Doon Valley spread over a time span of about 133 years, it can be concluded that after the 1991 earthquake of Uttarkashi, stress is again rapidly building up under the lithosphere due to continued North North East (NNE) movement and convergence of Indian plate under Eurasian plate. This has probably resulted in crustal shortening of the Indian plate. The rise in the block from Rajpur to Mussoorie may be due to the folding of Northern portion of the Indian plate beyond MBT towards Main Central Thrust which is located at about 120 km north of MBT.

From the analysis of these precision levelling data, the following concluding remarks can be made:

i) Subsidence just before, during and after (one year) the Uttarkashi earthquake of 1991 indicates release of strain and one can say that the subsidence of this nature may be a precursor.

ii) Rise is due to upthrusting of Mussoorie block along MBT with respect to Dehra Dun block which suggests that strain has again started accumulating rapidly in compressional regime between MBT and MCT.

In conclusion, it is suggested that more detailed geodetic & geophysical investigations including horizontal movements studies at closer interval should be carried out not only along Saharanpur Mussoorie route but also around Doon Valley and within the compressional regime beyond MBT towards MCT.

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