THE SUNDERNAGAR EARTHQUAKE (NW HIMALAYA) OF 29th JULY, 1997 FIELD OBSERVATIONS AND SEISMOTECTONICS

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ABSTRACT

On 29th July,1997 at 23 hrs 30 min (IST) an earthquake of magnitude ML =5.0 (WIHG) struck the Sundernagar region and its surroundings of Mandi district in Himachal Pradesh in NW Himalaya. The epicentral zone lies with in 2 km radius of Sundernagar town. The Main shock which lasted for a few seconds caused damage to about 1000 adobe houses. The main shock was felt over an area of 300 sq km and it caused wide extensive cracks in adobe houses within the epicentral zone with exceptional cases in other area where hair cracks to 1mm width developed in concrete houses, and fall of plasters and collapse of few adobe houses within 5 km radius from Sundernagar. This earthquake was the strongest one ever felt by the local residents, although they had felt one earthquake in 1962 but of mild nature. Based on the extent of damage to the buildings in the affected region, maximum intensity (Io) has been evaluated as VI on MSK-64 scale. The main shock was preceded by a few aftershocks for two or three days felt by the local residents and one aftershock of magnitude 4.3 was recorded on 14th August, 97. The isoseismal map shows long axis in N-S direction, which is parallel to the trend of N-S trending thrusts or a lineament present in the area. The pattern of the isoseismal suggests that the causative fault for the 1997 Sundernagar earthquake is parallel to MBT and the Chail Thrust. One of the interesting feature of the area is that the houses located on the MBT and the Chail Thrust suffered more damage, however, the houses located in the same locality but away from the thrust developed only hair cracks e.g. damage in village Lohakhar and Chambi is of Grade 4 in few houses whereas the houses located in nearby areas of the same vulnerability did not suffer much except cracks of Grade 1 and Grade 2.

INTRODUCTION

Sundernagar region of Himachal Pradesh is a part of active seismic belt of the north west Himalaya. The locality Sundernagar is situated in between two major thrusts i.e. the Chail Thrust to the east and the MBT to the west of Sundernagar. This area was also affected by the great Kangra earthquake on 4th April, 1905, and the other moderate to low magnitude earthquakes experienced in the region were below magnitude 4.0. On 29th July, 1997 a moderate earthquake of magnitude ML= 5.0 (WIHG) had shaken the Sundernagar town and adjoining regions at 23 hrs 30 min IST. The

Panjal Thrust in Chamba region and also locally called the Main Boundary Thrust(MBT). Other tectonic features are N-S trending transverse Rupar-Manali lineament and Chandigarh-Bilaspur lineament, which can be traced through Rupar, Bilaspur, Sundernagar, Mandi and Kullu to Manali (Virdi,1979). The Sundernagar basin filled with Quaternary sediments (Suketi Formation of Srikantia and Sharma, 1976) is situated at the junction of the Rupar-Manali lineament and the Chandigarh-Bilaspur lineament. It was probably formed as pull apart basin as a result of right lateral movement along the lineament. It is proposed by some workers (Vohra,1975) that earlier river Satluj used to flow due north through the Suketi basin to join the river Beas near Mandi, but later abandoned its course and followed the present course. The old channel is filled by the sluggishly flowing Suketi Khad which joins the river Beas at Mandi. The movement pattern along the Rupar-Manali lineament is dextral and N-S strike-slip. The dextral slip along the lineament seems to be responsible for the southward drag of the Chail Thrust and in the outcrop of Mandi Granite and pinching of Dhauladhar - Mandi Granite northeast of Mandi (Virdi, 1979).

FIELD OBSERVATIONS

A systematic field study was performed to infer the possible trend of the causative fault. The authors have used MSK-64 scale for studying the damage to different types of structures in the Sundernagar region specifying type of vulnerability of the buildings, type of structures and grade of damage. The field investigation was started immediately after the earthquake from the Sundarnagar town. In the town area the hospital building made up of stones with mud masonry suffered cracks of 2-3 mm width, whereas 75 years old DSP residence made up of mud bricks with mud masonary suffered wide extensive cracks along the corners of the house. The corners have widened to a maximum width of 4-5 cm . The PWD rest house suffered damage in chimney made of burnt bricks (3 feet high above roof) and developed cracks in the first floor along the joints and corners of ventilators. The concrete masonry structures developed cracks of Grade 2 in the second storey and Grade 1 in the first storey. Most of the damage have been reported from the Sundarnagar localities named as Bhojpur and Ambedkarnagar situated on both sides of the Lindi river alluvial plain. Most of the adobe houses of Ambedkarnagar and Bhojpur localities suffered wide extensive cracks of Grade 4 and 15% houses showed partial to total collapse (Fig. 3). The concrete masonry structures suffered cracks of Grade 2 but no diagonal cracks have been developed except in one house with fall of plaster in the Bhojpur locality. All the houses have shown opening along the joints in adobe and stone masonry houses in Bhojpur locality. The RCC structures developed very fine hair cracks in the second storey. The other

earthquake was felt strongly in the Sundernagar town and further south upto Bilaspur. In the north it was felt upto Jogindernagar and a few people reported upto Chauntra. To the west it was felt upto Sarkaghat and a few old people from Hamirpur reported some feeling of the event who were not sleeping at that time but resting on the bed on second story. To the east the earthquake was felt upto Giri and Karsog and to the northeast upto Kullu. The main effect of the earthquake was very localized and damaged badly adobe houses of 7-8 villages located within 5 km radius from the Sundernagar town. The tremors lasting for few seconds caused maximum damage in the houses located on the river bed in the Sundernagar town along the Lindi khad, a tributary to Suketi Khad. The authors visited the affected region the next afternoon i.e. on 30 th July in order to study the damage pattern to assess the intensity of the earthquake and to study the tectonics responsible for this earthquake.

EPICENTRAL PARAMETERS:

The earthquake was recorded in all the observatories operated by the Wadia Institute (Table-1, Fig.1). The event has occurred almost in the center of the array, hence could be located accurately. The hypocentral locations obtained from the phase data from these stations is given below along with the standard errors and number of stations used for locating this earthquake.

MAIN SHOCK

Date :	29th July, 1997	Magnitude	= 5.0
O-Time :	23.30 19.39 (IST)	RMS (Residue)	= 0.90
Latitude :	31° 37.87'	Standard error(Horizontal)	= 5.5
Longitude:	76° 48.90'	Standard error(Depth)	= 3.2
Depth :	10.40 km	No. of stations used	= 7

AFTERSHOCK

Date :	14th August, 1997	Magnitude	= 4.3
O-Time :	04.40 13.54	RMS (Residue)	= 0.92
Latitude :	31° 30.79'	Standard error(Horizontal)	= 5.0
Longitude:	76° 52.32'	Standard error(Depth)	= 5.1
Depth :	8.28 km	No. of Stations used	= 7

GEOLOGICAL SETTING

The geology of the area has been described by various workers (Singh and Srikantia, 1972; Rupke, 1974 and Srikantia, 1977). Figure 2 shows structural framework and the various rock units exposed in the area from west to the east are 1) the Tertiary rocks (Siwaliks, Murrees and Subathus) of Sub Himalaya 2) the Shali and the Sundernagar formations of Lesser Himalaya and 3) the Chail Formation metamorphic. The area is characterised by two major thrusts i.e. Chail Thrust, also called

affected villages are Dhanotu, and Mahadev located on the Sundarnagar Chambi road. In these villages the adobe houses suffered damage along the joints i.e. widening of the joints to 3-4 cm and the ground floor roofs have left spaces with the walls of the second storey. The concrete masonry houses showed Grade 2 damage in few houses and Grade 1 damage in almost all the houses. Only one house showed collapse of two walls in Mahadev village(Fig.5).The Shambu Nath Shiv Mandir in the same village developed cracks of Grade 1 and 2 at few places on the tomb of the temple with fall of plaster at number of places. This temple was destroyed during the 1905 Kangra earthquake, as reported by the old aged temple priest, and was repaired by the then King. This can be seen from the difference in architectural design in the upper part of the temple tomb which has been replaced by simple stones (Fig.6). Further north other affected villages are Senji and Khatrar. In the east the villages affected are Chambi, Kumrahoo, Kangar and Shusan. Out of these the Chambi village showed development of wide cracks along the joints in five adobe houses out of 100 adobe houses (Fig.7) and hair line cracks in almost all concrete masonry structures. The other villages also showed development of cracks of Grade 1 and 2 in almost all the adobe houses and hair cracks in all the concrete masonry structures. The other village affected on this side are Dadyala, Jai Devi which developed only Grade 1 damage in adobe houses and no cracks have been seen in the concrete masonry structure in these localities. To the west of Sundernagar, Kapahi, Pungi and Lohakhar villages were the main affected villages. In Kapahi village the adobe houses developed Grade 2 damage and the Pungi village showed damage of Grade 2 in almost most of the houses and Grade 3 in few houses. The Lohakhar village which is situated at the junction of the Mandi Thrust showed wide extensive cracks mainly along the joints in few adobe houses. Vertical cracks in the walls of Lohakhar village can also be seen in some adobe houses of Grade 3 and 4. The concrete masonry structures developed cracks of Grade 1 with exceptional cases in one or two houses which developed cracks of Grade 2 and 3 (Fig.8). Other affected villages of Kuthiaun and Ghadyatra, situated on the Murrees Formation showed Grade 2 damage in few adobe houses and Grade 1 damage in almost all adobe houses. Further in the south the adobe houses showed Grade 2 damage in Jarol on the Sundernagar-Bilaspur road toward South and no damage has been seen further south. From the Mandi, Sarkaghat, Rewalsar, Pandoh and Giri areas, report of fall of unbalanced utencils have been reported by few people but the earthquake was felt by every one in this region.

LAND FISSURES

No land Fissures generated by this earthquake have been seen in the area during the survey

ISOSEISMALS

Based on the damage survey of 29th July, 1997 Sundernagar earthquake, an isoseismal map has been prepared. The maximum intensity isoseismal VI surrounds the Sundernagar town especially both Bhojpur and Ambedkar localities, Mahadev and Dhanotu areas. The general trend of damage shows the elliptical shape of isoseismal oriented with its longest axis trending NNE-SSW or nearly N-S. It can be inferred that causative fault is trending NNE-SSW or almost N-S in direction (Fig.9).

SEISMOTECTONICS

The earthquake affected area of Sundernagar lies in between the Chail Thrust and the MBT. The damage shows that most of the damage in the area is located in the N-S direction and the event has also been felt by persons in localities falling in an area aligned north-south. The adobe houses located near or on the MBT and on the Chail Thrust have suffered extensive damage. The regional strike of Sub and Lesser Himalayan formations and tectonic elements take a bend from NW-SE to N-S and again NW-SE. This sudden change in trend appears to be related to a transverse, N-S trending fault or a lineament. Two lineaments, one trending NE-SW from Bilaspur to Sundernagar and the other trending N-S from Pinjour (Chandigarh) to Sundernagar and further north to Manali (Virdi, 1979). In our observations we find that Pinjour - Sundernagar- Manali lineament is an active fault, as evidenced by the right lateral displacement of the Siwaliks including the Upper Siwaliks on the southeastern margin of the Pinjour Doon. The epicentre of this earthquake lies very near to Sundernagar i.e. west of MBT and considering the depth as 10 km it can be said that if this earthquake would have caused due to the movement along the Chail Thrust or MBT, then the epicentre could have located further northeast of Sundernagar and one should also noticed the damage in the northeast of Sundernagar, which is not the case. So it means that the earthquake is not related to the thrust faulting but to the N-S trending fault with a strike-slip component. This is also corroborated with the depth as well as with the isoseismal trend of the earthquake.

RECOMMENDATION

The Chamba-Mandi-Sundarnagar Belt and Kinnaur region of the Himachal Himalaya are the seismically active regions of the Himalaya. The historical earthquake of Kangra region of 1905 (Middlemiss, 1910) reminds us the devastating effect to the dwelling and loss of lives totalling 20,000 lives during that time, and if the same type of earthquake will repeat in that area again then the causality rate will be in lakhs and economic loss will be hundred of crores rupees (Arya, 1990). Hence before we wait for an earthquake to occur it is high time to take safety measures like introducing building code in the constructions of buildings in these regions. The collapse of building during an earthquake is the main contribution to the loss of life and injuries to the people. It is the building which cause loss of human lives and property and not an earthquake. Therefore, it is necessary to have houses and other buildings with earthquake resistant design . The trend of high rise buildings in these region must be discouraged. The H.P. State Government may also initiate programs of public awareness towards mitigating the effects of earthquakes by educating local residents for building safer houses. It is also necessary to hold seminar/conferences to train the officials for meeting the emergency situations during an earthquake.

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REFERENCES

Arya A.S., 1990: Damage scenario of a hypothetical 8.0. magnitude earthquake in Kangra region of Himachal Pradesh. Bull. Ind. Soc. Earthq. Tech. Paper no. 297 (27) 3: 121-132.

Middlemiss 1910: "The Kangra earthquake of April 4, 1905". Mem. Geol. Surv. Ind. vol. 38.

Singh, H.N. and Srikantia, S.V., 1972: Geology and Structure of Mandi, Sundernagar area, Mandi District Himachal Pradesh. Him. Geol. G.S.I. Misc. Publ. 1, 15: 221-228.

Srikantia, S.V. 1977 . The Sundernagar Group its geology, correlation and significance as stratigraphically the deepest sediment in the Peninsular and Lesser Himalaya. Jour. gEol. Soc. India. 18: 7-22.

Srikantia S.V. and Sharma, R.P., 1976: Geology of the Shali belt and adjoining areas. Mem. geol. Surv. Ind., 106 (1): 31-166.

Srivastava H.N.: Earthquake prediction studies in Himalaya: Critical evaluation. Himalayan Seismicity (Eds: G.D. Gupta), Geol. Soc. Ind. Spl. Pub: 151-172.

Rupke, J. 1974: Stratigraphy and structural evaluation of the Kumaon, Lesser Himalaya. Sediment Geol. 11 (2-4): 81-265.

Vohra, C.P. 1975: A note on the terraces of the Satluj river in Dehra-Slapper area. Distt. Bilaspur. H.P. Pub. C.A.S. in Geol. Chandigarh, 7: 119-126.

Virdi, N.S.,1979: On the geodynamic significance of mega lineaments in the outer and Lesser Himalayan region of Western Himalaya. Him. Geol. 9(1): 79-99.

EXPLANATION OF FIGURES

Fig.1 Location map of Seismic Net work Station of WIHG in north west Himalaya.

Fig.2 Geological map of the Sundernagar area, Mandi District H.P.

Fig.3 Shows partial collapse of adobe Houses in the Sundernagar area (damage Grade 4).

Fig.4 Shows wide extensive crack and opening of walls along joint with damage Grade 3 in Mahadev village.

Fig.5 Shows partial collapse of adobe houses in Mahadev locality (damage Grade 4).

Fig.6 The Shambu Shiv Nath Mandir which was damage during 1905 Kangra earthquake .

Fig.7 Shows vertical cracks with 3-4 mm wide opening in village Chambi (damage Grade 3). The innerside of the wall opening up to 7-8mm width.

Fig.8 Shows partial collapse in adobe house in village Lohakhar .

Fig.9 Isoseismal map of the 29th July,1997 Sundernagar earthquake.

Fig.10 Epicentral map of microearthquake occurred in the Sundernagar region since 1980 of magnitude < 4.0. The bigger triangles denotes magnitude >= 4.0 and small traingles shows magnitude < 4.0. The square shows epicentral location of 29th July,1997 earthquake from instrument data.

TABLE - 1

COORDINATES AND STATION USED IN HYPO

S.No	STN	LAT	LONG	ELV
1.	RJA*	3202.56N	7615.68E	430
2.	RWS*	3137.90N	7649.48E	1300
3.	NAD	3214.90N	7618.90E	1995
4.	KLH	3243.91N	7606.56E	1650
5.	CHT*	3226.69N	7623.64E	1800
6.	LAN	3208.70N	7634.96E	1040
7.	TYR	3220.17N	7633.20E	1550
8.	RJL	3214.71N	7604.26E	690
9.	CHM*	3238.65N	7612.30E	1710
10.	DDN*	3019.71N	7800.70E	620
11.	KOT*	3210.56N	7712.00E	2527
12.	GRG	3027.50N	7926.67E	1500
13.	PAL*	3050.50N	7821.54E	1640
14.	BNK	3234.62N	7557.12E	1960
15.	UNA	3131.28N	7619.60E	550

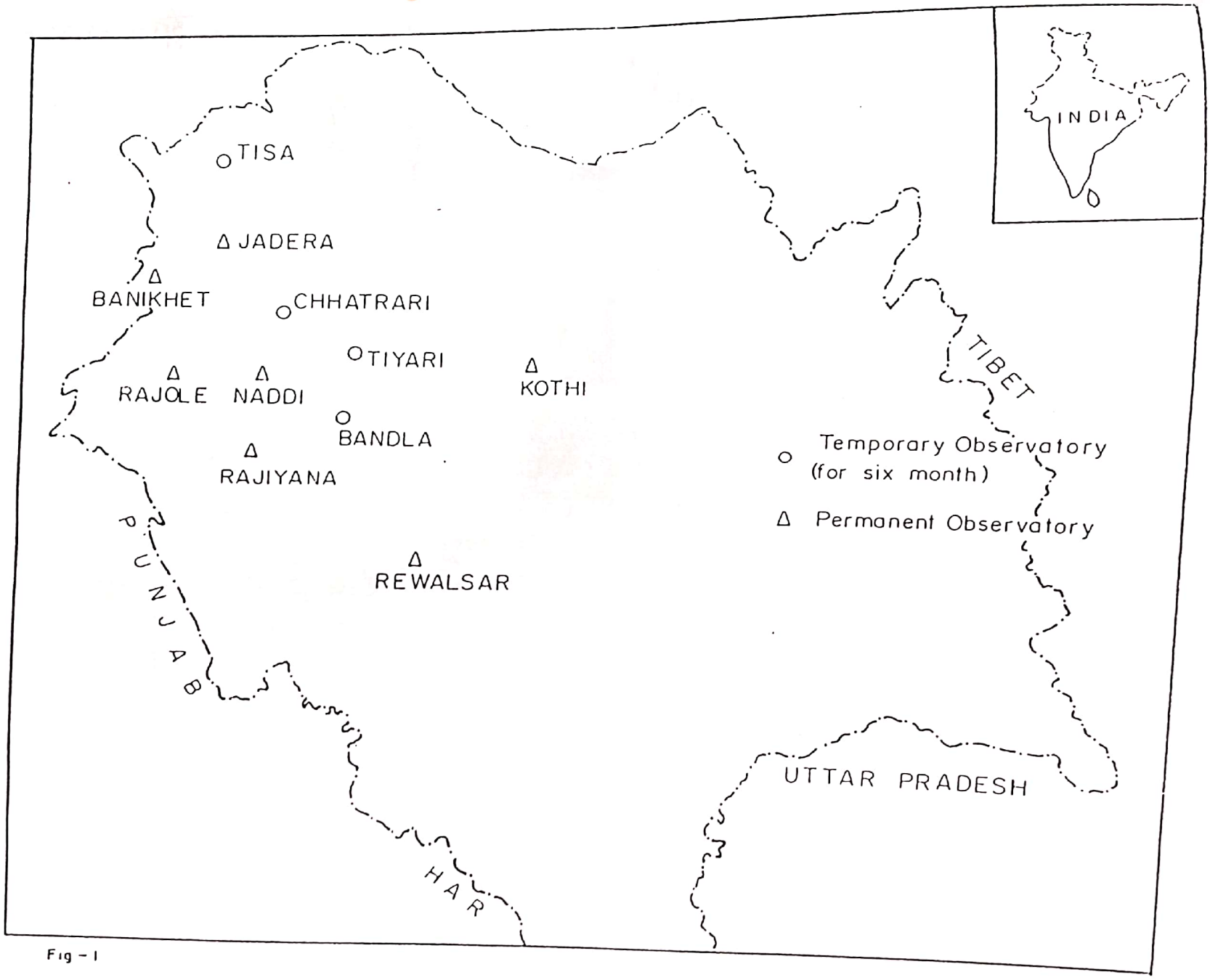


Fig - 1

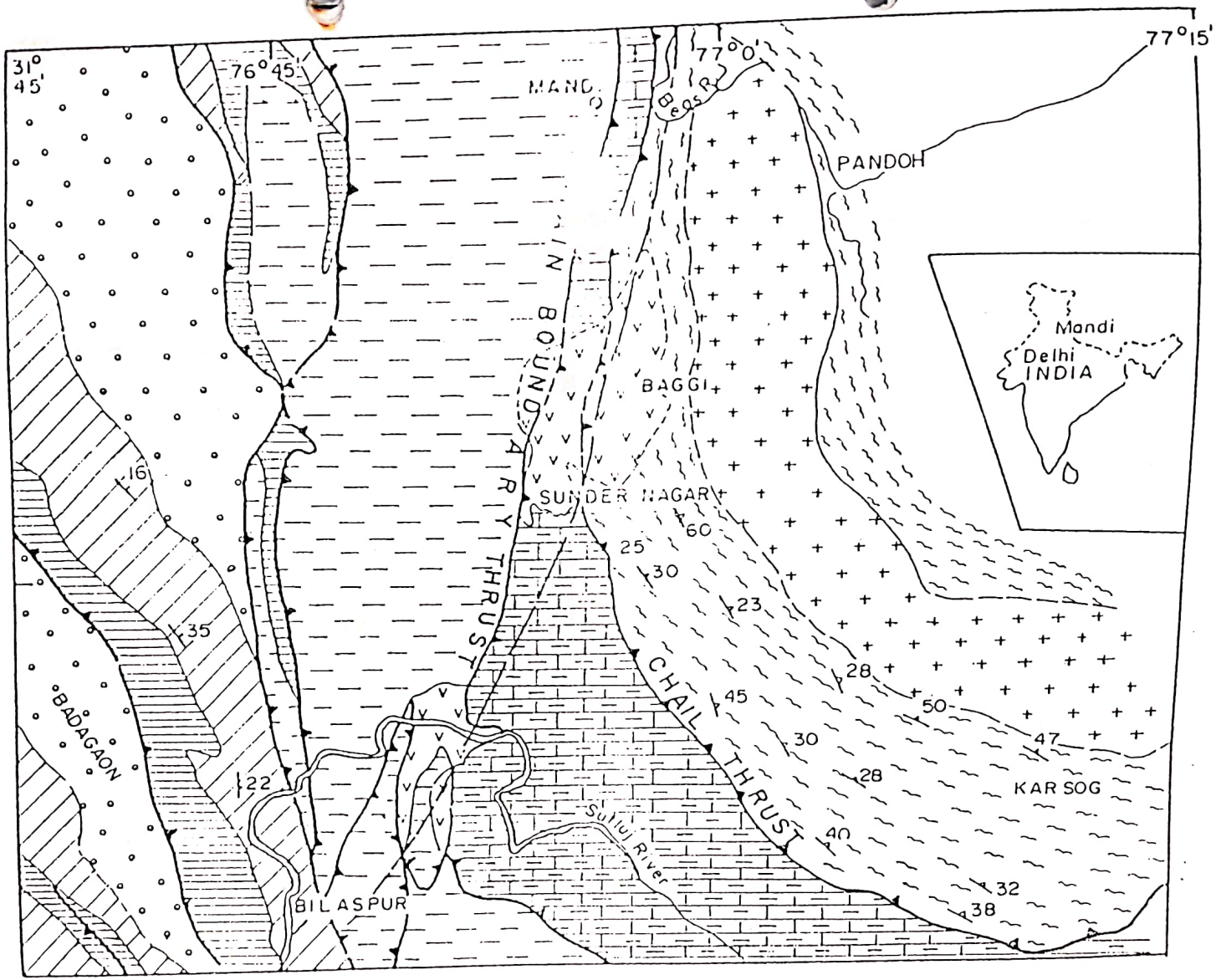


Fig – 2

Alluvium
Upper Siwalik
Middle Siwdlik
Lower Siwalik
Subathu / Murree
Shali - Sundernagar
Chail
Mandi Granite
Thrust
25 Foliation
28 Dip.
Rupar Manali Lineament
5 0 5Km
Scale

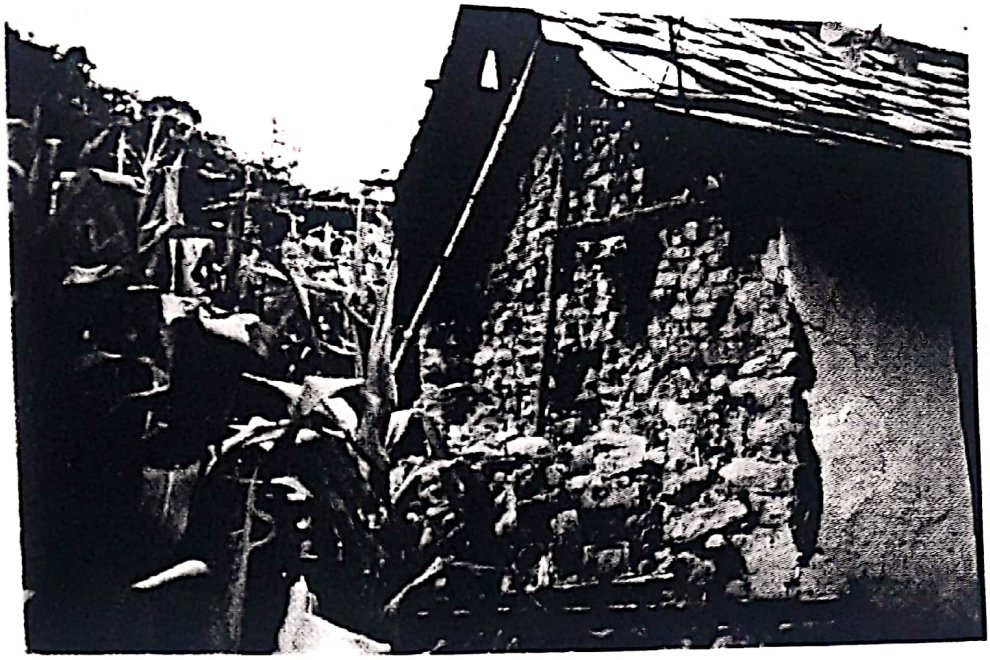


Fig – 3

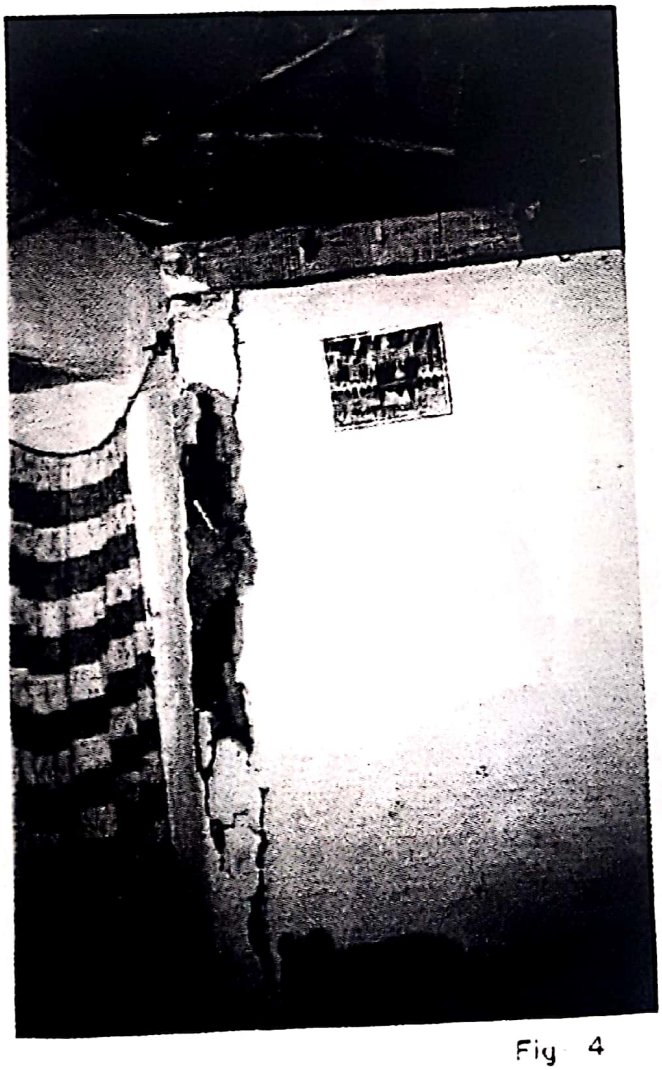


Fig 4

Fig – 5

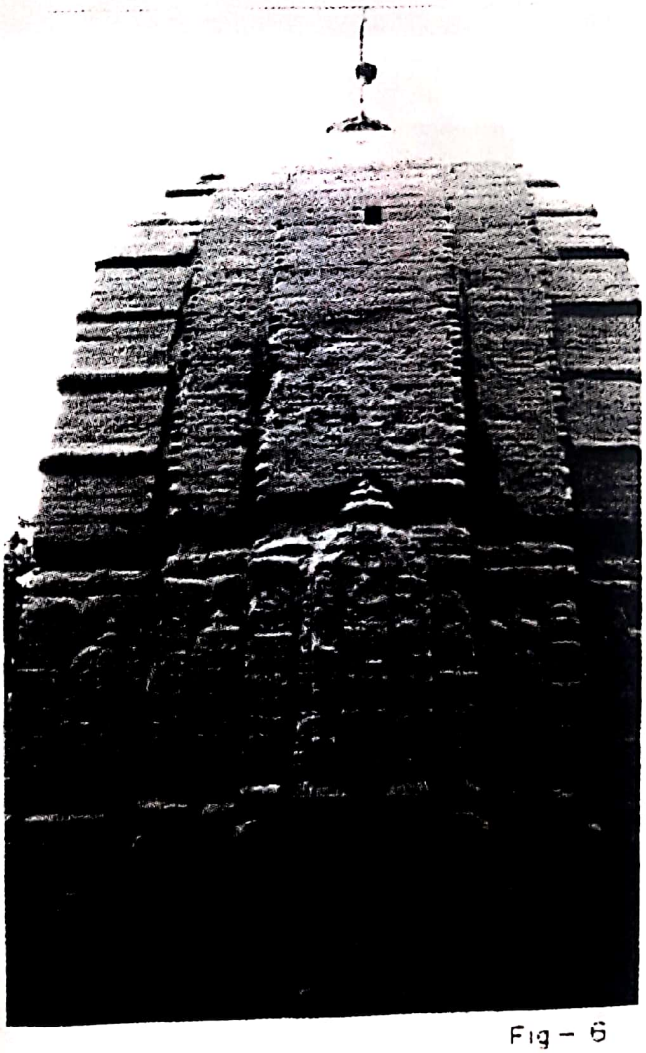


Fig – 6

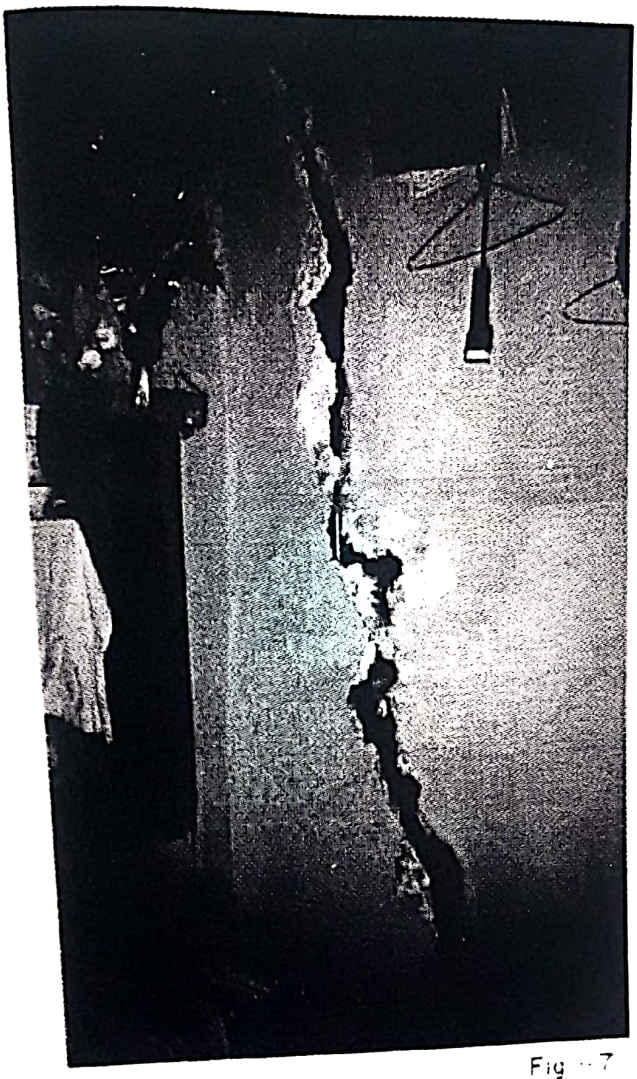


Fig — 7

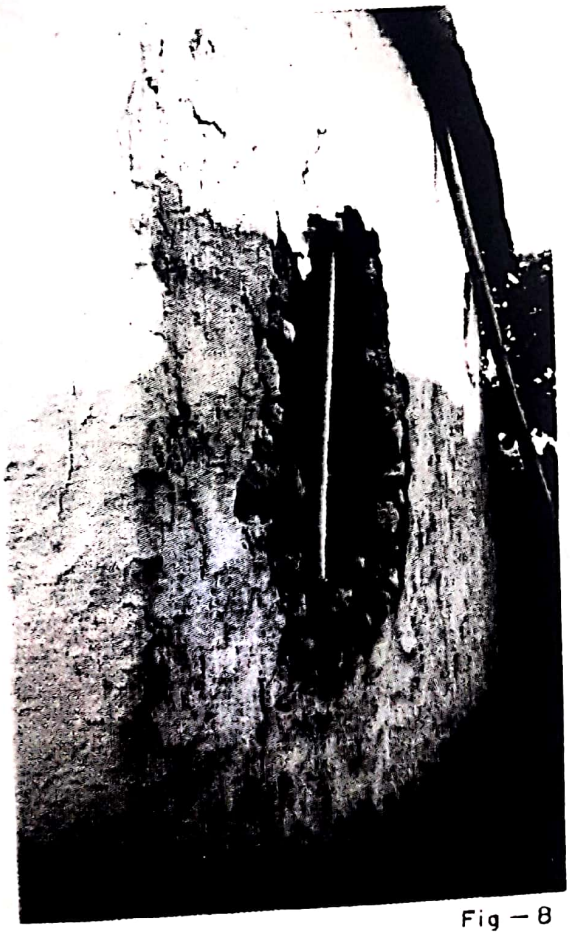
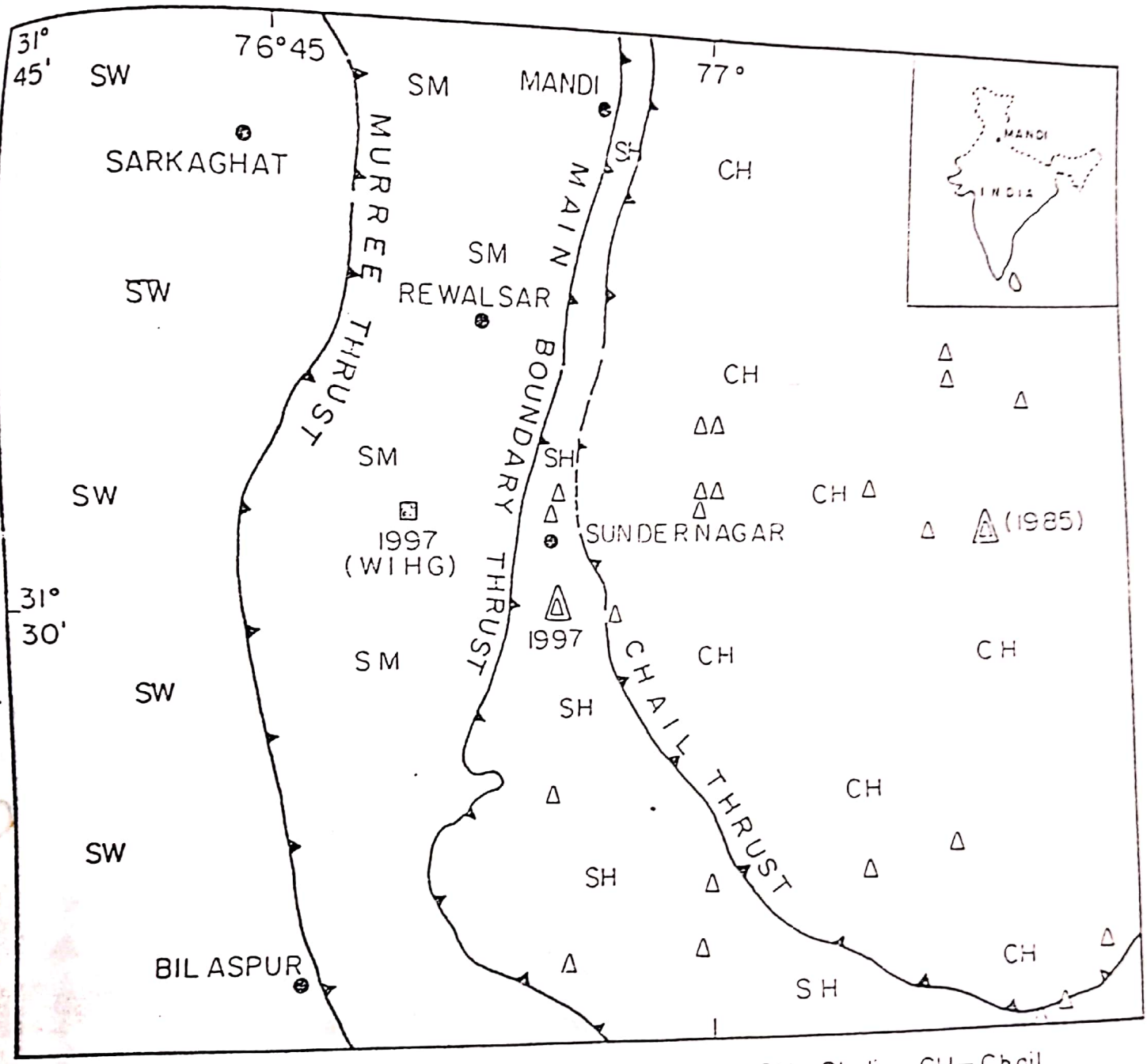


Fig — 8



Fig–10 SW — Siwalik SM — Subathu / Murree SH – Shali CH – Chail