

Earthquake Hazard Profile of the State

Though the State is prone to numerous hazard as narrated in the foregoing paras but earthquake hazard poses the serious challenge for the State. Hence, this aspect is dealt separately in detail in the succeeding paras.

The state of HP is located at 33.3-36.0 degree North latitude and 75.6-79.0 degree East longitude in the Western Himalayas. Seismically it lies in the great Alpine- Himalayan seismic belt running from Alps mountains through Yugoslavia, Turkey, Iran, Afghanistan, Pakistan, India, Nepal, Bhutan and Burma. The terrain is hilly all through the state of HP, the ranges varying from the Shivaliks in the south to the tall snow clad Pirpanjals in the North. These are traversed by major rivers Sutlej, Beas, Ravi and other tributaries. The state has not only been shaken by earthquake occurring in its territory but also in the neighboring areas of J&K in the North, Tibet in the East and UP hills in the South East. A number of damaging earthquakes have occurred in the HP territory during 20th century for which information is well recorded. Information about earthquake occurrence before the famous 1905 Kangra earthquake is not, however, available and is a matter of research through historical and archival records.

The earthquake activity in HP is attributed to the Himalayan orogeny. Based on the latest concept of plate tectonic model of the earth, the Himalayan mountains have formed due to continuous thrashing of the Indian plate with Eurasian plate since cretaceous times. The present geological structure and the tectonics of the Himalayas have been formed as a result of this continued collision. There are regional- tectonic features in the Himalayas like the main boundary fault (MBF) and Main Central Thrust (MCT) remaining parallel to the strike length of Himalayas. Besides, the Krol, the Giri, Jutogh and Nahan thrusts lie in this region. Besides that there are scores of smaller faults, like the Kaurik Fault which triggered the 1975 Kinnaur earthquake.

A part from these regional tectonic features there are lineaments running transverse to the Himalayan Trend. Slow movements result in the elastic strain build up and the sudden release of tectonic strain energy along any of these tectonic features causes the earthquake activity.

Due to its location it weathers dozens of mild earthquakes every year. Large earthquakes have occurred in all parts of Himachal Pradesh, the biggest being the Kangra Earthquake of 1905. There were two more big quakes, but they were not nearly as powerful as the 1905 jolt.

The first was in 1906, a 6.4 near Kullu and the second was a 6.8 in Lahaul-Kinnaur Spiti in 1975 along the Indo-China Border.

Chamba, Kullu, Kangra, Una, Hamirpur, Mandi, and Bilaspur Districts lie in Zone V. The remaining districts of Lahaul and Spiti, Kinnaur, Shimla, Solan and Sirmaur lie in Zone IV. The GSHAP gave these regions the probability of having the maximum peak ground acceleration (PGA) ranging from 0.16g to 0.4g.

A careful study of the Seismic hazard map of Himachal Pradesh and the damage risk to housing in the districts will show the following points:

The whole state is prone to severe earthquake hazard. It has been subjected in 1905 to one of giant earthquakes of the recorded seismic history of India having a magnitude of 8.0 on the open ended Richter Scale in which 20000 persons had lost their lives, the towns of Kangra and Dharamshala were razed to the ground and no-government functionary there was left alive even to report the happenings to the higher authorities. It had shaken an area of more than 416000 sq. km. in and around the present Himachal Pradesh. A maximum Intensity X on rossiforel Scale was observed in the epicentral area which when interpreted on the now current Modified Mercalli Scale would be between X and XI. There are 250 earthquakes of Magnitude 4.0 and more including more than 60 with Magnitude 5.0 or more, which have rocked the state of HP and adjoining areas of J&K or UP in the last about 90 years. The Kinnaur earthquake of January 19,1975 (M=6.7) and Dharamshala earthquake of April 26,1986 (M=5.7) are well recorded in respect of damages caused and losses incurred. A list of earthquakes of M=5.0 or more is given for ready reference in Table 1 and Figure 1 below which had their epicenters either within or close to the State Boundry.

It is also seen that according to seismic zoning map (Figure 1) of the state five districts, namely Chamba (53.2%) Hamirpur (90.9%), Kangra (98.6%), Kullu (53.1%), Mandi (97.4%) have 53 to 98.6 percent of their area liable to the severest design intensity of MSK IX or more, the remaining area of these districts being liable to the next severe intensity VIII. Tow districts, Bilaspur (25.3%) and Una (37.0%) also have substantial area in MSK IX and rest in MSK VIII. The remaining districts also are liable to intensity VIII.

Unfortunately, inspite of the probable maximum seismic intensities being high , the house types mostly fall under Category A, consisting of walls of clay mud, unburnt bricks or random

rubble masonry without any earthquake resisting features Now all such houses are liable to total collapse if intensity IX or more actually occurs in future and will have severe damage called “destruction” with very large cracks and partial collapses even in Intensity VIII areas.

Also, the burnt-brick houses, classified as Category B, as built in Himachal Pradesh do not have the earthquake resisting features, namely good cement mortar seismic bands and roof typing etc. therefore, they will also be liable to severe damage under intensity IX as well as in VIII when ever such an earthquake would occur. This became quite evident even in M 5.7 Dharamshala earthquake of 1986.

EARTHQUAKES HAVING MAGNITUDE 4 OR MORE ON RICHTER SCALE IN HIMACHAL PRADESH DURING THE LAST 200 YEARS

S.No	Year	Month	Day	Magnitude	Coordinates	Tentative location
1.	1809	-		5.5	30°42'00" 78° 30'00"	Near Labrang (Distt.Kinnaur)
2	1827	9		5.5	32°30'00" 76°00'00"	Near Dalhousie (Chamba Distt.)
3	1856	4	7	5.0	31°00'00" 77°00'00"	Near Ranhog(Distt.Solan)
4	1858	8	11	5.0	31°7'12" 77°10'12"	Shimla(Distt.Shimla)
5	1865	04	11	---	Shimla region	
6	1905	4	4	8.0	32°18'00" 76°15'00"	Karari Dal(Distt.Kangra)
7	1906	2	28	7.0	32°00'00" 77° 00'00"	Near Karshing(Distt.Kullu)
8	1930	5	11	5.5	31°42'00" 77°00'00"	Shila Kiepr (Mandi Distt.)
9	1940	04	07	-----	31 05 77 00	Near kali Hatti ,District Shimla
10	1945	06	22	6.5	32°36'00" 75°54'00"	Minu (Chmaba Distt.)
11	1947	7	10	6.2	32°36'00" 75°54'00"	Minu (Chmaba Distt.)
12	1950	8	12	5.5	32°36'00" 75°54'00"	Minu (Chmaba Distt.)

13	1951	09	22	6.4	32 36 76 30	East of Dhan Kanda ,District Chamba
14	1962	9	15	5.5	31 ⁰ 54'00" 76 ⁰ 12'00"	Near Dehra Gopipur (Distt.Kangra)
15	1965	02	21	4.5	32 14 76 54	Near Bara Banghal, District kangra
16	1967	09	20	---	32 36 76 06	Near Rajpura, District Chamba
17	1968	05	11	4.9	32 22 76 22	Near Atrori, District Chamba
18	1969	01	23	4.0	32 14 76 03	Near Trilokpur, District Kangra
19	1970	03	05	4.9	32 24 76 29	Near Sani, District Chamba
20	1972	01	29	4.7	32 51 75 54	
21	1973	12	16	4.9	32 17 76 01	Near Mordhu, District Chamba
22	1974	11	16	4.8	32 50 76 08	Tissa, District Chamba
23	1975	10	30	5.2	32 54 76 00	Near Bhujara, District Chamba
24	1975	12	11	5.1	32 50 76 58	Near Jankar, Sumdo, Lahaul & Spiti
25	1975	12	10	5.0	32 49 76 11	Near Chhajaut, District Chamba
26	1975	1	19	6.7	31 ⁰ 56'24" 78 ⁰ 31'48"	Distt. Kinnaur
27	1975	2	2	5.1	32 ⁰ 33'36" 78 ⁰ 53'00"	Indo China Border
28	1975	7	19	5.1	31 ⁰ 57'00" 78 ⁰ 35'24"	Near Chnago (Kinnaur Distt.)
29	1975	7	29	5.5	32 ⁰ 34'12" 78 ⁰ 29'24"	Near Kanum (Distt. Kinnaur)
30	1975	2	10	5.3	32 ⁰ 57'00" 76 ⁰ 06' 00"	Near Janu Pass (Chamba Distt.)
31	1975	2	11	5.0	33 ⁰ 00'00" 76 ⁰ 10'12"	Near Sathrundi (Chamba Distt.)

32	1976	1	7	5.3	32°58'12" 76°7'12"	Dunchili Gad (Chamba Distt.)
33	1976	01	09	4.7	32 59 76 01	Along J&K Border
34	1976	02	05	5.0	31°14'24" 77°01'48"	Near Chebri (Distt.Shimla)
35	1976	04	10	4.5	32 43 76 30	Near Balthal Got, District Chamba
36	1976	04	16	4.0	32 52 76 00	Near makkan, District Chamba
37	1976	7	6	5.1	32°26'24" 78°21'00"	Near Raksham (Kinnaur Distt.)
38	1976	9	8	5.3	32°14'08" 78°45'36"	Near Baspa origin(Kinnaur Distt.)
39	1977	2	19	5.4	31°48'00" 78°25'48"	Near Rangbar Thachang (Distt.Kinnaur)
40	1977	3	27	5.1	32°40'12" 78°39'36"	Lenchichi (Kinnaur Distt.)
41	1978	6	14	5.0	32°14'24" 76°36'36"	Near SinghauPass, along Kangra Border District.Chamba
42	1979	01	19	4.1	32 22 76 28	Near Chandota Pass, District Chamba
43	1980	05	29	4.2	31 33 76 33	
44	1980	09	04	4.0	32 00 76 54	Near Pajaund, District Mandi
45	1980	11	26	4.0	32 29 76 24	Near Khaddar, District Chamba
46	1981	02	14	4.0	32 35 76 37	Near Bara Kanda, District Chamba
47	1981	06	19	4.5	32 43 76 00	Near Lohari, District Chamba
48	1981	6	13	5.0	31°49'12" 78°27'36"	Nalpaya Thach (Distt.Kinnaur)
49	1981	5	28	5.2	31°49'48" 78°25'48"	Barling (Kinnaur Distt.)
50	1982	05	18	4.0	32 25 76 24	Near Chagrauta , District Chamba

51	1983	2	27	5.3	32°36'00" 78°34'12"	Khadi Thach (Distt.Kinnaur)
52	1983	04	13	4.0	32 46 76 14	Near Tikri Khas, District Chamba
53	1985	03	11	4.8	31 15 77 00	Near Malaun, District Shimla
54	1985	12	29	4.9	32 37 76 06	Near Theru, District Chamba
55	1986	4	26	5.5	32°19'00" 76°24'00"	Near Nag Dal (Boundary of Chamba and Kangra distt.)
56	1987	06	10	4.7	31 55 76 26	Near Daton, District Chamba
57	1987	12	26	4.3	32 07 76 41	Near Dewal Khas, District Kangra
58	1991	06	23	4.6	32 18 76 42	Near Gataunda, District Shimla
59	1992	01	26	4.5	32 16 76 24	Near Bhagsu Nath, District Kangra
60	1992	02	13	4.5	32 37 76 30	East of Dhan Kanda, District Chamba
61	1992	09	06	4.6	32 25 76 20	Near Darkund, District Chamba
62	1996	05	09	4.0	32 50 76 19	Near Kuntka Matha, District Chamba
63	1996	05	23	4.2	32 42 76 29	Near East of Kagal Dhar, District Chamba
64	1996	07	14	4.1	32 37 76 31	Near East of Dhan Kanda, District Chamba
65	1996	09	14	4.6	32 49 76 22	Near Kala Ka Bhandar, District Chamba
66	1997	07	29	4.7	31 33 76 48	Near Baldwara, District Mandi
67	1997	08	13	4.2	31 12 76 41	Near Jajjar, District Solan
68	1998	10	17	4.5	32 12 76 32	Near Kandha, District Kangra
69	1999	05	30	4.9	31 48 36 78 54 36	Near Miyang Lung, District Kinnaur
70	1999	01	08	4.2	31 26 24 77 18 00	Near Mehog, District Mandi

71	1999	05	30	4.9	31 48 36 78 54 36	Near Miyang Lung, District Kinnaur
72	1999	01	08	4.1	31 22 48 77 17 24	Near Karsog, District Mandi
72	2000	04	28	4.1	31 30 36 78 15 00	Near mehbar, District kinnaur
73	2000	08	28	4.5	32 01 48 78 18 00	
74	2000	09	26	4.0	30 55 12 75 39 00	
75	2000	06	17	4.3	31 48 00 78 27 00	Near Nalpaya, District Kinnaur
76	2001	06	17	4.2	32 42 36 78 26 24	
77	2001	01	22	4.0	31 04 12 77 55 48	Along Uttranchal Border
78	2001	02	23	4.0	30 55 48 78 00 00	Along Uttranchal Border
79	2001	09	18	5.1	33 13 12 75 36 36	
80	2001		14	4.7	32 31 12 76 06 00	Near Pundla, District Chamba
81	2001		23	4.6	33 07 12 75 40 12	
82	2002	01	27	5.1	33 06 36 75 49 48	
83	2002	03	17	4.1	32 46 48 75 55 48	
84	2002	02	17	4.1	33 06 00 75 40 48	

(Source: IMD: India Meteorological Department, DLDH- Oldam (1883), ISS: International Seismological Summary, PDE: Preliminary Determination of Earthquakes).

Table 2. Districts with EQ Intensities Types (Source: BMTPC Vulnerability Atlas for Himachal Pradesh)

Sr.No.	Name of District	MSK IX or more % area	MSK VIII % area
1.	Kangra	98.6	1.4
2.	Mandi	97.4	2.6
3.	Hamirpur	90.9	9.1
4.	Chamba	63.2	36.8
5.	Kullu	53.1	46.9
6.	Una	37.0	63.0
7.	Bilaspur	25.3	74.7
8.	Solan	2.4	97.6
9.	Lahaul & Spiti	1.1	98.9
10.	Kinnaur	--	100
11.	Shimla	--	100
12.	Sirmour	--	100

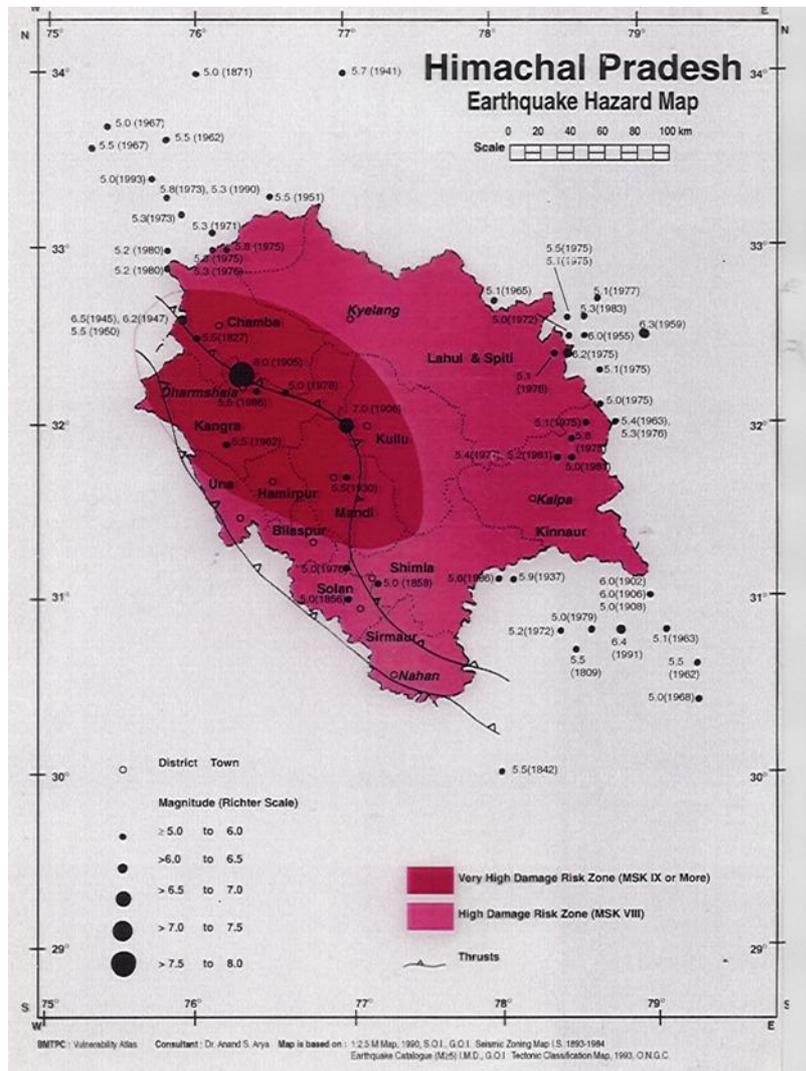


Figure 1. Epicentral and Earthquake Hazard Map of Himachal Pradesh. (Source BMTPC Vulnerability Atlas of Himachal Pradesh)

SOME OF THE IMPORTANT SEISMIC EVENTS OF H.P.

Given in the subsequent paras is the detailed analytical analysis of the some of the major earthquake events in Himachal Pradesh. Detailed seismic analysis of 1905 Kangra earthquake, 1975 Kinnaur-Lahaul earthquake, 1986 Dharamshala earthquake, 1995 Chamba earthquake and 1997 Sunder Nagar earthquake has been given with a view to analyze seismic history of the state and to co-relate these events with present study area of Dalhousie. The behaviors of building during these earthquakes has also be analysed so that conclusion can be drawn for the present study. Kangra earthquake of 1905 is certainly the biggest and first big event of great significance in the recorded earthquake history of the state hence it is taken fist for analysis.

1905 - Kangra (Himachal Pradesh), India, Mw 7.8

The earthquake having a magnitude 8.0 on Richter scale had its epicenter at 32.15 N, 76.15 E and occurred at 004 50 m GMT or 06h 20m IST. It had taken a toll of 20,000 lives, caused MM intensity X and more in the epicentral region and was felt over an area of 4,16,000 sq.kms. It was concluded that the earthquake may have been caused due to a displacement taking place along a low angle fault at a depth of 34 to 64 kms (ASC).

The earthquake that struck the Dharamshala-Kangra area in Himachal Pradesh on April 4th, 1905 is among the deadliest earthquakes in the history of India. According to the then provincial government of Punjab, 19,727 people were killed. Many of the fatalities were from Dharamshala, Kangra and neighbouring towns and villages (ASC).

The shock hit at 6:19 am I.S.T. on April 4th, 1905 and is thought to have lasted for at least 2 minutes. The worst damage was at Kangra (Middlemiss, 1910). All the buildings were destroyed including the Golden Temple, the Municipal Dispensary, the Thana and the Treasury buildings. Only the golden cupola of the Golden Temple remained resting on the debris of the destroyed structure below. The Devi Temple and the Mission Church which lay side by side were both demolished, their wreckage mingling with each other. The intense ground shaking can be gauged from the fact that two ladies, a Mrs. Decauble and a Ms. Lorbeer who were sitting on a verandah of the Mission House, and killed as they were unable to escape. At the Sessions House ridge, branches were broken off Pepal and Banyan trees, and fissures ran across the

earth. Kangra Fort was also ruined. Many landslides precipitated off the hill slopes in and around Kangra (ASC).

After Kangra, the hardest hit (Middlemiss,1910) were the towns of Dharamshala and Palampur. At Dharamshala, the motion was so strong that people were thrown to the ground as they tried to run outdoors. The European Barracks that were occupied by the 7th Gurkha Rifles from Kohima at the time, was completely wrecked. 272 soldiers were killed here and 363 were injured. Many buildings in the vicinity such as the Armoury were badly damaged. Some buildings however, namely the Magazine, the Treasury and the Sadr Kanungo's office and record room were untouched. A tombstone at the cemetery was found to have been twisted around by the earthquake. Many buildings were also destroyed on Dharamshala Civil Hill. McLeodganj Bazaar and Kotwali Bazaar were levelled to the ground. At the Jail house site, there were numerous fissures and at one location, there was a slump of 10 feet along an old fracture. The number of casualties was very high. Much of the deaths can be attributed to the severe shaking and the timing of the quake, when most people were indoors. Another major factor was that most of the government officials were killed and there was no one to help in or to supervise rescue and relief. It is believed that voices could be heard for many days from beneath the rubble crying out for help.

About 100 persons were feared dead at Palampur. Many buildings in the town, like the court house, church, school and sessions house were destroyed with a few sections of wall left standing. Some building however, escaped and like the Post Office were still in use after the quake. In the mountainous regions surrounding Kangra and Dharamshala, there were several major landslides, rockfalls and avalanches. Some rockfalls were so massive, such as the one at Barwar, that they created new lakes. At some other locations rockfalls resulted in several horrific deaths, when entire houses were crushed by a single fallen slab of rock. This was the case at a village near Mandi, where an entire family was killed when a massive rock fell onto their home (ASC).

Away from the hills, and in the plains of the Punjab in northern India (and now also northern Pakistan), there was slight to considerable damage. Sand vents and earthquake fountains were reported from near Bijnor, Khanki, Haridwar and Roorkee. Buildings were seriously damaged and some even partially collapsed at many major cities in the region, such as Amritsar, Lahore, Jullunder, Sialkot, Jammu, Rawalpindi and Amballa. The Lahore Town hall was damaged and so

was the Lahore Railway station and Mayo hospital. Several British administrators and missionaries were killed or injured. At Shimla, Lady Curzon, wife of the Viceroy Lord Curzon, had a close escape from death when a chimney crashed into the room in which she was sleeping. Strong tremors, strong enough to cause light damage were also experienced at New Delhi, Gurjanwala, Poonch and Rohtak to name a few. Light to moderate tremors rumbled across the sub-continent, and were felt as far as Ahmedabad, Surat, Quetta, Jalalabad (Afghanistan), Lucknow and at many locations in present day Bangladesh. Water oscillations were reported from many locations in the Bengal and Myanmar (ASC).

Initially it was believed that there had been some ground level changes (Wadia, 1938) in the region between Dehra Dun and Mussourie, however, it is now known that there were probably serious errors in the readings taken at the time (Ambraseys et al 2000). Recent studies indicate that this earthquake had Ms magnitude of 7.8, unlike previously inflated values as high as 8.6. The moment magnitude has also been reassessed and has been found to be 7.8 (Ambrasey 2000 & Pacheco et al 1992). It has also been pointed out that the low intensity area between two locations of high intensity, i.e. Kangra area and the Dehradun area, was as a result of an improper survey in the area, as it was sparsely populated and had few structures that might have been affected.

There were hundreds of aftershocks some of which were considerably strong and were even felt in the plains of northern India. The largest earthquake within a year of the main event on April 4th, 1905 was the magnitude 6.4 Bashahr quake, which caused damage in the Kullu area and was felt as far as Jaipur. This was undoubtedly a serious earthquake in its own right, but was referred to as the Bashahr "aftershock".

The first violent effect of this earthquake was observed at Shahpur at a distance of 55 kms from Pathankot towards Dharamshala. The shops at the roadside built in sun-dried bricks with heavy slate roofs were totally ruined (roofs collapsed, but walls standing). At Shahpur, half the buildings were ruined and rest were ruined a part. All buildings were built of roughly shaped sun-dried bricks and sometimes with stone foundations raised about 15 cm above ground. Roofs were normally of slate but sometimes thatch was also used.

Beyond Shahpur in the direction of Dharamshala and Kangra the damage was of ascending scale. The route between Shahpur and Dharamshala showed intensive damage to the small and

big villages and lines of communication. The road was broken at many places. At villages Chari, the effect was maximum and the whole village was destroyed with the exception of only one or two stronger buildings which were also half ruined. Generally speaking the house had become mere heaps of sun-dried bricks mixed with slates and rafters.

The Dharamshala Township suffered severe damage amounting to total destruction at many places and casualties reached very high figure. The Military and civil staff was reduced to about half by deaths. The barracks at the Cantonment consisted of long single storey buildings, the principal walls being built on sun dried bricks and the two end walls of cut stones. The roofs were of thick slates. In all cases, the two long walls had rocked over generally as a whole in the downhill direction with the exception of the partitions immediately connected with the stone at the gable ends. The buildings built throughout of dressed stone were badly cracked and rest of portion like gable ends had been flung out as a whole flat on to the ground. The iron framed roof with two roads across from wall to wall preserved the armory buildings from complete collapse. The magazine consisting of a central square rooms, very strongly built of well dresses stones and lime mortar with arched roof showed only cracks (ASC).

At Forsythganj Bazaar, buildings were constructed of sun dried bricks especially in the lower storey and partly of wood mortar in the upper stories and verandahs. All shops to the east of the road were ruined while on the west many of them survived total collapse.

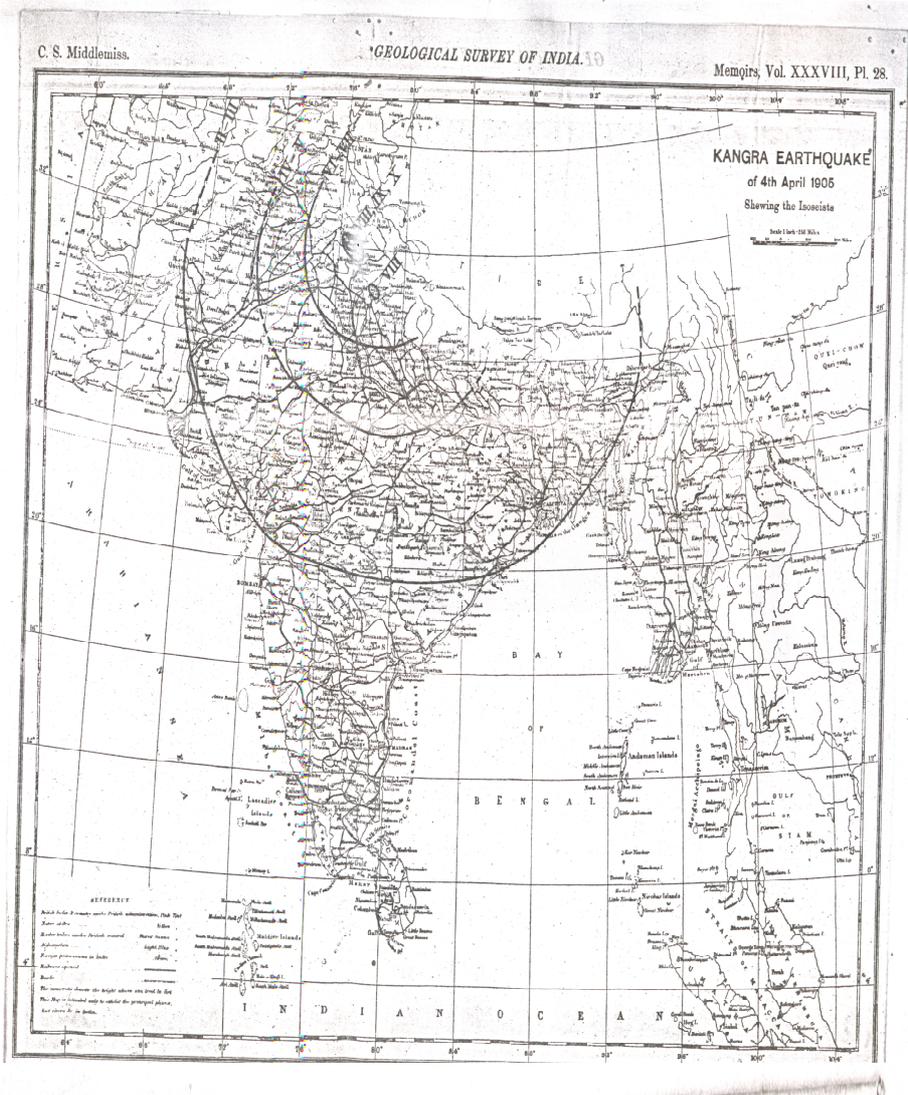


Figure. 2. Isoseismal map of 1905 Kangra earthquake

(Source: Middlemiss)

Mcleodganj bazaar was leveled to the ground with no building standing even partially. Same was the situation at Kotwali Bazaar which was reduced to a thick deposit of house rubble about 1.5 m high through which roads and lanes were cut for rescue and salvage operation. At Kangra the devastation was total. Not a single house was standing. The horror of actual calamity was beyond imagination. All the subordinate officials were killed and panic stricken people fled bearing that yet worse terror would envelop them.

After the earthquake, the district headquarters were shifted to Dharamshala which was built using wood framed bricks noggled buildings locally called Dhajji, the old office and present residence of the DC, there being the existing examples of this construction. This appears to have become the typical construction then, even being used by private people for their shops and houses. But later on gradually and more particularly after independence of the country when pace of development became fast and wood started becoming scarce, this very highly earthquake resistant construction methods, namely Dhajji, was superseded by plains type brick

and hill type stone constructions. Their unsuitability for meeting the earthquake shaking became clearly manifested in April 26, 1986 of M=5.7 and slightly obvious during the earlier earthquake of 15 June 1978 with M=5.0 occurring in the same general epicentral region (Expert Report 1998).

1975 - Kinnaur-Lahual & Spiti (Himachal Pradesh), India, Mw 6.7

A strong earthquake rocked the Indo-China border on January 19, 1975. It had a magnitude of 6.8 and caused damage in parts of Kinnaur, Lahaul and Spiti. Tremors were felt in many parts of northern India, as far as New Delhi. The earthquake was centred 24.1 kilometres SW of Chepzi (Xizang), China,
Or 26.7 kilometres ESE of Mt. Shilla (Himachal Pradesh).

60 people were killed and more than 100 were badly injured in the epicentral region (Singh et al 1975). 2500 people were also made homeless by the quake. A foreshock is believed to have been experienced a few minutes before the mainshock and was felt within the meizoseismal region. Casualties were low as the earthquake struck in the afternoon, at around 13:30 Indian Standard Time. A strong aftershock of magnitude (mb) 5.8 struck within 15 minutes of the mainshock. The worst damage was in the districts of Kinnaur and Lahual & Spiti in Himachal Pradesh bordering China. The village of Kaurik which consisted of 12 houses was completely destroyed. Severe damage also occurred at Sumdoh where government buildings were seriously damaged. Damage also occurred at Chango, Shalkar, Leo, Pooh and Tapri. The Tehsil office and the Post & Telegraph office at Leo completely collapsed. Collapses of masonry walls and sometime entire house collapses were also reported from Thabo, Giu, Sumera, Hurling, Namgia, Khab and other villages in the Spiti Valley. Wide cracks opened in the walls of houses at Shipkila, Ribba and Thangi. Minor damage was reported from Lari, Pangi, Moorang, Kalpa as well as from villages in the Pin Valley. The Hanley Gompa, on the Himachal Pradesh-Ladakh border also developed cracks in its walls (Singh et al 1975 & ASC) .

Rockfalls, landslides and avalanches were abundant in the Parachu and Spiti valleys. It was reported that dust from falling rocks, boulders and ice reduced the visibility for several hours following the earthquake. Rockfalls blocked the Hindustan-Tibet Road as well as other important roads in the region. At many places, telegraph poles and houses were damaged or destroyed by falling boulders. A police check post on the Hindustan-Tibet Road at Shalkar was destroyed by a 2.5 metre long boulder that fell during the earthquake. Along a 4-kilometre

stretch of the Hindustan-Tibet Road that followed the Spiti river, landslides obliterated many sections of the roadway. A rockslide between Chango and Shalkar damaged telegraph wires disrupting communication. Landslides and rockfalls were also observed on Chinese territory during the earthquake. A major landslide dammed the Parachu river in the valley of the same name between Sumdoh and Kaurik. The resultant debris dam was 60 metres high and created a reservoir that was 150 metres in length. Several hot springs in the vicinity were buried by the slide. Six days after the quake, the river made its way around the dam and began flowing in a new channel some 60-70 metres from where it once flowed. A hot spring at Shalkar ceased to flow following the earthquake but a new spring emerged in the same area at a lower elevation (Singh et al 1975 & ASC).

Ground fissures were extensive in the vicinity of Kaurik and Shalkar villages. The throw of the fissures ranged from a few centimetres to as much as a metre. Most of the fissures trended in a north-south direction. Fissures were also recorded along the Hindustan-Tibet Road. Scarps with upthrows of 0.5 to 1 metre were observed in the river bed of the Parachu River which was dammed by a landslide. This earthquake is believed to have been associated with the Kaurik fault and the ground fissures run in a north-south direction in the vicinity of this fault. The focal mechanism of this event indicates normal faulting.

The earthquake was felt over a wide section of northern India. It was felt strongly in much of Himachal Pradesh as well as in parts of Jammu & Kashmir, Punjab and Uttaranchal. Tremors were felt as far as New Delhi nearly 400 kilometres away, where the residents of high-rise buildings reported utensils rattling, furniture moving, and fans and other suspended objects oscillating.

Empirical relations between seismic moment (M_0) and surface wave magnitudes (M_s) for earthquakes in the Himalayan region yield a magnitude of 6.7 (M_w). Other relations between seismic moment (M_0) and body wave magnitude (m_b) give a moment magnitude of 6.4.

The Richter magnitude was estimated as 6.7 and maximum observed intensity in the region was IX on MM scale. The epicentral distance was about 25 kms from Kinnaur town. The traditional construction in the area was not seismic and had little resistance against the lateral forces. Nearly 2000 dwellings are reported to have suffered heavy damage even in the sparsely populated area.

Recent random rubble masonry and dressed stone masonry construction suffered extensive damage. Heavy flat roofs suffered great damage. Buildings constructed in hollow concrete blocks or dressed stone masonry in cement mortar developed small cracks in walls. Light structures made of corrugated iron sheets nailed to timber frames and arches did not suffer any damage. The temples(monasteries) and monuments also suffered badly (Expert Group 1998).

Dharamshala Earthquake: 26th April, 1986

The epicenter of this earthquake of $M=5.7$ was lat. 32.1 N and long 76.3 E, i.e. very close to that of 1905 Kangra earthquake. The origin time was 13 h 5 m 17 s i.e. IST and focal depth was shallow about 10kms. The loss of life was fortunately small, only about 6 persons, since the earthquake did not last long, although a very large number of dwellings got cracked including many govt. buildings in Dharamshala and other towns.

Most significant damage, requiring reconstruction of houses was to the adobe and stone houses in the village near Dharamshala, such as Nagrota, Nadi, Kaned, Sukar and Khaniara. The total financial loss was estimated as Rs. 65 Crore (1986 prices) according to newspaper reports.

In comparison to Kangra Earthquake of 1905, Dharamshala earthquake had a destructive energy of only about $1/28000$. The maximum MMI in the two earthquakes were X and VIII respectively showing again that 1986 quake was rather a minor one as compare to the giant earthquake of 1905 (Expert Group 1998).

The 24th March 1995 Chamba Earthquake

On 24th March 1995 at 17:22 hrs IST (11:52 UTC) an earthquake of magnitude 4.9 mb (USGS) struck the Chamba region in northwest Himalaya. The epicentral zone lies 8-10 kms northeast of Chamba township. Based on the isoseist characteristics, the source mechanism of this earthquake has been evaluated. The longest axis of the isoseismal is aligned in NW-SE direction, which is parallel to the trend of strike of rocks in the area. The pattern of isoseismals suggest that the causative fault for the 1995 Chamba earthquake is parallel to the local Himalayan trends and the strain has been released at a very shallow depth (Mahajan, 1998).

The Kangra-Chamba region is a part of the active seismic belt of the Himalaya. The area has experienced a great earthquake on 4th April 1905 which caused major damage in Bharmour area (Middlemiss 1910). The other damaging earthquakes of the Chamba region include that of 1945, 1947 and 1950 of magnitude 6.5, 6.0 and 5.5 respectively and of Dharamshala region are 1968, 1978 and 1986 of magnitude 5.4, 5.0 and 5.7 respectively. On 24th March 1995 a moderate earthquake of magnitude 4.9 mb (USGS) shook the Chamba region and its surroundings at 17:22 hrs. IST. The earthquake was felt strongly in Chamba Town and further southeast. To the northeast of Chamba it was felt up to Bharmour, in the northwest upto Tisa and in the southwest it was felt upto Dalhousie and Pathankot. Tremors that lasted for a few seconds caused low damage in a zone of about 8 kms radius maximum damage being in Pilure-Baraur sector localities.

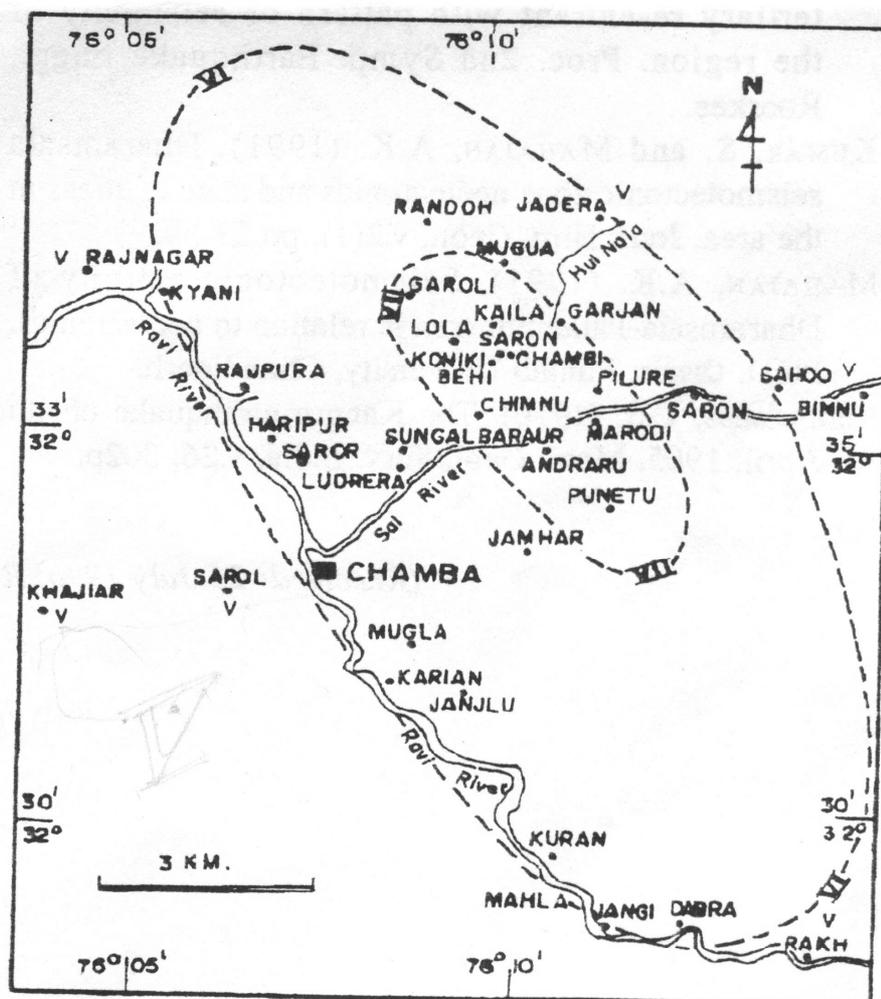


Fig. . Isoseismal map of 24th March, 1995 Chamba Earthquake (Himachal Pradesh).

Tension gashes were seen on the head ward side of the slope towards the Sal river in the valley. District Hospital (new building) made up of RCC structure developed wide cracks in the walls indicating damage of grade 2. The walls made up of burnt brick masonry showed diagonal cracks of 1-2 cm width and opening up of joints. In the CMO's residence, the damage was caused along the corners of the walls which opened up to a width of 2-3 cm and showed opening on both sides of the wall made up of burnt bricks. The bricks of the upper half portion of the walls show movement and tilt towards north at an angle of 20-30 degrees.

The damage to this building is of Grade 3. The wall hangings swung to one direction. Also, ceiling got separated from the walls. On the edge of the terrace on the bank of Ravi River, a few houses situated on loose soil developed cracks of Grade 2 in the ground floor and of Grade 3 in the first floor. The poorly constructed buildings (5%) suffered damage of Grade 4.

The Garur (God) pillar erected outside the famous Laxami Narayan Temple of Chamba town showed a movement of upper part of the pillar by 2-3 cm in the NE direction. The small bells, rang in the temple. The newly built Bhuri Singh Museum in the town suffered damage in the form of fine cracks in the walls of ground floor and first floor. In the Chamba town 90% of the people reported hearing zooming sound before the earthquake followed by strong jerk. The people also reported horizontal movement.

At village Ludera along the Sahoo road about 10% houses located on the right bank of river Sal on hard rocks suffered damage of Grade 3 in adobe houses. 90% houses located away from river Sal at Village Sungal suffered damage of Grade 2. At village Baraur the damage grade of type "B" buildings was of Grade 3 and in Type "C" buildings it was of Grade 2. The adobe houses suffered damage of Grade 4 in 25% of houses and Grade 3 damage in 70% houses. A total of 5% houses of type "A" had suffered damage of Grade 5. The school building of primary section suffered damage of Grade 4. The veterinary hospital building suffered damage of Grade 3 especially the gable portion. At Baraur, house of Mr. Piayar singh showed movement of slate roof N 270 direction. In the Chambi village large gaps were seen along joints of the walls which were tilted in ESE direction. The ground surface developed cracks of 3-4 cm width trending east-west direction.

Along the Jadera road in the Chambi village the walls in the ground floor suffered damage of Grade 3. The new building of Mr. Dev of the same village developed wide cracks. The separated

portion was pushed towards ESE direction. At village Garjan, the pillar of an IPH water tank showed damage of Grade 1. Most of the people of Chambi, Baraur and Pilure area reported blast like sound before the earthquake. Similar type of damage was noticed in Koni-Ki-Behi, Saron, Lola, Garoli and Kaila villages. In Mugua and Jadera villages the intensity of damage fell magnificently. Similar damage was reported from village Randoh by local residents.

Most of the inhabitants of Maredi, Jamhar, Puneta and Andraru villages heard a blast with cracking sound. In these villages the type "C" buildings suffered damage of Grade 1. However, many houses of type "A" structures suffered damage of grade 2 with few houses showing damage Grade 3 and 4. At Chaminu village 50% type "A" houses suffered Grade 3 damage. At Pilure village Grade 4 and Grade 5 damage was seen in few buildings of Type "A" structures. The type "B" buildings suffered damage of Grade 2 and 3. At the same village the driver of HRTC bus coming from Sahoo towards Chamba reported vibration during an earthquake followed by shaking in horizontal direction. The earthquake lasted 10-15 seconds as reported by local residents of the area (mahajan, 1998).

Along the Chamba-Tissa road at village Saror most of the type "C" buildings showed damage of Grade 1 with cracks in the walls and opening up of joints. Many type "B" buildings suffered Grade 2 damage. The Haripur, Rajpur and Kiyani villages fell under the same intensity zone VI but the damage decreased beyond Kiyani. The village Raj Nagar falls under intensity zone V.

Southeast of Chamba towards Bharmour road, damage was observed up to village Jangi. Further east, observations recorded loss of balance and falling of some unstable objects (like boulders) at a number of places. The Mehla, Karian, Kuran and Jangi villages located on Chamba-Bharmour road suffered Grade 1 and 2 damage in most of the type "B" and type "A" houses, respectively. Very few type "C" houses showed minor cracks. Beyond village Dabra the damage grade decreases and only finer cracks were seen in the Type "A" and Type "B" houses at village Rakh.

In the meizoseismal Zone, land fissures were observed at village Pilure running in the east – west direction which could be traced up to 400-500 metres. The fissures were seen on the soil cover which was about 1 meter thick over Manjir conglomerates dipping in opposite direction of the slope of the fields.

Based on the damage survey of 24th March 1995 Chamba earthquake, an isoseismal map has been prepared. The maximum intensity isoseismal VII surrounds the villages of Pilure, Baraur, Chambhi and some neighbouring small villages covering approximately 4x10 km area with its long axis in NW-SE direction and minor axis in NE-SW direction. The isoseismal VI covers an area of 11x26 km. The damage survey shows fast attenuation pattern towards the northeast side and slow pattern in the southwest direction. The isoseismal exhibits an elliptical shape whose major and minor axes run in NW-SE and NE-SW directions, respectively. The intensity VII covers approximately 4x10 km square area. The major axis of the isoseismal follows the regional Himalayan trend. Based on the above studies it can be proposed that the 24th March 1995 Chamba earthquake was caused due to slip along the NW-SE trending tectonic features (Mahajan, 1998).

The Sunder Nagar Earthquake (NW Himalayas) of 29th July, 1997

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 within a 2 km radius of Sunder Nagar 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 areas 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 (I_o) 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, 1997. The isoseismic 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 suffered more damage, however, the houses located in the same locality but away from the thrust. One of the interesting features 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 (VC Thakur et al).

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.

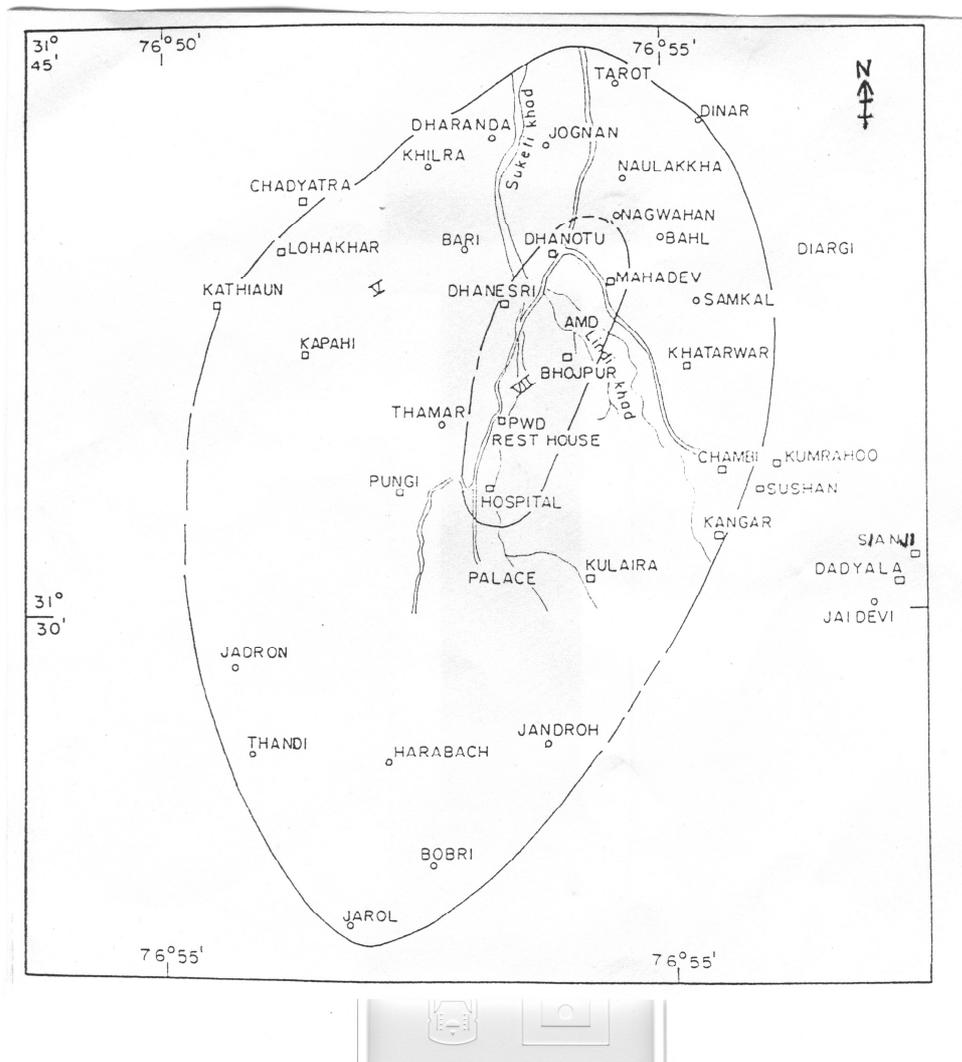


Figure 4 Isoseismal map of Sunder Nagar earthquake (Source VC Thakur et al)

In the town area the hospital building made up of stones with mud masonry suffered cracks of 2-3 mm width, whereas 75 year old DSP residence made up of mud bricks with mud masonry 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 has been reported from the Sundernagar localities named as Bhojpur and Ambedkar Nagar situated on both sides of the Lindi river alluvial plain. Most of the adobe houses showed partial to total collapse. 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 up to Bilaspur. In the north it was felt upto Joginder Nagar and a few people reported up to Chauntra. To the west it was felt up to Sarkaghat and a few old people from Hamirpur reported some feeling of the event who were not sleeping at that time resting on the bed on second storey. To the east the earthquake was felt up to Giri and Karsog and to the northeast up to Kullu. The main effect of the earthquake was very localized and damaged badly adobe houses of 7-8 villages located within 5 Kms radius from 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. No land fissures generated by this earthquake have been seen in the area during the survey.

Isoseimal plotted of various significant earthquakes have been given in the above figure. 1905 Kangra earthquake and 1976 Kinnaur earthquake had maximum MM intensity of IX in the epicentral region. 1995 Chamba and 1986 Dharamshala earthquake had maximum MM intensity of VII in the epicentral region whereas the 1978 Dharamshala earthquake and 1997 Sunder Nagar earthquakes had MM intensity of VI.

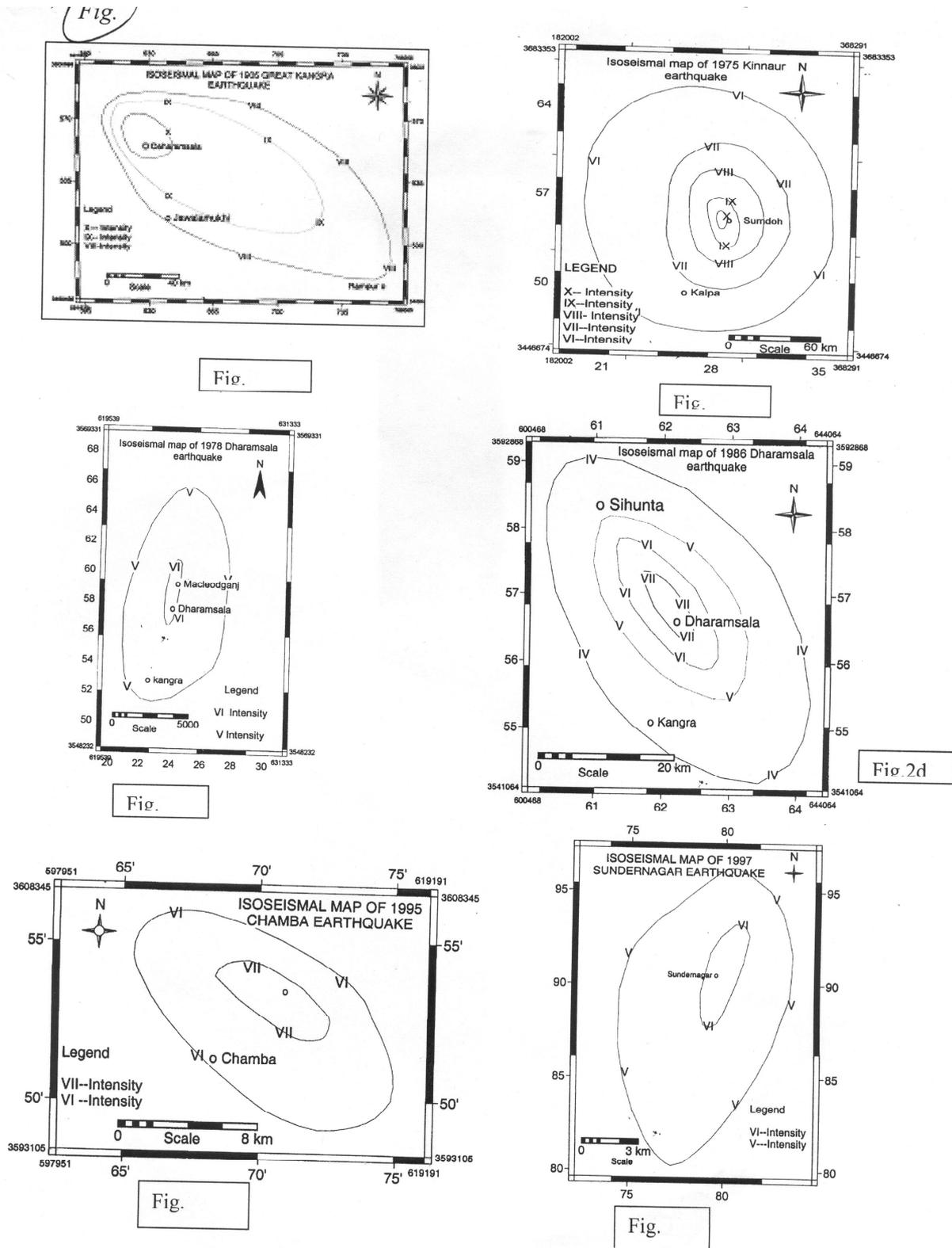


Figure. 5. Isoseismal Maps of Various earthquakes which rocked HP (Source A..K. Mahajan.)

Prediction of future earthquake in the Himalayas (Source Roger & Bilham).

According to Roger and Bilham the entire Himalayan region is highly vulnerable to a future great or mega earthquake. Due to locking of Indian and Eurasian plate the strain accumulation over the years has increased considerably. In the short span of 53 years from 1897 to 1950 four great earthquakes of Richter Magnitude ≥ 8.0 namely 1897 Shillong (8.0), 1905 Kangra (8.0),

1934 Bihar (8.3) and 1950 Assam (8.6) rocked the mighty Himalaya. No major or great earthquake has occurred along the Himalayan belt for more than 55 years now and several lines of evidence show that one or more great earthquakes may be overdue in a large fraction of the Himalaya, threatening millions of people in that region including millions of people in the towns and villages of Gangetic plains.

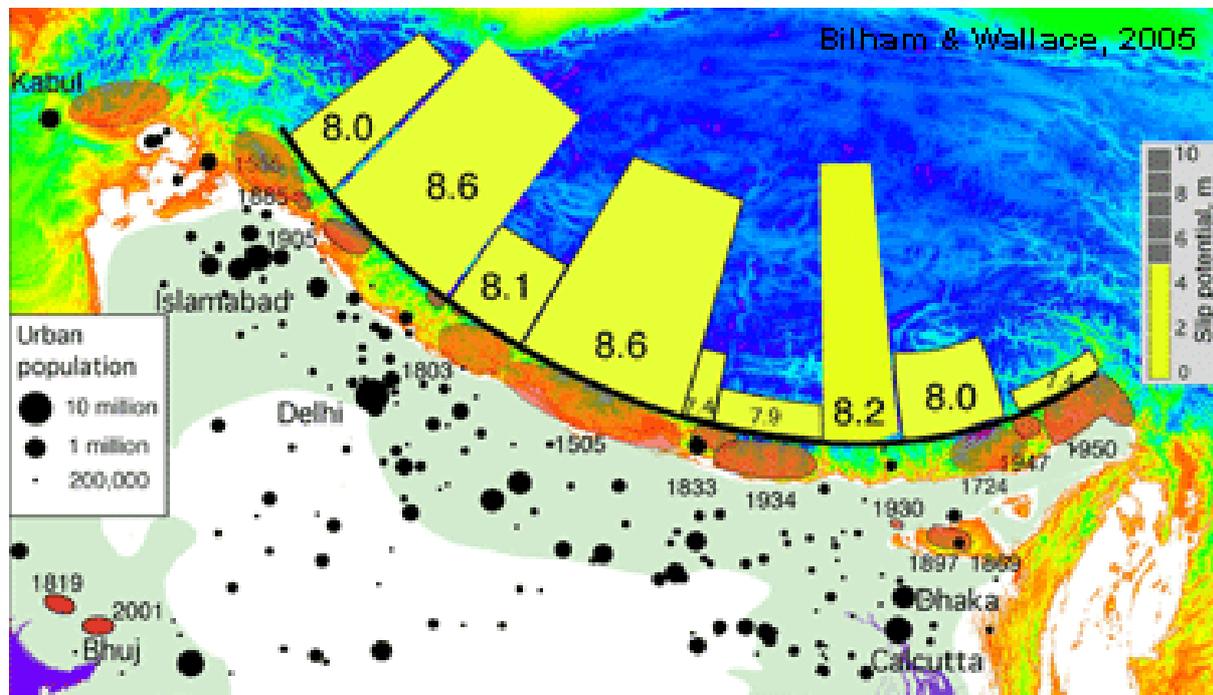


Figure 6. Prediction of future earthquake in the Himalayas (Source Roger & Bilham).

Along the Kangra Chamba region the model projects an earthquake with magnitude 8 or 8.6. The occurrence of an earthquake of such a magnitude in the region is a matter of serious concern.

TABLE : EARTHQUAKE OCCURRENCE IN INDIA, $M \geq 5.0$ (RICHTER SCALE)

S. No	Seismic Region	No. of Earthquakes having $M =$				Max MM Inten-sity	Average Return Period Observed For $M > 5.0$
		5-5.9*	6-6.9	7-7.9	8.0 or more		
1	Kashmir and Western Himalayas (J&K, Himachal Pradesh, Sub-mountain parts of Punjab)	25	7	2	1	X	2.5-3 Yrs.
2	Central-Himalayas (Uttaranchal, Nepal Himalayas, North Bihar)	68	28	4	1	XI	1 Yr.
3	North East India	200	130	15	4	>X	<4 months
4	Indo-Gangetic basin & Rajasthan (Rajasthan, Punjab, Haryana, Delhi, Plains of U.P., Bihar & Bengal)	14	6	-	-	VIII	5 Yrs.
5	Cambay and Rann of Cutch	6	5	2	1	IX-X	7 Yrs.
6	Peninsular India	32	10	-	-	VIII	2.5-3 Yrs.
7	Andaman & Nicobar	80	68	1	1	>IX	<8 months
	Whole in India	425	254	24	8		<2 months

* Numbers approximate

(Table Compiled by A.S. Arya)

Dr. A S Arya has in the table 4 above has worked out the average return period of earthquakes of varying magnitude for the country. And for HP the average return period of earthquake with $M \geq 5$ is between 2.5 to 3 years.

Dr. Anand S Arya (Department of Earthquake Engineering, University of Roorkee has worked out a hypothetical recurrence of earthquake of $M 8.0$ in Kangra area of Himachal Pradesh (like that of 1905). The scenario highlights the disastrous situation that could have developed if the repeat earthquake had occurred in the census year 1991. The results are obtained for two cases of all buildings being of traditional construction (i) without earthquake safety features, (ii) with earthquake resistant features as per the Indian Standard Building Codes.

It is seen that:

* If all the 18,15,858 houses are without earthquake safety provisions, the direct losses will amount to Rs. 51.04 billion. Since about 65,000 lives may be lost and 399,695 houses ruined completely, the trauma will be too great and cost of emergency relief will be exorbitant.

- If all the houses were made earthquake resistant as per IS:4326 and IS:13928, when built initially, the direct losses will amount only to Rs. 19.6 billion. The extra cost of earthquake safe provision for all houses would only be Rs. 6.35 billion. Hence, the lives lost will only be a net saving of Rs. 25.09 billion or about 50%. Besides, the lives lost will only be one-fifth and totally ruined houses reduced to about one-fourth. The damage scenario brings out clearly the economic and other social benefits of pre-earthquake preventive measures.

Table: Losses in magnitude 8.0 hypothetical earthquake if occurred again in Kangra, Himachal Pradesh in 1991 (total housing units in the affected area -1,815,858)

Sr.No.	Item	Scenario if all the buildings are without earthquake resistance		Scenario of all buildings are with earthquake resistance	
		Physical Damage	Loss in INR* (million)	Physical Damage	Loss in INR* (million)
1.	Loss of lives	65,000	6,500	12,000	1,200
2.	Total collapses of buildings (G5)	1,36,339	9,540	8,298	580
3.	Destroyed buildings (G4)	2,63,356	18,430	94,997	6,650
	2+3 Buildings to rebuild	3,99,695	27,970	1,03,295	7,230
4.	Heavily damaged buildings (G3; to repair and retrofit)	9,15,602	12,820	3,12,382	4,370
5.	Moderately damaged buildings (G2; to repair and retrofit)	3,57,510	3,750	6,48,040	6,800
6.	Total Loss		51,040		19,600

*INR-Indian rupees, 1US\$INR 40.0 in 1997; G5, G4, G3, G2 are grades of damage defined in MSK Intensity scale.

Losses estimated in 1997 at 1997 costs.

Source: Arya As, 12th World Conference on Earthquake Engineering, Auckland, 31st January-4th February, paper No.2824.

The above analysis is applicable to rest of the parts of the state. If no efforts are made to construct earthquake resistant houses and if existing housing stock isn't strengthened by way of retrofitting, the situation will be disastrous in the event of any major earthquake.