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Geonvironmental impact of October 8 Kashmir Earthquake in Karnah and Uri Tehsils of Jammu and Kashmir

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ABSTRACT

This paper embodies the field observations made on the geological conditions vis-à-vis damages caused to the structures and other property in the earthquake devastated areas of Karnah and Uri Tehsils. In both the areas, fissures and normal faults have developed on the mountain ridges, slopes and in the river valleys. Besides, liquefaction has taken place at number of localities in these areas and also in Jammu at Simbal Camp. The earthquake has destroyed almost all the road links in both areas triggering landslides and rock falls that have caused damage to the settlements in their close vicinity. Four types of building structures exist in the quake affected areas of Kashmir including Masonry types A, B, C, and D. According to the revised MMI scale by ABAG (2003) the intensity of the earthquake in Karnah and Uri areas range from VII to X.

Lithologically both the areas can be classified into three categories including 1) alluvial plains, 2) Old river terraces and 3) hard rock mountain slopes. All the three classes of strata have behaved differently to the earthquake of October 8, which is reflected by the varying amounts of damage caused to the same type of structures situated in the three stratal conditions. Our study suggests that building codes should be designed keeping in view the stratal conditions of the area.

Keywords : Geological conditions, damages, earthquake, Karnah, Uri, J&K

INTRODUCTION

On October 8, 2005 an earthquake struck the Northwestern Himalaya and devastated the northern Pakistan and Jammu and Kashmir State; its prediction was Mw 8 (Bilham and Wallace, 2005). The major earthquake of 7.6 Mw (USGS) struck the region at 09:20:38 Indian Standard Time (03:50:38 UTC, 08:50:38 Pakistan Standard Time). The hypocenter was located at a depth of 26 km (16.2 miles) below the surface (USGS). The earthquake epicenter (34°29'35?N, 73°37'44?E) was located approximately 19 km NNE of the city of Muzaffarabad, the capital of the Pakistan administered part of Jammu and Kashmir (PAK) and 125 km (75 miles) WNW of Srinagar, Kashmir (India). The earthquake caused intense havoc to the life and property and also to the ground and mountain slopes in the both parts of Jammu and Kashmir State and northern pakistan. The earthquake devastated about 40,000 km^2 in Kashmir and Northern Pakistan and killed more than 90,000 people and injured about one lac. The earthquake affected more than 500,000 families. About 3.5 million people got dislodged including about 1.6 million children. Besides, more than 3100 schools in PAK got damaged, 20000 children got killed and another 20000 injured in Pakistan and its administered part of Kashmir. In addition, approximately 250,000 farm animals died due to collapse of stone barns. It is estimated that more than 780,000 buildings were either destroyed or damaged beyond repair, and many more were rendered unusable for extended periods of time. Out of these, approximately 7,000 school buildings and most major hospitals close to the epicenter were destroyed or severely damaged. Property loss is placed at 4 billion US dollars. Three lac people got unemployed in the

aftermath. In our part of Kashmir 1360 people died, 6266 got injured and 150,000 have been rendered homeless (official figures). Lifelines were adversely affected, especially the numerous vital roads and highways that were closed by landslides and bridge failures. Several areas remained cut off via land routes even three months after the main event. Power, water supply, and telecommunication services were down for varying lengths of time, although in most areas services were restored within a few weeks. The Kashmir earthquake is claimed to be the worst disaster of the century. The earthquake aftershocks in the region continued for about four months. A total of 147 aftershocks were registered on the first day after the main shock among them included 29 aftershocks of magnitude more than 5.0 and two having magnitude 6.0 (IMD).

We visited the areas affected by earthquake in Kashmir from November 2nd to 12th, 2005 and carried out detailed geoenvironmental investigations in the Karnah and Uri Tehsils. The damage by the earthquake is severest in the areas close to the epicenter in Karnah and Uri Tehsils within a range of 50 km from the epicenter. The area was still trembling with aftershock tremors being felt every day. Most houses in the area have collapsed into heaps of rubble, and the remaining few that are left standing have developed severe cracks and can easily crumble due to aftershocks or even under the weight of snow. Almost all shops and schools in the area have been destroyed. Roads and footpaths leading to many villages off the main highway have also been blocked, being covered with massive boulders. Agricultural fields have developed deep cracks and the irrigation channels leading to the fields have been clogged. Lifelines have been adversely affected, especially the vital roads and highways that were closed by landslides and failure of bridges. Most of the affected areas are in mountainous regions where landslides and rockfalls blocked the roads. We document in this paper the damages caused to the geo-environment by the earthquake and the consequences on the road network and buiding structures in the region.

OBSERVATIONS

GEOLOGY

Bilham, who carried out research in PAK after the earthquake, confirmed a rupture of 100 km length, from very close to the surface down to a depth of 30-40 km of the Kashmir region, diagonally from the north-west to the south-east upto LOC in Kashmir. In our part of Kashmir we traced the continuity of this rupture zone in Tangdhar and Uri sectors upto Baramulla (Fig. 1 & 2). The October 8 earthquake that occurred on the Main Boundary Thrust has activated the subsidiary fault lines in the Karnah and Uri areas. The evidences are seen on either side of these fault lines along the mountain ridges whose expression is visible on the mountain slopes in the form of longitudinal cracks (Fig. 1 & 2). These cracks are tens of centimeters in aperture and a few meters deep on the mountain ridges. At places a vertical slip of about 1m is seen in these mountain ridge cracks. The Karnah area falls within the Kupwara district while the Uri area falls under the administrative control of the Baramulla district.

The Tangdhar-Tithwal valley (Karnah) is drained by two main streams (the Batmaji River and the Qazinag River) which together confluence with the Kishanganga (Neelam) River at Tithwal (Fig. 3).

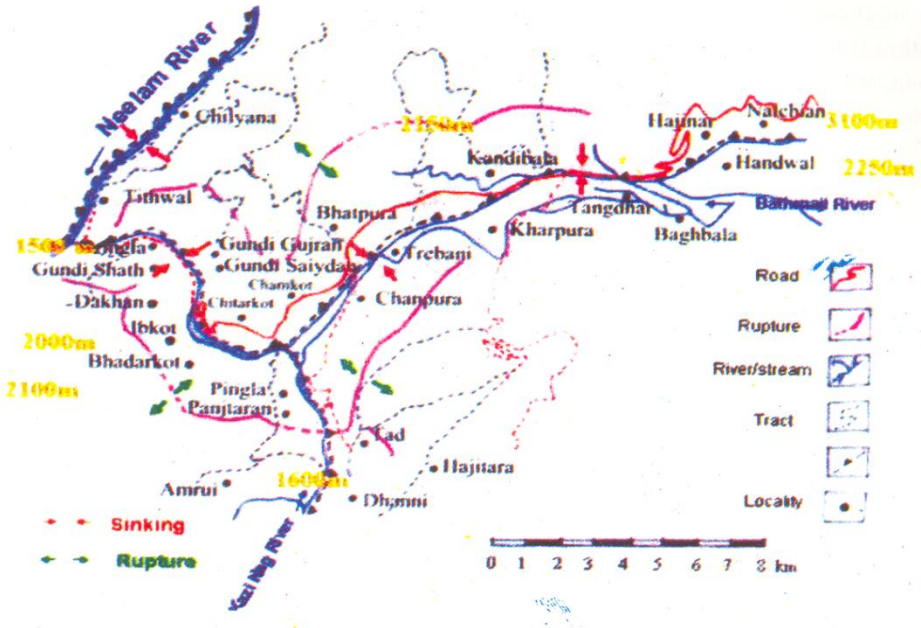


Fig. 1. Tectonic map of the Tangdhar-Tithwal sector, Karnah, showing the development of ruptures

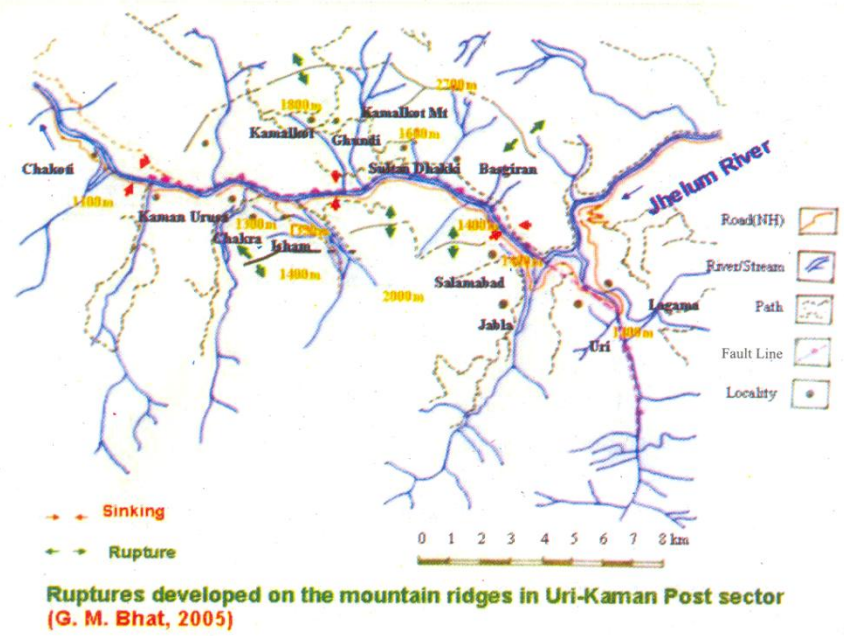


Fig. 2. Tectonic map of the Uri-Kaman Post Sector, Kashmir, showing development of ruptures on the mountain ridges in Uri Kaman Post Sector

These rivers are flowing along the fault lines in the Tangdhar-Tithwal area. On either side of the Bathmaji and Qazi Nag Rivers are lofty mountain ranges which are cut into narrow gorges and deep defiles. The terrain is rugged and remains snow covered during the winter months. The famous Sadana Pass (Nastha Chhun), which lies at an elevation of 3125m (10417 feet) above msl, cuts off the Karnah valley from the main Kashmir valley. In Uri the geological investigation was carried in the areas on the either side of the River Jhelum upto Kaman post. The Murree Thrust is running through the Jhelum Valley here. The area is drained by a number of small streams originating from the lofty mountains on both sides of the Jhelum River. The Srinagar-Uri-Muzaffarabad road is running on the left bank of the Jhelum River.

Geologically the entire landmass of the Karnah and Uri Tehsils surveyed can be categorized in the three classes including the older alluvium, older river terraces and the mountain- and hill slopes. a has Agriculture is being practiced on the older alluvium and at places the settlements also exist on these deposits. Most of the settlements are confined either to the older river terraces or to the mountain- and hill slopes. As a rule the mountain and hill slopes are vulnerable to landslips, landslides, debris flows and shooting stones. Also the older terraces are highly vulnerable to debris flows and slips during flash floods and seismic activities. The Tangdhar-Tithwal valley and the Uri area are prone to flash floods as is evident from the recent records and the geological evidences in the area. Our study reveals that in the past the entire area has witnessed the seismic activity comparable with the October 8 earthquake and even of more in intensity. This fact has been confirmed by the local people who claim that their elders have revealed to them the furry of flash floods in the entire valley in the past that compelled them to shift their settlements to the mountain slopes. The furry of nature did not spare them even at the higher elevations when severe earthquake struck the entire region in the past killing most of the inhabitants settled on the mountain slopes. The skeletons of the human beings which lay buried at a depth of about 20m are sometimes brought out of the debris due to landslides and slips in both the Karnah and Uri areas.

The October 8 earthquake has devastated the mountain cliffs, ridges, slopes and even the agricultural fields. Most of the settlements in the area are either in the plain areas on the old river terraces or on the vulnerable mountain slopes. The old river terraces are well known for instability against the natural processes and the mountain slopes are susceptible to landsliding, landslips, rock falls, etc. The road network traverses through these unstable zones and has further aggravated the situation. The only construction material available in these areas is rocks and timber. Almost all the residential and official buildings are multistoried and made up of rocks and timber. These structures are susceptible to collapse even at moderate earthquakes. It is because of the poor foundations and unstable ground conditions of the area that almost all the buildings within a radius of 50 km of the epicenter collapsed and within the radius of 100 km of the epicenter all the buildings were partially damaged. We noticed ridge cracks, landslides, rock falls, liquefaction and structural damages in Tangdhar-Tithwal and Uri-Kaman Post sectors. The salient characters of these features and field notes taken in these areas are briefly described as under:

LIQUEFACTION

Liquefaction is a process that occurs when a loosely packed grain framework is suddenly broken down;

the grains become temporality suspended in the pore fluid, and settles through the fluid, displacing it upward, until grain-supported structure is re-established. The lower threshold of shaking intensity of about MM VI can produce liquefaction in sensitive deposits. Liquefaction can be developed at earthquake magnitudes as low as about 5, but that a magnitude of about 5.5 to 6 is the lower limit at which liquefaction effects become relatively common. However, on November 3 liquefaction was triggered by an earthquake of magnitude 4.4 Mw at Karalapura. We also observed liquefaction caused by the October 8 earthquake at number of places in Kashmir and at Jammu whose salient features are described here.

Simbal Camp

Simbal camp is situated on the outskirts of Jammu municipal limits at a distance of about 225 km from the epicenter of the October 8 earthquake. Tension cracks are visible on the wet ground and on footpath in the Simbal Camp (Fig. 4). These NE-SW trending cracks range in aperture from 15 to 21 cm. These cracks show a vertical displacement of 2.5 to 5 cm and their depth ranges from 1.5 to 2 m. A few sand blow craters (Fig. 5) are also visible in the area through which brownish sand and water ejected into the air upto 1.5 m at the time of earthquake on October 8. The local youth who were playing in the area at that time narrated their experience of this earthquake. "The ground started trembling and we got frightened and started running away from the ground but could not stand. Suddenly water with sand started gushing out from all over the ground and from the nearby fields. All of a sudden the atmosphere became cloudy. The ground where we sat started cracking and in no time the multiple cracks developed in the field and the footpath".

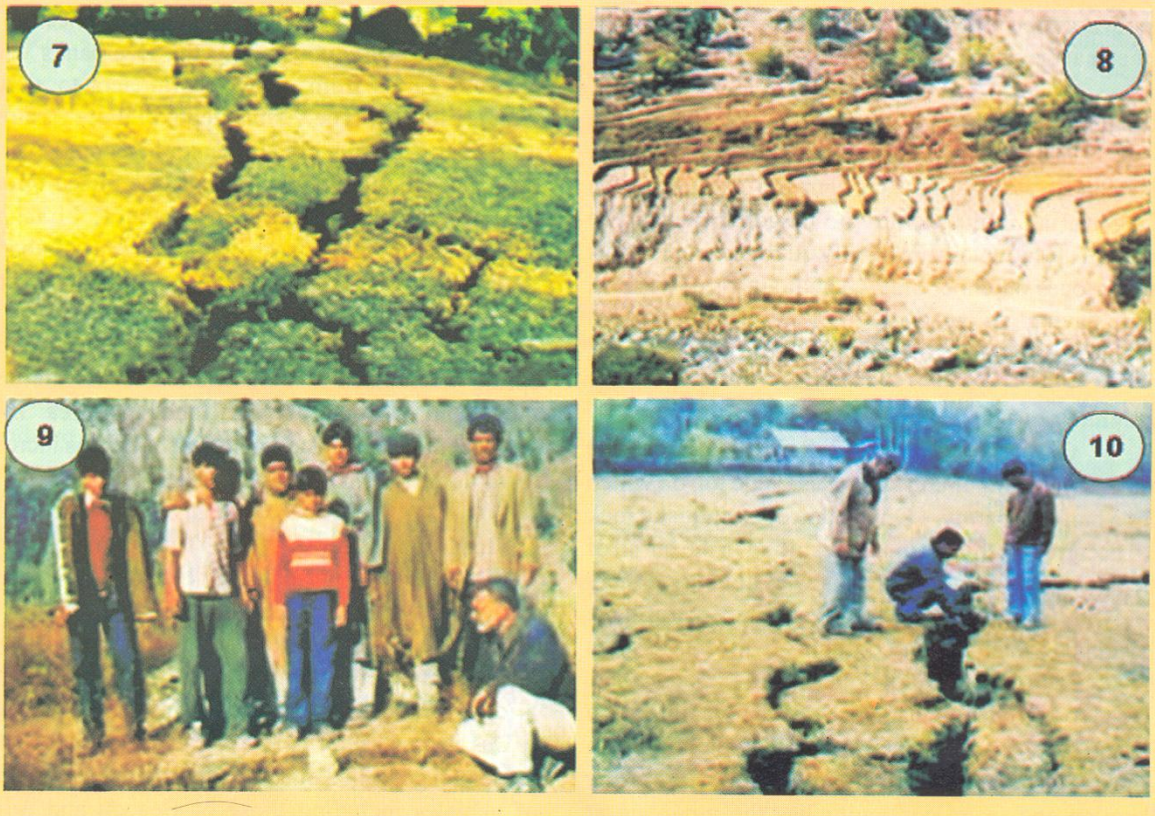
Kupwara

In Kashmir we observed liquefaction at Armpura, Nutnusa, and Badarkal in the Kupwara District. The local residents said that on the earthquake day blue coloured water ejected out of these liquefaction craters and at a few places brownish colored water emanated. The craters have dried since but the scars are still present in these areas. They also revealed that water in the springs in these areas has increased since the occurrence of the earthquake. An earthquake of magnitude 4.4 with its epicenter at lat 34.59^{0}N and long 73.62^{0}E on 3rd of November, 2005 at 0625 hours (IST) produced liquefaction in the village Karalpura (lat. 34°30' 20"E, long. 74°07'09"). On our return from Tangadhar on 7th of November the process was on and the area of activity had spread over about 4 km^2 in the vicinity. There are number of other sites in this area where water was oozing out of the paddy fields and in the Dar Mohalla of the Karalpura town. On the 3rd of November the water gushed out at three spots (Fig. 6) in the Mohalla and ejected black sand in large quantity and was thrown into the air upto 1.5 m. At Karalpura the sand blow craters are 0.7 m in diameter and have ejected black sand in great quantity. It is located at about 100 km aerial distance from the epicenter of the earthquake. Two peculiar things to be noted in this liquefaction event are 1) the magnitude of the earthquake 4.4 Mw which is far less than the threshold magnitude of 5.5 Mw and 2) time of occurrence i. e., one month latter than the main event on October 8. The ejected sand suggests the alluvial fan deposits at depth. The process of liquefaction has also occurred during the main earthquake at a number of places in the Kandi area in Karnah. The liquefaction associated with the October 8 earthquake and aftershocks offers an opportunity to develop relations to constrain the magnitude of the past earthquakes in the same tectonic setup. It is also the best reference to compare its dimensions with the palaeo-liquefaction and thereby to assess the recurrence interval for larger events for the same seismic source or an average interval for a region. The liquefaction process can help to identify the earthquake prone areas and contribute to the earthquake hazard assessment.

TENSION CRACKS

During the field survey conspicuous surface cracks several hundred meters in length, tens of centimeters in width and having partial determinate

Figs. 3 - 6. Geo-environmental impact of October 8 Kashmir earthquake
Fig. 3. Neelam Valley Road opposite to the Teethwal Township
Fig. 4. Tension cracks in the ground at Simbal Camp, Jammu;
Fig. 5. Sand Blows at Simbal camp, Jammu;
Fig. 6: Liquefaction crater at Kralapura, Kupwara



Figs. 7-10. Geo-environmental impact of October 8 Kashmir earthquake (continued)

Fig. 7. Tension Cracks at the ridge of Green Patch Mountain;

Fig. 8. Land sliding near Sikh Bridge inflicting loss of agriculture land

Fig. 9. Tension Cracks in Tangdhar Bakhain

Fig. 10. Tension Cracks along the Jhelum River Banks at Kichhama.

earthquake. The earthquake has ruptured the paddy fields situated between the road and the river Bathmaji. These fissures are oriented NNW-SSE with aperture upto 30 cm and depth seen upto 1.50 m. The mountain slope on the eastern side of the villages Trebani and Chanpura has been fissured at the ridge and at a number of places on its slope. The slip is about a meter at the ridge.

Tangdhar Bakhain

The mountain ridge at Tangdhar Bakhain has developed cracks (Fig. 9) which run parallel to the Tangdhar nar in the vicinity of Tangdhar town. The rocks of the mountain are mainly quartzite and form its steep slopes on either side. The main fissure is 3 m deep having an aperture of 1 m. The vertical displacement is about 0.5 m.

Sadana Pass (Nasta Chhun)

On the left side of the Sadana Pass lies the snow-covered mountain known as Eagle top on which lies a bunker of army. On the day of earthquake rock fall occurred on this mountain resulting in the burial of the army post killing 12 jawans who are buried there for ever. On the ridge of this mountain fissures have developed which are in continuity with the fissures developed in the mountain ridges of the Karnah valley. On the road from Kupwara to Tithwal 4 km before the Sadana Pass fissures have occurred on the mountain slopes which traverse the road also. In the same direction and in its continuity lies the mountain at Rangwar, which has developed large fissures similar to the ones that occur in the Karnah Valley Mountains. The Rangwar village has been totally devastated and a population of about 100 people has shifted from the village to the roadside (a walk of about 2 hours). In this locality parallel fissures have resulted in rock- and debris falls inundting the settlements and the agricultural fields.

Beyond Rangwar-Drangyare villages towards Kupwara the intensity of damage has progressively decreased. However, it is not known whether fissures have developed in the mountain ridges and slopes of this belt or not. The evidences of rupture in the agricultural fields and around the settlement at Karalpura suggest that fissures may have also occurred in the vicinity of these areas.

Kichhama

On the way to Uri from Baramulla we observed fissures developed on the banks of the Jhelum River at Kichhama village near Sheeri. The fissures are continuous along the riverbanks whose aperture varies from a few centimeters to about a meter (Fig. 10). The visible depth of these fissures is more than 2 m. On the left bank of Jhelum River the cracks in the mountain slopes can be traced through the villages of Malpura, Dangapura, Sultanpura Kandi, Dudhbug, Nilasar, Chunti Pathri, Babarishi upto Tangmarg and beyond. The spring situated at the foothill in this village has completely dried out immediately after the October 8 earthquake. The spring water used to be sufficient to irrigate about three hundred kanals of paddy land in the area. In this belt the intensity of damage to the buildings increases towards the mountain slopes.

Uri to Kaman Post

The National Highway 1A from Uri to Kaman Post, a stretch of 17.2 km, is totally damaged by the earthquake. The highway stretches have been washed away completely at number of places. Culverts, bridges and other infrastructures have been damaged. It was in this sector of the highway that 66 Beacon personnel got killed during the earthquake. A number of vehicles including those of Beacon and private sector have got damaged on this highway. Landslips, debris- and rock falls and shooting stones have struck most of the road sections. Almost total stretch of 17 km of the highway has developed cracks along and across its entire length from Uri to Kaman Post. The main bridges, which have been damaged, include those of Red Bridge, Twin Bridge and the Aman Sethu. The most damaged bridge is the Aman Sethu whose one abutment on the PAK side and one panel of 70 m in length has been completely destroyed (Fig. 11). All the buildings from Uri onwards have been damaged and the intensity of damage is complete beyond the Uri town. The area hosts a population of about 115 thousands.

vertical extent, were noted in the region. These cracks are distinctly tensile in nature with some vertical slip component. The mountain ridges, agriculture fields and the river banks have witnessed extensive damage in the form of extension cracks and down slip movement in both Karnah and Uri areas. Locality-wise description of these tension cracks is given as under:

Green Patch

Green patch is the mountain ridge at an elevation of about 1900 m above msl. Below this ridge are situated the villages of Beari and Dringla on its western and eastern slopes respectively. These villages host about 100 households with a population of about 700. The entire settlement has been razed to the ground. The mountain slopes have been cracked both longitudinally and transversely. The cracks run parallel to one another for a few hundreds of meters and are often cut across by subsidiary cracks. The aperture of the main cracks ranges from 1 m to 4 m and a visible depth of about 3 m. The vertical slip of the Green Patch ridge is about 1.0 m. At the ridge of the Green Patch there exists a large crack which runs all along the ridge for about 1.0 km till it coincides with the another crack developed in the adjoining mountain ridge cutting across the Green Patch ridge. On either slope of the Green Patch Mountain longitudinal and transverse cracks of different sizes have developed. The Longitudinal cracks run parallel to the main ridge crack. The multiple cracks running parallel to one another (Fig. 7) can be observed on the mountain slope while climbing the hill to Green Patch through the village Beari. These cracks are running along NW-SE direction with an aperture of 20 to 23 cm. The depth observed in these cracks is about 60 to 100cm, showing a displacement of about 10 to 15 cm.

Tithwal

The Tithwal Mountain ridge has developed fissures which are running in NNE-SSW direction with aperture of 13 to 25 cm. The rocks have been displaced by about 10 to 25 cm. These cracks have lead to rock fall and landslide that have partially inundated Tithwal Township.

Dakhen

The Dakhen Mountain is about 2000 m above msl. The villages Ibkot, Dakhen, Pati Thamni and Bahadarkot are situated on the eastern side of the village Dakhen and on its western side is situated the Green Patch. The mountain ridge is fissured all along the ridge for a few kilometers in the NNE-SSW direction. Main lithology of the mountain is quartzites and phyllites. On either side of the ridge occurs number of parallel fractures on the slopes whose aperture ranges from 30 to 100 cm. These fractures are deep and the visible depth is 1.5 m. At the mountaintop the vertical slip of about 0.75 m has taken place.

Chhamkot-Sikh Bridge

The villages between Chhamkot and Sikh Bridge include Pingla-Haridal and Chitarkot. At Pingla-Haridal is situated a hydroelectric power project of 2 MW capacity on the Qazinag River. This power project lies just below the confluence of the Batmaji River with the Qazinag River, has been severely damaged by the earthquake. The massive debris flow has occurred in this stretch of the valley and has resulted in the loss of a good amount of the agricultural land near Sikh Bridge (Fig. 8). Two human bodies are still buried under the huge debris fall deposit near the Powerhouse site in the Qazinag Riverbed. The paddy fields on either side of this stretch of the valley have developed parallel cracks running along the river course (NNW-SSE) whose aperture ranges from a 12 to 20 cm. The visible depth of these cracks is about 2 m. A large fissure cuts across the road at Chitarkot. The aperture of the fissure is 1.0 m and its visible depth is almost 3 m. From Chitarkot towards Sikh Bridge number of debris falls has occurred causing damage to the road leading to Tithwal.

Kandi

The Kandi village lies on either side of the road from Tangdhar to Tithwal. On the hill side of this township emanates a spring on the mountain slope, which ejects black and creamy slurry at regular intervals. The water content of the springs in the area has also increased since the occurrence of the

On either side of the Jhelum River the mountain ridges and their slopes have been fissured. The fissures run parallel to the river axis. The most devastated ridges include those at Sultan Dhaki and Kamalkot on the right bank of the Jhelum River. On the left bank fissured mountain ridges and slopes occur at Lagama, Salamabad, Jabla, Urusa and Kaman Post. At Lagama cracks have developed along the hill slope on the left bank of the Jhelum River in the E-W direction. These cracks are about 20 cm wide. In Salamabad, Jabla and Urusa villages multiple cracks have developed in the mountain ridges and the slope on the left bank of river. These cracks are 15 to 60 cm in width and show a displacement of upto 15 cm.

Sultan Dhaki and Kamalkot

The villages of Sultan Dhaki and Kamalkot are situated in the Murree Thrust zone. These villages are situated partly on the older river terraces and partly on the mountain slopes. On the mountain ridge above the township of Sultan Dhaki a large fissure has occurred on the eastern slope due to the October 8 earthquake (Fig 12). The aperture of the crack is more than a meter with more than 5 m visible depth. The rocks have been vertically displaced by about 3 meters. Black and brownish coloured water emanated from a number of spots which gushed out into the air a few meters at the time of earthquake, said one soldier posted at a near by post. Earlier the quantity of water emanating from this spring was a few centimeters, which is now flowing in the form of a large stream capable to run a few mills. The quantity of black colour water can be judged from the fact that the colour of the Jhelum River from this point downstream turned black for about 15 days of time. The rocks on the mountain slopes over which the stream is flowing have turned either black or brown, which can be seen from a distant site at the National Highway. A similar water ejection has taken place on the same mountain ridge at Kamalkot. In the sultan Dhaki village cracks in the fields are oriented in the NE-SW direction with apertures upto 40 cm. The depth in these cracks can be observed upto 6 m.

The fissures developed on these mountain ridges and slopes are continuous for a few kilometers. There are number of transverse cracks, which have developed across the longitudinal fissures. There is visible movement along these cracks in the entire area, which has frightened the local populace in general. At many places in this belt the agricultural land has been washed away by the landslips and debris falls. It is in this area that skeletons of human beings got exposed from the overlying debris, which has accumulated over them for the last few centuries. Possibly a strong earthquake may have struck this area devastating the settlements on these mountain slopes which got buried under the falling debris at that time. Similar is the situation today that at a number of places in the entire sector many of human bodies are lying under the huge mass of debris, which fell on them during the recent earthquake.

ROCK FALLS

In Karnah and Uri areas a number of rock falls triggered by the earthquake has resulted in considerable damage and disruption to roads, structures and communities. The frequent aftershocks further aggravate the situation as the unstable and loose rocks continuously play havoc in these areas. Some of the considerable rock falls observed in the affected areas are as under:

Tithwal

Tithwal town is situated in the foot hill of a steep mountain at the left bank of the River Kishanganga (Neelam River). The earthquake initiated a rock fall and debris flow which has inundated the village. Extensive damage was done by the rolling quartzite blocks, which went even inside the village. The road section beyond Tithwal town has been scrapped out into the Neelam River. Settlements in the foot of the mountain range are highly vulnerable to future slips and shooting stones.

Pati Thamni

There are about 90 households situated on both the sides of mountain slopes around village Dakhen with a population of about 400. All the houses are razed to the ground with heavy human casualty and tremendous loss to the livestock. The shooting stones from the hill slope have moved

through the village Dakhen and traveled beyond to the road. The slopes have become vulnerable to the landslips and debris flows, which can trigger during rains and future earthquakes including the aftershocks of the October 8 earthquake.

Tangdhar Bakhain

The rocks of the mountain around Tangdhar Bakhain are mainly quartzite and form its steep slopes on either side. A number of scarps have developed on either side of the mountain slope during the earthquake resulting in the rock falls. Boulders as big as a building have slipped down the mountain and hit the buildings situated at the foot of the mountain. There is high probability that in future these hanging rock blocks may slide down the mountain and can be of serious consequences. Evidence of the past human settlements exists on this mountain. It is said that Dub Wali Mosque was situated on this mountaintop in the past. An earthquake of severe intensity destroyed the settlement. There are a few Okhalies scattered on the mountain slopes and its top, which have been carved out in huge rock blocks of quartzites. Besides, a number of earthen parts (broken) are scattered on the slopes and mountaintop, a few of them embedded in the topsoil of the mountain. Besides, above mentioned rock fall locations a number of rock falls of smaller nature were observed at Kandi, Trebani, Sikh bridge, Chitarkot, Bahadarkot and Chamkot in Karnah area.

Kamalkot

The Kamalkot in the Uri sector has witnessed severe rock fall in the foot hill part of the village. The rocks in the mountain are mainly quartzite having various sets of joints. These rocks are exposed vertically on the steep hill slope. Big rock blocks rolled down the steep hillock and damaged a number of structures. Few blocks are hanging along the slope which may get loosened during the fresh earthquakes. These blocks will create havoc particularly in the vicinity of the mountain foot. Small rock falls were also observed at Sultan Dhaki and at number of locations along the Uri-Kaman Post road in the Uri sector (Fig. 13).

LANDSLIDES

The earthquakes of higher magnitudes not only destroy the structures and houses but also initiate huge landslides, rock falls and slope failures in the mountainous regions. The Kashmir earthquake has severely affected the mountain slopes in both parts of Jammu and Kashmir. In our part of Jammu and Kashmir landslides and slope failures were reported not only in the Karnah and Uri sectors, but along the Srinagar-Jammu National Highway at a number of places around Ramban. It was reported that number of people are still buried under the debris of these landslides at Pingla Haridal, Tangdhar Nar and Sultan Dhaki. During our survey in the Tangdhar area number of landslides were seen. These include, Beari, Dakhen, Tithwal, Dringla, Ibkot, Bahadarkot, Sikh bridge, Gundi Shath, Gundi Saiyidan (Fig. 14), Pingla Haridal, Chamkot, Chanpura, Tad, Trebani, Tangdhar Nar, etc. The concentration of these landslides was high in the mountain ridges where fractures were developed during the earthquake. Huge landslides were triggered in the older river alluvium along the banks of Bathmaji and Qazinag rivers. The National Highway 1A from Uri to Kaman Post is totally damaged by the earthquake. The highway stretches have been washed away completely at number of places. Culverts, bridges and other infrastructures have been damaged. It was in this sector of the highway that 66 Beacon personnel got killed due to landsliding during the earthquake. Landslips, debris- and rock falls and shooting stones have struck most of the road sections. Almost total stretch of 17 km of the highway has developed cracks along and across its entire length from Uri to Kaman Post. The main bridges, which have been damaged, include those of Red Bridge, Twin Bridge and the Aman Sethu in addition to number of small bridges and culverts.

Kaman Post

The Kaman Post Bridge (Aman Sethu) has been completely damaged on the PAK side. Its abutment on the PAK side is completely razed to the ground and one of the three panels on that side is also completely destroyed. The central two piers have developed cracks at the foundation level and are

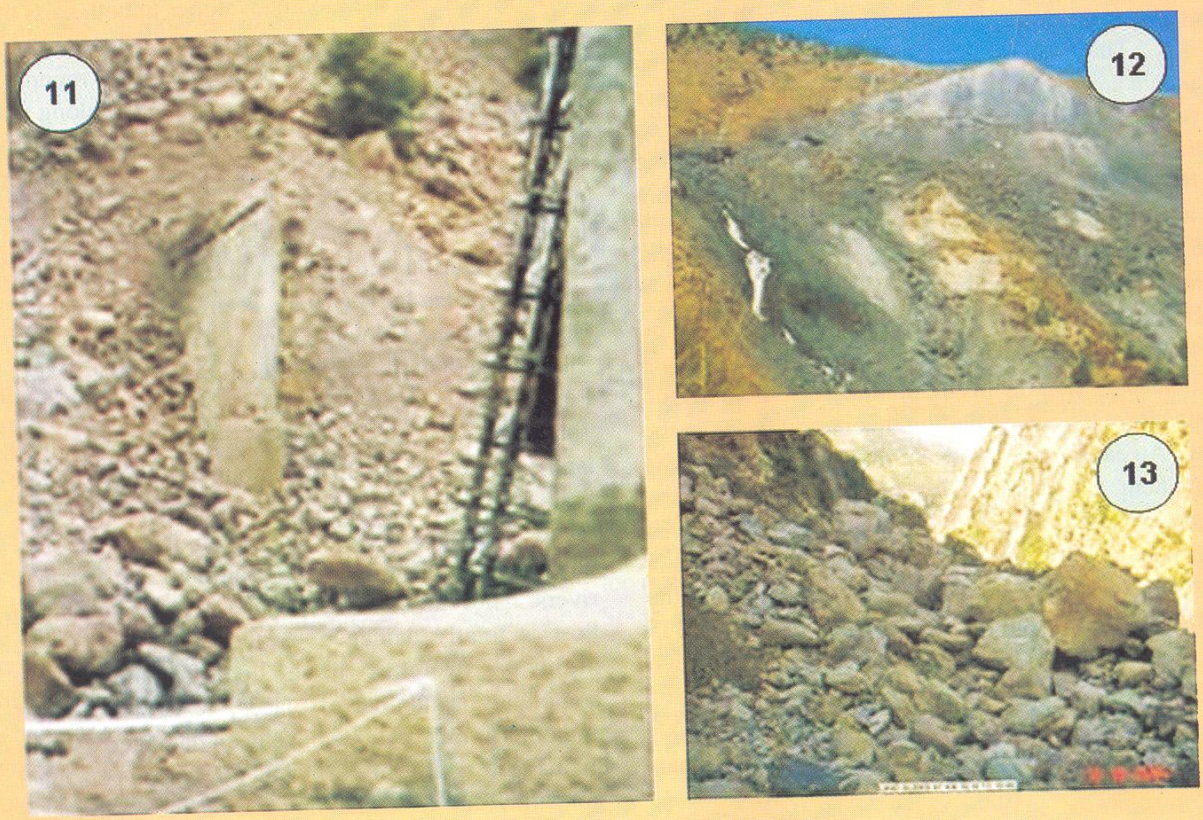


Fig. 11 - 13. Geo-environmental Impact of October 8 Kashmir Earthquake (continued)
Fig. 11. Destroyed Aman Sethu
Fig. 12. Land sliding at Sultan Dhaki, Kamalkot Area
Fig. 13. Rock Fall along the Uri Kaman Post road at Km 10.

unsafe for future use. On the Indian side abutment being partially built on the foundation rock has sustained the shock. However, the complete bridge has to be reconstructed on the firm foundation preferably at a new location. The bridge is located over the Khaliane de Kas through which runs a subsidiary fault of the Jhelum Tear Fault. The older river terrace at the Kaman Post on the PAK side has fallen into the Nala over which the bridge was constructed. Along the road section between Twin Bridge and Kaman Post a series of landslides and rock falls has occurred. Part of this 2 km road has been washed down into the Jhelum River.

Km 8 to 10

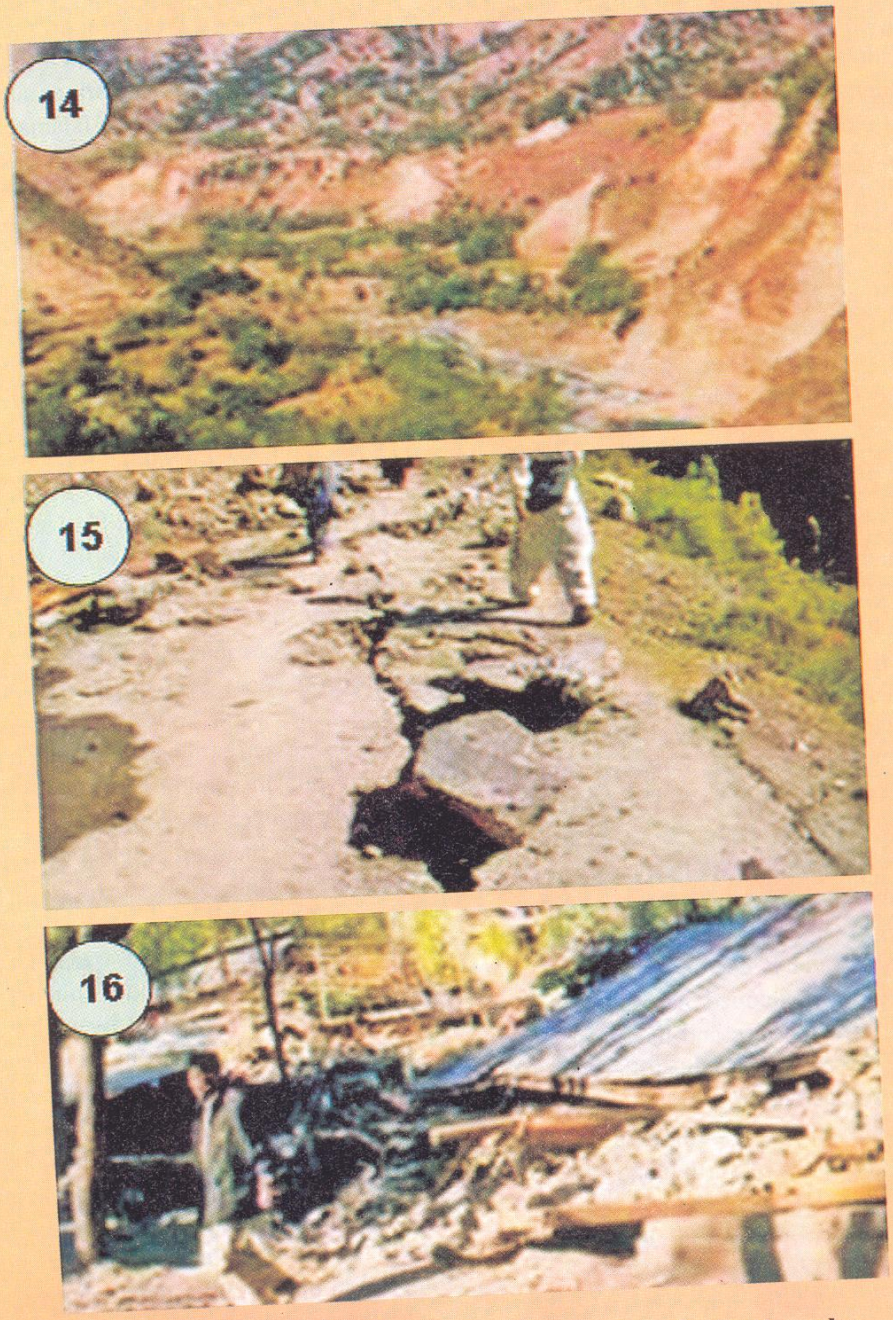
Between Km 8 to 10 from Uri the highway is severely damaged and a portion of it has been washed away. There exist number of longitudinal cracks on the highway (Fig. 15), which run parallel to the fissures, which have developed on the mountain ridges, and their slopes. The fissures are about 1 m in aperture and a few meters deep. There is a vertical slip of about 1-m along these cracks. These displacements have resulted in rock- and debris falls and shooting stones in this sector of the highway. The settlements on these mountain slopes have been completely destroyed. The flow of water in the springs emanating on these slopes has increased since the earthquake struck the area. However, slowly and steadily the content of increased water is decreasing. There are also cracks that have developed across the main fissures on the mountain slopes and have also been vertically displaced. Near Isham Jabla village around half a kilometer road has been washed away. At this place the landsliding has become a regular phenomenon since the October 8 earthquake.

SEISMOTECTONICS Vis-à-Vis BUILDING CODES

The intensity distribution estimated and interpreted by the Pakistan Geological Survey is closely associated with the rupture zone (Hussain et al., 2006). Within the rupture zone, the city of Muzaffarabad suffered great damage (IX-X on MMI scale), and the city of Balakot was almost totally destroyed (X on MMI scale). Outside the narrow (5-10 km) width of the rupture zone, the signs of damage appeared to be fairly minor. While damage has been reported in more distant locations such as Abbottabad (35 km from rupture zone), Islamabad (64 km), and Lahore (> 250 km distant), and has been attributed to local site effects or poor construction rather than direct intense shaking from the earthquake.

The damage by the earthquake in Karnah and Uri areas has been severe (Fig. 16) close to the epicenter in the range of 50 km and progressively decreasing away. The intensity of damage at various localities in the surveyed areas on the revised MMI Scale (ABAG, 2003) is given in Table 1. The type of the houses and the percentage of damages are shown in Table 2. In both the areas of Uri and Karnah most of the villages are built either on the older river terraces or on the hill slopes. The constructed houses in these areas are mostly single or double storey un-reinforced earthen wall stone masonry buildings. Stone masonry buildings are more common in these villages. The stone masonry walls consisted of irregularly placed undressed/dressed stones, rectangular and rounded, that were laid in cement sand and mud mortar. A significant number of casualties and injuries were associated with the total collapse of these structures. Un-reinforced one or two storey brick masonry buildings with roofs constructed with wood and CGI tin sheets are also seen in these areas. These structures were also razed to the ground within the 10 km range of LOC. The area affected by major shaking lies within a radius of 50 km from the epicenter with the destructiveness of the shaking reducing quickly as one move away from the epicenter. The intensity of the shaking has been severe in Karnah and Uri Tehsils in the vicinity of LOC. In these areas a very large vertical slip component has caused the extreme damage to the structures. These structures mostly collapsed in place, rather than being thrown over or developing diagonal tension cracks.

The Jammu and Kashmir State has been classified in the zone-IV with two patches placed in zone V in the seismotectonic map of India 2002. These estimates are based on scanty earthquake



Figs. 14 - 16. Geo-environmental Impact of October 8 Kashmir Earthquake
Fig. 14. Land slides in Karnah along the Qazinag River
Fig. 15 Longitudinal ruptures in Uri Kaman Post road Fig. 16 Destruction to the settlements in Kandi, Karnah.

Table 1. Locality wise intensity of earthquake affected areas in Jammu and Kashmir

Locality	Intensity	Locality	Intensity
Simbal Camp (Jammu)*	IX	Trebani	IX
Uri Tehsil		Chanpura	IX
Kamalkot	X	Tad	IX
Sultan Dhaki Village	IX	Chitarkot	X
Sultan Dhaki Hill	X	Chamkot	X
Urusa	IX	Pingla Haridal	X
Jabla	IX	Bahadarkot	X
Salamabad	VIII	Ibkot	X
Lagama	VII	Dakhan	X
Kichhama	IX	Gundi Saiyidan	IX
Nambla	IX	Gundi Gujaran	IX
Sadwanian	IX	Gundi Shath	IX
Isham	IX	Thamni	X
\Karnah Tehsil		Dringla	X
Rangwar	IX	Tithwal	X
Drangyare	IX	Beari	X
Nastachhun	VII	Green Patch	IX
Bagh Bella	IX	Kupwara and Handwara	
Nalchian	IX	Karalapura*	IX
Tangdhar	VIII	Natnus*	IX
Tangdhar Bakhain	VIII	Armpura*	IX
Kandi Bala	X	Badarkal*	IX

* Intensity measured on the basis of liquefaction only

Table 2. Locality-wise building types and percentage of damages

Locality	Building	% Damage
Simbal Camp (Jammu)	A & B	2-3%
Kamalkot	C & D	90-95%
Sultan Dhaki Village	B, C & D	90-95%
Urusa	B, C & D	60-70 %
Jabla	C & D	60-70%
Salamabad	B & C	65-75%
Lagama	B & C	40-50%
Kichhama	B	30-40%
Rangwar	C & D	80-90%
Tangdhar	A, B, C&D	50-65%
Tangdhar Bakhain	B&C	60-80%
Kandi Bala	B&C	80-90%
Chanpura	B&C	80-90 %
Tad	C&D	100%
Chitarkot	B&C	80-90 %
Chamkot	B&C	75-80 %
Pingla Haridal	B&C	80-90 %
Bahadarkot	C&D	90-95%
Ibkot	C&D	100%
Dakhan	C&D	100 %
Thamni	D	100 %
Dringla	B, C&D	80-90%
Tithwal	B, C&D	100%
Beari	C&D	100%

record of the area. The northwestern part of Himalaya has been neglected regarding the studies on earthquakes and crustal deformation as compared to other parts of India. A series of active thrusts and faults are running across the state. Seismic hazard is not given a great deal of attention in urban planning and policy decisions, and seismic design does not appear to be high priority in the state. There is no code enforcement in the region. Seismic activity in Himalayan region is a direct result of the collision of the Indian and the Asian plates, which results from the N 42° E motion of the Indian Plate at the rate of 53 mm year. The resulting collision has fractured the Indian plate into number of thrust zones i.e., Main Central Thrust (MCT), Panjal thrust (PT), Murree Thrust, Main Boundary Thrust (MBT) and Himalayan Frontal Fault (HFF) in the northwestern part of Himalaya, along which the stress has been building since India-Asia collision. The 7.6 Mw 8 October Kashmir earthquake occurred in a region where a great plate-boundary earthquake has long been considered overdue. Although the earthquake resulted in widespread devastation, theoretical considerations suggest it has released one tenth of the cumulative elastic energy that has developed since the previous great earthquake in the region in 1555 or earlier (Bilham, 2006). Regions to the NW and SE remain to go in future earthquakes since earthquakes in these regions appear insufficiently large to fully release cumulative plate motions. The area has experienced earthquakes of moderate to severe intensity in the past. The epicenters of major earthquakes in Kashmir are related with the mega- (more than 200 km) and intermediate lineaments (100-200 km). However, there is no documentation of seismic activity along the thrusts cutting across the area. Therefore, a plan of seismic surveillance of the area by establishing a network of seismic monitoring stations is the need of the hour. There are indications of neotectonic activity along the thrusts in the area; these thrusts should also be kept under the surveillance for such activities.

The pattern of aftershocks in our part of the ruptured zone (southern tip of the rupture zone upto Uri and beyond towards Jammu) does not conform to the norm of such high magnitude earthquakes and f 0.5 should be taken as a wakeup warning and measures should be taken for preparedness. About 1700 moderate aftershocks have occurred in the northwestern part of the rupture. The surprising and worrying calm as far as earthquake aftershocks in southeastern part of the faultline are concerned, means that pressure is building up around this tip of the rupture zone which extends to the plains below the Himalaya. Mountain ridges and slopes in the quake affected areas in Kashmir (Tangdhar and Uri Tehsils) are ruptured and normal faulting has occurred in these regions which are a reflection of blind thrusting deep in the crust. There is a vertical slip of 0.5 to 1.0 m along these normal faults in the region upto Uri which progressively fades towards Pirpanjal across the Poonch-Rajouri sector in Jammu. This means the rupture zone has got hooked around Uri-Poonch region and may rupture any time in near future. Bilham (2006) concluded that if the faultline slips in the south-east tip (Uri-Poonch sector) of the rupture zone, the shockwave is very likely to travel towards the plains of Punjab with inhabitation of millions of people. He concluded "From what we know of Kashmir's history, there may well be a sequence of earthquakes spread over the next 50 years". Of course 50 years may sound an awfully long time to a politician but it is the perfect length of time to get the structure of the buildings right." This should be a major concern for both India as well as for Pakistan while making future plans for massive constructions and developmental projects in the Himalaya and surrounding regions. The governments of both the countries and, of course, of other countries in the region as well, should ensure whatever new structures are built are able to withstand future major earthquakes. While framing the building codes for any region, particularly the Himalayan states, geological ground conditions should be seriously taken into account.

Our observations in Kashmir reveal that three types of ground conditions prevail in the earthquake affected areas. We also observed four types of building structures including Masonry A, B, C, and D existed in these areas. The intensity of damage varied in the three types of ground conditions even for the

same type of masonry structure (both vernacular and modern engineered structures). These observations should be kept in view while formulating building codes for these and other similarly situated areas ir Jammu and Kashmir. This also prompts we to conclude that micro-zonation of the major cities and towns are taken up at priority basis before the building codes are formulated for the state. In addition, other disasters which include floods, landslides, snowstorms, potential threat of dam bursts (particularly in the light of future predicted earthquakes in the region), etc. are also equally detrimental. The need of the hour is to wake up and put in concerted efforts with focused goals to safeguard tens of millions of people living in this region from the clutches of earthquakes. It is high time to take appropriate measures including monitoring of the seismic activity on either side of the LOC and formulate plans for preparedness to minimize the damages in case of any such future eventuality. If India and Pakistan have to save their people, they have to save them from the earthquakes and not from each others enmity.

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