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THE KASHMIR-HAZARA EARTHQUAKE, 2005: WHY, HOW AND WHAT NEXT

Abstract

The 7.6 magnitude shallow focus earthquake of October 8, 2005, with an epicenter few km NNE of Muzaffarabad, Kashmir, changed the lives and perceptions of the affected millions as well as of those not so affected. This article discusses such physical aspects of the earthquake as origin, geology, prediction, measurement and response of civil structure. The article emphasizes that it is not the magnitude but the destruction caused and lives lost that actually determine the status of an earthquake. Since Risk = magnitude of natural hazard x vulnerability, a lot of damage could have been averted by focusing on vulnerability, better preparedness and inexpensive building guidelines.

The devastating earthquake that struck the Kashmir Hazara region on the fateful 8th of October, 2005, measured 7.6 on the Richter scale with an epicenter few kilometers north-northeast of Muzaffarabad and a hypocenter variously reported between 13 and 26 km below the surface. This article attempts to answer some of the questions the earthquake raised in the minds of Pakistani people in general and the affected people in particular. These questions relate to physical or supernatural origin of the calamity, to what extent could the event be predicted, the significance of magnitude and intensity and who should he held responsible for the widespread destruction and loss of life, the nature or the state.

Origin

We know its movement along faults though many believe this movement takes place when God so desires to punish a people. However, natural hazards always kill the most susceptible who happen to be the poorest and the least protected. The connection of the killing with the most susceptible was so strong in the case of Kashmir-Hazara earthquake that many found it difficult to buy the traditional argument and explain the event as an act of punishment. Scientifically earthquakes have been occurring since long before man came into existence. They occur in areas, e.g. oceans where man does not live. Ninety five per cent occur specifically along well defined narrow plate boundaries, eighty per cent of these on the rim of the Pacific Ocean.

Although we say the earthquakes occur due to movement on the faults. In actual fact, the earthquakes of any consequence occur because there is non-movement on an otherwise active fault. On any fault or section of the fault where the movement is frequent it is in small bits and may not even be felt like the movement on the major Salt Range Thrust, the equivalent of the Main Frontal Thrust on the eastern side of the Himalaya. If movement on the Makran faults occur only east and west of Gwadar then Gwadar could be target for a relatively major earthquake because the Gwadar section is currently locked. That however, may not occur for the next 100 years. The probability could be calculated. All that is needed is more research and better data collection.

When movement does not take place in the active parts of a compressional or transpressional plate setting the stress is stored in the form of elastic bending of the rocks. The accumulated stress finally exceeds the strength of the rocks concerned and a failure occurs in the form of movement on an active fault or a fresh fault. The elastically bent parts of the rocks flip back to their original shape generating huge shock waves, jolting the structures sideways or jerking them up and down. All major earthquakes are followed by a series of smaller aftershocks. Independent earthquakes are generally triggered over long distances and over relatively long period of time.

The damage done depends upon the magnitude of the event, shaking intensity and duration, density of the population, distance from the epicenter, nature of ground and rocks and design and material of the structures. There is still another factor. It is called vulnerability. We shall come to that later.

Tectonic Setting

The faults and the earthquakes on them in Pakistan as elsewhere are the result of movement on the plate boundaries, driven by rising (leading to lithospheric spreading) or descending (leading to lithospheric subduction) convection currents in the hot mantle. The supercontinent existing on Earth called Pangaea dismembered some 200 million years ago and India has since moved north from its original position with Antarctica and south Africa some 4000 km in the last 100 my. It collided against the Eurasian continent some 50 my ago and its leading edge has imbricated and underthrust Eurasia and the Tibetan Plateau ever since. The continuing northward movement at the rate circa 4 cm/yr is the cause of failure and shock waves along various faults in the Himalaya and the western part of the country (Quetta, Chaman). A new convergent plate boundary in the Gulf of Oman and some 200 km offshore in Arabian sea is the reason behind the earthquakes along Makran coast.

Geology and Seismicity of the Balakot-Muzaffarabad Area

Let us have a look at the location map of the affected area (Fig.1). Mapping of the region between Balakot and Muzaffarabad in 1986-87 a major fault had brought up inliers of older light grey Cambrian dolomite in an area of much younger reddish Miocene molasse. The fault had been marked earlier by Calkins et al. (1975) who had mapped the area on small scale and named this fault as the Muzaffarabad Fault. In 1986-87 it was mapped on large scale and other facts got noticed that Calkins et al (1975) had not further described. It was a major fault which connected further southeastwards with the Riasi Fault beyond Jammu where again it had brought up inliers of Cambrian dolomite as it had also done nearer home at Balakot, Muzaffarabad and Kotli. Wherever in between, the inliers had not been brought up, the fault lay within the molasse and the trace of its outcrop was not noticeable. At places it is apparently blind or en echelon. The northeast dipping imbricate active rupture zone for the recent 2005 earthquake has been observed to extend for some 80 km through Balakot, Muzaffarabad, Kardalla, Bandi Karim, Haidershah, Sarain, Chikar and Sundangali towards Bagh (Baig, 2005). Realizing the Muzaffarabad Fault was a major fault marking a tectonic domain we later called it the Kashmir Boundary Thrust, KBT (Fig.1). The second most noticeable feature about this fault between Balakot and Muzaffarabad was many meter wide zone of degradation marked by occasional landsliding. This was due to a thick zone of fault breccia which showed rotation and reinduration. This indicated shallow level brittle deformation. Finally a very young relative age for the fault was indicated by a klippe (transported remain) of the Cambrian dolomite resting on the Main Boundary Thrust/Fault (MBT) across the River Kunhar on the western limb of the Hazara Kashmir Syntaxis, HKS, the famous bend of the rock units, folds, and faults of the Himalaya at this locality (Wadia 1931, Burg et al.2005). These features of the fault were noticed without investing further research about it. Add to this the fact that in 1905 a major earthquake was recorded on the same fault at Kangra. Now if we look at another map published by Seeber and Armbuster in 1979 we can see the area of KBT is marked by micro-seismicity. Even more prominent is the zone, further northwest of Balakot, between Jabori and Batagram which has shown a much greater density of microseismicity dots. This seismic lineation was called by Seeber and Armbuster (1979) as the Indus Kohistan Seismic Zone, IKSZ. It is the same area of KBT and the IKSZ that has become the location for the Hazara-Kashmir earthquake. Baig (2005) have reported that the shallow main shock also reactivated the Indus-Kohistan Seismic zone and the right lateral Chail Sar Thrust further northwest from Balakot in the area of Jabori and Batagram. The earthquake thus occurred in an area where it was quite probable. After the earthquake the outcrop of the Kashmir Boundary Thrust (KBT) zone between Balakot and Muzaffarabad has become even more prominent. Numerous landslides have covered the fault zone with gouge and breccia from the basal part of the overlying whitish Cambian dolomite.

Probability

Was the 2005 earthquake predictable? It is difficult to claim that with our current knowledge but it was highly probable. Scientists study the past frequency of large earthquakes in order to determine the future likelihood of similar large shocks. For example, if a region has experienced four magnitude 7 or larger earthquakes during 200 years of recorded history, and if these shocks occurred randomly in time, then scientists would assign a 50 per cent probability (that is, just as likely to happen as not to happen) to the occurrence of another magnitude 7 or larger quake in the region during the next 50 years. Sometimes however, the release of strain along one part of the fault system may actually increase it on another part and independent earthquakes may become clustered enhancing the probability as happened in California, Japan and along the Anatolian Fault in Turkey. These have sometimes been called earthquake storms (Stein, 2005). It is believed that the amount of stress needed to trigger a following earthquake does not have to be great at all.

Prediction

That was about probability. Is prediction, which is way beyond probability, possible? Yes, in one instance, in 1974, an earthquake was predicted in China, followed by a few more. About noon time on February, 4, 1974, the Chinese scientists asked the population of the city of Haicheng to come out into the open as an earthquake was imminent. It was freezing out there but the people complied. At 7 pm a 7.3M earthquake struck. Ninety per cent of the buildings collapsed but 100,000 people were saved. The success of the Chinese scientists was verified by a group of international scientists called the Haicheng Earthquake Study Delegation who visited the area in 1977. In the words of their report, "the first major shock to have been accurately predicted anywhere in the world" (Haicheng Earthquake Study Delegation, 1977). Over the next two years, earthquake scientists successfully predicted four more large earthquakes in the Hebei district (Montgomery, 1992). What was the basis of this prediction? The Chinese scientists had been researching many parameters, including physical, biological, radioactive etc. One of these was the pattern and relationship of the foreshocks and the main shock. They had noticed the foreshocks built up in frequency and intensity and then there was a lull in the seismicity. This was followed by the main shock. Many earthquakes that followed in China have not been predicted with the same accuracy, nor, all large earthquakes have discernable foreshocks or sudden change in precursor phenomenon. But the Haicheng and the other predicted earthquakes showed prediction was possible or could become possible. At that time some 10,000 scientists and technicians and 100,000 part-time amateur observers worked on earthquake prediction. Currently Western Scientists are also trying prediction through mathematic modeling of seismcity. However, research is increasingly becoming related to commercial profits. There are more profits in the aftermath of the earthquake than there are in the prediction of an earthquake. Most research has, therefore, focused on building of earthquake resistant structures where gains have been made. Although the magnitude records of international seismic station for Himalaya, are generally available, in our country it is difficult to calculate even probability for different faults because we do not have written records of events over long periods. Recent movements on the faults during the past few hundred years can be dated geologically but it is common to use historical records of the area for the same. Unfortunately written historical records are nearly non-existent in Pakistan.

Instruments are not the only instrument of prediction but we don't have to emphasize their importance. Sometimes common sense, history and tradition are invaluable. In the same fateful month of October, 2005 the United Nations awarded some ancient communities for saving lives during the Tsunami of December, 2004. These included the Simeulue community of Aceh, Indonesia, the coastal gypsies of southern Thailand and the tribals of the Indian Ocean islands of Nicobar and Andeman. All these communities sensed the impending storm and fled the area while across the rest of Indonesia's northern Aceh province the tsunami killed 163,795 people with an overall count of 224,495 deaths across eleven countries of the Indian Ocean. These communities neither had any instrument nor received any warning. It was their sense of history and tradition, the experience of generations which enabled them to notice changes in the behaviour of the sea and the activity of the animals. We now know the sea recedes as the wave builds in height and then advances. Their forefathers had noticed such changes in the sea much before they were incorporated in the modern science texts. Again the animals are no instruments but they have some built-in biotechnology. They sense acoustic and seismic signals from an impending earthquake/tsunami before it actually occurs. The Simeulue buffaloes fled the coast and the tribals followed. In Balakot, Muzaffarabad, and Jabori we asked a few locals if they had sensed any odd animal behaviour. Some reported the crows had disappeared, and the dogs howled early morning (the earthquake struck at 8.52 Hours local time). The Deputy Superintendent Police (DSP) at Balakot narrated his hunting dog started a frenzy of totally unexplained barking a minute before the earthquake. Some people in Battagram had noticed the snakes come out of their holes before the event.

A word about the possibility of new major earthquakes in the same area. The history of events shows the probability is low although theoretical considerations show most of the cumulative elastic energy may still not have been released. Major earthquakes triggering each other are generally either very closely spaced, within minutes and hours, or may be fairly distant in space (Bilham, 2005) as well as time. Then there are large earthquakes that come in pairs, separated by relatively small time and distances (Vorobieva, 1999). Based on this Vorobieva at the October 2006 Conference in Islamabad on Global Change reiterated her earlier prediction based on similarity of aftershock patterns that the Kashmir-Hazara earthquake would have a follow-up major earthquake within a 200 km radious before April 7, 2007, a prediction not come true. Baig (2005) has observed that the October 8^{th} earthquake has partially activated the Jhelum and Ambore faults, too, which occur further east from the Muzaffarabad on the right bank western slopes of rivers Jhelum and Kunhar.

Measurement

The earthquakes these days are measured on the Richter scale. It measures the amplitude of waves and the amount of energy released which, in turn, is related to amplitude. It is logarithmic which means the next unit indicates ten times greater amplitude and thirty two times greater energy so that a magnitude 6 earthquake has 100 times greater amplitude and releases 1000 times as much energy as an earthquake of magnitude 4. An earlier scale was Mercalli Intensity Scale which measured destruction over 12 grades. Intensity IV indicated vibrations like passing of heavy trucks and creaking of wooden walls and frames. The Kashmir-Hazara earthquake probably measured at Intensity IX which is characterized by general panic, serious damage even to partially reinforced masonry and conspicuous cracks in ground etc. Intensity XII indicated damage nearly total and objects thrown into the air. A more commonly used intensity scale these days is the Rossi-Forel (RF) scale. However, intensity grades can only be measured in habited areas and there is also the problem that construction methods differ from place to place making comparisons difficult. Richter scale on the other hand is quantifiable and machine measured for any area. Obviously Richter scale is in vogue. Still intensity scales cannot be written off. Because the importance of an earthquake relates directly to the destruction caused. If the Kashmir-Hazara earthquake had measured even higher like 8 on the Richter scale but there were no habitation in the area it would have caused no ripples and gone unnoticed. For example, the earthquake of March 2005 in Northern Sumatra on the same subduction zone that caused the Tsunami earthquake of December 2004, measured 8.7M, or very nearly the same magnitude as Tsunami, but largely went unnoticed because it caused much less destruction.

Vulnerability

But what causes destruction. The ground motion produced by an earthquake cannot kill if you are sitting out in the open. It is the collapse of structures or any secondary causes like landslides, fires or tsunami that kill. Many studies have indicated (Oxfam, 2004) that risk=magnitude of natural hazard X vulnerability

If you went to the affected area you found many private buildings have survived while nearly 100 per cent of the government structures had collapsed killing thousands of school children. It was their vulnerability that killed them. Again, for at least two days after the earthquake there was not a single crane, nor a bulldozer in Muzaffarabad. The civil administration had collapsed and the army said they needed helicopters to reach the area. As Kamal Munir (2005) put it, "A weakening state, which has been progressively relinquishing its responsibilities in all spheres of public life, is in no shape to protect the people from small economic shocks, let alone big ones. Its pro-market policies have wiped out social safety nets and diluted the glue which held people together." Absence of civil defence facilities, absence of a building code and its enforcement, lack of medical emergency or civil defence training to the population, even illiteracy and poverty all increase vulnerability. Lack of preparedness of the social set-up makes the people vulnerable and helpless. The 6.4M Bam earthquake of December, 2003, in Iran, killed 30000 people while the 6.4M Japan earthquake of March 2005 killed only one person. It is not the earthquake that kills it is the lack of preparedness. In the words of Daanish Mustafa (2005), "The earthquake in Northern Pakistan and Azad Kashmir did the same that Hurricane Katrina did in the United States --- show us a horrifying picture [of unpreparedness] of our society that we did not want to see." Cuba is a poor country but it has a highly educated and socially organised human resource and their preparedness is such that in the six major hurricanes that struck Cuba in the 7 years between 1996 and 2002 only 16 lives were lost (Oxfam, 2004). As against this the Katrina Hurricane in United States inflicted thousands of casualties not because US was underdeveloped or lacked resources or technology but because it was unprepared, and because it has privatized many of its public services.

Response of Structures and Reconstruction

Finally a look at the response of structures in the affected area. The destruction in Balakot was near complete, yet, we may ask, why did some structures survive. The Madina Market was left unscathed and the 60 m long concrete arch bridge across the River Kunhar at Balakot escaped with very minor damage. There is only one explanation, better design, better construction. A casual observation showed we could broadly classify the structures in the area into four different categories which, from 1 to 4, respectively, showed increasing resistance to earthquake:

1. Wooden beam roofs on masonry walls with little or no mortar
2. Tin roofs on stone masonry walls with little or no mortar
3. Lintel roofs on properly cemented masonry walls
4. Lintel roofs on RCC pillar and beam frame structures

The first two types, common on the mountain slopes proved the weakest, but because of the lighter roof and its disheveled collapse, provided some chance of survival to the inmates.

In cities like Muzaffarabad, Balakot, Bagh and Batagram, the heavy and strong lintel roofs with pillar and beam RCC frame structure showed up as the strongest if the pillars withstood and the most dangerous if the pillars collapsed. Wherever the pillars collapsed, invariably they disjointed from the roof/beam and the floor and fell flat on the ground bringing the roof on the floor and crushing the inmates. The joints of the pillars with the roof proved the weakest. Good foundation, use of mortar, strong RCC pillars, well jointed on top and bottom, square or U-shaped design and the rare arched roof proved the strongest. The traditional wooden houses have all but disappeared except way up in the Neelum Valley but they are flexible and light and therefore more resistant to earthquake. Many workers recently suggested minor inexpensive, modifications based on local materials and traditional design (e.g., Spence 2005). The overall moral is that buildings can be made sufficiently earthquake resistant with minor changes in material and design. What is important is public education, mobilization and association of people as well as large scale training of the builders or of the people in building techniques. Instead of blaming God or the earthquake for the disaster we should have a closer look at policy and governance. In the aftermath of earthquake in the reconstruction period, involving people at all levels like damage assessment, need assessment, formulation of a building code, selection of design options, choice and purveyance of materials and construction itself is a unique opportunity to organize, educate and raise the cultural level of people. This is the socio-centric approach. Providing them readymade solutions, readymade materials, deciding for them, and building mega projects for them is the techno-centric approach. In a backward society like ours it is always better to be socio-centric rather than techno-centric.

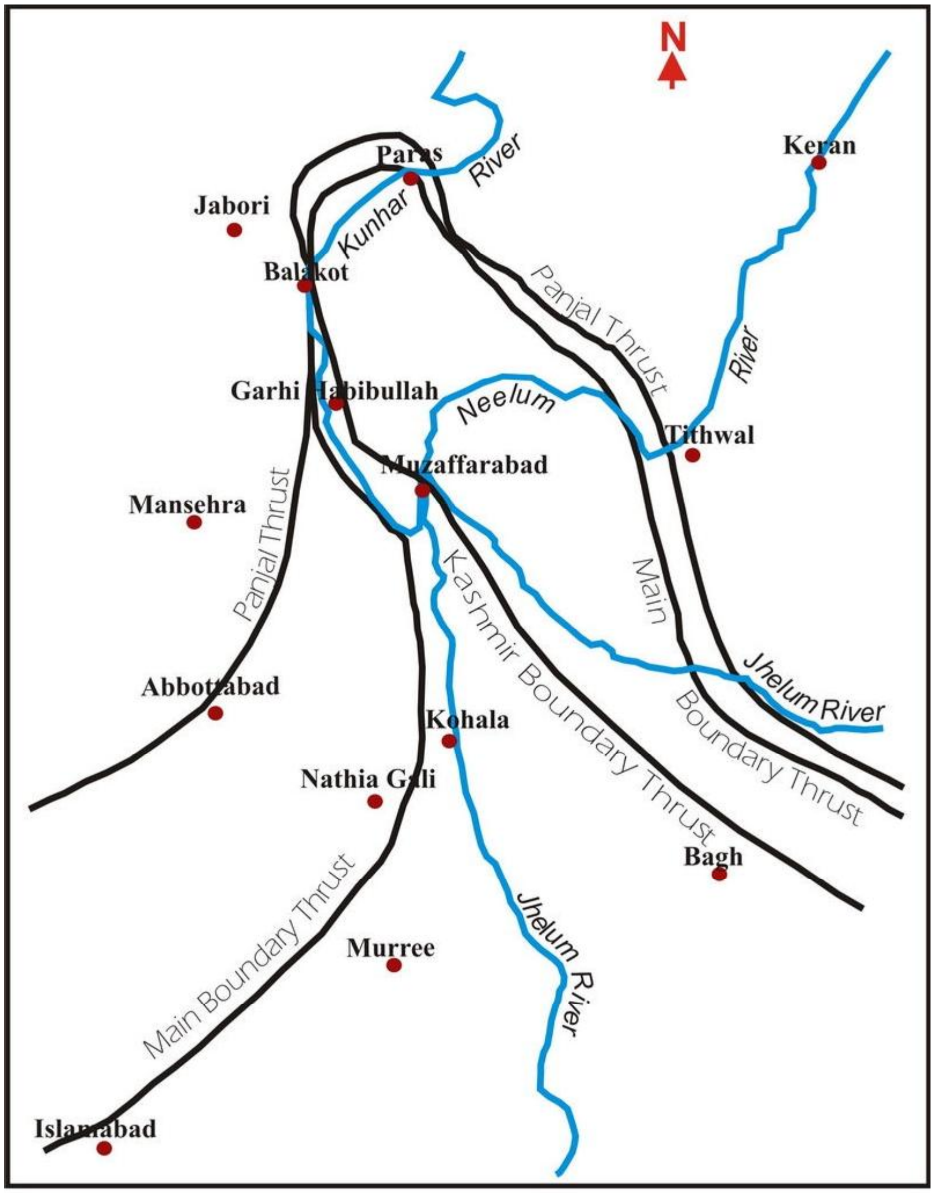

Fig 1. The October 8 earthquake was generated by movement on the Kashmir Boundary Thrust which passes through Balakot, Garhi Habibullah, Muzaffargarh and Bagh.

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