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Nepal earthquake of April 25, 2015

T G Sitharam
Indian Institute of Science, sitharam@civil.iisc.ernet.in

J S. Vinod
University of Wollongong, vinod@uow.edu.au

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Abstract

A powerful earthquake of magnitude (M) 7.8 occurred on April 25, 2015 at the plate boundary between Indian plate and Eurasian plate. The epicenter of this earthquake is located approximately 80 km northwest of Kathmandu, Nepal. This epicenter location is near to the district Gorkha for which it is also called as Gorkha earthquake. The convergent movement of the Indian plate with the Eurasian plate resulted in the strain accumulation along major faults and hence produced many significant earthquakes along the boundary in past. This earthquake is as severe as its predecessor event, the 1934 Nepal-Bihar earthquake where the fatalities was 10,600 while 8000 and above during this event. We describe in detail the seismotectonic aspects of the 2015 Nepal earthquake (Mw 7.8) and the damage caused by it. We also provide a background on the seismicity of the Himalayan region.

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INVITED COMMENTARY

Nepal Earthquake of April 25, 2015

T.G. Sitharam, Indian Institute of Science, Bangalore, India

J.S. Vinod, University of Wollongong, Wollongong, Australia

A powerful earthquake of magnitude (M) 7.8 occurred on April 25, 2015 at the plate boundary between Indian plate and Eurasian plate. The epicenter of this earthquake is located approximately 80 km northwest of Kathmandu, Nepal. This epicenter location is near to the district Gorkha for which it is also called as Gorkha earthquake. The convergent movement of the Indian plate with the Eurasian plate resulted in the strain accumulation along major faults and hence produced many significant earthquakes along the boundary in past. This earthquake is as severe as its predecessor event, the 1934 Nepal-Bihar earthquake where the fatalities was 10,600 while 8000 and above during this event. We describe in detail the seismotectonic aspects of the 2015 Nepal earthquake (Mw 7.8) and the damage caused by it. We also provide a background on the seismicity of the Himalayan region.

The tectonic framework of Indian subcontinent is spatio-temporarily varied and complex. The rapid drifting of Indian plate towards Himalayas in the north eastern direction with a high velocity along with its low plate thickness (Kumar et al. 2007) might be the cause for high seismicity of the Indian region. Indian plate is moving northward at about 45 mm/year per year and it collides with the Eurasian Plate (Figure 1, Bilham 2004). The collision resulted in the reduction of convergent movement of Indian plate approximately to 18 mm/yr. This collision also resulted in the development of potential slip available to drive large thrust earthquakes beneath the Himalaya. When continents converge, large amounts of shortening and thickening take place, like in the Himalayas and the Tibet. Due to this massive collision, the Himalayas were formed and also resulted in large numbers of earthquakes along the plate boundary. This plate boundary in the Himalayan regions is a major cause of earthquakes in this region. In a similar process, involving the Indian Plate and the Burmese micro-plate, results in earthquakes in the

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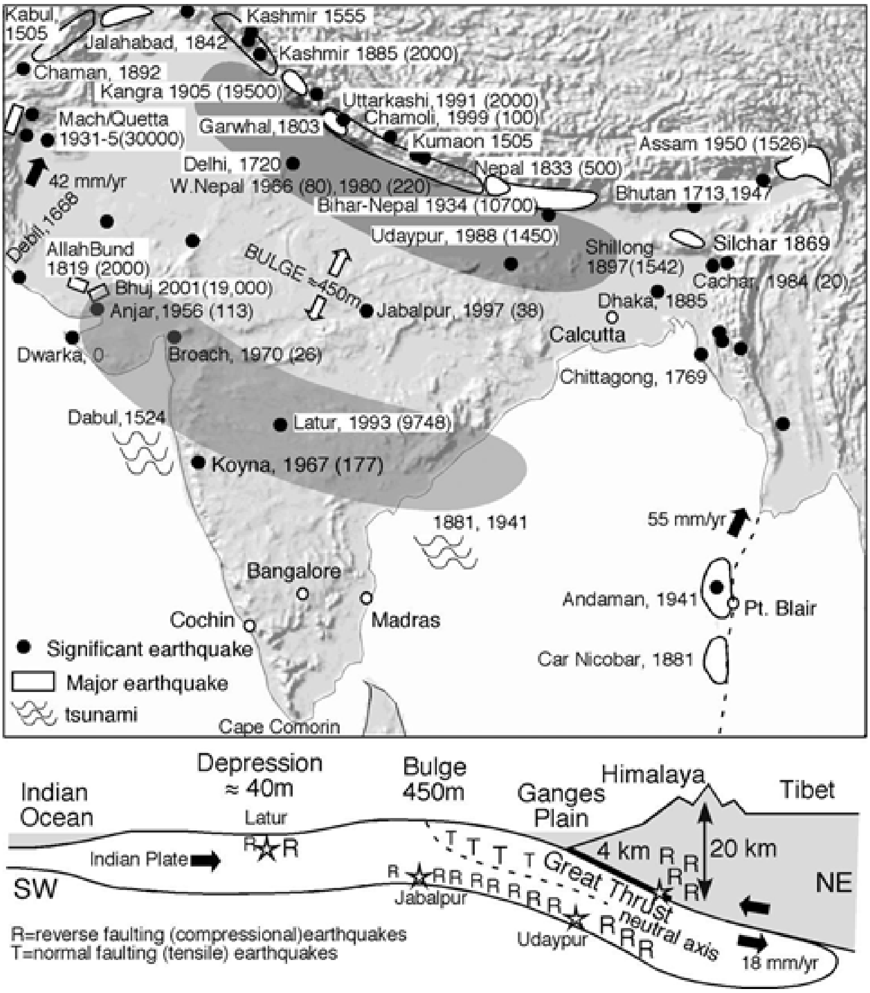
Figure 1. Schematic view of Indian tectonics (Bilham, 2004)

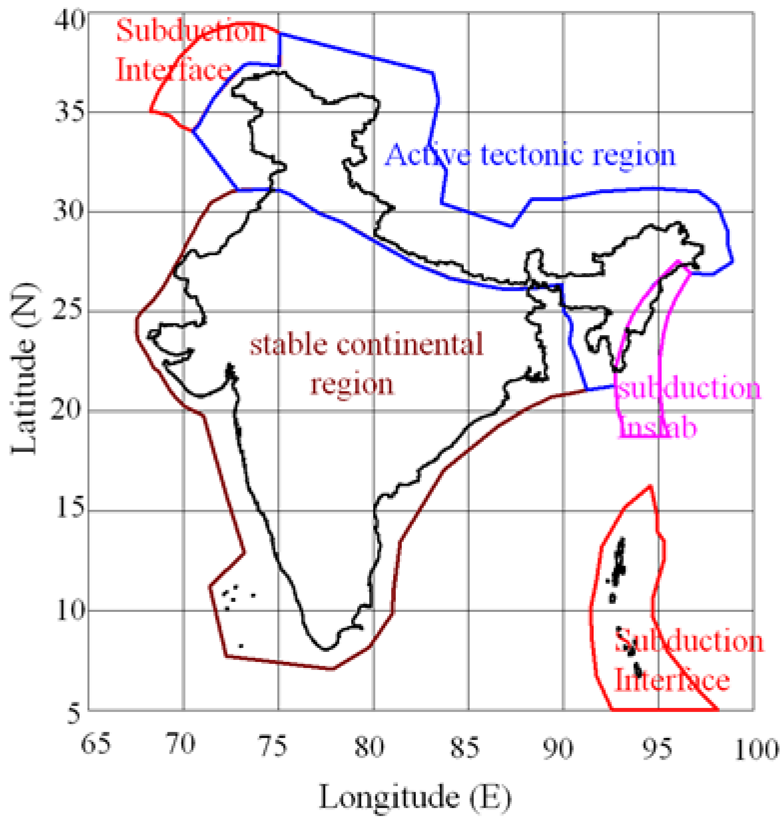


Andaman & Nicobar Islands. The plate boundary areas along the Himalayas and northeast India, are characterized by very high level of seismicity (Gupta 2006).

SEISMICITY OF INDIA

The analysis of the seismic activity in India can be broadly characterized by three general seismotectonic considerations (Nath and Thingbaijam 2010) as shown in Figure 2; they are tectonically active shallow crustal region, subduction zones and stable continental region. The subduction zone earthquakes can be further divided as regions with intraslab and interface earthquakes. In this report, the emphasis is given on tectonically active shallow crustal region. The seismicity of the Himalayan arc tectonic belt is connected with the underthrusting of the Indian plate beneath the Eurasian plate (Molnar and Tapponnier 1979; Krishnan 1953).

Figure 2. Tectonic provinces in and around India (Kolathayar and Sitharam, 2012)



The tectonically active interplate regions include the Himalayas and southern Tibetan Plateau, northwest frontier province of Indian plate (Nath and Thingbaijam 2010; Kayal 2008). The movement of the Indian plate in the North Eastern direction and its collision with the Eurasian plate has created the most gigantic mountain range of the world – the Himalayas with an average height of 4600 m and the biggest and highest plateau region in the world - the Tibetan Plateau. The Indian plate was considered as one of the fastest moving plates in the world. Before its collision with the Eurasian plate it has attained a very high velocity of around 20 cm / year (Kumar et al. 2007). The current movement of Indian plate is estimated to be around 5 cm/year. The collision and the subsequent formation of the Himalayas and the Tibetan Plateau are associated with very high seismicity. The entire North East Region is put under zone V of the Indian seismic zonation code (BIS-1893, 2002). This region falls at the junction of N-S trending Burmese arc and E-W trending Himalayan Arc. Due to this the entire region has suffered multiple phases of deformation processes and this has resulted in numerous geological structures (Sharma and Malik 2006). Significant earthquakes in this region include, the 1934 M8.0 Bihar, the 1905 M7.5 Kangra and the 2005 M7.6 Kashmir earthquakes. The latter two resulted in the highest death tolls for Himalaya earthquakes seen to date, together killing over 100,000 people and leaving millions homeless. The 1950 Assam earthquake of M8.6 is the largest instrumentally recorded Himalayan earthquake and widely felt over a broad area of central Asia, causing extensive damage to villages in the epicentral region.

SEISMOTECTONIC ASPECTS OF 2015 NEPAL EARTHQUAKE (M_W7.8)

The 2015 April 25th Nepal earthquake of M_w 7.8 occurred within the eastern region of the central seismic gap of Himalaya (Figure 3). The central seismic gap of Himalaya is considered to be the most vulnerable segment in the Himalaya plate boundary (Rajendran and Rajendran 2005). The epicentral location: 28.15° N 84.71° E (60 to 70km north to Gorkha) and the earthquake had a focal depth of 10-15km. Studies have shown that the thrusting mechanism on a shallow dipping fault of 7° dip is responsible for the 2015 Nepal earthquake of M_w 7.8. The maximum slip was estimated to be around 4.3 m with the eastward rupture propagation.

The USGS reports the shaking intensity ranging from IX (violent) in the epicentral region (within 30km radius from epicenter) to very strong in places at least 300km from the epicentral region as presented in Figure 4(a). The PGA in the epicental region ranges from 0.4g to 1.3g as shown in Figure 4(b).

The 25th April 2015 Nepal earthquake main event has more than 100 of aftershocks (Figure 5). Out of these aftershocks, the aftershocks on May 12th 2015, M 7.3 and M 6.3 are significant. The following Figure give a detail view of the aftershocks from 25th April 2015 to 14th May 2015.

DAMAGES AND CASUALITIES

The Nepal earthquake of 2015 has killed more than 8,800 people and injured more than 23,000, thus making it one of the deadliest earthquakes in recent times. The earthquake has caused extensive damages in Nepal and a significant number of displaced people and a high demand for public shelter. The entire villages and human settlements in Lamjung, Gorkha and Barpak districts were damaged during this earthquake. Other districts such as Dhading, Rasuwa, Nuwakot,

Figure 3. Map showing the location of Nepal earthquake of 25/04/2015 (after USGS)

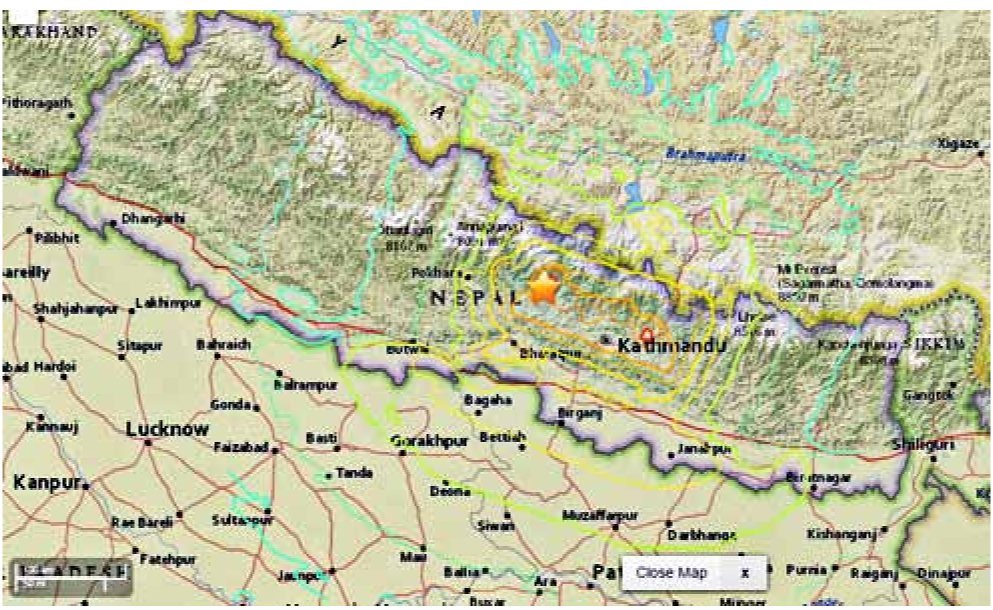


Figure 4. Shake map for 2015 Nepal earthquake of Mw 7.8 (a) instrumental seismicity map (b) Peak ground acceleration (PGA) map (After USGS)

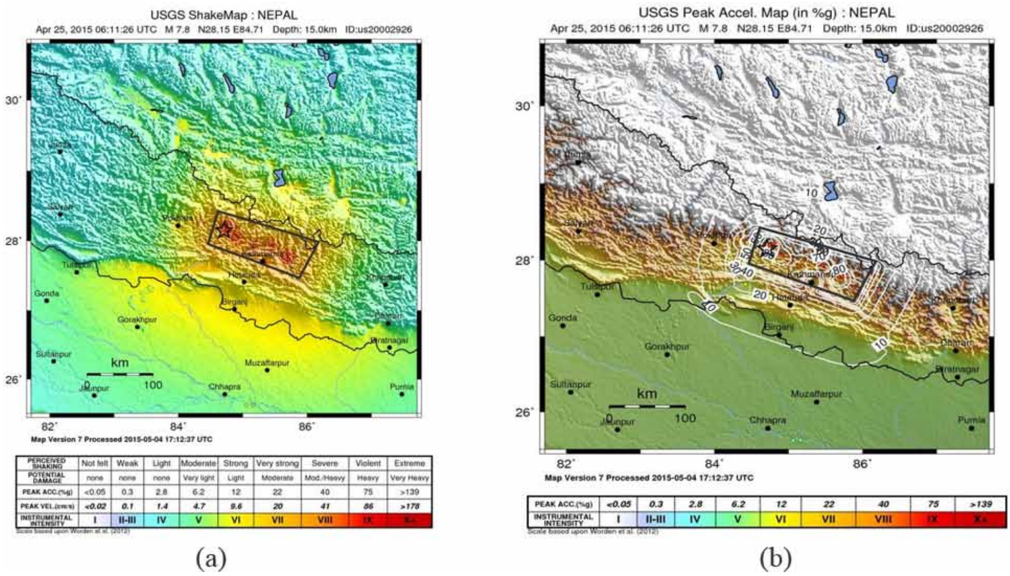
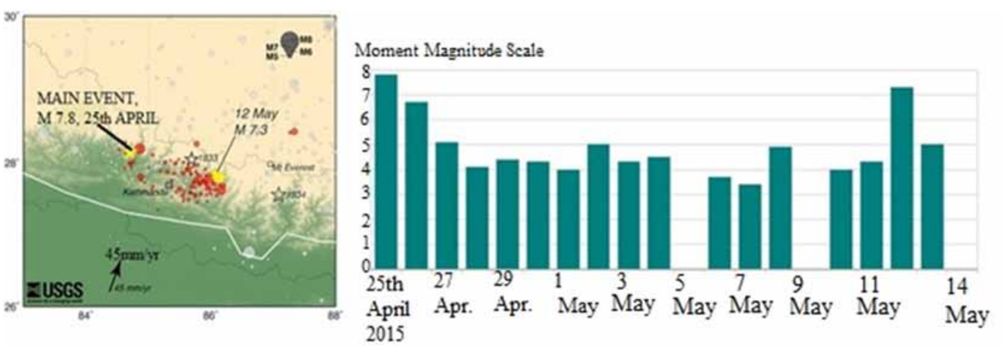


Figure 5. Aftershocks of the main event in Nepal (After USGS, Data shown in the Figure excludes the values<2.5)



Sindhupalchowk, Kavre were mainly affected, where significant damages occurred to houses, hospitals power stations, transmission towers and other infrastructures. As being most densely populated city in the country, Kathmandu also sustained heavy infrastructural damages (Figure 6) and human causalities during the earthquake. Due to the devastating effect of the earthquake, Nepal also lost many monasteries and historical monuments among which the Dharahara (or Bhimsen) tower (Figure 7) and Durbar square (Figure 8) of Kathmandu are significant.

Figure 6. Some structural damages in Kathmandu during 2015 Nepal earthquake of Mw 7.8 (after https://images.google.com) (a) Collapse road (b) collapsed building (c) Collapsed temple

The massive earthquake has triggered several large and small avalanches on and around mountains. A major aftershock of magnitude 6.7 M_w occurred on 26 April 2015 in the same region caused fresh avalanche on Mount Everest and was felt in many parts of northern India. The avalanche was originated on the nearby peak Pumori and swept into south base camp (Figure 9). The base camp got completely destroyed and after the quake the Indian Army mountaineering team recovered 19 bodies of mountaineers from south base camp and also rescued at least 61 stranded climbers from the mountain. The Nepal earthquake of 2015 Mw 7.8 has also triggered landslides in various part of Nepal-China border (Figure 10 and Figure 11) and Sikkim, India.

The economic loss stays reasonably similar at around 3.5 billion USD (2.8-4.6 billion USD) from the CATDAT model as released through Earthquake-Report and CEDIM. These loss estimates are comparable with the significant earthquake damages in past such as Haiti in 2010 (4.24

Figure 7. Dharahara Tower Before and After the Earthquake (after https://images.google.com)

Figure 8. Durbar Square Before and After the Earthquake (after https://images.google.com)

Figure 9. Triggered avalanche on Mount Everest (after https://images.google.com)

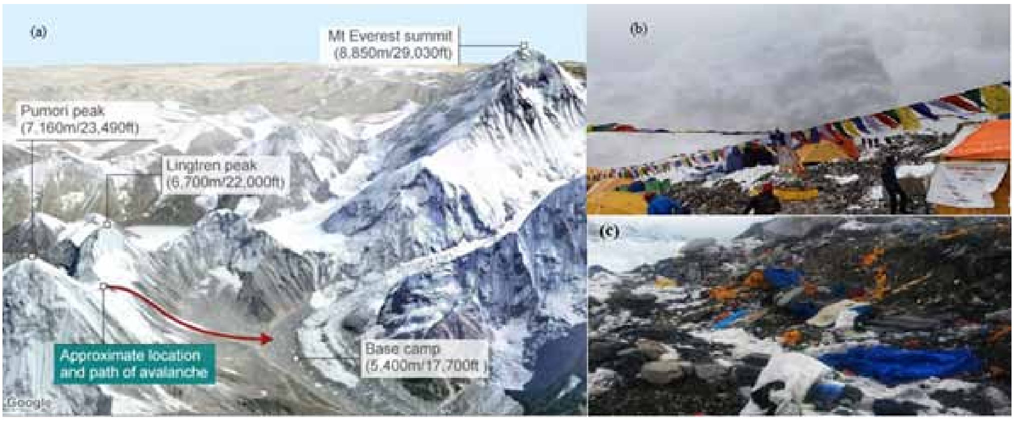


Figure 10. Landslide in Gyirong, close to the Nepal-Tibet border (www.thetelegraph.co.uk)

billion USD) and the Kashmir 2005 (2.25 – 4 billion USD). The replacement cost will be around 5.3 billion USD (4.28-6.84 billion USD) using the intensity patterns and historically observed losses. In following reports, the distribution of these losses will be examined with regard to the observed loss patterns (CEDIM 2015).

The Nepal earthquake of 25th April 2015 (M_w 7.8) is one of the worst earthquakes which caused more than 8000 causalities. The epicenter of the earthquake lies in the eastern part of seismic gap of Himalayan plate boundary, which is considered to be the most active plate boundary regions in

Figure 11. Massive landslide hits the area near the town of Dhunche (www.independent.co.uk)

the world. Very high intensity of ground shaking (≥ 0.4g) was observed in the epicentral region. Significant infrastructural damages were observed in Kathmandu and nearby districts. We can learn many lessons from this Nepal earthquake of 2015. In future, building codes and practices should be modified or updated from the lessons learnt from these earthquakes.

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