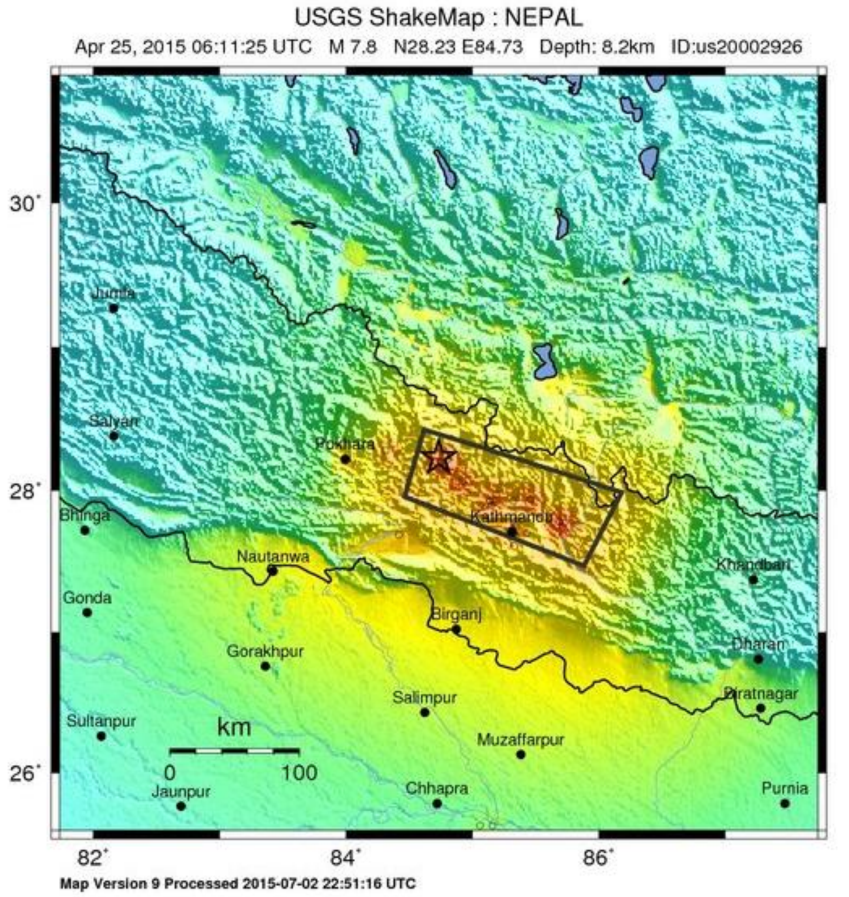
Seismic Risk in Nepal After the April 2015 M_W7.8 Earthquake

Fact sheet

What has happened?

On April 25, 2015, central Nepal was shaken by a magnitude 7.8 earthquake that occurred in direct vicinity of the densely populated capital of Kathmandu. It was the largest earthquake to strike the Kathmandu area in more than 80 years, which counts as one of the most seismically hazardous places on Earth. Although more than 9’000 people have lost their lives and the direct economic damage is estimated to exceed US$ 5 billion, the event was not the catastrophe that seismologists and engineers had expected and feared.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

Figure 1 Shake Map of the M 7.8 earthquake on April 25, 2015 in Nepal (http://earthquake.usgs.gov/earthquakes/shakemap/global/shake/20002926/)

What about aftershocks?

The M7.8 earthquake has triggered an intense aftershock sequence, with hundreds of earthquakes that have been felt by the local population. Aftershock sequences always follow large earthquakes and can cause severe further damage, in particular when the main shock has already weakened structures such as buildings and bridges. For events as large as this one, the sequence is expected to last for several months to years, although both the magnitude and the rate of aftershocks decrease rapidly over time.

Following the April 2015 event two aftershocks were comparable in size to the 1356 Basel earthquake (both M6.7), which is the largest known earthquake north of the Alps and which had completely devastated the city. In May 2015, 17 days after the main shock, an exceptionally large aftershock with magnitude 7.3 has occurred North-East of Kathmandu.

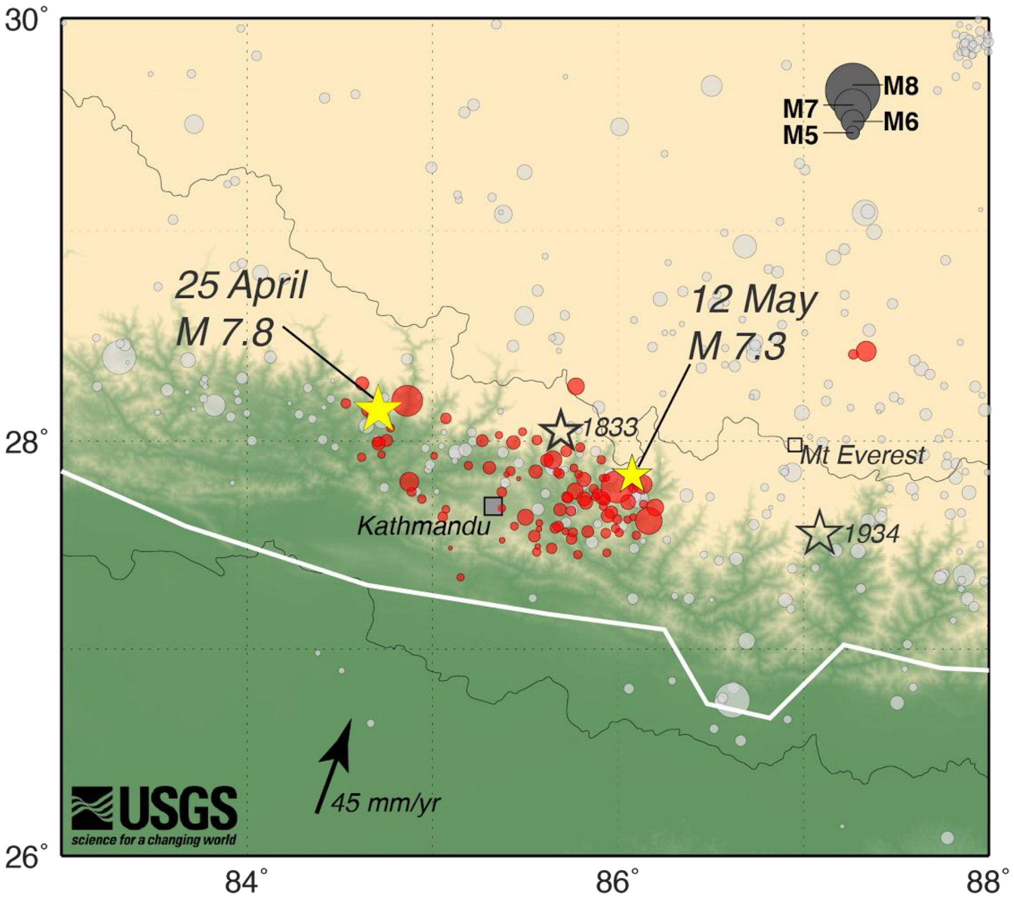


Figure 2 Aftershocks until May 12, 2015
(http://www.usgs.gov/blogs/features/usgs_top_story/magnitude-7-8-earthquake-in-nepal/)

Based on a statistical analysis, the United States Geological Survey (USGS) estimates an 80 percent probability of at least one aftershock with a magnitude between 5 and 6 in Nepal within the first year after the event. For aftershocks with magnitudes 6 to 7 the corresponding probability is 17 percent.

What to expect in the future?

Nepal is one of the seismically most active regions in the world, and will remain one for millions of years.

Although such large earthquakes release a lot of stress on the plate interface, it is unclear how much stress remains. According to simple mechanical models, the stress release makes future large events on the same fault segment less likely for some time. However, these models have been wrong for several previous earthquakes, and so large earthquakes (even larger than the April 2015 event) may strike anytime and in any place of the Himalayas, including Kathmandu.

Note, however, that even in the seismically most hazardous areas of the world, the seismic risk (the danger of having casualties and damage from earthquakes) is typically smaller than other risks such as those arising from traffic accidents or diseases. Still, the risk is substantial and destructive earthquakes can occur any time in any place of Nepal.

Why has this earthquake not turned out even worse?

Owing to the combination of high population density, the poor infrastructure quality, unfavorable ground properties (soft sediments that amplify earthquake shaking) and very high tectonic activity, a large earthquake in Kathmandu was (and still is) the textbook example for potentially huge seismic catastrophes. Fortunately, these fears have not been fully realized in the April 2015 event, although more than 9’000 people have lost their lives.

The reasons why the event was not more catastrophic are currently the subject of an intense scientific debate. The rupture pattern may have been somewhat fortunate with low amounts of displacements and little high-frequency ground motion right under Kathmandu. Furthermore, the rupture itself did not reach the surface, which is surprising for an earthquake of this size.

The earthquake has triggered large numbers of landslides and avalanches that killed hundreds of people and hindered relief operations. It may also have destabilized numerous slopes that will fail during the monsoon season. It has not, however, triggered many other types of secondary hazards, such as large fires or epidemics. Such secondary hazards have enormous damage potential and, in many of the past catastrophic earthquakes, have caused more damage than the shaking itself. A large-scale fire in the Kathmandu valley, for example, may be almost impossible to extinguish and could cause hundreds of thousands of casualties.

As a surprise to many experts, a majority of the buildings in Kathmandu have withstood the shaking, in particular new buildings; collapsed buildings were mostly old ones. The rural buildings outside the Kathmandu population center are typically small with relatively light roofs. Although many collapsed, collapses of such buildings typically lead to few casualties. Furthermore, the Ganges plain, which has extremely high population densities in some places, did not experience very high shaking intensities.

Finally, the earthquake could have been even bigger, such as the 1934 Nepal-Bihar (India) earthquake, which was about twice as large (M 8.1). Earthquakes as large as M 8.5 may be possible in the area. It is possible that a future large earthquake may claim hundreds of thousands of casualties.

Why do earthquakes happen in the Himalayas?

Such large earthquakes, or even larger ones, are not uncommon in this area but, to the contrary, are expected to happen. The Himalayan Arc is a tectonically active mountain range that results from the collision of the Indian plate with the Eurasian plate. The two plates converge at a rate of about 45 mm per year and thereby create the Tibetan Plateau. Along the Himalayas the India plate “dives” underneath the Eurasian plate at a rate of about 21 mm per year. The contact zone between the two plates – called “Main Frontal Thrust” – starts at the northern end of the Ganges plain and after a steep dipping section continues northwards sub-horizontally (see figure 3).

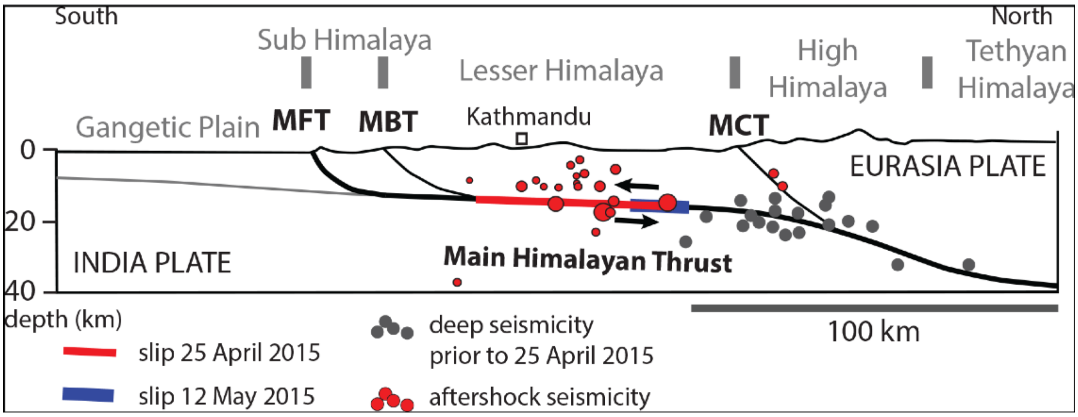


Figure 3 Tectonic cross section (http://earthquake.usgs.gov/learn/topics/Nepal_Slides.pdf)
MFT = Main Frontal Thrust, MBT = Main Boundary Thrust, MCT = Main Central Thrust.

Where Kathmandu is located, the Main Frontal Thrust has reached a depth of about 15 to 20 km. At large distances from the Main Frontal Thrust the plate motion is very steady; on the Main Frontal Thrust itself, on the other hand, the two plates are interlocked for most of the time: they cannot move past each other because they are hindered by friction. The difference in motion (steady motion away from the fault, no motion on the fault) leads to a significant buildup of stress. At some point in time this stress will become too large for the contact zone to bear and the plate motion that had been prevented by friction during years, decades or even centuries occurs in a matter of seconds or minutes. It is the release of the stresses and the rapid motion of the plates by several meters that causes the shaking felt at the Earth’s surface in what we call an earthquake.

In the 2015 Nepal earthquake, this plate motion has occurred over an area of roughly 120 x 80 km on the Main Frontal Thrust (Figure 4). In some places the relative motion of the rock mass on either side of the thrust amounted to several meters. On the surface, the maximum displacement has reached approximately 1 m. The shaking strength in some places reached IX on the Modified Mercalli Intensity Scale, which is the second highest possible level; the level is termed “violent”. In Kathmandu, the shaking intensity reached levels of VI (“strong") and VII ("very strong”). From historical and geological records it is known that the front of the Himalayas experiences such large earthquakes regularly, at different segments of the mountain belt. The last such earthquakes were the 1950 Assam (NE India, M8.6), the 1934 Nepal-Bihar (India, M8.1) and the 1905 Kangra (NW India, M7.9) events.

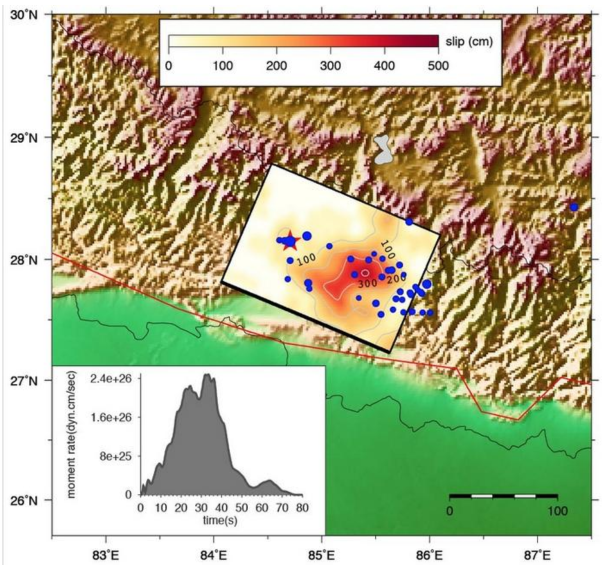


Figure 4 Estimated plate motion (http://www.earthobservatory.sg/news/april-25-2015-nepal-earthquake)