Great earthquakes as 'surprises' or our lack of understanding

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In past ten years there have been a few cases in which the occurrences of great and major earthquakes defied, in some way or other, our conventional understanding of their genesis. Their occurrences surprised all of us. The recent 2011 Tohoku, Japan earthquake (*M* 9) occurred in a region which was not considered to produce such a large earthquake and caused a tsunami with unprecedented height. The great 2010 Maule, Chile earthquake (*M* 8.8) rupture partly overlapped with that of a previous major earthquake which occurred just eight decades ago, defying the concept of seismic gap theory[1]. The great 2007 Solomon Island earthquake (*M* 8.1) rupture breached a mid-oceanic ridge, which is commonly considered to be segmenting the arc[2]. But the case of the great 2004 Sumatra Andaman earthquake (*M* 9.2), the region around it and the features associated with it, are most curious and continue to surprise us even now. The rupture length of the 2004 earthquake was as large as ~1400 km and was probably the largest in the history of the great earthquakes[3,4]. The slip during the earthquake continued for at least 10 min (ref. 5); some estimate it as almost half an hour[6]. The giant earthquake triggered thousands of earthquakes and two of them were great, the 2005 Nias (*M* 8.6) and 2007 Bengkulu (*M* 8.4) earthquakes, leaving a potential region between the two where a great earthquake is expected to occur[7]. The latest is a doublet earthquake on 11 April 2012 (*M* 8.6 and *M* 8.2; Figure 1). In the coming days to months, analysis of the data and models may suggest the linkage between the earthquake processes in the subduction zone, where the great 2004 Sumatra Andaman, 2005 Nias and 2007 Bengkulu earthquakes occurred, and the subducting Indian plate, where the 2012 earthquake had occurred. In case this amazing link is established, then this will further highlight our poor understanding of great earthquakes and how they interact over large distances and time. The 11 April 2012 earthquake occurred about 100 km west of the subduction zone within the subducting Indian plate, and thus is an intraplate event. Similar moderate to strong magnitude earthquakes have occurred close to the Andaman–Sumatra region trench during past four years[8–10]. Such earthquakes located oceanward close to the trench are referred to as earthquakes of the outer rise, which generally occur due to flexure of the subducting plate. This earthquake is unique and serves as an eye-opener to seismologists worldwide. This is probably the largest intraplate earthquake ever recorded anywhere over the globe occurring on the subducting oceanic plate, close to a subduction zone that is just emerging out of an *M* 9.2 event, the 2004 Sumatra Andaman earthquake. This earthquake also triggered another great earthquake (*M* 8.2) in its vicinity. The thickness of the oceanic lithosphere is low and the crust, where earthquake ruptures are generally confined, is not thicker than 10 km. It is possible that the ruptures of these two earthquakes extended into a part of the upper mantle as the crust is reported to be only about 5 km thick in this region[11] with age as old as about 50 Ma only. However, it is amazing how such great earthquakes could occur in a region with very low crustal thickness. The strength of the material must be

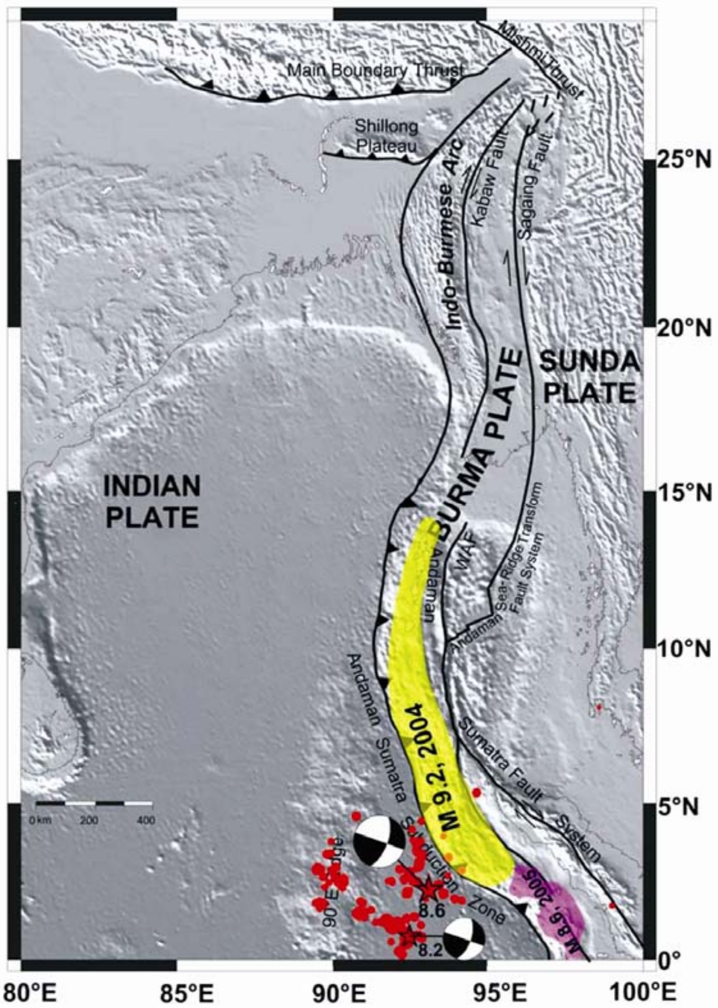

Figure 1. The two great earthquakes of 11 April 2012, their focal mechanisms and aftershocks in the following week shown by the red stars, beachballs and circles respectively. The ruptures of the 2004 Sumatra–Andaman earthquake (*M* 9.2) and 2005 Nias earthquake (*M* 8.6) in the subduction zone are shown in yellow and pink shades.

quite high to sustain such a large strain. The slip on the rupture during the earthquake reached a whopping 50 m and probably it did not occur on a single fault plane[12]. It appears that a network of conjugate faults (at least three) slipped during the two great earthquakes. This made the rupture process quite complicated. Also, there is something to learn for scientists involved in tsunami modelling and warning. Considering its large magnitude and its close proximity to the Sumatra subduction zone, it was probably assumed as a subduction zone earthquake, and using a scenario earthquake model for the region they predicted a major tsunami. But owing to predominantly strike–slip motion during the rupture, the earthquake caused only a minor and unnoticeable tsunami. We must now realize that each earthquake is special and unique, and hence treat it with humility, there is little room for empiricism, and each one needs to be studied carefully. There is still so much that we need to learn about the processes that govern the nucleation and mechanism of earthquakes.

The great earthquakes that have occurred over the past one decade, particularly the Indian Ocean events on 11 April 2012, have challenged our conventional wisdom and highlighted the complexities involved in the process. New models supported with more accurate data are the only key.

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