The great Sumatra–Andaman earthquake of 26 December 2004

The M 9.0 earthquake that occurred in the offshore regions of northwestern Sumatra on Sunday, 26 December 2004 is the largest event to have occurred in this region, since historic times (Figure 1), with devastating effect on human life and property, not restricted to a single country. It was also the world's largest earthquake since the M 9.2 Alaskan event of 1964. The earthquake originated along the boundary between the Indo-Australian and Eurasian plates, which are about 5500 km from Myanmar to Sumatra and Java to Australia. Near Sumatra, the Indo-Australian plate is reportedly moving in the NNW direction at about 6 cm/yr with respect to Southeast Asia. The potential for frequent great earthquakes in the region is related to the subduction processes that are taking place there. The earthquake generated large tsunamis that caused unprecedented damage in many of the affected countries.

Historic tsunamis

The large tsunami waves (reaching a height of 20 m in certain areas) caused by the 26 December earthquake affected the coasts of Thailand, Indonesia, India, Maldives and Somalia. The Andaman–Sumatra section of the subduction zone had produced many large and destructive earthquakes in the past, some of which have also generated destructive tsunamis. The M 8.7 earthquake of 1833 is reported to have ruptured about 550 km segment of this arc southeast of the current source and it also generated a tsunami. Another great earthquake of 1861 (M 8.5) broke a segment north of the equator, also triggering a tsunami. The 1833 and 1861 earthquakes and the attendant tsunamis occurred before the introduction of harbour tide gauges in most parts of the world and there are no tidal gauge data for these events. However, there are better documents of tsunamis due to the earthquakes of 7 December 1881 and 26 June 1941, both of which caused a run-up in the eastern coast of India. The 1881 tsunami is reported to have reached an amplitude of 1.04 m at Chennai. The 1881 earthquake is also the earliest for which slip geometry has been inferred. The 1941 earthquake occurred during the Japanese occupation of the Andaman Islands. It appears to have ruptured the region near the Andaman Island. There are anecdotal accounts 3000 deaths from the eastern coast, resulting from a tsunami associated with this earthquake. Thus, going by the documented evidence, there are only two earthquakes (1881 and 1941) that have caused tsunami run-up in the east coast of India (for more details, see http://cires.colorado.edu/~bilham/indonesiAndaman_2004.htm). Historically an earlier earthquake appears to have occurred in the Andaman offshore on 28 January 1679, with its felt area similar to the 1941 north Andaman event. This earthquake may have also generated sea surge, which was probably not properly documented. However, what is interesting to note is that the 26 December tsunami is unprecedented in terms of its scale and reach, and cannot be compared to its smaller preceding historical events, probably indicating the extreme rarity of such giant earthquakes in this region.

26 December 2004 earthquake: Aftershocks and rupture

The giant thrust faulting event of 26 December appears to have disturbed more than 1200 km length of the arc (at the time of writing this note on 3 January 2005, aftershocks continue to occur). Nearly 100 aftershocks have already been reported, 12 of which are of M ≥ 6.0. The broadband observatories in the Indian mainland have recorded nearly 120 events (based on the records at the Puechi Broadband Observatory, South India). The farthest earthquake of this sequence is located at 19.85 N, 95.88 E, north of Myanmar (2 January 2004, M 5). Considering its great distance away from the nearest aftershock, and with its location in a seismically active region, it may be treated as an independent earthquake. However, triggered earthquakes occurring a few thousands of kilometres away from the source are observed in association with many large/great earthquakes and in that sense, this may be considered as a triggered event. The possibility for more such future events in this region cannot be ruled out.

Figure 1. Location of the 26 December 2004 earthquake and aftershocks (blue dots); beach ball shows the Harvard Moment Tensor solution of the main shock. Red stars represent historic earthquakes (1982 Great Nicobar and 2002 Diglipur earthquake areas are also shown). Arrow shows the direction of plate motion.
NEWS

Initial models suggest a two-stage rupture, the first one being about 300 km to the northwest from the hypocentre during the initial 100 s (Yuiji Yagi, 2005; http://isec.kenken.go.jp/staff/yagi/eq/Sumatra/Sumatra2004.htm). The second slower rupture started about 100 s after the initial break. Much of the ongoing aftershock activity in the Andaman–Nicobar arc seems to be associated with this slow rupture. These initial models would be modified as more data are being analysed. We believe that the question whether these are in fact multiple ruptures associated with independent segments, needs to be resolved.

Implications for future

Recognizing the threat regarding earthquakes originating from the Andaman–Nicobar arc, various studies have been initiated in this region for quite some time. In addition to seismic monitoring, there are programmes to monitor plate deformation using GPS data. Pre- and post-earthquake GPS data would be most crucial to model the displacement caused by this great earthquake, the largest, to have occurred since the advent of the GPS technique to monitor plate deformation. Spatial-temporal pattern of subduction earthquakes needs to be understood in great detail and this gap-filling earthquake provides an opportunity to initiate such studies. A causal relationship and a 50-yr gap between great earthquakes and reactivation of magma chambers has been noted, a correlation has been suggested between the 1941 Andaman earthquake and the 1991 Barren Island volcanic eruption (Rajendran et al., and references therein). How this great earthquake would affect the stability of the magma chambers is another issue that needs to be addressed, particularly in the context of massive volcanic eruptions such as the 1883 Krakatoa. The other question concerns the threat from tsunamis on the Indian coast, which was generally not taken much into account in hazard-assessment scenarios.

Perhaps, the most important question that the December 2004 earthquake has triggered is whether the northern segments of the arc and parts of the Himalaya, which have not ruptured in any major earthquake during the last 55 years, will be the next candidates. This has already been pointed out by some workers (see http://cires.colorado.edu/~bilham/indoonesi_andaman2004.htm).

Scientifically, this earthquake would provide a wealth of data that would be useful in studying the stress release, pattern of displacement and slip on various segments. These studies have great implication for future seismic-hazard evaluation. Being the first known great plate boundary earthquake in the Andaman–Sumatra region, the plate dislocations that this event may have caused in other parts of the arc, notably the unbroken segments to the north, need to be monitored closely. While the reoccurrence of the existing benchmarks in the Andaman–Nicobar–Sumatra regions will help model the coseismic and post-earthquake stress relaxation, there is a compelling need to strengthen monitoring of the northern segments, including NE India.

Clearly, we had no strong evidence to foresee that an earthquake of M 9 could occur in the Sumatra arc and its tsunami run-up could reach even the southwest coast (Kerala) of India. However, various studies in this region have implied a locked fault zone, with potential for great earthquakes. This earthquake reminds us once again about how much we underestimate the threats from earthquakes both within and outside the Indian territory. The Indian coast is located far enough to get 1-2 h warning from earthquakes originating from this active plate boundary. The 26 December 2004 earthquake calls for more focused studies on earthquake sources in India and the neighbourhood, and estimation of direct and indirect threats posed by them.


Kusala Rajendran*, C. P. Rajendran and Anil Earnest, Centre for Earth Science Studies, Akkulam, Thiruvananthapuram 695 031, India. *For correspondence. e-mail: kusala@seires.net

RESEARCH NEWS

A ‘SOUND’ method for synthesis of single-walled carbon nanotubes under ambient conditions

C. Srinivasan

The discovery of carbon nanotubes (CNTs) by Iijima in 1991 is a milestone in the study of different forms of carbon and CNTs have been recognized as the quintessential nanomaterial. Potential applications of CNTs are well documented. Recently, an elegant and cost-effective synthesis of multi-walled carbon nanotubes (MWCNTs) has been proposed by Kang et al. and was also reported in this journal. It will be of interest to know whether such a simple method is possible for the synthesis of single-walled carbon nanotubes (SWCNTs), which were first reported in 1993. SWCNTs can have diameters varying from 1 to 3 nm and length of 100 μm and they are synthesized by the same methods employed for MWCNTs, viz. electric arc discharge, laser ablation, catalytic synthesis and chemical vapour deposition. The notable difference is that the presence of a metal catalyst is essential for the growth of SWCNTs. Several other strategies have been explored for the preparation of SWCNTs. A recent account by Rao and Govindan describes the synthesis of CNTs from organometallic precursors. Rao and co-workers have also shown that pyrolysis of dilute acetylene-metalloocene, M(4C2H2) (M=Fe, Co, or Ni) mixtures at 1100°C yields isolated SWCNTs.

Scientists from Samsung Advanced Institute of Technology, Korea, have recently achieved a breakthrough in the synthesis of SWCNTs by developing a sonochemical route to SWCNTs of high purity in a liquid solution at atmospheric pressure and room temperature, without the necessity of any specialized equipment and starting with the organometallic precursor, ferrocene.