SCIENCEWATCH®
July/August 2007

Tragic Earthquake Yields Rich Science

by Simon Mitton

At 8:00 a.m. on 26 December 2004, the BBC radio news bulletin began with an announcement that an earthquake had unleashed a tsunami in the Indian Ocean. The newscast put the number of dead at "about 200 people." My immediate reaction was that this estimate was wrong by a factor of 1,000. My forecast was chillingly close: the U.S. Geological Survey has estimated the casualties at 283,100 dead, mostly in Indonesia and Sri Lanka. *Science* magazine commissioned a special issue (308 [5725], 20 May 2005) to publish research papers on the seismic, satellite, and Global Positioning System (GPS) observations of the submarine earthquake and its consequences.

WHAT'S HOT IN PHYSICS

Rank	Paper	Citations This Period (Jan-Feb 07)	Rank Last Period (Nov-Dec 06)
1	M.F. Skrutskie, *et al.*, **"The Two Micron All Sky Survey (2MASS),"** *Astronom. J.*, 131(2): 1163-83, February 2006. [11 U. S. institutions] *010RX	35	2
2	Y.-B. Zhang, *et al.*, **"Experimental observation of the quantum Hall effect and Berry's phase in graphene,"** *Nature*, 438 (7065): 201-4, 10 November 2005. [Columbia U., New York, NY] *982BV	32	4
3	K.S. Novoselov, *et al.*, **"Two-dimensional gas of massless Dirac fermions in graphene,"** *Nature*, 438 (7065): 197-200, 10 November 2005. [U. Manchester, U.K.; Inst. Microelect. Tech., Chernogolovka, Russia; Radboud U., Nijmegen, Netherlands] *982BV	31	1

Our Physics Top Ten this period features two of the papers, #5 and #9.

The scale of the human tragedy has overshadowed a huge leap forward in our understanding of great earthquakes. The Sumatra-Andaman earthquake was the largest seismic event on Earth in four decades and produced the most destructive tsunami in history. In terms of data useful for scientific investigation, this was the first great earthquake to be observed by modern instruments, and that's why #5 and #9 are highly cited. The new tools in the hands of geophysicists included the global network of sensitive, broadband seismographs, satellite instruments with ability to measure ocean heights, and a GPS system able to record subtle positional shifts in the Earth's crust.

The quake had a moment magnitude of 9.3, which released 4.3 x 10^{18} J, or about half the annual energy consumption of the United States. Papers #5 and #9 answer the question: what actually

4	D.J. Eisenstein, *et al.*, **"Detection of the baryon acoustic peak in the large-scale correlation function of SDSS luminous red galaxies,"** *Astrophys. J.*, 633(2): 560-74, 10 November 2005. [29 institutions worldwide] *983NK	31	†
5	T. Lay, *et al.*, **"The great Sumatra-Andaman earthquake of 26 December 2004,"** *Science*, 308(5725): 1127-33, 20 May 2005. [12 U.S. and Japanese institutions] *928TA	30	†
6	J.K. Adelman-McCarthy, *et al.*, **"The Fourth Data Release of the Sloan Digital Sky Survey,"** *Astrophys. J. Suppl. Ser.*, 162(1): 38-48, January 2006. [61 institutions worldwide] *009RS	29	†
7	P. Astier, *et al.*, **"The Supernova Legacy Survey: measurement of Ω_M, $\Omega_{\langle V \rangle_\wedge}$ and *w* from the first year data set,"** *Astron. & Astrophys.*, 447 (1): 31-48, February 2006. [18 institutions worldwide] *007GS	29	†
8	T. Araki, *et al.* (KamLAND Collaboration), **"Measurement of neutrino oscillation with KamLAND: Evidence of spectral distortion"**, *Phys. Rev. Lett.*, 94(8): 081801, 4 March 2005. [13 institutions worldwide] *902VY	28	6
9	C.J. Ammon, *et al.*, **"Rupture process of the 2004 Sumatra-Andaman earthquake,"** *Science*, 308 (5725): 1133-9, 20 May 2005. [8 institutions worldwide] *928TA	27	†

10	J.R. Petta, *et al.*, **"Coherent manipulation of coupled electron spins in semiconductor quantum dots,"** *Science*, 309(5744): 2180-4, 30 September 2005. [Harvard U., Cambridge, MA; Weizmann Inst., Rehovot, Israel; U. Calif., Santa Barbara] *970NX	26	5

SOURCE: Thomson Scientific's Hot Papers Database. Read the Legend.

happened? The mainshock commenced at a depth of 30 km in a subduction zone where the Indo-Australian plate plunges below the Andaman Islands. The blow to our planet excited vibrational free oscillations that, at periods *T* > 1,000 s, registered on the global networks for several weeks. The data from this planetary bell-ringing will keep geophysicists busy for years finding new perspectives on Earth structure. Ground motions on Earth were everywhere at least 10 mm.

In #9, Charles Ammon (Pennsylvania State University) and his team use the extensive seismic data to construct an integrated view, on a global basis, of the event. They found that the earthquake began slowly, with a small slip and slow rupture speed for the first minute, during which about 100 km of plate boundary broke. But then the unzipping raced ahead, rocketing north-northwest at about 2.5 kilometers per second, extending 1,300 km along the Andaman trough. The lateral geometry of the rupture mirrored that of three other great earthquakes for which good seismic data exist: 1952 Kamchatka, 1964 Alaska, and 1960 Chile. When tectonic plates shake and then break on this scale the megacrack propagates along a straight line.

The most remarkable feature of the earthquake was the slowness of the subsequent slip. At the southern end of the disturbance the slippage occurred at the same rate as the rupture, launching the tsunami on its destructive course. The peak displacement along a 600-km section reached ~ 15 m. But in the northern section, near to the Andaman archipelago, the Indian plate took more than half an hour to slip a distance of 7 to 20 m. The slow slip dragged parts of the Andaman Islands 4 m south, sinking some shores and raising others.

The rupture speed and the total slip determine the frequency and strength of the radiated seismic waves, and therefore the tsunami. It is a sobering thought that had this slip not been so slow it would have triggered a catastrophic natural disaster along the coastlines of India and Thailand.

Paper #5 by Thorne Lay (University of California, Santa Cruz) and colleagues presents a full geophysical analysis of the earthquake rupture and its aftermath. This analysis is valuable because it provides a quantitative picture of the rupture scenario and the subsequent slip. The rupture itself took more than an hour, the longest ever recorded.

What do these papers tell us about the future? Paper #5 concludes with the concern that future large earthquakes are likely along the Sumatra Fault. A region adjacent to this failed in 1833 and has accumulated substantial strain. Given the inevitability of future thrust earthquakes in the Sumatra subduction zone, the tsunami warning systems in the Indian Ocean require massive international effort to improve effectiveness.■

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Science Watch®, July/August 2007, Vol. 18, No. 4
Citing URL: http://www.sciencewatch.com/july-aug2007/sw_july-aug2007_page6.htm