

# Intensity Distribution from the 2004 M 9.0 Sumatra-Andaman Earthquake

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The epicenter of the  $M_w$  9.0 Sumatra-Andaman earthquake on 26 December 2004 at 00:58 UTC occurred near the northwestern end of Sumatra and ruptured northward along the Andaman and Nicobar Archipelago (Figure 1). The principal rupture had a duration of more than 10 minutes (Park *et al.*, 2005) and was perceptible to a distance of 3,300 km westward and 2,600 km northward. The largest accelerations were perceived near the epicenter, but high intensities were also perceived along the archipelago with diminishing intensity northward. Presented here are 206 intensity reports interpreted in terms of EMS-98 (Grünthal, 1998), a scale with similarities to the MSK and Modified Mercalli Intensity scales but designed to take into account modern building practices. The data are culled from primary accounts, newspaper reports, and responses to an online intensity questionnaire

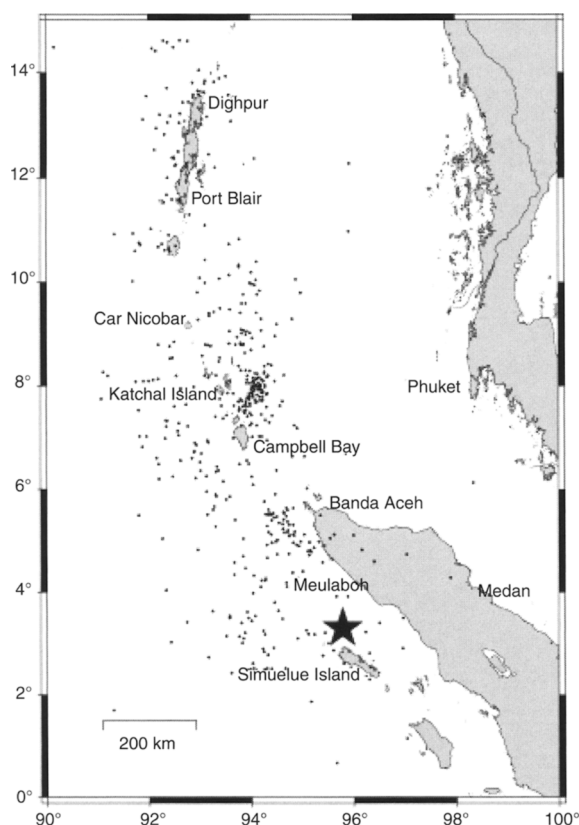
(<http://asc-india.org/menu/felt.htm>). Insofar as additional epicentral data will be forthcoming in the next several months, the data are presented with a minimum of interpretation.

## INTRODUCTION

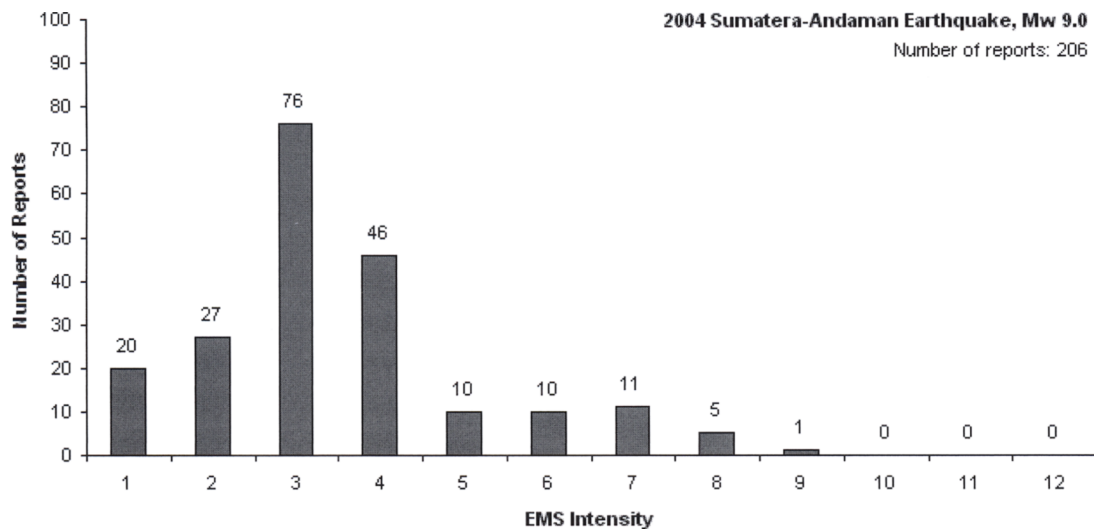
This study focuses on evidence for shaking intensity resulting from the earthquake, ignoring damage due to the tsunami, landslides, or liquefaction. Preliminary ground-based tsunami surveys are available (Borrero, 2005; NICEE, 2005); these provide some information about shaking intensities as well but are spatially limited. First-hand accounts of the disaster and damage reports that appeared in Web logs, conventional newspapers, and Web sites are evaluated along with 48 felt reports sent via the Internet by eyewitnesses in India. Multiple felt reports were received from places such as Bhubaneswar, Chennai, and Port Blair. The highest assigned intensity of 9 EMS was reported from Lameureum, on the northwest coast of Simuelue Island, Indonesia. The maximum number of observations for a single intensity level was for 3 EMS (Figure 2).

Modern multistory buildings represent a class of vulnerable structures that can inflate intensities (Ambraseys, 2002). With this in mind, particular attention was paid while considering places such as Banda Aceh and Port Blair, where newer taller buildings are known to have suffered various grades of damage. At distant locations in Malaysia, Singapore, Thailand, and western India, weak intensities were perceived by observers on the upper floors of high-rise buildings and were assigned 2 EMS (Grünthal, 1998).

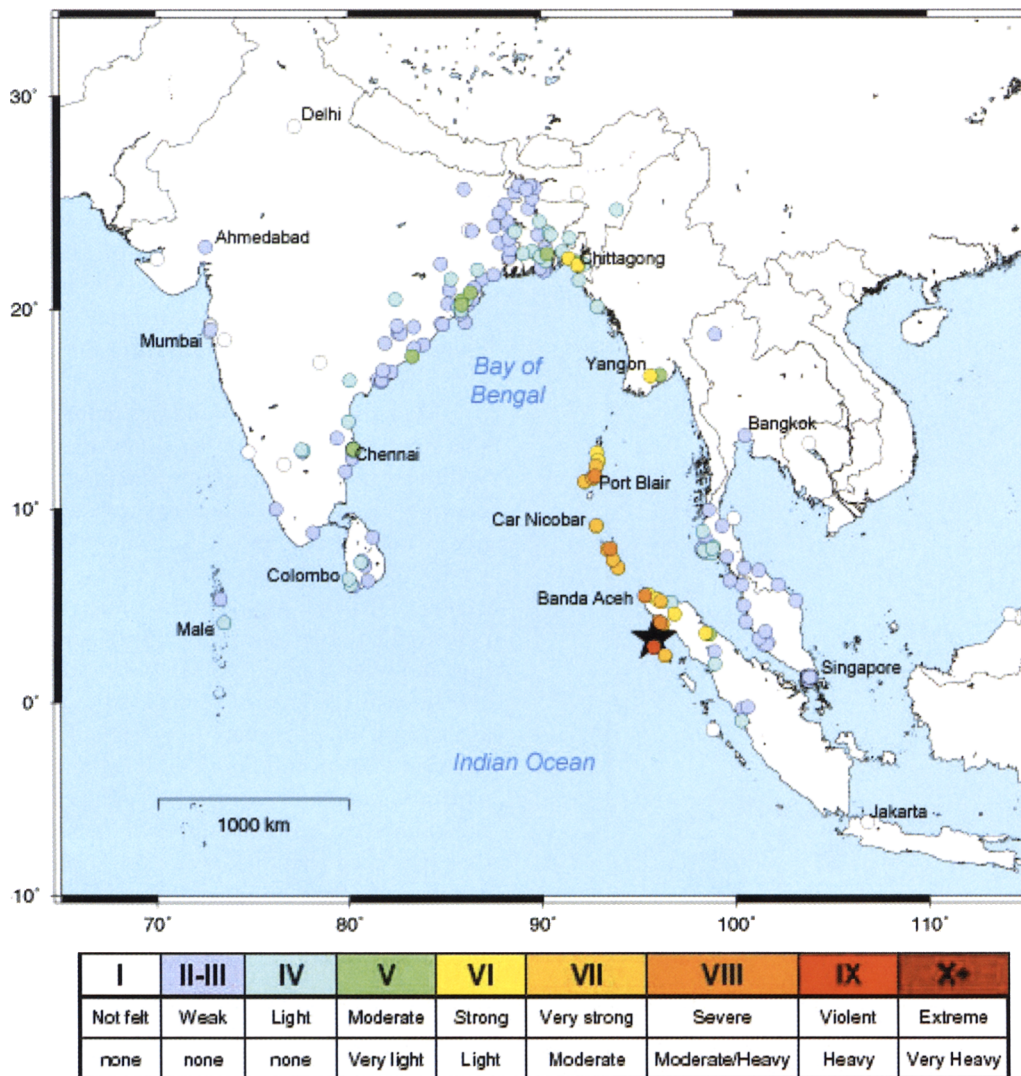
Intensities were first plotted as point data (Figure 3) and as a shaded intensity map using a simple mathematical interpolation (Wessel and Smith, 1991) between location coordinates and known intensity values. The edges of the map were constrained by artificially imposed low values. Intensity maps thus produced (Bendick *et al.*, 2001) provide a good overall description of the extent of ground motions but away from the data points do not reflect geological site conditions that affect shaking. In the past, such maps (Hough *et al.*, 2002) for the Bhuj earthquake were generally comparable to those published following ground surveys (GSI, 2003). This and additional maps relevant to this article can be viewed online (<http://asc-india.org/martin/>). A complete listing of the locations where the earthquake was felt, with the corresponding EMS intensities, is given in Table 1.



▲ **Figure 1.** Map showing the region of the rupture and its aftershocks (black dots). The location of the December mainshock is shown by a star. It is believed that the main rupture propagated to close to Port Blair.



▲ **Figure 2.** Histogram showing the number of reports per intensity level.



▲ **Figure 3.** Map showing the location of the December mainshock (black star) and the area over which it was felt. Colored circles depict the maximum observed EMS intensity at a single location.

**TABLE 1**  
**Locations from South Asia and Indochina Where the Mainshock was Either Felt or Not Felt,**  
**with EMS Intensity, Geographic Coordinates, Brief Descriptions, and Sources**

<b>Location*</b>	<b>Intensity</b>	<b>Latitude (°)</b>	<b>Longitude (°)</b>	<b>Report</b>	<b>Sources**</b>
Lameureum, ID	9	95.768	2.885	People were thrown to the ground due to the shaking.	SUAD
Banda Aceh, ID	8	95.324	5.554	Felt by everyone; people found it difficult to stand; water splashed in gutters; cracks in walls; false ceiling fell in one building; some modern high-rise buildings collapsed or suffered various grades of damage; traditional wood-frame buildings suffered little to no damage; damage described as being less than in Ahmedabad from the 2001 Bhuj earthquake.	BBCT, JKPT, UNDP
Kembang Cot, ID	8	96.045	4.208	Very violent; walls collapsed; cracks in floor.	AKIT
Meulaboh, ID	8	96.125	4.136	Felt by everyone, causing great panic; strong tremor for 10 minutes; some houses collapsed to the ground; many buildings damaged; everyone rushed outdoors.	AKIT
Nancowry Island, IN	8	93.549	7.981	Houses collapsed inland at Hinpawa village.	ANN
Port Blair, IN	8	92.761	11.668	Felt by everyone; electricity poles swayed considerably; people found it difficult to stand or walk; pictures fell from walls; heavy furniture moved; stationary automobiles shook visibly; some buildings collapsed and others suffered minor damage such as fall of roof tiles, broken windows, cracks, or damage to walls; minimal damage to wooden structures.	ASCN, NICE
Baratang Island, IN	7	92.806	12.190	Steel cupboard and racks fell; shear cracks in walls.	GSIP
Campbell Bay, IN	7	93.920	6.990	People had to hold onto poles, etc. for support; shaking was large but not sudden and fast; Grade 3 damage to a Type C building (control tower); very little damage to other buildings; jetty collapsed.	VNGT
Cape Daweh, ID	7	95.799	2.919	People could not stand during the mainshock that lasted 2 minutes.	SIEH
Car Nicobar, IN	7	93.920	6.990	Difficult to stand; cracks in ground; water jets from cracks; two people on a moving scooter were thrown down in the quake; control tower of IAF base collapsed; runway cracked; eyewitnesses saw buildings "crumbling."	ANN, TELK, MDDY, OUTL.
Katchal Island, IN	7	93.385	7.944	Violent shaking; cracks in the ground and water emitted; "buildings crumbled around me" — eyewitness.	LAT
Kuala (Nagan Raya), ID	7	93.234	4.064	14-year-old fell down on beach due to quake.	JKPT
Panteraja, ID	7	92.640	11.580	People found it difficult to stand.	JBOR
Pilo Panja Island, IN	7	93.673	7.395	Building shaken; person fell down.	AP
Rutland Island, IN	7	92.224	11.416	People fell on ground, grabbed grass for stability.	BILH
Sinabang, ID	7	96.367	2.471	Verandah of two-story house collapsed; tsunami inundated ground floor.	SUAD
Wandoor, IN	7	92.640	11.580	Walls collapsed; people found it difficult to stand; bookcases and diving canisters toppled over.	REEF
Bamboo Flat, IN	6	92.723	11.700	Many buildings developed cracks; one building suffered a soft story.	GSIP

**TABLE 1 (Continued)**  
**Locations from South Asia and Indochina Where the Mainshock was Either Felt or Not Felt,**  
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<b>Location*</b>	<b>Intensity</b>	<b>Latitude (°)</b>	<b>Longitude (°)</b>	<b>Report</b>	<b>Sources**</b>
Binjai, ID	6	98.478	3.598	Some damage.	BLOG
Chandpur Sadar, BD	6	91.916	22.153	Wall collapsed; many injured in panic-stricken escapes.	NATB
Huramia, BD	6	91.430	22.480	Mud houses collapsed, injuring three people.	INBD, NATB
Kreung Raya, ID	6	95.532	5.600	Very strong; did not cause severe damage to structures.	JBOR
Ma-Ubin, MY	6	95.650	16.730	College damaged	DVBN
Mayabander, IN	6	93.920	6.990	One building suffered a soft story; no other major damage.	NICE
Rangat, IN	6	92.930	12.470	One building suffered a soft story; no other major damage.	NICE
Sigli, ID	6	95.946	5.382	Dome of a mosque collapsed.	AFPN
Takengon, ID	6	96.849	4.618	Buildings damaged.	FGN
Barisal, BD	5	90.317	22.707	Concrete jetty cracked.	INBD, NATB
Bhubaneswar (Banaja), IN	5	85.870	20.260	Cracks in some buildings; people ran outdoors; beds, doors, and windows rattled.	SAMB, TLGH, UNDP
Chennai (Koyambedu), IN	5	80.248	13.069	People frightened and ran outdoors; hairline cracks in walls; stationary automobiles moved slightly.	ASCN
Chittagong, BD	5	86.345	20.844	Cracks in many buildings, including the court, railway building, and divisional public library.	NATB
Cuttack, IN	5	85.876	20.464	Cracks in some buildings; felt more prominently on the upper floors of high-rise buildings.	SAMB
Hat Yai, TH	5	100.466	7.000	Cracks in buildings and a few windows broken; felt strongly in the upper floors of buildings, causing panic.	BKPT
Jajpur, IN	5	86.345	20.844	"Pucca" houses developed cracks; windows and doors rattled; panic.	NWIP
Medan, ID	5	98.655	3.567	Cracks in some buildings; people frightened.	INDY
Vishakhapatnam, IN	5	98.655	3.567	Cracks in buildings; felt by many.	ASCN, HNDU
Yangon, MY	5	98.655	3.567	Cracks in some buildings; heavy tremor; people frightened.	DVBN
Bentota, SL	4	80.000	6.419	Felt outdoors by many, some frightened	ASCN
Bagerhat, BD	4	89.801	22.659	People went outdoors in panic.	INBD
Bandarban, BD	4	92.216	22.202	People went outdoors in panic.	UNB
Bangalore (Kaggadasapura), IN	4	77.667	12.992	Cot shaken; people awoke, were frightened, and ran outdoors; furniture shook.	DECN
Bangalore (Yellahanka), IN	4	77.550	13.042	Felt; gate seen shaking.	UNDP
Biruen, ID	4	96.686	5.211	Strong.	XINH
Chennai (Adyar), IN	4	80.259	13.008	Moderate; felt indoors by all on the ground floor.	ASCN
Chennai (Alwarpet), IN	4	80.245	13.049	Moderate; people woken up; felt indoors.	ASCN
Chennai (Perambur), IN	4	80.249	13.105	Mild; felt by all indoors; hanging objects shook slightly.	ASCN
Chennai (Thiruvannamiyur), IN	4	80.266	12.982	Felt indoors; people woken up; old cracks widened.	ASCN
Chennai (Villivakkam), IN	4	80.210	13.010	Mild shaking; rattling of household objects.	ASCN
Comilla, BD	4	91.178	23.458	People went outdoors in panic.	UNB
Cox's Bazaar, BD	4	91.983	21.437	People went outdoors in panic.	UNB

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Dhaka, BD	4	90.405	23.713	Houses shaken; people woke up.	BBCT
Gobindpur, BD	4	85.333	21.483	Felt by many; people frightened; mines evacuated.	PRBH
Hikkaduwa, SL	4	80.101	6.126	People woke up; tremor lasted two minutes.	YATV
Imphal, IN	4	93.938	24.787	People frightened and ran outdoors.	KGLA
Jatni, IN	4	88.635	23.771	People woken up and ran outdoors.	NWIP
Kandy, SL	4	80.619	7.293	Furniture and instruments at a hospital rattled; tremor lasted 2-4 minutes.	DNLS
Khulna, BD	4	89.541	22.843	People went outdoors in panic.	INBD
Koh Phi Phi, TH	4	98.775	7.739	Badly shaken.	MCOT
Krabi, TH	4	98.909	8.062	Hanging light and furniture shaken.	HELS
Male, MD	4	73.949	4.165	Doors rattled.	TOI
Mayurbhanj, IN	4	86.724	21.935	Rattling mistaken for the movements of a rat.	ASCN
Meherpur, BD	4	88.635	23.771	People went outdoors in panic.	UNB
Narayanganj, BD	4	90.498	23.619	People frightened and rushed outdoors.	NATB
Nellore, IN	4	87.838	24.650	Felt; people ran outdoors.	UNI
Noakhali, IN	4	91.098	22.818	People went outdoors in panic.	UNB
Padang, ID	4	100.327	-0.946	Panic; very strong; Christmas decorations shaken.	CNNL
Pakur, IN	4	87.838	24.650	Mild; water disturbed.	DAJG
Pataukhali, BD	4	90.239	22.365	People went outdoors in panic.	UNB
Phuket, TH	4	89.981	22.576	Buildings, cars, and furniture visibly shaken.	MCOT
Pirojpur, BD	4	89.981	22.576	People went outdoors in panic.	UNB
Rajabaria, BD	4	22.509	90.213	People went outdoors in panic.	UNB
Railey Beach, TH	4	22.509	90.213	Some people woken up; not widely felt.	SURF
Sakhigopal, IN	4	85.823	19.961	Felt for 5 seconds, causing panic.	NWIP
Salepur, IN	4	86.110	20.493	People frightened and left their houses.	NWIP
Satkhira, BD	4	89.076	22.708	People went outdoors in panic.	UNB
Sittwe, MY	4	92.898	20.143	Bells rang of their own accord.	DVBN
Sunabeda, IN	4	82.450	20.510	People woken up; household articles visible shaken.	ASCN
Takau Pa, TH	4	98.343	8.864	Strongly shaken.	MCOT
Tangail, BD	4	89.918	24.247	People went outdoors in panic.	UNB
Tarutung, ID	4	98.960	2.010	Strong but no damage.	INDY
Vijayawada, IN	4	80.063	16.516	Felt indoors by many; utensils fell in some instances.	HNDU
Balasore, IN	3	86.945	21.485	Felt.	NWIP
Bandarawela, SL	3	80.982	6.326	Mild.	HNDU
Bangalore (Coles Park), IN	3	77.588	12.996	Felt.	DECN
Bangalore (D'Costa Square), IN	3	77.588	12.996	Cot shaken in a circular fashion.	DECN
Bangalore (HSR Layout), IN	3	77.627	12.909	Felt.	DECN
Bangalore (Vidhyaranyapura), IN	3	77.549	13.032	Felt.	DECN
Behrampur (Orissa), IN	3	84.817	19.311	Felt.	SAMB
Behrampur (West Bengal), IN	3	88.247	24.090	Mild.	W123
Bhadrak, IN	3	86.524	21.057	Felt.	NWIP
Bheemawaram, IN	3	81.526	16.550	Felt.	NWIP
Birbhum, IN	3	87.583	24.000	Mild.	W123

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Bukit Tinggi, ID	3	100.358	-0.316	Felt.	WHO
Burdhwan, IN	3	87.869	23.235	Mild.	TLGH
Cape Panwa, TH	3	98.408	7.800	Felt.	BBCT
Clementi, SG	3	103.681	1.375	Mild.	CNHL
Chennai (Annanagar), IN	3	80.215	13.071	Mild shaking; felt on ground floor; slight movement of hanging objects.	ASCN
Chennai (Foreshore Estate), IN	3	80.272	13.030	Felt.	ASCN
Dhanbad, IN	3	86.429	23.789	Mild.	HIND
Digha, IN	3	87.548	21.683	Felt.	PTI
Faridpur, BD	3	89.847	23.605	Mild.	NATB
Galle, SL	3	80.218	6.038	Minor tremor; did not wake sleeping persons.	ASCN
Ganjam, IN	3	86.066	19.384	Felt.	TLGH
Gournadi, BD	3	90.225	22.973	Felt.	INBD
Gopalpur, IN	3	84.910	19.271	Felt.	SAMB
Hanguranketha, SL	3	80.778	7.177	Felt.	DNLS
Hoogly, IN	3	88.333	22.580	Mild.	TLGH
Howrah, IN	3	88.398	22.900	Mild.	TLGH
Jagatsinghpur, IN	3	86.188	20.254	Mild.	SAMB
Jeypore, IN	3	82.567	18.854	Mild.	NWIP, SAMB
Jhalakhati, BD	3	90.209	22.642	Felt.	INBD
Kakinada, IN	3	82.242	16.951	Felt.	NWIP
Kalapara, BG	3	90.231	21.981	Mild.	INBD
Kanahura, MD	3	73.321	5.366	Small tremor felt.	BLOG
Kendrapada, IN	3	86.423	20.502	Mild.	SAMB
Khandpara, IN	3	85.171	20.272	Mild.	NWIP
Kochi, IN	3	76.220	10.010	Mild.	HNDR
Koraput, IN	3	82.705	18.812	Mild.	NWIP
Kuala Selangor, ML	3	101.240	3.337	Felt.	BNMA
Langkawi, ML	3	99.735	6.333	Felt.	BNMA
Mahabalipuram, IN	3	80.191	12.620	Felt at Kalpakkam.	RAST
Maldah, IN	3	88.147	25.035	Mild.	W123
Malkangiri, IN	3	81.894	18.365	Mild.	NWIP
Mohipur, BD	3	90.133	21.868	Felt.	INBD
Murshidabad, IN	3	88.255	24.242	Mild.	TLGH
Nadia, IN	3	88.366	23.416	Mild.	W123
Nasarapur, IN	3	81.698	16.445	Felt.	NWIP
Nowrangpur, IN	3	82.544	19.224	Mild.	NWIP
Palakole, ML	3	81.728	16.527	Felt.	NWIP
Pangkor, ML	3	100.564	4.212	Felt.	MSTR
Parapat, ID	3	98.937	2.660	Felt.	WHO
Patharghata, TH	3	89.967	22.033	Felt.	INBD
Patong, TH	3	98.299	7.903	Felt.	BKPT
Pattani, TH	3	101.247	6.865	Felt.	PHKG
Paya Kunbah, ID	3	100.641	-0.228	Felt.	WHO

**TABLE 1 (Continued)**  
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Phang Nga, TH	3	98.527	8.457	Felt.	PHKG
Pondicherry, IN	3	79.825	11.935	Mild.	HNDU
Puri, IN	3	85.822	19.809	Felt.	NWIP
Rajamundhry, IN	3	81.785	17.012	Felt.	NWIP
Raurkela, IN	3	84.810	22.232	Mild	SAMB
Rayagada, IN	3	83.410	19.162	Mild	NWIP, SAMB
Rusera, IN	3	83.410	19.162	Felt.	DAJG
Shah Alam, ML	3	101.561	3.700	Felt.	MSTR
Siglap, SG	3	103.934	1.319	Mild.	CHNL
Srikakulam, IN	3	83.897	18.291	Low-intensity tremor felt for 8 seconds.	UNI
Surin Beach, TH	3	98.277	7.965	Felt chair shaking; later recognized it as an earth-quake.	CNN
Talcher, IN	3	85.229	20.948	Mild.	SAMB
Tirupati, IN	3	79.409	13.628	Felt.	AFPN
Toy Payoh, SG	3	103.848	1.366	Mild.	CNHL
Trang, TH	3	99.603	7.552	Felt.	PHKG
Trincomalee, SL	3	81.235	8.570	Minor tremor felt for 2 minutes.	BNMA
Tuticorin, IN	3	78.149	8.798	Felt.	ASCN
Vizianagaram, IN	3	83.406	18.110	Low-intensity tremor felt for 8 seconds.	UNI
Walapane, SL	3	80.833	7.116	Felt.	DNLS
Wattegama, SL	3	80.687	7.349	Felt.	DNLS
Ahmedabad, IN	2	72.593	23.033	Felt on the 10th floor of a 10-story building; slight vibrations and ceiling fans shook.	SEFI
Alor Setar, ML	2	100.362	6.121	Felt in high-rise buildings.	BNMA
Ang Mo Kio, SG	2	103.844	1.366	Felt in high-rise apartment buildings.	HDBS
Bangkok, TH	2	100.513	13.757	Felt strongly in high-rise buildings.	MSTR
Bhubaneswar (Chandrasekhar-pur), IN	2	85.840	20.300	Felt in high-rise buildings	UNDP
Bhubaneswar (I.C.R. Village), IN	2	85.830	20.280	Not felt at ground level but felt in apartment build-ings.	UNDP
Bhubaneswar (Jharpada), IN	2	85.850	20.250	Felt on the 2nd floor of a building, where a person was woken up.	UNDP
Bogra, IN	2	89.366	24.850	Very mild.	NATB
Chiang Mai, TH	2	99.010	18.787	Felt in high-rise buildings	MCOT
Choa Chu Kang, SG	2	103.681	1.375	Felt in high-rise apartment buildings.	HDBS
Dinajpur, BD	2	88.646	25.623	Very mild.	NATB
Gaibandha, BD	2	89.545	25.332	Very mild.	NATB
Johor Baharu, ML	2	103.757	1.147	Felt in high-rise apartment buildings; people felt dizzy; water in an aquarium seen oscillating.	BNMA
Jurong, SG	2	103.715	1.329	Felt in high-rise apartment buildings.	HDBS
Kota Baharu, ML	2	102.238	6.118	Felt in high-rise buildings; hospitals evacuated.	MSTR
Kuala Lumpur, ML	2	101.712	3.131	Felt in high-rise buildings.	MSTR
Kuala Terengganu, ML	2	103.140	5.317	Felt in high-rise buildings; hospitals evacuated.	MSTR
Kuriigram, BD	2	89.693	25.824	Very mild.	NATB
Lalmunirhat, BD	2	89.445	25.912	Very mild.	NATB

**TABLE 1 (Continued)**  
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Location*	Intensity	Latitude (°)	Longitude (°)	Report	Sources**
Mumbai (Worli), IN	2	72.830	19.010	Felt on the 5th floor of a 7-story building in the Century Bazaar area; weak shaking; slight shaking of hanging objects.	ASCN
Nilphamari, BD	2	88.846	25.938	Very mild.	NATB
Penang, ML	2	100.461	5.046	Felt strongly in high-rise buildings; some people woken up; many buildings evacuated.	MSTR
Port Klang, ML	2	101.450	3.040	Felt strongly in high-rise buildings; buildings evacuated.	MSTR
Putrajaya, ML	2	101.633	3.030	Felt in high-rise apartments.	MSTR
Rangpur, BD	2	89.252	25.740	Very mild.	NATB
Serangoon, SG	2	103.895	1.376	Felt in high-rise buildings.	HDBS
Surat Thani, TH	2	99.327	9.138	Felt in high-rise buildings; hospitals evacuated.	BKPT
Delhi, IN	1	77.226	28.660	Not felt.	UNDP
Jakarta, ID	1	106.839	-6.183	Not felt.	BBCT
Jamnagar, IN	1	70.065	22.467	Not felt.	ASCN
Hanoi, VT	1	105.836	21.026	Not felt.	BLOG
Hyderabad, IN	1	78.520	17.420	Not felt.	ASCN
Koh Samui, TH	1	99.935	9.537	Not felt.	FARA
Kolkata (Behala), IN	1	88.328	22.500	Not felt.	UNDP
Kolkata (Entali-Taltala), IN	1	88.366	22.547	Not felt.	UNDP
Kuala Belait, BR	1	114.183	4.595	Not felt.	BBCT
Mangalore, IN	1	74.802	12.870	Not felt.	ASCN
Mumbai (Borivali), IN	1	72.840	19.230	Not felt.	ASCN
Mumbai (Charni Road), IN	1	72.820	18.940	Not felt.	ASCN
Mumbai (Dahisar), IN	1	72.830	19.260	Not felt.	ASCN
Mumbai (Malad), IN	1	72.830	19.180	Not felt.	ASCN
Mysore, IN	1	76.648	12.311	Not felt.	ASCN
Pune (Camp), IN	1	73.580	18.520	Not felt.	ASCN
Rajganj, IN	1	86.250	23.840	Not felt.	ASCN
Saibi, ID	1	98.831	-1.399	Not felt.	SIEH
Shillong, IN	1	91.872	25.567	Not felt.	SLTI
Siamreab, CB	1	103.858	13.371	Not felt.	BLOG

\* Countries: BG: Bangladesh; BR: Brunei; CB: Cambodia; MD: Maldives; ML: Malaysia; MY: Myanmar; ID: Indonesia; IN: India; SG: Singapore; SL: Sri Lanka; TH: Thailand; VT: Vietnam.

\*\* Sources: AFPN: Agence France Presse; AKIT: Aceh Crisis Centre (<http://pusatkrisisaceh.or.id/>); ANN: <http://www.andaman.org/>, India; AP: Associated Press; ASCN: ASC felt report; BBCT: BBC Talking Point and BBC World; BILH: Roger Bilham; BKPT: *Bangkok Post*, Thailand; BNMA: Bernama, Malaysia; CHNL: Channel News Asia, Singapore; CNN: <http://www.cnn.com/> Your E-mails; DAJG: Dainik Jagran, India; DECN: *Deccan Herald*, India; DNLS: *Daily News* (Lakehouse group), Sri Lanka; DVBN: Democratic Voice of Burma; FARA: <http://faraway.co.th/>; GFN: Fair Grounds Newsletter, <http://www.cafecampesin.com/>; GSIP: preliminary reports by Geological Survey of India; HDBS: Housing and Development Board, Singapore; HELS: Helsingin Sanomat, Finland; HNDU: *The Hindu*, India; INBD: *The Independent*, Bangladesh; JBQR: preliminary reports by José Borrero; JKPT: *The Jakarta Post*, Indonesia; KGLA: <http://www.kanglaonline.com/>, India; LAT: *Los Angeles Times*, U.S.; MCOT: MCOT-TNA, Thailand; MDDY: *Midday*, India; MSTR: *The Star*, Malaysia; NATB: *The Nation*, Bangladesh; NICEE: preliminary reports by NICEE group; NWIP: <http://newindpress.com/>, India; OUTL: *Outlook*, India; PHKG: *The Phuket Gazette*, Thailand; PRBH: Prabhat, India; PTI: Press Trust of India; RAST: preliminary reports by B. K. Rastogi; REEF: Sarang, <http://www.reefwatchindia.org/>; SAMB: Sambaad, India; SEFI: Structural Engineers Forum, India; SIEH: Web logs of Kerry Sieh; SLTI: *Shillong Times*, India; SUAD: <http://www.surfaidinternational.org/>; SURF: <http://www.surferweb.com/>; TELK: *The Telegraph*, U.K.; TLGH: *The Telegraph*, India; TOI: *The Times of India*; UNB: United National Press of Bangladesh; UNDP: United Nations India personnel; UNI: United National Press of India; VKGT: V. Gahalaut; W123: <http://www.123webindia.com/>, India; WHO: World Health Organization (Situation reports: Indonesia); XINH: Xinhua News Agency; YATV: Young Asia TV, Sri Lanka.



## SHAKING EFFECTS OF THE EARTHQUAKE

The earthquake ruptured from the epicenter at  $3.3^{\circ}\text{N}$  to  $12.5\pm 2^{\circ}\text{N}$  (Lomax, 2005). Consistent with northward directivity is the observation that intensities diminished rapidly to the south of the epicenter—the earthquake was not felt in Jakarta, for example. Nearest the epicenter, on the island of Simuelue, people were “thrown to the ground” by the main-shock, indicating an EMS intensity of 9. Six accounts from coastal communities in Aceh suggest EMS intensities of 7 or 8 (Grade 5 damage to some buildings and difficult for people to remain standing). Landslides on steep slopes and large ground cracks were observed on Simuelue Island.

On the western coast of Sumatra, most villages and towns were decimated by the tsunami that followed the earthquake, making it difficult to assign intensities there. The few available accounts suggest EMS intensity 7 or 8, but other indications of these levels of shaking, such as the movement of heavy objects and the destruction of buildings, are unavailable. Aerial photographs of Meulaboh do not indicate very damaging levels of ground motion, as many modern buildings are visibly intact. There, the quake was strong enough to nauseate some people and cause widespread panic. Farther north in Banda Aceh, distinguishing between the damage caused by the earthquake and the tsunami would have been difficult if not for video footage shot before the arrival of the tsunami. Many buildings survived the earthquake reasonably well. Several inland high-rise buildings did suffer partial or total failure due to ground shaking. Traditional buildings and smaller newer buildings were either undamaged or developed minor cracks, while the collapse of high-rise buildings at this location has been attributed to poor structural design (Sandeep Parkhi, personal communication, 2005). The NEIC intensity map indicates MM IX at both Meulaboh and Banda Aceh ([http://pasadena.wr.usgs.gov/shake/ous/STORE/Xslav\\_04/ciim\\_display.html](http://pasadena.wr.usgs.gov/shake/ous/STORE/Xslav_04/ciim_display.html)), a value quite possibly biased by accounts of isolated, especially severe damage (David Wald, personal communication, 2005).

In the Andaman and Nicobar Islands, the shaking began as a moderate tremor that grew gradually in strength to the point that people found it hard to stand outdoors. A few newer constructions collapsed in Port Blair ( $11.5^{\circ}\text{N}$ ) and on Car Nicobar Island ( $8.5^{\circ}\text{N}$ ). Damage to many structures throughout the islands was restricted to minor cracks. Liquefaction was reported from the Andaman Islands (Vineet Gahalaut, personal communication, 2005), and on Car Nicobar people saw jets of water spurting out from newly formed cracks.

In the Indian subcontinent, the shock was felt most conspicuously in coastal Quaternary sediments along the east coast of India, in deltas such as those of the Ganga, Mahanadi, and Krishna Rivers, as well as in alluvial filled basins and valleys such as at Imphal in the Manipur Valley. It was especially pronounced in southern Bangladesh and at the mouth of the Ganges Delta.

The earthquake was not felt in the Cauvery Delta in Tamil Nadu, where shaking amplification from distant earthquakes has been inferred to have occurred historically (Oldham, 1926; Hough *et al.*, 2002). Away from the east coast, the quake was felt at Bangalore and Kochi in southern India and to the north as far as Rusera in Bihar. No felt reports came from cities and towns in areas underlain by the Deccan Traps in western and central India, with the exception of observers on the upper floors of apartment buildings in Ahmedabad and Mumbai, where distant earthquakes have been felt in the past (Oldham, 1899; Hough *et al.*, 2002).

Damage was sustained by a few southern Myanmar towns, and mud volcanoes erupted off the Arakan coast. To the east of the rupture, tremors were mainly felt in high-rise buildings in Malaysia, Singapore, and Thailand. On Phuket Island, some 600 km from the rupture, the quake was not felt outdoors, though it was strong enough to wake a few sleeping people and shake parked cars. Seiches in reservoirs and ponds were reported from many locales in eastern and northeastern India, Nepal, and Bangladesh. Remote aquifer response (changes in water color, taste, etc.) was reported from the districts of Chandauli, Mirzapur, and Sonebhadra in southeastern Uttar Pradesh and also from Bhopal in Madhya Pradesh.

Three  $M_w$  6 aftershocks were felt in Chennai. No reports came from any other areas along the Coromandel Coast or from Sri Lanka for these aftershocks. Based on the descriptions of the felt accounts and on the basis of the timing of the reports (Mark Leonard, personal communication, 2005), local amplification of  $T$  phases can be ruled out. A  $M_w$  6.1 aftershock centered near Little Andaman Island on 4 January 2005 at 09:13 UTC (14:43 IST) was felt by people in tall buildings in Nandanam in Chennai. An observer on the eighth floor of the Khivraj Complex felt mild vibrations and dizziness. Another building in the same area is also alleged to have developed a prominent crack following the quake. The  $M_w$  6.3 aftershock on 24 January 2005 at 04:16 UTC (09:46 IST), centered near Katchal Island, was felt in North Chennai at Choolaimedu and Nandanam. This quake was also felt at Campbell Bay on Great Nicobar (Vineet Gahalaut, personal communication, 2005). Mild tremors were also reported in high-rise buildings in Chennai following a  $M_w$  6.6 aftershock on 1 January 2005 at 06:25 UTC (11:55 IST) centered to the southwest of Great Nicobar Island. This is believed to be the first time that  $M_w$  6 earthquakes have been felt in Chennai at a distance of 1,800 km.

## DISCUSSION AND CONCLUSIONS

No strong-motion instruments were available for the earthquake, and hence the felt reports listed in this study are of particular importance for characterizing shaking intensity and understanding regional wave propagation. A future earthquake of this magnitude in the Andaman and Nicobar Archipelago may not occur for many centuries, so these data assume importance for future generations. The absence of extensive land area in the near field, and the length of the rup-

ture, makes the estimation of attenuation particularly difficult.

One surprise given a rupture length of more than 1,200 km is that fewer than 20 reports of intensity greater than 7 are available for the earthquake. These are all from the epicenter, or from islands following the rupture and within the area of aftershocks. Almost certainly the number of felt reports will increase as additional field studies are published, although much evidence for structural damage to coastal facilities was lost in the ensuing tsunami. Another surprise is the similarity in the intensities recorded from the east coast of India (1,200 km) and from the Malay Peninsula (800 km), despite the latter being located 50% closer to the closest points on the rupture zone. This presumably represents the effects of rupture directivity, but the absence of intervening land area will make this difficult to examine further. ☒

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