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SIGNIFICANT EARTHQUAKES OF THE WORLD

1991

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SIGNIFICANT EARTHQUAKES OF THE WORLD

1991

INTRODUCTION

This publication is a final listing of all the significant earthquakes for 1991. Significant earthquakes are defined for this publication as those of magnitude 6.5 or greater or ones that caused fatalities, injuries or substantial damage. The locations, comments and other data were taken from the Preliminary Determination of Epicenters Monthly Listing, U.S. Geological Survey. This listing of significant earthquakes was compiled to provide an accurate and readily available summary of the world's most important earthquakes for a given period of time.

DATE	ORIGIN TIME UTC HR MN SEC	GEOGRAPHIC COORDINATES LAT	LONG	DEPTH	MAGNITUDES GS MB	Msz	SD	NO STA USED	REGION, CONTRIBUTED MAGNITUDES AND COMMENTS
1991									
JAN 01	00 06 31.4	18.068 N	105.847 W	35	5.5	6.2	1.2	145	OFF COAST OF JALISCO, MEXICO. Ms 6.6 (BRK). Mo=2.8*10**18 Nm (HRV). Mo=6.0*10**18 Nm (PPT).
JAN 05	14 57 11.5	23.613 N	95.901 E	20 D	6.2	7.1	1.3	400	BURMA. Ms 7.3 (BRK), 7.0 (PAS). Mo=2.4*10**19 Nm (GS). Mo=3.1*10**19 Nm (HRV). Mo=4.0*10**19 Nm (PPT). Thirty-two buildings and 380 hectares of farmland damaged in the Thabeikkyin area. Some landslides reported. Felt strongly at Mandalay. Felt in much of northwestern Burma from Hkamti to Sittwe. Also felt in the Silchar area, India and in Thailand from Chiang Mai to Bangkok.
JAN 31	23 03 33.6	35.993 N	70.423 E	142 G	6.4		1.2	530	HINDU KUSH REGION. mb 6.6 (BRK). Mo=1.4*10**19 Nm (GS). Mo=2.2*10**19 Nm (HRV). Mo=1.6*10**19 Nm (PPT). Estimated 200-400 people killed, many injured and many homes destroyed or damaged in Konar, Nangarhar and Badakhshan Provinces, Afghanistan. At least 300 people killed, hundreds injured and several thousand houses damaged in the Malakand-Chitral-Peshawar area, Pakistan. Three people died of heart attacks, severe damage (VII) and landslides occurred in the Khorog area, USSR. Felt (VI) at Ishkashim, Parkhar, Dushanbe, Garm, Dzhirgatal, Lyangar and Gissar; (V) at Shoortuz, Sherkent, Gezan, Leninabad, Tashkent and Namangan; (IV) at Chimkent; (III) at Dzhambul and Frunze, USSR. Felt throughout northeastern Afghanistan, northern Pakistan and northern India as far away as Delhi. Also felt throughout Tajikistan and eastern Uzbekistan, USSR.
FEB 09	16 18 58.3	9.929 S	159.139 E	10 G	6.4	6.9	1.1	334	SOLOMON ISLANDS. Ms 6.8 (BRK), 6.7 (PAS). Mo=2.8*10**19 Nm (HRV). Mo=2.0*10**19 Nm (PPT). Complex event. Minor damage at Honiara. Felt strongly on Guadalcanal. Felt in the Florida Islands, on Malaita and in western San Cristobal. A small tsunami was generated with maximum wave height 4 cm (peak-to-trough) at Honiara.
FEB 12	09 54 58.3	40.816 N	28.878 E	10 G	4.8	4.6	1.3	183	TURKEY. ML 5.0 (ATH). MD 4.7 (THE), 4.5 (ISK). A few people injured slightly and minor damage in the Istanbul area. Felt at Balikesir, Burso and Kutahya.
FEB 13	15 49 38.9	44.885 N	6.760 E	5 G			0.9	107	FRANCE. ML 3.8 (LDG), 3.7 (GEN). MD 3.6 (STR). Nine people killed by an avalanche which was triggered by the earthquake.
FEB 18	02 37 25.1	8.870 N	126.480 E	24 G	6.0	6.6	1.3	319	MINDANAO, PHILIPPINE ISLANDS. Ms 6.6 (BRK), 6.1 (PAS). Mo=3.8*10**19 Nm (GS). Mo=1.6*10**19 Nm (GS). Mo=2.0*10**19 Nm (PPT). Felt (III RF) at Cagayan de Oro, Bislig and on Mactan and (I RF) at Cotabato.
FEB 21	02 35 34.0	58.427 N	175.450 W	20 G	6.2	6.5	1.0	472	BERING SEA. Ms 6.7 (BRK), 6.4 (PAS). Mo=7.2*10**18 Nm (GS). Mo=1.1*10**19 Nm (HRV). Mo=3.0*10**19 Nm (PPT). Two events about 3.7 seconds apart. Depth based on the first event. Believed to be the largest earthquake ever located in this area. Felt (IV) on St. Paul in the Pribilof Islands, Alaska. Felt (III) on Adak in the Andreanof Islands, Alaska. A small tsunami was generated with maximum wave heights (peak-to-trough) of 30 cm. at Dutch Harbor and 22 cm at Adak.
FEB 25	14 30 27.6	40.386 N	78.959 E	21 D	5.5	6.1	1.0	289	SOUTHERN XINJIANG, CHINA. Mo=1.3*10**18 Nm (HRV). Three people were injured and at least 120 houses collapsed and 8,441 houses damaged in the Kalpin area. Ground cracks and earthquake lights were reported in the epicentral area. Felt at Akqi, Aksu, Bachu and Wasi.
MAR 08	11 36 28.4	60.904 N	167.023 E	13 G	6.4	6.6	1.3	492	EASTERN SIBERIA. Ms 6.6 (BRK), 6.4 (PAS). Mo=7.9*10**18 Nm (GS). Mo=1.0*10**19 Nm (HRV). Mo=3.0*10**19 Nm (PPT). Believed to be the largest earthquake ever located in this area.
MAR 25	18 02 41.5	39.887 N	113.923 E	10 G	5.1	5.5	1.2	108	NORTHEASTERN CHINA. ML 5.5 (BJI). Mo=1.6*10**17 Nm (HRV). One hundred thirty-one people injured and 1,328 houses damaged in the Datong area.
APR 04	15 23 20.7	6.038 S	77.130 W	21 G	6.0	6.3	1.0	356	NORTHERN PERU. Ms 6.4 (BRK), 5.9 (PAS). Mo=5.5*10**18 Nm (GS). Mo=4.5*10**18 Nm (HRV). Mo=5.0*10**18 (PPT). At least 10 people injured and 15 houses damaged (V) in the Rioja-Nueva Cajamarca area. Felt (V) at Moyabamba and Tarapoto, (IV) at Chachapoyas and (III) at Chiclayo, Trujillo and Piura. Also felt (III) in El Oro Province and (II) at Guayaquil and Quito, Ecuador.

DATE	ORIGIN TIME UTC HR MN SEC	GEOGRAPHIC COORDINATES LAT	LONG	DEPTH	MAGNITUDES GS MB	Msz	SD	NO. STA USED	REGION, CONTRIBUTED MAGNITUDES AND COMMENTS
1991									
APR 05	04 19 49.5	5.982 S	77.094 W	20 G	6.5	6.8	1.0	534	NORTHERN PERU. Ms 6.7 (BRK), 6.4 (PAS). Mo=2.8*10**19 Nm (GS). Mo=5.1*10**19 Nm (HRV). Mo=5.0*10**19 Nm (PPT). Two events about 6 seconds apart. Depth based on second event. Fifty-three people killed, 252 injured and extensive damage (VII) to 8,063 homes in the Rioja-Moyobamba-Nueva Cajamarca area. Felt (VI) at Tarapoto, (V) at Chiclayo, (IV) at Trujillo and (II) at Lima. Felt throughout northern Peru. Felt (IV) at Guayaquil and (III) at Quito, Ecuador. Felt strongly in much of southern Ecuador.
APR 06	14 34 20.7	15.008 S	175.521 W	16 D	5.8	6.7	1.1	233	TONGA ISLANDS. Ms 6.4 (BRK), 6.1 (PAS). Mo=1.1*10**19 Nm (GS). Mo=1.1*10**19 Nm (HRV). Mo=3.0*10**19 Nm (PPT).
APR 18	09 18 30.4	37.457 N	68.273 E	33 N	5.4	5.1	1.0	193	AFGHANISTAN-USSR BORDER REGION. Mo=2.0*10**17 Nm (HRV). Several people killed and many injured in Badakhshan Province, Afghaniston. One person killed, 6 injured and about 1,000 buildings damaged (VII) in the Kabodiyen district, USSR. Landslides occurred in the Bogi-Dzhud area. Felt (VI) at Shaartuz, (IV) at Kolkhozabad and Leninskiy and (III) at Dushanbe, USSR.
APR 22	21 56 51.8	9.685 N	83.073 W	10 G	6.3	7.6	1.2	432	COSTA RICA. Ms 7.4 (BRK), 6.9 (PAS). Mo=1.1*10**20 Nm (GS). Mo=3.3*10**20 Nm (HRV). Mo=4.0*10**20 Nm (PPT). Forty-seven people killed, 109 injured, 7,439 homeless and severe damage (IX) in the Limon-Pandora area. Intensity X was observed in some zones of liquefaction within the epicentral area. Some damage (VI) also occurred in the San Jose-Alajuela area and landslides blocked roads between Limon and central Costa Rica. Twenty-eight people killed, 454 injured, 2,400 homeless and 866 buildings destroyed (VII-VIII) in the Guabito-Almirante-Bocas del Toro area, Panama. Slight damage (VI) also occurred at David and Puerto Armuelles, Panama. Felt (IV) at Colon and (III) at Panama City. Felt (III) in eastern El Salvador and (II) at San Salvador. Also felt in Nicaragua and Honduras and on San Andres Island, Colombia. Maximum uplift of 1.4 meters was observed near Limon and sandblows and liquefaction caused subsidence of soils in the Bocas del Toro area. Ground cracks also occurred in the epicentral area. A 2-meter tsunami with maximum runup of 300 meters was observed in the Cahuita-Puerto Viejo area, Costa Rica. Tsunamis were also reported on Bastimentos, Carenero and Colon Islands and at Portobelo, Panama. The maximum amplitude of the tsunami in Panama was about 0.6 m. A 7-cm tsunami (peak-to-trough) was recorded on the tide guage at Cristobal, Panama. Damage in Costa Rica estimated to be about 43 million U.S. dollars.
APR 24	10 54 35.7	39 597 N	41.118 E	33 N	4.5		0.8	48	TURKEY. One person killed, 3 injured and some houses damaged in Erzurum Province.
APR 29	09 12 48.1	42.453 N	43.673 E	17 G	6.2	7.0	1.2	500	WESTERN CAUCASUS. Ms 7.3 (BRK), 6.9 (PAS). Mo=3.3*10**19 Nm (HRV). Mo=8.0*10**19 Nm (PPT). Two events about three seconds apart. Depth based on second event. At least 114 people killed, about 1,000 injured, 70 missing, 67,000 homeless and severe damage (VIII) and landslides in the Dzhava-Chiatura-Ambrolauri area, USSR with 95 percent of buildings destroyed in the area. Felt (VI) in the Kutaisi area; (V) at Leninakan and Tbilisi; (IV) at Kirovakan and Spitak. Felt throughout the western Caucasus and Trans-Caucasus from Sukhumi to Groznyy and Yerevan, USSR. Landslides created a natural dam on the Patas River. This was breached several days later, causing additional damage in the Dzhava-Tskhinvali area. Also felt in Ardahan, Artvin, Kars and Rize Provinces, Turkey.
MAY 03	20 19 38.8	42.683 N	43.247 E	10 G	5.3	5.2	1.2	272	WESTERN CAUCASUS. Mo=3.1*10**17 Nm (HRV). At least 3 people killed by landslides in Georgia, USSR.
MAY 04	03 42 54.5	9.542 N	82.418 W	10 G	5.6	6.2	1.3	256	PANAMA-COSTA RICA BORDER REGION. Ms 6.2 (BRK). Mo=2.1*10**18 Nm (HRV). Mo=3.0*10**18 Nm (PPT). Thirty-six people injured, 400 families homeless, ground cracks and liquefaction in the Changuinola-Almironte-Bocas del Toro area, Panama. Felt strongly at Limon, Costa Rica. Felt from the Central Valley of Costa Rica as far east as Santiago, Panama.
MAY 19	00 58 01.7	1.156 N	122.957 E	33 N	6.0	6.8	1.2	228	MINAHASSA PENINSULA. Ms 6.9 (BRK). Mo=3.2*10**19 Nm (GS). Mo=2.5*10**19 Nm (HRV). Mo=3.0*10**19 Nm (PPT). Felt (III) in the Manado area. Two events about 4.5 seconds apart.
MAY 26	10 59 48.9	5.865 N	116.746 E	33 N	5.1	4.5	1.1	88	KALIMANTAN. One person died from shock and there was slight damage at Ranau, Malaysia. Felt at Melapap, Kota Kinabulu, Papar and along parts of the west coast of Sabah, Malaysia.
MAY 26	12 26 00.2	40.730 N	15.765 E	8	5.1	4.8	1.1	207	SOUTHERN ITALY. ML 5.2 (ZAG), 5.0 (TTG). A few people injured and minor damage in the Potenza area. Felt in the Avellino-Matera-Naples area. Also felt at Salerno and Bari.
MAY 27	18 40 27.9	9.482 N	82.694 W	10 G	5.0	5.0	1.1	53	PANAMA-COSTA RICA BORDER REGION. MD 5.1 (SJR). Mo=3.8*10**17 Nm (HRV). Several people injured slightly and damage (IV) at Changuinola, Panama. Felt (IV) on Bocas del Toro and Carenero Islands and (III) at Volcan and David, Panama. Also felt in Costa Rica.
MAY 30	13 17 41.9	54.567 N	161.606 W	28 G	6.3	6.7	1.1	584	ALASKA PENINSULA. Ms 6.8 (BRK). Mo=1.9*10**19 Nm (GS). Mo=3.1*10**19 Nm (HRV). Mo=1.8*10**19 Nm (PPT). Felt (V) at Cold Bay, King Cove and Sand Point; (IV) at False Pass and Perryville; (III) at Chignik Lagoon.

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1991									
JUN 10	17 35 49.4	23.771 N	45.368 W	10 G	6.1	6.5	0.8	557	NORTH ATLANTIC RIDGE. Ms 6.8 (BRK). Mo=5.3*10**18 Nm (GS). Mo=3.3*10**18 Nm (HRV). Mo=6.0*10**18 Nm (PPT).
JUN 15	00 59 20.3	42.461 N	44.009 E	9 G	6.1	6.1	1.2	458	WESTERN CAUCASUS. Ms 6.5 (BRK). Mo=1.5*10**18 Nm (GS). Mo=2.9*10**18 Nm (HRV). Mo=4.0*10**18 (PPT). Two events about 2 seconds apart. Depth based on second event. At least 8 people killed, 200 injured and extensive damage (VIII) in the Dzhavo-Tskhinvali area, USSR. Felt (VI) at Kutaisi, Sukhumi and Tbilisi and (V) in northwestern Azerbaijan. Landslides occurred at Khieti.
JUN 15	01 13 21.4	58.285 S	24.183 W	52 D	5.8	6.5	1.2	190	SOUTH SANDWICH ISLANDS REGION. Ms 6.3 (BRK). Mo=2.7*10**18 Nm (GS). Mo=7.7*10**18 Nm (HRV). Mo=5.0*10**18 Nm (PPT).
JUN 15	11 15 28.0	15.119 N	120.355 E	10 G	5.7	5.5	1.0	213	LUZON, PHILIPPINE ISLANDS. Mo=2.8*10**17 Nm (HRV). Felt at Manila. This is the largest of a series of earthquakes associated with the eruption of Pinatubo Volcano. At least 137 people were killed and extensive damage was caused in Zambales Province by the eruptions.
JUN 20	05 18 52.5	1.196 N	122.787 E	31 G	6.2	7.0	1.2	367	MINAHASSA PENINSULA. Ms 7.2 (BRK). Mo=1.6*10**20 Nm (GS). Mo=2.3*10**20 Nm (HRV). At least 1,500 houses were damaged (VI) in the Gorontalo area. Felt (IV) in the Manado area and (II) at Poso.
JUN 21	06 27 39.9	13.399 N	89.618 W	77	5.3		1.1	249	EL SALVADOR. Mo=6.3*10**17 Nm (HRV). Mo=1.0*10**18 Nm (PPT). One person killed and three injured when a short circuit caused a fire in a home in the San Salvador area. Felt (IV) at San Salvador. Felt lightly in Guatemala City, Guatemala.
JUN 28	14 43 54.5&	34.262 N	118.002 W	11	5.8	5.1		297	SOUTHERN CALIFORNIA. <PAS-P>. ML 5.4 (PAS), 5.7 (BRK). Mo=3.5*10**17 Nm (HRV). Mo=3.0*10**17 Nm (PPT). One person killed at Arcadia and one person died from a heart attack at Glendale. At least 100 people were injured although most involved only minor cuts and bruises. Damage in the Arcadia, Monrovia, Pasadena, San Marino and Sierra Madre areas estimated at 33.5 million dollars. Maximum intensity VII at Arcadia, Monrovia, Pasadena and Sierra Madre. Some rockslides occurred on mountain roads. Felt strongly throughout much of southern California from Santa Barbara to San Diego and east as far as the Palm Springs-Indio area.
JUL 04	11 43 10.4	8.099 S	124.681 E	29	6.2	6.5	1.1	328	TIMOR. Mo=2.3*10**19 Nm (GS). Mo=1.5*10**19 Nm (HRV). Mo=2.0*10**19 Nm (PPT). Two events about 2.5 seconds apart. Twenty-three people killed, 181 injured, at least 5,400 left homeless and about 1,150 buildings destroyed at Kalabahi, Alor. Estimated 7.7 million U.S. dollars damage occurred in the epicentral area. Felt at Dili.
JUL 06	12 19 49.5	13.108 S	72.187 W	105 G	6.2		1.2	449	PERU. mb 6.5 (BRK). Mo=3.1*10*19 Nm (GS). Mo=1.8*10**19 Nm (HRV). Mo=1.3*10**19 Nm (PPT). Two events about 4 seconds apart. Some damage (VI) at Cuzco. Felt (V) at Abancay. Also felt at Lima and Ica. Felt (II) at La Paz, Bolivia.
JUL 12	10 42 21.2	45.364 N	21.057 E	11 D	5.3	5.7	1.3	298	ROMANIA. MD 5.3 (TTG), 5.3 (TRI). ML 5.2 (BRA), 5.0 (KRA). Mo=2.5*10**17 Nm (HRV). At least 2 people killed, 30 injured and some buildings damaged (VIII) in the Banloc-Deta-Timisoara area. Slight damage at Belgrade, Yugoslavia. Felt in Subotica-Nis area, Yugoslavia. Also felt at Sofia, Bulgaria and Szeged, Hungary.
JUL 13	02 50 14.6	42.182 N	125.641 W	11 G	6.2	6.9	1.0	535	OFF COAST OF OREGON. ML 6.7 (BRK). Mo=1.9*10**19 Nm (GS). Mo=2.1*10**19 Nm (HRV). Mo=3.0*10**19 Nm (PPT). Felt (V) at Coquille, Harbor and Reedsport, Oregan. Felt (IV) at Bandon, Coos Bay, Langlois, Ophir, Port Orford and Wedderburn, Oregon. Also felt (IV) at Crescent City and Klamath, California. Felt throughout much of western Oregon and northern California.
JUL 18	11 56 30.6	44.888 N	22.407 E	12 G	5.7	5.5	1.2	436	ROMANIA. Ms 5.6 (BRK). ML 5.5 (TTG). Mo=1.3*10**17 Nm (GS). Mo=2.9*10**17 Nm (HRV). At least 615 houses damaged (VIII) in the Orsova area. Landslides occurred in the epicentral area. Felt strongly in western Romania and (IV) in northwestern Bulgaria. Also felt in southeastern Hungary and in parts of Yugoslavia.
JUL 23	19 44 50.2	15.679 S	71.574 W	5 G	5.0	4.7	1.3	51	SOUTHERN PERU. Mo=9.1*10**16 Nm (HRV). At least 12 people killed, 30 injured and about 80 missing in the Moco-Chivay area. Felt (V) at Maca, Yanque, Ichupampa and Achoma. Felt (II) at Arequipa. Landslides occurred in the epicentral area.

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1991									
JUL 24	09 45 41.8	36 520 N	44.066 E	26 D	5.4	5.1	1.1	273	IRAN-IRAQ BORDER REGION. Mo=2.2*10**17 Nm (HRV). At least 20 people killed, many injured; at least 100 houses destroyed and many damaged in the Arbil-Dibs area, Iraq. Felt at Mahabad and Piranshahr, Iran.
AUG 14	19 15 03.6	13.593 S	167.607 E	14 G	6.1	6.6	1.3	355	VANUATU ISLANDS. Mo=6.6*10**18 Nm (HRV). Mo=2.0*10*d19 Nm (PPT).
AUG 17	19 29 40.0&	40.235 N	124.348 W	12	6.0	6.2		507	NEAR COAST OF NORTHERN CALIF. <BRK>. ML 6.0 (BRK). Mo=3.3*10**18 Nm (GS). Mo=1.9*10**18 Nm (HRV). Mo=3.0*10**18 Nm (PPT). Damage (VII) at Haneydew and Whitethorn. Slight damage (VI) at Garberville, Myers Flat and Piercy. Also slight damage and landslides in the Petrolia area. Felt (V) at Alderpoint, Carlotta, Cavelo, Fields Landing, Finley, Fortuna, Fort Bragg, Leggett, Loleta, Manchester, Phillipsville, Redcrest, Redway, Rio Dell, Salyer, Weott, Westport, Willits and Zenia. Felt from Grants Pass, Oregon south as far as Sacramento and San Francisco.
AUG 17	22 17 14.6	41.821 N	125.397 W	14 G	6.2	7.1	1.2	431	OFF COAST OF NORTHERN CALIFORNIA. ML 6.8 (BRK). Mo=2.3*10**19 Nm (GS). Mo=4.4*10**19 Nm (HRV). Mo=6.0*10**19 Nm (PPT). Felt (V) at Klamath, Phillipsville, Rio Dell and Trinidad; (IV) at Bridgeville, Fortuna, Myers Flat and Whitethorn. Also felt (V) at Lakeside, North Bend and Pistol River, Oregon; (IV) at Coos Bay, Coquille, Murphy, Reedsport, Rogue River, Roseburg, Sixes and Scottburg, Oregon. Felt as far as Sacramento, California and Eugene, Oregon.
SEP 18	09 48 13.1	14.646 N	90.986 W	5 G	5.7	6.1	1.3	271	GUATEMALA. Ms 6.2 (BRK). Mo=2.1*10**18 Nm (GS). Mo=2.2*10**18 Nm (HRV). Mo=3.0*10**18 Nm (PPT). At least 25 people killed, more than 200 injured, 1,000 homeless and extensive damage in the Pochuta-Solola area. Landslides blocked many roads in the epicentral area. Felt (IV) at Guatemala City. Also felt (II) at San Salvador, El Salvador.
SEP 28	20 26 56.1	5.814 S	150.959 E	28 G	5.8	6.6	1.1	370	NEW BRITAIN REGION, P.N.G. Ms 7.1 (BRK). Mo=9.8*10**18 Nm (GS). Mo=8.2*10**18 Nm (HRV). Mo=1.3*10**19 Nm (PPT). Two events about 2.3 seconds apart.
SEP 30	00 21 46.4	20.878 S	178.591 W	566 G	6.3		1.0	452	FIJI ISLANDS REGION. mb 6.5 (BRK). Mo=2.3*10**19 Nm (GS). Mo=3.1*10**19 Nm (HRV). Mo=3.0*10**19 Nm (PPT).
OCT 14	15 58 12.7	9.094 S	158.442 E	23 D	6.3	7.1	1.3	377	SOLOMON ISLANDS. Ms 7.0 (BRK). Mo=6.4*10**19 Nm (GS). Mo=7.8*10**19 Nm (HRV). Mo=8.0*10**19 Nm (PPT). Two events about 10 seconds apart. Felt strongly throughout the Solomon Islands.
OCT 19	21 23 14.3	30.780 N	78.774 E	10 D	6.5	7.0	1.2	525	NORTHERN INDIA. Ms 7.0 (BRK). Mo=1.8*10**19 Nm (GS). Mo=1.8*10**19 Nm (HRV). Mo=6.0*10**18 Nm (PPT). Two events about 1.6 seconds apart. At least 2,000 people killed, more than 1,800 injured and 18,000 buildings destroyed in the Chamoli-Uttarkashi area. Some damage occurred at Chandigarh and New Delhi. Felt in northern India, western Nepal and northeastern Pakistan. Landslides occurred in the epicentral area. A 30-meter deep crack was noted in the Uttarkashi area.
OCT 28	01 09 10.8	33.827 N	131.222 E	17 D	5.1	4.9	1.1	115	KYUSHU, JAPAN. Mo=7.5*10**16 Nm (HRV). One person slightly injured in Yamaguchi Prefecture, Honshu. Felt (IV JMA) at Fukuoka, Kyushu and (III JMA) in southwestern Honshu. Also felt on Shikoku. Felt (III) at Iwakuni, Honshu.
NOV 01	16 23 22.3	30.255 S	177.981 W	21 G	6.4	6.5	1.1	484	KERMADEC ISLANDS, NEW ZEALAND. Ms 6.7 (BRK). Mo=9.5*10**18 Nm (GS). Mo=9.4*10**18 Nm (HRV). Mo=1.0*10**19 Nm (PPT). Two events about 5 seconds apart. Felt on Raoul Island.
NOV 04	01 50 31.6	30.666 N	50.218 E	39	5.4	5.4	1.2	298	NORTHERN IRAN. Mo=3.1*10**17 Nm (HRV). Fifty-one people injured and 290 houses destroyed or damaged in the Behbahan area.
NOV 10	15 19 14.2	30.585 N	50.268 E	44	5.0	4.4	1.1	195	NORTHERN IRAN. Fifteen people injured and damage in the Behbahan area. Also damage at Deh Dasht.
NOV 13	11 12 13.2	8.361 N	126.371 E	36 G	6.1	6.4	1.2	399	MINDANAO, PHILIPPINE ISLANDS. Ms 6.5 (BRK). Mo=1.6*10**19 Nm (GS). Mo=1.0*10**19 Nm (HRV). Mo=1.0*10**19 Nm (PPT). Some damage (VI RF) was reported in the Bislig-Butuan-Surigao area. Felt (IV RF) at Cagayan de Oro, (III RF) on Camiguin and (II RF) on Cebu.

DATE	ORIGIN TIME UTC HR MN SEC	GEOGRAPHIC COORDINATES LAT	LONG	DEPTH	MAGNITUDES GS MB	Msz	SD	NO. STA USED	REGION, CONTRIBUTED MAGNITUDES AND COMMENTS
1991									
NOV 19	22 28 51.0	4.554 N	77.442 W	21 D	6.4	7.0	1 2	447	NEAR WEST COAST OF COLOMBIA. MD 6.8 (UVC). Ms 6.4 (BRK). Mo=5.0*10**19 Nm (GS). Mo=7.3*10**19 Nm (HRV). Mo=5.0*10**19 Nm (PPT). Complex event. Two people killed and 28 houses damaged in Choco Department. Minor damage (VI) to buildings in the Buenoventuro and Cali areas. Felt strongly in many parts of western Colombia. Felt (II) at Quito and Guayaquil, Ecuador.
NOV 22	00 40 23.9	13.887 N	44.068 E	10 G	4.7		1.1	40	WESTERN ARABIAN PENINSULA. Ten people killed, 39 injured, 17 houses destroyed and 87 damaged in western Yemen.
NOV 28	17 19 55.5	36.924 N	49.603 E	16 D	5.6	5.0	1.0	349	WESTERN IRAN. Mo=3.2*10**17 Nm (HRV). At least one person killed, 70 injured and damage in the Rudbar area. Landslides occurred on the road between Rudbar and Rasht. Felt in other parts of northern Iran and at Tehran.
DEC 02	08 49 40.2	45.498 N	21.115 E	9	5.2	5.6	1.1	281	ROMANIA. ML 5.5 (LJU), 5.1 (WAR), 4.9 (TIR). MD 5.5 (VIE), 5.4 (TTG). Mo=1.9*10**17 Nm (HRV). Mo=2.0*10**17 Nm (PPT). Some people injured, about 4,500 people homeless and more than 5,000 buildings damaged (VIII) in the Vaiteg area. Slight damage in the Belgrade area, Yugoslavia. Felt along much of the Romania-Yugoslavia border. Also felt in southern Hungary.
DEC 11	20 39 39.2	23.368 S	171.044 E	37 D	5.8	6.5	1.4	418	LOYALTY ISLANDS REGION. MS 6.3 (BRK). Mo=6.4*10**18 Nm (HRV). Mo=4.0*10**18 Nm (PPT).
DEC 13	02 33 51.8	45.578 N	151.560 E	30 G	6.1	6.6	1.1	509	KURIL ISLANDS. Ms 6.2 (BRK). Mo=8.1*10**18 Nm (HRV). Mo=1.3*10**19 Nm (PPT).
DEC 19	01 33 40.4	45.253 N	151.176 E	27 G	6.0	6.6	1.0	529	KURIL ISLANDS. Ms 6.4 (BRK). Felt (III) at Kurilsk. Mo=1.5*10**19 Nm (HRV). Mo=1.0*10**19 Nm (PPT). Two events about 1.6 seconds apart.
DEC 22	08 43 13.4	45.533 N	151.021 E	25 D	6.3	7.4	0.9	552	KURIL ISLANDS. Ms 7.3 (BRK). Mo=2.2*10**20 Nm (GS). Mo=2.8*10**20 Nm (HRV). Mo=2.5*10**20 Nm (PPT). Complex event. Felt.
DEC 27	04 05 58.2	56.032 S	25.266 W	10 G	6.2	7.2	1.4	341	SOUTH SANDWICH ISLANDS REGION. Ms 7.1 (BRK). Mo=5.9*10**19 Nm (GS). Mo=6.0*10**19 Nm (HRV). Mo=1.3*10**20 Nm (PPT). Complex event.
DEC 28	00 52 10.1	56.102 S	24.614 W	10 G	6.1	6.7	1.1	285	SOUTH SANDWICH ISLANDS REGION. Ms 6.5 (BRK). Mo=7.1*10**18 Nm (GS). Mo=9.9*10**18 Nm (HRV). Mo=2.0*10**19 Nm (PPT).

EXPLANATION OF ABBREVIATIONS AND SYMBOLS APPEARING IN THIS PUBLICATION

Abbreviations in Heading

MB - Body wave magnitudes.
Msz - Vertical surface wave magnitudes.
UTC - Coordinated Universal Time. HR MN SEC - Hour, minute, second.
SD - Standard Deviation from the arithmetic mean of residuals.
No. Sta. - Number of stations reporting P or PKP phases used in computation.

Symbols and Abbreviations Used in Comments

BRK--University of California, Berkeley, CA. PAS--California Institute of Technology, Pasadena, CA.
ATH--Athens Observatory, Greece. BJI--State Seismological Bureau, Beijing, China.
BRA--Geophysical Institute, Bratislava, Czechoslovakia. GEN--University of Genova, Italy.
ISK--Kandilli Observatory, Istanbul, Turkey. KRA--Observatorium Sejsmologiczne, Krakow, Poland.
LDG--Laboratoire de Detection et de Geophysique, France. LJU--Seizmoloski Zavod, Slovenija, Ljubljana, Yugoslavia.
SJR--Universidad de Costa Rica, San Jose, Costa Rica. STR--Institute de Physique du Globe, Strasbourg, France.
THE--University of Thessaloniki, Greece. TIR--Seismological Center, Tirana, Albania.
TRI--Osservatorio Geofisico Sperimentale, Trieste, Italy. TTG--Seismological Institute of Montenegro, Titagrad, Yugoslavia.
UVC--Universidad del Valle, Cali, Colombia. VIE--Central Institute for Meteorology and Geodynamics, Vienna, Austria.
WAR--Instytut Geofizyki, Warsaw, Poland. ZAG--University of Zagreb, Yugoslavia.

GM U.S. Geological Survey, Menlo Park, California.
GS U.S. Geological Survey, National Earthquake Information Service (NEIS), Golden, Colorado.
HRV Harvard University, Cambridge, Massachusetts
PPT Laboratoire de Geophysique, Papeete, French Polynesia
JMA Japan Meteorological Agency, Tokyo (also used to indicate 7-point Japanese Intensity Scale).
MD Duration Magnitude.
RF Rossi-Forel Intensity Scale.
SPEC An NEIS solution based on use of dense local networks, a local crustal model, or other methods not routinely applied in calculating the hypocenter parameters.
Roman Numerals Used to indicate intensity (when not followed by RF or JMA they refer to the Modified Mercalli Scale or any 12-point intensity scale closely related to it).

Symbols Following Depth

N Indicates the depth was restrained at 33 km for earthquakes whose character on seismograms indicates a shallow focus but whose depth is not satisfactorily determined by the data.

D Indicates the depth was restrained by the computer program based on 2 or more compatible pP phases and/or unidentified secondary arrivals used as pP.

G Indicates the depth was restrained by a geophysicist. Some depths are from broadband displacement seismograms.

* Indicates a less well-constrained free depth. The 90% marginal confidence interval on depth is greater than 8.5 km and less than or equal to 16.0 km.

The lack of any symbol indicates that the 90% marginal confidence interval on depth is less than or equal to 8.5 km, or that a contributed hypocenter was computed with a free depth, regardless of the size of the confidence interval.

Symbols Following Origin Time

& Indicates that parameters of the hypocenter were supplied or determined by a computational procedure not normally used by the National Earthquake Information Service (NEIS). The source or nature of the determination is indicated by a 2 to 5 letter code enclosed by angle brackets and appearing in the first line of comments. These codes are included with the list of abbreviations above.

* Indicates a less reliable solution. In general, the geometric mean of the semi-major and semi-minor axes of the horizontal 90% confidence ellipse is greater than 8.5 km and less than or equal to 16.0 km.

? Indicates a poor solution, published for completeness of the catalog. In general, the geometric mean of the semi-major and semi-minor axes of the horizontal 90% confidence ellipse is greater than 16.0 km. This includes a poor solution computed using data reported by a single network.

The lack of any symbol indicates that the geometric mean of the semi-major and semi-minor axes of the horizontal 90% confidence ellipse is less than or equal to 8.5 km.

APPROXIMATE CORRELATION OF GRADES FOR INTENSITY SCALES REPORTED IN THIS PUBLICATION

Modified Mercalli 1931	Japanese, 1950 (JMA)	Rossi-Forel, 1873 (RF)
I	0	I
II	I	I-II
III	II	III
IV	II-III	IV-V
V	III	V-VI
VI	IV	VI-VII
VII	IV-V	VIII-
VIII	V	VIII+-IX
IX	V-VI	IX+
X	VI	X
XI	VII	X
XII	VII	X

TRAVEL-TIME TABLES

In general, all hypocenters have been computed based on the 1940 Jeffreys-Bullen P and 1968 Bolt PKP travel-time tables. Some other earth model or computational procedure may have been used for those hypocenters which have been indicated by an ampersand (&) following the origin time.

MACROSEISMIC INFORMATION

Macroseismic information is compiled from various sources, including newspaper articles, Foreign Broadcast Information Service messages, U.S. Geological Survey Earthquake Reports and seismological station reports. Sources of information for particular events can be supplied on request from: U.S. Geological Survey, National Earthquake Information Center, Stop 967, Box 25046, Denver Federal Center, Denver, CO 80225, U.S.A.

GEOGRAPHIC REGIONS

The regions shown in the comments column are from the seismic and geographical regionalization of Flinn, Engdahl and Hill (1974), with occasional name changes which have been given in various issues of the Preliminary Determination of Epicenters Monthly Listing. The boundaries of these regions are defined at one degree intervals and differ slightly from irregular political boundaries.

NEIS MAGNITUDES

All magnitudes are NEIS magnitudes unless otherwise indicated. Average magnitudes are computed by a 25% trimmed mean as described by Rosenberger, J. L. and Gasko, M., 1983, "Comparing location estimators: trimmed means, medians, and trimean" in Understanding Robust and Exploratory Data Analysis, ed. Hoaglin, D.C., Mosteller, F., and Tukey, J. W., John Wiley, New York.

Ms These surface wave magnitudes are computed from the I.A.S.P.E.I. formula:

$$Ms = \text{Log } (A/T) + 1.66 \text{ Log } D + 3.3$$

where:

A is the maximum ground amplitude in micrometers (microns) of the vertical component of the surface wave within the period range $18 \leq T \leq 22$.

T is the period in seconds.

D is the distance in geocentric degrees (station to epicenter) and $20^\circ \leq D \leq 160^\circ$.

No depth corrections are applied, and Ms magnitudes are not generally computed for depths greater than 50 km. The Ms value published is the average of the individual station magnitudes from reported T and A data.

If the uncertainty of the computed depth is considered great enough that the depth could be less than 50 km, an MS value may still be published, computed by the I.A.S.P.E.I. formula and not corrected for depth.

In general, the Ms magnitude is more reliable than the MB magnitude as a means of yielding the relative "size" of a shallow-focus earthquake.

MB These compressional body wave (P-wave) magnitudes are computed according to the formula:

$$MB = \text{Log } (A/T) + Q(D,h)$$

defined by Gutenberg and Richter (1956) except that T, the period in seconds, is restricted to $0.1 \leq T \leq 3.0$ and A, the ground amplitude in micrometers, is not necessarily the maximum in the P group. Q is a function of of distance (D) and depth (h) where $D \geq 5^\circ$.

mbLg These Lg body wave magnitudes are computed according to the formula:

$$mbLg = 3.75 + 0.90 \text{ Log } D + \text{Log } (A/T) \text{ for } 0.5^\circ \leq D \leq 4^\circ$$

$$mbLg = 3.30 + 1.66 \text{ Log } D + \text{Log } (A/T) \text{ for } 4^\circ \leq D \leq 30^\circ$$

as proposed by Nuttli (1973) where A is the ground amplitude in micrometers and T is the period in seconds calculated from the vertical component 1-second Lg waves. D is the distance in geocentric degrees.

ML These local magnitudes are computed according to the formula:

$$ML = \text{Log } A - \text{Log } Ao$$

defined by Richter (1935) where A is the maximum trace amplitude in micrometers recorded on a standard short-period torsion seismometer and Log Ao is a standard value as a function of distance where distance ≤ 600 km.

CONTRIBUTED MAGNITUDES

Magnitudes appearing in the comments which have been contributed by organizations operating a network of stations may have been calculated from any one station in the network or may be an average magnitude from a number of stations from the network.

REFERENCES

Gutenberg, B., and Richter, C. F., 1956, Magnitude and energy of earthquakes: Annali di Geofisica, v. 9, no. 1, p. 1–15.

Nuttli, O. W., 1973, Seismic wave attenuation and magnitude relations for eastern North America: Journal of Geophysical Research, v. 7B, no. 5, p. 876–885.

Richter, C. F., 1935, An instrumental earthquake scale: Bulletin of the Seismological Society of America, v. 25, p. 1–32.

Sipkin, S. A., 1982, Estimation of earthquake source parameters by the inversion of waveform data: synthetic seismograms: Physics of the Earth and Planetary Interiors, v. 30, no. 2–3, p. 242–259.

Romanowicz, B. and Guillemant, P., 1984, An experiment in the retrieval of depth and source mechanism of large earthquakes using very long-period Rayleigh wave data: Bulletin of the Seismological Society of America, v. 74, no. 2, p. 417–437.

Romanowicz, B. and Monfret, T., 1986, Source process times and depths of large earthquakes by moment tensor inversion of mantle wave data and the effect of lateral heterogeneity: Annales de Geophysique, v. B4, no. 3, p. 271–282.

Aki, K. and Richards, P. G., Quantitative Seismology, Volume 1, W. H. Freeman, San Francisco, 1980, 557 pp.

Dziewonski, A. M., Chou, T. A., and Woodhouse, J. H., 1981, Determination of earthquake source parameters from waveform data for studies of global and regional seismicity: Journal of Geophysical Research, v. 86, p. 2825–2852.

Knopoff, L. and Randall, M. J., 1970, The compensated linear-vector dipole: A possible mechanism for deep earthquakes: Journal of Geophysical Research, v. 75, p. 4957–4963.

Bolt, B.A. and Herraiz, M. 1983, Simplified estimation of seismic moment from seismograms: Bulletin of the Seismological Society of America, v. 73, p. 735–748.

Talandier, J., Reymond, D. and Okal, E.A. 1987, Use of a variable period mantle magnitude for the rapid one-station estimation of seismic moments: Geophysical Research Letters, v. 14, no. 8, p. 840–843.