Eastern Asia Earthquake and Volcanic Hazards Information Map

東アジア地域地震火山災害情報図

1:10,000,000

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Kirishima-Shinmoedake Volcanic Eruption, Japan, Jan. 27, 2011


Itozawa surface fault emerged during the April 2011 Fukushima earthquake, occurred 30 days after the M9 Japan Tohoku earthquake.

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1. Introduction

The Eastern Asia region is an area with high risk of catastrophic natural disasters such as earthquake, tsunami, and volcanic eruption. In today's highly globalized economy, when a major disaster occurs, it can create unpredictable turmoil not just in the affected area but also the rest of the world. Countermeasures against these disasters are crucial for the sustainable economic development of the region. We think that continuous efforts to develop an effective international framework to reduce the risk of earthquake, tsunami, and volcanic hazards are very important. The Sumatra-Andaman earthquake on December 26, 2004 and Tohoku earthquake on March 11, 2011 clearly show the urgency of developing an information and knowledge system for infrequent natural hazards. The volcanic ash ejected from Eyjafjallajökull eruptions in Iceland on April 2000 caused more than 20,000 commercial flight cancellations a day in Europe, resulting in the largest air-traffic shut-down since World War II. The G-EVER (Asia Pacific Region Earthquake and Volcanic Eruption Risk Management) Consortium promotes earthquake and volcanic hazards reduction activities through the collaboration of different research institutes worldwide. The "Eastern Asia Earthquake and Volcanic Hazards Information Map" is the first published map created by the G-EVER Consortium.

The Eastern Asia Earthquake and Volcanic Hazards Information Map shows geology and tectonics (Chapter 2), active faults (Chapter 3), earthquakes hypocenters and source areas (Chapter 4), fatalities of major earthquakes (Chapter 5), tsunami hazards (Chapter 6), distribution of volcanoes (Chapter 7), calderas, pyroclastic falls and ignimbrites (large-scale pyroclastic flows; Chapter 8), and fatalities of major volcanic events (Chapter 9). We believe that this hazards information map will provide useful information for earthquake, tsunami, and volcanic disaster mitigation efforts.

(Eikichi Tsukuda and Shinji Takarada)

2. Geology and tectonics of Eastern Asia region

The occurrences of earthquake and volcanic hazards are closely related with the geological settings. The geological map is recompiled on the basis of the Geological Map of Asia 1:5,000,000 (Teraoka and Okumura, 2011) and Digital Geologic Map of East and Southeast ASIA 1:2,000,000 2nd edition (Wakita *et al.*, 2004). Since the Eastern Asia Earthquake and Volcanic Hazards Information Map is 1:10,000,000 in scale, the legend is simplified from the original geological maps. Sedimentary, extrusive and metamorphic rocks are subdivided into Q (Quaternary; 2.58-0 Ma), Tpn (Paleogene to Gelasian; 66.0-1.81 Ma), Qp (Quaternary large-scale ignimbrite; <74ka), TnQ (Middle Miocene to Calabrian; 15-0.78 Ma), KTp (Late Cretaceous to Eocene; 100.5-33.9 Ma), Mz (Mesozoic; 252.1-66.0 Ma), PTr (Late Permian to Middle Triassic; 259.8-236.8 Ma), Pz2 (Devonian to Early Triassic, 419.2-247.4 Ma), Pz1 (Late Proterozoic to Silurian; 1000-419.2 Ma), SD (Silurian to Devonian; 443.4-358.9 Ma), Pz (Paleozoic: 541.0-252.1 Ma), PrPz1 (Middle Proterozoic to Early Ordovician; 1600-471.8 Ma), and P∈ (Precambrian; > 541.0 Ma). The intrusive rocks are subdivided into Cz_i (Paleogene to Early Pleistocene; 66.0-0.78 Ma), Mz_i (Late Permian to Cretaceous; 260.4- 66.0 Ma), Pz2_i (Late Paleozoic; 419.2-252.1 Ma), Pz1_i (Early Paleozoic; 541.0-419.2 Ma), and P∈_i (Precambrian; >541.0 Ma). Rock types of Phanerozoic extrusive volcanic rocks are subdivided into felsic (rhyolite, dacite, trachyte, and trachydacite), felsic to intermediate (rhyolite, dacite, andesite, trachyte, trachydacite, and trachytic andesite), intermediate (andesite, basaltic andesite, trachytic andesite, and basaltic trachyandesite), intermediate to mafic (andesite, basaltic andesite, basalt, trachyandesite, basaltic trachyandesite, and alkali basalt), mafic (basalt and alkali basalt), and undifferentiated. Rock types of intrusive rocks are subdivided into felsic (eg. granite), intermediate (eg. diorite), mafic (eg. gabbro) and ultramafic rocks/ophiolite.

Relatively younger volcanic rocks (Q, Tpn, TnQ and Cz_i) are mainly distributed in island arcs, such as Japan, Philippines, Indonesia, and Papua New Guinea. Therefore, volcanic hazards occur in these countries. The collision of the Indian and Eurasian plates resulted to significant deformations at the Himalayas and mainland China. Therefore, intracontinental earthquakes cause earthquake disasters in these regions. The worst earthquake in the world (M8.0, 830,000 fatalities) occurred in Shaanxi of China on January 23, 1556.

Plate boundary data are displayed on this map. The plate boundaries are drawn based on Yeats (2012), Bird *et al.* (2003) and Kato and Eastern Asia Natural Hazards Mapping Project (2002). The plate boundary data around Philippines is based on PHIVOLCS (2008). Relatively large-scale earthquakes (Magnitude 7-9) occur along the subductions zones (Chapter 4). The largest earthquakes in this map area occurred off the northwestern coast of Sumatra, Indonesia (Mw9.1) on Dec. 26, 2004 and off the coast of Tohoku, Japan (Mw9.0) on March 11, 2011.

Etopo1 (Amante and Eakins, 2009) and SRTM30 Plus (Becker *et al.*, 2009) are used as shaded relief on land and bathymetry maps.

(Shinji Takarada)

3. Active faults

Distribution of active faults in eastern Asia and its surroundings has been compiled from various sources including maps and scientific papers (Abers and McCaffrey, 1988; Adiya *et al.*, 2003; Bayasgalan *et al.*, 2008; Central Geological Survey, MOEA, 2010; Choi *et al.*, 2014; Delinom, 2009; Deng *et al.*, 2007; Department of Mineral Resources, 2006; Hall, 2002; Kumahara and Nakata, 2005; Nakata *et al.*, 1991; Petit *et al.*, 1996; Ruleman *et al.*, 2007; Styron *et al.*, 2010; Supartoyo *et al.*, 2005; Tingay *et al.*, 2010; Tregoning *et al.*, 2005; Tsutsumi *et al.*, 2005; Walker *et al.*, 2007, 2008; Wang *et al.*, 2014). Unpublished digital data provided by the Headquarters for Earthquake Research Promotion (HERP), Philippine Institute of Volcanology and Seismology (PHIVOLCS) and Vietnam Academy of Science (VAST) were used for the active faults distribution in Japan, Philippines, and Vietnam, respectively. Similar mapping efforts were made as part of the International Lithosphere Program (ILP) Project II-2 ''World Map of Major Active Faults'' as reported by Trifonov (2004). Active faults, generally defined as faults that show recent evidence of repeated movement and have the potential to slip causing earthquake in the future, are one of the primary elements in geological hazard (e.g., England and Jackson, 2011). A large quantity of maps and papers dealing with active faults in the Eastern Asian region has been published. Multiple fault data sources with significantly different results are present in some countries and regions. Data published by government agencies were preferred. The quality of active fault distribution on this map is not uniform, because definition of active fault, progress in active fault research, and map scale used during compilation vary in each country and region. Some active faults have considerable uncertainties in their location due to differences in scale and projection between the map and original data. On the map, confirmed active faults, inferred active faults, and concealed active faults are shown in red solid lines, broken lines, and dotted lines, respectively. Names of major active faults (Altyn Tagh fault; Chaman fault; Chelungpu fault; Haiyuan fault; Himalayan Front fault; Itoigawa-Shizuoka Tectonic Line; Kunlun fault; Longmenshan fault zone; Median Tectonic Line; Philippine fault; Red River fault; Sagaing fault; Sumatran fault; and Talas-Fergana fault) are denoted on the map. Note that active folds and offshore active faults as well as active faults with relatively low-activity and/or short length are also not included on this map. Hence, areas with no mapped active fault may be exposed to risk of earthquakes. Characteristics of major active faults that are included on this map were summarized by Yeats (2012).

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4. Earthquakes hypocenters and source areas

The hypocenter parameters of historical earthquakes (1000-1899) were adapted from the catalog of the Global Historical Earthquake Archive (1000-1903) (Global Earthquake Model, 2015). The ISC-GEM catalog by Storchak *et al.* (2013) is used for the earthquakes from 1900 to 2011. For the recent earthquakes (2012 to September, 2015), data from the Preliminary Determination of Epicenters of United States Geological Survey (USGS) are used. Only earthquakes with magnitudes equal to and larger than 6 are shown on the map based on the ISC-GEM data.

Earthquake source regions shown for major earthquakes (Table 1) are selected using the following procedure. The data of the Preliminary Determination of Epicenters by USGS are mainly used for the source area delineation. Earthquakes with focal depth equal to and shallower than 60km and with magnitude equal to and larger than 7.5 are chosen. The earthquake catalog of Japan Meteorological Agency is used for events in and around Japan, since the accuracy of hypocenters is more reliable. However, magnitude 7.0 is the minimum events shown with source region in and around Philippines. The source region of each event was mainly estimated from the aftershock distribution within one month after the main shock. The regions of 1920, 1927, 1950, and 1970 January 4 events are estimated by the intensity maps of the Department of Earthquake Preparedness and Mitigation of State Seismological Bureau (1999). The IX equal intensity line of Chinese intensity scale is adapted for the source region. The 1905 event is based from Avouac (2007) while the 1934 event is based from Sapkota *et al.* (2013). Other than these events, the spatial distribution of one-month aftershocks was used to delineate the source area. Major earthquakes, which generated the severe damage to each country in early 20th century, are selected below, because USGS did not make earthquake catalog in this period.

Japan

The March 11, 2011 M9.0 earthquake (East off Tohoku earthquake) was the biggest one in and around Japan. It was an interplate thrust event between the North American and Pacific plates that generated huge tsunami along the east coast of Tohoku district of Japan (see Chapter 6 Tsunami Hazards).

China

The 1920 Haiyuan (Gansu) M8.3 earthquake (Department of Earthquake Preparedness and Mitigation of State Seismological Bureau, 1999) was one of the biggest in China. It was an intraplate strike slip event that occurred along the Hayuan fault. The 1976 Tangshan M7.6 earthquake was also an intraplate strike slip event that killed more than 240,000 people. The earthquake caused extensive damage to a modern city with more than one million populations.

Nepal

The 2015 Gorkha M7.8 earthquake was an interplate thrust event between the Eurasian and Indian plates. It occurred in central Nepal and caused extensive damage. The 1934 Bihol M8.0 earthquake was the biggest earthquake in Nepal that killed about 10,700 people. More than half of the buildings in Kathmandu were damaged including the Indian side.

Philippines

The 1990 Baguio (Luzon) M7.7 earthquake was an intraplate strike slip event that occurred along the Philippine fault.

Indonesia

The 2004 Sumatra-Andaman M9.1 earthquake generated the huge tsunami that caused extensive damage in many countries around Indian Ocean. It was an interplate thrust event between the Eurasian and Indo-Australian plates.

Table 1. Hypocenter parameters of earthquake source regions, which shown on the map. When the local time date is different from the origin time, the local time date is shown onthe map.

Origin time (UT) (yyyy/mm/dd time)	Magnitude (M)	Moment M (Mw)	Latitute (N)	Longitude (E)	Depth (km)	Local time date	Location
2015/4/25 6:11	M7.8	Mw7.9	28.2	84.7	8.2		Gorkha, Nepal
2015/3/29 23:48	M7.5	Mw7.4	-4.7	152.6	41.0		New Ireland, Papua New Guinea
2014/11/15 2:31	M7.1	Mw7.0	1.9	126.5	45.0		Moucca Passage, Indonesia
2013/10/15 0:12	M7.1	Mw7.1	9.9	124.1	19.0		Bohol, Philippines
2012/8/31 12:47	M7.6	Mw7.6	10.8	126.6	28.0		East off Philippines
2012/4/11 8:38	M8.6	Mw8.6	2.3	93.1	20.0		Far off Sumatra, Indonesia
2012/4/11 10:43	M8.2	Mw8.2	0.8	92.5	25.1		West off North Sumatra, Indonesia
2011/3/11 5:46	M9.0	Mw9.0	38.3	142.5	20.0		East off Tohoku, Japan
2010/12/21 17:19	M7.4	Mw7.4	26.9	143.8	20.0	2010/12/22	Bonin, Japan
2010/10/25 14:42	M7.8	Mw7.8	-3.5	100.1	17.6		Mentawai, Indonesia
2010/4/13 23:49	M6.9	Mw6.9	33.2	96.7	15.0	2010/4/14	Qinghai (Yusu), China
2010/4/6 22:14	M7.8	Mw7.8	2.3	97.1	20.0	2010/4/7	West off North Sumatra, Indonesia
2009/9/2 7:55	M7.0	Mw7.0	-7.8	107.4	46.0		South off Java, Indonesia
2009/2/11 17:34	M7.1	Mw7.1	3.8	126.5	25.0	2009/2/12	Kepulayan, Indonesia
2009/1/3 19:43	M7.7	Mw7.6	-0.5	132.7	30.0	2009/1/4	Northeast Iryan Jaya, Indonesia
2008/11/16 17:02	M7.4	Mw7.3	1.3	122.1	34.0	2008/11/17	North Sulawesi, Indonesia
2008/5/12 6:28	M7.9	Mw6.9	31.0	103.4	10.0		Wenchuan, China
2007/9/12 11:10	M8.5	Mw8.5	-4.4	101.5	34.0		South off Sumatra, Indonesia
2007/1/21 11:27	M7.5	Mw7.5	1.1	126.3	22.0		Molucca Sea, Indonesia
2006/12/26 12:26	M7.0	Mw7.0	21.8	120.6	10.0		South off Taiwan
2006/7/17 8:19	M7.7	Mw7.7	-9.3	107.3	25.3		South off Java, Indonesia
2005/10/8 3:50	M7.6	Mw7.6	34.5	73.6	15.0		Pakistan
2005/3/28 16:09	M8.6	Mw8.6	2.1	97.2	30.0		Nias, Indonesia
2004/12/26 0:58	M9.1	Mw9.1	3.3	96.0	30.0		Sumatra, Indonesia
2004/11/11 21:26	M7.5	Mw7.5	-8.2	124.8	13.0	2004/11/12	Alor, Indonesia
2003/9/25 19:50	M8.3	Mw8.3	41.9	143.9	30.0	2003/9/26	Tokachi-oki, Japan
2003/5/26 19:23	M6.9	Mw6.9	2.3	128.9	31.0	2003/5/27	North off Halmahera, Indonesia
2002/11/2 1:26	M7.2	Mw7.2	2.9	96.1	28.1		Northwest off Sumatra, Indonesia
2002/10/10 10:50	M7.6	Mw7.5	-1.7	134.3	20.0		West Iriyan Jaya, Indonesia
2002/9/8 18:44	M7.6	Mw7.6	-3.4	143.0	13.0	2002/9/9	North New Guinea, Papua
2002/3/5 21:16	M7.5	Mw7.5	6.0	124.2	25.0	2002/3/6	South Mindanao, Philippines
2001/11/14 9:26	M7.8	Mw7.8	36.0	90.5	10.0		Kunlunshan, China
2001/10/19 3:28	M7.5	Mw7.4	-4.1	124.0	15.0		Banda Sea, Indonesia
2001/1/1 6:57	M7.4	Mw7.4	6.9	126.6	36.0		Southwest Mindanao, Philippines
2000/11/17 21:01	M7.8	Mw7.8	-5.5	151.9	37.4	2000/11/18	New Ireland, Papua New Guinea
2000/11/16 4:54	M8.0	Mw8.0	-4.0	152.3	30.0		New Ireland, Papua New Guinea
2000/8/4 21:13	M6.8	Mw6.8	48.7	142.4	15.0	2000/8/5	Uglegorsk, Sakhalin, Russia
2000/6/4 16:28	M7.9	Mw7.8	-4.6	102.1	35.0		South off Sumatra, Indonesia
2000/5/4 4:21	M7.5	Mw7.5	-1.1	123.6	30.0		East Sulawesi, Indonesia
1999/12/11 18:03	M7.2	Mw7.2	15.8	119.8	40.0	1999/12/12	West Luzon, Philippines
1999/9/20 17:47	M7.6	Mw7.6	23.8	120.8	25.0	1999/9/21	Chi-Chi, Taiwan
1999/3/4 8:52	M7.1	Mw7.1	5.3	121.8	15.0		Celebes Sea, Philippines
1998/11/29 14:10	M7.7	Mw7.7	-1.9	124.8	25.0		Taliabu, Indonesia
1998/10/28 16:25	M6.5	Mw6.5	0.9	125.8	35.0	1998/10/29	Molucca Sea, Indonesia
1998/5/3 23:30	M7.5	Mw7.4	22.5	125.5	20.0	1998/5/4	South off Ishigaki, Japan
1997/11/8 10:02	M7.5	Mw7.5	35.1	87.4	20.0		Xizang, China
1996/7/22 14:19	M7.0	Mw7.0	1.0	120.5	28.4		North Sulawesi, Indonesia
1996/6/11 18:22	M7.1	Mw7.1	12.7	125.2	31.7	1996/6/12	Samar, Phlippines
1996/4/29 14:40	M7.2	Mw7.2	-6.5	155.0	35.0	1996/4/30	Bougainville, Papua New Guinea
1996/2/17 5:59	M8.2	Mw8.2	-0.9	136.9	20.0		Irian Jaya, Indonesia
1996/1/1 8:05	M7.9	Mw7.9	0.7	120.0	33.5		North Sulawesi, Indonesia
1995/12/3 18:01	M7.9	Mw7.9	44.7	149.3	28.3	1995/12/4	East off Etrof, Japan
1995/8/16 10:27	M7.7	Mw7.7	-5.8	154.2	25.0		Bougainville, Papua New Guinea
1995/5/27 13:03	M7.0	Mw7.0	52.6	142.9	12.9		Neftegorsk, Sakhalin
1995/4/21 0:34	M7.2	Mw7.1	12.1	125.6	24.1		Samar, Phlippines
1994/12/28 12:19	M7.7	Mw7.7	40.5	143.4	24.8		Sanriku haruka-oki, Japan
1994/10/4 13:23	M8.3	Mw8.3	43.9	147.2	30.0		Hokkaido toho-oki, Japan
1994/6/2 18:17	M7.8	Mw7.8	-10.5	112.9	18.0	1994/6/3	South off Java, Indonesia
1994/1/21 2:24	M7.0	Mw6.9	1.1	127.7	19.2		Halmahera, Indonesia
1993/8/8 8:34	M7.8	Mw7.7	13.0	144.8	59.0		Guam, USA
1993/7/12 13:17	M7.7	Mw7.7	42.8	139.2	20.0		Hokkaido Nansei-oki, Japan
1992/12/12 5:29	M7.7	Mw7.7	-8.5	121.9	28.0		Flores, Indonesia
1992/5/17 10:15	M7.2	Mw7.2	7.2	126.7	30.0		Mindanao, Philippines
1991/12/22 8:43	M7.6	Mw7.6	45.5	151.1	25.3		East off Urup, Russia
1991/6/20 5:18	M7.5	Mw7.5	1.2	122.8	30.0		North Sulawesi, Indonesia
1990/7/16 7:26	M7.7	Mw7.7	15.7	121.2	24.4		Baguio, Luzon, Philippines
1990/4/18 13:39	M7.6	Mw7.6	1.2	122.9	36.6		North Sulawesi, Indonesia
1989/12/15 18:43	M7.5	Mw7.5	8.4	126.6	27.5	1989/12/16	Mindanao, Philippines
1988/2/24 3:52	M7.2	Mw7.2	13.5	124.6	28.1		Cataduanes, Philippines
1987/10/16 20:48	M7.3	Mw7.3	-6.2	149.1	45.0	1987/10/17	New Britain, Papua New Guinea
1986/11/14 21:20	M7.4	Mw7.3	24.0	121.8	35.0	1986/11/15	East Taiwan
1986/8/14 19:39	M7.5	Mw7.5	1.9	126.5	32.3	1986/8/15	Moucca Passage, Indonesia
1985/8/23 12:42	M7.0	Mw6.9	39.4	75.3	30.0		West Xinjiang, China
1983/5/26 3:00	M7.7	Mw7.7	40.4	139.2	15.1		Nihonkai-chubu, Japan
1982/1/11 6:10	M7.1	Mw7.1	13.9	124.4	31.8		Cataduanes, Philippines
1980/6/18 17:14	M6.9	Mw6.9	-5.1	152.2	51.0		New Britain, Papua New Guinea
1979/9/12 5:17	M7.5	Mw7.5	-1.7	136.0	20.0		Irian Jaya, Indonesia
1978/7/23 14:42	M7.2	Mw7.2	22.2	121.4	25.0		South off Taiwan
1978/6/12 8:14	M7.6	Mw7.6	38.2	142.0	45.0		off Miyagi, Japan
1978/3/23 3:14	M7.6	Mw7.6	44.2	149.0	35.0		South off Etrof, Japan
1977/8/19 6:08	M8.3	Mw8.3	-11.2	118.4	25.0		South off Sumbawa, Indonesia
1977/3/18 21:43	M7.2	Mw7.2	16.7	122.2	30.0	1977/3/19	Luzon, Philippines
1976/8/16 16:11	M8.0	Mw8.0	6.2	124.0	20.0	1976/8/17	Moro Gulf, Philippines
1976/7/27 19:42	M7.6	Mw7.6	39.6	118.1	15.3	1976/7/28	Tangshan, China
1975/10/31 8:28	M7.5		12.6	126.1	23.0		Samar, Philippines
1975/7/20 19:54	M7.3		-7.2	155.3	45.0	1975/7/21	Bougainville, Solomon
1973/6/17 3:55	M7.8		43.2	145.8	44.3		Nemuro offshore, Japan
1972/12/2 0:19	M8.0		6.4	126.6	60.0		Mindanao, Philippines
1972/4/25 19:30	M7.5		13.4	120.3	25.0	1972/4/26	Mindoro, Phlippines
1971/7/14 6:11	M8.0		-5.5	153.9	40.0		Papua New Guinea
1971/1/10 7:17	M7.7		-3.2	139.7	30.0		Irian Jaya, Indonesia
1970/4/12 4:01	M6.9		15.1	122.1	22.5		Luzon, Philippines
1970/4/7 5:34	M7.4		15.8	121.6	25.0		Luzon, Philippines
1970/1/4 17:00	M7.1		24.2	102.5	11.3	1970/1/5	Tonghai, China
1969/8/11 21:27	M8.2		43.4	147.9	30.0	1969/8/12	South off Shikotan, Japan
1968/8/10 2:07	M7.6		1.5	126.2	23.0		Molucca Passage, Indonesia
1968/8/1 20:19	M7.6		16.3	122.1	25.0	1968/8/2	Casiguran, Luzon, Phlippines
1968/5/16 0:49	M8.2		40.9	143.4	29.9		Tokachi-oki, Japan
1966/3/12 16:31	M7.5		24.1	122.6	30.0	1966/3/13	East off Taiwan
1965/1/24 0:11	M8.2		-2.6	126.0	20.0		Cream Sea, Indonesia
1964/6/16 4:01	M7.6		38.4	139.3	15.0		Niigata, Japan
1952/3/4 1:22	M8.1		42.1	143.9	45.0		Tokachi-oki, Japan
1951/11/24 18:50	M7.8		23.1	121.2	30.0	1951/11/25	Southwest of Taiwan
1950/8/15 14:09	M8.6		28.4	96.4	15.0		Assam, India
1946/12/20 19:19	M8.3		33.1	135.9	15.0	1946/12/21	Nankai, Japan
1944/12/7 4:35	M8.1		33.7	136.2	15.0		Tonankai, Japan
1935/12/28 2:35	M7.6		-0.3	98.3	30.0		West off Smatra, Indonesia
1934/1/15 8:43	M8.0		26.9	86.6	15.0		Bihar, Nepal
1927/5/22 22:32	M7.7		37.6	102.5	15.0	1927/5/23	Gulang, China
1923/9/1 11:58	M7.9		35.3	139.1	23.0		Kanto, Japan
1920/12/16 12:05	M8.3		36.9	105.6	15.0		Haiyuan, China
1905/4/4 0:49	M7.9		32.6	76.8	20.0		Kangra, India

Papua New Guinea

The 2000 New Ireland M8.0 earthquakes was a strange event. First, an M8.0 earthquake occurred off the coast of New Ireland Province. It was an interplate strike-slip event between the north and south Bismarck plates. It occurred along the transform fault on November 16 at 04:54 UTC. The M7.8 earthquake followed at 07:42 UTC. It was a thrust event between the Solomon Sea Plate and the south Bismarck plate located around 175 km south of the first earthquake. On November 17 at 21:01, the M7.8 third event occurred around 170 km southwest of the first event. It was a thrust event same as the second one.

(Yuzo Ishikawa)

5. Fatalities of Major Earthquakes

Earthquake Fatalities Map is compiled to facilitate visual understanding of earthquake disasters in terms of their number of fatalities (deaths) and the main causes of deaths. Major disastrous earthquakes in terms of number of fatalities are selected in each country or region: all the recent (after 1850) events with fatalities more than 1,000 (hereafter, F1000 event) are included; for a country with less than three F1000 events, two F100-F10 events are added; for a country with no F1000 events, up to two F100 events or one worst earthquake with fatalities are added. The number of fatalities is categorized by five causes; structure (building) damage, tsunami, landslide, fire, and others (related death), when possible. It is important to understand that an earthquake and ground motions do not directly kill people, but vulnerable structures, fire, landslide, or tsunami do. The number of fatalities is based on the Significant Earthquake Database (NGDC/WDS) provided by NOAA when no references are cited.

Japan

Subduction zones and active faults are the main sources of hazardous earthquakes in Japan. Disastrous earthquakes with more than 1,000 casualties after 1850 are shown on the map (Table 2). These include eight subduction earthquakes (including an outer-rise quake), seven earthquakes on the active faults, and one with unknown source.

Table 2. List of disastrous earthquakes in Japan (after 1850AD and >1,000 fatalities).

Date (yyyy.mm.dd)	Name	Mj	Number of fatalities	Reference
2011.03.11	Tohoku	9	21,839 (S:60, T:18,418, L:30, O:3,331)	Fire and Disaster Management Agency, Reconstruction Agency, Kahoku shinpo (local newspaper), National Police Agency of Japan
1995.01.17	Kobe	7.3	6,437 (S:5075, L:40, F:403, O:919)	Include 3 persons missing
1948.06.28	Fukui	7.1	3,728 (S, F)	
1946.12.21	Showa Nankai	8.0	1,443 (S:860, T:583)	Kawasumi and Sato (1947), Kanai *et al.* (1947)
1945.01.13	Mikawa	6.8	2,306 (S)	Iida (1978), CDPC (2007)
1944.12.07	Showa Tonankai	7.9	1,230 (S:779, T:451)	Iida (1977), CMO (1945), CDPC (2007)
1943.09.10	Tottori	7.2	1,083 (S)	
1933.03.03	Showa Sanriku	8.1	3,064 (T)	
1927.03.07	Kita-Tango	7.3	2,925 (S)	
1923.09.01	Kanto	7.9	105,385 (S:12,591, T:325, L:688, F:91781)	Moroi and Takemura (2004), CDPC (2006)
1896.06.15	Meiji Sanriku	7.6-8.2	21,959 (T)	
1891.10.28	Nobi	8.0	7,273 (S)	
1855.11.11	Ansei Edo	7.1	10,000 (S:8,000, F:2,000)	Nakamura and Matsuura (2011), CDPC (2004)
1854.12.24	Ansei Nankai	8.4	3,000 (S:1,500, T:1,500)	
1854.12.23	Ansei Tokai	8.4	3,000 (S:1,500, T:1,500)	

S: Structure, T: Tsunami, L: Landslide, F: Fire, O: Other related death

Among the eight subduction earthquakes, three are related to the Japan Trench (1896 Meiji Sanriku, 1933 Showa Sanriku, 2011 Tohoku), four of them are on the Nankai Trough (1854 Ansei Tokai, 1854 Ansei Nankai, 1944 Tonankai and 1946 Tonankai), and one is on the Sagami Trough (1923 Kanto). Principal cause of death varies by source region; Tsunami for the Japan Trench, tsunami and structure damage for the Nankai Trough, fire and structure damage for the Sagami Trough: 1923 Kanto earthquake.

The seven disastrous earthquakes that were attributed to the active faults are the 1847 Zenkoji, 1891 Nobi, 1927 Tango, 1943 Tottori, 1945 Mikawa, 1948 Fukui, and the 1995 Kobe (Hyogo-ken Nanbu) earthquakes. These earthquakes occurred just beneath cities causing huge numbers of structural collapse and succeeding fire, which resulted in many casualties. The 1855 Ansei Edo (Edo: previous name of Tokyo) earthquake occurred beneath Edo city but with unknown source, causing many casualties due to structural damage and fire. Table 1 shows the number of fatalities which was compiled from many reports.

Bangladesh

Active faults are the main sources of disastrous earthquake in Bangladesh.

China

Active faults are the main sources of disastrous earthquake in China. Twenty disasters in the 19th and 20th centuries are shown on the map with two historically deadliest ones in 1303 and 1556 (Table 3). The 2008 Wenchuan earthquake caused 87,210 fatalities, 20,000 of them by landslides (Huang and Fan, 2013). The 1933 Maowen earthquake caused 9,300 deaths including 2,500 caused by flooding and landslide resulted from a natural-dam break (EERI, 2008).

Table 3. List of disastrous earthquakes in China (after 1850AD, two significant historical events and >1,000 fatalities).

Date (yyyy.mm.dd)	Name	M	Number of fatalities	Reference
2010.04.14	Yushu	6.9	2,968 (S)	Lou (1996)
2008.05.12	Wenchuan	8.1	87,587 (S:67,210, L:20,377)	Huang and Fan (2013)
1976.07.28	Tangchan	7.6	242,800 (S)	Lou (1996)
1975.02.04	Haicheng	7.3	1,328 (S)	Lou (1996)
1974.05.10	Zhaotang	7.1	1,541 (S)	Lou (1996)
1970.01.04	Tonghai	7.5	15,621 (S)	
1966.05.07	Ninglin	7.2	8,064 (S)	Lou (1996)
1933.08.25	Maowen	7.5	6,865 (S)	Lou (1996)
1931.08.10	Fuyan	8.0	10,000 (S)	
1927.05.23	Gulang	8.0	41,419 (S)	Lou (1996)
1925.03.16	Talifu	7.0	5,808 (S)	Lou (1996)
1923.03.24	Sichuan	7.3	4,500 (S)	Lou (1996)
1920.12.16	Haiyuan	8.5	235,502 (S)	Lou (1996)
1918.02.13	Shantou	7.3	1,000 (S)	Lou (1996)
1917.07.30	Daguan	6.7	1,879 (S)	Lou (1996)
1902.08.22	Kashgar	8.2	5,650 (S)	Lou (1996)
1887.12.16	Yunnan	7.0	2,256 (S)	Lou (1996)
1879.07.01	Gansu	8.0	29,480 (S)	Lou (1996)
1870.04.11	Batang	7.3	2,300 (S)	NOAA
1850.09.12	Xichang	7.5	23,860 (S)	Lou (1996)
1556.01.23	Shaanxi	8.2	830,000 (S)	Lou (1996)
1303.09.25	Shanxi	8.0	200,000 (S)	NOAA

S: Structure, L: Landslide

India

The Himalayan collision zone and intraplate active faults are the main sources of disastrous earthquake in India. The 1905 Kangra and the 1991 Ultarkashi are Himalayan earthquakes. The 1897 Assam earthquake occurred on an active fault south of the Himalayan Front fault. The 2001 Bhuj (Gujarat) and the 1993 Latur earthquakes are shallow intraplate event in Indian subcontinent. Most casualties are caused by damage of structures.

Indonesia

Subduction zone and active faults are the main sources of disastrous earthquake in Indonesia. The 2004 Sumatra-Andaman earthquake (M9.1) caused huge tsunami (see Chapter 6) and most of the fatalities are due to tsunami. The 2005 Nias earthquake (M8.5) is a subduction earthquake with 1,346 deaths that caused structure collapses mainly on the Nias island located just above the source area. The 2009 Sumatra earthquake is an intra-slab earthquake with more than 1,000 deaths caused by the collapse of buildings. Inland earthquakes (2006 Yogyakarta, 1917 Bali) caused fatalities were also caused by building collapse and landslides. The 1992 Flores earthquake is shallow event with high tsunami induced by landslide (Tsuji *et al.*, 1995).

Myanmar

Active faults are the main sources of disastrous earthquake in Myanmar. The 1930 Pegu earthquake on the Sagain fault is the deadliest with 500 fatalities.

Mongolia

Active faults are the main sources of disastrous earthquake in Mongolia like the 1957 Gobi-Altai earthquake. The number of fatalities by earthquake in Mongolia has been small because those earthquakes struck remote areas; for example, none of the two M8.0 inland earthquakes in 1905 caused fatalities.

Nepal

Himalayan collision zone (Himalayan Front fault) is the main source of disastrous earthquake in Nepal. The 2015 Gorkha earthquake is typical with many death caused by structural damage and landslides. The 1934 Bihar and 1988 Udayapur earthquakes are also shown.

Pakistan

Active faults are the main sources of disastrous earthquake in Pakistan. The 2005 Kashimir and the 1935 Quetta earthquakes are the deadliest with more than 50,000 fatalities.

Papua New Guinea

Subduction zone and active faults are the main sources of disastrous earthquakes in Papua New Guinea. Two disastrous earthquakes are listed. The 1976 Irian Jaya earthquake caused about 6,000 fatalities, 90 percent of them were caused by landslides. The 1998 Papua New Guinea earthquake is a subduction event of relatively small-magnitude (M7.1) but caused 2,200 deaths by a landslide-induced tsunami.

Philippines

Subduction zones and active faults are the main sources of disastrous earthquakes in the Philippines. The 1990 Luzon earthquake is the deadliest inland earthquake. The 1976 Moro Gulf earthquake caused tsunami resulting in more than 7,000 fatalities.

Taiwan

Taiwan lies on the plate boundary and many shallow earthquakes occur. The 1906 Meishan, 1935 Hsinchu and 1999 Chi-Chi earthquakes caused fatalities, more than 1,000 of which were mainly due to structural failures.

Thailand

Seismicity in Thailand is low. Some damaging earthquakes are known in northern area.

Vietnam

Active faults are known in Vietnam, but recent earthquakes (e.g., 1983 M6.8 event; Ngo *et al.*, 2008) were not disastrous.

Earthquake fatalities in Afghanistan, Bhutan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, and northeastern part of Iran are also shown on the map.

(Masayuki Yoshimi)

6. Tsunami Hazards

Tsunami hazard distribution is compiled to facilitate visual understanding of the occurrence, extent and severity of tsunamis. This will also increase people's awareness on the importance of tsunami disaster mitigation endeavors. The map illustrates the regions affected by eight tsunami events which have caused considerable damages in East Asia area; 1771 Meiwa (Yaeyama), 1792 Unzen, 1883 Krakatau Volcano, 1976 Moro Gulf (Mindanao), 1983 Sea of Japan, 1998 Papua New Guinea, 2004 Indian Ocean and 2011 Japan Tohoku tsunamis. Brief description of tsunami is shown in Table 4.

The eight tsunami events were selected primarily on the basis of their severity (number of casualties) using a list of historical tsunami events (Global Historical Tsunami Events and Runups) on NGDC/WDS Global Historical Tsunami Database. However, some events have been excluded from the map illustration to avoid overlap with other tsunami events (for example, 1498 Meio (Nankai), 1707 Hoei (Nankai), and 1896 Sanriku tsunamis overlapped by 2011 Japan Tohoku tsunami around Japan). In addition, some disastrous events of which there are insufficient data of tsunami heights or uncertain evidences that distinguish tsunamis from other events such as storm and flooding were also not included in the map illustration. In contrast, 1976 Moro Gulf (Mindanao) tsunami, 1983 Sea of Japan tsunami, and 1998 Papua New Guinea tsunami are selected for illustration in spite of relatively minor damages. This is because they represent local tsunami disasters with wide extent of tsunami waves.

Coastal lines that have been severely affected by these tsunami events are highlighted in blue (seismic tsunamis) and pink (volcanogenic tsunamis). The colored lines indicate the regions with roughly 1m and higher runup height, except in the case of 2004 Indian Ocean tsunami with roughly 2m and higher runup height. The regions were determined by the data of runup heights in the historical documents, survey reports, scientific articles, numerical simulation results, and online databases cited in Table 4. It is noteworthy that the extent of these regions contains some degree of inaccuracy stemming from the quality and quantity of referred information. Maximum runup height of some tsunami event and its observation location are also indicated by blue bar and red circle on the map, respectively.

In East Asia area, tsunami events are usually triggered by seismic activity along subduction zones around the Pacific and Indian Ocean Rim. In some cases, tsunami waves are caused by other events such as an earthquake outside the subduction zone, volcanic eruption, onshore and submarine landslide. Each tsunami event is briefly described as follows (also see Table 4).

Table 4. List of the tsunami events.

Tsunami event name	Date	Cause	Approx. fatality	Approx. maximum runup height (location)
1. Japan Tohoku	11 Mar. 2011	Earthquake	18,378	40 m (Iwate, Japan)
2. Indian Ocean	26 Dec. 2004	Earthquake	290,000**	51 m (Banda Ache, Indonesia)
3. Papua New Guinea	17 Jul. 1998	Earthquake and submarine landslide	Over 2,200**	15 m (Sandaun, Papua New Guinea)
4. Sea of Japan	26 May 1983	Earthquake	103	15 m (Akita, Japan)
5. Moro Gulf (Mindanao)	16 Aug. 1976	Earthquake	Over 8,000**	4 m (Moro Gulf, Philippines)
6. Krakatau Volcano	27 Aug. 1883*	Volcanic eruption	36,417**	42 m (Sunda Strait, Indonesia)
7. Unzen	21 May 1792*	Debris avalanche by volcanic earthquake	10,000	50 m (Nagasaki, Japan)
8. Meiwa (Yaeyama)	24 Apr. 1771*	Earthquake and submarine landslide?	12,000	30 m (Ishigaki Island, Japan)
Sanriku	15 Jun. 1896	Earthquake	22,066**	38.2m (Iwate, Japan)
Hoei (Nankai)	28 Oct. 1707*	Earthquake	over 5,000**	27 m (Kochi, Japan)
Meio (Nankai)	20 Sept. 1498*	Earthquake	over 26,000**	12.6 m (Shizuoka, Japan)

* Local date
** Total fatalities in the event

1771 Meiwa (Yaeyama) tsunami

The Meiwa (Yaeyama) tsunami occurred in April 24, 1771 around Ryukyu Islands, Japan. It was triggered by an earthquake and probably by an accompanying submarine landslide (e.g., Matsumoto and Kimura, 1993), though it is still controversial. Based on historical documents, about 12,000 people were killed by the disaster, and Imamura (1938) estimated the earthquake magnitude at Mw 7.4. Goto *et al.* (2010) concluded that maximum runup height was estimated at 30m on Ishigaki Island, on the basis of historical documents and distribution of coral boulders.

1792 Unzen tsunami

The Unzen tsunami occurred on May 21, 1792 in the Ariake Bay, Japan. It was caused by the volcanic debris avalanche from Mt. Mayuyama, which was triggered by volcanic earthquake. Tsunami was propagated over the Ariake Bay and hit the opposite side (Kumamoto district). Based on historical documents analysis, Tsuji and Hino (1993) concluded that the tsunami casualties were 5,158 in Kumamoto district. They argued that the overall death toll may be over 10,000, and more than 15,000 people were killed through a sequence of the event. Akagi (2001) reported that maximum runup height reached about 50m based on his paleographical researches in the Nagasaki district.

1883 Krakatau Volcano tsunami

The Krakatau tsunami occurred on August 27, 1883 around the Sunda Strait, Indonesia. It was caused by the devastating eruption of Krakatau volcano. The maximum runup height reached 42m along the northern coast of the Sunda Strait (Choi *et al.*, 2003). Pararas-Carayannis (2003) reported 36,417 people were killed through a sequence of the events.

1976 Moro Gulf (Mindanao) tsunami

The Moro Gulf tsunami occurred on August 16, 1976 in Mindanao Island, Philippines. It was caused by an earthquake with a magnitude of 8.0, and killed over 7,500 people (Soloviev *et al.*, 1992). The maximum runup height reached 4-5m around Moro Gulf based on field investigations (Nakamura, 1977; Soloviev *et al.*, 1992).

1983 Sea of Japan tsunami

The Sea of Japan tsunami occurred on May 26, 1983 in the Sea of Japan. It was caused by an earthquake with a moment magnitude of 7.7 (Kanamori and Astiz, 1985). The tsunami waves hit the coastal areas around the Sea of Japan with a maximum height of 15m in Akita, Japan (Shuto, 1983; Hatori, 1991; Disaster Control Research Center (DCRC), Graduate School of Engineering, Tohoku University and Japan Nuclear Energy Safety Organization (JNES), 2010). The tsunami waves killed 100 people in Japan and three people in South Korea (Lander *et al.*, 2003).

1998 Papua New Guinea tsunami

The Papua New Guinea tsunami occurred on July 17, 1998 in Sandaun Province, Papua New Guinea. It was caused by a huge submarine landslide triggered by a relatively small earthquake with a magnitude of 7.1 (Tappin *et al.*, 2008). The tsunami waves with a maximum height of 15m killed more than 2,200 people (Lander *et al.*, 2003; Joku *et al.*, 2007). Davies *et al.* (2003) reported a wide extent of tsunami damages.

2004 Indian Ocean tsunami

The Indian Ocean tsunami occurred on December 26, 2004 in northwestern of Sumatra, Indonesia. It was caused by the Sumatra-Andaman earthquake with a magnitude of 9.1 (Chlieh *et al.*, 2007). The tsunami waves with a maximum height of 51m (Kim *et al.*, 2013) killed approximately 290,000 people around the Indian Ocean. Many measurements of runup height around the Indian Ocean have been published (e.g., Narayan *et al.*, 2005; Choi *et al.*, 2006; Tsuji *et al.*, 2006; Research Group on the December 26, 2004 Earthquake Tsunami Disaster of Indian Ocean, 2007). Data obtained from numerical simulation result for Indian Ocean Tsunami was used to complement the field measurements (Research Group on The December 26, 2004 Earthquake Tsunami Disaster of Indian Ocean, 2005).

2011 Japan Tohoku tsunami

The Japan Tohoku tsunami occurred on March 11, 2011 along the Japan Trench. It was caused by the East off Tohoku earthquake with a magnitude of 9.1 (Hirose *et al.*, 2011). The tsunami waves with a maximum height of about 40m (The 2011 Tohoku Earthquake Tsunami Joint Survey Group, 2011; Goto *et al.*, 2012), caused 18,378 fatalities (Mizutani, 2012). The 2011 Tohoku Earthquake Ts unami Joint Survey Group (2011) summarized the data of runup height measured by many researchers.

(Dan Matsumoto)

7. Volcanoes in Eastern Asia region

Distribution of Holocene volcanoes (<10ka) is shown on this hazard information map. The distribution and names of the volcanoes are based on "Volcanoes of the World (third edition)" (Siebert *et al.*, 2010). However, the distributions and name of the volcanoes in the Philippines are based on active volcanoes defined by PHIVOLCS. Most of the volcanoes are distributed in island arcs. Although, several volcanoes are distributed in the continental region. The total number of volcanoes in each country shown on the map are as follows: Indonesia (142), Japan (132), Papua New Guinea (56), Philippines (22), U.S.A. (19), China (12), Taiwan (7), Russia (6), Vietnam (6), Mongolia (5), R. Korea (3), D.P.R. Korea (3), Myanmar (3), Afghanistan (2), Malaysia (1) , and Pakistan (1) .

(Shinji Takarada)

8. Caldera, pyroclastic fall and ignimbrite

East and Southeast Asia (excluding Russia and the territories of the United States) experienced 3,446 eruptions during Holocene time based on the database of Smithsonian Global Volcanism Program (2013). Sorting by Volcanic Explosivity Index (VEI; Newhall and Self, 1982) allows us to list up 4 eruptions of VEI7, 19 eruptions of VEI6, and the rest of them are VEI5 or lesser (Table 5). There is no eruption of VEI8 or larger during Holocene time. The location of eruption is shown as solid triangle with resulting caldera rim of present topographic depression. Extent of pyroclastic fall deposit is shown as broken line mostly based on literature describing the area of pyroclastic fall deposits that currently exist. Exceptionally, recent eruptions including eyewitness observation of pyroclastic fall enabled us to draw wider extent of pyroclastic fall in Krakatau (1883AD) and Pinatubo (1991AD) cases. These two criteria are ideally identical but highly dependent on the conditions during observation and/or survey performed in each country. On this map, we adopted 4 eruptions of VEI7 (Tambora 1815AD, Rinjani 1257AD, Chambaishan 938AD, Kikai 7.3ka), and 7 eruptions of VEI6 (Pinatubo 1991AD, Krakatau 1883AD, Rabaul 6C, Witori 3.4ka, Mashu 7.6ka, Ulreung 10.7ka, and Moekeshi 9.5ka; Table 6). Lack of distribution information for the 6 eruptions in literature reflects the missing distribution in oceanic area. We added 3 Pleistocene large-scale eruptions (Aira 30ka, Toba 74ka, and Aso 90ka), which are well-documented and can be used for comparative

Table 5. Frequency of VEI of Holocene eruption occurred in East and Southeast Asia, excluding Russia and United States.

VEI	Number
8	0
7	4
6	19
5	37
4	144
3	384
2	1,728
1	534
0	88
not mentioned	508

Table 6. List of Holocene pyroclastic fall eruptions shown on the map.

Volcano	Age	VEI	Reference
Tambora	1815AD	7	Self *et al.* (2004), Zollinger (1855), Kandlbauer and Sparks (2014)
Rinjani	1257AD	7	Lavigne *et al.* (2013)
Changbaishan	938AD	7	Machida and Arai (2003), Wei *et al.* (2013), Horn and Schmincke (2000)
Kikai	7.3 ka	7	Machida and Arai (1978), Machida and Arai (2003)
Pinatubo	1991AD	6	Paladio-Melosantos *et al.* (1996)
Krakatau	1883AD	6	Verbeek (1885), Simkin and Fiske (1983)
Rabaul	6th century	6	Walker *et al.* (1981), Nairn *et al.* (1995), Nairn *et al.* (1989)
Witori	3.4 ka	6	Machida *et al.* (1996)
Mashu	7.6 ka	6	Katsui *et al.* (1975), Kishimoto *et al.* (2009)
Ulreung	10.7 ka	6	Lim *et al.* (2008), Machida (1990), Machida and Arai (1983)
Moekeshi	9.4 ka	6	Nakano *et al.* (2001), Nakagawa *et al.* (2013)
Pleistocene well-documented eruptions for comparison			
Aira	30 ka	7	Machida and Arai (1988), Machida and Arai (2003), Kawai and Miyake (1999)
Aso	90 ka	7	Machida *et al.* (2003), Machida and Arai (2003)
Toba	74 ka	8	Ninkovich *et al.* (1978), Self (2006), Lee *et al.* (2004)

examples for hazard assessment.

Distributions of calderas and large-scale ignimbrites (pyroclastic flow deposits; VEI6-8) are shown on the hazard information map. Information about the distribution of large-scale ignimbrites is very useful for the evaluation of hazards and risk mitigations for the future volcanic catastrophic events. The large-scale ignimbrites are shown on the map as “Qp”. Twelve large-scale ignimbrites are selected on the map (Table 7). We adapted one ignimbrite of VEI8: Toba (74ka; Toba Caldera, Indonesia; 2,500-3,000km^3), seven ignimbrite of VEI7: Aso 4 (90ka; Aso Caldera, Japan; 600km^3), Ito (30ka; Aira Caldera, Japan, 350km^3), Shikotsu (40ka; Shikotsu Caldera, Japan; 300km^3), Toya (110ka; Toya Caldera, Japan; 170km^3), Kussharo 4 (120ka; Kussharo Caldera, Japan; >150km^3), Changbaishan (938AD; Tianchi volcano, China and North Korea; >100km^3), and Tambora (1815AD; Tambora Caldera, Indonesia; 100km^3), four ignimbrite of VEI6: Hachinohe (15ka; Towada Caldera, Japan; 20km^3), Krakatau (1883AD; Krakatau Caldera, Indonesia; 13.6km^3), Pinatubo (1991AD; Pinatubo volcano, Philippines; 10.4km^3), and Rabaul (540AD; Rabaul Caldera, Papua New Guinea; 11km^3).

Table 7. List of large-scale ignimbrites shown on the map.

Ignimbrite	Age	Source	Volume (km^3)	VEI	Region, Country	Reference
Toba	74ka	Toba Caldera	2,500-3,000	8	Sumatra, Indonesia	Timmreck *et al.* (2012), Aldiss *et al.* (1983), Acharyya and Basu (1993), Rose and Chesner (1987)
Aso 4	90ka	Aso Caldera	600	7	Kyushu, Japan	Ono *et al.* (1977), Ono and Watanabe (1985), Machida and Arai (2003)
Ito	30ka	Aira Caldera	350	7	Kyushu, Japan	Aramaki (1984), Machida and Arai (2003)
Shikotsu	40ka	Shikotsu Caldera	300	7	Hokkaido, Japan	Yamagata (1992), Machida and Arai (2003)
Toya	110ka	Toya Caldera	170	7	Hokkaido, Japan	Okumura and Sangawa (1984), Machida and Arai (2003)
Kussharo 4	120ka	Kussharo Caldera	>150	7	Hokkaido, Japan	Okumura (1991), Machida and Arai (2003)
Changbaishan	938AD	Tianchi (Changbaishan, Baitoushan) volcano	>100	7	Ryanggang, North Korea and Jilin, China	Wei *et al.* (2013), Taniguchi (2004)
Tambora	1815AD	Tambora Caldera	100	7	Sumbawa, Indonesia	Sigurdsson and Carey (1989), Kandlbauer and Sparks (2014)
Hachinohe	15ka	Towada Caldera	20	6	Tohoku, Japan	Hayakawa (1983), Nakawaga *et al.* (1972), Machida and Arai (2003)
Krakatau	1883AD	Krakatau Caldera	13.6	6	Sunda Strait, Indonesia	Sigurdsson *et al.* (1991)
Rabaul	540AD	Rabaul Caldera	11	6	East New Britain, Papua New Guinea	Nairn *et al.* (1995), McKee *et al.* (1985), Walker *et al.* (1981)
Pinatubo	1991AD	Pinatubo volcano	10.4	6	Luzon, Philippines	Newhall and Punongbayan (1996)

VEI: Volcanic Explosivity Index (Newhall and Self, 1982)
Volume: include co-ignimbrite ash

(Ryuta Furukawa and Shinji Takarada)

9. Fatalities of major volcanic events

Fatalities of major volcanic events are compiled to facilitate visual understanding of volcanic disasters in Eastern Asia. The number of fatalities (deaths) and the main causes of deaths due to volcanic events are displayed. Five to thirty worst top volcanic events are chosen in each country: Japan (24; Table 8), Philippines (15; Table 9), Indonesia (30; Table 10) and Papua New Guinea (5; Table 11). The number of fatalities is categorized by seven causes; pyroclastic flow (pink), debris avalanche (yellow), tephra fall and ballistic (green), lahar (blue), tsunami (light blue), volcanic gas (orange) and other related death (purple; such as epidemic and starvation). The fatalities data are compiled mainly on the basis of Siebert *et al*. (2010).

Japan

The worst top 24 fatalities caused by volcanic events in Japan after 1400AD are listed in Table 8. The most hazardous volcanic event in Japan was the 1792 Unzen Mayuyama debris avalanche, which caused 15,000 fatalities. The debris avalanche produced large tsunami within Ariake Bay area and caused 10,000 fatalities (Chapter 6). The debris avalanche killed 5,000 people. The 2nd hazardous volcanic event was the 1783 Asama eruption, which caused 1,491 fatalities due to pyroclastic flow, debris avalanche, and lahar. The 3rd event was the Oshima-Oshima 1741 debris avalanche, which caused 1,467 fatalities at the coastal area due to tsunami. The 4th event was the Hokkaido-Komagatake 1640 debris avalanche, which caused 700 fatalities in Funka Bay area due to tsunami. The 5th event was Bandai 1888 debris avalanche, which caused 477 fatalities. The 6th event was the Tateyama 1958 debris avalanche, triggered by the Hietsu earthquake, and caused 279 fatalities mainly due to the associated lahar (This event is also one of the earthquake hazards). Table 8 indicates that the main cause of death from volcanic events in Japan is debris avalanche and associated tsunami or lahar. Recently, the number of fatalities of the 1822 Usu Bunsei pyroclastic flow was re-evaluated at 78 (Endo and Doi, 2013).

Table 8. Worst top 24 fatalities caused by volcanic events in Japan (after 1400AD).

Number	Volcanic Event	Year	Date	Fatalities (total)	Event Type	Causes and fatalities	VEI
1	Unzen Mayuyama	1792	May 21	15,000	Debris avalanche	T (10,000), D (5,000)	-
2	Asama Tenmei	1783	Aug. 5	1,491	Pyroclastic flow, debris avalanche	L (1,025), D (466)	4
3	Oshima-Oshima	1741	Aug. 27	1,467	Debris avalanche	T (1,467)	4
4	Hokkaido Komagatake	1640	May 24	700	Debris avalanche	T (700)	5
5	Bandai	1888	July 15	477	Debris avalanche, phreatic eruption	D (377), P (100)	4
6	Tateyama	1958	Apr. 9	279	Debris avalanche	L (279)	-
7	Nasu	1410	Mar. 5	180	Pyroclastic flow, tephra fall, lava flow	L (180)	3
8	Sakurajima An-ei	1779	Nov. 8	153	Pyroclastic flow, lava flow, tephra	F (100), T (53)	5
9	Tokachidake	1926	May 24	144	Pyroclastic flow, tephra fall, lahar	L (141), F (3)	2
10	Aogashima	1785	Apr. 18	130	Pyroclastic fall, lava flow	R (130)	3
11	Izu Torishima	1902	Aug. 7	125	Phreatic eruption	P (125)	2-3
12	Usu Bunsei	1822	Mar. 23	78	Pyroclastic flow (surge)	P (78)	4
13	Adatara	1900	July 17	72	Pyroclastic flow	P (72)	2
14	Ontake	2014	Sep. 27	63	Phreatic eruption	F (63)	2
15	Sakurajima Taisho	1914	Jan. 12	63	Pyroclastic flow, lava flow, tephra	R (40), F (23)	4
16	Kuchinoerabu-jima	1841	Aug. 1	>50	Pyroclastic flow	P (>50)	2-3
17	Unzen Heisei	1991	June 3	43	Pyroclastic flow	P (43)	2
18	Sakurajima An-ei	1781	Apr. 11	38	Pyroclastic flow, lava flow, tephra	T (38)	4
19	Bayonnaise Rocks	1952	Sep. 24	31	Base surge	P (31)	2
20	Esan	1846	-	>30?	Lahar	L (>30)	-
21	Unzen	1664	Apr. 15	>30	Lahar	L (>30)	-
22	Ontake	1984	Sep. 14	29	Debris avalanche, landslide	D (29)	-
23	Hokkaido Komagatake	1856	Sep. 25	25	Pyroclastic flow, tsunami	P (23), F (2)	4
24	Aso	1958	June 24	12	Phreatic eruption	F (12)	2

P: Pyroclastic flow and surge, F: Tephra fall and ballistics, T: Tsunami, L: Lahar, D: Debris avalanche, and R: Related death

Philippines

The worst top 15 fatalities caused by volcanic events in the Philippines after 1400AD are listed in Table 9. The most hazardous volcano in the Philippines is Mayon. Nine volcanic events of Mayon volcano are included in the worst 15 volcanic events. The worst event in Philippines is the Mayon 1875 lahar, which caused more than 1,500 fatalities. The 2nd worst event is the Taal 1911 eruption, which caused more than 1,335 fatalities

Table 9. Worst top 15 fatalities caused by volcanic events in Philippines (after 1400AD).

Number	Volcanic Event	Year	date	Fatalities	Event Type	Causes and fatalities	VEI
1	Mayon	1875	-	>1,500	Lahar (rain)	L (>1,500)	-
2	Taal	1911	Jan. 30	>1,335	Pyroclastic flow	P (>1,100), T (>235)	3
3	Mayon	2006	Nov. 30	1,266	Lahar	L (1,266)	-
4	Mayon	1814	Feb. 1	1,200	Pyroclastic flow and Lahar	P (1,100), L (100)	4
5	Pinatubo	1991	June 15	800	Pyroclastic flow and tephra fall	P (25), L (100), R (450)	6
6	Hibok-Hibok	1951	Dec. 4	>500	Pyroclastic flow	P (>500)	1-2
7	Mayon	1897	June 25	350	Pyroclastic flow and tephra fall	P (310), F (40)	4
8	Taal	1965	Sep. 28	>250	Pyroclastic flow and Base surge	P (>150), T (>100)	4
9	Mayon	1981	June 30	>200	Lahar (rain)	L (>200)	-
10	Parker	1995	Sep. 6	<100	Lahar (rain)	L (<100)	-
11	Mayon	1993	Feb. 2	77	Pyroclastic flow	P (77)	2
12	Hibok-Hibok	1950	Sep. 15	68	Pyroclastic flow	P (68)	1-2
13	Mayon	1766	Oct. 23	49	Lahar	L (49)	-
14	Mayon	1853	Sep. 13	34	Pyroclastic flow	P (34)	3
15	Mayon	1887	Mar. 9	15	Pyroclastic flow and tephra fall	F (15)	3

P: Pyroclastic flow and surge, F: Tephra fall and ballistics, T: Tsunami, L: Lahar, and R: Related death due to pyroclastic flow. The 3rd worst event is the Mayon 2006 lahar, which caused 1,266 fatalities. The 4th worst event is also the Mayon 1814 eruption, which caused 1,200 fatalities due to pyroclastic flow and lahar. The 5th event is the Pinatubo 1991 eruption, which caused 800 fatalities. The causes of the 1991 event fatalities were pyroclastic flow (250), lahar (100) and related death mainly due to disease at evacuation camp (450). The main causes of fatalities in the Philippines are pyroclastic flows and lahars as clearly shown on the list.

Indonesia

The worst top 30 fatalities caused by volcanic events in Indonesia after 1400AD are listed in Table 10. The worst event is the Tambora 1815 caldera-forming eruption (VEI7, Table 7) which caused 60,000 fatalities. About 11,000 people were killed by pyroclastic flows and about 49,000 people died due to famine and disease on Sumbawa and Lombok islands. The 2nd worst event is the Krakatau 1883 caldera-forming eruption (VEI6, Table 7), which caused 36,417 fatalities. About 2,000 people were killed by pyroclastic flows and 34,417 people were killed by the associated tsunami. The 3rd worst event is the Kelut 1586 eruption, which caused about 10,000 fatalities due to pyroclastic flows. The 4th worst event is also the Kelut 1919 eruption, which caused about 5,110 fatalities due to pyroclastic flow and lahar. The 5th event is the Galunggung 1822 eruption, which caused 4,011 fatalities due to pyroclastic flow. The 1979 eruption at Dieng volcano caused 149 fatalities due to volcanic gas. The main causes of fatalities in Indonesia are pyroclastic flows, tsunamis, lahars, and debris avalanches as shown in Table 10.

Table 10. Worst top 30 fatalities caused by volcanic events in Indonesia (after 1400AD).

Number	Volcanic Event	Year	Date	Fatalities (total)	Event Type	Causes and fatalities	VEI
1	Tambora	1815	Apr. 10	60,000	Pyroclastic flow and tsunami	P (11,000) and R (49,000)	7
2	Krakatau	1883	Aug. 27	36,417	Pyroclastic flow and tsunami	P (2,000), T (34,417)	6
3	Kelut	1586	-	10,000	Pyroclastic flow?	P (10,000)	-
4	Kelut	1919	May 19	5,110	Pyroclastic flow and lahar	L (5,110)	4
5	Galunggung	1822	Oct. 8	4,011	Pyroclastic flow	P (3,600), L (411)	5
6	Merapi	1672	Aug. 4	3,000	Pyroclastic flow	P (3,000)	3
7	Awu	1711	Dec. 11	3,000	Pyroclastic flow	P (3,000)	3
8	Papandayan	1772	Aug. 12	2,957	Debris avalanche	D (2,957)	3
9	Awu	1856	Mar. 2	2,806	Pyroclastic flow	P (2,806)	3
10	Makian	1760	-	2,000	Pyroclastic flow and lahar	L (2,000)	4
11	Awu	1892	June 7	1,532	Pyroclastic flow and lahar	P (1,150), L (382)	3
12	Merapi	1930	Dec. 18	1,369	Pyroclastic flow and lahar	P (1,369)	3
13	Gamalama	1775	-	1,300	Pyroclastic flow (base surge)	P (1,300)	3
14	Agung	1963	Mar. 17	1,148	Pyroclastic flow, tephra fall and lahar	P (820), F (163), L (165)	4
15	Raung	1638	-	>1,000	Lahar	L (>1,000)	-
16	Awu	1812	Aug. 6	953	Pyroclastic flow and lahar	P (700), L (253)	4
17	Iliwerung	1979	July 18	539	Debris avalanche and Tsunami	T (539)	3
18	Ruang	1871	Mar. 3	400	Collapse of lava dome and tsunami	T (400)	2
19	Sumeru	1981	May 14	372	Lahar	L (372)	-
20	Merapi	2010	Oct.-Dec.	353	Pyroclastic flow	P (353)	3
21	Makian	1861	Dec. 29	326	Pyroclastic flow	P (326)	4
22	Paluweh	1928	Aug. 4	226	Explosive eruption and Tsunami	T (226)	3
23	Sumeru	1909	Aug. 29	221	Lahar	L (221)	-
24	Kelut	1966	Apr. 26	215	Pyroclastic flow and lahar	L (214), P (1)	4
25	Sorikmarapi	1892	May 21	180	Lahar	L (180)	-
26	Merapi	1872	Apr. 17	170	Pyroclastic flow	P (170)	2
27	Dieng	1979	Feb. 20	149	Volcanic gas	G (149)	1
28	Sumeru	1976	Nov. 13	133	Pyroclastic flow and lahar	L (133)	2
29	Kaba	1833	Nov. 24	126	Lahar	L (126)	-
30	Dieng	1944	Dec. 4	117	Phreatic eruption	F (117)	2

P: Pyroclastic flow and surge, F: Tephra fall and ballistics, T: Tsunami, L: Lahar, D: Debris avalanche, G: Volcanic gas, and R: Related death

Table 11. Worst top 5 fatalities caused by volcanic events in Papua New Guinea (after 1400AD).

Number	Volcanic Event	Year	date	Fatalities	Event Type	Causes and fatalities	VEI
1	Ritter Island	1888	Mar. 13	3,000	Debris avalanche and tsunami	T (3,000)	2
2	Lamington	1951	Jan. 21	2,942	Pyroclastic flow	P (2,942)	4
3	Long Island	1660	-	2,000	Pyroclastic flow and tsunami	P (1,000), T (1,000)	6
4	Rabaul	1937	May 29	507	Pyroclastic flow and tephra fall	P (300), F (207)	4
5	Rabaul	1850	-	>500	Pyroclastic flow and tephra fall	F (>500)	4

P: Pyroclastic flow and surge, F: Tephra fall and ballistics, and T: Tsunami

The worst top 5 fatalities caused by volcanic events in Papua New Guinea after 1400AD are shown in Table 11. The worst event is the Ritter Island 1888 debris avalanche, with 3,000 fatalities due to tsunami. The 2nd worst event is the Lamington 1951 eruption, with 2,942 fatalities due to pyroclastic flows. The 3rd worst event is the Long Island 1660 eruption, with about 2,000 fatalities due to pyroclastic flow and tsunami. The 4th event is the Rabaul 1937 eruption, with 507 fatalities due to pyroclastic flow and tephra falls. The 5th event is also the Rabaul 1850 eruption, with more than 500 fatalities due to tephra fall. The main causes of fatalities in Papua New Guinea are tsunami, pyroclastic flow, and tephra fall.

(Shinji Takarada)

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1. はじめに

東アジア地域は，地震・津波・火山噴火などの大規模自然災害が多数発生している．今日の高度に発達した国際経済社会では，一旦大規模災害が発生すれば，被災国のみならず，周辺諸国にも多大な影響が起こり得る．こうした大規模自然災害への対策は，人間社会の持続的発展のためには，必要不可欠である．今後，大規模な地震・津波・火山噴火のリスク軽減のための国際的な枠組みを構築し，継続的な努力を進めて行くことが重要である．2004 年 12 月 26 日のスマトラ-アンダマン地震や 2011 年 3 月 11 日の東北地方太平洋沖地震は，低頻度大規模自然災害の情報整備やシステムの構築が急務であることを示している．2000 年 4 月のアイスランドの Eyjafjallajökul 噴火では，ヨーロッパで一日あたり 2 万便 の欠航が起こり，火山噴火による航空機の被害としては戦後最大の規模となった．アジア太平洋地域地震火山噴火リスクマネジメント（G-EVER）コンソーシアムでは，地震・津波・火山の災害軽減を目指し，アジア太平洋地域の各国と協力し活動を行っている．

東アジア地域地震火山災害情報図は，国立研究開発法人産業技術総合研究所地質調査総合センターの G-EVER 推進チームが中核となり，アジア各国の地質調査機関 (PHIVOLCS, CVGHM, CEA, VAST, Academia Sinica) のメンバーと共に作成した災害情報図である．ここでは，東アジア地域の地質とテクトニクス（第 2 章），活断層（第 3 章），地震の震央と震源域の分布（第 4 章），主要地震の犠牲者（第 5 章），津波災害（第 6 章），火山の分布（第 7 章），カルデラ，降下火砕物（降下火山灰）と大規模火砕流（第 8 章），主要火山の犠牲者（第 9 章）について取りまとめている．

（佃　栄吉・宝田晋治）

2. 東アジア地域の地質

地震と火山による災害の発生は，その地域の地質と深く結び付いている．本地震火山災害情報図の基図となる地質図は，500 万分の 1 アジア地質図（Teraoka and Okumura，2011）及び 200 万分の 1 東・東南アジア地質図（Wakita *et al.*, 2004）を再編集した．災害情報図は，1,000 万分の 1 のスケールであるため，オリジナルの地質図から凡例を簡素化した．堆積岩類・火山岩類・変成岩類は，Q（第四紀；2.58-0 Ma），Tpn（古第三紀〜ジェラ紀；66.0-1.81 Ma），Qp（第四紀大規模火砕流；<74ka），TnQ（中期中新世〜カラブリアン；15-0.78 Ma），KTp（後期白亜紀〜始新世；100.5-33.9 Ma），Mz（中生代；252.1-66.0 Ma），PTr（後期ペルム紀〜中期三畳紀；259.8-236.8 Ma），Pz2（デボン紀〜前期三畳紀；294.6-236.8 Ma），Pz1（後期原生代〜シルル紀；1000-419.2 Ma），SD（シルル紀〜デボン紀；443.4-358.9 Ma），Pz（古生代； 541.0-252.1 Ma），PrPz1（中期原生代〜前期オルドビス紀；1600-471.8 Ma），P∈（先カンブリア紀；>541.0 Ma）に区分した．また，貫入岩類は Cz_i（古第三紀〜前期更新世；66.0-0.78 Ma），Mz_i（後期ペルム紀〜白亜紀；260.4-66.0 Ma），Pz2_i（後期古生代；419.2-252.1 Ma），Pz1_i（前期古生代；541.0-419.2 Ma），P∈_i（先カンブリア紀；>541.0 Ma）に区分した．顕生代火山岩類は，珪長質・酸性（流紋岩，デイサイト，粗面岩，粗面デイサイト），珪長質・酸性〜中性（流紋岩，デイサイト，安山岩，粗面岩，粗面デイサイト，粗面安山岩），中性（安山岩，玄武岩質安山岩，粗面安山岩，玄武岩質粗面岩），中性〜苦鉄質・塩基性（安山岩，玄武岩質安山岩，粗面安山岩，玄武岩質粗面岩，玄武岩，アルカリ玄武岩），苦鉄質・塩基性（玄武岩，アルカリ玄武岩），及び未区分に分類した．貫入岩類は，珪長質・酸性（花こう岩等），中性（閃緑岩等），

表 1．災害情報図に示した震源域の震源パラメータ
現地時間の日付がUTMの日付と異なる場合は，現地時間の日付を災害情報図では表示した．

Origin time (UT) (yyyy/mm/dd time)	Magnitude (M)	Moment M (Mw)	Latitute (N)	Longitude (E)	Depth (km)	Local time date	Location
2015/4/25 6:11	M7.8	Mw7.9	28.2	84.7	8.2		Gorkha, Nepal
2015/3/29 23:48	M7.5	Mw7.4	-4.7	152.6	41.0		New Ireland, Papua New Guinea
2014/11/15 2:31	M7.1	Mw7.0	1.9	126.5	45.0		Moucca Passage, Indonesia
2013/10/15 0:12	M7.1	Mw7.1	9.9	124.1	19.0		Bohol, Philippines
2012/8/31 12:47	M7.6	Mw7.6	10.8	126.6	28.0		East off Philippines
2012/4/11 8:38	M8.6	Mw8.6	2.3	93.1	20.0		Far off Sumatra, Indonesia
2012/4/11 10:43	M8.2	Mw8.2	0.8	92.5	25.1		West off North Sumatra, Indonesia
2011/3/11 5:46	M9.0	Mw9.0	38.3	142.5	20.0		East off Tohoku, Japan
2010/12/21 17:19	M7.4	Mw7.4	26.9	143.8	20.0	2010/12/22	Bonin, Japan
2010/10/25 14:42	M7.8	Mw7.8	-3.5	100.1	17.6		Mentawai, Indonesia
2010/4/13 23:49	M6.9	Mw6.9	33.2	96.7	15.0	2010/4/14	Qinghai (Yusu), China
2010/4/6 22:14	M7.8	Mw7.8	2.3	97.1	20.0	2010/4/7	West off North Sumatra, Indonesia
2009/9/2 7:55	M7.0	Mw7.0	-7.8	107.4	46.0		South off Java, Indonesia
2009/2/11 17:34	M7.1	Mw7.1	3.8	126.5	25.0	2009/2/12	Kepulayan, Indonesia
2009/1/3 19:43	M7.7	Mw7.6	-0.5	132.7	30.0	2009/1/4	Northeast Iryan Jaya, Indonesia
2008/11/16 17:02	M7.4	Mw7.3	1.3	122.1	34.0	2008/11/17	North Sulawesi, Indonesia
2008/5/12 6:28	M7.9	Mw6.9	31.0	103.4	10.0		Wenchuan, China
2007/9/12 11:10	M8.5	Mw8.5	-4.4	101.5	34.0		South off Sumatra, Indonesia
2007/1/21 11:27	M7.5	Mw7.5	1.1	126.3	22.0		Molucca Sea, Indonesia
2006/12/26 12:26	M7.0	Mw7.0	21.8	120.6	10.0		South off Taiwan
2006/7/17 8:19	M7.7	Mw7.7	-9.3	107.3	25.3		South off Java, Indonesia
2005/10/8 3:50	M7.6	Mw7.6	34.5	73.6	15.0		Pakistan
2005/3/28 16:09	M8.6	Mw8.6	2.1	97.2	30.0		Nias, Indonesia
2004/12/26 0:58	M9.1	Mw9.1	3.3	96.0	30.0		Sumatra, Indonesia
2004/11/11 21:26	M7.5	Mw7.5	-8.2	124.8	13.0	2004/11/12	Alor, Indonesia
2003/9/25 19:50	M8.3	Mw8.3	41.9	143.9	30.0	2003/9/26	Tokachi-oki, Japan
2003/5/26 19:23	M6.9	Mw6.9	2.3	128.9	31.0	2003/5/27	North off Halmahera, Indonesia
2002/11/2 1:26	M7.2	Mw7.2	2.9	96.1	28.1		Northwest off Sumatra, Indonesia
2002/10/10 10:50	M7.6	Mw7.5	-1.7	134.3	20.0		West Iriyan Jaya, Indonesia
2002/9/8 18:44	M7.6	Mw7.6	-3.4	143.0	13.0	2002/9/9	North New Guinea, Papua
2002/3/5 21:16	M7.5	Mw7.5	6.0	124.2	25.0	2002/3/6	South Mindanao, Philippines
2001/11/14 9:26	M7.8	Mw7.8	36.0	90.5	10.0		Kunlunshan, China
2001/10/19 3:28	M7.5	Mw7.4	-4.1	124.0	15.0		Banda Sea, Indonesia
2001/1/1 6:57	M7.4	Mw7.4	6.9	126.6	36.0		Southwest Mindanao, Philippines
2000/11/17 21:01	M7.8	Mw7.8	-5.5	151.9	37.4	2000/11/18	New Ireland, Papua New Guinea
2000/11/16 4:54	M8.0	Mw8.0	-4.0	152.3	30.0		New Ireland, Papua New Guinea
2000/8/4 21:13	M6.8	Mw6.8	48.7	142.4	15.0	2000/8/5	Uglegorsk, Sakhalin, Russia
2000/6/4 16:28	M7.9	Mw7.8	-4.6	102.1	35.0		South off Sumatra, Indonesia
2000/5/4 4:21	M7.5	Mw7.5	-1.1	123.6	30.0		East Sulawesi, Indonesia
1999/12/11 18:03	M7.2	Mw7.2	15.8	119.8	40.0	1999/12/12	West Luzon, Philippines
1999/9/20 17:47	M7.6	Mw7.6	23.8	120.8	25.0	1999/9/21	Chi-Chi, Taiwan
1999/3/4 8:52	M7.1	Mw7.1	5.3	121.8	15.0		Celebes Sea, Philippines
1998/11/29 14:10	M7.7	Mw7.7	-1.9	124.8	25.0		Taliabu, Indonesia
1998/10/28 16:25	M6.5	Mw6.5	0.9	125.8	35.0	1998/10/29	Molucca Sea, Indonesia
1998/5/3 23:30	M7.5	Mw7.4	22.5	125.5	20.0	1998/5/4	South off Ishigaki, Japan
1997/11/8 10:02	M7.5	Mw7.5	35.1	87.4	20.0		Xizang, China
1996/7/22 14:19	M7.0	Mw7.0	1.0	120.5	28.4		North Sulawesi, Indonesia
1996/6/11 18:22	M7.1	Mw7.1	12.7	125.2	31.7	1996/6/12	Samar, Phlippines
1996/4/29 14:40	M7.2	Mw7.2	-6.5	155.0	35.0	1996/4/30	Bougainville, Papua New Guinea
1996/2/17 5:59	M8.2	Mw8.2	-0.9	136.9	20.0		Irian Jaya, Indonesia
1996/1/1 8:05	M7.9	Mw7.9	0.7	120.0	33.5		North Sulawesi, Indonesia
1995/12/3 18:01	M7.9	Mw7.9	44.7	149.3	28.3	1995/12/4	East off Etrof, Japan
1995/8/16 10:27	M7.7	Mw7.7	-5.8	154.2	25.0		Bougainville, Papua New Guinea
1995/5/27 13:03	M7.0	Mw7.0	52.6	142.9	12.9		Neftegorsk, Sakhalin
1995/4/21 0:34	M7.2	Mw7.1	12.1	125.6	24.1		Samar, Phlippines
1994/12/28 12:19	M7.7	Mw7.7	40.5	143.4	24.8		Sanriku haruka-oki, Japan
1994/10/4 13:23	M8.3	Mw8.3	43.9	147.2	30.0		Hokkaido toho-oki, Japan
1994/6/2 18:17	M7.8	Mw7.8	-10.5	112.9	18.0	1994/6/3	South off Java, Indonesia
1994/1/21 2:24	M7.0	Mw6.9	1.1	127.7	19.2		Halmahera, Indonesia
1993/8/8 8:34	M7.8	Mw7.7	13.0	144.8	59.0		Guam, USA
1993/7/12 13:17	M7.7	Mw7.7	42.8	139.2	20.0		Hokkaido Nansei-oki, Japan
1992/12/12 5:29	M7.7	Mw7.7	-8.5	121.9	28.0		Flores, Indonesia
1992/5/17 10:15	M7.2	Mw7.2	7.2	126.7	30.0		Mindanao, Philippines
1991/12/22 8:43	M7.6	Mw7.6	45.5	151.1	25.3		East off Urup, Russia
1991/6/20 5:18	M7.5	Mw7.5	1.2	122.8	30.0		North Sulawesi, Indonesia
1990/7/16 7:26	M7.7	Mw7.7	15.7	121.2	24.4		Baguio, Luzon, Philippines
1990/4/18 13:39	M7.6	Mw7.6	1.2	122.9	36.6		North Sulawesi, Indonesia
1989/12/15 18:43	M7.5	Mw7.5	8.4	126.6	27.5	1989/12/16	Mindanao, Philippines
1988/2/24 3:52	M7.2	Mw7.2	13.5	124.6	28.1		Cataduanes, Philippines
1987/10/16 20:48	M7.3	Mw7.3	-6.2	149.1	45.0	1987/10/17	New Britain, Papua New Guinea
1986/11/14 21:20	M7.4	Mw7.3	24.0	121.8	35.0	1986/11/15	East Taiwan
1986/8/14 19:39	M7.5	Mw7.5	1.9	126.5	32.3	1986/8/15	Moucca Passage, Indonesia
1985/8/23 12:42	M7.0	Mw6.9	39.4	75.3	30.0		West Xinjiang, China
1983/5/26 3:00	M7.7	Mw7.7	40.4	139.2	15.1		Nihonkai-chubu, Japan
1982/1/11 6:10	M7.1	Mw7.1	13.9	124.4	31.8		Cataduanes, Philippines
1980/6/18 17:14	M6.9	Mw6.9	-5.1	152.2	51.0		New Britain, Papua New Guinea
1979/9/12 5:17	M7.5	Mw7.5	-1.7	136.0	20.0		Irian Jaya, Indonesia
1978/7/23 14:42	M7.2	Mw7.2	22.2	121.4	25.0		South off Taiwan
1978/6/12 8:14	M7.6	Mw7.6	38.2	142.0	45.0		off Miyagi, Japan
1978/3/23 3:14	M7.6	Mw7.6	44.2	149.0	35.0		South off Etrof, Japan
1977/8/19 6:08	M8.3	Mw8.3	-11.2	118.4	25.0		South off Sumbawa, Indonesia
1977/3/18 21:43	M7.2	Mw7.2	16.7	122.2	30.0	1977/3/19	Luzon, Philippines
1976/8/16 16:11	M8.0	Mw8.0	6.2	124.0	20.0	1976/8/17	Moro Gulf, Philippines
1976/7/27 19:42	M7.6	Mw7.6	39.6	118.1	15.3	1976/7/28	Tangshan, China
1975/10/31 8:28	M7.5		12.6	126.1	23.0		Samar, Philippines
1975/7/20 19:54	M7.3		-7.2	155.3	45.0	1975/7/21	Bougainville, Solomon
1973/6/17 3:55	M7.8		43.2	145.8	44.3		Nemuro offshore, Japan
1972/12/2 0:19	M8.0		6.4	126.6	60.0		Mindanao, Philippines
1972/4/25 19:30	M7.5		13.4	120.3	25.0	1972/4/26	Mindoro, Phlippines
1971/7/14 6:11	M8.0		-5.5	153.9	40.0		Papua New Guinea
1971/1/10 7:17	M7.7		-3.2	139.7	30.0		Irian Jaya, Indonesia
1970/4/12 4:01	M6.9		15.1	122.1	22.5		Luzon, Philippines
1970/4/7 5:34	M7.4		15.8	121.6	25.0		Luzon, Philippines
1970/1/4 17:00	M7.1		24.2	102.5	11.3	1970/1/5	Tonghai, China
1969/8/11 21:27	M8.2		43.4	147.9	30.0	1969/8/12	South off Shikotan, Japan
1968/8/10 2:07	M7.6		1.5	126.2	23.0		Molucca Passage, Indonesia
1968/8/1 20:19	M7.6		16.3	122.1	25.0	1968/8/2	Casiguran, Luzon, Phlippines
1968/5/16 0:49	M8.2		40.9	143.4	29.9		Tokachi-oki, Japan
1966/3/12 16:31	M7.5		24.1	122.6	30.0	1966/3/13	East off Taiwan
1965/1/24 0:11	M8.2		-2.6	126.0	20.0		Cream Sea, Indonesia
1964/6/16 4:01	M7.6		38.4	139.3	15.0		Niigata, Japan
1952/3/4 1:22	M8.1		42.1	143.9	45.0		Tokachi-oki, Japan
1951/11/24 18:50	M7.8		23.1	121.2	30.0	1951/11/25	Southwest of Taiwan
1950/8/15 14:09	M8.6		28.4	96.4	15.0		Assam, India
1946/12/20 19:19	M8.3		33.1	135.9	15.0	1946/12/21	Nankai, Japan
1944/12/7 4:35	M8.1		33.7	136.2	15.0		Tonankai, Japan
1935/12/28 2:35	M7.6		-0.3	98.3	30.0		West off Smatra, Indonesia
1934/1/15 8:43	M8.0		26.9	86.6	15.0		Bihar, Nepal
1927/5/22 22:32	M7.7		37.6	102.5	15.0	1927/5/23	Gulang, China
1923/9/1 11:58	M7.9		35.3	139.1	23.0		Kanto, Japan
1920/12/16 12:05	M8.3		36.9	105.6	15.0		Haiyuan, China
1905/4/4 0:49	M7.9		32.6	76.8	20.0		Kangra, India

苦鉄質・塩基性（はんれい岩等），及び超塩基性岩/オフィオライトに区分した．

比較的新しい火山岩類（Q，Tpn，TnQ 及び Cz_i）は，主に，日本，フィリピン，インドネシア，パプアニューギニアなどの島弧に分布している．従って，火山災害は主にこれらの国で発生している．インドとユーラシア大陸の衝突により，ヒマラヤ山脈と中国大陸は大きく変形している．このため，これらの地域では，内陸型の地震が発生している．世界最大の地震災害（M8.0，犠牲者数 83 万人）は，1556 年 1 月 23 日に中国の陝西省で発生している．

本災害情報図では，プレート境界を示している．このプレート境界は，Yeats（2012），Bird *et al.*（2003），Kato and Eastern Asia Natural Hazards Mapping Project（2002）等を基に作成した．フィリピン付近のデータは，PHIVOLCS（2008）を使用した．比較的大きい地震（M7-9）は，沈み込み帯で発生している（第 4 章）．本地震火山災害情報図の最大クラスの地震は，インドネシアの 2004 年 12 月 26 日スマトラ島沖地震（M9.1）と，日本の 2011 年 3 月 11 日東北地方太平洋沖地震（M9.0）である．

陸域と海域の地形陰影図は Etopo1 (Amante and Eakins, 2009) 及び SRTM30 Plus (Becker *et al.*, 2009) を使用した．

（宝田晋治）

3. 活 断 層

東アジアとその周辺に分布する活断層を示した．そのうち，活断層であることが確実なものを実線，活断層であると推定されるものを破線，伏在しているものを点線で示した．主要な活断層については断層名を示した．東アジアとその周辺では，プレート境界周辺のみならず，大陸地域にも多数の活断層が分布している．なお，本図を利用する際には，活断層の定義，調査研究の進展，編集に用いた基図の縮尺が，各国・地域によって異なることを反映して，活断層の位置や分布の精度が一様ではないことに注意が必要である．海域の活断層及び活褶曲は本図には示されていない．また，活断層のうち，活動性の低いものや長さの短いものについても本図に示されていないものがある．そのため，活断層が示されていない地域で大地震が発生する可能性がないわけではないことに注意されたい．

（丸山　正）

4. 震源と震源域

震源データ： 歴史地震（1000-1899 年）の震源パラメータは，The Global Historical Earthquake Archive（1000-1903）のデータを利用した（Global Earthquake Model，2015）．1900 年から 2011 年までの震源は，ISC-GEM（International Seismological Centre – Global Earth Model）のカタログ（Storchak *et al.*，2013）のパラメータを用いた．2012 年から 2015 年 9 月末までの震源パラメータは米国地質調査所の Preliminary Determination of Epicenters（以下，PDE と略す）を用いた．1900 年以降は，マグニチュード 6 以上を採用した．

大地震の震源領域（表 1）: 対象とした大地震は，米国地質調査所の PDE から震源の深さ 60 km 以浅でマグニチュードが 7.5 以上とした．フィリピンとその周辺は，地震の規模がやや小さいのでマグニチュード 7.0 以上とした．震源領域は本震後 1 ヶ月間の PDE による余震分布の主要領域を囲む形で決めた．しかし，日本とその周辺は日本の気象庁震源データを用いた．また，1920 年，1927 年，1950 年 と 1970 年 1 月 4 日の地震の場合は，余震データが無いか，乏しかったため余震域分布では決められなかった．そのため，Department of Earthquake Preparedness and Mitigation of State Seismological Bureau（1999）による震度分布図の震度 9 等震度線で代用した．1905 年の地震は，Avouac（2007）による領域を，1934 年の地震は Sapkota *et al.*（2013）による領域を利用した．

（石川有三）

5. 主要地震の犠牲者数

西暦 1850 年以降の主な地震の犠牲者数を示す．地震被害はハザード（例えば地震動）と暴露（例えば構造物の数量）及び脆弱性（耐震性，耐火性など）で決まる．暴露及び脆弱性は地域と時代による違いが大きいため，同規模の地震でも地域や時代によって被害（犠牲者数）が大きく異なる．そこで，この情報図では犠牲者の原因別内訳も可能な限り示し，防災上の要請に応えることとした．

犠牲者数 1,000 名以上の地震は全て示し，国単位でリスト化した．ただし，犠牲者数 1,000 名以上の地震数が 1 ～ 3 件の場合は犠牲者数 10～1,000 名の地震を 2 件追加して記載した．犠牲者数の最大値が 100～1,000 名の場合は最大 2 件，100 名未満の場合は 1 件の被害地震を掲載した．

英語版の解説文には各国の被害地震の特徴を記載した．これらは震源域の分布と密接に関連している．多数の犠牲者をもたらした地震の多い地域のうち，中国大陸と台湾は主に内陸地震，日本とインドネシアは内陸地震と海溝型地震によるものである．海溝型地震でも揺れによる被害，津波による被害，海底地滑りに起因する津波による被害など，被害形態は様々である．こうした点も地図から読み取って頂きたい．

犠牲者数データ：主に NOAA の主要地震データベースを利用した．ただし，日本の地震及び文献のある近年の地震については各地震に対応する文献を参照しリストに示した．なお，犠牲者数は死者・行方不明者数の合計とした．

原因別内訳：日本の地震（表 2）については，一次情報に近いものを参照した．また，内閣府中央防災会議の「災害教訓の継承に関する専門委員会」の各報告を参照した．ほか，特記すべき事を示す．2011 年東北地方太平洋沖地震は警察・消防資料から復興庁資料の関連死分を差し引いて直接死者・行方不明者数の市町村別リストを作成し，河北新報記事による土砂災害，建物被害の犠牲者数（90 名）が内陸地方

表2．日本の地震災害リスト（西暦1850年以降，犠牲者数1, 000人以上）

Date (yyyy.mm.dd)	Name	Mj	Number of fatalities	Reference
2011.03.11	Tohoku	9	21,839 (S:60, T:18,418, L:30, O:3,331)	Fire and Disaster Management Agency, Reconstruction Agency, Kahoku shinpo (local newspaper), National Police Agency of Japan
1995.01.17	Kobe	7.3	6,437 (S:5075, L:40, F:403, O:919)	Include 3 persons missing
1948.06.28	Fukui	7.1	3,728 (S, F)	
1946.12.21	Showa Nankai	8.0	1,443 (S:860, T:583)	Kawasumi and Sato (1947), Kanai *et al.* (1947)
1945.01.13	Mikawa	6.8	2,306 (S)	Iida (1978), CDPC (2007)
1944.12.07	Showa Tonankai	7.9	1,230 (S:779, T:451)	Iida (1977), CMO (1945), CDPC (2007)
1943.09.10	Tottori	7.2	1,083 (S)	
1933.03.03	Showa Sanriku	8.1	3,064 (T)	
1927.03.07	Kita-Tango	7.3	2,925 (S)	
1923.09.01	Kanto	7.9	105,385 (S:12,591, T:325, L:688, F:91781)	Moroi and Takemura (2004), CDPC (2006)
1896.06.15	Meiji Sanriku	7.6-8.2	21,959 (T)	
1891.10.28	Nobi	8.0	7,273 (S)	
1855.11.11	Ansei Edo	7.1	10,000 (S:8,000, F:2,000)	Nakamura and Matsuura (2011), CDPC (2004)
1854.12.24	Ansei Nankai	8.4	3,000 (S:1,500, T:1,500)	
1854.12.23	Ansei Tokai	8.4	3,000 (S:1,500, T:1,500)	

S: Structure, T: Tsunami, L: Landslide, F: Fire, O: Other related death

（沿岸コンビナート分は考慮）に対応することを確認し，残りが津波によるものであるとした．1995 年兵庫県南部地震の内訳は公式資料に基づく．1946 年昭和南海地震は地震研究所の速報（河角・佐藤，1947，金井ほか，1947）の表及び内閣府中央防災会議資料から集計した．1944 年昭和東南海地震は，飯田（1977）による集計資料から，津波デジタルライブラリィ公開の中央気象台資料「昭和 19 年 12 月 7 日東南海大地震調査速報」を基に建物被害分を差し引き，残りを津波被害とした．1923 年関東地震は諸井・武村（2004）の集計を用いたが，集計のうち流失・埋没者数（1,013 名）については，津波と土砂災害による被災家屋数の比率で分けた内閣府中央防災会議による推計を採用した．1855 年安政江戸地震は，中

村ほか（2011）では史料からの信頼できる結果として江戸での死者数は 7,095 名以上とされているものの，中央防災会議資料に基づき全体の死者数は 1 万名，うち建物被害は 8 割程度とした．安政東海・南海地震の被害内訳は，昭和東南海・南海地震の比率を参考に，建物被害と津波被害が 1：1 であるものとした．

海外の地震については，内陸地震は基本的に構造物被害，津波のあった地震は津波被害とした．個別に資料が確認できたものについては内訳を示した．中国の被害地震を表 3 に示した．

表3. 中国の地震災害のリスト（西暦1850年以降，犠牲者1,000人以上，2つの主要歴史地震を含む）

Date (yyyy.mm.dd)	Name	M	Number of fatalities	Reference
2010.04.14	Yushu	6.9	2,968 (S)	Lou (1996)
2008.05.12	Wenchuan	8.1	87,587 (S:67,210, L:20,377)	Huang and Fan (2013)
1976.07.28	Tangchan	7.6	242,800 (S)	Lou (1996)
1975.02.04	Haicheng	7.3	1,328 (S)	Lou (1996)
1974.05.10	Zhaotang	7.1	1,541 (S)	Lou (1996)
1970.01.04	Tonghai	7.5	15,621 (S)	
1966.05.07	Ninglin	7.2	8,064 (S)	Lou (1996)
1933.08.25	Maowen	7.5	6,865 (S)	Lou (1996)
1931.08.10	Fuyan	8.0	10,000 (S)	
1927.05.23	Gulang	8.0	41,419 (S)	Lou (1996)
1925.03.16	Talifu	7.0	5,808 (S)	Lou (1996)
1923.03.24	Sichuan	7.3	4,500 (S)	Lou (1996)
1920.12.16	Haiyuan	8.5	235,502 (S)	Lou (1996)
1918.02.13	Shantou	7.3	1,000 (S)	Lou (1996)
1917.07.30	Daguan	6.7	1,879 (S)	Lou (1996)
1902.08.22	Kashgar	8.2	5,650 (S)	Lou (1996)
1887.12.16	Yunnan	7.0	2,256 (S)	Lou (1996)
1879.07.01	Gansu	8.0	29,480 (S)	Lou (1996)
1870.04.11	Batang	7.3	2,300 (S)	NOAA
1850.09.12	Xichang	7.5	23,860 (S)	Lou (1996)
1556.01.23	Shaanxi	8.2	830,000 (S)	Lou (1996)
1303.09.25	Shanxi	8.0	200,000 (S)	NOAA

S: Structure, L: Landslide

（吉見雅行）

6. 津波災害

津波分布図は，将来的に発生し得る津波に対する被害軽減や防災対策に活用されることを目的として，東アジア地域で発生した津波のうち特に大きな被害をもたらした 8 つの津波イベントを対象に津波が襲った範囲を図示したものであり，各津波の最大遡上高の値と観測した場所も併せて記載した．

表4. 津波災害のリスト

Tsunami event name	Date	Cause	Approx. fatality	Approx. maximum runup height (location)
1. Japan Tohoku	11 Mar. 2011	Earthquake	18,378	40 m (Iwate, Japan)
2. Indian Ocean	26 Dec. 2004	Earthquake	290,000**	51 m (Banda Ache, Indonesia)
3. Papua New Guinea	17 Jul. 1998	Earthquake and submarine landslide	Over 2,200**	15 m (Sandaun, Papua New Guinea)
4. Sea of Japan	26 May 1983	Earthquake	103	15 m (Akita, Japan)
5. Moro Gulf (Mindanao)	16 Aug. 1976	Earthquake	Over 8,000**	4 m (Moro Gulf, Philippines)
6. Krakatau Volcano	27 Aug. 1883*	Volcanic eruption	36,417**	42 m (Sunda Strait, Indonesia)
7. Unzen	21 May 1792*	Debris avalanche by volcanic earthquake	10,000	50 m (Nagasaki, Japan)
8. Meiwa (Yaeyama)	24 Apr. 1771*	Earthquake and submarine landslide?	12,000	30 m (Ishigaki Island, Japan)
Sanriku	15 Jun. 1896	Earthquake	22,066**	38.2m（Iwate, Japan）
Hoei (Nankai)	28 Oct. 1707*	Earthquake	over 5,000**	27 m (Kochi, Japan)
Meio (Nankai)	20 Sept. 1498*	Earthquake	over 26,000**	12.6 m (Shizuoka, Japan)

* Local date
** Total fatalities in the event

対象としたのは，1771 年の明和（八重山）津波，1792 年の雲仙（島原大変肥後迷惑）津波，1883 年のクラカタウ火山津波，1976 年のモロ湾（ミンダナオ）津波，1983 年の日本海中部地震津波，1998 年のパプアニューギニア津波，2004 年のインド洋大津波，2011 年の東北地方太平洋沖地震津波の 8 つのイベントである（表 4）．対象とした津波はアメリカ海洋大気庁（NOAA）Web 上のデータベース（NGDC/WDS Global Historical Tsunami Database）に掲載されている津波イベントリストから，特に被害者数の多いものを原則的にリストアップしたものである．ただし，被害者数が上位の津波でも，遡上範囲が重なってしまうものは表 4 及び災害情報図から外した．例えば，日本周辺で発生した津波イベントである 1498 年の明応津波，1707 年の宝永津波，1896 年の明治三陸津波は 2011 年東北地方太平洋沖地震津波と被害範囲が重なるために災害情報図から外している．また，台風など津波以外のイベントとの区別がはっきりせず，津波イベントであることが不確かなものや，津波の襲来範囲や波高データがほとんど存在しないイベントもリストから外した．一方，1976 年のモロ湾（ミンダナオ）津波や 1983 年の日本海中部地震津波，1998 年のパプアニューギニア津波は，被害者数は比較的多くなかったものの広い範囲に影響を与えたことから，今回のリストに加えた．

それぞれの津波イベントにおいて，古文書，被害調査報告書，科学論文，データベース，津波シミュレーション結果などのデータを利用し，おおよそ 1 m（2004 年インド洋大津波においてはおおよそ 2 m）以上の遡上高の津波が襲ったと考えられる海岸を着色して範囲を示した．なお，青色で示した海岸線は地震性津波（地震そのもの及び地震による地すべりなどにより発生した津波），赤色で示した海岸線は火山性津波（火山噴火及びそれらに伴う地震や火砕流・岩屑なだれにより発生した津波）によって襲われたことを示している．またそれぞれの津波イベントで最大遡上高を観測した地点を赤丸で示すと共に，最大遡上高値を青色の棒グラフと数字で記載した．なお，これらの範囲や値などは，引用した文献等の質・量によってある程度の不確かさを含んでいることに注意が必要である．

この津波分布図により 1 回の津波災害が広い範囲に甚大な被害を及ぼすこと，そして東アジア地域のどこにこのような津波のリスクがあるかを視覚的に把握することが可能である．今後の津波ハザードに対する防災対策の基礎情報として活用して頂きたい．

（松本　弾）

7. 東アジア地域の火山

本災害情報図には，完新世（<10ka）の火山の分布と名前を示した．分布と名前は，スミソニアンの「Volcanoes of the World（第 3 版）」（Siebert *et al.*，2010）に従った．ただし，フィリピンについては PHIVOLCS の定義する活火山の分布と名前を示している．ほとんどの火山は，島弧に分布している．しかし，いくつかの火山は大陸域にも分布している．各国と地域の火山数は，インドネシア 142，日本 132，パプアニューギニア 56，フィリピン 22，米国 19，中国 12，台湾 7，ロシア 6，ベトナム 6，モンゴル 5，韓国 3，北朝鮮 3，ミャンマー 3，アフガニスタン 2，マレーシア 1，パキスタン 1 である．

（宝田晋治）

8. カルデラ，降下火砕物，大規模火砕流

東アジア地域の大規模噴火による降灰実績を把握するため，スミソニアンデータベースから噴火イベントを抽出した．東アジア地域における完新世の爆発的噴火（ロシア，米国を除く）は3,446件である（2013年現在）．このうちVEI7は4件，VEI6は19件であり，VEI5以下はVEI2まで指数関数的に増加する（表5）．VEI8以上は存在しない．VEI7とVEI6のイベントの多くは広範囲に降下火砕物を分布させており，降下火砕堆積物の分布が公表されているものを破線で表現した（表6）．給源火口の位置を赤三角，地形的なカルデラ縁を緑実線で示した．クラカタウ（1883年）とピナツボ（1991年）の降下火砕物分布は地表での降灰記録がある範囲を示した．降下火砕堆積物の分布が確認される範囲と降灰記録がある範囲は有意に後者が広い傾向があり，前者は地層の保存ポテンシャルと調査密度に依存するのに対して，後者は真の拡散域に近い可能性が高い．更新世のVEI7-8の噴火のうち，分布がよく調べられている噴火として姶良（30 ka），トバ（74 ka），阿蘇（90 ka）を防災対策上の参考のために示した．

表5. 東・東南アジア地域の火山爆発指数と完新世火山噴火の頻度（ロシアとアメリカを除く）

VEI	Number
8	0
7	4
6	19
5	37
4	144
3	384
2	1,728
1	534
0	88
not mentioned	508

表6. 災害情報図に示した完新世火山噴火による主要降下火山灰

Volcano	Age	VEI	Reference
Tambora	1815AD	7	Self *et al.* (2004), Zollinger (1855), Kandlbauer and Sparks (2014)
Rinjani	1257AD	7	Lavigne *et al.* (2013)
Changbaishan	938AD	7	Machida and Arai (2003), Wei *et al.* (2013), Horn and Schmincke (2000)
Kikai	7.3 ka	7	Machida and Arai (1978), Machida and Arai (2003)
Pinatubo	1991AD	6	Paladio-Melosantos *et al.* (1996)
Krakatau	1883AD	6	Verbeek (1885), Simkin and Fiske (1983)
Rabaul	6th century	6	Walker *et al.* (1981), Nairn *et al.* (1995), Nairn *et al.* (1989)
Witori	3.4 ka	6	Machida *et al.* (1996)
Mashu	7.6 ka	6	Katsui *et al.* (1975), Kishimoto *et al.* (2009)
Ulreung	10.7 ka	6	Lim *et al.* (2008), Machida (1990), Machida and Arai (1983)
Moekeshi	9.4 ka	6	Nakano *et al.* (2001), Nakagawa *et al.* (2013)
Pleistocene well-documented eruptions for comparison			
Aira	30 ka	7	Machida and Arai (1988), Machida and Arai (2003), Kawai and Miyake (1999)
Aso	90 ka	7	Machida *et al.* (2003), Machida and Arai (2003)
Toba	74 ka	8	Ninkovich *et al.* (1978), Self (2006), Lee *et al.* (2004)

大規模火砕流堆積物（VEI6-8）の分布を災害情報図に示した．大規模火砕流堆積物の分布は，今後の大規模火山噴火におけるハザード・リスク評価を行う上で重要である．地質図上では，Qpとして図示している．ここでは12の代表的な大規模火砕流堆積物の分布を示した（表7）．VEI8では，インドネシアTobaカルデラ起源のToba火砕流堆積物（74 ka, 2,500-3,000 km^3）を示した．VEI7では，姶良カルデラ起源の入戸火砕流堆積物（30 ka，350 km^3），阿蘇カルデラ起源の阿蘇4火砕流堆積物（90 ka，600 km^3），洞爺カルデラ起源の洞爺火砕流堆積物（110 ka，170km^3），支笏カルデラ起源の支笏火砕流堆積物（40 ka，300 km^3），屈斜路カルデラ起源の屈斜路4火砕流堆積物（120 ka，>150 km^3），北朝鮮中国国境の白頭山カルデラ起源の白頭山火砕流堆積物（938 AD，>100 km^3），インドネシアのタンボラカルデラ起源のタンボラ火砕流堆積物（1815 AD，100 km^3）を示した．VEI6では，十和田カルデラ起源の八戸火砕流堆積物（15 ka，20 km^3），フィリピンのピナツボ火山起源のピナツボ火砕流堆積物（1991AD, 10.4 km^3），パプアニューギニアのラバウルカルデラ起源のラバウル火砕流堆積物（540 AD，11 km^3），インドネシアのクラカタウカルデラ起源のクラカタウ火砕流堆積物（1883 AD，13.6 km^3）を示した．

（古川竜太・宝田晋治）

表7. 災害情報図に示した主要大規模火砕流堆積物のリスト

Ignimbrite	Age	Source	Volume (km^3)	VEI	Region, Country	Reference
Toba	74ka	Toba Caldera	2,500-3,000	8	Sumatra, Indonesia	Timmreck *et al.* (2012), Aldiss *et al.* (1983), Acharyya and Basu (1993), Rose and Chesner (1987)
Aso 4	90ka	Aso Caldera	600	7	Kyushu, Japan	Ono *et al.* (1977), Ono and Watanabe (1985), Machida and Arai (2003)
Ito	30ka	Aira Caldera	350	7	Kyushu, Japan	Aramaki (1984), Machida and Arai (2003)
Shikotsu	40ka	Shikotsu Caldera	300	7	Hokkaido, Japan	Yamagata (1992), Machida and Arai (2003)
Toya	110ka	Toya Caldera	170	7	Hokkaido, Japan	Okumura and Sangawa (1984), Machida and Arai (2003)
Kussharo 4	120ka	Kussharo Caldera	>150	7	Hokkaido, Japan	Okumura (1991), Machida and Arai (2003)
Changbaishan	938AD	Tianchi (Changbaishan, Baitoushan) volcano	>100	7	Ryanggang, North Korea and Jilin, China	Wei *et al.* (2013), Taniguchi (2004)
Tambora	1815AD	Tambora Caldera	100	7	Sumbawa, Indonesia	Sigurdsson and Carey (1989), Kandlbauer and Sparks (2014)
Hachinohe	15ka	Towada Caldera	20	6	Tohoku, Japan	Hayakawa (1983), Nakawaga *et al.* (1972), Machida and Arai (2003)
Krakatau	1883AD	Krakatau Caldera	13.6	6	Sunda Strait, Indonesia	Sigurdsson *et al.* (1991)
Rabaul	540AD	Rabaul Caldera	11	6	East New Britain, Papua New Guinea	Nairn *et al.* (1995), McKee *et al.* (1985), Walker *et al.* (1981)
Pinatubo	1991AD	Pinatubo volcano	10.4	6	Luzon, Philippines	Newhall and Punongbayan (1996)

VEI: Volcanic Explosivity Index (Newhall and Self, 1982)
Volume: include co-ignimbrite ash

9. 主要火山現象の犠牲者

東アジア地域の主要火山現象の犠牲者数を取りまとめた．各国西暦1400年以降の上位5〜30のイベントを取り上げた．日本では上位24（表8），フィリピンでは上位15（表9），インドネシアでは上位30（表10），パプアニューギニアでは上位5（表11）のイベントを地図上及び表に示した．犠牲者数は，原因ごとに，火砕流（ピンク色），岩屑なだれ（黄色），降下火砕物及び噴石（緑色），火山泥流（青色），津波（水色），火山ガス（オレンジ色），その他関連事象（紫色，伝染病や飢饉）に区分した．これらの犠牲者数は，主にSiebert *et al.*（2010）を参照した．

日本の火山災害（表8）では，犠牲者の多い順に，1792年雲仙眉山岩屑なだれ（15,000人，津波，第6章），1783年浅間

表8. 日本の上位24位の火山災害のリスト（西暦1400年以降）

Number	Volcanic Event	Year	Date	Fatalities (total)	Event Type	Causes and fatalities	VEI
1	Unzen Mayuyama	1792	May 21	15,000	Debris avalanche	T (10,000), D (5,000)	-
2	Asama Tenmei	1783	Aug. 5	1,491	Pyroclastic flow, debris avalanche	L (1,025), D (466)	4
3	Oshima-Oshima	1741	Aug. 27	1,467	Debris avalanche	T (1,467)	4
4	Hokkaido Komagatake	1640	May 24	700	Debris avalanche	T (700)	5
5	Bandai	1888	July 15	477	Debris avalanche, phreatic eruption	D (377), P (100)	4
6	Tateyama	1958	Apr. 9	279	Debris avalanche	L (279)	-
7	Nasu	1410	Mar. 5	180	Pyroclastic flow, tephra fall, lava flow	L (180)	3
8	Sakurajima An-ei	1779	Nov. 8	153	Pyroclastic flow, lava flow, tephra	F (100), T (53)	5
9	Tokachidake	1926	May 24	144	Pyroclastic flow, tephra fall, lahar	L (141), F (3)	2
10	Aogashima	1785	Apr. 18	130	Pyroclastic fall, lava flow	R (130)	3
11	Izu Torishima	1902	Aug. 7	125	Phreatic eruption	P (125)	2-3
12	Usu Bunsei	1822	Mar. 23	78	Pyroclastic flow (surge)	P (78)	4
13	Adatara	1900	July 17	72	Pyroclastic flow	P (72)	2
14	Ontake	2014	Sep. 27	63	Phreatic eruption	F (63)	2
15	Sakurajima Taisho	1914	Jan. 12	63	Pyroclastic flow, lava flow, tephra	R (40), F (23)	4
16	Kuchinoerabu-jima	1841	Aug. 1	>50	Pyroclastic flow	P (>50)	2-3
17	Unzen Heisei	1991	June 3	43	Pyroclastic flow	P (43)	2
18	Sakurajima An-ei	1781	Apr. 11	38	Pyroclastic flow, lava flow, tephra	T (38)	4
19	Bayonnaise Rocks	1952	Sep. 24	31	Base surge	P (31)	2
20	Esan	1846	-	>30?	Lahar	L (>30)	-
21	Unzen	1664	Apr. 15	>30	Lahar	L (>30)	-
22	Ontake	1984	Sep. 14	29	Debris avalanche, landslide	D (29)	-
23	Hokkaido Komagatake	1856	Sep. 25	25	Pyroclastic flow, tsunami	P (23), F (2)	4
24	Aso	1958	June 24	12	Phreatic eruption	F (12)	2

P: Pyroclastic flow and surge, F: Tephra fall and ballistics, T: Tsunami, L: Lahar, D: Debris avalanche, and R: Related death

天明噴火（1,491 人，火砕流，岩屑なだれ，火山泥流），1741 年渡島大島岩屑なだれ（1,467 人，津波），1640 年北海道駒ヶ岳岩屑なだれ（700 人，津波）， 1888 年磐梯山岩屑なだれ（477 人，岩屑なだれ），1858 年立山岩屑なだれ（279 人，火山泥流，飛越地震に誘発された岩屑なだれと火山泥流）となっている．

表9．フィリピンの上位15位の火山災害のリスト（西暦1400年以降）

Number	Volcanic Event	Year	date	Fatalities	Event Type	Causes and fatalities	VEI
1	Mayon	1875	-	>1,500	Lahar (rain)	L (>1,500)	-
2	Taal	1911	Jan. 30	>1,335	Pyroclastic flow	P (>1,100), T (>235)	3
3	Mayon	2006	Nov. 30	1,266	Lahar	L (1,266)	-
4	Mayon	1814	Feb. 1	1,200	Pyroclastic flow and Lahar	P (1,100), L (100)	4
5	Pinatubo	1991	June 15	800	Pyroclastic flow and tephra fall	P (25), L (100), R (450)	6
6	Hibok-Hibok	1951	Dec. 4	>500	Pyroclastic flow	P (>500)	1-2
7	Mayon	1897	June 25	350	Pyroclastic flow and tephra fall	P (310), F (40)	4
8	Taal	1965	Sep. 28	>250	Pyroclastic flow and Base surge	P (>150), T (>100)	4
9	Mayon	1981	June 30	>200	Lahar (rain)	L (>200)	-
10	Parker	1995	Sep. 6	<100	Lahar (rain)	L (<100)	-
11	Mayon	1993	Feb. 2	77	Pyroclastic flow	P (77)	2
12	Hibok-Hibok	1950	Sep. 15	68	Pyroclastic flow	P (68)	1-2
13	Mayon	1766	Oct. 23	49	Lahar	L (49)	-
14	Mayon	1853	Sep. 13	34	Pyroclastic flow	P (34)	3
15	Mayon	1887	Mar. 9	15	Pyroclastic flow and tephra fall	F (15)	3

P: Pyroclastic flow and surge, F: Tephra fall and ballistics, T: Tsunami, L: Lahar, and R: Related death

フィリピンの火山災害（表 9）では，多い順に，1875 年マヨン火山（>1,500 人，降雨による火山泥流），1911 年タール火山噴火（>1,335 人，火砕流），2006 年マヨン火山（1,266 人，火山泥流），1814 年マヨン火山噴火（1,200 人，火砕流及び火山泥流），1991 年ピナツボ火山噴火（800 人，火砕流及び降下火山灰）となっている．

インドネシアの火山災害（表 10）では，多い順に，1815 年タンボラ火山噴火火砕流と津波（60,000 人，火砕流と関連死），1883 年クラカタウ火山噴火（36,417 人，火砕流と津波），1586 年ケルート火山噴火（10,000 人，火砕流），1919 年ケルート火山噴火（5,110 人，火砕流及び火山泥流），1822 年ガルングン火山噴火（4,011 人，火砕流）となっている．また，1979 年ディエン火山噴火では，火山ガスにより 149 人が犠牲者となっている．

表10．インドネシアの上位30位の火山災害のリスト（西暦1400年以降）

Number	Volcanic Event	Year	Date	Fatalities (total)	Event Type	Causes and fatalities	VEI
1	Tambora	1815	Apr. 10	60,000	Pyroclastic flow and tsunami	P (11,000) and R (49,000)	7
2	Krakatau	1883	Aug. 27	36,417	Pyroclastic flow and tsunami	P (2,000), T (34,417)	6
3	Kelut	1586	-	10,000	Pyroclastic flow?	P (10,000)	-
4	Kelut	1919	May 19	5,110	Pyroclastic flow and lahar	L (5,110)	4
5	Galunggung	1822	Oct. 8	4,011	Pyroclastic flow	P (3,600), L (411)	5
6	Merapi	1672	Aug. 4	3,000	Pyroclastic flow	P (3,000)	3
7	Awu	1711	Dec. 11	3,000	Pyroclastic flow	P (3,000)	3
8	Papandayan	1772	Aug. 12	2,957	Debris avalanche	D (2,957)	3
9	Awu	1856	Mar. 2	2,806	Pyroclastic flow	P (2,806)	3
10	Makian	1760	-	2,000	Pyroclastic flow and lahar	L (2,000)	4
11	Awu	1892	June 7	1,532	Pyroclastic flow and lahar	P (1,150), L (382)	3
12	Merapi	1930	Dec. 18	1,369	Pyroclastic flow and lahar	P (1,369)	3
13	Gamalama	1775	-	1,300	Pyroclastic flow (base surge)	P (1,300)	3
14	Agung	1963	Mar. 17	1,148	Pyroclastic flow, tephra fall and lahar	P (820), F (163), L (165)	4
15	Raung	1638	-	>1,000	Lahar	L (>1,000)	-
16	Awu	1812	Aug. 6	953	Pyroclastic flow and lahar	P (700), L (253)	4
17	Iliwerung	1979	July 18	539	Debris avalanche and Tsunami	T (539)	3
18	Ruang	1871	Mar. 3	400	Collapse of lava dome and tsunami	T (400)	2
19	Sumeru	1981	May 14	372	Lahar	L (372)	-
20	Merapi	2010	Oct.-Dec.	353	Pyroclastic flow	P (353)	3
21	Makian	1861	Dec. 29	326	Pyroclastic flow	P (326)	4
22	Paluweh	1928	Aug. 4	226	Explosive eruption and Tsunami	T (226)	3
23	Sumeru	1909	Aug. 29	221	Lahar	L (221)	-
24	Kelut	1966	Apr. 26	215	Pyroclastic flow and lahar	L (214), P (1)	4
25	Sorikmarapi	1892	May 21	180	Lahar	L (180)	-
26	Merapi	1872	Apr. 17	170	Pyroclastic flow	P (170)	2
27	Dieng	1979	Feb. 20	149	Volcanic gas	G (149)	1
28	Sumeru	1976	Nov. 13	133	Pyroclastic flow and lahar	L (133)	2
29	Kaba	1833	Nov. 24	126	Lahar	L (126)	-
30	Dieng	1944	Dec. 4	117	Phreatic eruption	F (117)	2

P: Pyroclastic flow and surge, F: Tephra fall and ballistics, T: Tsunami, L: Lahar, D: Debris avalanche, G: Volcanic gas, and R: Related death

表11．パプアニューギニアの上位5位の火山災害のリスト（西暦1400年以降）

Number	Volcanic Event	Year	date	Fatalities	Event Type	Causes and fatalities	VEI
1	Ritter Island	1888	Mar. 13	3,000	Debris avalanche and tsunami	T (3,000)	2
2	Lamington	1951	Jan. 21	2,942	Pyroclastic flow	P (2,942)	4
3	Long Island	1660	-	2,000	Pyroclastic flow and tsunami	P (1,000), T (1,000)	6
4	Rabaul	1937	May 29	507	Pyroclastic flow and tephra fall	P (300), F (207)	4
5	Rabaul	1850	-	>500	Pyroclastic flow and tephra fall	F (>500)	4

P: Pyroclastic flow and surge, F: Tephra fall and ballistics, and T: Tsunami

パプアニューギニアの火山災害（表 11）では，多い順に，1888 年リッター島火山岩屑なだれ（3,000 人，津波），1951 年ラミントン火山噴火（2,942 人，火砕流），1660 年ロング島火山噴火（2,000 人，火砕流と津波），1937 年ラバウル火山噴火（507 人，火砕流と降下火砕物），1850 年ラバウル火山噴火（>500 人，火砕流と降下火砕物）となっている．

（宝田晋治）

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