

Appendix B – Region 6

Country and regional profiles of volcanic hazard and risk:

Indonesia

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This download comprises the profiles for Region 6: Indonesia only. For the full report and all regions see Appendix B Full Download. Page numbers reflect position in the full report. The following countries are profiled here:

Region 6	Indonesia	Pg.342
	India	349
	Indonesia	356
	Malaysia	366

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This profile and the data therein should not be used in place of focussed assessments and information provided by local monitoring and research institutions.

Region 6: Indonesia

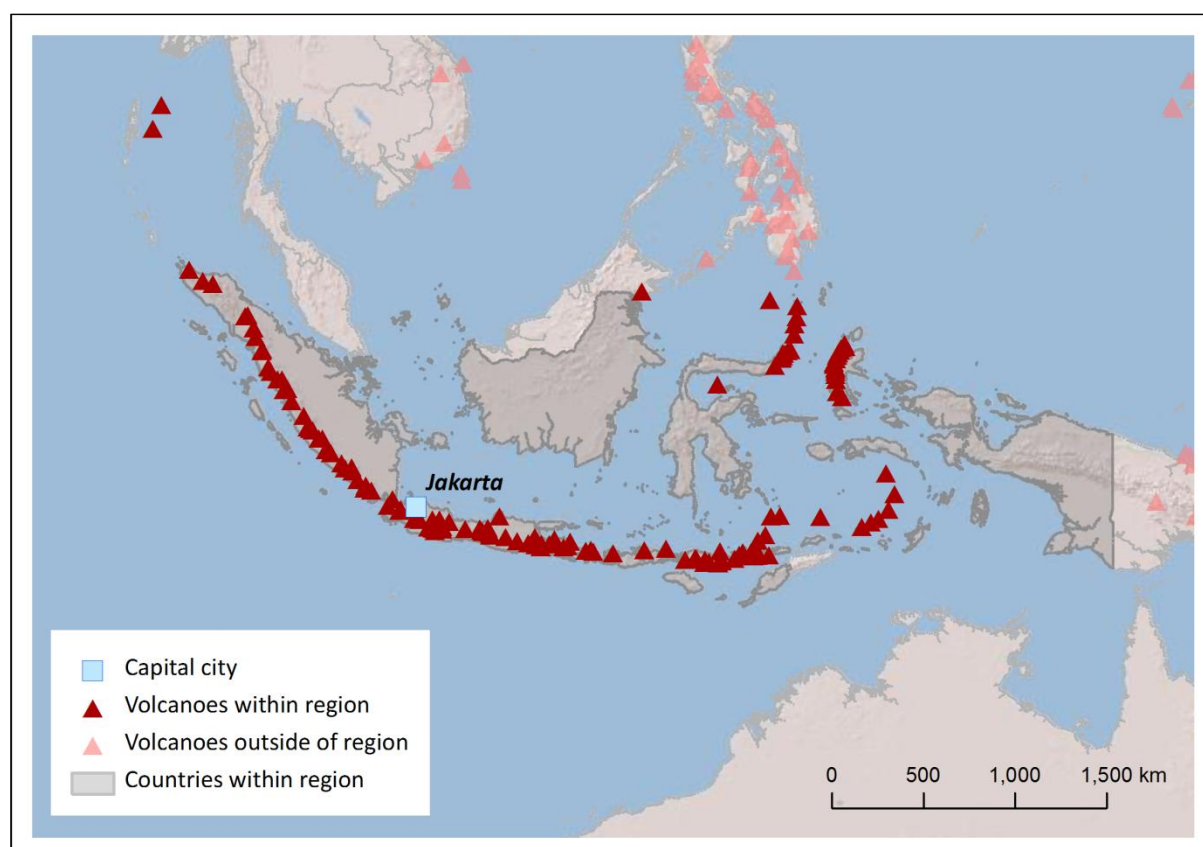


Figure 6.1 The distribution of Holocene volcanoes through the Melanesia and Australia region. The capital cities of the constituent countries are shown.

Description

Region 6, Indonesia, comprises volcanoes distributed throughout Indonesia itself, the Indian Andaman Islands in the north of the Indonesian arc, and one volcano in Malaysia.

Country	Number of volcanoes
India	2 + 1 from Region 3
Indonesia	142
Malaysia	1

Table 6.1 The countries represented in this region and the number of volcanoes. Volcanoes located on the borders between countries are included in the profiles of all countries involved. Note that countries may be represented in more than one region, as overseas territories may be widespread.

About 80% of this region's volcanoes are situated in the Sunda Arc, stretching from north-west Sumatra to the Banda Sea, east of Papua New Guinea. This arc results from the subduction of the Indo-Australian Plate beneath the Eurasian Plate. The remaining volcanoes, on either end of this arc result from more complex tectonic interactions. The Andaman Islands in the north result from short spreading centres. The Banda Arc, at the southern end of the Sunda Arc and turning back towards Borneo, results broadly from the subduction of the Pacific crust. Multiple subduction zones and

micro-plates north of this produce the Sulawesi-Sangihe volcanoes and Halmahera volcanoes in roughly north-south lineaments on either side of the collision zone. About 79% of volcanoes in this region are stratovolcanoes or other large-cone types, and 10% are calderas. This and the dominantly andesitic composition of volcanism here are associated with explosive activity.

Records of large magnitude eruptions date back into the Pleistocene, with 8 volcanoes having Pleistocene records of VEI ≥ 4 eruptions. The largest eruption recorded globally during the Quaternary (the last 2.5 million years), is recorded in this region. The Younger Toba Tuff eruption of Toba in Indonesia occurred 74,000 years ago. This was a magnitude 8.8 eruption which produced extensive pyroclastic flows and voluminous ashfall.

Despite records of large events extending back millennia, most activity in this region is under-recorded. 145 Holocene volcanoes are located in this region, with records of 1,277 confirmed Holocene eruptions. However, of these, 1,203 eruptions (94%) are recorded in historical times, illustrating that the eruptive activity prior to 1500 AD is relatively poorly known. Indeed, 96% of eruptions in this region are recorded through historical observations. Whilst recent activity is very well documented, the absence of comprehensive eruptive histories back in time makes assessment of hazard and full understanding of activity difficult and associated with significant uncertainties. There may be unrecognised volcanoes or volcanoes with long-recurrence periods of large activity that pose particular hazards.

Activity ranges from small to extremely large explosive eruptions in this region. Small VEI 2 eruptions dominant the record, however the history indicates that moderate to large explosive eruptions of VEI ≥ 3 occur roughly every 15 years. A large number of historical eruptions (10%) have produced pyroclastic flows and many have resulted in lahars.

This is a very populous region, dominated by the large population of Indonesia. Over 8.6 million people live within 10 km of one or more Holocene volcano, the highest of any region. Direct hazards such as lava flows and pyroclastic flows can commonly extend over this distance. Over 180 million people live within 100 km of one or more volcano. About 31% of classified volcanoes (18) are deemed at Risk Level III, due to the combination of high hazard and high local population. Largely due to this high proximal population, a large number of eruptions have resulted in fatalities (roughly 10% of historical events). However comprehensive monitoring now undertaken in Indonesia has led to a good record of evacuations prior to eruption. Regular monitoring is undertaken at many of the regions volcanoes, with focussed dedicated monitoring at many of the volcanoes of highest risk.

Volcano Facts

Number of Holocene volcanoes	145
Number of Pleistocene volcanoes with M ≥ 4 eruptions	8
Number of volcanoes generating pyroclastic flows	33 (153 eruptions)
Number of volcanoes generating lahars	31 (108 eruptions)
Number of volcanoes generating lava flows	39 (176 eruptions)
Number of eruptions with fatalities	125

Number of fatalities attributed to eruptions	142,903
Largest recorded Pleistocene eruption	The largest Quaternary explosive eruption globally is recorded in this region: The Younger Toba Tuff was erupted in a M8.8 eruption from Toba in Indonesia at 74 ka.
Largest recorded Holocene eruption	The largest recorded Holocene eruption was the 416 AD M7.1 eruption of Krakatau.
Number of Holocene eruptions	1,277 confirmed Holocene eruptions.
Recorded Holocene VEI range	0 – 7 and unknown
Number of historically active volcanoes	79
Number of historical eruptions	1,203

Number of volcanoes	Primary volcano type	Dominant rock type
14	Caldera(s)	Andesitic (7), Dacitic (4), Unknown (3)
2	Hydrothermal field	Andesitic (1), Unknown (1)
114	Large cone(s)	Andesitic (92), Basaltic (18), Dacitic (2), Unknown (2)
2	Lava dome(s)	Andesitic (2)
4	Small cone(s)	Andesitic (1), Basaltic (2), Unknown (1)
6	Submarine	Andesitic (1), Unknown (5)
4	Unknown	Andesitic (1), Dacitic (1), Unknown (2)

Table 6.2 The volcano types and dominant rock types of the volcanoes of this region according to VOTW4.0.

Eruption Frequency

VEI	Recurrence Interval (Years)
Small (< VEI 4)	1
Large (> VEI 3)	20

Table 6.3 Average recurrence interval (years between eruptions) for small and large eruptions in the Indonesia region.

The eruption record indicates that on average small to moderate sized eruptions of VEI <4 occur in this region with an average recurrence interval (ARI) of about a year, whilst the ARI for large eruptions is longer, at about 20 years.

Eruption Size

Eruptions of VEI 0 to 7 are recorded through the Indonesia region, representing a range of eruption styles from gentle effusive events to very large explosive eruptions. VEI 2 events dominate the

record, with nearly 70% of all Holocene eruptions classed as such. Just under 3% of eruptions here are explosive at VEI ≥ 4 .

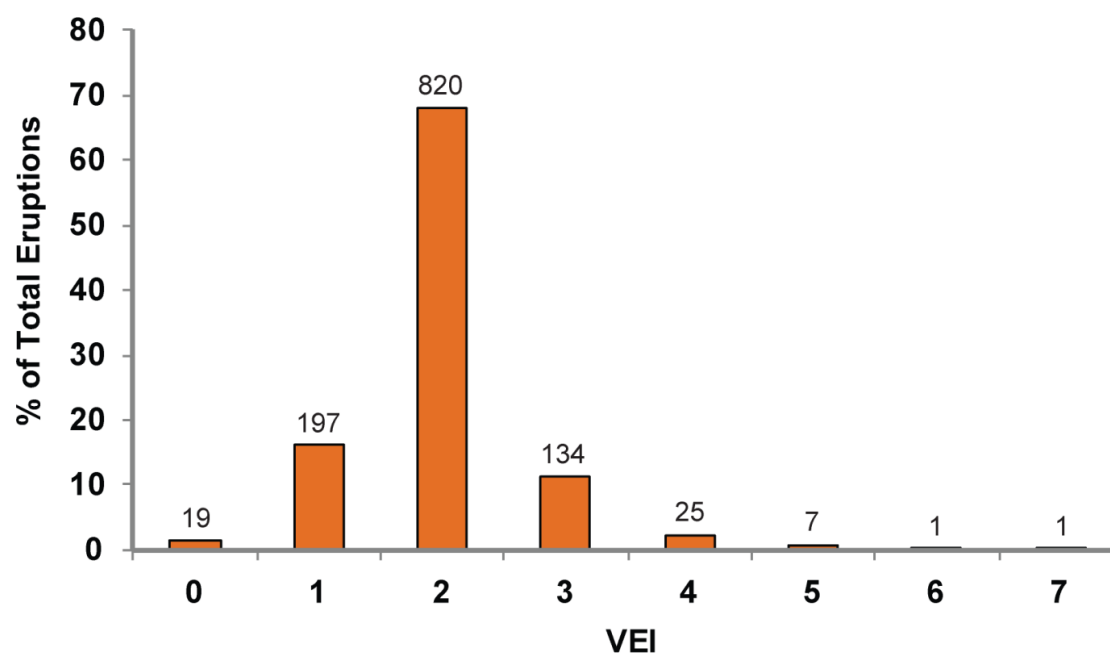


Figure 6.2 Percentage of eruptions in this region recorded at each VEI level; the number of eruptions is also shown. The percentage is of total eruptions with recorded VEI. A further 73 eruptions were recorded with unknown VEI.

Socio-Economic Facts

Total population (2011)	1,463,514,556
Gross Domestic Product (GDP) per capita (2005 PPP \$)	3,203 – 13,672 (Mean 6,990)
Gross National Income (GNI) per capita (2005 PPP \$)	3,285 – 13,676 (Mean 7,038)
Human Development Index (HDI) (2012)	0.554 – 0.769 (Medium to High, Mean 0.651 Medium)

Population Exposure

Number (percentage) of people living within 10 km of a Holocene volcano	8,631,561 (0.59 %)
Number (percentage) of people living within 30 km of a Holocene volcano	68,995,316 (4.71 %)
Number (percentage) of people living within 100 km of a Holocene volcano	180,040,137 (12.30 %)

Hazard, Uncertainty and Exposure Assessments

CLASSIFIED	Hazard III		Teon, Ruang	Karangetang [Apu Siau], Makian	Tambora, Awu	Semeru, Sopotan	Galunggung, Kelut, Lokon-Empung	Merapi
	Hazard II		Paluweh, Serua	Peuet Sague, Sorikmarapi, Sangeang Api, Iliwerung	Krakatau, Ebulobo, Gamkonora	Kaba, Raung, Ijen, Rinjani, Iya, Tongkoko	Cereme, Tengger Caldera, Mahawu, Gamalama	
	Hazard I		Nila, Banua Wuhu; Barren Island	Banda Api	Dempo, Lewotolo, Sirung, Ibu	Bur ni Telong, Marapi, Talang, Kerinci, Lewotobi, Leroboleng, Iliboleng, Egon	Perbakti-Gagak, Salak, Papandayan, Slamet, Lamongan	Gede, Tankubanparahu, Guntur, Dieng Volcanic Complex, Sundoro, Batur
UNCLASSIFIED	U – HHR		Batu Tara, Colo [Una Una] , Wurlali, Gunungapi Wetar	Sumbing (261180), Besar, Suoh, Dukono	Seulawah Agam, Kelimutu	Sibayak, Sinabung, Tandikat, Ranakah, Inielika, Ambang	Lawu, Arjuno-Welirang, Agung	Sumbing (263220), Merbabu
	U- HR				Inerie	Muria		
	U- NHHR	Manuk, Unnamed (267050); Narcondum	Yersey, Emporor of China, Nieuwerkerk, Amasing; Unnamed (235010)	Malintang, Hutapanjang, Pandan, Kunyit, Belirang-Beriti, Patah , Bukit Lumut Balai, Sekincau Belirang, Tobaru, Moti, Tigalalu, Bibinoi	Sibualbuali, Libukraya, Talakmau, Ranau, Ndete Napu, Ililabalekan, Tarakan, Todoko-Ranu, Jailolo, Hiri, Mare; Bombalai	Imun, Sarik-Gajah, Bukit Daun, Hulubelu, Iyang-Argapura, Baluran, Poco Leok, Sukaria Caldera, Ilimuda, Klabat, Tidore	Toba, Rajabasa, Pulosari, Karang, Patuha, Wayang-Windu, Kendang, Talagabodas , ngaran, Telomoyo, Wilis, Kawi-Butak, Lurus, Wai Sano, Sempu	Malabar, Tampomas, Kawah Karaha , Penanggungan, Malang Plain, Bratan, Tondano Caldera
		PEI 1	PEI 2	PEI 3	PEI 4	PEI 5	PEI 6	PEI 7

Table 6.4 Identity of the volcanoes in this region in each Hazard-PEI group. Those volcanoes with a sufficient record for determining a hazard score are deemed 'classified' (top). Those without sufficient data are 'Unclassified' (bottom). The unclassified volcanoes are divided into groups: U-NHHR is Unclassified No Historic or Holocene Record: that is there are no confirmed eruptions recorded in the Holocene. U-HR is Unclassified with Holocene Record: that is there are confirmed eruptions recorded during the Holocene, but no historical (post-1500) events. U-HHR is Unclassified with Historic and Holocene record. The unclassified volcanoes in **bold** have experienced unrest or eruptions since 1900 AD, and those in red have records of at least one Holocene VEI ≥4 eruption.

Population Exposure Index

Number of volcanoes	Population Exposure Index
16	7
30	6
34	5
24	4
23	3
15	2
3	1

Table 6.5 The number of volcanoes in the Indonesia region classed in each PEI category.

Risk Levels

Number of Volcanoes	Risk Level
18	III
30	II
10	I
87	Unclassified

Table 6.6 The number of volcanoes in the Indonesia region classified at each Risk Level.

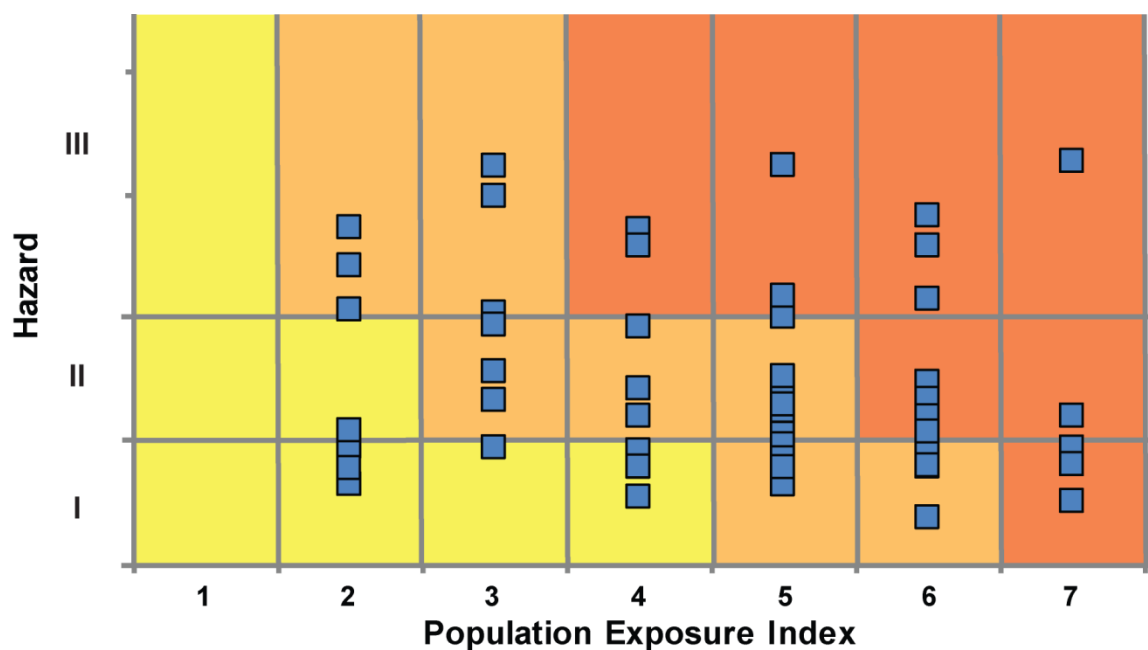


Figure 6.3 Distribution of the classified volcanoes of this region across Hazard and Population Exposure Index levels. The warming of the background colours illustrates increasing Risk levels from Risk Level I - III..

Regional Monitoring Capacity

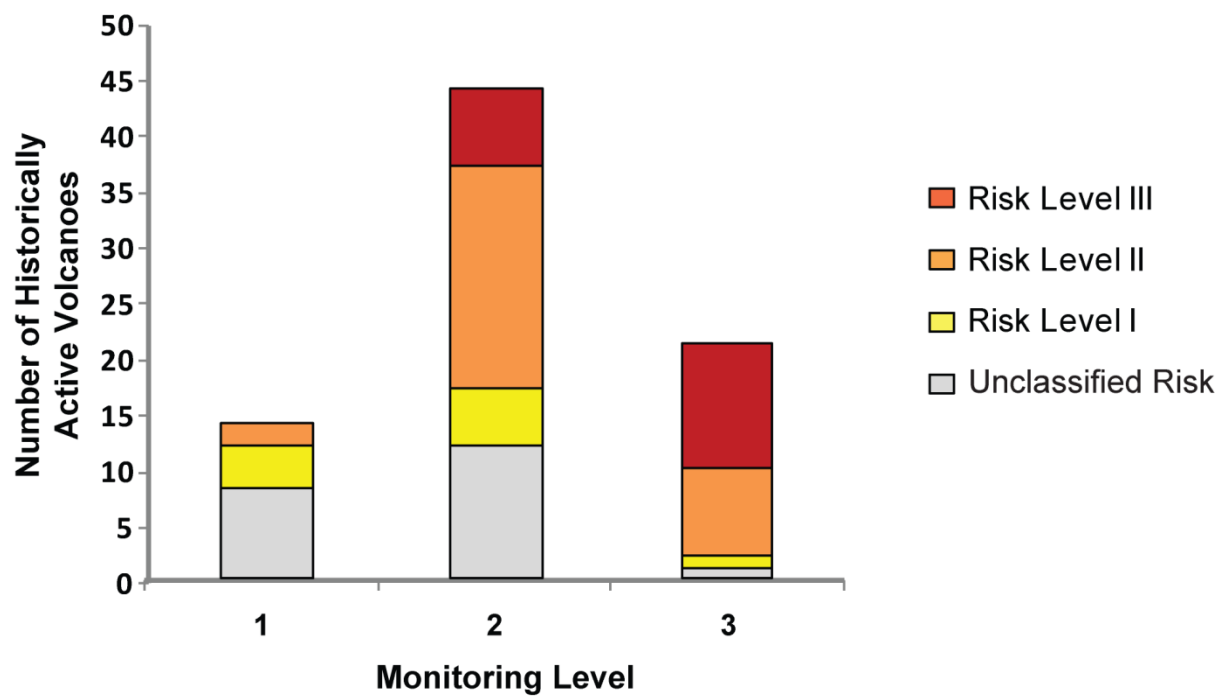


Figure 6.4 The monitoring and risk levels of the historically active volcanoes in the Indonesia region. Monitoring Level 1 indicates no known dedicated ground-based monitoring; Monitoring Level 2 indicates that some ground-based monitoring systems are in place including ≤ 3 seismic stations; Monitoring Level 3 indicates the presence of a dedicated ground-based monitoring network, including ≥ 4 seismometers

India

Note that we include the Indian unnamed submarine volcano located east of Chennai here (uncertain presence, see below), which is included in the Region 3 “Middle East and Indian Ocean” description as defined in this region by the Global Volcanism Program.

Description

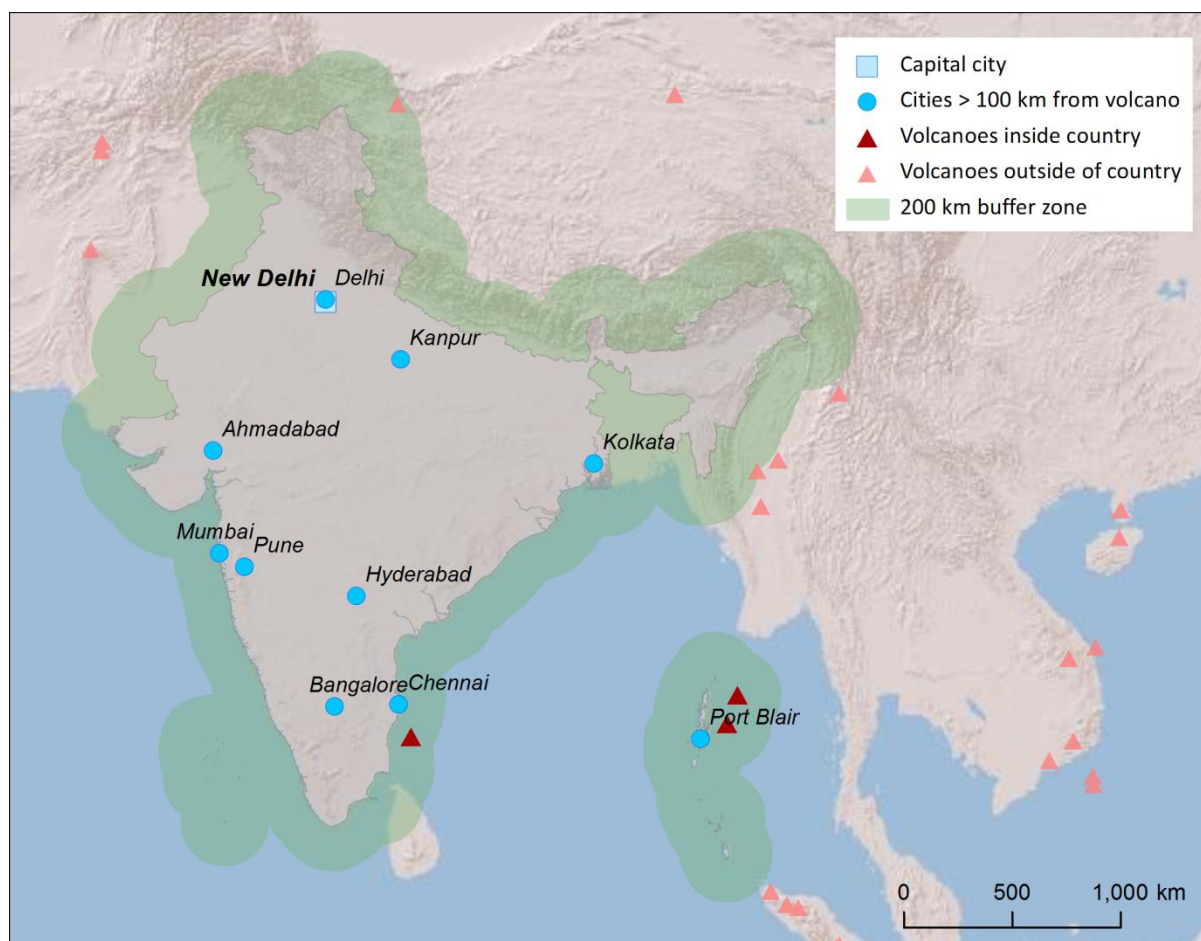


Figure 6.5 Location of India's volcanoes, the capital and largest cities. A zone extending 200 km beyond the country's borders shows other volcanoes whose eruptions may directly affect India.

There are three Indian Holocene volcanoes listed in VOTW4.0. Barren Island and Narcondam (Narcondum) are stratovolcanoes located in the Andaman Islands in the north of the volcanic arc stretching through Sumatra. These two volcanoes are broadly related to the subduction of the Indian Plate under the Eurasian Plate. An unnamed submarine volcano is recorded off the south-east coast of India by the Pondicherry coast, however the existence of this volcano is uncertain. The presence this volcano is indicated by a report from 1757 of phenomena suggestive of submarine volcanism, however this is unconfirmed.

Of the three volcanoes, only Barren Island has confirmed activity recorded in the Holocene. The unnamed volcano and Narcondam are suspected to have had Holocene activity. Barren Island has been frequently active in historical times, with 11 eruptions from 1787 to 2010 of VEI 2. No

eruptions greater than VEI2 are recorded, suggesting dominantly effusive to moderately explosive activity, however deposits are identified which suggest a history of large explosive eruptions generating pyroclastic flows back into the Pleistocene. Large explosive eruptions often have long recurrence intervals and may occur again in the future.

Both Barren Island and Narcondam form small, uninhabited islands of less than 5 km across. There is no permanent infrastructure or population on these islands, with the exception of a permanent police outpost on Narcondam manned by 10-20 personnel at any given time. Barren Island is classed at Hazard Level I, based on its historical record. The population may increase in the future, as a permanent field base is proposed for Barren Island to permit studies of the volcano and the potential as a site for geotourism is considered in Sheth et al. (2010).

One GPS monitoring system and seismograph has been installed on Barren Island by the National Geophysical Research Institute, though no other dedicated ground-based monitoring is in operation at any other Holocene volcano in India. The Geological Survey of India are the responsible organisation for providing information and monitoring in times of activity, and indeed have responded to past eruptions sending field parties to investigate activity. The Indian Coast Guard located at Port Blair in the Andaman Islands reports activity of Barren Island, but not regularly.

The Asian Disaster Reduction Center (ADRC) produced a report on the hazards in India in 2012, with a further five such reports dating back to 1998. In this they do not consider volcanic hazards. They describe how India has moved from a system of reactive relief efforts to proactive risk reduction, particularly in relation to the seismic hazard. The ADRC discuss how a Disaster Mitigation Fund and Disaster Response Fund are provided for following the enactment of the Disaster Management Act 2005 and provides for the establishment of Disaster Management Authorities on several levels – National (NDMA), State (SDMA) and District (DDMA). For full details of the disaster management and preparedness see the ADRC report.

See also:

Ray, J. S., Pande, K., and Awasthi, N. (2013) A minimum age for the active Barren Island volcano, Andaman Sea. *Current Science*, 104:7.

Sheth, H.C., Ray, J.S., Bhutani, R., Kumar, A., and Awasthi, N. (2010) The latest (2008 - 09) eruption of Barren Island volcano, and some thoughts on its hazards, logistics and geotourism aspects. *Current Science*, 98:5.

Asian Disaster Reduction Center: India:

www.adrc.asia/nationinformation.php?NationCode=356&Lang=en&NationNum=02

Volcano Facts

Number of Holocene volcanoes	3
Number of Pleistocene volcanoes with M \geq 4 eruptions	-
Number of volcanoes generating pyroclastic flows	-

Number of volcanoes generating lahars	-
Number of volcanoes generating lava flows	1
Number of fatalities caused by volcanic eruptions	-
Tectonic setting	The submarine volcano is located in an intra-plate setting whilst the large cones are in a subduction zone
Largest recorded Pleistocene eruption	-
Largest recorded Holocene eruption	There are 11 eruptions recorded at VEI 2 from Barren Island between 1787 and 2010 AD.
Number of Holocene eruptions	12 confirmed eruptions. 3 uncertain eruptions.
Recorded Holocene VEI range	2 and Unknown
Number of historically active volcanoes	1
Number of historical eruptions	11

Number of volcanoes	Primary volcano type	Dominant rock type
2	Large cone(s)	Andesitic (1), Basaltic (1)
1	Submarine	Unknown (1)

Table 6.7 The number of volcanoes in India, their volcano type classification and dominant rock type according to VOTW4.0.

Socio-Economic Facts

Total population (2012)	1,238,700,000
Gross Domestic Product (GDP) per capita (2005 PPP \$)	3,203
Gross National Income (GNI) per capita (2005 PPP \$)	3,285
Human Development Index (HDI) (2012)	0.554 (Medium)

Population Exposure

Capital city	New Delhi
Distance from capital city to nearest Holocene volcano	811.6 km

Total population (2011)	1,189,172,906
Number (percentage) of people living within 10 km of a Holocene volcano	278 (<1%)
Number (percentage) of people living within 30 km of a Holocene volcano	278 (<1%)
Number (percentage) of people living within 100 km of a Holocene volcano	893,001 (<1%)

Largest cities, as measured by population and their population size:

Mumbai	12,691,836
Delhi	10,927,986
Bangalore	5,104,047
Kolkata	4,631,392
Chennai	4,328,063
Ahmadabad	3,719,710
Hyderabad	3,597,816
Pune	2,935,744
Kanpur	2,823,249
Jaipur	2,711,758

Infrastructure Exposure

The Indian volcanoes of Narcondam and Barren Island lie in the Andaman Islands. Both islands measure less than 5 km across, therefore the entirety of these are exposed to volcanic hazards, however no permanent settlements or infrastructure exist here. The 100 km radius of Barren Island marginally encroaches on the much larger and inhabited Smith Island. An airport at Port Blair, the capital of the Andaman and Nicobar Islands, is located about 135 km from Barren Island.

Number of airports within 100 km of a volcano	0
Number of ports within 100 km of a volcano	0
Total length of roads within 100 km of a volcano (km)	0
Total length of railroads within 100 km of a volcano (km)	0

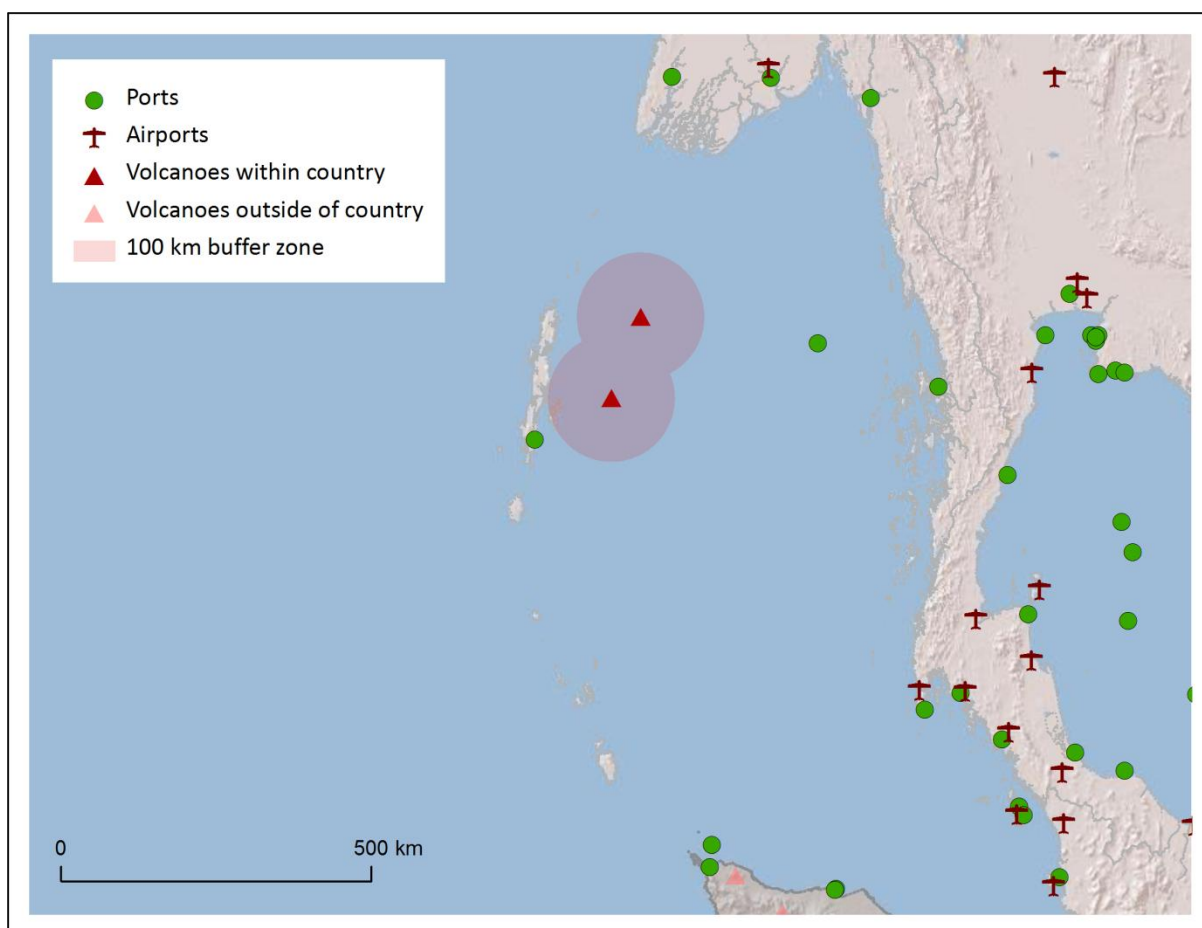


Figure 6.6 The location of India's volcanoes in the Andaman Islands and the extent of the 100 km zone surrounding them. Ports, airports and the major cities are just some of the infrastructure that may be exposed to volcanic hazards.

Hazard, Uncertainty and Exposure Assessments

Of the three Indian volcanoes, only Barren Island has a sufficiently detailed eruption record for calculation of the hazard. This volcano is characterised by lava flow production and eruptions of VEI 2 and is classed at Hazard Level I.

Narcondam and an unnamed volcano are unclassified, as no confirmed eruptions are recorded during the Holocene.

All volcanoes in India are classed at PEI 1 and 2, with only small populations within 100 km. Narcondam has no permanent population living within this distance however there is a police outpost with 10 to 20 personnel at any given time. The low PEI of Narcondam suggests low risk. Barren Island is classified at Risk Level I.

CLASSIFIED	Hazard III							
	Hazard II							
	Hazard I		Barren Island					
UNCLASSIFIED	U – HHR							
	U- HR							
	U- NHHR	Narcondam	Unnamed (235010)					
		PEI 1	PEI 2	PEI 3	PEI 4	PEI 5	PEI 6	PEI 7

Table 6.8 Identity of India's volcanoes in each Hazard-PEI group. Those volcanoes with a sufficient record for determining a hazard score are deemed 'Classified' (top). Those without sufficient data are 'Unclassified' (bottom). The unclassified volcanoes are divided into groups: U-NHHR is Unclassified No Historic or Holocene Record: that is there are no confirmed eruptions recorded in the Holocene. U-HR is Unclassified with Holocene Record: that is there are confirmed eruptions recorded during the Holocene, but no historical (post-1500) events. U-HHR is Unclassified with Historic and Holocene record. The unclassified volcanoes in **bold** have experienced unrest or eruptions since 1900 AD, and those in red have records of at least one Holocene VEI ≥4 eruption.

Volcano	Population Exposure Index	Risk Level
Barren Island	2	I

Table 6.9 Classified volcanoes of India ordered by descending Population Exposure Index (PEI). Risk levels determined through the combination of the Hazard Level and PEI are given. Risk Level I – 1 volcano; Risk Level II – 0 volcanoes; Risk Level III – 0 volcanoes.

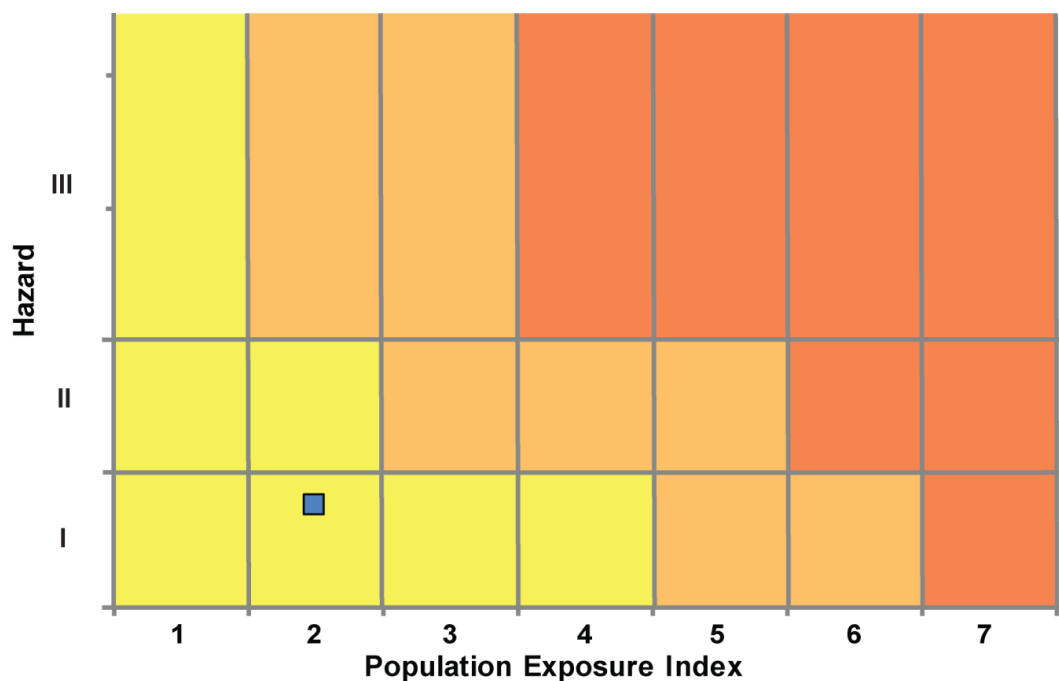


Figure 6.7 Distribution of India's classified volcanoes across Hazard and Population Exposure Index levels. The warming of the background colours illustrates increasing Risk levels from Risk Level I - III.

National Capacity for Coping with Volcanic Risk

One GPS station and a seismograph have been installed on Barren Island, but with no real-time data transmission. These have been installed and are operated by the National Geophysical Research Institute.

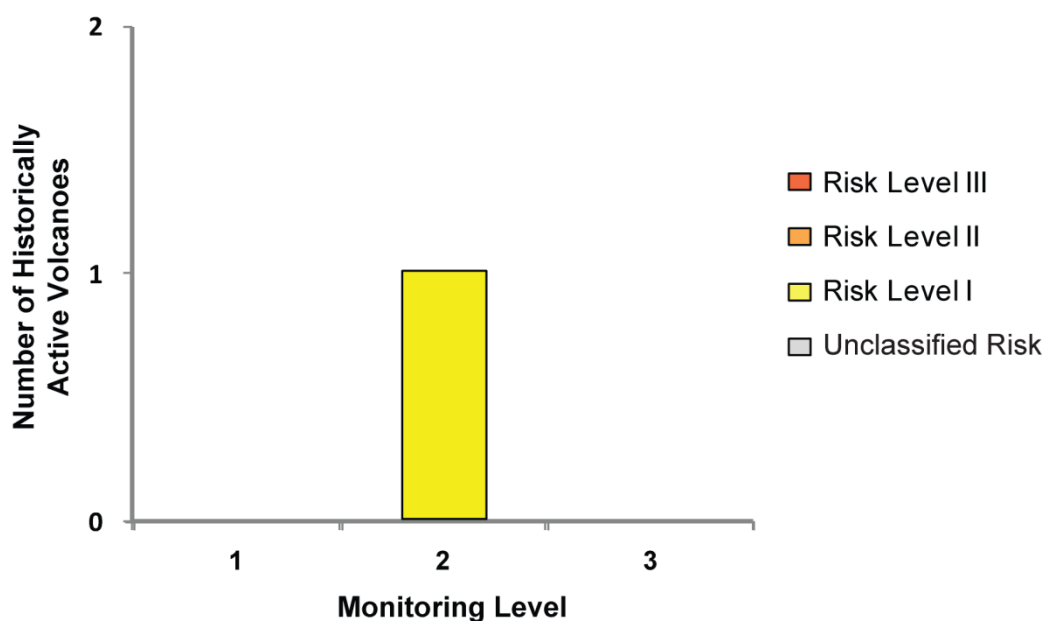


Figure 6.8 The monitoring and risk levels of the historically active volcanoes in India. Monitoring Level 1 indicates no known dedicated ground-based monitoring; Monitoring Level 2 indicates that some ground-based monitoring systems are in place including ≤ 3 seismic stations; Monitoring Level 3 indicates the presence of a dedicated ground-based monitoring network, including ≥ 4 seismometers.

Indonesia

Description

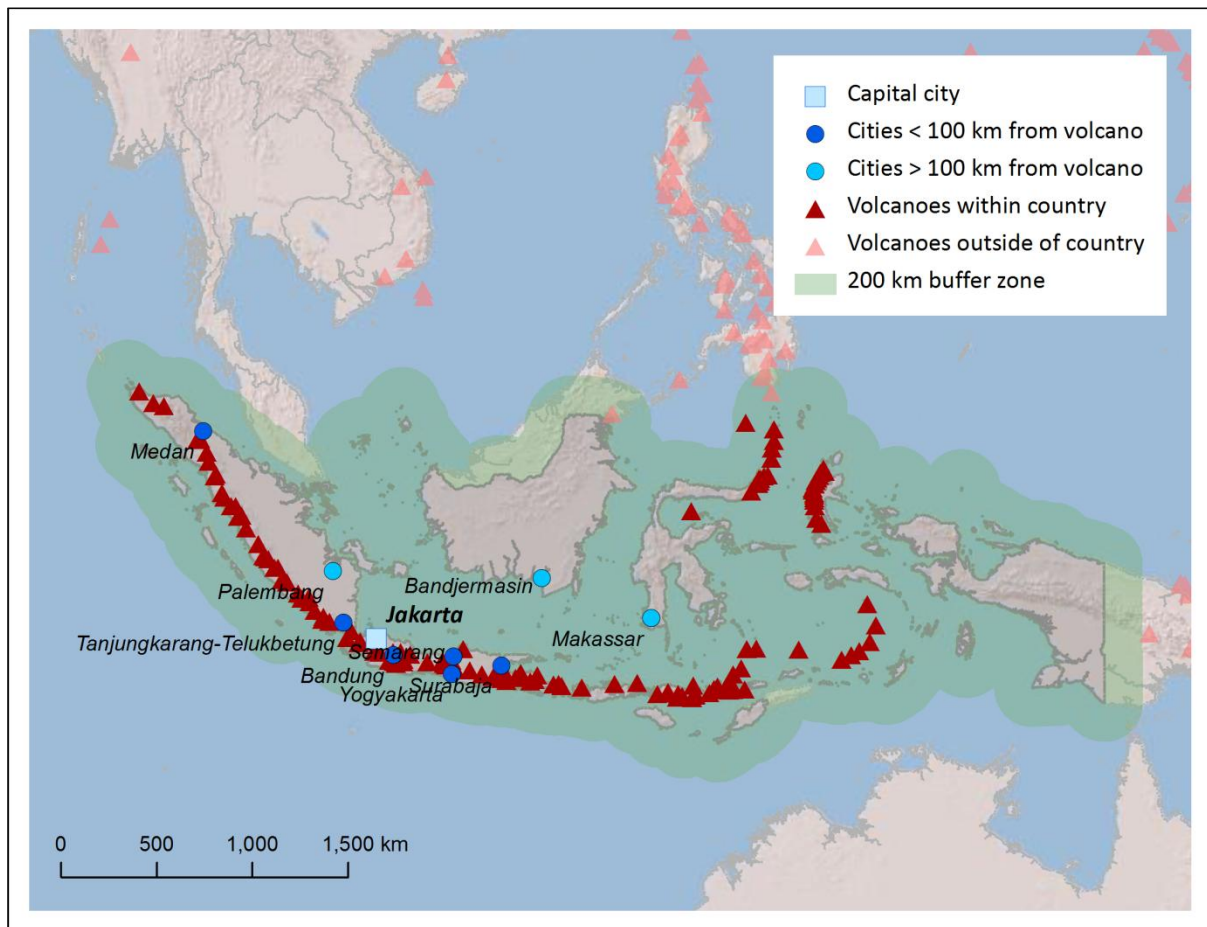


Figure 6.9 Location of Indonesia's volcanoes, the capital and largest cities. A zone extending 200 km beyond the country's borders shows other volcanoes whose eruptions may directly affect Indonesia.

The Smithsonian's Volcanoes of the World 4.0 database records 142 Holocene volcanoes distributed throughout much of Indonesia. Of these, 77 have a record of historical eruptions. Indonesia as a country and volcanic region covers a vast area, formed of over 13,000 islands stretching 5,271 km east-west and 2,210 km north-south. Volcanoes are spread across Java, Sumatra, Bali, Molluca, Nusa Tenggara and are located in the Celebes seas. The majority of these volcanoes lie along the Sunda Arc, caused by subduction of the Indo-Australia Plate below the Eurasian Plate. The Arc stretches over 3,000 km from northwest Sumatra in the east to the Banda Sea in the west, and accounts for 108 (76%) of the country's volcanoes. The tectonic setting north of the Sunda Arc is more complex, with converging plate fragments west of the Pacific Plate which itself is subducting to the west, creating multiple subduction zones that give rise to the volcanoes of Halmahera and Sulawesi-Sangihe. A wide range of volcano types are present in Indonesia, however stratovolcanoes are the dominant form with a dominantly andesitic composition.

The density of active volcanoes in Indonesia means that eruptions are frequent. 1,265 eruptions are recorded through the Holocene in VOTW4.22.94% of these are recorded post-1500 AD, indicating good historical records and severe under-recording with increasing age. Holocene eruptions of VEI 0 – 7 are recorded, indicating a range of activity styles from small, effusive events to catastrophic explosive eruptions. These large explosive eruptions are recorded back into the Pleistocene, with 8 Indonesian volcanoes with records of $M \geq 4$ eruptions, including the largest eruption recorded in the Pleistocene worldwide: the M8.8 Younger Toba Tuff eruption at Toba about 74,000 years ago. The Tambora eruption of 1815 is the largest magnitude historical eruption worldwide.

The widespread distribution of volcanoes throughout Indonesia means that much of the country lies within the 100 km radii of these Holocene volcanoes. Nearly 80% of the population live within these radii and much of the critical infrastructure is exposed, with many of the largest cities, including the capital, Jakarta, falling within this distance. Indeed, Jakarta lies within about 65 km of three Holocene volcanoes, Gede, Salak and Perbakti-Gagak, all of which have had eruptions as recently as the 1900s. Densely populated rural communities, particularly on Java, further increase population exposure; 28 of Indonesia's volcanoes have over 100,000 people living within 10 km of their summits, with over 8.6 million living at this distance throughout Indonesia. Ninety-one volcanoes have over 100,000 living within 30 km.

A range of hazards are posed by Indonesia's volcanoes, with many volcanoes hosting explosive eruptions. Thirty volcanoes have produced pyroclastic flows during 115 historical eruptions, and 31 have produced lahars during 102 historical eruptions. Hazard classifications range from Level I to III, and nearly 60% of Indonesian volcanoes have considerable uncertainties associated with the assignment of the hazard levels and are therefore unclassified here. Of the classified volcanoes in Indonesia, 18 are classed as Risk Level III, due to the high hazard and high local populations.

Three events, at Tambora in 1815, Krakatau in 1883, and Kelut in 1919, stand out in terms of devastating loss of life and these three events alone account for roughly a fifth of historic fatalities from worldwide volcanism. The largest historical eruption, the VEI 7 eruption of Tambora in 1815, caused approximately 60,000 deaths. Direct deaths resulted from tsunamis, bomb impacts, tephra falls, and pyroclastic flows that reached all but the west coast, with roughly 50,000 indirect deaths on Sumbawa and Lombok islands owing to starvation following the destruction of farmland. The caldera collapse eruption of Krakatau, situated in the Sunda Strait between Java and Sumatra, in 1883 was the second largest during historical time in Indonesia (after that of Tambora). The VEI 6 eruption destroyed Krakatau island, triggering tsunamis that swept the coastlines of Sumatra and Java and killed approximately 34,000; further deaths resulted from pyroclastic surges that travelled 40 km across the Sunda Strait to the coast of Sumatra. Kelut, a stratovolcano on west Java, highlights the potential hazard posed by crater lakes. Kelut's often short but violent eruptions have frequently released volumes of water from the crater lake that generate devastating lahars; lahars following the VEI 4 event in 1919 claimed 5,110 lives, and destroyed 9,000 homes and 104 villages. Tunnels draining the crater lake have been engineered to decrease this hazard. The February 2014 VEI 4 eruption of Kelut resulted in lahars following heavy rainfall. The CVGHM (Center for Volcanology and Geological Hazard Mitigation) monitors Kelut and from increases in seismicity, crater lake temperature and inflation were able to raise the alert level and evacuate many from a 10 km radius prior to this eruption.

An eruption of Merapi, beginning in October and November 2010, is one of Indonesia's most recent volcanic crises. The CVGHM raised the alert level to its highest possible on 25th October 2010, and recommended immediate evacuation for communities within a 10 km radius of the volcano (between 11,000 and 19,000 people). A day later, an explosive eruption generating pyroclastic flows began; on 27th October, reports noted roughly twenty-five deaths and several more injured. The eruption continued throughout November, with further pyroclastic flows and avalanches, and a particularly violent explosion on 5th November; ash caused diversions and cancellations at Solo and Yogyakarta airports. Activity began to decline in early December, with the CVGHM reducing the alert level to 3 (on a scale of 1 to 4) on 4th December, and to 2 on 9th January 2011. The overall death toll exceeded 380, over 400,000 people were temporarily evacuated, and financial losses were estimated at Rp 7.1 trillion (approximately US\$781 million). Lahars are an ongoing hazard.

The CVGHM was founded in 1920 to monitor the Indonesian volcanoes. CVGHM is part of the Ministry of Energy and Mineral Resources and is funded by the Indonesian government. Of a staff of over 220, about 70% have experience of responding to an eruption. The CVGHM has a number of volcano observatories distributed throughout Indonesia, responsible for monitoring the volcanoes and collecting data. Members of the public are encouraged to report unusual signs at volcanoes to CVGHM. Monitoring is undertaken at 68 volcanoes, all with at least one seismic station. Many of the high risk volcanoes have multiple seismic stations and other monitoring systems in place. Those monitored have baseline seismic data available which permits observations of unusual activity. Not all volcanoes in Indonesia are continuously monitored, however CVGHM has plans and some resources available to respond to an increase in activity at currently unmonitored volcanoes.

The CVGHM categorise Indonesia's volcanoes using a different classification system to that used in this report. The CVGHM consider 127 volcanoes to be active. These are classified into three groups: Type A volcanoes have had magmatic eruptions since 1600, Type B volcanoes had eruptions before 1600, and Type C volcanoes only exhibit fumarolic activity. The CVGHM focuses monitoring efforts at the Type A volcanoes, with 68 out of 77 of these volcanoes have continuous monitoring with at least one seismometer.

The CVGHM have a set protocol for responding to an increase in activity and they inform the local government, the BNPB (the National Disaster Management Agency) and BPBD (the Local Disaster Management Agency), local authorities and the population located in the hazard area. The CVGHM also communicates observations and advice to multiple agencies including the Indonesian National Armed Forces, National Police, Ministry of Transportation, Ministry of Health and Ministry of Social Affairs. The CVGHM are responsible for providing risk assessments and declaring alerts, with regular communication of the alert levels.

See also:

CVGHM: www.vsi.esdm.go.id/

Volcano Facts

Number of Holocene volcanoes

142

Number of Pleistocene volcanoes with M≥4 eruptions	8
Number of volcanoes generating pyroclastic flows	33
Number of volcanoes generating lahars	31
Number of volcanoes generating lava flows	38
Number of fatalities caused by volcanic eruptions	?>142,903
Tectonic setting	142 subduction zone
Largest recorded Pleistocene eruption	The M8.8 eruption of the Younger Toba Tuff from Toba at 74 ka.
Largest recorded Holocene eruption	The M7.1 eruption of Krakatau in 416 AD.
Number of Holocene eruptions	1265 confirmed eruptions. 121 uncertain eruptions.
Recorded Holocene VEI range	0 – 7 and unknown
Number of historically active volcanoes	77
Number of historical eruptions	1,192

Number of volcanoes	Primary volcano type	Dominant rock type
14	Caldera(s)	Andesitic (7), Dacitic (4), Unknown (3)
2	Hydrothermal field	Andesitic (1), Unknown (1)
112	Large cone(s)	Andesitic (91), Basaltic (17), Dacitic (2), Unknown (2)
2	Lava dome(s)	Andesitic (2)
3	Small cone(s)	Andesitic (1), Basaltic (1), Unknown (1)
5	Submarine	Andesitic (1), Unknown (4)
4	Unknown	Andesitic (1), Dacitic (1), Unknown (2)

Table 6.10 The number of volcanoes in Indonesia, their volcano type classification and dominant rock type according to VOTW4.0.

Socio-Economic Facts

Total population (2012)	247,273,000
Gross Domestic Product (GDP) per capita (2005 PPP \$)	4,094
Gross National Income (GNI) per capita (2005 PPP \$)	4,154
Human Development Index HDI) (2012)	0.629 (Medium)

Population Exposure

Capital city	Jakarta
Distance from capital city to nearest Holocene volcano	65.6 km
Total population (2011)	245,613,043
Number (percentage) of people living within 10 km of a Holocene volcano	8,631,283 (3.5%)
Number (percentage) of people living within 30 km of a Holocene volcano	68,995,038 (28.1%)
Number (percentage) of people living within 100 km of a Holocene volcano	179,107,855 (72.9%)

Ten largest cities, as measured by population and their population size:

Jakarta	8,540,121
Surabaya	2,374,658
Medan	1,750,971
Bandung	1,699,719
Palembang	1,441,500
Makassar	1,321,717
Semarang	1,288,084
Tanjungkarang-Telukbetung	800,348
Yogyakarta	636,660
Bandjermasin	572,837

Infrastructure Exposure

Number of airports within 100 km of a volcano	10
Number of ports within 100 km of a volcano	41
Total length of roads within 100 km of a volcano (km)	11,312
Total length of railroads within 100 km of a volcano (km)	3,178

The numerous Indonesian volcanoes are distributed throughout the country, placing much of the country within 100 km of these volcanoes. This means that an extensive proportion of the population and major cities, including the capital Jakarta, are exposed to volcanic hazards. Much of the critical infrastructure lies within the 100 km radii, including numerous airports and international airports, and over 40 ports. An extensive road and rail network is also exposed.

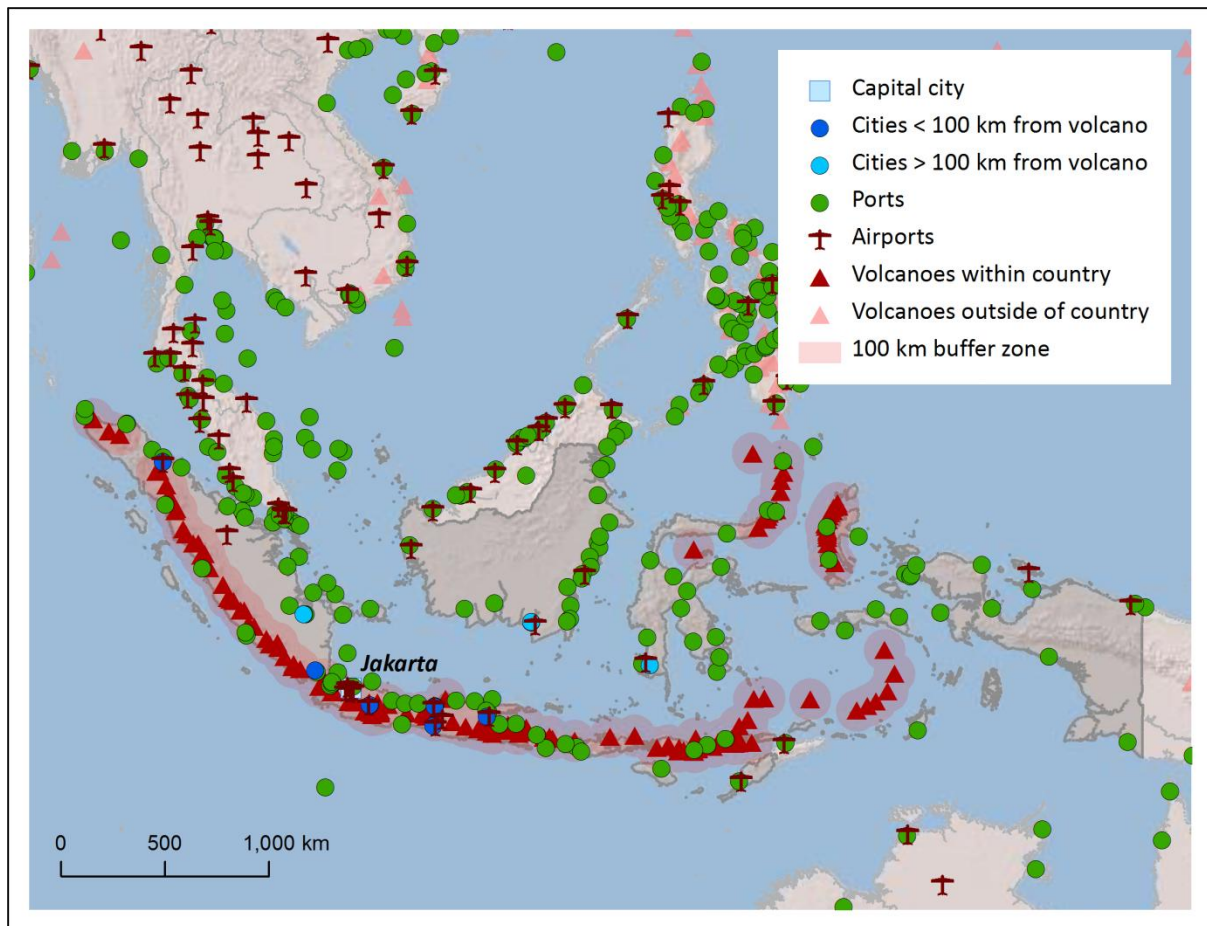


Figure 6.10 The location of Indonesia's volcanoes and the extent of the 100 km zone surrounding them. Ports, airports and the major cities are just some of the infrastructure that may be exposed to volcanic hazards.

Hazard and Uncertainty Assessments

The volcanoes of Indonesia have varying levels of data available in the eruption record. Just over 40% of volcanoes have appropriate eruptive histories to define the hazard. Of these classified volcanoes 54 are 'active' having had eruptions since 1900. Three classified volcanoes are 'semi-active', with historical eruptions between 1500 and 1900 and unrest recorded above background levels since 1900 (Guntur, Lamongan and Tongkoko). The classified volcanoes are classed at all three hazard levels: 26 at Hazard Level I, 19 at Hazard Level II and 12 at Hazard Level III.

Of the unclassified volcanoes, 13 have experienced eruptions since 1900; a further 10 have had Holocene age eruptions and 62 have had no confirmed Holocene eruptions. Thirty-six unclassified volcanoes have fumarolic activity ongoing or recorded since 1900, however seven of these have exhibited periods of unrest since 1900 in which fumarolic emissions, seismicity or other activity has been above background levels.

Exposure Assessments

CLASSIFIED	Hazard III		Teon, Ruang	Karangetang [Apu Siau], Makian	Tambora, Awu	Semeru, Soputan	Galunggung, Kelut, Lokon-Empung	Merapi
	Hazard II		Paluweh, Serua	Peuet Sague, Sorikmarapi, Sangeang Api, Iliwerung	Krakatau, Ebulobo, Gamkonora	Kaba, Raung, Ijen, Rinjani, Iya, Tongkoko	Cereme, Tengger Caldera, Mahawu, Gamalama	
	Hazard I		Nila, Banua Wuhu	Banda Api	Dempo, Lewotolo, Sirung, Ibu	Bur ni Telong, Marapi, Talang, Kerinci, Lewotobi, Leroboleng, Iliboleng, Egon	Perbakti-Gagak, Salak, Papandayan, Slamet, Lamongan	Gede, Tankubanparahu, Guntur, Dieng Volcanic Complex, Sundoro, Batur
UNCLASSIFIED	U – HHR		Batu Tara, Colo [Una Una] , Wurlali, Gunungapi Wetar	Sumbing (261180), Besar, Suoh , Dukono	Seulawah Agam, Kelimutu	Sibayak, Sinabung, Tandikat, Ranakah, Inielika, Ambang	Lawu, Arjuno-Welirang, Agung	Sumbing (263220), Merbabu
	U- HR				Inierie	Muria		
	U- NHHR	Manuk, Unnamed (267050)	Yersey, Emporor of China, Nieuwerkerk, Amasing	Malintang, Hutapanjang, Pandan, Kunyit, Belirang-Beriti, Patah , Bukit Lumut Balai, Sekincau Belirang, Tobaru, Moti, Tigalalu, Bibinoi	Sibualbuali, Libukraya, Talakmau, Ranau, Ndete Napu, Ililabalekan, Tarakan, Todoko-Ranu, Jailolo, Hiri, Mare	Imun, Sarik-Gajah, Bukit Daun, Hulubelu, Iyang-Argapura, Baluran, Poco Leok, Sukaria Caldera, Ilimuda, Klabat, Tidore	Toba, Rajabasa, Pulosari, Karang, Patuha, Wayang-Windu, Kendang, Talagabodas , ngaran, Telomoyo, Wilis, Kawi-Butak, Lurus, Wai Sano, Sempu	Malabar, Tampomas, Kawah Karaha , Penanggungan, Malang Plain, Bratan, Tondano Caldera
		PEI 1	PEI 2	PEI 3	PEI 4	PEI 5	PEI 6	PEI 7

Table 6.11 Identity of Indonesia's volcanoes in each Hazard-PEI group. Those volcanoes with a sufficient record for determining a hazard score are deemed 'classified' (top). Those without sufficient data are 'Unclassified' (bottom). The unclassified volcanoes are divided into groups: U-NHHR is Unclassified No Historic or Holocene Record: that is there are no confirmed eruptions recorded in the Holocene. U-HR is Unclassified with Holocene Record: that is there are confirmed eruptions recorded during the Holocene, but no historical (post-1500) events. U-HHR is Unclassified with Historic and Holocene record. The unclassified volcanoes in **bold** have experienced unrest or eruptions since 1900 AD, and those in red have records of at least one Holocene VEI ≥ 4 eruption.

Volcano	Population Exposure Index	Risk Level
Banua Wuhu	2	I
Nila	2	I
Paluweh	2	I
Ruang	2	II
Serua	2	I
Teon	2	II
Banda Api	3	I
Iliwerung	3	II
Karangetang [Api Siau]	3	II
Makian	3	II
Peuet Sague	3	II
Sangeang Api	3	II
Sorikmarapi	3	II
Awu	4	III
Dempo	4	I
Ebulobo	4	II
Gamkonora	4	II
Ibu	4	I
Krakatau	4	II
Lewotolo	4	I
Sirung	4	I
Tambora	4	III
Egon	5	II
Ijen	5	II
Iliboleng	5	II
Iya	5	II
Kaba	5	II
Kerinci	5	II
Leroboleng	5	II
Lewotobi	5	II
Marapi	5	II
Raung	5	II
Rinjani	5	II
Semeru	5	III
Soputan	5	III
Talang	5	II
Telong, Bur ni	5	II
Tongkoko	5	II
Cereme	6	III
Galunggung	6	III
Gamalama	6	III
Kelut	6	III
Lamongan	6	II
Lokon-Empung	6	III

Mahawu	6	III
Papandayan	6	II
Perbakti-Gagak	6	II
Salak	6	II
Slamet	6	II
Tengger Caldera	6	III
Batur	7	III
Dieng Volcanic Complex	7	III
Gede	7	III
Guntur	7	III
Merapi	7	III
Sundoro	7	III
Tangkubanparahu	7	III

Table 6.12 The classified volcanoes of Indonesia ordered by descending Population Exposure Index (PEI). Risk levels determined through the combination of the Hazard Level and PEI are given. Risk Level I – 9 volcanoes; Risk Level II – 30 volcanoes; Risk Level III – 18 volcanoes.

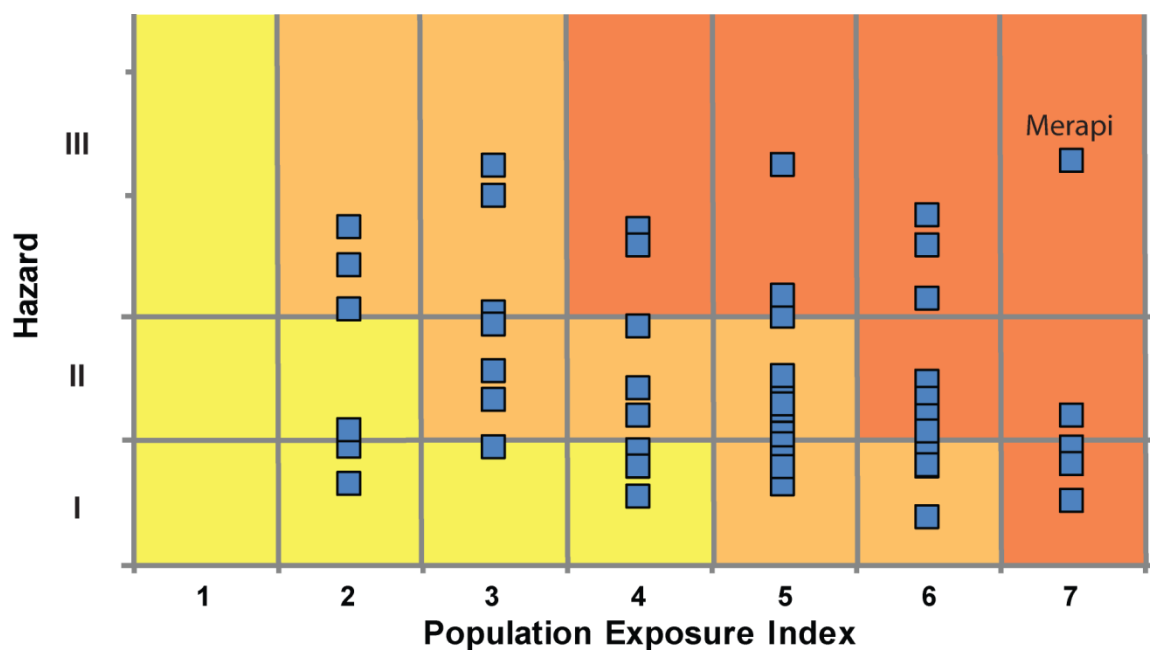


Figure 6.11 Distribution of Indonesia's classified volcanoes across Hazard and Population Exposure Index levels. The warming of the background colours illustrates increasing Risk levels from Risk Level I - III.

The population of Indonesia is high and this is reflected in the PEI classifications, with only 16 volcanoes having a low PEI of 1 or 2, 46 with a moderate PEI of 3 or 4, and 80 with a high PEI ≥ 5 . The classified volcanoes are found across the risk levels, with 9 Risk Level I volcanoes, 30 Risk Level II volcanoes and 18 Risk Level III volcanoes. Merapi, with the highest Hazard classification in Indonesia, has a very large local population with over 185,000 living within 10 km and is hence classified at Risk Level III.

National Capacity for Coping with Volcanic Risk

The Center for Volcanology and Geological Hazard Mitigation (CVGGM) is responsible for the monitoring of the volcanoes in Indonesia. Multiple observatories are in place and at 68 volcanoes have monitoring systems. The level of monitoring varies, with most volcanoes having fewer than three seismic stations and about 20 having seismic networks or seismic networks and deformation stations. All Risk Level III volcanoes are monitored to some degree, with 11 being designated monitoring level 3.

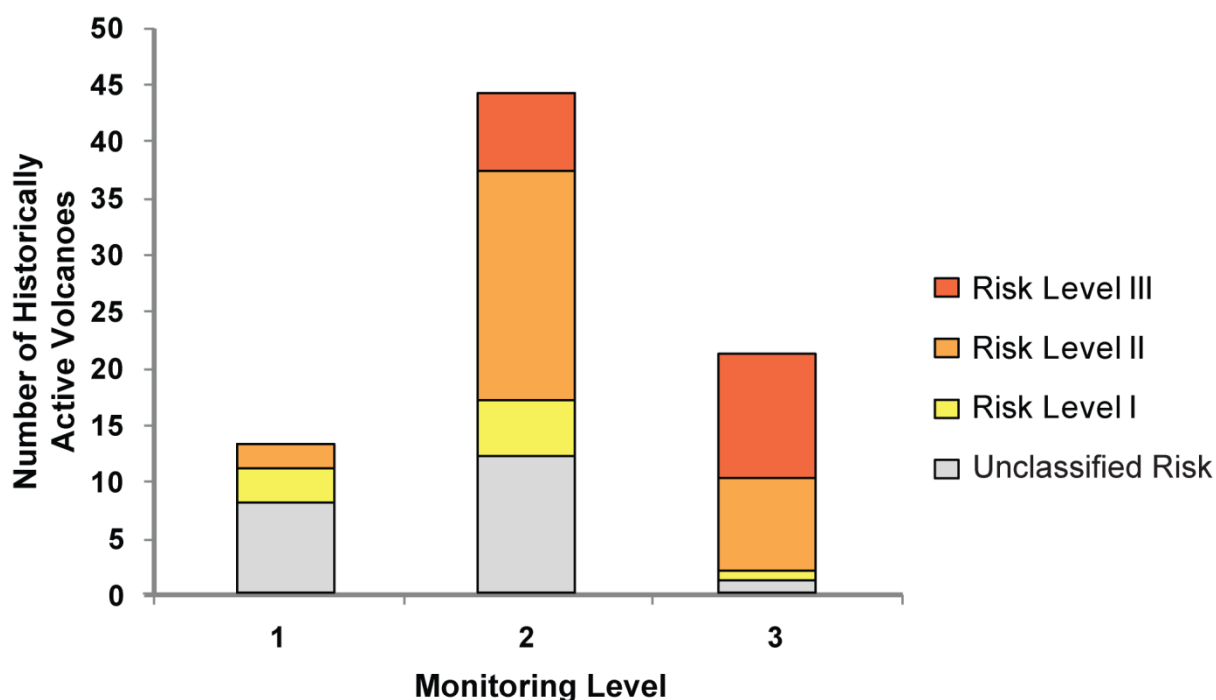


Figure 6.12 The monitoring and risk levels of the historically active volcanoes in Indonesia. Monitoring Level 1 indicates no known dedicated ground-based monitoring; Monitoring Level 2 indicates that some ground-based monitoring systems are in place including ≤ 3 seismic stations; Monitoring Level 3 indicates the presence of a dedicated ground-based monitoring network, including ≥ 4 seismometers.

Malaysia

Description

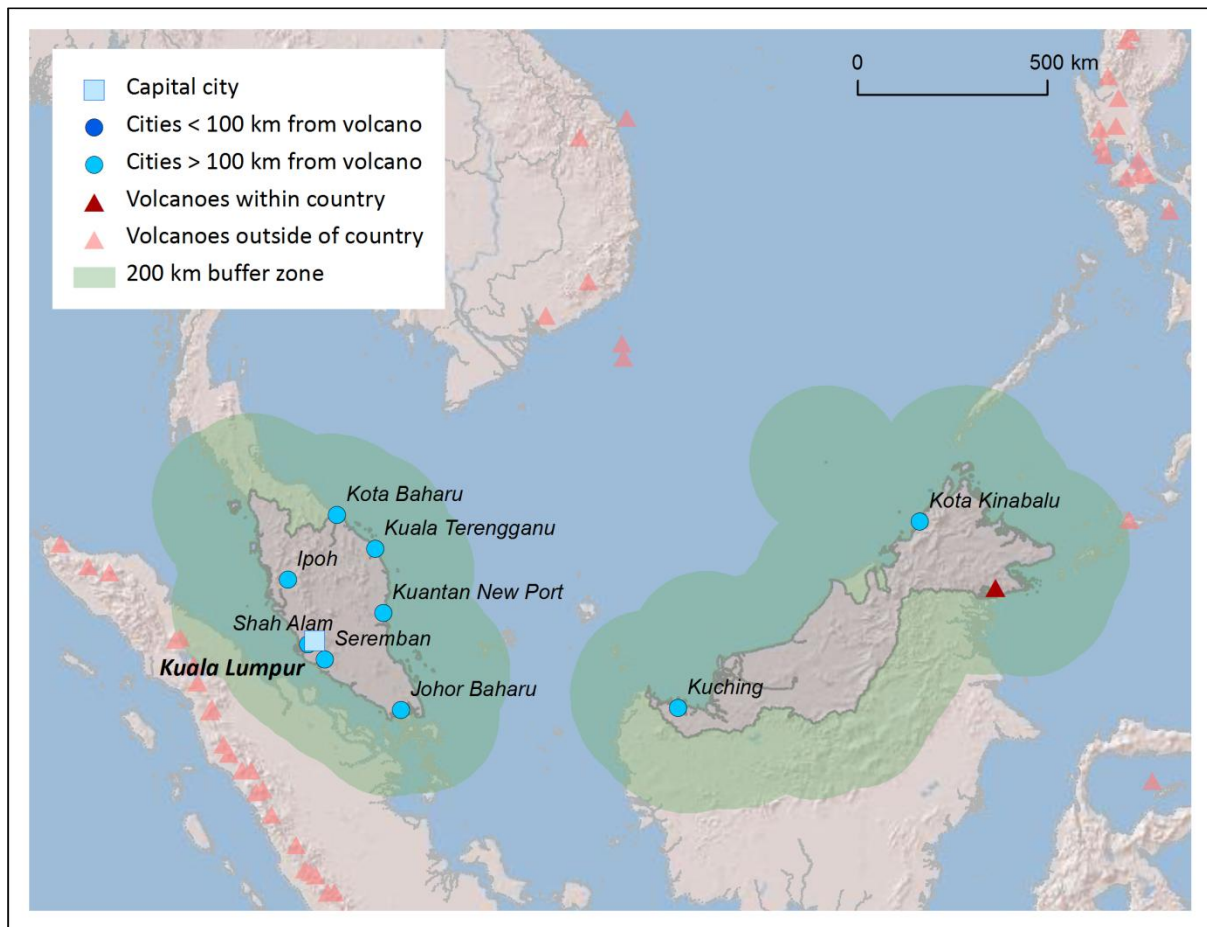


Figure 6.13 Location of Malaysia's volcanoes, the capital and largest cities. A zone extending 200 km beyond the country's borders shows other volcanoes whose eruptions may directly affect Malaysia.

One volcano with suspected Holocene age activity is identified in Malaysia. Mount Bombalai is situated in north-eastern Borneo, on the border with Indonesia. Volcanism here is broadly related to the subduction of the Philippine plate under the Eurasian plate.

Bombalai is a basaltic pyroclastic cone in a volcanic field. No confirmed eruptions are recorded in the Holocene, however effusive activity is suspected. Further research is required to date lavas and better constrain the eruptive history.

Less than 1% of Malaysia's population live within 100 km of Bombalai, and indeed there is no population within 30 km. The Hazard Level is poorly constrained due to the sparse eruptive history.

The 100 km exposure radius of Malaysia's volcano extends beyond the border into Indonesia and exposes some infrastructure here.

No information is available at the time of the writing of this report to indicate that regular ground-based monitoring is undertaken at Bombalai.

The Asian Disaster Reduction Center (ADRC) produced a report on the hazards in Malaysia in 2011, with a further six such reports dating back to 1998. In this they do not consider volcanic hazards, describing Malaysia as being ‘generally free from ... volcanic eruption’. They describe how disaster management in Malaysia operates on three levels – Federal, State and District. The Malaysian Meteorological Department (MMD) are responsible for monitoring disaster risk and strengthening disaster preparedness, specifically for meteorological, seismological and tsunami hazards. For full details of the disaster management and preparedness see the ADRC report.

See also:

Asian Disaster Reduction Center: Malaysia:

www.adrc.asia/nationinformation.php?NationCode=458&Lang=en&NationNum=16

Volcano Facts

Number of Holocene volcanoes	1
Number of Pleistocene volcanoes with M \geq 4 eruptions	-
Number of volcanoes generating pyroclastic flows	-
Number of volcanoes generating lahars	-
Number of volcanoes generating lava flows	-
Number of fatalities caused by volcanic eruptions	-
Tectonic setting	Subduction zone
Largest recorded Pleistocene eruption	-
Largest recorded Holocene eruption	-
Number of Holocene eruptions	-
Recorded Holocene VEI range	-
Number of historically active volcanoes	-
Number of historical eruptions	-

Number of volcanoes	Primary volcano type	Dominant rock type
1	Small cone(s)	Basaltic (1)

Table 6.13 The number of volcanoes in Malaysia, their volcano type classification and dominant rock type according to VOTW4.0.

Socio-Economic Facts

Total population (2012)	29,269,000
Gross Domestic Product (GDP) per capita (2005 PPP \$)	13,672
Gross National Income (GNI) per capita (2005 PPP \$)	13,676
Human Development Index (HDI) (2012)	0.769 (High)

Population Exposure

Capital city	Kuala Lumpur
Distance from capital city to nearest Holocene volcano	325.6 km
Total population (2011)	28,728,607
Number (percentage) of people living within 10 km of a Holocene volcano	0 (0%)
Number (percentage) of people living within 30 km of a Holocene volcano	0 (0%)
Number (percentage) of people living within 100 km of a Holocene volcano	39,281 (<1%)

Ten largest cities, as measured by population and their population size:

Kuala Lumpur	1,453,975
Johor Baharu	802,489
Ipoh	673,318
Kuching	570,407
Shah Alam	481,654
Kota Kinabalu	457,326
Seremban	372,917
Kuantan New Port	366,229
Kuala Terengganu	285,065
Kota Baharu	279,316

Infrastructure Exposure

Number of airports within 100 km of a volcano	0
Number of ports within 100 km of a volcano	4
Total length of roads within 100 km of a volcano (km)	205
Total length of railroads within 100 km of a volcano (km)	0

The Malaysian volcano Bombalai is located in the far east of the country, on the border with East Kalimantan, Indonesia. The 100 km radius around this volcano therefore affects Indonesia as well as Malaysia. Being located near the coast, four ports are proximal to this volcano. Only a small road network is within this radius, with the nearest airport being over 150 km away.

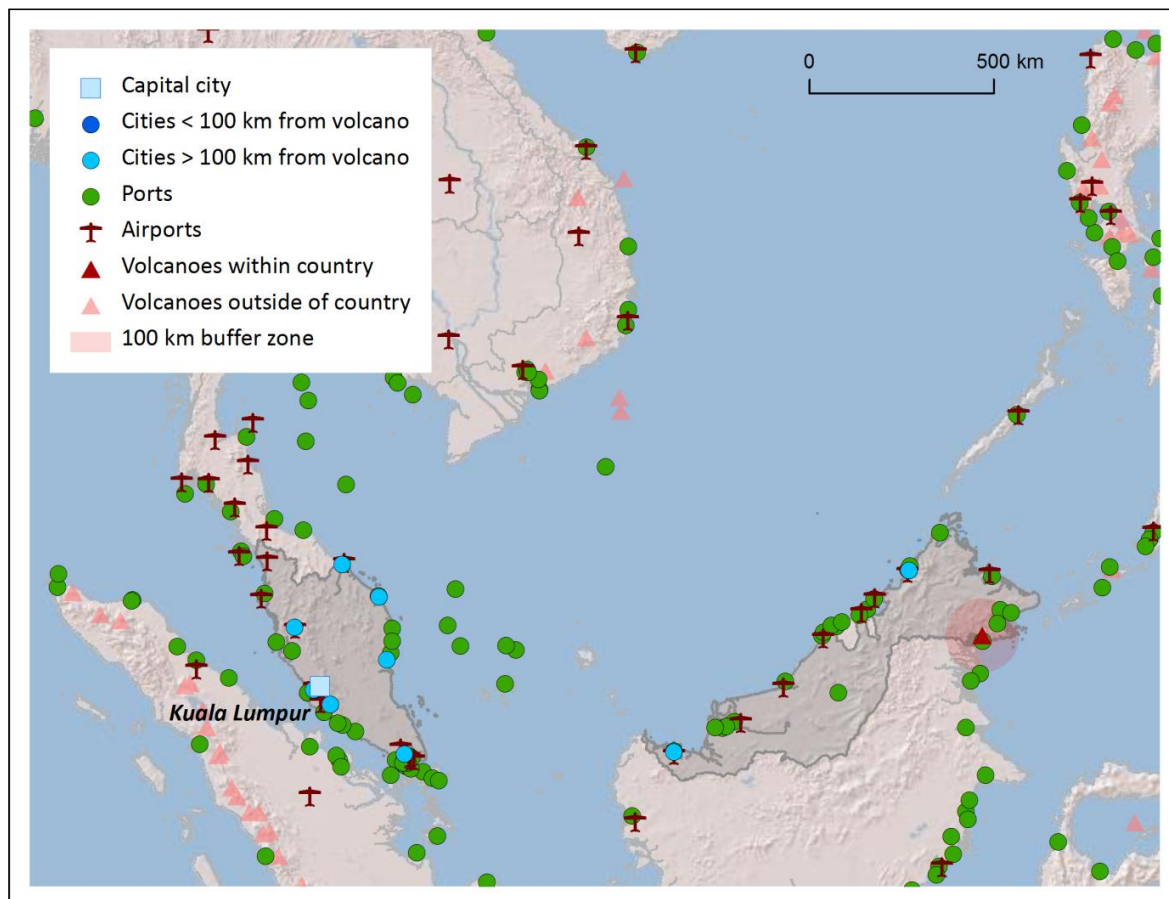


Figure 6.14 The location of Malaysia's volcanoes and the extent of the 100 km zone surrounding them. Ports, airports and the major cities are just some of the infrastructure that may be exposed to volcanic hazards.

Hazard, Uncertainty and Exposure Assessments

The calculation of the hazard score cannot be undertaken for Bombalai due to the absence of an extensive eruption record, with no confirmed Holocene eruptions here. Bombalai has a moderate PEI of 4.

CLASSIFIED	Hazard III							
	Hazard II							
	Hazard I							
UNCLASSIFIED	U – HHR							
	U- HR							
	U- NHHR				Bombalai			
		PEI 1	PEI 2	PEI 3	PEI 4	PEI 5	PEI 6	PEI 7

Table 6.14 Identity of Malaysia's volcanoes in each Hazard-PEI group. Those volcanoes with a sufficient record for determining a hazard score are deemed 'Classified' (top). Those without sufficient data are 'Unclassified' (bottom). The unclassified volcanoes are divided into groups: U-NHHR is Unclassified No Historic or Holocene Record: that is there are no confirmed eruptions recorded in the Holocene. U-HR is Unclassified with Holocene Record: that is there are confirmed eruptions recorded during the Holocene, but no historical (post-1500) events. U-HHR is Unclassified with Historic and Holocene record. The unclassified volcanoes in **bold** have experienced unrest or eruptions since 1900 AD, and those in red have records of at least one Holocene VEI ≥4 eruption.

National Capacity for Coping with Volcanic Risk

No volcanoes in Malaysia have recorded historical eruptions and no information is available at the time of the writing of this report to indicate that regular ground-based monitoring is undertaken at Bombalai.