Appendix B – Region 7

Country and regional profiles of volcanic hazard and risk:

Philippines and SE Asia

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This download comprises the profiles for Region 7: Philippines and SE Asia 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:

Brown, S.K., Sparks, R.S.J., Mee, K., Vye-Brown, C., Ilyinskaya, E., Jenkins, S.F., and Loughlin, S.C. (2015) Country and regional profiles of volcanic hazard and risk. In: S.C. Loughlin, R.S.J. Sparks, S.K. Brown, S.F. Jenkins & C. Vye-Brown (eds) *Global Volcanic Hazards and Risk,* Cambridge: Cambridge University Press.

Region 7: Philippines and SE Asia

The Philippines and SE Asia region comprises volcanoes throughout Myanmar, the Philippines, Vietnam and southern China (Table 7.1). Country profiles are provided for all, however see Region 10 (Kamchatka and Mainland Asia) for a country profile for China.

Country	Number of volcanoes
Myanmar (Burma)	3
China (See Region 10)	3
Philippines	47
Vietnam	6

Table 7.1 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.

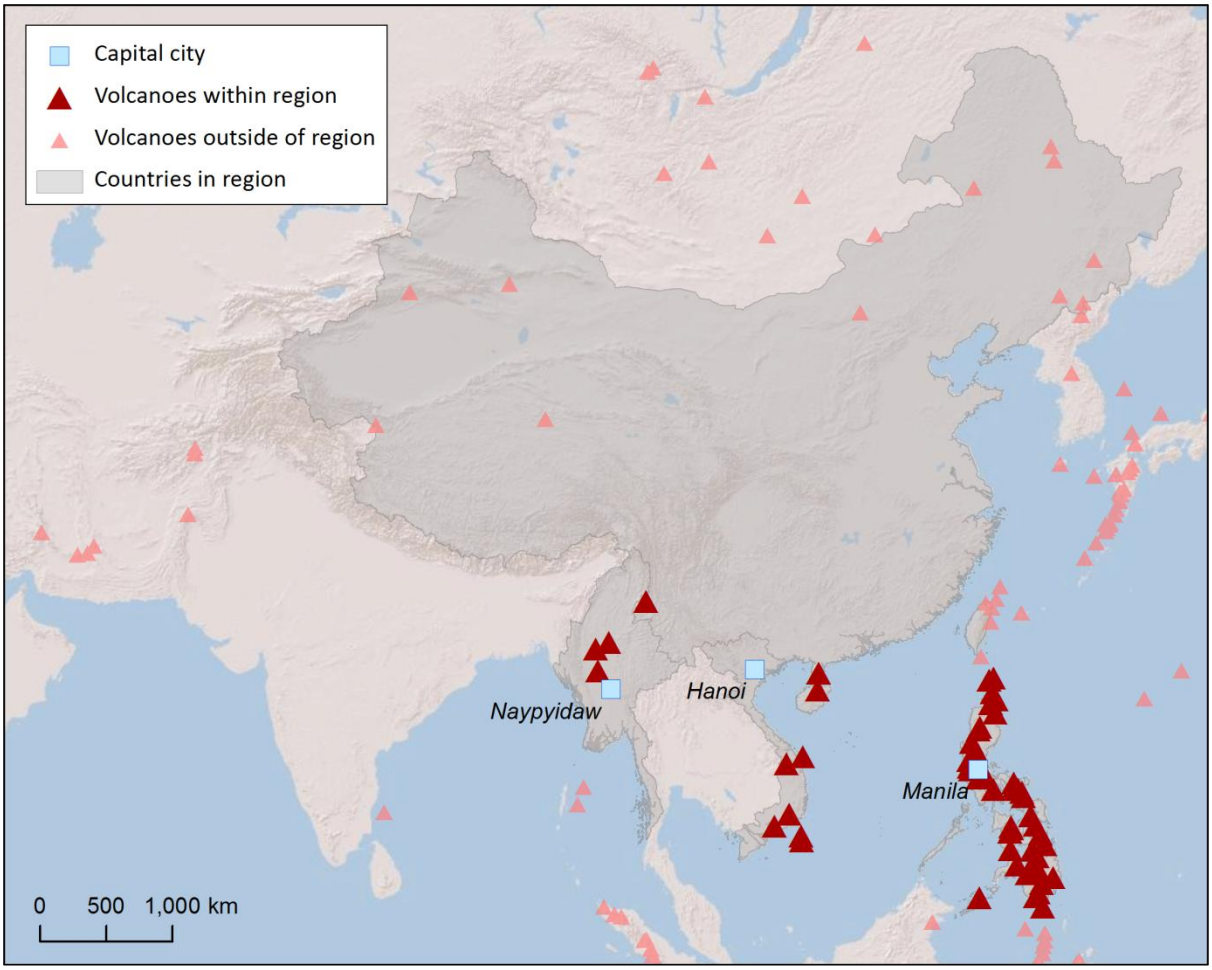

Figure 7.1 The distribution of Holocene volcanoes through the Philippines and SE Asia region. The capital cities of the constituent countries are shown.

Description

Fifty-nine Holocene volcanoes are located in Region 7: Philippines and SE Asia. Volcanism here is broadly due to the subduction of the Philippine Sea Plate beneath the Eurasian Plate. This has generated magmas of largely andesitic composition and dominantly (~75%) stratovolcanoes.

Of the 59 volcanoes, only 27 have confirmed Holocene eruptions recorded, with the remaining volcanoes having had activity of suspected Holocene age. This uncertainty in events complicates hazard assessment. Most (~88%) eruptions are recorded historically, post-1500 AD, and the Philippines dominates activity here.

Eruptions in this region have ranged from VEI 0 to 6 in size, indicating a range of activity styles, however about 9% of eruptions are classed at VEI ≥4. About 19% of historical eruptions have produced pyroclastic flows, and 20% have resulted in lahars. These mudflows remain a hazard for years after eruptions, with examples of secondary lahars at Pinatubo following the 1991 eruption burying thousands of homes years after the event. Tsunamis are associated with about 5% of historical eruptions here, making this region second only to the West Indies for proportion of tsunami-generating events.

The population density in this region is high, and about 2.9 million people throughout the region live within 10 km of one or more active volcanoes, rising to about 116 million within 100 km. Most volcanoes have a very high proximal population. The number of eruptions resulting in loss of life reflects the high local populations. About 17% of historical eruptions have resulted in fatalities; the largest proportion of any region. About a quarter of historical eruptions have resulted in property damage. This historical record extends to before the development of monitoring institutions and monitoring networks (PHIVOLCS, see Philippines). Monitoring is now dominantly focussed at Risk Level II and III volcanoes, with about 36% of historically active volcanoes monitored by regular dedicated ground-based systems.

Volcano Facts

Number of Holocene volcanoes	59
Number of Pleistocene volcanoes with M≥4 eruptions	4
Number of volcanoes generating pyroclastic flows	44
Number of volcanoes generating lahars	42
Number of volcanoes generating lava flows	35
Number of eruptions with fatalities	31
Number of fatalities attributed to eruptions	7,934
Largest recorded Pleistocene eruption	The 37.5 ka eruption of the Irosin Ignimbrites at Bulusan in the Philippines was the largest Quaternary explosive event in this region at M7.1.

Largest recorded Holocene eruption	Three eruptions of Pinatubo, including the 1991 eruption, are the largest recorded in the Holocene in LaMEVE at M6.1.
Number of Holocene eruptions	203 confirmed Holocene eruptions.
Recorded Holocene VEI range	0 – 6 and unknown
Number of historically active volcanoes	20
Number of historical eruptions	178

Number of volcanoes	Primary volcano type	Dominant rock type
2	Caldera(s)	Andesitic (2)
42	Large cone(s)	Andesitic (32), Basaltic (8), Dacitic (2)
2	Lava dome(s)	Andesitic (2)
7	Small cone(s)	Andesitic (1), Basaltic (6)
3	Submarine	Basaltic (1), Unknown (2)

Table 7.2 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)	60

Table 7.3 Average recurrence interval (years between eruptions) for small and large eruptions in the Philippines and SE Asia.

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 60 years.

Eruption Size

Eruptions are recorded through the Philippines and SE Asia region of VEI 0 to 6, representing a range of eruption styles from gentle effusive events to large explosive eruptions (Figure 7.2). VEI 2 events dominate the record, with nearly 60% of all Holocene eruptions classed as such. 9% of eruptions here are explosive at VEI ≥4.

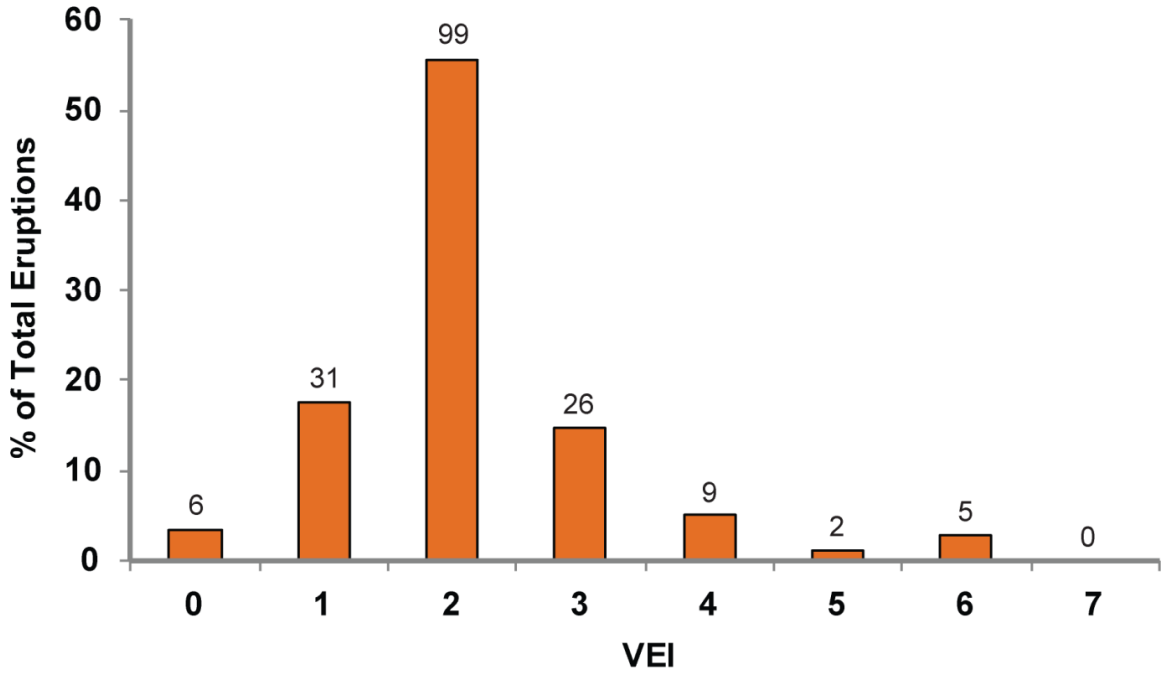

Figure 7.2 Percentage of eruptions in this region recorded at each VEI level; the number of eruptions is also shown. The percentage is of total eruptions with recorded VEI. A further 25 eruptions were recorded with unknown VEI.

Socio-Economic Facts

Total population (2011)	246,383,132
Gross Domestic Product (GDP) per capita (2005 PPP $)	3,013 – 3,631 (Mean 3,322)
Gross National Income (GNI) per capita (2005 PPP $)	1,817 – 3,752 (Mean 2,846)
Human Development Index (HDI) (2012)	0.498 – 0.654 (Low to Medium, Mean 0.590 Medium)

Population Exposure

Number (percentage) of people living within 10 km of a Holocene volcano	2,976,701 (1.21 %)
Number (percentage) of people living within 30 km of a Holocene volcano	34,041,940 (13.82 %)
Number (percentage) of people living within 100 km of a Holocene volcano	116,383,251 (47.24 %)

CLASSIFIED	**Hazard III**					Camiguin	Mayon	Taal
	Hazard II		Babuyan Claro			Bulusan		
	Hazard I		Didicas		Ragang	Kanlaon		
UNCLASSIFIED	**U – HHR**		Camiguin de Babuyanes; Unnamed; **Cendres, Ile des**	**Cagua**	Parker	Makaturing; Cabalían; **Biliran**; **Pinatubo**	Jolo; **Musuan**	**Hainan Dao**
	U- HR			Iraya	Leonard Range	**Matutum**; Popa	Mariveles; **Tengchong**	San Pablo Volcanic Field
	U-NHHR		**Veteran**	Balut; Mahagnao; Cù-Lao Ré Group; Toroeng Prong	Latukan; Balatukan; **Ambalatungan Group**	Apo; Kalatungan; **Malindang**; Paco; Cuernos de Negros; Mandalagan; Silay; Isarog; Malindig; Natib; Patoc	Pocdol Mountains; Masaraga; Iriga; Banahaw; Amorong; Santo Tomas; Haut Dong Nai; Singu Plateau	Laguna Caldera; Arayat; Leizhou Bandao; Bas Dong Nai; Lower Chindwin
		PEI 1	**PEI 2**	**PEI 3**	**PEI 4**	**PEI 5**	**PEI 6**	**PEI 7**

*Table 7.4 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
8	7
13	6
20	5
6	4
6	3
6	2
0	1

Table 7.5 The number of volcanoes in the Philippines and SE Asia classed in each PEI category.

Risk Levels

Number of Volcanoes	Risk Level
3	III
2	II
3	I
51	Unclassified

Table 7.6 The number of volcanoes in the Philippines and SE Asia region classified at each Risk Level.

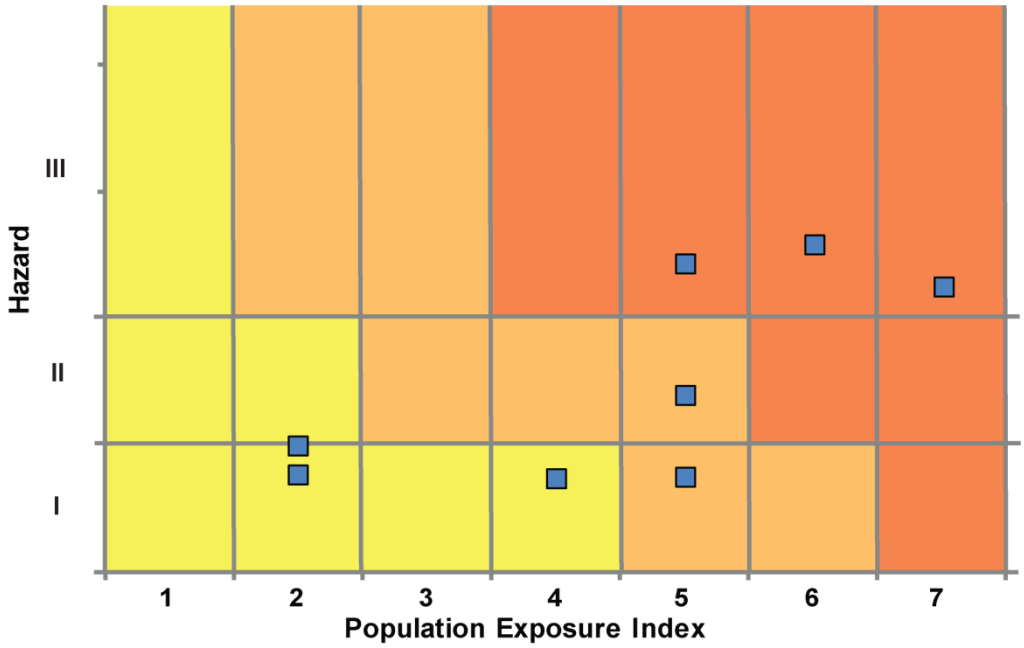

Figure 7.3 Distribution of the classified volcanoes of this region across Hazard and Population Exposure Index levels. The warming of the background colours illustrates increasing Risk levels from Risk Level I - III.

Regional Monitoring Capacity

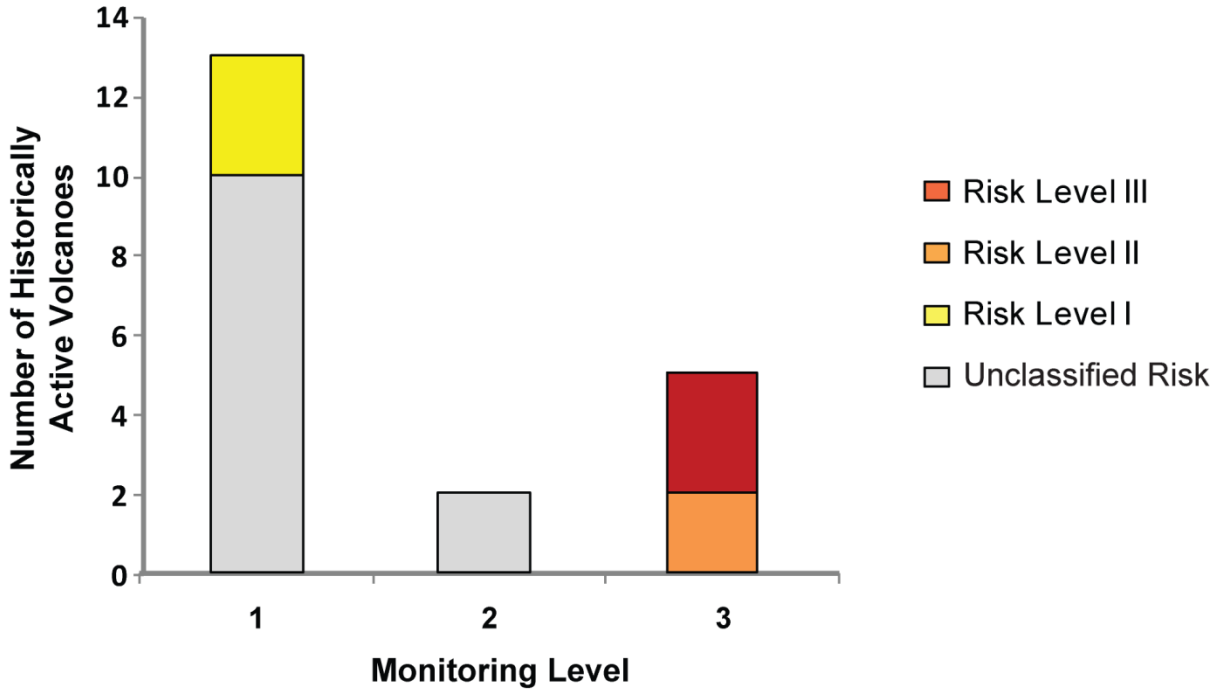

Figure 7.4 The monitoring and risk levels of the historically active volcanoes in the Philippines and SE Asia. Monitoring Level 1 indicates no known dedicated ground-based monitoring; Monitoring Level 2 indicates that some ground-based monitoring systems are in place including ≤3 seismic stations; Monitoring Level 3 indicates the presence of a dedicated ground-based monitoring network, including ≥4 seismometers.

Myanmar

Description

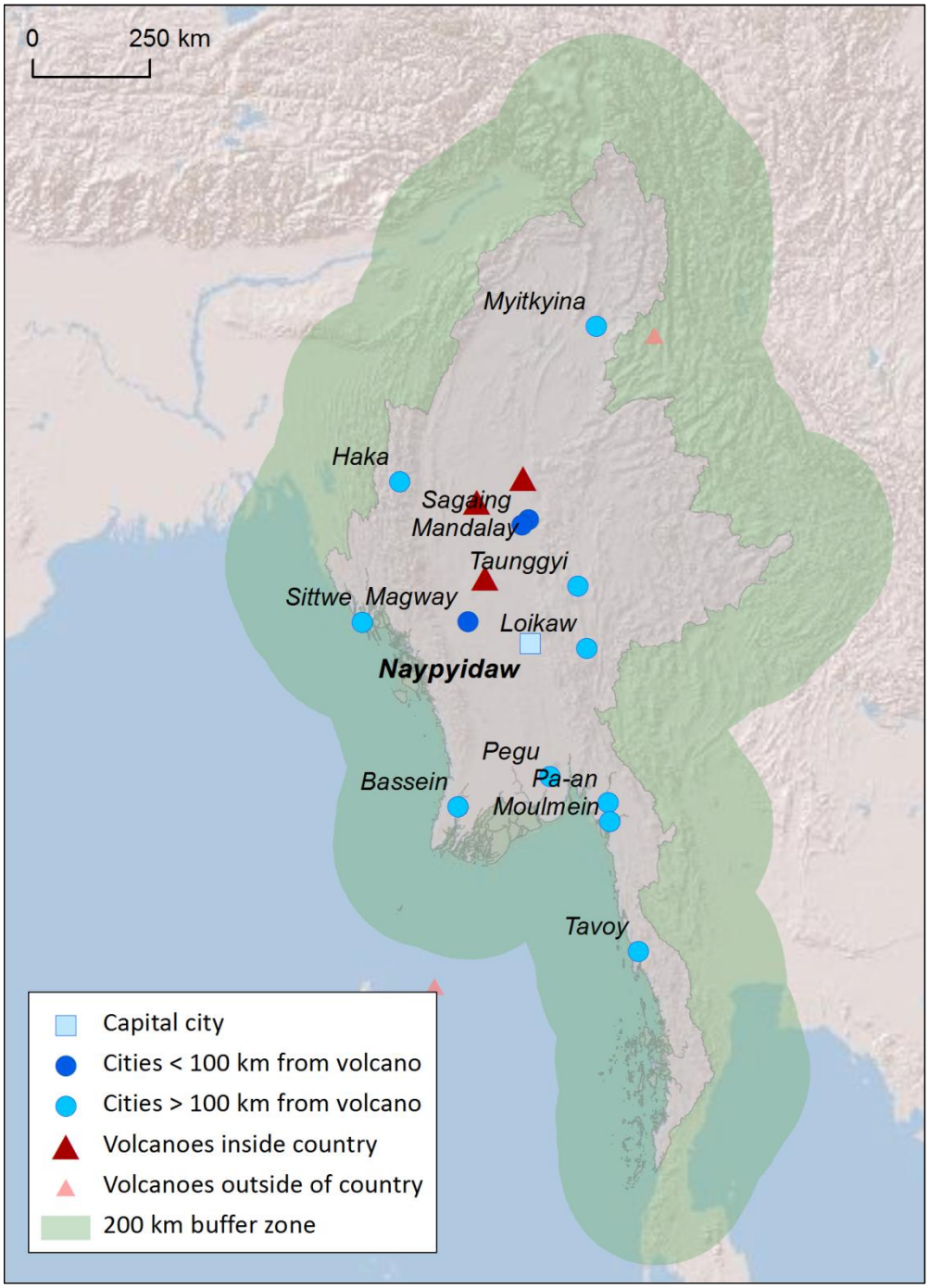

Figure 7.5 Location of Myanmar's volcanoes, the capital and largest cities. A zone extending 200 km beyond the country's borders shows other volcanoes whose eruptions may directly affect Myanmar.

Three Holocene volcanoes are located in central Myanmar. Of these, only Popa has a confirmed Holocene eruption. Lower Chindwin and Singu Plateau have suspected, but unconfirmed Holocene activity. These volcanoes are related to the subduction of the Indian plate under the Eurasian plate.

No volcanoes here have records of historical eruptions. The only recorded Holocene eruption occurred in 442 BC, and is of unknown VEI. The volcanoes here are basaltic to andesitic and comprise stratovolcanoes, small cones in a volcanic field and a fissure vent system. A range of activity could be expected from such features, from effusive to explosive, though the most recent activity appears to be largely effusive to Strombolian. The stratovolcano, Popa, has evidence of past flank collapse and debris avalanche, with a crater breached to the northwest.

The capital city, Naypyidaw, lies at about 160 km from Popa, however three of the largest cities in Myanmar lie within 100 km of the volcanoes and as such, all three volcanoes have large proximal populations of over 4 million within the individual 100 km radii. Nearly 23,000 people live within 10 km of Popa and a large proportion of this population live on the plain at the foot of the large channel from the crater. Hazardous flows of any kind originating at or around the summit vent here could be expected to be channelled through this topographic feature. The largest proximal population is found at Lower Chindwin volcanic field.

Tengchong volcano in southern China lies within 50 km of the border with Myanmar, and hence has the potential to affect the population and infrastructure here.

No regular ground-based monitoring is undertaken at the volcanoes in Myanmar.

The Asian Disaster Reduction Center (ADRC) produced a report on disaster risk reduction in Myanmar in 2013, in which they do not consider volcanic hazards. They describe how the Government of Myanmar established the National Disaster Preparedness Central Committees (NDPCC) and has Disaster Risk Management systems and plans on multiple levels including State, District and Local levels. Although volcanic hazards are not currently considered, it is likely these groups who would form the first response to activity. See the ADRC report for full details on DRR in Myanmar.

See also:

ADRC: Myanmar profile:
www.adrc.asia/nationinformation.php?NationCode=104&Lang=en&NationNum=17

Volcano Facts

Number of Holocene volcanoes	3
Number of Pleistocene volcanoes with M≥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	Intra-plate
Largest recorded Pleistocene eruption	-
Largest recorded Holocene eruption	Eruption was of unknown VEI
Number of Holocene eruptions	1 confirmed eruption
Recorded Holocene VEI range	Unknown
Number of historically active volcanoes	-
Number of historical eruptions	-

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

Table 7.7 The number of volcanoes in Myanmar, their volcano type classification and dominant rock type according to VOTW4.0.

Socio-Economic Facts

Total population (2012)	52,865,000
Gross Domestic Product (GDP) per capita (2005 PPP $)	
Gross National Income (GNI) per capita (2005 PPP $)	1,817
Human Development Index (HDI) (2012)	0.498 (Low)

Population Exposure

Capital city	Naypyidaw
Distance from capital city to nearest Holocene volcano	158.6 km
Total population (2011)	53,999,804
Number (percentage) of people living within 10 km of a Holocene volcano	124,041 (<1%)
Number (percentage) of people living within 30 km of a Holocene volcano	1,583,171 (2.9%)
Number (percentage) of people living within 100 km of a Holocene volcano	12,950,553 (24%)

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

Rangoon (Yangon)	4,477,638
Mandalay	1,208,099
Moulmein	438,861
Pegu	244,376
Bassein	237,089
Sittwe	177,743
Taunggyi	160,115
Tavoy	136,783
Magway	96,954
Myitkyina	90,894

Infrastructure Exposure

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)	2,905
Total length of railroads within 100 km of a volcano (km)	500

The volcanoes in Myanmar are situated in the centre of the country. Being inland volcanoes, no ports are located within 100 km. Whilst the capital, Naypyidaw, lies at nearly 160 km from Popa volcano, three of the largest cities in Myanmar lie within 100 km of the volcanoes placing significant infrastructure including an extensive road and rail network under threat.

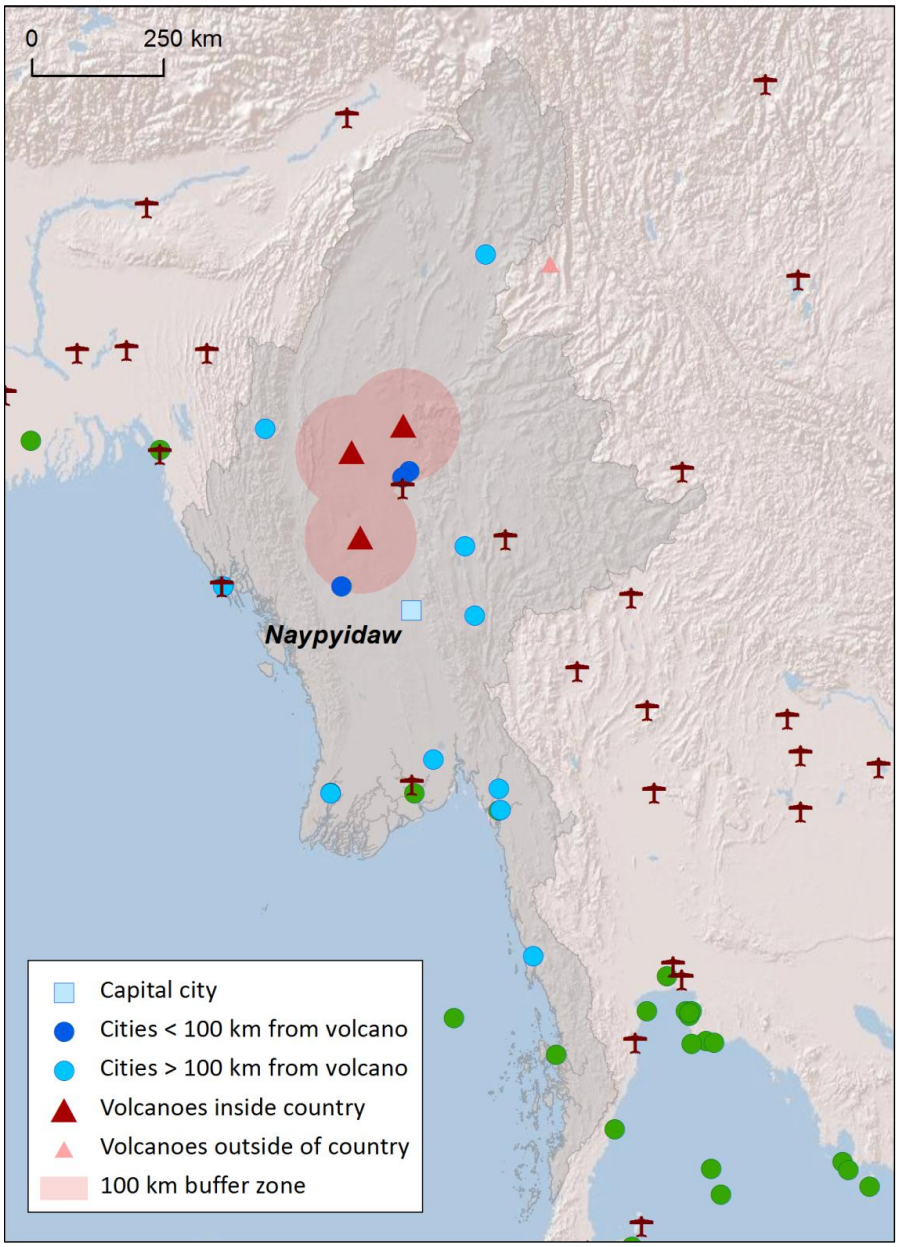

Figure 7.6 The location of Myanmar's volcanoes and the extent of the 100 km zone surrounding them. Ports, airports and the major cities are just some of the infrastructure that may be exposed to volcanic hazards.

Hazard, Uncertainty and Exposure Assessments

The eruptive record of the three volcanoes in Myanmar is insufficient for calculation of the hazard without large uncertainties. These volcanoes are therefore unclassified. Indeed, only Popa has a confirmed Holocene eruption record with just one eruption of unknown size in 442 BC.

At the Lower Chindwin volcano there is a high local population, represented by a PEI of 7. Although the hazard is unclassified here, the risk would classify at Risk Level III due to this population size. The risk level cannot be determined for Popa and Singu Plateau, although these also have high PEI levels of 5 and 6.

CLASSIFIED	**Hazard III**							
	Hazard II							
	Hazard I							
UNCLASSIFIED	**U – HHR**							
	U- HR					Popa		
	U- NHHR						Singu Plateau	Lower Chindwin
		PEI 1	**PEI 2**	**PEI 3**	**PEI 4**	**PEI 5**	**PEI 6**	**PEI 7**

*Table 7.8 Identity of Myanmar'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 Myanmar 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 any Holocene volcanoes in Myanmar.

Philippines

Description

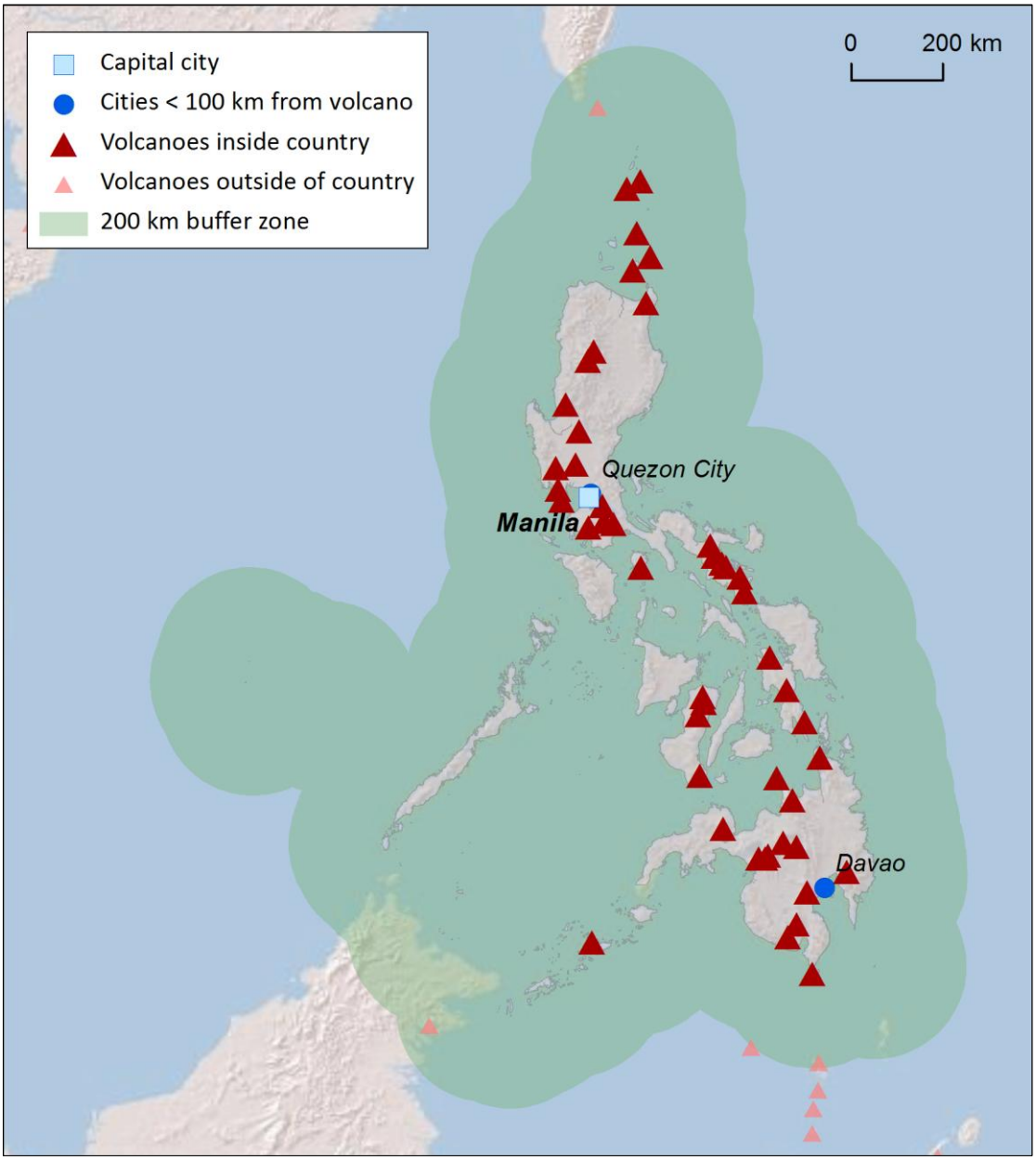

Figure 7.7 Location of the Philippines' volcanoes, the capital and largest cities. A zone extending 200 km beyond the country's borders shows other volcanoes whose eruptions may directly affect the Philippines.

Forty-seven Holocene volcanoes are located throughout the Philippines. These volcanoes are located primarily across four of the largest Philippine islands and off the coast of Luzon in the north. Volcanism here is due to a complex interaction between multiple tectonic plates and micro-plates,

with the Philippine and Eurasian Plates converging and undergoing subduction. There are two main volcanic arcs – the Luzon and Mindanao arcs, which roughly trend north-south.

The volcanoes in the Philippines are dominantly large cones, being principally stratovolcanoes and compound or complex volcanoes. Calderas and lava domes are also present. These volcano types along with the dominance of andesitic magmas illustrates that most of the volcanoes can be characterised by explosive activity. Indeed, the Holocene record includes 16 large explosive VEI ≥4 eruptions, including nine such historical eruptions. Five VEI 6 Holocene eruptions are recorded at Pinatubo and Taal, including the 1991 eruption of Pinatubo. The record of large explosive events in the Philippines continues into the Pleistocene with four recorded M≥4 eruptions, including the M7.1 eruption of Bulusan over 37,000 years ago. Such records of large explosive events indicate that similar sized eruptions could occur in the future.

VOTW4.22 lists 175 historical eruptions in the Philippines from 18 volcanoes. Eight volcanoes have produced pyroclastic flows, and lahars have occurred at six. Heavy rainfall and typhoons frequently produces lahars and secondary lahars due to the remobilisation of tephra. This remobilisation can occur for years following eruptions. With a record of explosive eruptions, the historical record of the human impact of volcanism in the Philippines is quite extensive. Between 1640 and 2013 AD 33 eruptions from Parker, Camiguin, Kanlaon, Bulusan, Mayon, Taal, Pinatubo, Didicas, Ragang and Ambalatungan Group resulted in fatalities. Fatalities are recorded in 18% of historical eruptions. Multiple evacuations are recorded and property damage is recorded in 24% of historical eruptions.

The volcanoes in the Philippines can be expected to have considerable impacts on the population, as around 80% of the population live within 100 km of one or more Holocene volcanoes. The capital, Manila, and many other major cities lie within these radii and thus much of the critical infrastructure of the country is exposed to volcanic hazards. A high local population is present at 37 volcanoes, as demonstrated by the classification of these at PEI≥5. Taal and Mayon have some of the highest hazard scores in the country, both with an extensive historical record of moderate to large eruptions, and also have a very large population within 10 km.

Nearly 250,000 people live within 10 km of Mayon and pyroclastic flows and lahars are commonly produced in eruptions here, many of which have devastated areas at the base of the cone. 1,200 fatalities occurred during the 1814 VEI 4 eruption here.

The 1991 VEI 6 eruption of Pinatubo was one of the largest in the 20th century in the world. Though the damage caused by the eruption led to huge socio-economic impacts, the number of fatalities was low relative to the eruption size as a result of successful monitoring and evacuation. An estimated 800 lives were lost, though up to half of these are attributable to disease in evacuation camps. In general, the emergency response to the eruption was widely viewed as a major success with many tens of thousands of people having been evacuated in time.

Two Indonesian volcanoes and one volcano in Taiwan lie within 200 km of the Philippines, indicating that eruptions from these could impact on the Philippines.

The Philippine Institute of Volcanology and Seismology (PHIVOLCS) is the institute responsible for the country's volcanoes. PHIVOLCS continuously monitors about 40% of the historically active volcanoes, including five Risk Level III volcanoes. Multiple monitoring methods are utilised at these

volcanoes. PHIVOLCS has responded to unrest at volcanoes in the past, increasing monitoring to better understand activity. PHIVOLCS assigns one of six alert levels for volcanic activity. 'No alert' is assigned to volcanoes in quiescence, and alert levels increase through '1. Abnormal', '2. Alarming', '3. Critical', '4. Eruption imminent' to '5. Eruption'. These levels are based on the level of unrest and trends in unrest. These alert levels are made available to the public as well as descriptors of activity and exclusion zones.

See also:

PHIVOLCS: www.phivolcs.dost.gov.ph/

Volcano Facts

Number of Holocene volcanoes	47
Number of Pleistocene volcanoes with M≥4 eruptions	4
Number of volcanoes generating pyroclastic flows	8
Number of volcanoes generating lahars	6
Number of volcanoes generating lava flows	6
Number of fatalities caused by volcanic eruptions	?>7,919
Tectonic setting	47 subduction zone
Largest recorded Pleistocene eruption	The M7.1 Irosin Ignimbrite eruption of Bulusan at 37.5 ka.
Largest recorded Holocene eruption	Three eruptions of Pinatubo are recorded at M6.1 – the Crow Valley eruptive period (5.5 ka), the Maraunot eruptive period (3 ka) and the 1991 AD eruption.
Number of Holocene eruptions	198 confirmed eruptions. 19 uncertain eruptions and 5 discredited eruptions.
Recorded Holocene VEI range	0 – 6 and unknown
Number of historically active volcanoes	18
Number of historical eruptions	175

Number of volcanoes	Primary volcano type	Dominant rock type
2	Caldera(s)	Andesitic (2)
41	Large cone(s)	Andesitic (32), Basaltic (7), Dacitic (2)
2	Lava dome(s)	Andesitic (2)
1	Small cone(s)	Basaltic (1)
1	Submarine	Unknown (1)

Table 7.9 The number of volcanoes in the Philippines, their volcano type classification and dominant rock type according to VOTW4.0.

Socio-Economic Facts

Total population (2012)	96,899,000
Gross Domestic Product (GDP) per capita (2005 PPP $)	3,631
Gross National Income (GNI) per capita (2005 PPP $)	3,752
Human Development Index (HDI) (2012)	0.654 (Medium)

Population Exposure

Capital city	Manila
Distance from capital city to nearest Holocene volcano	34.1 km
Total population (2011)	101,833,938
Number (percentage) of people living within 10 km of a Holocene volcano	2,708,394 (2.7%)
Number (percentage) of people living within 30 km of a Holocene volcano	30,511,866 (30%)
Number (percentage) of people living within 100 km of a Holocene volcano	80,918,982 (79.5%)

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

Davao	1,212,504

Infrastructure Exposure

Number of airports within 100 km of a volcano	7
Number of ports within 100 km of a volcano	60

Total length of roads within 100 km of a volcano (km)	9,424
Total length of railroads within 100 km of a volcano (km)	768

The volcanoes of the Philippines are distributed throughout the country, across the many islands. With the number of volcanoes and the distribution of the islands, almost all of the Philippines are located within 100 km of a volcano. This places almost all critical infrastructure within the country under threat, including the capital, Manila, and other major cities. An extensive road and rail network lies within 100 km of the volcanoes, as do 60 ports and 7 airports.

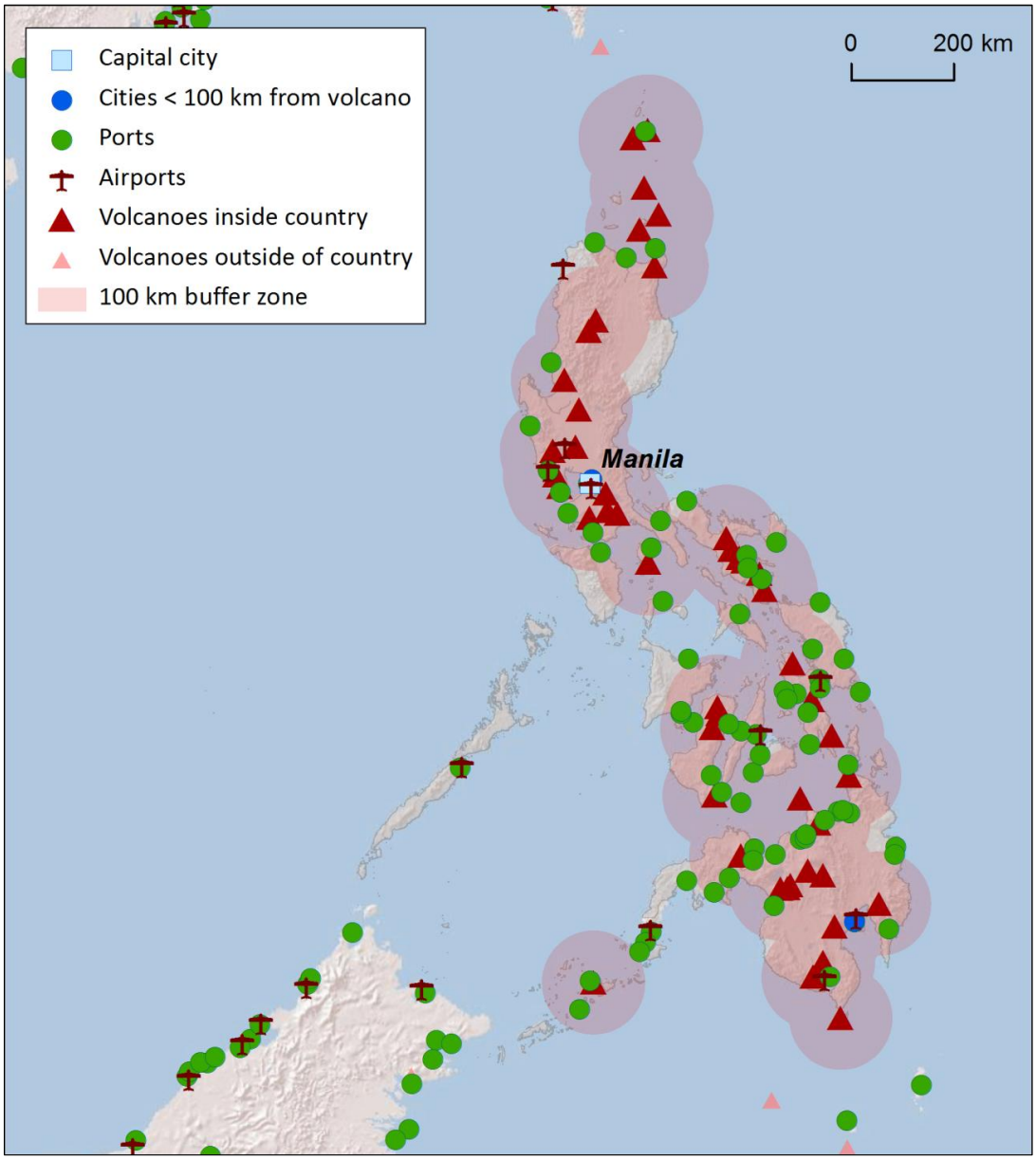

Figure 7.8 The location of the Philippines' volcanoes and the extent of the 100 km zone surrounding them. Ports, airports and the major cities are just some of the infrastructure that may be exposed to volcanic hazards.

Hazard, Uncertainty and Exposure Assessments

There are varying levels of data availability in the eruption records for the volcanoes of the Philippines. Less than 20% of volcanoes here have appropriate eruptive histories to define the hazard. These volcanoes are classified at Hazard Levels I, II and III, with just Camiguin, Mayon and Taal at Hazard Level III largely due to their history of explosive eruptions coupled with pyroclastic flow production.

Of the unclassified volcanoes, 24 have no confirmed Holocene eruptions. Though of these, Malindang and Ambalatungan Group have both shown unrest suspected to have been above background levels since 1900 AD. The remaining unclassified volcanoes have Holocene eruption records, including ten with historical eruptions. Biliran and Pinatubo both have erupted since 1900. Pinatubo is unclassified, but has eight Holocene eruptions including five of VEI 5 and 6 indicating that this volcano is highly explosive and hazardous. Parker is also unclassified, though has a Holocene record of three eruptions of VEI 4 and 5.

PEI ranges from low to very high in the Philippines, with most volcanoes having high local populations - 35 volcanoes are classed at PEI ≥5. This tendency towards higher populations in combination with the hazard levels classes over 60% of the classified volcanoes of the Philippines at Risk Levels II and III. Taal and Mayon, two of the volcanoes classified with the highest Hazard in the Philippines, have very large populations within 10 km at >700,000 and nearly 250,000 respectively.

CLASSIFIED	**Hazard III**					Camiguin	Mayon	Taal
	Hazard II		Babuyan Claro			Bulusan		
	Hazard I		Didicas		Ragang	Kanlaon		
UNCLASSIFIED	**U – HHR**		Camiguin de Babuyanes; Unnamed	**Cagua**	Parker	Makaturing; Cabalían; **Biliran**; **Pinatubo**	Jolo; **Musuan**	
	U- HR			Iraya	Leonard Range	**Matutum**	Mariveles	San Pablo Volcanic Field
	U- NHHR			Balut; Mahagnao	Latukan; Balatukan; **Ambalatungan Group**	Apo; Kalatungan; **Malindang**; Paco; Cuernos de Negros; Mandalagan; Silay; Isarog; Malindig; Natib; Patoc	Pocdol Mountains; Masaraga; Iriga; Banahaw; Amorong; Santo Tomas	Laguna Caldera; Arayat
		PEI 1	**PEI 2**	**PEI 3**	**PEI 4**	**PEI 5**	**PEI 6**	**PEI 7**

*Table 7.10 Identity of the Philippines' 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
Taal	7	III
Mayon	6	III
Camiguin	5	III
Bulusan	5	II
Kanlaon	5	II
Ragang	4	I
Babuyan Claro	2	I
Didicas	2	I

Table 7.11 Classified volcanoes of the Philippines ordered by descending Population Exposure Index (PEI). Risk levels determined through the combination of the Hazard Level and PEI are given. Risk Level I – 3 volcanoes; Risk Level II – 2 volcanoes; Risk Level III – 3 volcanoes.

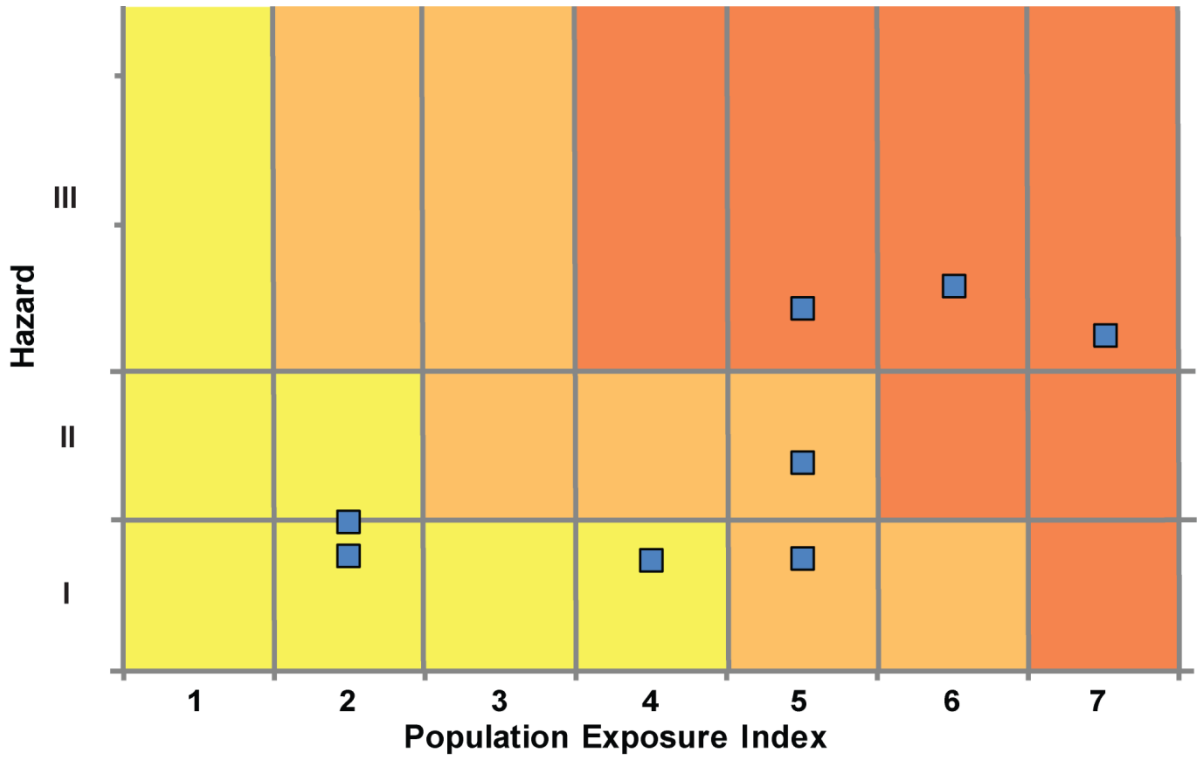

Figure 7.9 Distribution of the Philippines' classified volcanoes across Hazard and Population Exposure Index levels. The warming of the background colours illustrates increasing Risk levels from Risk Level I - III.

National Capacity for Coping with Volcanic Risk

The Philippine Institute of Volcanology and Seismology (PHIVOLCS) is responsible for the volcanoes in the Philippines, 18 of which have a historical eruption record. No information is available at the time of the writing of this report to indicate that regular ground-based monitoring is undertaken at 11 of these volcanoes.

Seven volcanoes are continuously monitored. Parker and Pinatubo are classed at Monitoring Level 2, with seismic networks in place and additional gas monitoring at Pinatubo. Gen. Santos Seismic and Volcano Observatory and Pinatubo Volcano Observatory are responsible for monitoring these respectively. Multi-system monitoring, including seismic and deformation surveillance, is undertaken

at Kanlaon, Camiguin, Bulusan, Mayon and Taal. Kanlaon Volcano Observatory, Quiboro Volcano Observatory, Bulusan Volcano Observatory, Lignon Hill Observatory and Taal Volcano Observatory conduct the monitoring. No Risk Level I volcanoes are of Monitoring Levels 2 and 3, suggesting prioritisation of resources.

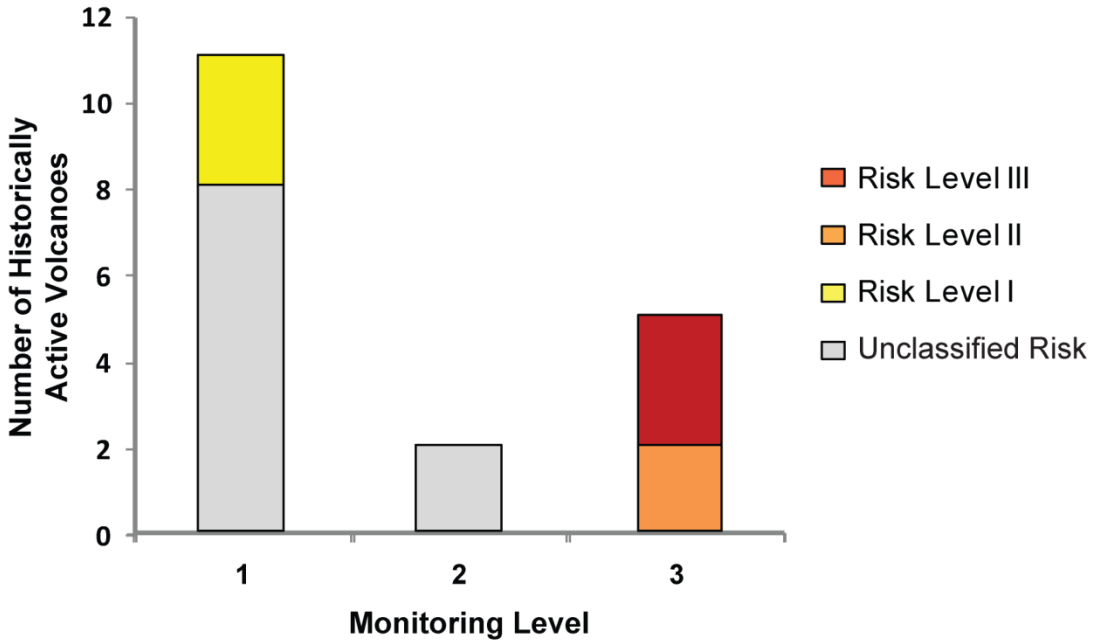

Figure 7.10 The monitoring and risk levels of the historically active volcanoes in the Philippines. Monitoring Level 1 indicates no known dedicated ground-based monitoring; Monitoring Level 2 indicates that some ground-based monitoring systems are in place including ≤3 seismic stations; Monitoring Level 3 indicates the presence of a dedicated ground-based monitoring network, including ≥4 seismometers.

Vietnam

Description

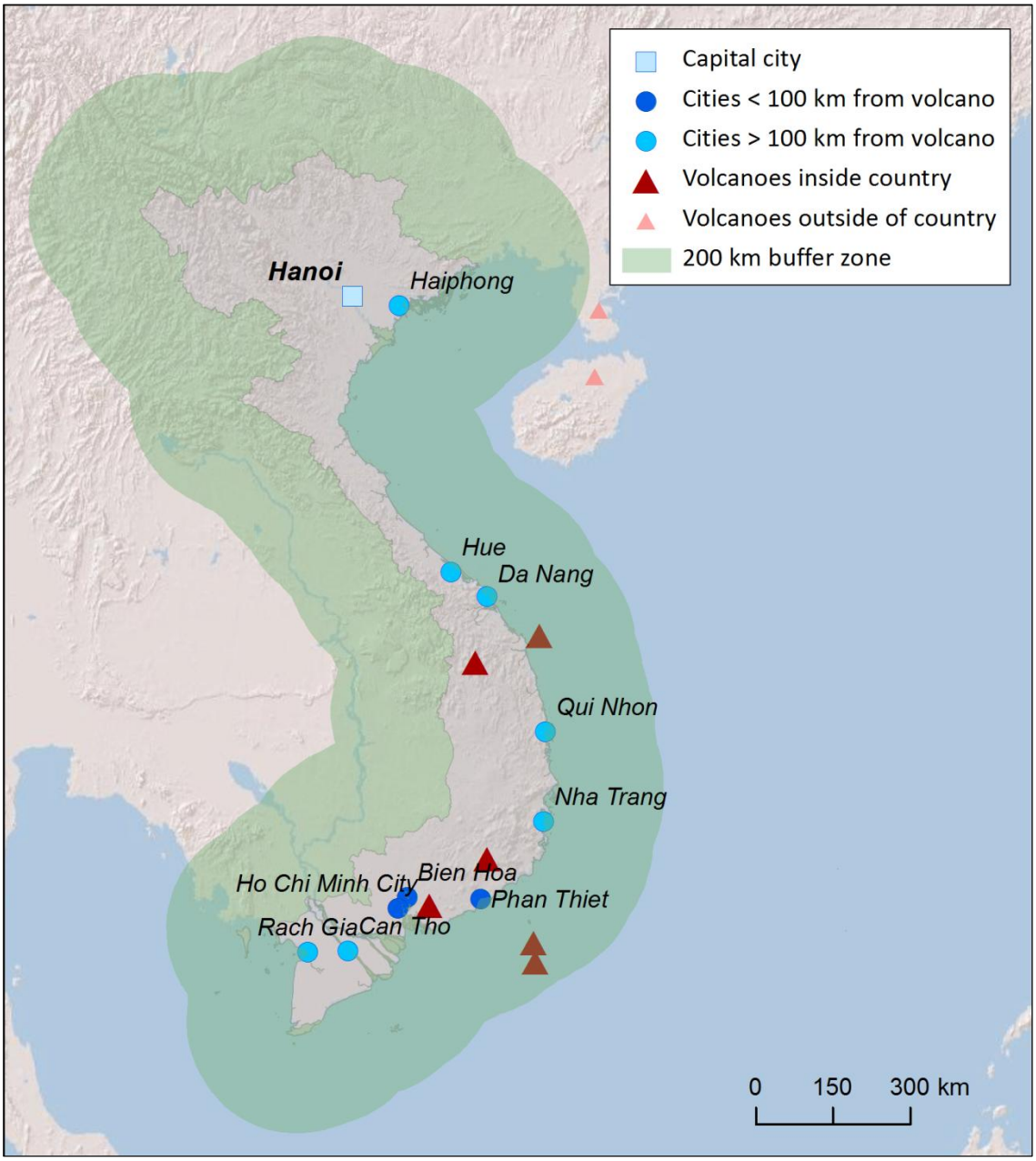

Figure 7.11 Location of Vietnam's volcanoes, the capital and largest cities. A zone extending 200 km beyond the country's borders shows other volcanoes whose eruptions may directly affect Vietnam.

Six Holocene volcanoes are distributed through the centre and south of Vietnam and within about 150 km of the coast. These volcanoes are located on the Sunda Plate, at the junction between the Eurasian and Philippine plates.

All volcanoes in Vietnam are dominantly basaltic, with the largest recorded eruption being a VEI 2. These volcanoes are dominantly effusive to moderately explosive forming cinder cones and volcanic fields.

Only one volcano in Vietnam has a record of historical activity. A confirmed VEI 2 eruption occurred at the submarine Ile des Cendres volcano in 1923, creating a new island. Two uncertain eruptions occurred at Veteran volcano in 1880 and 1928. Only the Ile des Cendres has a record of producing lava flows. No historic or Holocene records of explosive activity are present in Vietnam. Based on the volcano and rock types, effusive activity and the production of lavas can be expected to be the most frequent form of activity at these volcanoes, with potential for minor localised explosive activity.

No volcanoes lie within the 200 km buffer zone surrounding the country, though the capital of Vietnam, Hanoi, lies closer to Hainan Dao and Leizhou Bandao volcanoes in China than any Vietnamese volcano. Ho Chi Minh is the largest city in Vietnam, and Bas Dong Nai lies within 70 km of this city. This volcano thus has a very high local population. Most volcanoes here have a low to moderate PEI. Several of the largest cities in the south of Vietnam are located within 100 km of Haut Dong Nai and Bas Dong Nai and hence considerable infrastructure is exposed, and a very large population is located within 10 km of these volcanoes. The 100 km radius of Toroeng Prong extends beyond the Vietnam border and into Laos and Cambodia. No historical record of fatalities or property damage exists for eruptions in Vietnam.

No information is available at the time of the writing of this report to indicate that ground-based monitoring is undertaken at any of the volcanoes in Vietnam. The Institute of Geological Sciences and Geophysics at the Vietnam Academy of Science and Technology is responsible for undertaking research in geological hazards and for the prediction of geological hazards and mitigation of their effects. A network of seismometers is present through the country, with four broadband seismographs along the coast and two further inland in the north, which can be accessed through the Ocean Hemisphere Project Data Management Center at University of Tokyo.

See also:

Institute of Geological Sciences: www.vast.ac.vn/en/about-vast/organization-chart/institutes/institutes-established-by-the-government/1011-institute-of-geological-sciences

Volcano Facts

Number of Holocene volcanoes	6
Number of Pleistocene volcanoes with M≥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	Intra-plate
Largest recorded Pleistocene eruption	-
Largest recorded Holocene eruption	The VEI 2 eruption of the Ile des Cendres in 1923 AD.
Number of Holocene eruptions	1 confirmed eruption. 2 uncertain eruptions.
Recorded Holocene VEI range	2
Number of historically active volcanoes	1
Number of historical eruptions	1

Number of volcanoes	Primary volcano type	Dominant rock type
4	Small cone(s)	Basaltic (4)
2	Submarine	Basaltic (1), Unknown (1)

Table 7.12 The number of volcanoes in Vietnam, their volcano type classification and dominant rock type according to VOTW4.0.

Socio-Economic Facts

Total population (2012)	90,951,000
Gross Domestic Product (GDP) per capita (2005 PPP $)	3,013
Gross National Income (GNI) per capita (2005 PPP $)	2,970
Human Development Index (HDI) (2012)	0.617 (Medium)

Population Exposure

Capital city	Hanoi
Distance from capital city to nearest Holocene volcano	448.4 km
Total population (2011)	90,549,390
Number (percentage) of people living within 10 km of a Holocene volcano	144,266 (<1%)
Number (percentage) of people living within 30 km of a Holocene volcano	1,946,903 (2.2%)
Number (percentage) of people living within 100 km of a Holocene volcano	22,513,716 (24.9%)

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

Ho Chi Minh City	3,467,331
Hanoi	1,431,270

Da Nang	752,493
Haiphong	602,695
Bien Hoa	407,208
Hue	287,217
Can Tho	259,598
Rach Gia	228,356
Phan Thiet	160,652
Long Xuyen	158,153

Infrastructure Exposure

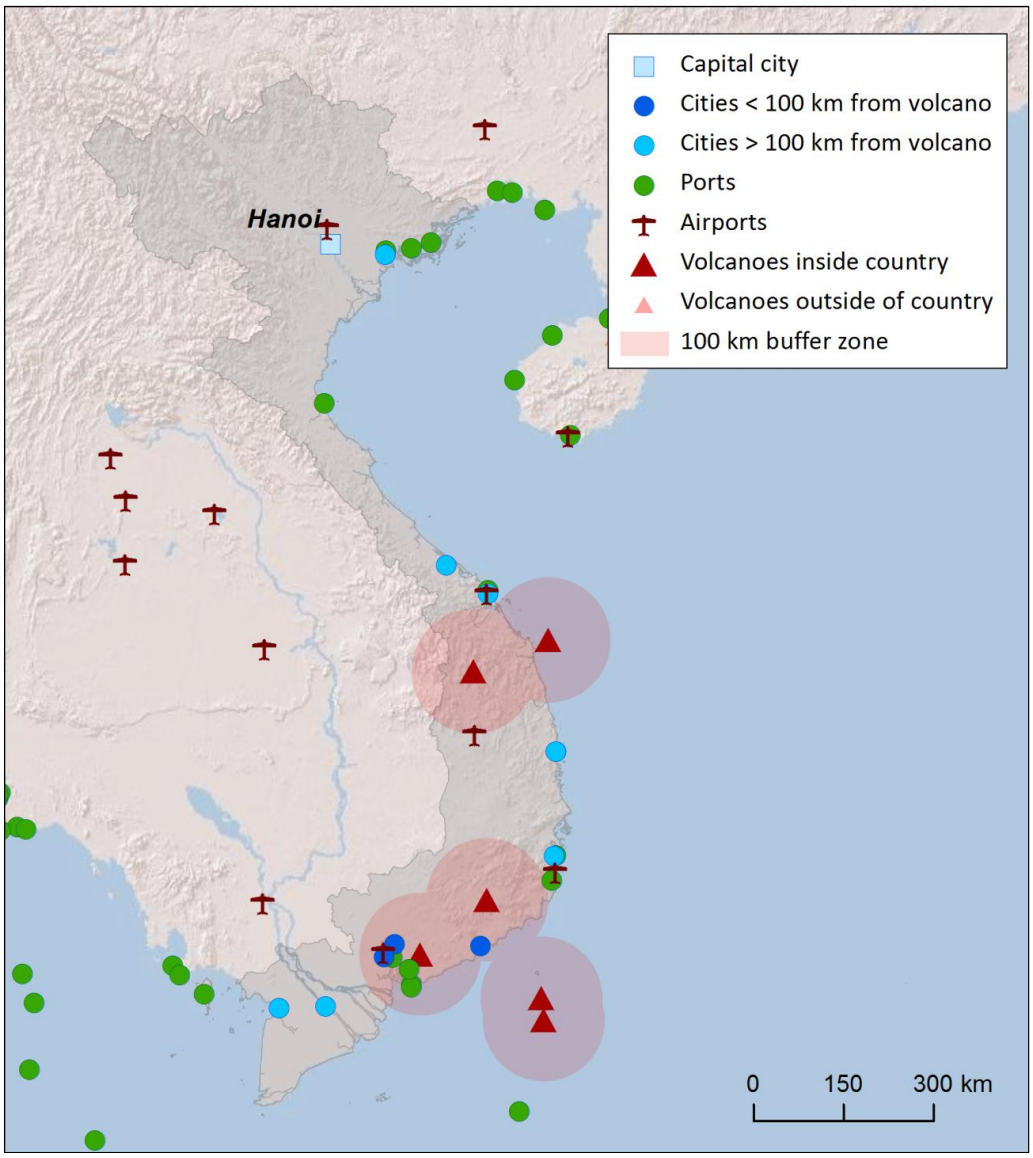

Figure 7.12 The location of Vietnam's volcanoes and the extent of the 100 km zone surrounding them. Ports, airports and the major cities are just some of the infrastructure that may be exposed to volcanic hazards.

Number of airports within 100 km of a volcano	1
Number of ports within 100 km of a volcano	6
Total length of roads within 100 km of a volcano (km)	2,271
Total length of railroads within 100 km of a volcano (km)	549

The Vietnamese volcanoes are situated in the south of the country and off the coast. Hanoi, the capital of Vietnam, is distal at over 400 km to the nearest volcano – Leizhou Bandao in China. Several of the largest cities in Vietnam are located within 100 km of Haut Dong Nai and Bas Dong Nai volcanoes, including Ho Chi Minh City, the largest city here. Significant infrastructure is located within 100 km of the volcanoes, including ports and airports, and an extensive road and rail network. The 100 km radius of Toroeng Prong extends beyond the Vietnam border and into Laos and Cambodia.

Hazard, Uncertainty and Exposure Assessments

The eruption record for Vietnam's volcanoes is too sparse to undertake calculation of the hazard without large associated uncertainties. Indeed, of the six volcanoes here, only Ile des Cendres has a confirmed Holocene record, with an eruption in 1923.

The PEI in Vietnam ranges from low to very high, with most volcanoes having a low to moderate PEI. Just one volcano, Bas Dong Nai located close to Ho Chi Minh, has a very high local population. Though the hazard level is unclassified here, the risk would be high due to this large population.

CLASSIFIED	**Hazard III**							
	Hazard II							
	Hazard I							
UNCLASSIFIED	**U – HHR**		**Ile des Cendres**					
	U- HR							
	U-NHHR		**Veteran**	Cù-Lao Ré Group; Toroeng Prong			Haut Dong Nai	Bas Dong Nai
		PEI 1	**PEI 2**	**PEI 3**	**PEI 4**	**PEI 5**	**PEI 6**	**PEI 7**

Table 7.13 Identity of Vietnam'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

Only the submarine Ile des Cendres volcano has a record of historical activity. No information is available at the time of the writing of this report to indicate that regular ground-based monitoring is undertaken at Ile des Cendres or any Holocene volcanoes in Vietnam. However, Vietnam has a network of broadband seismographs located along the coastline and in the north of the country.

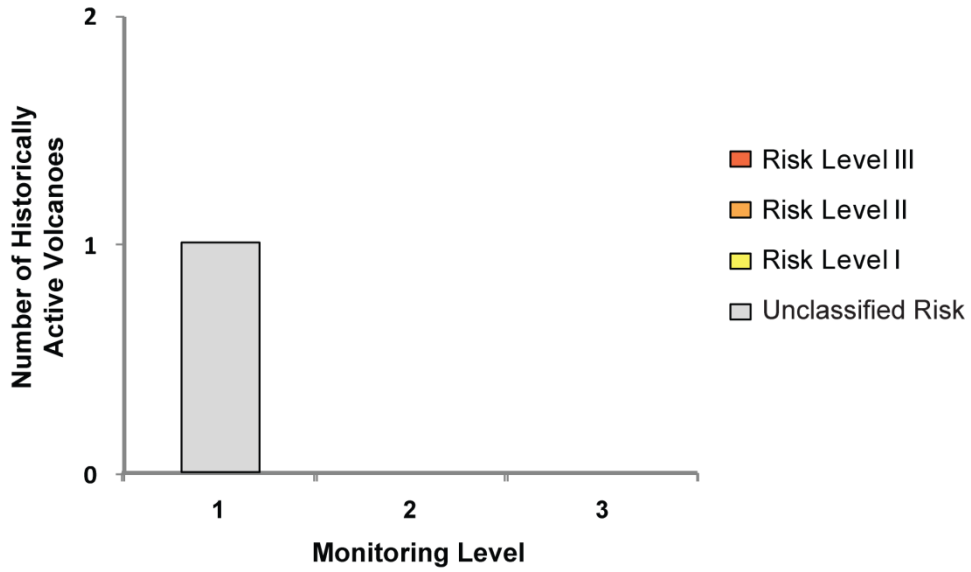

Figure 7.13 The monitoring and risk levels of the historically active volcanoes in Vietnam. Monitoring Level 1 indicates no known dedicated ground-based monitoring; Monitoring Level 2 indicates that some ground-based monitoring systems are in place including ≤3 seismic stations; Monitoring Level 3 indicates the presence of a dedicated ground-based monitoring network, including ≥4 seismometers.