Geoheritage, Geoparks and Geotourism

Patricia Erfurt-Cooper
Editor

Volcanic Tourist Destinations

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This book is dedicated to my family, who have endured my preoccupation with this work on many occasions

Foreword

For centuries people have been attracted by volcanic landscapes. Whether active or dormant, the unique dynamics of volcanic environments have encouraged travellers to visit to the remotest locations. Artists have been inspired to paint volcanoes such as the perfect shape of Mt. Fuji or Mt. Vesuvius erupting. Volcanoes have provided archaeologists with history and scientists with landscapes buried and preserved under layers of volcanic ash with examples including Pompeii and Herculaneum (Vesuvius), the Caribbean island of Montserrat (Soufrière Hills), the landscape that was buried by Mt. St. Helens and many others. Volcanoes have featured as dramatic backdrops in movies and as major topics in the literature, scientific as well as fiction, and have been regarded as an unforgettable visitor experience. Some volcanoes are easy to access tourist attractions, whereas others can only be found in more remote locations (e.g. Alaska, Antarctica or Kamchatka). While some volcanoes are visited for their special individual features, others are included in tour packages as highlights of the trip agenda.

More than 30 years ago (1980), Mount St. Helens in the USA (see Chap. 15) was making the news worldwide with a cataclysmic eruption which consequently claimed 57 lives. Apart from raising awareness about volcanic activity, this eruption opened a window of opportunity for volcanologists to study eruptive events and their precursors as never before possible. Some of the more destructive volcanoes require ongoing monitoring and there is constant pressure for reliable data on all mountains which have been identified as active. Despite all efforts, unfortunately, lives are still lost and economies are affected when volcanic eruptions take place and cause a natural disaster. The more recent events that affected not just the local population, but also disrupted air travel worldwide, were created by the volcanoes Eyjafjallajökull in Iceland and Puyehue in Chile. These and other eruptive events (Table 1) have contributed to further advancing research into volcanic processes and their impact on the environment, as well as leading to the development and upgrade of essential risk management strategies.

Heightened volcanic activity frequently attracts an increased number of visitors (e.g. Kilauea, Hawaii in early 2011; see Chap. 21) compared to 'normal' activity or quiescence. Chaitén volcano for example (Chile; see Chap. 26) was uncharted and not recognised as a potentially active volcano until its unexpected reawakening in early May 2008. The last eruption of this volcano is thought to have happened several thousand years ago and the recent events did not just take the locals but also the scientific community completely by surprise. On the economic side Chaitén's eruption stimulated the local tourism industry with a sudden increase of visitors to the area, an additional reason of concern for the local authorities.

When it comes to monitoring tectonic activity, funding is one of the main issues. This leaves dormant volcanoes with the potential to reactivate largely unsupervised and possibly even unrecorded. Although more volcano observatories are gradually established, some remote areas or volcanoes in developing countries are not yet monitored sufficiently to detect early warning signs indicating eruptions due to logistical, financial and political restrictions (Tilling 1989). Figure 1 gives an overview of the major distribution of active volcanoes worldwide.

Table 1 Examples of recent volcanic eruptions (countries in alphabetical order)

Recent major eruptive events	
2009 Redoubt, Alaska (ash)	2011 Bromo, Indonesia (ash, pyroclasts)
2006 Augustine, Alaska (lava, ash)	2012 Etna, Italy (lava, ash, strombolian)
2011 Mt. Erebus, Antarctica (lava lake)	2012 Stromboli, Italy (ash eruption)
2012 Soufriere Hills, Montserrat Caribbean (ash, lava dome, pyroclastic flows)	2001 Mt. Usu, Japan (lava domes, ash)
	1996 Mt. Unzen, Japan (lava dome, lahars, pyroclastic flows)
2010 Chaitén, Chile (ash, pyroclastic flows, lava)	2012 Mt. Sakurajima, Japan (ongoing ash eruptions)
2012 Puyehue Volcano, Chile (ash eruption)	2012 Karymsky, Kamchatka, Russia (lava, ash)
2010 Galeras, Colombia (ash, gas)	2007 Ruapehu, New Zealand (lahars, current unrest)
2012 Nevado del Ruiz, Colombia (ash, lahars)	2012 White Island, New Zealand (crater lake, ash eruptions)
2007 Mt. Karthala, Comoros Islands (lava flows)	2012 Tongariro, New Zealand (ash, pyroclasts)
2012 Rincón de la Vieja, Costa Rica (increased activity)	2011Ulawun, Papua New Guinea (gas, steam)
2011 Nyiragongo, DR Congo (lava lake)	2010 Mayon, Philippines (ash, gas, lava)
2012 Nyiamulagira, DR Congo (lava flows, gas)	1993 Pinatubo, Philippines (ash, pyroclastic flows)
2012 Reventador, Ecuador (ash, pyroclastic flows)	2010 Piton de la Fournaise, Reunion (lava flows)
2012 Tungurahua, Ecuador (lava, gas, ash)	2012 El Hierro, Spain (submarine eruption)
2012 Santa María/Santiaguito, Guatemala (ash, lava)	2011 Kilauea, Hawaii, USA (lava lake)
2011 Eyjafjallajökull, Iceland (fissure, ash eruption)	2008 Mt. St. Helens, Washington State USA (ash, pyroclastic flows)
2011 Grímsvötn, Iceland (subglacial)	2011 Ambrym, Vanuatu (lava lake)
2000 Hekla, Iceland (tephra, lava)	2008 Lopevi, Vanuatu (ash, pyroclasts)
2000 Mt. Batur, Indonesia (lava flows)	2012 Yasur, Vanuatu (strombolian, ash)
2010 Merapi, Indonesia (lava dome, pyroclastic flows)	
2012 Mt. Lokon, Sulawesi, Indonesia (ash eruption)	
2012 Krakatau, Indonesia (lava dome growth)	

Source Compiled by Author from various sources

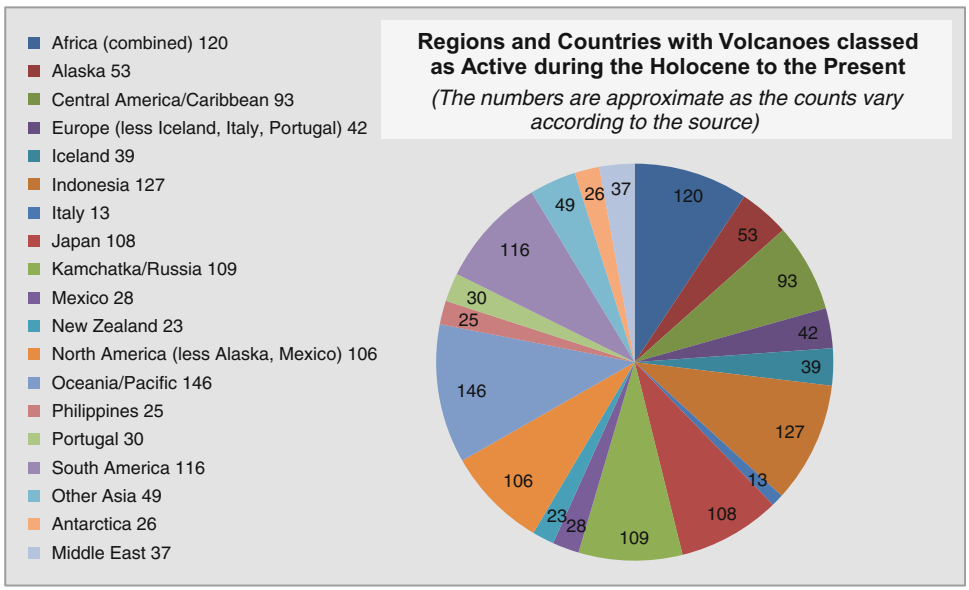

Fig. 1 Worldwide distribution of active volcanoes. Compiled by Patricia Erfurt-Cooper

Reference

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Preface

Volcanic landscapes, both active and dormant, and their related features provide priceless natural resources, which are used worldwide as tourist attractions that are popular with people from a wide range of backgrounds.

The preparation for this book has taken rather longer than anticipated but combining the collective information was a complex task. The delay, however, turned into a blessing, as in the meantime several more volcanic areas acquired protected site status, either as inclusion on the UNESCO World Heritage list or as members of the growing geopark associations such as the European Geopark Network, the Japanese Geopark Network and the UNESCO Global Geoparks Network.

Throughout this book, earth science and social science go hand in hand and some chapters may be more 'technical' than others. However, the aim is to provide a broad insight into volcano tourism and all factors involved. Some chapters focus predominantly on the geoscience aspects of the area described, while others emphasise the overall geodiversity of the natural and cultural heritage and its integration into various tourism sectors from geotourism, health tourism based on volcanic hot springs, adventure tourism and ecotourism. Therefore this is not an earth science text book as such, although the chapters are contributed by highly qualified scientists from various disciplines including volcanologists, seismologists, geologists, geomorphologists, geographers, tourism researchers and experts specialising in protected site management.

The main focus of this book is on the rich geodiversity in volcanic areas, which includes their geological heritage, with features and attractions of particular landforms as an important part of the whole geoexperience individual regions have to offer.

This book aims to contribute to the emerging geotourism literature as well as to the existing literature about protected sites. The individual chapters will enhance the knowledge of volcanic and geothermal environments and raise awareness about hazards and potential risks in these particular natural settings.

The chapters are separated into individual parts and provide a broad perspective on active and dormant volcanic destinations, although this is by no means exhaustive. Detailed descriptions of volcanic heritage and how it is showcased in geoparks are discussed in some chapters, while others include a focus on local biodiversity or cultural heritage as additional attractions and as an essential part of the overall learning experience. Widespread evidence suggests that volcanoes, dormant as well as active, have been and still are an important focal point within cultural and religious settings and in local histories. In many regions or countries (e.g. Japan, Indonesia), events and festivals related to volcanoes are held on a regular basis and attract large numbers of visitors.

Additional natural resources are frequently seen alongside the volcanoes with associated volcanic hot springs successfully used by resorts and spas for health and wellness purposes. These are another major draw cards for visitors, particularly in countries such as Japan, Iceland and New Zealand, where active volcanoes are common as a scenic backdrop to the spa experience.

Despite the time it took to edit this book it was an enjoyable and rewarding, although challenging undertaking, encouraged by the need for new and advanced information about an unusual tourism sector and the opportunity to fill a gap in the current tourism literature. I am sure that every reader will find something of interest and enjoy the different geosites and their aspects of conservation, sustainability and education based on their volcanic heritage as they are portrayed in this book.

June 2014 Patricia Erfurt-Cooper

Acknowledgments

With grateful thanks I wish to acknowledge all contributors to this book for sharing their knowledge, research findings and field experience to increase the awareness about the multitude of volcanic destinations. Without their efforts, time and commitment this book would not have been possible and their cooperation and patience throughout the duration of this project is greatly appreciated.

I also like to acknowledge the editorial support and encouragement from the staff at Springer, particularly Chris Bendall, Janet Sterrit and Annett Buettner, during the time of preparing this book.

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Part I
Introduction

Fig. 1 Volcano Tourists exploring the 'young' volcano Eldfell on the island of Heimaey, Iceland. *Photo* Patricia Erfurt-Cooper

Introduction

1

Patricia Erfurt-Cooper

1.1 Volcano Tourism

1.1.1 Geotourism and Volcanic Environments

Volcano tourism involves the exploration and study of active volcanic and geothermal landforms. Volcano tourism also includes visits to dormant and extinct volcanic regions where remnants of volcanic activity attract visitors with an interest in geological heritage (Erfurt-Cooper 2010).

In April 2010 the whole world was abruptly made aware of the power wielded by one volcano in Iceland—*Eyjafjallajökull*. The effects were far reaching. Volcanic ash clouds produced during the explosive eruptions of this volcano stayed in the atmosphere for several weeks and forced the closure of many European airports, which subsequently brought international air travel to its knees. There was no precedent for management action as this had never happened before to this extent. Travellers, unable to continue to their destinations by air were stranded around the world. Some had to wait weeks for the backlog of flights to clear before they could continue their journey, unless they were able to employ alternative travel options at considerable extra cost.

However, the news of the eruption of Eyjafjallajökull caused great interest, not just among scientists, but also attracted adventure seeking tourists, who arrived in Iceland to witness the initial eruption stage and its fiery activity. As the eruption entered its second phase, ash clouds erupted into the atmosphere, blanketing large parts of European airspace. When the eruption finally stopped, visitors kept travelling to Iceland to see the source of the chaos that almost shut down international travel. Suddenly volcano tourism was mentioned throughout the media, putting Iceland firmly on the map, and tour operators hit the ground running to profit from the potentially short-lived excitement. Global headlines indicated economic benefits for Iceland caused by the volcanic eruption with CNN reporting *'Erupting volcano boosts tourism in Iceland'* (Theodorou 2010) and National Geographic (2010) claimed that *'Eruption sparks tourist boom'*. A year later the Sydney Morning Herald newspaper described Iceland as a *'Hot Destination'* and the influx of adventure tourists with headlines such as *'After the ash comes volcano tourist cash'* (SMH 2011).

In May 2011 *Grímsvötn*, another active volcano in Iceland's south, erupted violently and again volcano tourism received a priceless boost, which no normal advertising campaign could have achieved. Grímsvötn is located under the Vatnajökull Glacier located in Europe's largest national park, the Vatnajökull National Park (established in 2008) and is hailed as Iceland's newest geological wonder along with Eyjafjallajökull —the star volcano of 2010 (IceNews 2011).

Tourist attractions and activities in Iceland are predominantly based on volcanic and geothermal environments set in dynamic landscapes which are celebrated as popular travel destination.

Not far from the action of Eyjafjallajökull and Grímsvötn a third volcano, Hekla, is expected to erupt any time based on reported signs of unrest. Since 1970, when Hekla's repose intervals changed from several decades to more frequent activity, eruptions have taken place on a more regular basis (approximately 10 years apart) with the most recent event in 2000 (Dekadevolcano.net 2011). Due to this pattern there is a common perception that another eruption may be 'overdue'. Any future activity of Icelandic volcanoes is certain to attract increasing numbers of visitors, who are prepared to take a calculated risk. Visitor guidelines and recommendations are essential and should be in place to assist with safe access to all active volcanic environments worldwide.

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Admittedly Iceland is a special showcase for volcano tourism due to the highly publicised activity and the relatively easy access to eruption sites. However, volcano tourism is not restricted to active environments; many protected sites worldwide such as National Parks, World Heritage areas and Geoparks, feature dormant or extinct remnants of volcanic activity, although expectations of heightened activity or possible eruptions seem to attract larger visitor numbers (Sigurdsson and Lopes-Gautier 2000) and do not appear to deter people with an interest in volcanism (Struck 2010). Apart from Iceland many destinations with active volcanoes (e.g. Sakurajima, Japan; Etna, Italy; Ruapehu, New Zealand; Arenal, Costa Rica) cater specifically for the demand of volcano tourists to be as close to the action as possible with eruption viewing from observation points (including hotel balconies and terraces) at night as an unforgettable experience. It is quite common that Hotels, Lodges, Bed & Breakfasts and other tourist facilities are located within close vicinity of active mountains to offer access to these unique environments, both physical and visual. Tourist activities like skiing or hiking on the flanks of active volcanoes are often combined with other local attractions.

In June 2011 the southern hemisphere was affected by the eruption of a volcano in Chile—*Puyehue*. When the ash cloud from this eruption drifted with the trade winds eastwards around the globe and reached New Zealand and the southern parts of Australia, closures of airspace lasting several days were the result. On 21 June 2011 the Australian media reported an AUD10 million loss of income per day for the tourism industry due to the impact of the volcanic ash clouds from Puyehue. This particular type of volcanic hazard can occur without much warning and potentially affects all countries within reach of the drifting ash clouds.

In Italy Mount Etna (Sicily) attracts approximately 1 million visitors annually, many of whom stay in accommodation around the volcano (Struck 2010). In New Zealand the 'Chateau Tongariro', a hotel next to the active volcano *Ruapehu*, caters for winter sport visitors as well as summer guests. And Hawaii is one of the greatest draw cards for volcano connoisseurs, offering a range of both active and dormant environments. These destinations are examples of volcanic areas where tourism is based on the existence of a particular geological heritage and is generally combined with cultural attractions of the area as well as with regional cuisine (e.g. food and wine tourism). Volcano tourism can be the primary revenue winner for a region with an active volcano and developed tourism infrastructure or it can be a secondary attraction as volcanic landforms are commonly used as a marketing feature to offer additional uniqueness to a destination (Table 1.1).

As an activity, volcano tourism can be broadly categorised into three groups: (a) tours and day trips which often include the visit to volcanic environments as a highlight of the trip agenda; (b) field trips and excursions of longer duration specially designed and offered worldwide on the internet for special interest groups; and (c) explorative travel or expeditions to more extreme destinations for participants in search of unusual experiences—adventure guaranteed. Activities in volcanic regions can include a wide variety of action packed excitement, from hot air ballooning above bizarre landscapes of eroded tuff layers as in Cappadocia, Turkey, through hiking across the Tongariro National Park in New Zealand, to climbing Mt Fuji at night to see the sun rise from the summit. For dedicated volcano tourists these experiences remain unforgettable travel memories.

1.2 The Aim and Structure of This Book

This comprehensive book addresses the increasing interest in up-to-date literature about volcanic destinations (active and dormant) and their role in tourism worldwide. It

Table 1.1 Active volcanic environments are tourist attractions worldwide

Examples of active volcanoes regularly visited by tourists		
Chile	*Iceland*	*Peru*
Chaitén, El Tatio Geysers, Villarica, Lascar, Osorno, Copahue (Border Chile/Argentina)	Askja, Eldfell, Eyjafjallajökull, Hekla, Katla, Krafla	El Misti
Colombia	*Indonesia*	*Portugal*
Galeras	Mt Batur (Bali), Mt Agung (Bali), Mt Rinjani (Lombok), Mt Merapi (Java)	Azores Volcanoes
Costa Rica	*Italy*	*Russia*
Arenal, Poás	Campi Flegrei, Mt Etna, Ischia, Stromboli, Vesuvius	Kamchatka Volcanoes
DR Congo	*Japan*	*Spain*
Nyiragongo	Mt Aso, Mt Fuji, Mt Sakurajima, Mt Unzen, Mt Usu	Canary Islands
Ecuador	*Mexico*	*Tanzania*
Galápagos Islands, Cotopaxi, Tungurahua	Colima, Popocatépetl, Iztaccíhuatl	Ol Donyo Lengai
Ethiopia	*New Zealand*	*USA*
Erta Ale	Ruapehu, Tongariro, White Island	Hawaii Volcanoes, Mt Rainier, Mt St Helens, Yellowstone
Greece		*Vanuatu*
Nisyros, Santorini, Milos		Ambrym, Mt Yasur

includes a range of significant volcanic areas and draws attention to the potential of volcano tourism by establishing the global extent of this particular tourism sector. The book aims to present a balanced view of volcano-based tourism worldwide and to discuss important issues such as the different volcanic hazards, the potential for disasters and accidents, as well as safety recommendations for visitors. Individual chapters and case studies are contributed by a group of international authors with expertise in geology and volcanology, risk management, environmental science and other relevant disciplines associated with volcanoes as well as in geotourism based on geological resources.

Even though the scientific study of volcanoes (volcanology) is not a new discipline, scientists in recent decades had several opportunities to experience some extraordinary learning curves. The 1980 eruption of Mt St Helens in the State of Washington (USA) heralded a new era of volcano research, which was followed in 1991 by the cataclysmic eruption of Mt Pinatubo in the Philippines. This book however is not competing with the earth science literature, but takes a look at volcanic regions and their role as tourist destinations. To cover all of these would require several books and therefore this volume is building on the first book published about volcano tourism by Erfurt-Cooper and Cooper (2010) with up-to-date assessments of the current situation related to this interesting tourism sector. Apart from providing information, especially regarding the eruptive events from 2010 and 2011, this book also includes the latest research in geotourism with a special focus on volcanic environments.

The decision where to start was difficult, but after considering the impact of the more recent events the geographical region of Europe took preference, with the remainder of the book divided into parts including the Pacific Ring of Fire and other volcanic regions spread over several continents including Asia, Australia, the Americas and Africa. Each contributing author was faced with the challenge of presenting current information about volcanic areas and their role in the local tourism industry. To produce an indispensable reference book for readers interested in this field of research, discussions include the demand for volcano tourism, geotourism and adventure tourism, some historical facts related to volcanoes, as well as case studies of interesting socio-cultural settings. Protected sites such as National Parks, World Heritage areas and Geoparks are the major locations where volcano tourism takes place and are listed and described. Moreover, additional aspects of volcano tourism such as risk perception, risk management and public safety in volcanic environments are discussed in Chaps. 26 and 27 and contribute to the existing risk management literature about nature based tourism with special consideration of volcanic environments.

1.3 Further Reading

In addition to the material contained in this book, the following titles are recommended for readers interested in the geological and cultural heritage of volcanic environments. They provide essential information for people intending to visit volcanoes and also present valuable references for the scientific minded audience:

- Edelmann, J. (2000). *Vulkane Besteigen und Erkunden. Reise know how*. Bielefeld: Verlag Peter Rump GmbH.
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1.4 Background: Volcanoes in History and Culture

The fascination of people with volcanoes goes back to ancient civilisations, to people who were in awe of the unpredictable natural forces generated by these geological phenomena which they could not explain. Many cultures have linked volcanoes and related natural features such as hot springs, geysers and hissing steam vents directly to the mythological 'underworld', where humankind was supposed to suffer in the eternal fires of hell. In fact, to envisage the grand entrance to everlasting damnation there is hardly a better place for the imagination to work overtime than the crater of an active volcano. The devastated landscapes shaped by lava flows, layers of ash and steaming fissures are less than inviting and present a hostile environment for both flora and fauna (Fig. 1.1). On a cold and rainy day a hike through the mist shrouded Eldgjá fissure in southern Iceland feels like being in a different world (Fig. 1.2), akin to a scene out of the Nordic mythology. In contrast a warm summer day on a tropical volcano summit in the Philippines

Fig. 1.1 The area of the Krafla Fires in the north east of Iceland. The fissure eruptions lasted from 1975 to 1984. *Photo* Patricia Erfurt-Cooper

Fig. 1.2 Eerie scenery in the cold and mist shrouded Eldgjá fissure, Southern Iceland. *Photo* Patricia Erfurt-Cooper

or Indonesia covered in ominous clouds can also evoke a disturbing atmosphere not just for superstitious minds. It is no wonder that local history and culture are often linked closely to past eruptive activity with examples like Pompeii and Herculaneum coming to mind. Both cities were buried by pyroclastic flows from Mt Vesuvius in 79 AD and are today famous tourist destinations with Pompeii attracting 2.3 million visitors in 2010 (Bailey 2012).

Volcanoes are still dominating cultural and religious traditions in many areas. In volcanic regions such as Indonesia, New Zealand, Iceland, Hawaii and Japan local legends and mythologies are closely connected to volcanoes and their unique geothermal features. Sacrifices in the form of food, flowers, live animals and money are a common means of trying to influence the 'mood' of active volcanoes; customs which are still practiced in many areas. In the past

even human sacrifice was used in an attempt to appease the 'angry mountain', although no doubt the success rate was rather unsatisfactory (Alvarado and Soto 2008; Erfurt-Cooper 2010a, b; Henderson 2007; Viramonte and Incer-Barquero 2008). Based on these traditions some communities that reside close to an active volcano, still carry out appeasement ceremonies under the guidance of their religious leaders. In some areas this is now also considered a tourist attraction and contributes to the local economy. In Indonesia for example special appeasement ceremonies conducted by ritual experts are held to *'placate the spirits believed to dwell in the mountain'* to withhold an imminent eruption (Chester and Duncan 2010; Marshall 2008). *Gunung Merapi* (meaning Fire Mountain), one of the most active volcanoes in Central Java, is considered by local residents as *'the heart of the universe'*. On the other hand, Merapi has erupted at least 13 times over the last thousand years, resulting in many human casualties, and offerings to placate the mountain are therefore by no means a thing of the past. Formal sacrifices to Mount Merapi are made annually on the 29th day of the seventh month of the Islamic calendar. This is based on the Javanese belief that a miniature world inside the crater of Mount Merapi resembles the everyday life of the Javanese people (Chester and Duncan 2010). To prevent further loss of lives the Indonesian government has tried unsuccessfully to resettle residents from endangered villages such as Turgo on the slopes of the mountain (Dove 2010). The villagers resisted to the point, that the government eventually agreed to allow the communities to continue to live in Turgo, but insisted that the village would be officially removed from government maps (Chester and Duncan 2010).

The case of Mount Merapi is not that uncommon. Villagers in volcanic areas often prefer to stay on their land, with one of the reasons the fertile volcanic soils. Being independent in their natural traditional environment is also preferable to living somewhere else. Despite the imminent danger of volcanic activity, ancestral homes, temples and family kinship are further strong determinants to stay compared with uncertain resettlement conditions. While the risk is certainly a calculated and accepted one based on experience, appeasement ceremonies are playing an important role for the peace of mind of the local populations.

Other examples of appeasement rituals come from Hawaii, where the 'goddess of fire', Madame Pele, is honoured with sacrificial ceremonies, including dancing and singing and special gifts like floral offerings to prevent disastrous eruptions. According to Knipe (1982) *'nowhere else in the world does volcanic mythology exist as it does in Hawaii'* with Pele as the central figure. All kinds of offerings have been made to Pele including chickens, pigs, money, chewing gum, sugarcane, leaf tobacco, taro roots, and sweet potatoes (Nimmo 1986). Despite initial scepticism, some tourists now believe that Pele is the cause of bad luck for people who have removed pieces of volcanic rock from Hawaii. Allegedly after returning home they started to suffer from misfortunes, which confirmed their belief that negative consequences can only be avoided by returning the rock to Pele in Hawaii (Hammond 1995).

Throughout the world volcanoes feature strongly in local legends and mythology. During archaeological excavations in Mexico near the volcano *Popocatépetl*, small effigy volcanoes were discovered and are thought to have been used commonly to appease the volcano which figured prominently in village rituals (Plunket and Uruñuela 2000). Even though the terms are mostly dictated by volcanic activity, people have learnt to co-exist with nature by focussing on advantages such as fertile soils and hot springs, and more increasingly in recent times as a 'priceless' attraction for tourists.

1.5 The Attraction of Volcanoes

1.5.1 Why are Volcanoes so Popular?

The popularity of volcanic environments has grown as a result of their featuring in movies such as *Dante's Peak* (1997); *Volcano* (1997); *Lord of the Rings Trilogy* (2001–2003); *Volcanoes of the Deep Sea* (2003) *and Krakatoa* (2006). In the literature volcanoes are the main topic with books including *Krakatau* by Winchester (2003); *Montserrat* by Davison (2003) and *A journey to the center of the earth* by Verne (1871). TV documentaries for example resulted in Yellowstone now commonly known as a 'Supervolcano'. But more importantly the interest in volcano tourism grows with every eruption that is covered in the international media and on the Internet. With access to remote destinations becoming easier and more affordable, essential infrastructure to cater for larger numbers of visitors is improving exponentially in many countries. Even unstable political conditions do not stop volcano tourism, but merely cause interruptions for a while. As a result of all these factors and trends, visitor numbers at individual destinations are an indication that volcano tourism is by no means a small niche market. And if the volcanic environment is not the main destination determinant, as an additional drawcard it fits in well with other local attractions.

In fact, volcanoes do not have to be active to be a tourist attraction as long as they are reasonably easy to access. To reach more remote locations to visit volcanoes with special individual features (e.g. lava lakes) requires more determination and planning. But often volcanoes are part of a tour package featuring local attractions and are included in the trip agenda. On the other hand research has shown, that

heightened volcanic activity attracts more visitors (e.g. Chaitén volcano—Chile, 2008 (Chap. 26); Kilauea—Hawaii, 2011 (Chap. 21)), compared to times of 'normal' activity or quiescence; however, this activity can be potentially dangerous (Gaudru and Erfurt-Cooper 2010). It is therefore essential for tour operators to provide sufficient information about any possible risks and hazards that can be encountered, even in quiescent times.

To better understand the role of volcanic environments as tourist destinations a conceptual framework (Fig. 1.3) was developed, which outlines not only the elements of volcano tourism, but also shows the integration of these dynamic environments in various tourism sectors (e.g. Ecotourism, Geotourism, Adventure Tourism). The model incorporates several tourism groups, each of which takes into account the distinctive characteristics of volcanic environments as a tourism resource. The individual sectors are geotourism, adventure tourism, ecotourism and dark tourism, and are based on specific visitor expectations and demand for unique settings. Although these four tourism sectors can be distinguished from each other, the potential for overlap from one sector to another frequently does exist; generally with a complementary result. The model also establishes correlations between the various integrated elements of volcano tourism, which are associated with environmental settings and natural resources, recreational attractions, cultural traditions and customs, as well as access and infrastructure. Together these represent the particular attractiveness of the dynamics of volcanic settings as a tourism resource. For example volcano tourists not only partake in sightseeing tours, but they also appreciate the opportunity to visit hot spring spas and resorts as well as other geothermal features of interest if these are present and accessible. In Iceland visitors can undertake daytrips to volcanic attractions including geyser fields and geothermal power stations, but they also have the opportunity to visit the geothermal Blue Lagoon for a relaxing soak after hiking over lava fields or viewing spectacular waterfalls. In New Zealand visitors of volcanoes and geothermal nature parks can take tours to nearby hot spring spas, and in Japan tourists commonly visit every worthwhile attraction at their destination as well as sampling the local hot springs (Erfurt-Cooper 2011).

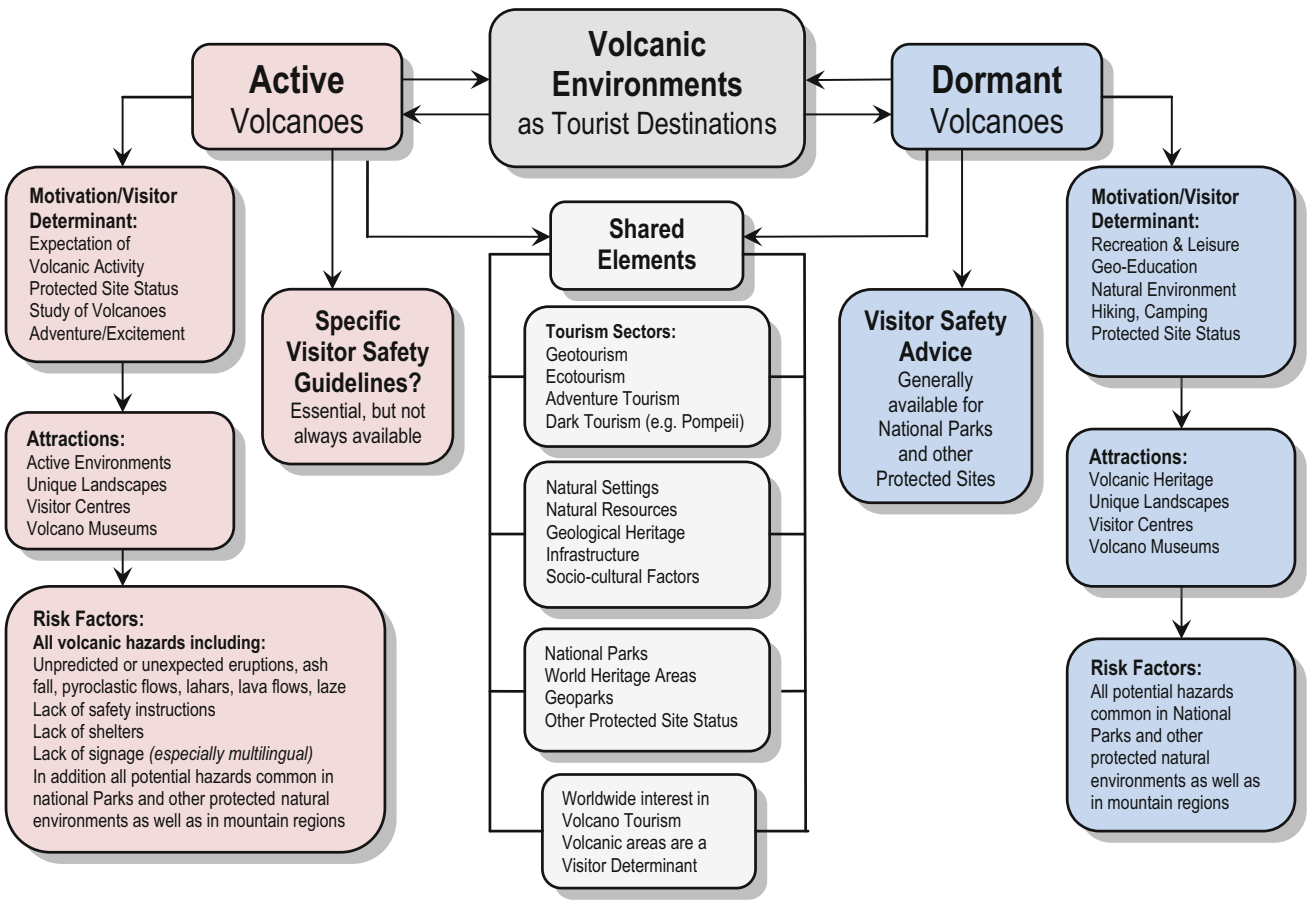

Fig. 1.3 A conceptual framework demonstrating the role of volcanic environments as tourist destinations. By Erfurt-Cooper (2012)

Table 1.2 Examples of volcano tours advertised on the internet

Volcano tours	
Volcano Tours, Grindavík	*Arenal Volcano Tours—Costa Rica Tours*
www.volcanotours.is	www.arenal.net/arenal-volcano-tour.htm
Unity Airlines—Vanuatu Volcano Discovery and Charter Services	*Volcano Tours*
www.unity-airlines.com/index.html	www.icelandtravel.is/our-tours/tours/daytours-activities/volcano-tours/
Volcano adventure travel	*Hawaii volcano hiking*
http://www.volcanolive.com/travel.html	www.volcanotours.com/
O.X. Outdoor Excursions—Guatemala	*Hawaii Volcano Tours*
www.oxexpeditions.com/	www.lavatours.com/
White Island Tours—New Zealand	*Lava Ocean Adventures*
www.whiteisland.co.nz/	www.seelava.com
VolcanoDiscovery—Study trips, photo expeditions	*Etna Excursions and Volcano Tours*
www.volcanodiscovery.com/volcanotours.html	www.volcanotrek.com/
Undara Experience—North Queensland	*Masaya Volcano National Park—Nicaragua*
http://undara.com.au/	www.virtualnicaragua.com/masaya-volcano-national-park.php
Volcano tours and photography—Indonesia	*Vulkan Reisen*
www.firevolcano.com/	www.v-e-i.de/
Viva Ethiopia Tour—Erta Ale	*Vulkane aktiv erleben*
www.vivaethiopiatour.com/	www.vulkankultour.de/
Vulkan Expeditionen International	*The Lakes and Volcanoes Adventure Tour—Chile*
www.vulkane.net/	http://www.southamerica.travel/

Source Compiled by Author from various sources

Table 1.3 Elements of destination marketing

Volcanic and geothermal environments		
Attractions	Activities	Motivations
Eruptive events	Eruption viewing	Adventure
Active lava flows	Hiking, trekking, skiing, canoeing	Curiosity
Crater lakes	Sightseeing	Field research
Lava lakes	Learning	Scientific interest
Lava tunnels	Hot spring bathing	Study, educational
Fumaroles, steam vents	Volcano museums	Part of trip agenda
Geysers, hot springs	Interpretive centres	Part of outdoor activity
Boling mud pools	Guided tours	Photography
Hot streams	Camping	
Unique rock formations		

Source Compiled by Author from various sources

1.5.2 Supply and Demand

The supply is impressive with thousands of active and dormant volcanoes worldwide. And as we have seen, the demand for volcano tourism is fuelled by the publicity from eruptions like Eyjafjallajökull in 2010, which was broadcast worldwide. A year later the eruption of the Puyehue volcano in Chile raised similar awareness about volcanic activity and its far reaching effects, this time in the southern hemisphere. While both eruptions caused substantial problems for the travel industry, they also highlighted the potential of unexpected volcanic activity anywhere in the world. Catering for this growing demand are volcano tours run by specialised tour operators to the most popular volcanic regions on Earth. Their offers include guidance by geologists and/or volcanologists while their marketing is Internet based to reach a worldwide audience (Table 1.2).

The local economic benefits from volcano tourism also play a central role in many areas. Visitor motivation is therefore important and encouraged with successful marketing of local attractions and activities (Table 1.3). Volcanoes, together with unique geothermal features are powerful drawcards for visitors and many regions (e.g. New Zealand, Iceland) have invested significantly in volcano and hot spring tourism as a viable market in combination with other local attractions. Package deals including snowboarding, ice climbing and skiing on active volcanoes are not unusual and are combined in many areas with hot spring spa resorts. Accommodation such as hotels and resorts are built as close as ‘safely’ possible to active volcanoes to benefit from the

Table 1.4 Educational facilities are in demand at volcanic sites

Volcano museums and interpretive science centres	
Penshurst Volcanoes Discovery Centre, Australia	Aso Volcano Museum, Japan
Vulcania—Volcanic Theme Park, France	Mt Unzen Disaster Memorial Hall, Shimabara, Japan (plus several memorial sites)
Eifel-Volcano Museum Daun, Maar-Museum Manderscheid and Vulkanhaus Strohn, Vulkaneifel, Germany	Sakurajima Volcano Museum, Japan
Nisyros Volcanological Museum, Greece	Usu Volcano Science Museum, Toyako, Japan
Ság [Volcano] Museum, Hungary	Jeju National Museum, Korea
Eldfjallasafn Volcano Museum Stykkishólmur, Iceland	Te Papa Museum Wellington, New Zealand
Eldheimar ('World of Fire') Museum Vestmannaeyjar, Iceland	Auckland Museum Volcano House, New Zealand
Eyjafjallajökull Visitor Centre Þorvaldseyri, Iceland	Maison du Volcan, Reunion
Batur Volcano Museum Kintamani, Indonesia	Museu del Volcans, Garrotxa, Spain
Merapi Volcano Museum, Indonesia	Hawaii Volcanoes NP Jaggar Museum, Hawaii, USA
Volcano Museum Etna, Italy	Mt St Helens National Volcanic Monument (several visitor centres and observatories), Washington State, USA
Museo Archeologico Eoliano, Lipari, Italy	Yellowstone NP Trailside Museums, Wyoming, USA
Museo Archeologico Virtuale Ercolano, Italy	
Museo dell'Osservatorio Vesuviano, Italy	
Nicolosi Vulcanological Museum, Sicily, Italy	
San Venanzo Volcano Museum, Italy	

Source Compiled by Author from various sources

Fig. 1.4 Volcano science museum in Toyako near Mt Usu, Japan. *Photo* Patricia Erfurt-Cooper

visual attraction, especially if eruptions can be viewed from a (hopefully) secure distance (e.g. Hekla, Iceland; Etna, Sicily; Arenal, Costa Rica; Sakurajima, Japan).

1.5.3 Visitor Centres and Volcano Museums

Volcanic and geothermal exhibitions at museums and visitor centres (Table 1.4) contribute significantly to educating the public about these unique natural environments. Most regions with active volcanism offer visitors extensive information through documentaries, geologic exhibits, guided tours and entertaining activities for all age groups. Also of interest are local cultural and historical connections with volcanic and geothermal events with retail areas usually offering books about the local geology along with general souvenirs and creations by local artists. Popular in Cappadocia in central Turkey are small pumice carvings of the Fairy Chimneys while at Mt Aso in Japan sulphur blocks and volcanic rock samples are sold on the viewing platform next to the crater.

Major volcanic events often result in a new exhibition or visitor centre being built near an eruption site to cater for the increasing demand for visitor information. Japan for instance has many volcano science museums (Fig. 1.4), which are frequently connected to the local volcano

Table 1.5 A selection of volcano national parks from countries around the world

Protected volcanic sites—National parks	
Lanín National Park, Argentina	Krakatau Volcano National Park, Indonesia
Crater Lakes National Park, Australia	Mt Rinjani National Park, Lombok, Indonesia
Mt Kaputar National Park, Australia	Mt Etna Provincial Park, Sicily, Italy
Undara Volcanic National Park, Australia	Vesuvius National Park, Italy
Warrumbungles National Park, Australia	Aso-Kuju National Park, Kyushu, Japan
Mt Cameroon National Park, Cameroon	Fuji-Hakone-Izu National Park, Honshu, Japan
Lauca National Park, Chile	Kirishima-Yaku National Park, Kyushu, Japan
Villarica National Park, Chile	Shikotsu-Toya National Park, Hokkaido, Japan
Haikou Shishan National Park, China	Unzen-Amakusa National Park, Kyushu, Japan
Volcano National Geological Park, China	Kilimanjaro National Park, Kenya
Zhangzhou Coastal Volcano Park, China	Tongariro National Park, New Zealand
Los Nevados National Park, Colombia	Masaya Volcano National Park, Nicaragua
Nevado del Huila National Park, Colombia	Mayon Volcano Natural Park, Philippines
Puracé National Park, Colombia	Volcanoes National Park, Rwanda
Arenal Volcano National Park, Costa Rica	Teide Volcanoes National Park, Canary Islands, Spain
Poas Volcano National Park, Costa Rica	Yangmingshan National Park, Taiwan
Rincon de la Vieja Volcano National Park, Costa Rica	Göreme National Park, Turkey
Galápagos Islands National Park, Ecuador	Crater Lakes National Park, Oregon, USA
Cotopaxi National Park, Ecuador	Hawaii Volcanoes National Park, USA
Virunga National Park, Democratic Republic of the Congo	Katmai National Park, Alaska, USA
Volcano Regional National Park, Auvergne, France	Lassen Volcanic National Park, California, USA
Eyjafjallajökull, Vatnajökull National Park, Iceland	Lava Beds National Park, California, USA
Þingvellir National Park, Iceland	Mt Rainier National Park, Washington, USA
Snæfellsjökull National Park, Iceland	Mt St Helens National Volcanic Monument, USA
Bromo-Tengger-Semeru National Park, Indonesia	Sunset Crater Volcano National Monument, Arizona, USA
Gunung Merapi National Park, Indonesia	Yellowstone National Park, USA

Source Compiled by Author from various sources

observatory, where visitors are provided with up-to-date data (e.g. web cams, seismographs), as well as exhibits relevant to the local geology. Film footage of past eruptive events and simulated pyroclastic flows complete with special effects as well as bird's eye views of eruption columns are a fascinating way of educating the public about the explosive powers of a volcano.

At the base of Eyjafjallajökull at Þorvaldseyri a new visitor centre and museum was established, which opened on the eruption's first anniversary in April 2011 (Edelstein 2011; Eyjafjallajökull Visitor Centre 2012; IceNews 2011; Visitor Centre Þorvaldseyri 2011). In May 2012 the Eldfjallasafn Volcano Museum in Stykkishólmur opened with an exhibition featuring international art and objects related to volcanic eruptions and their impact (Eldfjallasafn Volcano Museum 2012). Also in May 2012 plans were announced for a new volcano museum (Eldheimar, The Pompei of the North) on the island of Heimaey, were in 1973 a volcanic eruption forced the evacuation of all residents. Currently the opening is scheduled for early 2015 (Bjarnason, 2014). From the increasing demand for information the educational value of volcano museums and information centres cannot be disputed as a safe learning experience. They are a perfect option for visitors who are interested in the geological background, but prefer to watch the action from a safe distance via webcam and video footage, especially if the volcano is too active for a visit (Erfurt-Cooper 2011). Volcano museums also serve as an opportunity to ask questions and to put into perspective what has been observed 'in the field'.

1.6 Protected Areas: Volcanic National Parks, World Heritage Sites and Geoparks

Looking at the global distribution of volcanoes we discover that in many cases they are located within protected areas. With more than 1,500 volcanoes classed as active worldwide and many more dormant, large numbers of these volcanic landforms are integrated as unique attractions in protected sites such as National Parks (Table 1.5), World Heritage Areas (Table 1.6) and Geoparks (Table 1.7). Probably the most famous volcanic and geothermal national park is Yellowstone in the State of Wyoming, USA, where visitor numbers have reached around 3.5 million people annually in recent years.

Since the first estimated figures from 1872 of 300 visitors to Yellowstone there has been a steady increase over 140 years (The Total Yellowstone Page 2012). Although

Yellowstone visitor numbers			
2007	3,151,343	2010	3,640,205
2008	3,066,580	2011	3,394,322
2009	3,295,192	2012	3,447,729

Table 1.6 World Heritage areas with active and dormant volcanic landforms (in alphabetical order of countries and regions)

Active and dormant volcanic World Heritage areas		
Volcanic World Heritage sites	Country	Year listed
1. Ngorongoro Conservation Area	Tanzania, Africa	1979, Ext. 2010
2. Taï National Park	Ivory Coast, Africa	1982
3. Gondwana Rainforests	Australia	1868
4. Heard and McDonald Islands	Australian Territory	1997
5. Lord Howe Island Group	Australia	1982
6. Macquarie Island	Australia	1997
7. Wet Tropics of Queensland	Australia	1988
8. Fernando de Noronha Archipelago	Brazil	2001
9. Area de Conservación Guanacaste (*Rincon de la Vieja*)	Costa Rica	1997
10. Cocos Island National Park	Costa Rica	1997
11. Morne Trois Pitons National Park	Dominica, Lesser Antilles	1997
12. Rapa Nui National Park	Easter Islands, Chile	1995
13. Mt Huangshan	China	1990
14. Virunga National Park	Democratic Republic of the Congo	1979
15. Galápagos Islands	Ecuador	1978
16. Sangay National Park	Ecuador	1983
17. Joya de Cerén	El Salvador	1993
18. Pitons, Cirques and Remparts of Reunion Island	Reunion, France	2010
19. Þingvellir National Park	Iceland	2004
20. Surtsey Island	Iceland	2008
21. Bali Cultured Landscape	Bali, Indonesia	2012
22. Borobudur Temple (*Merapi*)	Java, Indonesia	1991
23. Komodo National Park	Indonesia	1991
24. Tropical Rainforest Heritage	Sumatra, Indonesia	2004
25. Ujung Kulon National Park	Indonesia	1991
26. Giants Causeway	Ireland	1986
27. Aeolian Islands	Italy	2000
28. Mount Etna	Sicily, Italy	2013
29. Pompeii and Herculaneum	Italy	1997
30. Mount Fuji	Honshu, Japan	2013
31. Ogasawara Islands	Japan	2011
32. Shiretoko National Park	Hokkaido, Japan	2005
33. Yakushima	Japan	1993
34. Mount Kenya National Park	Kenya	1997; Ext. 2013
35. Jeju Volcanic Island and Lava Tubes	Korea	2007
36. El Pinacate &d Gran Desierto de Altar Biosphere Reserve	Mexico	2013
37. Tongariro National Park	New Zealand	1993
38. Rock Islands Southern Lagoon	Republic of Palau (Micronesia)	2012
39. Pico Island	Azores, Portugal	2004
40. Volcanoes of Kamchatka	Russia	1996; Ext. 2001
41. Brimstone Hill Fortress National Park	Saint Kitts and Nevis, Lesser Antilles	1999
42. Pitons Management Area	Saint Lucia, Lesser Antilles	2004
43. Old and New Towns of Edinburgh (*Arthurs Seat*)	Scotland	1995
44. Garajonay National Park	La Gomera, Canary Islands, Spain	1986

(continued)

Table 1.6 (continued)

Active and dormant volcanic World Heritage areas		
Volcanic World Heritage sites	Country	Year listed
45. Teide National Park	Tenerife, Canary Islands, Spain	2007
46. Kilimanjaro National Park	Tanzania	1987
47. Göreme NP and the Rock Sites of Cappadocia	Turkey	1985
48. Pamukkale - Hierapolis	Turkey	1988
49. Hawaii Volcanoes National Park	Hawaii, USA	1987
50. Yellowstone National Park	Wyoming, USA	1978
51. Yosemite National Park	California, USA	1984

Source Compiled by Author from various sources

Table 1.7 Examples of volcanic Geoparks from Europe and Asia. The Geopark concept is rather new and so far no 'global' geoparks have been recognised in American and African countries, although regional and national geoparks may be under consideration or have been established as a first step towards global recognition

Protected volcanic sites—Geoparks (national and global)	
Kanawinka Geopark, Australia	Toya Caldera/Usu Volcano Global Geopark, Japan
Hong Kong Global Geopark, China	Unzen Volcanic Area Global Geopark, Japan
Leiqiong Volcano Geopark, Guangdong, China	Jeju Island, Korea
Wudalianchi Volcanoes Geopark, Heilongjiang, China	Magma Geopark, Norway
Vulkaneifel European Geopark, Germany	Azores Geopark, Portugal
Katla Geopark, Iceland	Penghu Geopark, Taiwan
Itoigawa Global Geopark, Japan	Geopark Shetland, Scotland, UK
Mount Aso Geopark, Japan	

Source Compiled by Author

Table 1.8 Examples of annual visitor numbers at volcanic and geothermal destinations. Precise visitor statistics are difficult to obtain as many parks do not check how many people enter the area

Destinations	Visitor numbers (p/a)
Fuji-Hakone-Izu National Park, Japan (Honshu)	103+ million[a]
Aso-Kuju Volcanics, Japan (Kyushu)	20+ million[a]
Shikotsu-Toya, Japan (Hokkaido)	16.3 million[a]
Kirishima-Yaku, Japan (Kyushu)	14.4 million[a]
Bandai—Asahi National Park, Japan (Honshu)	14.4 million[a]
Teide National Park, Spain	2.73 million (2011)[b]
Yellowstone National Park, USA (Wyoming)	3,18 million (2013)[c]
Hawai'i Volcanoes National Park, USA	1.58 million (2013)[d]
Vesuvius National Park, Italy	1 million[e]
Pompeii, Italy	2.3 million (2010)[f]
Tongariro National Park, New Zealand	1 million[g]
Giant's Causeway, Ireland	600,000 (2011)[h]
Mt Etna, Italy	1 million (2010)[i]
Haukadalur with original Geyser, Iceland	407,230 (2011)[j]
Arenal Volcano National Park, Costa Rica	273,000 (2005)[k]
Sunset Crater National Park, USA (Arizona)	184,864 (2013)[d]

[a] International EMECS Center 2012; [b] TM Tenerife Magazine 2012; [c] Yellowstone up close and personal 2014; [d] NPS Public Use Statistics Office 2014a, b; [e] Karkut 2010; [f] Bailey 2012; [g] www.nationalpark.co.nz; [h] Moriarty 2012; [i] Struck 2010; [j] Icelandic Tourist Board 2012; [k] Aguirre and Ahern 2007

Table 1.9 Examples of cities in close proximity of volcanoes classed as active

Country	City	Volcano(es)	Population
Costa Rica	San Jose	Arenal	365,799 (metro 1.7 million)
Colombia	Pasto	Galeras	399,723
DR Congo	Goma	Nyiragongo	377,112
Guatemala	Guatemala City	Pacaya	1.1 million (metro 4.1 million)
Ecuador	Quito	Cotopaxi, Guagua Pichincha, Pululagua	2.24 million (metro 3.34 million)
Indonesia	Jogjakarta	Merapi	388,088
Italy	Catania	Etna	291,000
Italy	Naples	Vesuvius	960,000 (metro 4 million)
Japan	Nagasaki	Unzen	446,007
Japan	Shimabara	Unzen	48,461
Japan	Kumamoto	Mt Aso and Unzen	731,286
Japan	Kagoshima	Sakurajima	605,855
Japan	Tokyo	Mt Fuji	8.7 million (metro 35.6 million)
Mexico	Colima	Volcán de Colima	662,500
Mexico	Mexico City	Popocatépetl	8.85 million
New Zealand	Auckland	Rangitoto, Auckland volcanic fields	1.37 million
New Zealand	Rotorua	Mt Edgecumbe, Tarawera	68,900
Nicaragua	Managua	Masaya	927,087 (metro 2.4 million)
Philippines	Manila, Luzon	Pinatubo and Taal	1.6 million
Philippines	Legazpi City, Luzon	Mt Mayon	182,000
Spain	Santa Cruz, Tenerife	Mt Teide	222,271
USA	Anchorage, Alaska	Redoubt	291,826
USA	Portland, Oregon	Mt Hood	593,820 (metro 2.26 million)
USA	Seattle	Mt Rainier	620,778 (metro 3.5 million)
USA	Vancouver, Washington	Mt Baker	603,562 (metro 2.3 million)

Source Compiled by Author from various sources

visiting Yellowstone is not officially promoted as volcano tourism, the geothermal activity based on volcanism is what the majority of the people come to see. Yellowstone has an unfortunate reputation as a super-volcano with publications and documentations reflecting increased media attention aimed at a potential future disaster site. Confirming these concerns the United States Geological Survey (USGS) states in their web-based information that *'Yellowstone's volcanic and hydrothermal history suggests the potential for various kinds of eruptions in the future'* (USGS Volcano Hazards Program 2012). Growing media interest in Yellowstone's earthquake activity in early 2014 has contributed to further public concern. To compare popular destinations, examples of annual visitor numbers of volcanic and geothermal areas were collected (Table 1.8), although it is nearly impossible to obtain accurate figures as many protected areas do not keep count of their visitor numbers.

Many cities, large and small, are located near active volcanoes and their populations are accustomed to the permanent risk to their personal living environment. Table 1.9 shows examples of cities and their population figures; both for the actual city as well as the greater metropolitan area at risk from eruptive activity.

1.7 Volcanic Processes

Volcanology is a complex field of earth science that investigates volcanoes and monitors their internal processes. Specific fields of study include plate tectonics, seismology, structural geology and geomorphology as well as geology disciplines such as igneous petrology, geophysics, geochemistry and mineralogy. For more in-depth information it is recommended to consult the earth science literature with a special focus on volcanology. A short overview of the principal volcano types is included here and describes briefly shield volcanoes, strato volcanoes, cinder cones and calderas. Additional information in the form of a glossary is attached as Appendix 2.

Fig. 1.5 The Shield Volcano Rangitoto (meaning bloody sky) in New Zealand is part of the Auckland volcanic field and can be reached by ferry from Auckland. The last eruption was possibly 600–700 years ago, although no accurate data is available. *Photo* Patricia Erfurt-Cooper

Fig. 1.6 Mt Fuji (stratovolcano) is located on the Japanese island of Honshu close to Tokyo and Yokohama and is a major tourist destination. *Photo* Patricia Erfurt-Cooper

Shield volcanoes are built from high temperature lava flows (800–1200 °C) which can spread out multi directional over vast areas. The Hawaiian volcanoes are an example of shield volcanoes which are located over a hot spot and still 'under construction'. Other shield volcanoes include Etna in Italy, Jeju Island in Korea, Erta Ale in Ethiopia and Rangitoto in New Zealand (Fig. 1.5).

Composite or strato volcanoes are built from layers of lava, tephra and pyroclastic debris and have steep sides compared to the rather broad shape of shield volcanoes. Strato volcanoes are known for explosive eruptions caused by built up pressure as magma moves through conduits slowly upwards. In their active state they generate pyroclastic flows and lahars and can be potentially dangerous to nearby residents and visitors. Strato volcanoes are located all over the world and some well-known mountains include Vesuvius (Italy), Damavand (Iran), Popocatépetl (Mexico), Mt St Helens (USA), Copahue (Chile), Tungurahua (Ecuador), Krakatau and Merapi (Indonesia), Fuji (Fig. 1.6) and Sakurajima (Japan), Pinatubo and Mayon (Philippines), Mt Ararat (Turkey), Hekla (Iceland) and White Island (New Zealand). These are only a few examples from a long list of

Fig. 1.7 Strombolian spatter covers the ground near cinder cones which were created by lava fountains from parasitic vents on the flanks of Mt Etna. *Photo* Patricia Erfurt-Cooper

Fig. 1.8 Scoria cones created from spatter during the Krafla fires in Iceland. The view is slightly obstructed by mist. *Photo* Patricia Erfurt-Cooper

strato volcanoes currently classed as active and which are popular tourist destinations.

Cinder cones are steep, cone shaped hills of fragmented lava particles (cinder, scoria) which have accumulated around a single vent (Fig. 1.7). They are a common form of volcano and can range in size from small spatter cones to hundreds of metres in elevation. Cinder cones can grow rapidly in groups on the flanks of parent volcanoes (Fig. 1.8) or they grow into one single mount like Paricutín in Mexico or Eldfell on the Westman Islands in Iceland (Fig. 1.9).

A *caldera* (Spanish for cauldron) is a collapsed magma chamber resulting from an explosive eruption during which the magma chamber was emptied. The overlying chamber roof is left without support and gives way by collapsing into the void below. Calderas can be any size and some of the largest calderas include the Taupo Caldera (New Zealand), Toba Caldera