



text YD BAR-NESS

EARTH'S FIRE

A geographical primer on Asian stratovolcanoes

SOME reach for the stars with their heads clad in frosted crowns, and some lay shattered in unrecognisable pieces. Some spit fire, and some lay cold and dead. The shredding claws of ice glaciers gouge their flanks, and green forests cling to their feet. They place gold within reach, and can easily destroy cities. The stratovolcanoes of Asia mark the geological borderlands of Earth and are some of the most prominent landforms on the planet. These smouldering pyramids – Fuji-yama in Japan, Damavand in Iran, Pinatubo in the Philippines – are landmarks and symbols for nations. The titanic eruptions of the Indonesian volcanoes Krakatoa and Tambora were detected around the world and reshaped landscapes.



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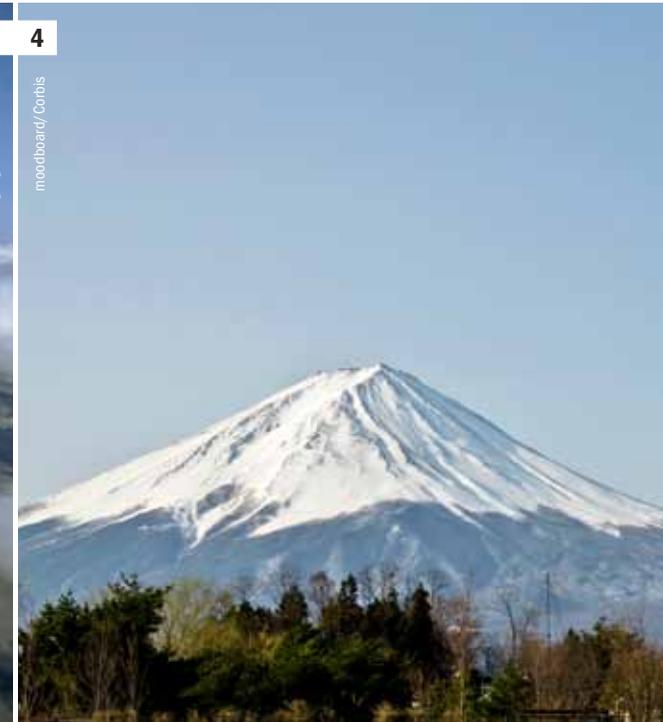


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IDENTITY OF A STRATOVOLCANO

What is a stratovolcano? Named for the Roman god of metal smithing, Vulcan, these massive accumulations of rock are the most visible result of the molten, infernal activity at the Earth's core. They can be found on Earth in a younger state as a relatively simple conical mountain or in a decrepit older state as the broken shards of a crater rim. Stratovolcanoes may appear in clusters, growing on top of one another, or they may appear singly.

During the formation of a stratovolcano, or a composite volcano, rock is forced from the interior of the planet. An eruption begins with an explosive outlet of flying powdery ash and followed by the slower extrusion of melted, liquid magma. These two types of material form geological layers, or strata, that accumulate into a conical mountain. While these eruptions may seem infrequent when compared to a human lifespan, they are regular occurrences on the geological time scale.

The stratovolcanoes incorporate characteristics of, but are distinct from, two other forms of volcano: the oozing, non-exploding shield volcanoes, such as those found in Hawaii, and from the non-magma cinder cones found scattered worldwide. Volcanic activity also occurs as hot springs, underwater seamounts, below-glacier tuyas and mud domes, but none of these is as dramatic or well known as the towering stratovolcanoes.

THE TECTONIC PLATES

Most of the stratovolcanic activity is found at the margins of tectonic plates. The Earth's crust is divided into massive segments that move slowly around, colliding with and separating from one another. These tectonic plates form the key to understanding the formation of volcanic regions.

The Pacific "Ring of Fire" refers to the abundance of volcanoes on the edges of the world's largest ocean. It occurs where the Pacific Oceanic tectonic plate collides with the Asian tectonic plate. The Asian volcanoes have their distant counterparts on the west coast of the American continents. The Pacific plate is made of heavy oceanic basalt, and therefore gets pushed under, or subducts, beneath the lighter granite of the continental Asian plate. As this oceanic rock slants below the crust into the Earth's mantle, it heats up.

At about 100 kilometres down, it converts into a denser rock and sinks more directly into the depths. The water that was carried with it mixes with the surrounding rock and begins to slowly rise towards the surface. It is this fluid rock, known as magma, that breaks through the Earth's surface as a volcano, bringing with it metals and minerals from deep underground: zinc, copper, mercury, cadmium, arsenic, copper, silver – and gold.

The oceanic rock, meanwhile, descends into the mantle, where it is churned and mixed over millions of years. The same material may be reborn on the Earth's surface (or

underwater) from the mid-oceanic trenches that extrude material between the tectonic plates. Earth is the only planet known to have this rock and gas recycling. This constant motion of titanic energy is one of the integral life-giving characteristics of our unique planet.

Besides the subduction of oceanic tectonic plates beneath continental ones, terrestrial volcanoes can also be found where two continents collide. The volcanoes of Western Asia – including those in Iran, Turkey, Armenia and Georgia – exist well away from any oceanic tectonic subduction. In this region, the meeting of the Arabian, African and Anatolian (Turkish) tectonic plates with the larger mass of the Eurasian plate has created a region of volcanic activity. The volcanoes here are again formed by subduction of tectonic plates, in contrast to the non-subducting Himalayan zone pushed primarily upwards at the collision of the Indian and Eurasian plates.

They may also be found – but not in Asia – above magma hotspots. Here, a plume of magma rises from the Earth's core, in a fixed position, as the tectonic plate moves above it. Some of these volcanoes have yet to break through the surface of the water, and are hidden sea mountains. Hawaii, the Galápagos and the Azores are island chains associated with hotspots. Furthermore, at the mid-oceanic ridges, where the tectonic plates of the ocean are pulling apart, vast trenches of underwater volcanic activity can occur.

1 | Russia's Klychevskaya volcano of Kamchatka, Russia, at 4,688 metres

2 | Three hikers make their final push towards the summit of Russia's Mount Elbrus (5,645m)

3 | The Koryaksky volcano that is on the Decade Volcanoes list

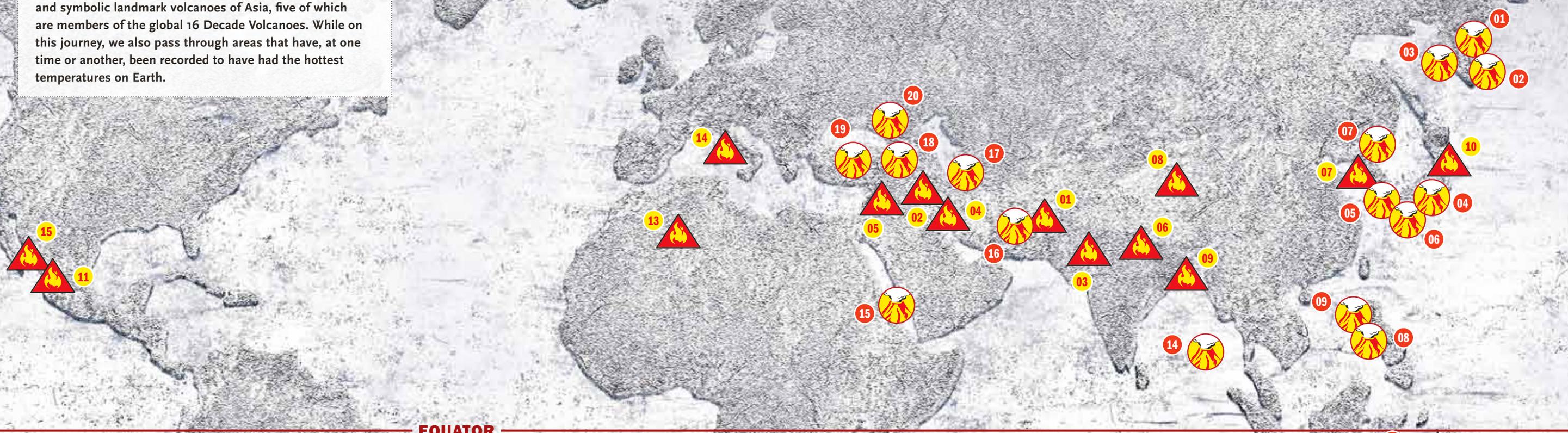
4 | Mt Fuji in Japan, as seen from Kawaguchi Lake

DANGER AND LIFE

But how do these natural phenomena impact our lives above ground on dry land? The stratovolcanoes can be sources of both grave danger and life-giving fertility. Pyroclastic flows, unstoppable fiery blasts of rock and gas, are deadly but usually localised. They can be directly blasted from the crater, or a side vent, of the stratovolcano, or they can be the deadly rain of material from an upward eruption. The Roman cities of Pompeii and Herculaneum were engulfed by pyroclastic ash from the stratovolcano Vesuvius, providing a snapshot of their lives as it was when instantly buried two thousand years ago.

LITERAL HOTSPOTS

From scorching to burning, we chart out the top 20 iconic and symbolic landmark volcanoes of Asia, five of which are members of the global 16 Decade Volcanoes. While on this journey, we also pass through areas that have, at one time or another, been recorded to have had the hottest temperatures on Earth.



ICONIC VOLCANOES

- 01 Klychevskaya
- 02 Avachinsky
- 03 Koryaksky
- 04 Fuji-yama
- 05 Unzen
- 06 Sakura-jima
- 07 Baekdu Mountain
- 08 Taal
- 09 Mount Pinatubo
- 10 Gunung Merapi
- 11 Semeru
- 12 Anak Krakatoa
- 13 Tambora
- 14 Barren Island
- 15 Jabal al-Tair
- 16 Taftan
- 17 Damavand
- 18 Ararat
- 19 Erciyes Dagı
- 20 Mount Elbrus

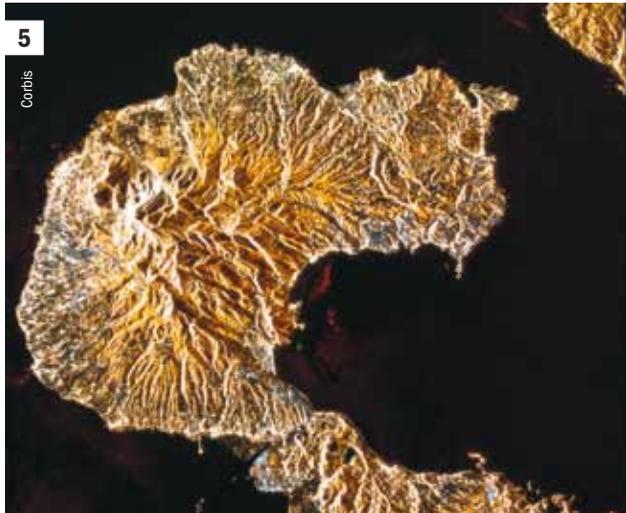
HOTTEST SPOTS ON EARTH

- 01 Farah, Afghanistan
49.8°C (Jun-Aug)
- 02 Baghdad, Iraq
51°C (Jun-Sep)
- 03 Mohenjo-daru, Pakistan
53.5°C (Jun)
- 04 Ahvaz, Iran
52.2°C (Jun-Sep)
- 05 Jericho, Israel
50.5°C (Aug)
- 06 Dholpur, India
50°C (May-Jun)
- 07 Daegu, South Korea
40°C (Jul-Aug)
- 08 Ayding Lake, China
50.2°C (Jul)
- 09 Rajshahi, Bangladesh
45.1 (May-Sep)
- 10 Kumagaya, Japan
40.9°C (Aug)
- 11 Mexicali, Mexico
52°C (Jun-Sep)
- 12 Oodnadatta, Australia
50.7°C (Sep-Apr)
- 13 In Salah, Algeria
50.6°C (Jun-Sep)
- 14 Catenanuova, Italy
48.5°C (Jul-Aug)
- 15 Lake Havasu City, USA
53°C (Jun-Aug)

CREATING THE ATMOSPHERE

On a grander geological time scale, volcanic activity has been responsible for fundamental shifts in the chemical composition of the air we breathe. Eruptions launch water vapour, carbon dioxide, sulphur dioxide and other minerals into the air in vast quantities.

During the early days of Earth's existence, the volcanic cycle would have provided a force for mixing of internal elements with the thin layer of gravitationally trapped atmosphere. It would be much later in geological time that the oxygen trapped in these volcanic gases would be released from those molecules (e.g., H₂O, CO₂, SO₂) by the activity of ultraviolet light and the photosynthetic activity of green plants.



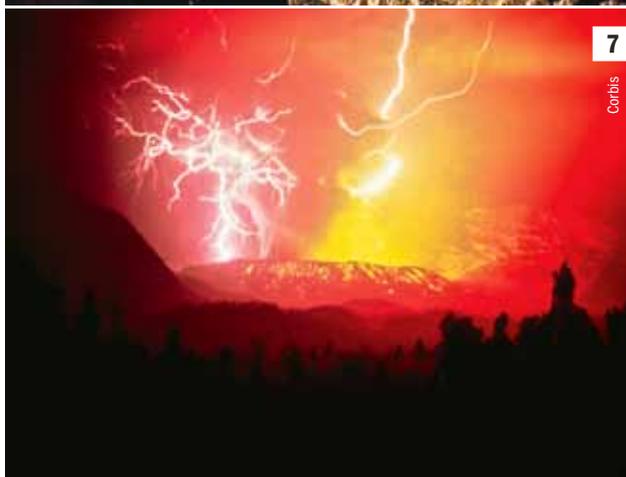
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Roger Ressmeyer/Corbis



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Martin Rietze/moodboard/Corbis



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Martin Rietze/moodboard/Corbis



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Guo Jian She/Redlmy/Corbis

5 | The 1,500-metre volcano Unzen (bright spot, middle left) dominates the Shimbara Peninsula, Japan

6 | The caldera of Mount Pinatubo in the Philippines has an elevation of 1,145 metres

7 | The lake-filled caldera of the 311-metre Taal volcano with a basaltic cinder cone rising from it

8 | Molten lava erupts from Sakurajima Kagoshima, Japan

9 | Baekdu Mountain, part of the Changbai mountain range, is also known as Changbai Mountain, and is at the border between China and North Korea

10 | Mount Merapi, an active volcano, is also known as the Fire Mountain

11 | Belonging to Yemen, Jabal al-Tair, literally "Island of the Birds", is situated offshore in the Red Sea

Besides the actual eruption of ash and magma, earthquakes and flowing lahars can destroy human life and activity. Volcanic activity is associated with earthquakes, although not all quakes come from volcanoes. Increasing tremors are often – but not always – an indicator of a potential eruption. In advance of Mount Pinatubo erupting in 1991 – the first eruption in recorded history – the Filipino government was able to evacuate citizens in time to avoid disaster. The earthquakes and eruptions associated with underwater volcanoes can cause tsunamis of incredible power and tragedy, as evidenced by the 2004 Indian Ocean Tsunami, which killed over 230,000 people in 14 countries.

The Indonesian word *lahar* describes the torrents of mud and rock that can potentially shrug off of the mountainside at any time. Whether triggered by an eruption or merely by gravity, water from melted glacial ice, rivers or lakes can mix with the rock and soil of the mountain. This avalanche can travel far down the mountain and valleys below, burying or sweeping away settlements and wildlands alike.



11

Arthur Thevenaz/Corbis

After these potentially tragic events, life returns quickly to the slopes of the stratovolcanoes. Through the uplifting of trace minerals and the weathering of the rock into fine-grained soil, the lands surrounding a stratovolcano are fertile. The vegetation grows quickly on once-devastated areas. And often, humans return to till the soil and restart their lives underneath the volcano.

CLIMATE IMPACTS

The volcanoes of the world – including the very old floods of basalt covering vast regions of Central India and Siberian Russia – are also directly involved with the atmosphere and climate of the Earth.

In the vicinity of the eruption, rain and lightning are triggered by the airborne dust. The cinders and chemicals that are thrown into the sky can stay airborne for years, skewing the Earth's solar dynamics. The massive explosion of the Indonesian Tambora volcano caused an average temperature drop of 3°C for the year 1815, resulting in major famines worldwide. More recently, in 1991, Pinatubo's eruption caused brilliant sunsets of crimson and scarlet around the world, and another colder year.

The vented gas sulphur dioxide drives this cooling more than does the atmospheric haze from dust particles. These cooling effects of volcanoes have been held up as potential counterbalances to human-induced global climate change. At this stage, few serious proposals to trigger or emulate similar volcanic atmospheric effects have been presented. While there may be some potential in using sulphur dioxide release as a climate change tool, the situation is at the moment not yet desperate enough to consider further atmospheric tampering.

EXPLORING ASIA'S VOLCANOES

Let's shift scales, from planetary geological to the Asian geographical. In the present day, Asia is bounded, east and west, by regions of recent stratovolcanoes. The northern and southern coastlines are almost completely absent of modern volcanic activity.

Starting in the farthest northeast corner of Asia, there are several distinct regions where active stratovolcanoes cluster. Let's travel around the continent, in a clockwise direction, and visit these areas. We'll explore some of the more notable individual volcanoes there, and along the way, we'll meet the five Asian members of the global 16 Decade Volcanoes. This set was declared as priorities for observation in the 1990s, the decade labelled by the United Nations for natural disaster reduction. They remain under close scrutiny to this day, as ambassador volcanoes with a high potential for impact on humanity.

■ **THE KAMCHATKA PENINSULA**

On the Pacific Coast, in the northeastern corner of the continent, the Kamchatka Peninsula of Russia is crowned with dozens of tall, ice-clad stratovolcanoes. In this region of evergreen trees and winter snows, the peaks are declared as UNESCO World Heritage. The largest and most active, Klychevskaya (#1), is Eurasia's tallest active volcano at 4,750 metres. It has been rumbling consistently since its first recorded eruption in 1697.

A local myth says that when the World Creator, Volkor, constructed the Earth, this mountain was the unfinished spot that he used as a handle. Three hundred kilometres to the south, the overlapping stratovolcanoes of Avachinsky and Koryaksky (#2 and #3) are also part of the Decade Volcanoes list.

THE ISLANDS OF JAPAN

The tectonic plate boundary runs south from Kamchatka to the northern Japanese island of Hokkaido and continues south through the volcanic Japanese archipelago. In the south, the most picturesque and famous of all stratovolcanoes towers above Tokyo metropolis: the 3,776-metre-tall Fuji-Yama (#4). The most recognisable symbol of Japan, Mount Fuji is climbed by thousands of people each year, and millions live within sight. While it has not erupted since 1707, it is still an active volcano; it is merely slumbering.

In the southwest of the nation, two smaller but more restless Decade Volcanoes can be found: Unzen (#5), a complex of overlapping cones, and Sakura-jima (#6), a volcanic cone growing on the edge of a once-larger crater. The eruption of Unzen in 1792 triggered a giant tsunami as a lava dome collapsed. Sakura-jima last erupted in 2010, and there were major eruptions in 1914 and 1947. Both of these highly active stratovolcanoes dominate natural harbours with high populations.

From Japan, a line of the Ring of Fire continues as a chain of underwater seamounts for almost 3,000 kilometres southeast towards the island of Guam.

■ **BETWEEN NORTH KOREA AND CHINA**

On the mainland, on the border between North Korea and China, Baekdu Mountain (#7) stands prominently with a spectacular lake hidden within its summit crater. To Koreans, this mountain marks their ancestral origin. The high point on the Korean Peninsula, it is fully a thousand kilometres distant from its nearest stratovolcanic neighbours in the Japanese volcanic chain.

■ **THE ARCHIPELAGO OF THE PHILIPPINES**

Three thousand kilometres southwest of Japan, another line of the Ring of Fire creates dry land as the Philippine Islands. Only 50 kilometres from the capital of Manila, Taal (#8) is a massive crater filled by a lake 15 kilometres across. In the centre of this lake, a younger volcanic cone grows. In the crater of this cone, another lake can be found, and on this lake, a rock outcrop can be found. This small island, Vulcan Point, is therefore a geographical rarity: an island on an island on an island. Historically tumultuous, it has been rumbling and on high alert throughout 2011. It is closely observed as one of the 16 Decade Volcanoes.

Only 150 kilometres northwest, past Manila, the reawakened Mount Pinatubo (#9) achieved worldwide notice when its massive 1991 eruption was predicted accurately enough to evacuate the region. Colouring skies worldwide, it was the first eruptive event in the mountain's recorded history. It contributed to the lowering of the Earth's temperature that year by half a degree Celsius.

■ **THE INDONESIAN ISLANDS**

Continuing clockwise, the next major volcanic archipelago in the Pacific Ring of Fire is Indonesia. From the eastern islands of the Moluccas and Celebes to the southern islands of Flores, Bali, Java and Sumatra, Indonesia is peppered with volcanoes. Straddling the equator, it is the most volcanic and the third most populous of the world's nations.

On Java, Gunung Merapi (#10) is Indonesia's most active, regularly erupting for 500 years. A steeply triangular and photogenic Decade Volcano, it poses a distinct danger to the large city of Yogyakarta. Two hundred kilometres west, the Javanese highpoint of Semeru (#11) reaches 3,676 metres into the sky. Both of these mountains are named for the mythological Hindu Mount Meru, which underlies the entire world and is a million kilometres in height. In a 500-year-old Javanese tale, Semeru is the anchor point at which the Hindu gods secured the free-floating island.

Two other Indonesian volcanoes are known for their fantastically immense eruptions in the 19th century. In the western parts of Indonesia, in the waters of the Sunda Straits between the main islands of Java and Sumatra, Anak Krakatoa (#12) grows. It is a newly forming cone in the shattered crater of Greater Krakatoa. During its 1883 eruption, as many as 100,000 people perished. The explosion was heard thundering almost 5,000 kilometres away in the Indian Ocean island of Mauritius, making it the loudest sound in recorded history. The changes in atmospheric pressure were measured with barometers around the world.



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To the east, on the island of Sumbawa, Tambora (#13) is now a hollowed-out crater remaining after the largest volcanic eruption in recorded history. In 1815, this explosion killed 70,000 people directly and caused a volcanic cooling of the globe that impacted countless more lives worldwide. Only five eruptions on this scale have occurred in the last 20,000 years.

■ **IN THE INDIAN OCEAN**

Barren Island (#14) lies isolated in the Andaman Sea. It is a small, unpopulated island, reaching 354 metres high. It is the only volcano in the Central Indian Ocean, and the only one in India. Looking at a global map, it is apparent that this volcano is at the far northwestern end of the Indonesian Ring of Fire axis; it is 800 kilometres to the nearest stratovolcano in Sumatra.

■ **THE WESTERN EDGE OF ARABIA**

Continuing clockwise to the western portions of Asia, the coastal regions of Arabia closest to Africa are the easternmost points of the extensive terrestrial volcanic rift of Eastern Africa. The Yemeni "Island of the Birds", Jabal al-Tair (#15) is a stratovolcano off the shore in the southern Red Sea. Other stratovolcanoes are found nearby on the African mainland, in the countries of Eritrea, Djibouti and Ethiopia.

■ **IRAN AND THE CASPIAN SEA**

Iran is home to several towering and iconic stratovolcanoes. Far to the southeast, Taftan (#16) and nearby Bazman are a pair of volcanoes more than 3,500 metres in height. Their nearest stratovolcanic neighbour is the famous Damavand (#17), 1,200 kilometres away in northern Iran.

Asia's highest volcano, rising dramatically to 5,670 metres, Damavand is an ancient symbol and landmark. It is only 70 kilometres from the capital of Tehran and is visible on the skyline from the metropolis. It has formed on top of the non-volcanic Elburz Mountains, standing prominently above their ridges. A remarkably conical peak, its natural form of accumulated volcanic material is relatively untouched by gouging glaciers or disrupting eruptions.

Damavand stands on the southern shores of the Caspian Sea, known locally as Mazandaran. This salty body of water is the Earth's largest inland water body, a topographical water trap. Water in the Caspian, which is 30 metres below sea level, does not flow to the ocean, but evaporates into the atmosphere.

■ **WEST OF THE CASPIAN**

Near the Caspian and the Black Sea, the volcanoes of the Caucasus Mountains and the Turkish Highlands arise from the subduction of continental plates. These include Ararat, Erciyes Dagı and Mount Elbrus.

Ararat (#18) is reputed to be the landing point for Noah's boat, following the great flood mentioned in the monotheistic traditions of West Asia. This 5,137-metre volcano is within present-day Turkey and near the borders of Iran, Azerbaijan and Armenia. Known to the Armenians as Masis, it is a national symbol and a mythological home to divinities.

To the west, crowning the central Turkish Highlands, Erciyes Dagı (#19) reaches a height 3,916 metres. White with snow throughout the year, this dormant volcano is now a popular skiing destination.

Northwards, beyond the volcanoes Aragats and Kazbek, the colossal Mount Elbrus (#20) forms the final destination on the clockwise journey. At 5,642 metres, Mount Elbrus is the highest peak in Russia, the highest peak in the Caucasus and, by certain geographical distinction, the highest point in Europe.

Dormant for two millennia, Elbrus is graced by glaciers and a permanent ice cap. A ski lift brings visitors high onto the slopes of the mountain. From here, skiers look downward and climbers look upwards. From the snow-clad slopes, these devotees of the mountains can look across towards the Pacific Ocean, 9,000 kilometres away, and imagine the titanic powers locked into those distant stratovolcanoes. And perhaps, they can detect a slight tremor... **AG**



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14

Yann Arthus-Bertrand/Corbis



12 | Beautiful destroyer: Anak Krakatau erupts

13 | Semeru erupts at Bromo Tengger Semeru National Park, Java, Indonesia

14 | Aerial view of the 4,750-metre Avachinsky volcano that lords over the north of Petropavlosk-Kamchatskiy, Russia

15 | A shepherd in front of the very controversial Mount Ararat at 5,137 metres

16 | Crowning the central Turkish Highlands is Erciyes Dagı at 3,916 metres

17 | Across the barren hills, snow-capped Mount Damavand rises into a hazy sky

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