

SUPERVOLCANOES

Volcanic activity is the driving force behind the formation of Planet Earth. It is the extrusive materials blown out by volcanoes that have produced the crust upon which life exists and the resultant plates that have been created as convection currents below the surface pull the crust in different directions allowing volcanic activity to take place at these boundaries. These are the constructive and destructive plate boundaries or margins. At the constructive plate margins the plates are moving apart and separating, thus allowing new magma to reach the surface in a non-violent manner. At the subduction zones oceanic plates slip below the continental crust leading to less frequent but more violent volcanic eruptions. Other volcanic activity occurs where the crust is thinner over what are called hotspots. These hotspots are stationary but as the plates move over them a line of past and present volcanic activity can be seen. In the Hawaiian volcanic chain,

extinct volcanoes are evident and active volcanoes are present over the current hotspot, such as the Mauna Loa volcano.

Of all types of volcanic activity the supervolcano is by far the most potent and dangerous. However, supervolcanoes are invisible as they do not display the classic shape of a composite volcano as they are large, flat collapsed calderas, often surrounded by higher mountains. The flatness is indicative of a major eruption in the past which has emptied the magma chamber and the surface structure then collapses into itself. The structure is so vast that it is only clearly visible from space.

What is a supervolcano?

'Supervolcano' is a term that applies to only a few of the many areas of volcanic activity on the planet and refers specifically to areas where the sheer volume of magma calculated to

exist below the crust is sufficient to cause a cataclysmic eruption, one which could have devastating effects upon the whole planet. Five locations are considered capable of producing a supervolcano and these are located in Indonesia, New Zealand, South and North America. Examples from previous geological eras have also been identified in these areas as well as in the English Lake District at Scafell and at Glen Coe in Scotland.

Any eruption on the scale of a supervolcano is expected to take one of two forms: either an immense volcanic eruption or a less violent but equally dangerous basaltic flood (Tables 1 and 2) similar to those described as either a caldera or a fissure eruption. This is based on the considerable research that has been undertaken in areas of present and past volcanic activity. Whichever the type of eruption, it is calculated that it would have a Volcanic Explosivity Index (VEI), or value, of Level 8,

Figure 1: The location of plate boundaries, hotspots and supervolcanoes

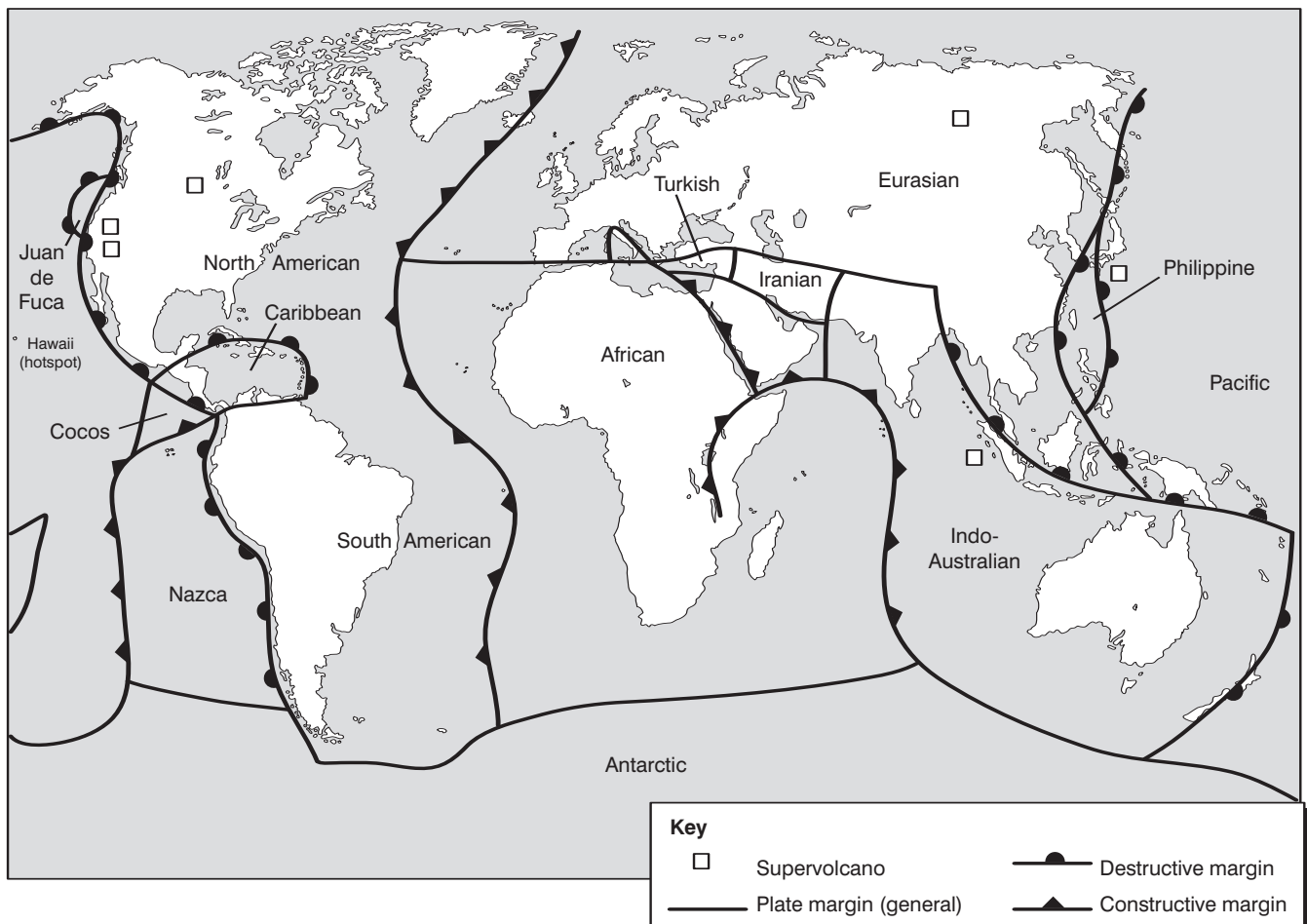


Table 1: Previous volcanic events of VEI8 magnitude

| | Location | Date |
|-----------------|--------------------|------------------|
| Mount Aniakchak | Alaska, USA | 3,500 years ago |
| Mount Mazama | Oregon, USA | 7,000 years ago |
| Campi Flegrei | Campania, Italy | 12,000 years ago |
| Lake Taupo | New Zealand | 26,500 years ago |
| Lake Toba | Sumatra, Indonesia | 74,000 years ago |

Table 2: Previous basaltic floods of VEI8 magnitude in Permian and Cretaceous times

| | Location |
|------------------------|----------|
| Brazilian Highlands | Brazil |
| Colombia River Plateau | USA |
| Deccan Traps | India |
| Siberian Traps | Russia |

which means an extrusion of at least 1,000 cubic kilometers of magma and pyroclastic material (Table 3).

In the past, the effect of such eruptions would have been to extinguish all life forms within a minimum radius of 200 kilometers and areas outside of the immediate zone of annihilation would have been covered with layers meters thick of volcanic ash which would smother life. Gases and dust released would also have spread across the surrounding areas causing further devastation.

This scenario, however, is not just a past geological relic, it is something that will occur again and could occur in our lifetime. Geologists and vulcanologists in particular have begun to detect activity which indicates that this dynamic planet of ours is changing continuously and that the swelling occurring in certain volcanic zones indicate that large amounts of magma are on the move which could lead to a volcanic explosion known as a supervolcano. One of these could lead to a cataclysmic event, similar to those experienced in the past, in the near future or at a date in the near distant future on the geological time scale which is far more extensive than the human interpretation of time.

Evidence from the distant past

As geologists, and in particular vulcanologists, have learnt more about the nature of volcanic activity and the effects it has had upon the

planet in the past, it has become evident that mankind should not be complacent about the effects it can have in both the short and long term for the people who inhabit Planet Earth.

In the distant past, in both the late Jurassic (190-130 million years ago) and late Cretaceous (130-65 million years ago) eras, two magmatic flare-ups enabled a period of extreme volcanic activity to occur. The evidence for this is found within the geological record of the Sierra Nevada region of Western America. Deposits of altered volcanic ash over 100 meters thick and tephra in the sedimentary deposits indicate massive volcanic activity which led to the extinction of the dinosaurs.

Evidence from the recent past

In February 2000, The UK Geological Society presented a paper to the House of Commons Science and Technology Inquiry about the effects of a volcanic winter based upon evidence from previous volcanic eruptions in recorded history.

The report discussed the effects of the eruption of Tambora or Toba on the Indonesian island of Sumatra approximately 74,000 years ago during a time when the planet was naturally cooling and seeing the

onset of a period of glaciation. The records contained within the ice core indicate that quantities of volcanic dust and aerosols were blown into the upper atmosphere. These may have remained aloft for up to six years and brought about a cooling of the whole planet of between 3 and 5 degrees Celsius. Mid-latitude locations, however, which are the primary bread baskets of the world, may have experienced falls of up to 10 degrees Celsius during the growing season. It is thought from DNA evidence that it also brought about a drastic decline in population numbers due to the effects of climate modification by the eruption.

The report documented the historical archives which recorded regional, hemispheric and global effects of the eruption at Tambora in 1815 which saw average winter temperatures fall by 1-2.5 degrees Celsius in Europe for two years. The effect of this was to bring about falls in agricultural yield or even a total failure of a crop and the resultant rise in prices when a product such as a wheat was in short supply. Famine was experienced in Europe. Meanwhile the USA experienced widespread snowfall, including areas where such snowfall is a rarity, and the global temperature fell by 1 degree Celsius and resulted in some of the coldest summers ever experienced in the Northern Hemisphere since records began.

Similarly when Mount Pinatubo in the Philippines erupted in 1991, global mean temperatures fell by 0.4 degrees Celsius the following year.

The aim of the report was to make government aware of the natural dangers facing the planet and that the effects of volcanic activity should not be under-estimated and may

Table 3: The Volcanic Explosivity Index

| VEI | Description | Plume height | Volume | How often | Example |
|-----|----------------|--------------|-----------------------------|------------------|-----------------------|
| 0 | non-explosive | <100 m | 1000s m ³ | daily | Kilauea |
| 1 | gentle | 100-1000 m | 10,000s m ³ | daily | Stromboli |
| 2 | explosive | 1-5 km | 1,000,000s m ³ | weekly | Galeras, 1992 |
| 3 | severe | 3-15 km | 10,000,000s m ³ | yearly | Nevado del Ruiz, 1985 |
| 4 | cataclysmic | 10-25 km | 100,000,000s m ³ | 10s of years | Galunggung, 1982 |
| 5 | paroxysmal | >25 km | 1km ³ | 100s of years | St Helens, 1980 |
| 6 | colossal | >25 km | 10s km ³ | 100s of years | Krakatau, 1883 |
| 7 | super-colossal | >25 km | 100s km ³ | 1000s of years | Tambora, 1815 |
| 8 | mega-colossal | >25 km | 1000s km ³ | 10,000s of years | Yellowstone, 2 Maa |

Figure 2: Location of Yellowstone

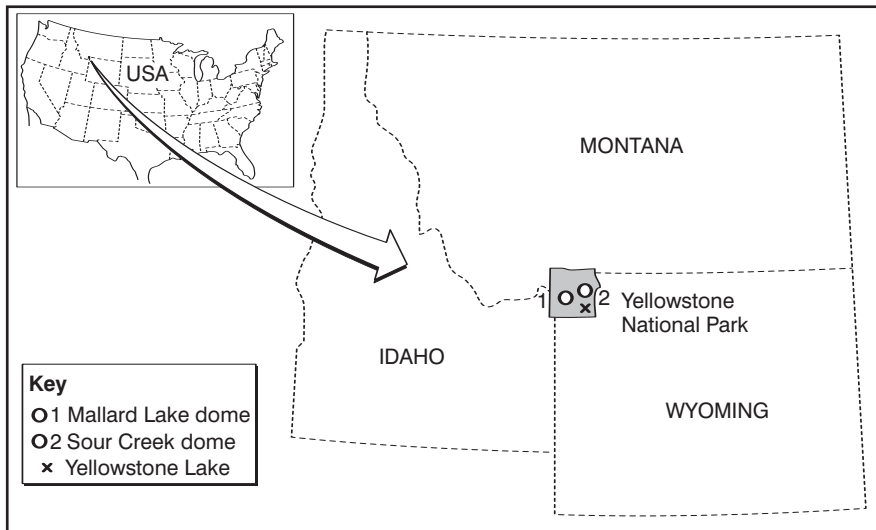
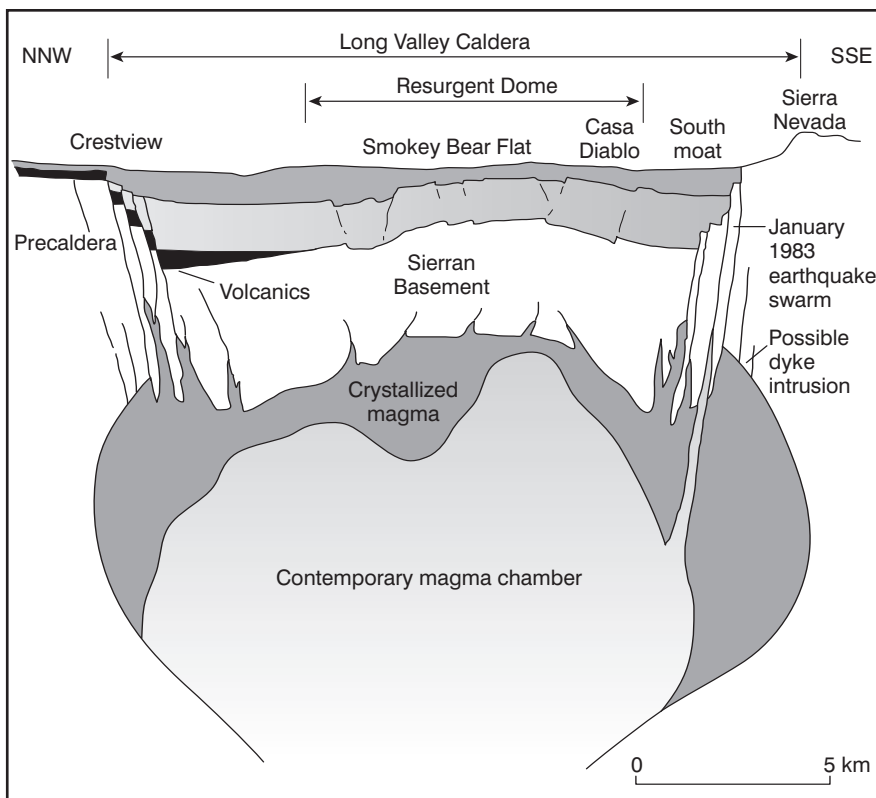


Figure 3: Cross-section of Yellowstone supervolcano



Source: <http://www.ccs.neu.edu/home/futrelle>

even outweigh the man-made effects of global warming and over-population. Although this report did not specifically mention a supervolcano a report in 2005 by the Geological Society went on to say that such an eruption is five to ten times more likely to occur than an asteroid impact with Earth and it would have an effect similar to an asteroid of 1.5 km in diameter hitting us. As Professor Stephen Self of the Open University stated, 'It's going to happen', and as it is estimated that such eruptions occur approximately every 500,000 to

600,000 years and the last one occurred approximately 640,000 years ago, it is felt that Planet Earth is overdue for such an event to take place.

Evidence of current activity

Vulcanologists are monitoring the most likely sites of such a future eruption. Research into Yellowstone in particular indicates that magma is on the move which may lead to the ultimate in volcanic events although there is a strong possibility that any eruption in our lifetime may not be

the supervolcano that is expected one day.

Case Study: Yellowstone, USA

Yellowstone crater is the world's largest volcano.

Located in Yellowstone Park, the largest of America's National Parks, it is one of the five volcanoes to have supervolcano status. It is visited each year by millions who come to see the largest array of hydro-thermal features on Earth. Its hot springs and geysers, such as Old Faithful, are powered by magma lying a few kilometers underground which heat the water creating the spectacular displays viewed by the visitors.

Yellowstone lies on a hot spot. Jake Lowenstern, of the Yellowstone Volcanic Observatory is conducting work for the US Geological Survey noted that the mountains surrounding the Yellowstone caldera are older than Yellowstone itself and that a gap 80 km long exists in the wall of mountains surrounding caldera. It is concluded that the break in the mountain chain was due to a supervolcanic eruption which occurred 2.1 million years ago. This was the first of the supervolcanic eruptions to occur at Yellowstone since it drifted over the hot spot. A second supervolcanic eruption occurred 1.3 million years ago and the most recent occurred 640,000 years ago. The cycle of 600-700,000 years means that another supervolcanic eruption is due.

In 1999, the US Geological Survey studying Yellowstone Lake located a new feature on the lake bed. It was a 700m bulge rising 30m above the lake floor. Sediments lying above the lake bed showed deformation indicating swelling of the crust from below. This could lead to a hydro-thermal explosion, but this is not guaranteed.

Similarly, research has noted that at the Norris Geyser Basin within the northern part of Yellowstone, that in 2003 ground temperatures rose to 100 degrees Celsius, there were more frequent geyser eruptions and new vents spewed out more volcanic gases. Five bison died of gas poisoning due to high levels of hydrogen sulphide and carbon dioxide, both found in magma. Trees died and it was decided to close the area to the public. With the

aid of the INSAR satellite and GPS instruments, whereby a fixed distance between a ground location and a satellite is known, images taken from the satellite have enabled geologists to prove that uplift has occurred in the area and that such activity had been happening for seven years. This indicates that 10–15 km below the surface either magma is rising or gas levels are increasing which bring about this swelling. If magma, it may not reach the surface or cause a major eruption if it does so.

Professor Bob Smith of the University of Idaho is analysing the pattern of earthquakes, of which there are between 1,000 and 3,000 per annum at Yellowstone, using seismometers positioned all around the park. This enables a three dimensional picture of the subterranean landscape to be built up. As sound waves are created whenever an earthquake occurs and they travel more slowly through the hot magma than the surrounding cooler rock, Smith has been able to establish the size of the magma chamber at Yellowstone. He believes the magma chamber to be 80 km long, 40 km wide and 8 km deep, and contains 20-25,000 cubic km of magma. This chamber is three times the size of New York City.

There is still no guarantee however that this will lead to a supervolcano style eruption. It may be that only 30% of the chamber is liquid rock and even if this is the case, it needs to be separated from the other materials within the chamber to create the ideal situation for a major eruption. The magma would need to be lying on top of all the other material, but whether this is the case is not known.

If it did lead to an eruption the subsequent eruption could be catastrophic as Yellowstone is estimated to contain five times the amount of magma needed to create a supervolcano which means that it has the capacity to eject 5,000 cubic km of magma.

The effects on the planet

Using Mount St Helens as an example and scaling up the explosive index to a VEI8 category eruption, the effects of such an eruption are considered to be:

1. A cloud of volcanic ash rising 40-50 km into the atmosphere (compared to 20 km for Mt St Helens).
2. An eruption equivalent to 1,000 Hiroshima bombs per second.
3. Grounding of all aircraft as ash stops the engines and the dust sandblasts the cockpit screen.
4. At 2,500 times bigger than Mt St Helens, 75% of America would be directly affected by the eruption and within 10,000 sq km of the eruption total destruction would occur, causing 87,000 deaths, a 90% mortality rate within 10,000 sq km of the eruption.
5. Within 1,000 km of the eruption ash layers would be at least 15cm deep leading to roof collapses and loss of homes and one in three people within this radius would die.
6. Beyond this distance, ash fall will affect transport, livestock, power lines, water quality.
7. Extra rainfall will occur as there are more particulates in the atmosphere on which water droplets can condense and this can mix with the ash to cause mudflows called lahars, as experienced in New Zealand recently. These could directly be responsible for the deaths of 50,000 people.
8. Within five days the UK Meteorological Office predicts that ash fall would extend to Europe.
9. The Met Office predicts that a sulphurous cloak would envelop the world within three weeks. The high latitudes of North America, Europe and Asia would see a temperature fall of 12 degrees Celsius and two to three years of almost permanent snow, crop failure and chaos.
10. In the Tropics a fall of 15 degrees Celsius, failure of the monsoon rains and 40% of the planet's population facing starvation.

Conclusion

A supervolcano is something that is inevitable, but in our lifetime it is considered to be an extremely remote possibility. Today, individuals, governments and other agencies are becoming more aware of what may face the planet and debate is ongoing about what plans, if any, should be put in place.

Where to find more information

BBC Supervolcano dvd 5 0144503 165925

Websites

www.bbc.co.uk
www.solcomhouse.com
www.geolsoc.org.uk
www.wikipedia.org
www.icr.org

FOCUS QUESTIONS

1. Using Figure 1, describe the location of the world's five supervolcanoes.
2. What type of eruption would a supervolcano generate and at what VEI level?
3. What would the effects of a VEI8 eruption have upon the planet? What contingency plans do you think should be made for such an event. Explain your reasoning.