

## LIVING ON A PLATE MARGIN: ECONOMIC OPPORTUNITIES AND REDUCING RISK

Mount Merapi in Indonesia is one of the most dangerous volcanoes in the world. Periodic eruptions cause devastating pyroclastic flows and lahars, yet thousands of people live on its slopes. This article explores the sometimes literally fatal attraction between people and active plate margins. Following a brief consideration of the main tectonic hazards associated with plate margins and why people live there, this **Geofile** examines how hazardous environments are utilised to make a living and the strategies employed to limit the risks posed by volcanoes and earthquakes.

### A dangerous place to live

Plate margins are inherently dangerous places to live. Natural hazards posing potentially the greatest threats to life and property include:

- **pyroclastic flows**, i.e. hot mixtures of gas, pumice, ash and hot lava which move rapidly downslope, killing all in their path
- **lahars**, or volcanic mudflows, which bury settlements and cause extensive flooding
- powerful **earthquakes** which cause buildings to collapse and trigger landslides
- **tsunamis**, generated by earthquakes and occasionally volcanic eruptions, which flood coastal settlements.

Heavy ash-fall also:

- prevents use of airspace, runways, roads and railways
- leads to crop failure where ash falls on leaves preventing photosynthesis
- contaminates pasture, making it unpalatable to livestock
- corrodes machinery
- causes respiratory illness.

Crops are also damaged by acid rain when sulphur dioxide, which is emitted during eruptions, mixes with rainwater.

Several world cities are located near active faults and volcanoes (Figure 1). Seattle, for example, on the US

Figure 1: Examples of world cities near plate margins at risk from tectonic hazards

City	Tectonic hazards	Type of margin
Seattle	Rainier volcano/earthquakes	destructive
San Francisco	San Andreas fault earthquakes	conservative
Mexico City	Popocatépetl volcano/earthquakes	destructive
Guatemala City	Pacaya volcano/earthquakes	destructive
Managua	Masaya volcano/earthquakes	destructive
Quito	Guagua Pichincha volcano/earthquakes	destructive
Arequipa	El Misti volcano/earthquakes	destructive
Yogyakarta	Merapi volcano/earthquakes	destructive
Kagoshima	Sakurajima volcano/earthquakes	destructive
Shimabara	Unzen volcano/earthquakes	destructive
Tokyo	Earthquakes	destructive
Istanbul	North Anatolia fault - earthquakes	conservative
Tehran	earthquakes	collision zone
Naples	Vesuvius volcano	collision zone

Pacific North West coast is close to Mount Rainier, a volcano which, if it erupted, would produce dangerous lahars. Cities near destructive margins i.e. those where plates collide, face the greatest risk because these locations produce powerful earthquakes and highly explosive types of volcanic eruptions. Movement along conservative margins those where plates move laterally past each other with no subduction, can also produce strong earthquakes. Constructive margins i.e. those where plates diverge, also generate earthquakes and volcanic eruptions, but these tend to be less powerful than those produced at other types of margin.

### Why people live on plate margins

Despite the risks, people often live near dangerous volcanoes such as Mount Merapi because ash weathers to produce fertile soils. Coastal areas are prone to tsunamis, but nevertheless offer fishing and trading opportunities. A detailed discussion of the ways people utilise hazardous environments on plate margins is set out later.

Many people live on plate margins through necessity, rather than choice. This is especially so where land is scarce and the population is rising. Some people are also unaware of the dangers, believing,

for example, that deeply-weathered volcanoes covered by lush vegetation in the tropics pose no threat. Moreover, many without any past experience of a volcanic eruption or earthquake, are unlikely to comprehend the devastation such events might cause. Yet others may be in denial, or believe that a past event was a one-off event, not to be repeated.

People choosing to live on plate margins are likely to have weighed up the risks of a disaster occurring. Risk assessments calculate the probability that a particular hazard will occur, multiplied by the number of people affected and damage caused, less the mitigation measures taken to reduce the impact. Such objective assessments, however, ignore personal perceptions of risk.

### Utilising volcanic resources on plate margins

Economic opportunities generated by volcanic and geothermal activity include agriculture, tourism, geothermal energy production and mining.

#### Agriculture

Volcanic soils cover 1% of the earth's surface, but support 10% of the world's population. Soils derived from volcanic ash and other volcanic ejecta are called andisols. They are characteristically light and fluffy



Figure 2: Crater Lake, Oregon

Source: Jane Dove



Figure 3: Mount Rainier, Cascades Mountains

Source: Jane Dove

and contain volcanic glass and clay minerals such as allophane.

Crops grow well because the soils have large pores which facilitate root development and drainage, as well as small pores which retain water for plant use. Additionally allophane forms strong bonds with organic matter which encourages humus to accumulate on the surface. Furthermore the soils are relatively young which means there has been little time for nutrients to have been lost through leaching.

Volcanic soils support rice cultivation in Japan, Indonesia and Philippines, coffee plantations in Central and South America and sugar cane and tropical fruit production in the Caribbean. Orchards and vineyards in temperate climates, such as those in Oregon, also thrive on volcanic soils.

### Tourism

Volcanic and geothermal areas have long attracted visitors, but in recent decades tourism has increased. Mount Fuji, for example, is climbed by 300,000 people a year. Volcanoes of course are not exclusive to plate margins; many instead occur over hot spots e.g. Hawaii, and as such are beyond the scope of this **Geofile**.

Improvements in air travel have turned once inaccessible volcanoes, such as Yasur in Vanuatu, into tourist attractions. Cruise ships also now offer excursions, during ports of call, to nearby volcanoes such as Masaya in Nicaragua. Climbing a volcano has also become easier, for example a paved road leads to the crater rim of Poás in Costa Rica and gondolas carry visitors to the summit of Mount Usu in Japan.

The global reporting of eruptions, as they happen, has also increased visitation, particularly since the eruption of Mount St Helens in the USA in 1980. Designation as a Geopark, or World Heritage Site (WHS) has also raised the profile of volcanic attractions. Jeju Island in South Korea for example, famed for its lava tubes, experienced a significant increase in tourism after its designation as a WHS in 2007.

Marketing has also increased visitation. Packages often combine a visit to a volcano with other attractions such as skiing on Mount Ruapehu in New Zealand, or bathing in hot springs in Japan. Some specialised adventure tourism companies offer opportunities to hike in remote areas where volcanoes are erupting, or to 'sand-board' down cinder cones as on Cerro Negro in Nicaragua.

Landscapes created by past volcanic activity, such as Crater Lake in Oregon, also attract visitors (Figure 2). Mountain areas, which often incorporate active and dormant volcanoes, are also important tourist attractions in their own right such as the Cascades in the USA (Figure 3). The mountains themselves have been created by past tectonic activity at destructive margins.

Geysers, hot springs, mud pools and fumaroles are tourist attractions in locations such as New Zealand, Iceland and Chile. Those on North Island, New Zealand are located in the Taupo Volcanic Zone within a back arc basin, an area of crustal extension developed behind a volcanic arc on the landward side of a subducting margin. The geysers in Iceland are the product of a

constructive margin and a tectonic hot spot.

Settlements buried by ash during eruptions and later excavated are another type of volcano-related tourist attraction. Pompeii and Herculaneum are the best known examples, but they are not unique. The Meso-American village of Joya de Cerén in El Salvador and the Datei houses buried by Eldfell ash in 1973 (Heimaey, Iceland) also have considerable tourist potential.

Managing the sustainable development of tourism in volcanic areas poses challenges. Eruptions often draw large crowds, placing pressure on accommodation and infrastructure. Excluding tourists on the grounds of safety from erupting volcanoes would result in loss of income. Rebuilding tourist facilities after eruptions can be very expensive. The Spirit Lake Memorial Highway, for example, constructed after Mount St Helens erupted in 1980, cost \$165 million.

Popular locations, such as the rim drive around Crater Lake in Oregon, can become very crowded in summer. Interpretative trails, such as those near Mount St Helens, often suffer from trampling pressure. Tourists sometimes damage volcanic features, by, for example, throwing things into geysers, or removing lava stalagmites as souvenirs. Managing safety in active volcanic areas as mass tourism increases is a growing concern, particularly where visitors ignore warning signs or stray into prohibited areas.

### Geothermal energy

Heat and hot water extracted from geyser basins provides energy

for electricity production. Hot water is also used for heating homes and commercial buildings. New Zealand is a world leader in geothermal energy production. Iceland derives 55% of its electricity from geothermal sources, based on its location on a constructive plate boundary and on a tectonic hot spot. In Chile the El Tatio geothermal area has considerable potential, but transporting electricity over long distances remains a problem.

Developing geothermal energy is an attractive option as fossil fuels decline and concerns about global warming grow. It does, however, have disadvantages in that removal of, or alterations to, groundwater in circulation causes geysers to decline or stop erupting. This, in turn, has led to conflicts between the tourism and geothermal energy production in New Zealand and Iceland.

### Minerals

Volcanic rocks have a wide variety of economic uses, for example pumice is used as an abrasive and cinder for road construction. In Arequipa, Peru, the volcanic rock, 'sillar', a type of ignimbrite or lithified pyroclastic flow, is used as building stone.

Rich veins of copper, zinc, silver and gold are mined in volcanic areas. They form where hot liquids concentrate trace elements in magmas, or in the surrounding rocks, which are later re-deposited as rich mineral veins. The world's largest reserves of copper are mined in Chile, while large gold deposits are extracted from the Grasberg Mine in Indonesia. The Grasberg Mine employs many workers, but there are concerns that profits from the mine are not benefiting local people and that mine tailings are contaminating water supplies, and many of the profits go outside the area.

Sulphur, precipitated around volcanic vents, is mined, for example, at Ijen volcano in Java, Indonesia. Here workers are exposed daily to high concentrations of volcanic gases. The sulphur is mined to bleach sugar, vulcanise rubber and make matches and fertiliser. Former mines, such as those on White Island in New Zealand, have become tourist attractions.

Mineral deposits currently forming on the sea-floor at mid-ocean ridges and in back-arc basins may one day become economically viable. Mining for these massive sulphide deposits which are rich in copper, silver, zinc and gold is at the exploratory stage in the Bismarck Sea off Papua New Guinea.

### Earthquake benefits

Earthquakes create faults which can trap oil and gas reserves. Faults can also sometimes help to bring water to the surface. Several Iranian cities for example, located on thrust faults created by movement between the Arabian and Eurasian plates, exploit such water supplies. Water-tables are often elevated here because rocks, ground down by the movement of the fault, create 'fault gouge', a type of impermeable clay which traps water. Irrigation schemes known as 'ganats' often tap into such underground changes in the water-table at faults, supplying water for crops on desert margins. The attraction between faults and settlements can, however, sometimes prove fatal, as for example when a major earthquake devastated Bam in 2003.

### Case Study: Utilising a plate margin for agriculture and tourism – Costa Rica

Costa Rica is located on a destructive plate boundary, where the Cocos Plate subducts under the Caribbean Plate (Figure 4). This creates a line of active volcanoes which periodically erupt in the north and central part of the country. Volcanoes tend to be absent in southern Costa Rica because the Cocos Ridge disrupts normal subduction here. The country is also affected by occasional earthquakes, such as that which affected Cinchona in 2009.

Rich volcanic soils and a favourable climate support crops such as coffee, an important Costa Rican export. Most coffee is grown in the 'Central Valley' which in reality is a high intermontane plateau, 3,000-4,000 m above sea-level. The soils in the Central Valley are derived from ash produced by past eruptions of volcanoes such as Poás and Irazú. The plantations themselves are also tourist attractions, e.g. Britt Coffee offers tours of its estate which explain how the crop is grown and processed.

Volcanic eruptions are, however, a mixed blessing because heavy ash-fall and acid rain damage native vegetation and crops. An eruption of Poás, which has a highly acidic crater lake, produces sulphurous gases which mix with rainfall creating acid rain which periodically destroys coffee plantations downwind of the volcano.

Volcanoes, as well as rainforests, are a major tourist attraction in Costa Rica.

La Fortuna, a settlement of 6,000 people, at the base of the Arenal volcano is almost entirely dependent on tourism. Formerly considered extinct, the volcano came to life in 1968. Damaging pyroclastic flows flowed down the sides of the volcano destroying the villages of Tabacón, Pueblo Nuevo and San Luis killing 87 people. Arenal remained highly active until 2010. Tourists flocked to see volcanic gases and pyroclastics exploding from its crater summit and lava flowing down its sides. Its dangers, however, were demonstrated in 2000 when a pyroclastic flow killed a tourist and a guide who had strayed into a restricted area. Although the volcano is now quiet, its imposing symmetrical profile still draws visitors. Thermal hot springs on its flanks, e.g. at Tabacón, also attract tourists.

Poás and Irazú, both highly accessible from the capital San José, also attract tourists. From the summit of Poás, tourists view turquoise-coloured crater lakes and take in a visitor centre. Poás, like many other volcanoes in Costa Rica, is located in a National Park, which means income is derived from park fees.

### Minimising risk on plate margins

Reducing risks which natural hazards pose on plate margins are achieved through a combination of structural controls, vulnerability modifications and post-disaster relief.

#### Structural controls

Structural mitigation measures include:

- earthquake-resistant buildings
- steep roofs to shed heavy ash-fall
- barriers to deflect lava flows and lahars
- draining crater lakes to reduce lahars.



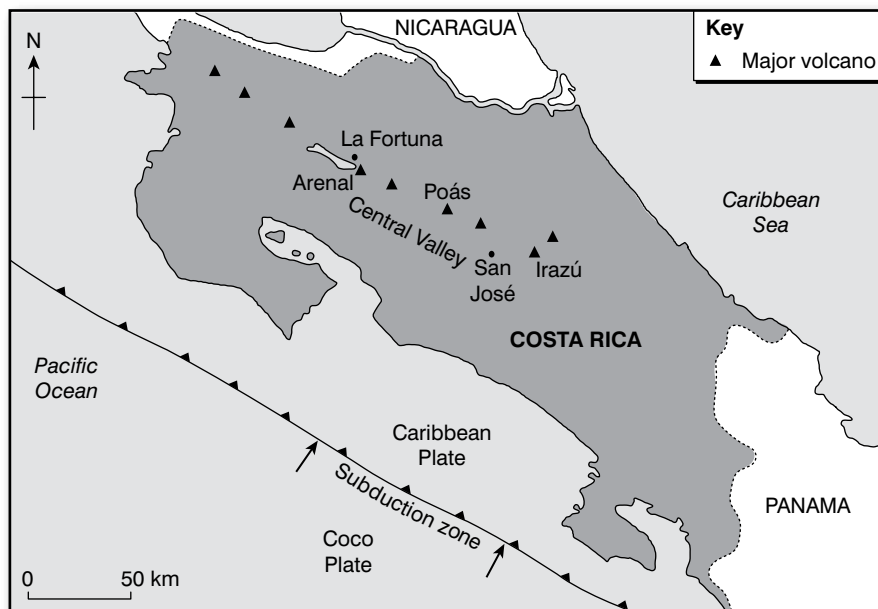


Figure 4: Map of Costa Rica

In Japan, for example, the impacts of lahars are reduced by: natural and artificial channels which confine flows; check dams which impound debris; together with large grates which intercept boulders. Such measures are, however, expensive and periodically have to be strengthened. Reliance on barriers can also lead to over-confidence in building down-slope, storing up trouble when a future disaster occurs.

**Vulnerability modifications**

Modifications include:

- hazard monitoring
- practising drills and designing evacuation routes
- issuing warnings
- land use planning.

Seismic monitoring is valuable because an increase in activity is one of the earliest indications of a pending earthquake or volcanic eruption. Ground deformation, changes in groundwater levels and alterations in volcanic gas and magma compositions also suggest an eruption may be imminent.

Accurate warnings and prompt evacuation can save many lives. This was demonstrated in 2010, when Mount Merapi erupted and evacuations saved an estimated 10,000 to 20,000 people. Issuing warnings can, however, be problematic because people may grow accustomed to false alarms, pre-eruptive events and earthquake foreshocks. Many may also be

reluctant to evacuate for fear their homes will be looted.

New building projects which avoid active fault lines, sediments prone to soil liquefaction and likely routes of lahars and pyroclastic flows can also save lives, as can the positioning of schools and hospitals on high ground on tsunami-prone coasts.

**Insurance and post-relief assistance**

Insurance and post-relief assistance helps to spread the financial burden when a disaster occurs. Insurance is, however, expensive and may not be available in areas deemed high risk. It can also lead to a false sense of security. Post-relief assistance, is in some cases misused or can lead to dependence.

**Conclusion**

This article has addressed how people exploit the resources of plate margins and limit the impacts when a natural hazard is realised. It is important to remember that natural hazards also occur within plates. The Tangshan earthquake for example, which killed at least

255,000 in 1976, occurred well away from a plate boundary. Nevertheless several major world cities are located near fault zones and active volcanoes which make a future disaster almost inevitable.

The negative impact of natural hazards has tended to obscure their beneficial effects. Moreover, technological and scientific advances are likely to reveal new economic opportunities. In geothermal areas for example, thermophilic organisms have been shown to produce heat-stable enzymes which can be used in a number of processes including DNA testing in the biotechnology industry.

Mitigation measures can reduce the impacts of natural hazards. Improvements, particularly in communications, now save many lives when volcanic eruptions and tsunamis occur. Nevertheless, plate margins still remain dangerous places to live, especially for the poor.

**References**

Blaikie, P. et al. (2003) *At Risk: Natural Hazards People's Vulnerability and Disasters*, Routledge, London.  
 Dove, J. (2012) 'Volcanic Tourism: Lessons from Mt St Helens', *Geography Review*, 26(2), 10-13.

**F O C U S Q U E S T I O N S**

1. Why are plate margins dangerous places to live?
2. How can humans utilise hazardous environments to make a living?
3. Essay: Critically evaluate measures to reduce risk on plate margins. Use case studies to exemplify your answer.