Chp 1 Gateway 2 – What landforms and associated tectonic phenomena are found at plate boundaries?

Main points:

- Formation of landforms at different plate boundaries
  1. Fold mountains
  2. Rift valleys & block mountains
  3. Volcanoes
- Formation of tectonic phenomena at plate boundaries
  1. Earthquakes
  2. Volcanic eruptions

Landforms at different plate boundaries

Landform	Plate boundaries	
	Divergent	Convergent
1. **Fold mountains**	/	
2. **Volcanoes**	/	/
3. **Rift valleys**		/
4. **Block mountains**		/

Fold mountains

Formation

Process	Explanation
1. Convergence	**Folding** • **compressional forces** → immense pressure • rock layers **buckle** & **fold**
2. Increasing compressional force	Changes of simple fold 1) asymmetrical fold 2) over-fold (one limb of fold rides over another) 3) recumbent fold (limbs of fold become parallel)
3. Tremendous continual compression	• **Fracture** occurs & one limb thrust over the other on the fracture → over-thrust fold • **anticline**: upfold **syncline**: downfold

Rock types

Type	Formation
1. **Sedimentary** rocks	Multiple layers of sediments
2. **Igneous** rocks	Molten rocks cool & solidify
3. **Metamorphic** rocks	Rocks changed by high temp & pressure within crust

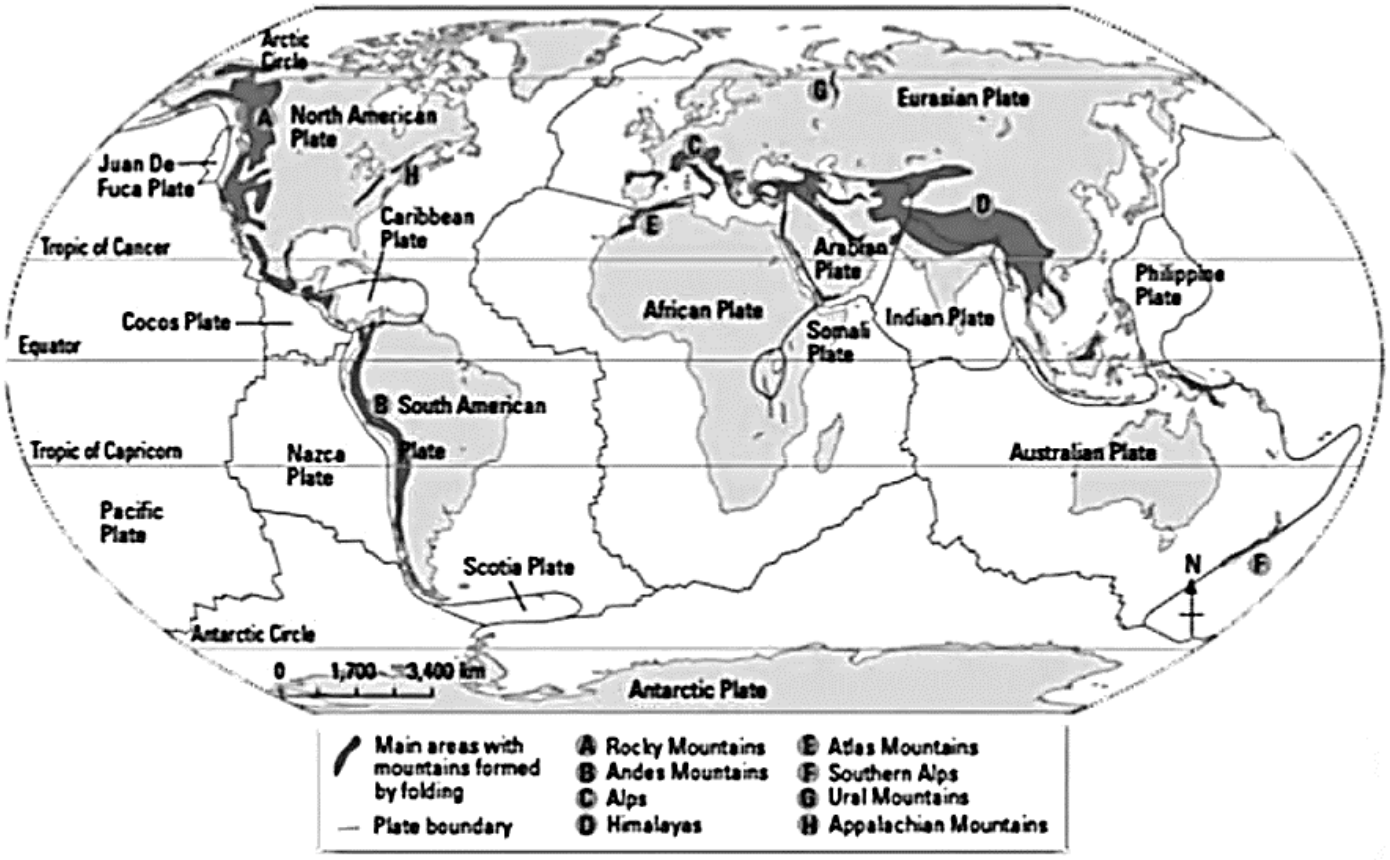
Location

- Convergent plate boundaries

Mountain	Plates	Location
1) Himalayas	Indian Plate & Eurasian Plate converge	Southern Asia
2) Rocky Mountains	Juan de Fuca Plate subduct under North American Plate	West coast of North America
3) Andes Mountains	Nazca Plate subduct under South American Plate	West coast of South America

- Types of fold mountains

Type	Characteristics	Exposure – weathering & erosion	Age (mil. yrs)	Examples
1. **Young fold mountains**	▪ Impressive heights ▪ Sharp peaks ▪ Steep slopes ▪ Jagged edges	Shorter time	100	1) Himalayas 2) Andes 3) Rockies
2. **Old fold mountains**	▪ Lower in heights ▪ Rounded summits ▪ Gentle slopes ▪ Smooth edges	Longer time	270 | 400	1) Appalachian Mountains 2) Urals



Rift valleys & block mountains

Formation & locations

	Rift valleys	Block mountains
Formation	**Faulting** • Plates pulled apart → **faults** (fracture in rocks along which rocks are displaced) • Tensional forces → parts of crust being fractured • Sections of crust extend along fault lines	
	• Tensional force → central block to subside between pair of parallel faults • Valley with steep sides	• Tensional forces → land masses surrounding block of land subside • Block of land with steep slopes left standing higher than surrounding land
Location	1) **East African Rift Valley** (African Plate – Somalian & Nubian boundary) 2) **Hutt Valley**, NZ (Australian Plate & Pacific Plate)	**Rhine Valley** (Eurasian Plate & North American Plate) 1) Vosges, France 2) Black Forest, Germany

Volcanoes

Formation

Process	Explanation
1. Subduction	• Mantle material above subducting plate melt → **magma** • Magma (less dense) rises → **magma chamber**, pressure builds up
2. Vulcanicity	• Magma (from chamber) rises through vents to surface → **lava** • Lava builds up around vent → **volcano**
3. Magma eject onto surface	• More magma seeps into magma chamber • More pressure builds up → explosive eruption • Magma (gases + stream + ash + rock fragments) eject through vent onto surface
4. Building up volcano, with crater on top	• Ejected materials build around vent layer upon layer • **Lava layer**: alternating with ash & cinder layer
5. Secondary cone	• Rapid cooling & solidification of viscous lava → **central pipe blocked** • Magma find new exit route to surface
6. Caldera	• Violent or explosive successive eruptions • Lack of structural support → **crater collapse inwards** → large depression

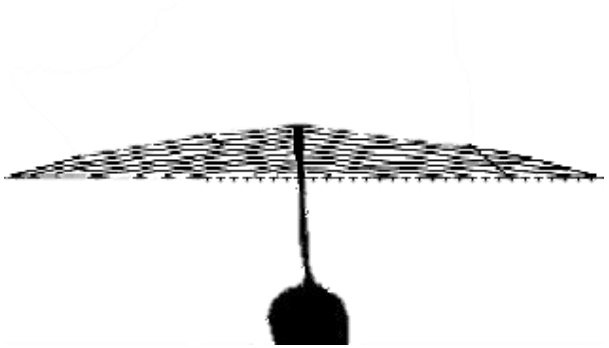
Types of lava

Lava	Viscosity	Trapping of gas	Result
1. **Low-silica**	Low	Gas escape easily, flows more easily through vent	Outer layer of cooling lava → thin crust
2. **High-silica**	High	Trap gas more easily	• Pressure build up below surface • Magma rises towards surface, gas expand → outward explosion • Eject into surrounding 1) lava 2) ash 3) rock fragments 4) gases

Classification of volcanoes

Type	Shape and size	Eruption	Examples
1. **Shield volcano**	• Gently sloping sides • Broad summit + broad base	• Usually less explosive • **Low-silica lava** – low viscosity, flow easily, spread over larger area before solidifying	(a) Mauna Loa (Hawaii) (b) Mt Washington (USA)
2. **Stratovolcano**	• Concave profile • Steep at top, gentle at base	• More explosive • **High-silica lava** – high viscosity, flow more slowly, spread over smaller area before solidifying • Develop from successive eruptions of lava + pyroclasts • Possess **secondary cones** (blocked central pipe – find new exit route) • Pyroclastic flows + lahar flows flowing down slopes during eruptions	(a) Mt Pinatubo & Mt Mayon (Philippines) (b) Mt Merapi (Indonesia)

Shield volcano:



Lava: magma ejected onto surface
Magma chamber: reservoir of molten rock
Vents: openings in surface with a pipe leading into magma chamber
Vulcanicity: upward movement of magma into crust, onto surface
Caldera: large depression due to inwards collapse of crater

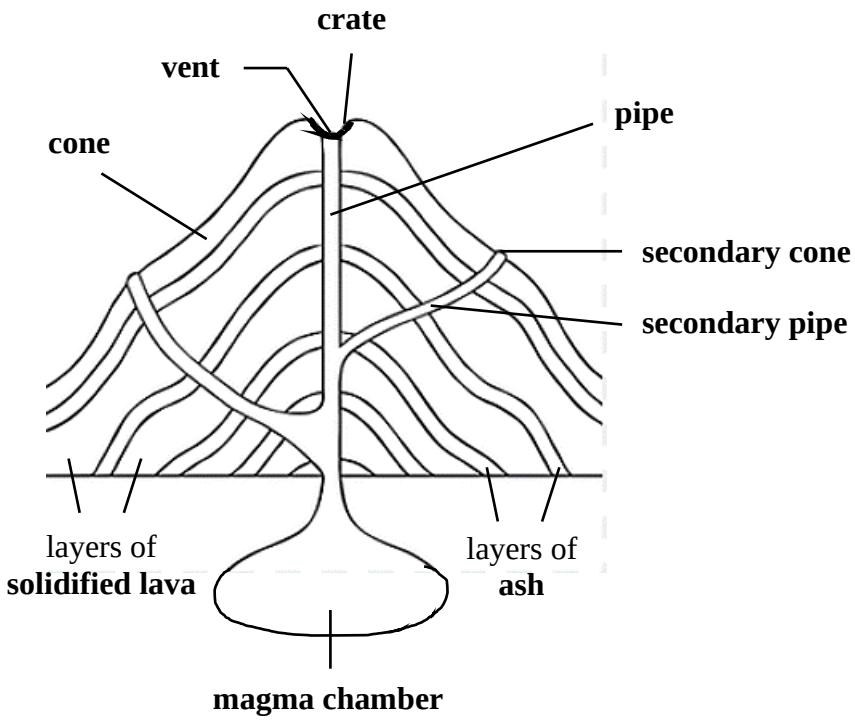
Pyroclasts: ash + rock fragments + volcanic bombs
Lahars: pyroclasts + water

Stratovolcano:

Distribution

Plate boundary	Location
Convergent	**Pacific Ring of Fire**
Divergent	Atlantic Ocean East Africa (Rift Valley)

Structure:



Tectonic phenomena at plate boundaries

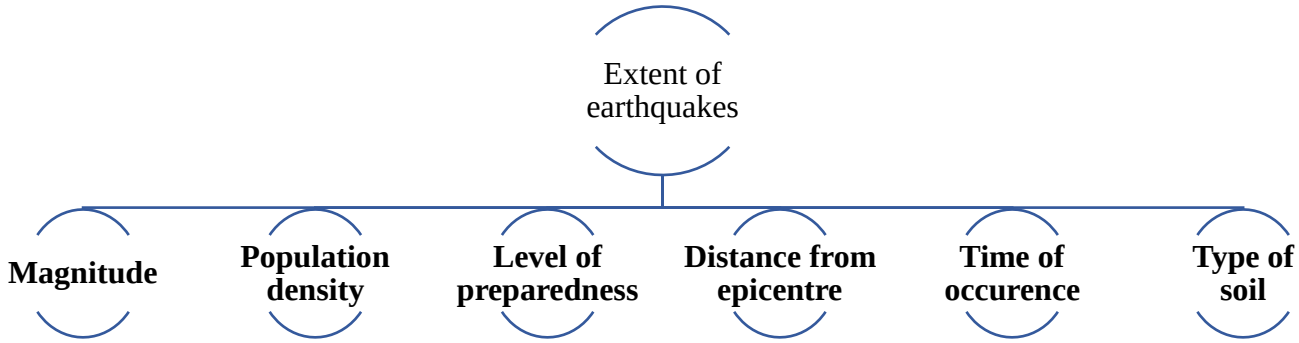
Earthquakes

Formation: vibration at surface caused by sudden release of energy stored in the rocks along fault lines

Process	Explanation
1. Plate movement	**Build-up of stress** on rocks on either side of the fault
2. Energy stored in earth's crust	• Rocks cannot contain the pressure and energy anymore • Rocks **slip** in the form of an earthquake • Energy released as **seismic waves**
3. Energy radiates away from focus as shockwaves	• Shockwaves reach **epicentre** • Rocks break up & move in a series of **sudden jerks**
4. Aftershocks	Stress within the ground → **several smaller earthquakes** along fault lines

Focus: source of the earthquake where seismic waves radiate out from
Epicentre: point on earth's surface directly above focus, where seismic waves are strongest

Magnitude: amount of energy released by earthquake
Ritcher Scale: used to measure magnitude of earthquake
→ for each increasing magnitude, impact becomes 10 times greater

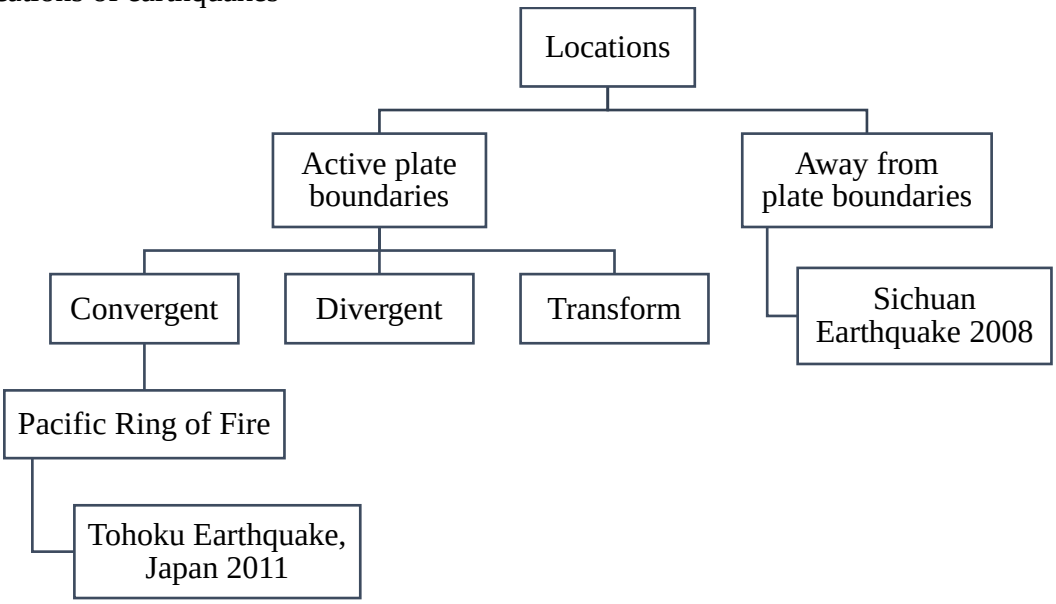


Extent of earthquakes

Factor	Explanation		Examples
1. **Magnitude**	High	• vibrations <u>stronger</u> • <u>more</u> shaking of earth's surface • <u>more</u> buildings collapse – <u>more</u> damage	Valdivia Earthquake (Chile): 9.5
	Low	• vibrations <u>weaker</u> • <u>less</u> shaking of earth's surface • <u>fewer</u> buildings collapse – <u>less</u> damage	
2. **Population density**	High (dense urban areas)	<u>more</u> damage, <u>more</u> casualties	
	Low (sparse rural towns)	<u>less</u> damage, <u>fewer</u> casualties	
3. **Level of preparedness**	Reduce damage 1) evacuation plans 2) trained rescue workers 3) range of action plans		

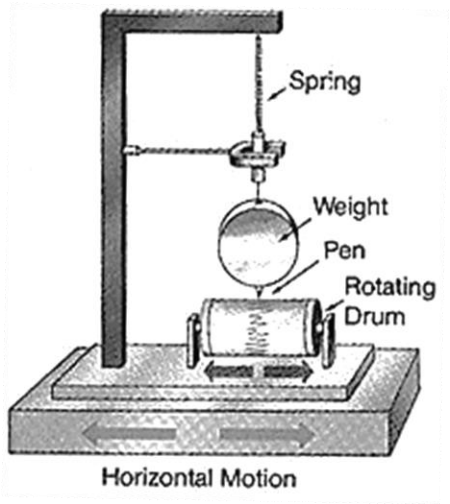
4. **Distance from epicentre**	closer	more severe damage	Christchurch Earthquake • epicentre near city centre • city suffered more damage
	further away	less damage	
5. **Time of occurrence**	day	people can escape in time → higher chance of surviving	Sun Moon Lake Earthquake • occurred at midnight • a lot of people died
	night	people are sleeping → lesser chance of surviving	
6. **Type of soil**	stable & consolidated		Christchurch Earthquake • liquefaction after earthquake • many houses & buildings abandoned
	loose & unconsolidated	• Seismic waves are amplified → greater damage • **Liquefaction**: ground becomes unstable & saturated soil flows like liquid	

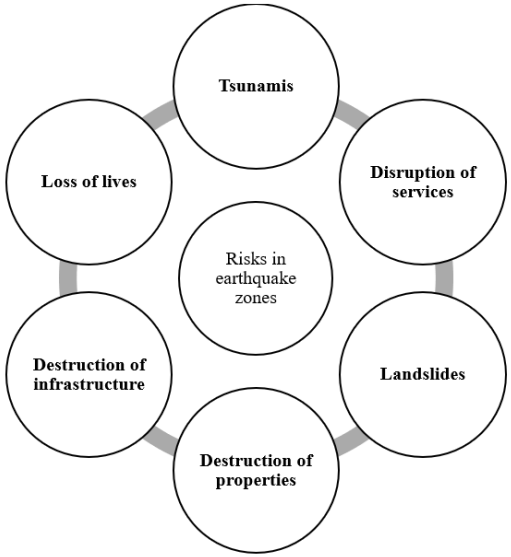
Locations of earthquakes



Measuring earthquakes

Method	Explanation
1. **Seismograph**	Records seismic waves released by earthquake • Spring-mounted weight: moves up and down when detect tremors • Ink marker: records motions of the ground → make vertical markings on graph paper (attached to rotating drum)
2. **Global Positioning System** (GPS)	Measure how far a location has shifted as a result of earthquake





Risks of earthquake zones

<table>
<tr><th>Risks</th><th>Explanation</th><th>Examples</th></tr>
<tr>
<td>1. Tsunamis</td>
<td>
• Unusually large sea wave
• Formed by:
1) Movement of sea floor during offshore earthquake
2) Explosive underwater volcanic eruption
3) Landslide – materials plunge into water
4) Partial collapse of volcano cone
• Formation process
1) Seismic energy from offshore earthquake forces out mass of sea water
2) Height and speed
<table>
<tr><th>Phase</th><th>Height</th><th>Speed</th></tr>
<tr><td>Start</td><td>low</td><td>high</td></tr>
<tr><td>Shallower water (greater friction)</td><td>increase</td><td>decrease</td></tr>
<tr><td>Point of impact on coast</td><td>great</td><td>low</td></tr>
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</td>
<td>
Indian Ocean Earthquake
• damaged coastal communities
• most damage: low-lying coastal areas of western Sumatra (city of Banda Aceh)
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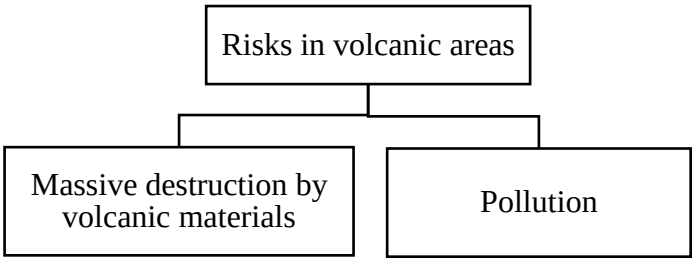
	• Travel long distances, widespread destruction at coastal areas when sweeps inland	
2. **Disruption of services**	1) Disrupt supply of electricity, gas and water 2) Outbreak of fires (i) snap pipes (ii) break cables 3) Communication services affected (i) television broadcasts (ii) telephone connections	Kobe Earthquake (Japan) • damaged pipes & transmission lines • disrupted electricity, gas and water supplies to residents
3. **Landslides**	• Shaking of ground → weaken slopes of hills & mountains • Landslides: rapid downslope movements of soil, rock & vegetation debris from slope • Mudflows: mixed soil debris flow down slope → heavy rainfall – saturates soil	Mount Huascaran landslide • flattened town of Ranrahirca • high death toll
4. **Destruction of properties**	Homeless → reside at temporary shelters	Tohoku Earthquake (Japan) • tsunami • extensive structural damage → a lot of people homeless • severe shortage of housing • concerns about long-term consequence on health
5. **Destruction of infrastructure**	1) Cracks in infrastructure 2) Disrupt transportation (damage roads)	Kobe Earthquake (Japan) • many places in city → inaccessible & difficult to reach • high cost of repair
6. **Loss of lives**	Threaten lives	Haiti Earthquake → 300,000 deaths

Volcanic eruptions

Volcanoes

Type	Current eruptions	Future eruptions
1. **Active volcano**	currently erupting	expected to erupt in near future
2. **Dormant volcano**	currently inactive	may erupt in future
3. **Extinct volcano**	no current seismic activity	no geological evidence of eruptions for past thousands of years

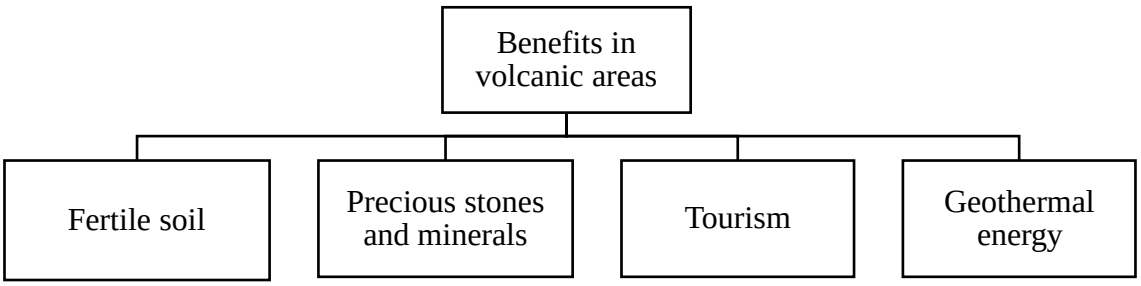
Risks of living near volcanic areas



Danger	Substances	Explanation
1. **Massive destruction by volcanic materials**	1) Lava	• High temperature – burns the areas it flows through • Low-silica lava: move rapidly and flow over long distances, damaging larger areas
	2) Pyroclastic flow	Destroy everything in its path with hot rock fragments (ash, boulders) travelling at high speeds
	3) Volcanic bombs	Fall in areas surrounding volcano → damage property
	4) Landslides	Structural collapse of volcanic cone during volcanic eruption (i) obstruct flow of rivers → floods (ii) block roads (iii) bury villages & farmlands
	5) Lahar	Flows of wet volcanic debris on the side of volcano
2. **Pollution**	1) Volcanic ash particles	• Disrupt human activities over large distances from volcano • Thick plumes of ash settle on the ground (i) block sunlight (ii) suffocate crops (iii) severe respiratory problems
	2) Fine ash particles	Carried by wind over long distances → impact areas further away from eruption source
	3) Harmful gases	(a) carbon monoxide (b) carbon dioxide (c) sulfur dioxide (d) hydrogen

Examples

Eruption of Nevado del Ruiz (Andes)	Eruption of Eyjafjallajokull (Iceland)
• Pyroclastic flow • Mixing of pyroclasts + glacial ice → lahars	Extensive volcanic ash clouds (tiny particles of abrasive gas + sand + rock) → danger to aircraft engines & structures
Lahar engulfed the town of Armero → killed more than 20,000 people	Closure of air space over much of Europe • connecting flights worldwide were cancelled • delays 1.2 million passengers daily • costing airline industry US$1.8 billion



Benefits of living near volcanic areas

Benefit	Explanation		Examples
1. **Fertile soil**	Ash + lava → fertile soil for agriculture (a) tea (b) coffee (c) rice		Fertile soils support large rural populations (rely on agriculture as a means of livelihood) (a) Java (b) Bali
2. **Precious stones & minerals**	1) Precious stones	(a) diamonds (b) opals (c) sapphire	Bring income to locals (a) Java: sulfur → make matches & fertilisers (b) Kimberly: diamond → make industrial tools (scientific research)
	2) Minerals	(a) gold (b) silver (c) diamond (d) sulfur	
3. **Tourism**	Scenic & great for trekking among tourists → locals earn money from tourism		Attract a lot of tourists (a) Mt Merapi (b) Mt Bromo (c) Mt Batur (culturally rich) (d) Mt Vesuvius (ruins of Pompeii destroyed and covered in ash)
4. **Geothermal energy**	Derived from the heat in earth's crust • groundwater comes into contact with hot rocks beneath surface • heats up & erupts as hot water / steam		Iceland • Use geothermal power to generate electricity • 70% homes: heated by volcanic steam