What is a Hazard ? How is it classified ?

Hazard may be defined as *"a dangerous condition or event, that threat or have the potential for causing injury to life or damage to property or the environment."*

The word 'hazard' owes its origin to the word 'hasard' in old French and 'az-zahr' in Arabic meaning 'chance' or 'luck'.

Hazards can be grouped into two broad categories namely natural and human origin.

1. Natural hazards are hazards which are caused because of natural phenomena (hazards with meteorological, geological or even biological origin). Examples of natural hazards are cyclones, tsunamis, earth-quake and volcanic eruption which are exclusively of natural origin.
Landslides, floods, drought, fires are socio-natural hazards since their causes are both natural and man made. For example flooding may be caused because of heavy rains, landslide or blocking of drains with human waste.

2. Manmade hazards are hazards which are due to human negligence. Manmade hazards are associated with industries or energy generation facilities and include explosions, leakage of toxic waste, pollution, dam failure, wars or civil strife etc.
The list of hazards is very long. Many occur frequently while others take place occasionally. However, on the basis of their genesis, they can be categorized as follows:

Table 1.2: Various types of hazards

Types	Hazards	
Geological Hazards	1. Earthquake 2. Tsunami 3. Volcanic eruption	4. Landslide 5. Dam burst 6. Mine Fire
Water & Climatic Hazards	1. Tropical Cyclone 2. Tornado and Hurricane 3. Floods 4. Drought 5. Hailstorm	6. Cloudburst 7. Landslide 8. Heat & Cold wave 9. Snow Avalanche 10. Sea erosion
Environmental Hazards	1. Environmental pollutions 2. Deforestation	3. Desertification 4. Pest Infection
Biological	1. Human / Animal Epidemics 2. Pest attacks	3. Food poisoning 4. Weapons of Mass Destruction
Chemical, Industrial and Nuclear Accidents	1. Chemical disasters 2. Industrial disasters	3. Oil spills/Fires 4. Nuclear
Accident related	1. Boat / Road / Train accidents / air crash Rural / Urban fires Bomb /serial bomb blasts 2. Forest fires	3. Building collapse 4. Electric Accidents 5. Festival related disasters 6. Mine flooding

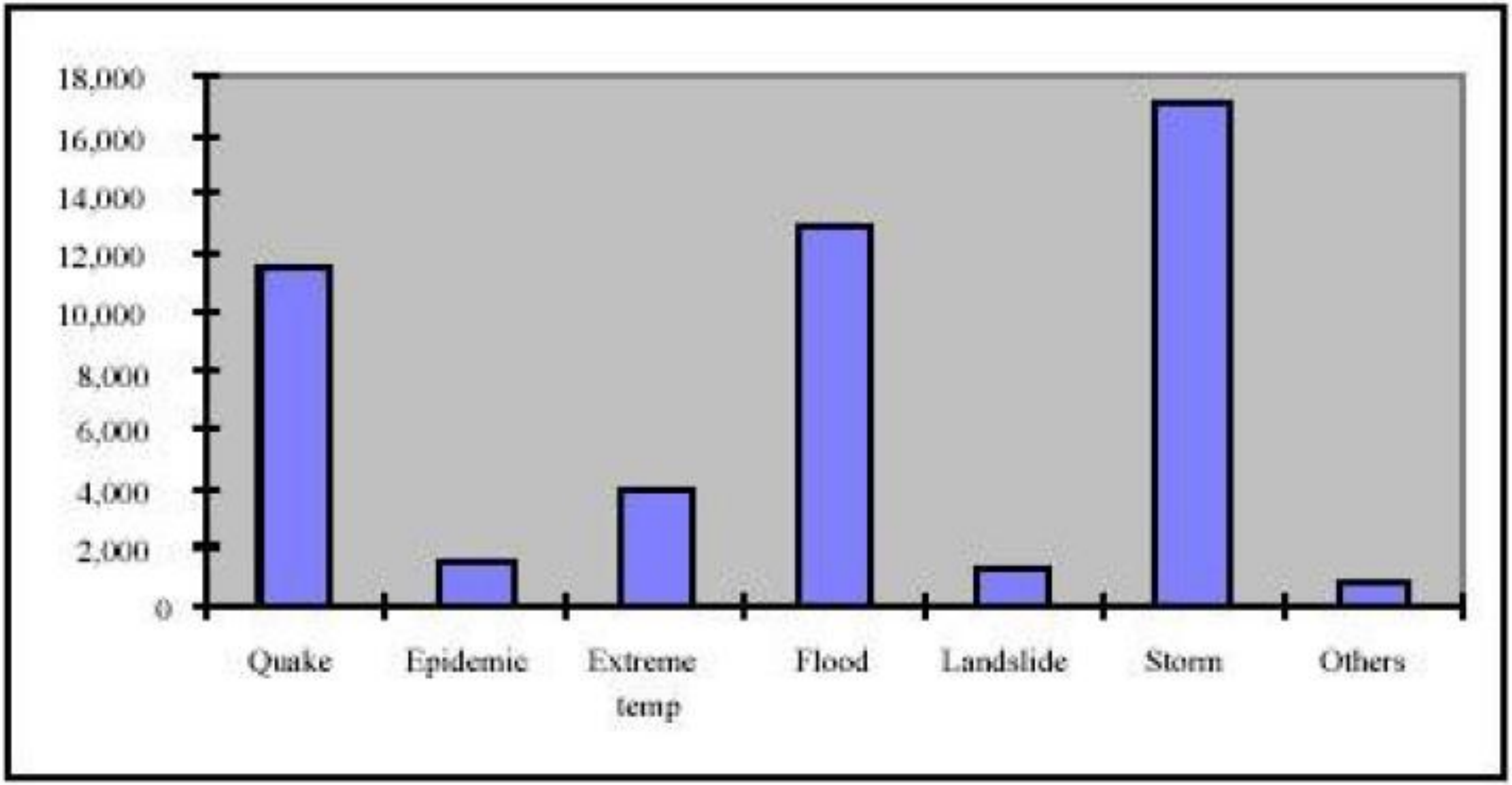
Classification based on Origin/ Cause

- Endogenous origin :
- sub surface in nature (earthquakes, volcanoes)
- Exogenous origin:
- Earth surface processes (floods and droughts)

Effects of Hazards

- Primary effects
  Direct result of the event (lava flow, ground motion, etc).
- Secondary effects
  Associated with, but not a direct response to the event (mudslides, tsunamis, famine and disease, etc).
- Tertiary effects
  Long term or permanent changes due to the event (change in topography, climate change, habitat loss, etc).

Mortality due to natural hazards, 1990 - 2000



Only for your information

What is a Disaster ???

Disaster, as defined by the United Nations, is a serious disruption of the functioning of a community or society, which involve widespread human, material, economic or environmental impacts that exceed the ability of the affected community or society to cope using its own resources .

Effects of Disasters

Enormous population pressures and urbanization

- *A flood, a drought or an earthquake millions of peoples are affected each time a disaster occurs*
- *Large-scale displacement and the loss of life, loss of property and agricultural crops*

Disaster management is how we deal with the human, material, economic or environmental impacts of said disaster, it is the process of how we "prepare for, respond to and learn from the effects of major failures" .

- OUR POPULATION IS SWELLING AND THE WORLD'S POPULATION IS EXPECTED TO INCREASE BY 2 BILLION PERSONS IN THE NEXT 30 YEARS
- 70% OF THAT POPULATION IS GOING TO CONCENTRATE IN AN URBAN AREA WHICH INCREASES THE VULNERABILITY
- POVERTY AND INEQUALITY IS RELATED TO THE IMPACT OF ANY DISASTER.
- TECHNILOGY THAT WE HAVE SHOULD BE USED TO RESPOND AND TO BETTER PREPARE. WE CALL IT DISATER RISK REDUCTION.
- According to the International Federation of Red Cross & Red Crescent Societies a disaster occurs when a hazard impacts on vulnerable people. The combination of hazards, vulnerability and inability to reduce the potential negative consequences of risk results in disaster.
- We can say that Disaster is a function of both VULNERABILITY & HAZARD.
- WE KNOW THAT 80% OF BANGLADESH IS FLOOD PRONE. IF FOOD OCCURS YEARS AFTER YAERS, WHY DO PEOPLE STILL LIVE THERE?
- BECAUSE THE FLOOD PLAINS ARE ONE OF THE MOST FERTILE SOIL. SO PEOPLE WILL MOVE BACK THERE TO FARM.
- Similarly, impoverished people in some parts of the world (like in Guatemala City) can only afford to live on the steep hillsides around the city, which are highly susceptible to landslides in the event of an earthquake

India's Vulnerability to Disasters

- 57% land is vulnerable to earthquakes. Of these, 12% is vulnerable to severe earthquakes.
- 68% land is vulnerable to drought.
- 12% land is vulnerable to floods.
- 8% land is vulnerable to cyclones.
- Apart from natural disasters, some cities in India are also vulnerable to chemical and industrial disasters and man-made disasters.

Only for your information

What is vulnerability ?

Vulnerability may be defined as *"The extent to which a community, structure, services or geographic area is likely to be damaged or disrupted by the impact of particular hazard, on account of their nature, construction and proximity to hazardous terrains or a disaster prone area."*

Vulnerabilities can be categorized into physical and socio-economic vulnerability.

Physical Vulnerability: It includes notions of who and what may be damaged or destroyed by natural hazard such as earth-quakes or floods. It is based on the physical condition of people and elements at risk, such as buildings, infrastructure etc; and their proximity, location and nature of the hazard. It also relates to the technical capability of building and structures to resist the forces acting upon them during a hazard event.

Socio-economic Vulnerability:

The degree to which a population is affected by a hazard will not merely lie in the physical components of vulnerability but also on the socio-economic conditions. The socio-economic condition of the people also determines the intensity of the impact.

For example, people who are poor and living in the sea coast don’t have the money to construct strong concrete houses. They are generally at risk and loose their shelters when ever there is strong wind or cyclone. Because of their poverty they too are not able to rebuild their houses.

Unchecked growth of settlements in unsafe areas exposes the people to the hazard. In case of an earthquake or landslide the ground may fail and the houses on the top may topple or slide and affect the settlements at the lower level even if they are designed well for earthquake forces.

Hazards are always prevalent, but the hazard becomes a disaster only when there is greater vulnerability and less of capacity to cope with it. In other words the frequency or likelihood of a hazard and the vulnerability of the community increases the risk of being severely affected.

To understand risk or disaster risk, one must have a very clear idea of its constituent parameters, which are hazard, vulnerability, exposure and coping capacity. While coping capacity and vulnerability are literally intertwined and are complementary to each other, the other three parameters (hazard, vulnerability and exposure) are primarily what defines disaster risk.

Hazard is not a disaster in itself but a phenomenon or an event which may cause some damage and it is the vulnerability of the individual or community or the system in consideration which defines the risk a hazard pose.

What is capacity ? What is risk ?

Capacity can be defined as *“resources, means and strengths which exist in households and communities and which enable them to cope with, withstand, prepare for, prevent, mitigate or quickly recover from a disaster”.*

People’s capacity can also be taken into account. Capacities could be:

Physical Capacity: People whose houses have been destroyed by the cyclone or crops, or have been destroyed by the flood can salvage things from their homes and from their farms. Some family members have skills, which enable them to find employment if they migrate, either temporarily or permanently.

Socio-economic Capacity: In most of the disasters, people suffer their greatest losses in the physical and material realm. Rich people have the capacity to recover soon because of their wealth. In fact, they are seldom hit by disasters because they live in safe areas and their houses are built with stronger materials. However, even when everything is destroyed they have the capacity to cope up with it.

What is risk?

Describes a potential set of consequences that may arise from a given set of circumstances.

• Risk is a combination of the interaction of hazard, exposure, and vulnerability, which can be represented by the three sides of a triangle.

• More the length of any side, more is the risk.

Risk is a *“measure of the expected losses due to a hazard event occurring in a given area over a specific time period. Risk is a function of the probability of particular hazardous event and the losses each would cause.”* The level of risk depends upon:

- ❑ Nature of the hazard
- ❑ Vulnerability of the elements which are affected
- ❑ Economic value of those elements

A community/locality is said to be at ‘risk’ when it is exposed to hazards and is likely to be adversely affected by its impact.
Whenever we discuss ‘disaster management’ it is basically ‘disaster risk management’.

Disaster risk management includes all measures which reduce disaster related losses of life, property or assets by either reducing the hazard or vulnerability of the elements at risk.

<u>No need to memorize line by line</u>

Hazard *vs* Risk

- Hazard assessment focuses on characterizing the physical effects of a geologic event.
- Risk assessment focuses on the extent of damage (loss) anticipated.
- Assessments must provide the information in a form that can be readily used by community planners and decision makers.

Let us explain the *risk* with the following example

What is hazard?

Any substance, phenomenon or situation, which has the potential to cause disruption or damage to people, their property, their services and their environment.

- In our case, water is a hazard

– Excess quantity (floods)

– Scarce quantity (droughts)

What is vulnerability?

Concept describing factors or constraints of an economic, social, physical or geographic nature, which reduce the ability to prepare for and cope with the impact of hazard

- For e.g., if you know swimming, chances are you less likely to drown in a river compared to someone who doesn't know swimming
- It means you are less vulnerable

Was this confusing?

- Let us continue the previous example of swimming to simplify the terms

– Hazard

- Water (River)

– Vulnerability

- (less if you know swimming)

– Exposure

- to be present close to a river

• So Risk? Hazards (the river) → Risks (consequence: drowning) by exposing pre-existing vulnerabilities (not knowing swimming)

• Disaster Risk - consequence of the interaction between a hazard and the characteristics that make people and places vulnerable and exposed.

But what can we do?

• We can reduce vulnerability by increasing capacity

• Capacity? Learn to swim, build dams/structures to control flow in river

• Resources, means and strengths possessed by persons, communities, societies or countries → enable them to cope with, withstand, prepare for, prevent, mitigate or quickly recover from a disaster

• People in Japan (who are more exposed to Earthquakes) have better capacity (hence less vulnerable) to deal with Earthquakes

When the impending risk is beyond the coping capacity of the system, the consequences are grave. In fact, when the risk exceeds the coping capacity, the event is regarded as a disaster provided there are human, material, economic and environmental losses and impacts.
Thus, to put it mathematically for understanding, a disaster risk will remain a risk if the coping capacity of the system under consideration is substantially high, but, if the coping capacity is not upto the mark, the disaster risk would eventually become a disaster or a massacre.

$$\textit{Disaster Risk} \propto \frac{\textit{Hazard X Vulnerability X Exposure}}{\textit{Coping Capacity}}$$

Understanding of disaster is often left to perception. One may even identify a small event as a disaster like fire in an apartment; such an event may be a disaster for the affected family but on a larger perspective, it cannot be termed as a disaster.

Sendai Framework - “Build Back Better”

THE SENDAI SEVEN CAMPAIGN - 7 Targets, 7 Years (2016-2022)

The United Nations General Assembly has designated 13 October as International Day for Disaster Reduction to promote a global culture of disaster reduction, including disaster prevention, mitigation and preparedness.

The Sendai Framework for Disaster Risk Reduction adopted at the Third UN World Conference on Disaster Risk Reduction in Japan in March 2015.

- 2016 – Target 1: Substantially reduce global disaster mortality by 2030, aiming to lower the average per 100,000 global mortality rate in the decade 2020-2030 compared to the period 2005-2015;
- 2017 – Target 2: Substantially reduce the number of people affected globally by 2030, aiming to lower the average global figure per 100,000 in the decade 2020-2030 compared to the period 2005-2015;
- 2018 – Target 3: Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030;
- 2019 – Target 4: Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030;

- 2020 – Target 5: Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020;
- 2021 – Target 6: Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of the present Framework by 2030;
- 2022 – Target 7: Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030.

7 points need to be remembered

RISK ASSESMENT: FAULT TREE ANALYSIS (FTA)

- FTA is a top down, deductive failure analysis in which an undesired state of a system is analyzed using boolean logic to combine a series of lower-level events.
- Fault tree diagrams (FTD) are logic block diagrams that display the state of a system (top event) in terms of the states of its components (basic events).
- Basic events at the bottom of the fault tree are linked via logic symbols (known as gates) to one or more TOP events.
- These TOP events represent identified hazards or system failure modes for which predicted reliability or availability data is required.
- The pathways interconnect contributory events and conditions, using standard logic symbols (AND, OR etc). The basic constructs in a fault tree diagram are gates and events.

Fault Tree Analysis (FTA)

- AND gate
  - Everything must happen for an successful event

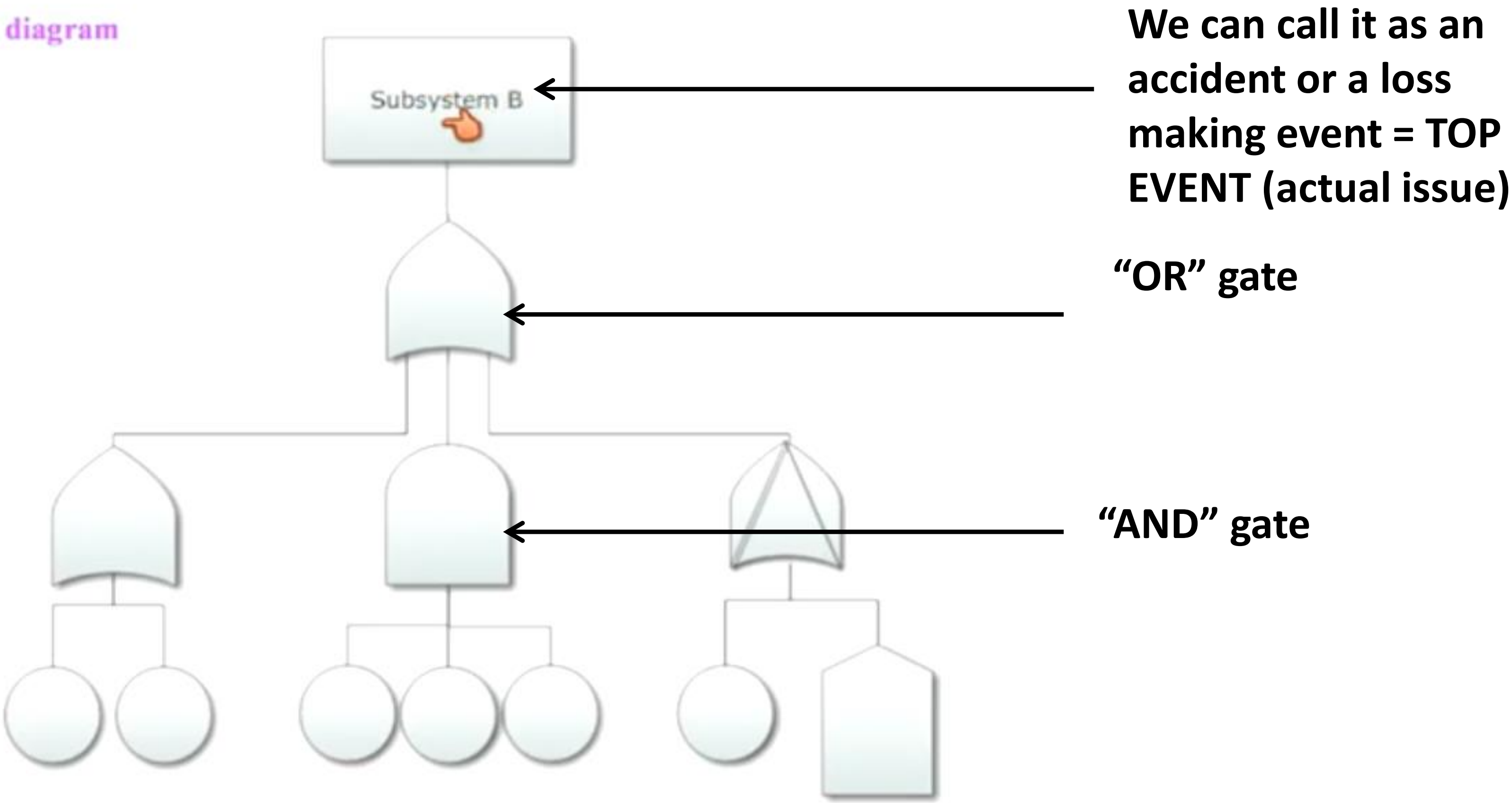
- OR gate
  - Any one input will cause a successful event

- Fault event that has to be evaluated further

- Basic Event at base level with no further development

- Undeveloped event that is inconsequential or does not have sufficient information for further development

FTA – Logic diagram



- In FTA analysis we break the problem down to its roots
- LOGIC GATEs are followed by a couple of intermediate events
- Circular event type represent is the BASIC EVENT .
- The basic event is the root cause that actually led to the problem which has been diagnosed.
- The DIAMOND SHAPE EVENT is called an underdeveloped event - meaning this type of an event would need further examination and further investigation

- ORIGINALLY IT WAS DEVELOPED IN THE BILL LAB in around 60s to help US air force for their missile failures.
- 2 most common logic gates that are used – AND & OR gate

Approach…

- A fault tree diagram is drawn from the top down.
- The starting point is the undesired event.
- You then have to logically work out (and draw) the immediate contributory fault conditions leading to that event.
- These may each in turn be caused by other faults and so on.
- The trickiest part of the whole thing is actually getting the sequence of failure dependencies worked out in the first place

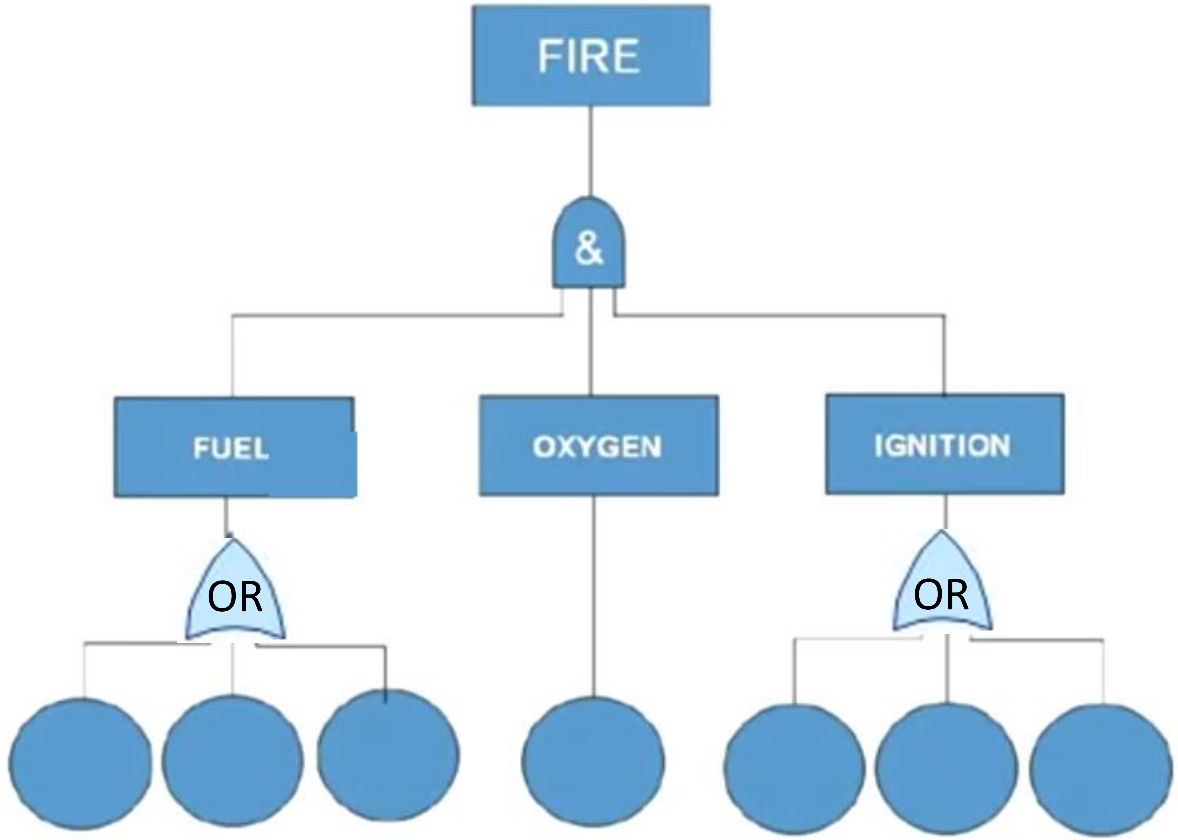
Understanding…

- For "**Fire**" to occur, there needs to be **all of these**
    - (a) Fuel **AND**
    - (b) Oxygen **AND**
    - (c) Ignition

- But **Fuel** can be either of Solid, Liquid **OR** Gases. And also **Ignition** could be done either with a spark, **OR** some other flames, etc.

- Therefore, we use AND gate for "Fire" to occur and OR gate for Fuel and Ignition. Oxygen doesn't have an alternate or combination, so Oxygen will be used As-Is.

Fault Tree for a FIRE



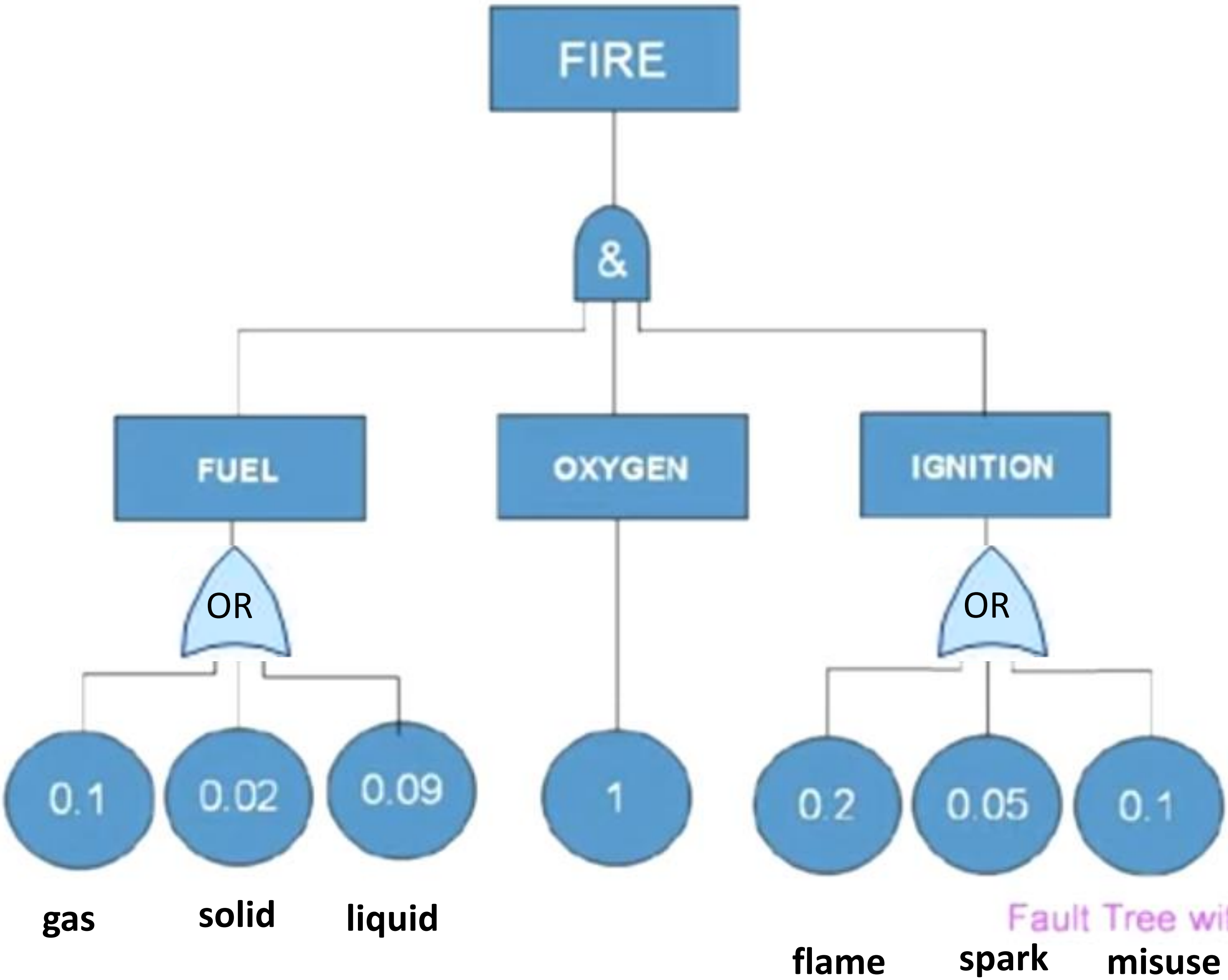
✓ The values are,

For Fuel : Solid – 2%, Liquid – 9% and Gases – 10%,

For Fire : Spark – 5%, misuse – 10%, Flames – 20%,

For Oxygen : atmosphere – 100%

Analysis of FIRE Triangle(contd…)



Fault Tree with values

Analysis of FIRE Triangle(contd…)

We use two well-established rules of combination of these probabilities and progress up the diagram to get at the probability of the top event, "Fire", occurring.

Rule – 1:

• **Add** the probabilities which sit below an **OR gate** (this isn't strictly correct, but is a 'rare event' approximation).

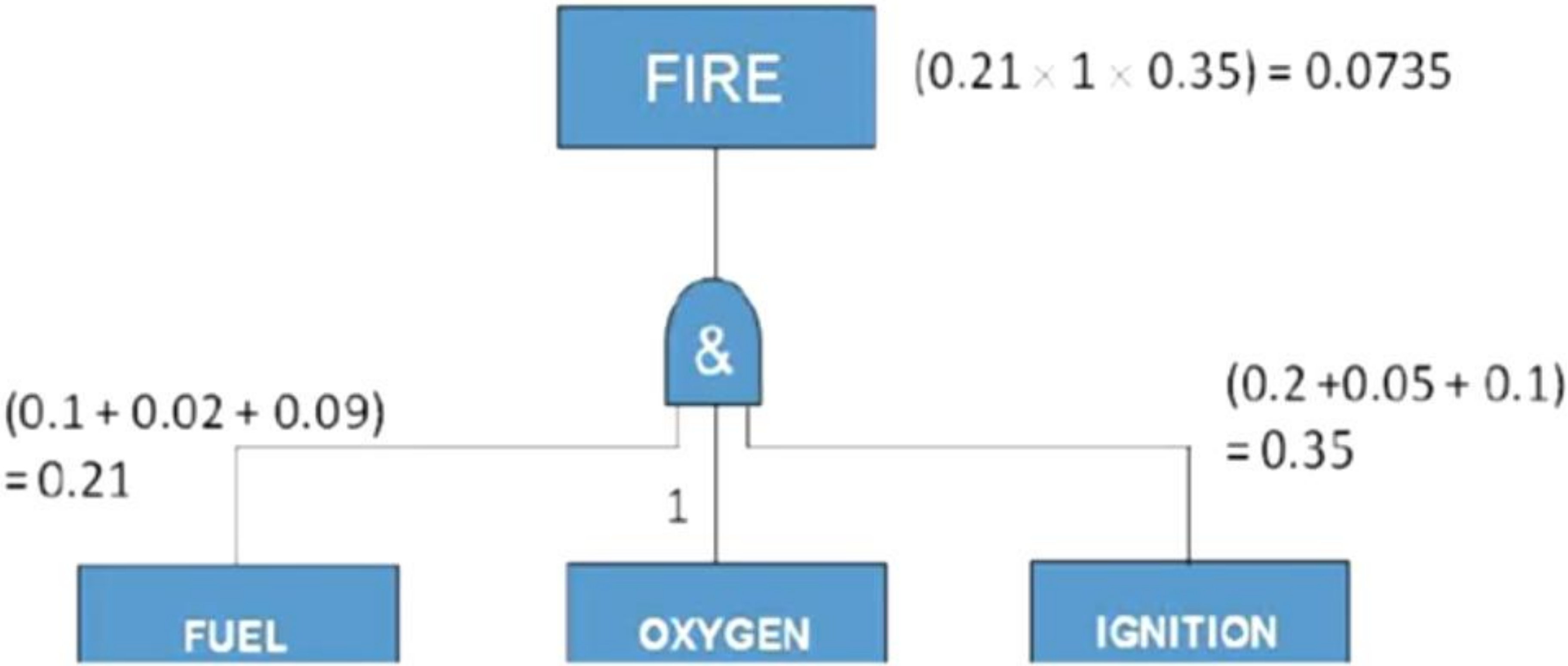
Rule – 2:

• **Multiply** the probabilities which sit below an **AND gate**

So, combining probabilities upwards to the next level gives:

- Probability of FUEL being present = 0.1 + 0.02 + 0.09 = 0.21
- Probability of OXYGEN being present = 1
- Probability of IGNITION being present = 0.2 + 0.05 + 0.1 = 0.35

Updated final Fire Triangle



- ✓ The probability of "Fire" to occur is found to be 7.35%
- ✓ Occurrence of "**Fire**" could be prevented by preventing **any one** among 'Fuel', 'Oxygen' and 'Ignition'. If preventing Oxygen is not advisable, then the other two options can be worked out.
- ✓ To prevent '**Fuel**' we need to prevent **all sources** of fuel.
- ✓ To prevent '**Ignition**', we need to prevent **all sources** of ignition.

Result of Analysis…

- ✓ Occurrence of "Fire" could be prevented by preventing

  (a) '**Fuel**'

  (b) **'Ignition'**

  (…Oxygen cannot be prevented, as it is essential for breathing…)

- ✓ **'Fuel'** and '**Ignition**' can be prevented only by preventing **all sources** that could be reason for a 'Fuel' and 'Ignition'.

Disaster Management Cycle

Disaster Risk Management includes sum total of all activities, programmes and measures which can be taken up before, during and after a disaster with the purpose to avoid a disaster, reduce its impact or recover from its losses. The three key stages of activities that are taken up within disaster risk management are:

1. Before a disaster (pre-disaster).

Activities taken to reduce human and property losses caused by a potential hazard. For example carrying out awareness campaigns, strengthening the existing weak structures, preparation of the disaster management plans at household and community level etc. Such risk reduction measures taken under this stage are termed as *mitigation and preparedness activities.*

2. During a disaster (disaster occurrence).

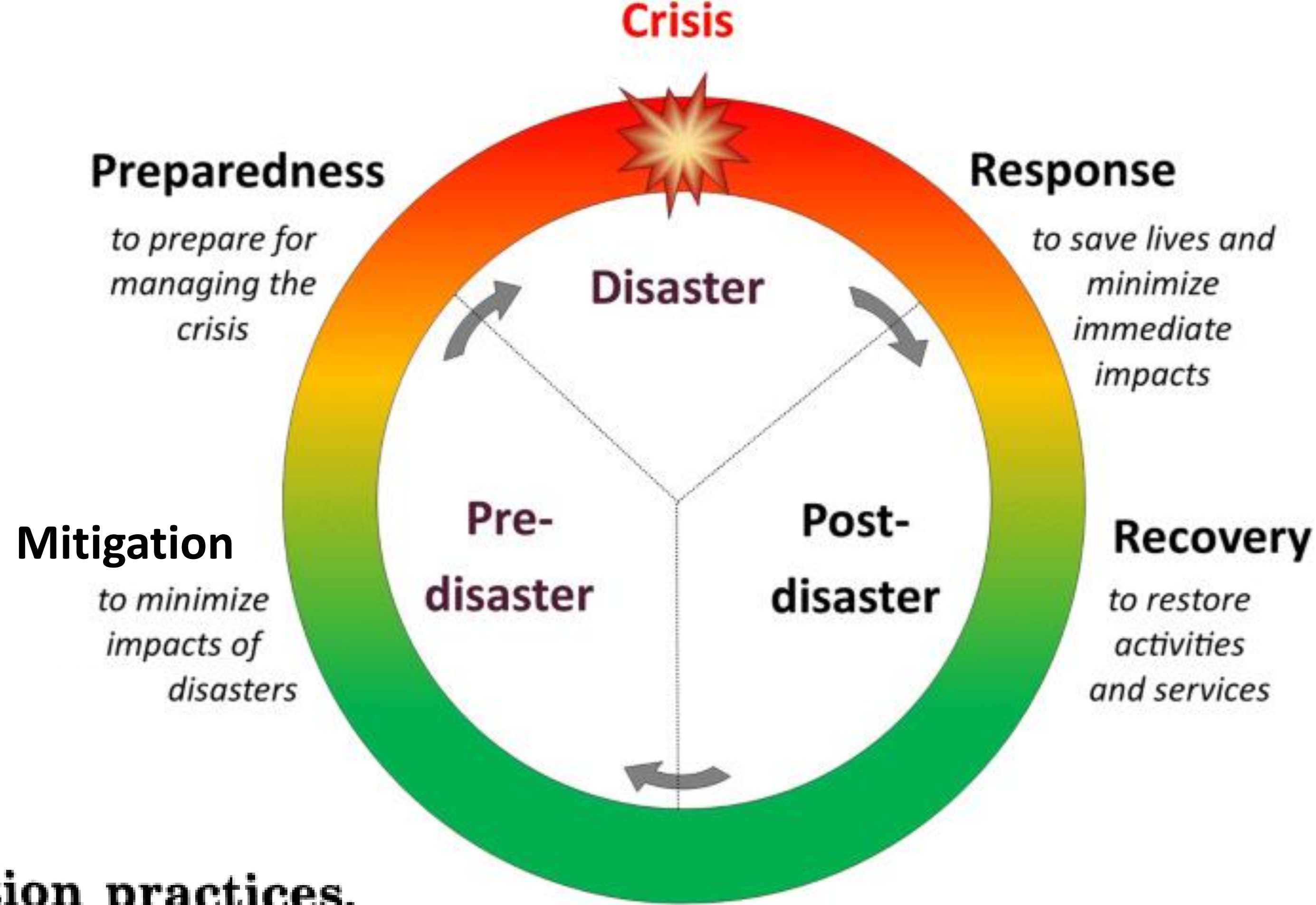
Initiatives taken to ensure that the needs and provisions of victims are met and suffering is minimized. Activities taken under this stage are called *emergency response activities.*

3. After a disaster (post-disaster)

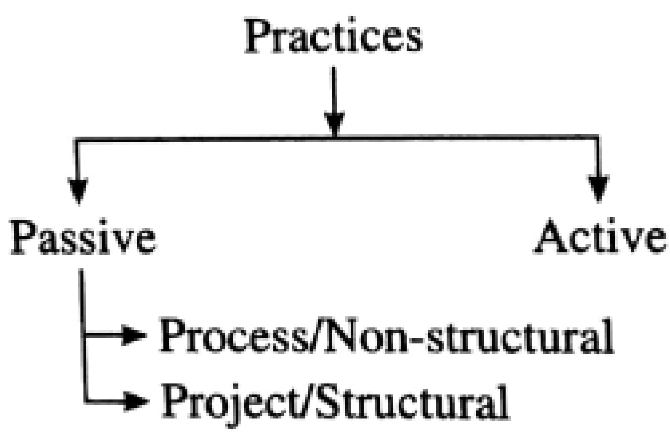
Initiatives taken in response to a disaster with a purpose to achieve early recovery and rehabilitation of affected communities, immediately after a disaster strikes. These are called as *response and recovery activities.*

No need to memorize line by line

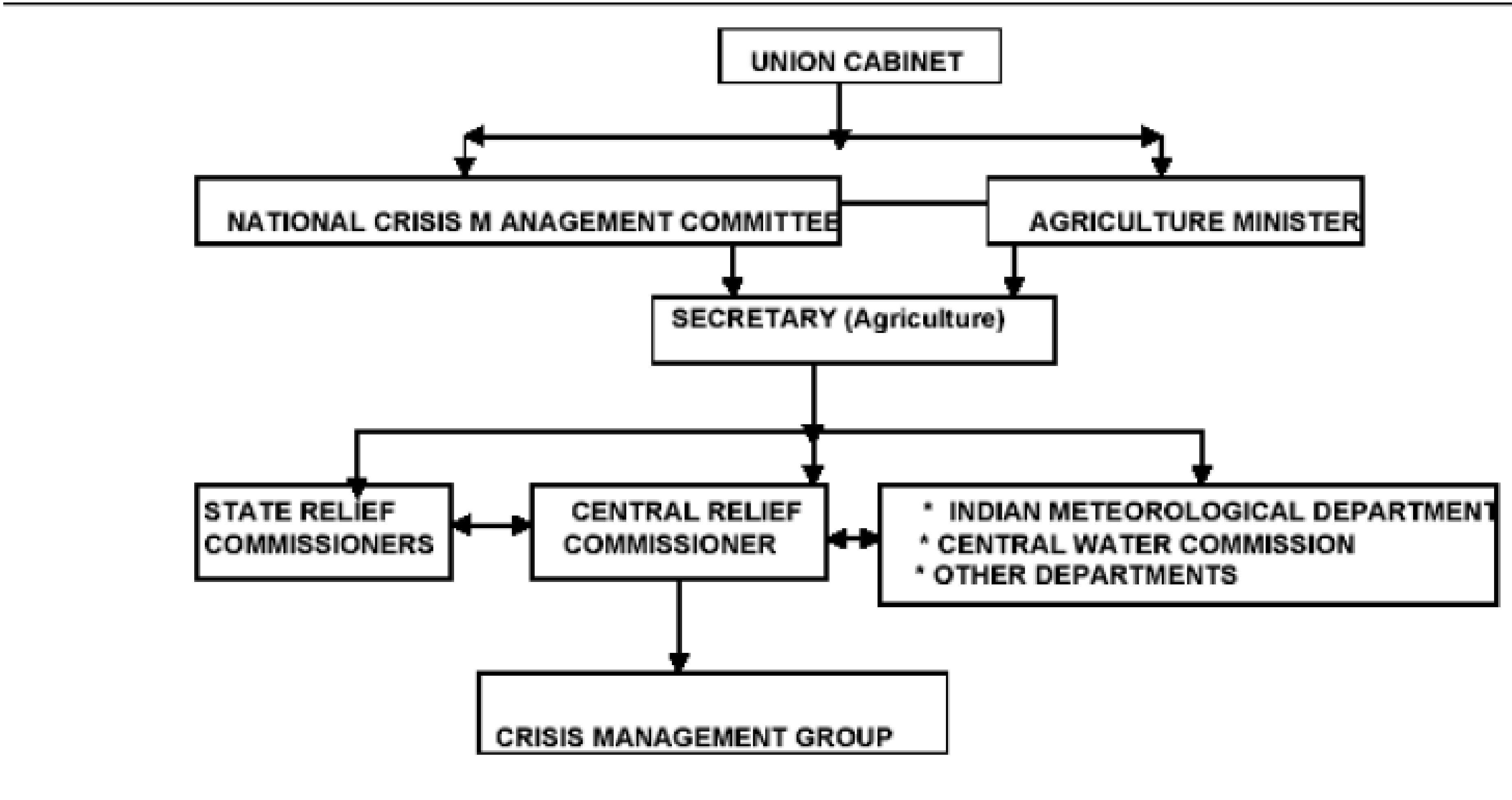
Disaster preparedness	➢ Disaster early warning ➢ Hazard monitoring ➢ Database construction ➢ Logistics preparation for disaster relief
Disaster mitigation	➢ Vulnerability assessment ➢ Hazard assessment ➢ Risk investigation and assessment ➢ Disaster characteristic factor monitoring
Reconstruction and recovery	➢ Disaster loss assessment ➢ Requirement assessment for disaster recovery and reconstruction ➢ Recovery and reconstruction monitoring
disaster	➢ Disaster information quick processing and analysis ➢ Disaster mapping ➢ Scenario simulation ➢ Disaster trend forecasting
Disaster relief	➢ Information integration and analysis ➢ Disaster monitoring ➢ Dynamic disaster loss assessment



Mitigation practices.



National response mechanism



GOVERNMENT OF INDIA : NODAL MINISTRIES / DEPARTMENT FOR DISASTER MANAGEMENT

DISASTERS	NODAL MINISTRIES
Natural Disasters	Agriculture
Air Accidents	Civil Aviation
Civil Strife	Home Affairs
Railway Accidents	Railways
Chemical Disasters	Environment
Biological Disasters	Health & family Welfare
Nuclear Accident	Atomic Energy

NATURAL HAZARDS - CAUSES, DISTRIBUTION PATTERN, CONSEQUENCE, AND MITIGATION MEASURES

VOLCANOES : NATURAL DISASTERS

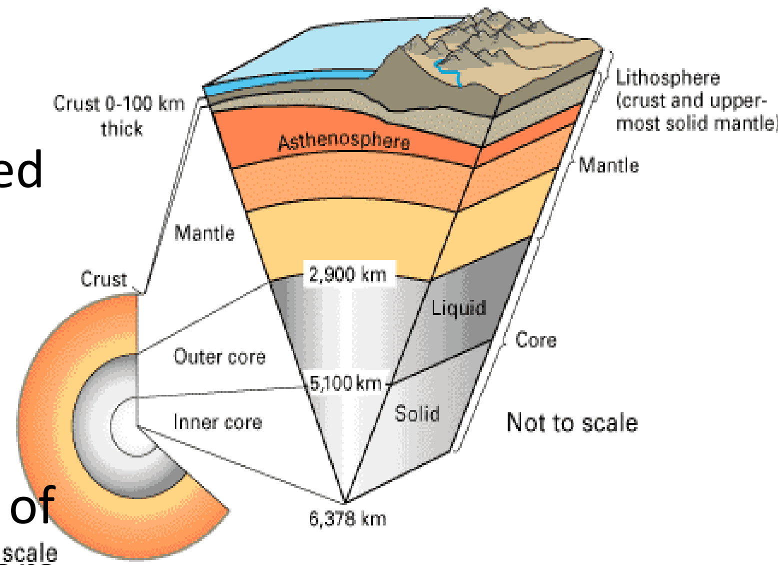
WHAT IS VOLCANIC ERUPTION ?

It is the sudden occurrence of a violent discharge of steam and volcanic material like volcanic bombs, lapilli, ash and lava are expelled violently in the land air and water surfaces

What is a volcano - A mountain built from magmatic eruptions.

The earth has three main layers: the crust, the mantle and the core.

- The crust is made up of solid rock and is found below the oceans as well as across the continents. It varies in thickness – the crust is more than 60km thick under mountain chains like the Alps and Hin oceans.



- The mantle is a thick layer of molten rock (called magma), and the core is made up of an outer liquid layer and a solid centre.
- Temperatures inside the earth are very high – over 5000°C in the core. This means that the planet on which we live is like a huge fiery ball of hot molten rock, surrounded by a few kilometers of relatively cool, hard rock – the crust. Because heat rises, the magma in the earth‘s mantle has to find a way to rise upwards though the crust above it, rather like the way that hot air rises.

Plate tectonics

- Plate tectonics is a discovery that revolutionized the field of geology!
- Plate tectonics is the theory that pieces of the earth's lithosphere, called plates, move about slowly on top of the asthenosphere
- Plate tectonics explain earthquakes and volcanoes

Wegener's Continental Drift

• When looked at in geological time scale, continents very mobile.

• Theory of continental drift proposes that continents were originally all connected, but bro up and are still drifting apart, so will continue to change position.

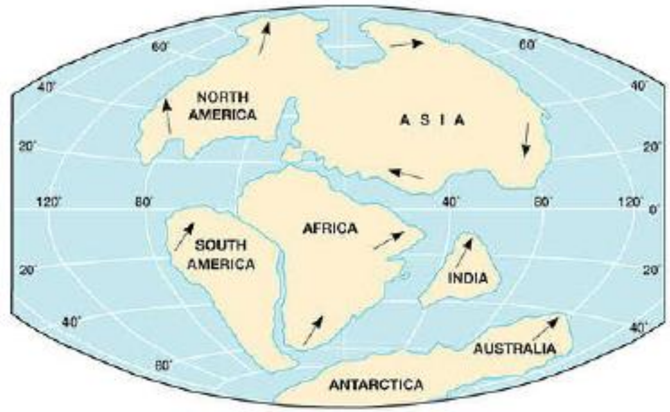
– Pangaea—the massive supercontinent that Alfred Wegener postulated to have existed about 250 million years ago.

• Evidence includes remarkable number of close affinities of geologic features on both sides of Atlantic Ocean.

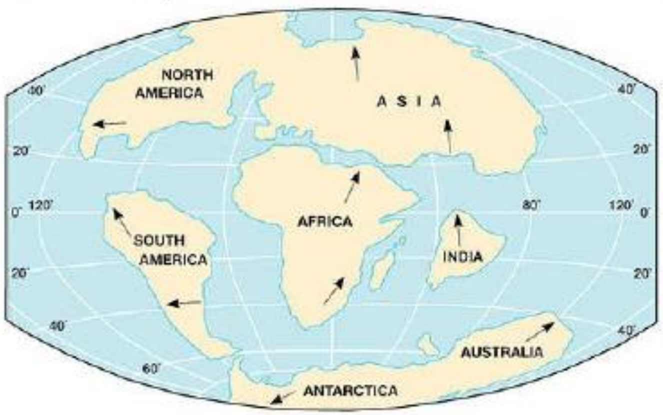
• Continental margins of subequatorial portions of Africa and South America fit together.

These plates lie above the hot, liquid mantle. There are 7 major plates and 10 minor plates. Each plate contains some continental crust (land) and some oceanic crust (sea-bed).

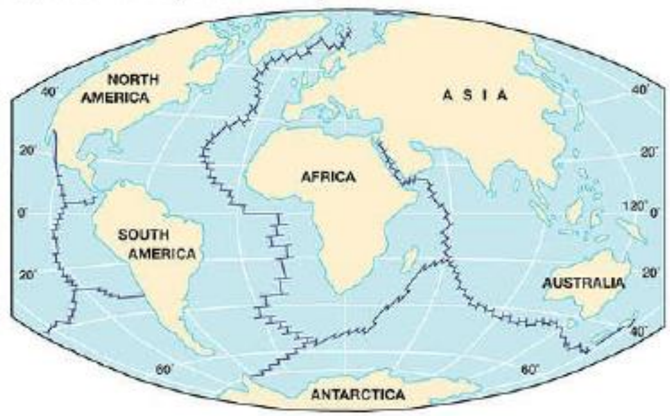
(a) 225 million years before present



(b) 135 million years before present



(c) 65 million years before present



(d) Today

Only for your information

Types of Boundaries

- Divergent ← →
  - Plates move apart / Rifting. Rifting causes seafloor spreading.
  - the movement of two oceanic plates away from each other (at a divergent plate boundary), which results in the formation of new oceanic crust (from magma that comes from within the Earth's mantle) along a mid-ocean ridge.

There are 3 types – continental-continental, oceanic-continental, oceanic-oceanic.

Land features include:

- Mid-Ocean Ridges
  Ex. - Mid-Atlantic Ridge
- Rift Valleys
  Ex. - African Rift Valley
- Earthquakes

Convergent →←

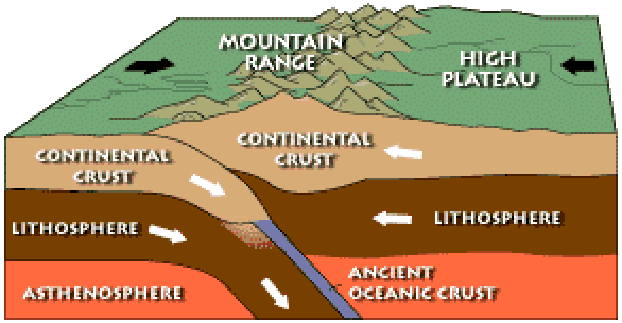
- Plates come together (Colliding / Sub-duction)

Transform ⇄

- Plates slide horizontally past each other –(Sliding)

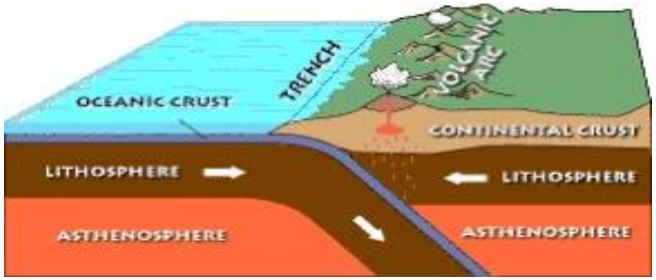
Continental-Continental Convergent

- ❑ When two continents collide.
- ❑ A collision place : where folded and thrust faulted mountains form.
- ❑ Forms mountains and deforms crust (folding and faulting).
- ❑ Metamorphism also a result
- ❑ Example: Himalayas and ancient Appalachians



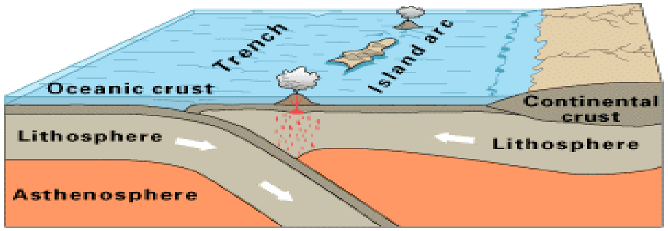
Oceanic-Continental Convergent

- More dense oceanic crust SUBDUCTS under less dense continental crust.
- Called Subduction Zones.
- Forms volcanoes and mountains from melting of overlying continental crust. Also earthquakes.
- Examples: Cascade Mountains in Washington and Andes Mountains in South America.

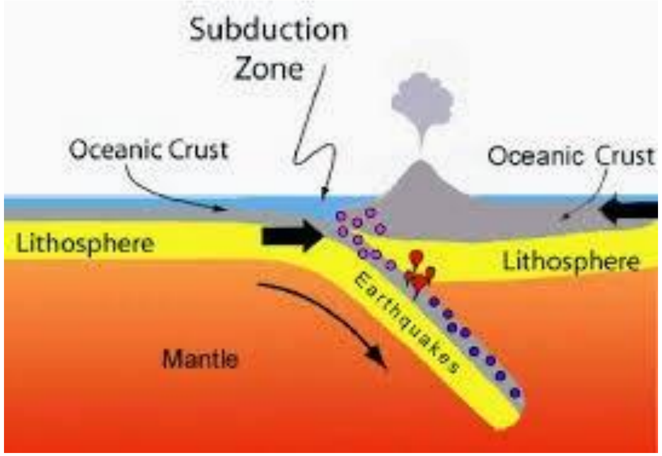


<u>Oceanic-oceanic Convergent</u>

- When older, more dense oceanic crust subducts under younger oceanic crust.
- Results in deep trenches (Marianas Trench) and Island Arcs of Volcanoes (Ex. Japan). Also earthquakes.
- The less dense plate slides under the more dense plate creating a subduction zone called a trench



Oceanic-oceanic convergence



<u>Subduction zone:</u> When a Continental plate overrides Oceanic plate, the Oceanic Plate gets driven down and a Subduction zone forms.

Divergent Boundaries

- Two plates move away from each other.
- Results in volcanoes, rift valleys, mid-ocean ridges.
- Youngest rock at spreading ridge.
- Normally Basalt is erupted to make new oceanic crust.
- Examples are East African Rift and Mid-Atlantic Ridge

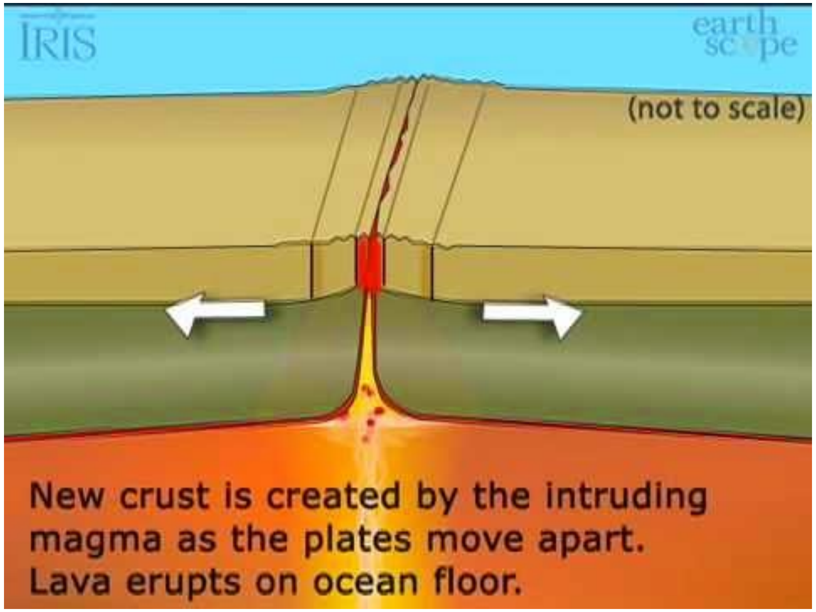
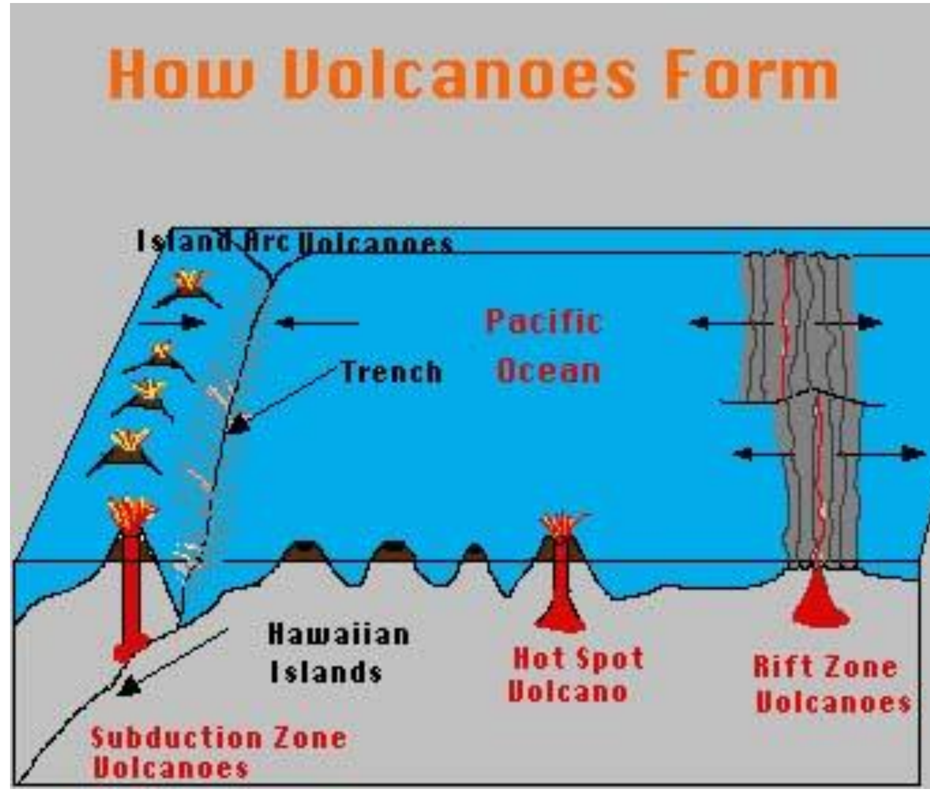


Plate Tectonics & volcanic activity

Where are volcanoes found?
Most volcanoes and earthquakes are found along plate boundaries.

- along mid-ocean ridges/rifts (divergent boundaries)
- at subduction boundaries
- over hot spots

- ❑ SUBDUCTION ZONES FORM WHERE A PLATE WITH THINNER (LESS-BUOYANT) OCEANIC CRUST DESCENDS BENEATH A PLATE WITH THICKER (MORE-BUOYANT) CONTINENTAL CRUST.
- ❑ TWO PARALLEL MOUNTAIN RANGES COMMONLY DEVELOP ABOVE SUCH A SUBDUCTION ZONE – A COASTAL RANGE CONSISTING OF SEDIMENTARY STRATA AND HARD ROCK LIFTED OUT OF THE SEA (ACCRETIONARY WEDGE), AND A VOLCANIC RANGE FARTHER INLAND (VOLCANIC ARC).

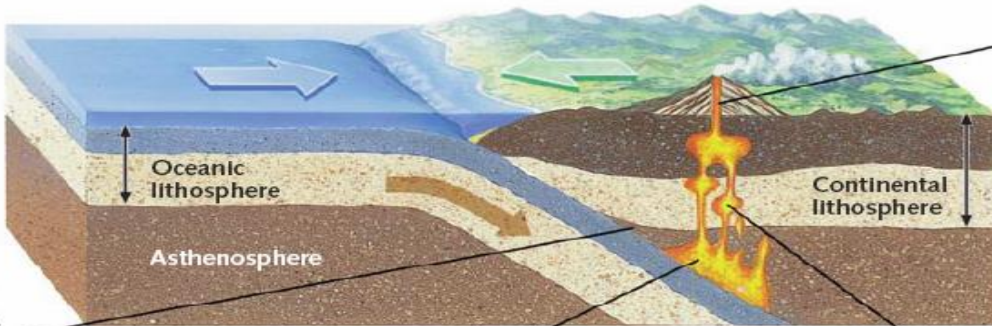


The diagram above shows the three ways that volcanoes form.

- Mid-ocean rift volcanoes form where two oceanic plates are spreading apart. There are more rift zone volcanoes than any other type. along mid-ocean ridges - plates moving apart (diverging)
- Most magma that reaches the Earth's surface is at divergent boundaries along mid-ocean ridges
- Where lithospheric plates diverge at a rift… mantle material rises from deeper, hotter regions. The pressure is lower than the surrounding area, so melting temperatures are lower… causes large amounts of magma to form.
  The magma is less dense than the materials around it, so it rises through the rift to the surface.
- These mid-ocean or rift zone volcanoes are the world's longest continuous mountain chain. This mountain chain encircles the entire Earth. It is more than 40,000 miles long.
- Subduction Zone volcanoes form at the boundaries of two plates, one overriding the other.
- Subduction zone volcanoes are the most violent and destructive of the volcanic types.
- at subduction boundaries - plates moving together & the denser plate is forced under the less dense plate. e.g., Mt. St. Helens, Mt. Pinatubo, Krakatoa, and Mt. Vesuvius
- Oceanic-Continental & Oceanic-Oceanic… Volcanoes always form on the overriding (top) plate
- On continental plate at oceanic-continental convergence, ex. Cascade Mountains (Pacific coast of N. America.
- On the overriding oceanic plate at oceanic-oceanic convergence, ex. Mariana Islands in Pacific
- The seafloor certainly does disappear at subduction zones along the Ring of Fire. Here, the seafloor (and all the oceanic crust beneath it) plunges down under the continents into Earth's mantle, to be recycled.

Volcanic Activity at a Subduction Boundary

BETWEEN AN OCEANIC PLATE AND A CONTINENTAL PLATE



1 Water in the subducted rock is released into the asthenosphere.

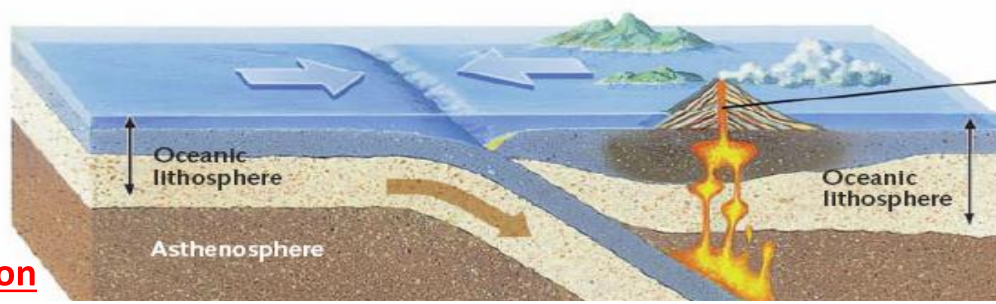
2 The water lowers melting temperatures of materials in the asthenosphere, leading to the formation of magma.

3 The magma is less dense than its surroundings, so it rises.

4 Some of the magma reaches Earth's surface, and volcanoes form on the overriding continental plate.

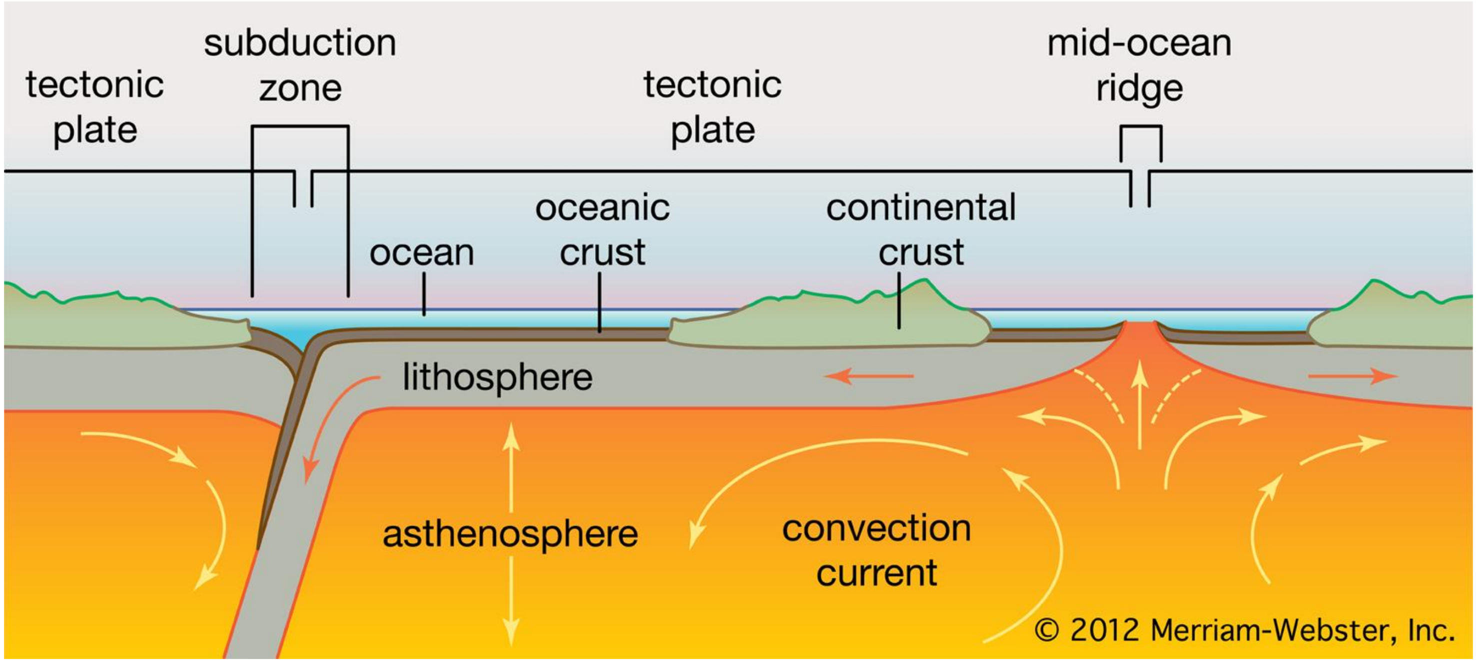
BETWEEN OCEANIC PLATES

The process by which magma forms at an oceanic-oceanic subduction boundary is similar to the process at an oceanic-continental boundary. Notice that the difference between the two processes occurs at step 4.



4 Magma that reaches Earth's surface is underwater. Thus, an arc of volcanic islands forms on the overriding oceanic plate.

Only for your information



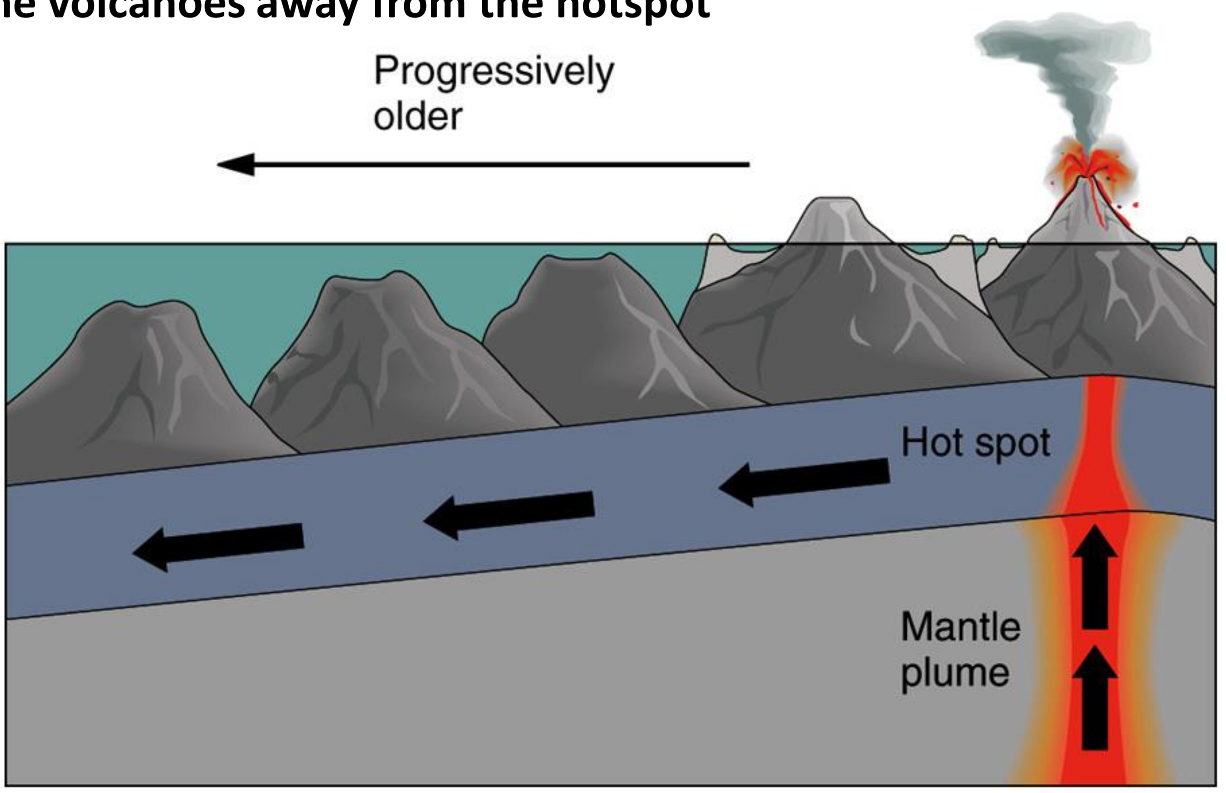
- Two well-studied mid-ocean ridges within the global system are the Mid-Atlantic Ridge and the East Pacific Rise.
- Mid-ocean ridges occur along divergent plate boundaries
- where new ocean floor is created as the Earth's tectonic plates spread apart.
- As the plates separate, molten rock rises to the seafloor,
- producing enormous volcanic eruptions of basalt.
- The speed of spreading affects the shape of a ridge – slower spreading rates result in steep, irregular topography while faster spreading rates produce much wider profiles and more gentle slopes.
- As this hot magma cools in the ocean water, it would expand and push the plates either side of it --- north America to the west and Africa-Eurasia to the east.
- This way, the Atlantic ocean getting wider

- Here is the thing: for all the seafloor and oceanic crust that disappears during subduction into the mantle, an equal amount of new seafloor and oceanic crust is made somewhere else to replace it. The new seafloor is made far away from the Ring of Fire, in the middle of the Pacific Ocean. !
- The same process happens in the middle of the Atlantic ocean, where the ridge is called the 'mid-Atlantic ridge'. the seafloor is destroyed at subduction zones, but it is simultaneously being created at mid-ocean ridges.

3. AT A HOTSPOT

- Over hot spots - an area of volcanic activity that results from a plume of hot solid material that has risen from deep within Earth's mantle. Hot spots are usually found under oceanic crust, but can be located under continental crust. Hot spots are found in the ocean, and on continents.
- There are a number of volcanoes that sit in the middle of plates. These volcanoes have formed above a hot spot - a single plume of hot mantle rising from deep within the Earth. Hot material that arise in the deep mantle and punch through the mobile, convecting, shallow mantle to reach the surface
- An increase in temperature can cause materials to melt. Often the hot spot creates a chain of volcanoes, as a plate moves across a relatively stationary mantle plume.
- The best example of a hot spot volcanic chain is the Hawaiian Islands in the Pacific ocean. From the volcanic track left by the moving plate we can tell the direction of motion of the plate (to the NW) and the rate at which it moves (8.6 cm/year). Currently the hot spot lies beneath the Big Island of Hawaii.
- Hotspot under the Big Island (making it the youngest of the Hawaiian Island) appears to have been there for 70+ million years, but as the plate slowly moves, a new island will be created. Indeed, it is in the process of being created now.

Plate carries the volcanoes away from the hotspot



- The submarine volcano Lo'ihi (meaning long one), lies off the southeast coast of Hawai'i. It is known as submarine volcano as the summit of Lo'ihi is below sea level.
- The islands and seamounts (submarine mountains) exhibit age progression, with the oldest Hawaiian island is Kauai (approx. 5 million years old) of the eight main island near the Aleutian Trench.

- A volcano above a hotspot does not erupt forever. Attached to the tectonic plate below, the volcano moves and is eventually cut off from the hotspot (plate moves overhead relative to the fixed plume source).
- Without any source of heat, the volcano becomes extinct and cools. This cooling causes the rock of the volcano and the tectonic plate to become denser. Over time, the dense rock sinks and erodes.
- A new and active volcano develops over the hotspot creating a continuous cycle of volcanism, forming a volcanic arc that parallels plate motion.
- Mantle plumes appear to be largely unaffected by plate motions. While a plume that feeds hot spot volcanoes remains stationary relative to the mantle, the plate above it usually moves. The result is that a chain of progressively older volcanoes are created on the overlying plate.
- The largest active volcano on earth is Mauna Loa on Hawaii Big Island, with 33 well-documented eruptions in historic times since 1843.
- Other hotspots with time-progressive volcanic chains – e.g., include Réunion (believed to have been active for over 66 million years, produced the Deccan Traps about 66 million years ago), the Chagos-Laccadive Ridge (Lakshadweep is a part of this ridge), the Yellowstone etc.
- Some hotspots are not time-progressive volcanic trails, e.g., Iceland, the Galapagos etc.

Earth's tectonic plates are made of: The crust and uppermost mantle.
Iceland is a volcanic hotspot, because

- Iceland formed by the coincidence of the spreading boundary of the North American tectonic plate and Eurasian tectonic plate
- and a hotspot or mantle plume (an upsurge of abnormally hot rock in the Earth´s mantle). As the plates moved apart, excessive eruptions of lava constructed volcanoes and filled rift valleys.

- Hotspot volcanoes do not grow very large, because, the lithosphere moves while the hotspot stays in one place.
- Hotspots are found within continents, but not as commonly as within oceans. They are not common because it takes a massive mantle plume to penetrate the thick continental crust.

Q. What are the top 2 compositions of Magna?
Oxygen, the most abundant element in magma, comprises a little less than half the total, followed by silicon at just over one-quarter. The remaining elements make up the other one-quarter. Magmas derived from crustal material are dominated by oxygen, silicon, aluminum, sodium, and potassium.

What is the composition of magma and how is it formed?
Magma is a molten and semi-molten rock mixture found under the surface of the Earth. This mixture is usually made up of four parts: a hot liquid base, called the melt; minerals crystallized by the melt; solid rocks incorporated into the melt from the surrounding confines; and dissolved gases

Eruption mechanisms - How a Volcano Erupts

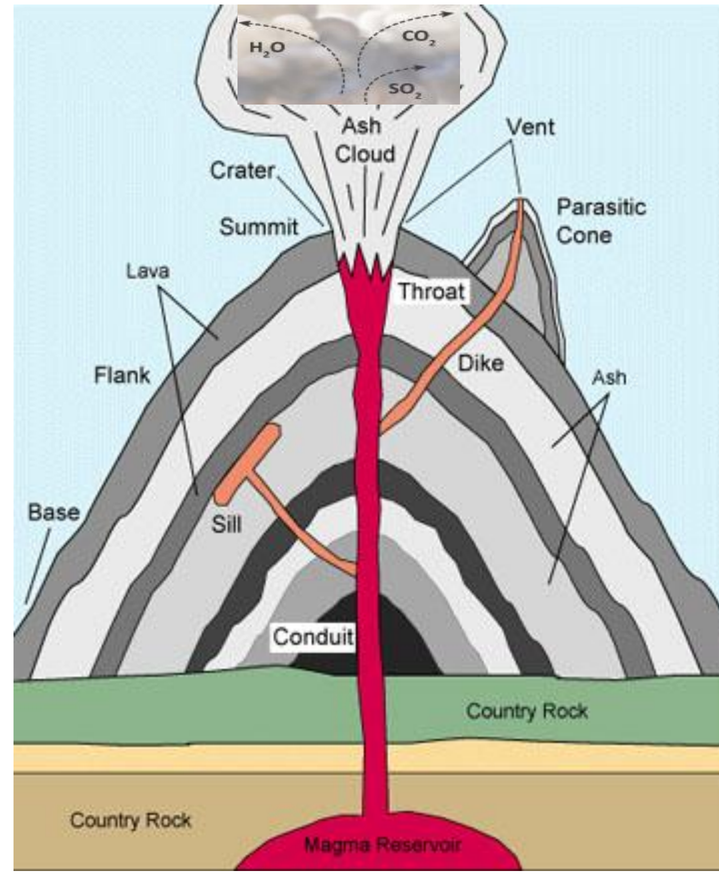
Volcanos can be either creators or destroyers. They can be mountains or hills, with a crater or vent where lava, molten rock, hot vapor, and gas erupt from within the earth.

Volcanoes are driven by pressure and heat in the mantle, as well as tectonic activity that leads to volcanic eruptions.

Beneath the Earth's crust, in the mantle region (solid body of rock), when rock from the mantle melts, moves to the surface through the crust, and releases pent-up gases, volcanoes erupt. Extremely high temperature and pressure cause the rock to melt and become liquid rock. Pressures increase considerably and temperatures can reach up to 1000 °C, which makes the rock viscous enough that it behaves like a liquid rock or magma. When it's beneath the surface, the molten rock is called magma. It experiences elastically on time scales of thousands of years or greater. This viscous, molten rock collects into vast chambers beneath the Earth's crust.

Since this magma is less dense than the surrounding rock, it " floats" up to the surface, seeking out cracks and weaknesses in the mantle. When a large body of magma has formed, it rises through the denser rock layers toward Earth's surface. Magma that has reached the surface is called lava.
When it finally reaches the surface, it explodes from the summit of a volcano, it erupts as lava, ash and volcanic rocks. With each eruption, rocks, lava and ash build up around the volcanic vent.

Inside volcanoes, magma often has dissolved gases as a function of the very high pressures and chemistry of the magma. Much in the same way you open a carbonated drink – when you take the lid off, the bubbles burst out – when magma erupts as lava, the pressure is relieved and the gases exsolve. In explosive eruptions, this phenomena is so strong that it fragments the lava, violently ejecting it, along with anything caught along.



In the case of the convergent boundaries (oceanic-oceanic/oceanic-continental), subduction zones are often the result, where the heavier plate slips under the lighter plate – forming a deep trench. This subduction changes the dense mantle into buoyant magma, which rises through the crust to the Earth's surface. Over millions of years, this rising magma creates a series of active volcanoes known as a volcanic arc.

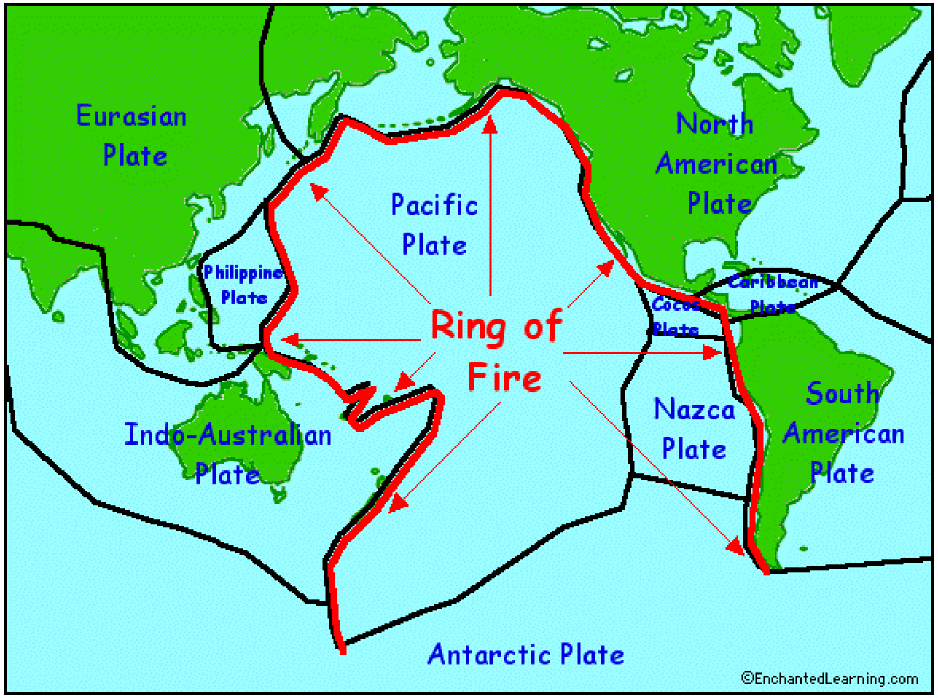
The Pacific 'Ring of Fire'

– Plate boundaries are found all around the Pacific basin—primarily subduction zones.

– Along these plate boundaries many volcanoes have formed giving this region the name the Pacific Ring of Fire

– More than half of all the world's volcanoes are found in the Pacific "Ring of Fire". This area forms a circle stretching down the eastern side of the Pacific Ocean, from Alaska in the north, through the Rocky Mountains of Canada and the USA, to the Andes mountains of South America. It loops back around the western side of the Pacific, up through New Zealand, Indonesia and Japan.

– e.g. include, Cotopaxi in Ecuador, which last erupted in 1928; Mt. St Helens in the USA, which erupted in 1980; and Krakatoa in Indonesia, erupted in 1883.



Magma Chemistry and Styles of Eruption - Eruption products take 3 forms

– Chemistry of magma largely determines nature of eruption.

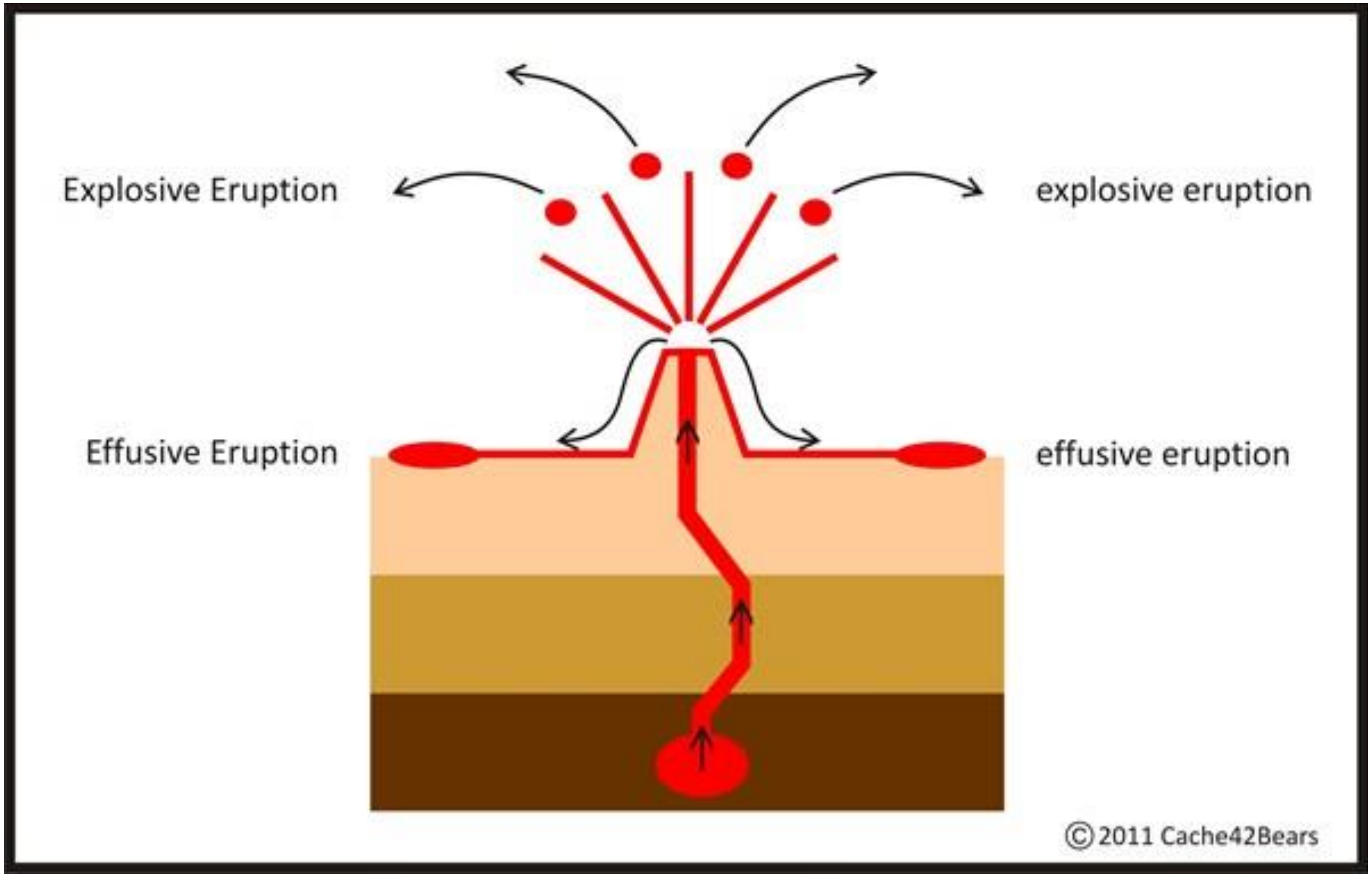
– Critical component appears to be relative amount of silica (SiO_2).

- Silica is the main ingredient in magma because, most rock forming-minerals are silicates
- Greater amounts of silica = High viscosity/resist flow (thick, gooey… syrupy)

  Type of eruption = explosive (because thick magma can clog a volcanic pipe, causing enormous pressure to build up. When the volcano finally explodes, lava and hot gasses are hurled outward.
- Lower amounts of silica = low viscosity/flow easily (thin, runny…. Like water)

  Type of eruption = gentle, flowing (“flood-like”, “fountain-like”).

	Basic (Basaltic) magma	Andesitic Magma	**Acid (rhyolitic/silicic) magma**
Silica content	Least (about 50%)	Intermediate (about 60%)	Most (about 70%)
Gas content	Least	Intermediate	Most
Viscosity	Least viscous	Intermediate	Most viscous
Type of eruption	Rarely explosive	Sometimes explosive	Usually explosive
Melting temperature	Highest	Intermediate	Lowest
Location	Rifts, oceanic hot spots	Subduction boundaries	Continental hot spots
	▪ **spread over a great distance** ▪ **Shield volcanoes, eg - Hawaii**	**Composite volcanoes**	▪ **eg - Yellowstone**



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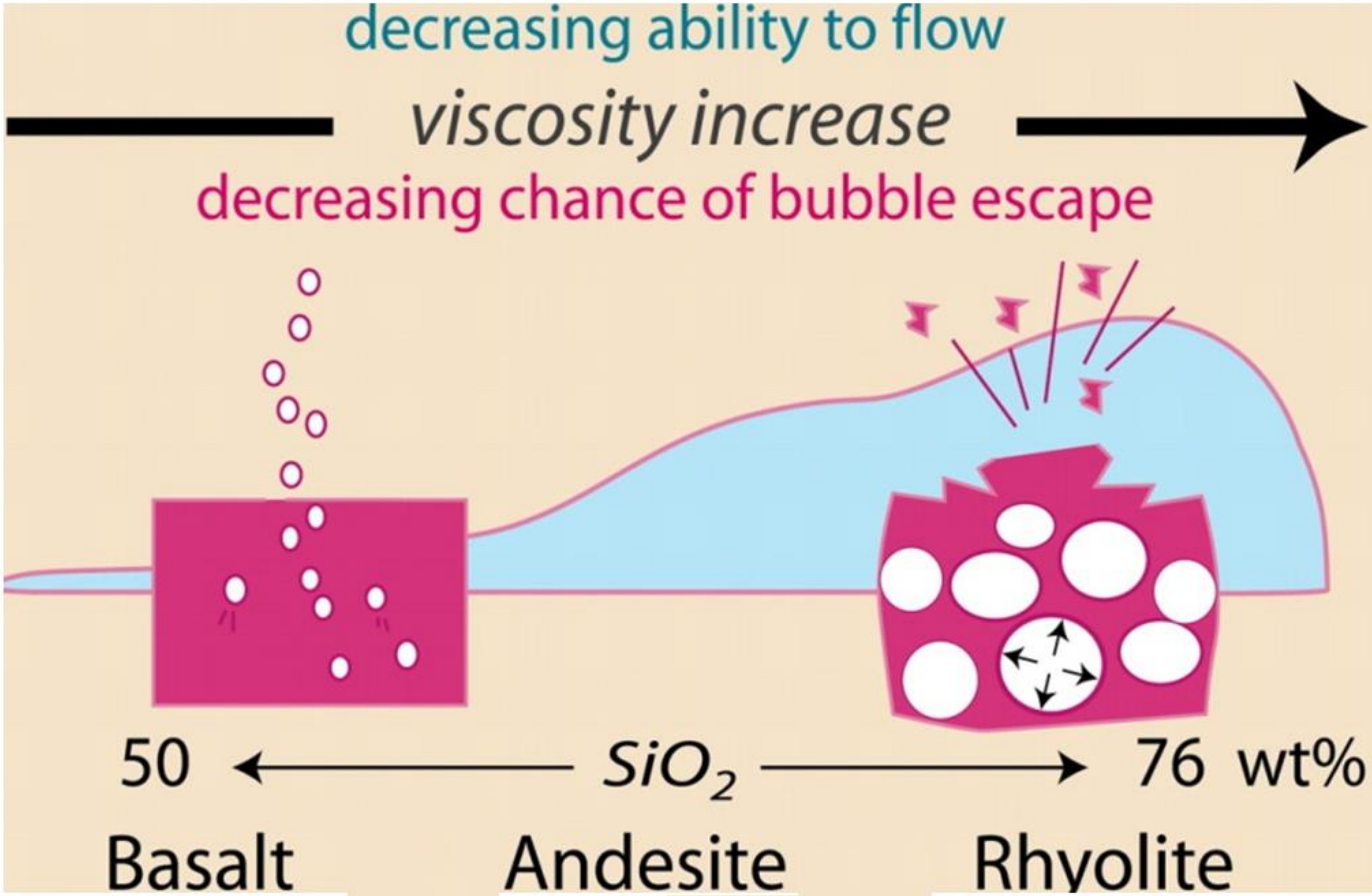


Long distance flow
(up to 100s km)

They mound near
vent, flow slowly

Rhyolitic lava rarely flows,
Plugs vent as a lava dome

Only for your understanding

Volcanic Material

- Pyroclastic materials - rock fragments, dust, ash & gases that are ejected from a volcano.
- Volcanic gases – vapor and aerosols that exit a volcano
- What is a pyroclastic flow?
  - when pyroclastic materials combine with hot gases - dense, superheated cloud → travels rapidly downhill

Explosive eruptions usually involve magmas which contain trapped gases - when gases are released, solid pyroclastic material may be ejected

- Classified by size
- Smallest → ash
- Intermediate → lapilli
- Largest → blocks & bombs

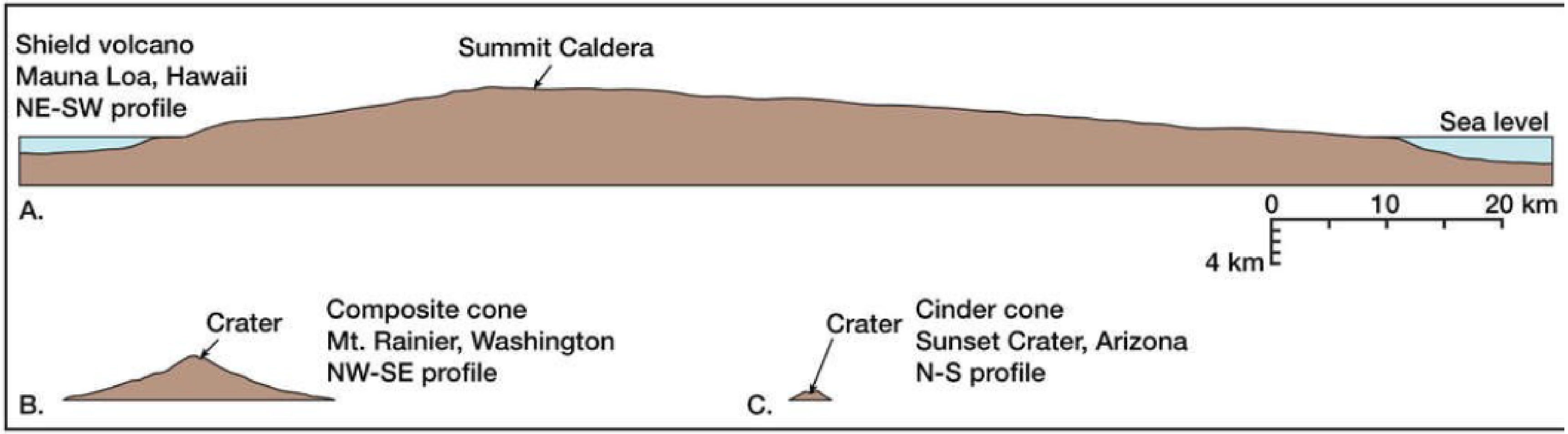
Volcanic Blocks
- Largest pyroclastic material, can be as big as a house!

- Volcanoes erupt explosively (Mt. St. Helens) or quietly (effusive eruption, e.g., Hawai'i), depending on the characteristics of the magma.
- Effusive eruptions, meanwhile, are characterized by the outpouring of lava without significant explosive eruption.
- Magma varies in viscosity (thickness) based on temperature, water content and silica content

Volcanic Gas

1-10% of magma may be gas.
Water (H2O)- most abundant gas
Carbon dioxide (CO2)- second most abundant
Sulfur dioxide (SO2)- rotten egg smell
Magma composition controls gas content.
Felsic (rholytic) magmas are gas-rich;

- Volcanoes come in many shapes and sizes, ranging from common cinder cone volcanoes that build up from repeated eruptions and lava domes that pile up over volcanic vents to broad shield volcanoes and composite volcanoes.
- The nature of the eruption depends on the viscosity of the magma.
- When the lava flows easily, it can travel far and create wide shield volcanoes.
- When the lava is very thick, it creates a more familiar cone volcano shape (aka. a cinder cone volcano)



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1. shield volcanoes- largest
2. cinder cones- smallest
3. stratovolcanoes- intermediate

- A volcano is active if it erupts lava, releases gas or shows seismic activity.
- It is dormant if it hasn't erupted for a long time but could again one day. Mt. St. Helens had been dormant for one hundred twenty-three years before it erupted in 1980
- An extinct volcano will never erupt again.

Active volcanoes— those that have erupted at least once in recorded history.
– U.S. has 10% of about 550 active volcanoes in world.
– Pacific Ring of Fire or Andesite Line has some 80% of world's volcanoes.

- Mount Vesuvius is an active volcano in Italy, It is the only volcano on the European mainland to have erupted in the last 100 years. It is not currently erupting. It is dormant, not extinct

Volcanic Architecture

- Volcanoes have characteristic features:
- A magma chamber - is usually located far beneath the surface of the Earth
- Vents - opening in earth's surface where magma flows through
- Fissures - linear crack which lava flows out
- Craters - A crater is a funnel-shaped pit at the top of the volcanic vent. This is where the lava, ash and rock erupt out of a volcano. Craters are usually much smaller than calderas, only extending to a maximum of one kilometer in diameter.
- Calderas - A caldera is a depression created after a volcano releases - gigantic empty chamber underground. Without any structural support below, the land around the erupting volcanic vent (s) collapses inwardly into the empty magma chamber. Volcanic eruptions can create calderas as much as 100 kilometers wide. E.g., Yellowstone National Park is mostly a giant caldera.

It's a caldera.

a small lake at the center of the crater.

Magma type governs volcano shape & size.

Types of volcanoes : size & shape

Volcanic Peaks often starts small, can grow into hill or mountain. Most have crater set at apex of cone.

- Shield Volcanoes—never steep-sided, though can be very high (e.g., Hawaiian Islands).

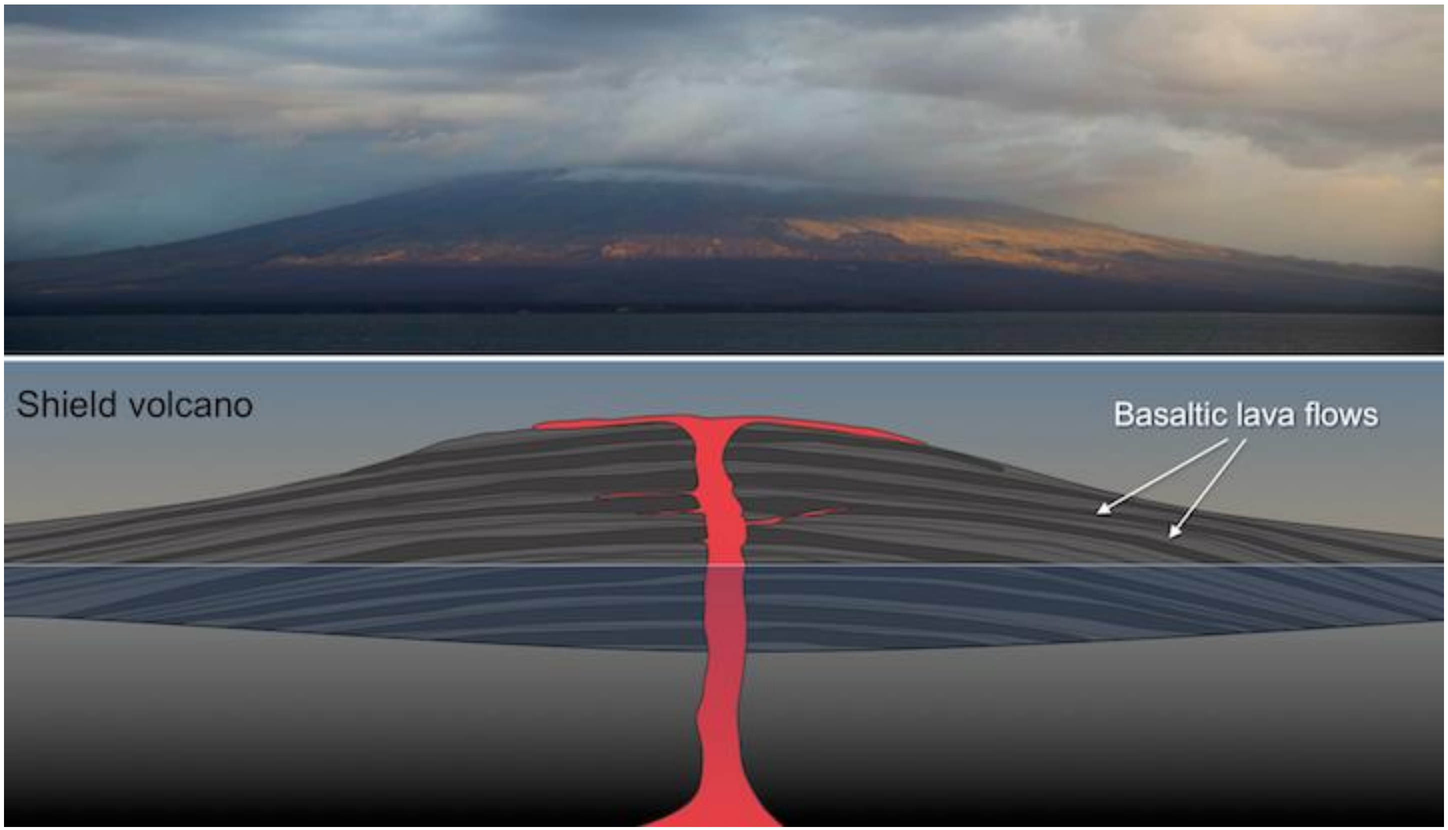
The eruption from a shield volcano is relatively nonviolent because the lavas are fairly fluid (less viscous). The slope of a shield volcano is less than 10°. quiet eruptions where lava slowly flows out.

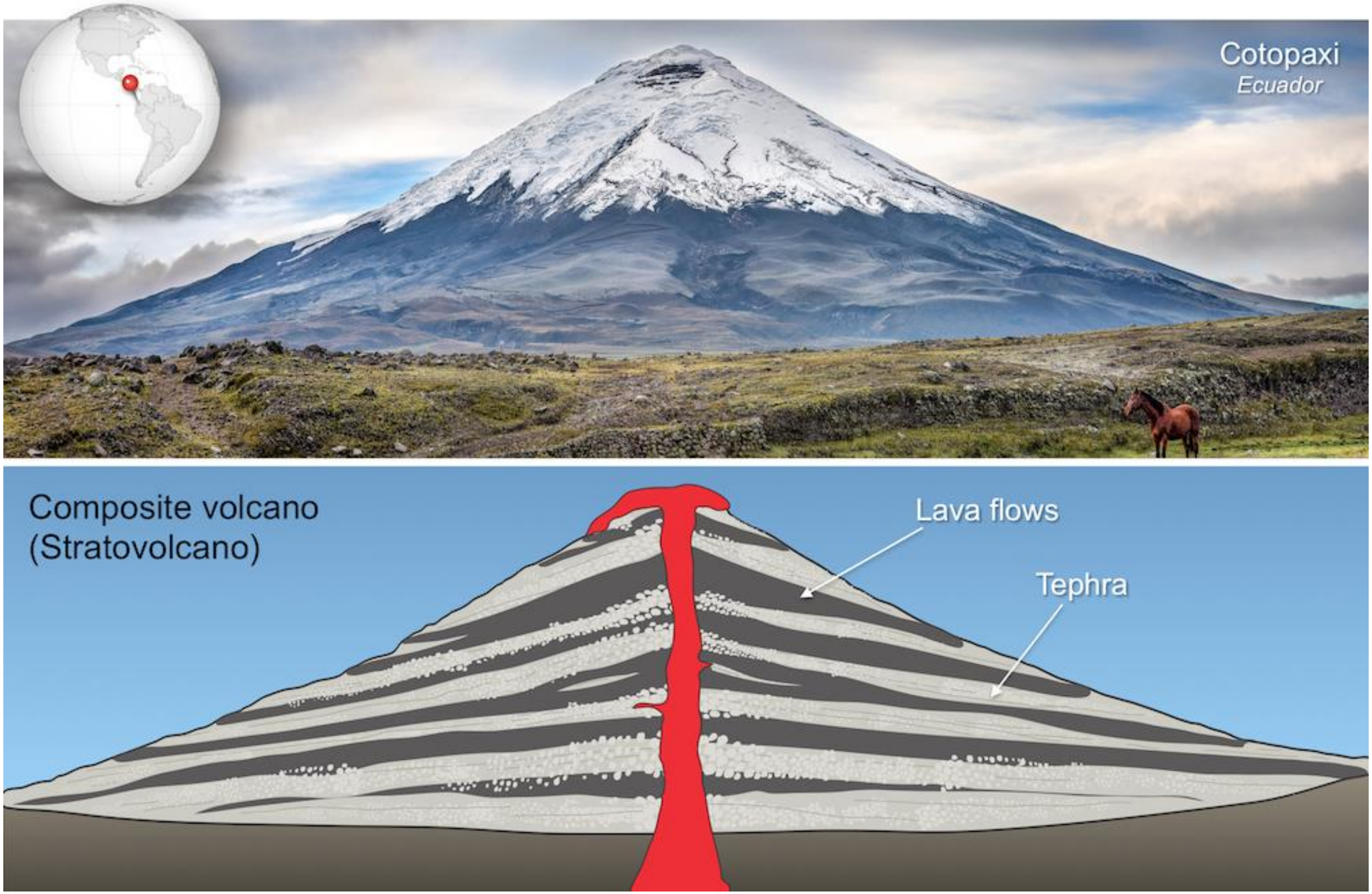
- Composite Volcanoes—steep-sided, large, symmetrical cones (e.g., Mt. Fuji, Japan, Mt. St. Helen, Mt Vesuvius, Mt. Pinatubo).
- Composite volcanoes (aka Stratovolcanoes) are constructed of alternating layers of pyroclastics and rock solidified from lava flow with slopes between those of cinder cones and shield volcanoes.
- Cinder Cones—smallest of volcanic mountains (e.g., Sunset Crater in Arizona).
- Cinder cones are constructed of loose rock fragments ejected from a central vent. Most of the ejecta lands near the vent to form a cone with a slope of up to 30°.
- Highly erodible slopes (loose pyroclasts) and found in association with other volcanoes

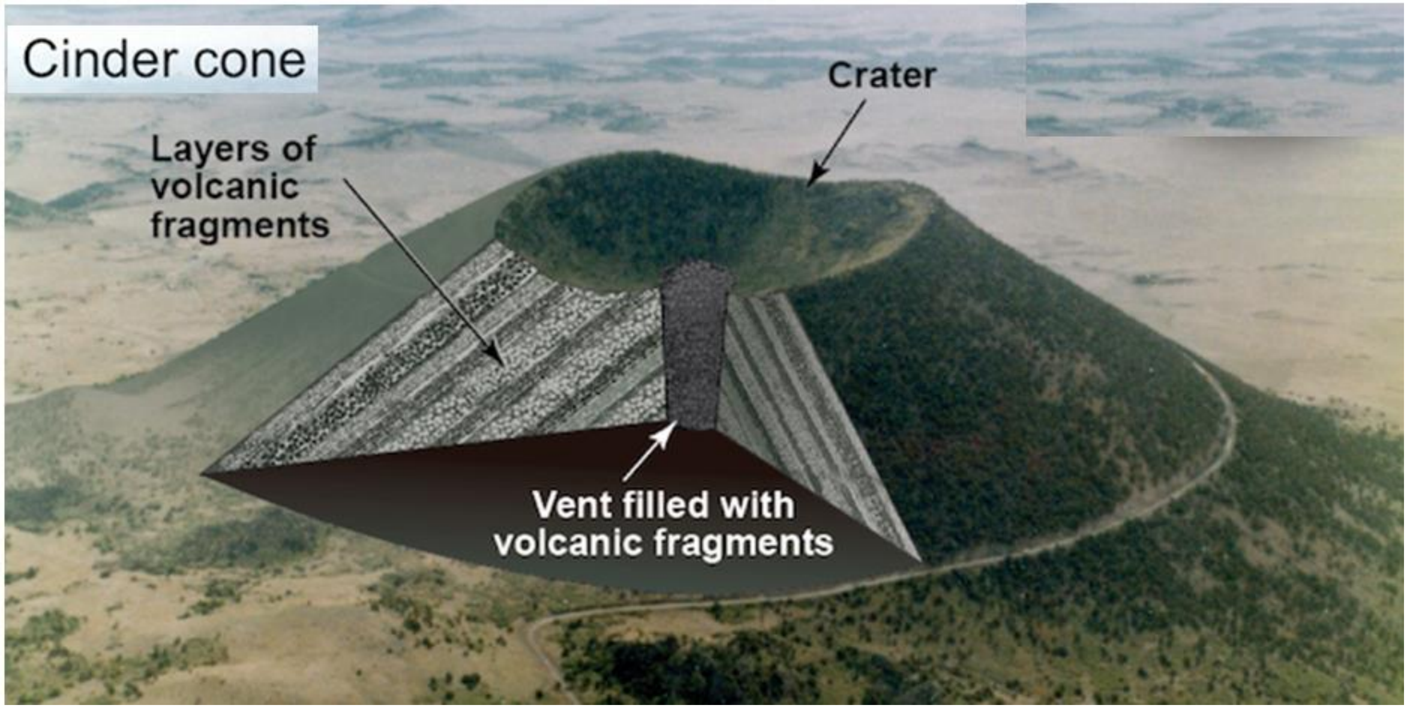
Pyroclastic Flows

– Pyroclastic flows —terrifying high-speed avalanche of searing hot gases, ash, and rock fragments

• Volcanic Mudflows (Lahars) —fast moving, and sometimes hot, slurry of mud and boulders; one of most common volcanic hazards.


Shield volcano
Basaltic lava flows


Cotopaxi
Ecuador
Composite volcano
(Stratovolcano)
Lava flows
Tephra


Cinder cone
Crater
Layers of
volcanic
fragments
Vent filled with
volcanic fragments

Volcanoes in history

- Dinosaurs went extinct about 65 million years ago during 5th Mass extinction at the end of Cretaceous Period. Some group of Scientists think that Deccan volcanic traps are more likely the culprit for the Cretaceous extinction. Gases erupted from the volcanoes blocked sunlight for years – plants died and death cascaded through out the food-chain. Long lasting cooling and lack of food led to the death of the dinosaurs.
- A.D. 79: One of the most famous volcanoes is Mount Vesuvius, which sits along the Bay of Naples in southern Italy. The A.D. 79 eruption, which buried Pompeii, made Vesuvius famous
- 1815: Eruption of Mount Tambora, in Indonesia - The volcano sent a cloud ejecta into the atmosphere leading to the "Year Without a Summer" of 1816 in Europe and North America. All vegetation on Sumbawa was destroyed. Later on, ash flows, tsunamis, and starvation led to the deaths of thousands of people. The world got colder, and the weather systems changed completely for three years. And so there was widespread crop failure and starvation all from Asia to the United States to Europe."
- 1883: Another Indonesian volcano, Krakatoa.
- 1980: Mount St. Helens in Washington state.
- 1991: After 600 years of dormancy, Mount Pinatubo in the Philippines rumbled for days before erupting and killing many people. This dust cloud temporarily lowered the global temperature as we were talking about almost like in 1 degree and then Mount Pinatubo eruption was the 2nd largest in 20th century.

Predicting Volcanoes

- Predicting exactly when a volcano will erupt is next to impossible.
- Scientists can not stop a volcano from erupting but with constant monitoring they can warn and evacuate people and save lives.
- Today geologists are becoming much more accurate in making the public aware that a volcano is showing signs that it may erupt in the near future.
- Seismographs : In the months before Mt. St. Helens erupted geologists knew the mountain was getting restless. A magnitude 4.1 earthquake was recorded about 2 months before the large eruption. Many shallow earthquakes were recorded over the next seven weeks.
- Magma moving higher and higher inside the mountain was causing these earthquakes. As the magma rose it formed a large bulge. This bulge was growing daily and the geologists knew that an eruption was soon to be.
- What the authorities did was evacuate most of the people in and near the mountain. Some decided to stay.

- Geologists study a tilt meter. A tilt meter is used to measure the growth of the lavadome in the foreground. The tiltmeter will show a different angle as the dome grows. With careful study the geologists can tell if magma is on the rise and that an eruption may occur in the near future.
- Because of technological advances, we're able to more accurately predict when volcanic eruptions will occur in time for evacuations and safety measures, like when flights are canceled in anticipation of eruptions.

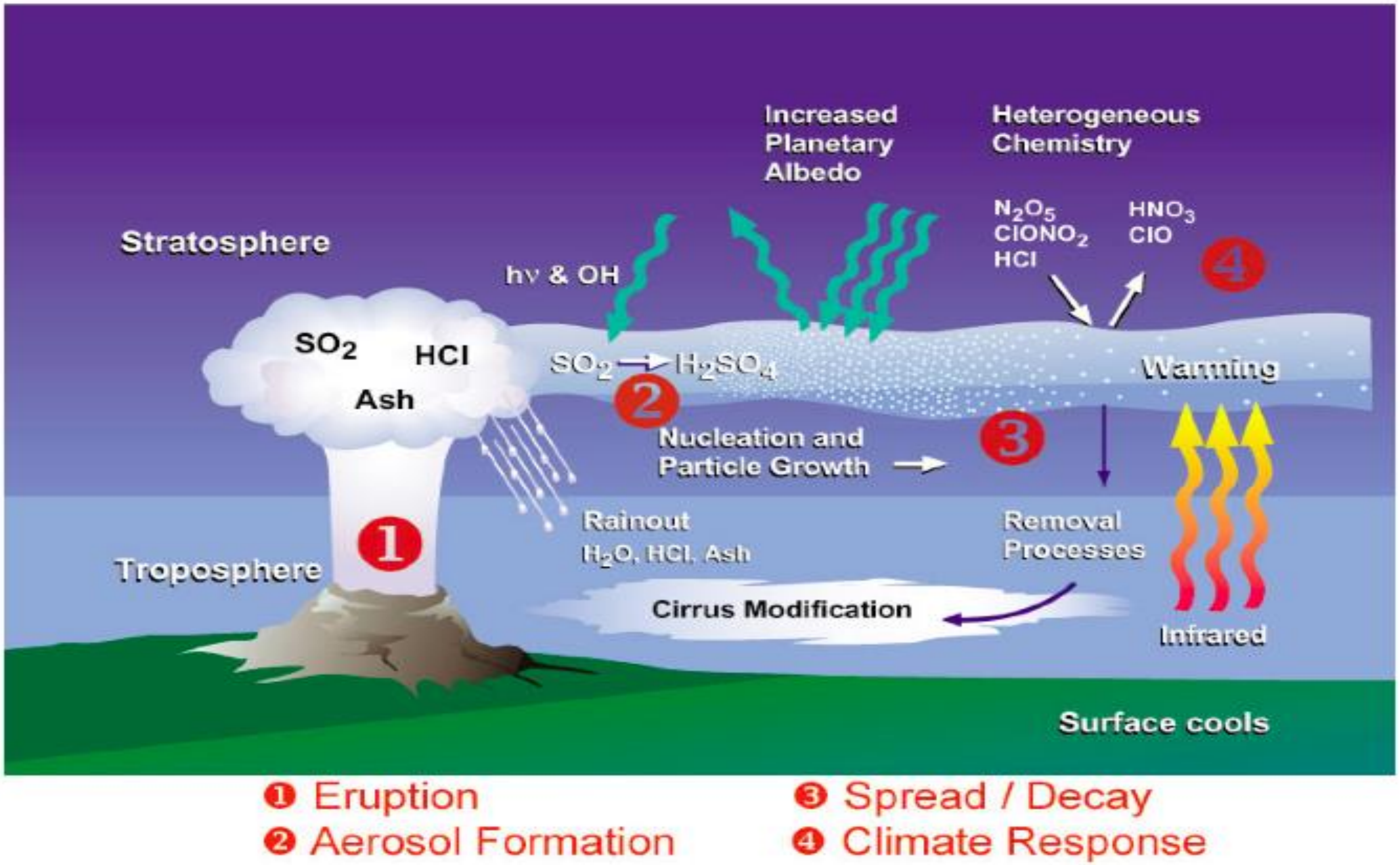
Only for your understanding

Effects of Volcanic eruptions

Volcanic eruptions can cause loss of life and livelihoods in exposed communities, damage critical infrastructure, displace populations, disrupt business and add stress to already fragile environments. Currently, an estimated 800 million people live within 100 km of a volcano that has the potential to erupt.

Volcanic eruptions are almost always preceded by ‘unrest’ including volcanic earthquakes and ground movements which can in themselves be hazardous. Volcanic earthquakes are typically small in magnitude (≤M5) and relatively shallow, but they may be felt and may cause structural damage.

- Volcanoes near the equator can cause global weather changes if their eruptions are powerful enough to release gases into the stratosphere.
- In the 1991 eruption of Pinatubo about many people died from roof collapse during the eruption.
- Volcanic ashes can often contain minerals that are beneficial to plants and is readily released on contact with water or body fluids. This can lead to both beneficial effects (such as the addition of agronomically-useful quantities of plant growth nutrients to pastoral systems); and harmful effects (such as fluorine toxicity to livestock).
- The prevalence of volcanic eruptions also has a profound impact on the local climate and geography in certain regions of the world – such as the Pacific Ring of Fire. Such regions are generally mountainous, have rich soil, and periodically experience the formation of new landmasses.
- Famines have occurred following some major eruptions due to destruction of food supplies due to ash fall.



Schematic of the events and processes beginning with a volcanic eruption and leading to the climate/atmospheric response.

- Destruction or damage to assets (e.g. buildings, bridges, electrical lines and power stations, potable water systems, sewer systems, agricultural land etc. can get covered with ash).
- The main effect on weather right near a volcano is that there is often a lot of rain, lightning, and
  thunder during an eruption. This is because all the ash particles that are thrown up into the atmosphere are good at attracting water droplets.
- If the ash fall is really heavy it can make it impossible to breathe. Inhalation of fine ash may trigger asthma and other acute respiratory diseases, although these effects are inconsistent between different eruptions.

<u>Volcanic gases and aerosols.</u>

- Volcanic gases can directly cause fatalities, health impacts and damage to vegetation and property. The impact of volcanic gases on people depends on the concentrations present in the atmosphere and the duration of exposure.
- Although the main component of gases released during most eruptions is water vapour, there are many other gas species and aerosols released, including carbon dioxide, sulfur dioxide, hydrogen sulphide and halogens (hydrogen fluoride and chloride).
- Volcanic gases emitted by a volcano may combine with rainfall to produce acid rain, which damages sensitive vegetation and ecosystems.
- Fluorine- and chlorine-bearing gases can also be hazardous and may adhere to the surfaces of erupting volcanic ash which subsequently falls to the ground. If people and/or animals consume affected water, soil, vegetation or crops they can be affected by fluoride poisoning.

How was the Deccan plateau formed?
It was formed by volcanic activity that lasted millions of years, causing the deposition of lava. After the volcanoes became extinct, the layers of lava transformed into a region of highland known as the Deccan plateau. The solid rocks formed by the lava are called igneous rocks. Continuous weathering and erosion of these rocks formed the black soil.

Is Deccan plateau a hotspot?
The Deccan volcanic province (DVP) formed during India's northward migration as it passed over the Reunion hotspot (which is today the Reunion Island). About 66-68 million years ago (near the end of the Cretaceous,) present-day India was above the hot spot and great volumes of basaltic lava erupted to produce the Deccan Traps.
As the plate moved northeast over the hot spot more volcanic centers formed: the Maldives, the Mauritus Islands are among the prime examples.

Which is India's only active volcano?
Barren Island
Barren Island is an island located in the Andaman Sea. It is the only confirmed active volcano in the Indian subcontinent, and the only active volcano along a chain of volcanoes from Sumatra to Myanmar.
When was the last volcanic eruption in India?
The volcano on Barren Island erupted on August 24, 2005.

- volcanism is a very important part in the evolution of life",
- Caused all the 5 extinctions – the last one results in the extinction of dinosaur era 65 million years ago after living on Earth for about 165 million years.
- And not just the dinosaurs; about 75% of all plants and animals went extinct.
- the eruption could have produced on the order of 30 billion pounds of sulfur dioxide and 9 billion pounds of hydrogen chloride for each cubic mile of lava.
- Tiny droplets of "sulfuric acid" formed high up in the air which blocked sunlight for several years and had a profound influence on life.
- Plants died and death cascaded through out the food chain. the droplets of sulfuric acid resulted in a long-lasting cooling, which was the most likely event that led to the death of the dinosaurs. The result was that the earth became very cold. Global annual mean surface air temperatures dropped by at least 26 degrees Celsius.