A Resource Booklet for SACE Stage 1 Earth and Environmental Science

The following pages have been prepared by practicing teachers of SACE Earth and Environmental Science. The six Chapters are aligned with the six topics described in the SACE Stage 1 subject outline. They aim to provide an additional source of contexts and ideas to help teachers plan to teach this subject.

For further information, including the general and assessment requirements of the course see: https://www.sace.sa.edu.au/web/earth-and-environmental-science/stage-1/planning-to-teach/subject-outline

A Note for Teachers
The resources in this booklet are not intended for 'publication'. They are 'drafts' that have been developed by teachers for teachers. They can be freely used for educational purposes, including course design, topic and lesson planning. Each Chapter is a living document, intended for continuous improvement in the future. Teachers of Earth and Environmental Science are invited to provide feedback, particularly suggestions of new contexts, field-work and practical investigations that have been found to work well with students. Your suggestions for improvement would be greatly appreciated and should be directed to our project coordinator:: lenaltman9@gmail.com

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Chapter 1

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Topic 1: Turbulent Earth

Natural hazards such as earthquakes, tsunamis, and volcanic eruptions affect life on Earth. In this topic students collect, analyse, and interpret data relating to the cause and impact of Earth hazards. They critically analyse the range of factors that influence the magnitude, frequency, intensity, and management of Earth hazards at local, regional, and global levels.

Students explore how the interactions of Earth systems may result in Earth hazards. They investigate ways in which scientific data are used to predict and mitigate the damage caused by these hazards, recognising their social responsibility and the need to plan for the future to protect the biosphere.

1.1 Interactions of Earth systems may result in Earth hazards.

The four Earth systems are the geosphere (land), atmosphere (air), hydrosphere (water and ice), and biosphere (living things). These systems and the interactions between them can generate Earth Hazards.

Types of Earth Hazards

Earthquakes

When rocks break under stress or pressure they produce shock waves or vibrations called earthquakes. Most major earthquakes are caused by sudden movement of rocks along a fault line in the lithosphere.

The focus (hypocentre) is the fracture point and the shock waves radiate out from here in all directions travelling through the earth as seismic waves.

Directly above the focus at the Earth's surface is the epicentre. This is the point on the surface where the earthquake is the strongest and usually does the most damage. While the shock waves lose power as they travel further away from the epicentre other factors such as building foundations, resonance and ground strength may determine how much damage occurs at different distances from the source of the quake.

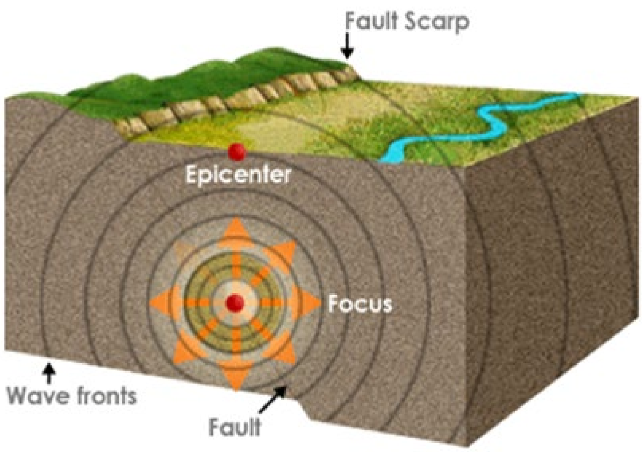


Figure 1.11: Focus and Epicentre of an Earthquake.

Figure 1.10: Philippines Earthquake damage.

Tsunamis

The sudden displacement of a large amount of water caused by a volcanic eruption, earthquake, landslide or meteorite impact can create a large wave (or series of waves) called **Tsunami**.
Tsunami translates from Japanese to "harbour wave" but are often call 'tidal waves' because small, distant-source tsunamis resemble tidal surges.

Figure 1.16: Japan Tsunami.

Figure 1.17: Japan Tsunami.

Most tsunami are generated in the Pacific Ocean 'Ring of Fire' where active plate boundaries cause frequent earthquakes and volcanic eruption.
Tsunamis move across the ocean extremely rapidly and when they hit shallower water near shore they slow down, increase in height but do not lose energy.
Tsunamis are usually composed of a series of successive waves that can compound the destructive force of the impact at shore.
Some tsunamis do not appear as large breaking waves but are more like a rapid surging tide.

Volcanic Eruptions

Deep within the Earth, under tremendous pressure and at great temperatures, rock exists as a hot liquid called magma. This molten rock is found in pockets called magma chambers. Sometime this magma is forced to the earth's surface and forms a volcano. A volcano is a mountain or hill, typically conical, having a crater or vent through which lava, rock fragments, hot vapour, and gas are or have been erupted from the earth's crust. The process of eruption may be extremely violent and destructive, or it may be a more gentle outpouring. The type of volcanic eruption and the volcano formed is largely determined by the type of magma. Once magma reaches the surface it is called lava.
The opening from which lava erupts is the vent. Volcanoes often have more than one vent.

Figure 1.35: Kilauea, Hawaii.

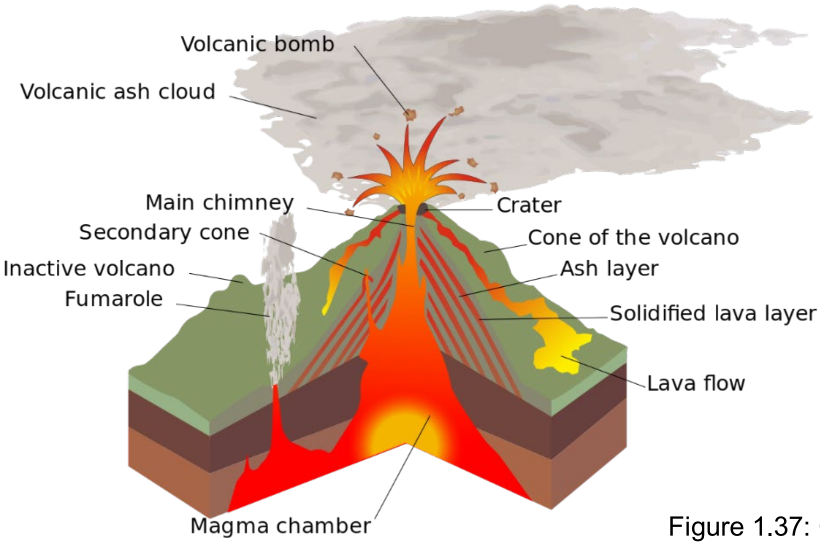


Figure 1.37: Cross section of a volcano.

The hazards generated from volcanic eruption include:

- Pyroclastic Debris Flows
- Lava flows
- Ash and ballistic projectiles
- Volcanic gas
- Tsunamis
- Volcanic Lightning

Landslides

When a mass of earth moving along a definite plane or surface the failure is termed a **Landslide**.
Landslides cause significant loss of life and cost billions of dollars each year.
Landslides can occur along a slope where the internal resistance of the rocks is reduced, or they lose their holding capacity. Most commonly, landslides occur after earthquakes or when part of the slope is removed due to construction, (particularly road construction).

The occurrence of landslides can also be exacerbated through land clearance and rainfall.

The scar above a landslide is easily visible

Figure 1.25: 2001 El Salvador Landslide.

Figure 1.26: Bolivia mud slide.

Extreme Weather

Extreme weather can also be an Earth Hazard. Examples of severe weather hazards include tornadoes, hurricanes, lightning, droughts and floods.

TORNADOES AND HURRICANES

Tornadoes or Twisters are rapidly rotating columns of air that come into contact with land or water and are of born out of thunderstorms. The most destructive tornadoes originate from huge thunderstorms called supercells. Tornado winds may exceed 400 kilometres an hour and can destroy a pathway as much as 1.6 kilometres wide and 80 kilometres long.

Fig.1. Tornado

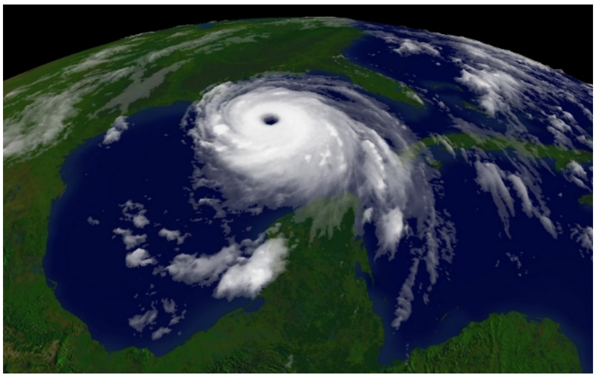


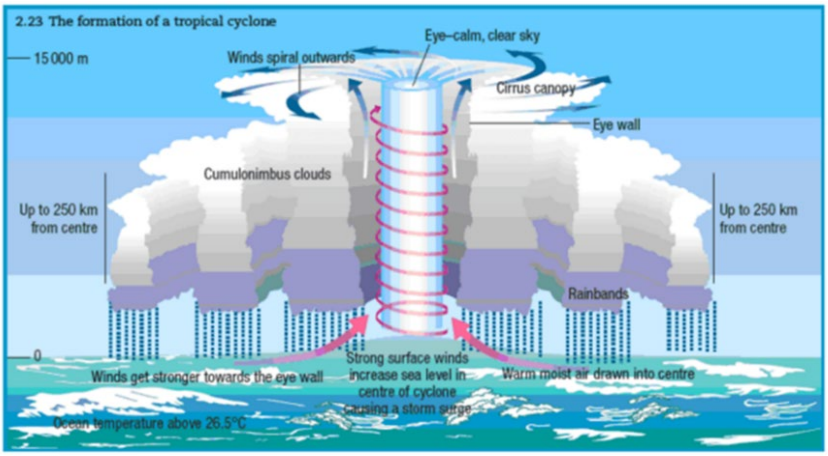
Figure 1.50: Satellite image of hurricane Katrina.

The terms hurricane, cyclone, and typhoon refer to the same weather phenomenon. In the Atlantic and Northeast Pacific, the term "hurricane" is used. The same type of disturbance in the Northwest Pacific is called a "typhoon" and "cyclones" occur in the South Pacific and Indian Ocean.

Tropical Cyclone Formation

Tropical cyclones are like giant engines that use warm, moist air as fuel.

The warm, moist air over the ocean rises upward from near the surface creating an area of low pressure. Air from surrounding areas with higher air pressure pushes in then becomes warm and moist and rises. As the warm air continues to rise, the surrounding air swirls in to take its place. As the warmed, moist air rises it cools and form clouds. The whole system of clouds and wind spins and grows, fed by the ocean's heat and water evaporating from the surface.



As the storm system rotates faster and faster, a calm area forms in the centre called an 'eye'.

FLOODING

Flooding is an earth hazard that occurs when overflowing water submerges dry land.
The sources of flooding can be from extensive rainfall via low pressure systems, tropical storms, king tides, tsunamis and rivers bursting banks.
Humans may contribute to flooding issues through poor land use practices and dam failure.

Flooding impacts built up regions but may also cause land use problems due to removal of topsoil and vegetation.

Fig. Rockhampton flooded

DROUGHT

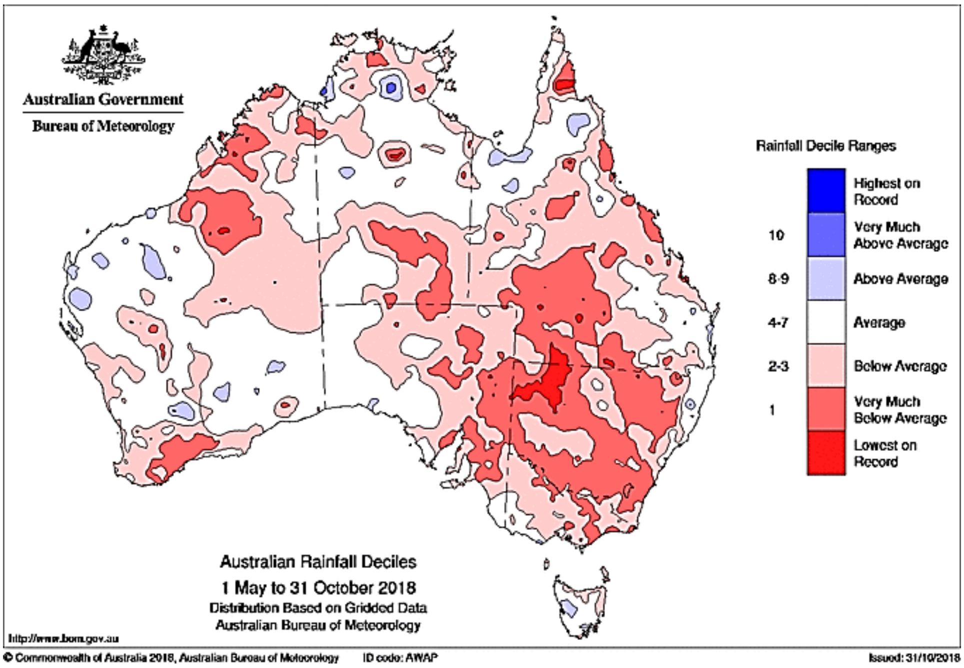
Drought is an earth hazard that is becoming increasingly common. Drought is a prolonged period of abnormally low rainfall which leads to a shortage of fresh water. While drought impacts fresh water supplies in rivers, reservoirs and lakes it also affects the quality of grazing and cropping land, along with farming stock, native vegetation and native animals.

Drought over extensive regions can lead to critical conditions that may impact food supplies, industries, the natural environment and the economy of entire states or countries.

Drought stricken regions are also vulnerable to other hazards such as fire.

Fig. Lake Hume at 4%

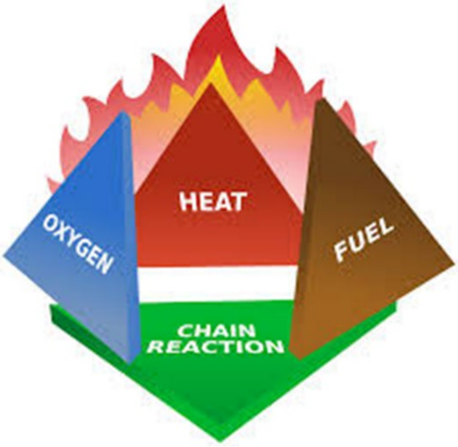
In Australia, inner Queensland and New South Wales have been experiencing significant drought in recent years. According to the Australian Bureau of Meteorology this extreme weather hazard has now reached an unprecedented crisis level.
(see map below)



LIGHTNING INDUCED FIRES

Extreme weather patterns may result in lightning storms. Fires that are started by lightning are another example of an Earth Hazard. Uncontrolled wildfires are often responsible loss of life, loss of property and livestock, infrastructure damage and long-term environmental impacts.

The factors which determine whether a wildfire will occur include the presence of fuel, oxygen and an ignition source. Lightning provides the ignition source. The fire intensity and the speed at which a wildfire spreads will depend on ambient temperature, fuel load, fuel moisture, wind speed and slope angle.



EXTRATERRESTRIAL IMPACT (IMPACT EVENT)

An impact event is a collision between astronomical objects causing measurable effects. A major impact event can release the energy of several million nuclear weapons detonating simultaneously when an asteroid of only a few kilometers in diameter collides with a larger body such as the Earth. While impact events are found to regularly occur in planetary systems, mankind has enjoyed a relatively stable time period where large impact events have been minimal (Research Tunguska event and Chelyabinsk 2013).
When large objects impact terrestrial planets like the Earth, there can be significant affects to other earth systems. The earth's atmosphere mitigates many surface impacts as meteoroids usually disintegrate during atmospheric entry.

Fig. Meteorite impact crater near Halls Creek, WA

REVIEW QUESTIONS

Question 1

(a) Complete the following table:

Type of Earth Hazard	Earth System Source	Possible System interactions

(b) Earth Hazards may affect a restricted area or may be wide ranging.

- State one of the Earth Hazards that is likely to affect a smaller region________________________
- State one earth Hazard that could potentially affect the greatest region and the greatest number of people. __________________________________

(c) There are many other types of Earth Hazard, these include **sinkholes**, **coastal erosion** and **avalanches**. *Investigate* one of these and determine it's Earth System source and what system interactions it may have.

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Affect on life, health, poverty, and the environment.

Earth hazards can significantly affect life, health, poverty and the environment.

Affect on Life:

Earth hazards can result in the loss of life and the causes vary extensively. Causes of death can range from different kinds of physical injury, smoke inhalation, burns, drowning or lack of food and water.

The data table below shows that the earth disasters which caused the greatest number of global human deaths in the last 115 years were drought, flood and earthquake.

FIG.

Despite the average number of extreme earth events increasing from 2.5 per year in the 1920s to 350 per year for the period 2000-2010, the deaths caused by these disasters have decreased since the 1920s (Reason Foundation, 2011).

Unusual circumstances can cause death. One example is the crater lake Nyos in northwest Cameroon. Formed by subterranean volcanic activity, crater lakes often have high levels of carbon dioxide. Under normal circumstances, these gases dissipate as the lake water turns over. But Lake Nyos is unusually still and had stored high concentrations of dissolved carbon dioxide in it's waters over a long period of time.

On August 21, 1986, something triggered a reaction and lake Nyos exploded, sending a fountain of water over 90 metres into the air. Hundreds of thousands of tonnes of carbon dioxide burst forth at 100 kilometres an hour. The CO_2 gas suffocated people up to 25 kilometres away and of the 800 local residents only six survived. In total, 1,746 people died and over 3,500 livestock perished in a matter of minutes.

On Health:

Natural disasters may have an immediate impact on human life but there is also a longer-term impact on the health and well-being of the people affected. Loss of food, clean water supplies and access to good sanitation can lead to malnutrition, poor health and the spread of disease.

A country's healthcare system is severely tested during and after a natural disaster. Emergency care supersedes longer term, less urgent medical treatment and this may impact the well-being and health of others outside of the disaster affected area.

If the disaster triggers mass movement of people seeking refuge this may lead to overcrowding and collective poor hygiene. Over-crowding can easily lead to an increase in the transmission rates of communicable diseases.

Earthquake deaths and health issues are largely caused through crush injuries from falling objects either in or near buildings. The injury severity is inversely related to the earthquake's epicentre. Injuries and deaths generally increase with the magnitude of the earthquake, the increase in ground motion, and the increase in structural damage. Victims may have various complications from crush injuries (e.g. shock, renal failure and heart attack) and those trapped in rubble for extended periods of time also risk wound infection.

Burn injuries and respiratory conditions can be caused by fires brought about by earthquakes, lightning or volcanic eruption. Severe burn injuries are often accompanied by shock and infection.

Inhalation of toxic fumes, skin irritation and severe injury or burns can be caused by volcanic ash, lava flows or pyroclastic debris during a volcanic eruption. Long term respiratory complications can develop from inhalation of volcanic ash.

Tsunami, high rainfall and extreme weather events such as cyclones and tornadoes can cause flooding. Aside from drowning, the health concerns from flooding include traumatic injury from the debris in fast moving water and exposure to the elements.

On Poverty:

Many factors play a role in determining how severe an impact the earth hazard has on a region's economy and poverty levels. The scope of a disaster is influenced by the country's current economic state, the extent of the loss of infrastructure and food supply, and the emergency management strategies the country is able to implement.

In 2016 an analysis carried out by the World Bank found that natural disasters force 26 million people into poverty and cost $520 billion each year. (World Bank, 2016)

> *"Severe (natural disaster) threatens to roll back decades of progress against poverty,"* said World Bank Group President Jim Yong Kim. *"Storms, floods, and droughts have dire human and economic consequences, with poor people often paying the heaviest price."*

If the emergency management strategies of a country are not able to cope with the extent of the natural disaster, then short term homelessness may extend to longer term internal displacement or rising refugee issues across neighbouring borders. All these factors contribute to the poverty levels in a region or country.

FIG: A crowd of stranded villagers gather on the banks of Ethiopia's Lake Tana (the source of the Blue Nile), as sacks of emergency food supplies are unloaded.

On the environment:

The impact of natural hazards on the environment can be wide ranging and varied. It is important to note that not all disasters result in significant ecosystem impacts and some extreme events may even have a positive impact on ecosystems (e.g. floods can help rejuvenate floodplain vegetation). Some ecological systems have adapted to infrequent extreme events such as floods, droughts and fires. If the hazards are too frequent, too intense or over too large an area then the natural ecosystems may not be resilient enough to cope.

The environmental problems generated by **drought** begin with changes in the quantity and quality of water available. Drought impacts plant and animal species by depriving them of food and water and increasing their vulnerability to disease and predation. Droughts cause a loss of biodiversity and often promote erosion when rain does eventually come. Other environmental impacts from drought include poor water quality and an increase in salinity along with poor air quality due to dust and pollutants.

The environmental impact of disasters such as **hurricanes and tropical storms** tend to be pathways of damage to trees and underbrush and sometimes erosion in coastal regions. Vulnerable coastal habitats are usually the most severely impacted.

Although the main damage from **earthquake**s is to structures and humans, these hazards may cause negative consequences to the environment. Animals, plants and habitats may be damaged or hydrologic systems disrupted.

The impact on the coastal environment caused by **Tsunami** can be significant. The sheer volume of the solid waste and disaster debris is usually the most critical environmental problem. Hazardous materials and toxic substances may also be mixed up with the debris (e.g. asbestos, sewage, oil and industrial chemicals). Soil and water is often contaminated and salinized, this affects plants, animals and long-term soil fertility.

FIG

Volcanic eruptions can impact the environment over thousands of kilometres from the volcano centre. The ash fallout can travel great distances and contribute to changes in weather patterns in other countries! The ash, volcanic bombs, toxic gases, lava and pyroclastic flows can all contribute significantly to loss of life- human, plant and animal. Areas of habitat can be wiped out under the relentless flow of molten rock. Some environmental benefits do come from volcanic eruption including the increase in soil fertility from volcanic ash.

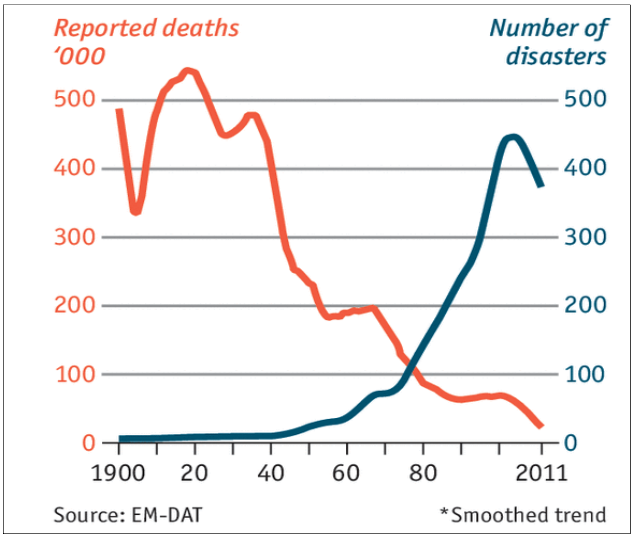
The potential environmental changes that could be caused through **extraterrestrial impact** would be significant. Research suggests a meteorite greater than 1 kilometre in diameter could alter Earth's ecosystems. A substantial meteorite would scatter dust and debris darkening the sky as dense ‘cloud’ cover and affecting the composition of the air. Heat from the impact would likely trigger fires which would contribute smoke to the atmosphere, blocking out the sunlight and creating an artificial winter. Alternatively, if a meteorite landed in the ocean, it could cause tsunami or widespread flooding.

REVIEW QUESTIONS

Question 2

Figure.   below illustrates both global deaths from natural disasters along with the number of natural disasters. Use this graph to answer the following questions.

Fig.



(a) **Describe** any trends and patterns in the graph above.

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(b) **Analyse** the relationship between the number of natural disasters and the number of reported global deaths.

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(c) **Propose** 2 possible reasons for this particular correlation between global deaths from natural disasters and the number of natural disasters.

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Question 3

Hurricane Katrina States of Louisiana and Alabama, city of New Orleans on August 29, 2005. Category 3 on the Saffir–Simpson scale (SSHWS) At least 1,245 people confirmed dead, and a further 135 known to be missing but total loss of life is still uncertain. Caused the levees around New Orleans to fail Wind speed 280km/h $81 billion damage 644 km wide	**Cyclone Tracey** Devastated the city of Darwin, Northern Territory, Australia, from Christmas Eve to Christmas Day, 1974 71 dead 240 km/h winds $837 Million in damage in 1974 (equivalent to 6.4 billion dollars today) Category 3 Hurricane Saffir–Simpson scale (SSHWS) Category 4 Severe Tropical Cyclone (Australian Scale)
Cyclone Yasi Category 5 severe tropical cyclone (Aus scale). Category 4 Saffir–Simpson scale (SSHWS). Wind speed 285 km/h. Over 600 km wide 1 indirect fatality: 23-year-old man who was asphyxiated by generator fumes when sheltering. $3.6 billion damage. Caused a 7m high ocean storm surge Occurred in Northern Queensland	**Cyclone Larry** Category 5 severe tropical cyclone (Aus scale). Category 4 Saffir–Simpson scale (SSHWS). Far north Queensland 205 km/h winds. 300 - 400km wide 1 Fatality. $1.1 billion damage. Cost of bananas rose to $15/kg.

Processing data.

(a) Using the data provided on the 4 tropical storms **construct** a suitable table and **organise** the data to logically consolidate and compare the information.

NOTE: The *correct scientific format* is required for the table. i.e. Independent Variable must be the left column, with 'measured' variables to the right. Consider – what is the 'independent variable' being investigated? (*Clue: what is being compared?)*

Table: Impact of Extreme Weather Events: Selected Tropical Storms

Hurricane Katrina was neither the largest of these tropical storms nor the had the fastest winds, but it had by far the greatest fatalities and damage cost.

(b) What other earth hazard did Hurricane Katrina trigger in New Orleans, Louisiana?

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(c) Human activity can influence the impact of Earth Hazards.

What human activity in New Orleans, Louisiana was to blame for what occurred in (b) and subsequently the loss of so many lives? (Research may be required!)

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(d) What other complicating factor(s) may have contributed to the volume of deaths from Hurricane Katrina? (Research required)

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Earth Hazards in one sphere can affect Earth processes in other spheres.

An Earth Hazard can **cause** changes to occur in one or more of the spheres.

Earth's spheres interact. An event, for example a wildfire, can impact one or more of the four spheres. An Earth Hazard can also be the *result* of changes in the spheres. The cause-and-effect relationship between an earth hazard event and a sphere is called an interaction. Interactions also occur between the spheres; for example, a change in the hydrosphere can cause a change or impact in the atmosphere.

FIG.

Example 1: Lightning Induced Fire

Lightning Induced Fire (Earth Hazard or 'Event' occurring in the *Atmosphere*)

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Burns trees and plants (*Biosphere*)

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The soil (*Lithosphere*) becomes more susceptible to erosion

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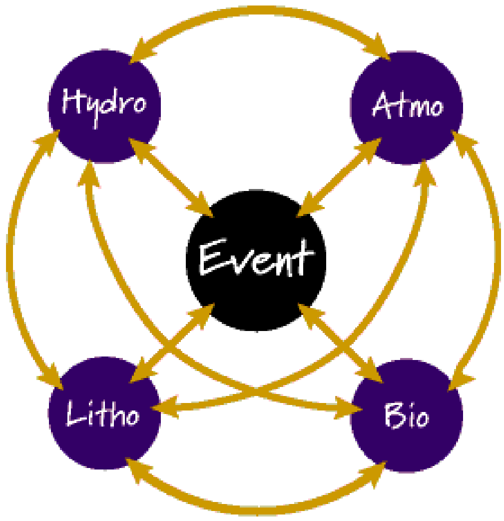
Eroded soil gets washed into streams (*Hydrosphere*)

↓

Sediment chokes aquatic organisms (*Biosphere*)



Example 2: Hurricane

HYDROSPHERE

Toxins leaked into groundwater

Raised water levels, flooding

BIOSPHERE

leaked wastes and toxins poison aquatic life

killing of people, wildlife and plants through trauma

impact through loss of habitat, smoke inhalation

ATMOSPHERE

HURRICANE

(Earth Hazard in the Atmosphere)

Increase in humidity

Powerful winds, low air pressure

Smoke from fires triggered by the hurricane

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LITHOSPHERE

Coastal erosion

Loss of topsoil

Toxins leaked into soil

REVIEW QUESTIONS

Question 4

(a) Watch Big Idea 3: Earth's Systems Interact (https://www.youtube.com/watch?v=BnpF0ndXk-8)

(b) Using the format of the interaction diagram above, illustrate the interactions between spheres for a **Tsunami** event in the space provided.

(c) How may each of the Earth's four spheres have ***caused*** the Tsunami to occur? (These are sphere vs. event impacts.)

(d) What are the effects of the Tsunami on each of the Earth's four spheres? (These are the event vs. sphere impacts.)

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(e) What are the effects of changes in one of Earth's four spheres on each of the other spheres (hydrosphere, atmosphere, lithosphere, or biosphere)? (These are the sphere-to-sphere interactions.)

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Human activity influences the frequency and intensity of some hazards.

As the human population rapidly heads towards 8 billion people (November 2018), the impact of our number and the actions we take inevitably influence the environment around us.

Human activity influences the frequency and intensity of some Earth Hazards. It could be argued that we have *some* affect on *all* Earth Hazards but those we most significantly impact will be discussed here.

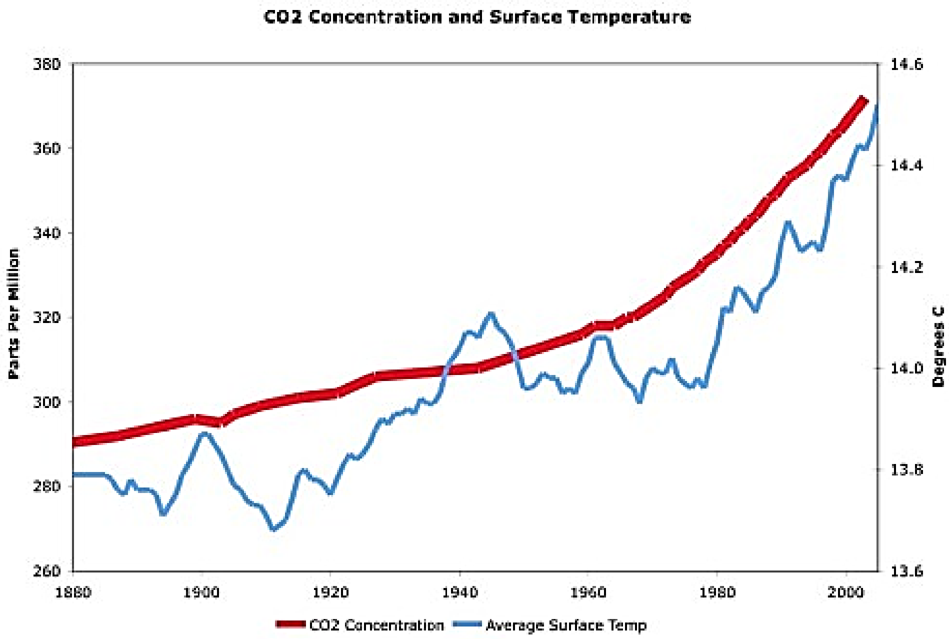
Some of the Earth Hazards that are significantly impacted by human activity include **extreme weather events** and **landslides**.

Extreme Weather Events

All extreme weather events are being influenced by global warming and climate change.

Humanity has been removing fossil fuels from the lithosphere and combusting them as an energy source at an ever-increasing rate. This combustion process releases carbon dioxide and other greenhouse gases into the atmosphere. As a result, there has been a rapid increase in global temperature which in turn changes climate and impacts weather patterns.

Fig:



While extreme weather events are a natural feature of the climate system, the atmosphere and hydrosphere contain significantly more heat today than in the past and this is influencing the frequency and intensity of weather events.

According to The Australian Climate Council (Hughes, Steffen and Rice, 2017) changes to the climate system is causing:

- increased evaporation and greater amounts of water vapour in the atmosphere which is leading to more intense rainfall in some regions.
- more destructive **storms** in the more energetic, moisture-laden atmosphere.
- A drying trend and reduced rainfall in other regions contributing to extended **drought**.
- Heatwaves are becoming hotter, lasting longer and occurring more often.
- An increase in the likelihood of dangerous **fire** weather and lightning storms to ignite them.
- increasing sea levels, which is exacerbating the impact of coastal **flooding** on coastlines around the world.

'The impacts of extreme weather events will likely become much worse unless global greenhouse gas emissions are reduced rapidly and deeply.' (Climate Council, 2017)

<u>Landslides</u>

Most landslides are caused by many factors that act together to destabilise the slope.

The primary cause of a landslide is the influence of gravity acting on weakened materials that make up a sloping area of land. Some landslides can occur slowly but the most destructive ones happen suddenly after an event such as heavy rainfall or an earthquake. Water is one of the most common triggers for landslides as it changes the pressure within the lithosphere surface and can destabilise the slope. Erosion and weathering also may contribute to the occurrence of landslides.

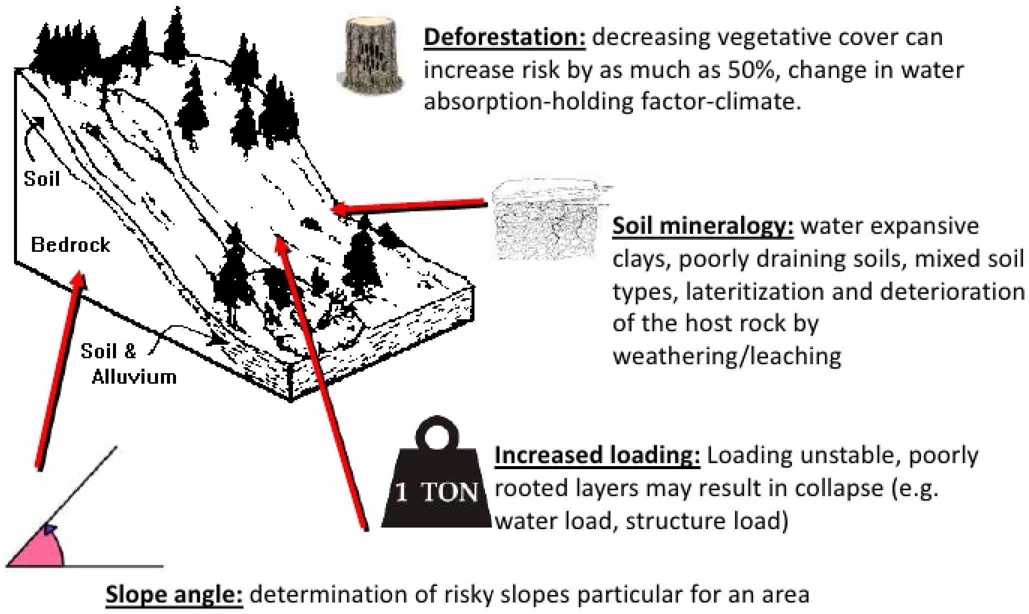
Human activities can also influence the frequency and intensity of landslides.

Examples include:

- deforestation, land clearance and logging
- changes made to the flow of groundwater
- construction work – particularly the building of roadways

Fig. The cause of the destructive 2014 Oso, Washington landslide is believed to be a combination of excessive rainfall and logging which lead to liquefaction of the slope.

Fig. Factors contributing to landslides



REVIEW QUESTIONS

Question 5

(a) How does human activity contribute to changes in the climate? Explain using a flow diagram.

(b) List at least 5 changes that could be made to reduce the negative impact of human activity on Earth Hazards (in your life or at government and industry level).

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(c) Construct a graph on the grid below using the data in the table provided. There will be 1 line per country and you must include a heading and a key to indicate which line represents which country. Different colours may be used.

Table: CO_2 Emissions by country.

Year	CO_2 emissions (tonnes per head of population)			
	China	Brazil	Australia	USA
1960	1.20	0.60	8.60	16.20
1965	0.70	0.70	10.60	17.70
1970	0.90	1.00	11.40	20.60
1975	1.20	1.40	11.90	19.70
1980	1.50	1.50	14.80	20.30
1985	1.90	1.30	15.20	18.50
1990	2.10	1.40	17.20	19.20
1995	2.70	1.70	17.10	19.50
2000	2.60	1.90	17.10	20.00
2005	4.30	1.90	18.10	19.50
2010	6.60	2.10	17.70	17.40
2015	7.00	2.60	16.70	17.00
2017	7.50	2.60	15.40	16.50

(d) Refer to your graph.

i. Which countries have reduced their carbon emissions per head in the last 10 years?

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ii. Which country has had the most significant *increase* in carbon emissions per head since 1960?

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iii. Calculate the **total** carbon emissions for Brazil and Australia in 2017.

2017 population of Brazil – 209.3 million x ________________ = ______________________ tonnes

2017 population of Australia – 24.6 million x _______________ = ______________________ tonnes

iv. Propose one reason for the differences in carbon emissions *per head* between countries like Australia and Brazil.

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Strategies that have helped lessen the severity of Earth Hazards

While humanity has contributed to earth hazards we also are employing strategies to reduce the impact or lessen the severity of them.

Some of the strategies include:

- the construction of Tsunami Barriers
- development of advanced early warning systems
- designing earthquake resistant buildings
- monitoring Volcanic and seismic activity
- reducing deforestation and development in landslide prone areas
- research and technological improvements for weather monitoring and prediction technologies
- improved public education, community preparedness and emergency response strategies
- interactive websites that provide public education and promote community strategies and allow contribution – e.g. 'I Felt It' when tracking earthquake tremors.
- intentional use of social media (e.g. Twitter) to provide emergency communication
- Communication and collaboration between relief organisations from all over the world.

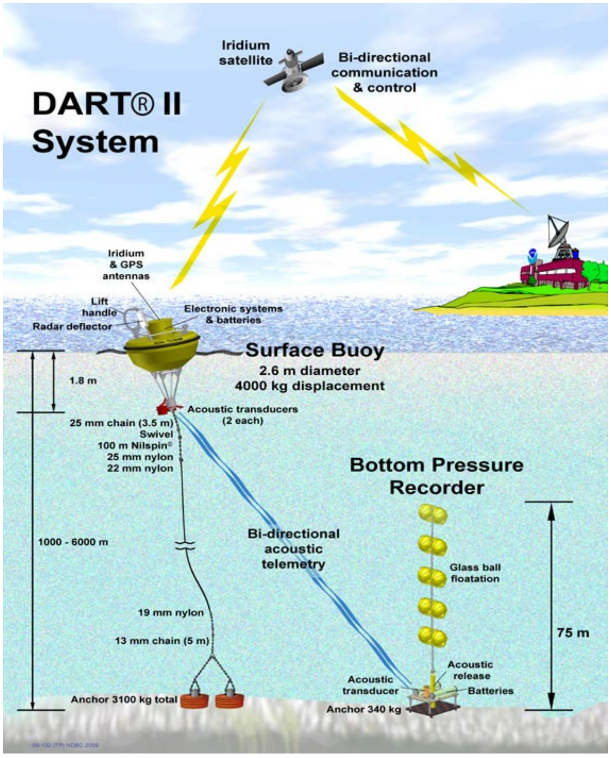
Figure 1.24: Tsunami hazard sign.

Tsunami Barriers

Fig . Workers build sea walls in Rikuzentakata, Iwate Prefecture, north-eastern Japan.

Tsunami Warning Systems

Example - *DART System*: As soon as an earthquake of magnitude >6.5 is detected in the sea, the alarms start. Using computer simulations and maps scientists forecast the time of arrival in different locations. The use of buoy and tide gauges help to verify the effective presence of a tsunami. Once that the alarm is given it is necessary that the local communities have effective emergency plans, that they receive the messages, and that the population knows what to do.



Can we improve our tsunami warning systems?

Warning systems are continually being developed and improved. These include sensor networks in hazard areas of the world (seismic, tide gauge, ocean buoys) and coordinated distribution and processing of data. More accurate and timely information enables more effective emergency assessment and response to the disaster.
Along with developing communication technology the coordination and integration between national, regional and local emergency response agencies and civil authorities is vital and is still improving.

Education and training of local communities, and governments at national, regional and local levels plays and integral part in effective emergency response. People can be warned of potential tsunamis from distant earthquakes but near source tsunamis have such a short time frame that notifying people in time is much more difficult. Therefore, prevention of tsunami catastrophes requires carefully planned use of low-lying areas. This is not always possible or affordable however, for some regions, particularly in impoverished areas.

Earthquake Resistant Buildings

Anti-seismic technologies are now quite advanced, and it is possible to build individual structures that can withstand a majority of earthquakes. Buildings can be designed with isolation systems and dampers to reduce the vibrations, and therefore the damage, of structures. This is valuable in developing settlements or when rebuilding in wealthier or newer regions but a large proportion of buildings in earthquake zones already exist and cannot easily be replaced (for economic or heritage reasons).

At the University of Brighton a new device has been designed – the **ViBA** – a vibrating barrier which reduces the vibrations of nearby structures caused by an earthquake's ground waves (Cacciola, 2015). The device can be buried in the soil and is detached from surrounding buildings. It is able to absorb a significant portion of dynamic energy arising from ground motion with the goal of reducing the consequent seismic response of the building it surrounds (between 40-80%). The application of this design would provide some protection for existing homes and structures.

Predicting Volcanic Eruptions
Volcanologists monitor volcanic activity. As a volcano becomes active, it gives off a number of warning signs. Techniques are becoming increasingly accurate however, as well as prediction, people need to be prepared for an eruption.

Key techniques for monitoring a volcano

Warning signs	Monitoring techniques
Hundreds of small earthquakes are caused as magma rises up through cracks in the Earth's crust.	Seismometers are used to detect earthquakes.
Temperatures around the volcano rise as activity increases.	Thermal imaging techniques and satellite cameras can be used to detect heat around a volcano.
When a volcano is close to erupting it starts to release gases. The higher the sulfur content of these gases, the closer the volcano is to erupting.	Gas samples may be taken and chemical sensors used to measure sulfur levels.

Figure 1.48: Monitoring volcanoes.

Surviving Extreme Weather Events

A study published by *The Reason Foundation* (Goklany, 2011) found that the following strategies contributed lessening the impact of extreme weather hazards such as drought and storms:

- global food production advancements, such as new crops, improved fertilizer, irrigation, and pesticides
- society's better ability to move food and medical supplies
- technological and telecommunication advances made it significantly easier to learn of and respond to weather events.
- broader news coverage
- an increased tendency by authorities to declare natural disaster emergencies

"The number of reported extreme weather events is increasing, but the number of deaths and the risk of dying from those events have decreased," said Julian Morris, the study's project director and vice president of research at Reason Foundation. "*Economic development and technological improvements have enabled society to protect against these events and to cope better with them when they do occur."*

REVIEW QUESTIONS

Question 6

Science as a Human Endeavour

Read the following article from the ***Adelaide Now*** newspaper on 5th November 2019:

A FLINDERS University academic has created a disaster warning system he says could be rolled out at a fraction of the cost of traditional technology, potentially saving thousands of lives in the Indo-Pacific.
Telecommunications Research Laboratory leader Paul Gardner-Stephen said his system, which uses satellite TV receiver hardware and small FM radio transmitters, creating "village radio stations" had been successfully tested in Vanuatu.
It could help prevent deaths during disasters like the tsunami that struck Palu, Indonesia, in September. An earthquake in Sulawesi and the subsequent tsunami killed more than 2000 people.

"Communications was one of the great challenges surrounding the Sulawesi earthquakes and tsunami," Dr Gardner-Stephen said.
"I received reports that the initial tsunami warning could not be distributed because of the damage to cellular communications systems. This new system can avoid this problem."

The technology could be used in the Pacific and Southeast Asia and also help warn people of tsunami threats on our own shores.

"It could be used in Australia, particularly anywhere we've got small communities, like around Cape York, where they may or may not have mobile phone connectivity," Dr Gardner-Stephen said.
"There are people that currently don't get warning of tsunamis, which leads to an increase in fatalities and if we provide an early warning it could save thousands of lives."

The system's development was funded by a grant from the Elrha Humanitarian Innovation Fund, based in the UK.
Dr Gardner-Stephen said regular tsunami warning systems used large towers that were expensive to buy and maintain. Few vulnerable communities had them and they often failed due to a lack of maintenance.
The Vanuatu trial showed the new system could deliver a tsunami alert in just 11 seconds, even if cellular networks failed.
The university will now look for funding partners for further trials in the Indo-Pacific, in the hope that the system's use and costs would eventually be covered by the affected nations.

"We want to create solutions that are sustainable for the people who need them – we don't want to create a culture of dependency," Dr Gardner-Stephen said.

About $500,000 would fund the lease of a satellite and the cost of running the service, which could reach about 70 per cent of the world's surface, Dr Gardner-Stephen said.
There would be an additional cost of about $200 per village for technology to receive the warning, with the system also used to broadcast local news and information on meteorology, horticulture and agriculture.
Locals could access it through their radios or mobile phones.
With the combined fees covered by a string of nations, its cost could work out to be a few cents per person, Dr Gardner-Stephen said.
That cost was about 1 per cent of the cost of the existing infrastructure on offer, he said.

"In Vanuatu, there would be between 2000 and 4000 villages that would need something like this and $1 million – $2 million could potentially cover all of Vanuatu".
"Saving lives in tsunamis is great, but it could also help avoid health-related outbreaks and improve food security, deliver weather reports."

HOW IT WORKS

■ *A satellite is leased to service the warning and information system*
■ *TV receiver hardware and small FM radio transmitters are used to create 'village radio stations' in the Indo-Pacific*
■ *Meteorology services or natural disaster management organisations produce tsunami alerts, which are sent to FM broadcasters and Flinders University*
■ *They issue the alert to the village radio stations*
■ *A siren at the stations is used to blast a warning signal to the area*
■ *Villagers can tune into the radio station via their own handheld FM radio receivers or mobile phones to hear more information about the threat*
■ *The radio stations also broadcast information such as news, weather forecasts, climate change, horticultural and agricultural information*

Questions:

(a) Describe how this new technology could improve the efficiency and sustainability of current tsunami warning systems and procedures.

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(b) Explain how the acceptance and use of this new system is likely to be influenced by social, economic, cultural and/or ethical considerations.

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1.2 Processes within the geosphere generate Earth hazards.

Plate tectonics generate earthquakes, volcanic eruptions and tsunamis.

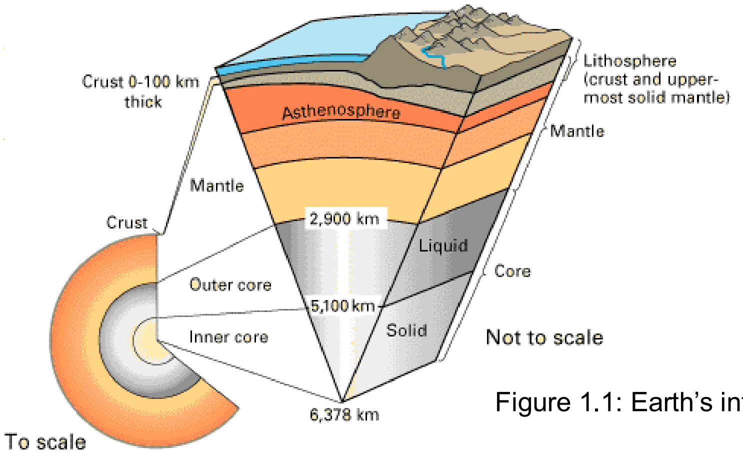
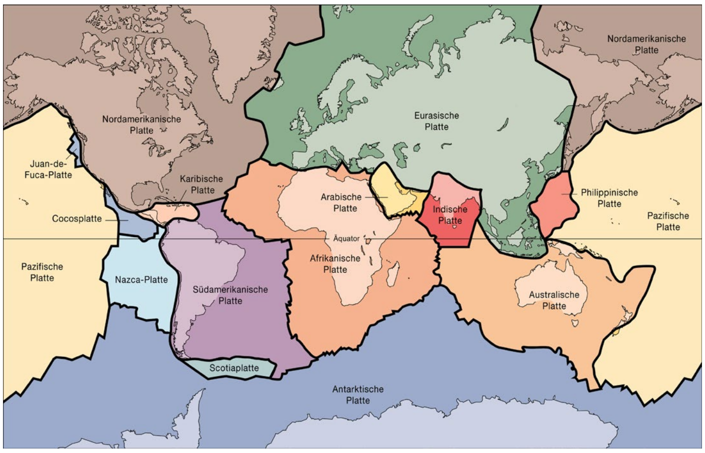


Figure 1.1: Earth's internal structure.

The Earth's outer layer is called the lithosphere. The lithosphere is made up of the outer crust layer along with the upper brittle region of the mantle. The lithosphere is broken up into a set of large rigid plates. These plates float and move on top of a fluid layer– the asthenosphere (the upper mantle).

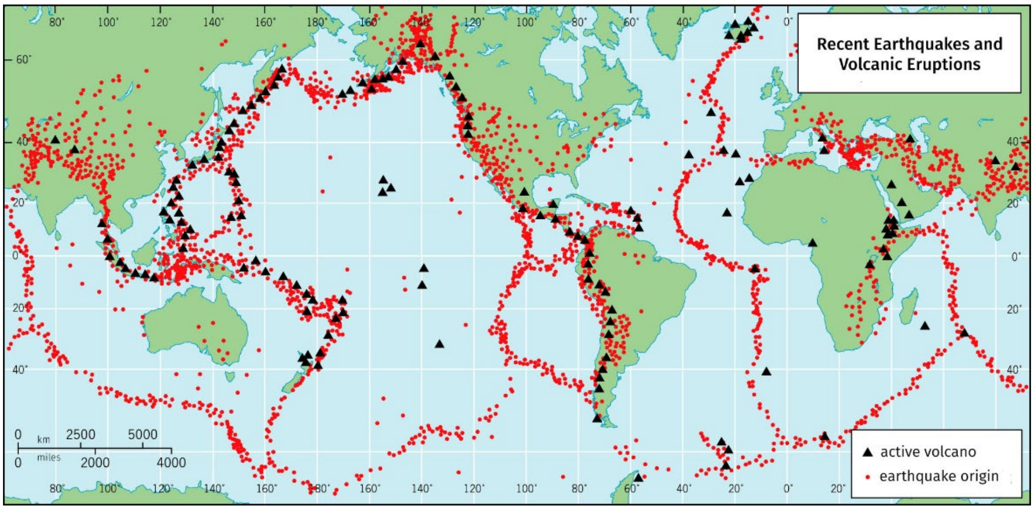
Where the plates meet are called plate boundaries. The movement of these plates over the surface of the mantle is called **PlateTectonics.**

Figure: Tectonic plates



There is a direct relationship between plate tectonics and volcanic activity and earthquake activity. Plotted on a map the vast majority of earthquakes and volcanoes lie on or near plate boundaries.

Scientists infer that plate movement and interaction between plates causes most volcanism and earthquakes.

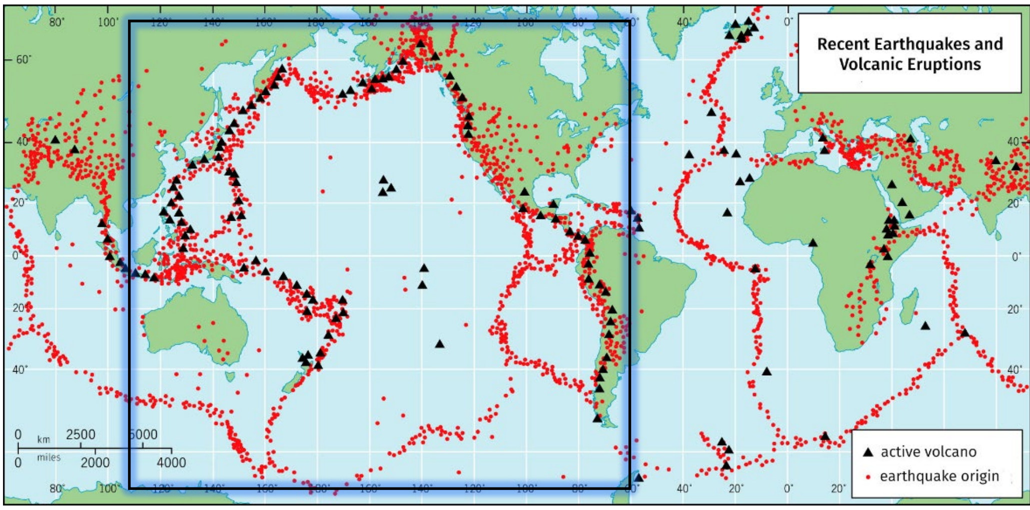


Volcano and Earthquake Zones

Most major earthquakes and volcanic eruptions occur in three zones of the world. Scientists believe that there is a great deal of movement and activity in the Earth's crust in these three zones. 80% of all earthquakes occur in the Pacific 'Ring of Fire' and most of these are from convergent margin activity (plates colliding). Around 15% of earthquakes occur in the Mediterranean-Asiatic belt and 5% occur in the interiors of plates or on spreading ridge centres.

More than 150,000 quakes strong enough to be felt are recorded each year.

Ring of Fire
One major earthquake and volcano zone extends nearly all the way around the edge of the Pacific Ocean. This zone goes through New Zealand, the Philippines, Japan, and Alaska, along the western coasts of North and South America. The San Andreas Fault is part of this zone.



gure 1.9: Map of rthquakes and lcanic eruptions ng of fire boxed t).

Mediterranean Zone

A second Major earthquake and volcano zone is located near the Mediterranean Zone and extends across Asia into India. Many countries in the zone, including Italy, Greece and Turkey, have violent earthquakes. Many volcanic eruptions also occur in this zone.

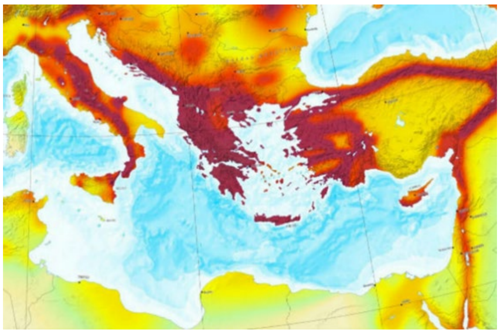
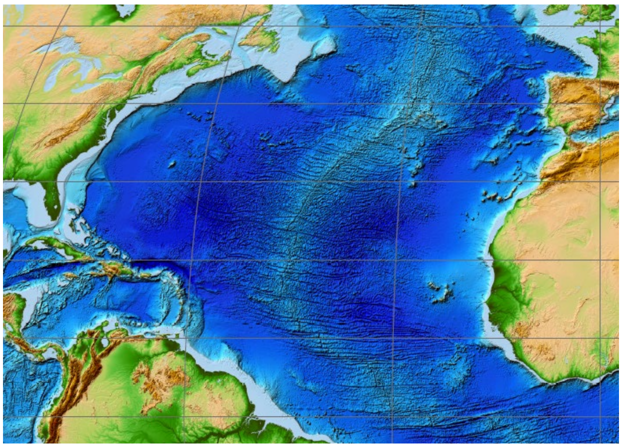


Figure 1.46: Mediterranean Earthquake and volcanic zone.



Mid-Atlantic Ridge Zone
The third major earthquake and volcano zone extends through Iceland and to the middle of the Atlantic Ocean. There is under the ocean a long range of volcanic mountains called the Mid-Atlantic Ocean Range. Scientists believe that the volcano and earthquake activity are due to the formation of new parts of the Earth's crust along the ridge. The volcanic island of Iceland is part of this zone.

Plate Tectonics generate earthquakes

The friction, stresses between plates and the subsequent sudden movement/release of tension can generate an earthquake.

There are three main plate tectonic environments: extensional, transform, and compressional. Each type produces different types of earthquakes in terms of power and depth.

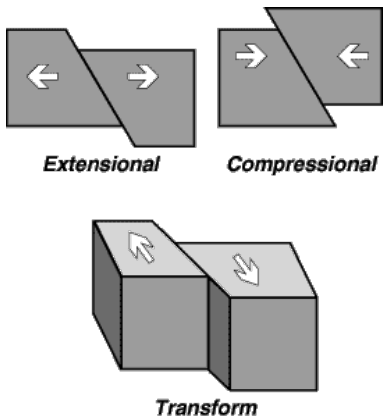


Fig:

Tsunami Source: Earthquake

Earthquakes that suddenly uplift or down-drop the sea floor drastically and suddenly shift a large volume of water generating a **Tsunami**.

Generally such surface deformation is largest for reverse and normal faulting earthquakes, and small for transform faulting events thus the potential for tsunamis is lower for strike slip faults.

In general tsunami are generated by reversal faults.

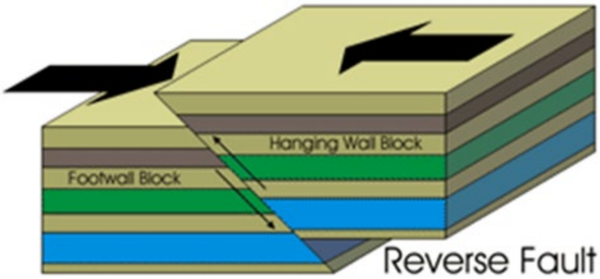


Figure 1.18: Reverse fault.

Large subduction zones produce the most tsunamis. The Pacific Ring of Fire, rimmed with subduction zones, has the most tsunamis.

Pacific Ocean ~ 80%

Atlantic Ocean ~ 10%

Elsewhere ~ 10%

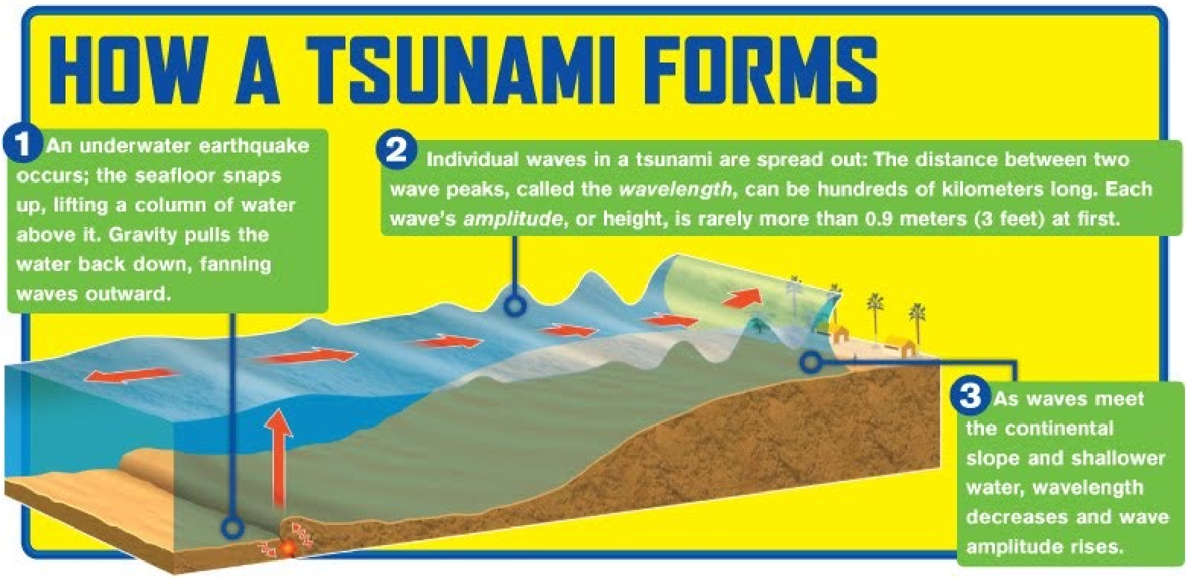


Fig:

Tsunamis are most devastating near the earthquake as they are usually larger and strike the region so soon after the earthquake that warning systems may not have time to be triggered.
Tsunamis also travel across entire oceans and cause damage and death thousands of kilometers from the earthquake focus. In a bay the waves can be focused and increase their amplitude- e.g. A landslide triggered by an earthquake in a fiord in Alaska in 1958 created waves 518m high.

Other Tsunami Source examples:

Volcanic eruptions
Krakatoa, 1883: tsunamis killed 30,000 people; Santorini, 2002.

Mass Movement/ Landslides (Alaska, 1958: waves up to 518 m high formed in Lituya Bay.

Extra-terrestrial Impacts - large impacts have the potential to create enormous tsunamis.

Other Hazards caused by Earthquakes and Tsunami - LIQUEFACTION

Figure 1.34: Liquefaction, Indonesia 2018.

When a devastating earthquake and tsunami struck central Sulawesi, Indonesia on Friday 28th September 2018, survivors found even the ground beneath their feet offered no safety: it had turned to liquid.

Watch a liquefaction demonstration here (https://www.youtube.com/watch?v=b_aIm5oi5eA)

Many who attempted to find shelter were trapped by waves of earth that churned like water, the result of an earthquake process known as **liquefaction**. Many people were trapped and buried under collapsed houses. The official death toll from the twin disasters — a 7.5 magnitude earthquake that triggered a tsunami — exceded 1400. Much of the damage was wreaked by liquefaction. In one neighbourhood, an estimated 1,700 houses were consumed by the roiling earth. Liquefaction as a process that occurs when water-saturated soil, shaken by an earthquake, acts like a liquid. The ground temporarily loses its ability to bear structures like buildings or homes, often with deadly results.
Earthquake tremors can cause the water-logged soil to oscillate like waves, flow down inclined slopes, or be ejected upward in formations called "sand boils." Liquefaction also often causes the ground to settle unevenly, which can upset roads, bridges, pipelines and other infrastructure.

Plate Tectonics generate volcanoes

Volcanoes are associated with three types of tectonic structures: convergent plate boundaries, divergent plate boundaries and hot spots.

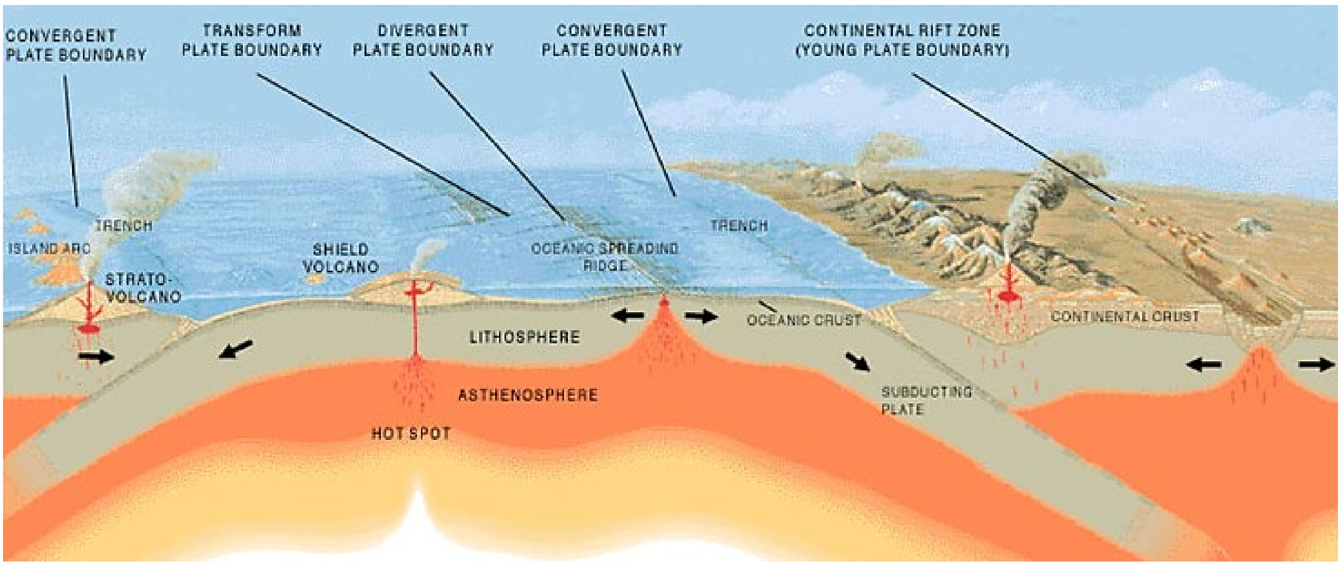


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Figure: TABLE: Association of plate boundary and volcano types

Tectonic Setting	Most common magma type	Typical type(s) of volcanoes	Most common hazards	Examples
DIVERGENT PLATE BOUNDARY				
oceanic plates	basaltic	mid-ocean ridge; fissures and vents; shield volcanoes	lava flows; ejecta	Mid-ocean ridges, Iceland
intracontinental plates	basaltic or bimodal silicic/basaltic	varied: fissures and vents, flood eruptions, cinder cones, stratovolcanoes, caldera complexes	lava flows; explosive volcanism including pyroclastic flows, ejecta, ash fall, lahars	Columbia River (OR, WA); Rio Grande Rift (NM, CO); Basin and Range (NV, UT, CA); East African Rift
CONVERGENT PLATE BOUNDARY				
	generally intermediate, but can be silicic or basaltic	stratovolcanoes	explosive volcanism: pyroclastic flows, ejecta, lahars, ash fall	Cascades volcanoes including Mt. St. Helens; Pacific rim, Central American, and Caribbean volcanoes; Krakatoa; Tambora; Galunggung; Pelee
HOT SPOTS				
under oceanic plate	basaltic	shield volcano	lava flows	Hawaii
under continental plate	silicic	caldera complex	explosive volcanism (see above)	Yellowstone

Types of Volcanos

Cinder Cone: Volcanoes made mostly of cinders and other rock particles that have been blown into the air are called cinder cones. Cinder cones form from explosive eruptions. Because the material is loosely arranged, the cones are not elevated. They have a narrow base and steep sides such as Paricutin in Mexico. Paricutin lies on a **convergent plate boundary**.

Figure 1.38: Paricutin volcano Mexico (Cinder cone).

Shield Volcano: Volcanoes composed of quiet flows are called shield volcanoes. Because it is runny, the lava flows over a large area. After several eruptions, a dome-shaped mountain is formed such as Mauna Loa (4km over sea level) in the Hawaiian Islands.

The volcanoes of Hawaii are **Hot Spot** Volcanoes.

Composite Volcano: Volcanoes built up of alternating layers of rock particles and lava are called composite volcanoes. During the formation of a composite volcano, a violent eruption first occurs, hurling volcanic bombs, cinder and ash out of the vent. Then a quiet eruption, produces lava flow that covers the rock particles. After alternating eruptions, a cone-shaped mountain forms such as Mount Vesuvius.

Figure 1.40: The Tengger massif in Java (Composite).

Fig: Erta Ale, East African Rift valley, Ethiopia (Divergent Boundary Volcano)

REVIEW QUESTIONS

Question 7

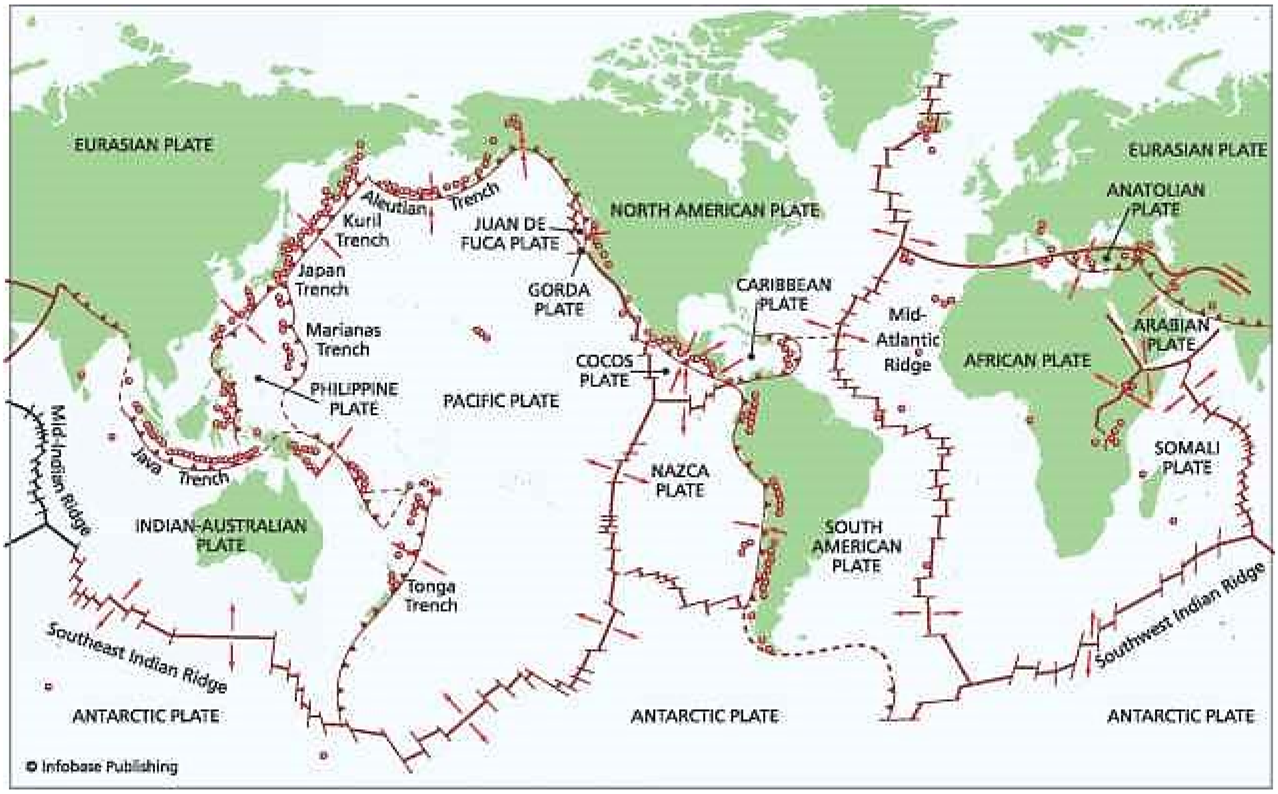


Figure:

(a) Go to Live Earthquakes Map: http://quakes.globalincidentmap.com/

Using this interactive, along with the plate boundary map above, choose 5 of the recent earthquakes and complete the table below. Note the scroll/magnifying function and incident list below the map.

Further research may be required. An example is provided.

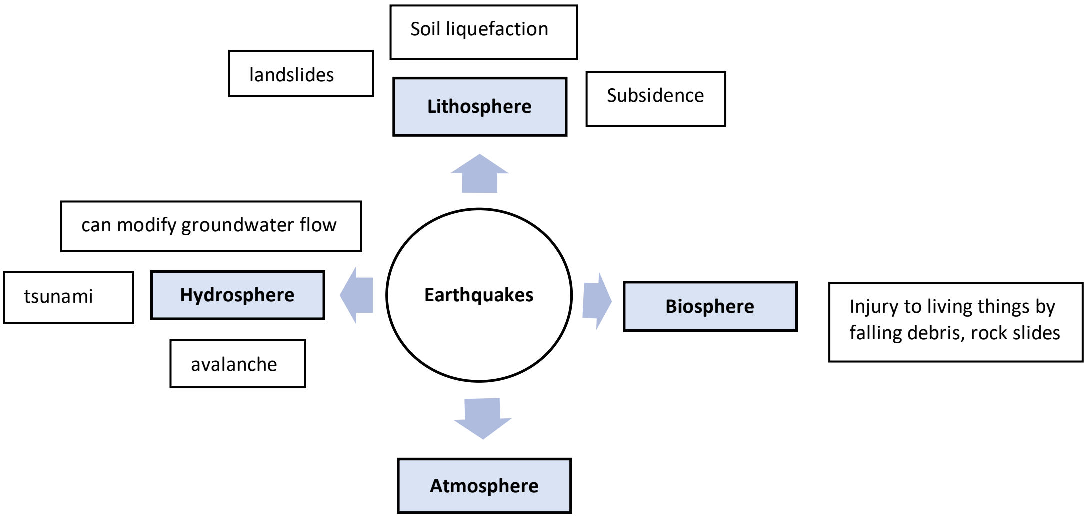
Region	**Date Time**	**Time ago (mins)**	**Magnitude**	**Depth**	**Plate(s) involved**	**Divergent, Convergent or Transform**
29km WSW of Carlsbad, CA (near Los Angeles)	18-11-2018 7.11.07	10	2	28.7	North American Plate and Pacific Plate	Transform

(b) Where are most earthquakes and volcanoes found?

(c) The most recent eruption of Kilauea in Hawaii began explosively in May 2018 but slowed by August and by the end of November 2018 no recent activity was reported. Over 700 homes were lost to the lava flows. Kilauea has been erupting *continuously* since 1983. Considerable damage has occurred over the years, including the loss of entire towns. Consider why people choose to live in known hazard zones such as active volcano sites. Provide 3 justified reasons for living in a volcanic zone.

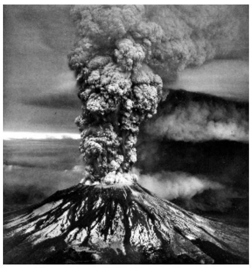
Earthquakes, volcanic eruptions, and tsunamis affect other Earth systems processes.

Earthquakes may affect other Earth system processes.



Volcanic eruptions can significantly affect other earth systems.

On May 18, 1980, Mount Saint Helens, in the state of Washington, erupted. This event altered the surrounding environment and provided scientists with an opportunity to study the effects of volcanic eruptions on the geosphere, hydrosphere, atmosphere and biosphere.



Volcanoes (an event in the geosphere) release a large amount of particulate matter into the atmosphere. These particles serve as nuclei for the formation of water droplets (hydrosphere). Rainfall (hydrosphere) often increases following an eruption, stimulating plant growth (biosphere). Particulate matter in the air (atmosphere) falls out, initially smothering plants (biosphere), but ultimately enriching the soil (geosphere) and thereby stimulating plant growth (biosphere).

Volcanoes (events in the geosphere) may release a substantial amount of hot lava (geosphere), which causes mountain glaciers (hydrosphere) to melt. Mudflows (geosphere) and flooding may occur downstream from volcanoes and may inundate streamside communities (biosphere).
Volcanoes (events of the geosphere) release a large amount of carbon dioxide (atmosphere), the raw material for sugar production in plants (biosphere). This may increase photosynthetic production and eventually increase the amount of biomass, which, after a very long time, forms coal and oil deposits (geosphere).

Volcanoes (geosphere) may emit large quantities of sulfur dioxide (atmosphere). When atmospheric sulfur dioxide combines with water (hydrosphere), sulfuric and sulfurous acid form. Rain (hydrosphere) may bring these acids to the Earth, acidifying soils (geosphere), lakes and rivers (hydrosphere). Acidic water leaches nutrients from the soil (geosphere) into the water table (hydrosphere), making the soil less fertile for plants (biosphere), and the subterranean water supply (hydrosphere) less potable for humans (biosphere). Acid rain falling on lakes and streams reduces the pH of the water (hydrosphere), which may result in a decrease in phytoplankton and zooplankton growth (biosphere). If photosynthesis is reduced, atmospheric concentrations of carbon dioxide can build up and stimulate global warming (atmosphere) which may contribute to increase melting of glaciers (hydrosphere). Tsunami can also be triggered by volcanic action.

Tsunamis can significantly affect other earth systems.

(see Review Questions for 1.1 Earth Hazards in one sphere can affect Earth processes in other spheres as well as the review questions below).

REVIEW QUESTIONS

Question 8

Read the following excerpt from a case study carried out by Hari Srinivas of GDRC Projects
https://www.gdrc.org/uem/disasters/disenvi/tsunami.html

CASE STUDY: **Indian Ocean Tsunami and its Environmental Impacts**

"At 0058 GMT on 26 December 2004, a massive earthquake of magnitude 9.0 struck the coastal area off northern Sumatra in Indonesia. A number of after shocks also occurred, some of magnitude 7.1. These earthquakes triggered tsunamis that affected Indonesia and neighbouring countries in Asia (including India, Malaysia, Maldives, Sri Lanka, and Thailand) and the east coasts of Africa (including Somalia and Yemen), causing serious damage to the coastal areas and small islands.

While the final death toll will never be known, an estimated 250,000 persons have perished in the tsunami, majority of them women and children. Millions more have been displaced or rendered homeless.

A number of observations on the impact of the tsunami on the environment were recorded in the affected countries. These related to both natural as well as man-made aspects of the environment.

Solid waste and disaster debris remain the most critical environmental problem faced by the countries. The sheer magnitude of the disaster meant that the volume and nature of the disaster debris was far beyond the coping capacities of the cities and towns that were affected. Disposing these wastes in an environmentally appropriate manner, and recycling the waste where possible (for example, crushing of concrete and brick to produce aggregate for road and building construction) have been identified as critical priorities.

Combined with the issue of waste is that of hazardous materials and toxic substances that have been inadvertently mixed up with ordinary debris. These include asbestos, oil fuel, and other industrial raw materials and chemicals. Rapid clean-up of affected areas has also resulted in inappropriate disposal methods, including air burning and open dumping, leading to secondary impacts on the environment.

Contamination of soil and water was the second key environmental impact of the tsunami. Salination of water bodies such as rivers, wells, inland lakes, and groundwater aquifers has occurred in many of the affected countries. This has also affected the soil fertility of agricultural lands, due to salination and debris contamination, which will affect yields in the medium and long term. Some water bodies have been contamination by damaged or destroyed septic tanks and toilets, with sewage infiltrating the water supply system.

UNEP reports extensive damage to environmental infrastructure, buildings and industrial sites. These include water and sanitation systems, solid waste disposal sites and waste treatment centres, particularly in urban areas (Maldives, Sri Lanka and Indonesia). Oil storage facilities have released oil and wastes into the environment, which have not been handled properly during the initial clean-up (Maldives and Indonesia).

With the earthquake epicentre less than 40 kilometres from the coast of the Sumatra island, Indonesia was the worst affected country. The resulting tsunami extensively flooded coastal areas, reaching inland from 500 metres to about two kilometres in the west coast. In some areas along rivers and estuaries, the sea surge extended more than six kilometres inland.

Besides the massive human toll of more than one million killed or displaced, the economic destruction and environmental damage of the Sumatra Island was extensive. Coral reefs, mangroves, coastal areas, wetlands, agricultural fields and forests, aquaculture areas etc. were badly damaged.

Indonesia's BAPPENAs (State Ministry of National Development Planning) damage assessment estimated that 20 percent of sea grass beds, 30 percent of coral reefs, and 25-35 percent of wetlands, and 50 percent of sandy beaches of the west coast, have been damaged. The most serious threat to coastal waters is due to the tsunami debris that was dragged into the ocean by the receding waters of the tsunami.

The on-going conversion of mangrove forests into shrimp farms and environmental destruction, were further damaged by the tsunami. Considering the critical function that mangroves play as a filter to the waters that flow from the estuaries to the ocean, their damage due to the tsunami will be incalculable – an estimated 90 percent damage has been reported to mangroves and coastal forests. Fragile wetlands and estuaries in the affected areas in Indonesia have also been affected. Preliminary analysis of satellite images have indicated subsided areas and modified flow of rivers and drainage patterns.

While the more than 70 streams and rivers in the region can be expected to be flushed clean over time, the contamination of ground water reservoirs due to saltwater intrusion, sewage, debris and hazardous materials will be much more difficult to remedy. FAO estimates that 30 percent of farmland has been affected in the north-east coast, and 70 percent in the west coast – with about 20 percent permanently damaged.

Cities and towns in the coastal area were also extensively damaged, including industrial areas and ports. The debris generated by the tsunami not only mixed different types of wastes (bricks, concrete, wood, vegetation, plastics and metals, etc.), but the backwash carried these wastes and deposited it in the ocean. Existing wastes in landfill sites (particularly those near the coasts in Banda Aceh) were also dredged out into the ocean by the tsunami wave.”

(a) Go through the above article and highlight all the earth system processes that were affected by the tsunami.

(b) List all the spheres affected by the tsunami and provide an example for each from the case study.

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(c) Which of the affected processes will likely have the greatest long-term impact in Indonesia? Why?

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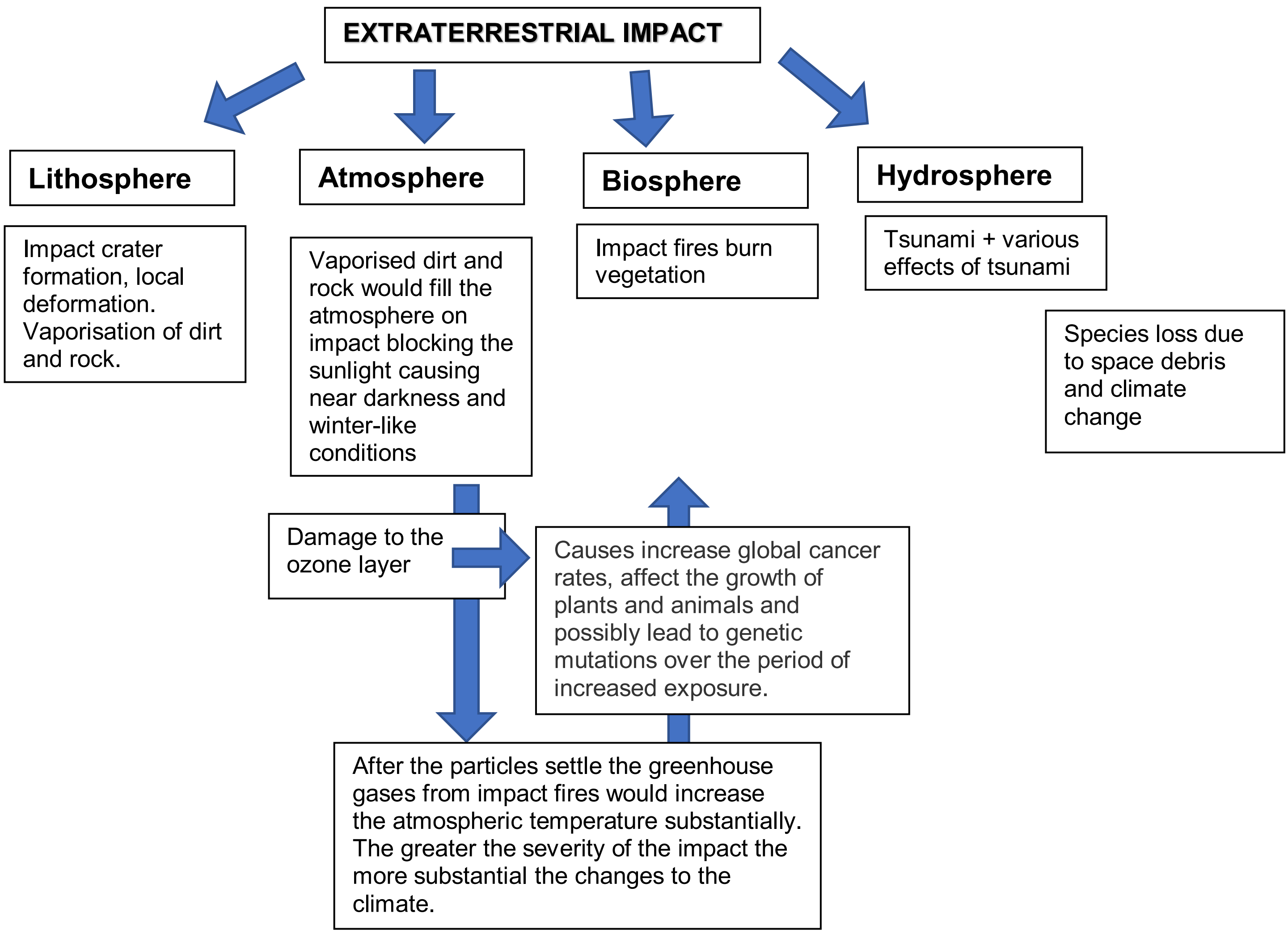
1.3 The impact of extraterrestrial bodies can affect Earth systems.

Extraterrestrial impact and how it can affect Earth systems

Below is a summary diagram of some of the possible influences an extraterrestrial impact may have on earth systems.



REVIEW QUESTIONS

Question 9

Article: Greenland impact crater could help explain disappearance of woolly mammoths and early humans.

Jamie Seidel, AFP, News Corp Australia Network, November 15, 2018 10:27am

A massive iron meteorite smashed into Greenland as recently as 12,000 years ago, leaving a crater bigger than Paris that was recently discovered beneath the ice with sophisticated radar. The crater is the first of its kind ever found on Greenland — or under any of the Earth's ice sheets — and is among the 25 largest known on Earth, said the report in the journal Science Advances.

It is estimated the asteroid would likely have been made largely of iron, measuring about 1.5km across and weighing about 12 tons. The impact which created the 31 kilometres wide crater under the Hiawatha Glacier would have had significant ripple effects in the region, possible even globally, researchers said.

But its story is just beginning to be told. If confirmed, it could have major implications for the tale of humanity itself. If confirmed, its dating could establish the Younger Dryas impact hypothesis as fact. It's a somewhat controversial idea that a large impact in North America some 11,000 to 13,000 years ago during the last Ice Age caused massive wildfires across much of the Americas and Europe, as well as unsettling the weather conveyor belt of the North Atlantic current.

This in turn lead to the extinction of many megafauna mammals, such as the mammoth and mastodons — and possibly the early humans then occupying the Americas. The hidden crater stretches nearly 20 miles (31km) wide. A prominent rim surrounds the depression.

DEEP IMPACT

It would have been a spectacle seen across much of the Northern Hemisphere — a huge fireball many times brighter than the Sun, streaking across the sky.

Then it struck Greenland.

The resulting impact would have flashed across North America — sending molten projectiles spearing into forests over thousands of square kilometres and setting off enormous fires. And then the tsunamis and clouds of vaporised ice and bedrock circled the globe.

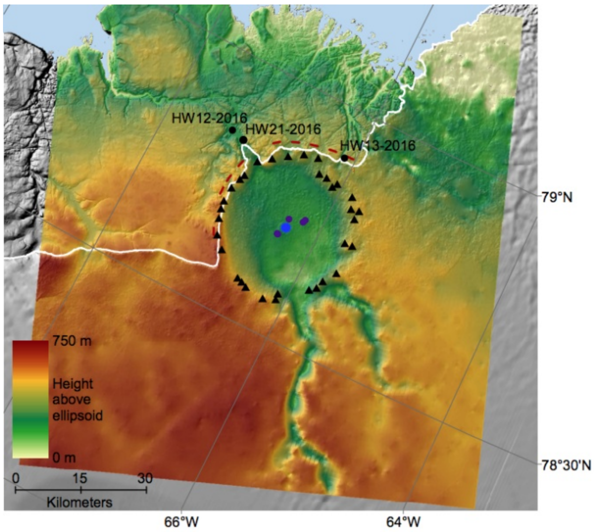


Figure: Topography under Hiawatha glacier in Greenland, mapped with airborne radar data (1997 to 2014, NASA; 2016 Alfred Wegener Institute). Black triangles and purple circles are elevated peaks around the rim and centre. Dotted red lines and black circles show locations of additional sampling. (Credit: Kjær et al. / Science Advances)

The impact would have been huge. But nowhere near as devastating as the dinosaur-killer strike that created the Chicxulub impact crater — some 200km wide — in Mexico some 66 million years ago.

"There would have been debris projected into the atmosphere that would affect the climate and the potential for melting a lot of ice, so there could have been a sudden freshwater influx into the Nares Strait between Canada and Greenland that would have affected the ocean flow in that whole region,"

said co-author John Paden, courtesy associate professor of electrical engineering and computer science at Kansas University.

"The evidence indicates that the impact probably happened after the Greenland Ice Sheet formed, but the research team is still working on the precise dating." That would suggest that the impact happened sometime before the end of the Pleistocene era some 11,700 years ago.

(a) From the article information only, identify all the spheres affected by this impact. Provide an example for each.

(b) Identify any affects in this article that are not shown in the previous summary diagram.

Practical Investigation

Earth Impact Activity –
How Big is That Crater?

Summary

This activity poses the question: What would happen if a meteor or comet impacted Earth? Students simulate an impact in a container of sand using various-sized rocks, all while measuring, recording and graphing results and conclusions. Then students brainstorm ways to prevent an object from hitting the Earth.

Scientist play a vital role in both the observation of what are called Near-Earth objects (NEO), as well as any future destruction of them.

After this activity, students should be able to:

- Explain the relationship between various-sized objects, impact speed and crater size (and have data to back it up).
- Describe at least one way to prevent a Near-Earth object from impacting Earth.

Materials List

Your group will need:

- 1 plastic container, about 60cm wide and 5-12 cm high
- enough sand to fill the entire container, to at least 4cm deep
- 4 different-sized, spherical-shaped rocks of equal density
- 30cm ruler
- Metre ruler
- 1 sheet of blank paper
- **How Big is That Crater**? Worksheet (below)

Introduction

What would happen if a giant meteor hit the Earth? Would civilisation as we know it continue to exist? Would the entire planet disintegrate because of the blast?

According to scientists, an event like this is possible in the future. To be prepared for such a potential catastrophe, scientists are working on solutions to prevent impact events from happening.

The Earth already passes through the orbit of many comets and asteroids. Fortunately, no object of appreciable size has impacted the Earth in modern times. Our planet has been hit by these objects before however; evidence can be found in the craters that exist all over the world. It is thought that dinosaurs became extinct after a large meteor stuck Mexico millions of years ago. If another impact as large as that one hit the Earth today, it would be just as devastating as it was then.

How could you prevent an asteroid or comet from hitting Earth? Today you will come up with a design for such an Impact defence strategy. To design a solution, scientists first learn more about the problem. For example, in 2005, NASA's deep impact probe intentionally slammed into a comet to help scientists understand the composition of comets first hand. In this activity, we will look at the devastating effects of falling objects (similar to what we would see if a meteor hit the Earth). This will help us make an informed design for a way to prevent a future catastrophe.

Procedure

1. Fill the container with sand to around 4cm deep
2. Decide which students in your group will start in the following roles: data recorder, crater measurer, and meteoroid dropper. Take turns at each role throughout the activity.

NOTE:

- *Remember to drop — not throw — the rocks, otherwise this will skew your data.*
- *For accuracy in measurements, be careful when removing your rocks from the sand so as to minimise any alterations to the crater depth.*

Experiment 1 (20 min)

In this experiment you will observe the crater size made by meteoroids (rocks) of different sizes.

1. Make predictions in the first question of your worksheet, describing what you think will happen as you drop the three meteoroids (rocks) into the sand container. Which rock will make the largest crater and why? You must drop the rocks from the exact same height. Why? (answer Qu 2) Record the decided height (Qu 3)
2. Carry out the experiment either starting with the smallest rock and move up in size, or the largest rock and move down in size.
3. Drop each rock three times and record the crater diameter, crater depth (after removing the rock from the container), as well as any other observations. Measure the crater diameter in centimetres, depending on the class convention.
4. Complete the questions under Experiment 1 on the worksheets.

Experiment 2 (20 min)

In this experiment, you will test the size of your craters in relationship to the speed of the impact of the rocks.

1. Choose only one of your rocks. (Why must you use the same rock for this experiment? Answer Qu 7)
2. Make predictions of what will happen with regards to the size of the craters if you increase your drop height. (Qu 8) Design your experiment based on ….. "As the drop height increases how will the crater size change?"
3. Plan your experiment and create a table for data collection (Qu 9,10). The data table should be similar to the first experiment, with rock height replacing rock size. Choose three rock drop heights that will be easy to repeat, such as, knee height, waist height, shoulder height, etc.
4. If time permits make a graph of crater diameter versus impact speed (height). (attach on graph paper)
5. Use your findings to make a prediction about what effect the velocity of a meteor would have on a crater it creates on the Earth.

Designing an Earth Protector (5 min)

Generate ideas for how to prevent the catastrophe that would ensue if a large meteor hit the Earth.

1. Reflect on your experimental results and consider what your new understanding of impact tells you about an actual meteor hitting the Earth. Note some ways in which this knowledge could be applied to the design of an Earth Protector, a device that would prevent a meteor from damaging the Earth.
2. Brainstorm ideas for designing an Earth Protector. In the designated space on the worksheet, draw a diagram of your Earth Protector, labelling the various components.
3. Discuss the advantages and disadvantages of various methods with another group. Choose one of the designs and a spokesperson to communicate that design to the rest of the class. Draw a diagram to help explain your idea.

WORKSHEET: Earth Impact Activity – How Big is That Crater?

Experiment 1: Crater Size

1. Predict the size of the crater based on the size of your rock.

   ____

   ____

   ____

2. The rocks all must be dropped from the same height. Why? ________________________________

   ____

   ____

3. What height are the rocks being dropped from? ____

4. Observe the crater size made by meteoroids (your rock drops) of different sizes. Record your observations in the table below. Once you have recorded three trial drops for each of the 4 objects, average the results per rock.

Rock	Crater diameter	Crater depth	Observations
Rock 1 (diameter = _______)			
Drop1			
Drop 2			
Drop 3			
Average			
Rock 2 (diameter = _______)			
Drop1			
Drop 2			
Drop 3			
Average			
Rock 3 (diameter = _______)			
Drop1			
Drop 2			
Drop 3			
Average			
Rock 4 (diameter = _______)			
Drop1			
Drop 2			
Drop 3			
Average			

5. In the space below, make an x-y plot of the average crater diameter versus rock number.

6. Based on the trends that you observed in your data and transferred to your plot, predict the effect on the size of crater should a meteor impact the Earth.

____

____

Experiment 2: Crater Size Related to Speed of Impact

7. Why must the same rock be used for this experiment? ____

____

8. Predict the effect on the size of the crater should you increase the height from which you drop your object. Write this as a ***hypothesis***

____

____

9. Increasing the height effectively increases the impact velocity. Why this is a better scientific strategy than just dropping the rock at varying speeds?

____

____

____

10. Label the table below to best record your data.

11. Use your findings to make a prediction about what effect the velocity of a meteor would have on a crater it creates once it impacts Earth.

12. Were your predictions correct? If not, why?

13. Consider what the world would be like if a meteor were to hit Earth.

What would be the impact on the environment? How would it affect our society?

14. How did your results compare with your prediction in Qu 8? Was your hypothesis supported?

15. Calculate the impact velocity for the second experiment.

This can be determined through using formulae.

Either $v=(2gh)^{1/2}$

or derive it from your understanding of the law conservation of energy PE = KE

$PE = mgh$ and $KE=1/2mv^2$

Impact Velocity is:

16. Designing an Impact Defence Strategy

In the designated space below, draw a diagram of your Impact Defence Strategy, labelling the various components

If time permits, students can investigate craters made by differently-shaped rocks. They might also observe the craters created when rocks impact the sand from an angle by underhand tossing of them into the container. It is near impossible to make exactly-the-same angled throws into the sand in order to collect and analyse data, but at least students can observe some of the effects of this type of impact and compare it to the vertical drops done earlier.

1.4 Earthquake and volcanic eruption data can be used to map hazardous zones and to predict future events.

Earth Hazards are monitored by measuring various factors
Data can contribute to further predictions of Earth hazards

Monitoring and Predicting Earthquakes

Why should earthquakes be monitored?

- To study earthquakes and their effects, where they occur, how big and how often
- To assess the vulnerability of structures – prevent collapse and minimise structural damage
- To assess the risk – alerts, warnings and alarms for preparation and emergency response

Multiple factors are examined when monitoring an earthquake (ref: Seismic Research Centre)

Earthquake Source Parameters
- origin time and rupture duration.
- earthquake location – epicentre and depth.
- earthquake size – magnitude, rupture area.
- rupture process – focal mechanism.

Seismic Wave Travel Path
- velocity models, needed to locate earthquakes.
- Attenuation (energy loss) functions, to quantify hazard.

Site Effects
- site amplification of ground motion by sediments or topography.

Regional Earthquake Catalogue
- activity rate, the proportion of small to large events, maximum credible magnitudes for particular structures or areas.
- delineation of active faults.
- an earthquake recurrence model.

Seismic Stations

Earthquakes are monitored at seismic stations in 2 ways – ***intensity*** and ***magnitude***

Seismographs and seismometers are used to measure ground motion.
Seismographs record that motion as a seismogram.

Historically seismograms were recorded on paper using rotating drums.

Modern seismographs are digital.

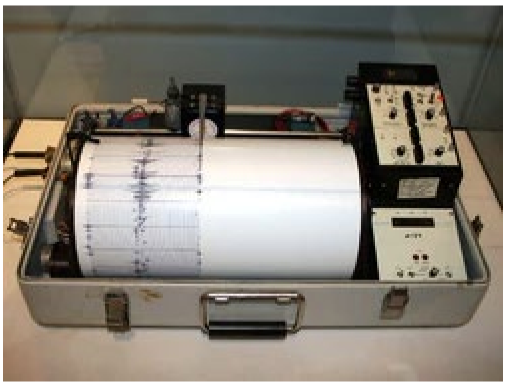


Figure: Example of an old model Seismograph

Figure: Example of a modern digital Seismograph (Australian Gecko Brand)

Earthquakes produce shock waves that pass through the earth and can travel extremely long distances. Seismic stations detect and record the type and magnitude of these waves.

There are 3 main types of waves produced by tectonic activity

P or **PRIMARY WAVES** - fastest waves travel through solids, liquids, or gases. They are compressional waves as the material movement is in the same direction as wave movement.

S or **SECONDARY WAVES** - slower than P waves, travel through solids only.

SHEAR WAVES - move material perpendicular to wave movement.

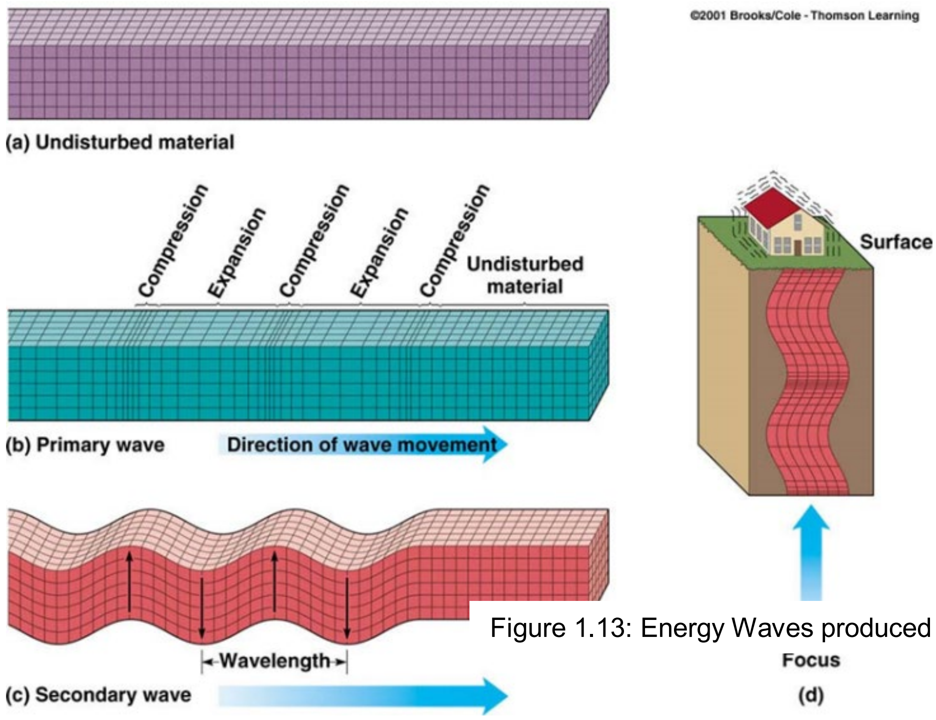
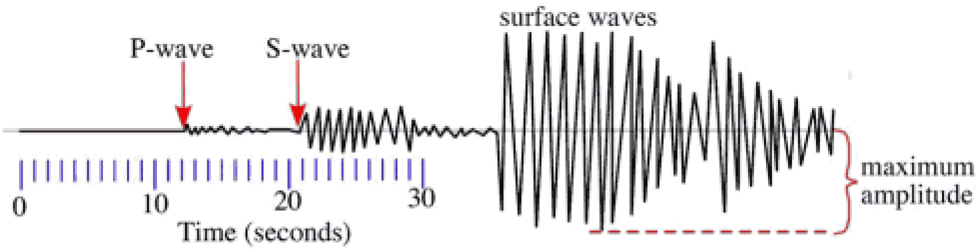


Figure:

Figure 1.13: Energy Waves produced by Earthquakes.

P Waves and S waves are shown on a seismogram



Figure

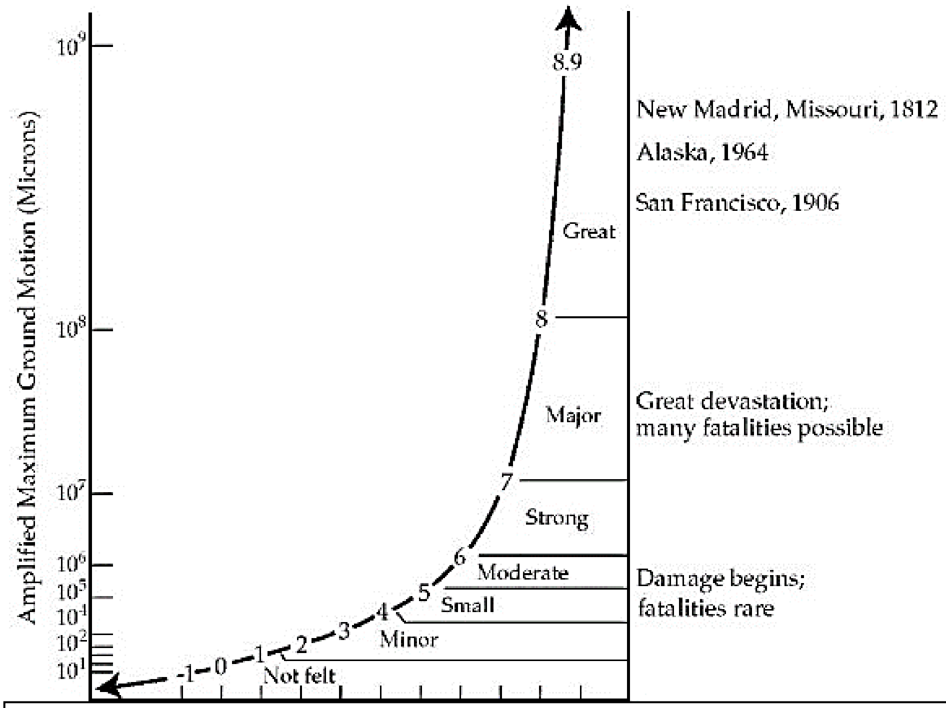
Recording and analysing the waves from an earthquake received at multiple stations enables scientists to locate the epicentre and focus of an earthquake.

The *difference* in arrival time between the P and S waves can be used to calculate the distance of the earthquake's epicentre from the seismometer.

Locating the epicentre enables scientists to *map hazard zones*, *monitor the region* and *make predictions* for the future.

Earthquake magnitude is measured on the Richter scale

The Richter scale is logarithmic, mean whole-number jumps indicate a tenfold increase. In this case, the increase is in wave amplitude. That is, the wave amplitude in a level 6 earthquake is 10 times greater than in a level 5 earthquake, and the amplitude increases 100 times between a level 7 earthquake and a level 9 earthquake. The amount of energy released increases 31.7 times between whole number values.



1954 Adelaide Earthquake Measured 5.6 on the Richter scale. No deaths, 16 Injured.

MISS TEENAGER, 1954 — SEE PAGE 25.

Creator of Alice in Wonderland—Page 20

THE NEWS

Today's News Today!

EARTHQUAKE ROCKS STATE

Terrified people run into streets: masonry crashes

An earthquake rocked Adelaide and a large area of South Australia for 20 seconds from 3.40 a.m. today.

Tens of thousands of men, women, and children were momentarily terrified by the noise of their trembling homes.

5 HOMES "BEYOND REPAIR"

40-lb. lump hit her pillow

Figure 1.14: 1954 newspaper front cover.

Figure 1.15: House damaged during the 1954 Earthquake.

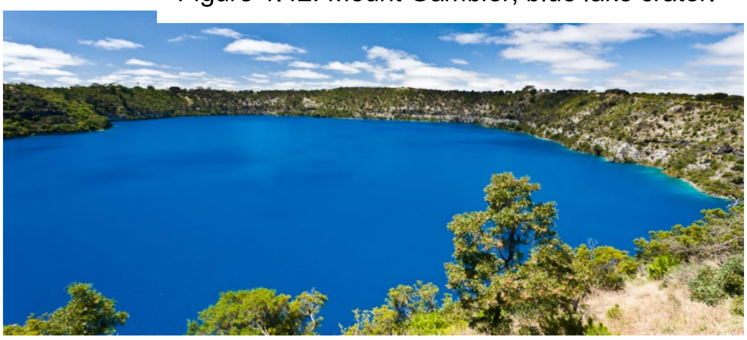
Earthquake intensity is measured on the Mercalli scale

Figure: Simplified Mercalli Scale

I. Instrumental	Generally not felt by people unless in favorable conditions.
II. Weak	Felt only by a couple people that are sensitive, especially on the upper floors of buildings. Delicately suspended objects (including chandeliers) may swing slightly.
III. Slight	Felt quite noticeably by people indoors, especially on the upper floors of buildings. Many do not recognize it as an earthquake. Standing automobiles may rock slightly. Vibration similar to the passing of a truck. Duration can be estimated. Indoor objects (including chandeliers) may shake.
IV. Moderate	Felt indoors by many to all people, and outdoors by few people. Some awakened. Dishes, windows, and doors disturbed, and walls make cracking sounds. Chandeliers and indoor objects shake noticeably. The sensation is more like a heavy truck striking building. Standing automobiles rock noticeably. Dishes and windows rattle alarmingly. Damage none.
V. Rather Strong	Felt inside by most or all, and outside. Dishes and windows may break and bells will ring. Vibrations are more like a large train passing close to a house. Possible slight damage to buildings. Liquids may spill out of glasses or open containers. None to a few people are frightened and run outdoors.
VI. Strong	Felt by everyone, outside or inside; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken; books fall off shelves; some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight to moderate to poorly designed buildings, all others receive none to slight damage.
VII. Very Strong	Difficult to stand. Furniture broken. Damage light in building of good design and construction; slight to moderate in ordinarily built structures; considerable damage in poorly built or badly designed structures; some chimneys broken or heavily damaged. Noticed by people driving automobiles.
VIII. Destructive	Damage slight in structures of good design, considerable in normal buildings with a possible partial collapse. Damage great in poorly built structures. Brick buildings easily receive moderate to extremely heavy damage. Possible fall of chimneys, factory stacks, columns, monuments, walls, etc. Heavy furniture moved.
IX. Violent	General panic. Damage slight to moderate (possibly heavy) in well-designed structures. Well-designed structures thrown out of plumb. Damage moderate to great in substantial buildings, with a possible partial collapse. Some buildings may be shifted off foundations. Walls can fall down or collapse.
X. Intense	Many well-built structures destroyed, collapsed, or moderately to severely damaged. Most other structures destroyed, possibly shifted off foundation. Large landslides.
XI. Extreme	Few, if any structures remain standing. Numerous landslides, cracks and deformation of the ground.
XII. Catastrophic	Total destruction – everything is destroyed. Lines of sight and level distorted. Objects thrown into the air. The ground moves in waves or ripples. Large amounts of rock move position. Landscape altered, or leveled by several meters. Even the routes of rivers can be changed.

<u>**Monitoring and predicting Volcanic Eruptions**</u>

Figure 1.42: Mount Gambier, blue lake crater.



Volcanoes can be unpredictable. Some erupt regularly, others have not erupted in modern history. Scientists classify them as *active*, *dormant* or *extinct*.
An active volcano is one that erupts either continually or periodically such as Mount Katmai in Alaska and Mount St. Helens in the Cascade Range.

Figure 1.44: Extinct volcano, Iceland.

A volcano that has been known to erupt within modern times but is now inactive is classified as a **dormant** volcano. Mount Gambier in the SE of South Australia is an example of dormant volcano.

A volcano not known to have erupted within modern history is classified as an **extinct** volcano. They have been worn away almost to the level of their magma chamber. Scientists can be wrong. Mount St. Helens was considered to be dormant but erupted after long periods of inactivity.

Figure 1.43: **Active** volcano, Mount Nyiragongo, Democratic Republic of the Congo.

To protect life and property it is beneficial for scientists to monitor volcanoes to better understand them and hopefully predict future eruptions.

There are 3 key ways volcanoes can be monitored and eruptions predicted

Assessing seismic activity:
Seismometers placed around the region of activity are used to record any movement data and can provide early warning of any changes beneath the volcano.

Detecting gases:
Changes in the composition of volcanic gases are an important early warning of changes below the surface. Some gases can be monitored from a distance (from the ground or air) using infrared devices, but to obtain more accurate data, air samples need to be collected and analysed. This can be achieved with instruments placed on the ground close to the source of the gases or by collecting samples of the air and analysing them in a lab.

Measuring deformation:
There are two main ways to measure ground deformation at a volcano.

- a **Tiltmeter**: a sensitive three-directional level that senses small changes in the tilt of the ground.
- using **GPS** (global positioning system) technology. GPS is more effective than a tiltmeter because it provides information on how *far* the ground has moved.

Along with these monitoring techniques knowing a volcanoes eruptive history is vital when making predictions.

"There is no doubt that the eruptive history of a volcano is the main key for long-term prediction," says Dr. Yuri Doubik (Tyson, 1996)

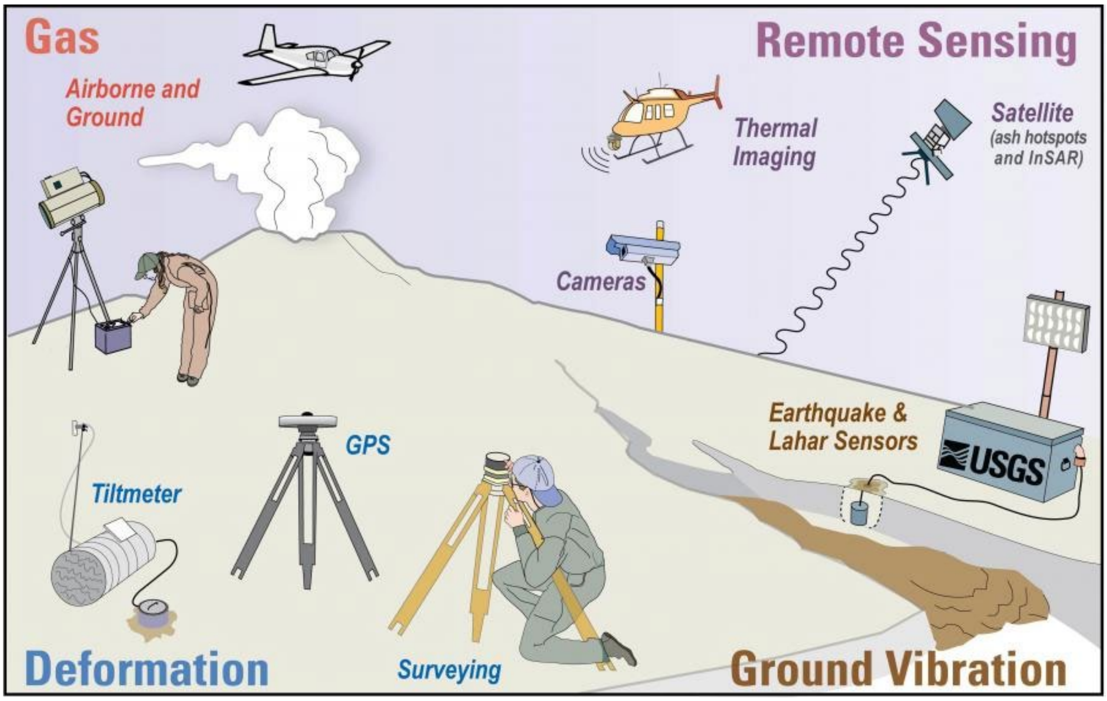


Figure: Volcanic monitoring types and methods

REVIEW QUESTIONS

Question 10

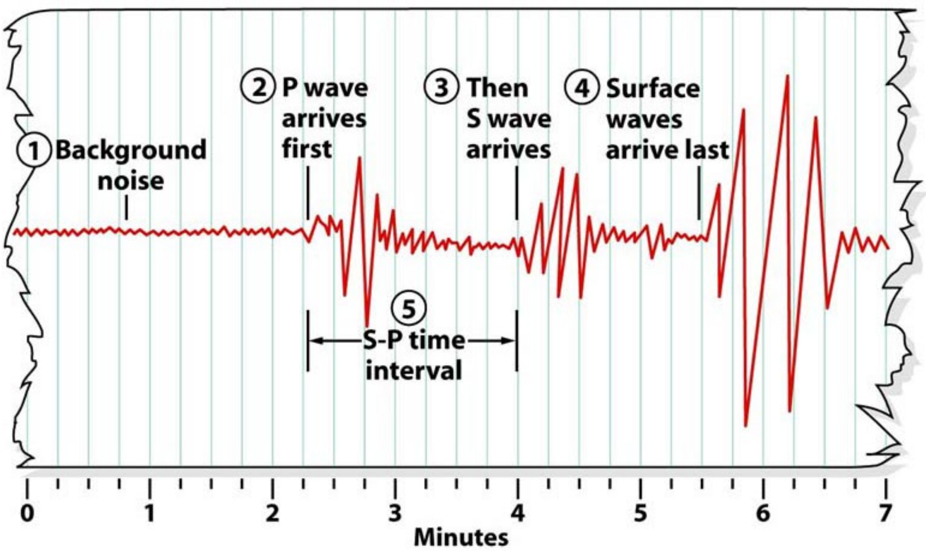
(a) Why does the Richter scale use a logarithmic scale to measure Earthquakes?

____

____

____

(b) Using the seismogram below to answer the following questions



The earthquake occurred at time 0.

i. At what time did the first P wave arrive? ___________________________

ii. At what time did the first S wave arrive? ___________________________

iii. What is the S-P time interval? ___________________________

iv. What is the S-P time used to determine? ___________________________

____

(c) Predicting when a volcano is about to erupt is not an exact science.
Eruptions can occur without any warning signs.

List some signs that may indicate the possibility of an eruption: ___________________________

____

____

____

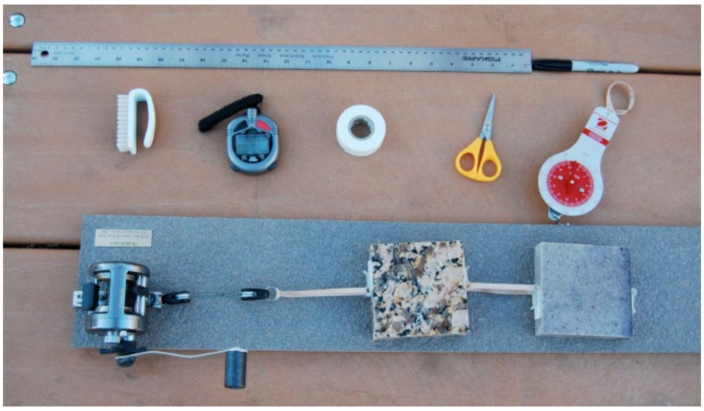
____

____

____

PRACTICAL INVESTIGATION

Can earthquakes be predicted?



Quake caster Apparatus

In this **summative assessment task** you will design and implement an investigation, using the 'Quake Caster' apparatus (shown above), to test a specific hypothesis about earthquakes.

You may choose your own hypothesis. Some examples include:

"Earthquakes are periodic"
"Earthquakes are time predictable"
"Earthquakes are slip predictable"
"Earthquakes are stress predictable"
"Earthquakes occur randomly and vary randomly in size"

You may choose one of these, or another appropriate hypothesis by negotiation.

CONDITIONS:

Working in groups of 2 or 3, you will have one hour of lesson time to familiarise with the Quake Caster and to plan your investigation. In the subsequent lesson, you will complete your data collection, followed by 1 week to submit your written report.
Reports must be written individually.

REPORT:

Reports must be written individually and have a maximum of 1000 words (Excluding materials, method, results).
Your work will be assessed according to the performance standards on the next page.
Reports should include:

● **Introduction:**
A clear statement of the aim of your investigation, the specific hypothesis that you tested, an identification of the dependent and independent variables, a brief geological background and statement of the importance of this area of scientific investigation as well as an indication of some important past work done in this area.

● **Equipment used:**
A well labelled diagram or annotated photograph of the Quake Caster, with a list of other equipment used.

● **Method:**
A sequence of steps that accurately describe how your data was collected;

● **Results:**
A table together with an appropriate graph/s are required.

● **Discussion:**
Your discussion should include an identification of the precision and reliability of your data, the possible sources of error, the reliability of transfer of results to real situations and a suggestion of ways in which your investigation might have been improved.

● **Conclusion:**
A clear and concise statement of your findings with particular reference to whether your hypothesis was supported or not supported.

● **References:**
Harvard or Oxford referencing system is required by SACE.

Performance Standards for Stage 1 Earth and Environmental Science

	Investigation, Analysis and Evaluation	Knowledge and Application
A	Designs a logical, coherent, and detailed earth and environmental science investigation. Obtains, records, and represents data, using appropriate conventions and formats accurately and highly effectively. Systematically analyses data and evidence to formulate logical conclusions with detailed justification. Critically and logically evaluates procedures and their effects on data.	Demonstrates deep and broad knowledge and understanding of a range of earth and environmental science concepts. Applies earth and environmental science concepts highly effectively in new and familiar contexts. Demonstrates a comprehensive understanding of science as a human endeavour. Communicates knowledge and understanding of earth and environmental science coherently with highly effective use of appropriate terms, conventions, and representations.
B	Designs a well-considered and clear earth and environmental science investigation. Obtains, records, and displays findings of investigations, using appropriate conventions and formats mostly accurately and effectively. Logically analyses data and evidence to formulate suitable conclusions with reasonable justification. Logically evaluates procedures and their effects on data.	Demonstrates some depth and breadth of knowledge and understanding of a range of earth and environmental science concepts. Applies earth and environmental science concepts mostly effectively in new and familiar contexts. Demonstrates some depth of understanding of science as a human endeavour. Communicates knowledge and understanding of earth and environmental science mostly coherently with effective use of appropriate terms, conventions, and representations.
C	Designs a considered and generally clear earth and environmental science investigation. Obtains, records, and displays findings of investigations, using generally appropriate conventions and formats with some errors but generally accurately and effectively. Makes some analysis of data and evidence to formulate generally appropriate conclusions with some justification. Evaluates some procedures and some of their effects on data.	Demonstrates knowledge and understanding of a general range of earth and environmental science concepts. Applies earth and environmental science concepts generally effectively in new or familiar contexts. Describes some aspect of science as a human endeavour. Communicates knowledge and understanding of earth and environmental science generally effectively, using some appropriate terms, conventions, and representations.
D	Prepares the outline of a earth and environmental science investigation. Obtains, records, and displays findings of investigations, using conventions and formats inconsistently, with occasional accuracy and effectiveness. Describes data and formulates a simple conclusion. Attempts to evaluate procedures or suggest an effect on data.	Demonstrates some basic knowledge and partial understanding of earth and environmental science concepts. Applies some earth and environmental science concepts in familiar contexts. Identifies some aspect of science as a human endeavour. Communicates basic earth and environmental science information, using some appropriate terms, conventions, and/or representations.
E	Identifies a simple procedure for an earth and environmental science investigation. Attempts to record and display some descriptive results of an investigation, with limited accuracy or effectiveness. Attempts to describe results and/or attempts to formulate a conclusion. Acknowledges that procedures affect data.	Demonstrates limited recognition and awareness of earth and environmental science concepts. Attempts to apply earth and environmental science concepts in familiar contexts. Shows some recognition of science as a human endeavour. Attempts to communicate information about earth and environmental science.

Stage 1 Earth and Environmental Science

Investigation Folio Task: Science as a Human Endeavour

Unlocking Tsunami Secrets

Introduction and Purpose of task:

"Science cannot be just in isolation. Science and society have to go hand-in-hand"
Satish Singh (Expedition Co-Leader: Megatera)

Geological hazards can be a threat beyond the countries in which they originate, causing wide scale devastation and deaths across national boundaries. Attempting to tackle an unstoppable, massive hazard such as earthquake generated tsunami takes effort on a global scale. In this task you will investigate how scientists are working to reduce the impact of tsunamis.

TASK: *Prepare a scientific communication, using a format of your choice and the information you have researched, analysed and connected to the Science as a Human Endeavour understanding.*

To complete this task you will need to consider the following stimulus materials and follow the steps outlined.

1. Go to the following the 'Schmidt Ocean Institute' website. https://schmidtocean.org/
   Explore the website and investigate the mission/purpose of this organisation.
   Search 'Tsunami' to find further information on their **Megatera Expedition.**

2. Watch- "FK150523 Megatera – Conclusions Final Video"
   - https://www.youtube.com/watch?time_continue=546&v=LgCILHbIYoA
   - or
   - https://schmidtocean.org/cruise-log-post/megatera-final-video/

3. Investigate further (beyond this website) the steps being made to reduce the impact of tsunami. Consider the involvement of various organisations, countries, scientists and the technology used.

4. **Choose at least one** of the Science as a Human Endeavour understandings, (*see SHE criteria below*) and *link* it to the information you have researched as a **focus** for your scientific communication. Consider how the understanding is demonstrated by the information you have found.

<u>Your report **must** include the following:</u>

An introduction, which links the focus of your analysis to the SHE understanding(s) chosen
Relevant earth science concepts and background information
An explanation of the impact of earthquake generated tsunami on society and how science is approaching the challenge with specific reference to aspects of the SHE Understanding(s).
A conclusion which provides a summary of your report.
In text referencing and Reference list using Harvard Referencing

<u>Your report *could* also include information related to:</u>

Scenarios of what could happen if this hazard is not effectively investigated and solutions sought.
The current at risk countries/regions
The countries involved in the research
Issues relating to the impact of Tsunami e.g. to the environment, country economies, etc.

SHE

Your research and article/report should have a focus on at least one of the understandings of Science as a Human Endeavour listed below:

Communication and Collaboration

Science is a global enterprise that relies on clear communication, international conventions, and review and verification of results.

Collaboration between scientists, governments, and other agencies is often required in scientific research and enterprise.

Development

Development of complex scientific models and/or theories often requires a wide range of evidence from many sources and across disciplines.

New technologies improve the efficiency of scientific procedures and data collection and analysis. This can reveal new evidence that may modify or replace models, theories, and processes.

Influence

Advances in scientific understanding in one field can influence and be influenced by other areas of science, technology, engineering, and mathematics.

The acceptance and use of scientific knowledge can be influenced by social, economic, cultural, and ethical considerations.

Application and Limitation

Scientific knowledge, understanding, and inquiry can enable scientists to develop solutions, make discoveries, design action for sustainability, evaluate economic, social, cultural, and environmental impacts, offer valid explanations, and make reliable predictions.

The use of scientific knowledge may have beneficial or unexpected consequences; this requires monitoring, assessment, and evaluation of risk, and provides opportunities for innovation.

Science informs public debate and is in turn influenced by public debate; at times, there may be complex, unanticipated variables or insufficient data that may limit possible conclusions.

Assessment Conditions:

3 weeks to complete. Class time provided for research and support.

Students may submit one draft for feedback.

Word Count: maximum of 1000 words, if written, 6 minutes for an oral presentation, or equivalent if a multimodal product.

Assessment Criteria

Knowledge and Application: KA1 3, 4

Performance Standards for Stage 1 Earth and Environmental Science

	Investigation, Analysis, and Evaluation	Knowledge and Application
A	Designs a logical, coherent, and detailed earth and environmental science investigation. Obtains, records, and represents data, using appropriate conventions and formats accurately and highly effectively. Systematically analyses and interprets data and evidence to formulate logical conclusions with detailed justification. Critically and logically evaluates procedures and their effects on data.	Demonstrates deep and broad knowledge and understanding of a range of earth and environmental science concepts. Develops and applies earth and environmental science concepts highly effectively in new and familiar contexts. Critically explores and understands in depth the interaction between science and society. Communicates knowledge and understanding of earth and environmental science coherently with highly effective use of appropriate terms, conventions, and representations.
B	Designs a well-considered and clear earth and environmental science investigation. Obtains, records, and represents data, using appropriate conventions and formats mostly accurately and effectively. Logically analyses and interprets data and evidence to formulate suitable conclusions with reasonable justification. Logically evaluates procedures and their effects on data.	Demonstrates some depth and breadth of knowledge and understanding of a range of earth and environmental science concepts. Develops and applies earth and environmental science concepts mostly effectively in new and familiar contexts. Logically explores and understands in some depth the interaction between science and society. Communicates knowledge and understanding of earth and environmental science mostly coherently with effective use of appropriate terms, conventions, and representations.
C	Designs a considered and generally clear earth and environmental science investigation. Obtains, records, and represents data, using generally appropriate conventions and formats with some errors but generally accurately and effectively. Undertakes some analysis and interpretation of data and evidence to formulate generally appropriate conclusions with some justification. Evaluates procedures and some of their effects on data.	Demonstrates knowledge and understanding of a general range of earth and environmental science concepts. Develops and applies earth and environmental science concepts generally effectively in new or familiar contexts. Explores and understands aspects of the interaction between science and society. Communicates knowledge and understanding of earth and environmental science generally effectively, using some appropriate terms, conventions, and representations.
D	Prepares the outline of an earth and environmental science investigation. Obtains, records, and represents data, using conventions and formats inconsistently, with occasional accuracy and effectiveness. Describes data and undertakes some basic interpretation to formulate a basic conclusion. Attempts to evaluate procedures or suggest an effect on data.	Demonstrates some basic knowledge and partial understanding of earth and environmental science concepts. Develops and applies some earth and environmental science concepts in familiar contexts. Partially explores and recognises aspects of the interaction between science and society Communicates basic earth and environmental science information, using some appropriate terms, conventions, and/or representations.
E	Identifies a simple procedure for a earth and environmental science investigation. Attempts to record and represent some data, with limited accuracy or effectiveness. Attempts to describe results and/or interpret data to formulate a basic conclusion. Acknowledges that procedures affect data.	Demonstrates limited recognition and awareness of earth and environmental science concepts. Attempts to develop and apply earth and environmental science concepts in familiar contexts. Attempts to explore and identify an aspect of the interaction between science and society Attempts to communicate information about earth and environmental science.

Figure 1.1

https://commons.wikimedia.org/wiki/File:Earth-cutaway-schematic-english.svg

Figure 1.2

https://commons.wikimedia.org/wiki/File:Tectonic_plates_de.png

Figure 1.3

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Figure 1.4

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Figure 1.5

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Figure 1.6

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Figure 1.8

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Figure 1.9

https://www.nationalgeographic.org/encyclopedia/ring-fire/

Figure 1.10

https://www.google.com.au/search?hl=en-AU&q=earthquake+in+the+philippines&tbm=isch&source=iu&ictx=1&tbs=simg:CAESrQIJ0CD1h0pL7cMaoQILEKjU2AQaBAgVCAMMCxCwjKcIGmIKYAgDEiiUGOkUlxjmFOEV4BWiDfsK4hWAC8Yr4DncOd05ij-aP4g_13jmJP5A_1GjBHB3c10dkVjSb7-QT5SWkUyzazDW5xZB0XAWIdDN2UToYAH-oTidnMwsoWaIkcCk8gBAwLEI6u_1ggaCgoICAESBDQdc5MMCxCd7cEJGowBChkKBnN0cmVldNqliPYDCwoJL20vMDFjOGJyChcKBGN1cmLapYj2AwsKCS9tLzA5cDNqegocCglkaXJ0IHJvYWTapYj2AwsKCS9tLzA2bm1qdgocCgplYXJ0aHF1YWtl2qWI9gMKCggvbS8wMnI5NwoaCgdtaW5pYnVz2qWI9gMLCgkvbS8wNDVqc2MM&fir=ek2JjwBJv1IN0M%253A%252C9JUAATHFMHb0JM%252C_&usg=AI4_-kROhB-gxqxWOyjpUEnXnXA_ORTKHQ&sa=X&ved=2ahUKEwjgtcycnerdAhVTMt4KHSutDmoQ9QEwAHoECAUQBA&safe=active&ssui=on#imgrc=ek2JjwBJv1IN0M:

Figure 1.11

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Figure 1.12

http://zackeeney.com/earthquakes-magnitude-and-success/

Figure 1.13

https://www.google.com.au/search?hl=en-AU&q=does+s+waves+move&tbm=isch&source=iu&ictx=1&tbs=simg:CAESzAIJaqEPoxWLKXIawAILEKjU2AQaBAgVCAkMCxCwjKcIGmIKYAgDEiiyE4wKqBS3A-MInRSbFJ8UjQiOCr02piiaPsM2lT63Pq0-qii5KKE-GjAZ1Q1-X-5o0TIq3L1xxFORyJRhDSW_1UWZaheHVE9SnI-DqYT3bhEsBk0AvDdQNSr0gBAwLEI6u_1ggaCgoICAESBLhNTWEMCxCd7cEJGqsBChoKB2RpYWdyYW3apYj2AwsKCS9tLzAydjBtMgomChJzaGlwcGluZyBjb250YWluZXLapYj2AwwKCi9tLzA2NHJkZjgKIQoNcGFwZXIgcHJvZHVjdNqliPYDDAoKL20vMGg4cDU5agobCghwYXJhbGxlbNqliPYDCwoJL20vMDMwemZuCiUKEmNvbXBvc2l0ZSBtYXRlcmlhbNqliPYDCwoJL20vMDE0cXpyDA&fir=1wmzy5q7qWxWFM%253A%252CO8xxwCbTXm4zsM%252C_&usg=AI4_-kTXkIwRMjhm7chPPjRKeuCRRQo4_g&sa=X&ved=2ahUKEwjU3LnJoerdAhVZZt4KHb2oBu4Q9QEwAnoECAYQBA&safe=active&ssui=on#imgrc=1wmzy5q7qWxWFM:

Figure 1.14

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Figure 1.15

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Figure 1.16

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Figure 1.17

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Figure 1.18

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Figure 1.21

http://tsun.sscc.ru/IMP_wld.htm

Figure 1.22

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Figure 1.23

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Figure 1.24

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Figure 1.25

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Figure 1.26

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Figure 1.27

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Figure 1.28

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Figure 1.29

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Figure 1.30

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Figure 1.31

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Figure 1.32

Unknown

Figure 1.33

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Figure 1.34

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Figure 1.35

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Figure 1.36

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Figure 1.37

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Figure 1.38

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Figure 1.39

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Figure 1.40

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Figure 1.42

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Figure 1.43

https://www.google.com.au/search?rlz=1C1GGRV_enAU770AU770&biw=1366&bih=608&tbs=sur%3Afmc&tbm=isch&sa=1&ei=Erq1W-TJLait0PEP9N-ksA8&q=Mount+Nyiragongo%2C+Democratic+Republic+of+the+Congo.&oq=Mount+Nyiragongo%2C+Democr

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Figure 1.45

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Figure 1.46

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Figure 1.47

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Figure 1.48

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Figure 1.49

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Figure 1.50

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uc2hvdNqliPYDCwoJL20vMDF6Ym53CiAKDWNvbnRyb2wgdG93ZXLapYj2AwsKCS9tLzA0ejdxcgooChR3b25kZXJzIG9mIHRoZSB3b3JsZNqliPYDDAoKL20vMDJ5XzNnZAokChFvYnNlcnZhdGlvbiB0b3dlctqliPYDCwoJL20vMDZnemgyDA&fir=REAsulo54bACcM%253A%252Cvr9usv1pr3iDHM%252C_&usg=AI4_-kQBtYH9QO4oZN7zwfQKlXUHmt3paA&ved=2ahUKEwijmvjwvOzdAhWkoFsKHVQEBIkQ9QEwAXoECAYQBA&safe=active&ssui=on#imgrc=REAsulo54bACcM:

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Classification or Earth Movement

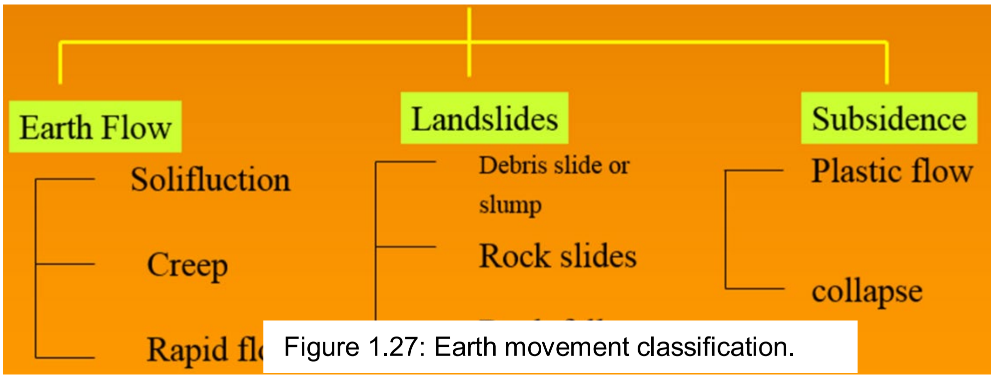


Figure 1.27: Earth movement classification.

Solifluction is a downward movement of wet soil along the slopes under the influence of gravity.

Figure 1.28: Solifuction.

Figure 1.29: Creep.

Creep is extremely slow downward movement of dry surficial matter.

Movement of the soil occurs in regions which are subjected to freeze-thaw conditions. The freeze lifts the particles of soil and rocks and when there is a thaw, the particles are set back down, but not in the same place as before.

Thredbo (NSW) Landslide
30 July 1997**.** Two ski lodges were destroyed.
18 died.

Figure 1.31: 1997 Thredbo landslide.

Figure 1.30: Rescue workers at the site of the Thredbo landslide.

Prediction of Landslides

Surveying equipment can be used to monitor the areas at risk of failing. Movement speed, several mm per month to catastrophic failure (instant). Costly to implement, Use strain gauges on each sensor column. Can measure changes in their length due to deformation.

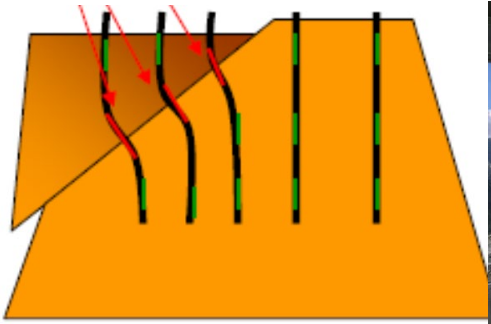


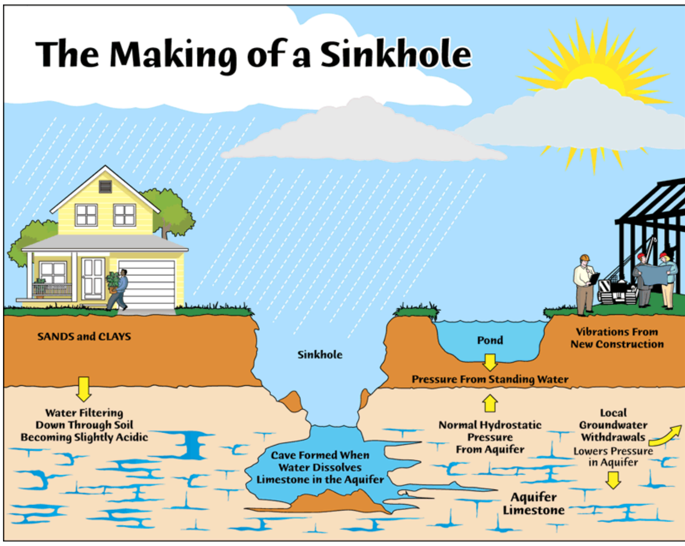
Figure 1.33: Total station surveying equipment with prisms.

Figure 1.32: Strain gauges.

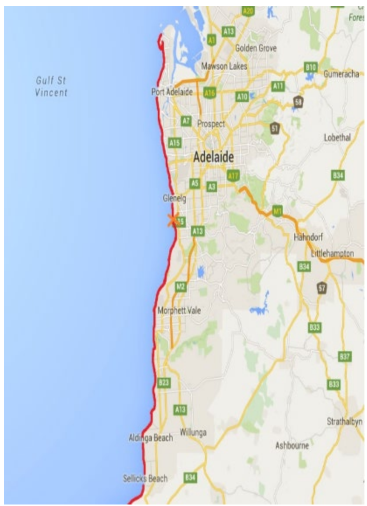
Sinkholes and Coastal Erosion

A cavity in the ground, especially in a limestone formation, caused by water erosion and providing a route for surface water to disappear underground

Mount Gambier in the SE of South Australia is built on Limestone.



Coastal Erosion is a natural process of waves, tides and currents striking the shore, sediments and rocks are washed away changing the landscapes shape. The map shows the tide and wave direction along Adelaide's shore line. This tide movement causes what is known as on shore drift. In short the further North you travel along Adelaide's coastline the finer sediments become due to weathering. Areas North of Port Adelaide like St Kilda have mangroves that are rooted in silts and mud.



Sea walls protecting beach front homes from coastal erosion.
Pictures from the North Coast of NSW where a road has been undermined by coastal erosion and an erected sea wall along Adelaide's Sothern coastline to protect homes.