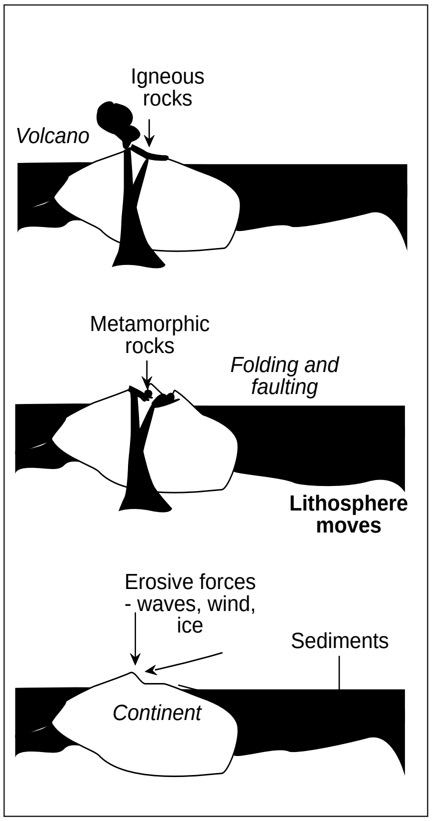


Fig 9 Igneous rocks, metamorphic and sedimentary rocks

Because the continental "crust floats on" the plastic mantle, forces from within the asthenosphere can move this crust around as shown in Figure 8.

Rock types

The crust is composed of rock materials which are either igneous, sedimentary or metamorphic. All of these rocks are made up of minerals. **Igneous rocks** are the class of rock from which all other rocks were made. The earth's mantle is almost exclusively igneous.

The name comes from the Latin ignus, which means fire formed. When in the molten state, igneous rocks are called **magma.**

The continent is made of different consistencies of rock and as it moves these rocks can buckle and fold. Parts of the continent can crack in earthquakes and some minerals in the igneous rocks are squeezed and changed as shown in Figure 9.

These changed rocks are called **metamorphic rocks.** When igneous rocks or metamorphic rocks are exposed to the atmosphere they become unstable and decompose. Wind, rain, ice snow or waves cause fragments to form and these are transported to the sea.

As they are transported they become smaller and form sediments. These sediments form part of the sands on our beaches and mud in our rivers. If the sediments are covered with other sediments they too can become rock called **sedimentary rock.**

Ocean shapes

All oceans have shallow places and deep places. The shallow places can consist of the **continental margin**, **ocean ridges** or **sea mounts** The oceans get deeper as we move off the continental margin down the **continental slope** and rise again in the **abyssal plain**. We can see this in the Figure 10. Sometimes the abyss dives deep into the earth as shown in Figure 13. These areas are called **trenches.**

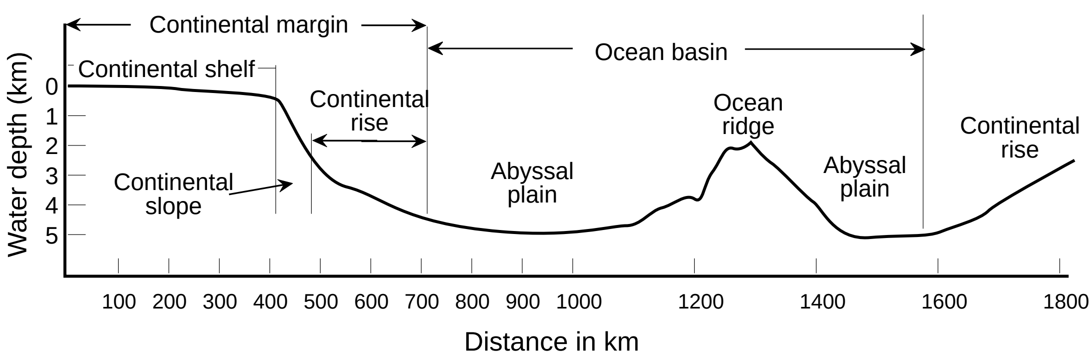
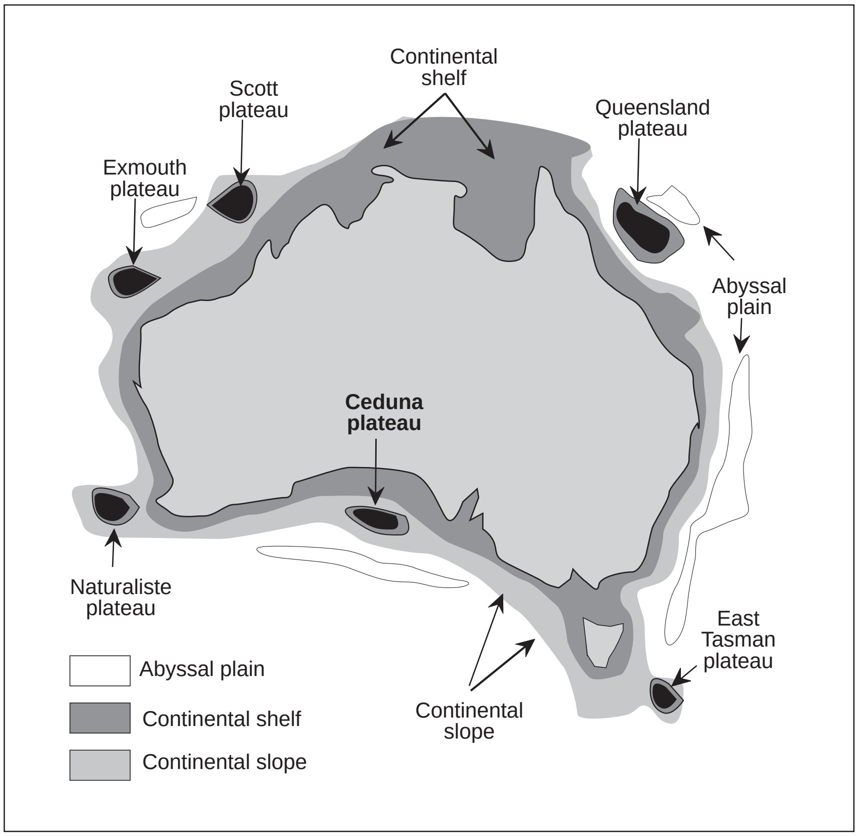


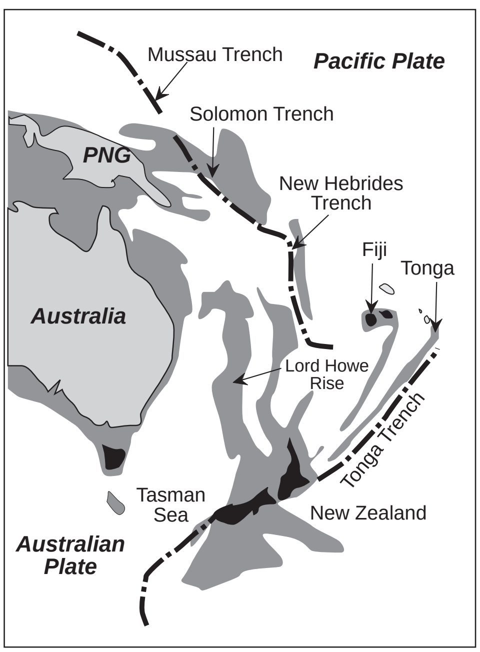
Fig 10 The main features of the continental margin and ocean basin (After Ross 1982)



Australia has a relatively narrow continental shelf leading to an abyssal plain in the Tasman Sea , Great Australian Bight and Indian Ocean as shown in Figure 11.

Fig 11 Source (Perspectives of the Earth 1983)

The Pacific Ocean continents are fairly flat and are surrounded by a continental shelf. There are however some deep places off the coast of New Zealand, New Hebrides and Solomon Islands. Here the abyssal plain plunges to a depth of some 10 kilometres in the deepest part of our oceans called **trenches**.



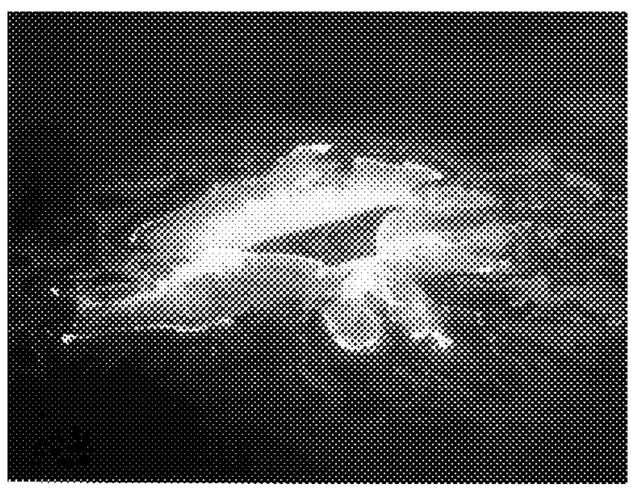


Fig 12 Australia in relation to its Pacific neighbours (left) and reef capping a seamount - from the Ha'apai (right) Photo - John Broadfoot

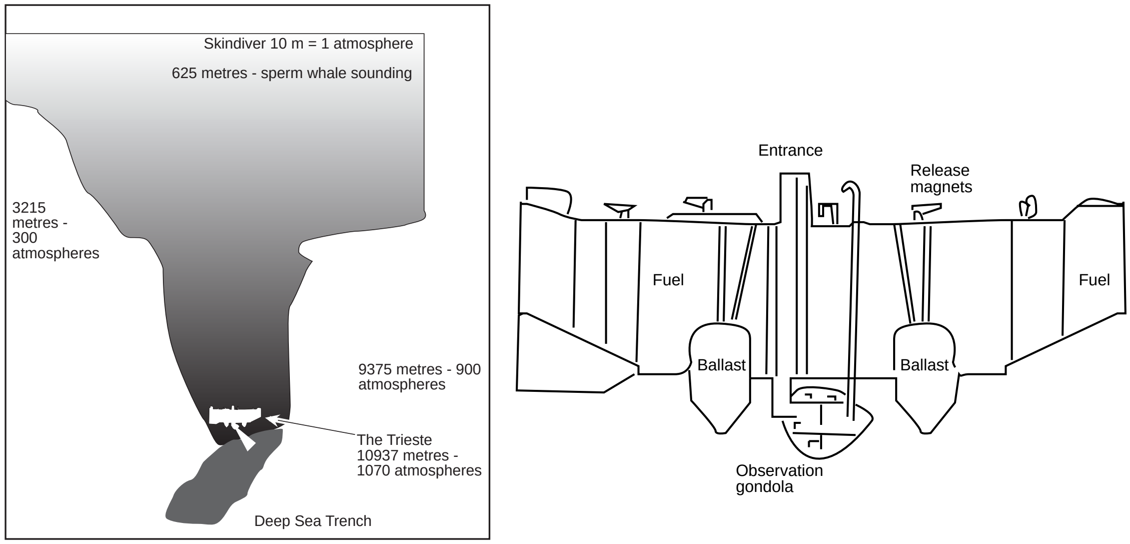


Fig 13 Simplified diagram of a deep sea trench and sketch of the research vessel the Trieste.

Bordering these trenches can be ridges, plateaus and rises, as discussed on Page 287. On these areas it is common to find **seamounts**, which can be formed when undersea volcanoes become extinct. Sometimes the volcanoes are above the sea and form island chains such as **Fiji**, **Tonga** or the **New Hebrides** Group. Other volcanoes lie submerged and can have reefs growing on top to form a capping like the one shown in Figure 12. In 1960 two scientists made a record dive into the deepest part of the ocean into the challenger deep in the Pacific over 10,000 metres and over 1000 atmospheres. The vessel was a bathyscape and was called the **Trieste.**

A illustration is shown in Figure 13 to give you some idea as to the depth and scale of this dive and the tanks involved to control the vessel. Eleven of these tanks are filled with 120,000 litres of petrol. The petrol is lighter than water and this makes the craft light enough to float. One tank at each end is left empty just before the dive. Then the tanks are opened and sea water flows in and the bathyscape begins to sink. To come to the surface the Trieste releases its pellets quickly and once on the surface the vessel floats.

Ocean plates

Because of the earth's gravitational force and depth, the pressures in the earth's interior are extreme. This pressure causes great heat which is lost from the crust at fracture zones in volcanoes or mid-oceanic ridges. In 1980 Mt. St. Helens erupted with the force of a Hydrogen Bomb (see Figure 6). The Newcastle earthquake shook Australia in 1990 and other smaller earthquakes occur in Australia each day. These events are all connected.

In the Pacific Ocean, there is a mid oceanic ridge which is found in the middle of the ocean some 2-3 km deep. We would expect that the middle of the ocean would be the deepest. In fact the average depth of oceans is about 5 km. Now this **ocean ridge** is a place where hot lava (**magma**) is coming out from the mantle and core of the earth. As we learned earlier, the earth has a red hot core which contains radioactive materials, which cause enormous heat. This heat expands upwards and moves towards the surface.

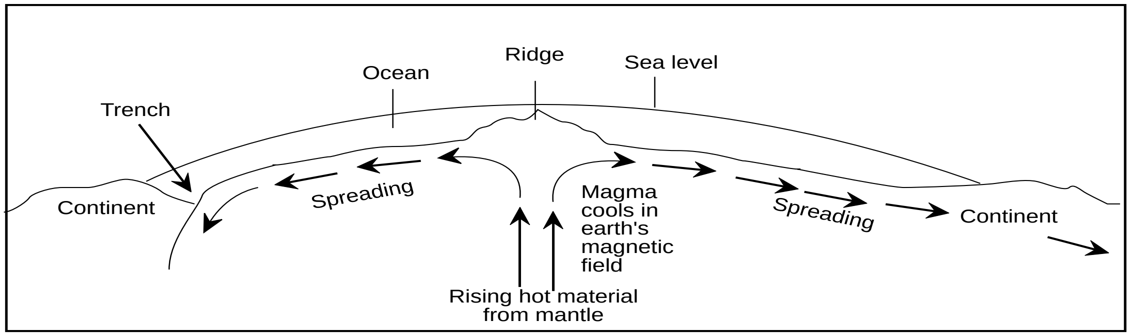


Fig 14 Forces from inside the earth move the lithosphere

Video

The Video, Volcanoes, can be purchased from Classroom Video, 81 Frenchs Forest Rd, Frenchs Forest, 2089.

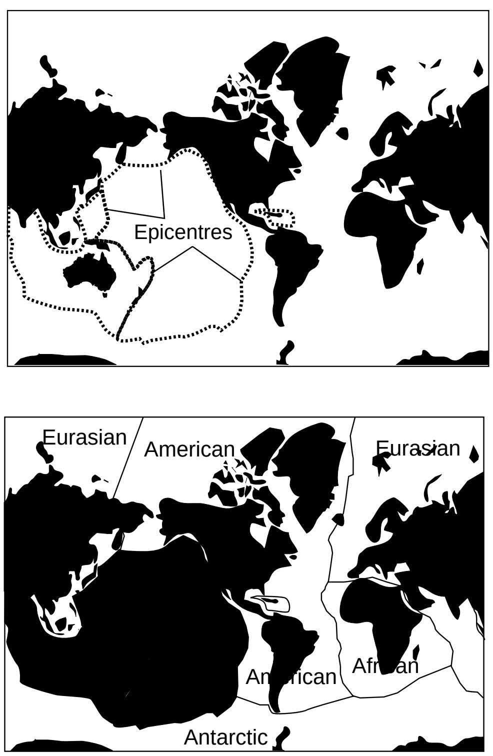


Fig 15 Top. Artists impression of records of earthquakes, 1961 to 1967. Each dot (30,000 in all) represents a point on the earth's surface directly above an earthquake. Data from US Coastguard and Geodetic Surveys. Is there any relationship between this figure and the bottom one showing the earth's plates

As it cools it sinks and returns to the centre. This rising and falling sets up **convection currents** which cause the lithosphere (crust and upper mantle) to move.

The area which moves in the lithosphere is called a plate. The plates move outwards from the ridges and anything on them such as islands or continents, moves. But the plates must go somewhere and it is in the trenches that they disappear . This causes friction or earthquakes.

The Newcastle earthquake and the eruption of Mt. St. Helens were both caused by the movement of the Pacific plate. If we study the incidences of earthquakes from 1963 in the Pacific region, a pattern emerges.

Over the past 20 years a great worldwide system of cracks in the oceanic and continental crust has been mapped and interpreted. These cracks break the lithosphere into plates as shown on the diagram above. The Australian plate is moving north at a rate of 2cm per year or the rate at which your fingernail grows.

An excellent video produced by John Davis of Classroom Video called *Volcanoes* shows these plates and also shows some magnificent footage of volcanoes. It is suggested that you watch this now to review these ideas.

The shaping of Australia

Now that we know plates on the earth move, we can use this idea along with a lot of other scientific evidence to explain Australia's shape.

The continents as we know them today were not always that way. The earth had cooled and the land formed but was possibly too hot for life to exist. The first life formed some 1000 million years ago and evolved in the seas to emerged onto a much cooler landscape between 500-300 million years ago.

Stromatolites grow extremely slowly (less than 1 m per year) and are formed by tiny, single celled organisms called cyanobacteria. They construct the stromatolite by trapping fine sediment particles from the water and binding them together with a sticky film of mucus. They are a living fossil and may give clues to what early life in the sea was like.

Information supplied CALM 50 Hayman Rd Como 6162

About this time the world was divided into two continents separated by the Theyes sea. Coral grew because this was located in the warm waters around the equator. Africa, South America, India, Antarctica and Australia were joined in one called **Gondwanaland** and North America and Asia in **Laurasia**. With plate tectonic movement, Australia was also covered by water in which coral grew. At a variety of times **Laurasia** and **Gondwanaland** were separated and joined and moved north and south. When joined they were called **Pangaea**. Evidence for the corals comes from the Kimberleys in Western Australia where large cliffs or limestone corals can be seen on land and the stromatolites at Shark Bay.

Fig 16 Laurasia and **Gondwanaland**. About 300 million years ago. Australian flora and fauna would have been distinctly polar and resemble that of Antarctica and South America (After Thurman and Webber 1984)

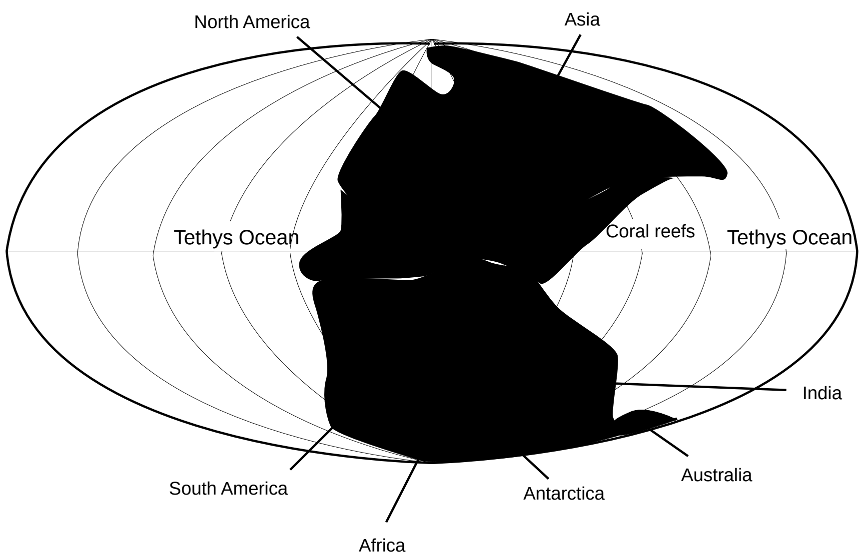
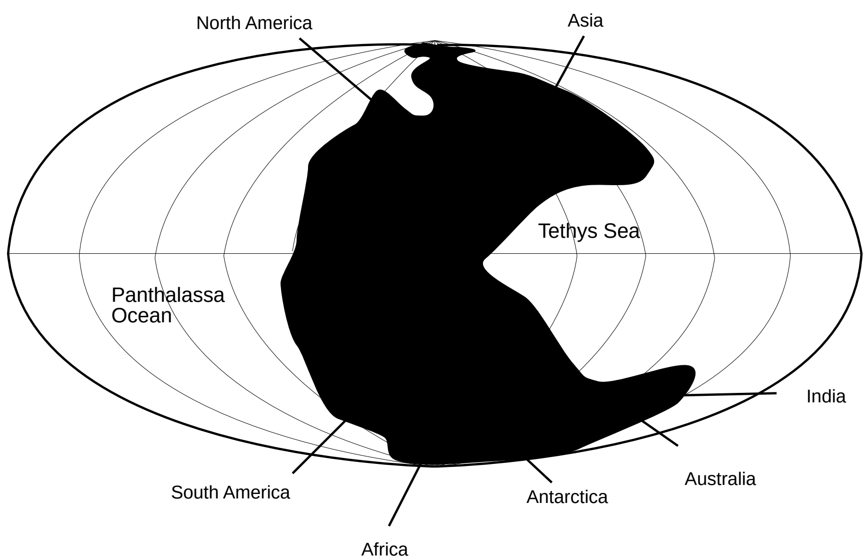


Fig 17 Pangaea. About 200 million years ago as a result of the moving lithosphere all continents as we know them today were joined into a super continent surrounded by the Panthalassa Ocean (After Thurman and Webber 1984)



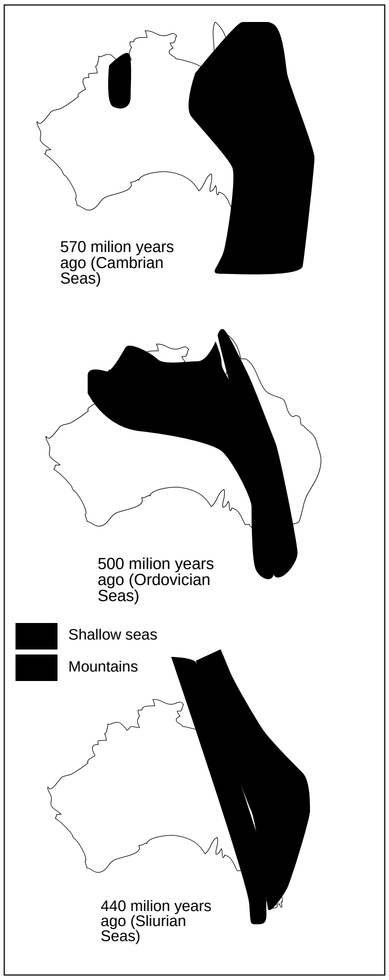


Fig 19 Australian seas before Pangaea or Gondwanaland

When plates collide

When two plates collide the continental crust they carry is pushed up into mountain ranges. The Great Dividing Range and Kimberlies were formed in this way. Similarly the mountains in Victoria and South Australia resulted from the Australasian plate colliding with the other plates in our geological history.

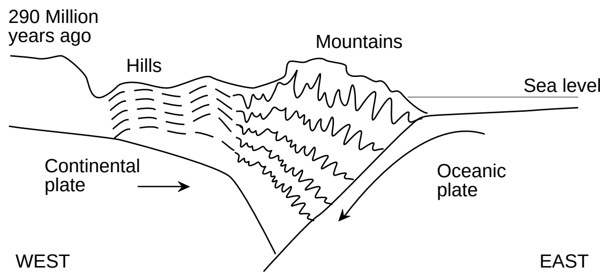


Fig 18 Possible formation of mountain ranges in Australian as a result of plates colliding in Pangaea (After Wilmont and Stevens 1988)

After collision and mountain building, plates can move under each other in a process called subduction.

When one plate moves under another

We can think of subduction as the earth claiming what was once hers. The dense oceanic crust material plunges under the continent. This can be seen in our east coast where the lithosphere moves under the continent at about 2-3 cm per year. Once the process of subduction starts, it seems to carry the sea floor downwards like a conveyor belt. This is called **subduction**.

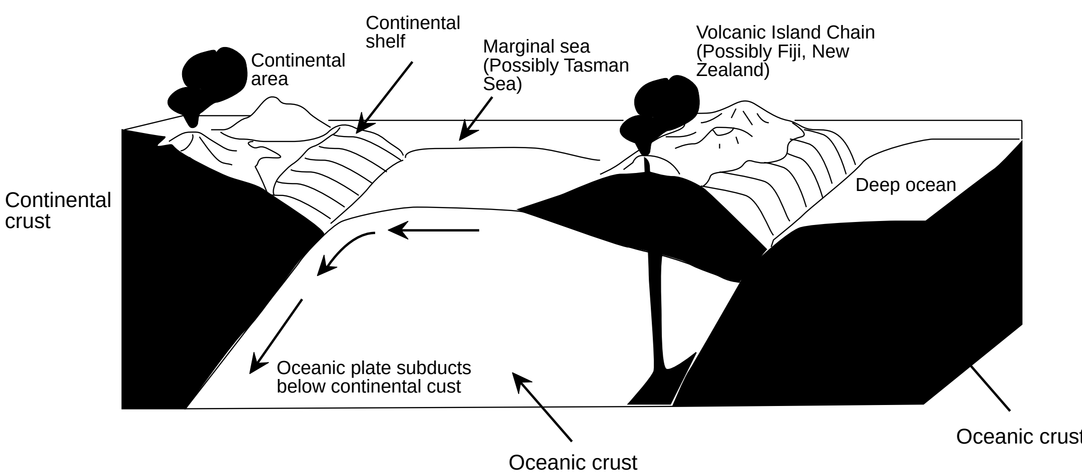


Fig 20 290 - 230 million years ago. Possible origin of East Australian Coastline and Islands (After Wilmont and Stevens 1988)

When plates spread or slip

As one boundary of an oceanic plate is pushed downwards into the asthenosphere by subduction, new oceanic crust is being formed at the opposite end by magma rising from the asthenosphere. The process is called sea **floor spreading**. Great cracks can form on the ocean floor and the hot magma pushes up the floor to a ridge (steep slope) or a rise (gradual slope). **Transverse faults** can occur as plates tend to break into two sections.

These can then slide past each other. However great pressure tends to build up and people living on the San Andreas Fault in California regularly experience earthquakes as a result of this pressure buildup. The four main ideas can be summarised in the diagram below:

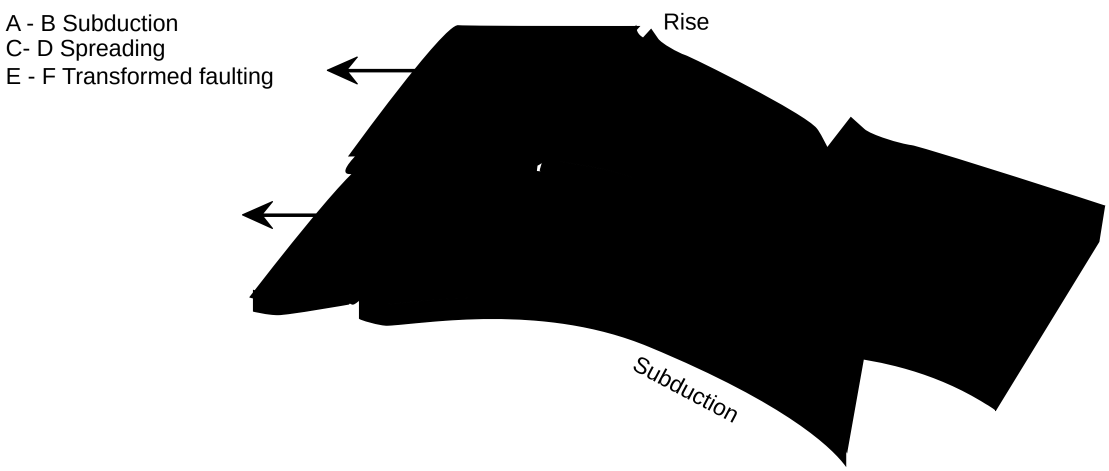


Fig 21 The movement of the ocean plates showing:- Subduction (A and B) - one plate beneath another, Spreading (C and D)- two plates are pushed apart, Transformed faults E and F) two plates slide past each other.

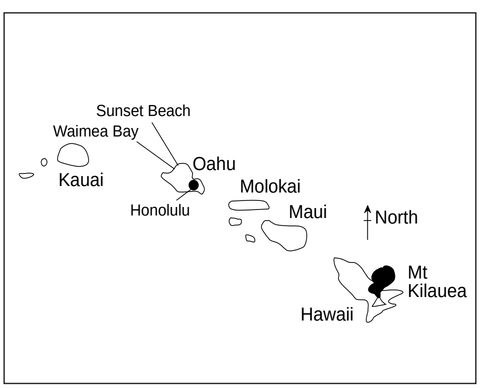


Fig 22 The Hawaiian islands have been formed by the plate moving over a hot spot. Why is the new vent of Kilauea always at the South Eastern end of the island?

What happens when the plate has a weak spot in it?

If we look at the island chains in the Pacific we can see that they form in a certain way. Mt. Kilauea on the island of Hawaii, is an example of how these islands were formed.

The source of the magma remains constant, and as the plate moves over the hot spot, the island forms. Mt. Kilauea is not a dangerous volcano and people can walk up to the crater and watch it erupt.

It can be seen that the other islands in the Hawaiian group have been formed in this way. One of the most famous Ohau, has a north shore famous for large surfing waves.

Other island chains in the Pacific have been formed this way. Western Samoa has very flat Volcanic cones. The islands of Fiji, Tahiti and Tonga all formed from volcanoes.

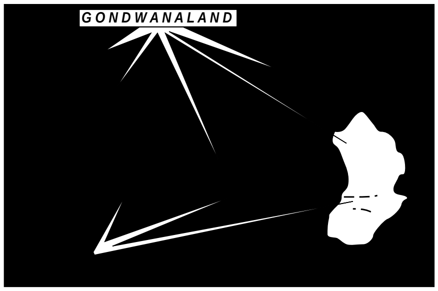


Fig 23 Australia in Pangaea

When land is exposed to the air the erosive forces of wind and rain cut deep gullies in any weaknesses. These sediments are washed out to sea and if the seas become uplifted, folded and dried, they create a variety of shapes.

With volcanic activity, further larva can cover river valleys and cave out new shapes. With the movement of Australia towards and away from the poles, and with the earth at different distances from the sun, a series of ice ages occurred over Australia.

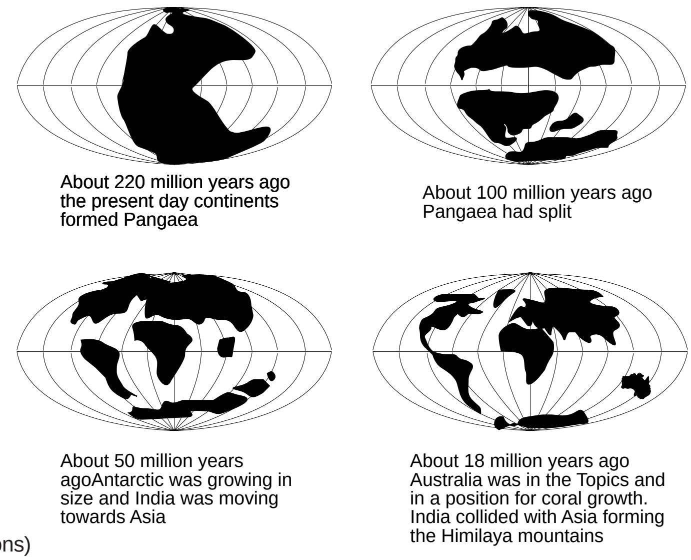


Fig 24 Continental drift (Approximate positions)

> **Barrier Reefs**
>
> Australia's Barrier reefs are found off the coast of Australia from as far south as Carnarvon in Western Australia and Bundaberg in Queensland .
>
> The Great Barrier Reef is made up of approximately 2,900 individual reefs and is approximately 2,000 kilometres long. It can be seen from the moon, is the largest single living thing on earth and is only a relatively recent geological event. Its history began many thousands of years ago as the Australian plate was moving northwards in its separation from Antarctica.
>
> As the coral polyp grows it secretes a limestone base called the corallite which is the white coral skeleton seen when a coral colony dies. As the coral colony grows so does the size of the coral skeleton.

This meant **glaciers** crushed igneous rocks to fine sand grains which now cover our beaches. With much of the water locked up in the poles, the water levels fell, exposing the continental shelf that was covered by water.

Australia gradually separated from Antarctica and moved north. During this time a series of ice ages raised and lowered the sea level, which had a profound influence on the biological activity of the continental shelf.

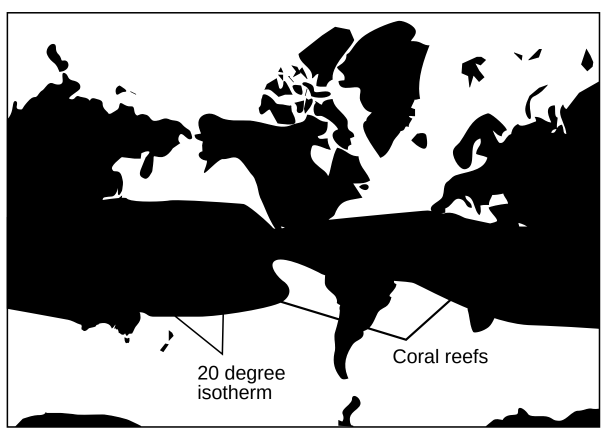


Fig 25 Coral reefs grow in warm tropical seas

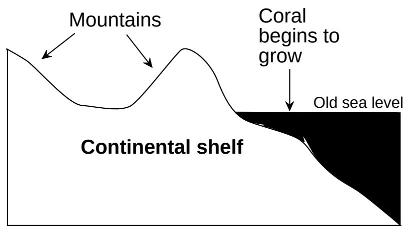


Fig 26 Australia was at the right latitude for coral to grow

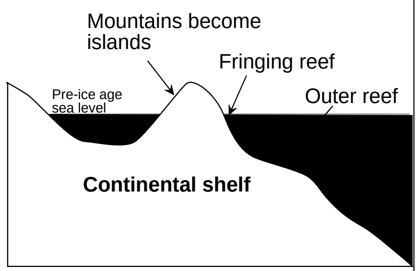


Fig 27 Corals grew upwards to pre-glacial sea levels forming reefs

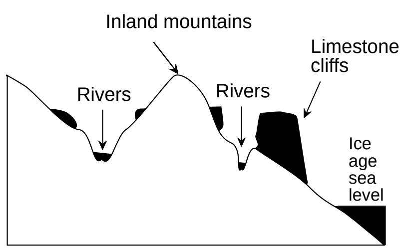


Fig 28 Glacial periods saw a drop in sea levels exposing the reefs to wind and rain. Rivers flowed in between accumulating sediments in and around reefs

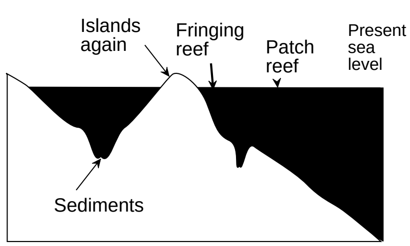


Fig 29 Present day reefs

Reefs off the east coast

The sequence of events that started the **reef's growth** began almost 18 million year ago as shown in Figures 26 and 27. Australia was at a latitude that promoted coral growth at a rapid rate. As the sea levels rose the corals began to grow in large numbers, forming a reef on the outside of the continental shelf. The sea level gradually rose and with it grew the corals. There were still mountains and plains on the continental crust as the age of the mammals increased and the Australian marsupials were coming into their own.

As the sea level rose, so did the reefs forming **fringing reefs** around the new islands and **outer reefs** on the edge of the continental shelf. Life abounded in the seas and the islands became separated by large expanses of water. Populations of birds may have developed because of the absence of natural predators such as snakes or dingoes. Turtles could nest and form rookeries also with the absence of larger predators. This continued until a series of ice ages began.

Then followed a series of ice ages as shown in Figure 28. Where ice formed at the poles it concentrated the water which meant that the sea level fell. Although it is difficult to calculate, scientists believe this fall to be about 150 metres below the present sea levels.

Continental shelf areas were now subjected to river systems and erosion. The limestone caves under and around old limestone cliffs were possibly the homes for our early aborigines. Trees and shrubs grew and kangaroos hopped around. Figure 28 shows the build up of sediments from rivers. About 18,000 years ago the ice caps from the last ice age began to melt.

The water level gradually rose as shown in Figure 29. With the rising waters grew more coral, forming a thin layer over the old fossil reefs. Gradually this layer increased and a thickness of 15 metres new growth has been measured today. All that has changed is the gradual weathering and erosion that gives each reef its characteristic shape. The reef therefore, rests on the limestone remains of ancient reefs which were "born" about 20 million years ago when Australia's continental shelf was formed and covered by the sea.

Three types of reef formed on the Great Barrier Reef:-

★ Fringing reefs around the mainland and offshore islands
★ Patch reefs which grow up from the continental shelf
★ Ribbon reefs which are at the edge of the continental shelf

It is important to understand that the major part of a coral reef is non-living limestone and the living plants and animals only form a veneer on its surface. On the reefs we see today are layers of new coral growth, about 15 metres deep, covering the old fossil reefs.

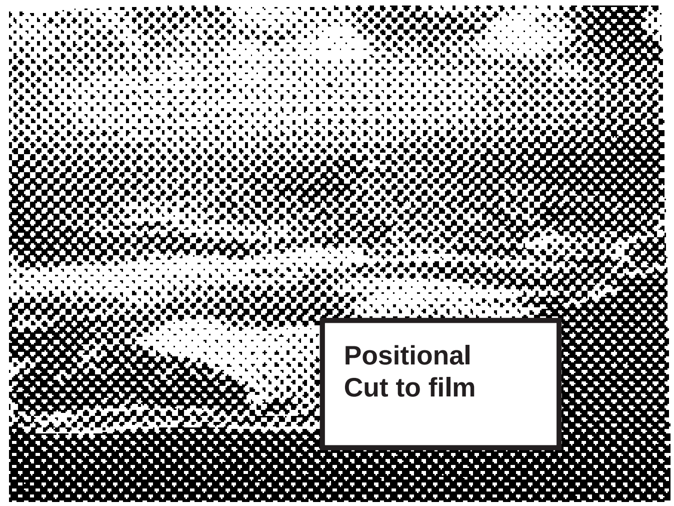


Fig 30 A fringing reef north of Cairns Photograph courtesy Great Barrier Reef Marine Park Authority

Reefs off the west coast

Reefs formed off the coast of Western Australia in much the same way as just previously described. The shape of the continental shelf is different as are the ocean currents. The Leeuwin current is responsible for coral reef communities to growing as far south as Perth, and the national parks of Ningaloo (Figure 32), Shark Bay, Abrolhos, Marmion, Swan Estuary and Shoalwater Islands give testament to this fact.

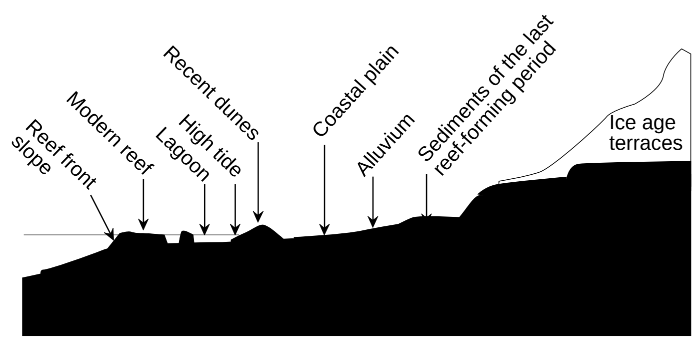


Fig 31 Diagrammatic cross section of the range to reef in Western

In their book "Range to Reef", the authors describe the evolution of the coastal zone as follows:- "Ten million years ago, the north west corner of Australia was covered by a shallow sea.

Later the crust of the earth crumpled and a huge anticline rose to form Cape Range Peninsula. The back bone of the range is hard fossil bearing limestones, laid down on the sea-floor in those earlier times. The western side of the peninsula exhibits four distinct limestone terraces" .. as illustrated in Figure 31 above.

According to Mercer (1991), " Fringing reefs in Western Australia can be found as close to shore as one hundred metres and can extend out as far as a few kilometres."

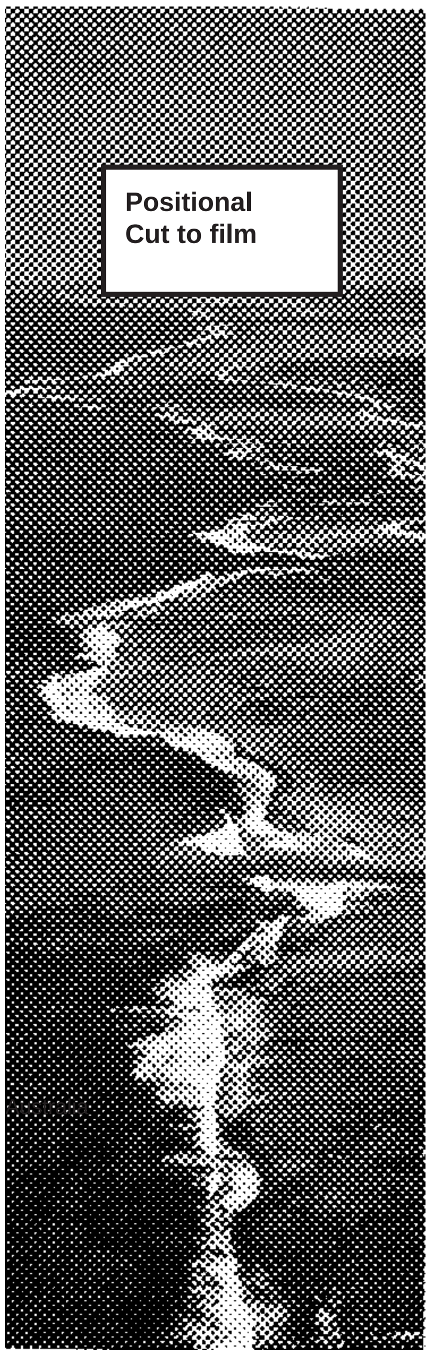


Fig 32 A fringing reef in Ningaloo off Exmouth Western Australia (Courtesy Department of Conservation and Land Management, W.A.)

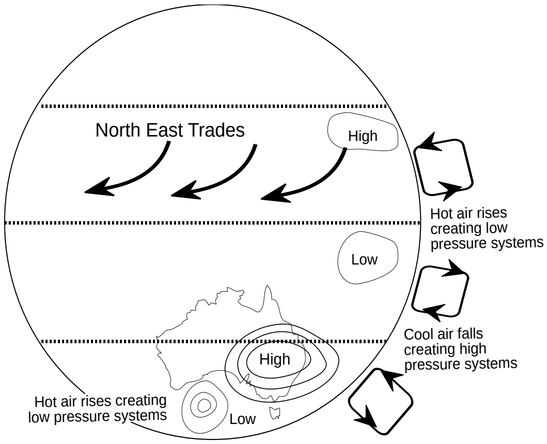


Fig 33 Wind cells are caused by air rising and falling

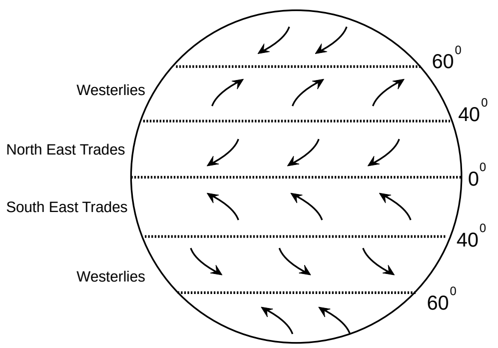


Fig 34 The winds of the earth are deflected by the earth's rotation

Important resources - WA

Your can read more about Western Australian Reefs and Conservation by purchasing the following:-

Shark Bay - A little book that's big on content - not only the Dolphins of Monkey Mia, but also the History of this special place, its Geography, and its plants

Range to Reef and Rugged Mountains, Jewelled Sea - describes Ningaloo National Park and

Landscope - Volume 7, No 2 - describes Dolphins, Dugongs and the Desert Coast

Write to:- CALM Publications , Department of Conservation and Land Management, 50 Hayman Rd, Como, 6152. Information courtesy Ron Kawalilak CALM Publications.

The moving waters

Ocean currents

The sun's rays heat the earth unequally causing more air to be heated at the equator than at the poles. This causes air at the equator to rise so creating areas of low pressure. When this rising hot air cools it falls, creating areas of high pressure. The spinning earth causes these systems to move. As the wind drags on the water it causes the water to move in what we call ocean currents. The ocean currents follow the wind patterns.

In the Pacific there are warm currents and cold currents. The cold Peru current and antarctic currents sweep past South America, where they move to higher latitudes and are warmed. It was in one of these currents that Thor Heyedahl attempted to prove that the inhabitants of Peru sailed to inhabit Tahiti, Hawaii, Tonga and possibly New Zealand.

However, wind is not the only cause. The density of the water also governs current direction. Cooler water tends to be more dense and sinks, displacing the warmer less dense equatorial waters. Salinity also plays a role. Water tends to flow from an area of low salinity to one of a higher salinity. Ocean currents had to be studied around oil rigs following disastrous oil spills overseas. Australia's tourist industry would be devastated if there were a large oil spill in the Coral Sea. Can you suggest why. A Frenchman, G.G. Coriolis showed in 1884, that water at different depth moves in different directions. This causes ocean currents to flow clockwise in the North and anticlockwise in the South.

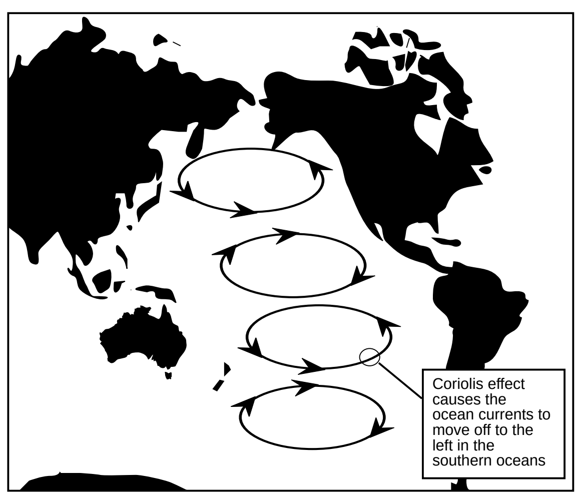


Fig 35 Pacific Ocean showing main direction of currents and Coriolis effect

An important current - El Nino

In the southern winter, a branch of the Peru current may cross the equator northward and continue with the Equatorial undercurrent in that direction. During the summer months however the counter current may cross the equator and turn south towards Equidor where it is referred to as El Nino.

In 1891, 1925, 1941, and 1957-58 it flowed as far south as Peru and caused the Peru current to move seaward. As it did, it stopped the upwellings that supported the prolific bird life off Peru.

Plankton production dropped dramatically causing the deaths of millions of fish and birds. The shifts caused enormous deaths of sea life in 1891, 1925, 1941, and 1957-58.

With El Nino came dramatic changes in the primary production in California, Australia Vietnam and South West Africa. Droughts occurred causing the deaths of millions of sheep and cattle. If anyone living in the great Australian outback ever thought they would never be influenced by the sea, they had better think again!

In fact a worldwide El Nino conference was held in Australia in 1986 to record changes in primary productivity related to this ocean current. The shift in El Nino may be due to changing atmospheric conditions, or it may be a fluke in nature.

We have no way of telling. Can El Nino be used as an index of primary production?

Just how much do the currents of the world affect the production on the land? We have only just begun to understand ocean currents.

Currents within the ocean are important biologically because they mix not only the oxygen and carbon dioxide from the atmosphere but also the elements from the rich benthic layers of the sea. Oceanic circulation transports heat from the equator towards the poles and brings frigid water from the poles to cool the tropics. This movement of heat is believed to control weather but to this day is poorly understood.

The Coriolis deflection mentioned on the previous page is responsible for a deflection of warm, nutrient deficient water from the coastline. This enables cold, dense bottom water rich in nitrates and phosphates from the "compost heap" in the benthos, to rise and mix with the warmer water to form an **upwelling**. One effect is to promote plant growth and hence abundant fish for harvesting. If this coriolis deflection is prevented by changing wind patterns, the warm waters are not pushed offshore and the upwelling cannot occur as happens in **El Nino** conditions as described opposite.

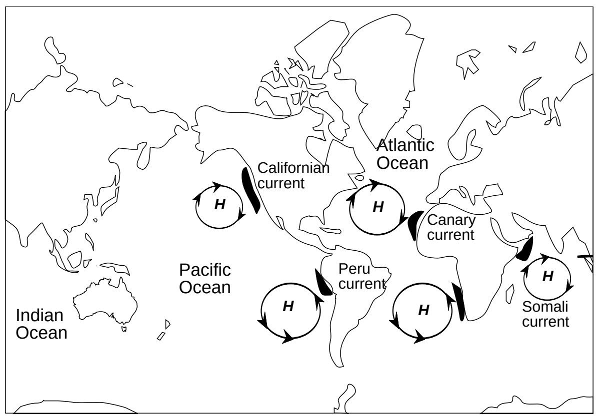


Fig 36 Significant coastal upwellings zones (After Lerman (1986)

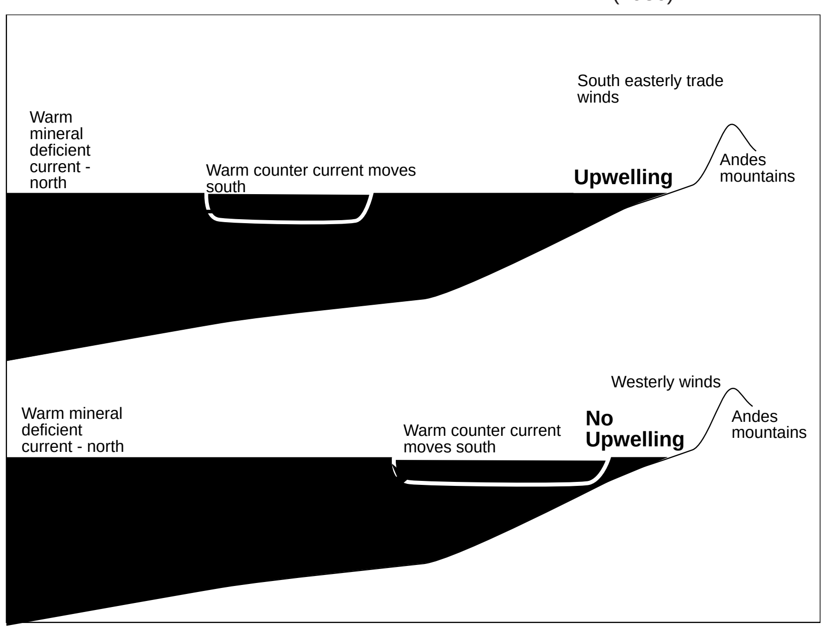


Fig 37 Upwelling along the Peruvian coast. (After Lerman (1986)