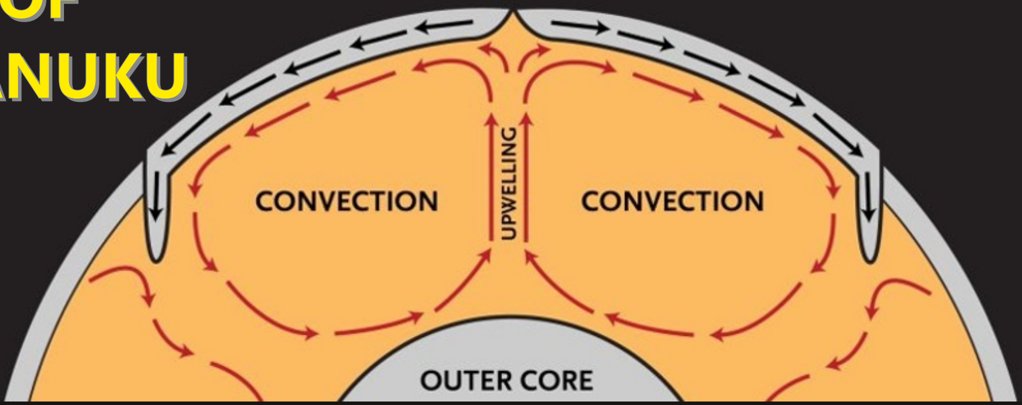
SECRETS OF PAPATŪĀNUKU



Convection currents in the mantle [LearNZ]

In younger years we may have learnt the Earth is divided into three layers – the solid crust, liquid mantle and solid core. But the reality is more complex than that. ***Guest author Mike Stone*** *investigates.*

A Māori worldview

While Māori did not originally have the technology to observe the layers that were deep beneath their feet, there are areas of mātauranga Māori that help support our understanding of our dynamic planet. There are several pūrākau that reference the idea that there are massive forces that operate below the earth's surface over long timelines and huge geographical scales. These forces are uncontrollable via human intervention, which is part of the reason why they were attributed to atua (gods or deities). There are Māori atua that are linked with earthquakes and volcanoes as well as those that link with specific geothermal features in New Zealand.

Each iwi has its own version of a story telling how the world came to be. Some of the common features include Papatūānuku, earth mother, and Ranginui, sky father, having several children who eventually separated their parents to allow light into the world. Seeing that their parents were grieving, as an act of sympathy, some children turned Papatūānuku face down, so that she would not spend eternity looking at her husband whom she could not embrace. One of the children of Ranginui and Papatūānuku, Rūaumoko, was feeding at his mother's breast when she was turned towards the earth and was taken underground. Rūaumoko was given fire to keep him warm and volcanoes and earthquakes are seen to be linked to the movement of Rūaumoko next to his mother or, with alternative pūrākau, as movements inside the womb of Papatūānuku.

Ranginui and Papatūānuku. From the pātaka of Te Pokiha Taranui of Ngati Pikiao, Te Arawa. [Kahuroa]

Each iwi has its own version of a story telling how the world came to be. Some of the common features include Papatūānuku, earth mother, and Ranginui, sky father, having several children who eventually separated their parents to allow light into the world.

Other pūrākau refer to Rūaumoko's brother, Mataaho, who also holds domain over earthquakes and volcanoes. Mataaho is linked with specific pūrākau that describe the deep-time formation of many of

Auckland's volcanic features which are collectively called Nga Maunga a Mataaho – the mountains of Mataaho.

The Earth's formation

When Earth was formed about 4.5 billion years ago, it was a ball made only of hot rock. This became even hotter, due to radioactive decay. After about 500 million years, our young planet's temperature heated to the melting point of iron, about 1,538°C.

This allowed more rapid movement of Earth's molten, rocky material and a differentiation into layers. Lighter material, such as silicates, water, and even air, stayed close to the planet's surface, becoming the early mantle and crust. Liquid iron, nickel, and other heavy metals gravitated to the centre of Earth, becoming the early core.

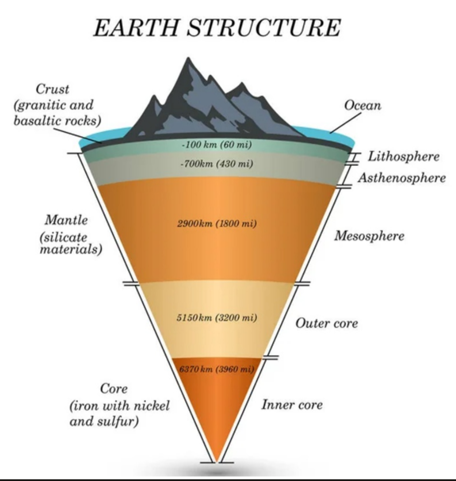
Over millions of years, the mantle cooled. Water trapped inside minerals erupted with lava, a process called "outgassing". As more water was outgassed, the mantle solidified. During this process, materials near the surface remained in the liquid phase, later solidifying and becoming the Earth's brittle crust.

The Earth's interior is still very hot, increasing by about 25°C for every km of depth. Pressure also increases with depth.

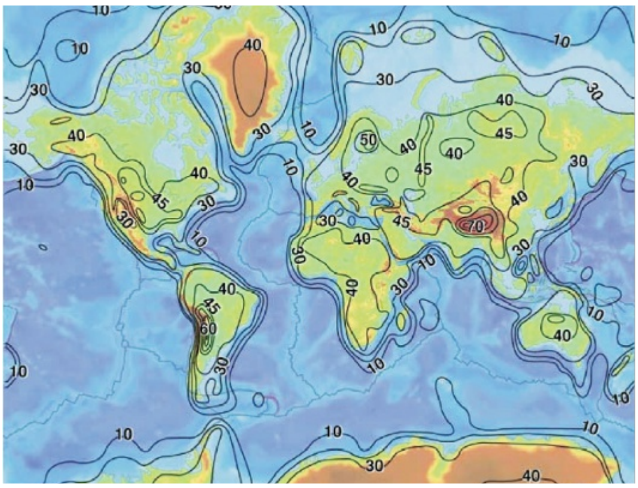
Naming the layers

The composition of the Earth can be considered in two ways: chemically (what each layer is made of) and mechanically (how each layer behaves).

Chemical Composition		**Mechanical Composition**
Crust: Surface layer, 10-65 km thick, deeper under continents **Continental crust**: Lighter felsic minerals (SiO_2, K, Na, Al) **Oceanic crust**: More dense, mafic minerals (Mg, Fe)		**Lithosphere**: Crust and upper mantle, rigid, brittle solid, 10-200 km thick **Asthenosphere**: Middle mantle, viscous, malleable, semi-solid, 500 km thick **Mesosphere**: Lower mantle, rigid, 2,200 km thick
Mantle: Middle layer, 2,900 km thick, made of Fe, Mg and SiO_2.		
Core: Central layer, 3,500 km thick, made of Fe and Ni.		**Outer Core**: Liquid, 2,200 km thick **Inner Core**: Solid, 1,300 km thick



Surface layer



A map showing the depth of the crust. [Cawood et al., 2013]

The planet is covered in a thin skin called the crust (or upper lithosphere). Earth's crust is composed of igneous, metamorphic, and sedimentary rocks. The crust under continents and oceans differs (see diagram) but the main minerals in both are silicates.

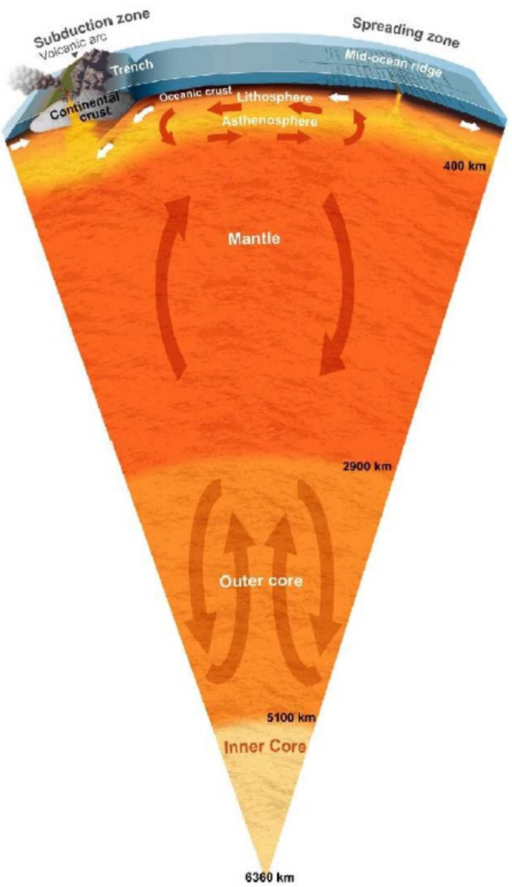
The solid crust can be thought of as floating on the mantle. It is broken up into large slabs which are created and destroyed by tectonic activity. Magma wells up to the surface at mid-ocean ridges, cools and solidifies. Under the sea that solid slab of crust very slowly moves away from the ridge. When it meets a continent, the solid slab dives into the mantle below (a process called subduction), and is destroyed in the process.

Oceanic crust is mostly basalt and covers two-thirds of the Earth's surface to a depth of 10 km. As it is continually being made, oceanic crust is much younger than continental crust, up to 200 million years old.

Continental crust is mostly granite and averages 40 km thick, although thicker under mountains. It is much older than oceanic crust, up to 4 billion years old, almost as old as the planet.

The boundary between the crust and the mantle is called the Mohorovicic discontinuity, or simply the Moho. It is shallow beneath the ocean and deeper beneath continents.

Geologists collect samples of oceanic crust by drilling at the ocean floor, using submersibles, and studying rocks of the oceanic crust that have been uplifted and exposed.



Convection currents in the mantle and outer core. [GNS]

Middle layer

The mantle is about 2,900 km thick and makes up 84 % of Earth's total volume.

In the mantle, heat and pressure generally increase with depth. The temperature of the mantle varies from 1,000°C near the crust, to 3,700°C near the core.

The mantle has several layers – hard and rigid at the top and bottom, but more fluid in the middle. In the middle layer, asthenosphere, the temperature and pressure are so high that rocks soften and partly liquefy, becoming semi-molten, with an ability to stretch and deform under stress. This ability to flow can be called viscosity or plasticity. The molten material from subducted tectonic slabs very slowly circulates by convection currents. This layer also holds a huge amount of water, which entered during subduction and has been trapped as hydroxide ions in the crystal structure of minerals.

Heat escaping from the Earth's core rises up through the mantle in magma. Some may escape to the surface; the rest cools, spreads out and then sinks. These convection currents in the mantle transfer heat and material, driving plate tectonics and orogeny (mountain-building).

Scientists study the mantle by analysing xenoliths in diamonds (minerals from the mantle, trapped inside the carbon), as well as seismic waves and their mapping in the mantle.

Core

All known planets have metal cores, including the gas giants. Earth's core is very hot, due to the decay of radioactive elements, leftover heat from planetary formation, and heat released as the liquid outer core solidifies near its boundary with the inner core. Temperatures in the core are estimated to range from 4,000–7,000oC, almost as hot as the sun. This heat radiates outward in all directions from the centre, conducting heat into the liquid core, establishing the convection currents in the outer core.

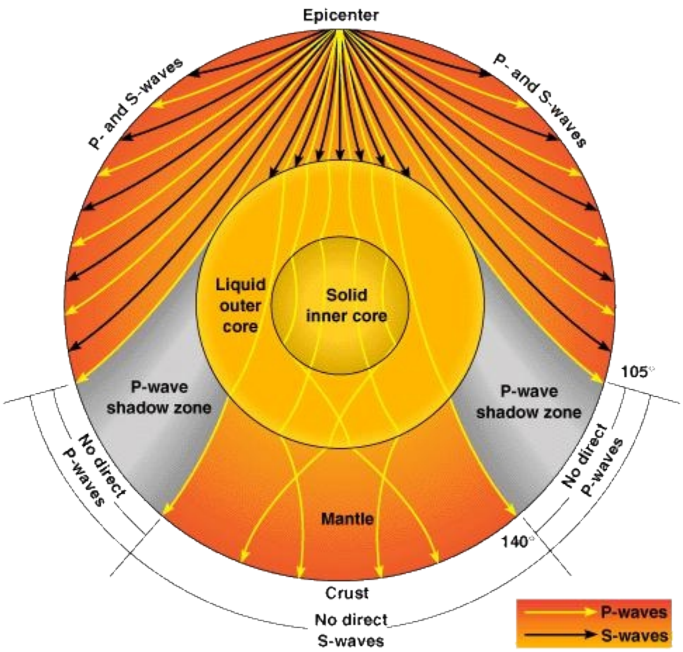
The core is mostly iron and nickel and also contains elements that dissolve in these metals, eg, gold, cobalt and platinum ('precious metals' rarely found on the crust), as well as sulfur.

There are two layers in the core. The thicker outer core is composed of liquid metal which churns violently, creating and sustaining Earth's magnetic field that protects us from the solar wind.

The inner core is a solid, hot, dense ball composed mostly of iron. Although its temperature is far above the melting point of iron, the pressure is so high it prevents the metal from melting.

As the entire Earth slowly cools, the lowest bits of the liquid outer core solidify, causing the inner core to grow by about a millimetre every year (80,000 tonnes of iron per second!). However, the Earth will be destroyed by the expanding sun long before the core completely solidifies.

Geoscientists cannot study the core directly. All information about the core has come from analysis of seismic data (see images), study of meteorites, lab experiments with temperature and pressure, and computer modelling.



Seismic waves pass differently through solids and liquids. [IRIS]

Questions

1. Find out:

A. How the patterns of p-waves and s-waves show the liquid and solid layers inside the Earth.

B. How seismologist Inge Lehman contributed to our understanding of earth's interior.

2. Answer the following:

A. Give a meaning for radioactive, melting point, silicate, convection.

B. Differentiate between lava and magma; lithosphere and asthenosphere.

3. Watch the teaser video clip for Ice Age 4 Continental Drift, then identify two pieces of correct science and two pieces that are incorrect.

4. Complete the following:

A. Complete this diagram https://geoetc.com/wp-content/uploads/2022/09/Earths-Layers.pdf

B. Construct a table comparing the key features of the crust, mantle and core

5. Describe how the heat in the core reaches the surface of the planet.

6. Investigate further:

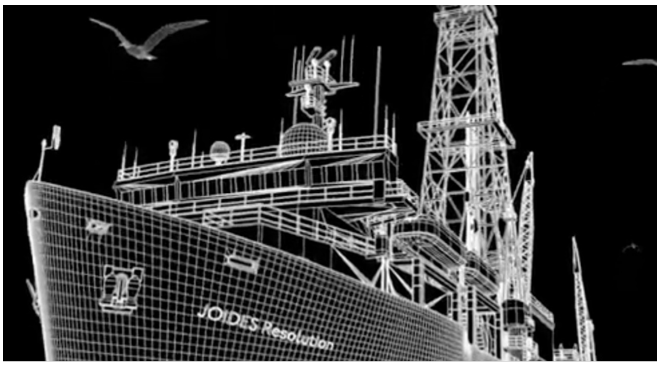
A. Try to find your local iwi story of Papa and Rangi and also find out about Rūaumoko.

B. What ideas are the same between the pūrākau?

This article was improved by critique from Nick Bryant (Ngāpuhi, Ngāti Whatua) and Ross Stephen ESS Teacher.

Ngā Kupu

kōwhatu: rock
Papatūānuku: the Earth
pātaka: food storehouse
maunga: mountains
pūrākau: traditional stories
rū whenua: earthquake
te ao mārama: the world of light
tīkākā: heat
tokarewa: molten rock
totoka: solid
wē: liquid, water, fluid
Source: Te Aka Māori Dictionary



This drill ship sampled the crust from 1984 – 2024. [Joides Resolution]