Creating Science – Volcanoes

What is happening inside a volcano? In what ways can they kill us? ***#CreatingScienceVolcanoes***

Suggested outcomes

(NOTE: This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes can or should be met. Science is a deeply interrelated activity, and you may find cross curriculum links you can and should use.)

Science understanding

- Earth and space sciences year 6: Sudden geological changes and extreme weather events can affect Earth's surface (ACSSU096)

Science inquiry skills

- Communicating 3: Represent and communicate ideas and findings in a variety of ways such as diagrams, physical representations and simple reports

Science as a human endeavour

- Nature and development of science year 5-6: Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions (ACSHE081)

Science vocabulary words

Tier 1 (everyday words): volcano, earth, rocks.

Tier 3:

- Magma – liquefied rock under the surface of the earth.
- Lava – once magma gets on the surface of the earth trapped gasses explode out, chemically changing the material into lava. The materials that are left, mostly basalt and quartz, turn dark and solid becoming new ground. Lava is chemically different than magma because lava has lost most of its trapped gasses (such as water and carbon dioxide).
- Theory – an explanation of how the natural world works. The best theories are always able to generate a testable prediction, and, indeed many consider a **testable prediction** to be the prerequisite of what makes a theory a **scientific theory**.
- Tectonic plates – the unbelievably massive chucks of earth's crust that the continents ride around on.

Warning

- Bicarb and vinegar are fairly benign, unless thrown around the room. Please exercise all appropriate caution.
- If you do decide to try to put vinegar and bicarb in a zip lock bag and let them explode, prepare for vinegar and bicarb to fly around the room. Probably better outdoors – the stronger the bag the bigger the explosion. YOU HAVE BEEN WARNED. Placing these chemicals in strong containers can result in explosions dangerous enough to not only damage ears, but severely damage hands as well. I'd rather you were disappointed than damaged, please do not use anything other than tiny, 5x5 cm or smaller, zip lock bags.

Preparation

- Lots of foam – a mattress will do well.
    - We used to use polystyrene for volcanoes, it is waterproof, but it's such an environmental disaster I don't recommend it. You would be better of stacking some boxes together and coating them with papier mache. But ripping up an old foam mattress is such fun!
- A world map, or geographical globe.

Suggestions for other year levels

As always, more material is presented here than can be used by the average class during the average lesson time. However, since the students questions can and should guide student learning, more material is presented for you convenience. Remember, it is not uncommon for students to only remember those points which answered their personal questions.

Younger:

This activity is well suited to this age group, with a focus on volcanoes and making them explode. You may need to shorten or avoid the discussion on plate tectonic theory.

Middle:

This activity is well suited to this age group.

Teen:

Focus on helping them understand tectonic theory, who came up with it, what evidence they used, and what it actually is all about.

Engage

Explore some rocks with the students, and ask students what they think about volcanoes.

- ⇨ Make sure all students write down any questions they may have generated during this phase regarding the topic for today.
- ⇨ Take a look at a model of the earth, and ask students if they think the continents could be a giant jigsaw puzzle that can be put together to make all the continents into one 'super continent'.

Explore

Get out your world map (see appendix), and see if students can work out where the continents 'fit' in a supercontinent.

- ⇨ Explain: remember, if you want to convince a scientist of a great idea, you need to have an underlying theory, or explanation, of how it will work. Having a **great idea** is not enough, **evidence** for your theory is not enough, **fame** is not enough. You have to have an answer to the question, 'Yes, but **why**?'
- ⇨ ASK STUDENTS: OK, so even if we take for granted that maybe the continents were once all joined together, can anyone think of HOW they have managed to move? What is powerful enough to push entire *countries* around?

Explain

History of tectonic theory

- German Meteorologist (weather scientist) Alfred Wegener in 1912, by matching up the continents, made 'sciency' a good idea that was at that time – that all the continents may have once been joined up (about 300 million years ago, dinosaurs being 65 million years ago) into a supercontinent he called 'Pangea' for "all lands". What evidence did he have?
    - One important piece of evidence was the shape of the continents. Of course, the jigsaw like fit is even closer if you use the underwater continental shelves, and not just the part of the continents above water. Misunderstanding regarding what Wegener was referring to may have contributed to the poor acceptance of a good idea.
    - Another piece of evidence is paleomagnetism – that the differences in the magnetic fields of certain magnetic rock deposits can successfully be explained by continental drift.
    - Another is the presence of fish fossils in mountains, far away from any current sea. Perhaps that area had once been a sea, and some enormous (but extremely slow) force had pushed it up.

- The importance of *theory* – People liked the idea, but they wanted to know **why** – that is, why had these continents moved around? They needed a **theory**. For example, people get sick *because* of germs, springs retract *because* they can store energy[1]. But Wegener was not so lucky; continents moved around because of … ??? (he didn't know), and *without an underlying theory* his idea was not well accepted. He tried, but his first two explanations were quickly thrown out, fortunately because they were 'wrong', but unfortunately it didn't do his theory and his reputation many favours.
- It wasn't till 1929 that Arthur Holmes was able to develop a theory that could explain continental drift: thermal convection. The theory still got laughed at in places, but at least 'continental drift' now had a workable hypothesis that could be rigorously tested. As the decades moved on and more and more evidence swung in favour of tectonic theory, it stuck.
- So what evidence is there for continental drift by thermal convection?
    - Magma (lava under the crust of the earth) can be seen to flow like water does. We can mathematically approximate the force of that flow underneath the continents.
    - We can approximate the density and state (solid, liquid, gas) of what is under the earth by listening to the echoes of earthquakes.
    - Studies of the deep ocean floors, particularly the mid-Atlantic ridge which runs along almost the entire length of the planet top to bottom, helped to generate further evidence that supported continental drift.
    - And of course, there is much, much more.
  - Now we wouldn't want to finish off on a simple note, of course! Modern geophysics admits that there must be more than just the movement of magma to account for all the movement of the tectonic plates, so there's much more involved here! If you want to, look up earth's rotation and gravitational pull.

Elaborate

⇨ Ask students if they can design new ways to test this explanation, is it really sufficient? Can they think of further or better explanations, and the experiments needed to test them?

Let's explore a little more about tectonic plates:

[1] Curiously, Isaac Newton didn't have an explanation for gravity, but it worked so well at explaining things that it stuck anyway. When asked 'why' he famously replied 'I make no hypothesis' – AKA 'I don't know'.

3 ways tectonic plates can move

The plates move an average of about 2.5cm every year – about as much as your fingernails grow! (And a hundred times less than the 250 cm Wegener originally suggested, which may also have contributed to making his theory less popular.) From Wikipedia, may 2017

1. They can rub past each other in what is called a 'transform boundary'. When they are unmoving or stuck, all is quiet, but as pressure builds they can rush past each other in seconds, crashing and bouncing, causing an earthquake. One example is the San Andreas fault in North America.
2. They can move away from each other, as in the mid-Atlantic ridge which runs almost the entire length of the planet, under the ocean. They are also called 'constructive' boundaries because new material is solidifying on the surface of the earth.
3. Convergent boundaries (Destructive, or active margins) occur where two plates slide toward each other to form either a subduction zone (one plate moving underneath the other) or a continental collision.
    a. At zones of ocean-to-continent subduction (e.g., Western South America, and Cascade Mountains in Western United States), the dense oceanic lithosphere plunges beneath the less dense continent. Earthquakes then trace the path of the downward-moving plate as it descends into asthenosphere, a trench forms, and as the subducted plate partially melts, magma rises to form continental volcanoes.
    b. At zones of ocean-to-ocean subduction (e.g., the Andes mountain range in South America, Aleutian islands, Mariana islands, and the Japanese island arc), older, cooler, denser crust slips beneath less dense crust. This causes earthquakes and a deep trench to form in a curve shape. The upper mantle of the subducted plate then heats and magma rises to form curving chains of volcanic islands. Deep marine trenches are typically associated with subduction zones, and the basins that develop along the active boundary are often called "foreland basins". The subducting slab contains many hydrous minerals which release their water upon being heated. This heat then causes the mantle to melt, producing volcanism.
    c. Closure of ocean basins can occur at continent-to-continent boundaries (e.g., Himalayas and Alps): collision between continents where neither mass sinks down; plate edges are compressed, folded and uplifted – resulting in mountains. Volcanoes aren't so common here, but entire slabs of earth the size of cities can get turned upside down, eventually.

So the movements of tectonic plates and the magma underneath can create… volcanoes…!!

For Upper Year Levels

- ⇨ Research other evidences that support tectonic plate theory. They include:
    1. The continents fit together like a puzzle
    2. Fossil evidence
    3. Rock type and structural similarities (such as paleomagnetism)
    4. Paleo climatic evidence
- ⇨ Research other causes of continental drift. Is the convection of magma the only underlying reason for the continents to move? [Certainly not!]

Volcano theory

Other ways to form volcanoes

The movement of tectonic plates are not the only way volcanoes can form, but they are the most common.

There are other conditions that can result in volcanoes. One is the famous 'hot spot' where, for reasons yet unknown, especially hot magma rises and melts it way through to the surface. Hawaii (and its island chain), the Galapagos Islands and Hawaii are just a few examples.

Thinning or stretching of the earth's crust can also cause volcanoes, e.g., in the East African Rift and the Wells Gray-Clearwater volcanic field and Rio Grande Rift in North America.

Volcano fun facts

- Most volcanoes are under water.
- Volcanoes help shape life on the planet. Large explosions can cause sudden and severe winters worldwide. They might have helped wipe out the dinosaurs, and have influenced the way humans look and live.
- Cryovolcanoes aren't made out of magma and stone, but of water and ice. They are actually quite common in the solar system.
- Jupiter's moon Io is the most volcanically active object in the solar system because of tidal interaction with Jupiter. It is a Cryovolcano.

Ancient volcano theories (from Wikipedia)

Many ancient accounts ascribe volcanic eruptions to supernatural causes, such as the actions of gods or demigods. To the ancient Greeks, volcanoes' capricious power could only be explained as acts of the gods, while 16th/17th-century German astronomer Johannes Kepler believed they were ducts for the Earth's tears.[40] One early idea counter to this was proposed by Jesuit Athanasius Kircher (1602–1680), who witnessed eruptions of Mount Etna and Stromboli, then visited the crater of Vesuvius and published his view of an Earth with a central fire connected to numerous others caused by the burning of sulfur, bitumen and coal.

Various explanations were proposed for volcano behavior before the modern understanding of the Earth's mantle structure as a semisolid material was developed. For decades after awareness that compression and radioactive materials may be heat sources, their contributions were specifically discounted. Volcanic action was often attributed to chemical reactions and a thin layer of molten rock near the surface.

Modern volcano theory

Magma is forced up towards the crust due to pressure, for various reasons:

- Tectonic plates are crashing together, causing the subducting plate to force up magma
- Plates are expanding, resulting in places like the mid-Atlantic ridge
- Hot spots, such as Hawaii

When magma escapes, the gasses are released from it, and the remaining material is now called lava.

Evaluate

- ⇨ Review with students what they felt they learnt from this lesson. Did they have any questions at the start that they feel were answered?

Success criteria

- ⇨ Review the Learning Intentions of this lesson with students. Was it met?

At the end of each class, review the learning objective and see how we did. Ask:

- ⇨ Did you achieve your learning goal?
- ⇨ What did you learn?
- ⇨ What worked to help you achieve it?
- ⇨ What might you do better next time?
- ⇨ (If needed) where can you go for extra help or information?

Assessment

Prior learning:

Take time to focus on planned content material during the engage phase, for example, how the IDEA of tectonic plates came about, how continental plates move, and how volcanoes are formed.

- ⇨ Look at a model of the earth, and ask students if they think the continents could be a giant jigsaw puzzle that can be put together to make all the continents into one 'super continent'

Formative:

Ask students:

- Do you think Australia is moving north at about the same speed as your fingernail grows? What could possibly push something as heavy as a country!?
- How do you think scientists can 'see' inside the earth? The deepest hole ever dug only reached a few kilometres before the hot rocks began to melt back against the drill bit[2]. Those few kilometres are only a tiny fraction of the Earth's crust.

Summative:

Help students consider ways they can communicate their new understanding to others, just as scientists need to do. Make your own volcano and explain the science within, including the limitations of your model.

- Younger groups – explain the working of a volcano, with the magma chamber, the throat, and the lava.
- Older groups – explain tectonic theory, when was it created, who came up with it, and why was it not originally very well accepted?

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[2] The *Kola superdeep borehole*, for instance.

So what?

Volcanoes are dangerous, keep away.

Some good ideas take time to be accepted.

Creating science

Science understanding

As we learned about the inner workings of earthquakes, continental drift, and volcanoes we experienced that;

- Earth and space sciences year 6: Sudden geological changes and extreme weather events can affect Earth's surface (ACSSU096)

Science inquiry skills

As we built our own volcanoes to use and share, we were;

- Communicating 3: Represent and communicate ideas and findings in a variety of ways such as diagrams, physical representations and simple reports

Further, you may challenge students to come up with their own research questions. Through asking around, and actually digging, find out about the land right under your feet. How old do scientists estimate it to be?

Science as a human endeavour

The importance of theory – continental drift was a great theory that we take for granted today. But it was not well received when it first came out, and one of the reasons was it had no underlying theory that explained it. Through this we saw that;

- Nature and development of science year 5-6: Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions (ACSHE081)

Appendix – history of the tectonic plate theory

Tectonic plates – from Wikipedia

In 1912 the meteorologist **Alfred Wegener** amply described what he called continental drift, expanded in his 1915 book *The Origin of Continents and Oceans*[22]and the scientific debate started that would end up fifty years later in the theory of plate tectonics.[23]

Starting from the idea (also expressed by his forerunners) that the present continents once formed a single land mass (which was called Pangea later on) that drifted apart, thus releasing the continents from the Earth's mantle and likening them to "icebergs" of low density granite floating on a sea of denser basalt.[24]

Supporting evidence for the idea came from the dove-tailing outlines of South America's east coast and Africa's west coast, and from the matching of the rock formations along these edges. Confirmation of their previous contiguous nature also came from the fossil plants *Glossopteris* and *Gangamopteris*, and the therapsid or mammal-like reptile *Lystrosaurus*, all widely distributed over South America, Africa, Antarctica, India and Australia. The evidence for such an erstwhile joining of these continents was patent to field geologists working in the southern hemisphere. The South African Alex du Toit put together a mass of such information in his 1937 publication *Our Wandering Continents*, and went further than Wegener in recognising the strong links between the Gondwana fragments.

But without detailed evidence and a force sufficient to drive the movement, the theory was not generally accepted: the Earth might have a solid crust and mantle and a liquid core, but there seemed to be no way that portions of the crust could move around. Distinguished scientists, such as Harold Jeffreys **and** Charles Schuchert, were outspoken critics of continental drift.

Despite much opposition, the view of continental drift gained support and a lively debate started between "drifters" or "mobilists" (proponents of the theory) and "fixists" (opponents). During the 1920s, 1930s and 1940s, the former reached important milestones proposing that convection currents might have driven the plate movements, and that spreading may have occurred below the sea within the oceanic crust. Concepts close to the elements now incorporated in plate tectonics were proposed by geophysicists and geologists (both fixists and mobilists) like Vening-Meinesz, Holmes, and Umbgrove.

One of the first pieces of geophysical evidence that was used to support the movement of lithospheric plates came from paleomagnetism. This is based on the fact that rocks of different ages show a variable magnetic field direction, evidenced by studies since the mid–nineteenth century. The magnetic north and south poles reverse through time, and, especially important in paleotectonic studies, the relative position of the magnetic north pole varies through time. Initially, during the first half of the twentieth century, the latter phenomenon was explained by introducing what was called "polar wander" (see apparent polar wander), i.e., it was assumed that the north pole location had been shifting through time. An alternative explanation, though, was that the continents had moved (shifted and rotated) relative to the north pole, and each continent, in fact, shows its own "polar wander path". During the late 1950s it was successfully shown on two occasions that these data could show the validity of continental drift: by Keith Runcorn in a paper in 1956,[25] and by Warren Carey in a symposium held in March 1956.[26]

The second piece of evidence in support of continental drift came during the late 1950s and early 60s from data on the bathymetry of the deep ocean floors and the nature of the oceanic crust such as magnetic properties and, more generally, with the development of marine geology[27] which gave evidence for the association of seafloor spreading along the mid-oceanic ridges and magnetic field reversals, published between 1959 and 1963 by Heezen, Dietz, Hess, Mason, Vine & Matthews, and Morley.[28]

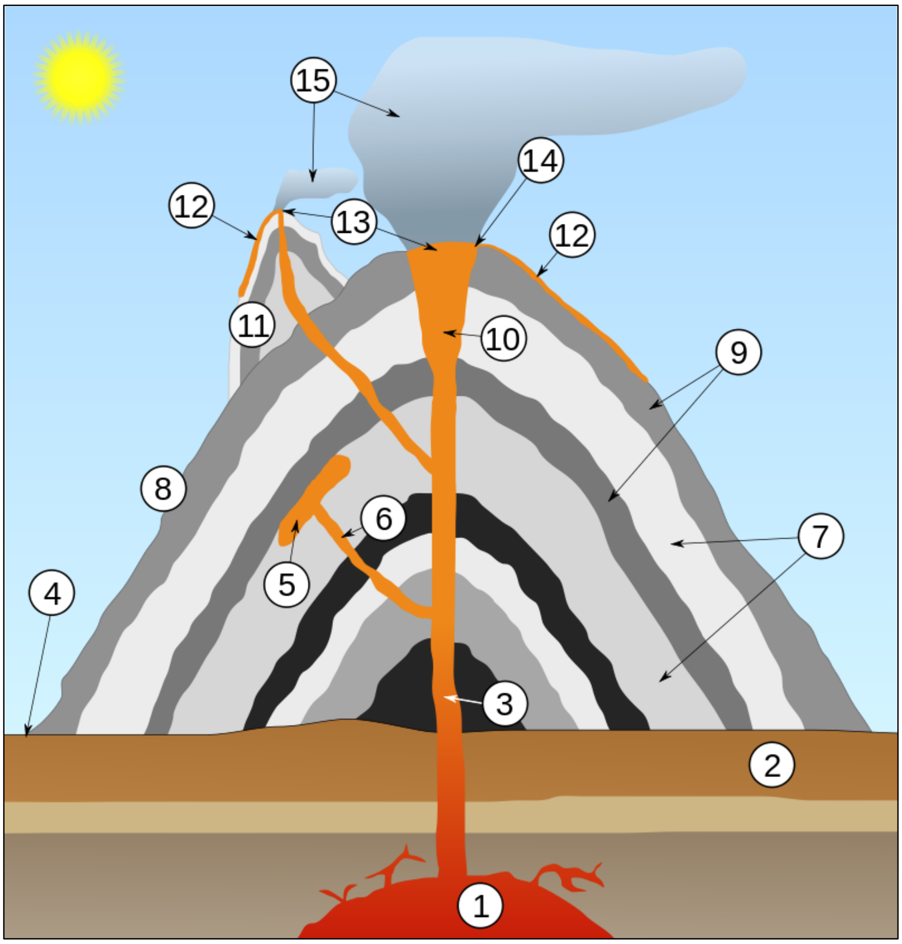
Simultaneous advances in early seismic imaging techniques in and around Wadati-Benioff zones along the trenches bounding many continental margins, together with many other geophysical (e.g. gravimetric) and geological observations, showed how the oceanic crust could disappear into the mantle, providing the mechanism to balance the extension of the ocean basins with shortening along its margins.

All this evidence, both from the ocean floor and from the continental margins, made it clear around 1965 that continental drift was feasible and the theory of plate tectonics, which was defined in a series of papers between 1965 and 1967, was born, with all its extraordinary explanatory and predictive power. The theory revolutionized the Earth sciences, explaining a diverse range of geological phenomena and their implications in other studies such as paleogeography and paleobiology.

Destructive, or creative? (from Wikipedia)

Cross-section through a stratovolcano (vertical scale is exaggerated):

1. Large magma chamber
2. Bedrock
3. Conduit (pipe)
4. Base
5. Sill
6. Dike
7. Layers of ash emitted by the volcano
8. Flank
9. Layers of lava emitted by the volcano
10. Throat
11. Parasitic cone
12. Lava flow
13. Vent
14. Crater
15. Ash cloud



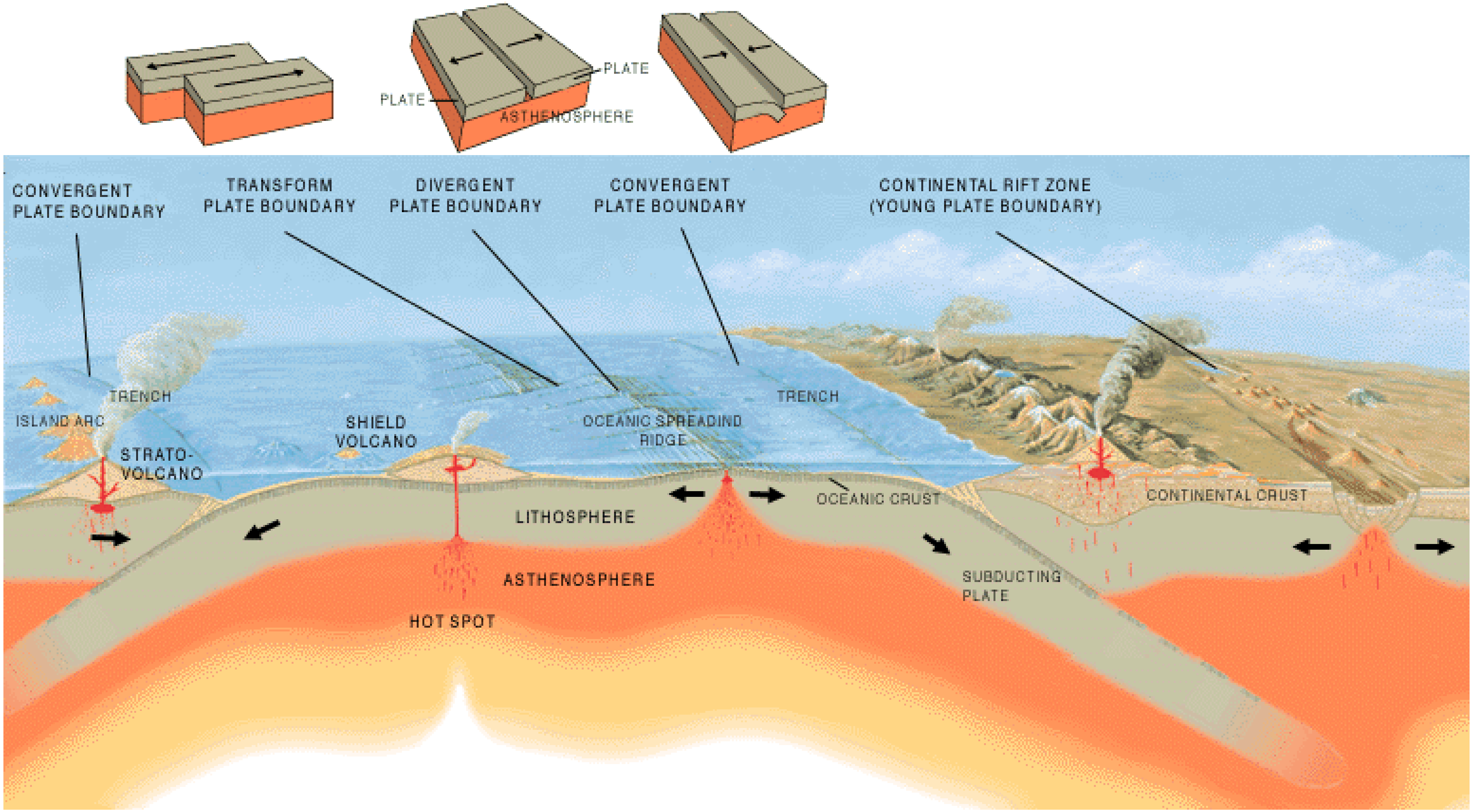
Ways in which a volcano can kill you:

- The lava can **incinerate** you, it is 4000°C,
- The **pyroclastic flow**, super-heated particles such as sand flows down like an avalanche and can flash burn entire forests in seconds. It moves away from a volcano at up to 700 km/h (450 mph).[2] The gas can reach temperatures of about 1,000 °C (1,830 °F).
- They can **change the climate** (and may have helped kill the dinosaurs). Several eruptions during the past century have caused a decline in the average temperature at the Earth's surface of up to half a degree (Fahrenheit scale) for periods of one to three years – sulfur dioxide from the eruption of Huaynaputina probably caused the Russian famine of 1601–1603.[19]
- The gasses can **suffocate you** - The concentrations of different volcanic gases can vary considerably from one volcano to the next. Water vapor is typically the most abundant volcanic gas, followed by carbon dioxide[17] and sulfur dioxide. Other principal volcanic gases include hydrogen sulfide, hydrogen chloride, and hydrogen fluoride.
- They produce **acid rain**, which can kill vegetation and harm human skin. Most of the hydrogen chloride (HCl) and hydrogen fluoride (HF) that is emitted from volcanoes is dissolved in water droplets in the eruption cloud and quickly falls to the ground as acid rain.
- **Airplane crashes** - Ash thrown into the air by eruptions can present a hazard to aircraft, especially jet aircraft where the particles can be melted by the high operating temperature; the melted particles then adhere to the turbine blades and alter their shape, disrupting the operation of the turbine. Dangerous encounters in 1982 after the eruption of Galunggung in Indonesia, and 1989 after the eruption of Mount Redoubt in Alaska raised awareness of this phenomenon.
- Hit by flying rocks, literally called '**lava bombs**'

Posters:

San Andreas fault

Taken 15 nov 2015 from https://en.wikipedia.org/wiki/File:Kluft-photo-Carrizo-Plain-Nov-2007-Img_0327.jpg

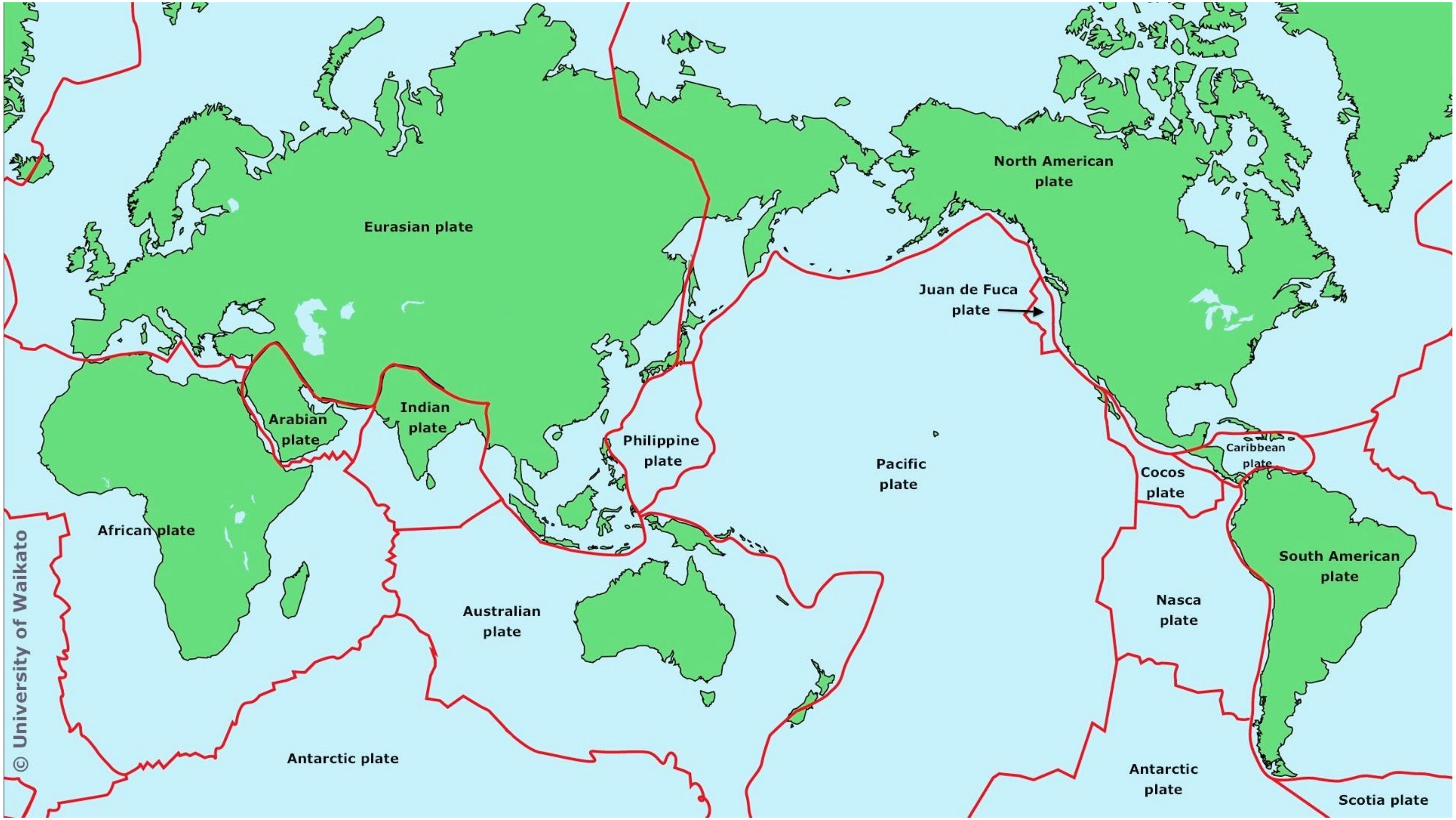


Tectonic plate boundaries, taken 15 Nov 2015 from https://en.wikipedia.org/wiki/Plate_tectonics#/media/File:Tectonic_plate_boundaries.png

The jigsaw earth: Taken 21st June 2016 from https://www.tes.com/teaching-resource/continents-and-oceans-6441665 – can you label and organise the continents?

This is actually a bad example: The **plates** join up, not the **continents** – can you make them join into one continent? And what could have moved them around?

Tectonic plate jigsaw – far more accurate than continents! Taken 21 June 2016 from http://sciencelearn.org.nz/Science-Stories/On-Shaky-Ground/Tectonic-jigsaw-puzzles USE THIS INSTEAD!!



Pangea – taken 21 June 2016 from https://au.pinterest.com/pin/174092341817501640/