NATIONAL GEOGRAPHIC™

8+

WARNING!

Not suitable for children under three years. To be used under the direct supervision of an adult. Choking hazard – small parts can be ingested or inhaled. Cut or stab wounds of the skin by sharp functional edges and points. Instructions for the parents or other responsible persons are included and must be followed. Keep Experiment Set out of reach of children under three years. Keep the packaging and manual because they contain important information!

0-3

MANUAL WITH EDUCATIONAL INFORMATION AND EXCITING EXPERIMENTS

VULKAN-SET
VOLCANO SET

BRESSER®

General Warnings

- Read these instructions before use, follow them and keep them for reference.
- Keep young children and animals away from the experimental area.
- Store this experimental set out of reach of children under 8 years of age.
- Clean all equipment after use.
- Ensure that all empty containers are disposed of properly.
- Wash hands after carrying out experiments.
- Do not use any equipment which has not been supplied with the set or recommended in the instructions for use.
- Do not eat or drink in the experimental area.
- Do not allow chemicals to come into contact with the eyes or mouth.
- Make sure that all containers are fully closed and properly stored after use.

General first aid information

- **In case of eye contact:** Wash out eye with plenty of water, holding eye open if necessary. Seek immediate medical advice.
- **If swallowed:** Wash out mouth with water, drink some fresh water. Do not induce vomiting. Seek immediate medical advice.
- **In case of inhalation:** Remove person to fresh air.
- **In case of skin contact and burns:** Wash affected area with plenty of water for at least 10 minutes.
- In case of doubt, seek medical advice without delay. Take the chemical and its container with you.
- In case of injury always seek medical advice.

Declaration of Conformity

Bresser GmbH has issued a ‚Declaration of Conformity' in accordance with applicable guidelines and corresponding standards. This can be viewed any time upon request.

DISPOSAL

Dispose of the packaging materials properly, according to their type, such as paper or cardboard. Please take the current legal regulations into account when disposing of your device. You can get more information on the proper disposal from your local waste-disposal service or environmental authority.

General disclaimer. Bresser GmbH has used their best endeavors to ensure that the Information in this book is correct and current at the time of publication but takes no responsibility for any error, omission or defect therein.

Get exclusive new Experiments – only available online!

Media about this product

You can dowload further media (experiments, manuals, etc.) from the BRESSER website* over the following QR code/weblink.

http://www.bresser.de/download/9130200

* Offer subject to the availability of media.

Write the telephone number of the local poison centre or hospital in the space below. They may be able to provide information on countermeasures in case of poisoning.

In case of emergency dial
Europe 112 | UK 999
USA 911 | Australia 000

Warranty and warranty term extension

The warranty term is two years from the date of purchase. Please keep your proof of purchase. Register at **www.bresser.de/warranty** and fill out a brief questionnaire to get your warranty term extended to **five years**. Registration must be completed within three months of purchase (date of receipt) to validate the warranty. If you register thereafter, the warranty term will not be extended.

If you have problems with your device, please contact our customer service first. Do not send any products without consulting us first by telephone. Many problems with your device can be solved over the phone. If the problem cannot be resolved by phone, we will take care of transporting your device to be repaired. If the problem occurred after the warranty ended or it is not covered by our warranty terms, you will receive a free estimate of repair costs.

Service Hotline: +49 (0) 2872 - 80 74-210

Important for any returns:
Please make sure to return the device carefully packed in the original packaging to prevent damage during transport. Also, please enclose your receipt for the device (or a copy) and a description of the defect. This warranty does not imply any restriction of your statutory rights.

Your dealer:.. Art. No.: ....

Description of problem:...

Name:.. Telephone: ....

Street:.. Date of purchase: ....

City/Postcode:.. Signature: ....

NATIONAL GEOGRAPHIC™

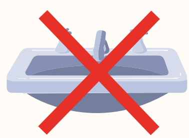
Index

LIST OF CHEMICALS SUPPLIED:

Chemical Substance	Molecular Formula	CAS number
Baking soda (Sodium bicarbonate)	$NaHCO_3$	144-55-8

DISPOSAL OF USED CHEMICALS

When you need to dispose of chemical substances, it is necessary to make reference to national and/or local regulations. In any case you sure never throw chemicals into sewers and garbage. For more details please refer to a competent authority. For disposal of packaging make use of the specif collections points.



ADVICE FOR SUPERVISING ADULTS:

Read and follow these instructions, the safety rules and the first aid information, and keep them for reference. The incorrect use of chemicals can cause injury and damage to health. Only carry out those experiments which are listed in the instructions. This experimental set is for use only by children over 8 years. Because children's abilities vary so much, even within age groups, supervising adults should exercise discretion as to which experiments are suitable and safe for them. The instructions should enable supervisors to assess any experiment to establish its suitability for a particular child. The supervising adult should discuss the warnings and safety information with the child or children before commencing the experiments. The area surrounding the experiment should be kept clear of any obstructions and away from the storage of food. It should be well lit and ventilated and close to a water supply. A solid table with a heat resistant top should be provided.

KIT CONTENTS

Description:	Quantity:
1. Volcano mould	1
2. Rolling pin	1
3. Large measuring cup	1
4. Food colouring	1
5. Baking soda	1
6. Modelling clay	2
7. Wooden stick	1
8. Pasteur pipette	1
9. Plastic spatula	1
10. Funnel	1
11. Protective goggles	1
12. Test tube with lid	1

1. Introduction

The word geology comes from the Greek *geo*, meaning the earth, and *logos*, meaning science.

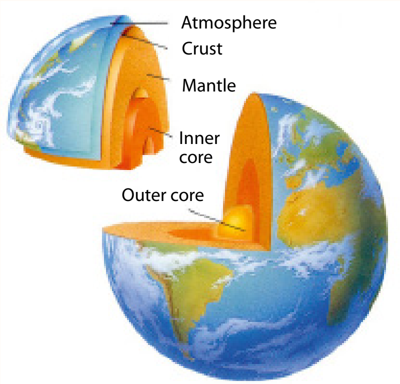


Image 1. Internal structure of the Earth.

Geology is the science that studies the planet Earth and the interaction between different terrestrial systems, bringing together various fields of knowledge.

Geology has been indispensable as a science in helping us understand the planet we inhabit, and how it functions.

It is thanks to geology that we know about the internal structure of the Earth, how a mountain range or desert is formed, what triggers an earthquake or a volcanic eruption and how continental drift works.

Geology also studies other processes and phenomena, such as the formation and changes in rocks, the water cycle, the formation of soils, meteors, crystals, fossils and the origin of the planets and the solar system.

Geology can also aid help economy by helping find and manage such natural resources as fossil fuels, ores and rocks for construction. Due to this, geology can be regarded as an instrument of economic development.

The word geology was first used by Jean-André Deluc in 1778, and was definitively introduced by Horace-Bénédict de Saussure in 1779. The defence of nature and of the environment permits the sustainable growth of society.

2. Why study volcanoes?

An active volcano is one of nature's most imposing elements. It represents the power that planet Earth holds, and all volcanoes tell us something about the planet on which we live. Volcanoes were essential to the evolution of our planet, as they act as a source of water and gases. These gave rise to the oceans and the atmosphere (both fundamental elements for the emergence of life). Volcanoes are an integral part of the Earth's landscape, and possess the ability to transform it.

They can also act as a topographical barrier, and may define the climate, promote fertile soils and act as reservoirs of mineral and energy sources. Knowing about volcanoes allows us to live in harmony with them so we are able to predict when they might erupt in order that we can may prepare ourselves.

Volcanoes, like earthquakes and continental drift, are originate from the exchanges that occur deep inside the planet because of the way in which internal heat is released. Heat transfer deep under the surface of our planet occurs by convection.

A current of hot material is generated deep underground and rises towards the surface. As it does so, it then cools down and starts to descend, creating a convection cell. This movement can be compared to hot and cold air masses in the atmosphere, or when you heat a liquid in a pot.

Convection is one of the main types of heat transfer that only happen in fluids - liquids and gases.

To get to know volcanoes, we have to better understand the base from which they emerge: **THE EARTH.**

3. The Earth

Our planet is old… very old: scientists estimate the Earth is about 4,500 million years old, which is a long, long time.

The history of the planet's formation is linked to the beginnings of the solar system. It follows on from the events that were started by the birth of the universe, which is what we are now going to talk about.

It is now generally accepted that universe started with a Big Bang. The Big Bang theory states that the universe appeared around 13.7 billion years ago with a monumental cosmic explosion. In the fraction of a second that followed, when space and time appeared, the universe and all the matter expand, giving rise to the galaxies and the stars. This is a process that continues nowadays.

Our solar system can be traced back to a rotating cloud of dust and gas (mostly hydrogen and helium). Because of the rotation and the force of gravity the matter began to move towards the centre of the cloud, forming a proto-sun.

Compressed under its own weight, the matter inside the proto-sun became denser and hotter. The temperature rose until it reached several million degrees and nuclear fusion began, giving birth to our sun. While most of the matter in the cloud was concentrated in the proto-sun, a small amount continued to rotate around it. This gas and dust condensed into small grains that collided with each other.

Over time these grains grew into large rocks a few kilometres wide, called planetesimals. Through collisions and coalescence these planetesimals became the planets of the solar system.

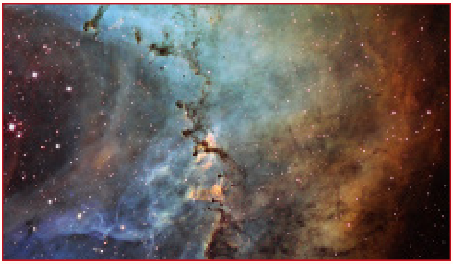


Image 2. Rosette Nebula.

How did a mass of rock turn into the living planet with continents, oceans, and the atmosphere we see today? The answer to this question is **differentiation**.

Differentiation is the process by which an aggregate of matter becomes a body with an interior structured in concentric layers with distinct physical and chemical properties.

This happened in the beginning of Earth's history, when the planet became hot enough to fuse. A meteor impact releases a lot of energy, and part of that energy is released in the form of heat.

At the beginning of its life, Earth was constantly bombarded by meteors and planetesimals, which released energy on impact and heated the planet up.

A decisive event happened about around 20 million years after the Earth's formation, when another planet the size of Mars crashed into it, releasing enough energy to fuse the Earth (this collision launched a cloud of debris into orbit that formed the moon). With this fusion the process of differentiation began.

Before the fusion, Earth would have been an relatively homogeneous mass of matter. With the fusion of the heavier materials, some, such as iron, began to sink towards of the centre of the planet.

Lighter substances, such as oxygen and silicon, floated to the surface. The movement of lighter material towards the surface also helped dissipate the heat into space, which in turn allowed the planet to cool and solidify. As a consequence, Earth became a differentiated planet: divided into several layers.

Let us now look at the structure of our planet in more detail.

3.1. The structure of the Earth

What's the first thing you do when you have a closed box and you don't know what's inside it? Most people will shake it and listen to hear the sound it makes, and then try and guess what's inside. With the Earth we can do something similar.

Even though we can't hear them, earthquakes send out waves (seismic waves) that behave in a similar way to sound waves. Studying these waves as they pass through the planet gives us many clues about what happens underneath our feet.

The study of these waves has enabled scientists to separate the Earth into various layers, each with distinct characteristics and properties. As we can see below, there are two models of the planet's internal structure.

a) Geostatic model

Separates the layers according to their composition:

Crust: the external layer, which is composed of solid rock. Its thickness varies between 20km and 80km.

Mantle: this is approximately 2,900km thick (about 45% of the Earth's radius) and is separated from the crust by the **Mohorovicic discontinuity**. It is largely made up of rock of intermediate density: compounds of oxygen with magnesium, iron and silicon. Due to the high temperature and high pressure, this material has a plastic behaviour. It is divided into the upper mantle and the lower mantle.

Core: its radius is approximately 3,400km. It is composed of iron and nickel. It is responsible for the Earth's magnetic field.

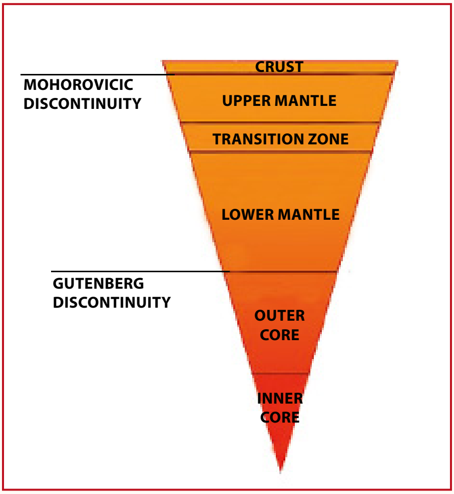


Image 3. Geostatic model.

b) Geodynamic model

This model separates the layers in terms of their physical properties:

Lithosphere: this is the outermost layer. It has an elastic behaviour and a thickness of approximately 250km, bringing together the crust and the upper mantle. It's formed by solid and rigid materials - the lithospheric plates.
Asthenosphere: this is the portion of the mantle that is in liquid form. The seismic waves lose speed in this layer. It is in this layer that lithospheric plates move.
Mesosphere: this corresponds with the lower mantle. It begins at a depth of about 700km, where the minerals are more dense but maintain their chemical composition. It is made up of very hot, solid state rocks, which have plasticity.
D-layer: this coincides with the Gutenberg discontinuity, and is the transition zone between the mesosphere and the core. Here rocks heat up substantially and can rise to the lithosphere, producing a volcano.
Core: as in the geostatic model, this is formed from an outer and inner layer. The fluid outer layer is where currents and fluctuations are generated, and the solid inner layer is very dense.

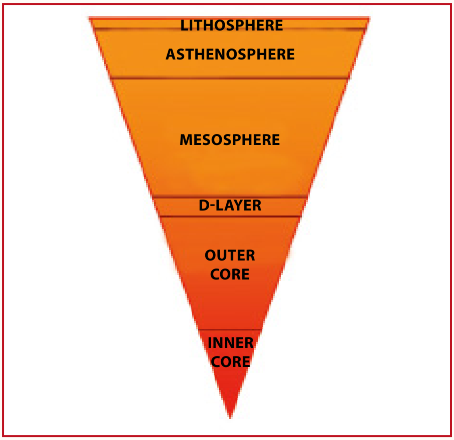


Image 4. Geodynamic model.

3.2. Plate tectonics

Tectonics is derived from the Greek word *téktōn*, meaning "which builds". This theory explains the movement of the plates making up the earth's crust over a period of thousands of millions of years.

This phenomenon occurs as a product of the convection of the mantle and is responsible for the constant reshaping of the lithosphere. The model explains the interchange of heat between the crust and the mantle.

According to plate tectonics, the first 100km of the planet's surface, which forms the lithosphere, behaves like a rigid material, is brittle and is not very dense. It is not a uniform layer, rather, it is split into various plates or blocks, like pieces of a puzzle, which move at an average speed of 2.5cm per year.

The plates interact with each other along their two outer edges, which can cause large deformations in the crust and the lithosphere. This can result in large chains of mountains like the Himalayas, or long fault lines, such as the San Andreas Fault in the United States.

The contact between the plate edges is also responsible for the majority of earthquakes.

Tectonic plate theory also explains why volcanoes and seismic activity are concentrated in specific regions of the planet (for example the ring of fire around the Pacific Ocean). These regions usually coincide with the edges of the plates. The theory can also explain the location of ocean trenches.

The direction of movement and composition of the plates determine the characteristics of the areas of contact between them. These areas can be of four different types:

Image 5. Main Tectonic Plates and direction of travel.

a) Divergent boundaries: zones where the plates move away from each other. They are new crust formation zones. Some of the most visible forms are the mid-ocean ridges, which are underwater mountain systems.

These are areas of primary volcanism, where the magma is composed of materials rising from the depths of the mantle. One of the best known examples of a divergent boundary is the mid-Atlantic ridge in the Atlantic Ocean, which stretches for 11,300km. It's highest point is Pico Island in the Azores. Another example is the African Great Rift Valley.

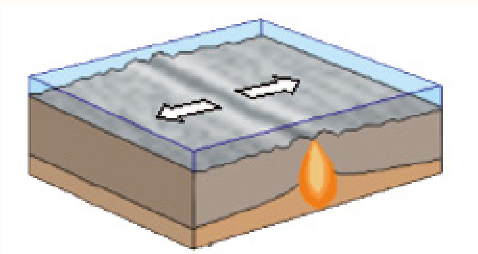


Image 6. Divergent boundaries.

b) Convergent boundaries: zones where the plates come together. When two plates of the lithosphere converge (two oceanic plates or an oceanic and a continental plate), they form a subduction zone (where one plate sinks underneath the other).

When two continental plates collide, they may form a metamorphism zone.

The subduction zones usually give origin to marine trenches such as the Mariana Trench. Convergent boundaries normally give rise to large mountain ranges such as the Himalayas or the Andes. These are areas of important seismic activity and volcanism (the magma is usually composed of fused material from the plate that sinks).

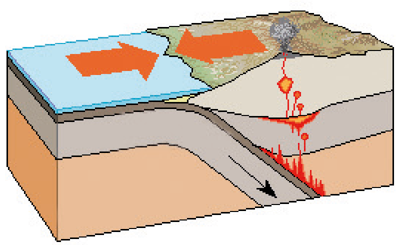


Image 7. Convergent boundaries.

c) Transform boundaries or conservative boundaries: zones where the plates grind past each other without any compression or distension. The plates slide past each other along transformative faults. There is wear and tear and crushing at the contact zones between the plates. These areas are associated with shallow earthquakes and some volcanism. An example of a transform boundary is the San Andreas Fault in California.

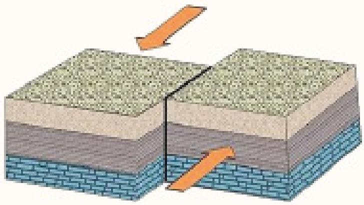


Image 8. Transform boundaries.

d) Hot Spots: zones that are not associated with any specific part of the tectonic plates. These zones stem from very hot regions at particular points in the lower mantle. Hot spots are where plumes of very hot material form, which rises to the surface and creates volcanoes. As these are fixed areas and are independent of the movement of the plates, the plumes remain in the same place as the tectonic plate moves. They form a chain of volcanoes, such as is the case of Hawaii. To visualise this phenomenon, imagine what happens when you slowly pass a sheet of paper over a lit candle.

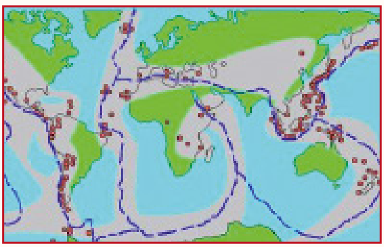


Image 9. Distribution of the Earth's hot spots.

3.3. Geothermal energy: Harnessing the Earth's internal heat

Geothermal energy comes from inside the planet. It is one of the alternative energies we use today. This heat comes from:

- Disintegration of radioactive elements;
- Heat left over from the formation of the planet.

This energy manifests itself in the form of volcanism derived from geological processes, such as geysers and hydrothermal vents.

Geothermal power plants operate using steam turbines powered by the steam produced by water heated by the Earth and channelled at high pressure through pipelines into turbines, which in turn produces electricity.

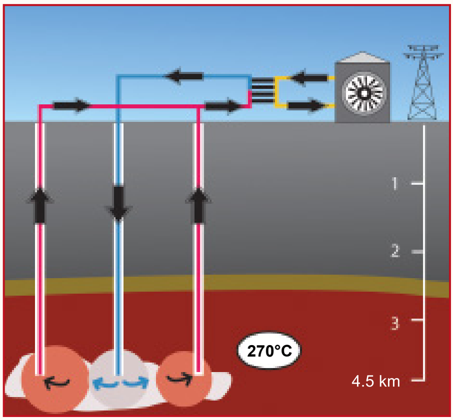


Image 10. Geothermal power station.

This energy can also be used for central heating and for heating water.

The water from hydrothermal sources can also be used industrially for the extraction of minerals (the water is quite rich in minerals), such as sulphur, ammonia and sulphuric acid salt.

Uses:

- Spas: hot springs that have health applications;
- Radiators and hot water;
- Extraction of minerals;
- Agriculture and aquaculture: for greenhouses and fish farming.

Drawbacks:

Although this source of power is very environmentally friendly and generates very little waste in comparison with fossil fuels, it's application is not very widespread because it:

- Releases hydrogen sulphide into the atmosphere;

- Releases carbon dioxide and its associated problems;

- May contaminate watercourses or ground water with harmful substances;

- Is limited to areas of active volcanism;

- Can damage landscape.

3.4. Volcanism

Volcanic eruptions are caused by magma rising to the surface. It is most abundant common in areas of contact between the plates:

a) In dorsal or rift areas, volcanism is related to the process of new crust formation. In the dorsal areas, with the separation of the plates, the oceanic lithosphere is increasingly thinner.

The pressure of the deeper material is powerful enough to break through this thin layer and rise to the surface. The vast majority of this volcanism is under water and can form large chains of volcanoes on the seabed.

In some cases these volcanoes are large enough to reach the surface, and form islands, such as the Azores and Iceland.

Image 11. Submarine volcano.

b) In areas of subduction, volcanism is associated with the way in which the subducted lithospheric plate penetrates the mantle.

An example of active volcanism in a subduction zone is the ring of fire around the Pacific. Here the subduction zone forms a large set of oceanic trenches, including the Mariana Trench (image 12).

At 11km, the Mariana Trench is the lowest point on Earth. In these trenches some of the material is introduced into the mantle where it melts and returns to the surface. This creates a zone of volcanism behind the subduction zone.

The material that rises to the surface is composed of the sinking plate's least dense components, which have the lowest melting points. If the subduction zone is between two oceanic plates, it can give rise to a rim of volcanic islands in the ocean, such as on the west coast of the Pacific Ocean.

A case of volcanism in subduction zones between continental and oceanic plates is the Andes range in South America.

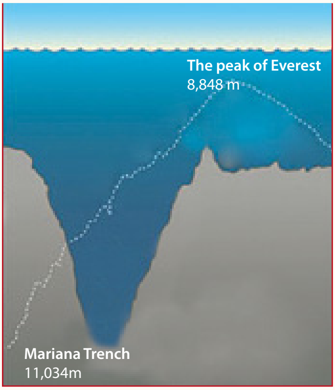


Image 12. Comparison between the depth of the Mariana Trench and the height of Everest.

c) Volcanism can also occur within tectonic plates away from contact zones, as is the case with **hot spots**. Another type of volcanism forms the volcanic islands located on the passive margin of Africa, such as the Canary Islands. Many of these volcanoes are associated with hot spots.

The sliding of the plates along a hot spot leaves a chain of volcanoes, in which only the most recent are active. Examples of this type of volcanism are the Hawaiian Islands, which are practically in the centre of the Pacific plate.


Image 13. Hawaii archipelago: a set of islands formed by volcanic eruptions.

There are five areas on the planet where volcanic activity is most pronounced. These are:

1. Circum-Pacific Zone: Also known as the ring of fire, which extends around the Pacific Ocean, the American coast, Asia and Oceania. It covers structures such as the Andes, the Rocky Mountains and various strings of islands. The most active volcanoes in this area are those in Hawaii, Alaska, Japan, Peru and the Philippines.

2. Asiatic-Mediterranean Zone: this extends from the Atlantic to the Pacific, in a west to east direction. The most active volcanoes in this region are in Italy, Turkey and Indonesia.

3. Indic Zone: this surrounds the Indian Ocean and connects to the Circum-Pacific zone in the Sumatra and Java islands. There are many islands and underwater mountains with active volcanoes in the dorsal Indic area, for example Reunion and the Comoros.

4. Atlantic Zone: this zone traverses the Atlantic Ocean from north to south through its central area. Volcanoes in Iceland, the Ascension Islands, St Helena, the Azores and the Canary islands stand out in this area.

5. African Zone: volcanoes like Kilimanjaro stand out in this area.

4. Volcanoes

4.1. Definition of volcano

Volcanoes are geological formations that consist of openings in the Earth's crust. They allow pockets of magma to reach the surface. They are called either central or fissure-like, depending on the lava that rises through the cracks and fissures.

Central volcanoes usually give rise to a volcanic cone, on top of which there will be a depression or crater. This is where a central conduit opens connecting the surface to the Earth's interior. The cone is formed by the deposit of matter that flows or is expelled through the volcano's conduit. The study of volcanoes and volcanic phenomena is called vulcanology.

DID YOU KNOW...

The word volcano comes from Vulcan? It was the name of the Roman god of fire.

Image 14. Volcano God

4.2. Structure of a model volcano

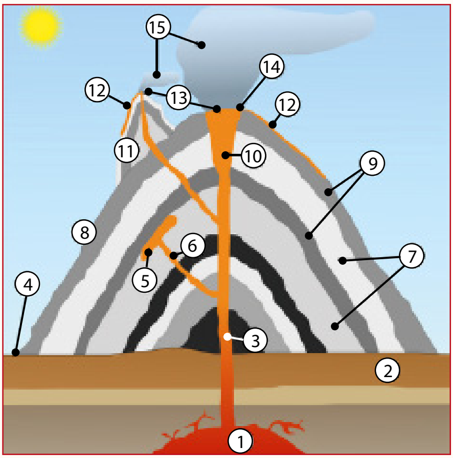


Image 15. Structure of a volcano.

1. Magma chamber: where the magma accumulates before it is expelled. Situated many kilometres beneath the surface, it can be hundreds of square kilometres in size. It can become partially empty after the eruption. In this case, the magma chamber may collapse, affecting the integrity of the volcano above.
2. Bedrock
3. Conduit (pipe): the part through which the magna passes to the surface.
4. Base
5. Sill
6. Secondary throat
7. Layers of ash emitted by the volcano
8. Cone: the visible part of the volcano, formed by the expelled materials.
9. Layers of lava emitted by the volcano.
10. Throat
11. Parasitic cone
12. Lava flow
13. Vent
14. Crater or caldera: the exit zone for the material expelled by the volcano. It is on top of the flanks with the conduit at its base. It can be small or very large. When all or part of the cone collapses, it creates a much larger crater, which is called a caldera.
15. Ash and gas cloud

4.3. Expelled materials

The material expelled by volcanoes can be of various types:

a) Solids

The solid materials expelled by volcanoes are called solid materials. These are classified according to their size:

- **Volcanic blocks and bombs:** these can be of many metres in diameter and are found nearest the volcano's crater. They are usually round because of their rotational movement as they fall (and cool down).

- **Lapilli:** expelled materials measuring 2-20mm in diameter.
- **Ash:** particles that are smaller than 2mm. They usually remain suspended in the air for a long time after the eruption and can travel hundreds of kilometres.
- **Debris avalanches:** a partial fall of the volcano flanks causing large avalanches. It can be caused by the instability of the materials on the flanks, which are poorly supported and can break loose due to the force of gravity. It could also be because of the magma pressure on the magma pressure on the inside or by an earthquake.

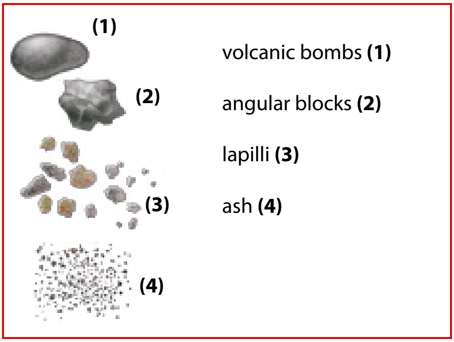


Image 16. Types of solid material: volcanic bombs (1), angular blocks (2), lapilli (3), ash (4).

b) Liquids

From the moment the magma rises to the surface it loses some of its components, particularly gases, and is called lava. Lava is molten rock expelled by the volcano. The lava's thickness depends on its chemical composition: lava rich in iron and magnesium is less viscous than lava rich in silica. The lava's viscosity also depends on its water content and temperature. Lava can be aerial or submarine.

There are three different types of aerial lava:

- Pahoehoe: this is a very fluid type of lava. It is formed by the solidification of a very thin surface layer, under which the lava continues to flow. This causes the superficial layer to billowy and heaving.

- Aa: this name has derived from the sound people make when walking barefoot over the solidified deposits of this type of lava. This is because it is irregular and has sharp edges. It is a thicker lava that cools down and breaks into blocks due to the pressure exerted by the rest of the lava flow pushing against it.

Image 17. Pahoehoe lava.

Image 18. Aa lava.

- Continuous surface lava, is different to the wrinkly character of the other two. It is smoother and more fluid.

Image 19. Continuous surface lava.

- Submarine lava (or pillow lava): this type of lava cools down very fast due to its contact with the water, which gives it a very unique look, similar to pillows.

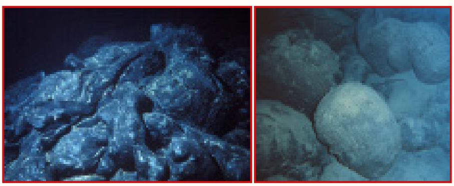


Image 20. Pillow-lava.

NATIONAL GEOGRAPHIC™

c) Gases

The gas portion of magma varies between 1% and 5% of its total weight. Of these gases, about 70-90% is steam.

The other gases are usually carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen (N_2), hydrogen (H_2), carbon monoxide (CO), sulphur (S), argon (Ar), chlorine (Cl) and fluorine (F). These gases can combine with water or hydrogen to form numerous toxic compounds such as hydrogen chloride (HCl), hydrogen fluoride (HF), sulphuric acid (H_2SO_4) and hydrogen sulphide (H_2S).

Image 21. Emission of sulphuric acid.

d) Sludge and debris flow

Sludge and debris flow: known as lahar, they are made up of a mixture of water and rocky materials that are mostly of a volcanic origin (rocks, pumice and ash).

They can roll down hills at great speed. Sludge and debris flows are a common phenomenon if there is a lot of water.

This could be due to the fusion of ice and snow masses, heavy rain or the point of contact at which a pyroclastic flow meets a lake or river.

The danger associated depends on the amount of water available, the quantity and size of the pyroclastic material and topography.

4.4. Types of volcanoes and other volcanic structures

a) Classification based on shape

1. Stratovolcano: has a conical shape with a central crater. The cone is formed by successive layers of lava, scoria and ash, as a result of previous eruptions. Most of the volcanoes in Guatemala are of this type.

Image 22. Mount Teide (Tenerife) Spain.

2. Calderas: these are the result of large eruptions, where there was a total or partial collapse of the volcanic structure, leaving a huge crater.

Craters with a diameter larger than one kilometre are called calderas. There are at least 138 calderas with a diameter of more than 5km on the planet. Some of these calderas are so vast that they can only be seen in their entirety from space.

Image 23. Caldera de Tambora (Isla de Sumbawa), Indonesia.

3. Shield volcano: it is a type of volcano with a low conical structure. These volcanos are made up of successive layers of a type of lava that is very fluid. It is a quite common volcano in Hawaii.

Image 24. Kilauea Volcano (Hawaii).

4. Lava domes: structures that emerge from the conduit of a volcano, formed by lava that is so viscous it does not flow. An example is the Santiaguito dome on the southwest of the Santa María volcano in Guatemala.

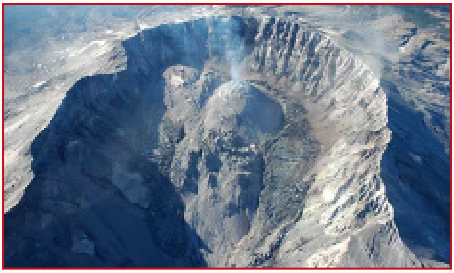


Image 25. Santa María Dome (Guatemala).

5. Cinder or scoria cone: these are relatively small cones that, as the name suggests, are formed by the accumulation of ash and scoria. Examples of this are the hills in the Jalpatagua Fault and the large land depression next to the Volcán Ipala in Guatemala.

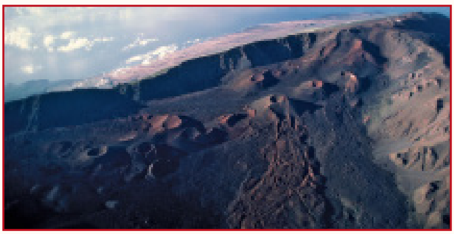


Image 26. Haleakala National Park (Hawaii).

6. Hot springs and geysers: these emit steam and water at high temperatures. They are usually in the form of gushes caused by the heating of water contained in subterranean deposits. The heat causes the water pressure to rise until it is great enough to force it to the surface, where it is expelled violently. The best known geysers are those in the Yellowstone National Park in America.

Image 27. Geyser (United States of America).

7. Fumaroles: openings or fissures on the planet's surface, usually around a volcano, from where gases are released into the atmosphere.

Image 28. Fumarole, Azores (Portugal).

8. Cold water geyser: cold geysers from which carbon dioxide is released.

Image 29. Cold water geyser in a Natural Park in the Czech Republic.

9. Solfataras: are geysers that release water vapour and sulphuric acid. Their temperatures do not exceed 100ºC.

Image 30. Solfataras: Deposits of sulphur crystals (yellow) are clearly visible.

10. Fissure eruptions and lava plains: most of the volcanic material is expelled through fractures in the crust called fissures.

These fissures allow the release of low viscosity lava that can extend over large areas. Fissure eruptions expel a runny basaltic lava. Successive layers cover the terrain to form extensive lava plains.

These lava flows are called flood basalts. This type of lava flow is more frequent on the seabed.

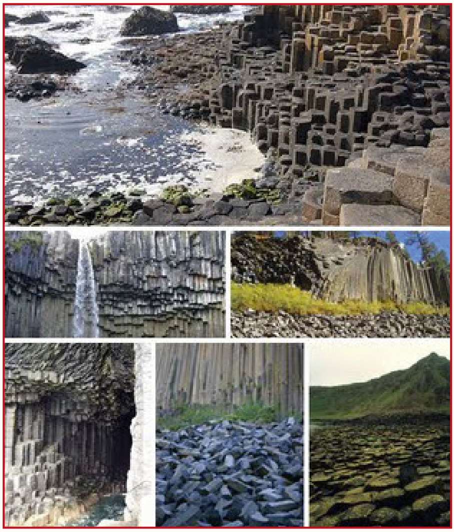


Image 31. Examples of fissure eruptions and lava plains.

11. Channels: cavities or channels present in volcanic rock and produced by the lava flow. These are formed at the same time as the surrounding rock and are not a result of erosion processes.

Image 32. Channels created by the passage of lava.

12. Volcanic conduits: these are composed of basalt. They are the result of lava that has solidified inside the volcano's conduit.

Erosion is constantly destroying and remodelling the surface of our planet.

The cone of volcanoes formed by ash or other less consolidated materials erodes much more rapidly than the more resistant solid rock formed by the lava that has solidified in the conduit. This rock can remain isolated in this way for a very long time. These structures have a very characteristic shape.

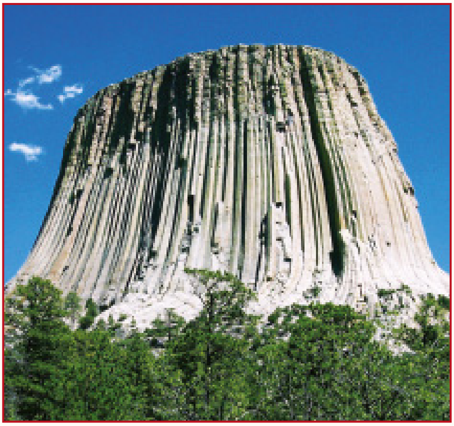


Image 33. Devil's Tower, United States of America: remains of a volcanic conduit uncovered by erosion.

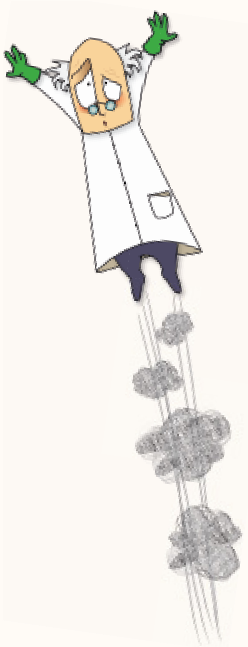
DID YOU KNOW...

The cooling of the magma gives rise to different types of rocks according to their initial chemical composition and cooling process?

Two main groups can be distinguished:

Extrusive: Formed by the rapid cooling of lava on the surface. They are formed by very small crystals that are, sometimes, difficult to see with the naked eye. They are usually composed of pyroxene or olivine and have a high iron content. Example: basalt

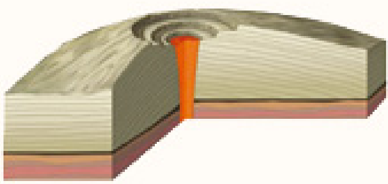
Intrusive: Formed by the slow cooling of magma at depth. They are composed of well-formed crystals and are visible to the naked eye. An example of this type of rock is granite, which is formed mainly from quartz, feldspar and mica.



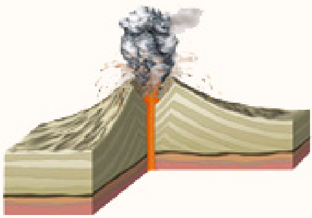
b) Classification based on the type of eruption

Volcanic activity can be classified according to the effusive and explosive nature of its eruption:

Hawaiian: characterised by an abundant output of very fluid magma, forming large lakes and rivers of lava. As a result of the level of fluidity, the release of gases is smooth. Violent explosions are rare, but the accumulated gases can cause lava fountains that reach tens of meters in height.

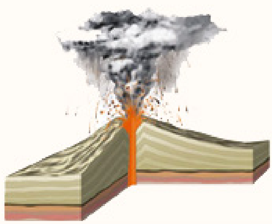


Strombolian: characterised by regular and constant explosions that launch incandescent lava into the air. The explosions are accompanied by rivers of lava and gas emissions. The lava is more viscous than the Hawaiian type. Ash and cinder cones can form very quickly from alternating layers of dried lava and pyroclastic rocks.



Volcanian: these are less frequent and more violent eruptions than the Strombolian type, mainly because of the type of lava. The lava is even more viscous than in Strombolian eruptions and does not easily allow the release of gases.

This type of eruption is often accompanied with clouds of ash and gases that rise several kilometres into the air. After the eruption, the central conduit is frequently unobstructed, because no lava flow occurs.

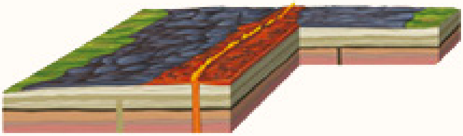


Plinian: these are very violent eruptions, which project pyroclastic material for several miles and form large vertical columns of gas and ash.

They are often accompanied by the collapse of the upper part of the volcano.

Pelean: this is also highly explosive and has very viscous lava with a high gas content. It can produce currents of gas, ash, rock and pulverized magma, which move downhill very quickly, destroying everything in its path. These currents of incandescent material are called pyroclastic clouds and are extremely dangerous.

Icelandic: this does not form the cone or crater characteristic of other types of volcanoes. Its main feature is the emission of large quantities of lava from fissures in the ground. Some emissions can form low-viscosity lava flows extending over large areas.



Groundwater or geyser-like: they are caused by the contact of magma with groundwater. There is no emission of lava but water vapour or water is expelled at high pressure and temperature, usually on the slopes or base of the volcano. In some cases they can be violent enough to produce small craters.

c) Classification in terms of activity

Active volcanoes

Volcanoes that can erupt. Most volcanoes erupt occasionally, remaining dormant for most of the time. There are very few constantly erupting volcanoes. The active period can last from a few hours to several years, while the dormant between eruptions may be months, years or even centuries.

Dormant volcanoes

Are those in a resting phase, which present sporadic evidence of secondary volcanism, such as hot springs or fumaroles.

Extinct volcanoes

These are volcanoes that have been active in the past but currently do not present any indication they could become active again.

These volcanoes are frequently encountered. In rare cases, a volcano that was thought to be extinct may reactivate. Usually a volcano shows no sign of volcanism for many centuries before being considered extinct. The eruptive activity is almost always intermittent, with periods of activity alternating with long periods of dormancy.

Image 34. Shiprock, United States. The remains of the conduit of an extinct volcano.

4.5. How are volcanoes studied?

The study of volcanoes is important because it provides us with information about the processes taking place inside the Earth. Understanding the way they function also allows us to predict eruptions and avoid disasters. About 10% of the world's population live in areas of volcanic activity. In order to help reduce the number of casualties and damage caused by volcanic activity, constant monitoring of volcanoes is carried out to determine any changes.

Areas of study:

- Geology

The geological study of volcanoes; deposits from previous eruptions and the surrounding terrain, are fundamental for understanding the history of a volcano and to predict its future behaviour.

- Thermodynamics

Volcanoes heat up as magma rises. It is therefore important to monitor the temperature of a volcano. This is done using:
- Thermometers;
- Radiometers.

- Geochemistry

The volcano will release smoke and gas dissolved in the magma. It is therefore important to measure the composition of released gases. This is done with:
- COSPEC;
- Spectrometer used to measure the flow of released substances;
- Local analysis.

- Geodesy

A volcano is deformed by changes in internal pressure from prior episodes of volcanism. This means much can be learned by measuring the angle and distance between various points around the outside of the volcano.

- Seismology

Volcano seismology is the study of seismic waves generated by volcanic activity in a given area. The volcano and surrounding area tremble due to dynamic variations caused by changes in internal pressure. These oscillations are measured using seismometers. They are often set up on the outside of the volcano or in the surrounding area. Six or more seismometers are normally interconnected, allowing accurate calculation of the speed and direction of seismic waves.

- Study methods and techniques

Gravity meter

Measures variations in gravity, as the gravitational field changes, when materials of different density enter the strata.

Magnetometer

- Measures variations in the intensity, inclination and declination of the magnetic field caused by the intrusion of material possesing magnetic properties.

Electrode

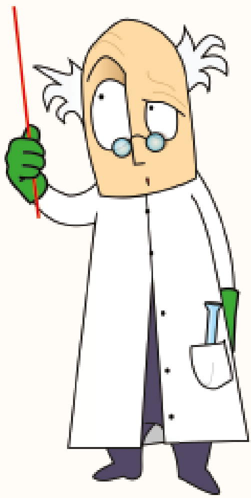
- Measures resistance and the differences in potential caused by the intrusion of material possessing different electrical properties.

Measuring instruments

- Spectrograms: An instrument for measuring the intensity of sound.

- RSAM Method (Real-time Seismic Amplitude Measurement)

The method of measuring real-time seismic amplitude. It is a quick method for quantifying the seismic activity in volcanoes. This method has been of great help in predicting eruptions, such as those at Pinatubo and Mount St Helens.



4.6. Some significant past eruptions

15th century BC: Santorini (Aegean Sea). It may have been one the eruptions responsible for the decline and disappearance of the Minoan culture.

79AD: Vesuvius (Italy). Destroyed Pompeii and Herculaneum.

122AD: Etna (Italy). It reached the city of Catania, the capital of Sicily.

1783: Laki (Iceland). Gases and pyroclastic rocks destroyed the country, resulting in around 10,000 deaths (20% of the population). It also caused deaths in the United Kingdom and northern Europe, having also affected the climate of these regions.

1812: Tambora (Indonesia). The explosions caused about 12,000 deaths.

1814: Mayon (Philippines). The lahars caused about 1,200 deaths.

1833: Krakatoa (Indonesia). One of the biggest explosions ever recorded, and was heard 5,000 km away. It caused a tsunami that caused at least 35,000 victims. The clouds of ash spewed into the atmosphere, affecting the planet's climate for years after.

1902: Santa Maria (Guatemala). 6,000 victims.

1902: Mount Pele (Martinique). A pyroclastic cloud destroyed the city of St Pierre. 28,000 victims.

1902: Soufriere (Saint Vincent). Pyroclastic clouds caused 1,500 deaths.

1911: Taal (Philippines). The explosions caused 1,400 casualties.

1911: Kelut (Indonesia). The existing lake in the crater overflowed, causing 1,000 deaths.

1931: Merapi (Indonesia). Lahars caused more than 1,000 casualties.

1951: Mount Lamington (New Guinea). A pyroclastic cloud caused the death of more than 3,000 people.

1963: Agung (Indonesia). There were around 1,000 victims, many of whom had refused to evacuate.

1976: Soufriere (Guadeloupe). A false alarm caused the evacuation of 70,000 people.

1980: Mount St Helens (United States). There were some casualties, and it caused more than a billion dollars worth of damage.

1981: Galunggung (Indonesia). 40,000 people had to be evacuated.

1982: Chichón (Mexico). The eruption caused about 2,000 deaths.

1985: Ruiz (Colombia). Lahars caused more than 20,000 casualties.

1986: Lake Nyos (Cameroon). Clouds of poison gas caused more than 1,700 deaths.

1991: Simultaneous eruptions in the Philippines and Japan:

- Mount Unzen (Japan): The volcanologists Katia and Maurice Krafft, and Harry Glicken, lost their lives as well as another 40 people, mostly journalists.

- Pinatubo (Philippines): Around 60,000 people were evacuated in the days preceding the eruption.

About 300 deaths resulted. The ash released into the atmosphere reached Malaysia, Vietnam and China. It had a large impact on the Philippine economy and had repercussions on the climate of the northern hemisphere for months, causing a decrease in temperature.

1993: The Mayon Volcano in the Philippines erupted again. 77 people died and it gave rise to a great cloud of ash.

2006: Eruption of the Merapi volcano in Indonesia. A large amount of debris was swept over a distance of 4km. It also caused a large shower of ashes, followed by explosions in the crater. The population was evacuated and days later an earthquake devastated the region.

2010: On April 17, 2010, the explosion of the Eyjafjallajökull volcano, situated on a glacier of the same name, released a fine, toxic ash that reached 10,000 metres into the atmosphere. The particles were invisible and caused severe damage to aircraft engines. This eruption caused chaos at European airports and thousands of people were prevented from travelling by air for several days.

DID YOU KNOW...
Iceland is the largest mass of land made entirely of volcanic origin?
It is formed by plateaus of lava expelled through fractures or large cone-shaped volcanoes.

Image 36. A volcanic glacier.

The mechanism of the Eyjafjallajökull explosion, which paralysed air navigation in much of Europe, was like a large pressure cooker. In the weeks before the eruption, the volcano had become a tourist attraction because of its tongues of lava, until it exploded.

Water from the glacier entered the volcano and vaporised on contact with the magma, which has a temperature of more than 1,000°C, causing the volcanic explosion.

In reality, the Eyjafjallajökull eruption was not very powerful — the volcanic explosion index (VEI) goes from 0 to 8, and this explosion was no more than 2 or 3. This index is an evaluation index and not a mathematical factor, such as is the Richter scale for earthquakes.

Image 37. The Eyjafjallajökull dust cloud.

DID YOU KNOW...
In Iceland there are more than 10 active volcanoes?
They all have female names.

5. Experiments

Material included in the kit.

Experiment 1
Build your Jurassic volcano

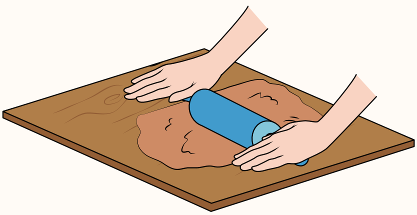
What you will need:

- Modelling clay
- Rolling pin
- Plastic cup
- Paintbrush and gouaches
- Chopping board

Steps:

1. Start by preparing your experiment area: choose a wide table where you can place the materials you need.

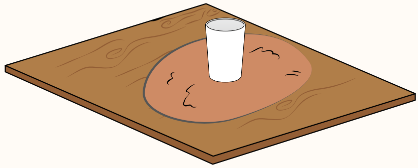
2. Open one of the modelling clay packages and create a base for your volcano: place the modelling clay on the chopping board and flatten it with the rolling pin.



3. Make sure the base gets a circular shape.

4. Turn the clay over and roll out it as well, so that both sides are flattened. If you see any imperfection on the clay, use your fingers to press on them.

5. Now, place your plastic cup on your modelling clay base made. The cup will be the mould for you volcano.



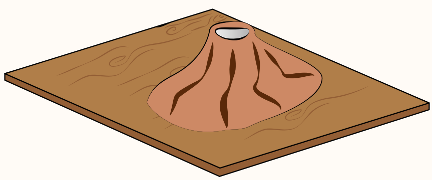
6. Now you need to make the walls for your volcano. Open the second package of modelling clay and, once again, mould the clay in a circular shape.

7. With the rolling pin and your fingers, flatten the clay.

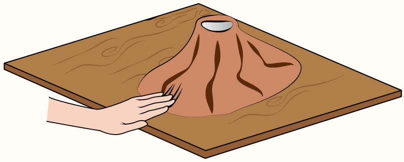
8. This circle you are creating has to be larger than the first one. In this case, the clay has to cover the cup and then be attached to the base of the volcano, in order to create a cone.

9. When the cup is completely covered, with the right diameter, attach it to the base of the volcano with you fingers.

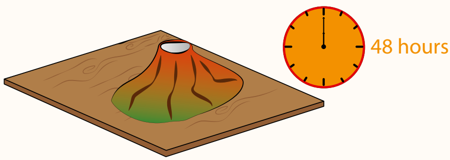
10. Remove the modelling clay from the top of the volcano (where the opening of the cup is located), in order to make the crater.
Attention: make sure you have enough clay to cover the rim of the cup.



11. In all the stages of building your volcano, you must always make sure that the clay is even: you must pass your fingers on it to join the clay, mainly between the base and the walls of the volcano. If you notice that the modelling clay is drying, wet your fingers and pass them on the clay.



12. Leave your volcano to dry on the chopping board for about 48 hours. Now it is time to paint your volcano with the paintbrush and gouaches!



13. When it is dry, your volcano is ready to use.

Explanation:
Some materials we use in our everyday life come from nature. The modelling clay that you have used in this experiment is from plant origin, this is to say, it comes form a plant: bamboo.

DID YOU KNOW...
That bamboo is the giant-pandas' favourite food?

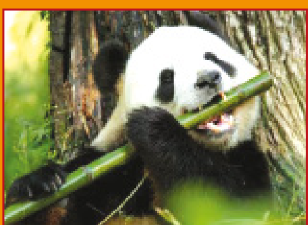


Image 38. Giant-panda eating bamboo.

For sure you have heard about other types of modelling clay, for example play dough or clay.

Play dough has a property which doesn't let it dry. Clay, on the other hand, is a material rich in water and that is why it is so mouldable. So that the clay becomes solid and a hard structure, all the water in it has to evaporate. This is why clay needs to be cooked in a stove.

The great advantage of the modelling clay you've used in this experiment is that it only needs to dry in open air to become solid.

Apart from this, when dry, you can wet the modelling clay and it doesn't lose its initial structure.

Experiment 2
The eruption of a volcano

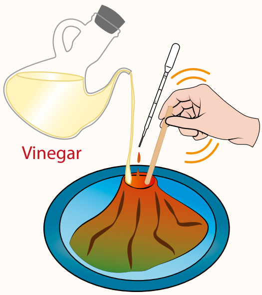
Let's see your volcano erupting. Can you see which type of eruption it is?

What you will need:
- Jurassic Volcano (built in experiment 1)
- Pasteur pipette ☆
- Red food colouring ☆
- Plastic spatula ☆
- Wooden spatula ☆
- Baking soda (Sodium bicarbonate) ☆
- Large measuring cup ☆
- Vinegar
- Wheat flour
- Deep dish

Steps:
1. Start by placing the Jurassic Volcano on the deep dish.

2. Fill in the volcano with vinegar.

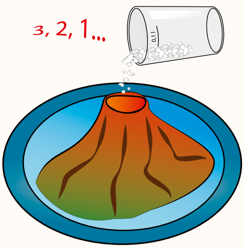
3. With the Pasteur pipette, add some drops of red food colouring and with the wooden spatula stir well.



4. With the plastic spatula, add 3 spoons of wheat flour to the volcano mould and stir well, until the flour is dissolved in the vinegar.

5. With the plastic spatula, add 5 spoons of baking soda to the large measuring cup.

6. Start a countdown and pour the content into the volcano.



7. Observe what happens.

ATTENTION: when you have finished, throw away all food products used during the experiment.

Explanation:

In this experiment you can simulate what happens during an **effusive** eruption through a chemical reaction.

The chemical reaction you have just seen is an **acid-base** reaction.

Vinegar has in its composition an acid, **acetic acid**. Baking soda is a base.

This way, when mixed with an acid, baking soda ($NaHCO_3$) decomposes and releases gas (carbon dioxide), in the following chemical reaction:

$$NaHCO_3 + \text{Acid} \rightarrow \text{Na-Acid} + CO_2 + H_2O$$

In this reaction, we get as reaction products, salt (Na-Acid) that dissolves in water (H_2O) and carbon dioxide (CO_2) that, for being a gas, bubbles in the liquid.

In this experiment, flour helps to simulate lava as it makes it smooth.

Experiment 3
Volcano

In this experiment we will see the eruption of a volcano.

What will you need:
- Safety goggles ★
- Baking soda ★
- Volcano mould ★
- Wooden spatula ★
- Water
- Red food colouring ★
- Vinegar
- Dinner plate
- Pasteur pipette ★

Steps:

1. Place the volcano mould on the plate.

2. Now, fill the volcano with vinegar.

3. Add 4 drops of colouring to the vinegar, using the Pasteur pipette.

4. With the wooden spatula, take a bit of baking soda and add it to the volcano.

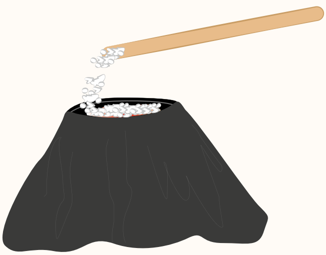
5. Watch the volcano in eruption!

NATIONAL GEOGRAPHIC™

Explanation:

Once again, this experiment you simulate what happens during a volcanic eruption, using a chemical reaction!

The chemical principles are exactly the same that happens in experiment 2.



ATTENTION: when you have finished, throw away all food products used during the experiment.

Experiment 4
Another way to make a volcano

Let us see another way to create volcanic lava.

What will you need:

- Basin or bowl
- Empty plastic bottle (330 or 500 ml)
- Lemon
- Baking soda
- Washing-up liquid
- Flour
- Red food colouring
- Modelling clay
- Pasteur pipette
- Glass
- Teaspoon

Steps:

1. You need to start by fixing the bottle to the basin or bowl. With a little bit of modelling clay, do a circular underlay and press it over the bowl. Finally, press the bottle against the modelling clay.

2. Pour half a lemon juice in the bottle. Then, with the Pasteur pipette, add 2 drops of food colouring.

3. Now, choose the kind of lava you will produce:
• If you want a lava with lots of foam and very viscous, add to the bottle one teaspoon of **washing-up liquid**.
• If you prefer a more fluid lava, add to the bottle a teaspoon of **flour**.
You may shake the bottle a little, in order to mix the ingredients. But be carefull, to prevent foam production.

4. Finally, in the glass, add 2 teaspoons of baking soda.

5. Now it's time to start the volcanic eruption: add the baking soda into the bottle and see what happens!

Explanation:
In this experiment happens the same chemical reaction that in the anterior one: an **acid--base** reaction.

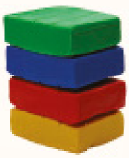
Lemon juice as **citric acid** in its composition. As the name shows, this is an acid that when mixed with baking soda (base), releases carbon dioxide.

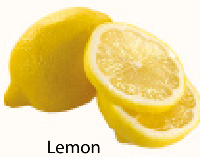
DID YOU KNOW...
That citric acid is present in all citric fruits, like lemon, orange or tangerine? This acid is responsible for the flavour of all this fruits!


Empty plastic bottle


Food colouring


Washing-up liquid


Modelling clay


Lemon


Flour


Basin or bowl

ATTENTION: when you have finished, throw away all food products used during the experiment.

Experiment 5
Volcano bottle

Why is it that when we drink a hot drink the first sip always seem much hotter than the others?

This simple experiment with water shows us what happens when we mix hot liquids with cold liquids. The hot water is expelled when it comes into contact with cold water, just like in a volcano.

What will you need:
- Small glass bottle
- Large glass jar (twice the size of the glass bottle)
- Wooden spatula
- Red food colouring
- Cooker or microwave
- Pasteur pipette
- String

Steps:
1. Cut a piece of string 30cm long and tie one end around the neck of the small bottle.

2. Tie the other end of the string around the neck of the small bottle to make a handle.

3. Fill the large jar with cold tap water. Do not fill it to the top because of you will need space to put the small bottle inside the large jar.

4. Completely fill up the small bottle with hot water.

5. Pour with Pasteur pipette a few drops of food colouring in the small bottle.

6. Holding the small bottle by the handle you made earlier from string, gently immerse it inside the large bottle, ensuring sure it stays upright.

NATIONAL GEOGRAPHIC™

Image 2. Volcano bottle.

Explanation:

When you immerse the small bottle containing hot water into a pool of cold water, the hot water is expelled into the cold water like a volcano.

The hot water will quickly rise to the top of the jar. When water is heated, it expands, taking up more space.

This makes hot water lighter (less dense) than the cold water, and that is why it rises to the surface of cold water.

Experiment 6
Geyser

In this experiment you will see the workings of a geyser.

What will you need:

- Funnel ⭐
- Bowl (bigger than the funnel)
- Straw
- Water

Steps:

1. Half fill the bowl with water.

2. Put the funnel into the bowl, with the widest part at the bottom.

3. Slightly tilt the funnel and place one end of the straw at in the tilted side.

4. Blow into the funnel from the other end of the straw. What happens? Try blowing harder.

Explanation:

By blowing into the funnel, the difference of pressure and density, makes the air rise quickly through the narrow part. Due to the speed and change in pressure, the air causes the water to rise out of the funnel, giving the effect of a geyser.

By blowing harder, you increase the pressure inside the funnel, causing a more spectacular effect. In real geysers, the pressure is caused by the boiling water in contact with the hot volcanic rocks underground.

Experiment 7
Another way to make a geyser

In this experiment you will experience the spectacular strength of a geyser.

What will you need:

- Bottle of *coca-cola*, preferably *diet coke*
- *Mentos* (sweets)
- Sticky tape

Steps:

1. In order to perform this experiment, choose a wide open place.

2. Now, you need to prepare the sweets so you can put it all at the same time into the bottle. For this, you need to use the sticky tape to fix all the sweets to each other: you only need to adhere the *mentos*, one by one, to the sticky tape. Don't forget to put sticky tape in both side of *mentos*. When you are finish, you had created a cylinder that will fit in the bottle, perfectly!

3. Prepare yourself, because you'll need to be quick! Ask an adult for help, open the bottle and quickly add the cylinder to the bottle!

4. Step aside of the bottle and observe what happens.

Explanation:

Sparkling soft drinks have in their composition a high amount of dissolved carbon dioxide, in balance and under pressure, ready to come out when the pressure at the surface of the solution diminishes. So, when we open the bottle this gas escapes to the outside. This is the reason why, when you open a soft drink bottle, you hear that characteristic sound.

When we drop a *mentos* in a soft drink bottle, the carbon dioxide bubbles start forming at the sweets surface. All these bubbles form so quickly that they end up dragging the soft drink out of the bottle.

When we add the sweets to the soft drink, we create carbon dioxide (that is dissolved) release nucleation points.

In fact, we know that when we put any porous object, for example salt, in a liquid with gas, we can observe that the carbon dioxide is released rapidly.

If we examine a *mentos* with a magnifying glass we see that its surface is porous and rough, and it's from these irregularities that the gas is released. The aspartame found in diet coke lowers the surface tension of the drink and allows for a more vigorous reaction than would be found in normal cola.

Many chewy sweets, including *mentos*, contain Arabic gum. This is a product used widely in the food industry, especially for its thickening properties (these sweets are chewy because of Arabic gum).

Arabic gum also lowers the surface tension of water molecules, which encourages the almost instantaneous release of carbon dioxide contained in the bottle. The expansion of the gas increases the pressure inside the bottle, which causes the liquid to be propelled out of the bottle.

ATTENTION: when you have finished, throw away all food products used during the experiment.

NATIONAL GEOGRAPHIC™

VULKAN-SET
VOLCANO SET

National Geographic supports vital work in conservation, research, exploration, and education.

Visit our website: *www.nationalgeographic.com*

BRESSER®

Bresser GmbH

Gutenbergstr. 2 · DE-46414 Rhede
www.bresser.de · info@bresser.de

ANL9130200GB1115NG