# *PRACTICAL ACTIVITIES TO ILLUSTRATE ISOSTASY*

***This activity has 18 demonstrations to illustrate the theory and effects of isostasy. The first fourteen use wooden blocks in water in a glass tank and the last three use a magnetic board.***

## *Demonstration 1 Basic principles*

***Requirements***
***Two blocks of wood 9.5cm by 15cm by 4.5cm and 9.5cm by 15cm by 3cm***

***Instructions***

1. ***Place the thickest block of wood in the water. Part of it will be above the water and part below.***

2. ***The volume of the wood below the water equals the volume of the water displaced. The weight of the water displaced is the same as the weight of the wood. Once this is understood the rest of isostasy follows***

3. ***Place a thinner block beside it in the water. Note how it floats with the same proportion above and below as the thicker block. It has less below the water because it is thinner and weighs less and therefore displaces less water.***

4. ***Mark on the glass the position of the top and bottom of the thick block using a felt tip pen.***

5. ***Now place the thinner block on top of the thicker one and note how the position of the lower block changes.***

6. ***Mark the position of the top of the thin block. Note that although it is higher than the original top of the thick block the increase in height is less than the thickness of the thin block you have added. When the second block is added the lower block sinks further into the water because the extra weight means that more water must be displaced in order that that the weight of the water displaced***

*equals the weight of the wooden blocks. The sinking of the lower block means that the change in height of the top was less than the thickness of the block added.*

7. *Remove the upper block and note how the position of the lower block changes.*

8. *Imagine the lower block to be the crust of the earth. Relate the changes in the level of the lower block to deposition and erosion.*

*The equations*

*Weight added = weight of water displaced*

*or*

*Thickness x density of wood added = thickness of water displaced x density of water*

*or*

*Thickness x density of sediment added = Thickness of mantle displaced x density of mantle*

*Change in height of surface = thickness added less thickness of water (or mantle) displaced*

$$= \text{thickness added} \times \left(1 - \frac{\text{density of sediment}}{\text{density of mantle}}\right)$$

## *Demonstration 2 Differing densities*

***Requirements***

***Two blocks of wood, one soft wood and one of oak or other dense wood 9.5cm by 4.5cm by 15cm***

***Instructions***

***The blocks of wood have different densities but the same thickness.***

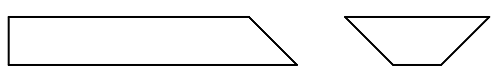
1. ***Place the two blocks in the water.***

***The denser wood rests lower in the water because it is heavier and must therefore displace more water.***

## *Demonstration 3 The effect of shape*

***Requirements***

***Blocks of wood 9.5cm by 4.5cm cross section cut to these shapes. There should be two of each shape.***



***Instructions***

***Place both copies of the first shape in the water different ways up. The block with the pointed end on the bottom floats with this end raised because this end is lighter and so floats higher in the water. The block with the pointed end on the top sinks slightly lower to compensate for the extra weight given by the projection which is above the water***

***Place both copies of the second shape in the water opposite ways up. You will see that when the large surface is upwards the block sinks lower than when the small face is uppermost. This happens because both blocks have the same weight so the same amount of water must be displaced for each block.***

# *The Effects of Isostasy*

## *Demonstration 4 Oceanic and continental crust*

***Requirements***

***One block of light wood 4.5cm by 9.5cm by 15cm, one block of dense wood 1.5cm by 9.5cm by 15cm***

***Instructions***

***1 Place the two blocks of wood which have differing densities and thicknesses in the water. The thick light block represents the continental crust and the thin dense block the oceanic crust.***

| | thickness | density |
| --- | --- | --- |
| Continental crust | 35km | 2.8 |
| Oceanic crust | 10km | 3.0 |

***The top of the oceanic crust is lower than the continental crust because it is both thinner and more dense.***

# Demonstration 5  Erosion and deposition

***The effect of adding (deposition) or removing (erosion) weight from the crust was illustrated in activity 1.  This activity looks at the effects of eroding the land area and depositing sediment in an adjacent sea.***

***Requirements***

***See diagram below. The central piece is plywood 45cm long, other pieces are made from 2.5cm thick wood, all pieces 9.5cm wide.. Top two layers are loose, others are screwed and glued. Screws should be positioned symmetrically.***

***Instructions***

1. ***Place the pieces of wood in the tank in the same arrangement as is shown in diagram 1.***

2. ***Remove the two top layers of the mountain and place them on the sea bed as in diagram 2. This represents erosion of the mountain and deposition on the continental shelf.***

***Diagram 1***

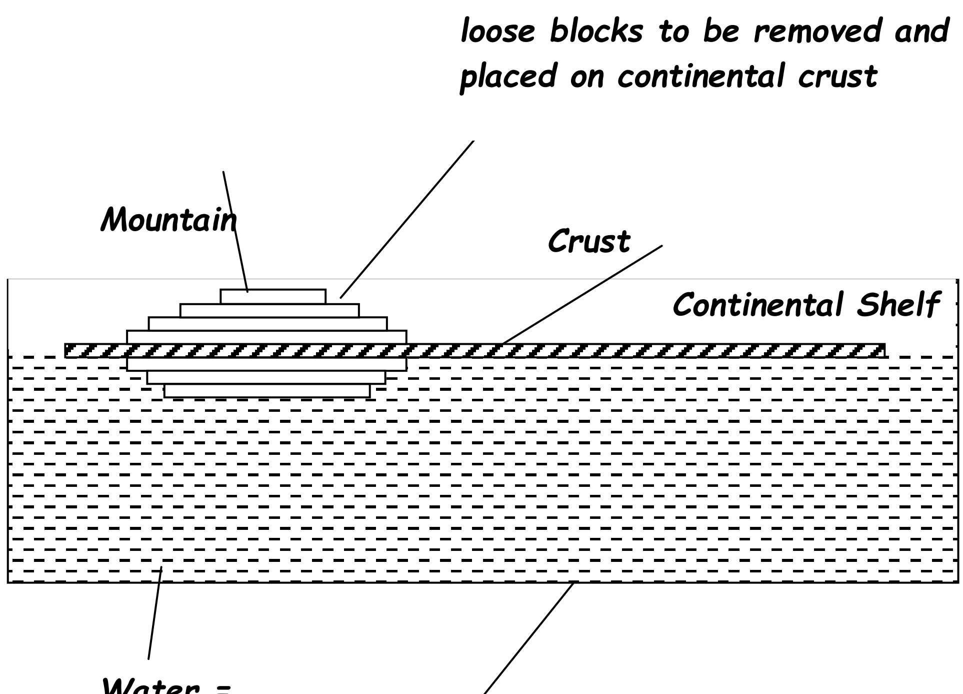
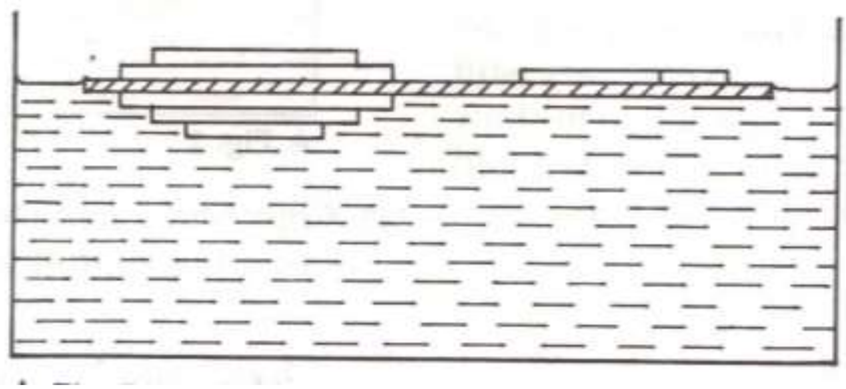


*Diagram 2*



***The  North Sea contains a great thickness of Tertiary and Quaternary sediments. In the areas bordering the North Sea the strata dip towards the North Sea.  So in eastern England the strata dip eastward and in mainland Europe they dip westward.***

***Note that the crust now dips towards the basin. This is because of the uplift of the land due to erosion and the depression of the sea bottom due to the extra weight of the sediment.***

***(A very small part of that dip is due to the stretching and consequent thinning of the crust below the North Sea during the Jurassic.)***

***In many sedimentary sequences there are minor unconformities as a result of isostatic adjustment due erosion and deposition. The isostatic adjustment is not a smooth continuous process but occurs as a series of jerks.  These sudden changes in the angle of slope of the surface are the cause of these minor unconformities.***

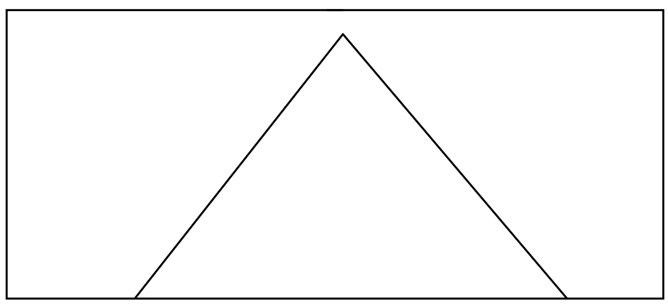
## *Demonstration 6     The erosion of a plateau*

***Requirements***

***A block of wood 9.5cm by 9.5cm by 15cm with a triangle cut out as in the diagram below.***

***Instructions***

1. ***Place to two pieces together in the water with the triangular piece on the bottom as in the diagram below.***



2. ***Note the level of the top of the plateau.***

3. ***Simulate the erosion of a plateau to form a mountain by removing the upper piece of wood.***

***The peak is now higher than the original level of the plateau because erosion has reduced the weight of the crust and thus caused it to rise. Because of the erosion the <u>average</u> height of the block is, of course, lower.***

4. ***Replace the top part, turn the whole block over and then remove the triangle to make a valley.  Note that the valley sides have risen.***

# *Demonstration 7 Himalayas and the Tibetan Plateau*

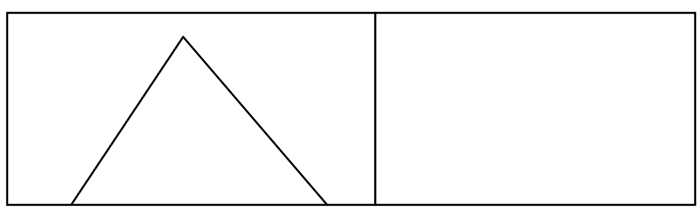
***Requirements***

***The block from demonstration 5 plus another block 9.5cm by 9.5cm by 15cm.***

***The Himalayas and the Tibetan plateau were originally two blocks of crust of the same thickness. The Himalayas take the full force of the Indian monsoon with some places having 8m of rain per year. Cambridge by contrast has 50cm per year. The result is that the Himalayas are undergoing the most rapid erosion anywhere in the world. The Tibetan plateau has very little rain and is thus not being eroded much. The highest peaks in the Himalayas are over 8000m while the Tibetan Plateau is all below 7,000m***

***Instructions***

***1 Place both blocks of wood in the water as in the diagram below. Compare the heights of the tops of the blocks.***



***2 Remove the top part of the Himalayan block. Compare the heights of the peak and the plateau.***

***The Tibetan plateau is not being eroded but the Himalayas are. The erosion of the Himalayas has caused that part of the crust to rise making the peaks higher than the Tibetan plateau.***

## *Demonstration 8 Mountain building*

***Requirements***

***A strip of single sided corrugated paper 9cm wide and 50cm long folded every 5cm into a zigzag. Single sided corrugated paper can be bought from Art shops. Newspaper or white tissue paper or crepe paper also works but not as well.***

***Instructions***

1. ***Stretch out the corrugated paper and place it in the water. It forms a thin layer partly above and partly below the water. It represents horizontal sedimentary rocks.***

2. ***Now fold the paper by compressing it to one end with your fingers. This represents folding of the strata during mountain building.***

***Note how the top of the paper is now much higher above the water but also the base is much lower. The upper part represents the mountain and the lower part the mountains "roots". The mountain has "roots" because the weight of the mountain chain must be compensated by an equal weight of mantle being displaced.***

## *Demonstration 9 The age of rocks at the surface*

***Requirements***
***5 pieces of wood 9.5cm by 2.5cm by 20cm Label the long edges of the blocks as in the diagram below.***

***Instructions***

***1. Place all the blocks in the water in the order shown below:***

| |
|---|
| *Sedimentary rocks* |
| *Slate* |
| *schist* |
| *gneiss* |
| *migmatite* |

***2. Simulate erosion by removing one block at a time.***

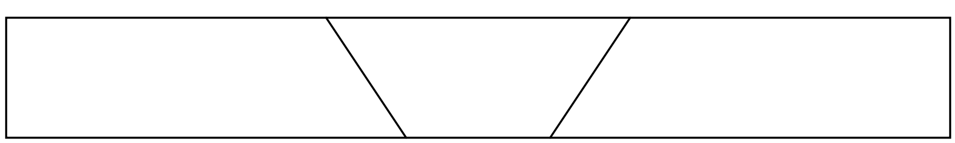
***3.As the upper layers are eroded away so the crust moves upwards, Rocks which were formed 50km below the surface can thus be exposed by erosion.***

## *Demonstration 10 The formation of rift valleys*

***Requirements***
***A piece of wood 40cm long by 9.5cm by 4.5cm cut as in the diagram below***

***Instructions***

***1 Place all three pieces of wood in the water together as in the diagram.***



***This represents the plateau before the formation of the rift valley.***

2  Rift valleys form when the crust is stretched so pull the outside two pieces of wood slightly apart but keep all three pieces touching.

Note how the outer long pieces slope down away from the rift which is why the edge of the rift valley is always higher than the surrounding plateau.  Note also how the central block has sunk down so that the volume and thus weight of the mantle displaced equals the weight of that piece of crust.

5  Below is a  cross-section of East Africa.  The formation of Lake Victoria is related to the formation of the rift valleys either side.


(Diagram modified from Principles Of Physical  Geology by A. Holmes 1965  Nelson)

Lake Victoria formed because it is between two rift valleys. The outside block of each rift valley slopes down away from the rift valley itself. Thus the land between the Eastern and Western Rift valleys forms a basin which filled up with water to form Lake Victoria.

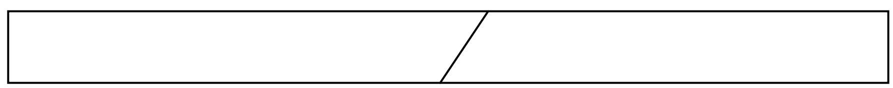
## *Demonstration 11 A one sided rift valley*

***Requirements***

***A 40cm long block of wood 9.5cm by 4.5cm cut as in the diagram below.***

***Instructions***

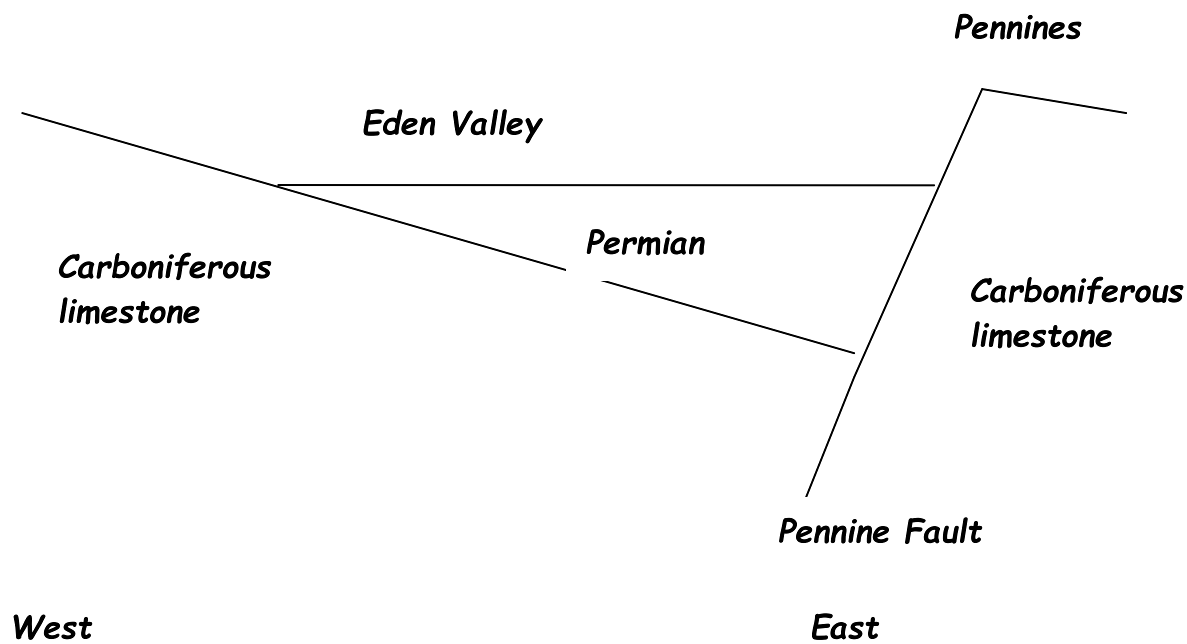
1. ***Place the two pieces of wood in the water touching each other as in the diagram.***



2. ***Now pull them slightly apart so that the one side is able to sink and the other to rise.***

***The side that has risen will be eroded and so will rise further whereas the extra weight of the sediments that will accumulate in the valley will cause the side which had sunk to sink further.***

***The Eden Valley in Cumbria is a single sided rift valley. The east side rose forming the Pennine escarpment made of Carboniferous Limestone whereas the west sank and filled with Permian sediments.***




## *Demonstration 12 The effect of ice-sheets*

*In this activity the water represents the mantle, the wood the continental crust and the white painted piece represents an ice-sheet.*

*Requirements*

*The crust is made from wood 20cm long by 4.5cm thick by 9.5cm and the ice from white painted wood 20cm by 3.5cm by 9.5cm*

*Instructions*

1. *Place the larger piece of wood in the water and mark the height of the top of the wood (= crust) above the mantle.*

2. *Now place the white painted wood (= ice) on the crust.*

*The additional weight of the ice on the crust caused the crust to sink further into the mantle.*

3 *Now melt the ice by removing it and describe what happens this time.*

*Scotland was covered with a great thickness of ice but there was no ice south of the Thames. The melting of the ice has reduced the weight on the crust and thus allowed it to rise, so Scotland is rising compared to southern England.*
*Isostatic adjustment is a very slow process so although the ice has all melted Scotland is still rising relative to sea level. There are many raised beaches around Scotland's coastline, each indicating that sea level was once higher than it is now. Isostatic adjustment is not a continuous smooth process but occurs in a series of steps. Each fossil cliff represents a time of rapid upward movement of the crust and each raised beach the time between movements.*

## *Demonstration 13 A large continental ice sheet*

*Requirements*
*The crust is made from sponge 48cm long by 9.5cm wide by 2cm thick and the ice from white painted wood 20cm by 9.5cm by 3.5cm Place the sponge on the water.*

*Instructions*
1. *Place the white painted block which represents an ice sheet on the sponge. Note the troughs which form either side.*

*The trough forms because the crust is depressed by the weight of the ice sheet but the crust is too rigid to be depressed only where the ice is resting. So the area of the crust that is depressed is actually larger than the base of the ice sheet.*
*Once the ice starts to melt the troughs will fill up with water forming large lakes against the remaining ice sheet. Such a lake, called Lake Algonquin, formed south of the Canadian ice sheet about 12 million years*

***ago. The Great Lakes are the all that is now left of that extensive lake. The eventual draining of Lake Algonquin caused huge floods.***

## *Demonstration 14 A large volcano*

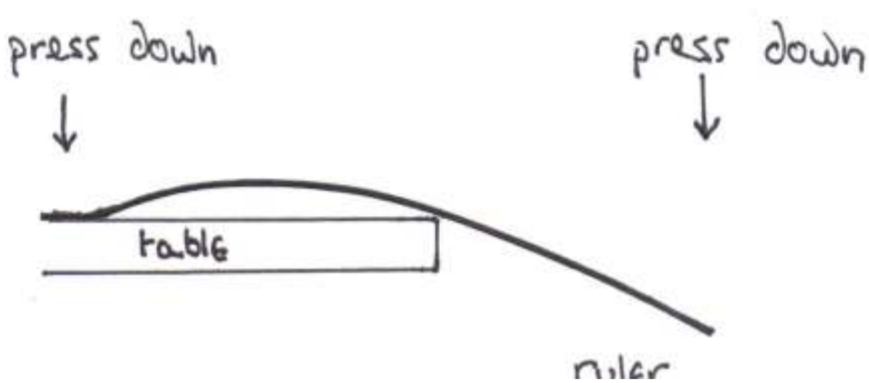
***The triangle of wood represents the volcano and the piece of sponge the underlying crust. The mantle is represented by the water.***

***Requirements***

***A triangle cut from a piece of 9.5cm by 9.5cm by 9.5cm wood. One piece of sponge rubber 48cm long, by 9.5cm wide by 2cm thick. Place the sponge rubber in the glass tank.***

***Instructions***

1. ***Place the "volcano" on the sponge. Note the trench that forms around the volcano. The oceanic crust around Hawaii is depressed in a similar way but there is also an outer bulge. The start of the bulge can be seen at either end. The trench forms because the crust is depressed by the weight of the volcano but the crust is too rigid to be depressed only where the volcano is resting. The outer bulge is also due to the rigidity of the crust. This can be shown with the same arrangement as above but with a two metre long piece of sponge in a two metre long tank. You can also see the bulge if you place a steel or plastic ruler over the edge of a desk and press down on both ends.***



## *Demonstration 15 Simulating the slow sinking of the crust*

***In this activity the sponge represents the mantle.***

***Requirements***

***Make a wooden box with a glass front with internal dimensions of 50cm by 10cm by 10cm and place in it a piece of "memory foam" of the same size. The volcano is a triangle made from lead and is 5cm high. Make it by pouring molten lead into the end of a tilted wooden box 9.5cm wide.***

***Instructions***

1. ***Place the volcano on the sponge and watch it slowly subside. Be careful the "volcano" is very heavy. A large volcano sinks down very slowly, about 1cm per year, because the mantle adjusts to the extra weight very slowly.***

2. ***Now remove it and watch the "mantle" readjust.***

***The mantle is, like ice, a solid but it is able to "flow" very slowly just as a glacier is able to flow. The depression of the crust is due to the mantle below flowing away. The sponge in this model does not flow but it compresses under the extra weight.***

# *Demonstration 16 Formation of Atolls*

***An atoll is a ring shaped coral reef***
***Sometimes a coral reef would grow around the extinct volcanic cone. While the cone was still above sea level it would have been a fringing reef but as the cone sank due to isostatic adjustment and disappeared below sea level the coral continued to grew upwards forming a ring of coral reef called an atoll.***

***Requirements***
***A4 card with coloured paper stuck on and a triangular piece of red card to represent the volcano. See photos.***

***Instructions***
***1 Place the volcano so that its base rests on the top of the oceanic crust.***

***2 Now move it slowly downward to represent the sinking due to isostatic adjustment. The coral reef will appear and eventually the volcano will be below sea level just leaving the ring of coral above the surface.***

## *Demonstration 17 The formation of guyots*

***A Guyot is a flat topped submerged volcanic cone.***
***The volcano built up rapidly from the sea floor until it formed a volcanic island. After the volcano ceased erupting the waves eroded away the top of the cone. Then the cone slowly disappeared below the waves as it sank into the mantle due to isostatic adjustment.***

***Instructions***
***1 A volcano builds up rapidly. Place the volcano including the top part so that the base rests on the oceanic crust, level with A.***

***2 The volcano ceases to erupt and the waves erode that part of the volcano above sea level. Remove the top part of the volcano.***

***3 The volcano begins to sink due to isostatic adjustment until the weight of the remaining volcanic cone equals the weight of the displaced mantle. Lower the volcanic cone until its base is at position B.***

***The depths of some guyots below sea level is also partly due to post glacial rise in sea level and due to the depression of the oceanic crust where it is being subducted.***

## *Activity 18  Isostasy and Gravity*

***The pull of gravity at any point varies with the mass of the rock below. If there are more rocks or rocks of greater density then the value of gravity will be higher than normal (= positive anomaly). If there is less mass below then the value will be lower. Normal can be taken as the pull of gravity over the oceanic crust where there are no volcanoes.***

***Instructions***
***1  A volcano builds up rapidly. Place the volcano including the top part so that the base rests on the oceanic crust, level with A.***
***The extra mass of the volcano means that the pull of gravity will be greater than normal, so there will be a positive gravity anomaly if gravity is measured at point x.***

***2  The volcano ceases to erupt and begins to sink into the mantle until the weight of the volcano is the same as the volume of mantle which has been displaced. It is now in isostatic equilibrium.***
***Move the volcano including the top part so that its base is level with B.***
***After the volcano has sunk and reached isostatic equilibrium there will be no extra mass because the extra weight of the volcano is compensated for by the mantle which has been displaced. So there is no gravity anomaly. However, either side of the volcano, over the trough there will be a negative anomaly.***

***3 The waves and rain now erode away that part of the volcano above sea level.***
***Remove the top part of the volcano.***
***After the volcano has been eroded the mass of the remaining part of the volcano is insufficient to compensate for the mantle that has been displaced so there will be a negative anomaly.***

## *Organisation*

***During the conference these demonstrations were laid out as a circus with every one doing activities 1 and 2 first. The advantages of students completing the activities/demonstrations as a circus are that the students can discover the facts for themselves and need to think for themselves.***

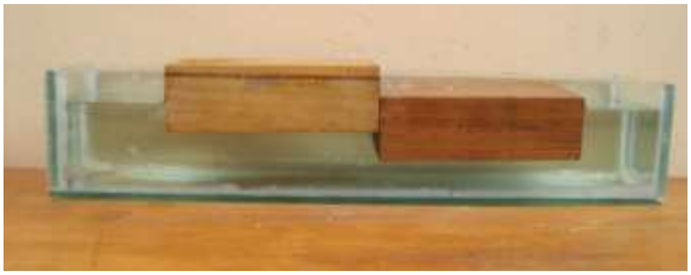
*The disadvantages are you will need at least 10 glass tanks and setting up will take much more time.*

*General instructions and requirements.*
*Do not leave the wooden blocks in the water for too long. They will expand and may crack the tank.*
*It is useful to have cloths or towels to mop up spilt water.*
*The paper used in demonstration 12 mountain building will sink completely if left for more than 10 minutes which rather spoils the effect. It should be removed as soon as the activity is finished.*

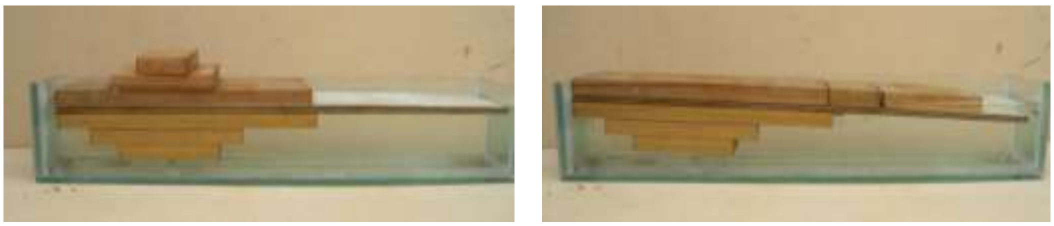
*Glass tank*
*The glass tank should have internal measurements of 50cm by 10cm by 10cm and be made from 6mm glass. It can be made by a glazier or ordered through a pet shop but it is cheaper to make it yourself.*

*Wood*
*All wooden blocks are cut from 100mm wide planed timber and should not contain knots. Planed 100mm timber is usually 95mm and this size allows for expansion when the wood is soaked.*

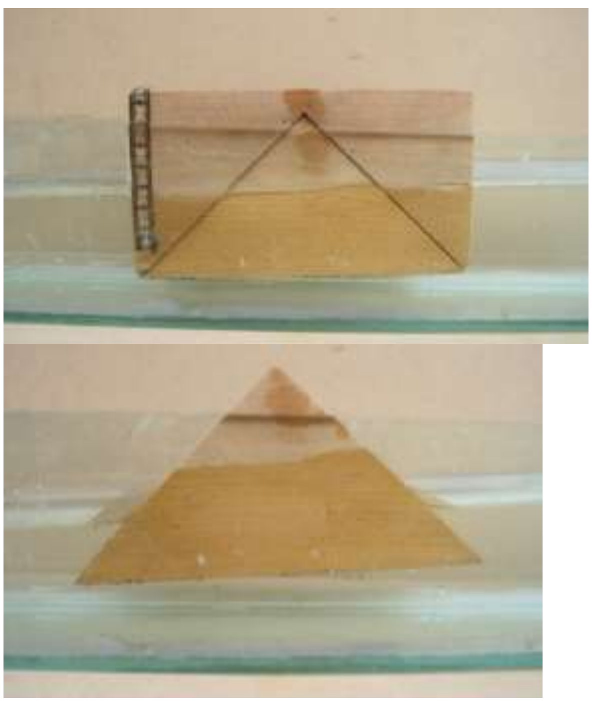
*Magnetic models*
*Demonstrations 16, 17 and 18 are magnetic models and need to be placed on steel surface, e.g. white board or sheet of galvanised steel. They are made from an A4 sheet of thin card with coloured paper stuck on it as in the photos below. Magnetic strips are stuck onto the back. The volcano is made from stiff card and both parts have magnetic strips on the back.*



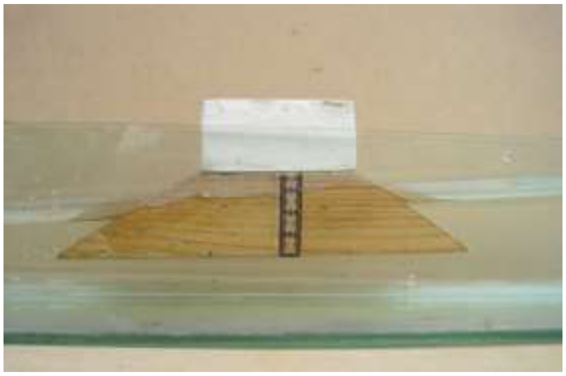
***2 Varying density***



***5 Erosion and deposition***

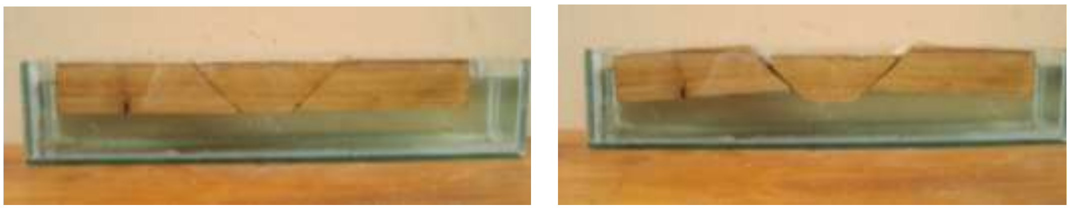


***6 Erosion of a plateau***



***12 Effects of Ice sheets***


*9 Ages of the rocks at the surface*



*10 Rift valley formation*


*16 Base of magnetic model for atoll formation.  The pink strips are the coral reef.  The volcano is placed on top and gradually lowered to real the coral*

*The base for the guyot and gravity magnetic models is the same but without the pink strips.*


*18 Gravity magnetic model. The volcano as it first builds up prior to isostatic adjustment*


*The volcano after erosion and after isostatic adjustment*