The Eruption of Mount St Helens

Science content

Volcano, plate tectonics, magma.

Science curriculum links

AT 9 Earth and atmosphere

Syllabus links

- GCSE Science
- Geography

Lesson time

1 hour

Links with other SATIS materials

1205 Earthquakes

NERIS

search on

MOUNT ST. HELENS

Additional search terms:

VOLCANOES

VOLCANIC ERUPTIONS

PLATE TECTONICS

SUMMARY

The unit tells the story of the eruption of Mount St Helens in 1980 and illustrates the work of geologists in hazard assessment.

STUDENT ACTIVITIES

- ☐ Reading the narrative.
- ☐ Producing a diary of events leading up to the eruption.
- ☐ Discussion in small groups.

AIMS

- ☐ To complement work on plate tectonics and volcanoes
- ☐ To provide narrative and discussion material illustrating the role of geologists in hazard assessment

USE

- ☐ Reading this unit could be set for homework and answers to the questions later discussed by students working in small groups. Alternatively, the whole unit may be used for individual study.

USING AND ADAPTING THE UNIT

- ☐ Science teachers may wish to liaise with geography departments when using this unit.

Author **Richard Curry**

First published 1991

Teaching Notes

The explosion was heard as far away as Vancouver in Canada (450 km) and Redding in northern California (630 km). The blast could not be heard close to the volcano because the sound travelled upward due to the shape of the crater and was reflected down from a layer of warm air.

Answers to the questions

Q1 *Indian legend, low tree line, fewer species, lush vegetation (recent volcanic soils are very rich), reports of eruptions by nineteenth century explorers and traders. (Lack of erosion of the cone is sometimes cited too.)*

Q2

March 20th	*earthquake of magnitude 4.1*
March 25th	*frequency of earthquakes increased to every 15 minutes*
March 27th	*explosions and new crater formed on summit*
April 1st	*volcanic tremor*
to	*steam and ash eruptions*
April 12th	*bulging of the north face*
May 10th	*earthquakes of magnitude 5.0*
May 11th	*swelling of north face continues*
May 18th	*earthquake triggers explosive eruption*

Q3 *Suggestions may include:*

Keeping sightseers from endangering themselves and obstructing the work of the emergency services; persuading people to leave their homes when danger is imminent; reaching people when roads are blocked with mudflows, bridges ripped away by torrents of water; lack of electric power if power lines are down, volcanic ash and choking gases, fires caused by the eruption (home and forest fires) etc.

Q4 *Monitor earthquakes, bulging of the volcano, hot spots by infrared imaging, gases if vented, changes in gravity etc.*

Q5 *This is a real dilemma. Premature warnings can have a negative effect on the local economy and reduce people's alertness to the realities of the danger. Warnings can also bring out sightseers.*

Q6 *Volcanic areas with mild climates are very fertile and in the Pacific Northwest provided good farmland for the immigrants. No volcano had erupted since settlement in the late nineteenth century and most people felt the hazard was unreal (although Lassen Peak in California last erupted in 1915.) Taking the risk seriously would cause a slump in property values. The area is very beautiful and people regard the risk as low.*

Q7 *These geologists are undertaking a public service and may help save many lives.*

Other resources

Volcanoes, a booklet by the Institute of Geological Sciences (1974), ISBN 011 8806211, available through HMSO provides a good short guide to volcanoes. The illustrations are excellent but the text is addressed to adults.

Acknowledgements

Dr H. Pinkerton of Lancaster University read and commented on the trial version.

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The Eruption of Mount St Helens

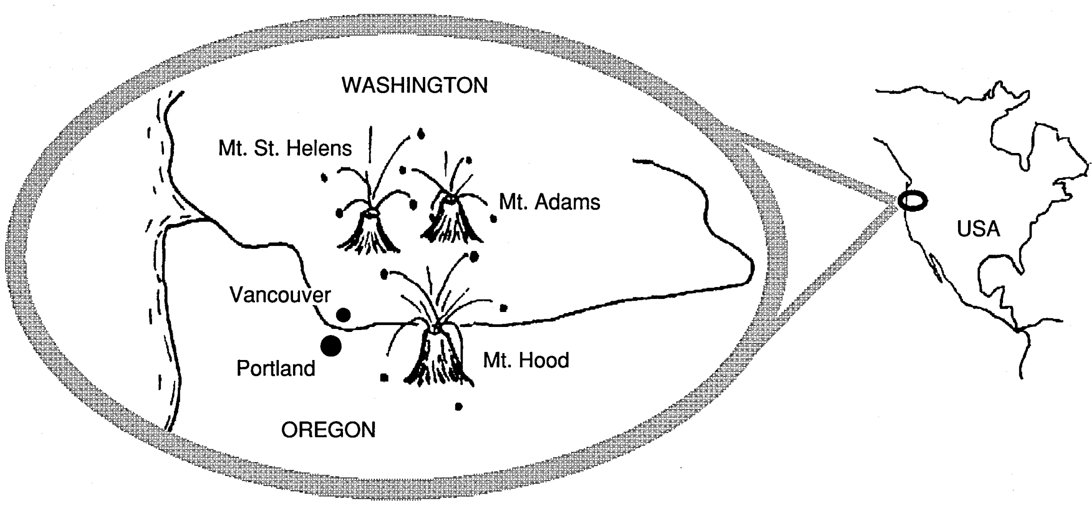
The beautiful maiden of fire

Once upon a time two rival warriors were fighting for the favours of a beautiful maiden. They hurled huge fiery rocks at each other; they blotted out the Sun and shook the Earth. The people were frightened and begged help from the Great Spirit. On hearing of their plight, the Great Spirit was so angered he turned all the three into mountains of stone. There they stand to this very day.

So, according to American Indian legend, goes the history of three volcanoes: Mount Adams, Mount Hood and Mount St Helens.

Local indians called Mount St Helens Loo-Wit, the maiden of fire. They would not go near her. Scientists may explain the history of these volcanoes differently. Nevertheless, they have confirmed Loo-Wit's fearsome reputation.

> This is a case study of the eruption of Mount St Helens in the USA in 1980, its geology and its impact on the community.
>
> Read right through the unit before attempting the questions.
>
> There is a glossary of geological terms on page 7.



Figures 1a and 1b The location of Mount St Helens in the USA

The test case

The Earth experiences between 15 and 25 volcanic eruptions a month. Most pass almost unnoticed in isolated areas.

One of the largest and best studied eruptions of recent times occurred in 1980 in the Pacific Northwest of the USA.

The US Geological Survey published a report in 1978 which said, 'Mount St Helens has been more active and more explosive during the past 4500 years than any other volcano in the United States'. The report predicted that Mount St Helens would erupt within 100 years.

Mount St Helens was to provide a good test for the scientific forecasting of eruptions.

Geologists made their base for work on Mount St Helens at Vancouver, Washington, 70 km south of the mountain (not to be confused with Vancouver in Canada).

Mount St Helens erupts

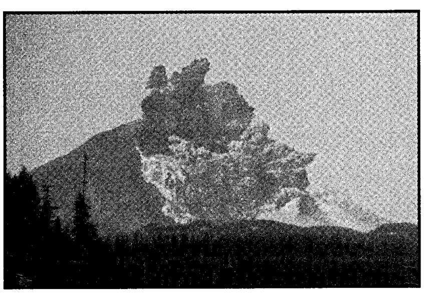
On May 18th, 1980, two years after predicting that Mt St Helens was dangerous, the mountain exploded. At 8.32 a.m., the voice of geologist David A. Johnston, who was working on the mountain, was heard calling excitedly on his radio, 'Vancouver, Vancouver, this is it' . . . . . . and nothing more.

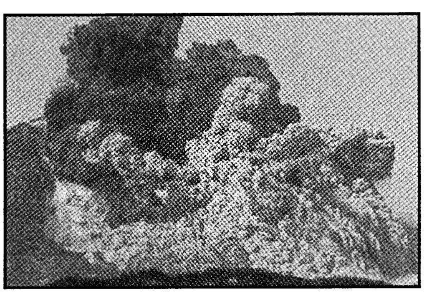
Geologists estimate the initial explosion was the energy equivalent of 500 Hiroshima atomic bombs. Over a period of nine hours 1.7×10^{18} joules of energy were released, equivalent to 27 000 Hiroshima bombs.

Temperatures were high enough in the centre of the cloud to set fire to any living thing around. Steam clouds surged forth while ground-hugging black clouds rolled over ridges and valleys. More than two cubic kilometres of fluidised rock and crushed ice rushed north at up to 250 kilometres an hour. An eye witness described it as a 'boiling mass of rock – just as high as you could see'.

Near to the volcano very little sound was heard; but a series of loud booms rocked cities far away.

An ash column 20 kilometres high blew eastwards and engulfed the small town of Yakima 135 kilometres away. Day turned into night by 9.30 a.m. Streetlights came on, cars, buses and planes had to stop. Electricity transformers were shorted out by ashfall and many areas were without electricity. Food distribution and other basic services broke down. The people of Yakima later removed 600 000 tonnes of volcanic ash; the job took over ten weeks and cost $2.2 million. Other towns experienced similar problems.





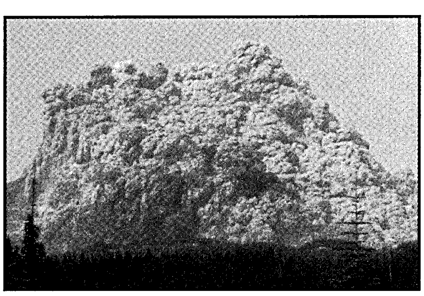


Figure 2 The eruption

At 8.32: 11 a.m., an earthquake broke the bulge on the north face loose. The landslide released the pressure on the superheated steam inside the mountain causing an explosion.

Water from melting snow and ice along with the material erupted from the volcano caused major mudflows. Walls of water carrying logs, parts of buildings, blocks of ice and burning wood ripped away bridges and blocked evacuation routes.

Dust rose high into the atmosphere and was blown around the world. It was even feared the eruption would cause a drop in global temperature. It did not happen. However, the two summers that followed were cool.

The volcano devastated an area of more than 500 square kilometres. It lost 400 metres in height. The north side of its beautiful cone was gone. Fifty-seven people were dead. Most suffocated from breathing hot ash.

Fortunately, few people lived in the path of the blast. Had the south side of the mountain blown away, the story might have been very different.

Mount St Helens continued to erupt sporadically during the year and there have been minor eruptions since. It affected millions of people, depositing ash for hundreds of kilometres around. Local TV stations even included ash fall in their weather forecasts.

See glossary on page 7 for the meaning of: **fluidise, ash, mudflow**.

Predicting the eruption

Geologists describe volcanoes as either active, dormant or extinct. Volcanoes which have erupted in the recent past are **active** and likely to erupt again. Those which have not erupted for many thousands of years, as shown by the erosion of their peaks, are likely to be **extinct.** Those which might erupt again but show no signs of doing so are said to be **dormant.**

Mount St Helens is a strato-volcano, formed from layers of erupted material. The layers and deposits of huge mudflows showed geologists that Mount St Helens was a young volcano which had erupted 20 times in the past four and a half thousand years.

Botanical studies of the plant life on the mountain also hinted at recent volcanic activity. The tree line was lower than on mountains nearby, there were less species and the vegetation was very lush.

The recorded history of the area starts only a century and a half ago. Between 1831 and 1857 European explorers and traders witnessed eruptions. They reported in letters home of an atmosphere filled with ashes and the red-coloured sky at night. Since then, many people have settled in the area.

The hazards of an eruption were not considered until a similar mountain, Arenal, in Costa Rica erupted in 1968, killing 80 people.

In 1969 the University of Washington in Seattle put two seismometers in the area of Mount St Helens. Geologists had great difficulty in obtaining more funds to monitor the mountain. The Government and the public did not take the threat of an eruption seriously. Only by March 1980 did they have a set of seismometers to radio information directly to their computers.

Geologists knew Mount St Helens was going to erupt, but they did not know when or how violent the eruption would be. Seven weeks before he died in the blast, geologist David A. Johnston had said, 'This mountain is like a powder keg and the fuse is lit, but we don't know how long the fuse is'.

Before eruptions there are usually swarms of small earthquakes. On March 20th an earthquake of magnitude 4.1 on the Richter scale rattled the windows of the communities in the area. This was followed by many others, one every 15 minutes on March 25th.

The first explosions were two days later, forming a new crater on the ice-covered summit.

On April 1st, seismometers recorded the first volcanic tremor, a more or less continuous ground vibration seen at many active volcanoes. It is thought to have been caused by the movement of magma (molten rock) underneath.

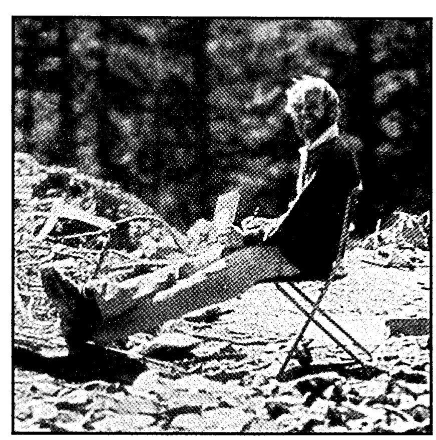


Figure 3 Geologist David Johnston, later killed by the blast.

See glossary on page 7 for: **strata, seismometer.**

Small steam and ash eruptions continued. The ash consisted of fragments of old volcanic rock; the gases included small quantities of carbon dioxide, sulphur dioxide, hydrogen sulphide and hydrogen chloride, with large volumes of steam. The small explosive eruptions were caused by groundwater high in the volcanic cone being superheated and suddenly flashing to steam like a geyser.

Emergency officials worked on plans to deal with a major eruption. Geologists were asked for forecasts. They set up more seismometers to record earthquakes; gravity meters to detect vertical swelling; tiltmeters and laser targets to detect bulging. Gases from the volcano were collected and analysed – an increasing amount of sulphur dioxide would indicate magma moving up from below.

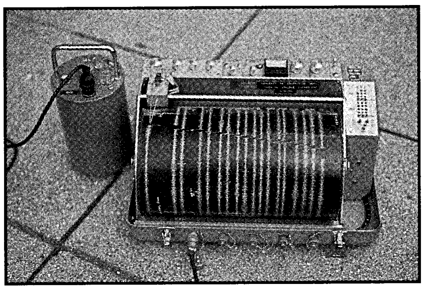


Figure 4 A portable seismometer

The north side of the mountain started to bulge outwards, cracking its cover of snow and ice. By April 12th the bulge was nearly two kilometres in diameter and had moved outwards by 100 metres. The bulge was directly over the centre of the earthquake zone two kilometres below. Scientists believed this was evidence of magma moving upwards. They expected a major eruption or earthquake on the north face.

The mountain was considered so dangerous that only scientists were allowed near it. Sightseers were kept away. People were evacuated from homes inside the danger zone. One elderly resident, 84-year-old Harry Truman, admitted he was 'scared all to hell' but refused to leave.

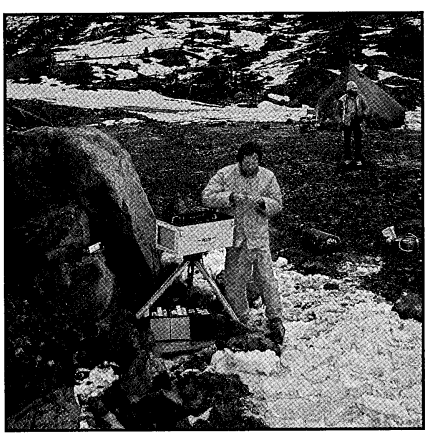


Figure 5 A geologist adjusting a laser which is used to detect bulging of the surface of the volcano

By May 10th, some earthquakes measured 5.0 on the Richter scale. Infrared aerial photographs showed hotspots in the summit crater while the north face was swelling by 1.5 metres every day.

On May 11th, samples of new ash were analysed in an attempt to predict how explosive the eruption might be. Swelling of the north face continued.

On May 18th Harry Truman's home was in the direct path of the blast. He and his 16 cats perished.

The violence of the eruption took even geologists by surprise. An earthquake had caused a major landslide on the north face, releasing the pressure inside the volcano. The dissolved gases had expanded rapidly. The resulting mixture of hot gas and molten magma was devastating.

After the explosion, magma continued to rise inside the volcano to form a dome inside the crater.

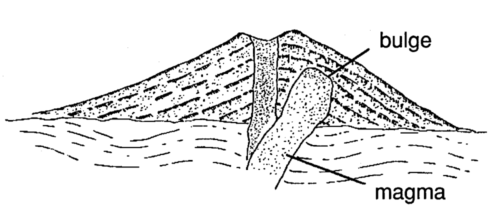


Figure 6 Magma causing the bulge in the north face of Mount St Helens

See glossary on page 7 for: **magma, Richter scale.**

Questions

Q1 What evidence suggested that Mount St Helens was active relatively recently?

Q2 Make a diary of events leading up to the eruption.

And after?

Lessons learned on May 18th enabled geologists to predict further eruptions that year and to evacuate geologists, biologists and foresters working on the mountain. Mount St Helens has remained active since, though none of the later eruptions has been so severe.

The biggest job after the Mount St Helens eruption was to stop the remains of the mountain's north side from sliding into nearby towns. Most of the damage was caused by mudslides which poured into local rivers. Construction of a new dam will make the area safer.

Communities which suffered from the eruption now benefit from tourism. New roads have been built to allow visitors access to the area. A visitor centre provides information, film shows, talks by rangers and hikes into the wilderness area.

Although countless plants and animals died in the eruption, wild flowers are poking through the ash and life is gradually returning.

Geologists are still monitoring almost daily earthquakes, often risking their lives to check equipment on the snow-covered summit. Mount St Helens may continue to erupt for several decades.

Geologists believe that what happened in the recent past can happen again. Mount Hood was one of Mount St Helens' warring suitors of Indian legend. Its last major activity was two hundred years ago. It was shaken by earthquakes during the eruption of Mount St Helens and it may well be the next volcano to erupt in the area. At 3424 metres high, Mount Hood towers over a million people in the Portland area of Oregon.

Geologists cannot predict for certain when, where or how violent another eruption will be. They are keeping a watchful eye on *all* large volcanoes in the area.

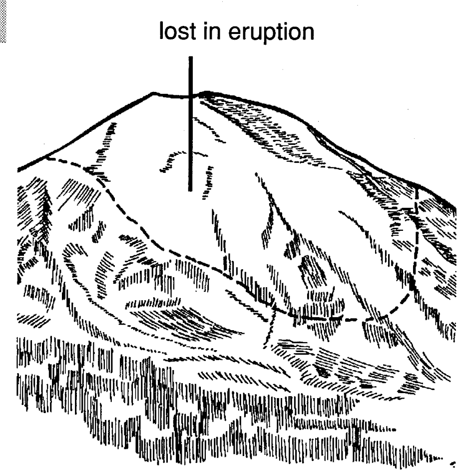


Figure 7 Mount St Helens before and after May 18th, 1980. Previously 2950 metres high the mountain lost 400 metres from its summit

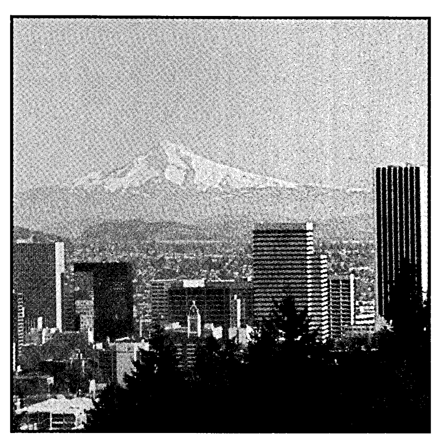


Figure 8 Mount Hood from Portland, 70 kilometres away

Organising the discussion

- Work in a small group.
- Appoint someone to chair the group and to report back to the class if required.

Questions for discussion

Q3 What sort of problems do the emergency services have to deal with when a volcano like Mount St Helens erupts?

Q4 Mount Hood has erupted in the past at about the same time as Mount St Helens. Based on the experience of Mount St Helens, what should geologists do to find out if it is going to erupt?

Q5 Geologists cannot tell exactly when a volcano will erupt. If they warn the public and then nothing happens, the next time nobody will take any notice. What sort of warnings should scientists give to the public about the dangers they face from Mount Hood?

Q6 Suggest why people continue to live in areas where there are active volcanoes like Mount St Helens or Mount Hood. Would you move away, whatever the problems?

Q7 Many Government geologists risked their lives working on Mount St Helens and one was killed. The work continues. Should scientists risk their lives to monitor volcanoes?

What made Mount St Helens erupt?

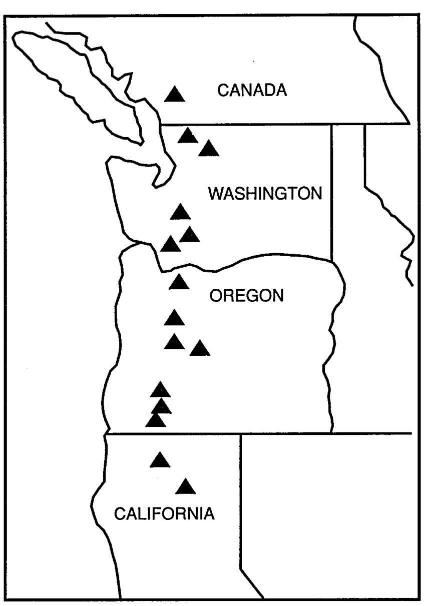


Figure 9 Volcanoes of the Cascade Range

Mount St Helens is part of a range of snow-capped volcanoes which runs parallel to the Pacific Coast from Canada to California. This mountain range is called the Cascades.

About 80 kilometres offshore, the floor of the Pacific Ocean (here the Juan de Fuca Plate) is sinking beneath the west coast of the North American Plate. Continental crust is less dense than oceanic crust and so the denser oceanic crust sinks into the mantle. The process is called **subduction**. A deep ocean trench forms at the subduction zone and is being filled by sediment scraped off the sinking sea floor.

As one plate disappears under the other they 'crunch' together causing frictional heating. An enormous amount of energy is involved. At a depth of about 100 kilometres very high pressures and temperatures cause the plates to start melting and form magma. Hot magma is less dense than the surrounding rocks and rises in great mushy blobs known as granite plutons. If the magma reaches a crack in the crust it may erupt.

The volcanoes of the Cascade Range erupt parallel to the ocean trench and form part of the 'Ring of Fire' of volcanoes around the Pacific Ocean.

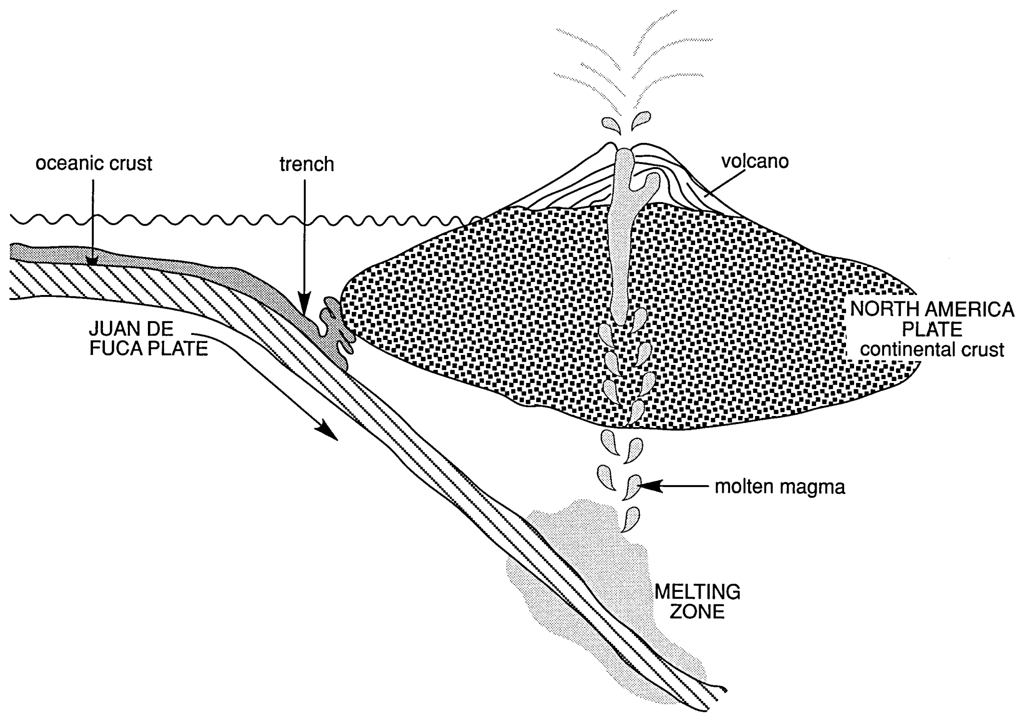


Figure 10 This diagram shows oceanic crust sinking under continental crust and how volcanoes like Mount St Helens are formed

Glossary

Ash Airborne particles erupted from a volcano. Larger particles are called cinders, blocks and bombs.

Lava Magma erupted at the surface.

Magma Partially or completely molten rock. It usually has gases dissolved in it. It can have a widely different chemical composition depending on the rock from which it was formed. Volcanoes in the Cascade mountians have **viscous** magmas which are likely to produce explosive eruptions. (Viscosity is a fluid's resistance to flow. A fluid with a low viscosity is very runny, one with a high viscosity is thicker, like syrup.)

Fluidised flows Mixtures of solid particles and gases or liquids can behave rather like fluids and flow. **Pyroclastic flows** (nuée ardente) were a feature of the Mount St Helens eruption. They are hot fluidised avalanches of volcanic fragments and hot gases which can travel at high speed.

A **mudflow** is debris, mostly volcanic ash and lava fragments, fluidised by melting ice or water.

Richter scale A logarithmic scale for measuring the size of earthquakes by the amount of energy released. The maximum ever recorded is 8.9.

Seismometer / seismograph An instrument for recording earthquakes.

Strata Layers of rock

Suggested answers to questions are in the *Teachers' Notes.*

Telephones Telephones Telephones

Science content

Telephone, telephone exchanges, pulse and tone dialling, sound waves, transmitter, receiver, electrical resistance.

Science curriculum links

AT11 Electricity and magnetism
AT12 IT including microelectronics
AT17 The nature of science

Syllabus links

- GCSE Science, Physics,

Lesson time

1–1½ hours

Links with other SATIS materials

306 Fibre Optics and Telecommunications

NERIS

Search on TELEPHONES and UPPER SECONDARY

SUMMARY

The unit covers the invention and development of the telephone up to the electronic tone dialling instruments of today.

STUDENT ACTIVITIES

- **Part A** Reading and answering questions about the development of the telephone and its human benefits, group discussion and investigation activities, role-play situations.
- **Part B** The physics of the telephone.
- **Part C** Information and calculations: how many telephones you can have on a line.

AIMS

- To complement work on information transmission systems and on electrical resistance
- To illustrate the development of the telephone and the human benefits of new technologies
- To provide students with an understanding of the science involved in the telephone system

Author **Raymond Walker**

First published 1991

Teaching notes

Telephones like the 'Venue 24E' incorporate a microprocessor chip to allow a versatile display and memory access. It was hoped that all such telephone instruments could be operated by line current provided by the exchange but BT's policy of restricting the drain to μA's prevented all but the simplest of modern 'phones working without a battery.

Electronic sounders are transducers and it may be appropriate to point this out to the students.

Answers to the questions

Q1 *Diagram.*

Q2 *The government gave him the sole right to make, use or sell his invention for a limited period. Bell's patent application prevented Elisha Gray developing his telephone.*

Q3 *A 10 digit number would take 10 s to dial, ignoring the dial return time.*

Q4 *With MFD the dual tones are to prevent anybody whistling tones down a telephone.*

Q5 *Exchange connection – in the case of electromechanical exchanges, the slow movement of the mechanism.*

Q6 *1876 patent granted; 1877 first commercial telephone; 1878 first telephone exchange; 1906 Strowger dialling system and automatic exchange (gradually introduced into Britain) necessitating the use of dial telephones; 1974 push-button telephone introduced to Britain; late 1980s tone-dialling telephones.*

A1 *The order of importance might be – push-button dialling; 10 memories (some 'phones have 24); last call redial; tone dialling; etc.*

(b) the elderly may prefer – push-button dialling (keys are easier to work); 10 memories (to program numbers for relatives, doctor etc.); call timer; etc.

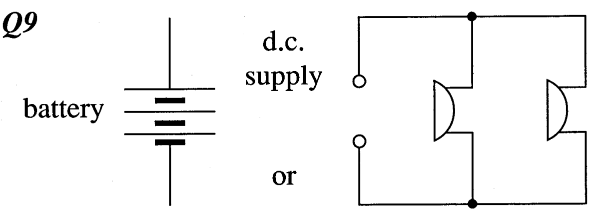
A2 *(a) A modem is a device for connecting two computers over the telephone line. It has a MOdulator for converting binary voltage signals into analogue audio signals and a DEModulator for decoding them again. Schools use a modem to communicate with data bases such as NERIS and PRESTEL. Shop tills, bank computers etc. also communicate with each other over telephone lines.*
(b) Fax (facsimile) machines are widely used for transmission of the images of documents by telephone line. A fax machine combines the functions of electronic scanner, modem and printer.

A3 *Answers may include suggestions such as:*
(a) memory telephone, tactile telephone adaptor;
(b) extra loud telephone bell, flashing bright light;
(c) public payphones are equipped with an inductive coupler which produces a magnetic field that can be picked up by the hearing aid,
(d) cordless phones.
For more details see the BT guide to equipment and services for the disabled.

Q7 *(a) Similarities – work by varying the current from a d.c. supply; sound waves act on a diaphragm; receiver is based on an electromagnet. Differences – the transmitters; the receiver causes the vibration of a metal reed instead of a diaphragm in modern telephones.*

Q8 $V = IR = (0.01\ A) \times (4000\ \Omega) = 40\ V$

Q9



Q10 *(a) 4, (b) 1.*

Q11 *(a) Telephone (4000 Ω) + line (1000 Ω) = 5000 Ω.*
(b) $V = IR = (0.01\ A) \times (5000\ \Omega) = 50\ V.$

It is different because energy is dissipated in the line from the exchange.

Further information

- British Telecom: 'Electricity and Telecommunications'
- British Telecom: 'Guide to equipment and services for disabled customers' is available from BT shops.
- The Science Museum, London.
- *National Geographic Magazine*, 'Alexander Graham Bell', September 1988.

Acknowledgements
Figure 1 is reproduced from material held by the United States Library of Congress.

Telephones Telephones Telephones

Part A Talking about the telephone

'Mr Watson, come here, I want to see you', were the first words ever transmitted by telephone.

The speaker, Alexander Graham Bell was a Scottish-born doctor who had emigrated to the USA. The device he invented gave rise to the first commercial telephones.

It was on the 14th February 1876 that the US Patent Office received two similar descriptions of a 'talking telegraph'. The first was from Bell and the second, only hours later, was from Elisha Gray, a professional inventor. Gray did not contest Bell's invention, believing that the telephone was not worth serious attention. Bell, however, wrote to his father, 'I am sure of fame, fortune and success'.

Part A Talking about the telephone – its development, features available on electronic telephones.

Part B The physics of the telephone.

Part C How the telephone transmits speech, how many telephones you can have on a line, simple calculations.

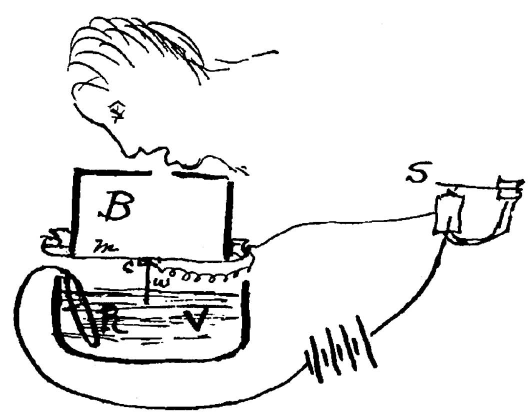


Figure 1

This sketch was produced by Bell, on 9th March 1876. The telephone worked by varying the resistance to a current from a battery.

A voice spoke into the box (B) and would make the diaphragm (m) vibrate. This caused a wedge-shaped needle (w) to move in and out of a bath of liquid (V), changing the resistance of the circuit.

The receiver consisted of an electromagnet (s) which caused a metal reed to vibrate.

Q1 Redraw and label Bell's sketch and see if you are a better artist than one of the world's great inventors.

Q2 Suggest what benefits Bell may have had from patenting his telephone.

In fact, Bell's telephone gave very poor sound. The quality was improved using Edison's carbon-granule microphone for the transmitter and keeping Bell's design of receiver.

Commercial telephones appeared in 1877 and soon became popular in the USA. At first they were connected in pairs, rather like the tin-can telephones you may once have made. You could talk to one person at the other end of the line and that was all.

1900 The world's first automatic telephone exchange in New Bedford, MA, USA.

1909 Europe's first automatic exchange, operating on Strowger's dialling system.

1912 London's first automatic telephone exchange with 480 lines.

1960 An experimental electronic telephone exchange is built by the Bell Telephone Co in the USA.

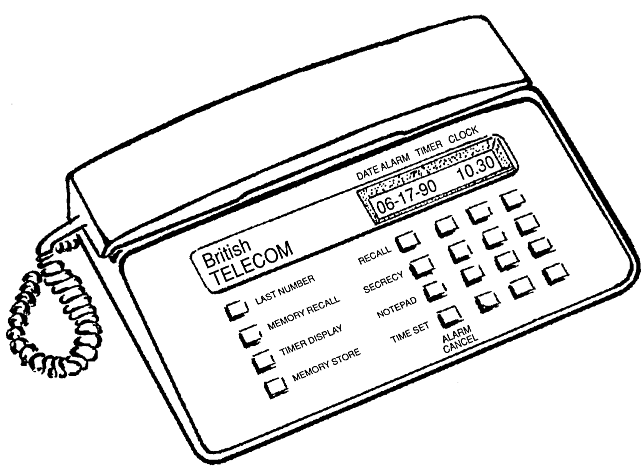
1990s Old exchanges in Britain are being replaced by digital ones.

The first telephone exchange was opened one year later with 21 subscribers. Early telephones did not have dials or push buttons, the caller simply asked the operator to connect the call.

Then in 1906 an American undertaker called Almon Brown Strowger discovered that telephone calls were being switched to his rival's business. He was so furious he invented an automatic switching system. A dial on the telephone sent pulses down the line to work electromechanical switchgear in the exchanges.

From the 1930s to 1970s the telephone remained relatively unchanged. Strowger electromechanical exchanges were installed in Britain and used until electronic exchanges began to replace them in the late 1970s.

When electronics and chips became part of telecommunications changes started to happen. In business speed of communication is important: time costs money. Electronic telephones are able to offer extra features and electronic exchanges have no moving parts. They connect calls faster than the older electromechanical switch gear, which was slow and not always reliable.



- Attractive design
- Push-button dialling
- Call timer
- 10 memories
- High quality microphone
- 16 digit display
- alarm clock
- Last call redial
- Secrecy button (switches off the microphone)
- Ringer volume control
- Dual signalling (may be set to pulse or tone dialling)

Figure 2 An electronic telephone with a microprocessor

Push-button telephones were introduced to Britain in 1974, designed to be used with the electronic exchanges of the future.

Today, newer telephones use tone dialling. When used with digital exchanges they offer the customer greater speed, reliability and access to more services. However, electronic telephones have two disadvantages – electrical storms may damage their chips and those with large memories or timers need batteries. The problem is that when the batteries run down the memory is lost.

From the outside, the telephone seems little changed, although most have a key pad instead of a dial. Although today's telephones are available in many styles and colours, the real advantages lie hidden inside.

Dialling

How does the telephone signal to the exchange what number you are dialling? There are two different methods in use at the moment.

Pulse dialling

A dial telephone uses pulse dialling. As you dial a number, the line is quickly disconnected and reconnected over and over again. This produces a series of pulses. The number of disconnection pulses represents the number being dialled. A number 9 would be 9 pulses and this would take a second to dial.

Q3 Dialling a long distance call in Britain needs 10 digits. (For example, the STD code for Worksop is 0909 followed by a six digit local number.) How long would it take to dial 0909 - 900909 with a dial telephone? You may assume that a '9' or a '0' take about a second each to dial.

Figure 3 A telephone with dial

Tone dialling

Tone dialling works with digital exchanges. When you press a number on the key pad, the telephone sounds a musical note or tone. The notes are different for each number and are made up of two tones sounded together. The exchange equipment recognises the tones as soon as they sound – faster than you can press the push-buttons. (Some telephone instruction books refer to tone dialling as *Multi-Frequency Dialling*, or *MFD* for short.)

Figure 4 A telephone with keypad

Q4 Would it be possible for someone whistling down the telephone to tone dial a number on a digital exchange?

New push-button telephones can be set to pulse or tone dial. Although digital exchanges can recognise pulse or tone signals, tone dialling produces much quicker call connections.

Q5 What causes the delay between the time you dial a call and the time the number rings at the other end?

Q6 Produce a time chart showing the development of the telephone.

Organising the discussion

- Work in a small group.
- Appoint someone to chair the group who will report back to the class if needed.

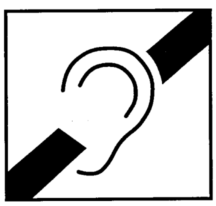


Figure 5 Inductive coupler symbol

Activities for group discussion and investigation

A1 *Arrange the list of features of a typical electronic telephone in order of importance*
(a) to a teenager, (b) to an elderly person living alone.

A2 *Find out what the following are used for*
(a) a modem, (b) a fax machine.

A3 *Disabled people may have difficulty in using a normal telephone. Find out what is available to help*
(a) blind people to dial telephone numbers
(b) partially deaf people to know when the telephone is ringing
(c) hearing aid users to use public payphones
(d) people who have difficulty moving around the house or use a wheelchair.

Role-play situations

Consider these situations. Jot down some ideas about how you could act out the scene.

Scene one

The year is 1876 in the USA.

A: You are Alexander Graham Bell, age 29. You are about to test your invention. You send your assistant into the next room to listen at the other end.

B: You are Mr Watson, age 22 and assistant to Mr Bell.

Scene two

The year is 1875 in the home of Mr and Mrs Hubbard in the USA.

A: You are Alexander Graham Bell. You believe you are going to make a fortune from your invention of the telephone.
You are interested in deafness and you tutor deaf students. You have fallen in love with one of them, Mabel Hubbard.

B: You are Mabel Hubbard, age 17. You are deaf and in love with Bell. Your parents say you are too young to marry.

C: You are Mr Gardiner Hubbard, Mabel's father. You cannot see how Mr Bell can support your daughter on money from inventions. Your daughter is deaf and also too young to marry.

Scene three

A: You are a grandparent. You have an old dial telephone.

B: You are a grandchild. You are giving your grandparent the eletronic telephone in figure 2 for a birthday present. Explain how useful it will be.

Part B – The physics of the telephone

How does the telephone transmit speech?

Nowadays, the mouthpiece (transmitter) and earpiece (receiver) are usually made the same. In design they are similar to a loudspeaker. They contain a strong circular magnet, a plastic diaphragm and tiny coil through which the current flows.

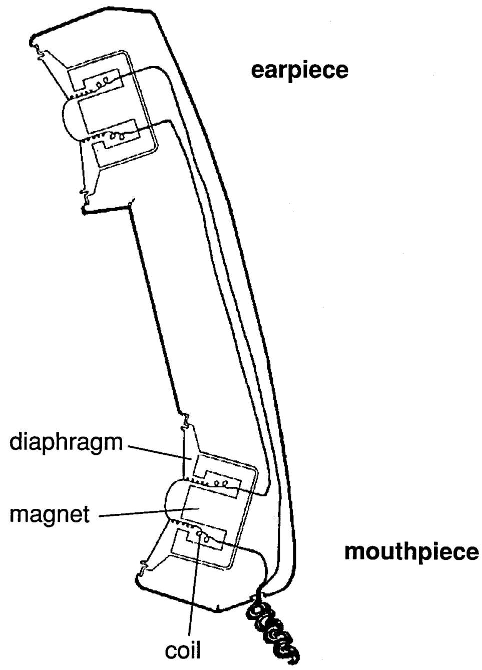


Figure 6 The parts of a modern telephone

The transmitter is a moving-coil microphone. When someone speaks into the mouthpiece, their sound waves hit the plastic diaphragm and make it vibrate. The coil is fixed to the diaphragm and moves to and fro in a magnetic field. The vibrations cause the current through the coil to increase and decrease with the sound.

At the other end, the changing current in the earpiece causes the force on the coil in the magnetic field to vary. The coil moves the diaphragm to and fro sending compressions and rarefactions which make sound to the listener's ear.

> *Q7 Describe the similarities and differences between the modern telephone and Bell's original design (on page 1).*

Part C – How many telephones can you have?

Modern telephones have **electronic sounders** instead of bells. You can use more telephones with sounders on the line than telephones with bells. Sounders have a high resistance and draw less current from the exchange. For example, a typical electronic telephone has a resistance of 4 kΩ (4000 ohms) and the current required to work it is only 10 milliamps (0.01 A)

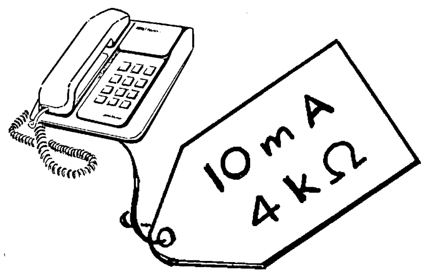


Figure 7 A telephone with an electronic sounder

The rule for connecting telephone equipment is that its total resistance must always be greater than the resistance of the telephone line. But how do you work this out?

Modern extension telephones have their sounders wired in parallel. The more telephones you connect to the system, the lower the total resistance. If you want to find the total resistance (R) of all the telephones (r_1, r_2, r_3, etc.) on a single line, you will need to use the formula

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \text{etc.}$$

Some customers could find this a little daunting!

Instead, telephones are given a **REN** number (the **R**inger **E**quivalence **N**umber) and you just add them up. The total you can connect to a single line is 4 REN. Most modern telephones have a REN of 1. Some modems have a REN of 3.

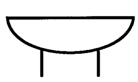


Figure 8 Circuit symbol for a sounder

Telephone lines have a resistance of about 1 kΩ (1000 ohms). About one-fifth of the power sent by the exchange to operate the sounder is wasted in the line.

The local telephone exchange has a large battery room of lead-acid cells which can supply about 2000 A at 50 V. They allow the exchange to carry on operating in the event of a power cut for about six hours.

Useful formulas

in series

$R = r_1 + r_2$

in parallel

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \frac{1}{r_4}$$

$$\text{resistance} = \frac{\text{p.d.}}{\text{current}}$$

$$R = \frac{V}{I}$$

Use the figures given for the telephone in figure 7.

Q8 *Calculate the voltage needed to make it work.*

Q9 *Draw a circuit diagram showing 2 sounders wired in parallel with a d.c. supply.*

Q10 *The total load on a line is 4 REN. If your telephones have a REN of 1 and you have a modem with a REN of 3,*
(a) how many telephones can you connect to a line?
(b) how many telephones can you connect with a modem to a single line?

Q11 *(a) What is the total resistance of telephone and line?*
(b) Work out the exchange voltage needed to ring your telephone. Why is the answer different from that in Q8?

Answers to the questions are in the *Teachers' Notes*.