IS THERE ANYONE OUT THERE?

A science investigation pack for teachers of 9–12 year olds

CENTRE *for* INDUSTRY EDUCATION COLLABORATION

UK esero

UK SPACE AGENCY

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A science investigation pack for teachers of 9–12 year olds

This resource was funded by the UK Space Agency and developed by ESERO-UK and the Centre for Industry Education Collaboration.

ESERO-UK

The aim of the European Space Education Resources Office in the UK (ESERO-UK) is to support the space sector by helping teachers open doors for young people from all backgrounds, by delivering inspiring world-class teaching in science, technology, engineering and mathematics (STEM).

Working alongside STEM Learning, ESERO-UK is able to provide influence, funding and services to improve the teaching of STEM subjects in schools and colleges and inspire young people through enrichment activities.

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The Centre for Industry Education Collaboration

CIEC creates and sustains links between school science and industry's people and practices; by promoting excellence in primary science teaching and learning, and increasing children's and teachers' awareness of STEM industries and careers.

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Introduction

This resource is based upon the quest to discover more about our solar system through space projects such as the European space agency's aurora programme, and NASA's curiosity mission seeking to gather evidence of life on the planet Mars. The children take on the role of space scientists or space engineers to discover more about Mars

AGE RANGE

The activities in this resource are designed for children aged 9-12 years. Activities in the Life and Landscape themes are suitable for children in Years 5-6. Activities in the Landing theme are intended for children in Year 7 or to challenge. Gifted and Talented primary children

APPROXIMATE DURATION

The activities vary in duration from approximately 1 to 3 hours, depending on the circumstances in each school and class

ACTIVITIES

The activities are organised into three themes: Life, Landscape and Landing. They are designed to appeal to the imagination of children. See the table overleaf for a summary of the activities in each theme. Themes can be taught independently, and teachers can select the ideas in a particular section according to the interests of their pupils.

The investigative activities and images in each theme provide a sequence that helps the children to explore features of the planet Mars in practical ways involving the use of key skills. They introduce the children to a range of challenges each requiring the use of enquiry skills, discussion and problem solving consistent with UK curricula requirements.

It is intended that children develop their own ideas, and methods of recording and presenting their results and conclusions. To support this approach, hints and facts, and ideas for investigation and recording are provided, to be adapted by teachers to suit the needs of their children.

RESOURCE WEBSITE

The following websites can be used to download the images and .pdf of the written resource.

www.stem.org.uk/rx7kt

www.cciproject.org/topicBank/space.htm

GLOSSARY

The glossary contains definitions of words that appear throughout the teachers' notes as highlighted text.

ACTIVITY SUMMARY

Title	Description
Life	Children consider the criteria essential for life and discuss what formlife might take. They go on to: • compare and test samples of 'soil' identifying properties that indicate characteristics of Martian 'soil'. • test for the possible presence of microorganisms. • investigate conditions affecting their growth.
Landscape	The children study images from Mars to note significant features and make hypotheses about their formation. They carry out and evaluate practical tasks to mimic crater formation, **lava** flow, and the creation of channels and **deltas**.
Landing	Children consider data from the viewpoint of scientists or engineers to identify the best landing site for the rover. They estimate the age of landing sites, identify landscape features such as craters, rocks, deltas, canyons, elevations and interpret scales, data and images. The class debates to decide the most appropriate location.

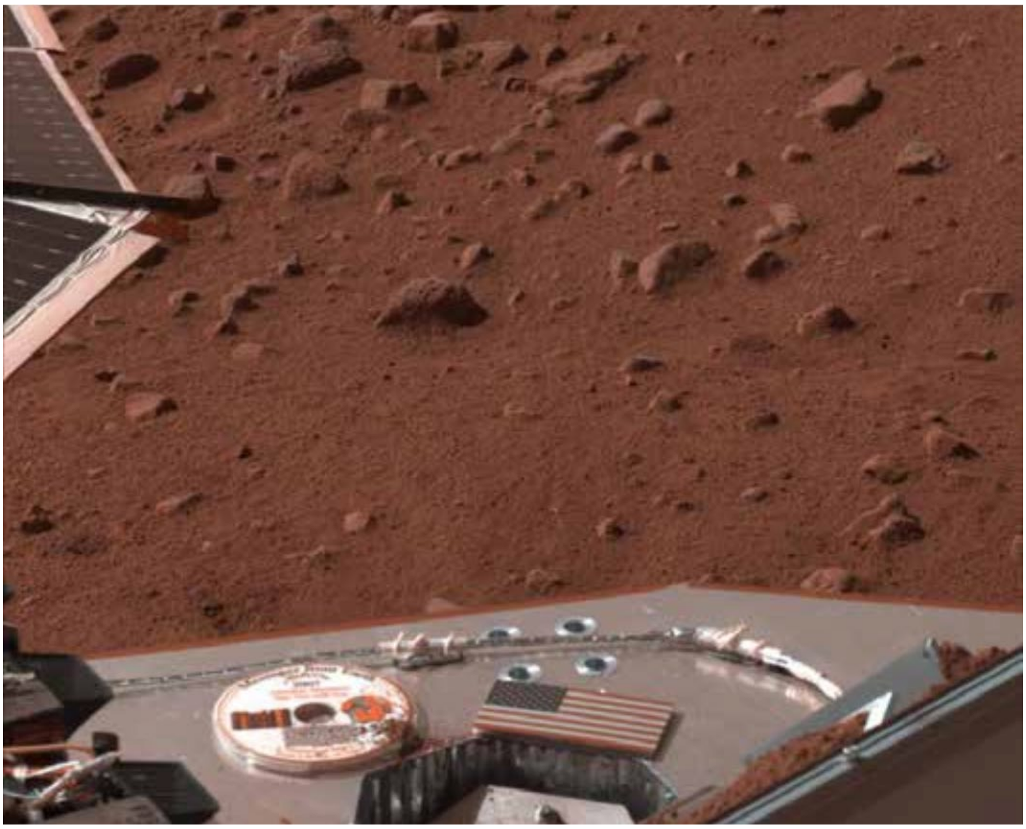


Image of Mars surface from a lander

1. Martian Soil

3 hours

OBJECTIVES

- To plan different types of scientific enquiries to answer questions
- To identify scientific evidence that has been used to support or refute ideas or arguments
- To compare and group together everyday materials on the basis of their properties

RESOURCES

(Per group of 4 children unless otherwise stated)

- Activity sheets 1-3
- Images A-J from www.cciproject.org/topicBank/space.htm
- Role badges (optional)
- Soil samples A, B, C
- Magnifying lens
- 2 teaspoons
- 3 Petri dishes/shallow bowls
- Blue and red litmus paper (supplied by TTS or other suppliers)
- or vinegar and bicarbonate of soda (1/4 cup)
- 3 filter funnels and filter paper.
- 3 plastic cups
- 3 measuring cylinders
- Tea light and stand
- Foil evaporating dish
- Sand tray
- 4 pairs of safety glasses

ADVANCE PREPARATION

- Activity sheets 1-2 made into a set of cards
- Soil samples A,B, C (Appendix 1)
- Role badges (Appendix 1)

All the classroom sessions involve children working together in groups of four. A set of role badges for each group should be prepared before the lesson should the teacher wish to use them. (See page 56).

INTRODUCING THE ACTIVITY

The teacher uses the images A-D (see page 15 or website) to begin a discussion about the possibility of life on Mars and asks the children Can we see evidence of life on the surface? Where else could we look? 'Rovers' are being designed to search for signs of life on and below the Martian surface. Each pair in the group is asked to discuss how we know if something is alive. Pairs share their initial ideas with their group. Images of living/non living things (Activity sheet 1) can be used as a revision aid in a sorting activity to support discussions. The 'Snowball technique' (Appendix 2) could be used to share ideas between groups, before the class produces a consensus of key criteria for life.

The teacher describes conditions on Mars, using information in Appendix 3 and asks the children if they can suggest extreme places on Earth; they should consider examples of adaptations of living things in such environments. Images E-J of extremophiles and extreme habitats are shown. Considering this information about extremophiles, Is it possible that there has ever been life on Mars? What might that life look like? We need to find out as much as we can about conditions on Mars to answer these questions. They next consider the kinds of life (possibly microbial) and evidence that astrobiologists may be searching for on Mars.

ACTIVITY

The teacher explains that one day, space scientists hope that real samples of Martian soil will be brought back to Earth but in this activity, they will simulate the work of space scientists investigating 'mock samples'. The Space Agency has given each group three different samples of 'soil' and through observations and tests they must decide which might be most like Martian soil. Each child in the group is given a card from Activity sheet 2. The children should take turns at sharing their information with the rest of the group; the key facts will help them in their investigation. This activity is intended to be child-led and therefore they decide what evidence they need to collect and how they might record their observations, measurements and conclusions.

The children should be encouraged to observe each sample of soil closely, to feel the soil texture and note its characteristics. They use small quantities of each sample to carry out further tests. Activity sheet 3, if required, is provided for children to summarise their observations, results and conclusions.

SAFETY NOTES, PRACTICAL TIPS AND GUIDANCE

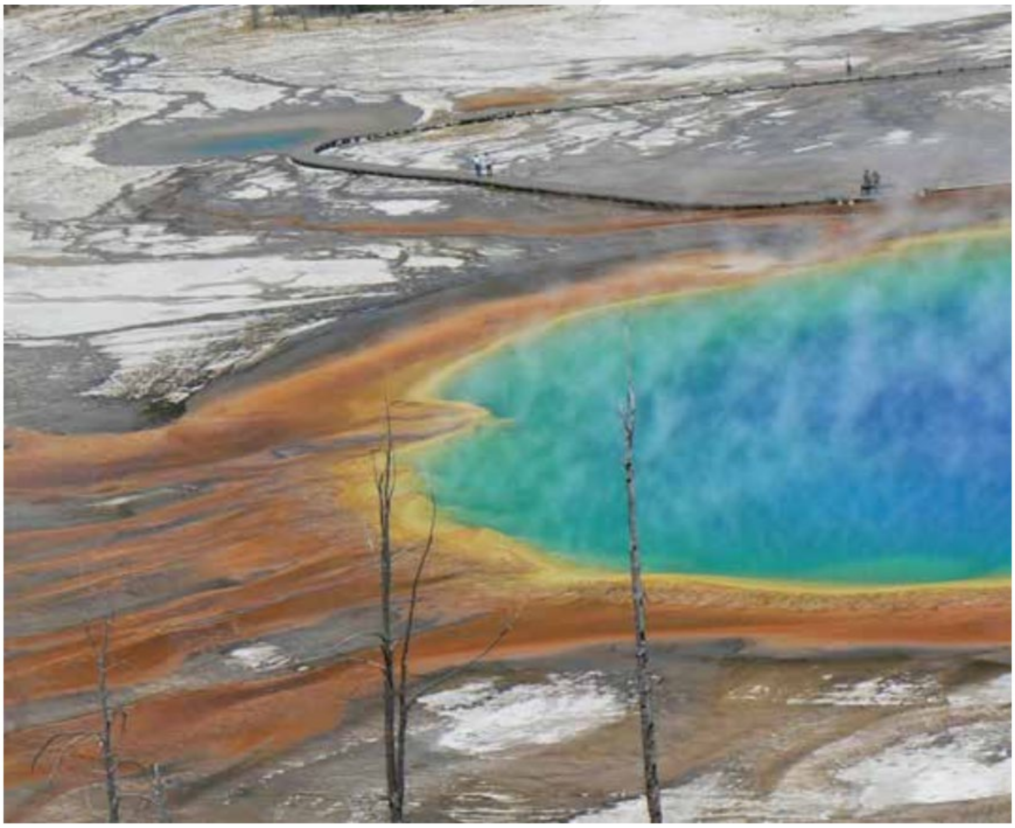
- Children should wear safety glasses to protect their eyes when evaporating water from salt solution, due to potential spitting.
- Tea light stands should be placed in a tray of sand for safety. Consult ASE's Be Safe! for further guidance.
- Teachers should ensure that each soil recipe is mixed thoroughly. It is recommended that eachers test the mixtures before the lessons.
- Litmus paper[1] can be used to show whether a liquid is acidic or not. Just add a teaspoon of soil to a cup, add water to cover the soil and mix. Then dip the paper into the liquid.

1 If you do not have litmus paper, put a teaspoon of soil into each of two containers. Then, add vinegar to one. If the soil bubbles or fizzes, it's not acidic. If there's no reaction, add water to the second sample and mix. Then, add two teaspoons of bicarbonate of soda. If the soil bubbles or fizzes the soil is very acidic.

PLENARY

The communications manager from each group reports their observations, measurements, results and conclusions to the class. The results may be collated on the whiteboard for display and discussion by the class. Unusual or unexpected results or observations may be noticed. The teacher can ask some of the following questions:

- *Did all groups identify the same sample as most like Martian soil?*
- *Were there any disagreements?*
- *How did you decide which sample was the most like Martian soil?*
- *Did you recover any salt crystals?*
- *What methods did you use and what evidence did you have?*



Hot springs in Yellowstone Park: a suitable extremophiles' environment.

2. Looking for Evidence of Microorganisms

1 hour

Children consider what life might look like if it exists on Mars and think about how scientists could prove that life was (or ever had been) present. They are then given 'Martian soil' samples. They plan and carry out a test to ascertain whether any of them contain microorganisms.

OBJECTIVES

- To plan different types of scientific enquiries to answer questions, including recognising and controlling variables if necessary
- To report and present findings from enquiries, including conclusions, causal relationships and explanation of and degrees of trust in results in oral and written forms such as displays and other presentations.
- To develop their understanding of microorganisms as living things

RESOURCES

(Per group of 4 children unless otherwise stated)

- Activity sheets 4-5
- 2 tsp soil samples A-C
- ¼ cup sugar
- Thermometer
- Teaspoon
- Warm water (45-50°C)
- Plastic cup or beaker

ADVANCE PREPARATION

- Soil samples (Appendix 1)
- Add a packet of dried instant yeast to sample C, ensuring it remains completely salt-free.

INTRODUCTION

The teacher explains that the children will look for evidence of the presence of life (microorganisms) in the soils and record their observations. If life is present, adding warm water and sugar to each sample may result in the production of gas (carbon dioxide). Groups are provided with helpful hints and facts cards (Activity sheets 4-5).

ACTIVITY

The children:

1. Dissolve 2 teaspoons of sugar in 30ml of warm water (45-50°C) and quickly add this to the sample.
2. Press the bag to remove air excess air and seal.
3. Mix the contents together by gently pressing the contents with their fingers, ensuring that the bag is completely sealed to prevent escape of carbon dioxide should microorganisms be present.

The children may record the gradual inflation of the samples using drawings, video or photographs.

Photograph showing the inflated bag of Sample C after 20 minutes

PLENARY

The children share their observations with the class.

- *Did the groups all have similar results?*
- *Were there any unexpected results?*
- *Can they explain what happened?*

The teacher should explain that scientists take great care when they draw conclusions from tests such as these. The production of gas does not necessarily mean that life is definitely present.

SAFETY NOTES, PRACTICAL TIPS AND GUIDANCE

Teachers check that the water is no hotter than 50°c to avoid killing the yeast. If yeast is present, the children should see the formation of bubbles of carbon dioxide very quickly. The bag should begin to swell after about 20 minutes and after an hour should be well-inflated.

EXTENSION

The children could be encouraged to suggest further investigations to discover how different conditions may affect the growth of micro-organisms. They may wish to try investigating the effect of light, temperature or different nutrients upon the growth of the yeast.

BACKGROUND INFORMATION

When scientists study very small samples or fossilised material, the characteristics of present or past life are very difficult to determine. The tests used by previous missions to Mars were based around the belief that life would cause changes in the air or soil, in a similar way to life on Earth. The missions did not detect the presence of life. It is intended that the children will not find evidence of life in the sample most like Martian soil.

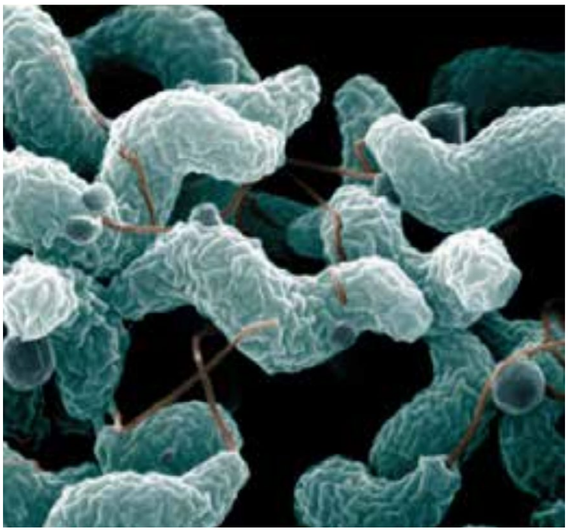
One of several signs of life scientists search for is the exchange of gases in respiration or fermentation, as modelled in this activity. Here, the micro-organism yeast is using sugar as a source of energy and is producing carbon dioxide. Most living things on Earth need oxygen to survive, but some organisms have adapted to extreme conditions where oxygen is absent, as on Mars. Sensitive techniques are used by scientists to detect minute quantities of gases that might indicate evidence (but not prove) that some form of life exists or once existed on Mars.

Activity Sheet 1: Living/non-living discussion cards

1

Images can be downloaded from the website.

Activity Sheet 1: continued



Activity Sheet 2

Soil Challenge Card 1

You have 3 samples of soil; A, B, C. As space scientists you are to decide which one you think is most like Mars soil.

Helpful Hints
Salt disolves in water. Sand does not

Fabulous Facts
Soli from Mars is mostly dust that falls out of the air from big dust storms.

Soil Challenge Card 2

You should feel and observe each sample.

Helpful Hints
You can use special paper called indicator paper to show whether a liquid is acid or not.

Fabulous Facts
Mars soil is made from very fine dust like taolc, bits of sand, tiny rocks and larger lumps from meteorites. Some sample of Mars soil are acid but most are not.

Soil Challenge Card 3

You should carry out some investigations and use the Mars facts to help you.

Helpful Hints
Filtering can be used to separate materials that do not dissolve in water.

Fabulous Facts
Mars soil is so rusty. It looks reddish/brown. Under the surface are tiny bits of rock that let water pass quickly through them.

Soil Challenge Card 4

You need to collect evidence, decide how to record it and present your findings.

Helpful Hints
Evaporation can be used to get back materials that have dissolved in water.

Fabulous Hints
Almost every Mars lander or rover has found some salt or crystal salts in the soil.

Activity Sheet 3: Space scientists Martian soil studies

✓ Yes or X No	A	B	C
Red-brown colour			
Feels like talc or flour			
Range of particle sizes			
Contains salt			
Lets water pass through quickly			
Acidic			

We think sample ____________________ is most like Martian soil because

____

____

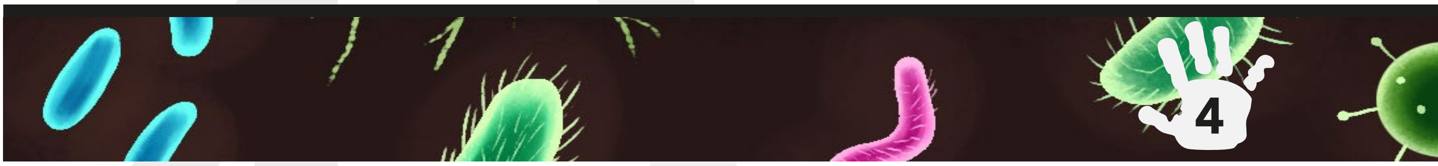
____

____

____

____

Activity Sheet 4



Life Helpful Hints

If microorganisms are present, you may see bubbles of gas (carbon dioxide) and the bag may begin to swell up.

Life Helpful Hints

When the bag is sealed, mix the food with the soil by pressing it with your fingers.

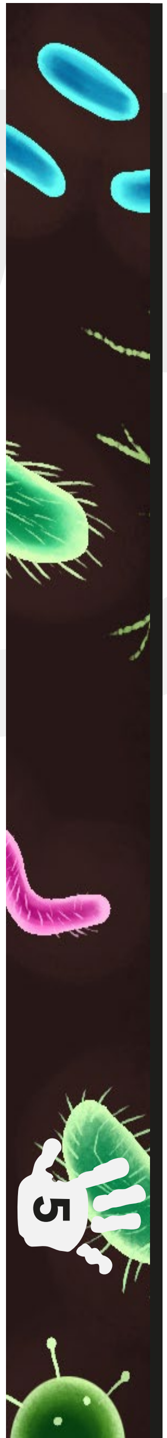
Life Helpful Hints

You can make some food for the microorganisms by dissolving 2 teaspoons of sugar in 30ml of warm water (between 45°C and 50°C).

Life Helpful Hints

Make sure you press the bags flat before sealing them!

Activity Sheet 5



Life Fabulous Facts

Living things need water and food and the right conditions to survive.

Mars is very cold, dry, dusty and windy.

It has hardly any oxygen and has a third of Earth's gravity.

Life Fabulous Facts

Scientists believe water existed on Mars 1 million years ago. Water may be present under the surface of Mars.

Life Fabulous Facts

Microorganisms can live in very extreme places on Earth. They may once have lived on Mars!

Most living things need oxygen but not all microorganisms do.

Life Fabulous Facts

Microorganisms may produce gas when given water and food.

Space scientists test soil samples for materials that have come from living things in the past.

IMAGES OF THE MARTIAN SURFACE

Images can be downloaded from www.cciproject.org/topicbank/space.htm

Image A

Mars through a telescope showing the canals

Image B

Surface of Mars taken from orbiting satellite

Image C

Mars Rover

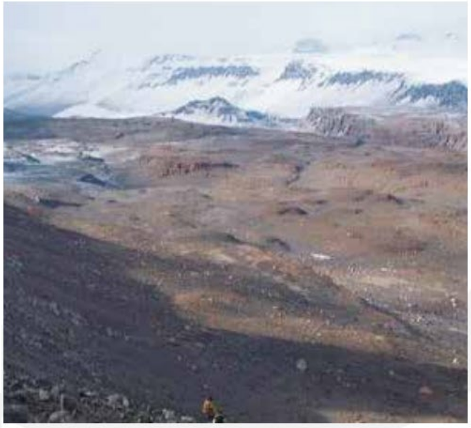
Image D

Surface of Mars taken from Rover

EXTREMOPHILE HABITATS

Images can be downloaded from www.cciproject.org/topicbank/space.htm

Image E



Antarctica

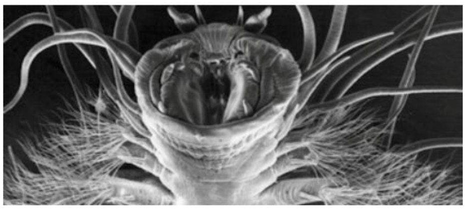
Image F

Volcanic lava

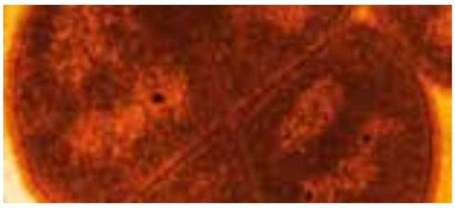
Image G

Volcanic ash

Image H



Methane worm

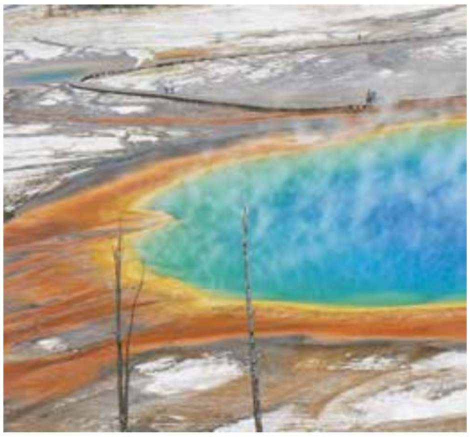


Deinococcus radiodurans

Image I

Ocean depths

Image J



Yellowstone hot springs

3. Landscape Discussion

30 mins

Children study images from Mars to note significant features. They compare them with images from Earth to help them to make hypotheses about their formation.

OBJECTIVES

- Identifying scientific evidence that has been used to support or refute ideas or arguments
- To know that science is about thinking creatively to try to explain how living and non-living things work, and to establish links between causes and effects.
- To know that comparing Mars' key landscape features with similar features on Earth can help us to understand their formation.

RESOURCES

(Per group of 4 children unless otherwise stated)

- Activity sheets 6-7 and 12
- Images K-U (Q for teacher use only)

ADVANCE PREPARATION

- Activity sheets made into cards

INTRODUCTION

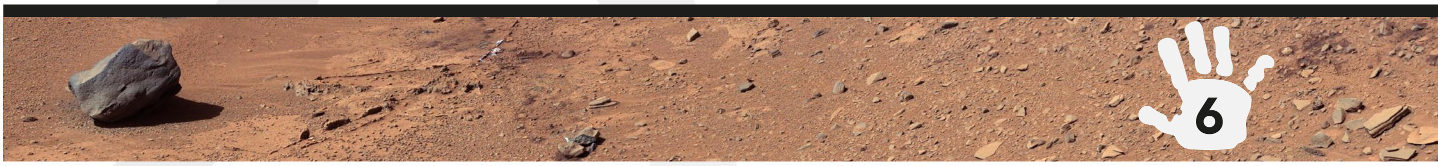
The teacher explains that the new Mars rover, searching for evidence of past or present life, will look in particular for the presence of water. Where water is or has been there is a chance of discovering evidence of life. On Earth, where volcanic heat and water interact, scientists have found life. The groups study images K-P. The task is to identify what each might be and how each might have been formed by comparing images of similar features from Earth to aid identification (Images R-U).

Groups may choose one of the key features and perform one of three practical tasks. The three practical tasks use models to simulate how the key Martian features may have been formed. Children use Activity sheets 6-7 to help them decide which feature to investigate. The whole class could try all three activities (3-4 hours) or a third of the class could each investigate one feature and report back to the others (1- 11⁄2 hours). Later, they will compare their ideas with those of the 'experts' (Activity sheet 12). Finally, they share their ideas and evidence and suggest suitable locations for the rover landing and sampling sites.

Practical tasks, described in detail later in this section, include:

1. Exploring how the mass, size, shape, velocity, and angle of impact of falling bodies **(meteorites)** and the surface might affect the size and shape of the crater produced.
2. Investigating lava flow and layering patterns by making a 'volcano'.
3. Studying patterns produced by flowing water across a surface.

Activity Sheet 6



Landscape Helpful Hints

Comparing images taken on Earth, may help you to identify important features on Mars.

Landscape Helpful Hints

Doing practical tests and investigations may help you to find out how these features were made.

Scientists call this 'modelling'.

Landscape Helpful Hints

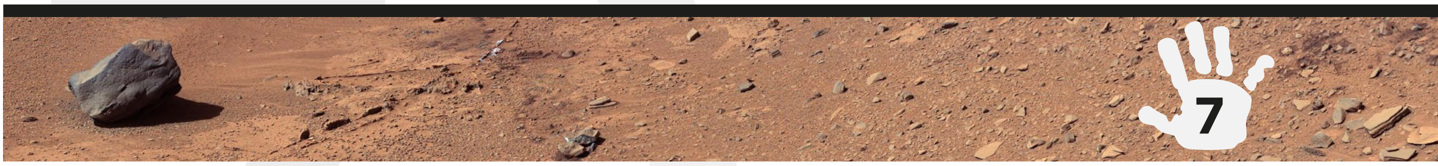
Talk about your observations and measurements. How do you think the features were made?

Do your conclusions agree with the experts?

Landscape Helpful Hints

After your experiments, read the experts information about the important features you have been investigating. You could find out more from books on the internet.

Activity Sheet 7



Landscape Fabulous Facts

Mars is very cold and temperatures average -55 C but it may not always have been so cold. There could be ice on or under the surface. Scientists believe that where water is, or has been there, may may be a chance of finding evidence of Life.

Landscape Fabulous Facts

Where heat from volcanoes and water are close together on Earth, scientists are finding life. In hot springs they have found different kinds of living things.

Landscape Fabulous Facts

A crater is a hole, usually circular in shape, made when a piece of rock (meteorite) or an ice/rock mixture (comet) from outer space crashes into a rocky planet such as Mars.

Landscape Fabulous Facts

Volcanoes and/or lava flows can be found on all large rocky planets . Lava can make channels similar to those made by water.

4. Investigating Craters

1 hour

Children carry out and evaluate practical tasks to mimic crater formation and consider what information can be gained about meteorites by studying the craters they make.

OBJECTIVES

- Identifying scientific evidence that has been used to support or refute ideas or arguments
- To know that science is about thinking creatively to try to explain how living and non-living things work, and to establish links between causes and effects.
- To know that comparing Mars' key landscape features with similar features on Earth can help us to understand their formation."

RESOURCES

(Per group of 4 children unless otherwise stated)

- Activity sheet 8 cut into cards
- Tray 1⁄2 filled with sand
- A variety of 'meteorites' (e.g. marbles, rubber balls, stones)
- Tube for safely directing dropping/rolling 'meteorites'
- Measuring device (see diagram on Activity sheet 8)
- Ruler
- Metre stick

ACTIVITY

The children begin by investigating the effects of dropping various masseses , such as marbles, into a tray of sand. The children should be alerted to the safety issues when dropping objects. Using a tube through which to drop the objects would direct them safely to the tray.

Trays could be placed on the floor to allow the height of drop to be increased safely. Encourage discussion about fair testing, how the speed, density, size of the projectile is important, and how and why this affects the size of the crater produced.

PLENARY

The communication manager from each group shares their results with the class. The results can be collated and displayed on the whiteboard for comparison. Interesting patterns or unusual figures could be highlighted. The importance of replication of results is emphasised. This is also an opportunity for graphs to be constructed and suitable graphing software to be employed. The children compare their craters with the images from Mars:

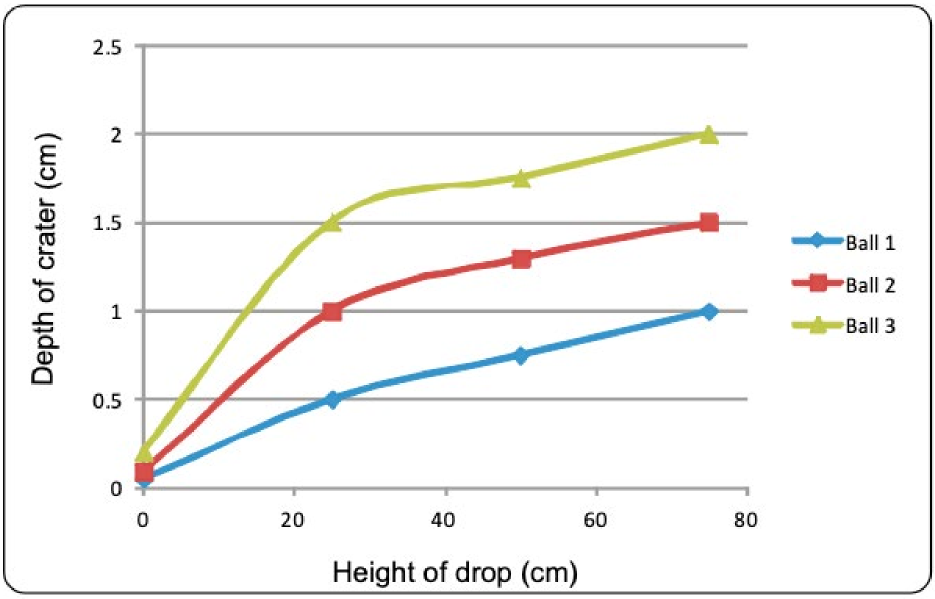
- *Are they similar or not? Why?*
- *What are the limitations of the model?*
- *How would they improve their tests? Were they fair?*
- *Were the results reliable? Were they repeated?*
- *What have they learned about real crater formation?*

The only fair comparison is to change only one variable at a time; different sizes or mass of ball should be dropped from the same height, or the same mass from different heights and craters compared. In reality, meteorites would break up into pieces and possibly produce secondary craters, but in this case, the masses dropped stay in the craters produced.

	Crater depth (cm)		
Height of drop (cm)	25	50	75
Ball 1	0.5	0.75	1.0
Ball 2	1.0	1.3	1.5
Ball 3	1.5	1.75	2.0

The table below shows the depth of crater produced when dropping balls with identical volume but increasing mass.

The graph below shows the depth of crater produced when dropping balls with identical volume but increasing mass into damp sand.



EXTENSION

The children may suggest investigating dropping the masses at different angles rather than straight down or dropping rocks of similar mass but different size or shape. They could make meteorites from a material that will break on impact, such as damp sand.

SAFETY NOTES, PRACTICAL TIPS AND GUIDANCE

An example of an easily-made device for measuring crater depth is shown on Activity sheet 8. Ensure that the bottom of the straw, on which has been placed a blob of Blu-Tack, is resting lightly on the bottom of the crater.

The card circle can be moved up or down the straw to gently rest on the edge of the crater, whilst the depth is marked on the straw. The straw can then be placed next to a ruler and the depth measured. A possible way to achieve same size/different masses is to use plasticine wrapped around objects of varying weight. Alternatively, various weights could be placed inside hollow spheres.

5. Investigating Powdery Surfaces

1 hour

Children carry out and evaluate practical tasks to mimic crater formation and discover how meteors expose deeper layers of soil and rock on a planet's surface making it easier for scientists to collect samples.

OBJECTIVES

- Identifying scientific evidence that has been used to support or refute ideas or arguments
- To know that science is about thinking creatively to try to explain how living and non-living things work, and to establish links between causes and effects.
- To know that comparing Mars' key landscape features with similar features on Earth can help us to understand their formation.

RESOURCES

(Per group of 4 children unless otherwise stated)

- As in Activity 3 plus:
- A tray ½ filled with layers of sand, flour and thin top layer of chocolate
- Powder (to represent layers of Martian 'soil')
- Basalt rock samples (optional)
- 4 pairs of safety glasses

INTRODUCTION

In order to simulate what may happen to the surface and underlying layers of Mars when a meteorite impacts, a second tray can be prepared to represent the Martian surface. The teacher points out that the cocoa/chocolate powder could be the iron oxide (rust) covering and the layer below represent the rocks of Mars, then explains what types they might be, e.g. Basalt (rocks from volcanoes). If rock samples are available in school, they could be shown to the children.

ACTIVITY

The children choose suitable 'meteorites' and drop them on to the surface. After one or two drops, the children are encouraged to look at the pattern produced e.g. ejecta blanket (ejected matter that surrounds a crater) of white flour, and may notice that the material which was once low down is now on top. Explain that this can help scientists, allowing them access to look at the rocks under the surface of Mars.
The children continue to investigate dropping meteorites of various sizes and from different heights. They can smooth the surface and add a fresh layer of flour and chocolate powder when necessary.

PLENARY

The children look again at the images and compare the patterns produced by their investigations with those on the images from Mars. Can they find similarities? What conclusions can they make?

SAFETY NOTES, PRACTICAL TIPS AND GUIDANCE

Since there is a danger of fine particles being dispersed into the air, it is advised that the children wear safety glasses during this investigation to prevent fine powder entering the eyes and care should be taken to prevent powder inhalation.

6. Investigating Muddy Surfaces

1 hour

Children investigate what patterns are left when objects are dropped onto a wet surface. They compare these with images of craters on Mars and discuss whether this is evidence that previously there was water on Mars.

OBJECTIVES

- Identifying scientific evidence that has been used to support or refute ideas or arguments
- To know that science is about thinking creatively to try to explain how living and non-living things work, and to establish links between causes and effects.
- To know that comparing Mars' key landscape features with similar features on Earth can help us to understand their formation.

RESOURCES

(Per group of 4 children unless otherwise stated)

- Activity sheet 8 cut into cards
- A variety of 'meteorites' (eg marbles/rubber balls/stones).
- Tube for safely directing dropping/rolling 'meteorites'
- Mud
- Large sheet of paper/card
- Ruler
- Metre stick

ACTIVITY

The children are challenged to predict what patterns might be produced if meteorites had landed onto a wet Martian surface. They can prepare a mix of soil and water. The mud should be sufficiently sloppy to eject mud splats when the mass is dropped! The mud is placed into the middle of a large sheet of paper or card. The children drop a variety of 'meteorites' into the mud from different heights and observe the patterns produced. They measure the distance travelled by the mud ejected on impact.

PLENARY

The teacher shows the children the information about Tooting Crater provided by the experts (Activity sheet 12). The children look again at the images L and M of Tooting Crater and look for similarities between the images and the patterns they produced in their investigations. Teachers can ask the following questions:

- *Did they find a link between the heights of drop and distance the mud travelled or size/weight of body dropped and the area covered by the splats?*
- *What do they think produced the patterns in the images?*
- *Do their conclusions agree with those of the experts?*

EXTENSION

The children could be encouraged to discover more about the key landscape features of Mars and reinforce their understanding by further reading or through internet-based research.

SAFETY NOTES, PRACTICAL TIPS AND GUIDANCE

It is advisable to use soil rather than compost and to conduct this investigation outdoors. Dropping masses onto mud and observing ejecta would simulate meteorites landing in wet terrain. Allowing the splattered surface to dry would enable further observations and comparisons to be made between the images of Martian channels and the patterns produced. Children should wash their hands thoroughly after handling soil or wear protective gloves during the activity. For further information, see ASE's Be Safe![1]

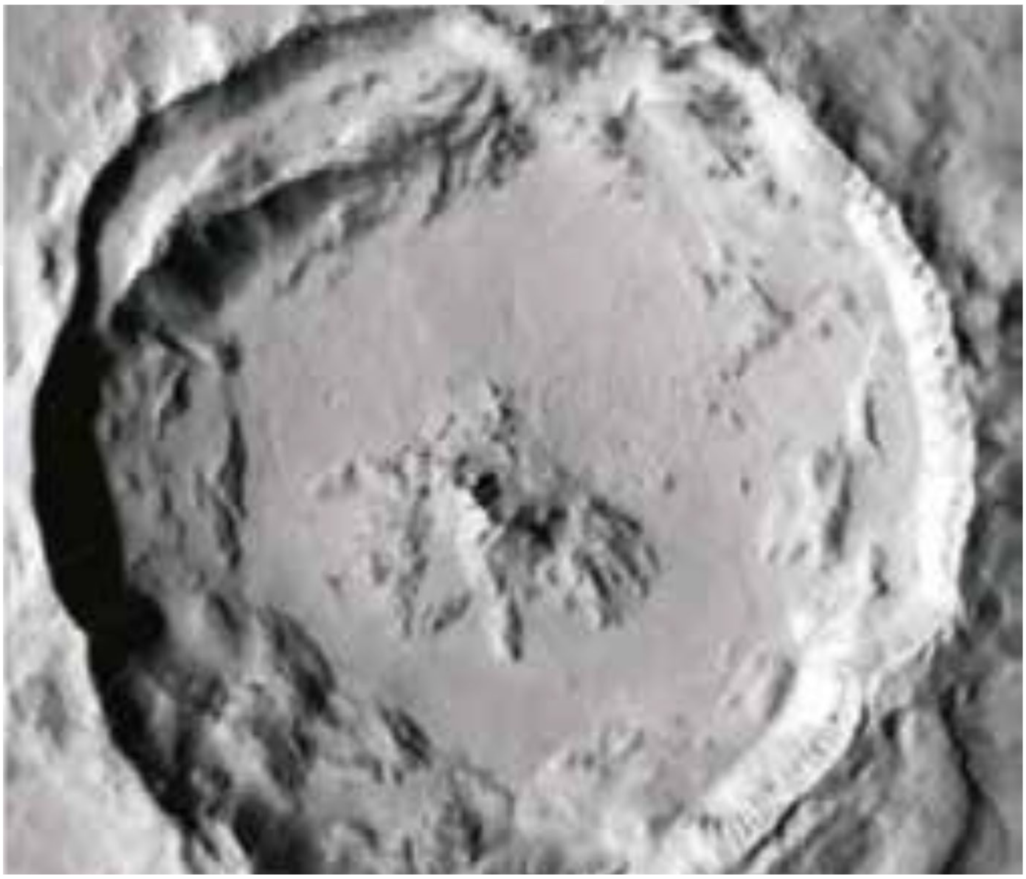
BACKGROUND INFORMATION FOR TEACHERS

An object's weight depends upon gravity. Since this investigation is taking place under the same gravitational conditions, we can use either weight or mass, depending upon the level of understanding of the children. The higher the drop, the greater the speed on impact. The greater the speed, the larger the impact crater. When dropped from a given height, the greater the mass (weight) the larger the crater. When dropped from a given height, the greater the size (volume), the larger the crater.

Impact craters are caused when a body (**bolide**) collides with a planet. It may be composed from rock (**meteorite**) or ice or a mixture of the two (**comet**). A crater's size and features depend on the nature of the surface and the speed, size and mass of the body. The speed of the balls dropped in this case is low. In real impacts, compression shock waves run through the bolide and the surface; the body or meteorite would vaporise or be broken into small pieces. The target material is melted or fractured. Rebounds of the bolide cause further excavation of the surface and possible collapse caused by gravity. Secondary craters can be formed and material can be ejected on impact.

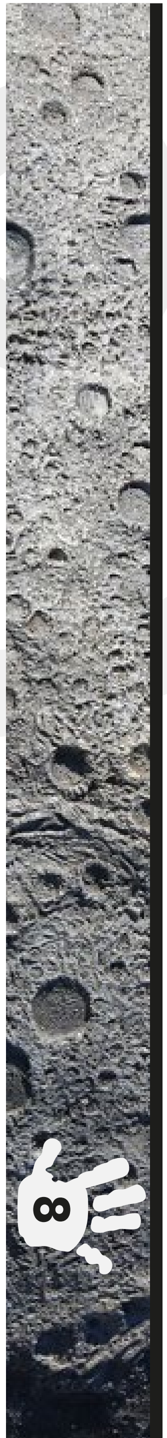
1 For further information regarding safety in the classroom see Be Safe – Health and Safety in School Science and Technology, available from the Association for Science Education.

Mars is densely cratered. Some Martian craters have central peaks; some are surrounded by material that has been ejected, called the **ejecta blanket**. Impact craters are interesting to study and provide insights into the age and geology of a planet's surface. They can give a view of the types of subsurface rock. Scientists hypothesise that large craters may create a **transient atmosphere** that may have induced rainfall in the past. Images from Mars suggest that there may have been water on or under the surface at some time in the past. Certainly, some patterns are just like those made when rocks are thrown into mud! Impact craters on Earth older than about 200,000 years are worn by weathering, **erosion**, and **plate tectonics**. Lack of these events on Mars leaves craters in their original form.



Tooting Crater image taken from orbiting spacecraft

Activity Sheet 8



Crater Challenge Card 1

Look carefully at the image of Tooting Crater on Mars. Can you make craters?

Helpful Hints
You could try using marbles or balls as meteorites!

You could make one of these to measure how deep the craters are.

Crater Challenge Card 2

The Space Agency would like you to find out whether different kinds of meteorite make different kinds of craters.

Helpful Hints
Try dropping the 'meteorites' into sand.

Questions
If the 'meteorite' lands on damp sand instead of dry sand, is the crater different?

What happens to the crater when the 'meteorite' is dropped from a great height?

Crater Challenge Card 3

The Space Agency would like you to test dropping meteorites on different surfaces.

Helpful Hints
You could try dry flour with a thin coating of chocolate powder on top, like Mars' dry, rusty surface.

Questions
What happens to the surface and the layer below when the 'meteorite' lands?

What happens when the 'meteorite' lands on mud?

Crater Challenge Card 4

The Space Agency would like you to find out whether the size or weight of a meteorite can affect the crater made.

Helpful Hints
Try 3 different sized balls of different weight.

Questions
Is there a link between the size of the 'meteorite' and how wide and deep the crater is?

Is there a link between the weight of the 'meteorite' and the diameter and depth of the hole made?

7. Volcanoes And Lava

1 hour

Children carry out and evaluate practical tasks to mimic lava flow.

OBJECTIVES

- Identifying scientific evidence that has been used to support or refute ideas or arguments
- To know that science is about thinking creatively to try to explain how living and non-living things work, and to establish links between causes and effects.
- To know that comparing Mars' key landscape features with similar features on Earth can help us to understand their formation.

RESOURCES

(Per group of 4 children unless otherwise stated)

Two methods are described for this activity. Option A mimics volcanic eruption and lava flow by using vinegar and sodium bicarbonate. Option B models lava flow by using melted chocolate. The teacher may choose either one. If choosing option A, teachers might want to point out to children that it is not a chemical change like this one that causes volcanoes to erupt but melting of the rock and pressure from within the Earth.

Option A: Vinegar and Sodium bicarbonate volcano	Option B: Chocolate volcano
Activity sheets 9-10	Activity sheets 9-10
A3 sheet of card	Large card or plate
Small egg cup or tealight container	Filter funnel or cardboard cone
1/2 cup bicarbonate of soda	3 x 100g baking chocolate (white, milk and dark
1/2 cup clear vinegar	3 small jugs or beakers
Teaspoon	Apple corer
2 Plastic cups or containers	Plastic straw
4 colours play dough* or plasticine	Microwave and 3 microwavable bowls or hob, pan and glass bowl
Cylinder	
2 waterproof markers	
Paper towes	
(5-10ml)ml measuring cylinder or syringe	
Pipette	
Large straw or transparent biro case	
Cocktail stick or match stick	
* there are many playdough recipes on the internet	

OPTION A: VINEGAR AND SODIUM BICARBONATE VOLCANO

ADVANCED PREPARATION

A die made or covered with the numbers 3, 4, 4, 5, 5, 6.

INTRODUCTION

The teacher explains that the children are going use vinegar and sodium bicarbonate to mimic the eruption of a volcano and flow of lava. A set of volcano facts cards (Activity sheet 10) is provided. A throw of a die will decide the number of 'eruptions' that the children will model.

ACTIVITY

Each group throws the die to determine how many eruptions there will be. The children then follow the first set of instructions on Activity sheet 9 to produce the 'foam' lava and record the flow with layers of coloured play dough. The teacher should encourage the groups to make a drawing of the distance, pattern and shape of each lava flow. Finally, a plastic drinking straw may be used to remove samples from the play dough layers.

SAFETY NOTES, PRACTICAL TIPS AND GUIDANCE

Ideally, more than one group will choose to try the volcano activity, and then on completion, the volcanoes and their lava layers may be swapped between groups. Each group can map and take samples from a volcano whose pattern of lava flow is different from their own. This will simulate more closely how geologists study the geologic history of an area or feature. The children are encouraged to look carefully at the model volcano and suggest how they could discover what is below the surface without lifting the play dough layers. They should decide where to drill for samples and how many they would need in order to obtain most information. Straws or transparent biro cases can be used to simulate the drill taking the samples. They should be pushed gently and deeply through all the layers of play dough at each sampling point. Extracting the sample requires care.

OPTION B: CHOCOLATE VOLCANO

ADVANCED PREPARATION

For the 'volcano' either block the tip of a filter funnel or make a small cone from card.

INTRODUCTION

The children follow the second set of instructions on Activity sheet 9 to produce layers of chocolate lava flow. A roll of the die determines the number of lava flows. The children could take photographs or draw the shape of the lava flow whilst waiting for the chocolate to begin to solidify. They can try putting obstacles , such as small stones in the lava path and observing the effect. When all thel ayers have been added, the children may then take samples of the chocolate lava layers, using an apple corer.

SAFETY NOTES, PRACTICAL TIPS AND GUIDANCE

The tables can be covered with newspapers or plastic sheeting. The children should wear aprons, old shirts or lab coats to protect clothes. Melt the chocolate in either a microwave oven or on the hob in a bowl over a pan of hot water. Stirring a little warm water into the melted chocolate improves its runniness, and reduces the amount of chocolate needed. Have 3 small beakers or jugs available for the children to collect the chocolate. As a guide, a minute in the microwave oven on full power should be sufficient to melt 100g chocolate.

PLENARY

The children look again at the images N and S and read the information about Volcano Ceraunius Tholus provided by the experts (Activity sheet 12). They report upon the success of their models and sampling and consider:

- *What have they learned about lava flow patterns and layering?*
- *Did the lava always flow in the same direction or as far?*
- *Did they observe any lava flow patterns similar to the image on Mars?*
- *Do they agree with the experts' opinions on how Ceraunius Tholus was formed?*
- *Do they believe that the rover should take samples from this area?*

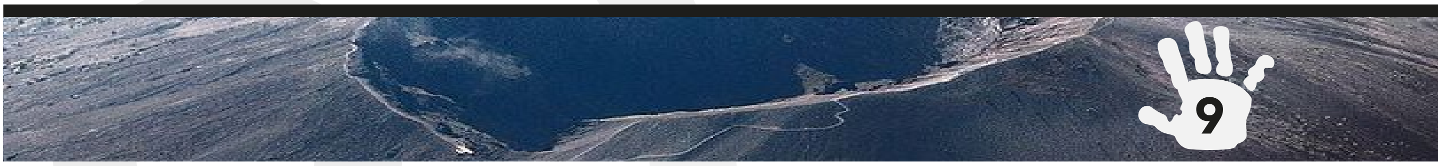
They should realise that the oldest flows are the deepest layers on the model and the newest are on the surface. They could reflect upon whether the process was similar to real life.

BACKGROUND INFORMATION

Photo geologists use images taken by planes and satellites to interpret the history of a planet's surface. If they can get to the surface, they take samples and draw maps.

Not all lava flows are buried by the next. Sometimes older flows can be visible. The direction of the lava flow can be affected by previous flows, by old lava or channels on the surface, and also by the speed of the eruption. The energy of an eruption can determine how far the lava can flow and how easily it passes obstructions. In real field studies, geologists would, of course, be unable to take such deep samples through all the lava layers. On Mars, scientists hope that a new rover will drill below the surface in order for samples to be collected and analysed.

Activity Sheet 9



Make a volcano

1. Put an egg cup in the centre of a big piece of card
2. 2. Put a teaspoon of bicarbonate of soda into the egg cup. Slowly pour 5-10 ml of vinegar to the cup. Your volcano should fizz!
3. When the lava has stopped flowing, quickly draw a line all around the lava and then mop it up with a paper towel.
4. Take a ball of play dough and roll it flat. Completely cover the shape left by the lava with the play dough – but not the egg cup!
5. Soak up the mixture from the egg cup with a paper towel. Place the egg cup in the centre of the flow and repeat the eruption. Use a different colour of play dough each time, and don't worry if the last layer of play dough is covered a little.
6. When you have finished, try taking a sample of the lava layers by using a large straw. Push the straw vertically down into the play dough, twist and pull out the straw. Cut the straw just above the top of the play dough sample. Push out the sample with a cocktail stick or matchstick.

Make a chocolate volcano

1. Put a cone or an upside down filter funnel in the middle of a plate or card.
2. Pour melted chocolate over the cone or funnel letting it run down the sides.
3. Leave the chocolate to cool and harden a little on the cone or funnel.
4. Choose a different colour of melted chocolate and pour it over the cone or funnel.
5. Repeat each time using a different colour of chocolate.
6. When the chocolate has cooled and hardened, push the apple corer right down into the chocolate layers, twist and pull out a sample.

Chocolate volcano

Volcano Fabulous Facts 1

Volcanoes or evidence of volcano activity are found on Mars.

On Mars, the north is covered by lava rock from lots of very big volcanoes. One of these is called Olympus Mons.

Volcano Fabulous Facts 2

Olympus Mons is about 24km tall; thats more than twice as tall as Mount Everest and its area is almost the size of Spain! About a hundred of the biggest volcanoes on Earth could fit inside it.

It is the largest volcano in the solar system.

Volcano Fabulous Facts 3

On Mars, the volcanoes grew bigger as the lava layers built up on the top of one another. As the volcanoes are so big this means that thre must have been heat under each volcano for a very long time.

Volcano Fabulous Facts 4

Missions to Mars have not found any active volcanoes. As well as volcanoes there are dark flat layers of lava rock on Mars. Scientists take samples of rock by drilling and pulling out a column of rock layers.

8. Investigating Water Channels

1 hour

Children carry out and evaluate practical tasks to mimic the creation of channels and deltas.

OBJECTIVES

- To think about what might happen or try things out when deciding what to do, what kind of evidence to collect and what equipment and materials to use
- To know that it is important to test ideas using evidence from observation and measurement
- To know that flowing water can wash away or make patterns in a surface body text

RESOURCES

(Per group of 4 children unless otherwise stated)

- Activity sheet 11
- Images O-P, T-U
- Trough (wallpaper or planting) or deep tray
- 3cm layer of sand/gravel mixed, covering ¾ of tray's length
- ½ cup of fine grit
- ½ cup small stones
- ½ cup larger stones
- Jug
- Filter funnel
- Bucket

ADVANCED PREPARATION

- Drill a drainage hole at one end of the tray or trough
- Activity sheet 11 made in to cards

INTRODUCTION

The teacher asks the children to look carefully at the two images O-P, showing some interesting patterns on the surface of Mars, and explains that scientists believe that they could possibly have been made by water flowing across and washing away its surface a long time ago. Their task is to carry out investigations to discover whether water can change a surface such as sand. Their measurements and other observations could help scientists to understand more about the fascinating landscape of Mars.

ACTIVITY

The children prepare their trough with sand, grit and gravel, to a depth of 2-3cm. They smooth the surface of the sand and press out a short channel at one end. Pouring water through a funnel directs the water flow to the channel. The pupil cards (Activity sheet 11) provide challenges, hints and facts to support the activity.

The children are encouraged to:

- make predictions about the effects of altering the angle of the trough
- change the volume or speed of the water they pour
- make careful observations and measurements of shapes and patterns formed on the surface or channels carved into the sand
- test whether water flows faster on the inside or outside of a bend
- discover how obstacles such as pebbles placed along the channel might produce
- a delta
- put tiny particles, such as grit, at the head of their 'stream' measuring how far and how quickly they are carried
- investigate adding a mixture of different sized particles

Images T-U showing channels from Earth or deltas, such as the Nile delta could be compared to the patterns they have made. They should discover that tiny particles are carried further along their 'stream' than larger particles. This would represent sediment in a natural situation.

The children can record their observations in a variety of ways, including video, photographs or drawings

PLENARY

When discussing their observations, the children should look again at the image of channels on Mars and draw conclusions based on patterns they noted. They read the information about Eberswalde provided by the experts (Activity sheet 12), and consider the following:

- *Do their ideas match those of the experts?*
- *How do they think the channels were made?*
- *Do they think water once flowed on Mars?*

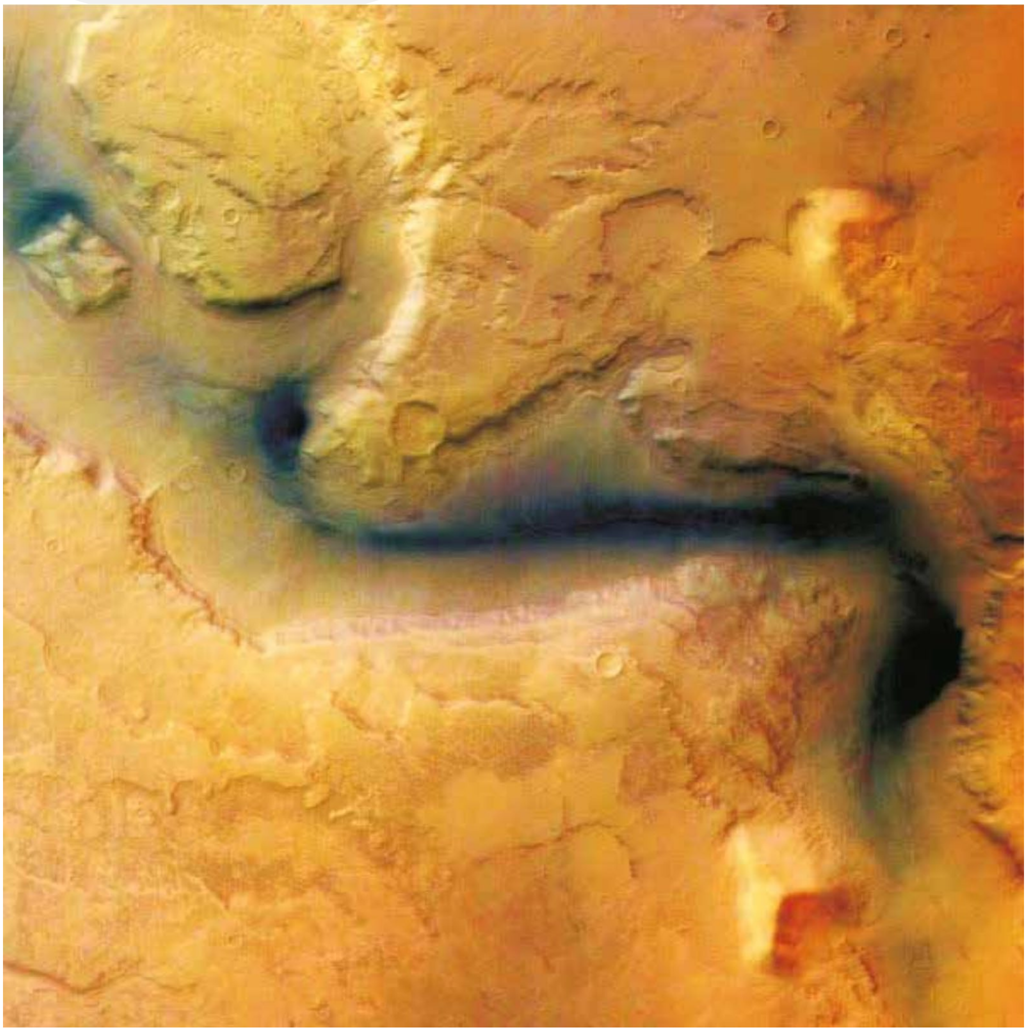
The children could prepare a report for the UK Space Agency. The children should be encouraged to include any measurements or other evidence to support conclusions. Communications managers from each group could act as 'envoys' (Appendix 2), moving on to a new group in order to summarise and explain their group's ideas to others.

SAFETY NOTES, PRACTICAL TIPS AND GUIDANCE

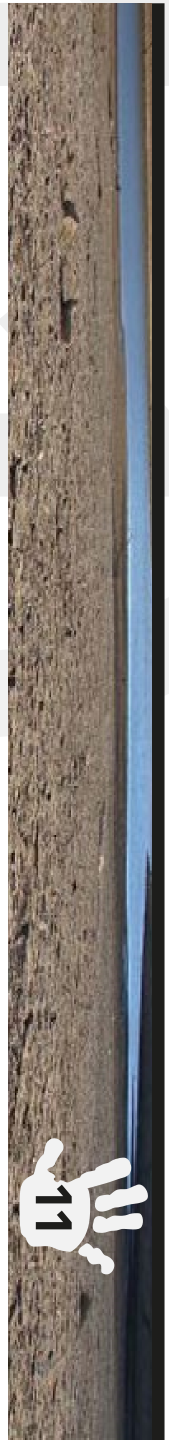
Teachers should ensure that excess water is drained or scooped out of the trough and into a bucket. A fresh layer of sand and gravel may be added each time if required. The children will soon discover that the sand is washed along the trough if they pour too much water too quickly or if the trough is supported at too steep an angle. If a small volume of water is poured slowly then the pattern of flow can be seen. The best results are obtained by positioning the tray at a very slight inclination.

BACKGROUND INFORMATION

Water makes distinct patterns when it erodes a landscape and deposits sediment. Most river beds have a very slight incline, less than 5 degrees. Gently flowing rivers carry sediment and distribute the particles. Small, light particles are carried further and more easily than large heavy ones. Martian images seem to support the hypothesis that water once flowed on its surface. Mars would have to have had a different climate in the past, warmer with greater pressure, to have allowed water to flow.



European Space Agency image showing possible evidence of erosion by water



Investigating Water Channels 1

Your task is to investigate whether flowing water can change the shape of a surface or channel.

Helpful hints
Pour water very gently through a funnel into the channel. Let the water run along the sand.

Fabulous facts
Today, nearly all liquid water would either freeze or evaporate on Mars.

Investigating Water Channels 2

Can you discover whetherthe steepness of a river can affect the patterns made by the water?

Helpful hints
Lift one end of the tray a little and see what happens.

Fabulous facts
Some scientists believe that there may have been huge floods on Mars in the past.

Investigating Water Channels 3

Are tiny stones carried along by the water? If so, how far do they move? What difference does the size of the stone make?

Helpful hints
Try putting tiny stones or grit at the top of the channel

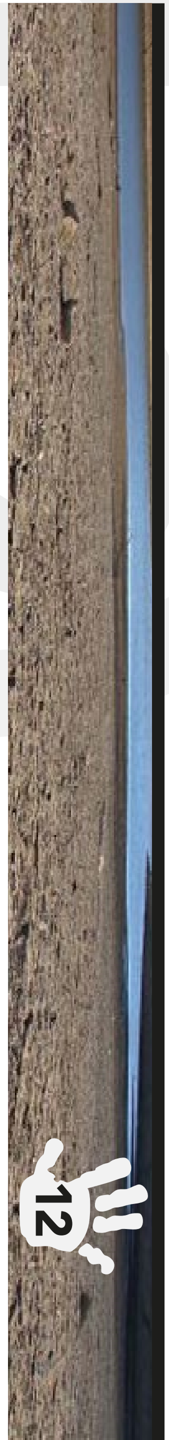
Fabulous facts
On Earth, rivers can carry sand and other particles and drop them onto their banks or into lakes and seas.

Investigating Water Channels 4

If the water flows faster, do stones travel further?

Helpful hints
You can scoop out the water each time into a bucket and repeat.

Fabulous facts
Rivers can wash away the land. This is called erosion.



Tooting Crater

The photographs (Images L and M) were taken by a special camera on a spacecraft.

The crater is west of a big volcano called Olympus Mons (see Mars map Image Q).

Crater age:

Scientists think that the crater is very young, less than 2 million years old!. The crater is very deep. It seems that there has not been time for its edge to be worn away.

Main features:

The crater is 29km in diameter and 2200m deep. It is a very large crater.

The photograph shows the inside of the crater.

We can see the craters raised edge, the lower level crater floor and the craters peak in the centre. We can see shapes that look a bit like those that would be made by 'splatting' an object into a wet muddy surface! This tells us that water ws in the rocks hit by the meteorite to form Tooting Crater.

Volcano Ceraunius Tholus

It is north east of a very big volcano called Olympus Mons.

Volcano age:

The volcano is thought to be roughly 3 billion years old! It has not been active since this time.

Main features:

This is a medium sized volcano. It is 6km high. It has a big , deep hole in the centre that has a smooth floor inside.

This is where lava bursts out onto the volcano's surface.

Main features

Ceraunius Tholus is though to be a shield volcano. This means that it was built by lots of eruptions of runny lava so its sides are not steep.

You may notice that the volcano has dark coloured 'lines' which run from the top to the bottom, all around its edges. These are thought to be ditches made by water

What is the Eberswalde feature?

It is made from small rock particles carried and dropped, usually by wind or flowing water.

In Eberswalde, scientists think that most of the rock has been carried away by water, as you can see big channels in the photograph.

Scientists thing that the feature is similar to the deltas on Earth. When a river flows into a lake or sea, a delta can be made. In Eberswalde, they thing there used to be a lake in the crater floor.

Delta age:

Scientists think it is 1.5-2 billion years old because there are lots of small craters on the surface.

You can see wide channels or ditches in image P. They are up to 150 metres wide. Just like rivers on Earth you can see bends in the channels.

Water flows fastest around the outside of river bends.

Landscape

Images can be downloaded from www.cciproject.org/topicbank/space.htm

Image K

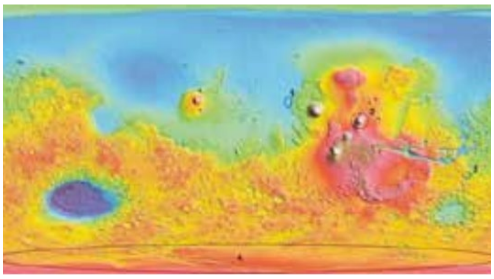


Image of Mars with landscape features for pupils

Image Q

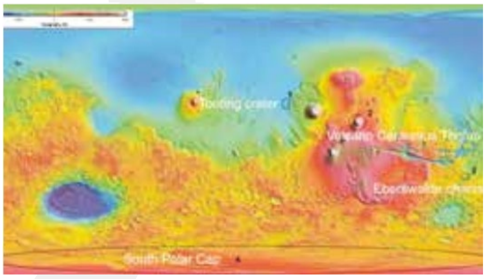
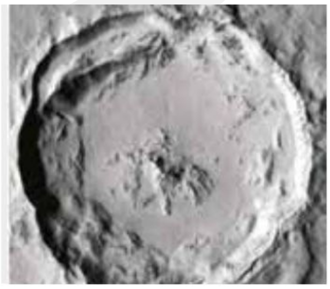


Image of Mars with landscape features marked and named for teachers pupils

Image L

Tooting Crater

Image M

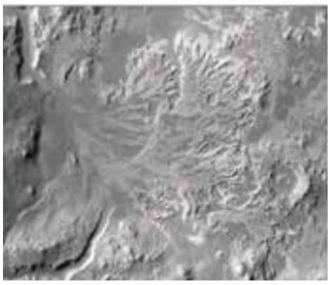


Tooting Crater close up

Image N

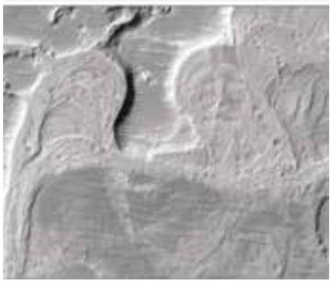
Volcano Ceraunius Tholus

Image O



Eberswalde Channels

Image P



Eberswalde Channels close up

Image R

Crater on Earth viewed from space

Image S

Volcano on Earth

Image T

Water channels on Earth

Image U

River delta on Earth viewed from space

9. Identifying The Best Landing Site for a Mars Rover

3 hours

Children consider data from the viewpoint of scientists or engineers to identify the best landing site for the rover. They estimate the age of landing sites, identify landscape features such as craters, rocks, deltas, canyons, elevations and interpret scales, data and images. The class debates to decide the most appropriate location.

OBJECTIVES

- Identifying scientific evidence that has been used to support or refute ideas or arguments.
- To know that science is about thinking creatively to try to explain how living and non-living things work, and to establish links between causes and effects.

RESOURCES

(Per group of 4 children unless otherwise stated)

- Activity sheets 13-19
- Image V
- Calculator
- Activity sheets 13-14 made into two sets of cards bullets

ADVANCED PREPARATION

- Laminate images W-Z (see page 51-54)
- Half the class in groups of 4 scientists
- Half the class in groups of 4 engineers

INTRODUCTION

To help the children to understand and identify craters and channels on Mars. Introduction Landing images 1-5 from the website should be displayed on the whiteboard and discussed. The table, on page 55, provides details of each of these images.

The teacher explains that the children have been asked by the Space Agency to identify the best landing site for a Martian rover. They are to study photographs from four different locations on Mars. The four photographs are real images, taken from space, of the surface of Mars. They are so detailed that if a car was parked on the surface of Mars, it could easily be seen! Image V is a topography map showing high and low areas on Mars and the positions of the four landing sites. The children are to analyse and interpret data from Mars. They are to consider the information from the viewpoint of either space scientists or space engineers when identifying the best landing site. The scientists are interested in finding evidence of life. Their main mission is to identify landing sites close to where water and/or heat may once have been. The engineers' main concern is to identify sites that are stable, without obstacles and are ow enough for the parachute on the lander to have enough time to slow down the rover's descent so that it makes a safe landing. Laminate images W-Z.

ACTIVITY

Small groups of children study the images provided to identify the best landing site for the next Mars mission. Children in turn share the information on their challenge cards within their group. Engineers and scientists have different aims and concerns about the mission. Scientists and engineers identify landscape features such as craters, rocks and elevation, interpret scale and calculate the age of the landing sites using crater concentration data (Activity sheet 15). The scientists must decide where the rover should take samples and why (Activity sheet 16). In addition, the engineers consider the safety of each site by extracting rock concentration data and calculating crater concentrations. (Activity sheets 17-19).

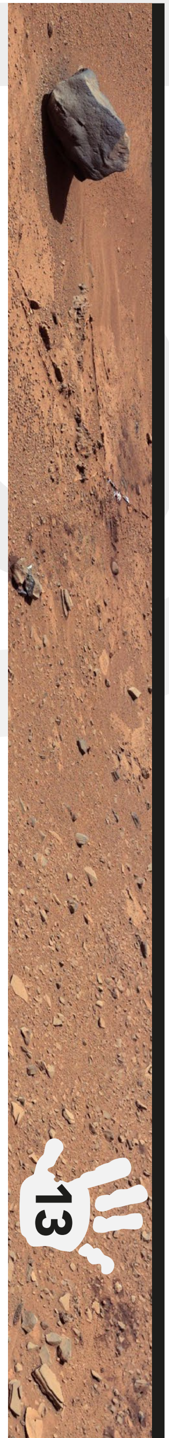
We suggest that the teacher runs through the task with the scientists and engineers in two separate groups. Each group uses different criteria to select a suitable landing site. Later, in class debate, each must provide evidence to justify this choice. It is important that the children pick out the key information contained in the challenge cards. They are looking for old sites; the older the site, the higher the number of craters. They use the scale and look for circular craters larger than 200m. Engineers need to use the table and rock safety chart provided, to determine the safety of the site. They should also look at the topography map of Mars to determine the elevations of each landing site. Answers are provided for teachers on Activity sheet 20 together with detailed information about each landing site to help the children to understand and identify craters and channels on Mars, Introduction Landing images 1-5 from the website.

PLENARY

Each group clarifies its reasons for its chosen landing site and begins to prepare a presentation to justify the choice. Groups should then have a whole class debate to decide the best landing site from both the scientists' and engineers' perspectives. This models current practice within the Space Agency, with one person then responsible for making the final decision.

Mars showing the polar cap

Activity Sheet 13



Landing Challenge Card 1 Scientist

Your main mission is to find a landing site where evidence of life on Mars is more likely to be found.

Helpful hints
Evidence of life might be fossils in rocks, so you need to look for an old site. Old sites usually have lots of craters. Use the crater calculations on Activity sheet 15 to help you.

Fabulous facts
The rover can collect samples on and under the surface. The rover can take very detailed photographs. The new rover is expected to work on Mars for seven months.

Landing Challenge Card 2 Scientist

Living things need water. Can yo find a landing site close to where water might once have been.

Helpful hints
Mars may have had water a long time ago. So, scientists think we should look for the oldest surfaces and rocks.

Fabulous facts
The new rover is the size of a mini cooper or a long go card. The rover can find sources of water, past and present.

Landing Challenge Card 3 Scientist

As space scientists you have been asked to find a landing site close to interesting features. A new Mars rover has to take samples and photographs to find out what Mars used to be like long ago.

Helpful hints
It might be good to land close to rocks to take samples. You will need to find rocks that have been there for a long time.

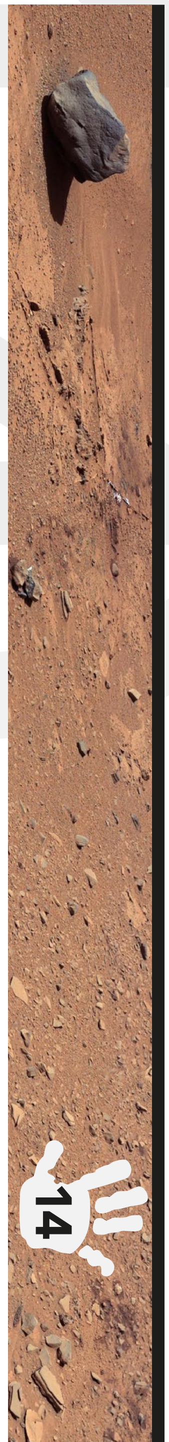
Fabulous facts
The rovers toolkit has nine science instruments to examine rocks, soil and atmosphere. The rovers laser can turn rock into gas from a distance.

Landing Challenge Card 4 Scientist

Your team of scientists must choose from the four photos a landing site that is safe for the rover to drive around to take samples.

Helpful hints
The rover could land anywhere shown on the photo but it has to save energy and can only travel 2 km in total.

Fabulous facts
The rover has 6 wheels that can ride over obstacles. Ots maximum speed is 5 metres per hour.



Landing Challenge Card 1
Engineer

Your team of engineers will need to look for a low, clear sit to enable the parachute to gently land the rover on the surface of Mars.

Helpful hints
Mars has lots of places for a safe landing. Remember, the rover could land anywhere on the landing site photograph.

Fabulous facts
The rover must land at a level that is lower than -1000m so that it goes through enough of the Martian air to slow down without crashing.

Landing Challenge Card 2
Engineer

You will need to look for an old site as this is more stagble and safer to land on.

Helpful hints
A high number of craters mean a site is old.

Fabulous facts
The rover can only travel at 5m per hour (An olympic athlete sprints 100m in less than 10 seconds).

Landing Challenge Card 3
Engineer

You will need to look for a site with enough light to let the solar panels work well.

Helpful hints
The safe areas to land this rover on Mars are the landing sites between 30 N and 30S on the coloured map.

Fabulous facts
The rover can only travel short distances to save energy. The Mars rover can take the energy from the sun using solar panels.

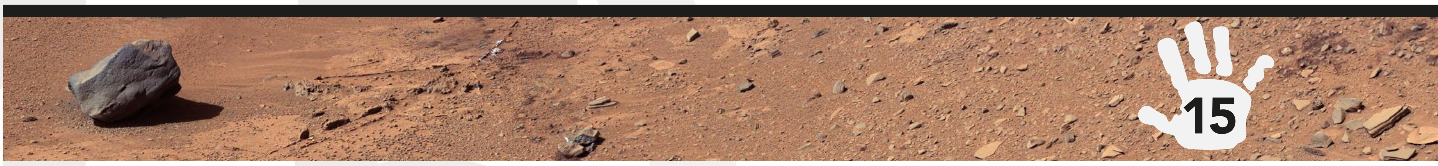
Landing Challenge Card 4
Engineer

You will need to look for a smooth surface with no obstacles like rocks or craters to allow the rover to move easily.

Helpful hints
Use the rock and craters to decide whether your landing site is safe enough for the rover.

Fabulous facts
The rover can roll over obstacles up to 75 cm high.

Activity Sheet 15: Age of landing site

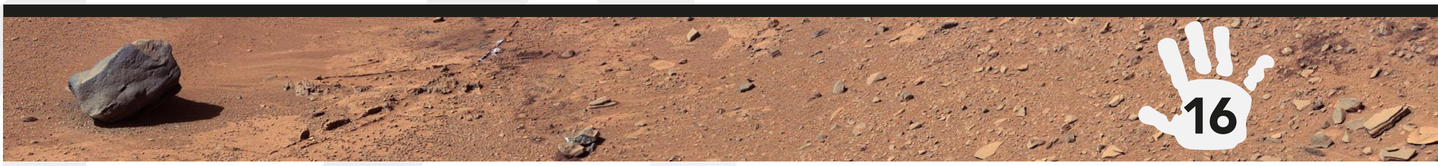


	Landing site 1	Landing site 2	Landing site 3	Landing site 4
Total area of landing site (km2)	19	29	29	28
Number of craters with diameter bigger than 200m (your counts)				
Number of craters bigger than 200m per km2 (divide your count by total area)				
Age (from below, in years)				

Results of crater concentration calculation	Age (years)	
< 0.02	100 million	100,000,000
0.02 - 0.2	1 billion	1,000,000,000
0.2 - 0.4	2 billion	2,000,000,000
0.4 - 0.6	3 billion	3,000,000,000
0.6 - 1	4 billion	4,000,000,000

Concentration Definition: The quantity of something (number of craters for example) over a specific area. Example: there are 10 children per 100 m2 area of the classroom.

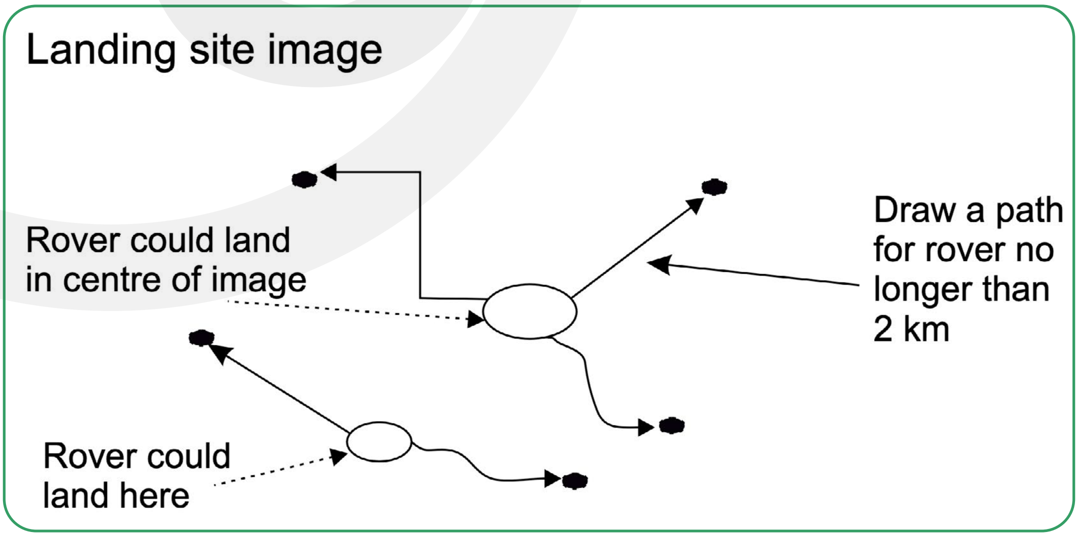
Activity Sheet 16: Sample locations work sheet (Scientists)



The rover can drive only 2 km. It has to save energy. It can take five samples. Pretend that your rover lands at the very centre of the image. Use the scale

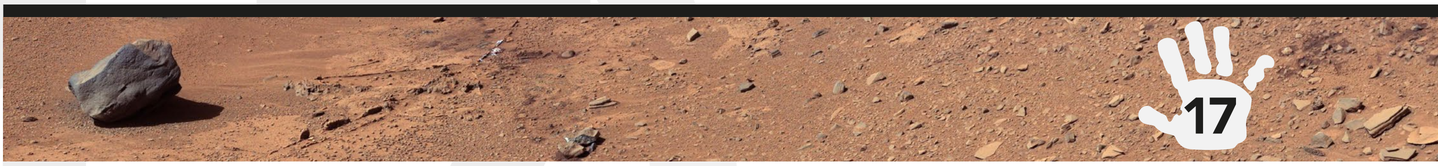
to help you draw a rover path that is 2 km long and draw dots to show your preferred locations for obtaining samples. All five sample sites need to be on the same 2km path.

The diagram shows examples of alternative pathways.



	Taken from	Why
Sample 1		
Sample 2		
Sample 3		
Sample 4		
Sample 5		

Activity Sheet 17: Sample locations work sheet (Engineers)

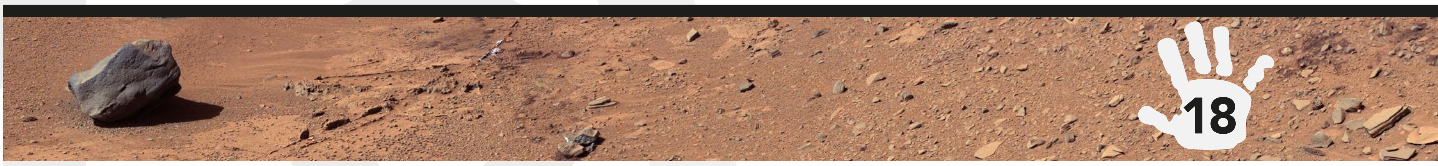


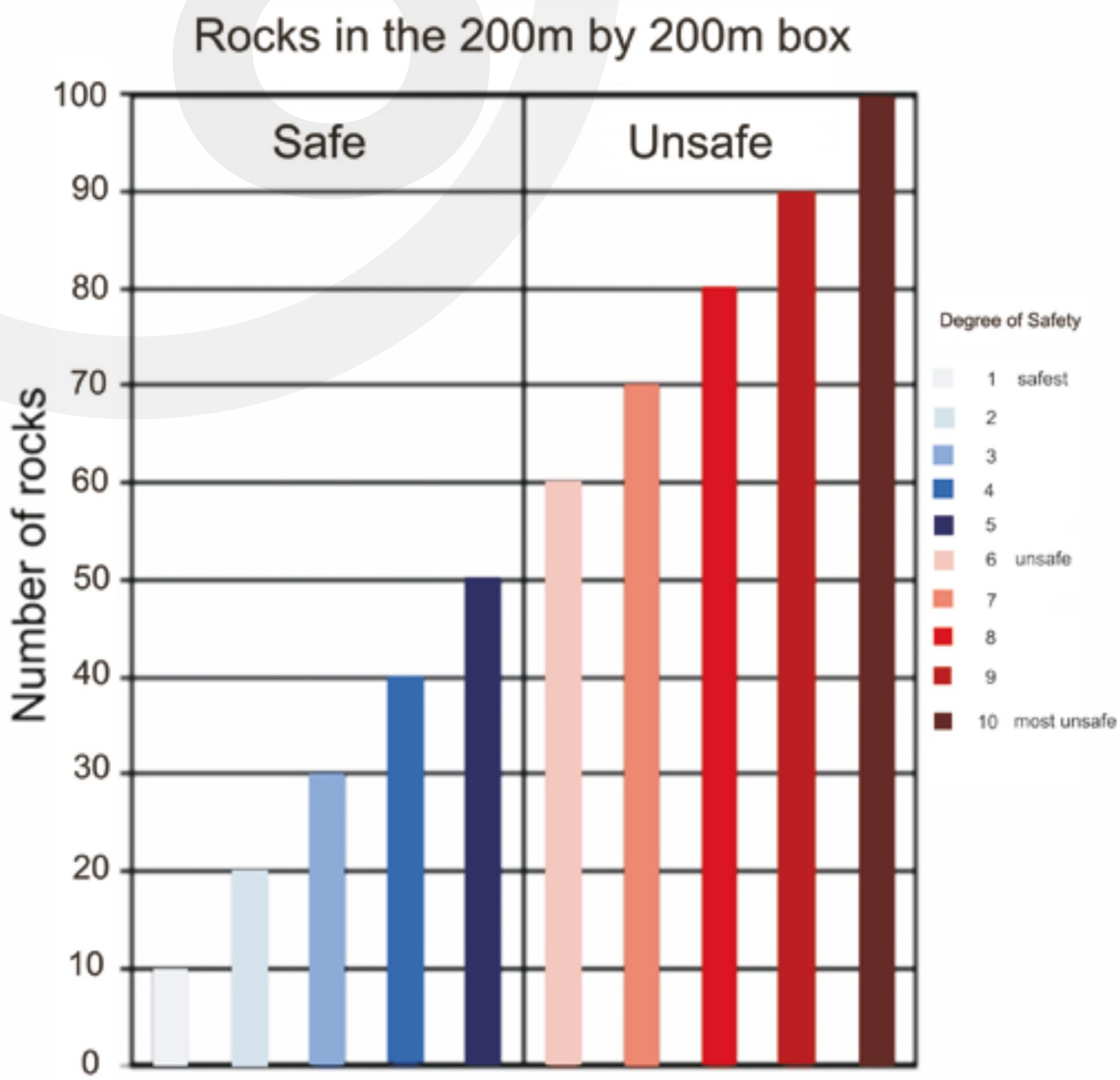
Any big rock on the photograph is a danger to the rover. If you can see a rock that is about the size of your pencil head, it is the size of a table or car and could damage the rover when it lands.

Rocks look like small dark blobs on the image and they are casting small shadows. Look at the table to find out how many rocks there are and then use the rock safety chart to decide whether each landing site is safe enough to land.

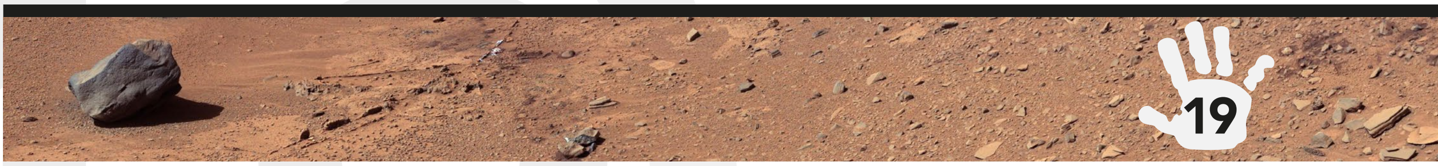
	Landing site 1	Landing site 2	Landing site 3	Landing site 4
Number of rocks in the 200m by 200m box	More than 50	Fewer than 50	10-20	More than 50
Safe? Yes or No				

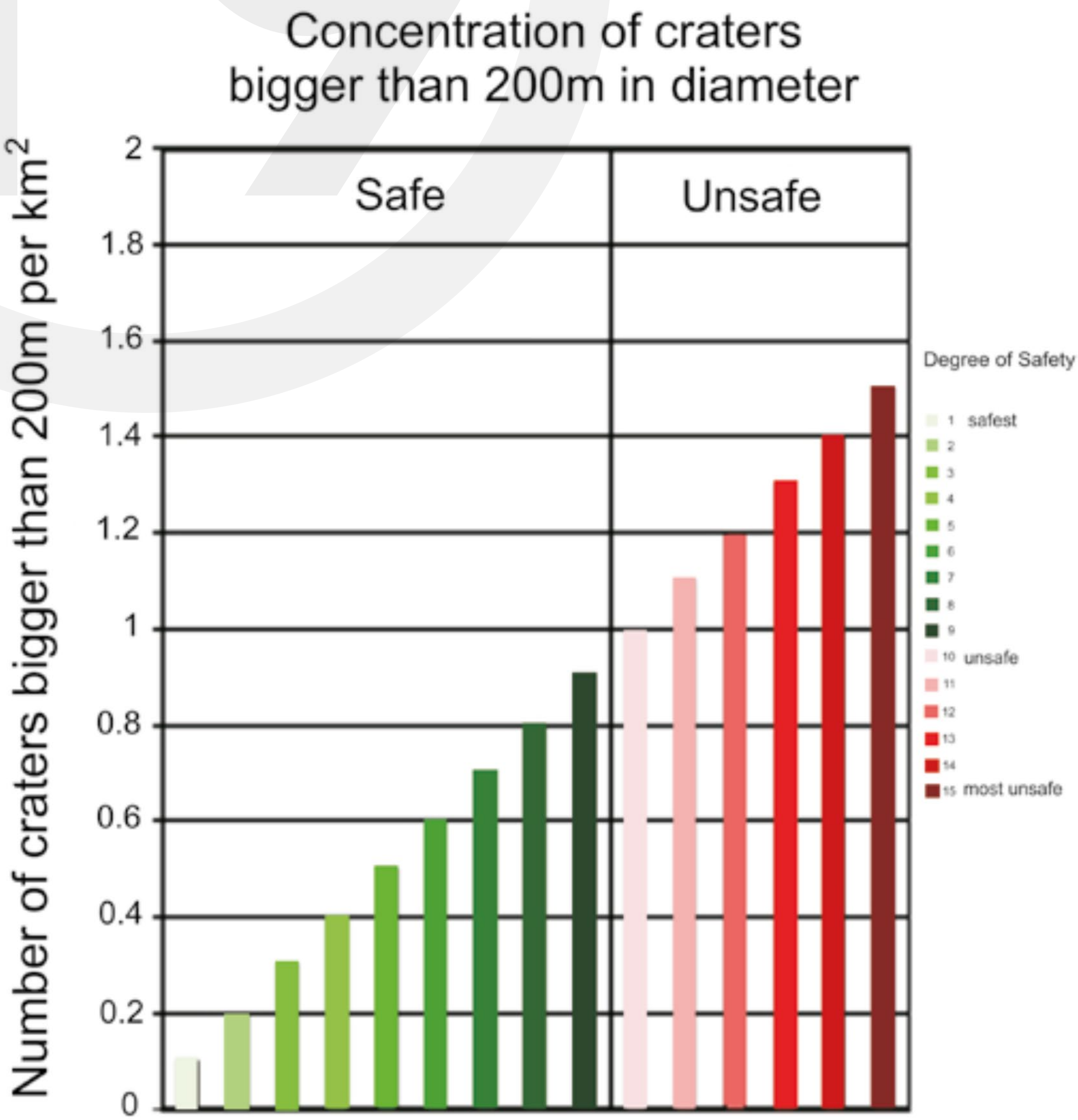
Activity Sheet 18: Rock safety chart (Engineers)



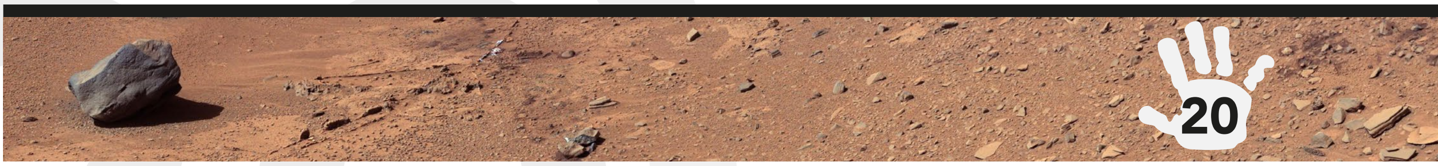


Activity Sheet 19: Crater concentration chart





Activity Sheet 20: Answers for teachers



	Landing site 1	Landing site 2	Landing site 3	Landing site 4
Number of rocks in a 200m by 200m box	More than 50	Fewer than 50	10-20	More than 50
Safe? Yes or No	no	yes	yes	no

	Landing site 1	Landing site 2	Landing site 3	Landing site 4
Total area of landing site (km2)	19	29	29	28
Number of craters with diameter bigger than 200m (your counts)	0 or 1	9	4	13
Number of craters bigger than 200m per km2 (divide your count by total area)	0.05	0.31	0.14	0.46
Safe? Yes or No	yes	yes	yes	yes
Age (from below, in years)	about 100 million	1 - 2 billion	almost 1 billion	2 - 3 billion

Results of crater concentration calculation	Age (years)	
< 0.02	100 million	100,000,000
0.02 - 0.2	1 billion	1,000,000,000
0.2 - 0.4	2 billion	2,000,000,000
0.4 - 0.6	3 billion	3,000,000,000
0.6 - 1	4 billion	4,000,000,000

NOTE: We are here using the US definition of a billion as one thousand million

LANDING SITE DETAILS FOR TEACHERS

Landing site 1, Lat. Long. 47.5 S, 5.3 E

Engineering Constraints

Sunlight: too far south

Elevation: too high

Rock Concentration: parts are too rocky, category 10 on the chart in places

Crater Concentration: very safe, category 0 on the chart

Science Constraints

Life: Has very small gullies that were carved by water, possibly melted snow or groundwater coming from cliffs. If the source is groundwater, there is more potential here for life. Limited access to a lot of sediments deposited by water is a problem here.

Age: About 100 million years, very young surface for Mars (essentially modern). But, if the water came from underground, the water may carry with it evidence of much older things!

Secondary Science Objectives: Very interesting cliff of rocks here that will allow you to access millions of years of Mars history. This is the best landing site for secondary objectives.

Path Length: No matter where you land here, you can get to the gullies.

Landing site 2, Lat. Long. 13.2 S, 42 W

Engineering Constraints

Sunlight: OK

Elevation: OK

Rock Concentration: Safe, category 1-2

Crater Concentration: Safe, category 3

Science Constraints

Life: Landing site is centered on an amazing channel system that is cut into a large fan of sediment. Any place on this image is a spot where water has deposited sediment. Similar to landing site 1, the channel itself may not have had water in it for long but the sediments carried by the channel might have a variety of rock types carried from far away and therefore deposits that might contain fossilized evidence for life.

Age: About 1 to 2 billion years, this is not the time of the ancient 'Earth-like' Mars but it is much older than landing site 1 and a better candidate for being a time when Mars had a thicker atmosphere.

Secondary Science Objectives: Sediment fans like this are excellent for accessing a variety of rock types. The channel carried with it materials that were eroded from distant mountains. These rock types can tell us something about the geologic history of the planet but without layers we don't know the exact origin of the rocks.

Path Length: If you land at the north part of the image, you will not be able to access the southern-most fan. If you land to the south, you might not be able to access the northern most fans. But, there are other things that can be sampled here, such as the sediment in and surrounding the channel.

Landing site 3, Lat. Long. 23.8 S, 33.6 W

Engineering Constraints

Sunlight: OK

Elevation: OK

Rock Concentration: Not very rocky, highest between 10 – 20, category 1 - 2

Crater Concentration: very safe, category 0-1

Science Constraints

Life: This landing site contains a large fan of layered materials that can be sampled by the rover. Space scientists believe that the meandering features are the remnants of channels. The pattern is most similar to a river delta where channels enter a lake or sea. The obvious bonus of this landing site is that it not only contains channel sediments, but because it is a delta, there must have been a standing body of water here. The rover can now access river and lake sediments to look for life. Life enjoys calm water environments, so the lake is an ideal setting.

Age: Almost 1 billion years. This is a fairly young surface so it might not capture the early "Earth-like" period. Also, it's a fairly unique feature on Mars. However, we know there was a river here and a lake. These are ideal ingredients for life.

Secondary Science Objectives: The delta contains river sediments that were carried from far away. This might be a good way to access multiple rock types.

Path Length: No matter where you land here, you can access the delta.

This is Eberswalde delta. It was a finalist landing site for the Mars Science Laboratory mission. All the issues raised above are the reasons why the site was not chosen in the end. It was considered too young, and did not capture the period of warm-wet Mars.

Landing site 4, Lat. Long. 29.9 S, 81.8 E

Engineering Constraints

Sunlight: OK

Elevation: OK

Rock Density: parts are too rocky, category 10 on the chart in places to the south of the image

Crater Concentration: safe, category 4-5 on the chart

Science Constraints

Life: This is a fairly ancient surface of the crust of Mars, almost 3 billion years old (or older as the craters are not well preserved here). The image contains a series of very poorly-preserved intersecting streams. This is an indication of ancient surface water flow, possibly by rainfall. The sediments in these streams may have been carried from far away sources, but it's unclear in the image where these sediments are or if water was here long enough for life to have arisen or survived. The channels here are very hard to see; they are very poorly preserved. This means they were present at the surface of Mars for a very long time and were subject to wind and water erosion. Compare these channels to the channel in landing site 2 for example.

Age: 2-3 billion years, the oldest of the landing sites.

Secondary Science Objectives: Little or no evidence of sediment deposited by the channels. Also, there are no obvious exposures of bedrock apart from the small boulder pile to the south of the image.

Path Length: Access to all the channels.

Landing Site Images

MAP OF MARS

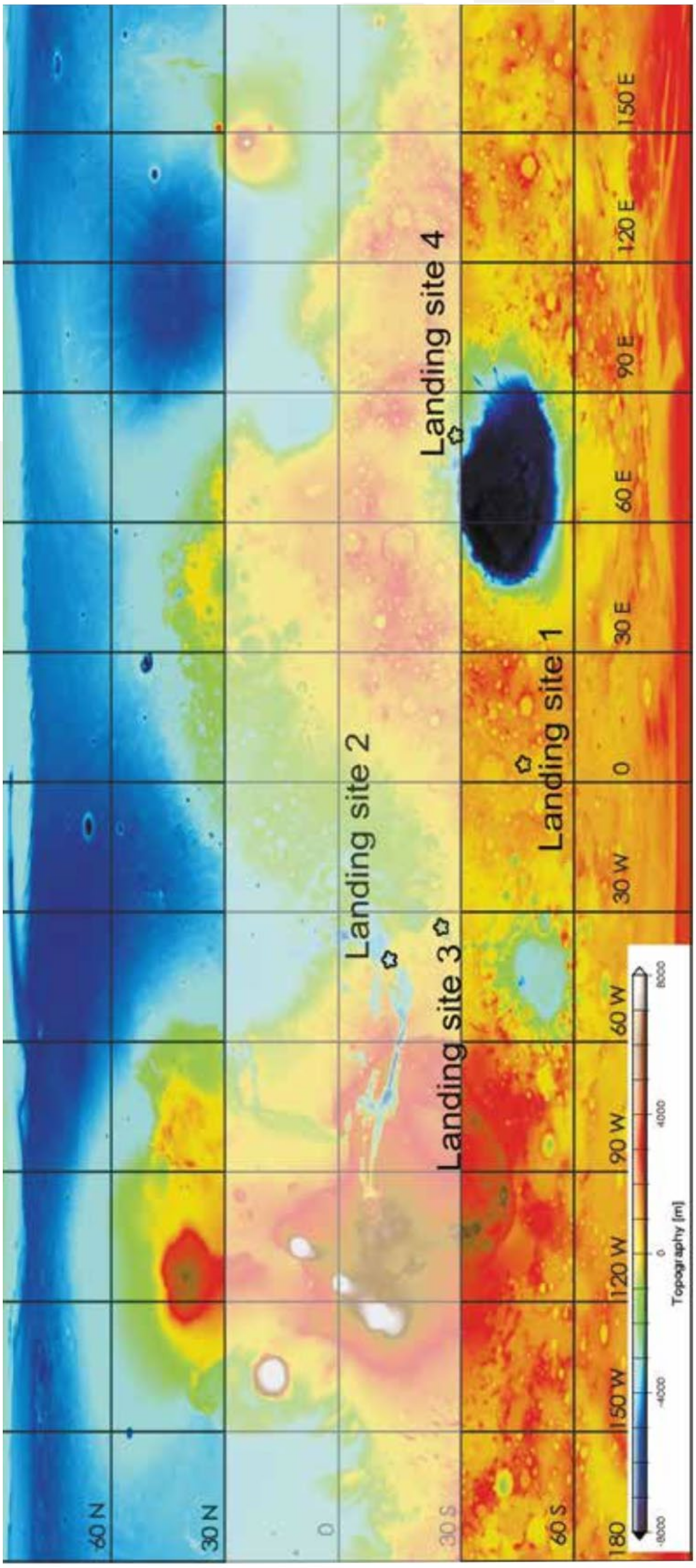


Image V

LANDING SITE 1

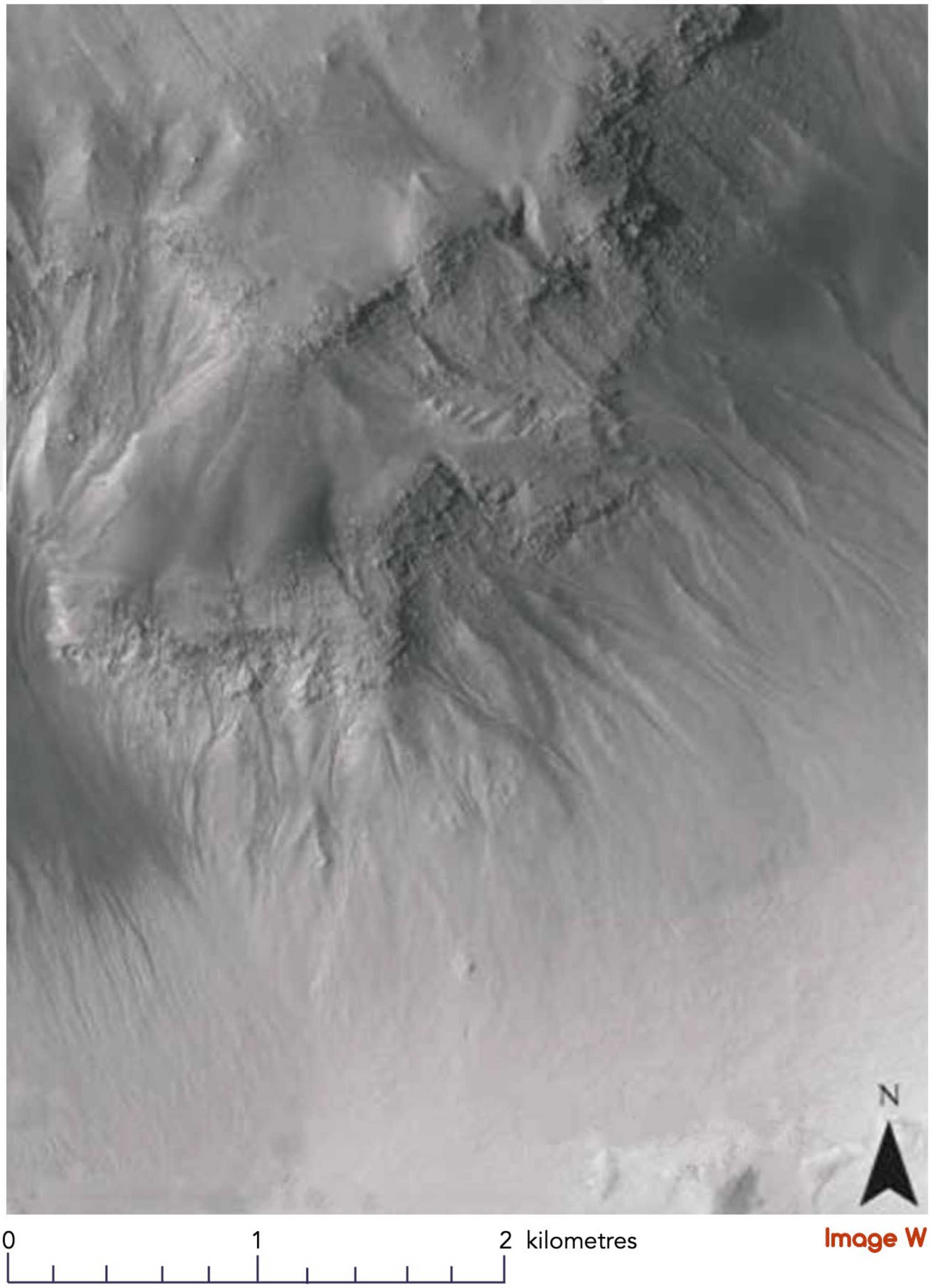


Image W

LANDING SITE 2

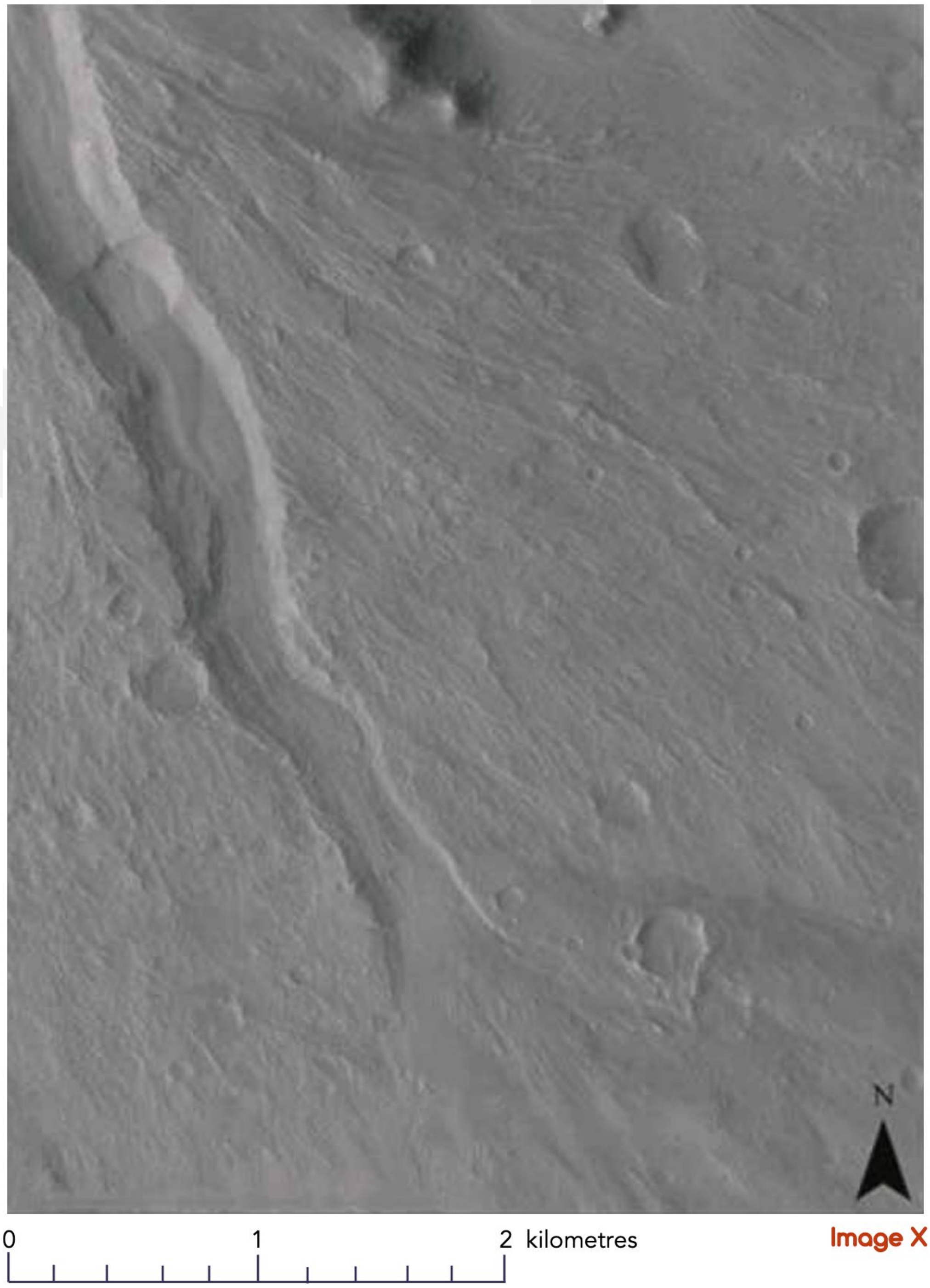


Image X

LANDING SITE 3

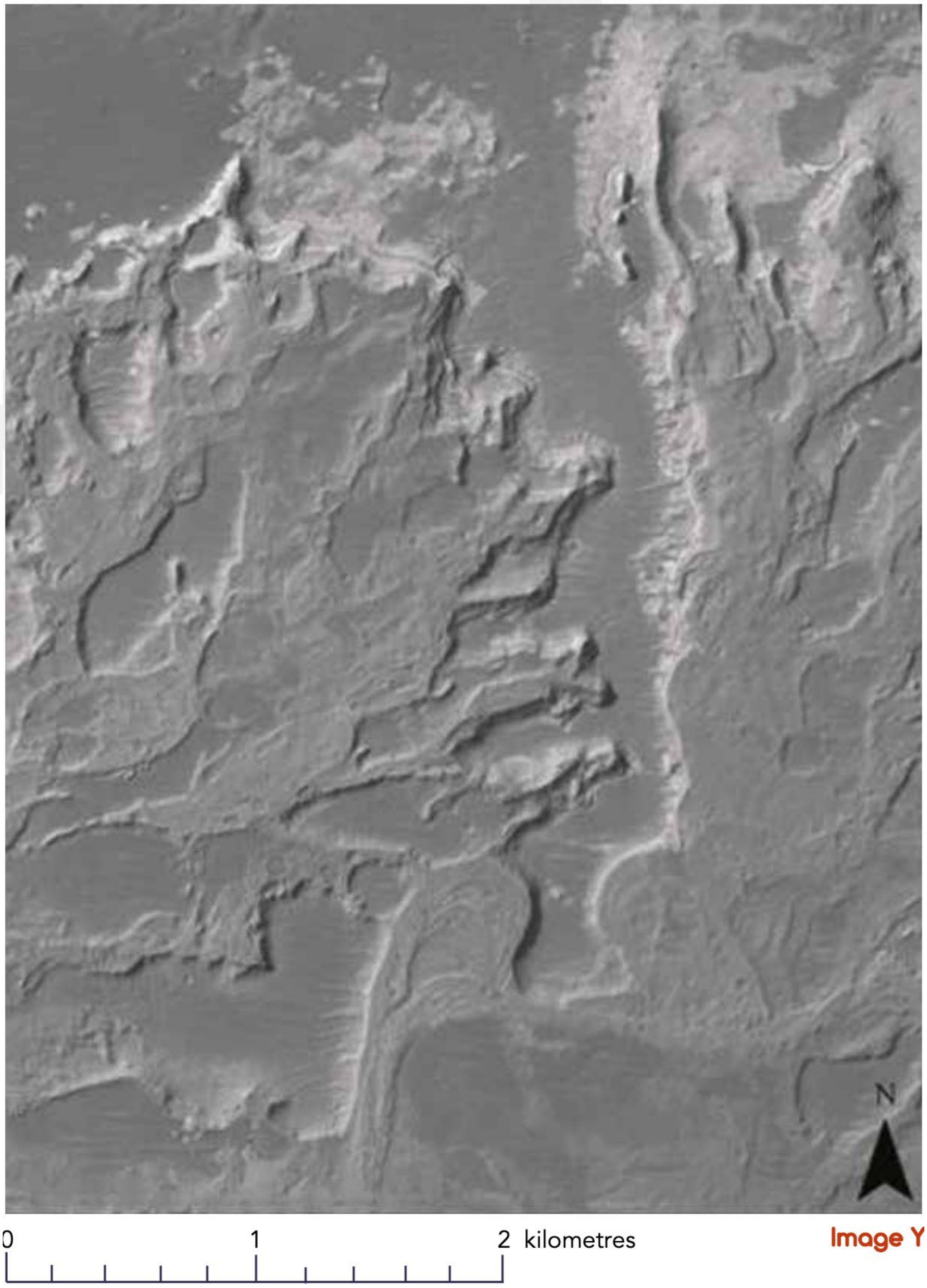


Image Y

LANDING SITE 4

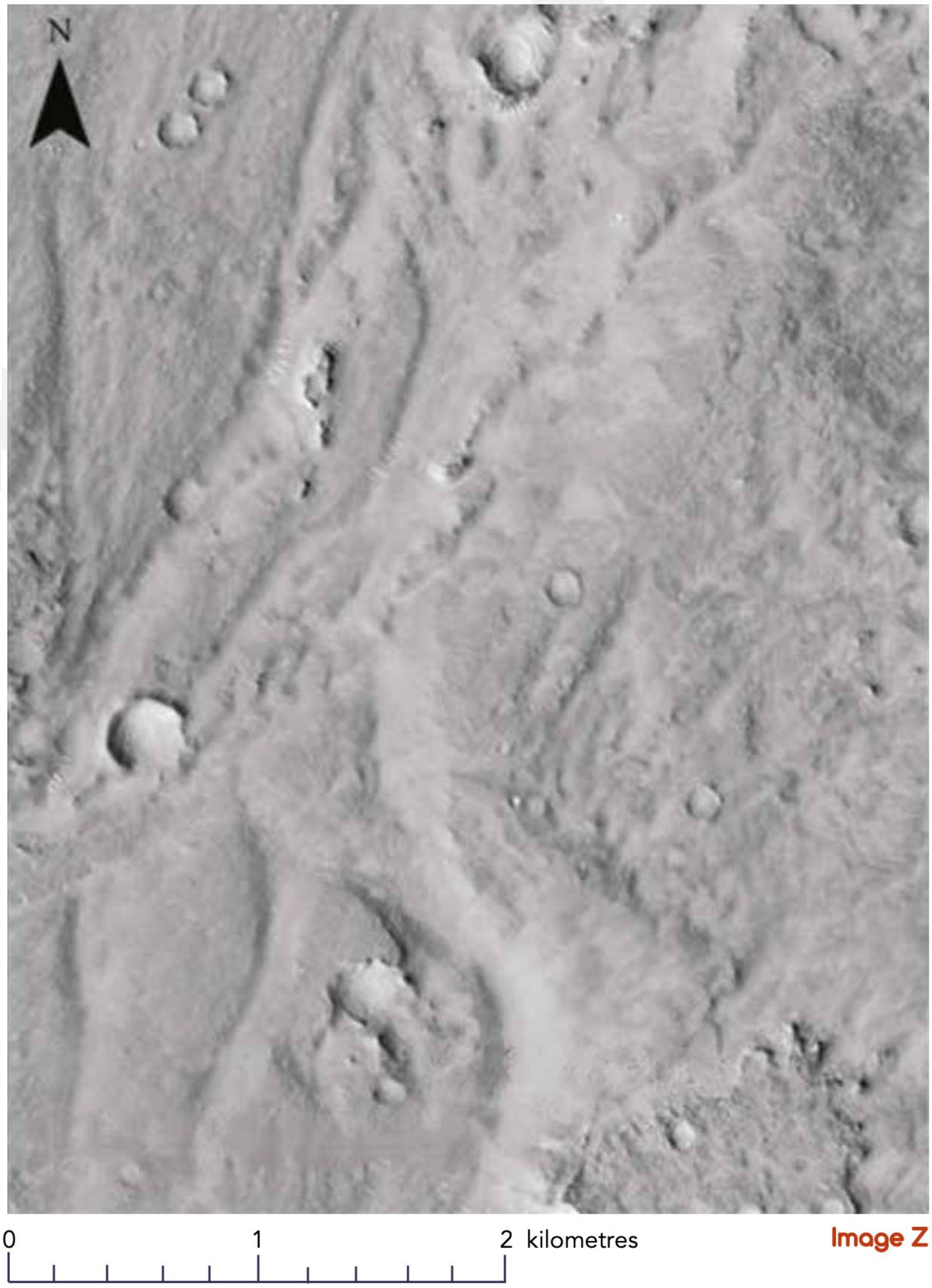


Image Z

Appendix 1: Advance Preparation

ACTIVITIES 1 AND 2[1] SOIL TESTING

3 samples of 'Martian soil' in sealable sandwich bags, labelled A, B, C.

Sample A	Sample B	Sample C
2 tbs building sand	2 tbs building sand	2 tbs building sand
2 tbs rock salt	2 tbs rock salt	1 tbs fine grit
1 tbs table salt	1 tbs table salt	1 tbs gravel
1 tbs fine grit	1 tbs fine grit	1 tbs flour or talc
1 tbs gravel	1 tbs gravel	
	1 tbs flour or talc	

ACTIVITY 7 CHOCOLATE VOLCANO

Milk chocolate	White chocolate	Dark Chocolate
Any supermarket own Belgian chocolate	Any supermarket own brand	Any supermarket own brand
Green & Black, 34% Cocoa solids	Green & Black	Green & Black cooking chocolate 72% Cocoa solids
Ryelands	Ryelands	Ryelands

1 For the microorganism test, Activity 2, yeast should be added to sample C and it should remain salt free.

ADDITIONAL IMAGES FOR LANDINGS SECTION

Image number	Name of feature	Description of feature
Introduction Landing 1	Depositional fan of sediment.	Fan of material in unnamed crater.
Introduction Landing 2	Impact crater.	Well preserved 'simple' structure. 4 km impact crater.
Introduction Landing 3	Fissure formed by tectonic faulting with boulder-covered scree slopes coming down the fissure edges.	Boulder slopes in Cerberus Fossae. The Cerberus Fossae are a series of semi-parallel fissures on Mars formed by faults which pulled the crust apart. Ripples seen at the bottom of the fault are sand blown by the wind. The faults pass through pre-existing features such as hills, indicting that it is a younger feature. The formation of the fossaeis suspected to have released pressurised underground water.
Introduction Landing 4	Impact crater superimposed on a ridge formed by folding of lava.	Impact crater of top of wrinkle ridge close to the Viking 1 landing site.
Introduction Landing 5	Fresh impact crater with prominent rays.	Fresh impact crater formed February-July 2005.

ROLE BADGES

All of the classroom sessions involve children working together in groups of four.

Each child is responsible for a different job or role within the group and wears a badge to identify this. The images below may be photocopied onto card and made into badges, by slipping them in to plastic badge sleeves. Keep sets of badges in 'group' wallets, to be used on a regular basis in all science lessons.

Children should be encouraged to swap badges in subsequent lessons; this will enable every child to experience the responsibilities of each role.

Administrator keeps a written and pictorial record for the group.

Resource Manager collects, sets up and returns all equipment used by the group.

Communications Officer collects the group's ideas and reports back to the rest of the class.

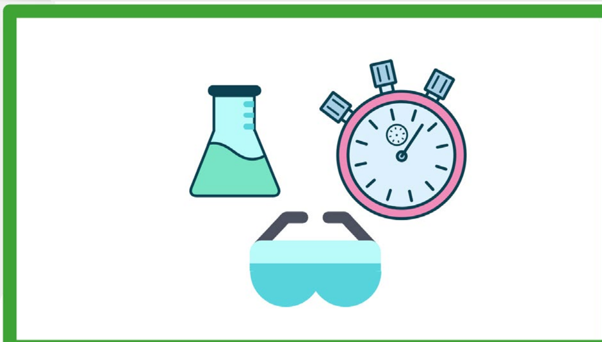
Health and Safety Manager takes responsibility for the safety of the group, making sure everyone is working sensibly with the equipment.

Where groups of 5 are necessary, the following role can be used:

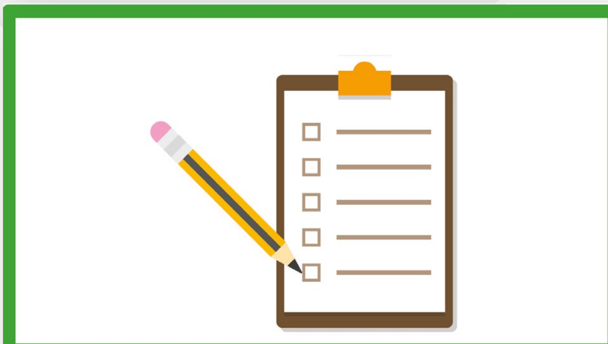
Personnel Manager – takes responsibility for resolving disputes within the group and ensuring the team works cooperatively.

Appendix 1: Role Badges

Space Engineer:
Personnel Manager



Space Engineer:
Resources Manager



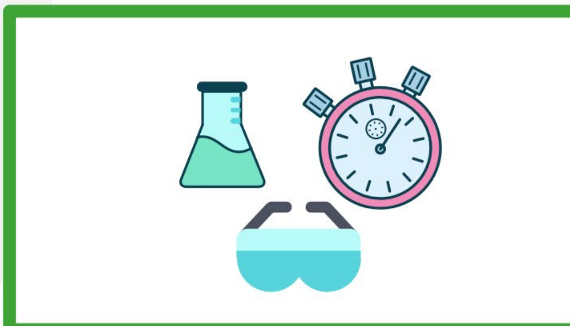
Space Engineer:
Administration Officer

Space Engineer:
Health and Safety Manager

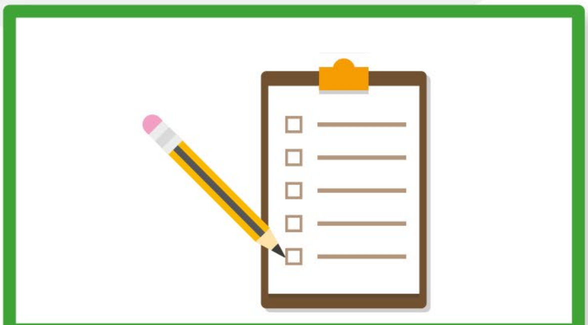
Space Engineer:
Communications Officer

Appendix 1: Role Badges

Space Scientist: Personnel Manager



Space Scientist: Resources Manager



Space Scientist: Administration Officer

Space Scientist: Health and Safety Manager

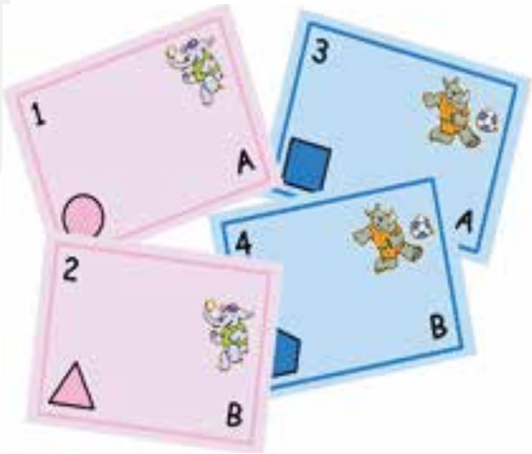
Space Scientist: Communications Officer

Appendix 2: DIPS STRATEGIES

DISCUSSION STRATEGIES

The following strategies are used extensively as part of the Discussions in Primary Science (DiPS)[1] project, and have been proven to be successful when developing children's independent thinking and discussion skills.

Use of these strategies is strongly recommended during the activities on this website. Icons shown here with a description of each strategy are provided on each activity's web page, suggesting the type of discussions best suited to each activity.



TALK CARDS

Talk cards support the teacher in facilitating these discussions, with the letters, numbers, pictures and shapes enabling the teacher to group children in a variety of ways.

The example provided here shows one set for use with four children. The set is copied onto a different colour of card and talk groups are formed by children joining with others who have the same coloured card.

Children can then pair up by finding a partner with the same animal or a different letter eg. elephant, rhino or a + b pair. Each TALK pair would then have a card with a different number or shape.

The numbers or shapes may then similarly be used to form alternative groupings and pairings.

Note: The example talk cards are provided in MS Word format so you may make changes if you wish.

ITT (INDIVIDUAL THINK TIME)

Each child is given time to think about the task individually before moving into paired or group work.

TALK PARTNERS

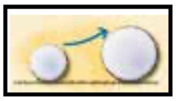
Each child has a partner with whom she/he can share ideas and express opinions or plan. This increases confidence and is particularly useful where children have had little experience of talk in groups.

A > B TALK

Children take turns to speak in their pair in a more structured way, e.g. A speaks while B listens B then responds. B then speaks to A while A listens and then A responds to B.

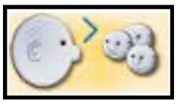
1 For more information go to www.azteachscience.co.uk

SNOWBALLING



Pupils first talk in pairs to develop initial ideas. Pairs double up to fours to build on ideas. Fours double up to tell another group about their group's ideas.

ENVOYING



Once the group have completed the task, individuals from each group are elected as 'envoys', moving on to a new group in order to summarise and explain their group's ideas.

JIGSAWING

Assign different numbers, signs or symbols to each child in a group. Reform groups with similar signs, symbols or numbers, e.g. all reds, all 3s, all rabbits and so on. Assign each group with a different task or investigation. Reassemble (jigsaw) the original groups so that each one contains someone who has knowledge from one of the tasks. Discuss to share and collate outcomes.

Appendix 3: Mars Facts and Missions

INFORMATION FOR TEACHERS

Mars is the fourth planet from the sun and the seventh largest. It has two tiny saellites Phobos and Deimos. Mars' orbit is 227,940,000km, its diameter 6,794km and mass 1/10th of Earth's. Early in its history, Mars was much more like Earth. Most of its carbon dioxide was used to form carbonate rocks but as it cannot recycle any of this back into the atmosphere, it is much colder than the Earth would be at that same distance from the sun. Mars' orbit is elliptical. Its average temperature is approx -55°C but surface temperatures range widely from as low as -133°C at the winter pole to almost 27°C on the day side during summer. Mars is much smaller than Earth but its surface area is similar to Earth's land surface. Mars has a very thin atmosphere composed of a tiny amount of carbon dioxide, nitrogen, argon and traces of oxygen and water. The average pressure is 1% of Earth's but it is thick enough to support very strong winds and huge dust storms that cover the planet for months. Early telescopic observations revealed that Mars has permanent ice caps at both poles. We know they are composed of water ice and solid carbon dioxide (dry ice). Mars has some of the most highly varied and interesting terrain of any of the terrestrial planets, including;

- Olympus Mons - the largest mountain in the solar system rising 24km above the surrounding plains
- Tharsis - a huge bulge on the surface 4000km across and 10km high
- Valles Marineris - a system of canyons 4000km long and 2-7km deep
- Hellas Planitia - an impact crater in its southern hemisphere over 6km deep and 2000km in diameter

Much of the Martian surface is very old and cratered but there are younger rift valleys, ridges, hills and plains. None of this can be seen in detail with a telescope, not even the Hubble telescope but can be seen from spacecraft.

There does not appear to be any current volcanic activity but it is likely to have tectonic activity in the past. There is evidence of erosion in many places including large floods and small river systems. At some point in the past there was clearly some kind of fluid on the surface. Liquid water is a likely fluid but other possibilties exist. There may have been large lakes or oceans. Scientists believe that there were wet episodes that occurred briefly but very long ago.

Canals of Mars are apparent systems of long straight markings on the surface of Mars that we now know are caused by the chance alignment of craters and other natural surface features, observed through telescopes when the telescopes are nearly at the limit of their resolution. The Italian astronomer Giovanni Virginio Schiaparelli reported observing about 100 of these markings in 1877 and described them as canali (Italian for channels) but did not imply anything about their origin. Around the turn of the 20th century, American astronomer.

Percival Lowell described canal networks covering most of the planet. Many believed them to be bands of vegetation bordering irrigation ditches dug by intelligent beings to carry water from the polar caps. The controversy was finally resolved only when close-up images of the Martian surface were taken from spacecraft beginning with Mariner 4 (1965), 6 and 7 (1969). These images showed many craters and other features but nothing resembling networks of long linear channels.

Since 1960, the Russians and American Space Agencies have sent many spacecraft to Mars; some have been very successful. Mariner 4 was the first mission to make it successfully to Mars. Mariner 4, 6, 7 and 9 missions took many phot graphs of Mars and its moons. Then, the Russians sent Mars 2- 6, bringing back data about the Martian surface, atmosphere, temperature and gravity. The Viking missions were very successful in the 1970s, providing in excess of 50,000 images. After a quiet decade, Martian exploration took off again in the 1990s. In April 2001, the Mars Odyssey was launched. It has been successfully collecting data about the minerals and chemicals that make up the Martian surface.

In December 2003 the European Space Agency's Mars Express Mission, including Beagle 2 Lander, arrived at Mars. NASA's Mars Exploration Rovers, landed in 2004 and have been sending back information ever since!

The UK Space Agency is providing 165M Euro contribution to the European ExoMars programme, in addition to 25M for the development of instruments to search for signs of past or present life on Mars. The instruments are part of the scientific payload on a new rover currently being developed. Rovers have to be designed and built from materials that will not contaminate the planet in any way. The new rover is a robotic scientist which will search for evidence of past and present life and study the local Martian environment to understand when and where conditions that could have supported the development of life may have prevailed.

Appendix 4: Glossary

Active volcano	Volcano that is currently erupting lava.
Astrobiologist	Scientists seeking to understand the origin of the building blocks of life, how these compounds combine to create life, how life affects - and is affected by the environment from which it arose, and finally, whether and how life expands beyond its planet of origin.
Basalt	Hard, dull, black igneous volcanic rock, the most common in the solar system and common on the Martian surface.
Bolide	Astronomers tend to use “bolide” to identify an exceptionally bright fireball, particularly one that explodes.
Comet	Small icy solar system body that, when close enough to the sun, displays a visible fuzzy atmosphere and sometimes also a tail. They are composed of loose collections of ice, dust, and small rocky particles.
Delta	A landform that is formed at the mouth of a river where that river flows into an ocean, sea, estuary, lake.
Ejecta blanket	Generally symmetrical apron of ejected matter that surrounds a crater; it is layered thickly at the crater’s rim and thin to discontinuous at the blanket’s outer edge.
Erosion	The process by which material is removed from a region of a planet’s surface. It can occur by weathering and transport of solids (sediment, soil, rock and other particles) in the natural environment, and leads to the deposition of these materials elsewhere. It usually occurs due to transport by wind, water, or ice, by down-slope creep of soil and other material under the force of gravity or by living organisms, such as burrowing animals, in the case of bio erosion. Erosion is distinguished from weathering which is the process of chemical or physical breakdown of the minerals in the rocks. The two processes may occur concurrently, however.
Extremophile	Organism that thrives in physically or geochemically extreme conditions that are detrimental to most life on Earth.
Lava	Molten rock that has been released from a volcano across the surface of a planet.
Magma	Molten rock within a planet, building up beneath a volcano before it erupts.
Meteoroid	Sand to boulder sized particle of debris in the solar system.

Meteor	The visible path of a meteoroid that has entered the Earth's or another body's atmosphere.
Meteorite	Derived from small astronomical objects called meteoroids, but they are also sometimes produced by impacts of asteroids.
Photo geologist	Geologist using images taken by plane or satellite to interpret the history of a planet's surface.
Plate tectonics	Scientific theory that describes the large scale motions of plates making up the Earth's crust, which move in relation to one another to create continental drift.
Shield volcano	Types of volcano common on Mars, with very broad and shallow slopes formed as flow after flow gradually build up on top of one another.
Tectonic	Relating to, causing, or resulting from structural deformation of the Earth's crust.
Topography	Relating to the surface shape, features and elevation of Earth or planets. Elevations are usually marked in colour.
Transient atmosphere	Localised weather conditions caused by the trapping of moisture in a sheltered area
Volcano	Mountain formed from the build up of magma beneath a planet's crust.

Appendix 4: Useful Websites

CIEC Promoting Science Table text	www.ciec.org.uk www.cciproject.org/topicBank/ space.htm
European Space Agency (ESA)	www.esa.int/SPECIALS/Aurora/ESA9LZPV16D_0.html
Information on everything from rockets to planets, the site offers regular news plus puzzles and other activities	www.esa.int/esaKIDSen/
I ESA's Education section. Information for teachers on current space news and links to children's activities.	www.esa.int/education
UK space agency	www.bis.gov.uk/ukspaceagency
Website of ESERO-UK, the UK Space Education Office, a project funded by ESA and the Department for Education.	www.esero.org.uk/
National STEM centre's treasure chest of resources for teachers of Science Technology, Engineering & Maths.	www.nationalstemcentre.org.uk/ elibrary/
International Space Station (ISS) education kit :ESA's resource pack with ideas for primary schools with ISS as the theme.	www.nationalstemcentre.org.uk/elibrary/ resource/826/international-space-stationiss- education-kit-primary
NASA's home site providing links to missions and activities for schools.	www.nasa.gov/
All about the Mars rover missions on NASA website.	http://marsrover.nasa.gov/home/index.html
Discovery.com: excellent site with information on the international space station, with interactive space walk.	www.discovery.com/stories/ science/iss/ interactives.html
Hubble telescope site: excellent images of stars,and galaxies	www.hubblesite.org/the_ telescope/
Arizona State University Mars Education Programme	http://tes.asu.edu/
Primary Projects. Useful for children's research. Hands-on section on Earth and other planets	www.learning-connections.co.uk/curric/cur_pri/ space/frames.html
ExoMars rover prototypes conceived by Astrium	http://event.astrium.eads.net/en-wsw/morespace/ the-exomars-rover-will-be-able-to-gowhere-no-rover-has-gone-before.html
Astronomy and space for children	www.kidsastronomy.com
Coxhoe Primary School website filled with lesson plans, information and interactive games.	www.schooljotter.com/showpage.php?id=35519
Lunar and Planetary Institute Host of images and information for teachers.	www.lpi.usra.edu/
Lesson ideas based on Mars rovers	http://marsrovers.jpl.nasa.gov/classroom/ roverquest/

Earth Science Teachers' Association website	www.esta-uk.net
'Astronomy for kids'. Simple information for children on the solar system	www.frontiernet.net/~kidpower/astronomy.html
Information and images from Mars	http://ircamera.as.arizona.edu/ NatSci102/ NatSci102/lectures/mars.html
Fear of Physics: animations of the movement of planets.	www.fearofphysics.com/SunMoon/ sunmoon.html
Sea and Sky: some excellent images in the sky gallery	www.seasky.org/space-exploration.html
Liverpool telescope: free use of the telescope for teachers.	www.schoolsobservatory.org.uk/teach
Faulkes telescope: free use of global telescopes	www.faulkes-telescope.com/aboutus
Bradford telescope: free interactive learning resource for schools.	www.telescope.org/schools.telescope
Free lessons and ideas	www.teachingideas.co.uk/science
Sets of lesson plans for KS1 & 2	www.hamiltoneducation.org.uk
Science & Technology Facilities Research Council supports astronomy, space science, particle and nuclear physics	www.stfc.ac.uk/teachers
Network of providers of space-related experiences across Yorks and Humber	www.YES-net.net
Journal aims to promote inspiring science teaching	www.scienceinschool.org/online

It is a cold, dry, inhospitable place, with an atmosphere comprising almost entirely carbon dioxide. Even the Grand Canyon would be dwarfed by one of its valleys and the solar system's largest volcano can be found here. Dust storms darken its skies. Despite this, Mars is the planet most like Earth and where scientists believe there may be a possibility of finding evidence of primitive life. After news of tantalising new evidence of frozen water lurking beneath its rusty surface, the UK Space Agency released funding for the development of instruments to search for signs of past or present life on Mars. The instruments are part of the potential scientific payload on a Rover being designed as part of a potential joint mission between the European Space Agency (ESA) and US space agency NASA.

CIEC offers support for the teaching of science across the primary age range and beyond. This support includes CPD programmes, bespoke in-school CPD, interactive websites for teachers to use with their pupils, and a wide range of downloadable resources which encourage collaborative, practical problem solving. For more information, please visit our website:

www.ciec.org.uk

or contact:

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