PUPIL
RESEARCHER
INITIATIVE

Mars-ology

Setting the Scene

You will be working as a new research student at the Institute of Planetary Research. The US National Aeronautical and Space Administration (NASA) has asked for ideas from scientists from all over the world about what research a series of space probes to Mars can carry out on their missions. You will present a research proposal which suggests some possible Mars probe projects.

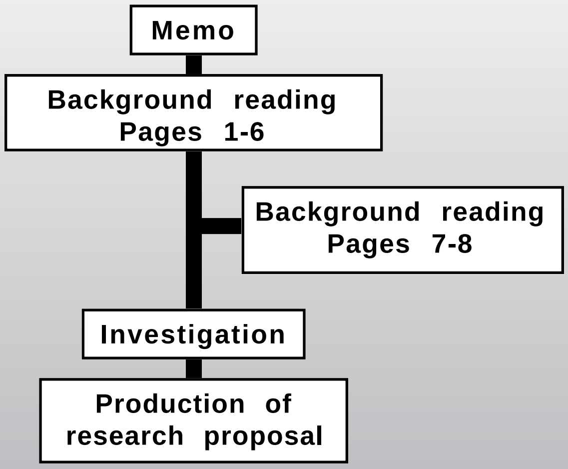
Pupil Research Brief

Study Guide

Syllabus Targets *Science you will learn about in this Brief*

- ❑ igneous rocks are formed from solidifying molten rock (magma)
- ❑ magma may rise through the crust to form volcanoes
- ❑ when molten rock erupts from volcanoes it is known as lava and forms extrusive igneous rocks
- ❑ when magma solidifies deep in the crust it forms intrusive igneous rocks
- ❑ different igneous rocks are made of different minerals
- ❑ igneous rocks are composed of randomly arranged, interlocking crystals
- ❑ if crystals are small, the rock probably formed from extruded lava and cooled rapidly, as in a volcanic eruption
- ❑ if crystals are large, the rock formed from magma that cooled more slowly, probably deep in the Earth's crust

Route through the Brief



Outcome Checklist

You will write a research proposal, outlining to NASA which experiments could be carried out by the Mars probes. You should make sure you produce the following items as you work through the Brief.

Page 1

- ❑ notes about the shape factor (SF) equation

Pages 4 and 5

- ❑ calculations of SF values for Earth volcanoes
- ❑ notes about patterns identified in Earth volcano data
- ❑ calculations of SF values for Martian volcanoes
- ❑ some ideas for Mars probe experiments

Page 6

- ❑ investigation plan
- ❑ investigation report

Pages 7 and 8

- ❑ more ideas for Mars probe experiments

Institute of Planetary Research

Memorandum

Memo from the Office of the Research Director

To: Research Teams: New Principal Investigators

Subject: Future Missions: Mars probes

Date:

I have read a report on the World Wide Web that NASA are looking for suggestions for experiments which could be carried out by their Mars probes. These spacecraft will be launched as a series, over the next few years. I think this gives us a great opportunity to put forward some of our ideas about Martian geology (mars-ology).

As new members of the Institute's staff, I think you should have a go at writing a section of the proposal to NASA, based on some of these ideas.

I have put together a set of notes which explain some of the background science. You will need to read through them, and come up with some experimental evidence to help us develop our view that similarities between structures on Earth and Mars are the result of similar process going on in the two planets. This is partly based on comparisons of volcano shapes. We want to suggest to NASA that they should bring back rock samples from a range of different sites on Mars. They will want to know which sites, and why.

Other staff in the Institute will be working on other parts of our submission to NASA, and so you will be on your own for much of the time. To help you I have written some suggestions on the accompanying papers which will guide you through your task. Since all your team members are either engineers or space scientists, I have included some information on basic geology, which may be new to you. You will need to understand this in order to carry out the task.

What you will need to produce is:

- background notes explaining how different volcano types on Earth are linked to different processes going on in the Earth's crust (based on pages 1 to 5);
- an account of any investigations you carry out;
- suggestions for experiments which the Mars probe can carry out to provide further evidence for our hypothesis (based on your investigation,and page 6);
- suggestions for Martian sites from which rock samples should be brought back.

Good Luck

The shapes of volcanoes

Volcanoes on Earth come in many shapes and sizes, but they can be grouped into two classes.

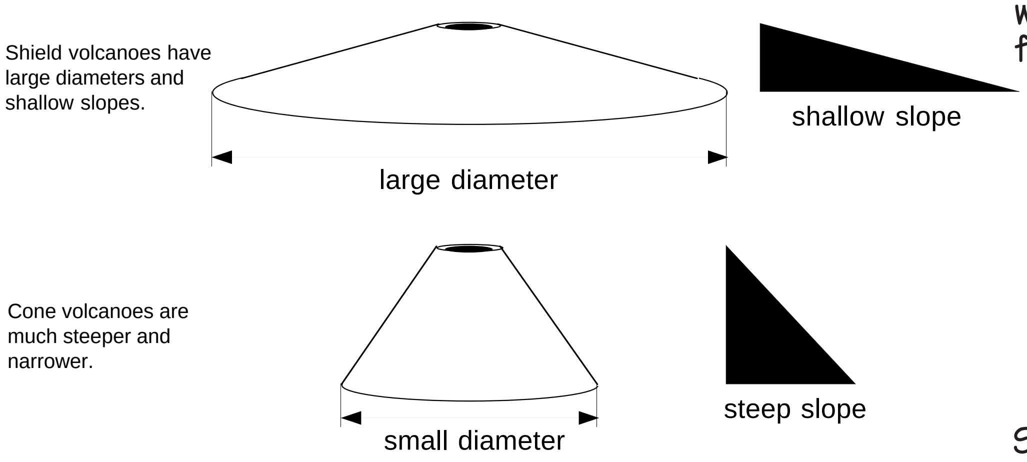
- **Shield volcanoes** which have shallow slopes and large diameters
- **Cone volcanoes** which are steeper and narrower.

A simple way to describe the shape of a volcano is by its **shape factor** (SF). This is calculated as follows:

shape factor = diameter/height

Figure 1. The shapes of volcanoes

Volcanoes on Earth come in many sizes, but they can be broadly grouped into two classes:



Volcanoes are formed when molten rock (magma) is forced out of the ground. Magma is called lava when it is flowing on the surface of the Earth. The lava cools and solidifies to form rock. If the lava flows a long way before it cools it forms a low, shallow shield volcano. If the lava does not flow as far it forms a cone or dome. Extrusive rocks cool very quickly and so crystals do not have much time to grow and are therefore very small. Some cone volcanoes are made of ash produced during explosive eruptions.

The composition of volcanoes

Rocks formed from solidifying magma are called igneous rocks. Those which form in the Earth's crust are called **intrusive** igneous rocks. Rocks which form on the Earth's surface are called **extrusive** igneous rocks, although some extrusive rocks are made of

I have copied three pages from a basic geology text explaining how differences in volcano shapes arise. There are also some pages from a journal and some of my own notes - I have numbered these pages 1 to 6.

Make a note of this equation - you will need to use it to work out SF values for the volcanoes listed on page 4

So - volcano shape depends, at least partly, on the composition of the lava. This is an important point. Also, crystal size can tell us about how long the lava took to cool. I'm sure each of these points can be used as a starting point for the Mars probe research.

compacted ash formed when a volcano explodes. However, the ash is not formed by burning. Igneous rocks are composed of a range of minerals, depending on the composition of the original magma, and are made of interlocking, randomly arranged crystals.

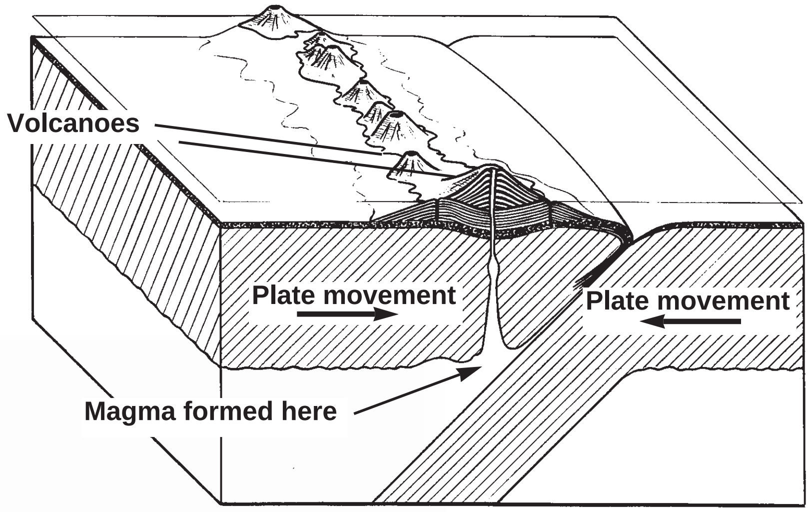
Lava can have different compositions, depending on the mineral content. The lava may also contain solid particles, such as crystals which have already formed. In addition it may contain bubbles of gas. Crystal and gas content affect the flow properties of a lava. Lava cools rapidly when it is extruded onto the Earth's surface. As it cools, crystals start to form. Due to the speed of cooling, the crystals do not have much time to grow. As a result, volcanic rocks formed from lava usually have very small crystals which can only be seen using a hand lens. Intrusive igneous rocks, forming deep in the crust, have larger crystals, due to the longer period for cooling and solidifying. Volcano shapes are also dependent on the type of lava which form them. If the lava is runny and flows a long way before it cools, it forms a shallow, shield volcano. If the lava is more viscous and does not flow far it forms a cone. Volcanoes formed from ash are also cone shaped.

You could investigate these two factors

Volcanoes are usually formed of **basalt**, **rhyolite** or **andesite.** These have different mixtures of minerals. Basalt is much more runny than andesite or rhyolite. Rhyolite has similar minerals in it to **granite**, an **intrusive** igneous rock formed deep in the Earth's crust, and having crystals clearly visible to the naked eye. Rhyolite is very viscous and usually produces explosive eruptions resulting in volcanoes made of ash, and craters (calderas). Andesite has a composition somewhere between basalt and rhyolite. Andesite volcanoes are cones made of a mixture of lava and ash.

Where volcanoes are found

Figure 2. A subduction zone

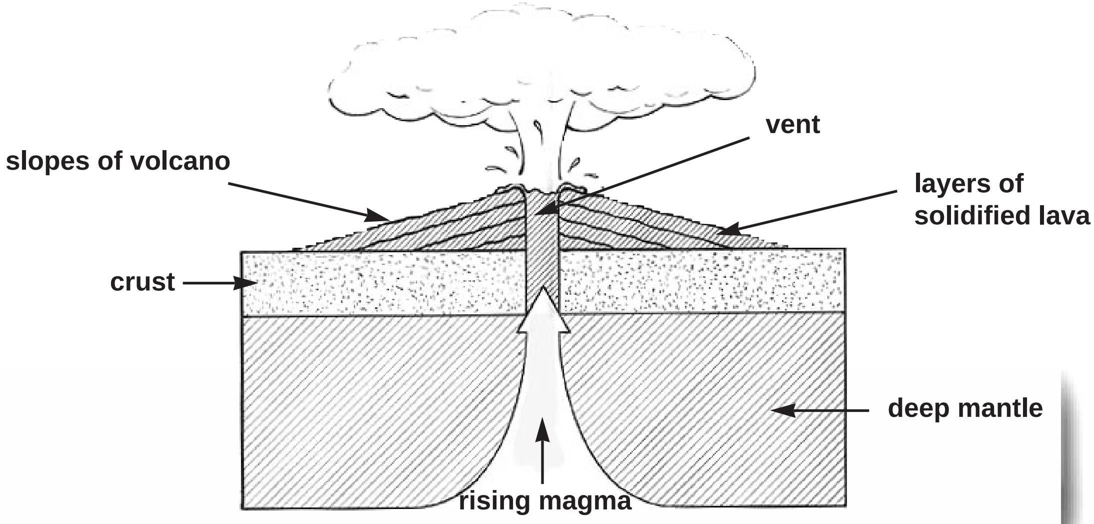


Volcanoes are found in two types of location.

- at **subduction zones**, where one **tectonic plate** is moving down under another. These areas are called **destructive plate boundaries**. The energy transferred when the plates rub against each other heats the rocks around the plate boundary, deep in the Earth. This causes the rock to melt and form magma which rises up through the surrounding rock. Some of this might escape onto the Earth's surface as a volcanic eruption;

- at **hot spots** where there is an area of rising convection currents beneath a tectonic plate. Magma rising with the convection currents can break through onto the surface. This might occur along the length of a crack which forms in the crust, or at a single spot. New crust forms as lava solidifies along the cracks which develop in the plate as it splits apart, effectively forming two separate plates. These areas are called constuctive plate margins. Single point hot spots can occur in a **mid-plate region**, where the plate is not splitting apart.

Figure 3. A volcano at a single point hot spot



The information on these pages links the existence of two types of volcano to different types of crystal structures - subduction zones and hot spots. The Mars work could gather evidence to see whether Martian crust is similar to Earth's - remember this when you need to write the last section of your report - 'suggestions for the experiments to be carried out by the Mars probe'. Also, page 1 talks of crystal size and what it tells us about igneous rock formation - is there a possible investigation here for the Mars probe?

International Geology Review April 1995

Characteristics of major volcanoes

Calculating SF values works best if you convert the heights from metres into kilometres

Name	Location (mid-plate or subduction zone)	Height (m) above sea level	Diameter (km)	Composition
Mauna Loa	mid-plate	4169	90	basaltic
Maui	mid-plate	3055	40	basaltic
Fuji-san	subduction zone	3776	30	rhyolitic
Tenerife	mid-plate	3715	40	basaltic
Mount St Helens	subduction zone	2549	25	rhyolitic
La Palma	mid-plate	2423	30	basaltic
Tahiti	mid-plate	2235	30	basaltic
Nevado Ojos Del Salado	subduction zone	6887	8	rhyolitic
Gran Canaria	mid-plate	1949	45	basaltic
Great Sitkin	subduction zone	1740	9	rhyolitic
Kanaga	subduction zone	1312	10	rhyolitic
Moffett	subduction zone	1200	9	rhyolitic
Reunion	mid plate	2631	35	basaltic

I have photocopied this table from the International Geology Review.

You could use the equation on page 1 of these notes to work out the SF of each volcano, and classify each as either shield (SF greater than 10) or cone type (SF less than 10).

Are there any patterns in this data in the table - do any of the characteristics seem to be linked, such as location and shape?

You now need to look at the data in table 2 about volcanoes on Mars and do SF calculations.

You can use the Earth and Mars SF values when you write the background notes section of your report.

Is there any sign that there are different lava types on Mars?

Volcano	Diameter (km)	Height (m)
Olympus Mons	520	23000
Ascraeus Mons	400	17000
Uranius Tholus	83	3500
Ulysses Tholus	91	4000
Elysium Mons	170	9000
Hecate Tholus	170	6000

Data about
Martian Volcanoes - I'd convert the heights to kilometres

Is there enough evidence from your calculations to make a firm conclusion about the existence of different lava types on Mars?

What does this mean for our suggestions for Mars probe experiments?

Suggestions for your investigation

Now that you have worked through some of the background science, you could start thinking about a practical investigation into factors which affect volcano shape.

Remember, we are trying to provide some evidence to back up our theory about Martian volcanoes mentioned in my Memo, i.e. that structures on Mars are caused by the same processes as those causing structures on Earth. How about looking at the different flow rates of a number of substances, to investigate whether composition affects flow rate? Does the temperature of the liquid affect flow rate? What about crystal content? Does viscocity affect flow rate?

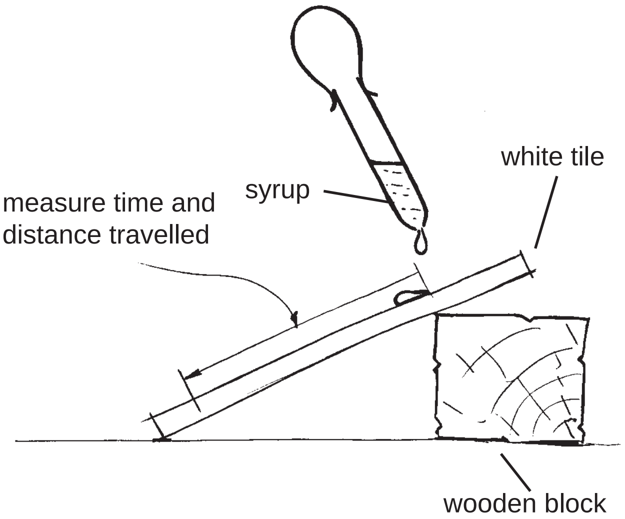
I have searched through the journals and found a number of reports of experiments which have already been carried out into the flow rates of lava,. These don't use real lava, simply substances which flow like lava.

Be sure to plan the investigation carefully, bearing in mind the need to control all the variables except the one you are going to vary- eg the type of substance or the temperature or the crystal content.

When you have written up a plan, it would be a good idea to let me see it so that I can make any suggestions which might help you - since you are not geologists!

Your investigation plan should start by stating the hypothesis you are testing, followed by an explanation of the background science which the hypothesis is based on - use your own knowledge and what you have learned from working through these papers to help you.

When you have completed your investigation and written your report, pass it on to me so I can use it to help me write the final proposal.



This is a sketch of a possible method to make the 'lava' flow.

Public Appreciation of Science, May 1995

EXPLORING THE PLANETS

MARS

Extract from Public Appreciation of Science, May 1995 - this is interesting - the author must have been reading some of my papers!

Mariner 4 flew past Mars in 1965 and sent back TV pictures of the surface. Mariners 6 and 7 flew past in 1969 and sent back images and other information. Mars was revealed as a cold, rocky place, its atmosphere 98% CO_2, and its south polar cap consisting of frozen CO_2. In 1971 Mariner 9 went into orbit around Mars, and sent back images for almost a year. These images showed volcanoes and giant valleys, and included evidence that water once flowed across the surface of the planet.

The first landing on Mars was made by the Soviet lander Mars 3 - unfortunately it only lasted 20 seconds before contact was lost. The Mars 3 orbiter sent pictures back for nearly a year. The USA had more luck with their landers. The Viking landers 1 and 2 touched down in 1976. They carried out chemical analyses and biological experiments - which failed to show any indications that life existed on Mars. The Viking orbiters sent back photographs, including colour and stereo* images.

This article may help you come up with suggestions for experiments for the Mars probe - what could we look for, and why? We will need to back up each suggestion (which will need to be set out as a hypothesis) with some background science - explaining the scientific basis of what we are suggesting they look for.

Planetary exploration continues, with the Galileo mission heading for Jupiter and sending back data starting in December 1995. However, Mars remains the most interesting planet, since conditions there seem to be closest to those on Earth. Research is continuing into the possible geological (is that the right word?) structure of the planet. NASA's Mars programme provides us with a fascinating picture of what makes the planet tick. Providing, that is, the scientists ask the right questions, and design the right experiments to provide some of the answers we need. The space science research community certainly has a challenge ahead, to make the most of what may be a one-off opportunity.

What, for instance, is the origin of the volcano-type structures visible on the Martian surface? Does their origin indicate a plate tectonic structure to the planet? Does it have a crust, which varies in composition between oceanic and continental areas, as happens on Earth? If so, where are the oceans? What happened to them? If not, what does this tell us about the possible cause of volcanic activity? Framing the right questions will be vitally important to the future of planetary research. We await the outcome with interest.

* Stereo images are pairs of images taken from slightly different places. They give a 3D effect, and they can be used to work out the heights of different parts of the terrain.

Missions to Mars

Date	Mission	Type of spacecraft	Notes
5/11/96	Mars Global Surveyor	Orbiter *US funding*	Will relay information back to Earth about Martian surface
16/11/96	Mars '96	Orbiter and landing craft *European funding*	Will penetrate surface of Mars
5/12/96	Mars Pathfinder	Lander and microrover *US funding*	Aims to demonstrate technology for future missions
12/98	Mars Surveyor 98	Orbiter *US funding*	Used for infrared radiation analysis
1998	Planet B	Orbiter *Japanese funding*	Looking at upper atmospheric physics of Mars
4/1/99	Mars Surveyor 98	Lander *US funding*	Will have robot arm to dig up samples
2001	Mars 2001	Lander and rover *Russian funding*	May involve collaboration with US Mars probes
2001	Mars Surveyor '01	Orbiter *US funding*	Analysis of gamma rays
2001	Mars Surveyor '01	Lander *US funding*	Mission to be defined following proposals to NASA
2003	Intermarsnet	Orbiter and landers *European funding*	Mission to be decided by European Space Agency (ESA)
2003	Mars Surveyor '03	Not decided *US funding*	Mission to be decided by NASA may link with Intermarsnet
2005	Mars Surveyor '05	Not decided *US funding*	Not decided, but may be to obtain and return samples to Earth

Figure 1. Planned Missions to Mars 1996-2003