Researchers in Schools

Volcano CSI: imaging inside a volcano

Key Stage 4 Programme

Pupil Name

Coursebook Designed by Dr. K. Saunders

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Uni Pathways launch event

Welcome to Uni Pathways! We are delighted to be able to launch the Uni Pathways programme with you. We hope that you are ready to embark on your Uni Pathways journey and that you enjoy the video.
You will be asked to pause the video at times to complete some work in this workbook, so make sure you have a pen / pencil to hand when you start the video.

By the end of the video, you will have

- Learnt about what studying at university means
- Learnt about some of the skills that you will develop during Uni Pathways
- Heard from pupils who have participated in Uni Pathways or The Scholars Programme (which is the same programme!)
- Heard from current university students talking about what life is like at university

If you are in school your teacher will play the video. If you are at home and logged in to a session with your teacher, your teacher will play the video and show it to you. If you are participating independently your teacher will email you the link to the video or the video file. There are opportunities for you to answer some questions, and you will be told when to pause the video to answer them.

Introduction to Uni Pathways

1. Write down what you think a supra-activity is

_____
_____
_____

2. Independent learning is

_____
_____
_____

3. Write down in your own words what resilience means, and come up with a different example to the one mentioned in the PowerPoint.

_____
_____
_____
_____

4. Why do you think analysis and evaluation skills are useful in your academic career?

_____
_____
_____
_____
_____

5. Why do you think analysis and evaluation skills are useful in life in general?

_____
_____
_____
_____
_____

6. What are the different types of learning that university students do?

Pupils' experience of Uni Pathways

You will now watch some pupils talk about their experience of learning a PhD topic and producing a final assignment. Some may refer to The Scholars Programme rather than Uni Pathways. As you heard in the introduction PowerPoint, The Scholars Programme is a very similar programme to Uni Pathways. Listen carefully and then respond to the questions below. Be prepared to share some of your responses with your peers.

1. How did the pupils describe talking about writing a long essay for their final assignment?

2. Write down something that one of the pupils mentioned was particularly interesting in their course.

3. What were some challenges that the pupils met?

Virtual campus tours

You will now go on a virtual tour of some universities! Once you have seen some of the university campuses, respond to the questions below.

1.Note down something that you liked out of any of the campus tours you saw. It may be a particular building, space, city etc.

2. Were there any similarities between the different university campuses? If so, what are the similarities?

3. If you had to pick one of those universities to go and visit in person, which one would it be and why?

4. Note down some of the societies that you could join at different universities

Meet university students!

You are about to virtually meet or hear from some current university students.
If you are virtually meeting them, think about what questions you would like to ask the students, share your questions with a partner and note those questions down in the space below.

If you are not meeting them but watching some videos that they have made, use the space below to note down what else you would like to find out about university. You can then ask your teacher during Uni Pathways tutorials!

Reflection

Congratulations on completing the launch of the Uni Pathways programme. Before you go, take some time to reflect on what you have learnt by answering the following questions:

1. Are there any aspects of university style learning that you would look forward to? If so, what are they?

2. What challenges do you think students face when learning at university? How would you try to overcome these challenges?

3. What skills do you hope to develop during your Uni Pathways course?

4. What part of Uni Pathways seems the most challenging for you?

5. What are you most looking forward to about Uni Pathways?

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1		3:05 pm	HE
2		3:05 pm	HE
3		3:05 pm	HE
4		3:05 pm	HE
5		3:05 pm	HE
6 (Feedback)		3:05 pm	HE
7 (Feedback)		3:05 pm	HE

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1	Living with Volcanoes assignment	
Tutorial 2	Igneous minerals	
Tutorial 3	Chemistry of volcanic rocks	
Tutorial 4	Media and Science	
Tutorial 5	Probing inside Whakamaru Volcano	

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after midnight on due date	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Course Rationale

Volcanic eruptions can be spectacular, but also extremely dangerous. Volcanoes are unpredictable but with careful monitoring, scientists can understand their behaviour and may (and it's a big may) potentially forecast future eruptions. This is really important for the communities living around a volcano. During periods of volcanic unrest regions may need to be evacuated, but this can cause large disruption to societies with economic and society consequences.

In order to understand a volcano and even consider forecasting an eruption, scientists (called Volcanologists if they study volcanoes) must really try to understand a volcano to the best of their ability. This takes lots of detailed work using scientific methods from chemistry, physics, maths, environmental science to name a few. Here, we will consider the evolution of an active volcano from a chemical perspective and the different hazards the volcano may pose.

In this course you will become Earth Science investigators and use chemical fingerprinting of crystals (solid particles) grown within magma to deduce the conditions within a magma chamber (an area in the volcano where the magma resides) and whether it is likely to erupt. You will learn how we can take rocks, representing the solidified cooled magma, and how they are prepared for scientific study. Using micro-analytical techniques and theories, you will identify different crystals and learn about their chemical properties. You will then use chemical data of the crystals to investigate different magma properties, including the temperature and depth the magma formed at. Combining all this scientific evidence together will enable you to consider the conditions beneath the volcano and whether it is likely to erupt.

The course will use university-style teaching to provide an insight into Higher Education of Earth Sciences. Through a series of tutorials, you will learn how light travels through volcanic crystals and can be used to identify crystals; how you can manipulate chemical data to provide insights into the behaviour of an active volcano and gain experience writing a scientific repo

Uni Pathways Mark Scheme 2020

	Subject Knowledge	Critical Thinking	Written Communication
1st	The work shows a depth of knowledge and understanding of key concepts and scientific methods, through engaging with relevant sources. Knowledge is used to build and support highly effective scientific arguments and explanations.	Analyses key scientific evidence, arguments, and reasoning. Interprets meaning and makes connections. Identifies and critically evaluates key scientific arguments and evidence, deciding on their credibility, strength, and relative significance, drawing convincing conclusions.	The work has a coherent flow and is well structured. The writing style is appropriate; scientific language and key scientific terms are used accurately and effectively to support the arguments and explanations made. There are no, or very few, errors in spelling or grammar. Consistent referencing, appropriate paragraphing and use of correctly labelled tables and graphs matching the style taught in the course.
2:1	The work shows an understanding of key concepts and scientific methods, drawing on relevant sources. Knowledge is used to build and support effective scientific arguments and explanations.	Analyses relevant scientific evidence, arguments, and reasoning. Identifies and critically evaluates relevant scientific arguments and evidence, deciding on their credibility and strength, drawing reasonable conclusions. Shows some understanding of the relative value of evidence and arguments.	The work is well-structured. The writing style is appropriate; scientific language and key terms are used correctly. There are few errors in spelling or grammar. Mostly consistent referencing and use of tables and figures; matching the style taught in the course.
2:2	The work shows an understanding of key concepts and scientific methods, with no major misconceptions. Beginning to apply this knowledge to build and support effective scientific arguments and explanations.	Identifies and uses basic scientific evidence, arguments, and reasoning. Showing some understanding of the quality of scientific arguments and evidence. Not yet showing understanding of the relative value of evidence and arguments.	The work has some structure. The writing style can sometimes be informal; occasionally scientific language and key terms are not used when it would be appropriate to do so. There are some errors in grammar and spelling do not get in the way of communicating the content. Referencing has some consistency; matching the style taught in the course Limited use of tables and graphs.

3rd	Shows a developing understanding of key concepts and scientific methods, with some misconceptions. Does not yet apply this knowledge to build and support scientific arguments and explanations.	Beginning to analyse scientific evidence, arguments, and reasoning. Describes evidence and arguments, while not yet evaluating them.	The grammar, spelling, style, and structure of the work need improving in order to communicate ideas to the reader. Scientific language, key terms and references are not always used correctly. Limited, or no use of tables and graphs.

Baseline Assignment: Pupil Feedback Report

Name of Pupil	
Name of School	Oasis Sholing
Name of RIS teacher	Dr. K. Saunders
Title of Assignment	

How your assignment is graded:

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-level
2:1	60-69	Performing to a good standard at A-level
2:2	50-59	Performing to an excellent standard at GCSE
3rd	40-49	Performing to a good standard at GCSE
Working towards a pass	0-39	Performing below a good standard at GCSE
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Marks

OVERALL MARK / 100		FINAL MARK / 100 (including any deductions)	
DEDUCTED MARKS		FINAL GRADE	

If marks have been deducted (e.g. late submission, plagiarism) the teacher should give an explanation in this section:

Mark Breakdown and Feedback

Subject knowledge	
	mark
Critical thinking	
	mark
Written communication	
	mark

Final Assignment: Pupil Feedback Report

Name of Pupil	
Name of School	Oasis Sholing
Name of RIS teacher	Dr. K. Saunders
Title of Assignment	

How your assignment is graded:

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-level
2:1	60-69	Performing to a good standard at A-level
2:2	50-59	Performing to an excellent standard at GCSE
3rd	40-49	Performing to a good standard at GCSE
Working towards a pass	0-39	Performing below a good standard at GCSE
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Marks

OVERALL MARK / 100		FINAL MARK / 100 (including any deductions)	
DEDUCTED MARKS		FINAL GRADE	

If marks have been deducted (e.g. late submission, plagiarism) the teacher should give an explanation in this section:

Mark Breakdown and Feedback

Subject knowledge	
	mark
Critical thinking	
	mark
Written communication	
	mark
Problem Set	
Comment	*mark*

Subject Vocabulary

Word	Definition	In a sentence
ash	volcanic melt that on eruption is frozen as fine powder	
ignimbrite	a rock type formed by the deposition of a pyroclastic flow, composed of ash, ripped up crust, pumice and crystals	
magma	molten rock while underground	
magma chamber	a region underneath a volcano where magma accumulates prior to eruption and is considered fully molten	
melt inclusions	small bubble of melt trapped within a crystal as it grows	
plagioclase	a crystal that is a sodium-aluminum silicate	
plumbing system	pathways in the crust under a volcano through which magma passes	
pyroclastic flows	a fast flowing 'cloud' of hot, dense ash, gas and ripped up crust and lava, erupted explosively often erupted from a rhyolite caldera	
pyroxene	a magnesium-iron rich silicate crystal	
quartz	a silica rich volcanic crystal	

Tutorial 1 – Volcanoes: the basics

What is the Purpose of Tutorial 1?

- I will understand how Uni Pathways works
- I will be able to label a volcano and describe different volcanic landforms
- I will be able to summarise the main hazards associated with an active volcano

Volcanoes

A volcano is a landform built during a volcanic eruption, where magma (molten rock) and/or gas is extruded at the Earth's surface. Volcanoes come in many different shapes and sizes. The process by which magma is transferred from the Earth's interior to the surface is known as volcanism.

Activity 1: Describing a volcano

Using the terms given below, label the volcano

magma conduit lava flow pyroclastic flow

fumaroles volcanic bombs eruption cloud

ash vent magma chamber plumbing system

crystals

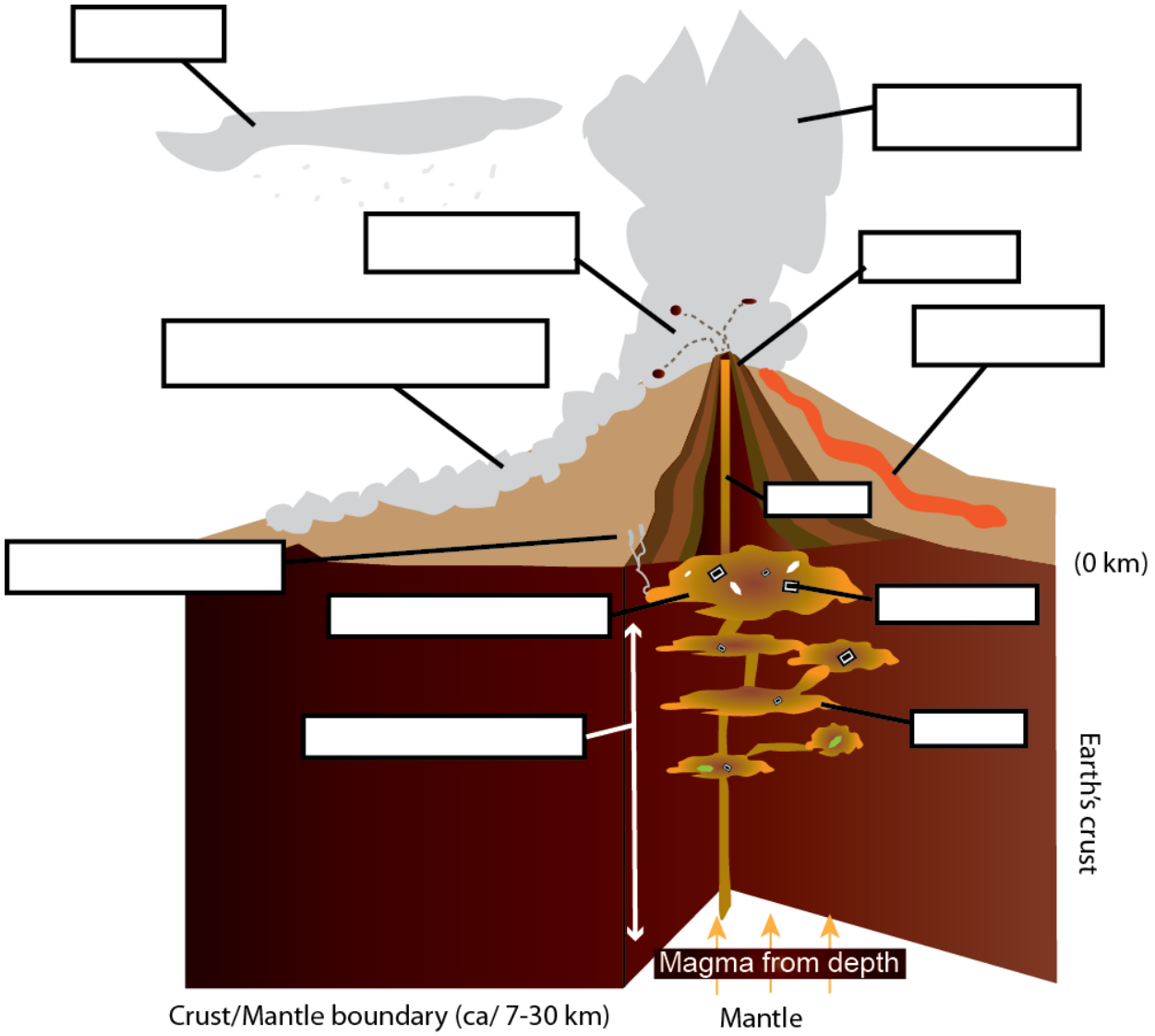


Figure 1: Outline of an active volcano and potential eruption deposits/hazards

Activity 2: What do volcanoes look like?

Magma is composed of crystals (solid particles), dissolved gas and melt (liquid rock). When erupted on the surface it is called lava. A volcanic eruption is a surface discharge of gas and/or magma. A volcano is any landform through which gas or magma is discharged.

What do volcanoes look like?

Have a look at the images on the next page. In your pairs discuss whether you think these images are volcanoes or not and why.

Make any notes you would like in the space below.

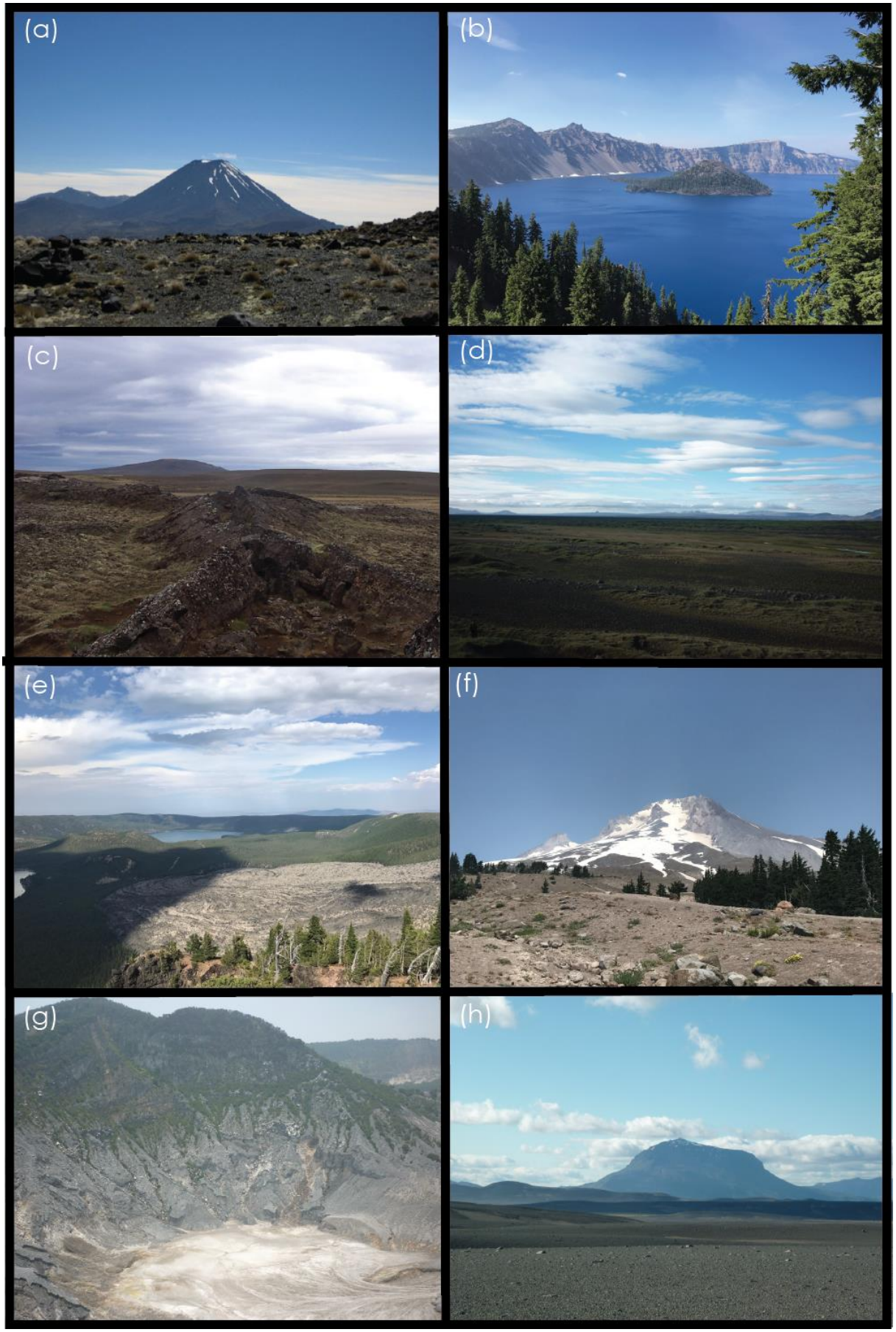


Figure 2: Images of potential volcanoes

Activity 3: Living with active volcanoes

In Indonesia over 179 million people live within 100 km of a known active volcano (Brown et al., 2015). Indonesia is one of the most volcanically active countries in the world with over 120 active volcanoes (or 13% of the world's active volcanoes) (www.wovo.org; Global Volcanism Program, 2013). Out of these 120 volcanoes, 79 are known to have erupted over the last 400 years. This means 75% of Indonesia's population live within a shadow of an active volcano.

In the box below, draw a cartoon volcano and either draw or annotate all the volcanic hazards you can think of.

Don't worry if you cannot think of many now. You will revisit this topic during your first homework assignment and may like to come back and add more hazards to your diagram later.

References

Brown, S.K., Auker, M., Sparks, R.S.J. (2015). Population around Holocene volcanoes and development of a Population Exposure Index. Pp223-232. In Loughlin, S., Sparks, S., Brown, S., Susanna, J and Vye-Brown C (eds). Global Volcanic Hazard and Risk. Cambridge University Press.

http://www.wovo.org/1601_1607.html - accessed 21st October 2015

Homework: Baseline Assignment

Living with Volcanoes

At university, lecturers will often give you an overview of the topic and then direct you to resources whether this is a further practical class, science journals, textbooks or internet resources to develop your knowledge. During today's tutorial we have been learning and discussing volcanoes.

Using your own knowledge, coupled with some research using the (school's) computer/internet, research the following and write a 400-500-word summary of the following points. You can include tables and diagrams too if you wish.

a) Basalt and rhyolite are two different types of magmas at either end of the extrusive igneous rock spectrum. From our discussion of volcanoes, we saw that different magmas tend to produce volcanoes that are different shapes and sizes.

Think why this may be so and compare and contrast basaltic and rhyolite magmas. You may like to consider the following;

i) Do you find basalt and rhyolite volcanoes together or in different locations?
ii) Is there a difference in size of basalt/rhyolite volcanoes?
iii) Does the composition of basalt/rhyolite vary?

b) Many people globally live in the shadow of an active volcano. Discuss the hazards that may be associated living near to an active volcano. How could you mitigate (make the effect of volcanic eruptions less severe) against some of these hazards? How would you feel if you lived near an active volcano?

In order to help you answer these questions, it may be useful to do some research using external sources. A couple of suggestions are given below (at university Wikipedia is generally not considered a good reference source!).

Success criteria

- Describe the different properties of basalt/rhyolite volcanoes
- Comment on the size, composition and location of these volcanoes
- Discuss a range of hazards at active volcanoes
- Write answers in full sentences
- Bonus points to include diagrams and correctly reference these

Web Resources

BGS (British Geological Survey)
https://www.bgs.ac.uk/discoveringGeology/hazards/volcanoes/home.html

USGS (United States Geological Survey)
https://volcanoes.usgs.gov/vhp/about_volcanoes.html

Global Volcanism Programme (lists all the volcanoes in the world)
https://volcano.si.edu

GNS Science (New Zealand Geological Survey)
https://www.gns.cri.nz/Home/Learning/Science-Topics/Volcanoes/New-Zealand-Volcanoes

Geonet (New Zealand monitoring network)
https://www.geonet.org.nz/volcano/ruapehu

Tutorial 2 – Journey to the centre of the Earth: inside a volcano

What is the Purpose of Tutorial 2?

- I will be able to contrast basalt and rhyolite magma compositions
- I will learn to identify and describe key volcanic crystals under a microscope
- I will learn to distinguish basalt and rhyolite samples using microscope techniques

Global Volcano Activity

Figure 3: Eruption of Nyamuragira Volcano on the 8th January 2012.
Photo courtesy of Dr. L. Field.

Activity 1

While you read this sentence and look at the photo above, how many volcanoes have erupted worldwide? Write your answer in the space below.

……

Magma

Magmas have a range of compositions. These vary on where/how magmas have formed. These compositions are not discrete but can be thought of as a continuum with one composition merging into the next.

You should be familiar with terms such as basalt, rhyolite and granite from previous work on the rock cycle and from your homework assignment.

Have you ever looked at a rock and wondered how geologists can tell what the rock is and how it formed? Have a think, if you are reading this now and you understood it, why is this? It's because you have learnt the English alphabet and can use it to communicate. It's the same for a geologist, but to identify rocks, it's not the alphabet that needs to be learnt; instead it is the different mineral properties, their characteristics and the chemistry of different parts of a rock.

Let's start by considering the difference between basalt and rhyolite magmas (figure 4).

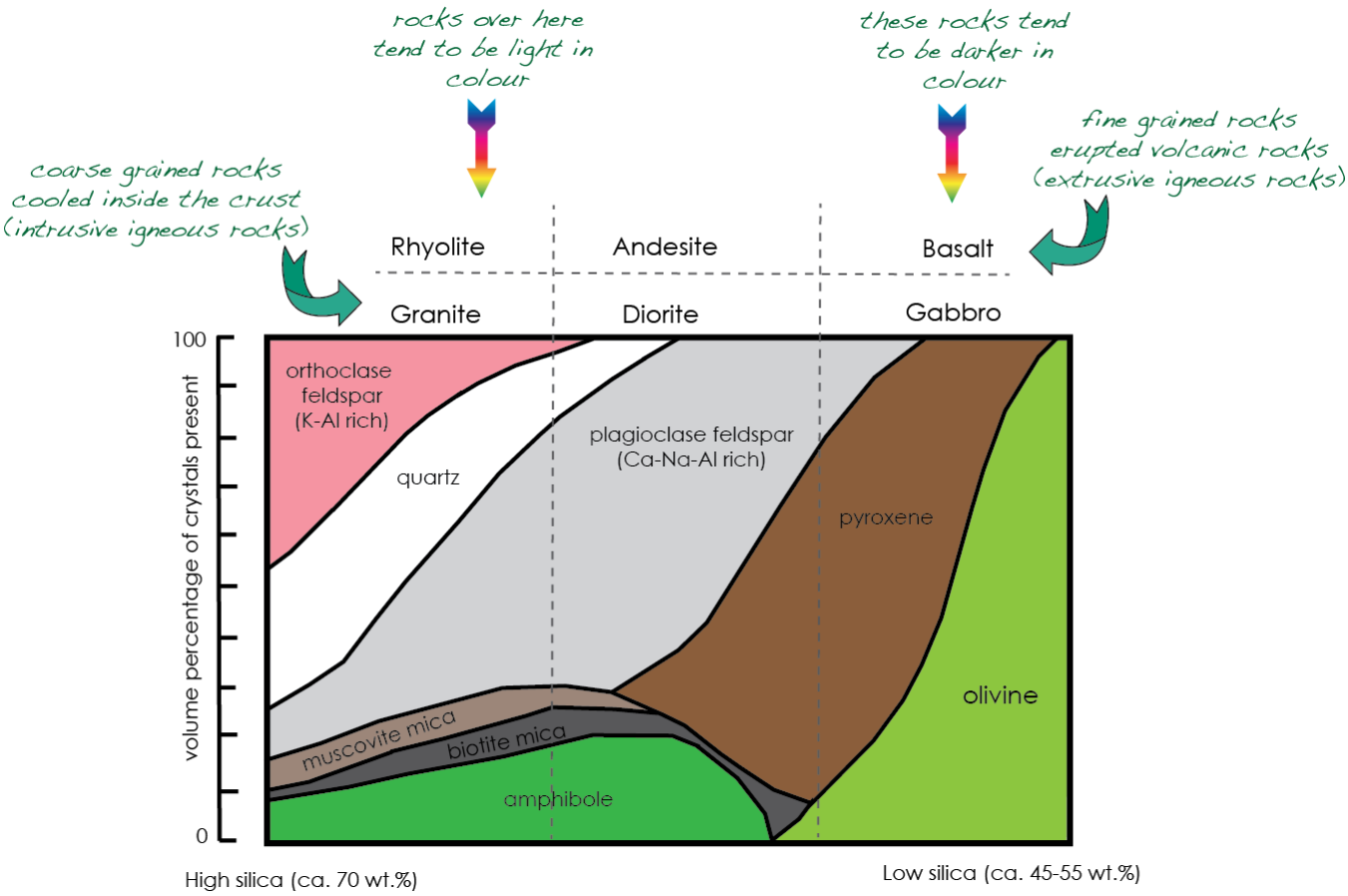


Figure 4: Diagram showing the typical minerals present in different magma types, the amount of minerals present and silica content. Fine-grained extrusive igneous rocks are rhyolite, andesite and basalt. The coarse grain intrusive igneous rocks are granite, diorite and gabbro respectively. Adapted from Bowen's Reaction series.

The simplest difference could be the colour of the rocks. Rhyolite tends to be lighter and basalt darker in colour, but colour can be misleading and is not a definite diagnostic property, but a useful first starting point (figure 5).

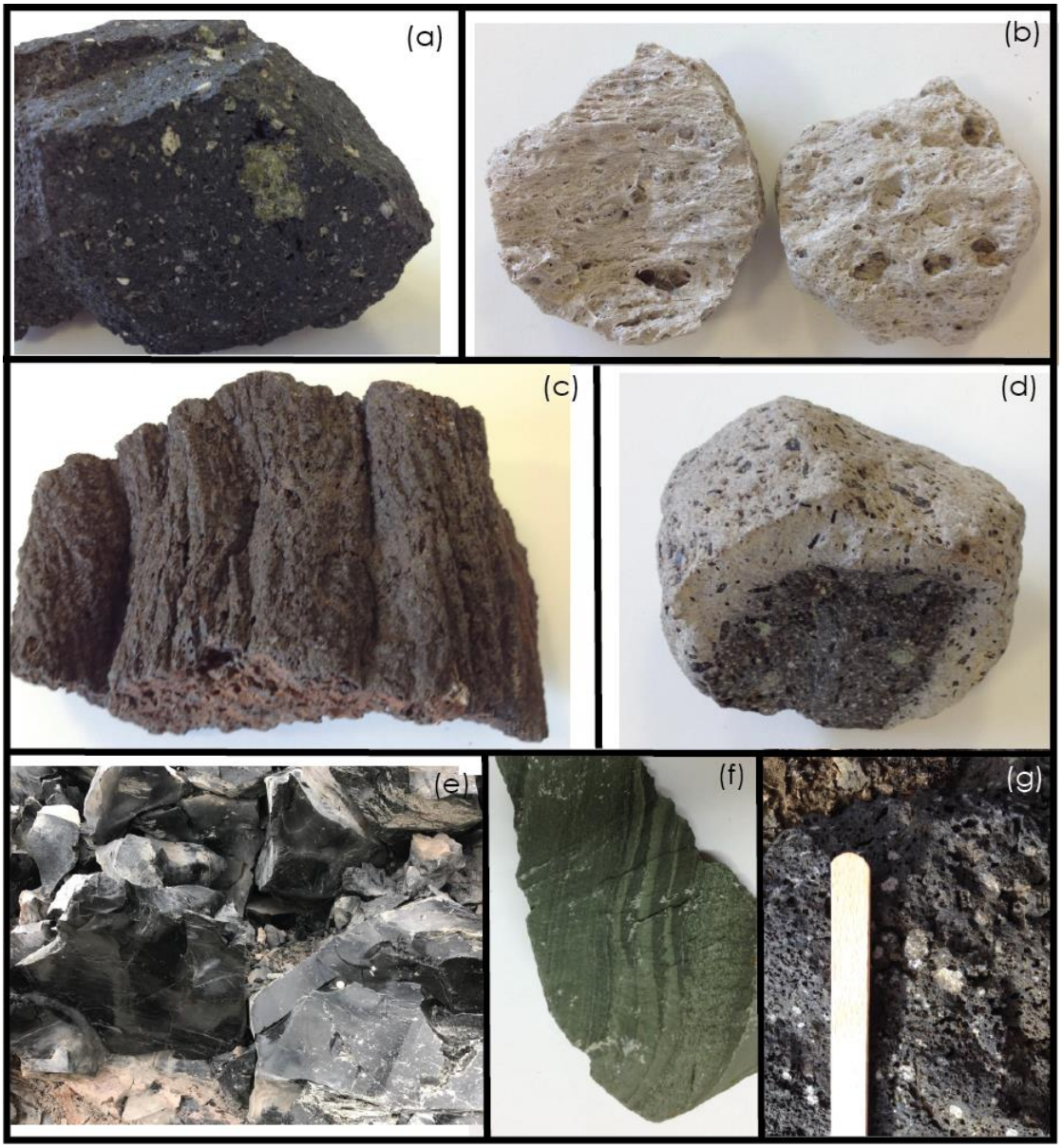


Figure 5: Examples of basalt and rhyolite rocks.

Activity 2: Basalt or rhyolite?

With a partner spend two minutes looking at the photos in figure 5. Decide if you think they are basalt or rhyolite. Be ready to share your thoughts with the group in a few minutes.

Photo	Basalt or rhyolite	Explain why
a		
b		
c		
d		
e		
f		
g		

It is much better to look at the minerals present and/or chemistry of a rock sample to decide what type of rock/magma it is. Figure 4, shows us that basalt and rhyolite have different igneous minerals present. In actual fact there are lot more rock types we could add to figure 4 than just basalt and rhyolite but we are going focus on these two in this course.

Geological Fieldwork

In order to study a rock, a geologist must first sample the rock. They will either do this themselves on field work or perhaps for rarer samples or samples that are hard to access ask other geologists/scientists for access to their samples.

Where to collect the sample during fieldwork has to be carefully considered and will involve looking at previous work, studying geological maps before a decision is made. Once the geologist is happy, they know where they would like to sample, careful preparations for the field trip will be made.

Things to think about when planning a geological field trip may include:

- How will you travel to the location?
- How far are sample sites from transport (will you need to walk kilometres from the nearest road, what other transport options are there)?
- Do you need a local guide?
- What is the local vegetation/wildlife like?
- Do you need to take camping equipment?
- Is the volcano active?
- How much food do you need to take?
- What is the weather like?
- How much are you sampling? Rocks are heavy so if you need to carry them out, you need to work out how to do this.
- Do I need permission to visit the area and sample the rocks?

Figure 6: Geologists conducting volcanic fieldwork in the North Island of New Zealand.

Once geologists have located their sample in the field (figure 6) it is carefully recorded in their field notebook, describing the location, context and description of the rock. This is just the same as when you make observations and measurements in the laboratory during an experiment. Geologists do the same, but out in the field. Most geologists say fieldwork is one of the most fun aspects of their work.

Sample Preparation

In order to analyse rock samples, they must be carefully cleaned and prepared.

For the samples we will look at during this course, the samples were first washed to remove any dirt and dried. For the chemical analyses we are going to consider here, we need to mount small pieces of the sample either on to a glass slide (similar to slides you may have used in biology lessons) or in an epoxy mount (Figure 7).

Figure 7: Stages of sample preparation: (a) an ignimbrite hand sample; (b) scan of an ignimbrite thin section; (c) quartz (clear crystals) and plagioclase crystals (misty crystals) extracted from an ignimbrite sample; (d) a semi-circular epoxy mount with quartz and plagioclase feldspar crystals.

Thin/Polished Sections

Thin sections are thin (30 micrometre) thick pieces of rock glued to a glass slide and polished (figure 7b). Rocks are cut with a rock saw into small blocks. These are then glued onto the slide and ground down to just above 30 μm, before a final polish is given. This means the rock slice is thin enough to let light through, which will be important for mineral identification, and the surface is flat for chemical analysis.

What's the difference between a thin section and a polished section?

- a thin section has a cover slip over the rock sample. This is great for protection and light microscope work, but prevents chemical analysis.
- a polished section has no cover slip, so is suitable for chemical analysis, can be used under the microscope but is open for contamination so must be stored carefully.

Epoxy Mounts

Sometimes geologists may only wish to analyse a part of the sample such as the crystals (figure 7c). Polished sections may have insufficient crystals to be a good representative sample. Instead, lots of crystals are picked from the sample and can be mounted in a circle or semi-circle that is then filled with epoxy (figure 7d). This is then polished in the same manner as a polished section and can be used for chemical analysis. The disadvantage is that you cannot use the same identification techniques for minerals under the microscope as you can with sections. Thus, you have to know what your crystals look like!

Observe, document, classify

No matter whether you are observing a sample in a hand specimen (a piece of rock), or as a section or epoxy mount, we record our observations in a systematic order.

Observe, document, classify

If you were to study geology at A-level or university, you will be taught an in-depth method. Here, we are just going to look at some key features of basalt and rhyolites and the minerals they contain.

First, **observe** just look, what does it look like? Colour, shape, density? Does it change within the sample?

Once you are happy you have observed all you can, then you can **document**. This is when you can record all your observations in a systematic order.

Only and only once you have documented all your observations can you then start to **classify** your samples.

Observations in hand specimen

Table 1 shows some of the key properties of igneous minerals shown in figure 4 that are found in basalt and rhyolite rocks.

Activity 3: Rocks in hand sample

Using table 1. Spend a few minutes looking at figure 8 recording your observations of the highlighted minerals. If you are able try and classify the mineral using table 1. Be ready to share your thoughts with the group in a few minutes.

……

……

……

……

……

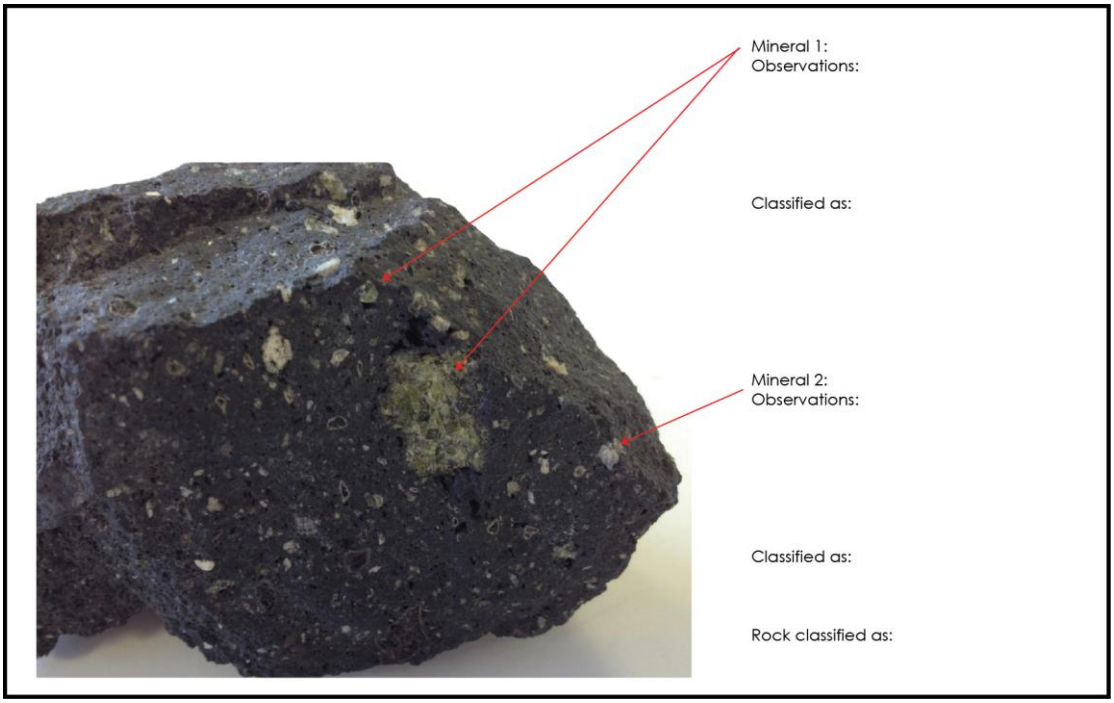


Figure 8: Hand specimen of a volcanic rock sample

How did you find this? Was it easy to identify the mineral from your observations?

It can be really hard. Sometimes experience helps and sometimes we just need more evidence…

So, let's get some more evidence to help identify minerals and hence rock types.

Table 1. Some common properties of minerals you may find in volcanic rocks and how to identify them

Mineral name	Mineral formula	hand specimen	under plane polarised light	under polarised light
Amphibole	$NaCa_2(Mg,Fe)_4Al(Si_6Al_2)O_{22}(OH)_2$	black, brown, dark green	two cleavages at 120°/60° Prismatic crystals Pleochoric - green	
Olivine	$(Fe,Mg)_2SiO_4$	green to yellowish-green	conchoidal fracture, rare cleavage	blues/high intensity yellows
Orthoclase feldspar	$KAlSi_3O_8$	pink/white	two cleavages close to 90°, can be hard to see	greys
Plagioclase feldspar	$NaAlSi_3O_8$ – $CaAl_2Si_2O_8$	white/grey Rectangular shape	two cleavages close to 90°, can be hard to see	often twinned or zoned
Pyroxene	$(Fe,Mg,)_2SiO_6$ $(Ca,Na)(Mg,Fe,Al)(Si,Al)_2O_6$	dark green, brown, black	two cleavages at 90 °	yellows/oranges
Quartz	SiO_2	colourless to pale grey	no cleavage, conchoidal Fractures	grey to pale yellow

Petrographic microscopes

Remember we said thin sections were useful for mineral identification. Well this is because we use a microscope to look at the slide. As the light travels through the sample, the light is bent and refracted. Each different mineral alters the light path differently. Therefore, we can use the resulting observations to identify minerals.

A petrographic light microscope is used for mineral identification. If we allow the light to travel through our sample with no filters, we call it **plane polarised light;** sometimes we will put a polariser in, this often causes amazing pretty colours in the minerals and this is called **polarised light**.

Activity 4

Let's look at some samples underneath a microscope. The next page is left blank so you can record your observations and sketch any interesting crystals.

We are going to use the Virtual Microscope (https://www.virtualmicroscope.org) website. This is a joint venture between The Open University and partners and is an amazing resource. If you have time, you could look at the other samples in your own time. We will also look at some photos of Dr. Saunders' own research samples.

Left blank for notes/sketches of volcanic samples studied.

Activity 5

Now we have looked at lots of samples together. Using your newly gained knowledge of mineral identification see if you can identify the three minerals highlighted in the figure below.

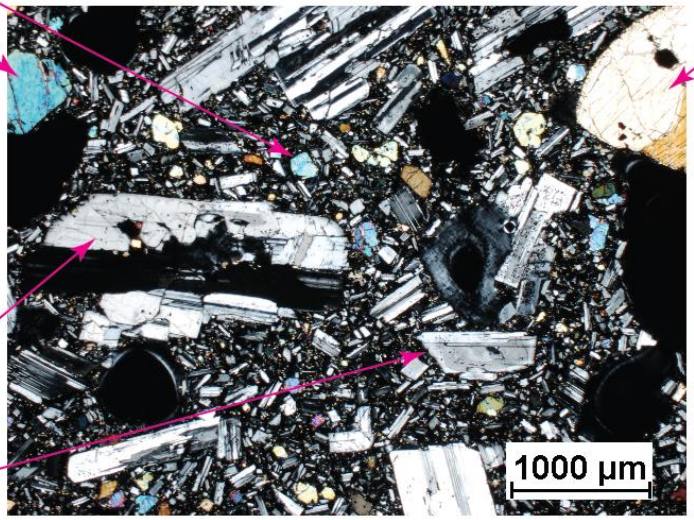
Remember: Observe, document, classify.

Mineral 2:
Observations:

Identification:

Mineral 1
Observations:

Identification:



Mineral 3
Observations:

Identification:

Figure 9: Thin section image of a volcanic rock

Homework: Igneous minerals

1. Which two elements are present in all the minerals?

   ……

2. Complete the following sentences;
   a. State three things you may have to think about when planning geological fieldwork?
      i.

      ii.

      iii.

   b. Thin sections are _____ thick rock sections glued to a glass slide.

   c. The advantage of a polished section allows _____, which a

      cover slip on the thin section prevents.

   d. The advantage of using an epoxy mount for chemical analysis of crystals is

      _____ _____ .

   e. To describe samples you: observe, _____ , _____ .

3. What am I?

   Using your new knowledge of mineral identification can you solve the following riddles?

   a. I have two cleavages at 90°, but these can be hard to see. I contain potassium and often appear pink in hand specimen.

   b. I am the first mineral to form in basalt magmas. I love to fracture and appear to be green to yellow in hand specimen.

   c. My favourite elements are calcium, sodium and aluminium. I am rectangular and often found with twins.

   d. Green is my favourite colour. I have two cleavages at 120/60°.

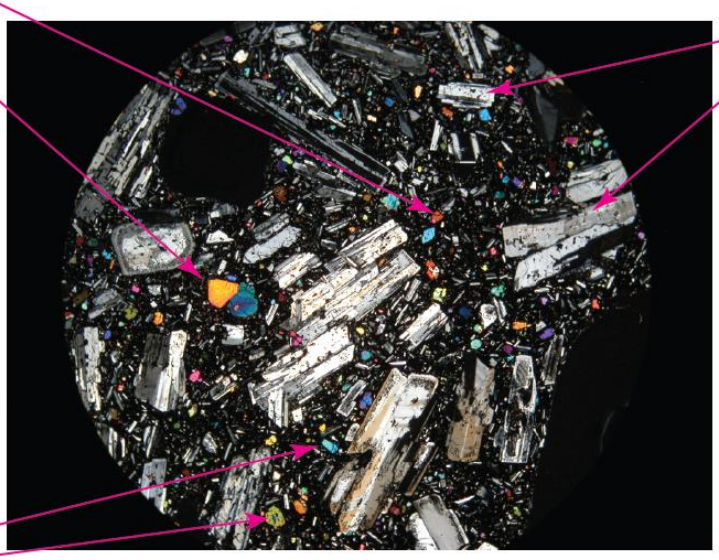
   e. I'm colourless, like to fracture and have few impurities, so almost 100% silica and oxygen.

   f. I have two cleavages at 90°, am dark in nature, with lots of iron and magnesium, but may also invite calcium and sodium to the party.

4. Using your newly gained knowledge can name the minerals highlighted on the below microscope image.

Mineral 2:
Observations:

Identification:



Mineral 1
Observations:

Identification:

Mineral 3
Observations:

Identification:

Figure 10: Thin section image of a volcanic rock from Sumatra.

Tutorial 3 – Active Volcanic Systems

What is the Purpose of Tutorial 3?

- I will be able to provide an overview of volcanoes in New Zealand in the last two million years
- I will be able to describe the generalised plumbing system of a volcano
- I will learn to analyse the chemistry of volcanic crystals to establish how they grow in the magma reservoir

Why do we find volcanoes in New Zealand?

Activity 1

Consider your knowledge of plate tectonics. Spend a few minutes considering why there are active volcanoes in New Zealand. Be ready to share your thoughts with the group.

New Zealand Volcanism

New Zealand is one of the most volcanically active countries in the world. Current volcanic activity is located on the North Island in a region called the Taupo Volcanic Zone (figure 11) or TVZ for short. The TVZ has been volcanically active for the last 1.6 million years and has experienced many small and some really large volcanic eruptions.

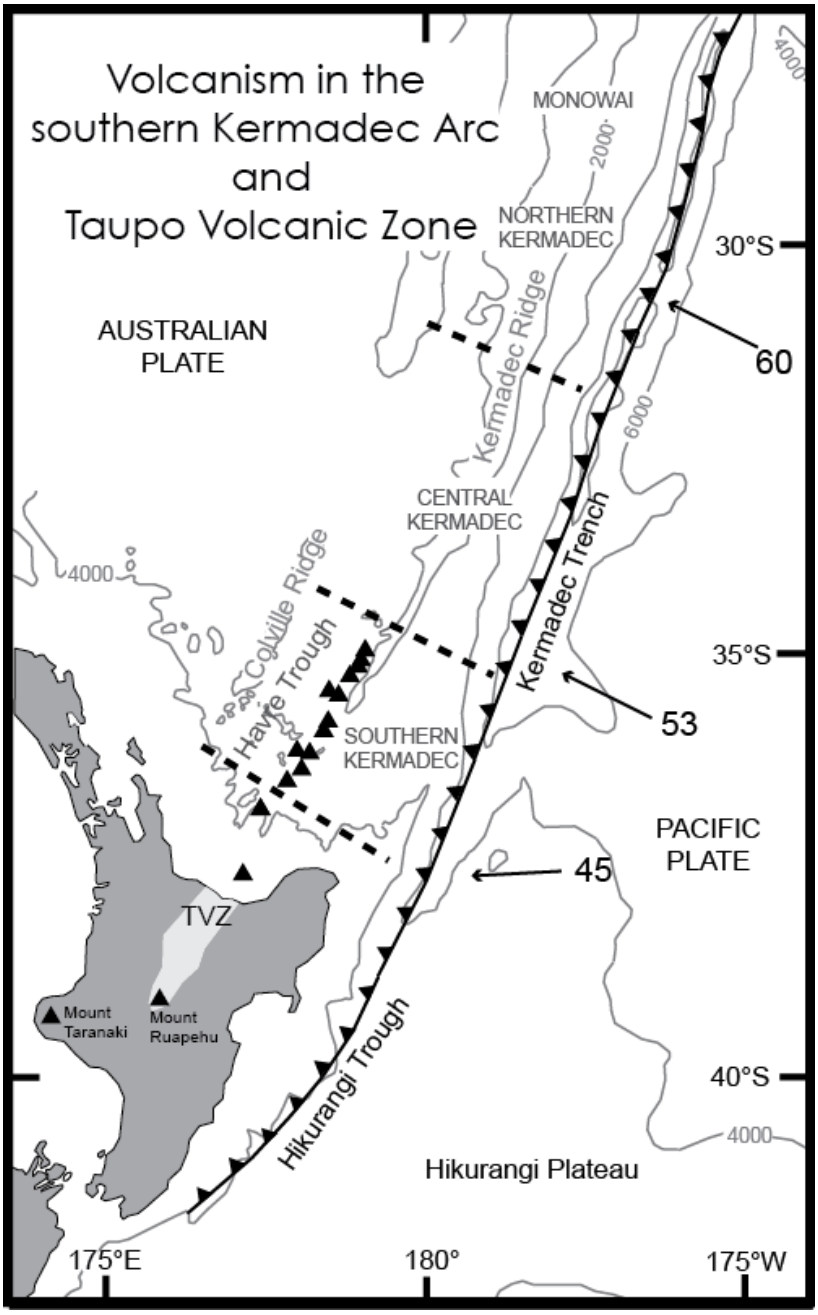


Figure 11: Overview of volcanism and arc in the North Island of New Zealand. Black triangles depict active volcanic centres (not all shown). Adapted from Saunders (2009).

It is these really large eruptions this area of New Zealand is known for. These are caldera volcanoes (the crater of these volcanoes form depressions and are often filled with a lake e.g. figure 2b). Such eruptions are potentially devastating, destroying large areas. As humans we have not witnessed such large eruptions but can see they occur from the geological record (rocks we can see in the landscape). These types of eruptions can produce large volumes of rhyolite (think 500-1000 km^3 of rock erupted), erupted as pyroclastic flows which blanket the whole landscape, destroying everything in its path and depositing a rock known as an ignimbrite (figure 12).

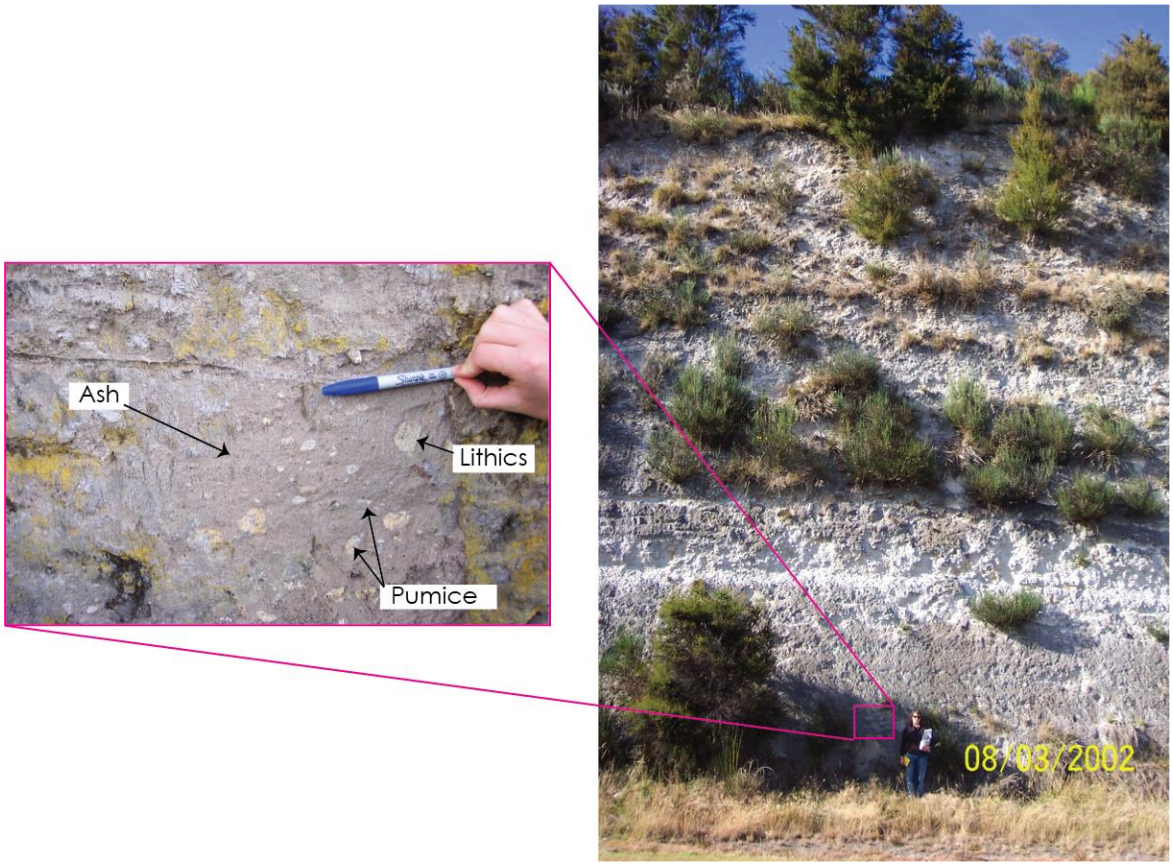


Figure 12: Ignimbrite deposit in the field from the 26.5 Oruanui eruption, TVZ. Note the person for scale. Close up of an ignimbrite texture in the field.

In the TVZ, eight caldera centres have been recognised, with over 25 caldera-forming eruptions over the last 1.6 million years (Wilson et al., 2009). Dispersed between these eruptions are many smaller eruptions, erupting basalt and andesite (a composition mid-way between basalts and rhyolites), from multiple volcanoes throughout the region. It is these smaller volcanoes that are likely to pose a greater volcanic hazard on a historical timescale.

Activity 2: Volcanoes of the Taupo Volcanic Zone

Now we have discussed the different volcanic centres. On the diagram below, complete the missing information about the different volcanoes.

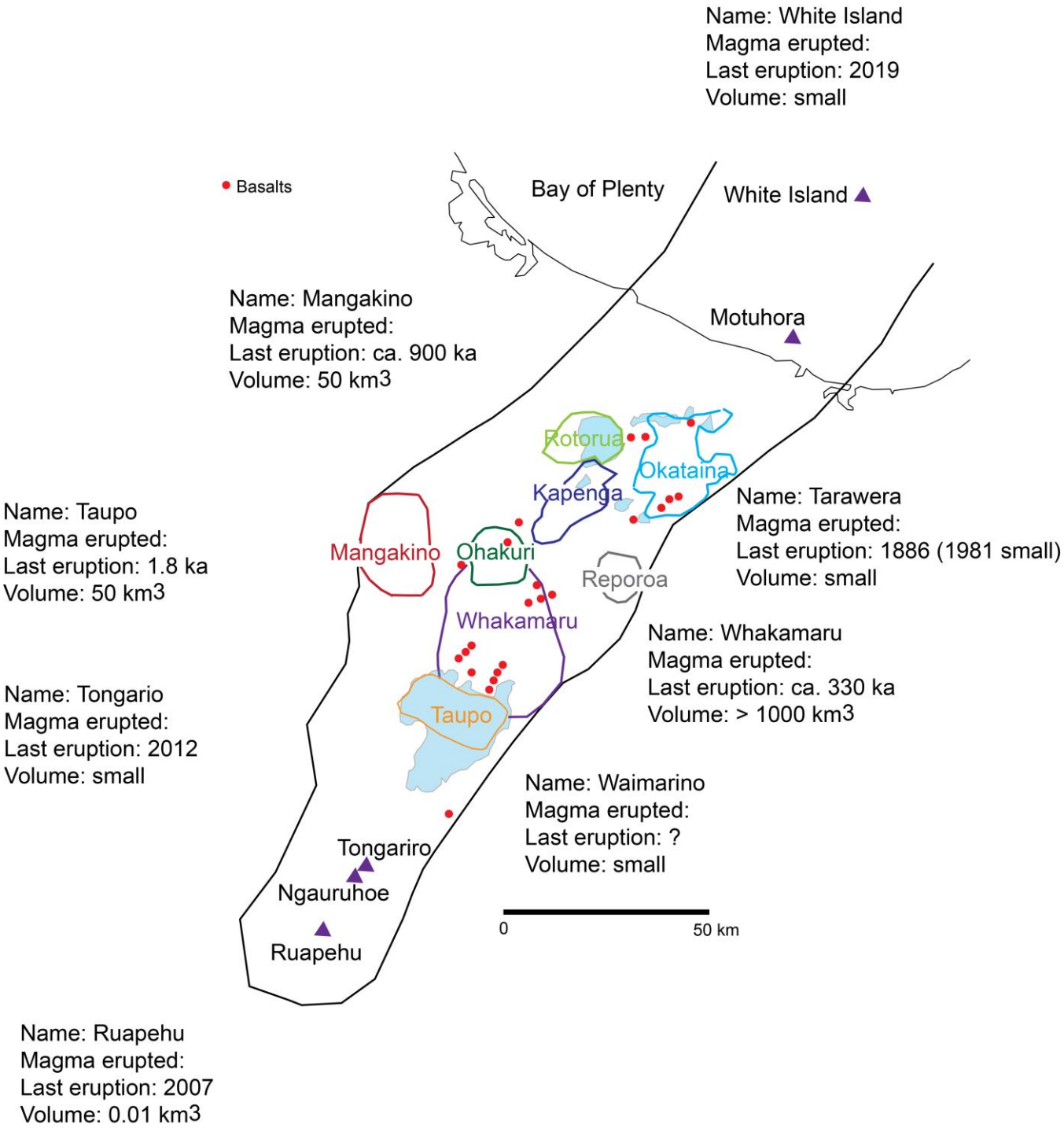


Figure 13: Overview of some of the major volcanic centres in the TVZ.

Volcanic Plumbing Systems

Have you ever wondered what the inside of a volcano looks like and how it works? If Volcanologists knew this, it would greatly assist in forecasting future eruptions.

It is not possible to get inside active volcanoes directly, but we can use proxies to probe them. For example, earthquakes can be used to track where the magma is in the crust. We can also use the chemistry of different parts of the magma to determine the processes occurring beneath a volcano, such as the temperature, pressure and depth of this magma. We will look at this more in a moment.

One great source of information on the internal structure of volcanoes is to look at extinct volcanoes. These volcanoes tend to be old, so time has occurred for erosion to occur, this can if we are lucky dissect a volcano. Thus, we can walk right inside the magma chamber, make observations and interpret the data. The best thing to do if possible is to combine all the lines of evidence we have available to build the most detail picture of the internal structure of a volcanic plumbing system we can.

Magma Chemistry CSI

Magma grows and evolves in the crust beneath our active volcanoes (see figure 1). Magma will ultimately start to form in small volumes in the mantle, but will evolve and accumulate larger volumes as it migrates through the crust. The rising magma will be hot (anywhere from 700-1200°C) and is warmer than the surrounding crust. This means if the magma is resident in the crust it promotes melting of the surrounding rock, increasing the volume of magma. New magma batches may be sent episodically from the mantle further increasing the volume of magma in the crust.

The migration of magma is, however complex and the composition of the magma will change. The magma chamber is a dynamic environment; with many different processes occurring continuously changing the composition of the magma. The earliest magma composition will often be erased, overprinted by new compositions.

The ideal scenario would be if there were a part of the magma that recorded the composition throughout the magma evolution that is preserved and then erupted. This is where the crystals in the magma are key. Different crystals grow at different stages of the magma evolution (figure 14). Thus, if we can chemically fingerprint the different parts of a volcanic crystal it may just be possible to unravel the chemical composition of the magma from the earliest stages through to eruption.

Activity 3: When and where do crystals grow?

a) Add arrows to the diagram in figure 14 to show where the different crystal types are likely to grow beneath the volcano.
b) Add arrows (in a different colour) to show where the different melt inclusions may be trapped.

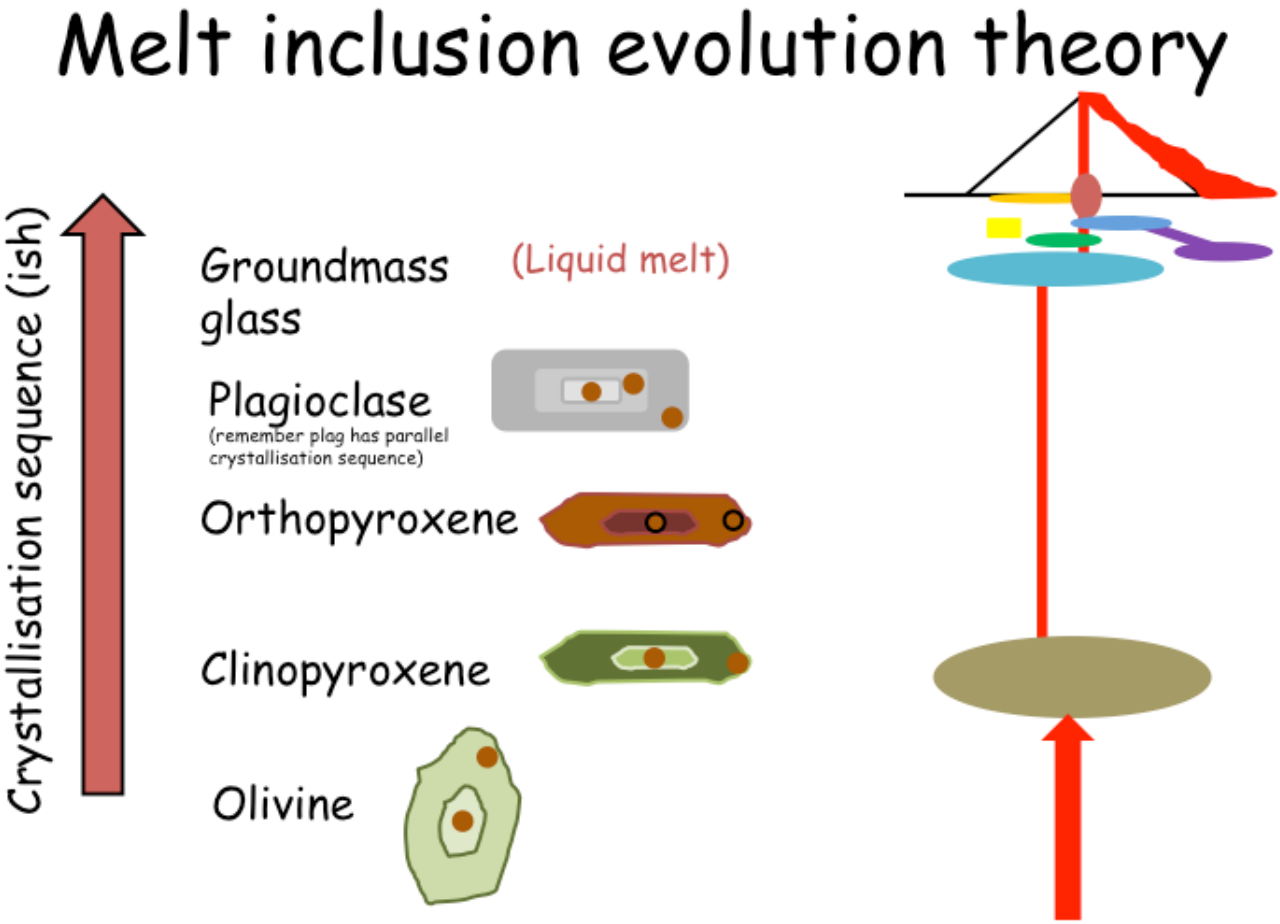


Figure 14: Cartoon showing the timing of different crystal growth and melt inclusion in a volcanic plumbing system

The life cycle of a crystal is complex involving periods of growth, melting, migration and periods of residence in different magma bodies, until the crystal is eventually erupted and the composition is frozen in. Each of these experiences is frozen in as either chemical or textural markers (figure 15).

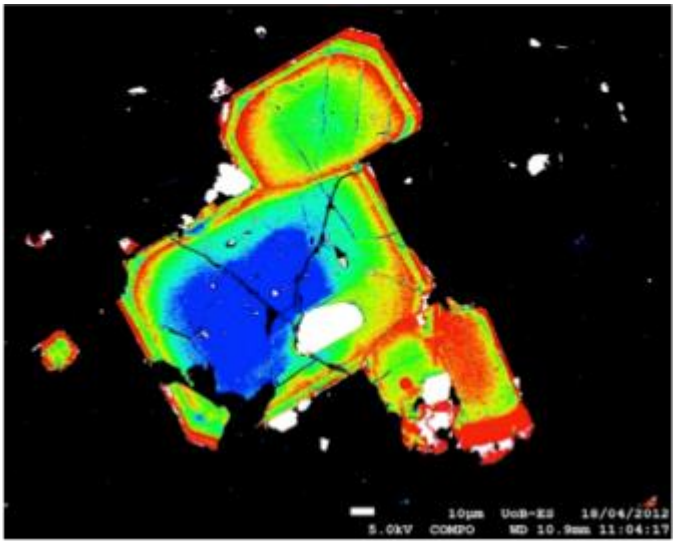


Figure 15. False coloured image of a zoned pyroxene crystal from the 1980 eruption of Mount St. Helens. The blue colours are more magnesium rich and red colours more iron rich. Each zone represents a different part of the crystal's evolution.

If we can learn to read these signals we should be able to unravel the chemical evolution of magma and hence draw a picture of the sub-volcanic magma system. If, we are really lucky during a crystal's growth, a bubble of melt may be trapped (figure 16). These bubbles represent the composition of the melt at the time they were entrapped. Once sealed the melt composition inside these bubbles are protected from changes occurring in the external melt and can provide a window into past melt compositions. These bubbles are called melt inclusions, are small often less than 100 μm and can be fundamental to unravelling the changing composition of a melt through time.

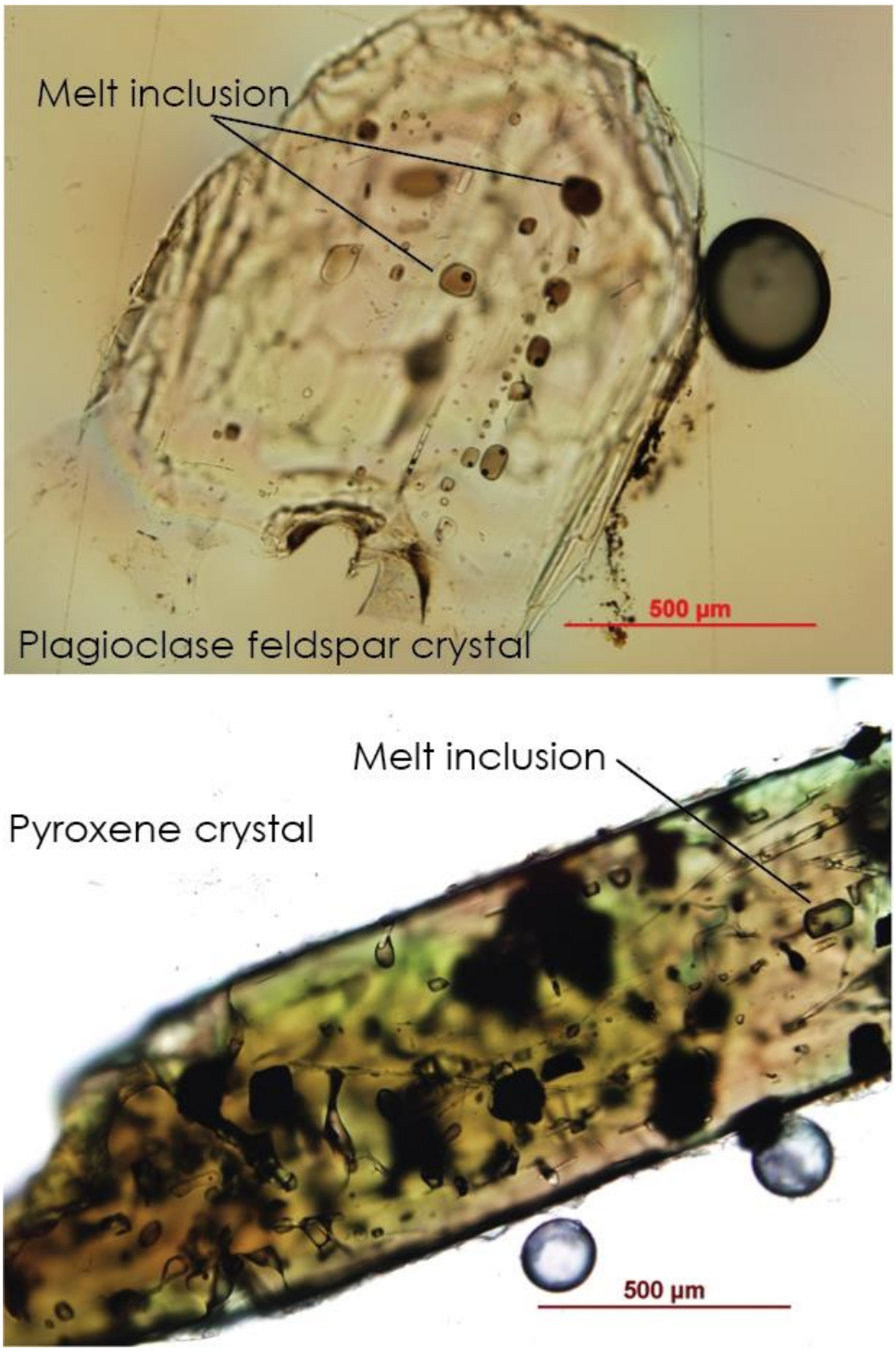


Figure 16: Melt inclusions trapped in plagioclase and pyroxene crystal from the Taupo Volcanic Zone.

Homework: Chemistry of volcanic rocks

Determine if the following statements are true or false. If false write in the correct answer.

1. The first magmas to form deep in the mantle are iron and magnesium rich.

2. Rhyolite magmas are rich in silica, potassium and water.

3. Groundmass glass represents the last melt composition immediately prior to eruption.

4. Basaltic magmas are hot when they are erupted (1000-1200 °C).

5. Olivine is the last type of crystal to grow deep within the magma system.

6. Plagioclase can grow throughout the sub-volcanic plumbing system.

7. Melt inclusions are trapped bubbles of melt.

References

Saunders, K.E. (2009) Micro-analytical studies of the petrogenesis of silicic arc magmas in the Taupo Volcanic Zone and southern Kermadec Arc, New Zealand. PhD thesis, Victoria University of Wellington, Wellington.

Wilson, C.J.N., Gravley, D.M., Leonard, G.S. & Rowland, J.V. (2009). Volcanism in the central Taupo Volcanic Zone, New Zealand: tempo, styles and controls. In: T. Thordarson, G. Larsen, S. Self, S. Rowland & A. Hoskuldsson (Eds.) Studies in Volcanology: The Legacy of George Walker, (Special Publications of IAVCEI 2, 225–247). London, UK: Geological Society.

Tutorial 4 – Using chemical data of active volcanoes

What is the Purpose of Tutorial 4?

- I will be able to interpret chemical data of volcanic rocks to determine the depth at which they grew beneath the volcano
- I will be able to integrate the results of the chemical calculations with my prior knowledge of volcanic plumbing systems to image the magma chamber

Volcanic chemical data

In the last tutorial we saw how we could use different parts of magma to start to deduce how it is formed. Today, we are going to do some quantitative calculations to put numbers to our observations.

Samples are analysed through a variety of techniques to determine the chemical composition. The most common techniques used in petrology (the study of the composition of rocks) involve firing a beam of ions or x-rays at the surface of the sample and measuring the behaviour of the refracted beam. Each technique has its unique features and you choose the one most suitable for your sample and the element/s you wish to measure.

For chemical analysis of our volcanic crystals and melt inclusions they would typically be analysed by electron probe micro-analyser (EPMA) for major elements, secondary ion mass spectrometry (SIMS) or laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) for trace elements and SIMS or Fourier transform infrared spectroscopy (FTIR) for water and carbon dioxide (figure 15). These techniques allow us to measure samples down to 5-10 µm, although we trace elements a sample size of 30 µm plus would be preferred.

Figure 17: Instruments used to chemical analyse crystals in volcanic samples. (a) EPMA at Victoria University of Wellington, New Zealand (this EPMA was about 30 years old and replaced with a new one a few months after this photo was taken); (b) LAICPMS at Victoria University of Wellington; (c) FTIR at JAMSTEC, Japan.

Major elements compose 99.9% of the sample and include elements such as Si, Ti, Al, Mg, Fe, Ca, Mn, K, Na, P. Normally in geology these will be given as element oxides, e.g. SiO_2. Trace elements compose the other 0.1 % and include alkali metals, transition metals and rare earth elements for example. As the concentration are so low, these elements are typically reported as parts per million (ppm).

Temperature and Pressure of magma

Two of the fundamental properties of magmas are the temperature and pressure. These properties can be calculated by a variety of methods. The most common methods involve analysing the chemical composition of crystals, melt, melt inclusions and then using the behaviour of different elements between two or more of these magmatic components to determine the temperature, pressure or both.

Depth of crystallising magma body

Melt inclusions are small bubbles of melt trapped within a crystal. The surrounding crystal acts as a pressurised vessel. If the crystal and melt inclusion is not broken during eruption it is possible to use the chemical composition of the melt inclusion to calculate the depth at which the melt inclusion was trapped. This allows us to in turn work out the depth of the crystallising magma.

Magmatic water concentrations

Volcanic eruptions are triggered when the pressure inside the magma chamber exceeds the surrounding pressure controlled by the surrounding crust. One of the ways pressure builds up in magma is from magmatic volatiles dissolved in the magma; the most common being H_2O and CO_2. As magma migrates through the crust towards the surface, these volatiles exsolve (come out of solution), form bubbles and can increase the pressure in the magma chamber. On eruption, the magma rapidly degasses, leaving no record of the magmatic volatile concentration pre-eruption.

Melt inclusions, as they are isolated from the melt in a pressurised vessel (the crystal), can be used to measure volatile concentration of the magma pre-eruption. This means not only can we work out the concentration of volatiles pre-eruption but also, we can use this information to work out the pressure the melt inclusions became trapped at and hence the depth of the magma from equation 1.

$$\text{Pressure (P)} = \rho g h \qquad [1]$$

Where pressure is in Pascal's, ρ is density in kg/m^3, h is depth in metres and g is gravity (9.81 ms^{-2}).

Activity 1: Pressure, water and depth calculations of melt inclusions

Using the data in the table 2 from Sholing volcano calculate the depth at which the following melt inclusions (MI) were entrapped and hence the depth of the crystallising magma body at the time the crystals were growing in the magma.

For all calculations use a crustal density of 2700 km/m^3.

Table 2: Pressure data of melt inclusions in Sholing Volcano

Crystal type	Location of MI	Pressure (bars)	Pressure (Pascals)	Depth (km)
olivine	core	1453		
olivine	rim	1324		
pyroxene	core	1298		
pyroxene	rim	893		
plagioclase	core	1285		
plagioclase	middle	875		
plagioclase	rim	665		
quartz	core	689		

Activity 2: Cartoon cross section of Sholing volcano

Once we have a set of data, it is imperative we find a concise, simple and effective way to present the data for others. Images are often a good way to do this in volcanology.

Using your knowledge of volcanoes, the data in table 2 and additional data below. Draw a cartoon cross-section in the box below. Use colours, annotations and remember this is a scientific drawing and not an artistic drawing, it does not have to be perfect.

Dr. Saunders performed some temperature calculations from the volcanic crystals from Sholing volcano. She found that olivine-melt resulted in temperatures of 1065 °C; plagioclase rim-melt pairs of 820 °C and Ti-in-quartz of 760-830 °C.

Homework: Media and Science

1. Write down all the places where you or your family get news from.

2. For many of the media sources you noted down above, most will use headlines to attract you to an article. Have a look at three media science articles with headlines that attract you. Have a quick read of them and then choose one to study in detail.

3. Read the headline and then the article. Ensure you are looking at science articles. Note down below, your thoughts on the following. Be ready to discuss them at the next tutorial.

    a. Does the headline accurately reflect the full article? If, so why? If not, why is this?
    b. Does the headline exaggerate the study? Is it selective about the study?
    c. Does the article, cite the scientific study it is reporting on?
    d. If the scientific study is cited. Can you easily access the study? Try and find it online if you can, don't worry if you cannot or it is behind a pay wall.

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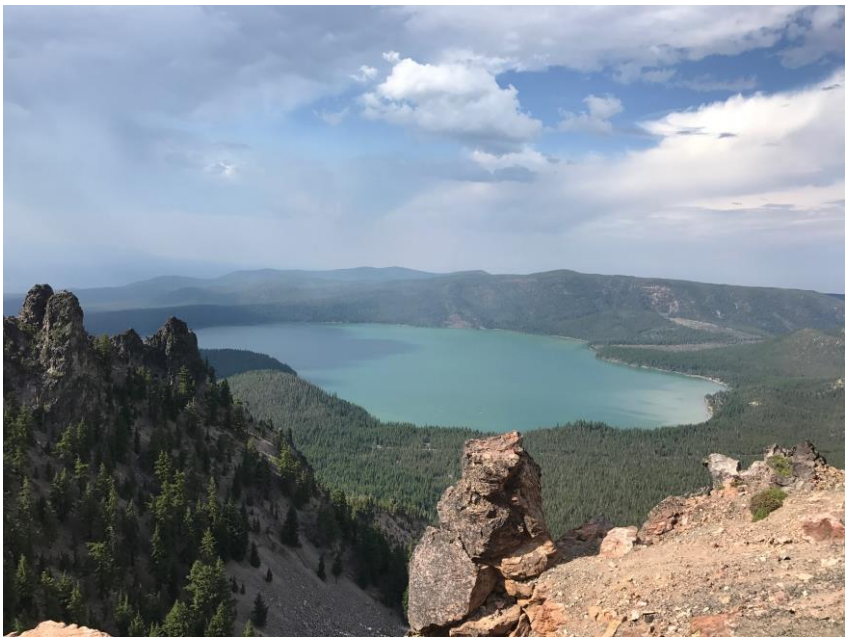
Tutorial 5 – Science, science and more science



What is the Purpose of Tutorial 5?

- I will be able to explain the structure of a scientific report
- I will be able to extract key facts from a piece of scientific writing
- I will know how to correctly reference external sources

Over the last few weeks we have built up a dataset about volcanic rocks, learning how to identify them, the minerals they contain; and key magma properties. This is all great, but now you to need to advertise the results of our studies to others.

Scientists publish their research in science journals. Think about your favourite magazine that you enjoy reading. Science has magazines, which we call journals. These journals are focused on science topics. Some such as Nature or Science feature studies from all field of science; other journals will be specific to one discipline.

Generally anyone can submit an article to be considered for publication in a journal. However, before these are published, the article is sent to other scientists to review it, this is called peer-review. If the scientists reviewing the article agree the science is good it can be published. Sometimes these scientists will ask for revisions, or more work. They can even recommend the article is not published. Science articles published in this way are considered a reliable source of information on a topic. The general format of a science report is given in appendix 2.

Activity 1: Science in the media

For homework, you looked at science reporting in the media. Let's see what we thought about this.

Were headlines useful? Were the scientific articles reported fairly? Were they biased, exaggerated, or fairly reported? Record the thoughts of the group below.

Now let's think why this may be. Have a chat with your partner and think about why the media may portray science as such. Be ready to share your thoughts with the group in a few minutes.

Activity 2: Reading scientific articles

Scientific articles are full of useful information, but there are many articles published per week and no one has time to read them all. Therefore, scientists must prioritise those they read, but also need to learn how to read them to gain the information they required in a concise manner.

With your partner look at the journal extract you have been given. Spend a few minutes, reading it. Consider the following:

Do you understand it?
Is there too much new terminology?
Can you answer the questions given on your extract?

Note your thoughts in the box below and be ready to share in a few minutes.

Activity 3: Referencing

You may have noticed that in your extracts many of them had "(Saunders et al., 2012)" in brackets at the end of a sentence for example. This is a reference to the study from which the information was gained.

Anything that is not your own work, you must reference the original source (as Appendix 1). This is to give the person/group credit for their work and so others do not steal/gain credit for work that is not their own. It is really important and you may have heard or hear in the future of plagiarism (this is when you take the work of others and try and pass it off as your own).

Think about this course, can you list some of the references/sources Dr. Saunders has used? Take a few minutes looking back through the workbook and/or think about the PowerPoints.

Note down any references you can find and/or remember in the box below.

Final Assignment:

Probing inside Whakamaru Volcano, New Zealand

During the course we have used lots of case studies from many different volcanoes from around the world. You have learnt how erupted volcanic rocks can be used to see inside the volcano, assess the conditions of the magma chamber and to consider whether it is likely to erupt or not.

For your final assignment you are going to use data from the Whakamaru Volcano in the North Island of New Zealand.

Assignment

A sample and pressure data from the Whakamaru volcano are given below in figure 18 and table 3. Using this data, the local nearby town council has asked you to prepare a report outing the conditions inside the Whakamaru volcano during the last eruption.

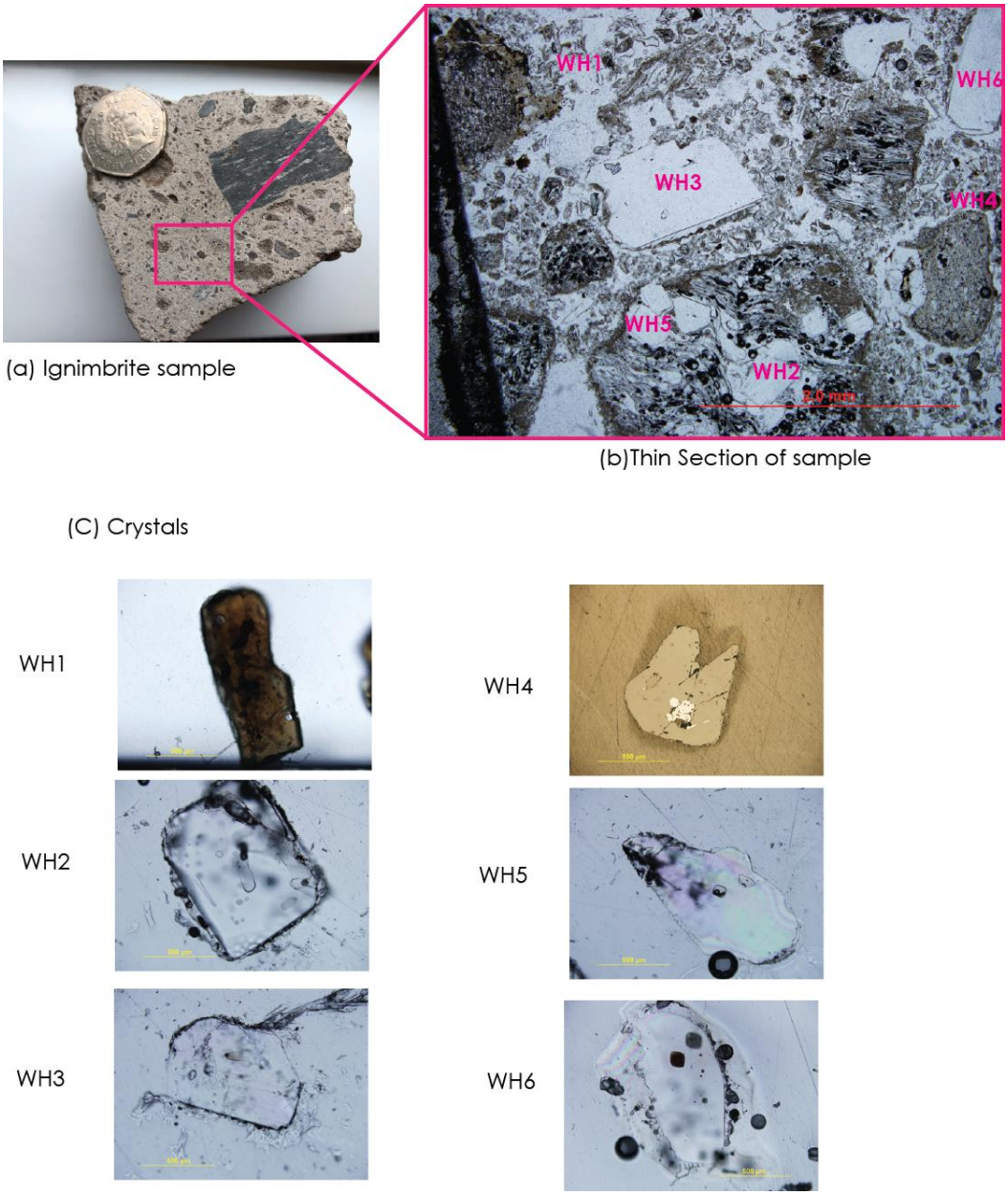


Figure 18: Sample from the Whakamaru Volcano; (a) hand specimen; (b) thin section and; (c) images of crystals

Table 3: Data from the Whakamaru Volcano for use with final assignment		
Crystal ID	Properties under the microscope	Pressure (bars)
WH1	90° cleavage, pale orange colour in cross polars	769
WH2	Colourless, fractures	696
WH3	Grey, cleavage, zone or twins observe	1114
WH4	90° cleavage, pale orange colour in cross polars	1098
WH5	Grey, cleavage, zone or twins observe	658

Assume the crustal density is 2700 kg/m^3

Your report should be approximately 2000 words (6-8 pages) and structured as a scientific report, as detailed in Appendix 2.

Copies of photos/images we have used in tutorials can be obtained on request.

Success criteria

- Using your new scientific knowledge of volcanic processes summarise why studying them is important.
- Use your knowledge of crystal identification using a microscope to show which crystals are present in the erupted rocks of the Whakamaru volcano.
- Calculate the depth of the magma from the given chemical data for the Whakamaru volcano.
- Discuss the results of your calculations about the Whakamaru magma to estimate how deep the magma is stored below the surface.
- Justify all your assumptions/ideas with evidence in your text and/or diagrams.
- Include diagrams/figures where suitable to justify your ideas, such as summary diagram of the Whakamaru volcano and magma chamber.
- Remember to reference any sources of information you have obtained from external sources.

Tutorial 6 – Feedback tutorial

What is the Purpose of Tutorial 6?

- To receive feedback on your final assignment
- To respond to the feedback from your Uni Pathways teacher
- To write targets for improvement on your final assignment

Final assignment feedback from your Uni Pathways Teacher

(Remember to look at the mark scheme to help you understand what you have done well so far, and how you can do even better in your final assignment)

Here are three things that my Uni Pathways Teacher thought I did well in my draft assignment
•   •   •

Here are three things that my Uni Pathways Teacher thinks that I could do to get a higher mark in my final assignment
•   •   •

Tasks from my Uni Pathways Teacher to do during the feedback tutorial to help me improve
•   •   •
My response:

Actions I will take to improve my final assignment after this tutorial…
•   •   •

Hand in date for my final assignment:	

Tutorial 7 – Final tutorial

What is the Purpose of Tutorial 7?

- To receive feedback and a grade on your final assignment.
- To reflect on the programme including what you enjoyed and what was challenging.
- To ask any questions you may have about university.

Final assignment feedback from my Uni Pathways Teacher

Final mark:	University style grade:
Feedback: Here are three things that my Uni Pathways teacher thought I did well in my final assignment • • •	

Here are three things that my Uni Pathways teacher thinks I should remember for when I am doing this kind of study in the future
• • •

University

What questions do you still have about University after taking part in Uni Pathways?
• • •

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?
• • •

What did you find challenging about the programme?	How did you overcome these challenges?
• • •	• • •

Appendix 1 – Referencing correctly

When you get to university, you will need to include references in the assignments that you write, so we would like you to start getting into the habit of referencing in your Brilliant Club assignment. This is really important, because it will help you to avoid plagiarism. Plagiarism is when you take someone else's work or ideas and pass them off as your own. Whether plagiarism is deliberate or accidental, the consequences can be severe. In order to avoid losing marks in your final assignment, or even failing, you must be careful to reference your sources correctly.

What is a reference?

A reference is just a note in your assignment which says if you have referred to or been influenced by another source such as book, website or article. For example, if you use the internet to research a particular subject, and you want to include a specific piece of information from this website, you will need to reference it.

Why should I reference?

Referencing is important in your work for the following reasons:

- It gives credit to the authors of any sources you have referred to or been influenced by.
- It supports the arguments you make in your assignments.
- It demonstrates the variety of sources you have used.
- It helps to prevent you losing marks, or failing, due to plagiarism.

When should you use a reference?

You should use a reference when you:

- Quote directly from another source.
- Summarise or rephrase another piece of work.
- Include a specific statistic or fact from a source.

How do I reference?

There are a number of different ways of referencing, and these often vary depending on what subject you are studying. The most important to thing is to be consistent. This means that you need to stick to the same system throughout your whole assignment. Here is a basic system of referencing that you can use, which consists of the following two parts:

1. **A marker in your assignment**: After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written it your own words) you should mark this is in your text with a number, e.g. [1]. The next time you use a reference you should use the next number, e.g. [2].
2. **Bibliography**: This is just a list of the references you have used in your assignment. In the bibliography, you list your references by the numbers you have used, and include as much information as you have about the reference. The list below gives what should be included for different sources.

    a. **Websites** – Author (if possible), title of the web page, website address, [date you accessed it, in square brackets].

    E.g. Dan Snow, 'How did so many soldiers survive the trenches?', http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [11 July 2014].

    b. **Books** – Author, date published, title of book (in italics), pages where the information came from.

    E.g. S. Dubner and S. Levitt, (2006) *Freakonomics*, 7-9.

    c. **Articles** – Author, 'title of the article' (with quotation marks), *where the article comes from* (newspaper, journal etc.), date of the article.

    E.g. Maev Kennedy, 'The lights to go out across the UK to mark First World War's centenary', Guardian, 10 July 2014.

Appendix 2: How to structure a scientific report

Below is a typical structure for a scientific report in the Earth Sciences.

Title	Think of an informative, yet interesting title.
Abstract	This is a summary of the report, briefly include why this report is important and key finding (about 50-100 words).
Introduction	Summarise why it is important to study volcanoes and how we can use chemistry to investigate the conditions in a magma chamber (500 words)
Methods	Here, briefly describe how you would prepare rocks for analysis, how you identified the different crystals, and the equations you used to calculate properties (about 150 words).
Results	Describe the data results and calculations you performed for the Whakamaru volcano, but do not interpret them as this is the discussion (about 150 words).
Discussion	This is where you interpret your results and draw any conclusions you can about them. Here, is where you can show all your scientific knowledge and discuss your opinions on the data and what it shows us (about 500-800 words).
Conclusions	What are the key findings? (100-200 words).
References	Include any sources of information you have used to write this report, that are not from your own knowledge (words here are not included in the word count ☺)

Notes

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