A Resource Booklet for SACE Stage 1 Earth and Environmental Science

The following pages have been prepared by practicing teachers of SACE Earth and Environmental Science. The six Chapters are aligned with the six topics described in the SACE Stage 1 subject outline. They aim to provide an additional source of contexts and ideas to help teachers plan to teach this subject.

For further information, including the general and assessment requirements of the course see: https://www.sace.sa.edu.au/web/earth-and-environmental-science/stage-1/planning-to-teach/subject-outline

A Note for Teachers
The resources in this booklet are not intended for 'publication'. They are 'drafts' that have been developed by teachers for teachers. They can be freely used for educational purposes, including course design, topic and lesson planning. Each Chapter is a living document, intended for continuous improvement in the future. Teachers of Earth and Environmental Science are invited to provide feedback, particularly suggestions of new contexts, field-work and practical investigations that have been found to work well with students. Your suggestions for improvement would be greatly appreciated and should be directed to our project coordinator:: lenaltman9@gmail.com

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SOUTH AUSTRALIA

Government of South Australia
Department for Energy and Mining

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Earth and Environmental Science, Stage 1

Topic 2: Composition of the Geosphere

This topic will introduce you to the geosphere, the solid part of the Earth. Y0u will investigate how minerals are classified and used according to their properties, while rocks are classified according to their origins through igneous, sedimentary, and metamorphic processes, as well as according to their compositions and textures.

The Geosphere

The geosphere considers the earth as a whole, from inner core to outer core.

- Inner core is solid due to gravity and extreme pressure.
- Outer core is liquid, mostly considered the reason for our magnetic field.
- Mantle is a hot, dense semi-liquid magma composition. The heat from the outer core causes convection currents in the mantle. These convection currents move plates and support the theory of continental drift.
- The topmost part of the mantle is the ***asthenosphere***, which sits right underneath the crust and is forced onto the surface during volcanic activity and divergent plate movement.
- The crust, or lithosphere, consists of two main parts: the Oceanic crust, and Continental crust.

Draw a section of the Earth, representing all layers. Research the relevant chemicals and minerals found in each layer.

Diagram	Layer	Chemical/mineral found

The geosphere consists of rocks and regolith.

Rock ……

………

Regolith ……

………

2.1 Minerals

Minerals are constituents of the geosphere and are classified according to their chemical composition.

- *A mineral is a natural, inorganic solid with a specific internal structure and chemical composition.*
- All rocks are made up of minerals. Most rocks are mixtures of minerals, although some rocks consist essentially of a single mineral.
-
- Each mineral type has a specific chemical composition.
- Each mineral has its own physical and chemical properties that make it unique.
- Over 2, 000 minerals make up the Earth's crust and mantle, but only about 9 of them are common

A mineral is a naturally occurring, solid element or compound with a definite chemical composition and an ordered arrangement of atoms. It is capable of crystallising under the right conditions. .

A mineral must have the following characteristics.

- Solid
- Naturally occurring
- Inorganic
- Definite chemical composition
- Regular Internal structure

Minerals must have a crystalline structure that consists of a repetitive structure involving a regular arrangement of atoms. Crystals have a wide variety of different shapes.

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Experiment: Minerals and Rocks

Aim: to examine the properties of some minerals and rocks, and hence determine the relationship between minerals and rocks.

Requirements:
Hand specimens of the minerals: quartz, biotite mica and a feldspar, and of the rock granite also specimens of calcite and conglomerate, ahand lens or other magnifier.

Lustre
The **lustre** of a mineral is a description of how a freshly broken surface of the mineral shines when it is exposed to light.
To find the lustre of a mineral specimen, rotate the specimen until light is shining on a freshly broken surface
Three terms that may be used to describe the lustre of a mineral are:

__________________ meaning that ____

__________________ meaning that ____

__________________ meaning that ____

Procedure
1

Ex
amine your hand specimens of the three minerals, quartz, biotite, mica and feldspar. Note their colours and lustres (how they shine) and any special features.

E
nter your observations in the **RESULTS** table below.

Results

NAME OF MINERAL	COLOUR	LUSTRE	ANY SPECIAL FEATURES

2. Use your hand lens to examine a specimen of the rock granite. Describe the appearance of the granite.

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3. Suggest a connection between the granite and the mineral specimens you have already studied.

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4. Suggest how minerals are related to rocks

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5. Examine the specimens of calcite and conglomerate. Decide whether each is probably a mineral or a rock.

Calcite is probably a ___________ because ____

____

Conglomerate is probably a ___________ because ______________________________________

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Special features of minerals

1 Suggest one or more reasons why mineralogy – the study of minerals – is a very important topic in Geology.

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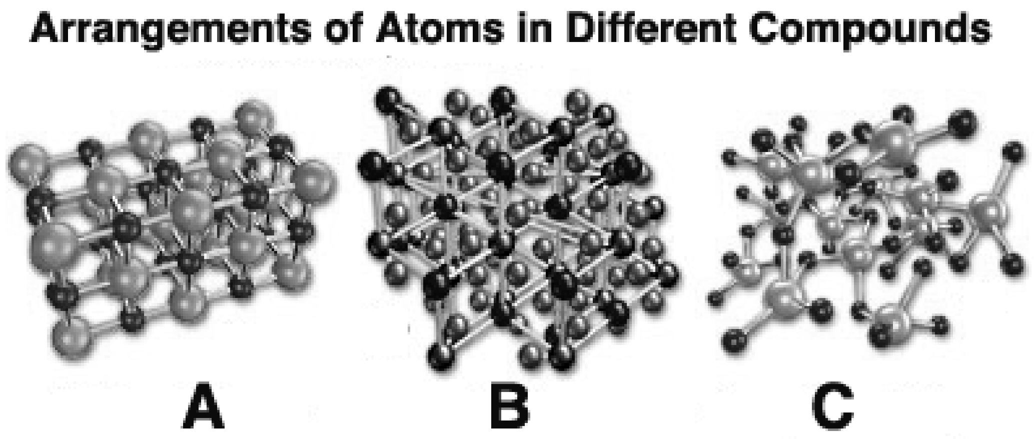
2 Suggest five properties that must be possessed by a substance defined as a mineral by crossing out the incorrect words in the following sentences:

a. A mineral (must be a solid/can be a solid, liquid or gas)
b. A mineral (can be a mixture of many substances/ must consist of a single substance)
c. The atoms within a mineral (must be arranged in an orderly fashion/ can be arranged randomly)
d. A substance made my humans may be a mineral/a mineral must be a naturally occurring substance
e. Minerals are formed by (either living organisms or non- living Earth processes/ only by non-living Earth processes).



3 Which of the above diagrams does **not** show the internal structure of a mineral?

4 Examine a specimen of fossiliferous limestone. State, giving reasons, whether you think fossiliferous limestone is a mineral.

5 In the left-hand column of the table below, write the five mineral properties you have already discussed.

6 The remaining column headings give the names of well-known substances.

a. In each cell of the table, place a tick or a cross to say whether the substances meet the criteria.
b. How many ticks does a substance need to be classified a mineral?

____

c. In the last row of the table, indicate which of the substances are minerals.

MINERAL PROPERTIES	SALT	GOLD	COAL	WATER	ICE	IRON	GRANITE	GLASS
Mineral?								

Summary of Rock and Mineral Properties

1 Describe the criteria that are used to distinguish between minerals and rocks

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2 What is the difference between a rock and a mineral?

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3 Consider the limitations of these criteria.

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4 Why are minerals classified separately from rocks?

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Mineral Identification

The properties listed in the table below, together with a reference book or key, are commonly used to identify minerals.

Mineral properties are interpreted by the human senses and simple equipment.
Specific equipment which can absolutely identify minerals is too expensive for everyday use.

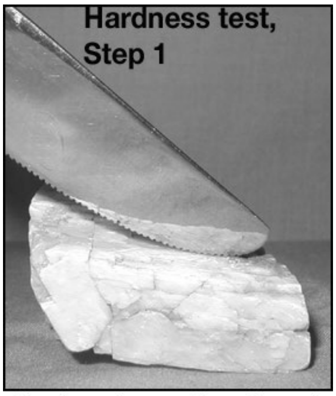
DIAGNOSTIC PROPERTY	DESCRIPTION	TESTING PROCEDURE/NOTES
Colour	Overall colour of the specimen	Not always a useful diagnostic feature, as many minerals are white or black, and many exist in several different colours.
Lustre	Appearance of the mineral's surface	Rotate the metal under a light and see how a freshly broken surface shines. Choose from: **Metallic** — the surface shines like a metal. **Vitreous** — the surface shines like glass. **Dull**— the surface has no shine.
Streak	Colour of the mineral in powder form	Rub the specimen on a streak plate (unglazed tile) and determine the colour of the powder
Hardness	Resistance to scratching. Expressed as a number between 1 and 10 on Mohs' scale. See table below	See whether a freshly-broken surface of the specimen can be scratched by: 1 Your fingernail — yes, H< 2.5, no, try 2 A copper coin — yes, 2.5<H<3.5, no, try 3 A knife blade — yes, 3.5<H<5.5, no try 4 A quartz crystal — yes, 5.5<H<7, no H>7
Density (or specific gravity)	An estimate of how heavy a mineral is, compared with other minerals.	Hold similar sized specimens of different minerals in each hand, and compare how heavy they are. Densities of minerals may be described as low, medium or high.
Reaction to acid	Does the specimen	Place a drop of acid on a freshly broken surface of a

	effervesce (fizz) when acid is added?	mineral and see if effervescence occurs.
Magnetism	Does the specimen affect a magnet?	Use a magnet to find whether a mineral specimen is strongly magnetic, slightly magnetic or non-magnetic. To find whether a specimen is slightly magnetic or non-magnetic, scrape some fragments on to a piece of paper, and move the magnet around **under** the paper.
Taste	Use mainly for halite (salt)	Lick your finger, touch the mineral surface with your wet finger, then place your finger on the tip of your tongue.
Crystal form	Geometric shape formed by minerals under suitable conditions	Look for the geometric shape of the specimen, cubic, hexagonal etc. Not usually seen in the specimens we use.

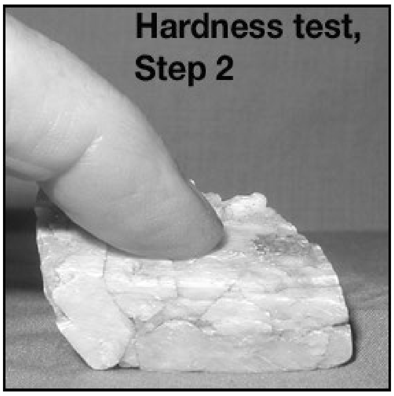
Procedure for testing minerals

Hardness Tests

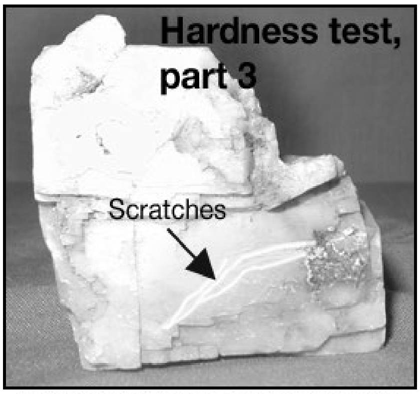
The photographs below illustrate a procedure for carrying out hardness tests.



Place the specimen on a firm surface and scratch it firmly with the test equipment.



Rub the surface with your finger to remove the powder that has been formed.



Examine the mineral's surface to see if any scratches are visible.

Density (Weight)

The **density** of a mineral, as estimated by the **weight** of a specimen, is another diagnostic property.

You only have to decide whether each of your minerals is **light**, **medium** or **heavy**. Do this by holding similar sized specimens of two different minerals in your hands, and comparing their weights, as shown in the adjacent photograph.

Cleavage Planes

DIAGNOSTIC PROPERTY	DESCRIPTION	TESTING PROCEDURE/NOTES

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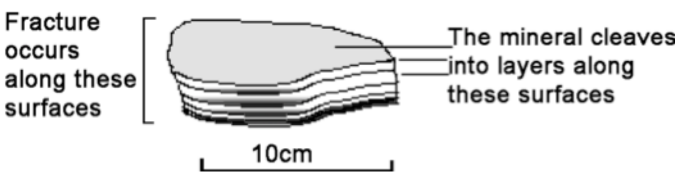
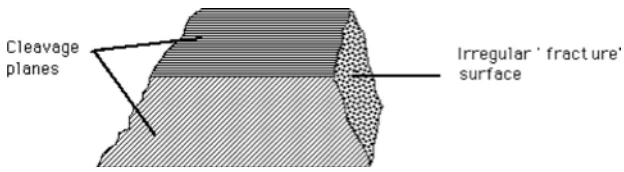
Cleavage	Breakage of a mineral along flat surfaces that are planes of weakness in the crystal structure. See diagrams below	The overall shape of a mineral specimen is unlikely to give you its cleavage. Look for areas where the light is reflected from flat surfaces. The specimen may show: • One flat surface • Two flat surfaces at 90° to each other • Two flat surfaces not at 90° to each other • Three flat surfaces at 90° to each other • Three flat surfaces not at 90° to each other

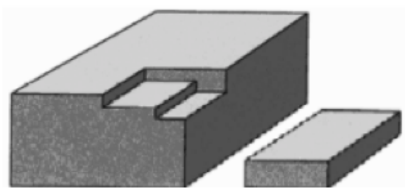
The following diagrams show different mineral cleavage planes



One Cleavage Plane



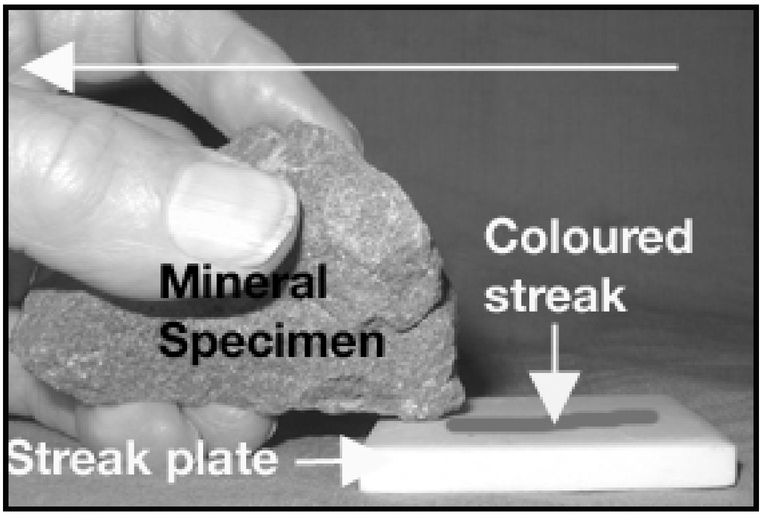
Two Cleavage Planes at 90°


Three Cleavage Planes at 90°


Three Cleavage Planes **not** at 90°

Streak

Streak is the colour of the mineral in powder form, and it is a useful diagnostic property for many coloured minerals — especially those with a metallic lustre. It is found by rubbing the specimen across a piece of unglazed tile, or streak plate, as shown in the adjacent photograph.



Drag the mineral specimen across the streak plate

A white mineral can only have a white streak, so there is no point in doing a streak test on white specimens.
You will find that some coloured minerals also have white streaks.
If a mineral is harder than the streak plate, it will not leave a streak.

Summarize the various methods of mineral identification that can be done in the field or in the laboratory

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In pairs, research the following questions:

1What can elements tell us about the mineral?

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2 Which minerals are the most common in Earth's crust?

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3 Compare the properties of felsic and mafic minerals

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4 If a mineral has a **hardness** of less than 2.5, lustre of '*vitreous* 'description, one plane of perfect cleavage and is a sulphate, what is it?

____

5 Which minerals bubble with acid? Why is that reaction significant to their identification?

____

6 Discuss reasons why identifying minerals is significant

____

7 Differentiate between cleavage and fracture

____

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8 What information could magnetism provide about the mineral?

____

9 Discuss streak and why it is important regarding mineral identification.

____

Non-metallic lustre (cont.)	Coloured minerals (cont.)	Scratched by knife blade, scratches fingernail	Greenish colours, white streaks, greasy looking, poor cleavages	APATITE
	Increasing hardness ↓	Hardness similar to that of knife blade	Black, sometimes two cleavages, short thick crystals, eight-sided. Vitreous lustre	AUGITE
			Black, sometimes two cleavages, long thin crystals six-sided. Shinier lustre than augite	HORNBLENDE
		Scratches steel blade, does not scratch microscope slide	Glassy green grains, partly transparent	OLIVINE
			Pink or flesh colour, sometimes shows two cleavages	ORTHOCLASE FELDSPAR
		Scratches microscope slide	Colour variable, vitreous lustre, conchoidal fracture. Amethyst = purple, rose quartz = pink, smoky quartz = grey	QUARTZ Varieties
Lustre is partly metallic, partly earthy	Black or coloured	Does not scratch steel blade	Brown to black in colour, brown streak, vitreous lustre, sometimes metallic. Often shows cleavage	SPHALERITE
			Yellow-brown in colour, yellow to brown streak. Dull lustre	LIMONITE
		Approximately same hardness as steel blade	Red or grey colour, red streak, red rubs off onto fingers	HAEMATITE
		Scratches steel blade	Black, magnetic. May be too hard for streak plate	MAGNETITE
Metallic lustre	Gold colour	Scratched by steel blade	Dark brass colour, tarnishes to purple	CHALCOPYRITE
		Scratches a steel blade	Pale brass colour, crystals may be seen	PYRITE
	Silver colour (may be dull)	Scratched by a copper coin, not by fingernail	Very dense (heavy), grey streak, three good cleavages and forms tiny cubes	GALENA

Key to identification of minerals

Non-metallic lustre	White or pale in colour	Scratched by fingernail	White to pale green, greasy feel. Often flaky	TALC
			Vitreous lustre, breaks along cleavage planes to give smooth faces. Often transparent	GYPSUM
			Shiny lustre, breaks along one cleavage plane giving flat sheets. Sheets are flexible. Transparent	MUSCOVITE MICA
		Hardness similar to that of fingernail	Vitreous lustre, cleaves into tiny cubes. Salty taste	HALITE (ROCK SALT)
	Increasing hardness ↓	Scratched by knife blade, scratches fingernail	Pale colour, white or yellow, often transparent. Three good cleavages, not at right angles. Forms tiny blocks	CALCITE
		Scratches knife blade, may just scratch microscope slide	White or grey, sometimes shows two cleavages at 90°	PLAGIOCLASE FELDSPAR
			Pink or flesh colour, cleavage same as plagioclase feldspar.	ORTHOCLASE FELDSPAR
		Scratches microscope slide with ease	Vitreous lustre, no cleavage transparent or milky. Forms six-sided crystals, conchoidal fracture sometimes seen	QUARTZ
	Coloured minerals	Scratched by fingernail	Black, shiny lustre, breaks along cleavage plane giving thin flexible sheets	BIOTITE MICA
			Orange red, earthy lustre, orange or red-brown streaks	BAUXITE
	Increasing hardness ↓	Scratched by knife blade, scratches fingernail	Orange brown, earthy lustre, yellow-brown streak	LIMONITE
			Bright green, green streak	MALACHITE
			Bright blue, blue streak	AZURITE
			Bluish purple, white streak, vitreous lustre, four cleavages giving pyramid shape in good specimens	FLUORITE

Mineral Identification Experiment

Lab coat & Glasses required

Aim: To identify some minerals

Materials:

- Mineral samples (numbered)
- Moh's Hardness Kits
- Unglazed ceramic Tiles
- HCl
- Magnet
- Reference book or key

Mohs' Hardness Scale

Hardness	Standard Mineral	Test Object
10	Diamond	
9	Corundum	
8	Topaz	
7	Quartz	
6	Feldspar	Steel File (6.5)
5	Apatite	Glass (5)
4	Fluorite	Iron Nail (4.5)
3	Calcite	Copper Coin (3.5)
2	Gypsum	Fingernail (2.5)
1	Talc	

Procedure

1. Select one of your mineral specimens. Write its number in the left hand column of the table on page 12.

2 Carry out the testing procedures described in the table below and on pages 7 to 9.

3 Record your results in the table on page 12.

4 Use the attached key or any other referencec to identify the mineral.

5 Repeat steps 1 to 4 using the remaining minerals.

Testing procedures (see also pp7 to 9)

Hardness

Using Moh's hardness kit, starting with the softest (your fingernail) scratch the surface of your mineral until you find the 'hardness' of the specimen (the tool in the kit which

Colour

Observe colour of mineral.

does not scratch the mineral).

Lustre

Using the terms described earlier, describe the lustre/shine of the mineral.

Streak

Using your ceramic tile, gently scratch your mineral along the tile, until some residue/powder is left behind. Identify the colour.

Density

Density can be compared by holding similar sized pieces of minerals in each hand.

Cleavage (see also p8)

Look at how the mineral breaks.
Does it break along a plane (*cleavage*)
One cleavage plane will have two smooth, parallel flat surfaces.
(a cube would have 3 cleavage planes)
If it breaks irregularly, with no pattern, it *fractures*.

Magnetic

Hold a magnet near the mineral. Record if it reacts and thus, if it has magnetic qualities.

Acid

Drop two drops of HCl onto the mineral. Record observation.

Other

Hold UV light over specimens. Record observations.

Other

Any other relevant observations.

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SPECIMEN No:	**DIAGNOSTIC TESTS**						**SPECIMEN NAME**
	Colour	Lustre	Streak	Hardness	Density	Reaction to acid	

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Discussion

1 Draw two of the above minerals. Compare them visually and by their properties. Give an indication of the size of each one.

Name:	Name:

Comparison:
____

____

____

____

____

2 Name the hardest mineral on Earth

____

3 Compare hardness and streak ____

____

____

4 Identify the most common mineral in the mantle ___________________________________

____

5 Name a mineral that scratches calcite, but cannot scratch topaz ______________________

____

6 Why is density important in identification? ______________________________________

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7 What causes some minerals to fluoresce? ______________________________________

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8 Discuss why halite will dissolve in water. ____

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9 Explain what cleavage tells about the composition of a mineral _____________________

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12 Discuss why it is important to know the chemical composition of minerals, not just for identification, but for everyday use. Give examples.

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____

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13 Which type of mineral is most abundant in the oceanic crust?

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14 What type of rock-forming minerals are most abundant in the continental plate?

____

____

15 In your own words, explain what rock-forming minerals are.

____

____

Discuss how the uses of minerals are related to their properties.

A mineral is a naturally occurring inorganic solid with definite chemical composition. A gem, or gemstone is a *piece* of mineral that has been cut, treated and used in jewelry.

- Gemstones are chosen for their significant visual attractiveness as well as their hardness.
- Gemstones are also considered precious or semiprecious.
- Precious stones come with premium price for their color, brilliance and rarity.
- These include diamond, ruby, sapphire and emerald.
- Semiprecious stones include amethysts, amber and bloodstone because they are easier to find.

Diamond is a perfect gemstone because not only does it reflect and refract light really well, giving its shine, it also, being the hardest mineral on Earth, will not be damaged should the jewelry be dropped.

- Given its strength, diamond is used to cut, grind or drill in industry
- Physicists are working on using diamonds to super power lasers for industry use
- Diamond, being pressurized carbon is composed of one carbon atom surrounded by other carbon atoms.
- Its price is high because of very well created marketing techniques, which restrict supply.

Discuss, in detail the benefits of restricting supply of diamond and whether it should still be considered a precious mineral. Give reasons diamond is so highly sought after and discuss in depth one use of diamond that is not jewelry. Draw diamond's structure.

Structure of Diamond.

Talc.

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Used mostly when crushed in talcum powder, or baby powder. Suggest why talk is crushed and sold as a powder.

Pyrite

- Referred to as ‘fool’s gold’
- Brass-yellow with bright metallic lustre, very common worldwide
- Chemical composition (FeS_2) iron sulfide
- Limestone can be used to start a fire and to trick tourists into thinking they have found real gold.
- Used occasionally as a gemstone.

- One easy, test, its streak test, identifies pyrite when it is confused with gold. Pyrites streak is black and green, where golds is gold.

  Suggest why gold miners would use non-destructive tests before destructive tests when identifying pyrite or gold.

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Assessment:

Choose another mineral and research its use and how that relates to its properties.
This cannot relate to jewellery. Mineral use spans further than jewellery, so take the time to look for yourselves.

- Describe the mineral's use and explain why it is used in such industry.
- Discuss how its qualities have benefitted people and suggest another mineral (if applicable) that was used prior.
- Discuss the mineral's chemical composition and why it may only be suitable for a handful of uses. Some minerals have a wide variety of uses.

Indigenous connection ....

Aboriginal people traditionally used stones and rocks as tools – they found some useful and some not.
Rocks and minerals were classified according to their use.
Quartz was struck to make flint knives, used to gut kangaroos. By attaching quartz using spinifex gum to a handle allowed the rocks to become knives.
Why was quartz used for these purposes?
Possible activity/task:
Excursion to Adelaide Museum to see traditional tools and equipment used by Indigenous Australians.
When on the excursion, look into the use of tools and objects and list what they were used for.

Look into the type of rock or mineral used for specific jobs. Was there a reason some types were only used for specific tasks?

Research into history of stone tools and use. Focussing on one tool, discover how it was made, the rock type used and its effectiveness. Discuss whether it could be an effective tool today. Attempt to replicate tool and use.

Indigenous Australians were limited to the land around them. The use of not only different types of rock, but different sizes had deliberate significance. Explain.

2.2 Rocks

Rocks are composed of characteristic assemblages of mineral crystals or grains that are formed through igneous, metamorphic and sedimentary processes, as part of the rock cycle.

The Rock Cycle

The rock cycle is the concept that throughout geological time, there are constant processes affecting rock at or near Earth's surface. This rock is constantly being modified by natural processes, and constantly moving between being metamorphic, sedimentary and igneous rock. This process is natural and continuous.

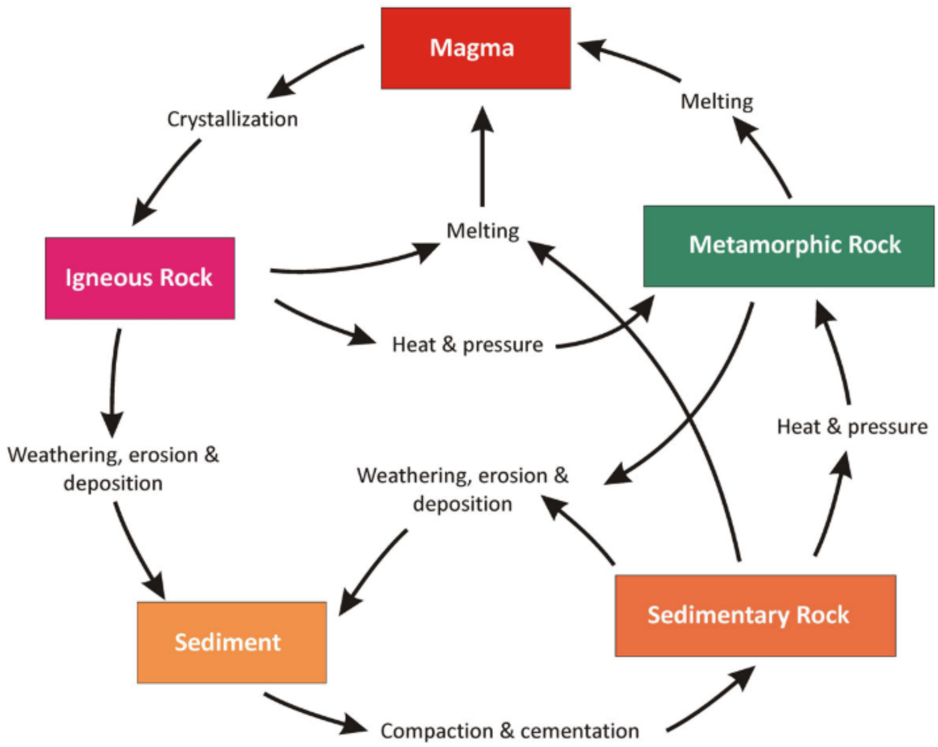
- Uniformitarianism: processes that occurred millions of years ago are still happening today just as effectively.

Natural processes of modification include:

- Metamorphism (altering chemical composition of rock by heat and pressure)
- Melting
- Crystallization
- Lithification (compaction and cementation under pressure)
- weathering

The rock cycle:

- A key concept in geology, looking at never ending processes
- Some aspects of the cycle are evident but others take eons of time
- The aim is to describe the relationship between the three basic rock types.



The Rock Cycle

<u>Types of rock found in different parts of the Lithosphere</u>.

Oceanic Crust	Mainly basalt and gabbro. Contain plagioclase feldspar and pyroxenes. Traces of olivine, amphibole and mica.
Continental Crust	Mainly granite and andesite. Contain alkali feldspar, plagioclase feldspar and quartz. Traces of amphibole and mica.
Sedimentary Cover	Sits on oceanic and continental crusts. Mainly clastic rock including limestone, shale, siltstone, and carbonates calcite, and dolostone.

2.2.2 Igneous Rocks

The 'first' rocks, igneous, make up parts of the crust and upper mantle. From Latin, *igneous* means fire.
Igneous rocks are form by the solidification of molten rock, or magma.
Most igneous rocks are identifiable by colours and grain sizes, or texture.
Colour identifies minerals. Olivine appears dark green because of the amount of iron. The silica in granite makes it appear light coloured.
<u>There are two types of igneous rock: *intrusive* and *extrusive*.</u>
<u>Intrusive</u> igneous rocks crystallise below Earth's surface, likely in small magma chambers. These rocks cool slowly, which means crystals have a chance to form and grow.
Intrusive igneous rock will have the following qualities:

- Very hard to break
- Easy to see large crystals within
- Large grained
- Possibly multiple colours, visible interlocking crystals
- E.g. Diorite, gabbro (all black), granite.

<u>Extrusive</u> igneous rocks erupt onto Earth's surface, usually at divergent plate boundaries or volcanic eruptions. They cool quickly, being exposed to air, forming small crystals only visible under microscope. Some extrusive rock cools so quickly that they form glass.
Extrusive igneous rock will have the following qualities:

- Hard
- Strong
- Fine grained
- Visible vesicles (sometimes), or holes where air or gas has been
- Some shine and appear like glass
- E.g. basalt, andesite, scoria, rhyolite, obsidian

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Two examples of igneous rocks

Igneous Intrusive Rock: Granite

Minerals in Granite

a. What percentage of visible rock is biotite? ___________________________________

b. What percentage of visible rock is feldspar? __________________________________

c. What percentage of visible rock is quartz? ___________________________________

d. How can we tell this is an intrusive igneous rock? ______________________________

____

____

e. Would this be expected to be strong or weak? What uses could this information lead to? ____

____

Black - Biotite

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Igneous Extrusive Rock: Obsidian

Obsidian

a. Why is obsidian shiny? ______________________________

b. How do we know obsidian is extrusive? ______________________________

c. Explain its lack of visible crystals, such as granite ______________________________

____

d. Explain how obsidian would likely break ______________________________

e. Would obsidian be considered strong, or weak? What possible uses could we have for it? ______________________________

____

Igneous Rock Identification Experiment Lab coat & Glasses required

Aim: Using the identification chart, successfully identify and name several igneous rocks.

Materials:

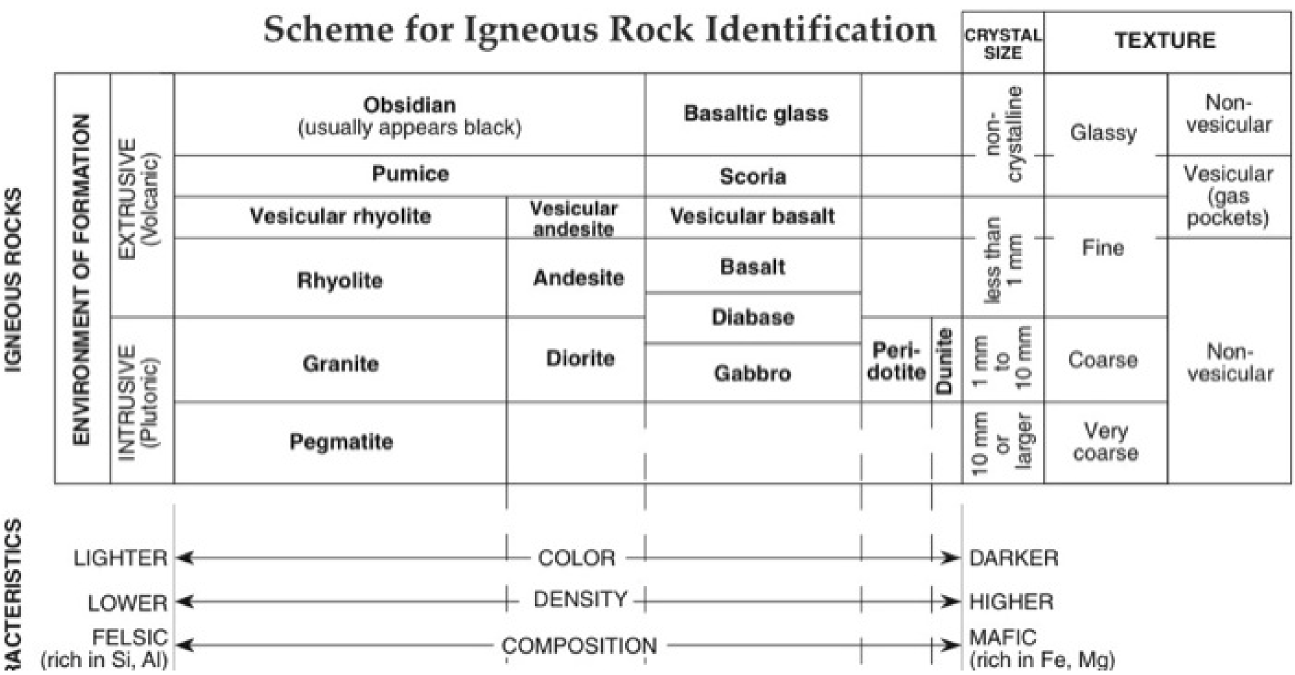
- Identification scheme below
- Numbered specimens of intrusive and extrusive igneous rock.
- Magnifying glass

Procedure

1 Examine each of your Igneous rock specimens to determine the colours and textures (grain sizes)

2 Use your Scheme for Igneous Rock Identification to name the rock type that fits the combination of properties that you have listed.

3 Write the name you have selected in the final column of the table.



Results table

Specimen no	Colour		Texture				Vesicles		Name of Rock
	Lighter	Darker	Glassy	Fine	Coarse	Very coarse	Yes	No	

5 Describe any difficulties you found in identifying these rocks.

____

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2.2.3. Sedimentary Rocks

According to the rock cycle, from erosion, weathering and compaction, all rock types will become sedimentary. Any rock exposed at Earth's surface can become sedimentary. Over 75% of Earth's surface is covered in sedimentary rock.

Sedimentary rock is formed by the constant deposition of sediment forming layers. Over time, pressure on the lower layers compresses them and concretes them into place. Sedimentary rock can tell of the earth's surface in Earth's geologic past.
The sedimentary rocks become cemented together by the chemicals in the ground.
There are three basic types of sediment:

- Clastic - pieces of weathered rock
- Chemical - minerals crystallising from solution
- Organic - dead animal/plant

Weathered rock: sediments are known as clastic sediment. Often fossils are found, or preserved organisms. Most sedimentary rocks are clastic.
Natural cement includes calcium carbonate, iron oxide or clay.
Sedimentary rocks compress, lose water and form layers called **strata**, evident at cliff sides.
The strata can tell the environment, species and atmospheric change over time.
Natural clastic structures:

- Victoria: the 12 Apostles
- Arizona, USA: The Grand Canyon.

Chemical structures:

- Dissolved materials sink and pressure allows crystallization.

Organic Sedimentary Rocks:

- Form when dead plants or animals lie and accumulate. There are often fossils and preserved animals cemented within.

As seen on the rock cycle, heat and pressure causes sedimentary rock to become metamorphic. Through melting of sedimentary or metamorphic rock into magma and crystallisation, igneous rock forms.
Classification of Sedimentary Rock
Can be Clastic, Chemical or organic

Classification of Non-Clastic (Chemical/Inorganic)

- Crystalline texture:
  Minerals form as crystals. Identifying the size of the crystals is a key identifier.

- Skeletal texture:
  Marine organisms remove $CaCO_3$ from seawater to form shells, like coral. This makes for a healthy reef system. When they die, the material accumulates and can form limestone.
- Oolitic texture:
  Oolites are large grains of calcite. They form on the sea floor and appear spherical. Oolites are held together by calcite cement.

Grain Size

- Classifying the size of sediments that make up a rock help to identify the rock.
- The Wentworth scale is a scale that classifies sediments based on their diameter.
- Particles larger than 64mm across are cobbles.
- Smaller particle sizes are pebbles (between 4-60mm) and 2-4mm are granules.

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Millimeters (mm)		Micrometers (µm)	Phi (ϕ)	Wentworth size class	
	4096		-12.0	Boulder	Gravel
	256		-8.0	Cobble	Gravel
	64		-6.0	Pebble	Gravel
	4		-2.0	Granule	Gravel
	2.00		-1.0	Very coarse sand	Sand
	1.00		0.0	Coarse sand	Sand
1/2	0.50	500	1.0	Medium sand	Sand
1/4	0.25	250	2.0	Fine sand	Sand
1/8	0.125	125	3.0	Very fine sand	Sand
1/16	0.0625	63	4.0	Coarse silt	Silt
1/32	0.031	31	5.0	Medium silt	Silt
1/64	0.0156	15.6	6.0	Fine silt	Silt
1/128	0.0078	7.8	7.0	Very fine silt	Silt
1/256	0.0039	3.9	8.0	Clay	Mud
	0.00006	0.06	14.0		

Chester K. Wentworth

WENTWORTH (1922) GRAIN SIZE CLASSIFICATION

The canonical definition of sediment grain sizes as defined by geologist Chester K. Wentworth in a 1922 article in *The Journal of Geology*: "A Scale of Grade and Class Terms for Clastic Sediments".

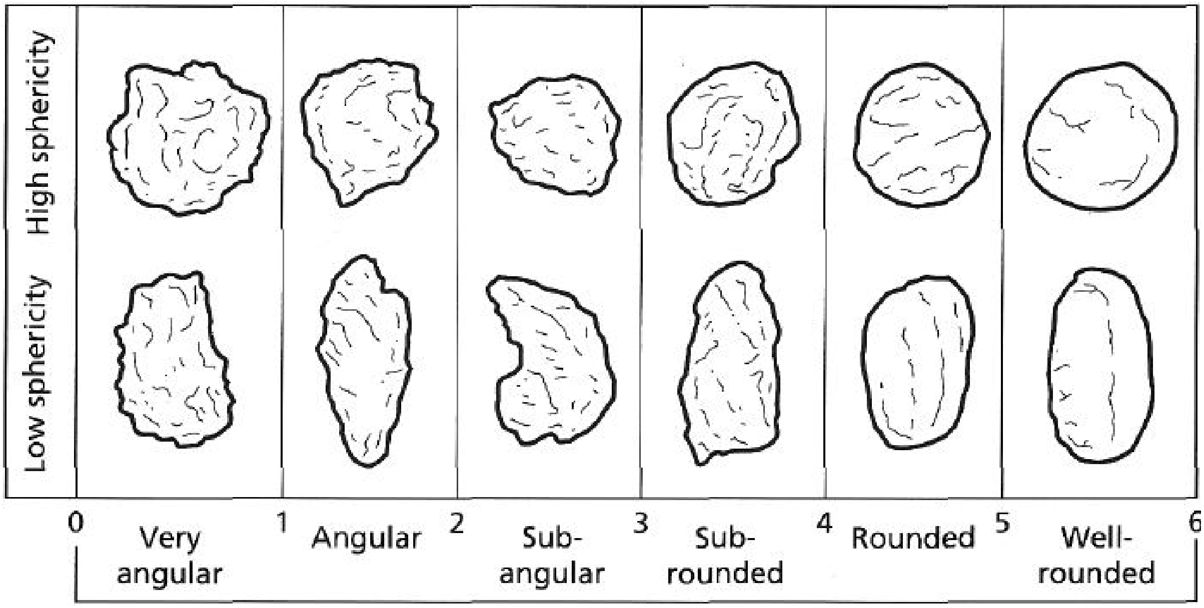
- Anything below 2mm and 1/16th of a mm is a sand and anything smaller is silt.

CLASTIC rock consists of fragments which are considered under grain size, roundness and sorting.

Grain Size

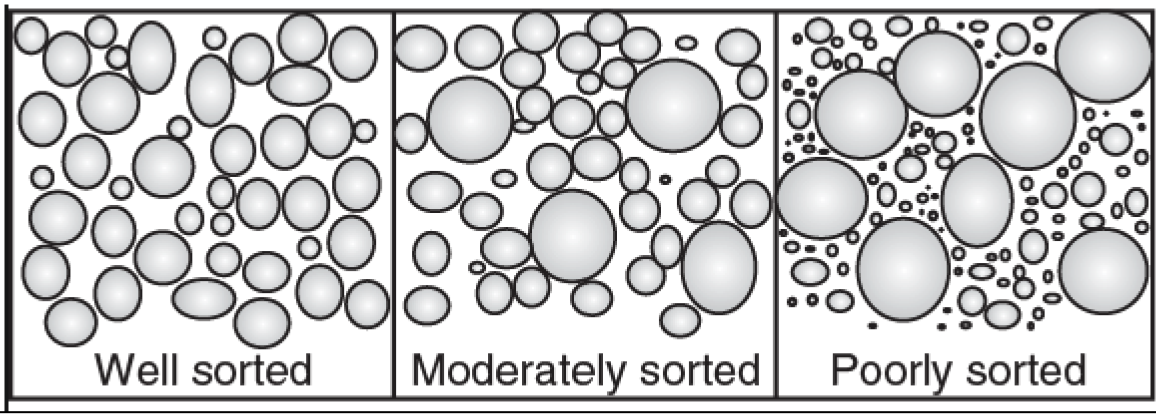
Conglomerate	Rounded Pebbles
Breccia	Angular clasts
Sandstones	Grains (1/16th-2mm)
Siltstones	Silt <1/16mm
Mudstones	Clay particles

Roundness



Resource: http://strata.uga.edu/4500/labs/silicithin/silicithin.html

Sorting: Variety of grain sizes



Resource: http://geology1403.blogspot.com/2016/11/siliciclastic-sedimentary-rocks_82.html

Non-clastic sediments are either chemical or materials with an organic origin, such as a coral reef.

Sediments come from three main sources

- Pre-existing rock (clastic) undergone weathering and erosion
- Organic, incorporating fossils or preserved species within
- Chemical – such as salt

Quartz is the most common mineral found in sedimentary rock because it is hard and chemically stable.

Clay minerals result from fine particles, from weathering, take a long time to settle and settle as mud.

2.2.3.1 Two examples of Sedimentary Rocks


Conglomerate

Conglomerate is a clastic sedimentary rock. Often found in or near a water source, most clasts have been rounded by the water erosion and weathering before being cemented together to form Sedimentary Rocks
As a sedimentary rock, conglomerate can contain clasts of any other rock type.
Often, clasts are minerals such as quartz or feldspar. Other clasts can be rock fragments like quartzite, granite, limestone and gneiss.
Fragments are mostly cobble- and pebble-sized, with come very coarse sand and granule sized pieces.
All clasts are bound together by a sand, mud or chemical cement.

Discussion Questions

Why is conglomerate easy to identify? ____

____

Suggest which pieces in the image above would be considered cobble sized fragments. ___

____

Suggest why there would be a mix of larger and smaller clasts in this rock.______________

____

Why is conglomerate not considered a mineral, if it contains mineral pieces? ____________

____

____

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Sketch an actual sample of conglomerate and estimate both its actual size and its grain sizes.

Siltstone

Siltstone is another clastic sedimentary rock. Given the name siltstone because of the silt sized particles within. Silt is usually a mix of clay minerals together with micas, feldspars and quartz.

As a sedimentary rock, conglomerate can contain clasts of anything.

Often, clasts are minerals such as quartz or feldspar. Other clasts can be rock fragments like quartzite, granite, limestone and gneiss.

Fragments are mostly cobble and pebble sized, with come very course sand and granule sized pieces.

All clasts are bound together by a sand, mud and chemical cement.

How could you tell that the particles here are silt sized if they are less than 1mm?

____

Why would silt appear to be different colours? ________________________________

____

Where are silt particles likely to occur? ____________________________________

____

Silt contains minerals including micas and quartz, so why is it not considered a mineral?___

____

____

Sketch an actual sample of siltstone and estimate its size, as well as its grain size.

2.2.3.2 **Sedimentary Rock Investigation** Lab coat & Glasses required

Collect the sedimentary rocks listed in the table below, examine them carefully and enter their properties in the table below.

Name	**Colour**	**Grain Size**	**Sorting**	**Grain shape**	**Harder or softer**	**Layers present**	**Fossils present?**	**Reacts with Acid?**
Breccia								
Sandstone								
Shale								
Conglomerate								
Mudstone								
Fossiliferous limestone								

2.2.3.3 (alternative practical)

Use the scheme below to identify a variety of clastic sedimentary rocks.

Scheme for Sedimentary Rock Identification

INORGANIC LAND-DERIVED SEDIMENTARY ROCKS				
TEXTURE	GRAIN SIZE	COMPOSITION	COMMENTS	ROCK NAME
Clastic (fragmental)	Pebbles, cobbles, and/or boulders embedded in sand, silt, and/or clay	Mostly quartz, feldspar, and clay minerals; may contain fragments of other rocks and minerals	Rounded fragments	Conglomerate
			Angular fragments	Breccia
	Sand (0.2 to 0.006 cm)		Fine to coarse	Sandstone
	Silt (0.006 to 0.0004 cm)		Very fine grain	Siltstone
	Clay (less than 0.0004 cm)		Compact; may split easily	Shale

2.2.4 Metamorphic Rocks

2.2.4.1 Formation of Metamorphic Rocks

Heat and pressure form metamorphic rocks from sedimentary, igneous or metamorphic rocks that have been exposed to intense temperature or pressure (sometimes both) under the Earth's surface.
If they are buried deep enough, because of the intensity of the heat and pressure they are under, new minerals can be formed due to chemical changes in the rocks. Fine grains in the rock undergo chemical reactions because of the temperature change and the pressure causes them to meld together. Mostly this occurs in the mantle.
From Greek *meta* means change and *morphe* means form, therefore changing form.
Minerals in metamorphic rocks are some of the most highly valued in the world. Some include garnets, sapphires, rubies and diamonds.
There are two types of metamorphic rocks: *Foliated,* and *non-foliated.*
Foliated metamorphic rocks have a layered appearance caused by directed pressure.
Non-foliated metamorphic rocks lack this layered appearance. Whilst many foliated rocks are hard and dark, non-foliated rocks often appear lighter and are quite brittle.
Most metamorphic rocks have the following qualities:

- Extremely hard (exceptions include schist and marble)
- Dense, heavy.
- Some will have distinct colouring
- Some non-foliated metamorphic rocks may appear lighter and weigh less.

Regional metamorphism: caused by large processes such as mountain building. Rocks bend and break under the pressure of collision and constant force.

Thermal metamorphism: changes the structure and texture of minerals. This can occur over a wide area and is usually associated with contact with magma.
Metamorphic rocks often look pleasing and as a result, and because of their strength and density, they are often used aesthetically. Often, metamorphic rocks like marble are used as work surfaces, chopping boards, knives, ornaments and around fireplaces. Gneiss is used in outdoor furniture, as tombstones and for flooring.
As seen on the rock cycle, metamorphic rock can be melted into magma and upon cooling and crystallisation, become igneous rock. During erosion, weathering and compaction, metamorphic rocks become sedimentary.

2.2.4.2Metamorphic Rock Investigations Lab coat & Glasses required

Aim: Using visual cues, identify and characterize various Metamorphic rocks.

With the aid of the diagram below, identify a collection of common metamorphic rocks and state whether they were formed by thermal or contact metamorphism.

Name the 'parent' rock from which each of your metamorphic rocks was formed.

Scheme for Metamorphic Rock Identification

TEXTURE		GRAIN SIZE	COMPOSITION	TYPE OF METAMORPHISM	COMMENTS	ROCK NAME
FOLIATED	MINERAL ALIGNMENT	Fine	MICA	Regional (Heat and pressure increases)	Low-grade metamorphism of shale	**Slate**
		Fine to medium	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET		Foliation surfaces shiny from microscopic mica crystals	**Phyllite**
			MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET		Platy mica crystals visible from metamorphism of clay or feldspars	**Schist**
	BAND-ING	Medium to coarse	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET, PYROXENE		High-grade metamorphism; mineral types segregated into bands	**Gneiss**
NONFOLIATED		Fine	Carbon	Regional	Metamorphism of bituminous coal	**Anthracite coal**
		Fine	Various minerals	Contact (heat)	Various rocks changed by heat from nearby magma/lava	**Hornfels**
		Fine to coarse	Quartz	Regional or contact	Metamorphism of quartz sandstone	**Quartzite**
			Calcite and/or dolomite		Metamorphism of limestone or dolostone	**Marble**
		Coarse	Various minerals		Pebbles may be distorted or stretched	**Metaconglomerate**

Alternative investigation

Use the table on the next page to summarise the properties of some common metamorphic rocks.

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Name	Foliated?	Colour/s	Grain size	Harder/softer	Any other features
Augen Gneiss					
Gneiss					
Phyllite					
Hornfels					
Schist					
Marble					
Slate					
Quartzite					
Talc					

2.2.5 Summary of Igneous, sedimentary and Metamorphic Rocks

2.2.5.1 Igneous Rock

Igneous rock crystallize from melt. They form through magma cooling and solidification of magma or lava. Intrusive, or plutonic rock form quite slowly in the crust, under the surface. Intrusive rocks form slower allowing larger crystals to form and interlink. They have a much stronger integrity and can be found filling cracks or faults in the crust.
Igneous extrusive, or volcanic rock erupt to the surface from underneath. They, exposed to air, cool much more rapidly than intrusive and as a result, do not form large crystals. Extrusive rocks often have air pockets or holes in them. Often with an eruption there is a large amount of gas present, which prevents rock from forming one strong shape, but rather a rock filled with holes such as scoria. The type of rock formed can be influenced by the type of volcanic eruption.
The composition of igneous rock range from *siliceous*¸ or acid rocks, to *mafic* or basic rock. Siliceous, or acid rocks such as granite, are rich in silica ($Si0_2$). Silica is common in continental rock and has lots of quartz/ they are lighter and less dense.
The main silicates come from feldspars (plagioclase and orthoclase), micas (biotite and muscovite) and amphiboles (hornblende).
Texture (mineral or grain size) depends on how quickly they cool. The minerals can define the type of rock they are.
Mafic igneous rocks are the absolute opposites of silicas. These rocks such as gabbro are dark in colour and found in the upper mantle, generally quartz free.
Mafic rocks often have more heavier elements such as Fe Mg, Ca, K and Na.

2.2.5.2 Sedimentary rocks

Sedimentary rocks are comprised of material from pre-existing rocks that have been weathered, eroded, transported and deposited in an environment such as a beach, sand dune or river channel. These are **clastic** sediments.
Non-clastic sediments are either chemical or materials with an organic origin, such as a coral reef.
Sediments come from three main sources

- Pre-existing rock (clastic) undergone weathering and erosion
- Organic, incorporating fossils or preserved species within
- Chemical – such as salt

Quartz is the most common mineral found in sedimentary rock because it is from continental crust which contains igneous siliceous rocks.
Clay minerals result from fine particles, from weathering, take a long time to settle and settle as mud.

2.2.5.3 Metamorphic Rock

These rocks do not undergo melting. The key characteristic of these rocks is that they form by high temperatures and pressure. These rocks undergo significant fundamental changes chemically and new minerals form. Foliation, or layering comes about by constant pressure coming from one direction. Foliated rock are stronger and heavier than most others. Sedimentary rock is significantly affected by metamorphism.

Sandstone becomes quartzite. At low temperatures the pressures quartz welds together forming one dense rock.
Limestone becomes marble. Low temperature and pressure compacts the limestone into marble.
Gneiss is a common metamorphic rock group. It is coarsely banded and crystalline. Gneiss forms under extreme pressure and temperatures.

Questions

Distinguish between intrusive and extrusive igneous rocks ____________________________

____

____

____

____

Why would metamorphic rock be used for tombstones?______________________________

____

____

What are the key characteristics that make a sedimentary rock? ______________________

____

____

In which environment would obsidian form? ____

____

In which environment would fossils be found?_______________________________________

____

Why can metamorphic rocks not go through a melting process?______________________

____

Name the term used to describe the never-ending rock cycle. _______________________

What characteristics would you expect to find on rocks which form in areas of high oxygen or gas exposure? ____

Metamorphic rocks change in what kind of conditions? ____________________________

How do the two types of igneous rock form? ____________________________________

____

What are the two main chemical compositions of igneous rocks? ____________________

____

Gneiss is what kind of rock? Where is gneiss used? ________________________________

____

What elements mostly make up gabbro? _______________________________________

____

Why is limestone formed in coral reefs? _______________________________________

____

What is an oolite? ____

____

Why is $CaCO_3$ important for coral reefs? _____________________________________

____

____

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Cynthia Pyle

Extended Response Question:

Metamorphic rock is not rock which has melted, but rock which has been exposed to high heat and pressure.

- Metamorphic rock is often used in building big structures such as monuments, gravestones, and furniture. Explain the use of metamorphic rock in society. Suggest reasons why certain metamorphic rock is used over others.

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Extended response question 2:
Calcium carbonate is important in the formation of coral reefs.
Explain how it is used, what it does and why it is important in a heathy reef.
Discuss the effects of CO_2 in the water in relation to the calcium carbonate levels and overall reef health.

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