Earth and Environmental Sciences

Module 1

Earth's Resources

Educator-led Session

Zircon
S. Humphreys © Australian Museum

AUSTRALIAN MUSEUM

INTRODUCTION

Earth is one of the four terrestrial (rocky) planets in our solar system, the other three being Mercury, Venus and Mars. They are composed mainly of silicate rocks and metals, as opposed to Jupiter, Saturn, Uranus and Neptune, where the lighter elements, hydrogen and helium, are abundant.

Earth probably began life as a loose mixture of dust and debris (**planetesimal**) in the **solar nebula** about 4.6 billion years ago. It is thought that it took 100 million years for Earth to reach its current size. Intense heat from **radioactive decay** resulted in a molten core, and rocky layers formed as it collided with debris during its formation.

Today, extra-terrestrial objects rarely reach the Earth's surface. Our understanding of the Earth's formation, however, has come from investigating the composition and age of those rare stony and iron meteorites that have survived the fiery journey through the Earth's atmosphere.

Everything you see is formed from **elements** – substances made up of only one kind of atom. There are 118 identified elements, of which 94 are natural and the rest are human-made. Most of these elements are combined with other elements as chemical **compounds**. **Minerals** are naturally occurring elements or compounds. By weight, 99.5 per cent of minerals are formed from only 12 of the 94 natural elements. Some elements are far more common than others. The same goes for minerals. Of the 5000 or so known minerals, nine make up 95 per cent of the Earth's crust.

Life as we know it wouldn't exist without rocks. Aboriginal people have used them for millennia, crafting them into tools, grinding them into ochre for art and decoration, and using them to build shelters and fish traps. Today, the lights would not come on without rocks, aeroplanes would not exist and smartphones would be science-fiction. That's because rocks are composed of elements and minerals, the raw materials that are needed to build, invent, and travel.

Rocks are the foundation of ecosystems, forming the structure of mountains, rolling hills and deep ocean canyons. Soils, full of life sustaining minerals, are the worn remains of rocks that feed grasslands and forests, the primary producers of our world. Unfortunately, Earth's original rocks have probably been destroyed; melted, compressed, eroded, and reformed in the rock cycle. Some resistant minerals, such as zircon, however, have helped us to figure out age of the oldest rocks on Earth. They are right here in Australia!

Without rocks, the story of the history of life on Earth would be untold. The remains of past life are preserved in rocks as fossils. The largest dinosaur footprint on Earth near Broome, the mineralised skeletons of Australia's megafauna, or the 20,000 year-old human footprints at Willandra Lakes, would not exist without rocks.

In this study day, you will hear anecdotes about incredible specimens in a behind-the-scenes tour of the Australian Museum's mineralogy collection. You will learn to identify and measure properties of rocks, view one of Australia's best meteorite collections, and learn about basalt quarrying and trading by the Darginung people on the central coast on NSW.

SYLLABUS LINKS

Outcomes	Content	Educator-led	Self-guided
A student: › conducts investigations to collect valid and reliable primary and secondary data and information EES11/12-3 › selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media EES11/12-4 › analyses and evaluates primary and secondary data and information EES11/12-5 › describes the key features of the Earth's systems, including the geosphere, atmosphere, hydrosphere and biosphere and how they are interrelated EES11-8	***Structure of the Earth, the Early Geosphere, Atmosphere and Hydrosphere*** **Inquiry question**: How did the compositional layers of the Earth develop? Students: • investigate evidence for the structure of the Earth using technologies, including: – meteorite evidence to demonstrate differences in density and composition (ACSES009, ACSES018) • conduct a practical investigation to compare the differences in the density of representative rock samples found in the crust, mantle and core (ACSES003) • analyse evidence of the Earth's age, including: – radiometric techniques – meteorite evidence (ACSES009)	Activity 2 Activity 2 -	Activity 2 - Activity 2
	Rocks, Minerals and the Rock Cycle **Inquiry question:** What are the components of rocks and soils? Students: • investigate methods of classifying rocks and minerals used by Aboriginal and Torres Strait Islander Peoples • investigate the chemical composition of a variety of minerals and explain their formation, including: – felsic minerals – mafic minerals • investigate a range of rocks and minerals and classify samples using dichotomous keys • explain the formation of rocks as characteristic assemblages of mineral crystals or grains that are formed through igneous, sedimentary and metamorphic processes, as part of the Rock Cycle (ACSES019)	Activity 3 Activity 1 Activity 1 Activity 1	- Activity 1/3 - Activity 1
	Geological Timescale **Inquiry question:** How is the age of geological materials determined? Students: • describe relative and absolute dating of the geosphere (ACSES017) • use data of both relative and absolute dating from secondary sources to determine the age of geological materials (ACSES013, ACSES015, ACSES016, ACSES017)	- -	- -
	Geological Resources **Inquiry question:** How are non-renewable geological resources discovered and extracted? Students: • investigate traditional Aboriginal quarrying and mining methods • locate and relate a range of non-renewable resources to their location, for example: – minerals	Activity 3 -	- Activity 4

GLOSSARY

Crust
The thin, outer rocky shell of the Earth.

Mantle
The layer between the crust and the outer core of Earth.

Outer core
The fluid layer of mostly iron and nickel that lies between the mantle and inner core.

Inner Core
The primarily solid centre of Earth that is mainly composed of iron-nickel alloy.

Element
A pure substance made of only one type of atom.

Rock
A naturally occurring aggregate of minerals.

Sedimentary Rock
Rocks formed by the breakdown and lithification of pre-existing rocks.

Igneous Rock
A rock formed through the cooling and solidification of magma.

Metamorphic Rock
A pre-existing rock whose mineralogy and/or texture has been changed by processes within the Earth.

Conchoidal fracture
A rock breaks along a region of weakness, resulting in a smoothly curved surface.

Cubic cleavage
A rock breaks along three, intersecting 90° planes, resulting in a cube surface.

Lithification
The process whereby sediment is converted into rock.

Meteorite
Extraterrestrial debris that lands on the Earth's surface.

Mineral
A naturally occurring, inorganic solids (apart from liquid mercury and a few organic minerals) made up of chemical elements.

Isotope
A variant of an element that contains the same number of protons but a different number of neutrons.

Planetesimal
A rocky object formed by colliding objects in the solar system.

Solar nebula
The gaseous cloud from which the solar system formed by condensation, according to the nebular hypothesis.

ACTIVITY 1. THE CLASSIFICATION OF ROCKS

Read the introduction about rocks and minerals and then complete the activity on the next page.

Introduction

Everything you see is formed from **elements** – substances made up of only one kind of atom. **Minerals** are naturally occurring, inorganic solids (apart from liquid mercury and a few organic minerals) made up of chemical elements. Each mineral is defined by its particular chemical composition and crystal structure. Minerals are made in lots of different ways. Some form when salt water evaporates or when chemicals come out of hot fluids. Others are made when hot gases or molten rock cool or when heat and/or pressure change pre-existing minerals.

Minerals make **rocks**. Rocks can be made of just one mineral, such as quartzite, or a group of different minerals, such as granite. They have no set chemical composition or atomic structure. This means no two pieces of granite are the same. The types of minerals found in a rock, and the way they are arranged, give a rock its name. Rocks are classified into three main groups according to how they are formed.

No rock is forever. Our active Earth – from storms and rivers to glaciers and volcanoes – recycles rocks from one form to another. Changes in heat and pressure or exposure to the elements can melt, dissolve, freeze and erode rocks.

Basalt
S. Humphreys © Australian Museum

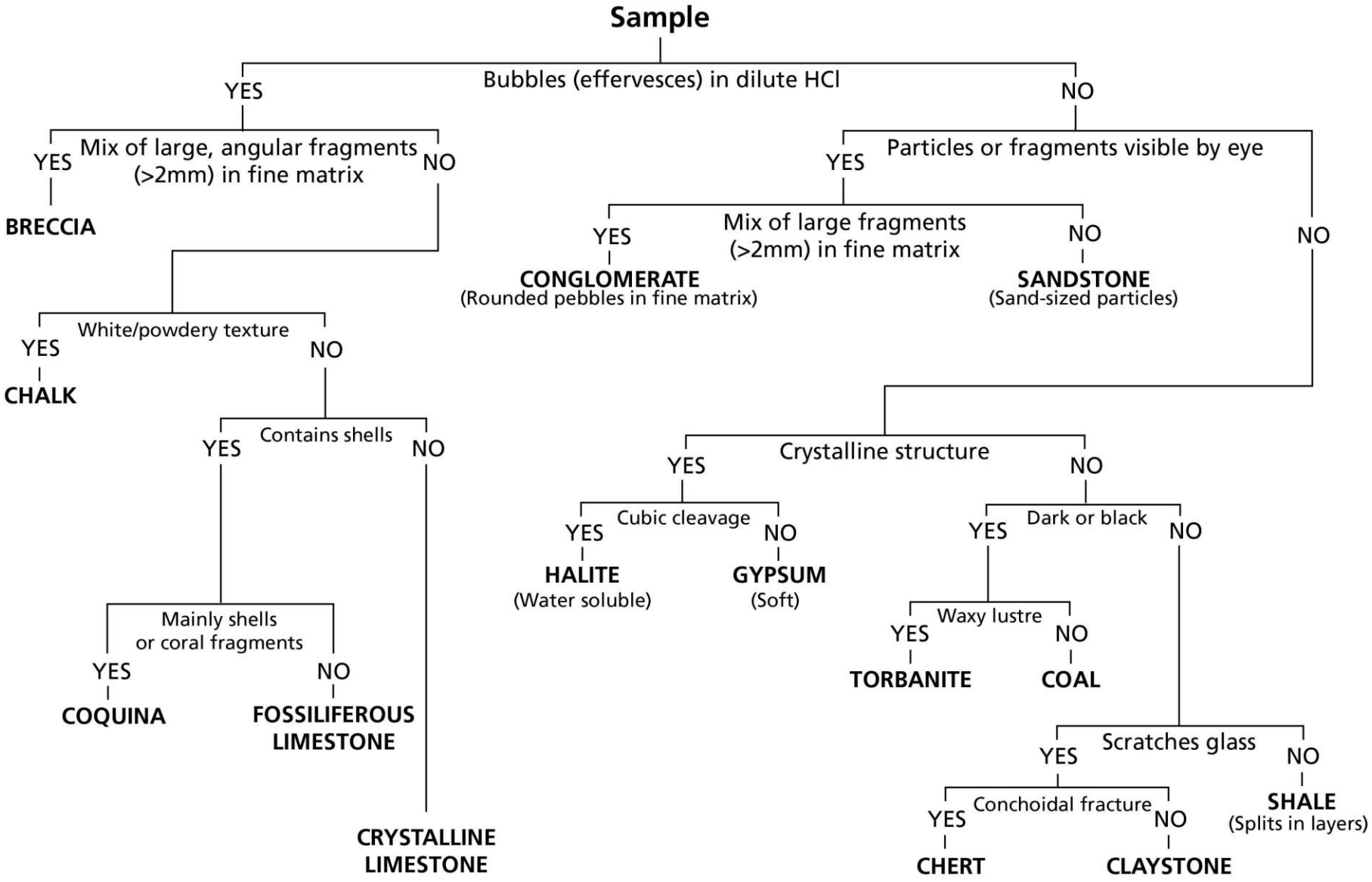
Activity

Identify and write down the features of each specimen using the dichotomous keys. There are 3 sedimentary rocks (**S1**, **S2**, and **S3**), 3 igneous rocks (**I1**, **I2**, and **I3**) and 3 metamorphic rocks (**M1**, **M2** and **M3**).

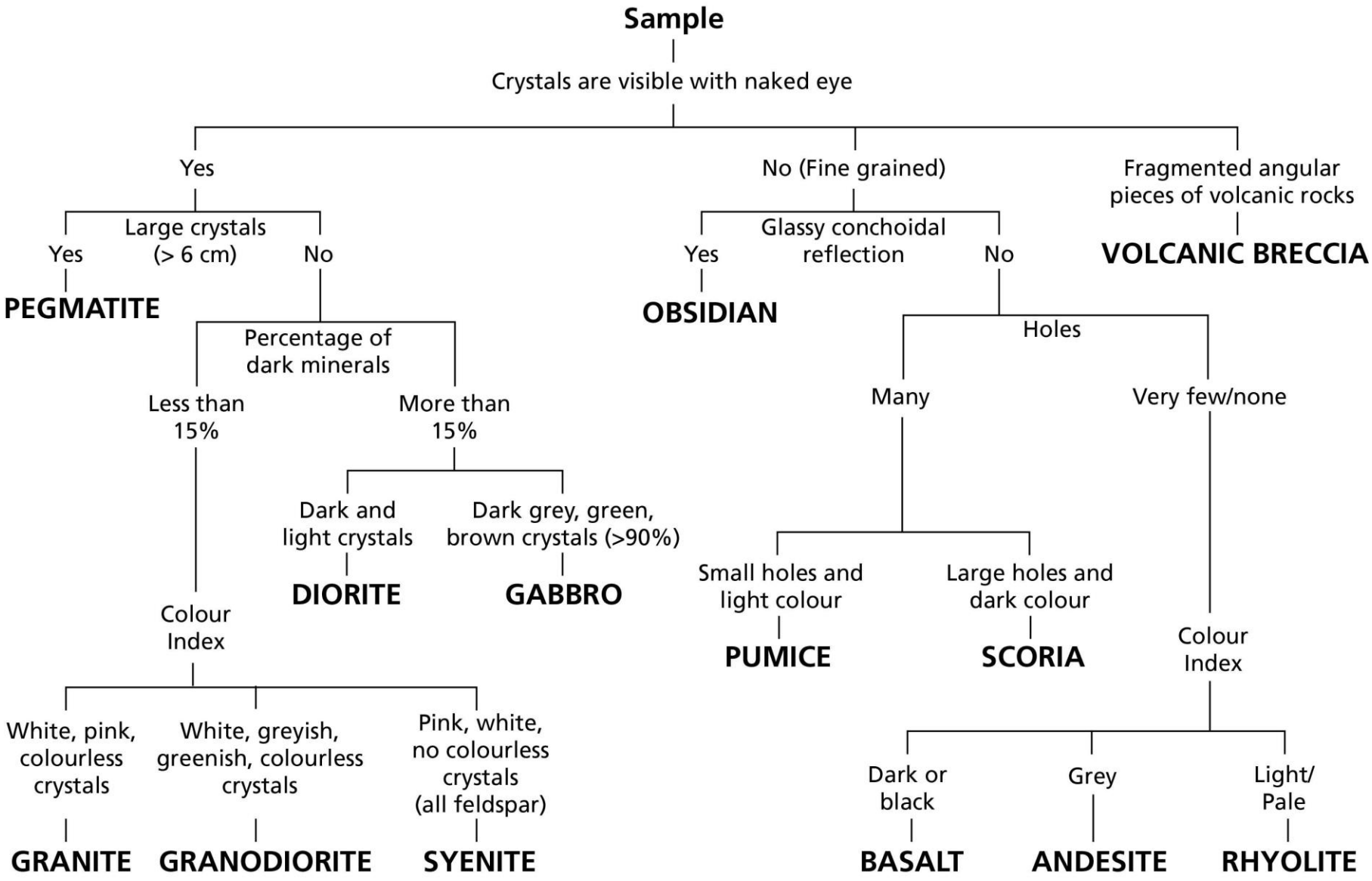
Group number: _____

Rock Group	Specimen	Features	Name
Sedimentary	**S1**		
	S2		
	S3		
Igneous	**I1**		
	I2		
	I3		
Metamorphic	**M1**		
	M2		
	M3		

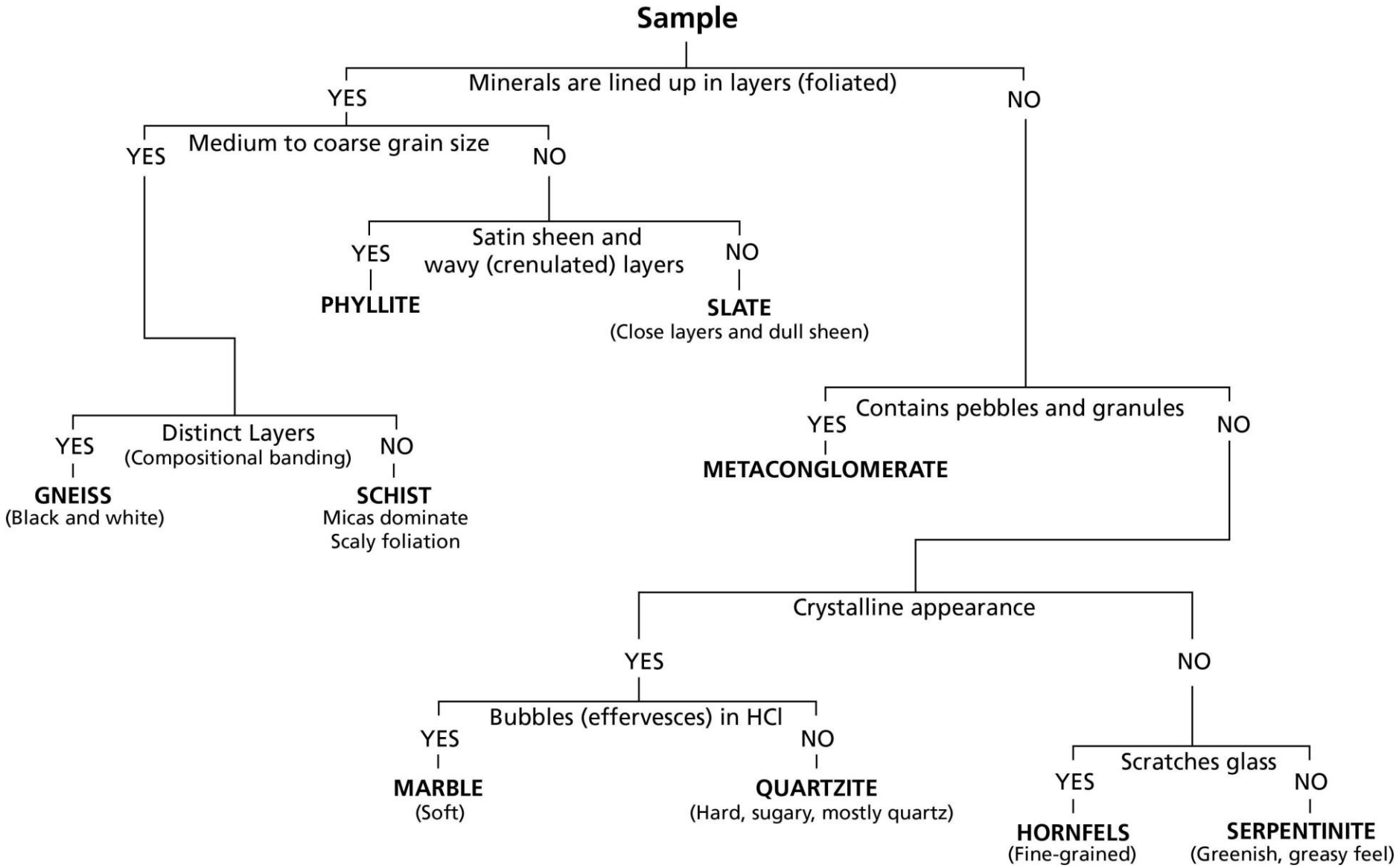
SEDIMENTARY ROCK KEY



IGNEOUS ROCK KEY



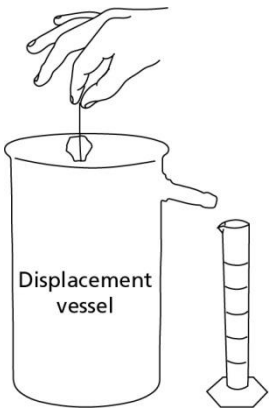
METAMORPHIC ROCK KEY



ACTIVITY 2. MEASURING THE DENSITY OF ROCKS

Geologist can't see into the Earth, or take samples from it's deep interior. They have deciphered the Earth's structure by measuring how quickly waves produced by Earthquakes travel through the planet. A dense metallic **core** is at the heart of the Earth, and rocks become less dense as you travel through the **mantle** to the **crust**.

ACTIVITY

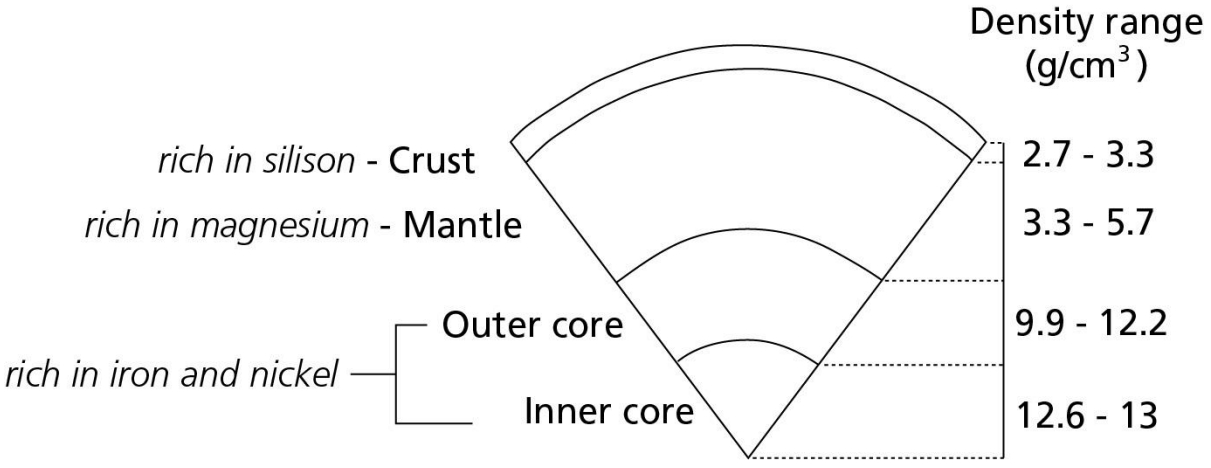


1. Set up your equipment as shown in the diagram.
2. Weigh each specimen on the scales.
3. Place each specimen in the displacement vessel and measure the overflow in the measuring cyclinder.
4. Calculate the density (p) of each specimen. p = mass ÷ volume
5. Use the diagram of the Earth's interior to predict if the specimen comes from the crust, mantle or core.

Specimen	Mass (g)	Volume (mL)*	Density (p) (g/cm^3)	Earth's Interior
Peridotite				
Basalt				
Granodiorite				
Sandstone				
Meteorite		5		

* 1 mL of water is equal to 1 cm^3

Earth's Internal Structure



Why can a meteorite represent the Earth's core? _____

ACTIVITY 3. QUARRYING BY ABORIGINAL PEOPLE

CASE STUDY: Basalt ground-edged artefacts on the central coast of NSW

Read the introduction about ground-edged artefacts and then complete the activities on the next page.

Introduction

Ground-edged artefacts, including hatchet heads (stone axes), bulga knives and hammer/pounders, were multi-purpose tools used by Aboriginal people. They were used to perform tasks such as crafting wood, processing plants and hunting possums.

The earliest evidence of ground-edged artefacts in south-eastern Australia dates from between 3,800-5,600 years ago. These tools were made of hard igneous (e.g. basalt) or metamorphic (e.g. hornfels and quartzite) rocks.

The **lithography** of the central coast of NSW is dominated by Triassic sandstone and shale, as well as localised outcrops of mafic igneous rocks, such as basaltic dykes and plugs, and remnant mafic flows high on the landscape.

Portable X-ray Fluorescence (pXRF) is a non-destructive technique that has recently been used by researchers at the Australian Museum to locate the geological source of rocks used to make ground-edged artefacts by the Darginung people on the central coast of NSW. pXRF determines the elemental 'signature' of an artefact and cross matches it to the signature geological sites. Unlike more traditional geological techniques, such as thin-sectioning to determine the minerology of a rock specimen, pXRF does not destroy the valuable artefact.

Ground-edged artefacts made from basalt from Peats Ridge-Popran Creek have been found throughout the central coast of NSW, with most of it coming from the outcrops at Mangrove Mountain. Basalt from this site consists of relatively hard minerals (pagioclase feldspar, clinopyroxene, and olivine) and very fine-grained mineral crystals (0.02 – 0.3 mm); ideal for making strong and durable tools. The widespread distribution of artefacts sourced from Peats Ridge indicates the Darginung people had a deep knowledge of the rocks' properties.

The isolated sites of basalt meant that people would travel long distnaces to obtain valuable rock. Rocks could not simply be taken and exchange took place at ceremonial gatherings. Valuable rock may have been exchanged for other objects such as net bags, grinding slabs, wooden objects (e.g. spears and shields), and ochre, as well as ideas, songs and arrangement. Exchanges may have taken place at quarries or at the borders between clans. Basalt artefacts from the central coast of NSW have been found as far as 430 km away from theire geological source.

ACTIVITY

1. Use the Aboriginal languages map to identify the traditional custodians of the land at Peats-ridge. Draw the outline of the region on the map of Australia.

An interactive map can be found at:
https://aiatsis.gov.au/explore/articles/aiatsis-map-indigenous-australia

Who are the traditional custodians of the land upon which your school is located?

_____.

Extension: Who are the neighbouring Aboriginal communities of your school. What language do they speak? Are there any local landmarks with an Aboriginal name? You could find out more information about your local Aboriginal communities through the NSW Aboriginal Land Council (http://alc.org.au/).

2. Closely examine the two Aboriginal artefacts. What is the name of this igneous rock? _____

3. List two properties of the rock that would have made it useful as a tool?

(i) _____

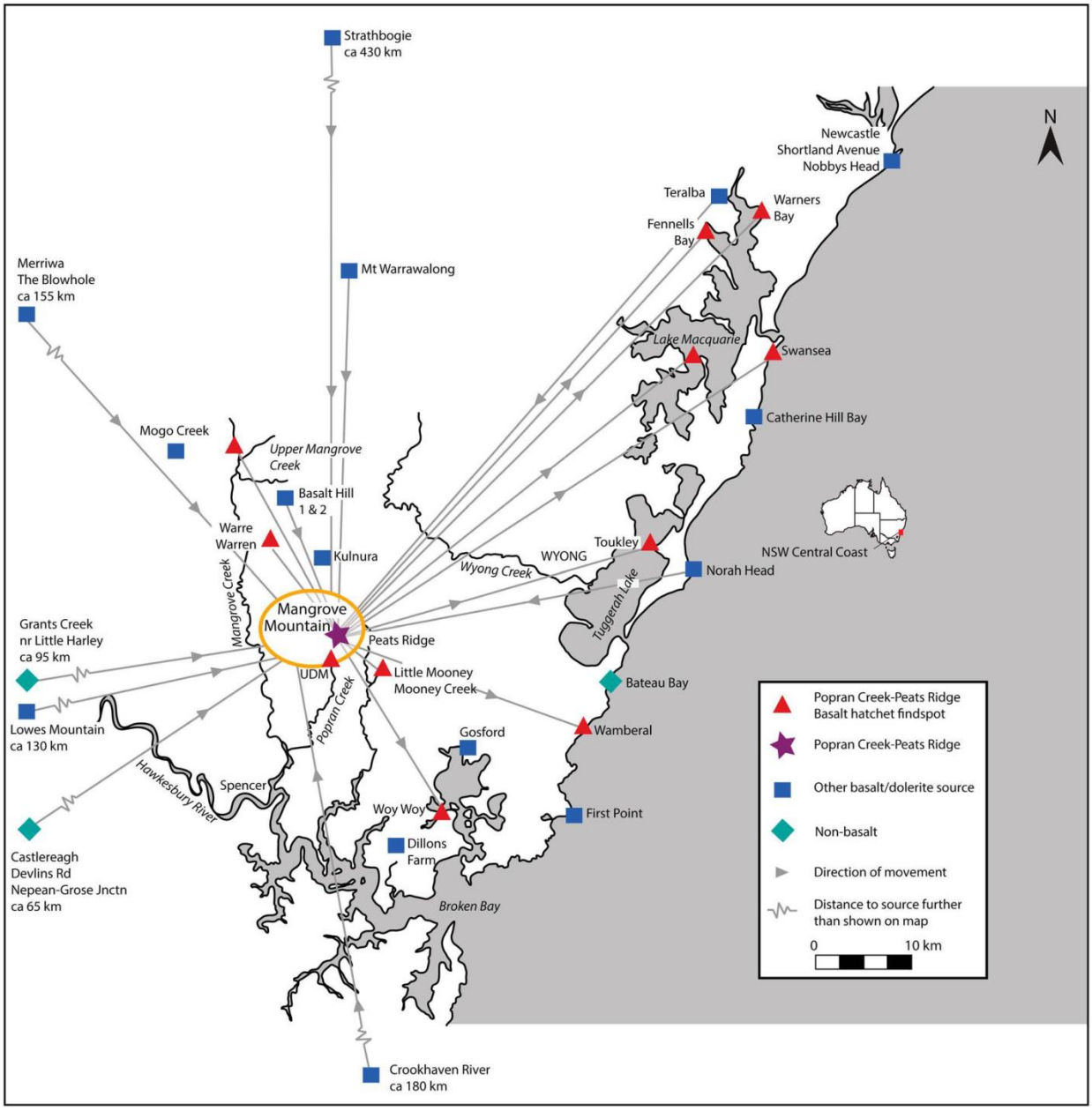
(ii) _____

4. Closely examine the surfaces of two Aboriginal artefacts. Draw a diagram of each artefact on the next page and label the main features. Also describe the possible function of each feature or how you think it was made.

Artefact 1: _____	**Artefact 2: _____**

Artefact	Feature	Function/How it was made
1		
2		

The distibution of Peats Ridge-Popran Creek basalt ground-edged artefacts on the central coast of NSW



Reference

Attenbrow, V. *et al.* (2017). Non-destructive provenancing of ground-edged mafic artifacts: a holocene case-study from the Sydney basin, Australia. *Journal of Field Archaeology*.

Additional Case Study: Ochre Mining in Central Australia

The article in the link below describes how red ochre was collected and traded by Warlpiri men in central Australia. It describes the tools that were used to mine the ochre, custodianship of the mine and trade routes in the region.

https://australianmuseum.net.au/uploads/journals/17646/333_complete.pdf

SEDIMENTARY ROCKS

Sedimentary rocks are formed by the breakdown (both physical and chemical) of pre-existing rocks, which may be of igneous, metamorphic or sedimtary origin. They are classified according to the predominant grain size present, as well as by their mineral content.

Texture	CLASTIC (Composed of rock fragments)					BIOCLASTIC (Organic)		CRYSTALLINE		
Sediment	Rounded pebbles	Angular fragments	Sand	Silt	Clay	Plant remains	Cemented shells	Fine to coarse crystals		
Rock Examples	Conglomerate 	Breccia 	Sandstone 	Siltstone 	Shale 	Bituminous coal 	Limestone  	Rock gypsum 	Rock salt 	
Composition	Mainly composed of quartz, feldspar and clay minerals.					Carbon	Calcite	Precipitated $CaCO_3$	Gypsum	Halite

IGNEOUS ROCKS

Igneous rocks are formed when magma cools and solidifies.

	Intrusive		Extrusive
	Plutonic	**Sub-volcanic**	**Volcanic**
Formation in Earth	Deep	Shallow	Surface
Grain size	Coarse	Medium	Fine
Composition			
Felsic rich in Al, Si	 Granite		 Rhyolite
Mafic	 Gabbro	 Dolerite	 Basalt
Ultra Mafic rich in Fe, Mg	 Peridotite		 Picrite

lighter → Colour → darker

Other common volcanic rocks

Bomb

Molten projectile

Pumice

Pyroclastic rock (rhyolitic)
Abundant cavities

Obsidian

Dark, volcanic glass (<1% water)

Scoria

Pyroclastic rock (basaltic)
Abundant cavities

METAMORPHIC ROCKS

Metamorphic rocks are pre-existing rocks whose mineralogy and/or texture has been changed by processes within the Earth. They form because of changes in temperature and depth of burial within the Earth without melting.

Texture	FOLIATED (Leaf-like layers)			NON-FOLIATED (No layers)		
	Mineral Alignment		Visible Banding Pattern	No mineral alignment or visible banding pattern		
Grain Size	Fine	Fine to Medium	Medium to Coarse	Fine	Medium to Coarse	Medium to Coarse
Parent Rock	Shale Mudstone Siltstone	Slate / Phyllite	Schist	Bituminous coal	Limestone Dolomite	Quartz sandstone
	↓	↓	↓	↓	↓ or ↓	↓ or ↓
Examples of Metamorphic Rock	Slate	Phyllite / Schist	Gneiss	Anthracite	Marble	Quartzite
		 				
	Increasing metamorphism →					
Main Composition	Mica	Mica, quartz, feldspar, amphibole, garnet	Mica, quartz, feldspar, amphibole, garnet, pyroxene	Carbon	Calcite and/or Dolomite	Quartz

Key: **Regional** (heat and pressure) metamorphism — **Contact** (heat) metamorphism