GOLD INDUSTRY GROUP

NATIONAL **GOLD** **EDUCATION** PROGRAM

GOLD RESOURCES KIT
TEACHER GUIDE

An education initiative by the Gold Industry Group

education.goldindustrygroup.com.au

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1 INTRODUCTION

1.1 About your Gold Resources Kit

The Gold Resources Kit is designed to provide schools with real rock and gold samples from Australian gold mines, along with complimentary learning tools as part of the Gold Industry Group's National Gold Education Program. These rock samples showcase some of the amazing geological and gold deposit diversity across Australia. They also provide a window into the spectacular and long geological history of the Australian continent.

Gold Industry Group members have provided samples that are of appropriate size, striking and diverse so they can be used for a variety of purposes. This Guide includes a variety of lesson plans linked to the Australian Curriculum, as well as fun and engaging activities that incorporate STEM (Science, Technology, Engineering and Mathematics) learning to excite and engage students about Australia's diverse gold sector.

Along with this Guide, the Gold Resources Kit also includes the Discover Gold in Your Life booklet, the Origins of Gold Specimens map, the Get into Gold flyer, the Careers in Gold poster and a Golden Country brochure.

These and other gold educational resources are freely accessible on the Gold Industry Group's website: **goldindustrygroup.com.au**.

1.2 Behind your Gold Resources Kit

The Gold Industry Group worked together with Australian Earth Science Education (AusEarthEd) in the planning and creation of the Kit and their associated materials. Through this partnership, useful samples and equipment were identified, providing activities that link to Curriculum content for a number of subjects (Science, Mathematics and Humanities and Social Sciences in particular) and the background information for teachers to make the most of their Kit.

Discover more free Earth Science and STEM teaching resources on AusEarthEd's website: **ausearthed.com.au** and **ausearthed.blogspot.com**.

2 OVERVIEW

2.1 About this Teacher Guide

This Teacher Guide is designed to support teaching and learning practices, with a wide variety of unique materials to excite students about Australia's diverse and evolving gold industry.

Through activities and lessons linked to the Australian Curriculum that cover STEM (Science, Technology, Engineering and Mathematics) and HASS (Humanities and Social Sciences) subject areas, Primary and Secondary school students can develop acute problem-solving skills and logical reasoning to expertly handle the tasks and challenges of tomorrow.

Additional gold educational resources for teachers are also highlighted in this Guide to further students' learning in what gold is and how valuable it is to their everyday lives. Students can also dive into the sector's history, its inner workings and impacts on Australia's community and economy, as well as explore precise areas of interest and study.

2.2 Engaging with your Kit

Fun and engaging STEM activities have been developed as part of the Gold Resources Kit. These activities will help teachers to make the most of students' engagement with the Kit according to their year level.

Year	Activity	Subjects	Type	Description	Page
4	How big is that?	Mathematics	Hands-on investigation	Students work out the volume, surface area, weight and density of rock samples from your kit.	17
5	Going for gold	HASS	Comprehension and analysis	Students learn more about the history of Australia to understand the experiences and contributions of migrant groups within a colony.	19
5	Gold hunt!	Mathematics	Problem solving	Students describe the route they used when moving from gold claim to gold claim in a letter to be sent home.	27
8	How about that rock?	Science	Hands-on investigation	Students investigate the properties of rocks linked to gold deposits (using samples from your kit).	30
10	The formation of gold in stars	Science	Research, Discussion	Students examine the gold leaf available in your kit and research where the gold originally came from.	33

2.3 Additional gold education resources

2.3.1 Gold Class Session

Book a free, interactive Gold Class Session delivered by an industry professional, which includes hands-on activities that incorporate STEM learning. The sessions designed for Upper Primary students (Years 4-6) and Lower Secondary students (Years 7–10), are freely available across several regions of Australia.

Visit **education.goldindustrygroup.com.au** to book a free Gold Class Session for your class.

2.3.2 Heart of Gold Australia app

The free Heart of Gold Australia app provides several interactive activities that students can use in the classroom or with friends and family. Download the free Heart of Gold Australia app to your classroom devices from the App Store for iOS or Google Play for Android, ensuring the bundle in the app is also downloaded, and explore its many features, including:

- **Discover Gold Game:** students select an interactive scene in which to locate seven items that contain gold in order to uncover twelve uses of gold. Take the quiz to test their knowledge! Refer to the Discover Gold in Your Life booklet included in your Gold Resources Kit.
- **Virtual Gold Trails:** the Perth and Kalgoorlie Heart of Gold Discovery Trails make for a fun outdoor class excursion or in-class exploration. These virtual gold trails combine learning with technology and the outdoors, to provide students with an appreciation for the golden history of their region. If you do not live near one of the gold trails, why not take the tour from the comfort of your classroom?
- **Gold Attractions and Tours:** use the interactive map to identify gold attractions and tours near you.
- **Gold Facts:** learn interesting facts and figures about the gold industry.
- **Photo Booth:** students can use the fun filters to take gold-themed photos of themselves.
- **Games:** try out various interactive games to get a sneak peek into what the trails have in store.
- **Videos:** access a large catalogue of short videos featuring people from the gold industry and beyond, including a Mining Engineer, Aboriginal Rangers, an Emergency Response Team and a Mayor.

2.3.3 Gold Jobs website

The Gold Industry Group's Gold Jobs website provides a central, online hub of career pathways and employment opportunities in Australia's gold industry. A first of its kind, the website collates current vacancies across the sector along with an abundance of helpful career tips and industry insights, including worker and employer profiles, workplace programs, study and training options, scholarships, news and more.

Visit **jobs.goldindustrygroup.com.au** to inspire the next generation of gold leaders.

2.3.4 Further gold learning

Lessons plans linked to the Australian Curriculum have also been created by AusEarthEd in addition to the trails for Year 4, 5, 7, 8 and 9 students to continue their education on Australia's gold industry. The lesson plans are freely accessible on **goldindustrygroup.com.au/trail-teacher-resources**.

Year 4

Activity	Subjects	Type	Description
Gold properties	Science, Design and Technologies	Hands-on investigation	Students explore the properties of gold by running tests for; ductility, malleability, conductivity and more.
Earth surface changes and mining	Science, Design and Technologies, HASS	Hands-on investigation	Students plan and construct an open pit mine.

Year 5

Activity	Subjects	Type	Description
Walking in their footsteps	HASS, Mathematics	Discussion, Research	Students revisit their favourite elements of the #heartofgold Discovery Trail and ponder how people may have travelled from Perth to the Goldfields around Kalgoorlie.
Whose gold is it anyway?	HASS, English	Research, Discussion	Students learn more about significant people in Australia's history, including C.Y. O'Connor and John Forrest, through exploring the #heartofgold Discovery Trail (in the app) and conducting their own research. They can then use this information to play a game of 'Who Am I'.
Gold rush radio	HASS, English	Discussion, Interview	Revisit the life of C.Y. O'Connor and mock-up a radio interview with him.
Events that changed Western Australia	HASS, English	Performance	Students produce a short performance focussing on a significant event in the gold timeline.
Time for gold	HASS, English, Mathematics	Research, Discussion	Students use the #heartofgold Discovery Trail (in app) to post events to a classroom timeline.

Year 7

Activity	Subjects	Type	Description
Separation of gold	Science	Hands-on investigation	Students separate 'gold' from the mixture of rock, sediments or soil it is contained in, through panning and or designing and creating a dry washer.
The importance of water	Science, HASS, Design and Technologies	Hands-on investigation	Students design and test an effective water filter using everyday materials.

Year 8

Activity	Subjects	Type	Description
Models of gold	Science and Mathematics	Problem solving	Students create models to represent gold found in elemental, compound and mixture forms.
Placer gold	Science, Design and Technologies	Hands-on investigation, Problem solving	Students construct a model of the formation of various placer gold deposits.

Year 9

Activity	Subjects	Type	Description
Chemical processing of gold	Science	Hands-on investigation	Students model the chemical leaching process that is often used as part of the gold recovery process.
Plate tectonics and gold	Science	Hands-on investigation	Students model hydrothermal mineralisation in rock cracks and fractures.
Events that changed Western Australia	HASS	Performance	Students produce a short performance focussing on a significant event in the gold timeline.
Gold rush radio	HASS	Discussion, Interview	Revisit the life of C.Y. O'Connor and mock-up a radio interview with him.
Walking in their footsteps	HASS	Discussion, Research	Students revisit their favourite elements of the #heartofgold Discovery Trail and ponder how people may have travelled from Perth to the Goldfields around Kalgoorlie.
Time for gold	HASS	Research, Discussion	Students use the #heartofgold Discovery Trail (in app) to post events to a classroom timeline.

2.4 Australian Earth Science Education teaching resources

Primary Australian Literacy Mathematics and Science Program (PALMS)

A suite of free Earth Science activities produced by the Primary Australian Literacy Mathematics and Science Program, an initiative supported by Santos and Australian Earth Science Education, are available on **palms.edu.au**.

Activity	Subjects	Type
Earth's surface (Year 4)	Science, Mathematics, HASS, Design and Technologies	Hands-on investigation, Problem solving, Discussion, Research, Comprehension
Solar system (Year 5)		
Surface changes (Year 6)		

Woodside Australian Science Project (WASP)

A suite of free earth science based activities produced by the Woodside Australian Science Project, an initiative supported by Woodside and Australian Earth Science Education, are available at **wasp.edu.au**.

Activity	Subjects	Type
Weathering and erosion (Year 4)	Science, Mathematics, Design and Technologies	Hands-on investigation, Problem solving, Discussion, Research, Comprehension, Digital resources
Solar system (Year 5)		
Geological changes (Year 6)		
Oil and water (Year 7)		
Rocks and minerals (Year 8)		
Global systems (Year 10)		

3 ABOUT THE MATERIALS

3.1 Banded Iron Formation (BIF)

Donated by AngloGold Ashanti Australia
Rock origin: Sunrise Dam Gold Mine, Western Australia (see 'Origins of Gold Specimens' map)
Rock type: Sedimentary

Formation
This sedimentary rock was formed in an ancient ocean when sediments (broken rock materials) and precipitated minerals (like iron-rich minerals) settled to the seafloor. This rock is composed of fine sediments that are rich in iron oxides (magnetite-hematite) and could be classified as an iron-rich shale. These rocks come from a larger scale formation that is iconic to Western Australia of iron-rich and iron poor beds laid down in an ancient ocean, the Banded Iron Formations.

These rocks are surrounded by a sequence of siltstones and sandstones with a composition mirroring the underlying andesitic (intermediate) volcanic chemistry.

The rocks in this formation were later deformed and altered. They have also been intruded by dolerite sills.

A BIF rock sample

Notable features
In most samples you will see dark, very fine-grained, magnetic silts (magnetite) bound by lighter (intermediate) silts and sands.

Association to gold
This rock is one of many different ore (gold containing) rocks at Sunrise Dam. Coarse gold can typically be found within brecciated veins, suggesting this gold was transported into the rocks within hydrothermal fluids.

Sample variation
Some samples will have micro-folds throughout them as they have experienced multiple phases of deformation.

Samples will also vary in grain size, from silt to sand, and bands will vary in size, depending on where in the sequence they were picked out.

Some samples may even have a little dolerite (dark, medium-grained, igneous rock) intruded into them.

More information from geologists at the mine
Banded Iron Formations (BIFs) from the Sunrise Dam are typically very brittle which allows for the high fractionation of the rock throughout deformation events. The high fractionation allows for gold bearing fluids to penetrate throughout the beds to form steep breccia lodes. When fluids containing Sulphur-gold complexes interact with the iron-rich beds, intense sulphidation of the iron oxides (pyrite replacing magnetite) will often see coarse gold precipitate within veins.

Geologists can use the strike and dip of BIF bedding data that is gathered through open pit and underground mapping, and drill core analysis to project the position of unexplored BIF packages. As BIF has a good correlation with gold mineralisation, these areas can generate great targets for exploration.

These samples have originated from diamond drill core that was drilled from an underground drill rig at Sunrise Dam. The core has been cut in half because the other half of the core was sent to a laboratory where it was assayed for its gold content. Drill core is very useful for geologists as it provides an in-situ representation of geology deep in the ground. Measurements can be taken of veins, bedding, and contacts to determine their actual orientation beneath the surface.

3.2 Pegmatite

Donated by Ramelius Resources Limited
Rock origin: Edna May Gold Mine, Western Australia (see 'Origins of Gold Specimens' map)
Rock type: Igneous

Formation
This igneous rock formed from molten material that intruded (cut through) the main rock in the area (gneiss) after gold mineralisation.

A felsic (light coloured) magma cut through the existing gneiss in the area cooling slowly to form large crystals of quartz, feldspar, muscovite and biotite. Crystals typically range from one to three centimetres in diameter (with some standout samples displaying much larger crystals).

The pegmatite can be found as large veins (or sheets) within the gneiss, which it cut through. The samples within the kits have come from these veins.

A pegmatite rock sample

Pegmatite dykes cutting through host rock of gold mineralisation at the Edna May pit
(light coloured horizontal or dipping zones at the far end of the pit)

Notable features
Note the large, clearly interlocking crystals that make up this rock, a classic texture for an igneous rock.

Association to gold
These rocks formed after gold mineralisation in the area, therefore they do not contain gold.

Sample variation
Crystal size will vary strongly in these samples. Some will have crystals not much bigger than your typical granite; others will have very large crystals.

More information from geologists at the mine
These samples are very coarse crystalline quartz-feldspar-muscovite igneous rock. Known as pegmatites, these rocks occur as dykes which intrude (cut through) the Edna May Gneiss and other rocks in the region after gold mineralisation. Pegmatites are frequently the source of rare earth minerals, such as lithium.

3.3 Dolerite

Donated by Regis Resources Limited
Rock origin: Rosemont Gold Mine, Western Australia (see 'Origins of Gold Specimens' map)
Rock type: Igneous

Formation
This igneous rock was formed from a mafic magma intruding the existing rock in the area, forming a sill. As the magma cooled it settled and separated (differentiation), forming zones of differing texture and chemistry. For example, some zones have course crystals in them moving towards a gabbro.


A dolerite rock sample

After intruding, the rock has been regionally metamorphosed (greenschist facies), deformed and hydrothermally altered (impacted by fluid movement). The regional metamorphism caused some of the primary igneous minerals to be replaced (pyroxene by actinolite and chlorite, plagioclase by albite and epidote, and magnetite by ilmenite). Hydrothermal alteration (associated to the formation of gold bearing veins) caused further alteration of the minerals, including iron sulphides, and the formation of quartz-carbonate veins.

Notable features
In rocks from the less altered part of the sill you can see distinct plagioclase crystals (lighter coloured and often quite rectangular in shape). There may also be rounded quartz with a blue tinge to it. It is worth noting that this quartz was introduced during alteration, it is not original to the sample. Most of the rock will be made up of very fine-grained pyroxene (dark minerals) and plagioclase (lighter minerals).

Association to gold
These rocks are host to the gold in this area. Their chemistry and the structure of the sill make them an ideal host for gold.

Sample variation
Some samples will have a courser texture (and could be classified as gabbro for simplicity) and are magnetite rich.

Some samples will be highly altered, resulting in significant changes to the texture and mineralogy of the rock. Typically, the more altered a sample has been the larger the grain size and the higher the quartz (and albite) content.

More information from geologists at the mine
This unit (dolerite sill) extends about 50km (in the Duketon Belt) and is the host of gold mineralisation across three major deposits.

3.4 Gneiss

Donated by Ramelius Resources Limited
Rock origin: Edna May Gold Mine, Western Australia (see 'Origins of Gold Specimens' map)
Rock type: Metamorphic

Formation
This metamorphic rock formed when original igneous granites were subjected to heat and pressure. The original granites in this area were subjected to high temperatures and pressures, altering them significantly.

This resulted in the alignment of the minerals that make up this rock, known as foliation, as well as the formation of new minerals. This type of foliation is called gneissic and results in the division of lighter minerals (typically quartz and feldspar) and darker minerals (typically biotite) into clear lines.

These gneiss samples do not exhibit the exaggerated separation/alignment of samples in typical educational kits. You will need to look carefully to identify the foliation. Alteration of these rocks is also clear in quartz veining and the presence of sulphide minerals (which may contain gold in their structure).

A gneiss rock sample

Notable features
Note the crystal alignment (foliation), quartz veining and sulphide minerals (gold in appearance) in these samples.

Association to gold
Gold can be found in many of these rocks, typically within the small quartz veins that host sulphide minerals.

Sample variation
Crystal size and foliation will vary in samples. Some samples have crystals that are smaller than your typical gneiss and foliation that is less clear.

More information from geologists at the mine
Put simply, this is the metamorphosed granite unit, which hosts the gold mineralisation in the area. Known as gneiss, these rocks are medium to coarse grained, semi-schistose (deformed) metamorphic rocks, comprised of quartz, feldspar and biotite minerals. They were originally an igneous granite rock.

Gold typically occurs in small quartz veins with sulphides, predominantly pyrrhotite and pyrite. Evidence of alteration of these rocks can be seen in the assemblages of diopside, calcic-amphibole, plagioclase, K-feldspar and biotite. Many of the minerals display a degree of lineation (or stretching/layering) due to metamorphism/ deformation.

3.5 Basalt

Donated by Northern Star Resources Limited
Rock origin: Kundana Operations, Western Australia (see 'Origins of Gold Specimens' map)
Rock type: Igneous

Formation
This igneous rock was formed when mafic (dark) lava poured onto the ancient seafloor. Before the material erupted to the surface it had begun to cool and therefore, some of the minerals in this basaltic rock are larger.

The mafic magma that these rocks formed from was composed of minerals like pyroxene and plagioclase feldspar. Before it erupted to the surface the magma began to cool so the first minerals to crystallise, the plagioclase feldspars, grew larger (some are up to 2cm in length – typically stubby or rectangular prisms, cream to greenish in colour). Then as the magma erupted onto the surface of the seafloor the remaining minerals, like pyroxene (dark black/greenish crystals), cooled quickly so are therefore significantly smaller.

A basalt rock sample

The smaller crystals that make up this rock are called the groundmass and the large plagioclase crystals are called phenocrysts. Over time the rocks in this region were subjected to several metamorphism events (increasing temperatures and pressures) altering them slightly. In these rocks the metamorphism can be seen in the alteration (squashing) of some of the minerals and in smoothed surfaces. These rocks have not been altered significantly enough, however, to warrant their reclassification.

Notable features
Some of the samples have distinct greenish crystals in them; these are plagioclase feldspars (not olivine crystals as people often suspect).

Association to gold
These basalts are ore rock, meaning that they host gold mineralisation in the region.

Sample variation
Some of the samples will have clearly larger crystals (phenocrysts) than others and some will be from more altered zones (meaning that the crystalline textures may be harder to distinguish, but the colouring will still be clear).

More information from geologists at the mine
These samples are fine to medium grained porphyritic basalt. The texture is comprised of a dark black to medium green, fine-grained matrix with large white plagioclase crystals. They are extremely hard and brittle. Some areas exhibit extreme shearing and biotite-chlorite alteration, resulting in almost unidentifiable crystals. This basalt hosts the Pode, Hera and Hornet HW orebodies.

3.6 Tonalite

Donated by Evolution Mining
Rock origin: Mungari Gold Mine, Western Australia (see 'Origins of Gold Specimens' map)
Rock type: Igneous

Formation
This igneous rock was formed when a felsic to intermediate (light-coloured) magma intruded (squeezed into) the existing rock in the area. It cooled very slowly, allowing visible crystals to grow. This rock is 2,600 million years old and is called the Kintore Tonalite.

A tonalite rock sample

Although this tonalite formed in a similar way to, and has a similar texture to, granite, it is chemically different (featuring sodium-rich plagioclase).

The formation of this rock represented a big change for this area (the Yilgarn Craton) as during the Archaean (4,000 million – 2,500 million years ago) conditions allowed for very high temperature magmas which produced komatiitic (ultramafic) rocks and then basaltic (mafic) rocks. These rocks are green in colour and heavier than other rocks.

After a few thousand years the magmas cooled and with the reduced availability of iron and magnesium (major components of mafic minerals) more intermediate and felsic rocks were formed.

Notable features
A nice clear interlocking texture which is typical of igneous rocks. Visible minerals include plagioclase feldspar (cream coloured and often rectangular in shape) quartz (more than 20% of the rock composition), biotite (black and sometimes flakey) and pyroxene and hornblende (black to greenish rectangles).

Association to gold
The tonalite in this area are hosts to gold, but the rock samples come from a section with low concentration of gold or have been sent to waste. There may be microscopic amounts of gold in the rock samples, which is impossible to see with the naked eye.

The gold travelled within hydrothermal fluids and when it reached a bend in the local shear zone the fluids passed through these rocks, allowing the gold to precipitate out.

Sample variation
Samples may vary a little in crystal size and composition but are generally very similar to that described.

The gold in this sample, if present, is microscopic and on average is less than 0.01 grams of gold per tonne of rock.

More information from geologists at the mine
Ingredients/composition:
The tonalite rock type is of felsic to intermediate composition, which means it has both felsic and mafic minerals with a high silica ($SiO2$) composition. These minerals are lighter in colour and in specific gravity. The majority of the sample is made up of feldspar (the most common of all minerals) and at least 20% quartz. Some of the rock samples contain heavy elements such as Iron (Fe) or Magnesium (Mg) within their crystal structure, which gives the crystal its black to green coloring. One of these dark minerals is biotite which has a plate-like structure allowing it to break off into flakes.

Texture:
Your sample has a phaneritic texture which is a fancy way of saying it has crystals big enough to be seen with the naked eye. The bigger the individual crystals are, the longer it takes for the magma to cool down and the atoms to arrange themselves, known as mineral structures.

What can we tell?
From all these observations, we can determine this rock is a tonalite, which formed as an igneous, plutonic (intrusive) rock. This is when magma is trapped deep inside the earth and slowly cools and solidifies.

3.7 Gold leaf

Donated by AngloGold Ashanti Australia

Gold leaf is made by hammering gold into very thin sheets. This is possible since gold is very malleable. In fact, gold leaf can be just a few atoms thick.

The sample in your Kit is 23 carat double gold leaf. Unfortunately, there is not a lot of value in these gold leaf samples as they have been cut to size for the vials. The value of the gold in these vials is likely less than $1 (depending on the current gold price) but it is still a very useful resource to show students, so they can appreciate the beauty of gold.

Fun fact
One or more of the rock samples in your Kit may contain gold of a higher value than the gold leaf in this vial!

A gold leaf sample

3.8 Geological hand lens

This Westernex 21mm 10x Triplet Hand Lens offers fantastic magnification with a robust triple lens system. The 10x magnification is suitable for examining crystals and gold bearing minerals in your rock samples.

Note: Students will often place the hand lens to the rock and wonder why the image is blurry, best practice is to place the hand lens to your eye and bring the rock towards your face (slowly). Students are always surprised by how close the lens and rock need to be to their face to achieve the best magnification and focus.

A geological hand lens

4 ACTIVITY GUIDES

4.1 Activity guide Year 4

Activity: How big is that?

Type: Hands-on investigation

Australian Curriculum links:
(ACMMG084) / Year 4 / Mathematics / Measurement and Geometry
(ACMMG087) / Year 4 / Mathematics / Shape
(ACSSU074) / Year 4 / Science / Science Understanding / Chemical Sciences

Background information:
There are a few ways in which rocks can be sorted and this can sometimes help us learn more about them. Rocks can be made of many different types of minerals, not only can this make them look very different, but it can also make them feel very different. How the rock has formed will also make it feel and look different to other rocks. Some rocks will feel very heavy, whereas others will be very light for their size. Pumice is a type of rock that is so light (and impermeable) it can float on water. Gold is very heavy for its size. The term we use to describe how heavy something is for its size is **density**.

Aim:
To measure the surface area, volume and weight of different rocks to compare them.

Materials:
- Centimetre grid paper
- Rock specimens
- Ice-cream container
- Plastic tray
- Measuring jug
- Weighing scales

Safety notes:
- Be careful when carrying rocks not to drop them on your feet (wear enclosed shoes).
- Make sure any spills are cleaned up straight away to avoid slippage.

Method:

A - Measuring the volume

1. Place the ice-cream container into the plastic tray and use the measuring jug to carefully fill the container right to the top.
2. Put the first rock into the ice-cream tub so that the water overflows into the tray.
3. Carefully empty the water in the tray into the measuring jug to work out its volume and record this into a table.
4. Repeat this for each rock sample.

B – Measuring the surface area

1. Place a rock specimen on the centimetre grid paper and draw around it.
2. Turn the rock so a different side is now on the paper and draw around it again. Keep doing this until you have marked out all the sides on the paper or as best as you can. (You may like to ask students if this is an accurate method of measurement).
3. Count the squares inside the areas you have drawn over and add them all up. Record this information in your table.
4. Repeat this for each rock sample.

Note*: Students could also try wrapping the rock in the paper and cutting away any excess, then counting up the squares of the paper used to cover the rock.*

C - Weighing the rocks

1. Place each rock, one by one, on the scales and write down how much each rock weighs in your table.
2. Ask students to compare their results with those of others.
3. Write the rock names down, in order from largest volume to smallest volume, then do the same for surface area and weight.
4. Was the largest rock also the heaviest, and the smallest also the lightest?

Students might be surprised to find that just because one rock is bigger in size it is not necessarily the heaviest. The rocks have different densities. A high-density rock will be heavy for its size and a low-density rock will be light for its size.

There are a few reasons why a rock might be very dense, it could be because it is made of interlocking crystals, which have no space between them. The crystals fit together like Lego, as opposed to rocks like sandstone or pumice which have lots of pore spaces. Rocks might also be very dense because of the material that they are made of. If a rock contains lots of heavy minerals, like iron and nickel, it will be much heavier than a rock made of light minerals like silica (a major component in sand).

4.2 Activity guide Year 5

Activity: Going for gold

Type: Comprehension and analysis

Australian Curriculum links:
(ACHASSK109) / Year 5 / HASS / Knowledge and understanding / History

Background information:
When gold was initially recorded in Australia, by assistant surveyor James McBrien at Fish River, the government tried to keep it hushed up. They thought that if people got wind of it, they would leave the colonies, and this would cause a labour shortage leading to financial trouble. However, after the Californian Gold Rush began in 1848, Edward Hargraves returned from California to Bathurst, New South Wales (NSW). He understood the geology of the area and from his experiences of 'gold country' felt it could contain lots of gold. The NSW Government rethought their policies regarding gold and started to offer rewards for finding it. Soon after this more discoveries were made throughout NSW and Victoria (Victoria broke away from NSW and became a separate colony in 1851).

By 1853, the word had spread to China about the gold discoveries and Chinese people migrated by the thousand. However, tensions between the Chinese and European diggers were rife. The Europeans resented the way the Chinese worked together in teams (often making them more effective), and the fact that they also worked on Sundays, among other things. In some locations, such as Lambing Flats, these tensions grew to aggression and rioting. Anti-Chinese feelings increased, and the government put in place policies to make it more difficult for Chinese people to enter Australia, including charging higher entrance taxes.

Figure 1. The California Gold Rush

The Californian Gold Rush, accessed at thoughtco.com/the-california-gold-rush-1773606, on 30/05/19

Aim:
To understand the reasons people migrated to Australia and the experiences and contributions of a particular migrant group within a colony.

Method:
Part A
Show students the picture on the previous page (Figure 1) and ask them what they can ***observe***? What can they ***infer*** about life in the goldfields from the picture? You might ask them to write a list or draw up a table. Please refer to Table 1.

Part B
Print the information sheets provided for your students. Dot them around the classroom to create a fact hunt. Ask the students to read the information and answer the following questions:

1. Why did European diggers resent the Chinese?
2. When did Chinese people start migrating to Australia to look for gold?
3. When did the Lambing Flat Riots happen?
4. Who's recording the gold which led to the gold rush and where was it discovered?
5. How did some Chinese people avoid paying the landing tax in Victoria?
6. What is another name for the Immigration Restriction Act and when was it passed?

Part C
Ask students to create a timeline of the key events which affected Chinese migration during this time.

Extension:
Students could write a journal entry from the perspective of a Chinese gold miner. They could add illustrations to show what the conditions were like.

Table 1

Observation	Inference
There are only two women in the picture.	Women were not usually at the goldfields.
Men are digging and near the river.	The work was hard and physical.
People panning in and near the river.	The river became dirty with mud. It was hard to get fresh drinking water.
There are tents and one hut.	The men mainly slept in tents - there was little comfort.
Men are standing in the river.	It could be a cold and wet job - you might have problems with your feet if they are always wet.

Information Sheet 1

When gold was initially found in Australia, the government tried to keep it hushed up. They thought that if people got wind of it, they would leave the colonies, and this would cause a labour shortage leading to financial trouble. However, after the Californian Gold Rush began in 1848, the New South Wales (NSW) Government rethought this policy and started to offer rewards for finding gold.

Edward Hargraves returned from California to Bathurst, NSW and discovered gold in 1851 on a site he named Ophir (after the Biblical city made of gold). After this discovery people tried to get to Ophir as quickly as they could to make their fortune! People came from Europe as well as Asia.

Figure 2. Mr E. H. Hargraves, 12 Feb 1851, returning the salute of the gold miners, painted by T.T. Balcombe
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Mr E. H. Hargraves, the gold discoverer of Australia, painted by T.T. Balcombe, accessed at en.wikipedia.org/wiki/Edward_Hargraves, on 16/05/19

Information Sheet 2

By 1853, word had reached China that gold had been discovered in Australia. This led to a massive increase in Chinese immigrants, reaching 17,000 by 1855.[1]

To raise money for the fare to Australia, a man would take a loan from a local trader and send payments back. If he was unable to pay the debt, his wife and children would have to work for the trader.

The conditions on the goldfields were harsh, with people living in tents at first. Food and other goods had to be brought in by cart and were therefore expensive. It was hard to get clean water and there were no sewerage systems. Many people died of diseases due to poor hygiene.

Gold mining was very much a 'man's game'. Though some women did come to join their husbands when conditions improved, particularly as people started living in wooden huts and the towns became more established.

Figure 3. Gold diggings, Ararat, c. 1895, by Edwin Roper Loftus Stocqueler

Gold diggings, Ararat, Victoria, painted by Edwin Stocqueler, accessed at en.wikipedia.org/wiki/Australian_gold_rushes, on 16/05/19

[1]openresearch-repository.anu.edu.au/bitstream/1885/49261/39/09chapter7.pdf

Information Sheet 3

The space where someone was digging was called their "claim". To keep a claim, a person had to work on it every day excluding Sunday which was an observed day of rest. If no one was working a claim, someone else could take it and this was known as "claim jumping".

The European diggers (prospectors) generally worked on their own, or sometimes with their families if they had come out to join them.

However, when the Chinese arrived at the goldfields they tended to stay together and work in large teams. These teams were usually made up of men from the same village. One man would lead the teams and the men were separated into groups, with some men mining and others cooking or growing vegetables to feed the team.

Because of the way the Chinese worked as a team it made them very efficient and often much more successful than the Europeans. The Chinese also worked on Sundays. This led to resentment. Also, the appearance and habits of the Chinese were unfamiliar to the European diggers and this led to a great deal of racism and prejudice.

Information Sheet 4

To prevent large numbers of Chinese people coming to Australia to work on the goldfields, a law was passed in 1885. It stated that any Chinese person entering Victoria had to pay a tax of ten pounds (the equivalent of around $2,000 in today's money) for the right to mine and live in the colony.

This tax was only for Chinese people, no one entering from any other country had to pay this tax. Many of the Chinese people coming to Australia would land in South Australia, instead of Victoria, and then walk 400 kilometres to the goldfields to avoid paying the tax.

Figure 4. Can you imagine walking 400 km with all your belongings?
____
Chinese prospector walking to the gold mines, accessed at kidcyber.com.au/gold-rush-in-australia, on 16/05/19

Information Sheet 5

The 1850's through to the early 1860's saw rising resentment toward Chinese miners. The Lambing Flat Riots occurred across goldfields in the Burrangong region in New South Wales (NSW). Between 1860-1861 a wave of anti-Chinese disturbances happened in the goldfields of NSW at an area called Lambing Flat (now called Young). White (European) miners started rioting, saying that the Chinese were wasting the water supply. The disturbance became violent and the white miners entered the Chinese settlement, killing several people and injuring many others. Not feeling safe, many Chinese people fled the area.

The army came to restore order, staying from March until June 1861, and many of the Chinese people returned. However, when the army left a massive riot occurred on June 30, 1861. Several thousand miners attacked the Chinese settlement, turning the Chinese people out, beating and robbing them as they tried to flee. A detachment of soldiers, sailors and police stayed in the area for a year and at the end of the affair there was peace and a Chinese contingent.

Figure 5. Anti-Chinese poster used to make the Chinese feel unwelcome.

Roll Up banner, Lambing Flat riots, accessed at en.wikipedia.org/wiki/Lambing_Flat_riots, on 16/05/19

Information Sheet 6

In 1901, the new federal government of Australia passed the Immigration Restriction Act. This is also known as the "White Australia Policy". It was the government's way of preventing non-Europeans from coming to live in Australia.

The law aimed to stop non-whites from entering Australia. Any immigrant that wanted to move to Australia had to complete a listening test. The test was carried out in a European language, deliberately to make it harder for non-Europeans to enter the country unless they had a sponsor.

The Act also regulated how long Chinese people could stay, whether or not they could bring their families, whether or not they could work (and for whom) and their opportunities to employ others.

The Act was not changed until the 1950's when the laws became less restrictive and the government got rid of the listening test.

4.3 Activity guide Year 5

Activity: Gold hunt!

Type: Problem solving

Australian Curriculum links:
(ACMMG113) / Year 5 / Mathematics / Measurements and Geometry / Location and transformation

Background information:
Gold was first recorded in Australia on the 15th February 1823 by assistant surveyor James McBrien at Fish River, between Rydal and Bathurst in New South Wales. The find was considered unimportant at the time and was not pursued for policy reasons. However, after the Californian Gold Rush began in 1848, Edward Hargraves returned from California to Bathurst, New South Wales (NSW). He understood the geology of the area and from his experiences of 'gold country' felt it could contain lots of gold. The NSW Government rethought their policies regarding gold and started to offer rewards for finding it.

This started the Australian Gold Rush, where many men moved to the goldfields in the hope of finding their fortunes. The work was hard; the men had to dig the ground and then swirl it in a special way with water in a technique known as panning. The area men dug was called their "claim". If a man took a day off (other than Sunday), another man could move into his claim. This is one of the reasons that men often slept in tents next to their claim. If somebody found a lot of gold, other men would try to move their claims to be closer to where it was found in the hope that they might also strike it rich.

Women did not usually stay in the goldfields, but in the towns nearby to look after the children. Therefore, the diggers (miners) had to write letters to keep in contact with their families to let them know what was going on.

Aim:
To describe the route and what you found when moving from claim to claim in the search for gold in a letter to be sent home.

Materials:

- A large copy of the map provided for each rock sample available
- A map for each student
- Your Gold Resources Kit (or a range of rocks available to you)

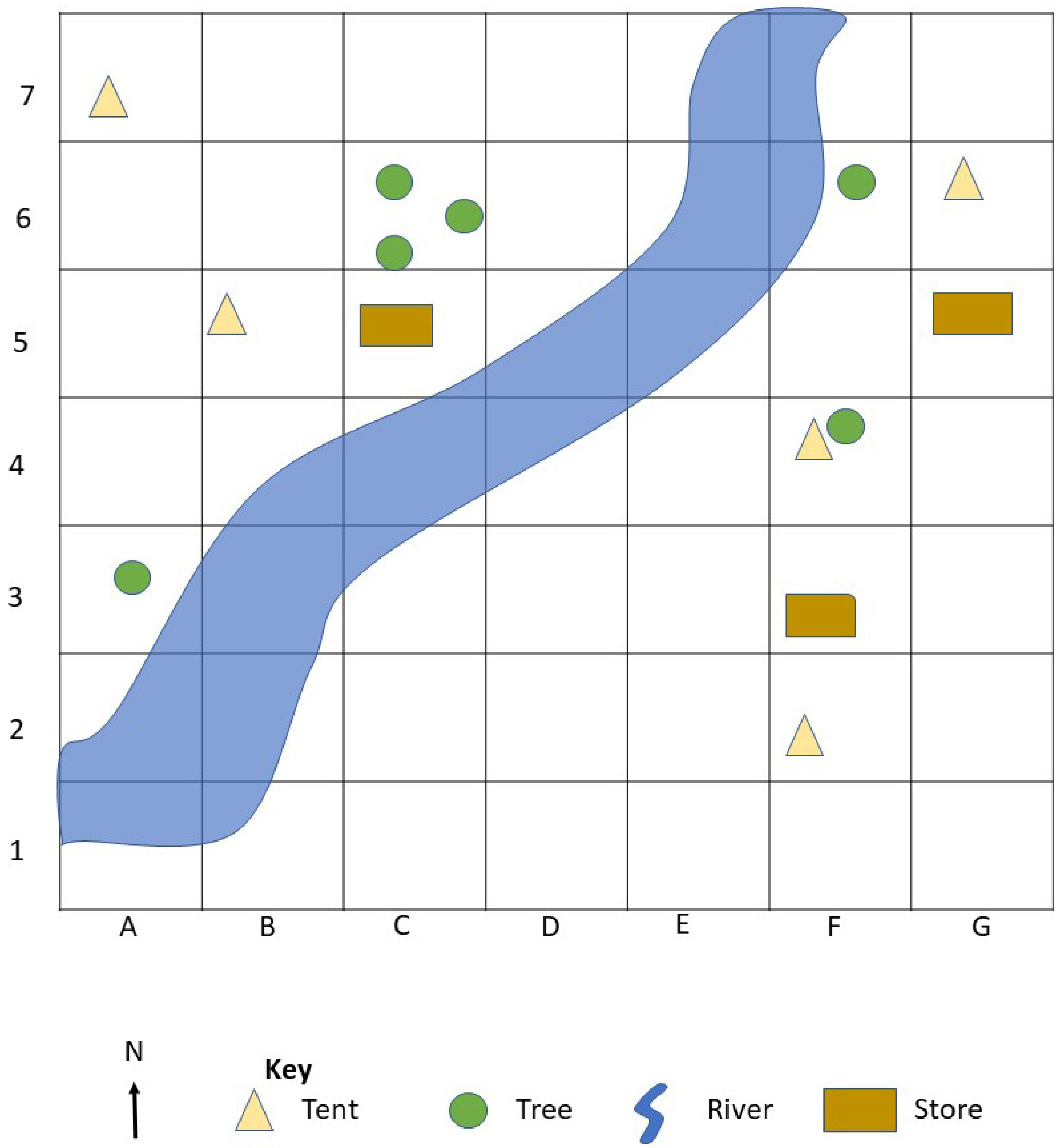
Method:

1. Set up tables around the room with a large print out of the map (provided on the following page) and a rock sample (located at a different grid reference, next to a tent - representing a claim) on each one.
2. Give each student a smaller copy of the map provided.
3. Scatter students across the tables letting them know that their claim is where the rock is.
4. They should draw and label a picture of the rock that they have found in their workbooks (noting the grid reference it was found at, to be added to their letter later). Key features students might include in their descriptions are; colour(s), if they have any layers, if they can see crystals, are the rocks shiny, how do they feel (heavy, rough etc.).
5. Suddenly they hear of a gold discovery in another area and 'jump claim'. Ask students to move to the next claim (table) and make observations of the rock found there. They should also draw their pathway from one claim to the next on their map.
6. This should continue until they have worked on all 'claims'.
7. Finally, they should write their letter. Their family is not familiar with maps so they must describe their travel in words.

An example of a letter might start like this:

Dear __________,
I have been working very hard, digging and panning for gold. I have jumped claim a few times to try and find the best place for gold. I started in the northwest of the goldfield but didn't find anything, ***so moved eastward, closer to the river, staying north.*** *Here I found* ***a very dark, heavy rock. It was made of small crystals that were hard to see.*** *Below is my drawing. I couldn't find any gold here so moved on…*

Gold hunt map



4.4 Activity guide Year 8

Activity: How about that rock?

Type: Hands-on investigation

Australian Curriculum links:
(ACSSU153) / Year 8 / Science / Science Understanding / Earth and Space sciences
(ACSIS140) / Year 8 / Science / Science Inquiry Skills / Planning and Conducting

Background information:
All rock samples in your Gold Industry Group's Gold Resources Kit have been selected as they might contain gold. One of the ways that gold can be brought closer to the surface is in hot, mineral-rich fluids.

Dolerite is an intrusive igneous rock, which has been formed by magma cooling inside the Earth. It is dark in colour as it contains mafic (magnesium and iron rich) minerals. Dolerite often forms in the pipes and dykes (spelt 'dike' in the US), which lead off from a magma chamber towards the surface.

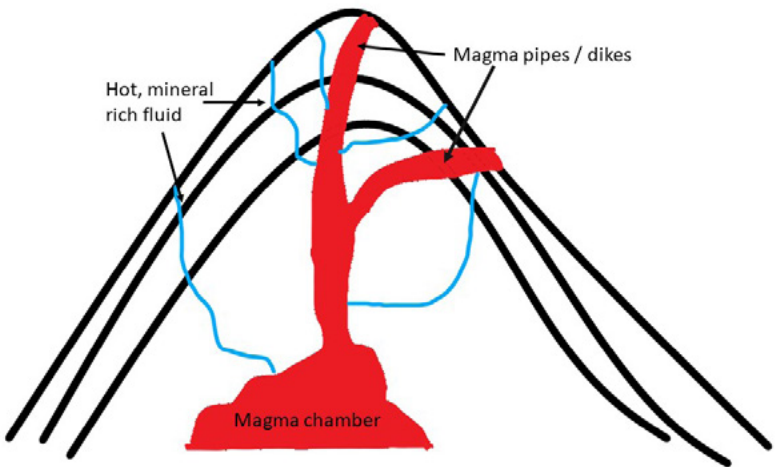


Figure 1. Gold is often brought up from deep within the Earth with magma or in hot, mineral-rich fluid.

Hot, mineral-rich fluid often moves up into cracks, where the minerals will precipitate. This leads to the formation of veins. Gold may be brought up in the hot fluids, so veins are a likely target for gold. A rock that has been very hydrothermally altered (altered by heated water), may also be a likely target for gold.

Although 'fool's gold' (pyrite) is not actually gold, pyrite can often be found near where gold is. **Pyrite** is a gold coloured mineral that usually grows in cube shapes. If pyrite is rubbed on a white tile (streak test), it will leave a greenish black mark (known as its streak colour). **Gold**, on the other hand, will leave a yellowish coloured streak.

Exploration Geologists look for rocks that may contain gold in the field. They may also study **geophysical surveys**, such as gravity, conductivity and magnetism. Gold is dense, giving it a strong gravitational pull and the rocks associated with gold tend to have high densities. Gold is also highly conductive, so rocks containing gold may also be conductive. Some minerals that are associated with gold also have high magnetism, which is why magnetic surveys are often carried out in the search for gold.

Most rocks associated with gold are **highly crystalline**, which means there is little to no pore space in them. This is another reason why they are very dense. Their crystalline structure also means that they are not usually porous or physically permeable.

Aim:
To investigate properties of rocks linked to gold deposits and record observations.

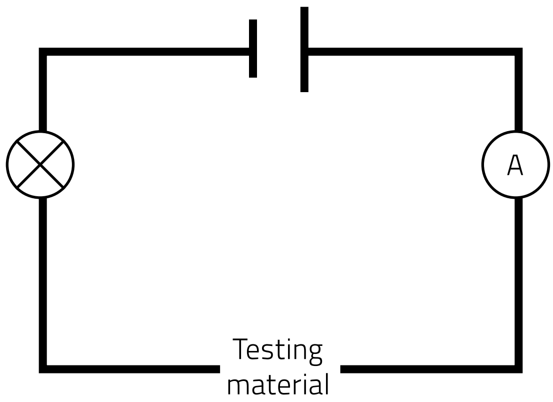
Materials:
- Gold Resources Kit (or a range of rocks available to you)
- Hand lenses or suitable magnifiers
- Electrical leads
- Batteries/power pack
- Light bulb
- Ammeter
- Displacement cans
- Weighing scales
- Measuring cylinder
- White tile
- Magnet/magnetic field sensor
- Plasticine
- Pipette

Method:
A – Making observations
Students should draw and label diagrams of the rocks, adding a scale. Key observations are colour, crystal size and if there are obvious layers. Students can use the hand lenses to look at the rocks in more detail.

B – Testing conductivity
1. Students set up a simple series circuit using a battery or power pack, wires, a bulb and an ammeter as shown on the following page.
2. Place each rock sample one at a time in the space between the wires to complete the circuit.
3. Students observe if the light has gone on and record current readings from the ammeter, if any.

Note: *Gold is a good conductor although it is advised not to test the gold leaf as it can be easily damaged.*

C - Sensing magnetism
By placing the magnet or magnetic field sensor next to the rocks and recording any readings, students determine if any of the rocks show magnetism.



D - Determining density
1. Students fill displacement cans to just below the spout.
2. A measuring cylinder is placed below the spout to catch the water when it comes out.
3. Place one sample into the displacement can and determine the volume of the rock (equal to the volume of water displaced into the measuring cylinder). Record results in a table. Remember 1 mL = 1 cm^3

Repeat for all samples.

Note: *If samples are too large for a displacement can use an ice-cream tub (or equivalent) on top of a larger vessel such as a tray. Fill the tub to the brim and then place the sample in the tub. Pour the water which has been displaced into a measuring beaker/cylinder and measure the volume of water displaced.*

4. Weigh the rocks on the scales to determine their mass in grams (g).
5. Calculate the density by dividing the mass (g) by the volume (cm^3).
6. Compare the density with that of sandstone (2.1 – 2.4 g/ cm^3) and limestone (2.5 – 2.75 g/ cm^3). How different are they? Discuss how they form to consider what might cause them to have a very different density. Usually they will find that the igneous gold bearing rocks have a higher density than sedimentary rocks, like sandstone.

E – Porosity and permeability
1. Use the pipette to drop some water on each sample.
2. After 5 minutes and again after 10 minutes take a photo of the rock and observe if the water has soaked in or if it is still on top of the rock.
3. If it has soaked into the rock, create a “chimney” on top of the rock using plasticine and pour about 20 mL of water into it. Place the rock on some paper and wait about 15 minutes to see if it has soaked through to the paper to determine if the rock is permeable. You could also measure how much water is left in the chimney to determine how much has passed into the rock as some rocks are permeable, but it can take a long time for the water to filter through.

Discussion:
1. Describe any common features of gold bearing rocks.
2. Which investigations were the most useful for identifying properties of gold bearing rocks?

4.5 Activity guide Year 10

Activity: The formation of gold in stars

Type: Research and discussion

Australian Curriculum links:
(ACSSU188) / Year 10 / Science / Science Understanding / Earth and Space Sciences
(ACSSU186) / Year 10 / Science / Science Understanding / Chemical Sciences

Background information:
As cosmologist Carl Sagan famously said, "The cosmos is within us. We are made of star-stuff. We are a way for the universe to know itself." To understand what he meant one must first understand the life cycle of stars.

Stars form in clouds of dust and gas called **stellar nebulae**. If the cloud is large enough, its own gravity starts to pull it together making it denser and hotter. This forms a **protostar**. Eventually the particles start to fuse together, and once **fusion** has started the star begins to shine. Inside the star, hydrogen atoms fuse together to form **helium**, this creates the energy of every star. The radiation **pressure** caused from fusion pushes outwards, creating an equilibrium with the force of gravity pushing inwards. Once fusion commences, the star enters the **main sequence** stage which is the longest, most stable period of a star's life.

What happens next will depend on the size of the star. An average star, like our Sun, will eventually run out of hydrogen and the core will start to collapse in on itself. This leads to it becoming denser and hotter, and the helium atoms start to fuse together creating carbon and oxygen. The outer layers start to expand, cool and become less bright; forming a red giant. Eventually our Sun will grow so large it will engulf the Earth. The outer layers of the **red giant** will start to drift off into space forming a planetary nebula. Eventually the red giant collapses in on itself, forming a white dwarf which is a very hot, dense star. Over time the white dwarf cools and will finally become a **black dwarf**.

A giant star is able to fuse heavier elements inside its core and will become a **red supergiant**, up to 1,000 times the size of our Sun. Fusion will continue until it has fused elements all the way up to iron. Once it has formed an iron core, the core collapses rapidly in on itself. The outer material rebounds off the core, this leads to a massive shockwave and the star explodes in a **supernova** blasting the outer layers off into space.

The explosion is so violent and has so much energy that elements start to come together in a process called **neutron capture**. This is where neutrons, which have no repelling charge, are captured by the iron group elements. The addition of neutrons increases the mass of any element and this allows heavy elements up to **uranium** to form. This is when gold is formed.

As opposed to the time taken for fusion within a star, neutron capture occurs extremely rapidly (in a matter of seconds). The shockwave then ejects the newly created material into space, creating a swirling mass of gas and dust which is the stellar nebula. Thus, we are back to the start of the cycle. Planets as well as stars form from these swirling clouds of dust, and some of the gold particles which were made during the supernova will be part of the material making up these planets.

When the Earth first formed it was in a molten state, allowing heavier elements to sink to the core. This is known as gravity differentiation (or the Great Iron Catastrophe). Gold, which is a heavy element, would have also sunk downwards towards the core. Researchers from the University of Bristol have proposed that reserves of precious metals closer to Earth's surface, including gold, are the result of a bombardment of meteorites which hit the Earth more than 200 million years after it was formed. At this stage, the Earth was no longer molten.

Aim:
To explain the life cycle of stars and describe the process that forms gold and heavy elements.

Method:
Part A
Locate gold on the periodic table and ask students what its periodic (atomic) and mass numbers are.

Pass the gold leaf sample (available in your Gold Industry Group's Gold Resources Kit) around the class and brainstorm ideas on the whiteboard as to where the gold could have originated from.

Part B
Students research the life cycle of stars and produce a diagram to represent this cycle. They then answer the following:

1. Where are stars born?
2. What force pulls all the matter together at the beginning of a star's lifecycle?
3. What causes the expansion forces pushing outwards in a star?
4. Which elements fuse together to make helium during the main sequence stage of a star's life?
5. What will happen to a star with the same mass as ours once the hydrogen runs out?
6. Describe what will happen in a super-giant star, before the core collapses.
7. Describe the process that makes gold and other elements heavier than iron.
8. Using a periodic table, colour all the elements created during a supernova one colour and all the elements that are created before the core collapse of a red supergiant another colour.

Extension activities:
Students research why all the gold is not at the centre of the planet and where this gold may have originated from.

Useful videos and websites:

- BBC Bitesize, "The life cycle of a star" (notes and quiz): **bbc.com/bitesize/guides/zpxv97h/revision/1**.
- BBC Two, "Star death and the creation of elements – Wonders of the universe: Stardust preview" (video): **youtube.com/watch?v=DEw6X2BhIy8**.
- Encyclopaedia Britannica, "Star formation and evolution": **britannica.com/science/star-astronomy/Star-formation-and-evolution**.
- National Aeronautics and Space Administration (NASA), "The birth, life, and death of a star": **map.gsfc.nasa.gov/universe/rel_stars.html**.
- TED-Ed, "Where does gold come from?" by David Luney (video): **youtube.com/watch?v=jf_4z4AKwJg**.
- The Institute of Physics "The life cycle of stars" (video): **youtube.com/watch?v=PM9CQDlQI0A**.

Further free hands-on activities for teaching Earth and Space Science can be found at ***ausearthed.com.au****.*
Australian Earth Science Education is a proud partner of the Gold Industry Group.

The Gold Industry Group provides a united voice for Australia's gold industry, championing the sector and supporting communities across Australia by leading long-term educational and community initiatives.

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