AGSO

Geoscience Education

The Science of Gold

Teacher Notes and Student Activities

by Gary B. Lewis

Record No. 1995/53

AGSO
AUSTRALIAN
GEOLOGICAL SURVEY
ORGANISATION

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Primary Teaching Resource

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AGSO Geoscience Education
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Peter D'Arcy, Red Hill Primary School

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Contents

Curriculum Links

The *Science of Gold* has been specifically developed to incorporate a science component to the historical teaching of the Gold Rushes in Australia. Listed below are the curriculum links for both the National Curriculum and the NSW and Victorian Curriculum.

National Curriculum

Science

Natural and Processed Materials
- Materials and their Uses (Level 1-3)

Working Scientifically
- Processing Data
- Evaluating Findings
- Using Science

NSW Science And Technology Syllabus (K-6)

Knowledge and Understanding
- Products and Services (Stage 1-3)
- Earth and its Surroundings (Stage 2)
- Skills (Stage 2-3)

Suggested Units of Work
- Material World (Stage 2)

Victorian Curriculum & Standards Framework (CSF)

Science

Natural and Processed Materials
- Materials : structure, properties and uses (Level 3)

Earth and Beyond
- The changing Earth (Level 2)

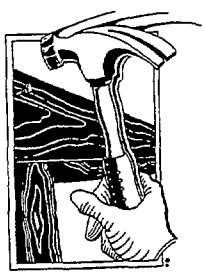
The Science of Gold

Gold is a very rare substance making up only 5 ten millionths of the Earth's outer layer. (Imagine 10 million Smarties in one place and only 5 of them were made of gold!). Its rarity and its physical properties have made it one of the most prized of Earth's natural resources.

Physical Attributes

Metal

Gold, like iron, copper, lead, tin etc. is a metal. Metals are substances which are good conductors of heat and electricity and are almost all solid at room temperature (except mercury). They are malleable and ductile (see below).

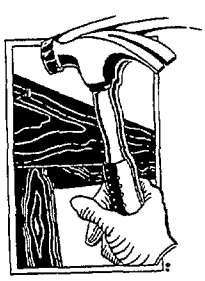


ACTIVITY! *(see Activity 1)*

Make a list of the different objects in the classroom made of metal. This is harder than you think! Can you recognise any different types of metal - iron, copper, brass, tin etc. Do you have a computer or TV in the room - there will be some gold in the computer chips in these pieces of equipment!

Mass

Gold is heavy - it weighs over nineteen times more than water, almost twice as heavy as lead. If you had enough Gold to fill a litre milk carton it would weigh 19 (kilograms - the same volume of milk weighs only 1 kilogram).

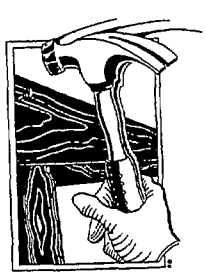


ACTIVITY! *(see Activity 2)*

Fill some empty one litre milk cartons to the top using different materials such as feathers, sawdust, soil, sand, leaves, water, bean-bag filling, wool etc. Weigh the cartons using a set of kitchen scales and write down their weights. How much heavier than the heaviest measurement would a carton of gold be (gold would weigh around 19 kilograms)?

Hardness

Gold is quite soft. It is slightly harder than a fingernail but not as hard as a coin or glass.



ACTIVITY! *(see Activity 3)*

Take some common solid materials found in the classroom (plasticene, chalk, steel, plastic, wood, crayon, glass etc) and place in their order of hardness from softest to hardest. Use the scratch test to tell each other apart - that is if chalk scratches crayon it is harder. Check carefully what is scratching what! Where on your scale would gold fit in knowing that it is not as hard as a coin but harder than a fingernail. If you can get some gold - try it!

Ductility and Malleability

Gold, like most metals, can be hammered into thin sheets (malleable) or drawn out into thin wires (ductile). This has made gold sought after for a wide range of applications, like jewellery and in electronics. "Gold leaf" for example, is gold that has been beaten into a sheet less than one tenth of a millimetre thick. It is then used for lettering on honour rolls in schools, or for putting gold onto picture frames and ornaments.

ACTIVITY! *(See Activity 4)*

Modelling clay (plasticene) is malleable and ductile - but not as good as gold. Give each student the same sized small amount of plasticene and ask them to make it into the longest "wire" they can without it breaking. Measure the best with a ruler. Once complete, ask the class to now make it into the thinnest sheet they can. This is hard to measure, but the size of the sheet is a good comparison.

Chemical stability

Gold is chemically very stable. It does not readily combine with other substances and therefore does not corrode or tarnish. Because of this property it is found in natural almost always as pure gold. This is referred to as "native gold". This meant that the early humans could collect the gold and use it without having to smelt or refine the metal from a mineral - such is the case of iron. Also, because it does not tarnish or corrode it makes excellent jewellery, it is good as material for filling cavities in teeth, it makes excellent fine wire for electronics and coatings on space craft.

Melting and Boiling point

Gold melts at 1 060 ^{o}C and boils at 2 660^{o}C. Compare this to some other common metals such as : Lead melts at 327^{o}C, iron melts at 1535^{o}C, tin melts at 232^{o}C.

Chemical Symbol

All of the Earth's chemical building blocks, the elements, have been given an identifying symbol. The chemical symbol for gold is Au and this comes from the Latin word for gold Aurum. The actual word "gold" comes from the Old English and Old German languages.
Some other chemical symbols are O for oxygen, Ag for silver, Pb for lead, Cu for copper, Fe for iron and C for carbon.

Pure Gold?

While gold does not readily combine chemically with other substances, it is often "watered" down by impurities of other metals such as silver, copper or mercury (in the form of mixtures called alloys). The term "carat" is used to describe the purity of gold and is based on a total of 24 parts. Pure gold (100% gold and nothing else) is known as 24 carat. 18 carat gold, for example, has 18 of the 24 parts as gold and the remaining 6 parts as another metals, such as silver.
The properties of pure gold discussed above are obviously altered when you add other metals. For example 24 carat gold is probably too soft to make long lasting jewellery so 18 or 9 carat gold is used as it is harder.

"Fineness" is another way to express the purity of gold and it works in a similar way to the carat system except there are 1 000 parts.

On gold bars and coins often the purity is referred to as a percentage. Gold bars for example are often stamped 99.99%. These are often just called "four nines" gold bars.

Why so many systems?

Gold has been used as currency for thousands of years and by many different cultures. Each culture has developed its own method of ensuring the purity of gold, hence the number of systems which are used.

Archimedes

Archimedes was a Greek scientist who lived in the city of Syracuse two hundred years before the birth of Christ. One day he was summoned by the king who had just been made a new crown and had been told that it was made of pure gold. He asked Archimedes to test the crown, without damaging it, to prove that it was truly pure gold and not a mixture of gold and silver. Archimedes pondered long and hard about how to solve this problem. One day, as he got into the bath, he noticed that the water in the bath rose up and ran over the top as he lowed himself in. Straight away he knew how to solve the problem given to him by the king! If he got a piece of pure gold exactly the same weight as the crown and lowered it into a bath of water it would make the water rise in the bath a certain amount which he could record with a mark. If he then removed the gold and lowered the crown into the water it should make the water rise up to the same mark if it was made of pure gold. If the water didn't rise to the same mark, then it was not pure gold.

He was so excited by his discovery that he jumped out of the bath and ran through the streets of the city without his clothes on shouting "Eureka" (which means "I have found it!")

Gold Units

As well as purity, there are a number of ways the weight of gold is measured. The most common is the troy ounce (named after the French town of Troyes). One troy ounce of gold weighs approx. 31.1 grams.

Other units used to weigh gold are pennyweights (dwt), grains and troy pounds. The following table gives the conversion factors for these measures :

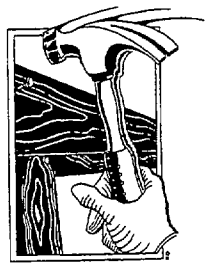
31.103477 grams	=	1 troy ounce
1.555 grams	=	1 dwt (pennyweight)
20 dwts	=	1 troy ounce
12 troy ounces	=	1 troy pound
24 grains	=	1 dwt

What is gold worth?

Gold is bought and sold every day around the world on the gold markets. The price of the gold fluctuates according to the demand of the buyers and the amount being sold by the sellers. On 20 March 1996, the price was about $A520 (Australian dollars) per troy ounce. You can look up the prices of gold every day in the newspaper - in the financial/share section. You will actually see a number of prices as different markets have slightly different prices. Also the paper will publish the prices for both selling and buying. Which ever price you look at, try to use the same one each time if you want to draw comparisons.

ACTIVITY!

Each student can weigh themselves on a set of bathroom scales and write their weight up on a sheet of cardboard. To convert their weight from kilograms to troy ounces use the following equation :



$$\frac{\text{weight (kg)} \times 1000}{31.1} = \text{troy ounces}$$

To make this a "worth your weight in gold" multiply this figure by the current $A price for gold published in the paper (or use the figure $533 per troy ounce as above).

Or . .

Weigh yourself in front of the class (if you are game!) and convert your own weight into troy ounces using the equation in the activity above. Every day have a student find the price of gold in $A in the newspaper. Convert your weight into a price for that day and write it up on the board. You may also like to convert this into a commodity students will better understand - such as number of Mars bars, or number of cars.

Not all that glitters is Gold

Often inexperienced gold prospectors will mistake other golden coloured minerals for gold. The most common mineral mistaken for gold is pyrite - commonly called fools gold. The physical properties of pyrite make it easy to tell the difference between gold and pyrite. For example, if you scratch gold (which is quite easy to do because it is soft), the powder you make is gold in colour. If you scratch pyrite (which is quite difficult to do because it is hard), the powder you make is black in colour.

Where do I find Gold - everywhere!

Very minute amounts of gold can be found everywhere, including in your skin and hair and the water we drink. The amount of gold in normal tap water is about one part per thousand million - or one gold Smartie in one thousand million Smarties!

At these very low concentrations, gold is not very useful and impossible to extract. To find gold in a useful quantity some natural process has to have occurred which has concentrated the very minute amounts from a large area into one place.

Natural Concentration

The most common natural method of concentration of Gold is through the ancient action of hot water inside the Earth's crust. (Water deep in the crust are heated by the Earth's internal heat. As they move towards the surface they cool down.) These waters moved through the rocks over a large area and "dissolved" the gold. When these waters cooled or reacted with other rocks the dissolved

gold precipitated (came out of the water) in cracks or fractures forming veins. If the waters move over a large enough area, and dissolve then precipitate gold for a long enough period of time, gold can be concentrated in amounts in the parts per thousand or even greater.. As well as gold, these waters carried other dissolved minerals, such as quartz, so gold is often found with quartz. These are known as primary gold deposits and to extract the gold the rock containing the veins of gold has to be dug up (mined), crushed and processed.
In Australia this concentration of gold took place in the Earth hundreds of millions of years ago in the eastern states and thousands of millions of years ago in Western Australia. The rocks containing the gold veins have now been exposed on the surface and are eroding away. The gold that these rocks contained has been washed down into creeks to form alluvial gold deposits . Here, the gold is further concentrated by the action of water. Because gold is heavier than most of the material moved by a creek or river, it can become concentrated in hollows and traps in the bed of the river. These are known as secondary gold deposits and they can be worked using a gold pan, cradle or more modern methods such as dredges.

How does a gold pan work?
Gold is a very "heavy" substance. When it is found in creeks and rivers it is normally mixed up with sand and gravel which are much lighter. The movement of the sand-gravel-gold mixture in a gold pan allows the heavier substances (i.e. gold) to move towards the bottom of the mixture. With the correct movement of the pan the gold becomes concentrated at the bottom, allowing the "lighter" materials to be tipped off the top. Most gold pans have a small gutter running around close to the edge of the pan. This is used to help trap the gold when most of the lighter materials has been removed.

Other gold concentrating devices, such as cradles, work using the same principal - separation due to differences in "mass". They rely on a number of ridges or baffles to trap the "heavier" gold.

How is gold found now?

During and since the 1850's goldrushes, most of the gold lying at or close to the surface (alluvial and vein quartz) was found and removed by the miners. This means that gold deposits have now become harder to find. In some places the early miners did not have the technology or equipment to remove all of the gold and modern mining companies have been able to "rework" old gold deposits. However, there are still gold deposits which occur below the surface which await to be discovered.

The modern gold explorer uses a number of sophisticated methods to locate these hidden deposits. It is not unlike detective work - hunting for clues and narrowing the possibilities down until you find what you are looking for. These include the use of geological maps, geophysical data and geochemical data.

Geological Maps

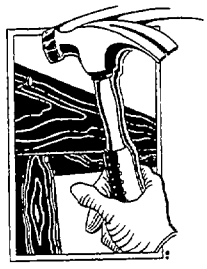
Every part of Australia has been mapped by government geologists. Their work is compiled into geological maps which show the type and ages of the rocks which outcrop in an area. Some of these maps show the location of old mines and mineral deposits which have been discovered in the past. (These maps are available from the Australian Geological Survey or from your State/Territory Geological Survey - see the contact list at the back of this booklet).

Geophysical Data

While geological maps show the rocks at the surface, scientists have developed equipment which allows them to map the Earth's surface for changes in its physical properties of gravity, magnetism, natural radiation and electrical currents. Using this equipment geologists can map an area to find places which appear to be "different" from the surrounding area in these characteristics. These

places may contain minerals below the surface which have not yet been discovered. Most of Australia's surface is covered by soil, so the use of geophysics is important to study the rocks under this "cover".

A metal detector is an example of one of these pieces of geophysical equipment. It works by creating a "force field" which penetrates the ground. If there is any metal in the ground it interferes with the field causing the detector to beep.



ACTIVITY!
Tape a large magnet underneath a big table top (but not right in the centre). Take a simple bushwalkers compass, and move it around the table and have the students observe what happens to the needle. When it moves above the magnet the needle of the compass will swing.
Do the same activity using a number of magnets (big and small) and tape a large piece of paper onto the top of the table on which you have drawn a grid pattern. Have the students move the magnet from square to square marking each square with a black cross if the compass needle remains the same or a red tick if the compass needle swings. Once all the squares have been filled you will have a geophysical map which shows the location of the "unseen" magnets.

Geochemical Data

Over long periods of time gold deposits "rot" (weather) and "spread" (erode) away from where they outcrop and leaves the gold in the surrounding soil or in the sand and silt of creeks. This "spreading" makes the target much bigger to find, however the gold is only in very small amounts. Geologists can try to find these larger targets by taking soil or stream sediment samples. If they find a sample which has abnormally high levels of gold (remember that all the samples will have a minute amount of gold) they can go back to the site and collect more samples.
Because this is a sampling of the soil or stream sediment chemistry, it is referred to as geochemistry.

Australian Geological Survey Organisation

The Australian Geological Survey Organisation (AGSO) was established in 1946 (as the Bureau of Mineral Resources) to provide a national geological survey focus during the post war boom period. Since this time, the Organisation has been instrumental in the discovery of numerous mineral and petroleum deposits and continues to provide the very best survey data and geological advice to government, industry and research institutions. The research which AGSO undertakes covers almost all areas of geoscience including mineral exploration, on-shore and off-shore petroleum exploration, environmental and ground water geoscience and geological hazards. Associated with this research is the storage and manipulation of geological and geophysical data and the production of cartographic and geographic information system (GIS) products.

Map Sales

Information on the current availability and prices of geological maps can be obtained from the following organisations :

Australian Geological Survey Organisation

Sales Centre
Constitution Avenue
Parkes, ACT 2600
ph (06) 249 9519
fax (06) 249 9982

or
Reply Paid Service 538
AGSO Sales Centre
GPO Box 378
Canberra ACT 2601
(no stamp required)

States

New South Wales
Customer Services
Department of Mineral Resources

ph (02) 901 8269
fax (02) 901 8247

Queensland
Information Services
Queensland Department of Minerals and Energy

ph (07) 237 1434
Fax (07) 221 9517

Tasmania
Data Management Group
Mineral Resources, Tasmania

ph (002) 33 8351
fax (002) 44 2117

Western Australia
Mining Information Centre
Department of Minerals and Energy

ph (09) 222 3459
fax (09) 222 3444

Northern Territory
Northern Territory Geological Survey

ph (089) 98 5355
fax (089) 89 6824

South Australia
Department of Mines and Energy

ph (08) 274 7595
fax (08) 272 7597

Victoria
Geological Survey,
Department of Energy and Minerals

ph (03) 412 7801
fax (03) 412 7803

Activities !
Teachers Guide

Some of the activities suggested in the text have been expanded in the following section so you can copy and use the worksheets with your students. The worksheets are language based and use a standard format.

What will you need for each activity?

Activity 1
Be a Metal Detector!
No equipment or materials needed.

Activity 2
Heavy Metal
Lots of empty one litre milk cartons (washed out or they will smell).
Kitchen scales whih will weigh up to 5kg (more than one if you can get it)
Bathroom scales (more than one if you can get it)

Substances - you could provide sand, soil, potting mix, feathers, leaves, bean bag filling, saw dust etc and/or let the students find some substances around the school yard. Waht ever it is, it needs to be able to completely fill the container.

Activity 3
Harder than . .
Substances - many are listed on the activity sheet (chalk, pencil lead, wood, plastic etc. You might also like to bring in some other materials such as minerals (quartz, talk, mica).

Activity 4
Snakes and Places
Modelling clay (plasticene) divided up into exactly equal parts (one for each student). One way to do this is to make a snake of equal thickness then cut into equal lengths. About one cubic cm is ideal.
Your school might have a policy about using plasticene on tables (due to the clean up problem) - try using plastic wrap streched over the table top.

Be a Metal Detector!

Au
The Science of Gold

A lot of items around the classroom, school and at home are made from different metals. For example, some school chairs have steel legs and soft drink comes in aluminium cans - steel and aluminium are types of metals.

Can you find where the following metals are used around school or home? (make sure you write your answers as full sentances.)

Copper

Copper is used to make . . . . . .

. . . . . .

Brass

. . . . . .

. . . . . .

Tin

. . . . . .

. . . . . .

Zinc

. . . . . .

. . . . . .

Silver

. . . . . .

. . . . . .

Can you find other metals around the school or around home? List the names of the metals and what they are being used for :-

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Did you find any gold?

A Metal Detector is a device that is used to locate hidden metals, often when they are buried under soil or sand. See if you can find a picture of a metal detector in a book (try the library) and draw it on the back of this page.

Heavy Metal

Some materials weigh more than others. Gold weighs about 19 times heavier than water. To compare how heavy one substance is to another substance we have to weigh exactly the same amount (known as volume).
In this activity we will use old one litre milk cartons so that we weigh the same amount of each substance we are going to test (the volume will be one litre).

Equipment

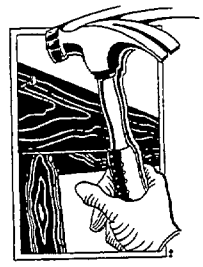
For this activity you will need :

- Four (4) empty one litre milk cartons
- Set of kitchen or bathroom scales
- Four different materials to test

The four different materials I will be testing are :

1. . . . . .
2. . . . . .
3. . . . . .
4. . . . . .

Activity



- Take an empty milk carton and fill it to the very top using the first substance.
- Place the full carton on the scales and read the weight of the full carton.
- Write a sentence about the weight in the space below. The first one has been started for you!
- Do the same for the other three substances.

One litre of _____ weighed _____grams.

. . . . . .

. . . . . .

. . . . . .

. . . . . .

? One litre of Gold weighs 19,300 grams (that is over 19 kg!). How much greater is this than your heaviest substance?

Harder than . . .

Au The Science of Gold

Every substance has a hardness - and it is either harder than or softer than other substances. Gold is harder than your fingernail but softer than a twenty cent coin! In this activity you are going to make your own hardness scale using substances around your classroom.

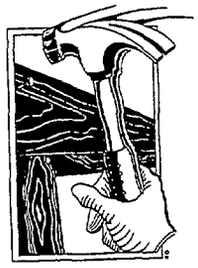
Equipment

For this activity you will need five (5) different substances. Try to find five that are very different from each other (some soft and some hard and some in between). You might like to try : chalk, pencil lead, wood, plastic, steel, glass, aluminium, fingernail, crayon, plasticene, lego block, eraser

The five substances I have chosen are :

1. . . . . .
2. . . . . .
3. . . . . .
4. . . . . .
5. . . . . .

Activity



• Arrange your five substances with the first substance being the hardest and the fifth substance being the softest. You can guess if you don't know the correct order.

• With those substances that are close in hardness, try to scratch one with the other. If it does, it must be harder. Be careful to check which is scratching which! Rearrange your substances once you have tested them all, and complete the list below from hardest to softest.

1. . . . . is the hardest substance.
2. . . . . .
3. . . . . .
4. . . . . .
5. . . . . is the softest substance.

? Where do you think Gold would fit on your scale?

Snakes and Plates

Au The Science of Gold

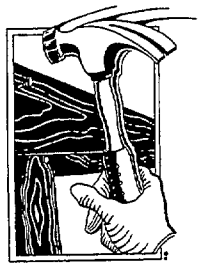
A property of metals is that they can be made into wire or beaten into flat plates. Gold can be made into very thin wires and beaten into very thin plates.

In this activity you will see how long a piece of "wire" and how large a "plate" you can make from modelling clay.

Equipment

For this activity you will need a small piece of modelling clay that your teacher will give you. Your classmates will also have a piece of modelling clay exactly the same size.

You will also need a ruler and a piece of graph paper.

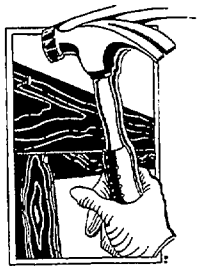


Activity 1

- Take your piece of modelling clay and roll it into a "snake" or "wire".
- How long a piece of "wire can you make with your piece without it breaking.
- Use your ruler to measure the longest "wire" you can make and write the length in the space below.

The longest wire I could make was _____ cm long.

Activity 2



- Roll your piece of modelling clay into a ball.
- Now try to flatten the ball into the thinnest sheet you can. As you do this the sheet will get bigger.
- When you can't make the sheet any bigger, place it on a sheet of graph paper and draw around the outside of the modelling clay sheet.
- Remove the sheet then count the number of squares on the graph paper inside the line. This will give you the size of your sheet.

The largest sheet I could make covered _____ graph paper squares.

? How did your wire and sheet compare to other people in your class?