Strike It Rich: A Supplement To Teaching Rocks And Minerals

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Preface

The Alberta Research Council Teacher Research Experience Program offers six weeks of summer employment for elementary, junior high of high school teachers interested in learning more about the application of science by working with a scientist at the Alberta Research Council (ARC). In 1993 Ms. Claudine Coleman of T.D. Baker Junior High School in Edmonton was hired to work with Mr. Dixon Edwards of the Alberta Geological Survey (a department of the ARC). The current research of Mr. Edwards involves the investigation of rocks and minerals which may lead to the discovery of diamonds.

The purpose of this project was to give Ms. Coleman the opportunity to experience geological research during her employment with the ARC. In addition to this personal development a report was produced which can supplement the teaching of rocks and minerals in the classroom. The report uses diamonds as a theme and a springboard for teaching students about rocks and minerals because at present Alberta is experiencing an exploration boom for diamonds. Each section contains background information on the topic and a lesson plan along with some question sheets and/or activities the teacher can use. The background information is meant to supplement what is already in most textbooks and although it is meant for the teacher it is written so that the information can be given to the students. Each lesson is designed so that it ties in with the lesson before it and any question sheets or other activities accompanying the lesson can be assigned or used in the classroom however the teacher chooses.

It is important to emphasize with the students that many of the theories involving diamonds and diamond formation are still quite young. As our knowledge and technology increases, new evidence may surface to change the theories we believe to be true today. This is the same with any scientific theory and it is important to emphasize this when introducing new theories, like diamond formation, to students.

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Introduction To Minerals

Minerals are inorganic, naturally occurring solid substances. When something is inorganic it means that it is not formed from the remains of plants, animals or other living things. Minerals, alone or in combination with other minerals, make up the crust of the earth upon which we live. More than 3000 different minerals have been identified and out of those only 150 to 200 are common or widespread. Each mineral is made up of elements. These are the elements you will find on a periodic table. An element can be defined as a pure substance that cannot be broken down into other substances by chemical means. A mineral will always have the same chemical makeup wherever it is found. A diamond, for example, no matter where it is found, is made up of the element carbon. The type of element present also helps to classify minerals into different groups.

Minerals also have distinctive physical properties. These physical and chemical characteristics provide the basis for tests which can be done to identify the mineral.

1. **Lustre**: Lustre is the property that results when light is reflected from the mineral. All minerals can be classified as either metallic or non-metallic. A metallic mineral will look like a metal, although it will not necessarily be "shiny". Any other mineral will be classified as non-metallic. Non-metallic minerals are then further classified according to a familiar substance that the mineral may resemble: pearly, greasy, silky etc. This is the first property you should examine when you are identifying a mineral. Most mineral tables use this property as the primary property to separate the minerals, so if you misclassify a minerals lustre you will have a difficult time identifying it from the table. Again, the problem with lustre is that it is a very subjective. What one person sees as metallic may be non-metallic to another.

2. **Color**: It would simplify mineral identification if each mineral had a unique color that never varied from sample to sample. However, color cannot be relied upon to identify the mineral because the color of a mineral can change due to impurities present or tarnishing and you also can get a range of different colors within one type of mineral due to chemical composition. An example of how chemical composition varies from mineral to mineral is

iron. Iron silicate minerals are usually light to dark green but the intensity of the green depends on the iron content in the mineral. Some minerals do however have a distinctive color and can be identified according to their color.

3. **Streak**: This is the color of the finely powdered mineral particles when the mineral is scraped across a porcelain plate. The streak is an useful tool in identifying minerals. Not all minerals will have a streak because a porcelain plate has a hardness of about seven, so any minerals with a hardness above seven will not leave a streak. Many minerals also leave a white or colorless streak.

4. **Hardness**: The hardness of a mineral is looking at the strength of the bonds between the atoms, the size, and the density of packing of the atoms in the mineral. It can be simply described as a minerals resistance to scratching. The hardness is tested by comparing the mineral to a relative scale of minerals (Mohs scale) ranked from 1 to 10 in hardness. The softest mineral, talc, is a 1, and the hardest mineral, diamond, is a 10. To determine the hardness you would try scratching each of the minerals on your sample. If the mineral is harder than the sample it will leave a scratch on the softer one. In the textbook there is a chart that shows common materials you could use since most schools do not have all ten minerals needed to do the hardness test.

5. **Relative Density (Specific Gravity)**: A minerals relative density is determined by comparing it's weight with the weight of an equal volume of water. Essentially you are determining how many times heavier the mineral is than water. This reading will lead you in the direction of what types of elements make up the mineral. Minerals like silver and gold will have a much higher relative density than minerals like quartz and feldspar.

6. **Crystals:** One distinctive property about all minerals are their atomic structure. Each mineral has a distinct structure that determines what the crystal of that mineral will look like. However this structure cannot always be observed by the naked eye. Sometimes if we are lucky we find a euhedral or perfectly developed crystal of a mineral that reveals the structure. Usually we do not see the crystal faces developed, instead, we see the mineral as an irregular shaped grain in a rock. The way a crystal will form

depends on the time and space available to the mineral at the time of crystal formation. A larger crystal will form if the mineral has a long time to form. Smaller crystals tend to develop when the mineral cools quickly.

7. **Cleavage and Fracture:** Some minerals will have a tendency to split on planes parallel to the crystal face so that they will resemble their crystal structure. This is called cleavage. If a mineral tends to just break into fragments and has rough, uneven surfaces, the mineral is said to fracture.

There are a number of other tests that can be done to identify minerals but they are either too sophisticated to do in the classroom or too dangerous. Some of these tests are possible to do in the classroom but only under strict supervision. Some of these types of tests include:

-acid test	-taste test
-fluorescence test	-refraction test

There are a small number of minerals that make up a large percentage of the earths crust. They are:

Feldspar	Calcite	Pyroxene	Mica
Quartz	Dolomite	Serpentine	Halite
Amphibole	Gypsum	Olivine	Chlorite

Even though these are the most common minerals, every day we walk on quartz, mica and calcite and don't think twice about it. But flash a ruby or a diamond in front of us and we notice. Minerals that are unusually beautiful and rare are called gemstones.

So why do we need to identify minerals? Why are minerals important? The type of mineral and size of the mineral crystals can tell us a lot about the earths crust. Only certain minerals will form under specific conditions (ie. high temperatures) so the discovery of some minerals can tell us what the earths conditions were when that mineral formed, when during the earths history it formed etc.. Certain minerals will also help us discover other mineral sources. An example of this would be diamond exploration. Some minerals like garnets, olivine and chromite only form under the same conditions as diamonds. The discovery of high concentrations of these and other minerals in rocks or sediments indicates that diamonds may also be present. Minerals are also important because they are the building blocks of the land we are standing on.

Lesson #1: Introduction To Minerals

Purpose: To introduce the students to minerals and mineral identification by discussing a commonly known but rare mineral, the diamond.
To have the students perform mineral tests on selected minerals

Time: Two to three class periods (approximately 43 minutes each)

Preparation: Read the information sheets on minerals and diamonds and if you choose you can make copies for the class. The materials you will require are:

3-4 minerals, 2 of the same color (ie. quartz, halite, pyrite)
5-10 different minerals for each group to identify
streak plates (1 per group)
copper coins (1 per group)
sandpaper (1 per group)
knife blades (1 per group)
steel files (1 per group)
emery paper (1 per group)

Optional materials: From Science Directions Teacher Resource Manual:
mineral identification table
identification data of common minerals
Specific Gravity Lab

Directions: To judge the level the class is at start with brainstorming. Write the word **DIAMOND** on the board and ask the students to tell you everything they know about diamonds. Write down all the responses including those that are not correct. If they are having some difficulty here are some leading questions you can use:

Where are diamonds found?
What do we use diamonds for?
What is a diamond?

You want to direct the students in the direction of the fact that a diamond is a mineral. They may come up with that on their own or you may have to tell them. Once you have established that a diamond is a mineral, the discussion should be directed towards minerals in general. Here are some questions you can ask:

> ***Name some other minerals that you know.***
> ***What is a mineral? (inorganic, naturally occurring substance)***
> ***How are they formed? (crystallize from magma or lava)***
> ***How many minerals are there? (approximately 3 000)***

Since there are 3000 minerals in the earths crust, how can you tell which one you have? Identifying minerals is a scientific classification, it puts minerals into an orderly arrangement based on the scientific observations you make about the mineral. Each mineral is different because each mineral has its own distinctive atomic structure that is the same wherever you find it in the world. You can test a mineral for characteristics that are fundamental to that minerals atomic structure.

Bring out three or four minerals or an entire set. It is important to make sure that you have two minerals that are the same color and one that is dramatically different. Explain to the students that these are all minerals and that there are a number of properties that geologists look at to identify minerals.

> ***What is one thing you could examine to tell these minerals apart? (color)***
> ***What about the two that are the same color. What are some ways we can tell these minerals apart?***

Introduce the class to the different minerals tests geologists use to identify minerals (refer to information sheet). There are a number of different ways you can go about this.

1. Demonstrate the tests.
2. Demonstrate the tests while you have the students take notes.
3. Hand out the information sheet at this time and work through it with them or have them read it.

It is important to emphasize that the students know the procedure and that they do not need to memorize the minerals. Even professional geologists need to consult mineral tables. Once the students are familiar with the different tests they can attempt to identify some unknown minerals. I would say anywhere from 5-10 would be a good number depending on how long the class is. Have the students prepare a chart that has the headings of the tests you choose for them to do or use a copy of the chart that is available in the Teacher Resource Package.

Mineral #	Color	Lustre	Hardness	Streak	Other	Name

Once they have performed all of the tests they can compare their results with a prepared table to identify the minerals. They can refer to the chart in the Science Directions Textbook on page 159 or there are more extensive tables in the Teaching Guide that accompanies the textbook.

Summary:
Questions you can ask to summarize:

Why is hardness important? (key test)
What is the hardest mineral? (diamond)
If you found a diamond, how could you test for hardness? Would this be a good criteria? (scratch it with another diamond, yes)
What is the "look" of a diamond? How is it's lustre described? Is this natural? (sparkly or greasy, non-metallic, yes but a diamonds lustre is enhanced by cutting)
What is the specific gravity of a diamond? Is this useful in helping you identify a real diamond? (3.5, yes)
If you thought you found a diamond, what tests would you do to determine that it was? (hardness, lustre)

Optional: The one test that you will need a separate class to do, if you choose, is specific gravity. The instructions for this lab are included as part of this lesson.

Mineral Identification Table

SAMPLE NUMBER (OR COLOUR)	COLOUR	LUSTRE	STREAK	HARDNESS	OTHER	NAME

Identification Data of Common Minerals

Minerals with Metallic Lustre

MINERAL	COLOUR	LUSTRE	STREAK	HARDNESS	RELATIVE DENSITY	COMMENT
native copper	copper	metallic	copper	2.5 - 3	8.8 - 8.9	malleable
hematite	red	metallic	red/ black	5 - 6	4.9 - 5.3	red ochre
gold	yellow	metallic	yellow gold	2.5 - 3	19.3	no tarnish
chalco-pyrite	brassy yellow	metallic	greenish black	3.5 - 4	4.1 - 4.3	rainbow tarnish
pyrrhotite	bronze yellow	metallic	greyish black	3.5 - 4.5	4.4 - 4.7	brittle
pyrite	yellow	metallic	brown/ black	6 - 6.5	4.8 - 5.2	often cubic
native silver	silver white	metallic	white	2.5 - 3	10 - 11	cubic crystals
galena	grey	metallic	dark grey	2.5 - 3	7.4 - 7.6	cubic crystals
magnetite	blackish grey	metallic	black	5.5	5	magnetic rusty
graphite	black	almost metallic	grey/ black	1 - 2	2 - 2.3	greasy feel

Minerals with Non-metallic Lustre

MINERAL	COLOUR	LUSTRE	STREAK	HARDNESS	RELATIVE DENSITY	COMMENT
bauxite	variable red-brown	dull	red to grey	1 - 3	2 - 2.6	clay-like, mottled
chromite	black	sub-metallic	brown	3.5 - 4	4.3 - 4.6	brittle
opal	whitish grey	glassy	light yellow	0.5 - 1.5	1.5	rainbow colours
native sulphur	earthy yellow	resinous	yellow-brown	1.5 - 2.5	2 - 2.1	
malachite	green	glassy to silky	light green	3.5 - 4	3.9 - 4	banded colours
calcite Iceland spar	clear to white	glassy	colourless	3	2.7	
calcite	whitish yellow	glassy to dull	white	2 - 3	2.7	
obsidian	black to grey	glassy	white	6	2.2 - 2.8	glass-like
talc soapstone	green to whitish	pearly to dull	white	1 - 1.5	2.7 - 2.8	soapy feel
gypsum	whitish to grey	pearly to glassy	white	1.5 - 2	2.3	
halite	white	glassy	white	2 - 3	2.1 - 2. 6	
mica muscovite	light brown	glassy	white	2 - 2.5	3.7 - 3	appears as sheets
mica biotite	black	glassy brilliant	white	2.5 - 3	2.7 - 3.4	appears as sheets

Minerals with Non-metallic Lustre

MINERAL	COLOUR	LUSTRE	STREAK	HARDNESS	RELATIVE DENSITY	COMMENT
mica phlogopite	clear to brown	glassy	white	2.5 - 3	2.75	appears as sheets
dolomite	white to grey	glassy to dull	white	3.5 - 4	2.8 - 2.9	
apatite	greenish	glassy to resinous	white	5	3.2	
feldspar microcline	pink to whitish	glassy	white	6 - 6.5	2.55	shows edge of cube
feldspar albite	grey to whitish	glassy to pearly	white	6 - 6.5	2.6	shows edge of cube
feldspar orthoclase	whitish to orange	glassy to pearly	white	6 - 6.5	2.5 - 2.65	shows edge of cube
quartz chalcedony	multi-coloured	glassy to waxy	white	7	2.6 - 2.7	
quartz agate	multi-coloured	glassy	white	7	2.6 - 2.7	wavy colour bands
quartz onyx	multi-coloured	glassy	white	7	2.6 - 2.7	straight colour bands
quartz crystal	clear, colourless	glassy	colourless/ white	7	2.6 - 2.7	shows crystals
quartz amethyst	purple	glassy	white	7	2.6 - 2.7	
quartz smokey	black to grey	glassy	white	7	2.6 - 2.7	if pink, called rose
quartz chert	black to grey	glassy	white	7	2.6 - 2.7	no cracks, called flint
corundum	many purples	glassy	white	9	3.9 - 4.1	
diamond	colourless to tinted	glassy	white	10	3.5	

Name: ____________________

Minerals Question Sheet

1. Why doesn't a geologist rely solely on color as a method of identification?

2. If the mineral does not leave a streak on the plate, what can you infer about the minerals hardness?

3. What are the two types of lustre that a mineral can have?

4. What is the specific gravity of a mineral?

5. Why can you not rely solely on one test to identify a mineral?

6. What is the hardest mineral known to man?

7. What mineral cannot be scratched by any other mineral?

8. What is the softest mineral on the hardness scale?

9. Many scouring powders (such as Ajax) are made up of the mineral quartz Explain why this particular mineral is used?

Minerals Answer Key

1. Color can be a very useful tool in identifying a mineral but even a small amount of an impurity can change the color drastically. So it cannot be relied upon.

2. The mineral would have to have a hardness that was more than 7 if it did not leave a streak on the plate.

3. A mineral can have either a metallic or nonmetallic lustre.

4. The specific gravity of a mineral is a measure of how much heavier the mineral is than an equal volume of water. Specific gravity helps us to identify the types of elements that make up the mineral.

5. In each individual test there are too many minerals that fall under each category. An example would be the hardness test. If it had a hardness of 10 that would identify it as a diamond but if it had a hardness of 6, there are hundreds of minerals with a hardness of 6.

6. A diamond is the hardest mineral known.

7. A diamond cannot be scratched by any other mineral.

8. Talc is the softest mineral known.

9. Quartz has a hardness of 7 so it is quite abrasive. It you have dirt embedded in a surface, the quartz in the powder will actually scratch or rub the surface of what you are cleaning and lift the dirt out.

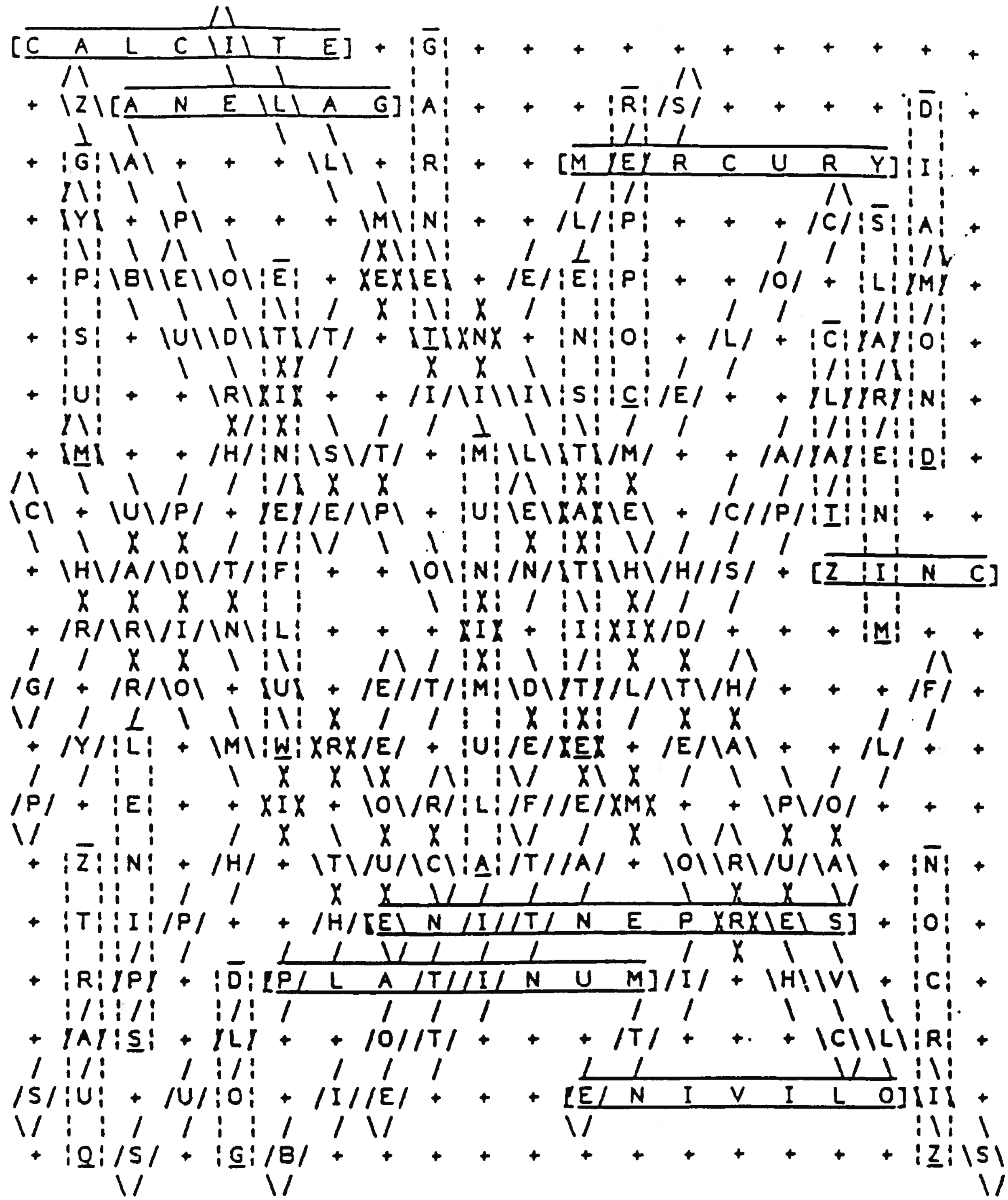
COMMON MINERALS

C	A	L	C	I	T	E	S	G	D	R	G	H	D	M	I	J	S	N	O
Q	Z	A	N	E	L	A	G	A	W	G	P	R	S	W	C	O	L	D	E
R	G	A	M	F	P	L	C	R	E	K	M	E	R	C	U	R	Y	I	Z
D	Y	H	P	A	P	Q	M	N	P	A	L	P	N	T	Y	C	S	A	M
D	P	B	E	O	E	R	E	E	L	E	E	P	K	Y	O	Y	L	M	X
C	S	W	U	D	T	T	C	T	N	F	N	O	Z	L	F	C	A	O	E
J	U	M	S	R	I	G	Z	I	I	I	S	C	E	G	S	L	R	N	B
M	M	W	O	H	N	S	T	U	M	L	T	M	Z	V	A	A	E	D	T
C	W	U	P	G	E	E	P	N	U	E	A	E	A	C	P	T	N	K	V
J	H	A	D	T	F	G	X	O	N	N	T	H	H	S	Y	Z	I	N	C
K	R	R	I	N	L	P	I	I	I	X	I	I	D	L	E	E	M	A	Q
G	W	R	O	Q	U	C	E	T	M	D	T	L	T	H	A	C	P	F	D
R	Y	L	F	M	W	R	E	Q	U	E	E	U	E	A	Z	J	L	K	Y
P	V	E	P	G	I	J	O	R	L	F	E	M	A	V	P	O	A	F	F
A	Z	N	Z	H	S	T	U	C	A	T	A	O	O	R	U	A	U	N	Y
I	T	I	P	O	P	H	E	N	I	T	N	E	P	R	E	S	Q	O	U
O	R	P	C	D	P	L	A	T	I	N	U	M	I	W	H	V	Z	C	C
U	A	S	A	L	V	Q	O	T	O	L	M	T	G	X	X	C	L	R	E
S	U	E	U	O	I	I	E	W	J	S	E	N	I	V	I	L	O	I	M
Y	Q	S	S	G	B	T	Q	X	J	R	D	A	Y	L	M	Q	C	Z	S

WORD LIST: COMMON MINERALS

ALUMINUM
APATITE
BIOTITE
CALCITE
CHROME DIOPSIDE
CHROMITE
COLEMANITE
COPPER
CORUNDUM
DIAMOND
ENSTATITE
FELDSPAR
GARNET
GOLD
GRAPHITE
GYPSUM
HALITE
HEMATITE
ILLMENITE
MALACHITE
MERCURY
MINERALS
OLIVINE
PLATINUM
RUBY
SAPPHIRE
SELENITE
SERPENTINE
SILVER
SPINEL
SULPHUR
TALC
TOPAZ
WULFENITE
ZINC
ZIRCON

SOLUTION: COMMON MINERALS



Relative Density (Specific Gravity)

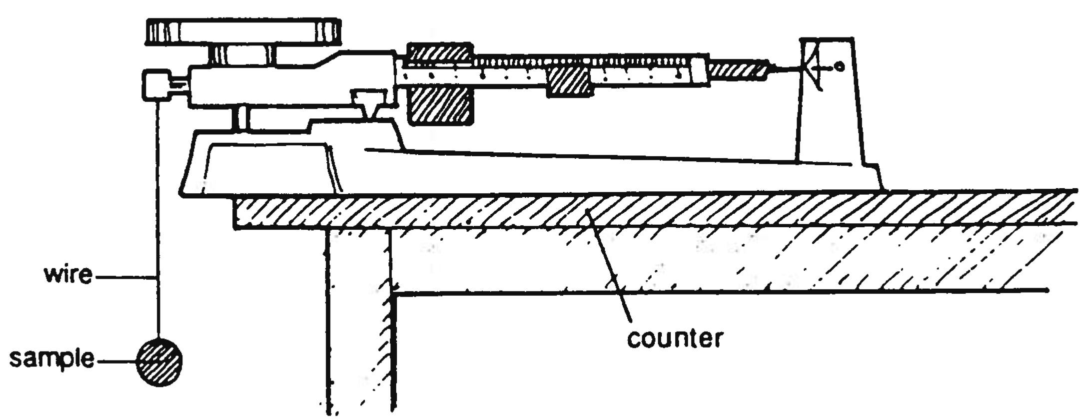
Calculating the relative density of a sample produces a numerical value that relates the mass of the mineral to the mass of an equal volume of water (at a specified temperature). The relative density of a pure mineral sample provides some of the most accurate data that can be obtained on a sample and is therefore very useful in identification. Futhermore, the test for relative density is very easily done in the school lab. The following Activity shows a procedure to do this important test.

Materials

triple-beam balance
light wire or thread
1000 mL beaker
mineral sample

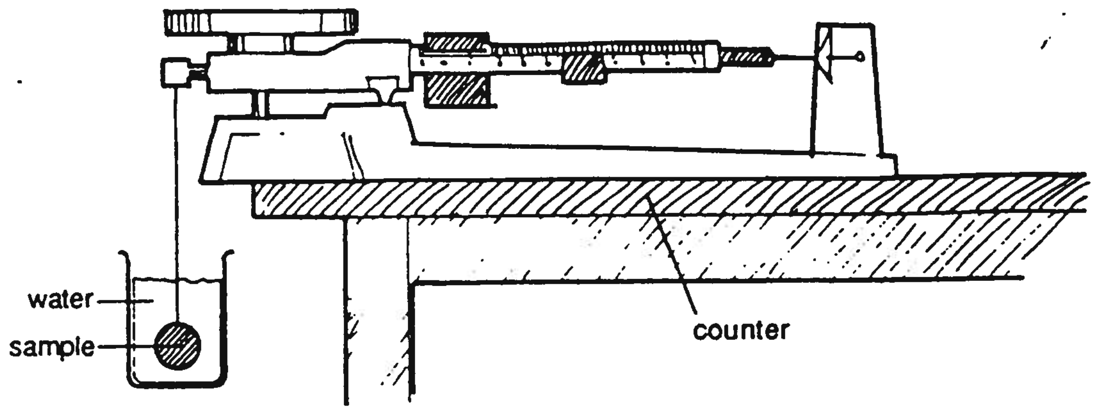
Procedure

1. Attach wire or thread to the bottom of the triple-beam balance pivot point. Be careful not to interfere with the movement of the arm.
2. Set the balance on the edge of a counter so that the wire or thread hangs free.
3. Use the adjustment to set the balance at zero (to account for the mass of the wire).
4. Attach a mineral sample to the bottom of the wire as shown below.



5. Use the balance to calculate the mass of the sample hanging in the air. Record this measurement as MASS IN AIR.

6. Move a beaker of water under the sample and submerge the sample in the water as shown below. Determine the apparent mass of the sample suspended in the water. Record this as APPARENT MASS IN WATER.



7. Subtract the figure obtained from Step 6 from the figure obtained from Step 5

MASS IN AIR = ______________________ g

— APPARENT MASS IN WATER = __________ g

____

= DIFFERENCE = ______________________ g

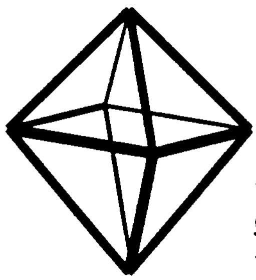
RELATIVE DENSITY = $\frac{\text{MASS IN AIR}}{\text{DIFFERENCE}}$ = $\frac{\text{\_\_\_\_\_\_\_\_\_\_\_\_ g}}{\text{g}}$

Note: Relative density has no unit, as the mass units cancel in the calculation.

Crystal Formation

One method commonly used by geologists to identify minerals is to observe the crystal structure. Many minerals have a distinctive crystal structure or geometric shape that can aid in identifying some minerals.

A crystal is a naturally occurring solid with straight edges, flat sides and regular angles.

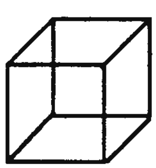


The flat smooth sides of a crystal are called faces.

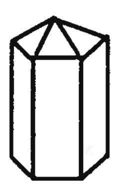
Minerals when spilt or broken, tend to break along surfaces parallel to the crystal faces. This is called cleavage. If you were to break a diamond you would find that most of the smaller pieces will resemble the larger crystal that they formed from. Not all minerals will cleave, some minerals when broken just break into rough uneven crystals with no defined shape or pattern. These minerals are said to fracture. Why does this happen?

Minerals, like all other substances on earth, are made up of particles. These particles are attracted to each other. Some of those attractions between the particles can be strong and some can be weak. The result is that you have some particles that are held tightly together and some that are held weakly.

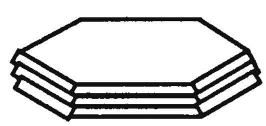
The crystal structure of a mineral depends on the type of particles that make up the minerals as well as the strength of the force holding those particles together. Different combinations of particles will produce different shapes. For example, halite or rock salt is made up of particles of sodium and chlorine. These atoms combine to from a box shape and thus their crystals are box shaped.



(halite)

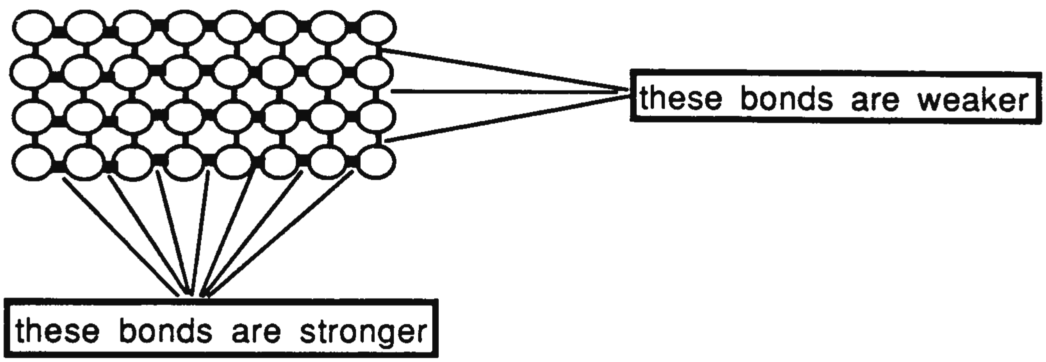


(quartz)

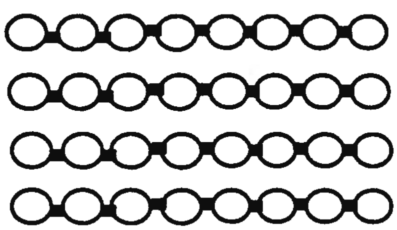


(mica)

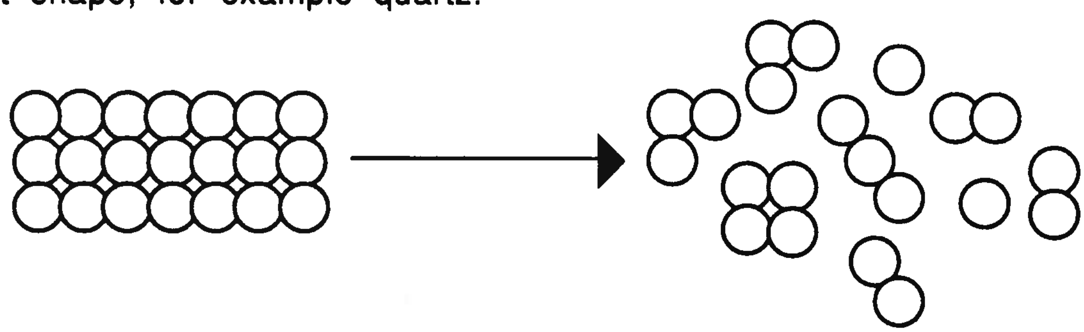
When a mineral cleaves or fractures, the particles are being torn apart from each other. When this happens, the particles that are being held together weakly usually separate first, and the ones that are being held together strongly will separate only with considerable force. A good example would be mica. Mica is a mineral that cleaves into very thin sheets.



Since the bonds holding the particles together in the mica layers are stronger than the bonds holding the layers together, the mineral will split into sheets.



When a mineral fractures all of the particles are equally attracted to each other in all directions, resulting in broken and rough edges rather than any distinct shape, for example quartz.



The size and quality of crystal formation depends on the conditions in which the crystal forms. The symmetrical patterns you see microscopically usually don't show up large enough for you to actually see the crystals. Most minerals we find are not in the perfect crystal form. However, if you do see crystals, if the magma from which the mineral forms cools slowly, large crystals will form. If the magma cools quickly, small crystals will form. Factors such as pressure, movement, impurities and a change in temperature during crystal formation can also affect the crystal shape and size.

A number of mineral crystals are difficult to see without the aid of a microscope. In fact in nature, most mineral crystals we find are irregular shaped grains in a rock. This next activity allows you to see the growth of crystals within one class period.

Lesson #2:
Microcrystals

Purpose: To introduce students to crystals and crystal formation.

Time: One class period

Preparation: -read and/or photocopy attached information sheet
-prepare 3 saturated solutions of potassium dichromate, ammonium chloride and salt (take the amount of water you will need- about 20 ml per class- and add the substance very slowly while stirring until no more substance will dissolve)
-OPTIONAL: 1 or .. days before prepare solutions and place enough solution in a petri dish (or any other flat container) to cover the bottom. Place the dish in a window and in an undisturbed place for 1 to 2 days. This will allow you to have a larger version of what the students will be looking at under the microscope.

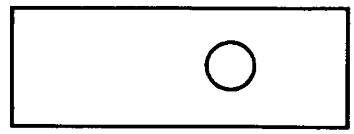
Materials:

prepared solutions (see above)
hot plate
microscope slides
eye droppers
microscopes (works extremely well with reflecting microscopes but it will work with transmitting microscopes)
tweezers
goggles
optional: prepared crystals

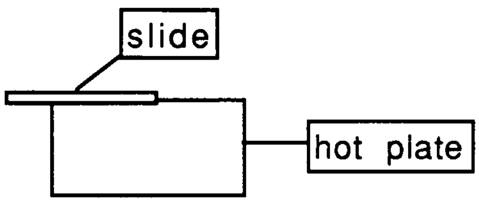
Procedure:

1. Warm up hot plate to the low-medium heat range (no higher).

2. Place one drop of the prepared solution on a slide. Make sure to place the drop slightly off center.



3. Place the slide on the hot plate with tweezers so that the drop is on the hot plate. Let the slide over hang so you have something to hold on to.



4. Let the slide sit until the solution just starts to crystallize (form a solid) around the edges (15-60 sec).

5. Quickly remove slide with tweezers and place under microscope to see crystals form.

6. Draw a brief sketch of what you see. For the salt and ammonium chloride solution, you may want to put a contrasting color underneath the slide so you can see the crystals easier.

TEACHER TIPS:

1. Be sure to prepare saturated solutions.
2. Do not turn up the hot plates too high. If they are too hot the students will burn themselves.
3. More than one drop on the slide will result in it taking longer for the crystals to form and then the slide will end up getting very hot.

Name: ____________________

Crystal Question Sheet

1. Why is there a difference in the crystal shapes you observed under the microscope?

2. What do you think would have happened if you had heated the slide for a longer time?

3. What would happen if you did not heat the slide?

4. Why do we heat the slide?

5. What could you infer about a rock that has large mineral crystals in it?

6. What ould you infer about a rock that has tiny mineral crystals in it?

OPTIONAL:

7. What is the main difference between the set that was prepared before this lab and the ones you were looking at under the microscope? Explain the difference.

Crystals Answer Key

1. Different substances will form different crystals. Each crystal you are looking at is distinctive of that substance.

2. The crystals would have formed much quicker on the slide and they might have been much smaller.

3. It would have taken a longer time for the crystals to form and they would have been larger crystals.

4. To speed up the evaporation of the water and thus speed up the formation of the crystals.

5. If a rock has large mineral crystals in it then it cooled slowly.

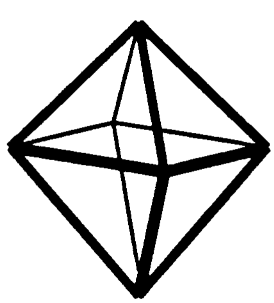
6. If a rock has tiny crystals in it then it cooled quickly.

7. The prepared set has crystals that are larger than the ones under the microscope. The reason why is because the prepared set had a longer time to cool.

Introduction To Diamonds

Diamonds are a very rare mineral that almost everyone is familiar with. In North America and Japan we consume about 60% of the worlds "gem" diamond production. Here in Alberta diamonds may have an even bigger impact on our lives. It is believed that Alberta has the right conditions for diamonds to be brought near to the surface. In fact a number of large diamond mining companies are exploring right here in our own backyard. In the North West Territories several diamond "pipes" have been confirmed. The discovery of a profitable diamond pipe is possible and if one is found it will have a dramatic impact on Alberta and Canada.

A diamond is a mineral made up of one element only; carbon. A diamond is pure, crystallized carbon. A close relative of diamond is graphite or pencil lead which is also a mineral made up of only carbon. The large difference in the minerals results from where and how the carbon crystallized. A diamond has very strong attractions between the carbon atoms in a 3-D structure we call an octahedral crystal, while graphite also has strong bonds, the strong attractions hold the carbon atoms together in sheets rather than a 3-D structure, resulting in two distinctly different minerals. The 3-D crystal structure of the diamond makes it the hardest mineral known to man. It rates a 10 on the hardness scale. A diamond can scratch all other minerals but none of the other minerals can scratch a diamond except another diamond. Even though it is the hardest mineral (resists scratching) that does not mean that it will not break, in fact, a diamond is quite brittle. A good analogy to this is a piece of glass. Glass is very difficult to scratch but if you hit it with a quick blow, it will shatter. The same is true of a diamond. It will break quite easily along the octahedral faces if it is smashed.



octahedral crystal

It was believed for a number of years that the way to test if a diamond was genuine was to smash it with a hammer. If it broke into pieces, it was a fake diamond. This is now known not to be true. Many people think that this rumor was started by the diamond merchants as a ploy to prevent miners from removing the diamonds from the mines. If a stone was found the miners would test the stone, find it to be fake and leave the pieces behind. The merchants would then pick up the pieces after the disappointed miners had left and keep them for themselves.

A diamond has non-metallic, adamantine lustre and it is a very good heat conductor. Since a diamond is such a good heat conductor it is commonly used as a heat sink in electronic application and they are commonly used as points on cutting tools. They are useful in these applications because the diamond will absorb a large amount of heat without having it's temperature raised. For this same reason a diamond will always feel quite cold when you touch it. A diamond has a specific gravity of 3.51 and is also hydrophobic, meaning water will not stick to it but grease or fat will (now you know why you have to clean those rings so often). It is non magnetic and it will fluoresce under x-rays. A diamond is also extremely resistant to chemical attack so most chemical procedures will not damage a diamond. Many of these unique characteristics have led to the development of some very efficient techniques that can separate diamonds from the sediments or rocks that they are found in.

Diamonds form under very high temperatures (approximately 900-1400°C) and very high pressure (45-60 times greater than the pressure at the earths surface). At this amount of pressure that would mean that diamonds form at a depth of approximately 130-200 km below the surface of the earth. So how on earth can we mine for diamonds when they form that deep within the crust? Lucky for us they are brought to the surface by magma which forms a type of rock called kimberlite. A kimberlite would be where you would find diamonds. Kimberlites are a rare occurrence and so it follows that the minerals you would find in a kimberlite are also relatively rare but they are more abundant than the diamonds. If you can find these indicator minerals in high concentrations you should be able to locate a kimberlite and potentially some diamonds.

This procedure of looking for indicator minerals actually was developed based on a natural biological occurrence. It was known that white ants had inhabited the desert for thousand of years. These ants live in the sand and dig tunnels down as deep as 92 m. While they are digging these tunnels they bring up debris from those depths to the surface. Traces of many minerals were brought to the surface with the sand and debris and so one could determine what was below the ground by looking at the debris in the ant hill. It was believed that this is how the Egyptians determined where to dig their gold mines. They would look for an ant hill that was rich in tiny gold deposits and they would dig under that ant hill.

The same principle is used to find diamonds. However we unfortunately do not have any organisms that will bring the minerals or diamonds to the surface for us. Locating a diamond pipe involves looking for a number of "indicator minerals" in rocks or sediments. If you can find these indicator minerals in

high enough concentrations then you will be able to locate the diamond pipe they came from. In areas where geologists or prospectors think there might be a diamond pipe or kimberlite they take surface samples of the rock and sediments from the area. The samples are crushed and then separated into the different parts based on the different densities. Because the minerals that indicate diamond formation are "heavy" minerals, they will separate out quite easily from the rest of the material. These minerals are then examined under the microscope to identify them.

Some of the major minerals you would look for are (there are approximately 25 minerals all together)

-chrome diopside
-garnet (a specific type)
-ilmenite
-chromite

Sounds easy, right? If you take a 25 kg sample of rock and sand from the land or river you will get approximately 12 kg of gravel and 12 kg of sand. The sand is where you will find your minerals. Of that 12 kg of sand only 5-10% of that will be heavy minerals. That's 600 to 1200 grams of heavy minerals! Of that, more than half of that will be magnetite, the remainder will be a combination of ilmenite, garnet, gold and the other indicator minerals you are looking for. To find one kimberlite you may have to take tens or even thousands of samples. If you want the samples analyzed by a laboratory you are looking at a price of about $500 a sample. Even if you are in an area that has a kimberlite you may take a sample of land that does not have any indicator minerals in it. It takes a lot of patience and luck to find a diamond pipe.

There have been 3 000 kimberlites discovered in the world. One thousand of those contain diamonds, and out of those 1 000, 12 were found to have economic quantities of diamonds and are actively mined.

Diamonds are used in a number of applications today, especially in the modern metalworking industry. Diamonds are used to make metal cutting tools and are commonly put on the blades of these tools. Diamonds are used in drills because of its high resistance to scratching. The most common types of drills they are used in are dental and oil well drills. The low grade diamonds (not the gem quality) are crushed and are used to make an abrasive grit (somewhat like Comet or Ajax) for industrial purposes. They are also used in saws, glass cutters, phonograph needles, hardness testers and are used to cut very thin wire.

Diamonds are best known and most valuable for their use as a gemstone in jewellery.

Name: ____________________

Diamond Question Sheet

1. What are indicator minerals?

2. Which identification tests, from the ones we did, could geologists use to identify the indicator minerals for kimberlite?

3. What conditions do diamonds need in order to form?

4. What is one feature of a mineral you could look at that would tell you where or how it formed?

5. Why do diamonds seem to lose their shine over time?

6. Why can we mine for diamonds so close to the earths surface if diamonds are formed very deep within the earth's crust?

Diamond Answer Key

1. Indicator minerals are tiny mineral grains that help us to locate a diamond pipe. They may be found in river or glacial sediments or can be extracted from rocks.

2. The minerals could be tested for color and lustre. When geologists are working with such small grains, much more sophisticated methods are use to identify the minerals like scanning electron microscope identification.

3. Diamonds form under very high pressure and high temperatures correlating to a depth of about 130-200 km below the earths surface.

4. One feature you could look at would be the crystal shape and size. Larger crystals indicate a longer cooling process and smaller crystals indicate a quick cooling process.

5. Diamonds are hydrophobic so that means oil or grease will stick to the diamond but water will not. A diamond will collect this grease easily but it is difficult to wash off because water will not stick to the diamond.

6. Diamonds are brought to the surface of the earth by a rock formation called a kimberlite. This kimberlite transports the diamonds from great depths and brings them close to the surface of the earth.

Panning For Indicator Minerals

When you gold pan on the North Saskatchewan River, you are using many of the same principles that diamond prospectors use to locate and separate diamonds or diamond indicator minerals from the rest of the sediment it is found with. One mineral in particular, is easy to identify and is commonly found during gold panning and the collection of indicator minerals for diamonds. That mineral is garnet. Another mineral you will find is ilmenite, but it is not as easy to identify as garnet.

Gold panning works on the principle that, by using the proper techniques, you can separate the heavy sediments from the light sediments based on specific gravity. By "jiggling" the gold pan the "heavier" sediments will sink to the bottom and the lighter ones will stay on top thus allowing you to separate the two. This is also why you can find these minerals where the current slows down because the heavy minerals do not swirl around in the river currents like quartz sand does, instead they settle out. Common minerals you will find in the sand and gravel of the North Saskatchewan River are:

quartz	specific gravity = 2.7
garnet	specific gravity = 3.5
magnetite	specific gravity = 5.2
gold	specific gravity = 19.3

The garnet, magnetite and gold are "heavy" minerals, the quartz is part of the "light" fraction. To actually have your class pan for these minerals is easy to do here in Edmonton. A good place to collect the sample is Emily Murphy Park. You need to collect one or two, 2 gallon, buckets full of sand from right along the rivers edge. You will scoop up some large cobbles and pebbles along with the sand but I would advise you not to transport those back to the classroom. Screen or pick them out at the site and leave them (unless you want to examine the rock types). Once you get back to the school you can add your own sand or small gravel to have your concentrate go farther. This panning can be done in the classroom or out in a field (you will need to have a large amount of water out in the field).

How To Collect Heavy Minerals (Panning)

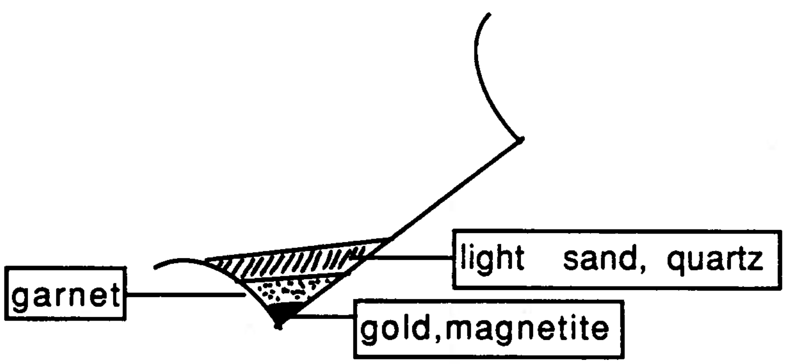
1. Fill the pan with the sample provided by your teacher.

2. Add some water to the pan but do not fill it up all the way.

3. Mix up the sample with your hand. If you have rocks and clay in your sample make sure that they are thoroughly wet. Your mixture should look soupy. At this stage the heavy minerals will be suspended in the mixture. To concentrate these minerals at the bottom of the pan you need to shake the pan back and forth and up and down. If you shake it too hard the gold will not settle out or you may lose some when it slops over the side.

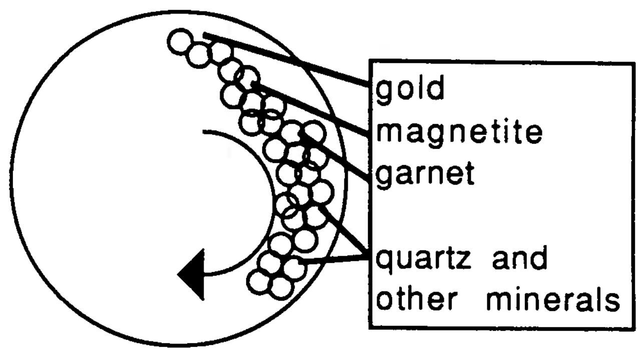
4. Pick out an, larger material r debris that is in the pan. Rinse them in the pan before throwing them out.

5. Tilt the pan and rotate it from side to side, allowing the water to run out and take with it the lighter sands from the top of your mixture.
Be careful not to slop the water around because the water might carry away some of the minerals you are looking for.



5. Level the pan. Pick out any pebbles or other large material. Shake vigorously again and repeat Step 4 until nothing remains except dark sandy material. This is a long process so you will need to be patient.

6. Once you have eliminated most of the sand and are left with the minerals you want to look at and separate further, (about 1 to 2 cupfuls), you should fill the pan 1/8 -1/4 full of water. Move the pan in a circular direction and you will start to see the heavy minerals separate. Be patient with this procedure, it will take a beginning panner 10 to 15 minutes. You will become faster with more practice.



7. Take small amounts of minerals from different parts of your pan and look at them on a slide under the microscope.

8. Sketch a small portion of what you see. If you are having difficulties seeing any of the grains, you may want to put a brightly colored piece of paper underneath the sample.

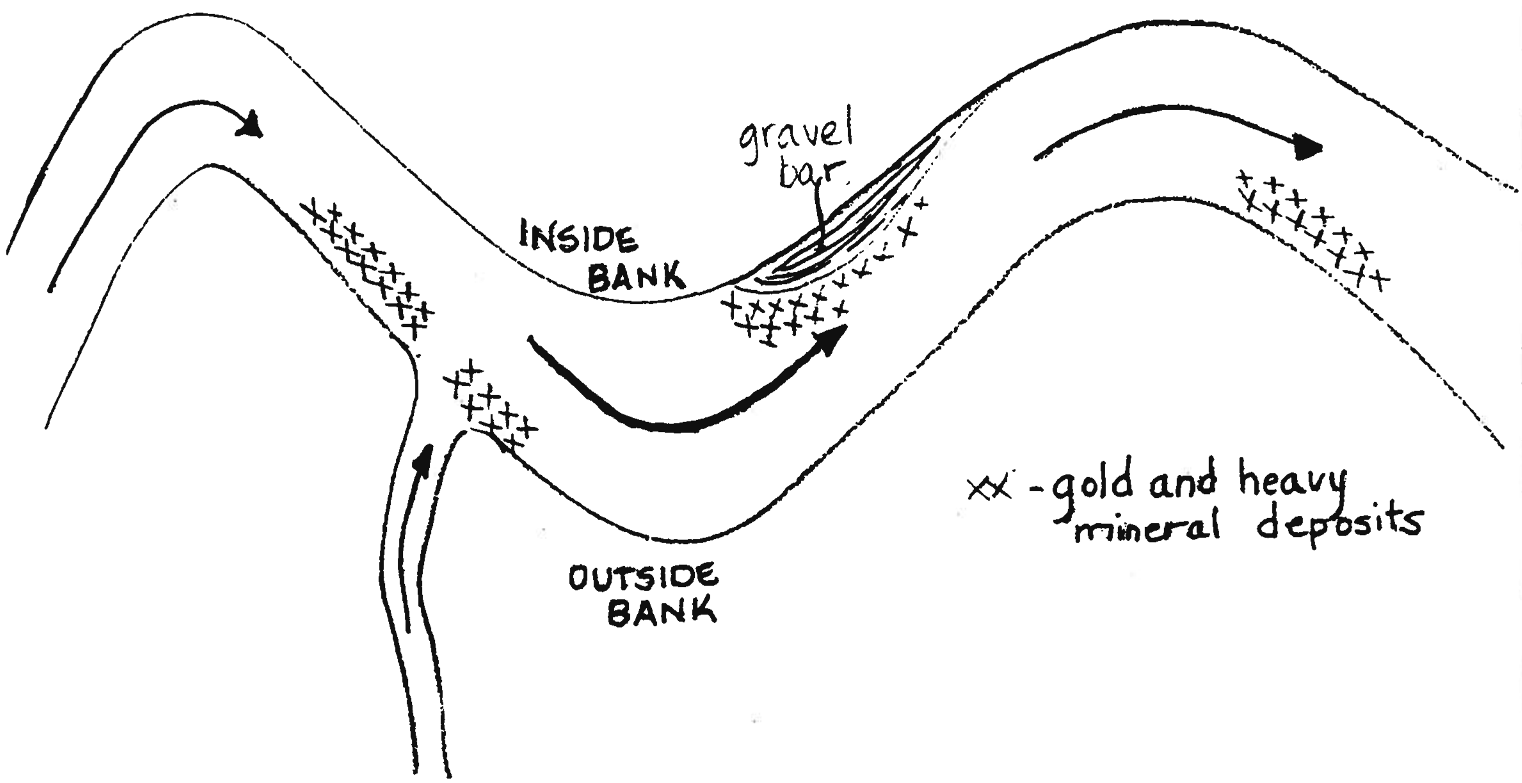
Lesson #3:
Panning For Indicator Minerals

Purpose: To have the students separate heavier sediments from lighter sediments using the proper panning techniques.

Time: 1 class period

Preparation: You will need to collect some sample for the students to concentrate using a pan. You will need to find a stream or a river to collect the sample. This is best done in the late summer or early fall.

You should look for places along the river where the current slows down. When the current slows down it allows for the gold and other heavy minerals to settle out. Anywhere where there is a bend in the river or just past corners on the outside bank are good places to start. Gravel bars and black sand are also good indicators of gold and other minerals.



Once you find a good area you will need to collect one quarter of a bucket of concentrated sample. To do this you will need a shovel, some rubber gloves, and a gold pan. Take one shovel full of the sand (including rocks etc.) and place it in the pan. You will essentially be following the same steps that your students will be, only you will be removing the larger sediments so that the students do not have to do this. Once you have carefully removed the larger sediments and the gravel (following the panning technique), you should eliminate some sand by panning and put the remaining sand mixture into the bucket (there should only be a small amount from that one shovel). On the average it will take about 10 shovels full to make a good concentrate but that will also depend on the area you picked. Some areas will require more shovels and some areas will require less. Once you have collected the sample, you can take this back to the classroom and mix it with some more sand or gravel before you give it to the students.

If your class has real gold pans you can bring them sample with pebbles in it but if they are using aluminum or tin pie plates it is very difficult to pan if there are pebbles, so you will need to bring the concentrate down to a useable size for the students.

If you are not near a river or a stream, you can do this experiment using a sand and gravel mixture with lead shot added to it. If you use a specific amount of lead shot you can see how well your class is at recovering all of the lead shot.

This technique is sometimes difficult to do from following written instructions so if you have any questions or want a demonstration you can contact Claudine Coleman at T.D. Baker School or Dixon Edwards at the Alberta Research Council.

Gold pans can be purchased for under $10 each. One distributor in Edmonton is Bedrock Supply Ltd., 9617 63 Ave in Edmonton.

Kimberlite: A Type Of Igneous Rock

Imagine yourself standing somewhere in the NorthWest Territories (or Alberta) on a rocky plain millions of years ago. You start to hear what sounds like the approach of a freight train only there are not any train tracks within hundreds of kilometres from you, in fact trains have not even been invented yet. The sound keeps getting louder and louder, until you are sure the train is right behind you. In the distance you can see rocks flying into the air and the earth trembles beneath your feet. No, it's not he approach of the worm from the movie Tremors, it's what scientists believe it would feel like when a kimberlite pipe forms. Kimberlites are one of the most sought after rock formations in Canada today. This is the rock formation in which diamonds are found.

A kimberlite is essentially an **intrusive igneous rock**. That means, the minerals in the rock crystallized from magma under the surface of the earth. It is formed from magma that moves up to the surface of the earth through deep cracks in the earths crust. The formation of a kimberlite pipe is quite similar to a common volcano only the kimberlite is rarer, usually smaller and does not continually erupt. The kimberlite magma moves quickly to the earths surface. It has been estimated that the magma moves at a rate of 10 to 30 km/hour and when it gets quite close to the surface of the earth it moves up to several hundred km/hour. The increase in speed is due to the decrease in pressure as there is less crust pushing down on the magma as it gets closer to the surface. Kimberlites originate from a depth of approximately 100 to 300 km below the earths surface so at the above speed it takes anywhere from 4 to 15 hours to reach the surface. In recorded history, humans have not witnessed the formation of a kimberlite pipe.

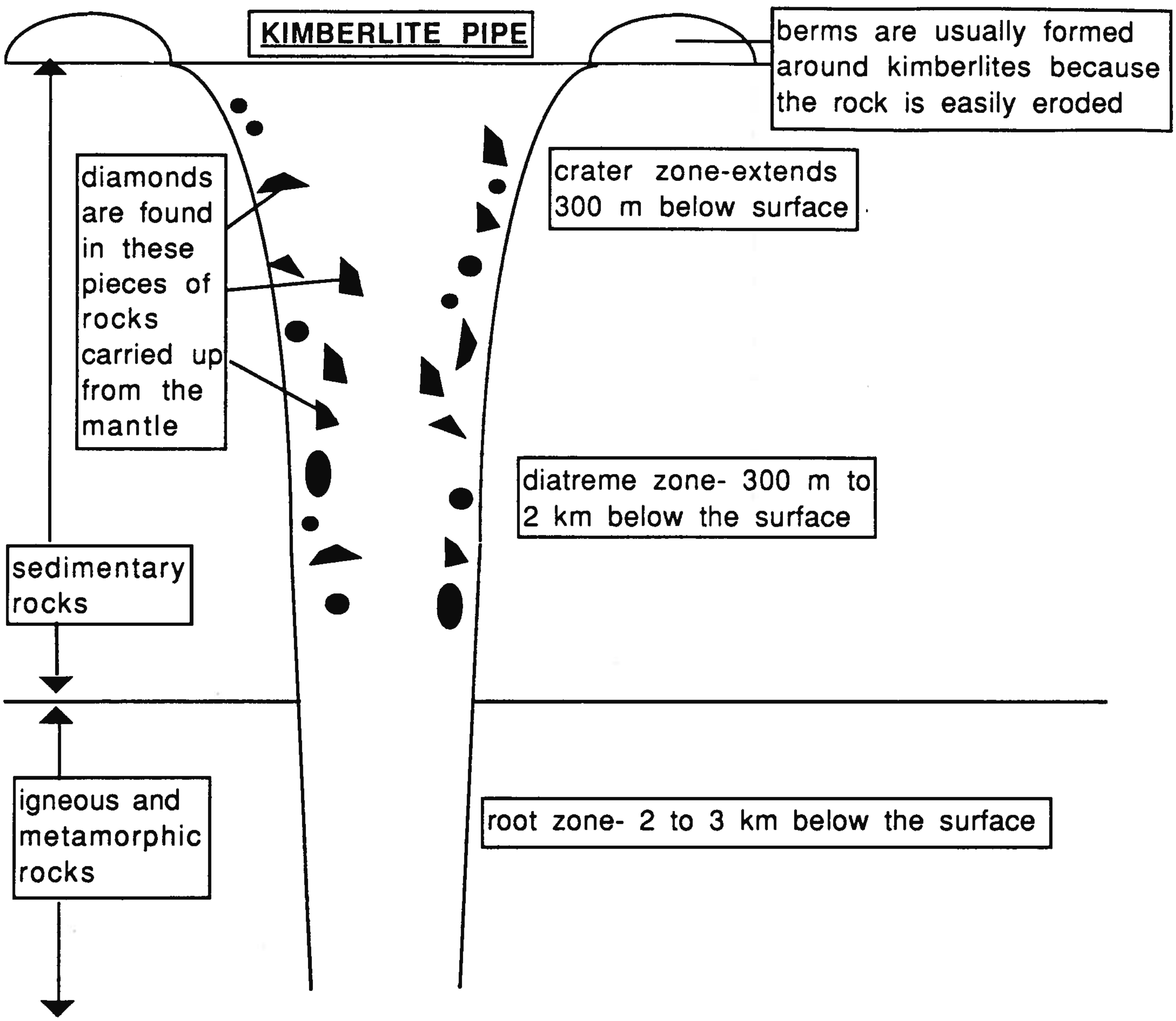
A kimberlite formation, pipe or intrusion is usually cone shaped and is composed of dark colored rock. It is cone shaped because as the kimberlite reaches the surface of the earth, it spreads out because of the decrease in pressure. Kimberlite is an easily eroded rock so often surrounding a kimberlite many of the sediments can contain diamonds. Often berms will also be found surrounding kimberlites. Many kimberlites, because they are eroded more easily than the rocks around it, will form depressions on the earths surface and then fill up with water to form lakes. One of the kimberlites discovered in the North West Territories is located underneath a lake.

So why do we find diamonds in a kimberlite? Diamonds obviously do not crystallize in the magma as it is zooming to the surface of the earth. A diamond will only form under high temperatures and high pressures located deep under the earth. Why then do we find diamonds in a rock that has crystallized from magma so close to the earths surface?

A good analogy would be that a kimberlite is quite similar to an elevator. As this elevator (magma) is moving up to the surface of the earth it picks up passengers (diamonds and rocks) along the way. Because the kimberlite moves so quickly, the diamonds are preserved on the ride up to the surface rather than changing into graphite or carbon. The diamonds are actually found in the rock fragments that are brought up to the surface by the kimberlite. These rock fragments are called xenoliths (defined as a rock fragment that is foreign to the igneous mass in which it occurs). As the magma moves up to the surface of the earth it takes with it pieces of the wall rock from the fracture in the earth that the magma is moving through. The discovery of this formation has helped the advance of our knowledge of the deep mantle greatly. The deepest we can mine is about 3 km so we are limited to hands on knowledge to the upper 3 km of our crust. These kimberlites are bringing up to the surface minerals and rocks from as deep as 300 km. We now know much more about the minerals and rocks located far beneath the surface because of the xenoliths that the kimberlites have brought to the surface.

Kimberlites can be located through the process of looking for indicator minerals. There are a number of minerals that are distinctive to a kimberlite pipe and if you can find and trace those minerals to the source then you have located a kimberlite. Since kimberlites can be diamondiferous, once a pipe has been located, samples are taken to see the quantity and quality of diamonds that the pipe might be carrying. Of the 3000 kimberlite pipes discovered, 1000 of them have diamonds in them. Of those 1000 pipes, only 12 were found to be economic to mine.

It is important to note that the study of kimberlites is a relatively new science. The theory that has developed is based on evidence geologists have gathered. As technology increases over the years and we discover more evidence this theory may be altered or completely changed. This is true of any scientific theory but it is important to note since kimberlites are a young discovery.


KIMBERLITE PIPE
berms are usually formed around kimberlites because the rock is easily eroded
crater zone-extends 300 m below surface
diamonds are found in these pieces of rocks carried up from the mantle
diatreme zone- 300 m to 2 km below the surface
sedimentary rocks
igneous and metamorphic rocks
root zone- 2 to 3 km below the surface

Lesson #4:
An Introduction To Rocks

Purpose: To introduce the students to the three different types of rocks

Time: 1 class period

Preparation:
1 bag of Rainbow Chocolate Chip Ahoy cookies per class
1 or two cookies of any other type
paper towels (1 for each student)

Directions: You need to set up the scenario for the class that a unusual rock has been found by you. It can be here on earth or from another planet if you choose. The students will need to identify the new minerals (the ingredients in the cookie) in this rock (the cookie) using what they learned in the previous classes. Have them draw up a chart with the appropriate headings. Remind the class that you do not want to see any of this rock go missing and that, if they are good scientists, they might get to take the rock home. I would then hand out a paper towels and a cookie to each student.

They will need about 5 minutes to finish the mineral identification.

At this point you can explain to the students that a rock is simply a combination of minerals. Different rocks have different minerals and those minerals are in different combinations. The minerals are just like the ingredients we put in when we are making these cookies. We can tell a lot about a rock by looking at the types of minerals in a rock and the amounts of minerals.

> **How could we determine the percentage of each mineral that makes up this rock? (guess, crush it, slice it)**

Rocks are classified according to how they formed. The rock (cookie) they have in front of them right now is analogous to an igneous rock. This rock has formed from a molten (liquid) material we call magma. This is analogous to the batter before it is cooked. This magma cools to form a solid rock. You can have many different types of igneous rocks based on the types of minerals present in the magma before it cools. Show them the different types of cookies.

How would we tell whether the rock cooled quickly or slowly?
(Ties in to crystal lab) (large chunks or crystals mean it cooled slowly)

In grade 7 students should have learned what erosion is. Ask them to explain the following questions:

What would happen to this rock if it was left exposed on the ground? (erode)
What would happen if this rock was picked up by a river? (carried away to a different spot, erode)
Imagine this cookie was as hard as a rock, how would it look like after travelling down a river for a number of years? (rounder, flatter, smoother)

<u>Sedimentary rock</u>, the second type of rock, can be formed from this occurrence. Sedimentary rocks are formed when bits and pieces from other rocks are put together to form new ones. You can demonstrate this by taking two or three different cookies, eroding (breaking) these cookies and then combining them into a new rock. The sediments over the years become compacted and cemented together by heat, pressure or chemicals.

What conditions do we need in order for this new rock to form? (heat and/or pressure and/or addition of other substances or chemicals)

The last type of rock is what we call <u>metamorphic rock</u>. This rock is formed when existing rocks are put under heat and/or pressure. An analogy would be putting the cookie back in the oven or stepping on it very carefully so that it gets compacted even further (similar to stepping on fluffy snow).

What would some of the characteristics of the new rock be? (harder, different color)
Can metamorphic rocks be eroded to form sediments? (yes)
Can sedimentary rocks be eroded to form sediments? (yes)
Could a rock be put under so much heat and pressure that it turns into magma? (yes)

Summary:

What are the three ways rocks can be classified? (igneous, sedimentary and metamorphic)

Other Discussion Questions or Assignments:

Draw a diagram to show how all three rocks are related to one another. (Rock Cycle)

What would a diamond look like if it was eroded from the rock it formed in and then travelled down a stream for a number of years? (might be slightly eroded or rounded from violent action but otherwise the same because of it's hardness)

Other Suggestion For Linking Diamonds To The Curriculum

1. Recent newspaper articles about diamonds in Alberta are an excellent way to link science and society. I have chosen two that will lend themselves toward excellent discussions and some questions sheets to accompany them. There are may other excellent articles you can use.

2. When constructing any time line for geological time (ie. Activity 4-7 on page 182 of Science Directions) also include the time period when most diamonds were formed (3000 to 100 million years ago).

3. Mapping of earthquakes and volcanoes can also include mapping of major diamond pipes. You will see that the diamond pipes are not near to the earthquakes or volcanoes. Here are the locations of the major diamond pipes:

Russia- Mir and Undachnaya
Botswana- Orapa, Letlhakane, and Jwaneng
Australia- Argyle
South Africa- Kimberley, Finsch and Premier

Other countries that had or have diamond mines are:

India (Majhgawan)	Angola (Dundo)
Brazil	Venezuela
Namibia	Zaire
Guyana	Tanzania

4. Diamond formation can also be tied into teaching about the layers of the earth and the crust. Diamonds come near to the surface in geologically stable areas called cratons. The diamonds are carried from the mantle to the crust in these areas. They come to the surface through fractures or cracks in the crust. Many geologists believe that the carbon that forms diamonds originates on the surface of the earth and is subducted into the mantle where the continents collide. If you are interested in more information on this topic you can contact Dixon Edwards at the Alberta Research Council or Claudine Coleman at T.D. Baker School.

5. An interesting discussion could result from the discussion as to the function of the Central Selling Organization and whether or not it is a monopoly.

St. Albert Gazette
December 26, 1992

From diamond strike to finished product

Twelve per cent of the diamonds mined annually bring in more than 50 per cent of the profit, says De Beers spokesman Andrew Lamont. Almost 40 per cent of the diamonds are lost in the cutting process.

By Leslie Peppler
Staff Writer

Diamond fever has struck deep in the heart of Alberta and exploration and mining companies anticipate a major diamond strike.

In the past six months, more than 37 million acres across the province have been staked for exploration. Last week alone, Alberta Energy received 400 permit applications.

Edmonton-based Takla Star Resources, just one of several companies registering claims, has staked a claim on 1.7-million acres extending from Namao west to Evansburg and from northwest of St. Albert to Fort Assinboine.

Company president Jim Stewart told *The Gazette* last week a decision to proceed with mining operations would likely be based on the quality and quantity of diamond finds.

But a spokesman for South Africa's De Beers Consolidated Diamond Mines warns developing a diamond mine and associated industries can be a lengthy process, often taking more than a decade.

"Since diamond mines were first discovered, there have been 5,000 kimberlite occurrences (fields typically associated with diamond discoveries) and less than half of one per cent yield major diamond finds," said Andrew Lamont.

Diamonds are found in kimberlite pipes which are funnel-like deposits of volcanic rock that can extend several thousand metres beneath the earth's surface.

Some gems, washed off pipes by erosion over millions of years, are occasionally found along river-beds or coastal strips.

Diamonds are initially mined in an open cast or pit. When the pit reaches a certain depth, mining continues underground.

On average, approximately 250 tonnes of kimberlite ore must be mined and processed to produce one carat of polished gem-quality diamond.

"One-half of all the diamonds mined are used for industrial purposes. Another 12 per cent are cut and polished for use in jewelry. The remainder are lost in the cutting process," Lamont said.

Gems slated for cutting, by far the most profitable, are sorted by size, shape, quality and color.

While industrial diamonds sell for $1 to $8 a carat, a gem-quality diamond will sell for several hundreds of dollars per carat depending on the quality, Lamont said.

"Japan and the United States account for 60 per cent of gem-quality diamond purchases throughout the world."

There are diamond mines in 20 countries. The top seven diamond-producing nations, accounting for 90 per cent of the world's rough diamond supply, are Russia, Botswana, South Africa, Australia, Zaire, Namibia and Angola.

"One-third of industrial-quality diamonds come from Australia. The country has a high-volume, low-value diamond industry. It is estimated about five per cent of their diamonds are gem-quality, while 45 per cent are cheap gems used for industrial purposes," he said.

Most industrial diamonds are used in machines, including mining drill bits and tooling machines in factories.

"Every car off the production line requires at least a quarter of a carat of industrial diamonds in the tooling machinery."

Diamond mines produce only half (100 million carats) of what is needed worldwide to meet annual consumer demands.

Synthetic diamonds fill 80 per cent of the void. They are cheaper to produce and industrial consumers can rely on consistent quality and predetermined sizes for tooling equipment.

The majority of diamond mines market gems through De Beers Central Selling Organization (CSO).

CSO, De Beer's marketing arm, controls diamond stockpiles to ensure values remain constant.

"In times of strong consumer demand, we'll supply the market at a rate it can absorb. The goal is to keep diamond values up during hard times, like a recession. We also assist in the development of new mines so they have a market for their products," Lamont said.

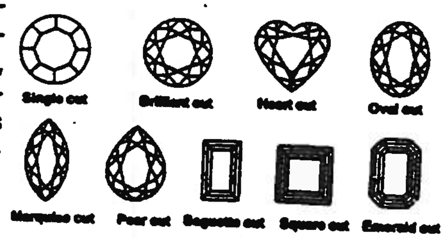
Diamonds are shipped from the CSO to De Beer's industrial or gem-manufacturing centres where artisans have passed their skills from generation to generation. Major gem-cutting centres are located in Belgium, India, Israel and New York.

De Beers has formed partnerships with countries like Russia and Botswana that have insisted on establishing their own cutting industries.

Lamont said those countries have had difficulty making the industry cost-effective and often their home-cut diamonds do not have the same reputation for quality as those cut in one of the four major centres.

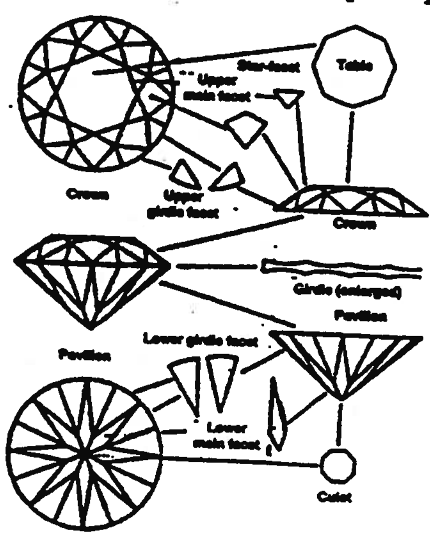
Best-known cuts

Four major cutting centres in the world are located in India, Belgium, Israel and New York. Artisans pass on their skills from generation to generation.



Even with the best possible cut, about 40 - 60 per cent of the weight of the raw material is lost during the cutting process.

A good cut is recognizable by the optimal concentration of light and the effective reflections through the upper surfaces. The dispersion of light through the diamond is one of the highest of any natural gem stone.



To have confidence in the quality of the diamond's cut it is necessary to depend upon the knowledge and experience of the jeweller.

The five best-known types of cut: Marquise cut, Emerald cut, Oval cut, Pear cut and Brilliant cut.

"Diamond Strike" Article Questions

1. How long does it take to develop a diamond mine?

2. How much kimberlite must be mined to produce one carat of gem quality diamonds?

3. Where are most industrial or low grade diamonds used?

4. How many carats worth of diamonds does it take to make a car?

5. What does the CSO (Central Selling Organization) do?

6. What percentage of the weight of a diamond is lost during the cutting process?

HOT ROCKS

Globe and Mail
June 5, 1993

Here's a tour through the Canadian carat patch — from the Northwest Territories tundra, where Charles Fipke hit paydirt, to the big city canyons, where another kind of prospector drills for dollars.

A guide to diamonds, diggers and dealers

BRIAN GABLE / *The Globe and Mail*

BY ALLAN ROBINSON
Mining Reporter

WHAT'S hotter than Hemlo? Crazier than the Klondike? It's the Great Canadian Diamond Hunt of the 1990s.

Once again, a mining play has emerged to tickle the imagination — and greed — of stock market speculators. Professionals and punters are betting hundreds of millions of dollars that one or more of the world's largest diamond mines lie beneath the tundra and lakes of the Northwest Territories.

Over the next few months, a flood of preliminary exploration results will hit the street, setting off cheers or tears in a few boardrooms — and a lot of living rooms.

Should you be in or out of the diamond action? Here's a bag of gems on what makes it so tantalizing — and so risky:

THE PRIZE

Ninety per cent of the world's diamonds are mined in Russia, Botswana, South Africa, Australia, Zaire, Namibia and Angola.

Canada would like to join this club. But for a mine to make money in the remote north, it would have to be a jewel — one of the richest anywhere.

If a big enough lode is found, developing a mine could cost more than $500-million (U.S.). But a good mine might be worth more than $1-billion and generate cash flow of $500-million a year, estimates Christopher Jennings, president of an exploration company.

Mining industry officials say it takes five to 10 years on average to create an efficient mining operation once a deposit has been proved viable. A return on investment would take several years longer.

THE HUNTERS

The discovery of diamonds in the Lac de Gras area about 350 kilometres northeast of Yellowknife is the product of geochemical detective work worthy of Sherlock Holmes.

The detective is Charles Fipke, who during the 1980s followed a trail of "indicator" minerals (stones that can indicate the presence of diamonds) east from the Mackenzie River valley.

These microscopic stones, scattered far and wide by glaciers, pointed to the presence of kimberlite, a volcanic rock often associated with diamonds. Kimberlite is found in narrow carrot-shaped "pipes" that originate 150 kilometres beneath the Earth's surface. When they were in molten form 100 million years ago, they served as a conduit for three-billion-year-old diamonds to be carried to the surface.

Mr. Fipke patiently followed the mineral trail to tiny Point Lake in the Arctic region, whose round shape suggested that diamonds lay on its bottom.

Why? Elementary, deduced Mr. Fipke. Kimberlite is a soft rock that is easily eroded, causing lakes to form on top of the kimberlite pipes. Sometimes, kimberlite contains diamonds. The test drilling bore him out.

His discovery in late 1991 set off the largest staking rush in Canadian history, covering more than 12 million hectares. It also revived Canada's penny stock market, which had been languishing for almost a decade.

For Mr. Fipke, it was the end of an odyssey that had taken the Canadian geologist to New Guinea, Australia, South Africa, and Brazil in search for diamonds. Since 1977, he had concentrated on Canada.

Mr. Fipke's company, Dia Met Minerals Ltd. of Kelowna, B.C., owns 29 per cent of the property surrounding the discovery. Dia Met is valued at $705.6-million (Canadian), which implies the property, which contains several diamond-bearing pipes, is worth $2.4-billion. The market is betting there will be a mine, but much exploration work needs to be done.

Mr. Fipke thus joins the ranks of Canada's mining legends. Move over, Gilbert Labine (of the Great Bear Lake radium find) and George Carmack (of Yukon gold rush fame.) He has also made paper millionaires of some folks around Kelowna, who bought the stock in the early going.

But other searchers have followed the same trail, including Mr. Jennings, a former vice-president of gold producer Corona Corp. who now runs Southernera Resources Ltd., and Hugo Dummett, a geologist for Broken Hill Proprietary Co., of Australia.

HITS AND MYTHS

Fipke's Curse: Mr. Fipke had the first crack at staking what he felt was the best ground. He is reported to have said that any ground outside of the Dia Met area will turn out to be worthless.

The Corridor of Hope: One geological theory holds that kimberlite pipes containing diamonds can be found along a northwest-southeast corridor in the Northwest Territories, bounded by geological formations known as dykes. (A dyke is a long, thin body of igneous rock.) Nice theory, but the land-staking activity has extended well beyond any corridor.

Diamond lore . . . The major purpose of mined diamonds is adornment. "Worldwide, some 300 million women own at least one piece of diamond jewelry, and each year husbands, lovers and women spend almost $40-billion (U.S.) on about 60 million pieces containing some 15 million carats of diamonds."

— *Diamond People*, by A. J. Wannenburgh and Peter Johnson (Norfolk House, 1990).

. . . and Lorelei

Men grow cold as girls grow old
And we all lose our charms in the end
But square cut or pear shape
These rocks don't lose their shape
Diamonds are a girl's best friend

He's your guy when stocks are high
But beware when they start to descend
It's then that those louses
Go back to their spouses
Diamonds are a girl's best friend

From *Gentlemen Prefer Blondes*
Words by Leo Robin

WHERE THE CARIBOU ROAM

How wild is the Northwest Territories diamond scene? Caribou pasture held by nine of the leading exploration companies and landholders is valued by stock markets at $3.8-billion.

That's almost half the market value of South Africa's De Beers Consolidated Mines Ltd., the world's biggest diamond miner.

And remember: De Beers is more than just diamonds. Its holdings include a 38.6-per-cent interest in Anglo American Corp., the world's largest gold producer, and 27.5 per cent of Anglo American Industrial Corp. The Anglo group controls about one-quarter of the quoted South African market capitalization, according to The Economist.

GRAPHITE IS FOREVER

Natural diamonds are pure carbon crystals — up to 3.5 billion years old — formed under high pressure and heat deep in the Earth and thrust to the surface by volcanic action.

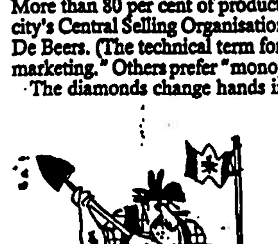
But not all diamonds are natural. Graphite can be turned into diamonds, using high-pressure presses that replicate conditions and processes that occur in the Earth. These man-made gems are used in grinding equipment, saws, drills and other precision cutting tools for industrial, medical and scientific purposes.

About 85 per cent of industrial diamonds used each year are made by synthetic methods. "In the industrial diamond business, a diamond press is now more important than a diamond mine," says *Diamond People*.

ROUGH CUTS

For more than 350 years, London has been the world distribution capital for rough, or uncut, natural diamonds. More than 80 per cent of production is sold through the city's Central Selling Organisation, the marketing arm of De Beers. (The technical term for this is "single channel marketing." Others prefer "monopoly.")

The diamonds change hands in offices in London, in Lucerne, Switzerland, and in Kimberley, South Africa, before being made into polished gems around the world. In 1992, De Beers sold $3.4-billion worth of diamonds this way.



De Beers is both a supplier and a market-maker. It estimates its own mines produce half of the world's rough diamonds, with the Russians supplying another 25 per cent. It also stabilizes the market, using its deep pockets to buy particular sizes and qualities when demand is weak, and selling when markets are stronger.

Ten times a year, De Beers' 150 established clients, which are manufacturers and dealers, attend "sights" where they are offered at a fixed price a box of diamonds tailored as much as possible to their needs. During negotiations, buyers can ask De Beers to alter the types of diamonds in the box.

Any Canadian diamond mine might want to join the De Beer's cartel, with its tried-and-true distribution channels, But some diamond watchers fear that if the hunt is successful Canadian gems could flood the market, threatening the cartel's clout.

THE PIPES ARE CALLING

Inspired by Fipke's Find, more than 220 companies are exploring North America for the elusive kimberlite "pipes."

There are about 5,000 such pipes in the world and 1,000 contain diamonds. But fewer than 15 have been developed into major mines. The pipes can be found in clusters of 10 to 50 over an area of 125 to 250 square kilometres.

In Canada, the kimberlite search has been going on for more than 30 years. Diamonds had been found in Ontario, Saskatchewan and British Columbia. But it was not until last year that the hunt captured the imagination of investors.

Hundreds of targets are being drilled this summer across Canada. In the Northwest Territories, more than 20 pipes have been discovered. Several have shown high concentrations of diamonds.

VALUE JUDGMENTS

- An average of 250 tonnes of kimberlite ore must be mined and processed to produce one carat or 0.2 grams of polished diamond of gem quality.
- There are 5,000 different categories of diamonds based on shape, quality, colour and size.
- An ounce of gold is valued about $370. An ounce of diamonds (about 150 carats) might fetch hundreds of dollars for small industrial-quality stones; or buyers might fork out millions for one gem-quality flawless "fancy" diamond. Fancies are rare coloured stones.
- The Geological Survey of Canada estimates that the average price of a typical gem is $180 a carat; for an industrial stone, it's $8 a carat.

The value of diamonds is crucial in assessing the potential of a profitable mine. Yet, no data have emerged on the value of any diamonds found in Canada. Exploration companies say the samples are too small. For investors, it's still "blind poker."

THE MINERAL RUSHES

International mining giants have joined the Canadian diamond hunt in a big way. De Beers is here, as is RTZ Corp. of Britain, and Dia Met's Australian partner, Broken Hill Proprietary. For the most part, the Canadian senior gold and base metal miners have missed out on the action in their own backyard.

The pattern is clear, suggests Dennis Gorc, geologist with Imperial Metals Corp. of Vancouver. There's a big mineral rush in Canada every decade — copper in the 1960s, uranium in the 1970s, gold in the 1980s, diamonds in the 1990s. Any bets on the hot ticket in 2003?

THE SCIENTISTS

The Canadian diamond quest is good business for the world's mineral laboratories. Minerologists with tweezers in hand peer through binocular microscopes at chemical grains extracted from rock samples. The grains look like sand on a beach, but the green, yellow, brown and purple particles are the first clues that kimberlite might be nearby.

Of these indicator minerals, the most significant are the G-9 and G-10 pyrope garnets, ilmenites, chrome diopsides and chromites, all of which can indicate the presence of kimberlite.

Lab processing of kimberlite itself may reveal microdiamonds less than half a millimetre in diameter. Barely visible with the naked eye, they have no intrinsic value but can indicate the presence of bigger, commercial diamonds.

Bulk samples of 10,000 to 20,000 tonnes have to be processed to determine if a kimberlite pipe is something more than an interesting geological feature. At the moment, stock investors are making their bets on sample sizes ranging from only 23 kilograms to 208 kilograms.

CANARIES, HIJACKS, ICE ROADS

The diamond hunt has had its share of drama. Late last year, the shares of one exploration company soared after rare and expensive "canary yellow" diamonds were discovered in a laboratory sample.

The excitement died a few days later when red-faced researchers discovered the precious stones had fallen off a diamond drill bit. The lab process had caused the bit's synthetic green diamonds to change colour and look like natural yellow stones. Canary diamonds can fetch up to $85,000 a carat.

Another company lost its bulk samples when a truck carrying the cargo was hijacked in South Africa. In the early days, companies taking magnetic surveys by airplane complained that wires and generators were being strung across properties to mess up their readings.

Aur Resources Ltd. hit a snag this year when a drill it was hauling to its northern site broke through the ice. It took a week to get it out of the water.

The territory's lakes, rivers and difficult terrain make winter the best time to bring in equipment. One of the major thoroughfares has been the ice road from Yellowknife to Echo Bay's Lupin gold mine, which is 150 kilometres northwest of the kimberlite discoveries. Exploration equipment is hauled north and bulk samples south

THE 'ME TOOS'

A lot of prospectors do not want to find an act... amond mine, says Bram Janse, a diamond expe head of Mintel Pty. Ltd. of Australia. "They want to find an interesting property to flog off for cash."

That prospect has sparked exploration activity from Arkansas to the Arctic Islands, from Alaska to Quebec.

One of the biggest plays outside the Northwest Territories is in Saskatchewan. Since 1988, Uranerz Exploration and Mining Ltd., Cameco Corp. and a De Beers subsidiary have found almost 300 macrodiamonds (larger than 0.5 millimetres in diameter) in the Fort à la Corne area, but nothing that can be mined for profit.

Peter Gummer, president of Rhonda Mining Corp., has set out to prove a new theory that there are huge sheets of uneroded kimberlite in the province — as well as pipes. His company owns mineral rights on 0.9 million hectares.

Some firms are looking again at Ontario and Quebec, poring over data from aeromagnetic and geophysical surveys. After all, the largest diamond found in Canada — a 33-carat beauty — came from Peterborough, Ont.

THE PROMOTERS

Still thinking about buying a diamond stock? Don't do it, unless you're comfortable with risk.

Think about it: nine companies active in the Northwest Territories command a $1.7-billion (Canadian) market value. If that doesn't scare you, press ahead. You may find yourself in business with some of these people:

- Fred Christensen and Desmond Alexander hail from sunny Casa Del Cerro in Tucker's Town, Bermuda, a long way from the frozen north. They're the promoters of Lytton Minerals Ltd., a company with a huge land position valued at about $471-million by the stock market — but with only one kimberlite pipe so far. However, there are Bay Street rumours of well-heeled European investors who have shown a willingness to buy when the shares show signs of weakening.

Lytton's last major stock play was restaking the Eskay Creek gold discovery in British Columbia and heading for the courts. It ended up with a financial settlement from the original owners.

- Southernera, headed by Christopher Jennings, has cherry-picked many of the best sites in the Northwest Territories, including parts of the property held by Lytton, and has varying interests in 1.3 million hectares. The market gives it a value of about $117-million.
- The DHK syndicate of companies has been described as an "orphan" because it has no high-powered promoter backing the play. Gemologist George Stewart and his group went from hunting gold and copper to diamonds. "We're exploration people," says one member.

The syndicate staked some land in the area and ended up with a diamond discovery that could rival the Dia Met pipes and put an end to the dreaded Fipke curse. Based on the market value of its companies — Dentonia Resources Ltd., Horseshoe Gold Mining Inc. and Kettle River Resources Ltd. — its property is worth $588-million.

And that's just skimming the surface. Any promoters worth their salt now have a diamond property in their back pocket. As one stockbroker said: "Diamond properties are like navels — everybody has one."

"Hot Rocks" Questions

1. How much does it cost to develop a diamond mine?

2. What is a kimberlite?

3. How many women own at least one piece of diamond jewellery?

4. What do we use man made diamonds for?

5. What do diamond watchers think will happen if diamonds are discovered in Canada?

6. How long have they been looking for kimberlite in Canada?

7. How many pipes have been discovered in the North West Territories?

8. How many different categories of diamonds are there?

9. How much is one carat of gem quality diamonds worth?

10. What are the most significant indicator minerals for finding diamonds?

11. Would you invest in diamond stock if you had the money? Explain why.

12. What do you think would happen to Canada's economy if a diamond pipe was discovered in Canada? How about if one was discovered here in Alberta?