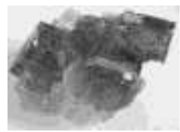
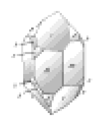
How to Identify Rocks and Minerals


epidote


fluorite


calcite


gypsum


quartz


pyrite


galena


fluorite


copper

By Jan C. Rasmussen
(Revised from a booklet by Susan Celestian)
2012

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NUMERICAL LIST OF ROCKS & MINERALS IN KIT

See final pages of book for color photographs of rocks and minerals.

MINERALS:

1 Talc
2 Gypsum
3 Calcite
4 Fluorite
5 Apatite*
6 Orthoclase (feldspar group)
7 Quartz
8 Topaz*
9 Corundum*
10 Diamond*
11 Chrysocolla (blue)
12 Azurite (dark blue)
13 Quartz, var. chalcedony
14 Chalcopyrite (brassy)
15 Barite
16 Galena (metallic)
17 Hematite
18 Garnet
19 Magnetite
20 Serpentine
21 Malachite (green)
22 Muscovite (mica group)
23 Bornite (peacock tarnish)
24 Halite (table salt)
25 Cuprite
26 Limonite (Goethite)
27 Pyrite (brassy)
28 Peridot
29 Gold*
30 Copper (refined)
31 Glauberite pseudomorph
32 Sulfur
33 Quartz, var. rose
34 Quartz, var. amethyst
35 Hornblende*
36 Tourmaline*
37 Graphite*
38 Sphalerite*
39 Biotite*
40 Dolomite*

IGNEOUS ROCKS:

50 Apache Tear
51 Basalt
52 Pumice
53 Perlite
54 Obsidian
55 Tuff
56 Rhyolite
57 Granite

METAMORPHIC ROCKS:

60 Quartzite*
61 Schist
62 Marble
63 Slate*
64 Gneiss
65 Metaconglomerate*
66 Phyllite
(20) (Serpentinite)*

SEDIMENTARY ROCKS:

70 Sandstone
71 Limestone
72 Travertine (onyx)
73 Conglomerate
74 Breccia
75 Shale
76 Silicified Wood
(Quartz, var. chert)
77 Coal
78 Diatomite

*= not generally in kits. Minerals numbered 8-10, 25, 29, 35-40 are listed for information only.

ALPHABETICAL LIST OF ROCKS & MINERALS IN KIT

See final pages of book for color photographs of rocks and minerals.

MINERALS:

Apatite*	5
Azurite (dark blue)	12
Barite	15
Biotite	39
Bornite (peacock tarnish)	23
Calcite	3
Chalcopyrite (brassy)	14
Chrysocolla (blue-green)	11
Copper (refined)	30
Corundum*	9
Cuprite*	25
Diamond*	10
Dolomite*	40
Fluorite	4
Galena (metallic)	16
Garnet	18
Glauberite pseudomorph	31
Gold*	29
Graphite*	37
Gypsum	2
Halite (table salt)	24
Hematite	17
Hornblende	35
Limonite (Goethite)	26
Magnetite	19
Malachite (green)	21
Muscovite (mica group)	22
Orthoclase (feldspar group)	6
Peridot	28
Pyrite (brassy)	27
Quartz, var. amethyst	34
Quartz, var. chalcedony	13
Quartz	7
Quartz, var. rose	33
Serpentine	20
Sphalerite*	38
Sulfur	32
Talc	1
Topaz*	8
Tourmaline*	36

ROCKS:

Apache Tear	50
Basalt	51
Breccia	74
Coal	77
Conglomerate	73
Diatomite	78
Gneiss	64
Granite	57
Limestone	71
Marble	62
Metaconglomerate*	65
Obsidian	54
Perlite	53
Phyllite	66
Pumice	52
Quartzite*	60
Rhyolite	56
Sandstone	70
Schist	61
(Serpentinite)*	(20)
Shale*	75
Silicified Wood	76
(Quartz, var. chert)	
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INTRODUCTION

ACKNOWLEDGEMENTS

This collection of Arizona rocks and minerals used to come to Arizona teachers through the efforts of many volunteers and organizations. The individual rock and mineral specimens had been donated to the Arizona Mining and Mineral Museum by:

- Mineralogical Society of Arizona members
- Arizona Leaverites Rock & Gem Society
- Zeox: White Cliffs Diatomite Mine
- Arizona Public Service
- Asarco Incorporated: Silver Bell Mine, Mission Mine
- Barretts Minerals Inc., Dillon, MT (talc)
- Harborlite: Superior Perlite Mine
- Peabody Western Coal Co.
- Freeport McMoRan Copper & Gold Inc., Morenci Mine
- Pinal Harvest: White Cross Gypsum Mine
- Pioneer Talc Co., Van Horn, TX
- Tufflite Inc.

The kits used to be assembled by Arizona Mining and Mineral Museum volunteers. Many of these volunteers are members of rockhound and prospecting clubs in the Phoenix Valley. These people contribute many hours of their time to this project and without them these kits would not be available.

This booklet was written by the former museum Curator, Jan C. Rasmussen. It incorporates material written by Susan Celestian, previous Curator, and suggestions by Mary Graf of the Arizona Foundation for Resource Education (AFRE).

ARIZONA MINING INDUSTRY

Arizona ranks first in non-fuel mineral production in the U.S. and produces more than 65% of the Nation's domestic copper. The value of mineral output from Arizona in 2008 was near $7.8 billion. The Arizona mining industry directly employs tens of thousands of Arizonans. In addition to copper, Arizona also produces gemstones, molybdenum, silver, gold, industrial minerals, and coal.

Dear Arizona Educator,

These kits were specially designed to aid Arizona's educators and their students as they explore the world of rocks and minerals and mining. You'll find that the Arizona Science Standard Strands 1 (Inquiry) and 6 (Earth & Space Science) can be directly addressed through the use of these materials. The recently revised Arizona Social Studies Standard stresses knowledge of Natural Resources and Economics at all levels K-12, and the kit can complement your teaching in this area as well, particularly with reference to the uses of minerals and rocks. As you explore the materials, you'll find much content information that matches your curriculum and will enrich your classroom instruction at any grade level.

As a professional educator, you are an expert in designing content-rich learning experiences for your students. The materials in this kit were planned to allow you to construct open-ended activities or more structured investigational labs. Some suggestions for grade level appropriate use will be given in the first section.

On the following pages are descriptions of the properties and uses of the rocks and minerals in the teachers' kit. The rocks and minerals are presented in alphabetical order with their assigned numbers shown to the left. Terminology can be referenced in the illustrated glossary of terms that is located at the end of the descriptive information.

For more information about how to determine the name of a sample of unknown identity, refer to the mineral key or the rock classification charts.

It is our hope that the samples and information will be of use to you in your classroom explorations into the world of earth materials and mining.

Thank you for your interest and dedication in sharing the exciting study of geology and mining with Arizona's students!

Sincerely,
Jan C. Rasmussen
Jan C. Rasmussen, Ph.D., Registered Geologist
Curator

INVENTORY OF TEACHER KIT CONTENTS

Teacher PAC - CD of Classroom Activities

Arizona Rock Products - video

"What on Earth" newspaper educational supplement

Mining Careers (SME) (if available)

Copper Mining poster (if available)

Gold Mining poster (if available)

The Mining Industry and Minerals activities and information

From the Ground Up, Stories of Arizona's Mines and Early Mineral Discoveries booklet by former Arizona Governor Jack Williams

How to Identify Rocks and Minerals – this booklet (also available in color at **www.mines.az.gov**)

Downtown Rocks (from Phoenix Downtown magazine Dec. 2003)

Minerals in Unexpected Places in Everyday Life (Dept. Mines & Mineral Resources reprint)

U.S. Geological Survey World Wide Web Information (USGS Fact Sheet 037-00, 2000)

Arizona Copper Facts small poster

Your Car Comes from a Mine small poster

Your House Comes from a Mine small poster

Map to Museum

45 Minerals, Rocks, or Fossils

SUGGESTIONS FOR USING THIS TEACHER KIT

By Mary Graf
Center for Teacher Success
(Formerly AFRE - Arizona Foundation for Resource Education)
(website is www.azresourceed.org)

Level I (K-2)

Matches Arizona Science Standards Strand 6: Earth-Space
Grades K-1, describing physical properties.
Grade 2 not applicable.
All are appropriate for ELL students for language and literacy growth.

- Pre-select any 10 kit minerals or rocks showing a wide variety of differences in color, texture, etc. In small group or as a circle time activity, direct students to use their senses of sight and touch to explore all specimens. Encourage discussion, no right or wrong answers!

- Leave the rocks/minerals out on a tray for further exploration during free time.

- After exploring, chart their responses in two columns (sight and touch), accepting any words (i.e. brownish, bumpy, rough, poky, pretty, dark, white and black, sparkly, etc.) Goal is vocabulary growth and describing properties of things, not exact scientific terms. Read their responses back frequently. Suggest vocabulary if children need a boost.

- From charted vocabulary words, print each descriptive word on a 3x5 'sense card'. (Draw a small *eye* for sight, *hand* for touch.) With specimens on display, read one card at a time and select all rocks/minerals that match (i.e. dark, or smooth). Continue. Are there any that fit in more than one category?

- Using 'sense cards', read aloud and hand out each card to an individual student. In turn, ask each student to select one specimen that best describes their word. Great for circle time!

- Non-readers can pair up with readers or older students to continue this on their own.

- Make two cards, one YES, one NO card. Using the 'sense cards' one at a time, have students divide the specimens into two piles. i.e. “shiny” YES and “shiny” NO. Introduce the prefix “non-”, for example, “shiny” (YES) and “non-shiny” (NO). To expand, use two or more cards, for example: Shiny, dark and smooth (YES) and non-shiny, not dark and not smooth (NO).

- Arrange specimens lightest to darkest, smoothest to roughest, lightest (weight) to heaviest.

- Put blindfold on student, tell them "I am thinking of something that is: bumpy, smooth, etc.", and using only their sense of touch, locate a specimen with that property. OR, put some samples in a small bag or sock, and have child select the sample that you or other student describes. "Which is the smoothest?" "Which feels sandier?"

Level I-II (3-4-5)

Levels I-II (and ELL, Special Ed in Level III as needed.)

Students will have their own unique way of describing the specimens. Accept their words and suggest or rephrase as needed. The following chart lists words K-1 children have used, and some additional vocabulary words you can introduce are shown in *italics*. This is a great way to introduce and review opposites! Explain to the students that everything has *properties*. *Properties* tell about and describe a person or thing. The words they are using are the *properties* of the rocks and minerals.

SIGHT ("I see...")
Different colors (listed)
Red, white, etc. (any single color)
Black and white (any mix of colors
Dark-light
Sparkling
Shiny-dull (*introduce as opposites*)
Like glass (*glassy*)
Layered
Wavy
Shows lines, has lines
Little things in it (or medium or big)
Chunks in it
Holey, has holes in it
Bubbles, bubbly, like a sponge
Square, round, roundish (*any shapes*)
Thin-thick
Big-little (comparisons)
Pretty, fancy
Ugly, boring
Diamond-y, diamond, *diamond-dlike*
Jewel**,** *jewel-like*
More or less _______ (word here)
Looks like metal, *metallic*
Dull, opaque, transparent, translucent

TOUCH/FEEL ("I feel...")
Soft-hard *(introduce opposites)*
Rough-smooth
Heavy-light (weight)
Poky
Bumpy (little or big bumps)
Sandy, sand
Slick
Like glass (*glassy*, *glasslike*)
Dirty (*earthy*, *clayey*, *clay like*)
Wavy
Chunky
Ribbed
Pebbles, *pebbly*
Spiny
Prickly, has prickles
Different size stuff in it

Students in upper grades (4-8) can compare their vocabulary with the actual scientific vocabulary used to describe mineral properties and descriptions of rocks. Use their original vocabulary to re-label with appropriate scientific and geological terms.

Level II (3-4-5)

Matches Arizona Science Standards
Grade 3 - Strand 6: Earth-Space (geology)
Grade 4 - Earth processes
Grade 4 - Arizona Social Studies Standard
Grade 5 - Solar system/planets
All are appropriate for ELL students for language and literacy growth.

- Any Level I activities may be adapted to grades 3-4-5 and are good for quick vocabulary building and review, especially with ELL students.

- Divide class into co-op groups of 5-6 each. Students develop their own descriptions of all the specimens (or rock only, or mineral only, as you prefer). Compare lists together. Which words are the same in all teams? Which team had the most unique descriptive words for properties?

- Use more specimens, and divide into minerals and rock groups (minerals = no. 1-39; rocks = no. 50-78) as you teach the difference between minerals and rocks.

- As you teach the rock cycle, pull out the igneous/volcanic rocks from the kit (no. 50-57). Use them as teaching aids.

- Planetary geology (5th grade) features volcanic rocks (especially lunar), with sedimentary features on Mars. Students research and find specimens from the kit that have also been found in space!

- Pull out sedimentary (no. 70-78) and metamorphic rocks (no. 60-66, and 20) and use as teaching aids.

- Develop a basic mineral ID chart (see the kit sample) using only a few properties (such as color, streak, hardness, metallic or non-metallic) for 5-6 mineral samples you have preselected that show large differences. (Example: sulfur, fluorite, quartz, chrysocolla, pyrite). Use their variety to teach the specific properties and how they can vary from mineral to mineral.

- Make your own classroom “Hardness Test Kit” (penny, nail, tile, small glass plate) to test for hardness on Moh's Hardness Scale.

- Have students divide and sort specimens into mineral and rock groups, and explain why.

- Make classroom posters of each rock group (igneous, sedimentary, metamorphic) and use the kit specimens as part of the display. (Place in small plastic bag and tape to the poster.)

- Use "From the Ground Up" book in kit. Select a story(ies) to read aloud and have the children illustrate.

- Using the "From the Ground Up" book, individually or in peer pairs, assign different selections; do a written or brief oral report, or oral "living history" report. (Parent night!)

- Using "From the Ground Up", develop an Arizona Time Line from the reports students give, displaying the reports from oldest to most recent Arizona mining story.

- Make a large bulletin board Arizona with counties shown. Display reports in the proper county.

- Pull out the copper minerals (no. 11, 12, 14, 21, 23, 25, 30). Arizona history is rich in mining—use these hands on samples as part of your social studies unit. Where were the mining towns? Where are they now? How does copper play a part in Arizona's economy today? (Websites will help research.)

- How did the native Americans in Arizona use minerals such as hematite and copper minerals? (Cosmetics, paint, pottery, turquoise trade beads—check the websites for information.)

- Arizona Map: place rock and mineral samples where they could be found, i.e. basalt and obsidian in volcanic Flagstaff area, limestone on the Mogollon Rim, sandstone in Coconino County, copper minerals in the mine areas. (Use websites for more information.)

Level III (6-7-8/Middle School or Junior High)

Matches Arizona Science Standards
Grade 6, Strand 6 - Earth-Space (water cycle/hydrology),
Grade 7, Strand 6 - Geology
Grade 8, Strand 5 - Chemistry
Arizona Social Studies Standard
Strand 5 - Economics C1-Foundations of Economics Grades 6-7-8
(All are appropriate for ELL students for language and literacy growth.)

- Water cycle/hydrology (6^{th} grade): when teaching about aquifers and the water table, use the rock samples in the kit, i.e. basalt is a poor aquifer, little water is found in granites unless they are heavily fractured, Arizona limestones are a good source of spring water, etc. Research with websites.

- Geology/rock cycle (7th grade): Check Levels I-II and expand and enrich the activities and include measurement and report writing. Many are easily adaptable to your introductory geology/rock cycle unit. More advanced students could possibly handle the Mineral Identification activity as written, or you can adapt it by selecting only some of the mineral properties as previously described in Level II.

- Use the kit's mineral specimens to supplement your existing mineral identification lab or teaching of mineral properties.

- Use the rock and mineral specimens to supplement your teaching of the rock cycle.

- Assign individual students a specific rock or mineral from the kit to research. Present their information orally or with a display using the sample as part of the display. Research the uses of their rock or mineral.

- Make your own classroom sets of the Moh's Hardness Scale Testing Kits (see websites)

- Copy the glossary to have numerous sets available for classroom use during the unit.

- For Social Studies (Economics), research the value of copper as a commodity. (Supply-demand, natural resources, raw material, product, manufacturing, etc.)

- Check the business section of a newspaper for the daily changes in the commodity prices of metals such as copper, gold, silver, molybdenum. Graph the changes over a week or a month (or past years.)

- Using the Periodic Table of Elements, find the kit minerals that contain some of the more common elements. (Example: copper, sulfur, quartz/silica, limestone [calcium carbonate], fluorite, hematite/iron.) Use the minerals as hands-on examples of elemental compounds.

- Research human nutritional requirements of elements (copper, iron, etc.)

- What economic (Social Studies) value do many elements have? Which are found in Arizona?

- Select a mineral and research its crystal form, making a 3-D model (toothpicks with tiny marshmallows work fine!). Or Draw various crystal structures. Check various web sites for examples.

- Make a Moh's Hardness Scale display for the classroom using minerals from the kit.

- Start a classroom display of objects made from minerals or rocks. (Examples: gypsum = drywall; quartz = silica sand/glass; copper = electrical wiring/plumbing; granite = countertops/floor tile.

- Using kit rocks, make a large Rock Cycle display for the classroom.

Level IV High School

High School (advanced Middle School or Junior High) = appropriate as written, or adapt other level's activities.

- The mineral identification kit may be used as is, with the mineral lab outlined. You may select which minerals you wish your students to identify (using the accompanying mineral identification key) based on your classroom needs.

- Copy the glossary to have a number of classroom sets available for reference.

- Use the rock and mineral kit samples to supplement your existing rock or mineral identification labs.

- Make your own classroom sets of Moh's Hardness Scale Testing Kits (see websites.)

- Review Level III for some suggestions to use with ELL students or adapt for enrichment, research or extra credit activities.

PHYSICAL TESTS FOR MINERAL IDENTIFICATION

DEFINITION OF A MINERAL

Minerals are **naturally occurring** chemical compounds.

They are **inorganic.** They are made of material that has never been a living plant or animal.

They are also **solid,** so they are not in their liquid or gaseous form.

Each mineral has a definite chemical content, which can be described by a **chemical formula** or symbol. For example, halite (salt) is always NaCl, which means that one atom of sodium always coordinates with one atom of chlorine. Quartz is always SiO_2, which means there are two atoms of oxygen for each atom of silicon.

Each mineral has a **regular structure,** in which the atoms are always put together in the same pattern. For example, salt is always put together with an atom of sodium next to an atom of chlorine in all three directions (up-down, left-right, front-back) to make a cube shape. Some minerals are made of only one element. Examples of minerals that are made of a single element are: gold (Au from the Latin aurum, meaning gold), graphite (C or carbon), diamond (C or carbon), and copper (Cu from the Latin *cuprum* for copper).

Following is a discussion of the most useful physical and chemical properties and how to most effectively use them.

COLOR

Color is the first characteristic you notice, BUT it is generally the least diagnostic. For some minerals, color is constant and diagnostic. For other minerals, color varies depending upon composition. For other minerals, color varies with impurities. Most minerals can exhibit a wide range of colors with slight changes in chemistry.

TIPS: (a) Always evaluate the true color of a mineral on a *fresh, unweathered* surface.
(b) Make note of the color of the weathered surface or of any tarnish because it may be a valuable clue to its chemistry or identity.

LUSTER

Luster is the way in which a mineral reflects light.

Metallic Luster = Looks like a metal.

If the surface appears opaque, shiny, and in metallic shades (gold, silver, brass, bronze, aluminum, lead, iron, steel, cast iron, etc.), it has a metallic luster.

Non-Metallic Lusters – Does not look like a metal.

Light will pass through thin sheets of non-metallic minerals. The mineral is transparent (can see through it), or translucent (light passes through), or opaque (light does not pass through, but it is not metallic). Many non-metallic minerals contain metals in their chemical makeup, but they do not look like metals, so they are not classified as having metallic luster.

More detailed descriptive terms for specific non-metallic lusters:

Adamantine = very refractive; sparkles like a diamond
Vitreous = glassy
Earthy = like dried mud
Resinous = golden yellows and browns of pine resin (pitch); like amber
Pearly = pale iridescence like a pearl or shell
Silky = like a bundle of threads, fibrous
Greasy = like oily glass
Dull = no shine

Always evaluate luster on a *fresh, unweathered* surface.

CLEAVAGE

Cleavage and fracture describe how a mineral breaks. **Cleavage** is produced when a mineral **breaks along fixed, smooth, flat, repeatable surfaces** that correspond to planes of atomic weakness. Fracture is produced when a mineral does not have flat broken edges, but has irregular broken sides. Because both cleavage and fracture depend on the nature of the chemical bonds within the mineral, they are characteristic of a particular chemical composition or mineral.

Cleavage is the pattern of breaking into regular planes. Minerals with good cleavage have broken sides that are flat, parallel planes. They make shapes that are layers, cubes, or pyramids. Cleavage is the splitting or tendency to break along planes that are determined by the crystal structure. When you rotate the mineral under sunlight or a bright light, all the cleavage planes that are the same direction will reflect light at the same time, making one flash like a set of mirrors lined up parallel to each other, even though some of the faces are higher or lower than others. This generally looks like stair steps. You may have to look at the mineral with a hand lens or magnifying glass to see these parallel planes.

If you are not sure if the flat plane is a crystal face or a cleavage face, look with a hand lens on the edge of the shiny face to see if it has been broken. If it is a cleavage face, the breaks will be parallel to the other shiny surfaces. If it does not have cleavage, the breaks will be slightly curved, like broken glass, or the broken sides will be irregular.

Some minerals are composed of crystalline aggregates. If these have cleavage, the broken surface of the mineral will have many flat sparkles.

For example, halite (common name is salt) has cubic cleavage, which means that there are 3 directions or planes that are at 90^o to each other; in other words, it breaks in cubes.

A sample of halite can be broken over and over and over into ever smaller pieces and it will ALWAYS break along the same 3 planes — as will ALL other specimens of halite. You can crush rock salt (used in an ice cream making machine) to see if it makes smaller cubes, like the salt in your salt shaker.

You are NOT determining the number of flat surfaces that are produced, but instead are counting the number of directions of the flat planes that are broken surfaces (not crystal faces). For example, a cube has 6 flat surfaces, but opposing faces are parallel (in the same orientation), so there are 3 planes represented.

Types of Cleavage:

Types of cleavage include:

- 1 direction (ex. muscovite) (layers)
- 2 directions at 90^o (ex. orthoclase)
- 2 directions not at 90^o (ex. hornblende)
- 3 directions at 90^o = cubic (ex. halite)
- 3 directions not at 90^o = rhombohedral (ex. calcite)
- 4 directions = octahedral (ex. fluorite)
- 6 directions = dodecahedral (ex. sphalerite)

One Direction (Layers or Basal)

The mineral breaks into layers or breaks so the flat surfaces are parallel to only one direction, such as the top and bottoms parallel. An example of basal cleavage is mica.

layered or 1 direction of cleavage

Two Directions:

The mineral breaks into flat surfaces parallel to two directions. One direction is parallel to the top and bottom and a second direction is parallel to the front and back, while the third direction (such as the sides) are irregular surfaces.

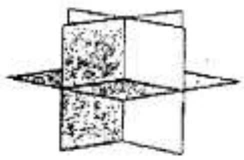
Minerals that have two directions of cleavage that are at right angles to each other are the feldspars, such as the minerals orthoclase and plagioclase. A mineral that has two directions of cleavage that are not at right angles to each other is hornblende, which has planes at 60 and 120 degrees to each other.

Orthoclase feldspar – 2 directions 90 degrees

Hornblende – 2 directions, 60 & 120 degrees

Three Directions:

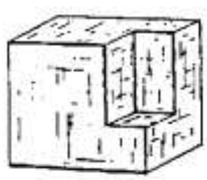
The mineral breaks into flat surfaces in three planes, such as top and bottom, back and front, and left and right sides.



3 directions of cleavage (cubic)

Cubic Cleavage:

The mineral breaks in three directions that are at right angles to each other. This produces small cubes or cube-shaped holes that have all three planes perpendicular to each other. Examples are galena and halite (salt).



Cubic cleavage

Rhombohedral Cleavage:

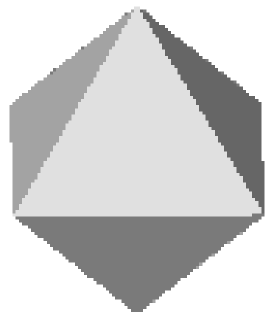
The mineral breaks in three directions, two of which are at right angles and the third of which is slanted at an acute angle. Rhombohedrons look like a rectangular solid or cube that has been pushed over from one side. An example is calcite.

Rhombohedral cleavage

Four Directions (Octahedral):

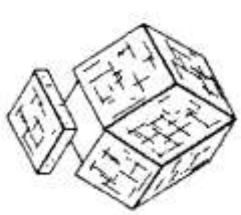
The mineral breaks in four directions that are at acute angles to each other. A perfect specimen of this type of cleavage would look like two pyramids with square bases placed with their bases together and with one pyramid upside down. The eight faces have a triangular shape. An example of octahedral cleavage is the common cleavage octahedrons of fluorite.

Octahedral cleavage



More than Four Directions:

This type of cleavage can be distinguished by counting the different cleavage faces, while not counting the surfaces that are parallel to a surface that has already been counted. An example is sphalerite.



More than 4 directions of cleavage

FRACTURE

Fracture describes any break other than the flat planes of cleavage. Its irregular, uneven broken surfaces result from a lack of weak atomic planes. Fracture describes an irregular, random, non-repeatable surface. No two breaks in one sample are the same; no two samples break in identical directions.

Types of Fracture:

Conchoidal = smooth, shell-like, or glass-like breaks (ex. quartz)

Uneven = irregular, but not conchoidal (ex. bornite)
Hackly = jagged, as of a metal (ex. native copper)
Splintery = occurs in aggregates of many slender, brittle crystals
(ex. gypsum of the variety called satin spar)
Fibrous = occurs in aggregates of many slender, threadlike crystals
(ex. asbestos)

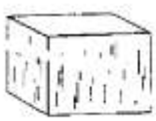
Conchoidal fracture

Look at broken edge of pyrite crystal for conchoidal fracture

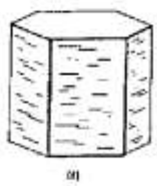
CRYSTAL FORM

Crystal form is the outward expression of the internal atomic order of a mineral. Because the atoms are arranged in regular patterns, the outer angles and shapes are consistent and typical within mineral species. This is often a good clue to the identity of a mineral.

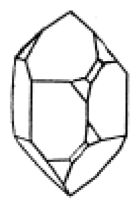
Crystal shapes can be prismatic, acicular, tabular, cubic, scalenohedral, hexagonal, etc.



prismatic



hexagonal



Quarz (hexagonal)

Garnet (isometric)

Calcite (hexagonal)

Quartz (hexagonal)

HARDNESS

Hardness is a measure of how hard it is to scratch the mineral. It is the resistance that a smooth surface offers to scratching. This is determined by comparing the resistance of a mineral of unknown hardness to one with an assigned hardness value.

The **Mohs Scale of Hardness** is a sequence of minerals arranged in order of increasing hardness. The Mohs Scale of Hardness consists of ten minerals that have been assigned arbitrary hardness values of 1 through 10 (softest to hardest).

These mineral hardnesses can be approximated with a few common, ordinary tools: 2 = fingernail, 3 = copper penny, 5 = knife blade, 5.5 = glass, and 6.5 = steel file.

Mohs Scale of Hardness

1	Talc	**5.5**	**Glass**
2	Gypsum	6	Feldspar
2.5	**Fingernail**	**6.5**	**Darning needle/steel file**
3	Calcite	7	Quartz
3	**Penny**	8	Topaz
4	Fluorite	9	Corundum
5	Apatite	10	Diamond
5-5.5	**Penknife**		

To test an unknown for hardness, you can try to scratch an unknown mineral with an object of known hardness or vice versa. If the unknown mineral scratches the known object, then the unknown mineral is as hard or harder than the known object. The mineral scratched is softer than the one doing the scratching. For example, feldspar (hardness 6) will scratch any mineral with a hardness of 1 through 6, but not minerals with hardnesses 7 through 10. The bigger the difference in hardnesses, the easier feldspar will scratch the softer minerals.

Hints: (a) Always use a *sharp* point or edge to do the scratching.
(b) Always scratch with a *fresh, unweathered* point or edge.
(c) Always scratch a *fresh, unweathered* surface.
(d) Press hard if necessary. No matter how hard you press, if the scratcher is softer than the scratchee, there will be no scratch. The closer the two minerals are in hardness, the harder you must press.

Cautions: Do the least amount of damage to the mineral as possible by scratching it in an unobtrusive spot and with a very small scratch. If other observations give you an idea of what the mineral is, use the hardness test after you do the other tests. This way, you can distinguish between a few very similar minerals whose hardness you know. Thus, you only have to make one or two tests.

Test the hardness both ways if necessary or if in doubt. Scratch the tool with the mineral and scratch the mineral with the tool.

A scratch will be a groove that you can't rub off. Sometimes a softer mineral rubs off on the harder tool, which may look like a scratch, but the powder can be rubbed off with your finger. The surface is often altered and softened by weathering, so you must test a freshly broken surface whenever possible. If a mineral is granular or splintery, it may not give an accurate hardness test because the grains or splinters rub off easily.

STREAK

Streak is the color of the powdered mineral. It is usually determined by boldly rubbing the mineral across an unglazed porcelain tile. These are found in the hardware or do-it-yourself construction stores. Any mineral harder than the tile (hardness 7) will not leave a streak, because it will not make a powder.

Streak test

SPECIFIC GRAVITY

Specific gravity is the ratio of the mass of a mineral to the mass of an equal volume of water at a specified temperature. Specific gravity can be measured by weighing the mineral in air and dividing by the weight of an equal volume of water (the weight of the amount of water displaced by the mineral).

$$\text{S. G.} = \frac{\text{mass of mineral}}{\text{mass of same volume of water}} = \frac{\text{weight of mineral in air}}{\text{weight of equal volume of water}}$$

This is a similar property to density. You can estimate the relative weight of the mineral compared to common stones as an approximation of specific gravity.

Average = like quartz, feldspar, calcite = 2.6-2.8;
Heavy = like galena (lead sulfide) = 7.5;
Light = lighter than quartz, like opal = 2.0 or graphite = 2.3 or gypsum = 2.3 or halite 2.16.

Most metallic minerals are heavy and many nonmetallic minerals are average. Very few minerals are lighter than average.

TENACITY

Tenacity describes the <u>ease</u> with which a mineral breaks.

- **Brittle** = shatters when struck with a hammer (ex. pyrite)
- **Ductile** = can be changed in shape by pressure, or drawn out into a wire
- **Elastic** = can be bent without breaking and will return to unbent condition (ex. muscovite)
- **Flexible** = can be bent without breaking, but will not return to unbent condition (ex. gypsum, var. selenite)
- **Friable** = crumbles (typical of granular or highly fractured minerals)
- **Malleable** = can be flattened with a hammer blow without breaking or crumbling into fragments

Sectile = can be cut by a knife without breaking up; usually produces curved shavings (ex. graphite)

DIAPHANIETY

Diaphaneity describes the way in which a mineral transmits light.

Transparent = light goes through; can be seen through
Translucent = light goes through; can not be seen through
Opaque = light does not go through; can not be seen through

EFFERVESCENCE (FIZZ) IN ACID

Fizzing (vigorous bubbling or effervescence) occurs when dilute hydrochloric acid (10% HCl) or dilute muriatic acid is dropped on calcite. A few other minerals, such as dolomite, malachite, azurite, and siderite, will slowly fizz if the mineral is first powdered.

Reaction to acid: Carbonate (CO_3) minerals will effervesce (fizz) with varying intensities when a drop of dilute (10%) hydrochloric (HCl) or acetic acid (vinegar, for example) contacts the mineral. Be sure you have tissue to wipe up the acid after the test.

OTHER TESTS

Taste:

Some minerals, particularly the salts, have distinctive and diagnostic flavors.

Odor:

Sulfide minerals often emit a sulfurous odor when struck. For example, the streak of sphalerite (zinc sulfide) has a “rotten egg” odor. Sulfur also has a characteristic odor. Another mineral, kaolinite, will smell earthy when wet (as will other clays).

Magnetism:

Magnetite will strongly attract a magnet. Some hematite will be weakly magnetic.

Radioactivity:

Minerals consisting of unstable isotopes of some elements, such as uranium, will emit enough radiation to register on a Geiger counter.

Fluorescence:

Some minerals emit green, orange, blue, purple, red or yellow light when exposed to an ultraviolet light. Fluorite gives its name to this property.

MINERAL IDENTIFICATION TABLES

Luster Cleavage	Hardness	Color Streak St=	Diagnostic Features	Formula	Name
Metallic Good Cleavage					
Metallic good cleavage	1-1.5	Lead gray to blue gray St=Gray-black	Heavy (Sp.Gr. = 4.6-4.7)	MoS_2	Molyb- denite
Metallic good cleavage	1-2	Dark gray to black St=Black	Writes on paper Greasy look and feel	C	Graphite
Metallic good cleavage	2.5	Lead gray St=Gray to gray black	Cubic cleavage Very heavy (Sp.Gr.=7.5)	PbS	Galena
Metallic good cleavage	3.5-4	Yellow brown to brown black St=Yellow brown	Good cleavage -6 directions Resinous luster Streaks lighter than color	ZnS	Sphalerite
Metallic No Cleavage					
Metallic No cleavage	1-2	Sooty black - iron black St=Black	Soft - soils the fingers Splintery fracture Black dendritic growths (fernlike on surfaces)	MnO_2	Manganese Oxide
Metallic No cleavage	2.5-3	Silver white color St=silver white	Tarnishes brown - gray-black Hackly fracture Heavy (Sp.Gr-10) Malleable and ductile	Ag	Silver
Metallic No cleavage	2.5-3	Golden yellow color	Heavy (Sp.Gr.=15-19) Malleable, ductile, sectile Hackly fracture Irregular octahedral crystals and dendritic shapes	Au	Gold
Metallic No cleavage	3	Black to shiny gray St=Black	Dull black tarnish Sectile = leaves a shiny groove when scratched	Cu_2S	Chalcocite
Metallic No cleavage	3	Bronze on fresh surfaces St=gray black	Purple iridescent tarnish	Cu_5FeS_4	Bornite
Metallic No cleavage	2.5-3	Copper color on fresh surface St=metallic copper	Black to dark brown tarnish Malleable Copper color	Cu	Copper
Metallic No cleavage	3.5-4	Red of various shades St=brownish red	Luster metallic to adamantine Red glassy highlights	Cu_2O	Cuprite
Metallic No cleavage	3.5-4	Brassy yellow color St=greenish black	Brassy color, greenish streak Bronze or iridescent tarnish	$CuFeS_2$	Chalco- pyrite
Metallic No cleavage	5.5-6.5	Rusty red brown to silvery gray St=reddish brown	Red brown earthy, platy crystals if silvery gray Streak is important Earthy variety is softer	Fe_2O_3	Hematite
Metallic No cleavage	6	Black St=black	Black color Magnetic - sticks to magnet	Fe_3O_4	Magnetite
Metallic	6.5	Brown to black St=black	Prismatic crystals and massive, botryoidal or concretionary masses	SnO_2	Cassiterite
Metallic No cleavage	6-6.5	Pale brass yellow St=greenish black or brownish-black	Silvery pale brass yellow on fresh surface (Fool's gold) Harder than glass	FeS_2	Pyrite
Non-metallic Good Cleavage					

Luster Cleavage	Hardness	Color Streak St=	Diagnostic Features	Formula	Name
Non-metallic good cleavage	1	Green, grey, white, variable St=white	Greasy to soapy feel Very soft	$Mg_2(Si_4O_{10})(OH)_2$	Talc
Non-metallic good cleavage	2	Clear to white St=white	Good layered cleavage Selenite=clear layers; Alabaster = white grainy, massive; Satin Spar = fibrous	$CaSO_4.2H_2O$	Gypsum
Non-metallic good cleavage	2.5-4	Colorless to greenish St=White	Thin sheets=clear mica Transparent to translucent	$KAl_2(Si_3O_{10})(OH)_2$	Muscovite
Non-metallic good cleavage	2-2.5	Dark green, variable color St=greenish white	Flexible folia, not elastic Layers irregular, crumbly	$Mg_3(Si_4O_{10})(OH)_2Mg_3(OH)_6$	Chlorite
Non-metallic good cleavage	2.5	Colorless to white color St=white	Salty taste Cubic cleavage colorless to white	NaCl	Halite
Non-metallic good cleavage	2.5-3	Black to brown	Thin sheets Flexible sheets, black to smoky in color	$K(Mg,Fe)_3(AlSi_3O_{10})(O_4)_2$	Biotite
Non-metallic good cleavage	3	Clear to white common, other colors possible	Good rhombohedral cleavage (3 directions, slanted cube) Fizzes in dilute acid (HCl)	$CaCO_3$	Calcite
Non-metallic good cleavage	3-3.5	White, gray, various colors; St=white	Rectangular cleavage	$CaSO_4$	Anhydrite
Non-metallic good cleavage	3-3.5	White to pinkish, clear, blue, yellow, etc.	Very heavy for nonmetallic Sp.Gr.=4.5; good cleavage Crystals usually tabular or roses	$BaSO_4$	Barite
Non-metallic good cleavage	3.5-4	White to pink, etc.	Good rhombohedral cleavage Crystal faces often curved Fizzes in dilute HCl acid only if powdered first	$CaMg(CO_3)_2$	Dolomite
Non-metallic good cleavage	4	Any color from purple, white yellow, green, etc.	Good octahedral cleavage (4) Cubic crystals common	CaF_2	Fluorite
Non-metallic good cleavage	3.5-4	Yellow, yellow brown to black if more Fe is present St=reddish brown to yellow	Resinous luster Nonmetallic to metallic Good cleavage in 6 directions	ZnS	Sphalerite
Non-metallic good cleavage	4.5-5	White, yellow, light brown St=white	Fluoresces bluish white in ultraviolet light Heavy Sp.Gr.=6 Pyramid shaped crystals	$CaWO_4$	Scheelite
Non-metallic good cleavage	6	Dark green to black or brown	Prismatic crystals Good cleavage in 2 directions at 60^o and 120^o	$Ca_2Na(Mg,Fe)_4(Al,Fe,Ti)_3Si_8O_{22}(O,OH)_2$	Hornblende (a type of amphibole)
Non-metallic good cleavage	6	Dark green to black	Short prismatic 8-sided crystals Good cleavage in 2 directions at 90^o	$(Ca,Na)(Mg,Fe,Al)(Si,Al)_2O_6$	Augite (a type of pyroxene)
Non-metallic. good cleavage	6	White, some greenish	Columnar or fibrous aggregates	$Ca_2Mg_5Si_8O_{22}(OH)_2$	Tremolite
Non-metallic good cleavage	6-6.5	White, pink, or blue green	Good cleavage in 2 directions at 90^o	$KAlSi_3O_8$	Orthoclase (a type of feldspar)
Non-metallic	6-6.5	White, gray, blue gray,	Good cleavage in 2 directions at	$NaAlSi_3O_8$	Plagioclase

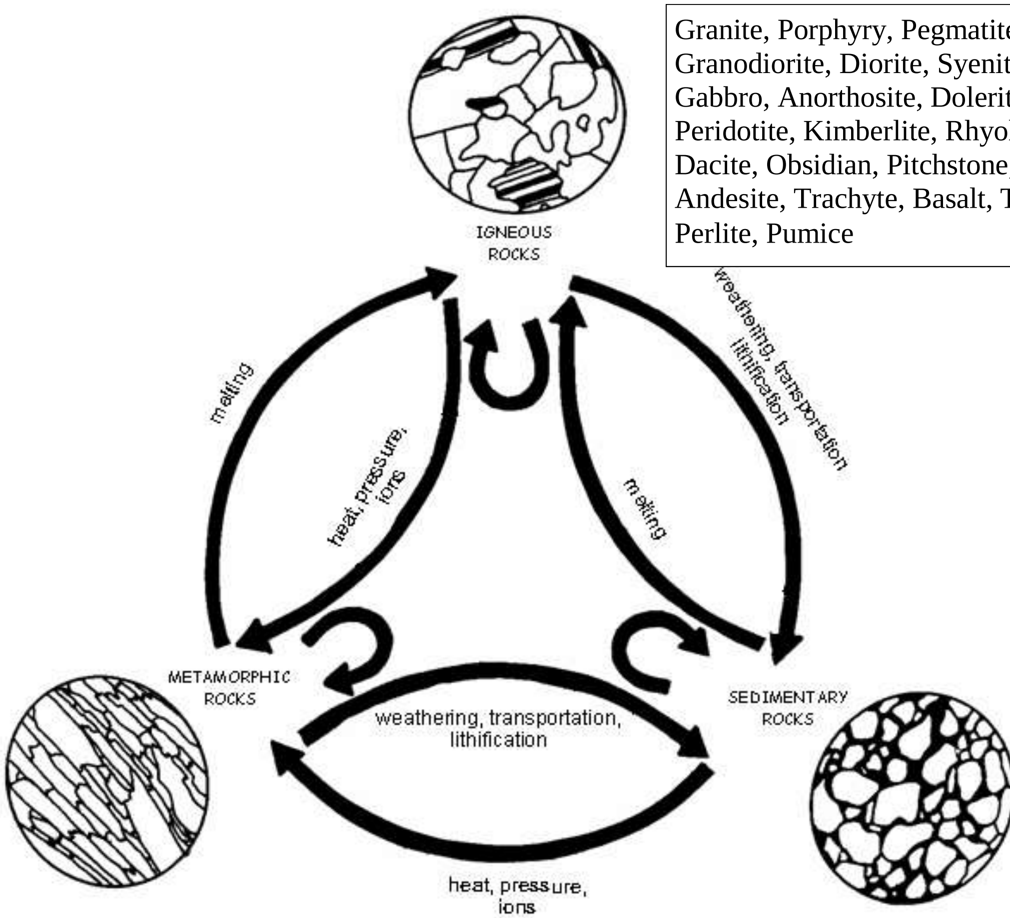
Luster Cleavage	Hardness	Color Streak St=	Diagnostic Features	Formula	Name
good cleavage		gray black	90° Striations (fine parallel grooves) on some cleavage faces	to $CaAl_2Si_2O_8$	(a type of feldspar)
Non-metallic good cleavage	6-7	Brown or black St=light colored	Heavy (Sp.Gr.=6.8-7.1) Poor cleavage in 1 direction Stream tin is globular	SnO_2	Cassiterite
Non-metallic good cleavage Massive varieties = no cleavage	6-7	Yellow green to blackish green St=none (too hard)	Poor basal cleavage Yellowish green color Very hard If granular, no apparent cleavage	$Ca_2(Al,Fe)_3 Si_3O_{12}(OH)$	Epidote
Non-metallic good cleavage	9	Brown, pink(=ruby), blue (=sapphire)	Hexagonal crystals Heavy nonmetallic Poor basal cleavage	Al_2O_3	Corundum
Non-metallic No Cleavage					
Non-metallic no cleavage	1.5	Yellow brown to brown St=yellow brown	Earthy luster Yellow brown streak	$FeO(OH).nH_2O$	Limonite
Non-metallic no cleavage	1.5-2.5	Bright yellow color St=yellow to white	Smells sulfurous Brittle - has no cleavage Crackles with heat of hand	S	Sulfur
Non-metallic no cleavage	2 – 2.5	White, dull, earthy, plastic	Generally chalky, clay Sticks to tongue	$Al_4(Si_4O_{10})(OH)_8$	Kaolinite
Non-metallic No cleavage	2-6	Rusty red brown to silvery gray St=reddish brown	Red brown earthy Streak is important Earthy variety is softer	Fe_2O_3	Hematite
Non-metallic no cleavage	3.5-4	Bright green, light to dark	Luster earthy to glassy Botryoidal or stalactitic form Powder fizzes in dilute HCl	$Cu_2CO_3(OH)_2$	Malachite
Non-metallic no cleavage	3.5-4	Bright blue	Luster earthy to glassy Complex radiating crystals Powder fizzes in dilute HCl	$Cu_3(CO_3)_2(OH)_2$	Azurite
Non-metallic no cleavage	2-4	Bluish green	Luster earthy to glassy Cryptocrystalline to massively compact; Conchoidal fracture	$CuSiO_2 .nH_2O$	Chrysocolla
Non-metallic no cleavage	2 - 5	Green to yellowish green St=white	Luster = greasy, silky or waxy Asbestos is fibrous form	$Mg_6(Si_4O_{10})(OH)_8$	Serpentine
Non-metallic poor basal cleavage	5	Green, blue, pink, white, yellow, brown, colorless, violet etc. St=white	Slightly heavier than average Sp.Gr.= 3.1; Hexagonal prism-shaped crystals	$Ca_5F(PO_4)_3$	Apatite
Non-metallic no cleavage	6	Blue, bluish green, green	Luster = wax-like Cryptocrystalline	$CuAl_6(PO_4)_4(OH)_8.2H_2O$	Turquoise
Non-metallic good cleavage; massive var. no cleavage	6-7	Yellow green to blackish green St=none (too hard)	Poor basal cleavage Yellowish green color Very hard If granular, no apparent cleavage	$Ca_2(Al,Fe)_3 Si_3O_{12}(OH)$	Epidote
Non-metallic No cleavage	6.5-7	Green, generally olive green to dark green or brown	Conchoidal fracture Vitreous, transparent to translucent, generally green glassy grains	$(Mg,Fe)_2SiO_4$	Olivine
Non-metallic no cleavage	7	Colorless or white, also gray or any color	Glassy luster to greasy Conchoidal fracture Prismatic crystals	SiO_2	Quartz

Luster Cleavage	Hardness	Color Streak St=	Diagnostic Features	Formula	Name
		Purple or violet (+ferric iron) Rose red or pink (+titanium) Smoky yellow to brown and black (+radiation) Light yellow quartz Milky white (+fluid inclusions Opalescent or chatoyant quartz (due to fibrous inclusions)			Amethyst Rose quartz Smoky quartz Citrine Milky quartz Cat's Eye quartz
Non-metallic no cleavage	7	Colorless, white or any color Red = carnelian Brown = sard Apple green = chrysoprase (nickel oxide) Alternating layers of opal and chalcedony or granular quartz = agate Green chalcedony with small red spots of jasper Layers of chalcedony Onyx with sard alternating with white or black layers	Cryptocrystalline (hidden crystals or fibrous quartz) Waxy luster, translucent	SiO_2	Chalcedony Carnelian Sard Chryso-prase Agate Heliotrope Bloodstone Onyx Sardonyx
Non-metallic no cleavage	7	Colorless, white or any color Dull to dark, massive = flint Light colored, massive = chert Red (from hematite inclusions) = jasper Dull green = prase	Cryptocrystalline (hidden crystals or granular quartz)	SiO_2	Granular quartz Flint Chert Jasper Prase
Non-metallic no cleavage	6.5-7.5	Red, green, brown, yellow, white, green, black	Vitreous to resinous luster Somewhat heavy (Sp.Gr .= 3.5-4.3) Crystals often dodecahedrons (with diamond shaped faces) Conchoidal fracture	Mg,Fe,Mn,Ca, Al,Cr $(SiO_4)_3$	Garnet
Non-metallic base cleavage	8	Colorless or white, others if impurities	Prismatic crystals terminated by pyramids, flat base	$Al_2SiO_4(OH),F)_2$	Topaz

ROCK CYCLE

ROCK CYCLE

Granite, Porphyry, Pegmatite, Granodiorite, Diorite, Syenite, Gabbro, Anorthosite, Dolerite, Peridotite, Kimberlite, Rhyolite, Dacite, Obsidian, Pitchstone, Andesite, Trachyte, Basalt, Tuff, Perlite, Pumice



Slate, Phyllite, Schist, Gneiss, Amphibolite, Marble, Hornfels, Metaquartzite (Quartzite), Metaconglomerate, Skarn, Anthracite Coal

Conglomerate, Breccia, Sandstone, Greywacke, Arkose, Siltstone, Mudstone, Claystone, Shale, Marl, Gypsum, Rock Salt, Limestone, Chalk, Coquina, Micrite, Travertine, Dolomite, Tufa, Bituminous Coal, Lignite, Peat, Chert, Flint

IDENTIFICATION OF ROCKS

Rocks are made of minerals. Rocks can be a mixture of different kinds of minerals, a mixture of many grains of the same kind of mineral, or a mixture of different grains of rocks. When you split a rock into very small pieces, the pieces are different from each other. For example, when you break granite apart, you get small pieces of quartz (clear), feldspar (pink or white), and mica (black). When you split a mineral into pieces, you still have pieces of the same mineral. If you break a big chunk of quartz into smaller pieces, you still have pieces of quartz.

SUMMARY OF ROCK TYPES

The three basic rock types are: **igneous, sedimentary, and metamorphic**.

Igneous Rocks

Igneous rocks are "born of fire". That is, they were once so hot they melted. Igneous rocks (fiery rocks) are made when molten material inside or outside the earth cools and becomes solid. The melted rock is called magma when it is inside the earth. When it cools, the magma crystallizes into a mass of interlocking crystals. The rate of crystallization (as shown by the size of the crystals) is one of the clues used, along with composition, to decide the name of the igneous rock.

When magma finds its way to the surface through cracks or volcanoes, it is called lava. When lava cools on top of the earth's surface, it forms extrusive or volcanic igneous rock because it was extruded or pushed out onto the surface. Because it cools quickly, it only has time to make very tiny crystals. When magma cools rapidly near or at the Earth's surface, the rock contains many small crystals that are not easily seen without a microscope. Extrusive or volcanic igneous rocks look dull and do not sparkle much because they are fine grained. This group of igneous rocks is called EXTRUSIVE and they typically are formed in a volcanic eruption. When cooling is so rapid that crystals do not have a chance to form, a glass is produced.

If the magma stays inside the earth and takes thousands of years to cool, it has time to make big crystals. Slow cooling deep beneath the Earth's surface allows crystals to grow to large size (larger than a pencil point and usually an eighth of an inch or more). These crystals are easily visible and distinguish this group of igneous rocks as INTRUSIVE. These crystals make a coarse-grained igneous rock called plutonic or intrusive igneous rock, because the magma was intruded into cracks deep under the earth's surface. These coarse-grained crystals make the rock look sugary because the flat crystal faces reflect the light in hundreds of little sparkles. The name of the igneous rock depends on what minerals are present. If there are lots of light colored minerals and the rock is coarse grained, it is granite. If there are mostly dark colored minerals and the rock is fine grained, it is basalt.

Sedimentary Rocks

Sedimentary rocks (layered rocks) are made by the deposition of particles carried in air or water or by the precipitation of chemicals that were dissolved in water. Generally, sedimentary rocks occur in layers, although the layers may be thicker than you see in a rock.

Particles and chemicals come from the weathering (breaking apart in place) and erosion (carrying away and breaking apart while moving) of rocks on the Earth's surface. Boulders, rocks, gravel, sand, silt, clay, and mud are carried by water currents in streams, rivers, lakes, and oceans. These particles are deposited in stream beds, shores, lake and ocean bottoms, and deltas where rivers empty into lakes and oceans. These particles are cemented together and hardened to form the sedimentary rocks called conglomerate, sandstone, siltstone, shale or claystone or mudstone. Those sedimentary rocks that are composed of particles of pre-existing rocks are considered to be Fragmental or Clastic Sedimentary rocks. These fragments show evidence of transport, such as rounding of the grains and sorting of the grains into similar size grains.

Chemicals that are leached or dissolved from other rocks are carried invisibly in streams and oceans. When these dissolved chemicals reach a lake or ocean and the water evaporates, the chemicals are left behind in evaporite deposits. Salt around salt lakes and limestone from sea bottoms are examples of these chemical sedimentary rocks. Plants and animals are sometimes buried and preserved in the finer grained sedimentary rocks, such as shale or limestone. Chemical or Nonclastic sedimentary rocks are the result of either precipitation of solids from solutions (like salt from water) or by organic process like creation of shells by marine organisms.

Metamorphic Rocks

Metamorphic rocks (changed rocks) are made when existing rocks are subjected to high temperatures and high pressures for long periods of time. Metamorphism (meta = change, morph = form) happens when molten rock intrudes other rocks and bakes the contact zone where the molten rock touches the preexisting rock. Metamorphism also happens when rocks are buried deeply during the process of mountain building.

The kind of metamorphic rock made depends on the kind of original rock. For example, sandstone is turned to quartzite, shale is turned to slate, and limestone is turned to marble. Other kinds of metamorphic rock are named for the kinds of minerals present, the size of the grains and other textures. For example, mica schist has very thin layers of mica, and garnet gneiss (pronounced like nice) has garnet crystals in thick layers of quartz and feldspar.

The amount of time, amount of pressure, and high temperature determine which type of metamorphic rocks is made. When the rock is heated or squeezed, the atoms in the pre-existing rock get rearranged without melting. Adding or subtracting certain chemical elements also metamorphoses rock, usually when hot water comes in contact with the rock. Metamorphism involves an increase in grain size, formation of new minerals, or rearrangement of the minerals into a parallel alignment called foliation. Parallel alignments result when minerals that are long or flat re-orient themselves parallel to each other and perpendicular to pressures.

Igneous, Sedimentary, or Metamorphic?
Hints or clues to look for when trying to decide if it is igneous, sedimentary or metamorphic:

IGNEOUS:

- Crystals — random mixture or
- Fine grained — then look for occasional large crystals (appear to be "floating" in the finer material) or
- Gas bubble holes or
- Glassy looking or
- Frothy looking

SEDIMENTARY:

- Pieces of other rocks/minerals visible or
- Fossils or
- Crystals — only 1 mineral (salt, gypsum, calcite) or
- Chert — does not look sandy at all; and/or associated with sedimentary rocks or
- In general, if there is a reaction to HCl (acid) — on a fresh, unadulterated surface — it is sedimentary (except marble)

METAMORPHIC:

- Foliation — Thin layers
    - Mica flakes all parallel to each other
    - Black and white banding
- May be harder than similar sedimentary rocks or
- May be shinier than sedimentary or igneous rocks or
- Marble — generally large sugary crystals; no fossils or
- Quartzite — very compact or durable, but looks sort of sandy; and/or is associated with metamorphic rocks

IGNEOUS ROCKS

Textures of Igneous Rocks

Porphyritic igneous rocks have coarse crystals in a fine background.

Matrix or ground mass is the fine-grained background.

Phenocrysts are the crystals surrounded by the matrix; these are usually large, straight-sided, and glassy minerals unless they have been weathered.

Porphyritic is used as an adjective to modify the name of any fine grained igneous rock that has less than 50% phenocrysts in it. Ex. - porphyritic basalt, porphyritic andesite.

Porphyry is used as a noun after the rock name if more than 50% of the rock is made of phenocrysts. Ex .- basalt porphyry.

Vesicular volcanic rocks. Vesicular is the adjective used to modify the name of any fine-grained igneous (volcanic) rock which has vesicles (holes from gas bubbles). Ex. vesicular basalt.

Scoria - basalt with over 50% vesicles; it looks like cinders. It is irregularly porous with rough surfaces and sharp edges and is often red brown.

Characteristics of Important Minerals in Igneous Rocks

Quartz = irregular, glassy grains, commonly clear to smoky, no cleavage, conchoidal fracture

Muscovite = brassy or clear, gray-colored flakes associated with quartz or orthoclase (potassium-feldspar). Perfect cleavage in 1 direction (layers)

Orthoclase (potassium [K]-feldspar) = porcelain luster; commonly colored pink, white, or gray. Cleavage in 2 directions at right angles may be detected by a reflection of light when specimen is rotated.

Plagioclase = usually gray or white in granite, dark-bluish color in gabbro. Striations (like fine corduroy) are common. Two cleavage directions at right angles may be detected.

Biotite = small black flakes; perfect cleavage in 1 direction (layers); reflects light.

Amphibole (hornblende) = long, black crystals in a light-colored matrix. Cleavage at 60 and 120 degrees.

Pyroxene (augite) = short, dull, greenish-black minerals in darker rocks. Cleavage in two directions at 90 degrees.

Olivine = glassy, light-green to dark green grains.

IGNEOUS ROCK IDENTIFICATION KEY

Texture V	**Color >**	**light colored; pink, white, gray, green, lavender**	**medium to dark colored; purple, greenish**	**dark gray to black**	**dark green to black**
	Minerals >	15 - 30% K-feldspar; 10 - 40% quartz; 0-33% Na plagioclase; 8-15% amphibole and biotite	55-70% plagioclase; feldspar 15-40%; biotite & amphibole or pyroxene	25-70% Ca plagioclase; 25-75% dark mafic minerals (pyroxene, amphibole, olivine)	0-5% Ca plagioclase; 65-100% olivine; 0-25% pyroxene; 0-10% ore minerals (magnetite, ilmenite, chromite)
	Compo-sition >	felsic	intermediate	mafic	ultramafic
Coarse = Can see crystals = crystals are larger than a pencil point >	intrusive plutonic >	**Granite** Gray or pink. Can see quartz - gray, glassy grains. Can see feldspar = pink, buff, or white.	**Diorite** About the same amount of light colored minerals grains as dark colored minerals. No quartz. Looks like salt and pepper with more pepper	**Gabbro** Many black, flat shiny cleavage faces. Black to greenish black. **Amphibolite** = contains mostly amphiboles such as hornblende. **Pyroxenite** = contains mostly pyroxenes such as augite.	**Peridotite** Composed of 90-100% olivine (peridot)
Fine = cannot identify minerals in matrix; = dull, finer grains than a pencil point >	extrusive volcanic >	**Rhyolite** Usually gray, pink, pastel. Might see small clear, rectangular crystals. Sometimes banded.	**Andesite** Light to dark gray, purple or green. Usually has larger rectangular feldspar crystals in a dull matrix (porphyritic texture).	**Basalt** Usually black or rust red. May have some or lots of gas bubble holes (called vesicular), some holes may be filled.	**Komatiite** Usually black.

Igneous - glassy

Texture	Composition	Characteristics	Rock Name
Glassy	Mafic	Massive, dark colored glass (usually black, but also dark brown, reddish, and greenish)	**Obsidian**
Glassy	Felsic	Frothy, gray glass, with many squashed air bubbles; very light weight and may float; abrasive; subparallel glass fibers bubbles	**Pumice**
Glassy	Felsic	Pearly gray, glass, rounded spherical structures, may contain Apache Tears	**Perlite**

Igneous - pyroclastic (fragmental = ash and bombs = fire particles)

Texture	Composition	Characteristics	Rock Name
Pyroclastic	Volcanic ash, pumice fragments, some rock fragments or glass	Light colored volcanic ash, sometimes with glass and pumice fragments; less than 4 mm diameter ash fragments	**Tuff**
Pyroclastic	Volcanic ash, pumice fragments, some rock fragments or glass	Fine grained or gritty, light in weight if not compacted; light color	ash fall tuff
Pyroclastic	Volcanic ash, pumice fragments, some rock fragments or glass	Particles or grains are fused or welded, with flow lines	ash flow tuff
Pyroclastic	Round pebbles and bombs that were blown out of a volcanic vent, with ash	Rounded volcanic fragments larger than 4 millimeters (about 1/4 inch in diameter)	**Agglomerate**
Pyroclastic	Volcanic bombs, pebbles, ash, pumice fragments, some rock fragments, or glass	Sharp, angular volcanic fragments larger than 4 millimeters (1/4 inch diameter) mixed with others	**Volcanic Breccia**

SEDIMENTARY ROCKS

Sedimentary rocks are derived from pre-existing rocks by weathering and erosion. The resulting particles settle out of water or air (clastic rocks such as sandstone and mudstone) or the resulting chemicals precipitate from concentrated solutions (non-clastic rocks such as limestone and salt).

Clastic Sedimentary Rocks

How formed:

1. Pre-existing rock undergoes chemical and mechanical weathering by roots, acid rainwater, gravity, wind, and water.
2. The broken particles are carried through water or air until they settle out in a lower area when the current wasn't fast enough to carry the particles.
3. Quartz is the most stable and has the greatest resistance to the mechanical and chemical abrasion during erosion, so most sand size grains are quartz.
4. Feldspar alters to clay with chemical weathering and erosion, so arkose, which is sandstone with more than 25% feldspar, indicates the sediment was deposited close to the source rock and wasn't in transport long.
5. Grain size, shape, and composition can indicate the composition, distance, and height of the source rock.
6. Textures & structures (ripple marks, cross-bedding, sorting, etc.) and size, shape, and composition can indicate the environment of deposition.

Characteristics:

1. Soft, compared to igneous rocks.
2. Occur in layers or beds from a few millimeters thick to 100 feet thick, most commonly 1-5 ft. thick.
3. Granular and gritty if composed of sand and silt-sized particles; sand is often rounded, sometimes angular.
4. Sedimentary structures (cross-bedding, mud cracks, ripple marks, worm trails and burrows, fossil shells) are not usually visible in hand specimens, but are noticeable in outcrops.
5. Color is not usually significant, because as little as 3% hematite (iron oxide) gives a rich red color. Some pinkish sandstones get their color from feldspar.
6. Fossils are more common in shales than sandstones, because of the higher current activity in sandstones.

Non-Clastic Sedimentary Rocks

How formed:

Non-clastic sedimentary rocks are formed by chemical precipitation from a concentrated solution in water as salt, gypsum, or calcite (which forms limestone).

Characteristics:

l. Soft, because they are composed of soft minerals such as halite, gypsum, calcite. They can easily be scratched with steel or a copper penny.

2. Commonly fine-grained and homogeneous.

3. Fossils are common in limestone.

4. Limestone fizzes in dilute hydrochloric (HCl) acid, because it is composed of the mineral calcite, $CaC0_3$.

5. Some limestone contains chert, which is very, very hard silica (like flint). It typically weathers to brown on the surface and occurs in nodules and occasionally replaces fossil shells.

SEDIMENTARY ROCK IDENTIFICATION KEY

Clastic Sedimentary Rocks Identification Key

Particles	Size	Minerals	Characteristics	Grain Size	Rock Name
Round Gravel	> 2 mm	Rock fragments, quartz, feldspar	Rounded pebbles, cobbles, boulders	Coarse (or large pieces in fine-grained matrix)	**Conglom-erate**
Sharp Gravel	> 2 mm	Rock fragments, quartz, feldspar	Angular pebbles, cobbles, boulders	Coarse (large pieces in fine matrix)	**Breccia**
Sand	2-1/16 mm	Quartz, feldspar	Granular	Predominantly quartz sand; Looks sandy May shed sand grains); Feels rough	**Sandstone**
Sand	2-1/16 mm	Has 25% or more feldspar Quartz is most abundant mineral Cement is clay, calcite, iron oxide	Granular - Coarse, moderately sorted	Sandy; With visible feldspar; Often reddish or red-brown	**Arkose**
Sand	2-1/16 mm	Immature sandstone, Consists of significant quantities of dark, very fine grained material Consists of clay, chlorite, micas, silt	Poor sorting, angular grains, mixed sorting With visible mica and or rock fragments Dark gray or green-gray color	Sand-sized grains separated by finer matrix particles Matrix = 30% Coarser grains with poured-in appearance	**Graywacke**
Sand	2-1/16 mm	Quartz sand	Well sorted, Rounded grains	Clean quartz sand	**Quartz arenite**
Silt	1/16-1/256	Clay, quartz, feldspar	Gritty, but smoother than sandstone, Massive	Gritty, fine grained	**Siltstone**
Clay	<1/256 mm	Clay	Shale is platy in very thin layers. Claystone is massive.	Smooth, very fine grained, dull luster Sounds like a dull thunk when tapped	**Shale, Claystone**
Silt & Clay	< 1/16 mm	Clay, quartz	Massive	Smooth, very fine grained	**Mudstone**

Non-Clastic Sedimentary Rock Identification Key

Mineral composition	Chemical formula	Characteristics	Rock Name
Calcite	$CaCO_3$	Fizzes (bubbles) in HCl or acetic acid	**Limestone**
Calcite	$CaCO_3$	Sugary texture (medium to coarse grained), Fizzes in acid, Usually light colored, white to gray	**Crystalline Limestone**
Calcite	$CaCO_3$	Microcrystalline (very fine grained), Conchoidal fracture, fizzes in acid	**Micrite (fine-grained limestone)**
Calcite	$CaCO_3$	Aggregates of small spheres, fizzes in acid	**Oolitic Limestone**
Calcite	$CaCO_3$	Shells and shell fragments loosely cemented with little or no matrix, Fizzes in acid	**Coquina (shelly limestone)**
Calcite	$CaCO_3$	Fossils in calcareous matrix, Fizzes in acid	**Fossiliferous limestone**
Calcite	$CaCO_3$	Shells of microscopic organisms and clay, Soft, fizzes in acid	**Chalk (very fine-grained limestone)**
Calcite	$CaCO_3$	Banded calcite, usually from cave deposits, Microscopic calcite shells of plants and or animals, fizzes in acid	**Travertine (cave limestone)**
Dolomite	$CaMg(CO_3)_2$	Fizzes in acid only if scratched into a powder	**Dolomite**
Halite	$NaCl$	Tastes salty, Fine to coarse crystalline, cubes	**Salt**
Gypsum	$CaSO_4 \cdot 2H_2O$	Fine to coarse crystalline, Softer than fingernail, White, grainy; may be sugary as in alabaster, fibrous as in satin spar, or clear as in selenite	**Gypsum**
Microscopic quartz = chalcedony	SiO_2	Crypotocrystalline (hidden crystals) quartz, Dense, conchoidal fracture, Dull or waxy luster, very hard (scratches glass) Microcrystalline quartz; may be any color. (black = flint, red = jasper)	**Chert**
Silica	SiO_2	Composed of the microscopic silica shells of plants and animals. White. Diatomaceous Earth	**Diatomite**
Carbon	C	Brownish plant material, Soft, porous, fibrous	**Peat**
Carbon	C	Black, crumbly, Vitreous (glassy)	**Bituminous Coal**

Sediment Grain Sizes

Particle Size (mm)	Sediment Name	Particle Name	Rock Name
256 128 64 32 16 8 4	Gravel	Boulders Cobbles Pebbles Granules	Conglomerate
2			
1.0 0.5 0.25 0.125	Sand	Coarse sand Medium sand Fine sand	Sandstone
0.0625 (1/16 mm)			
	Silt	Silt	Siltstone grading to
0.0039 (1/256 mm)			Shale or Claystone
	Clay (as size term)	Clay (as size term)	

METAMORPHIC ROCKS

Metamorphic rocks are formed when pre-existing rocks are changed by heat and pressure.

How formed:

1. Pressure from the weight of overlying rocks or from stresses of mountain building rearranges the minerals in rocks into bands or rearranges the atoms of the minerals into new minerals.
2. Heat from the intrusion of a large igneous mass can metamorphose a large area.
3. Heat from the intrusion of a dike or sill or flow can bake the adjoining rocks in a contact metamorphic zone.

Texture - The term texture refers to the size, shape, and boundary relationships of the minerals, particles, and other substances that make up a rock. There are two major textural groups in metamorphic rocks: Foliated and Non-foliated.

Foliated (Banded) Metamorphic Rocks

Foliated = the mineral crystals in the rock are aligned parallel with each other, like stacked leaves or foliage.

Foliation may show as:

- parallel planes along which the rock splits,
- by overlapping sheets of platy minerals such as micas,
- by the parallel alignment of elongate minerals such as amphiboles, or
- by alternating layers of light and dark minerals.

Foliated texture is further subdivided based on the size of the layering or color banding in the rock. Rocks with distinct alternating bands of light and dark minerals are described as gneissic foliation. Foliated textures are further described on the basis of the grain (crystal) size in the rock. Examples of different sizes of foliation include: slate = very thin layers; gneiss = thick bands (> ¼ inch). Foliated textures can also be produced by shearing and breaking, such as in a fault zone or a meteor impact crater, and these are referred to as mylonitic textures.

Non-Foliated Metamorphic Rocks

Non-foliated = Mineral crystals in the rock grew in many directions and are not aligned in any regular way. As a result, non-foliated rocks commonly appear massive and structureless, with only a few lines of impurities through the rock. These rocks may break across the mineral grains, rather than around the mineral grains.

Composition = The name of the non-foliated rock is chosen based on the mineral composition of the rock based on observations with a hand lens and physical or chemical tests.

Probable Parent Rocks(s) – All metamorphic rocks are made by the action of heat and/or pressure or chemical solutions on pre-existing igneous, sedimentary, or metamorphic rocks. The pre-existing rock is called the parent rock.

METAMORPHIC ROCK IDENTIFICATION KEY

Foliated (banded) Metamorphic Rock Identification Key

Characteristics	Minerals Contained	Rock Name
Very thin layers, like blackboards, Very fine-grained, separate grains not visible, Smooth, flat surfaces, from slaty cleavage, Black, gray, or red, Dense, brittle, clinking sound	Mica Quartz Clay (microscopic)	**Slate**
Very, very thin, irregular layers of fine mica, Usually pale gray green, Satin sheen to rock rather than individual flakes, Fine to medium-grained, Uneven surfaces, Grains visible	Mica Quartz Other minerals	**Phyllite**
Thin, irregular layers of mica & platy minerals, Commonly pale gray green, Medium-grained, grains visible, Uneven surfaces, Crystals of garnet or other minerals in mass of mica flakes	Mica (muscovite, biotite), Chlorite, Talc, Hornblende, Quartz, Garnet, or Feldspar	**Schist**
Thick bands, wavy, semi-continuous layers of white quartz, feldspar, and mica Medium to coarse-grained Ganded, Coarsely crystalline - large, crystalline grains	Feldspar, Quartz, Mica, Hornblende, or Garnet	**Gneiss**

Non-foliated Metamorphic Rock Identification Key

Characteristics	Parent Rock	Rock Name
Very hard, smooth, Sometimes stretched cobbles and pebbles, Fractures through grains, not around them, as it does in the rougher conglomerate, Composed of rock fragments, quartz, chert	Conglomerate	**Metaconglomerate**
Very hard (scratches glass), Smooth, can see sand grains, Welded sand grains - fractures through grains, not around grains as it does in the rougher sandstone; Composed mostly of quartz	Sandstone	**Quartzite**
Fizzes in dilute acid, Medium to coarse grained, sugary to crystalline, White to pink or other colors, Composed of calcite ($CaCO_3$), Will not scratch glass	Limestone	**Marble**
Very hard, flint-like fracture, Smooth, very fine-grained, Dark colored to black, Very dense, compact	Claystone, Slate, Mudstone, Shale	**Hornfels**
Composed of minerals in the serpentine family (includes chrysotile asbestos); Generally light greenish gray to greenish black; Has a waxy luster; Often has curved and scratched surfaces	Olivine (peridotite), serpentine, other ultramafic igneous rocks	**Serpentinite**
Black to brown, Dense, highly altered plant remains , Carbon, opaque, noncrystalline	Peat, Bituminous coal	**Anthracite Coal**

ROCK CLASSIFICATION CHART

Rock Name	Description	Texture	Type (I,S,M)	Subtype
Granite	Light colored	Coarse	Igneous	Intrusive
Diorite	Medium colored			
Gabbro	Dark colored			
Rhyolite	Light colored	Fine	Igneous	Extrusive
Andesite	Medium colored			
Basalt	Dark colored			
Tuff	Fine-grained ash	Ash particles	Igneous	Pyroclastic
Pumice	Light weight	Frothy glass		Glassy
Perlite	Light colored	Glass		Glassy
Obsidian	Dark colored	Glass		Glassy
Breccia	Coarse, angular	Particles	Sedimentary	Clastic
Conglomerate	Coarse, round			
Sandstone	Medium (<2mm)			
Shale	Fine			
Limestone	Fizzes in HCl acid	Chemical	Sedimentary	Non-Clastic
Dolomite	Fizzes in HCl acid only if scratched			
Halite	Salty taste			
Gypsum	Scratched by fingernail			
Chert	Scratches glass, conchoidal fracture			
Coal (bituminous)	Black, light weight			
Slate	Very thin layers	Wavy layers or bands	Metamorphic	Foliated
Phyllite	Wavy layers with satin sheen			
Schist	Thin layers of mica			
Gneiss	Thick layers of quartz, feldspar, mica			
Quartzite	Welded quartz sandstone	Massive	Metamorphic	Non-Foliated
Marble	Sugary to coarse crystals; fizzes in HCl acid			
Hornfels	Dense, black, fine grained, massive			
Coal (anthracite)	Black, very shiny, light weight			

NUMERICAL LIST OF ROCKS & MINERALS IN KIT

See color photographs at the end of the book.

MINERALS:

1 Talc
2 Gypsum
3 Calcite
4 Fluorite
5 Apatite
6 Orthoclase (feldspar group)
7 Quartz
8 Topaz*
9 Corundum*
10 Diamond*
11 Chrysocolla (blue-green)
12 Azurite (dark blue)
13 Quartz, var. chalcedony
14 Chalcopyrite (brassy)
15 Barite
16 Galena (metallic)
17 Hematite
18 Garnet
19 Magnetite
20 Serpentine
21 Malachite (green)
22 Muscovite (mica group)
23 Bornite (peacock tarnish)
24 Halite (table salt)
25 Cuprite
26 Limonite (Goethite)
27 Pyrite (brassy)
28 Peridot
29 Gold*
30 Copper (refined)
31 Glauberite pseudomorph
32 Sulfur
33 Quartz, var. rose
34 Quartz, var. amethyst
35 Hornblende*
36 Tourmaline*
37 Graphite*
38 Sphalerite*
39 Biotite*
40 Dolomite*

IGNEOUS ROCKS:

50 Apache Tear
51 Basalt
52 Pumice
53 Perlite
54 Obsidian
55 Tuff
56 Rhyolite
57 Granite

METAMORPHIC ROCKS:

60 Quartzite*
61 Schist
62 Marble
63 Slate*
64 Gneiss
65 Metaconglomerate*
66 Phyllite
(20) (Serpentinite)*

SEDIMENTARY ROCKS:

70 Sandstone
71 Limestone
72 Travertine (onyx)
73 Conglomerate
74 Breccia
75 Shale
76 Silicified Wood
(Quartz, var. chert)
77 Coal
78 Diatomite

*=generally not present. Minerals numbered 8-10, 25, 29, 35-40 are listed for information only. Serpentine is metamorphic and when massive, it is considered to be a rock.

ALPHABETICAL LIST OF ROCKS & MINERALS IN KIT

See color photographs of rocks and minerals at the back of the book

MINERALS:

Apatite	5
Azurite (dark blue)	12
Barite	15
Biotite	39
Bornite (peacock tarnish)	23
Calcite	3
Chalcopyrite (brassy)	14
Chrysocolla (blue)	11
Copper (refined)	30
Corundum*	9
Cuprite*	25
Diamond*	10
Dolomite*	40
Fluorite	4
Galena (metallic)	16
Garnet	18
Glauberite pseudomorph	31
Gold*	29
Graphite*	37
Gypsum	2
Halite (table salt)	24
Hematite	17
Hornblende	35
Limonite (Goethite)	26
Magnetite	19
Malachite (green)	21
Muscovite (mica group)	22
Orthoclase (feldspar group)	6
Peridot	28
Pyrite (brassy)	27
Quartz, var. amethyst	34
Quartz, var. chalcedony	13
Quartz	7
Quartz, var. rose	33
Serpentine	20
Sphalerite*	38
Sulfur	32
Talc	1
Topaz*	8
Tourmaline*	36

ROCKS:

Apache Tear	50
Basalt	51
Breccia	74
Coal	77
Conglomerate	73
Diatomite	78
Gneiss	64
Granite	57
Limestone	71
Marble	62
Metaconglomerate*	65
Obsidian	54
Perlite	53
Phyllite	66
Pumice	52
Quartzite*	60
Rhyolite	56
Sandstone	70
Schist	61
(Serpentinite)*	(20)
Shale*	75
Silicified Wood (Quartz, var. chert)	76
Slate	63
Travertine (onyx)	72
Tuff	55

*=generally not present. Minerals numbered 8-10, 25, 29, 35-40 are listed for information only. Serpentine is metamorphic and when massive, it is considered to be a rock.

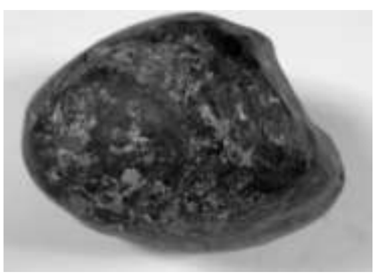
DESCRIPTION OF ROCKS & MINERALS IN ALPHABETIC ORDER

Notes:

a. Properties marked by an asterisk (*) are considered diagnostic properties.
b. (rock) designates rocks; all others are minerals.
c. Sp. Gr. = Specific Gravity
d. Luster descriptions include Diaphaneity (after the semi-colon).
e. **ACID**: For your classroom use, you should put the acid in a dropper or small squeeze bottle, keeping a paper towel nearby to blot up the excess drops on the rock. You can use: (a) **vinegar**, which is weak acetic acid (*but it will **not** cause <u>vigorous</u> fizzing in calcite*) or (b) **10% hydrochloric acid (may use dilute Muriatic acid** (pool acid, as diluted by 3 volumes of distilled water). For the latter, while testing on a piece of calcite, in a dropper or squeeze bottle, slowly add acid to a small amount of water until a drop of the solution makes vigorous fizzing when dropped on the calcite.
f. For unfamiliar terms, refer to the **GLOSSARY**.

See the color photographs at the end of the book. Many minerals have a characteristic color and are difficult to identify from a black and white photograph.

50 APACHE TEARS (rock)



This is obsidian or volcanic glass. "Apache Tear" is a local Arizona name. The "tears" are nearly spherical globules of structurally homogeneous, dark-colored glass, generally black, gray, or dark brown. This is a glassy, igneous rock.

The official name is marekanite, which is obsidian containing low amounts of water. Apache Tears occur in perlitic volcanic rocks OR they are rounded, stream worn fragments of any obsidian. The former are abundant in the perlite just west of Superior, Arizona and the latter in the desert west of Wickenburg.

Uses of Apache Tears: After being tumbled and polished, they are used as pendants or in other jewelry.

5 APATITE

$Ca_5(PO_4)_3(F,Cl,OH)$ Calcium Phosphate Fluoride (often with some Lead, Barium, Chlorine, Strontium, Carbonate or Hydroxyl)

Apatite is a mineral series consisting of phosphates of calcium with varying amounts of chlorine, fluorine, carbonate or hydroxyl. The most common variety is *fluorapatite*. Apatite is #5 on Mohs Scale of Hardness. The outside layer of your teeth is made of the mineral apatite, which is why fluoride in toothpaste helps prevent cavities. Distinguishing characteristics of apatite are the hexagonal (six-sided) crystal prism shapes with flat bottoms and tops and the hardness. **Apatite is generally not included in the kits.**

Apatite

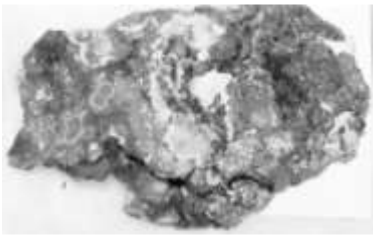
Cleavage:	Poor in 1 direction (basal)
Fracture:	Conchoidal (uneven to smooth)
Hardness:	*5
Sp. Gr.:	3.1-3.2
Color:	Green or brown, but also blue, yellow, pink, violet, colorless
Streak:	White
Luster:	Non-metallic -- vitreous, resinous, oily; transparent to translucent
Crystals:	Hexagonal; prismatic to tabular
Name:	The name is from the Greek ***apate***, “deceit”, because it is often mistaken for other minerals.

Uses of Apatite: Crystallized apatite was used extensively as a source of phosphate for fertilizer, but now phosphorite deposits supply most of the phosphate for fertilizer. The calcium phosphate is treated with sulfuric acid and changed to super-phosphate to render it more soluble in the dilute acids that exist in the soil. Transparent varieties of apatite of fine color are occasionally used for gems. The mineral is too soft, however, to allow its extensive use as a gemstone.

12 AZURITE

$Cu_3^{+2}(CO_3)_2(OH)_2$ (Copper Carbonate)

Azurite is the blue carbonate of copper and occurs in nearly all Arizona copper deposits associated with chrysocolla and malachite. *** Note: Most often the Azurite specimens in the Study Kits are associated with other copper carbonate (malachite) or silicate (chrysocolla) minerals. Azurite is the dark or light blue mineral.**



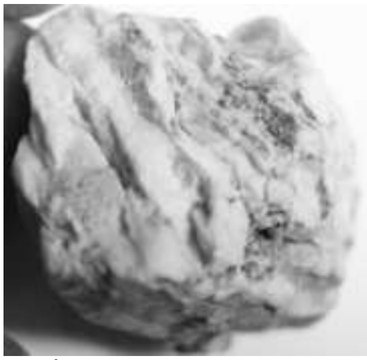
Azurite (bright blue)

Cleavage:	good in two directions if a crystal; no cleavage if massive
Fracture:	Conchoidal
Hardness:	3.5 – 4
Sp. Gr.:	3.77
Color:	*****dark to medium blue
Streak:	Blue
Luster:	non-metallic -- vitreous to dull; transparent (in thin chips) to opaque
Crystals:	monoclinic; tabular, also can be radiating, botryoidal or earthy
Other:	*****powder will weakly fizz in weak hydrochloric or acetic acid
Name:	The name is from the characteristic azure-blue color of the mineral.

Uses of azurite: An important ore of copper. It is commonly mined in open pits, piled in heap pads, leached of its copper with weak acid, and recovered by solvent extraction-electrowinning. It is also used in jewelry and as a “natural blue” in cosmetics.

15 BARITE

$BaSO_4$ (Barium Sulfate)



Barite

Cleavage:	Perfect in one direction; good in the second
Fracture:	Uneven
Hardness:	3-3.5
Sp. Gr.:	4.3-4.6 *Its high density or heaviness is a distinguishing feature.
Color:	White, yellow, red or brown
Streak:	White
Luster:	Non-metallic -- vitreous; transparent to translucent to opaque
Crystals:	Orthorhombic; thin to thick, tabular in divergent groups, compact fibrous. Tabular plates common
Name:	The name is from the Greek *barys*, "heavy".

Uses of barite: Barite is used in oil and gas well drilling to add weight to the mud. Heavy mud supports the drill rods and helps prevent gas blowouts. It is also used in the manufacture of paint, paper, cloth, cosmetics, glass, and medical chemicals.

51 BASALT (rock)

Basalt is a dark, fine grained rock that is often vesicular (having gas pockets). The gas pockets may be filled with secondary minerals, such as quartz, zeolite minerals, calcite, opal, etc. and then it is called amygdaloidal basalt.

Basalt with large masses of olivine (sometimes called peridot) or gas pockets filled with zeolite minerals are found in Arizona. The peridot is thought to have originated in the Earth's mantle; the zeolites are secondary minerals filling vesicles (gas bubble holes).

Basalt is an extrusive igneous rock occurring as thin to massive lava flows. The flows sometimes accumulate to thicknesses of thousands of feet and cover thousands of square miles. The volcanoes that produce basaltic lavas are relatively quiet, like the Hawaiian Islands volcanoes.

The name is of uncertain origin, but may have originated with Pliny who used the Ethiopian word basal for iron-bearing rocks.

Uses of basalt: Basalt is used as road bed material, ground cover and as a raw material for the manufacture of mineral wool thermal insulation. Non-vesicular basalt is denser than common rocks such as granite and rhyolite. Therefore, basalt is used where its weight is important, such as in levees to hold back flood waters.

39 BIOTITE

$K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2$ Potassium Iron Aluminum Silicate

Biotite

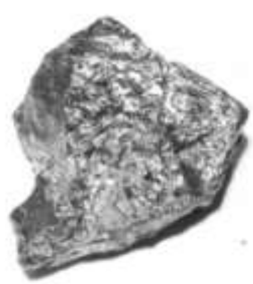
Cleavage:	***Perfect in one direction -- cleaves so readily that sheets peel off by hand
Fracture:	None
Hardness:	2.5 -3
Sp. Gr.:	2.8-3.2
Color:	*Black, dark brown
Streak:	White
Luster:	Non-metallic --vitreous; translucent to opaque
Crystals:	Monoclinic. Tabular crystals.
Other:	Cleavage sheets of most micas are elastic, i.e. they bend without breaking and return to the unbent condition.
Name:	Biotite is named for J.B. Biot, a French physicist.

Biotite is a sheet silicate, which results in parallel, thin, crystal plates or scaly aggregates. It is generally not included in the kit.

Uses of Biotite (mica group): Because of its high di-electric and heat-resisting properties, sheet mica, single cleavage plates, mica is used as an insulating material in the manufacture of electrical apparatus. Many small parts used for electrical insulation are built up of thin sheets of mica cemented together. They may thus be pressed into shape before the cement hardens. Ground mica is used as a lubricant when mixed with oils; as a filler; and as a fireproofing material.

23 BORNITE

Cu_5FeS_4 (Copper Iron Sulfide)



Bornite

Cleavage:	Indistinct
Fracture:	Uneven, conchoidal
Hardness:	3
Sp. Gr.:	4.9 to 5.07
Color:	*Copper-red to bronze; *Tarnish deep blue, purple, variegated
Streak:	*Grayish black
Luster:	Metallic; opaque
Crystals:	Isometric; crystals (rare) cubic, dodecahedral, rarely octahedral
Name:	Bornite is named after Ignaz von Born (1742-1791), famous Austrian mineralogist.

Bornite is commonly referred to as "Peacock Copper", because its surface tarnishes to blues, purples, reds and golds.

Uses of bornite: Bornite is a sulfide ore of copper, which is used in wiring and plumbing.

74 BRECCIA (rock)

Breccia is a sedimentary rock made of varying sized grains that are larger than sand of *angular* minerals and/or rocks cemented together.

The name is from the Italian word for "broken stones" or "rubble".

Many are the result of fault movement. Faults are often conduits for hydrothermal fluids, and as a result, fault breccias are often hosts for economic minerals.

3 CALCITE

$CaCO_3$ (Calcium Carbonate)

Calcite

Cleavage:	*Perfect in three directions forming rhombohedrons
Fracture:	Conchoidal, seldom observed because it cleaves so easily
Hardness:	3
Sp. Gr.:	2.7
Color:	Clear to white, to shades of nearly all colors
Streak:	White
Luster:	Non-metallic -- vitreous to dull; transparent to translucent.
Crystals:	Hexagonal; showing rhombohedron, scalenohedron and prism faces; also acicular.
Other:	*Effervesces vigorously (fizzes or bubbles of CO_2) in weak hydrochloric or acetic acid
Name:	The name is from the Latin *calx*, *calcis*, "lime"; originally from the Greek *chalx*, "burnt lime".

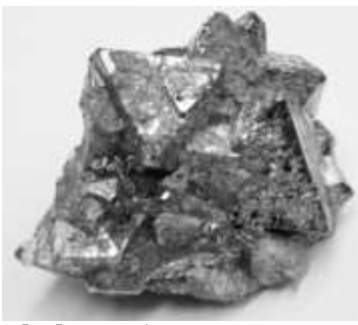
Calcite is the most common of carbonate minerals. It develops in many environments including igneous, sedimentary and metamorphic. It also occurs in a greater number of crystal forms than any other mineral (600+). Calcite is the basic mineral in limestone and marble and is often associated with metallic deposits. Calcite is #3 on Mohs Scale of Hardness.

Uses of Calcite: The main use of calcite (and limestone and marble, which are made of calcite) is in cement and lime mortars. Calcite is also used as a filler in paper, paint, and plastics. A minor use for its optical properties is in scientific instruments. Calcite is used in agriculture and horticulture as a soil amendment to treat acidic soils and provide calcium to livestock. It is also the main ingredient in antacid tablets.

The most important use for calcite is for the manufacture of cements and lime for mortars. Limestone is the chief raw material in quicklime, which when heated to about 900°C, forms quicklime, CaO. The reaction is: $CaCO_3$ + heat –> CaO + CO_2. The CaO, when mixed with water, forms one or several CaO-hydrates (slaked lime), swells, gives off much heat, and hardens or, as commonly termed, "sets." Quicklime, when mixed with sand, forms common mortar.

14 CHALCOPYRITE

$CuFeS_2$ (Copper Iron Sulfide)



Chalcopyrite

Cleavage:	Poor
Fracture:	Uneven
Hardness:	3.5 - 4
Sp. Gr.:	4.1-4.3
Color:	*Brass yellow
Streak:	*Greenish black
Luster:	Metallic; opaque
Crystals:	Mostly compact, masses of very small crystals
Name:	The name is from the Greek *chalkos*, "copper".

Uses of Chalcopyrite: It is the primary sulfide ore mineral that is mined in Arizona for the production of copper.

11 CHRYSOCOLLA

$(Cu^{+2}, Al)_2 H_2Si_2O_5(OH)_4 \cdot nH_2O$ (Copper Silicate)

Chrysocolla (blue green)

Cleavage:	None
Fracture:	Uneven to conchoidal
Hardness:	*2 (often tests harder due to associated silica)
Sp. Gr.:	2 to 2.5
Color:	*Green to bluish green
Streak:	White to pale green or blue
Luster:	Non-metallic--vitreous to dull; translucent
Crystals:	Usually compact-dense; botryoidal masses often found with a thin overlay of clear crystalline quartz.
Other:	*Will absorb water so that it sticks weakly to your tongue
Name:	The name is derived from the Greek *chrysos*, "gold", and *kolla*, "glue", in reference to a similar-looking material that was used in soldering gold.

*** Note: Most often the Chrysocolla specimens in the Study Kits are associated with the copper carbonate minerals malachite (green) and azurite (blue). Chrysocolla is the light blue-green mineral.**

Uses of Chrysocolla: Chrysocolla is a secondary copper mineral associated with azurite, malachite, and tenorite in copper deposits. Chrysocolla is a major 'oxide' ore of copper and is also used in jewelry.

77 COAL (rock)

C (Carbon)

	Coal is composed of the remains of large volumes of vegetation that accumulated in a wet, low oxygen environment, such as a swamp or marsh. Coal is considered a sedimentary rock when it is low grade *peat, lignite,* or *bituminous coal,* and is considered a metamorphic rock if it is high grade *anthracite.*

Uses of Coal: Peat is used as a soil additive for humus and for water retention. Coal is burned as a fuel. Lignite and bituminous varieties burn cooler and with more emissions such as sulfur oxides; while anthracite coal burns hotter and cleaner. Some anthracite is carved for knick knacks. Also, a dense black form of lignite that takes a good polish is called *jet* and is used in jewelry.

73 CONGLOMERATE (rock)

	Conglomerate is a sedimentary rock made of varying sizes (larger than sand) of ***rounded*** rocks cemented together. The name is from the Latin ***conglomeratus*** for "heaped, rolled or pressed together".

Uses of Conglomerate: Conglomerate is frequently used as a source of construction aggregate.

30 COPPER

Cu (native copper or refined copper in the teacher kits)

Copper

Cleavage:	None
Fracture:	Hackly
Hardness:	2.5-3
Sp. Gr.:	8.95
Color:	*Ppale red, tarnishes to brown or green
Streak:	*Shiny pale red
Luster:	*Metallic; opaque
Crystals:	Isometric; dodecahedrons, cubes, octahedrons; more often nodules, sheets or branching masses
Other:	*Malleable, conductive
Name:	The name copper is from the Greek *kyprios*, the name of Cyprus, the island that once produced copper.

Some of the specimens are a nodule of copper that grew on the sides of the electrowinning tanks during a refining process in which copper in solution is electrolytically plated onto cathodes to produce 99.9 percent pure copper.

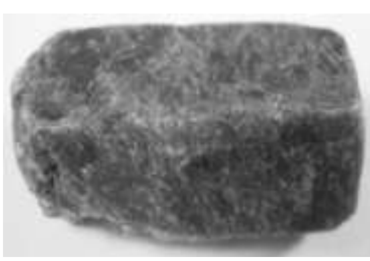
Uses of Copper: Native copper is a minor ore of copper. Copper sulfides are the most important ore of copper.

The greatest use of copper is for electrical purposes, mostly as wire. Copper is also common as plumbing pipes, pots/pans, and decorative containers. Coins (pennies, dimes, quarters) use significant amounts of copper. Copper is also used as roof cover (often tarnishing green).

Copper is also extensively used in alloys, such as brass (copper and zinc), bronze (copper and tin with some zinc), and German silver (copper, zinc, and nickel). These and many other minor uses make copper second only to iron as a metal essential to modern civilization.

9 CORUNDUM

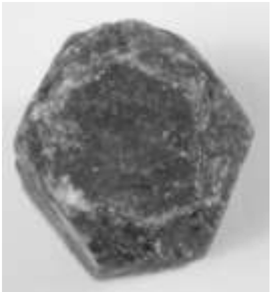
Al_2O_3 (Aluminum Oxide)



Corundum side view

Corundum top view

Cleavage:	None, but parting in one plane common
Fracture:	Uneven
Hardness:	*9
Sp. Gr.:	4.0-4.1
Color:	Varied; red is *ruby*, all others are *sapphire*
Streak:	White
Luster:	Non-metallic – vitreous (glassy and almost adamantine); translucent to transparent
Crystals:	*Hexagonal; smooth faces uncommon, *Horizontal striations common



Other:	*Asterism (stars & cat's eyes) occurs when inclusions grow along the three horizontal axes

Corundum is an oxide of aluminum. It is most common in metamorphic rocks but also occurs in a variety of igneous rocks. Due to its resistance to abrasion, corundum often can be found in stream gravels (placer deposits). It is #9 on Mohs Scale of Hardness. **Corundum is not included in this study kit.**

Uses of Corundum: Corundum is used as an abrasive material in sandpaper (its impure form = emery) and as a polishing powder. Transparent and colorful crystals are faceted as precious & semi-precious gems (ruby – red corundum birthstone for July, sapphire – blue corundum birthstone for September).

25 CUPRITE

Cu_2O (Copper Oxide)

Cleavage:	None
Fracture:	Uneven
Hardness:	3.5-4
Sp. Gr.:	6.14
Color:	*Purplish red
Streak:	*Shiny brownish red
Luster:	*Submetallic to non-metallic -- vitreous, adamantine; translucent to opaque
Crystals:	Isometric; cubic, also compact or granular
Name:	The name cuprite is from the Greek *cuprum*, copper.

Cuprite is the red oxide of copper. It is a secondary copper mineral found in the upper levels of copper-bearing deposits and is associated with native copper, azurite, and malachite.

Uses of cuprite: A minor copper ore.

10 DIAMOND

C (Carbon)

Diamond
(photo from
www.mindat.org)

Cleavage:	Perfect in one direction
Fracture:	Conchoidal
Hardness:	*10
Sp. Gr.:	3.50-3.53
Color:	Colorless; rarely yellow, brown, green, pink, blue, gray, black
Streak:	White
Luster:	Non-metallic -- *adamantine; transparent to opaque
Crystals:	Isometric; octahedrons usual, also dodeca-hedrons, cubes, tetrahedrons
Uses:	Diamond is used as an abrasive in grinding, polishing & cutting. Very clear and lustrous crystals are faceted as precious gemstones, and are the birthstone for April.
Name:	The name diamond is from the Greek *adamas*, "invincible" or "hardest"

Diamond is a form of carbon, formed under conditions of very high pressures and temperatures. It occurs in kimberlite pipes, roughly circular masses that are thought to have shot to the surface of the Earth at very high speeds (120 mph) from very great depths (at least 120 miles, or as great as 1200 miles). Diamond is #10 on Mohs Scale of Hardness. **Diamond is not included in this kit**.

78 DIATOMITE (rock)

Diatomite, also known as diatomaceous earth, is a sedimentary rock. It is composed of the siliceous shells (tests) of microscopic alga called diatoms. Diatomite is very light weight and is generally white and chalky or powdery.

Uses of Diatomite: Diatomite is siliceous (containing silica) and diatoms often have spikey tests (silica shells). Thus, diatomite is an excellent abrasive material. It was once put into toothpaste, but it proved to be too abrasive for tooth enamel.

The sharp projections and broken edges of the diatoms will scratch the exoskeleton of insects that crawl through diatomite "powder". A scratched insect will dry up and die; thereby, making diatomaceous earth a non-toxic insecticide. It also makes a good abrasive additive for polishes and cleaners.

Diatom tests are also very porous, making diatomite very effective as a filtering medium; it is used in pool and other filters to sieve out particulates and as an absorber of water and oils.

Diatomite is used in paint and coatings to speed up drying time, to control the shine/flatness and to increase the durability of the coating. In paper, diatomite makes a good inert filler, lends its natural bright color, and controls opacity. Also, its porosity makes diatomite a good additive for plaster, stucco, concrete, grout and insulation, as it is lightweight and will retain water.

40 DOLOMITE

$CaMg(CO_3)_2$ (Calcium magnesium carbonate)

Dolomite

Cleavage:	*Perfect in three directions forming rhombohedrons
Fracture:	Conchoidal, seldom observed because it cleaves so easily
Hardness:	3 1/2 – 4
Sp. Gr.:	2.7
Color:	Pink to white to grey to tan
Streak:	White
Luster:	Non-metallic -- vitreous to dull; transparent to translucent.
Crystals:	Hexagonal; showing rhombohedron, bladed with curved crystal faces
Other:	*Effervesces (fizzes or bubbles) in weak hydrochloric or acetic acid only if scratched first into a powder
Name:	Named in 1791 after the French mineralogist and geologist, D. de Dolomieu (1750-1801)

Uses of Dolomite: Dolomite rock is used as a building and ornamental stone and for the manufacture of certain cements. The mineral dolomite is used for the manufacture of magnesia used in the preparation of refractory linings of the converters in the basic steel process. (Dolomite is a rock made of the mineral dolomite and is not usually included in Teacher Kit)

4 FLUORITE

CaF_2 (Calcium Fluoride)

Fluorite

Cleavage:	***perfect in four directions forming octahedrons.
Fracture:	subconchoidal to splintery
Hardness:	*4
Sp. Gr.:	3.2
Color:	clear, purple, blue, green, yellow, pink and brown colors due to impurities
Streak:	white
Luster:	non-metallic -- vitreous; transparent to translucent.
Crystals:	isometric; cubic & octahedral common
Other:	fluoresces easily under ultraviolet light
Name:	The name is from the Latin ***fluere***, “to flow”, because fluorite melts easily and is used as a flux in the smelting of metallic ores.

Fluorite is found as secondary deposits in sedimentary and metamorphic rocks and in veins by itself or with barite or metallic minerals.

Uses of Fluorite: Fluorite is used as a flux in the making of steel and is the raw ingredient for making hydrofluoric acid. Fluorite is used in the pottery, optical, and plastics industries, in the manufacture of opalescent glass, and in enameling cooking utensils. Fluorite is used to make the chemicals added to toothpaste and drinking water to help prevent the formation of cavities in teeth. It is also used in the processing of aluminum ore (bauxite).

16 GALENA

PbS (Lead Sulfide)

Galena

Cleavage:	*Perfect in three directions at 90 degrees, forming cubes
Fracture:	Rare (subconchoidal)
Hardness:	2.5
Sp. Gr.:	*7.4-7.6
Color:	Lead gray
Streak:	Dark lead gray
Luster:	*Metallic; opaque
Crystals:	Isometric; cubes or octahedrons; also massive, fine to coarse grained
Name:	The name is from the Latin *galena*, which was applied to lead ore or the dross from melted lead; OR from the Greek *galene*, "lead ore".

Uses of Galena: It is the main source of lead and silver-rich galena deposits are an important source of silver. The largest use of lead is in storage batteries, but nearly as much is consumed in making metal products such as pipe, sheets, and shot. Lead is converted into the oxides (litharge, PbO, and minium, Pb_3O_4) used in making glass and in giving a glaze to earthenware. However, the use of lead carbonate in paints is now diminished because of the poisonous nature of lead-based paints. Diminishing also is its use in gasoline antiknock additives because of environmental restrictions. Lead is a principal metal of several alloys as solder (lead and tin), type-setting metal (lead and antimony), and low-melting alloys (lead, bismuth, and tin. Lead is used as shielding around radioactive materials.

18 GARNET group

$A_3B_2(SiO_4)_3$ Cubic silicates, where:
A = Ca, Mg, Fe^{+2}, Mn^{+2} and where B = Al, Fe^{+3}, Cu^{+3}

Garnet

Cleavage:	None
Fracture:	Conchoidal to uneven
Hardness:	*6.5-7.5
Sp. Gr.:	3.4-4.3
Color:	See below in listing of species
Luster:	Non-metallic -- vitreous; transparent to translucent
Streak:	White (if any, generally harder than tile)
Crystals:	*Isometric, commonly as dodecahedrons and trapezohedrons, granular
Name:	See below in listing of species

Garnet is the name for a group of minerals that are aluminum silicates and calcium silicates. They occur in igneous and metamorphic rocks. The main mineral species in this group are as follows:

Almandine: deep red to brown
Andradite: wine red, greenish, yellow or brown
Grossular: (known as Essonite) colorless, white, yellow, green, brown
Pyrope: deep red to reddish black
Spessartine: brown to red
Uvarovite: emerald green

Uses of Garnet: It is chiefly used as an inexpensive gemstone (birthstone for January). At Gore Mountain, New York, large crystals of almandite in an amphibolite are mined. The unusual angular fractures and high hardness of these garnets make them desirable for a variety of abrasive purpose including garnet ‘sand’ paper. Large amounts are used for sand blasting and water filtration.

Names of Garnet:

Almandine is named after Alabanda, a town of ancient Caria (Asia Minor).
Andradite is named after J.B. de Andrada e Silva (1763-1838), a Brazilian geologist.
Grossular is from the New Latin *grossularia*, “gooseberry”, because some crystals are pale green like the fruit.
Pyrope is from the Greek *pyropos*, “fire-eyed”
Spessartine is named for the Spessart District, Bavaria, Germany.
Uvarovite is named after Count S. S. Uvarov (1785-1855), Russian statesman and mineral collector.

31 GLAUBERITE (A PSEUDOMORPH)

$Na_2Ca(SO_4)_2$ Sodium calcium sulfate

	This crystal is a ***pseudomorph*** (false form). That means that another mineral is using the crystal shape of the mineral glauberite. This occurred in the muds of lakes that occupied the Verde Valley during the mid-late Tertiary. Glauberite is a salt -- $Na_2Ca(SO_4)_2$ -- that was deposited in shallow evaporating water. The glauberite crystals were completely replaced by calcite (yellowish-white), gypsum (sugary white) or aragonite (honey brown); i.e. calcite, gypsum or aragonite *after* glauberite. In some cases, the glauberite crystals dissolved, leaving holes in the muds. These holes were later filled in with the other minerals.

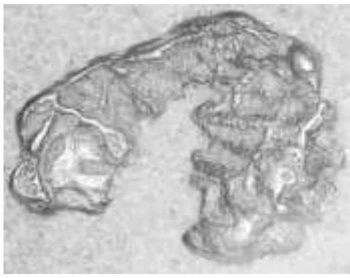
64 GNEISS (rock)

	Gneiss is a metamorphic rock that was formed under conditions of high temperatures and pressures at great depth during regional metamorphism. It is characterized by foliation that generally looks like black and white banding. The name originated with Saxon miners in Germany.

Uses of gneiss: Gneiss is sometimes used as a facing stone for buildings or as floor tile or counter top material.

29 GOLD

Au (a Native Element)



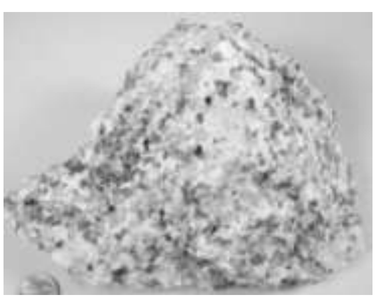
Gold

Cleavage:	None
Fracture:	Hackly
Hardness:	2.5-3 (very soft)
Sp. Gr.:	*15.6-19.3 (very heavy)
Color:	*Gold yellow that does not tarnish
Streak:	*Gold yellow
Luster:	Metallic; opaque
Crystals:	Msometric; cubes and octahedrons; more often in grains, leaves, lumps, or wires
Other:	*Ductile and *malleable -- it can be worked into very thin sheets and wire; resistant to corrosion & tarnish
Name:	The name gold is thought to be Anglo-Saxon, and is of uncertain origin.

Gold is a native element that does not usually occur in any other compound. It is usually found as natural alloys with more or less silver, and sometimes copper (and then is economically recovered during the smelting of metallic ores). In addition, gold occurs in veins in igneous rocks and in placer sedimentary deposits.

Uses of gold: Gold is used for jewelry, dentistry, as a decorative overlay material (foil), in electrical conductors (very fine wire) in microcircuits, as a filtering film on the face plates of astronauts' helmets and in many other high technology applications. **Gold is not included in this kit**.

57 GRANITE (rock)



Granite is a coarse to medium grained igneous rock that forms from the cooling of magma deep within the Earth. It is made up mainly of varying amounts of the minerals: quartz, orthoclase, muscovite, biotite and hornblende.

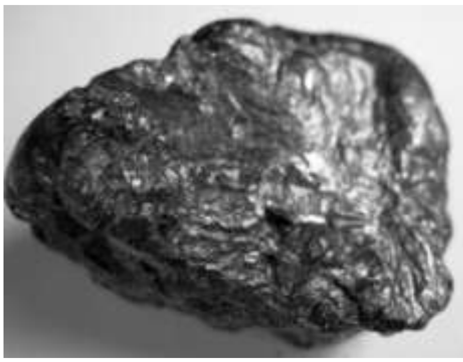
The color of granite can be light or dark brown or reddish depending on the amount of light colored minerals (quartz or orthoclase feldspar) or dark colored minerals (biotite, hornblende or plagioclase feldspar) or stain of iron oxides.

The name is from the Latin ***granum,*** for "grains".

Uses of granite: Because of its resistance to breaking and weathering and its ability to take a high polish, it is used in construction as an ornamental stone, monuments, floor tiles, cutting boards and countertops (*in fact, some of the teachers' kits may* *contain cut and polished scraps*). Granite may also be crushed for construction aggregate and desert landscaping.

37 GRAPHITE

C (Carbon)



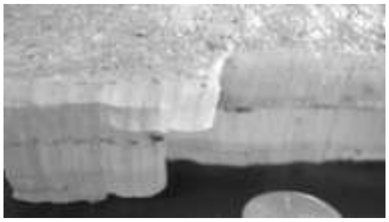
Graphite

Cleavage:	*Perfect parallel to the long axis and distinct in two others. Layers are curved due to the softness of the graphite.
Hardness:	1-2
Sp. Gr.:	2.1-2.3
Color:	Dark gray and black
Streak:	Black
Luster:	Metallic greasy; opaque
Crystal:	Hexagonal, platy crystals not common
Other:	G'reasy, slippery feel. Writes on paper
Name:	The name graphite is from Greek "*graphein*", 'to write'; named by German chemist and mineralogist A. G. Werner in 1789".

Uses of Graphite: It is used in the manufacture of refractory crucibles for the steel, brass, and bronze industries. Graphite is used as a lubricant, which you can buy at a home construction store in tubes to unstick locks. Graphite, when mixed with fine clay, forms the 'lead' of pencils. It is used in the manufacture of protective paint for structural steel and is used in foundry facings, batteries, electrodes, generator brushes, and in electrotyping.

2 GYPSUM

$CaSO_4 \cdot 2H_2O$ (Calcium Sulfate Hydrate)



Gypsum

Cleavage:	***P**erfect parallel to the long axis and distinct in two others
Fracture:	Splintery
Hardness:	***1.5-2**
Sp. Gr.:	2.3-2.4
Color:	White, colorless, gray, and brown
Streak:	White
Luster:	Non-metallic -- vitreous to dull; transparent to translucent
Crystal:	Monoclinic; bladed to tabular, often twinned
Other:	***Thin cleavage fragments are flexible,** i.e. they will bend without breaking, but will not return to their unbent condition.
Name:	The name gypsum is from the Arabic ***jibs,*** "plaster" and then to the Greek ***gypsos***, for gypsum of plaster or "chalk".

The variety of gypsum called ***selenite*** grows as large clear bladed crystals; the variety ***satin spar*** grows as white fibrous masses; and the variety ***alabaster*** occurs as white sugary masses.

Uses of Gypsum: Gypsum is used chiefly for the manufacture of wall board for interior walls and ceilings and in the production of plaster of Paris. In the manufacture of this material, the gypsum is ground and then heated until about 75 % of the water has been driven off, producing the substance $CaSO_4 . ½\ H_2O$. This material when mixed with water, slowly absorbs the water, crystallizes, and thus hardens or "sets." Plaster of Paris is used extensively for "staff," the material from which temporary exposition buildings are built, for gypsum lath, wallboard, and for molds and casts of all kinds. Gypsum is employed in making adamant plaster for interior use.

Gypsum is used in agriculture to neutralize alkali soils and to break up hardpan and caliche. It serves as a soil conditioner. Uncalcined gypsum is used as a retarder in Portland cement. Satin spar and alabaster are cut and polished for various ornamental purposes but are restricted in their uses because of their softness.

24 HALITE (salt)

NaCl (Sodium Chloride)

Halite

Cleavage:	*Perfect in three directions at 90 degrees, forming cubes
Hardness:	*2 to 2.5
Sp. Gr.:	2.17
Color:	Colorless or tints of gray, yellow, red, blue, green, purple
Luster:	Non-metallic -- vitreous; transparent to translucent
Crystals:	Isometric; usually the simple cube
Streak:	White
Other:	*Salty taste
Name:	The name halite is from the Greek *hals*, "salt".

Halite occurs in widespread evaporite deposits of chemical sedimentary rocks and is commonly associated with gypsum, thenardite, borax, and other salts.

Uses of Halite: Halite is used in the chemical industry and is a source of chlorine for the manufacture of hydrochloric acid and sodium for many sodium compounds. It is a food supplement for humans and animals (table salt). In addition, it is used in water softeners and as a road de-icer. Salt is used extensively in the natural state in tanning hides, in fertilizers, in stock feeds, in salting icy highways, and as a weed killer. In addition to its familiar functions in the home, salt enters into the preparation of foods of many kinds, such as the preservation of butter, cheese, fish, and meat.

17 HEMATITE

Fe_2O_3 (Iron Oxide)

Hematite

Cleavage:	None, parting common
Fracture:	Splintery, uneven, conchoidal
Hardness:	*5-6
Sp. Gr.:	4.9-5.3
Color:	Metallic steel gray to dull red, brown, black
Luster:	Metallic to non-metallic -- earthy; opaque
Crystals:	Hexagonal; thin to thick tabular, rosettes, compact, radiated or botryoidal
Streak:	*Deep red brown
Name:	The name hematite is from the Greek *haimatites*, "bloodlike," in reference to the vivid red color of the powder.

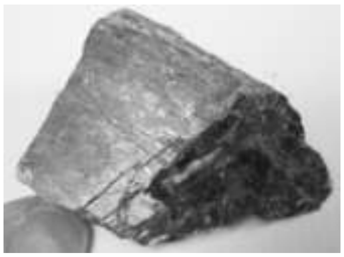
Hematite is an oxide of iron. Huge deposits of hematite were found in sedimentary rocks in Michigan and Minnesota. Excellent crystals are found in quartz near Bouse, Arizona and large massive deposits are found in many parts of Arizona.

Uses of Hematite: Hematite is the most important ore of iron for steel manufacture. It is also used in pigments, red ocher, and as polishing powder. Hematite with a metallic luster is sometimes used in jewelry and is referred to as *specular hematite*. The earthy red form is used as a red pigment and sometimes as a source of iron in agricultural soils.

35 HORNBLENDE

$Ca_2Na(Mg,Fe)_4(Al,Fe,Ti)_3Si_8O_{22}(O,OH)_2$

Calcium Sodium Magnesium Iron Aluminum Silicate



Hornblende

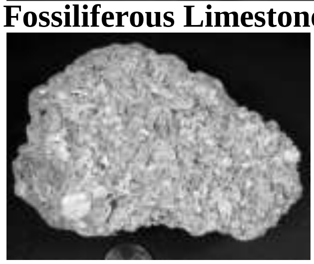
Cleavage:	Good in 2 directions; about 60º and 120º
Fracture:	Uneven on 3rd side
Hardness:	*5-6
Sp. Gr.:	3.2
Color:	Black, to dark green
Luster:	Non-metallic -- glassy; opaque
Crystals:	Monoclinic, prismatic; columnar or fibrous
Streak:	No streak
Name:	From the old German word for any dark prismatic mineral occurring in ores but containing no recoverable metal

Uses of Hornblende: None

71 LIMESTONE (rock)

$CaCO_3$ (Calcium Carbonate)

Fossiliferous Limestone



Coquina

Limestone is a chemical sedimentary rock composed primarily of calcite. Generally it is dense, fine grained, non-clastic and usually white to dark gray with a hardness of 3-4. Its most distinguishing feature is the fizzing in weak hydrochloric or acetic acid. (See calcite; travertine)

Coquina is limestone made entirely of sea shells.

Uses of Limestone and Marble: The greatest consumption of limestone is in the manufacture of lime and Portland cement. It is composed of about 75% calcium carbonate (calcite) with the remainder essentially silica and alumina. Small amounts of magnesium carbonate and iron oxide are also present. When water is mixed with cement, hydrous calcium silicates and calcium aluminates are formed, creating hard concrete.

Limestone is an important raw material for the chemical industry, and finely crushed limestone is used as a soil conditioner, for whiting and whitewash. Great quantities are quarried each year as a flux for smelting various metallic ores, and as an aggregate in concrete and as road metal. A fine-grained limestone is used in lithography.

Calcite in several forms is used in the building industry. Limestone and marble as dimension stone are used both for construction purposes and decorative exterior facings. Polished slabs of travertine and Mexican onyx are commonly used as ornamental stone for interiors.

It is also used to collect sulfur dioxide from the smokestack gases that result from burning coal for energy or smelting sulfide ore minerals. It is finely ground and used for a filler in many products such as paint, kitchen counter and bathroom vanity tops, chalk for lining athletic fields and plastics; also as a dusting on chewing gum, to keep the gum from sticking to the wrapper. Being relatively soft (hardness 3), it makes a mild abrasive additive to toothpaste. Limestone is used extensively as a building stone and is often carved into monuments. It is used in soil conditioners and as a flux in processing iron ores to make steel and in smelting copper ores.

26 LIMONITE (GOETHITE)

$Fe_2^{+3}O_3 \cdot H_2O$ (Iron Oxide Hydrate)

Limonite

Cleavage:	None
Fracture:	Conchoidal to uneven
Hardness:	5-5.5 (often tests harder due to associated silica)
Sp. Gr.:	2.7-4.3
Color:	*Yellow to brown
Luster:	Non-metallic -- earthy; opaque
Streak:	*Yellow-brown
Crystals:	Orthorhombic; crystals rare; usually massive, mammillary or fibrous; often replaces cubes of pyrite (as a pseudomorph)
Name:	The name limonite comes from the Greek *leimons*, "meadow", in allusion to its occurrence in bogs. Goethite is from Johann Wolfgang von Goethe, German author and scientist.

Limonite is a general name for a group of minerals that are hydrous oxides of iron. It is a common coloring agent in soils and gives a characteristic brown color to the weathered surfaces of rocks.

Uses of Limonite (goethite): Limonite is an ore of iron. It often occurs in hematite deposits and is thus used as an iron ore. It is also used as yellow, brown, or orange pigments and is then referred to as ochre.

19 MAGNETITE

$Fe^{+2}Fe_2^{+3}O_4$ (Iron Oxide)

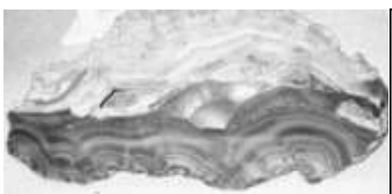
Magnetite

Cleavage:	None
Fracture:	Sub-conchoidal
Hardness:	5.5-6.5
Sp. Gr.:	*4.9-5.2
Color:	Black
Streak:	*Black
Luster:	Metallic to non-metallic -- earthy; opaque
Crystals:	Isometric; octahedrons, usually massive
Other:	*It is strongly magnetic.
Name:	The name magnetite is derived from Magnesia, an ancient district bordering on Macedonia.

Uses of Magnetite: It is an important ore of iron, which is one of the raw materials used in making steel. Iron is used in construction (such as bridges and rebar in house foundations), cars other vehicles such as trucks and trains, machinery, cans and containers, appliances such as stoves and refrigerators.

21 MALACHITE

$Cu_2^{+2}CO_3(OH)_2$ (Copper Carbonate)



Malachite

Cleavage:	Perfect in one direction (although rarely exhibited)
Fracture:	Splintery
Hardness:	3.5-4
Sp. Gr.:	3.6-4
Color:	*Banded light to dark green
Streak:	Light green
Luster:	Non-metallic -- adamantine to silky dull; opaque
Crystals:	Monoclinic; short tabular, radial and botryoidal
Name:	The name malachite comes from the Greek *malache*, "mallow" in reference to the mineral's leaf-green color.

***Note: Most often the Malachite specimens in the Study Kits are associated with other copper carbonate or silicate minerals. Malachite is the green mineral.**

Uses of Malachite: It is an ore of copper. It has been used, particularly in Russia, as an ornamental material for vases, veneer for table tops, carvings, and boxes. It is also used as a semi-precious gemstone for lapidary art and jewelry. Nicely banded malachite is used for jewelry and other ornamental purposes.

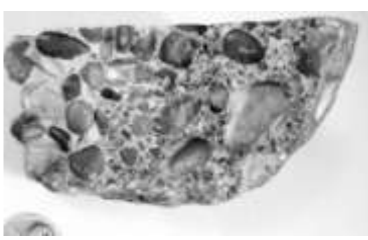
62 MARBLE (rock)

$CaCO_3$ (Calcium Carbonate)

	Marble is a metamorphic rock formed from limestone or dolomite. The colors can vary from pure white to gray, green, yellow, brown, black, red or any combination thereof, depending on the 'impurities' in the parent limestone. Bands or streaks result from plastic flow during extreme deformation due to high pressure and temperature. It is still calcite (as is limestone) and therefore will effervesce vigorously in weak hydrochloric or acetic acid. (See calcite; limestone; travertine)

Uses of Marble: Marble is an important industrial rock. It can be cut into slabs, polished and used for finished exteriors and interiors of buildings, floors and counter tops (although it is quite soft and dulls easily from abrasion or acid exposure). It is also used for carved statuary. Coarsely crushed marble is used as landscaping, paving and roofing rock; finely crushed it makes poultry grit; and very finely ground marble is used as fillers and extenders for paints, plastics, paper and adhesives.

65 METACONGLOMERATE (rock)

	Metaconglomerate is a metamorphic rock. It is a sedimentary conglomerate that has been subjected to increased heat and/or pressure. While a sedimentary conglomerate will break around the pebbles, a metaconglomerate will break through the pebbles. If temperatures are high enough in the presence of pressure, the pebbles may become flattened and will be elongated parallel to each other.

Metaconglomerate is not generally included in the kit.

22 MUSCOVITE

Mica Group of the general formula: $\mathbf{WXY_{2\text{-}3}Z_4O_{10}(OH,F)_2}$ where: W = K, Na; X&Y = Al, Mg, Fe, Li; Z = Si, Al

Potassium Aluminum Silicate Hydrate $KAl_2(AlSi_3O_{10})(OH)_2$

Muscovite

Cleavage:	*Perfect in one direction -- cleaves so readily that sheets peel off by hand
Fracture:	None
Hardness:	2.5 on cleavage face; up to 4 on cleavage edge
Sp. Gr.:	2.8-2.9
Color:	Clear to grey muscovite; others see below
Streak:	White
Luster:	Non-metallic --vitreous to pearly; transparent to opaque
Crystals:	Monoclinic; Muscovite crystals are tabular, parallel to the cleavage. Biotite crystals are tabular. Phlogopite crystals are platy to parallel sheets. Lepidolite and vermiculite crystals are usually scaly aggregates.
Other:	Cleavage sheets of most micas (especially muscovite) are elastic, i.e. they bend without breaking and return to the unbent condition.

The minerals of the mica group all have a similar physical structure. They are sheet silicates and this is reflected in their growth of *parallel thin crystal plates or scaly aggregates. The group is made up of the following varieties:

Biotite: black -- potassium, magnesium, aluminum silicate
Lepidolite: pink or lilac -- potassium, aluminum, lithium, fluorine silicate
Muscovite: white to colorless, green, pink -- potassium, aluminum silicate
Phlogopite: brown or yellow -- potassium, magnesium, aluminum, iron silicate
Vermiculite: brownish -- potassium, magnesium, aluminum silicate

Uses of Muscovite (mica group): Because of its high di-electric and heat-resisting properties, sheet mica (single cleavage plates of mica) is used as an insulating material in the manufacture of electrical apparatus. The isinglass used in furnace and stove doors is sheet mica. Many small parts used for electrical insulation are built up of thin sheets of mica cemented together. They are pressed into shape before the cement hardens. Ground mica is used in the manufacture of wallpapers to give them a shiny luster; as a lubricant when mixed with oils; as a filler; and as a fireproofing material.

Micas are used in the making of sparkling cosmetics. Their platy structure is advantageous for use as a strengthener, binder and spreading agent in paint, wall board joint compound, plastics, adhesives, caulks and sealants. Historically, clear sheets were used as a glass substitute in windows of homes and oven and furnace doors (Isinglass). Lepidolite is a lithium source. Vermiculite is used in insulation and as a soil conditioner (it absorbs and holds water).

Origin of the names:

Mica is from the Latin ***micare***, “to shine”.
Muscovite comes from ***Muscovy***, the old name for Russia.
Biotite is named for J.B. Biot, a French naturalist.
Vermiculite is named for its wormlike forms.
Phlogopite comes from the Greek ***phlogopos***, “firelike” because of its red-brown color.
Lepidolite is from the Greek ***lepidos***, “scale” due to its characteristic scaly aggregate crystal form.

54 OBSIDIAN (rock)

	Obsidian is an extrusive igneous rock often referred to as "black glass" -- although it may be red, black & red (mahogany), gray, green or iridescent. Obsidian is a name that has been in use since the time of Pliny. Its glassy, lustrous and sometimes banded appearance makes it rather easy to distinguish from other volcanic rocks. Obsidian is composed of quartz, feldspar and iron magnesium minerals that have cooled so quickly that the minerals could not develop and crystallize.

Uses of Obsidian: It often exhibits perfect conchoidal fracture, which makes it good for native peoples to use as projectile points (arrow and spear heads). Present day lapidarists use polished obsidian in jewelry; and it may be faceted. It is also fabricated into surgical blades with a razor sharp, naturally burrless edge that is perfect for delicate surgery. ***Be careful of the razor sharp edges of obsidian.***

6 ORTHOCLASE

$KAlSi_3O_8$ (Potassium Aluminum Silicate)
Feldspar Group general formula **is XZ_4O_8 where X = K, Na, Ca, Ba; and Z = Al, Si**

Orthoclase

Cleavage:	*Perfect in two directions at 90 degrees
Fracture:	Uneven
Hardness:	*6
Sp. Gr.:	2.5-2.6
Color:	White, pink, gray, brown, green yellowish
Streak:	White
Luster:	Non-metallic -- vitreous; transparent to opaque
Crystals:	Monoclinic; tabular, square or rectangular in section, also granular masses.

Name:	The name orthoclase is from the Greek *orthos*, "upright", and *klasis*, "fracture," in reference to orthoclase's two prominent cleavages at right angles to each other.

Orthoclase is one of the important igneous and metamorphic rock forming minerals (it is the pink or chalky white mineral in granite). (Other feldspars -- including the plagioclase family -- are also important components of nearly all igneous and metamorphic rocks.) Feldspar is #6 on Mohs Scale of Hardness.

Uses of Orthoclase (K-feldspar group): Feldspar is used mainly to make porcelain. It is ground very fine and mixed with kaolin or clay, and quartz. When heated to high temperature, the feldspar fuses and acts as a cement to bind the material together. Fused feldspar also furnishes the major part of the glaze on porcelain ware. A small amount of feldspar is used in the manufacture of glass to contribute alumina to the batch. *Amazonite* (the green variety of microcline) is polished and used in semi-precious jewelry as cabachons. *Moonstone* is the gem variety of orthoclase and is the birthstone for June. Ground feldspars are used as a scouring powder that is harder than glass.

Uses of Plagioclase (Na-Ca feldspar group): Plagioclase feldspars are less widely used than potash feldspars. Albite, or soda spar, as it is called commercially, is used in ceramics in a manner similar to microcline. *Labradorite* that shows a play of colors is polished and used as an ornamental stone for counter tops and semi-precious stones. Those varieties that show opalescence are cut and sold under the name of *moonstone*.

28 PERIDOT

Olivine Group of the general formula **$A_2^{+2}SiO_4$** **where A = Fe, Mg, Mn, Ni**

Olivine (peridot)

Cleavage:	Indistinct in 2 directions at 90 degrees
Fracture:	Conchoidal
Hardness:	*6.5-7
Sp. Gr.:	3.2-4.4; peridot typically 3.34
Color:	*Usually light to dark yellowish to olive green
Luster:	Non-metallic -- vitreous; transparent to translucent
Streak:	White
Crystals:	Orthorhombic; crystals are rare, usually in rounded grains
Name:	Olivine is named for its olive-green color.

Olivine is a common constituent of the black volcanic rock, basalt. Crystalline masses of peridot (thought to have originated in Earth's mantle) are sometimes included in basalt. This is the case in the classic peridot location on the Apache Indian Reservation at San Carlos, AZ.

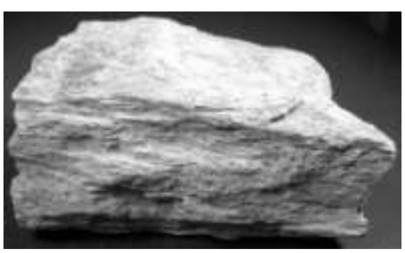
Uses of Olivine: As the clear dark green variety, *peridot*, it is the gem birthstone for August. Olivine is mined as refractory sand to make molds for the casting of iron.

53 PERLITE (rock)

	Perlite is a light gray volcanic glass having numerous concentric cracks which give rise to a perlitic or onion skin structure. (The name has been written as pearlstone by those who thought that the perlitic structure resembled pearls or due to its pearly luster.) It is generally of rhyolitic composition, consisting of an oxide of silica, an oxide of aluminum and water.

Uses of Perlite: When perlite is heated to the softening point (about 2,000 degrees Fahrenheit), it expands due to formation of steam from its included water. The expanded form resembles pumice. This form is used in thermal and acoustical insulation, in liquid fuel systems, in nursery potting soils, in filtering of liquids for human consumption and as a lightweight aggregate. Finely ground and expanded perlite is used as a specialty filler in paints, light weight cast plastic resin products and sealants.

66 PHYLLITE (rock)

	Phyllite is a metamorphic rock. It is somewhat more metamorphosed than slate, but less metamorphosed than schist. The platy crystals of mica have grown and the rock displays a subtle, satiny shine or sheen. The name comes from its leaf-like (many fine layers) appearance.

Uses of Phyllite: Phyllite is used as a decorative stone for wall and building facings.

52 PUMICE (rock)

	Pumice is an igneous rock that is highly vesicular (i.e. it has lots of gas bubble holes). It is generally of rhyolitic composition and light gray or tan in color. It is very light in weight and will float on water until the vesicles are full of water.

Uses of Pumice: It is used as a lightweight aggregate with Portland cement to produce lightweight concrete. Pumice is also used in cleansing powders, in abrasive soap (Lava soap), and to produce "stone washed" blue jeans.

27 PYRITE

FeS_2 (Iron Sulfide (Fool's Gold)

Pyrite

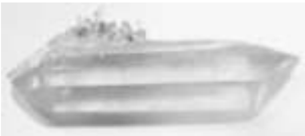
Cleavage:	None
Fracture:	Uneven to conchoidal
Hardness:	*6-6.5
Sp. Gr.:	4.9-5.02
Color:	Yellow to brassy yellow often tarnished with a brown film.
Streak:	*Greenish black
Luster:	Metallic; opaque
Crystals:	Isometric; cubes, often with parallel striations on the faces. Commonly in nodular, massive, fine to coarse granular, fibrous, mammillary and stalactitic forms.
Other:	*Brittle, NOT malleable
Name:	The name pyrite is from the Greek *pyr*, "fire" or *pyrites lithos*, "stone which strikes fire" because of the sparks produced when iron or steel is struck by pyrite.

Pyrite is a very common mineral and found in igneous, sedimentary and metamorphic rocks. Often metallic mineral veins containing gold are associated with pyrite. The pyrite weathers to produce iron oxides that stain the surrounding rocks with rust. Prospectors often look for "rusty quartz" when seeking gold-bearing rocks.

Uses of Pyrite: Pyrite is often mined for the gold or copper associated with it. Because of the large amount of sulfur present in the mineral, it was formerly used as a source of sulfur for sulfuric acid and copperas (ferrous sulfate). Copperas is used in dyeing, in the manufacture of inks, as a preservative of wood, and as a disinfectant. It is also processed into iron sulfate for use as an iron supplement for soils, a wood preservative, ink manufacture, and in dyeing. Additionally, pyrite is used as the brown pigment in brown glass bottles.

7, 13, 33, 34 QUARTZ

SiO_2 (Silicon Oxide)



Cleavage:	None
Fracture:	*Conchoidal
Hardness:	*7
Sp. Gr.:	2.6
Color:	Colorless, purple (*amethyst*), pink to deep red (*rose*), yellow (*citrine*), brown to black (*smoky*), white (*milky*)
Streak:	White
Luster:	Non-metallic -- vitreous; transparent to translucent
Crystals:	Hexagonal; six sided, often with one or more faces striated crosswise
Name:	The name quartz is from the German *Quarz*, of uncertain origin.

Quartz is an important rock forming mineral that develops and persists in many different environments. It is one of the common minerals in granite and rhyolite and in metamorphic rocks. Much of the world's sand and consequently sandstone (a sedimentary rock) is quartz, the result of the physical breakdown of rocks containing quartz and quartz's resistance to physical and chemical attack. It is also associated with many ore bodies, particularly gold and pegmatites containing many rare earth elements (lithium, beryllium, etc.).

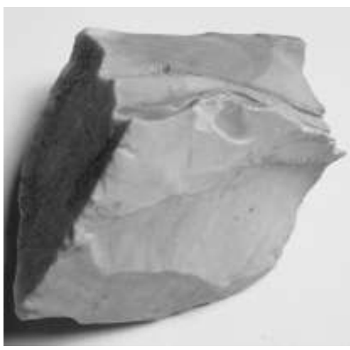
Uses of Quartz and microcrystalline varieties of quartz: Quartz is widely used as gemstones or ornamental material, as amethyst, rose quartz, cairngorm, tiger eye, aventurine, carnelian, agate, and onyx. As sand, quartz is used in mortar, in concrete, as a flux, as an abrasive, and in the manufacture of glass and silica brick. In powdered form it is used in porcelain, paints, sandpaper, scouring soaps, and as a wood filler. In the form of quartzite and sandstone, it is used as a building stone and for paving purposes.

Quartz has many uses in scientific equipment. Because of its transparency in both the infrared and ultraviolet portions of the spectrum, quartz is made into lenses and prisms for optical instruments. The optical activity of quartz (the ability to rotate the plane of polarization of light) is used in making an instrument to produce monochromatic light of differing wavelengths.

Because of its piezoelectric property, quartz has specialized uses. It is cut into small oriented plates and used as radio oscillators to permit both transmission and reception on a fixed frequency. The tiny quartz plate used in digital quartz watches serves the same function. This property also renders it useful in the measurement of instantaneous high pressures such as result from firing a gun or atomic explosion.

Quartz sand is the base mineral for the glass and fiberglass industries and is also used in concrete. Quartz crystals, both natural and synthetic are used for electronic radio frequency control and in quartz watches; also in optical instruments. Finely ground quartz is used as filler in porcelain, paints and wood filler. Quartz is also used as an abrasive in sandblasting and sandpaper. Colored varieties are considered semi-precious gemstones. Amethyst is the birthstone for February.

Except for form, the finely crystalline varieties of quartz have the same mineral properties as the larger-crystallized varieties. The very finely crystalline (massive or cryptocrystalline) varieties of quartz are very common in Arizona and occur in the following subvarieties:

Chalcedony   **Chert**	Non-metallic -- waxy luster, vitreous to dull; translucent to opaque . The name chalcedony is derived from ***Chalcedon***, an ancient Greek city of Asia Minor. **Varieties of chalcedony include:** **Agate:** vari-colored, banded or patterned; translucent. **Jasper:** vari-colored, generally red (or green), sometimes banded or patterned; opaque. **Carnelian:** red; translucent **Bloodstone:** green with red spots; opaque **Flint:** vari-colored, generally solid dull colors; opaque **Chert:** a general term for cryptocrystalline quartz, of any color **Chrysoprase:** apple green; translucent **Tiger's Eye:** quartz after asbestos (pseudomorph); fibrous character retained; yellow or brown
Opal (not really a form of quartz, but with a similar composition)	**Opal** is a hydrous silica with no crystal structure, but instead it is composed of closely packed silica spheres. Hardness = 5.5, Sp. Gr. = 2.0-2.25; Luster is non-metallic -- vitreous; transparent to translucent; clear, white, milky/bluish, yellow, black are common colors; sometimes displays "fire" or a play of colors due to refractive properties of the aggregate of spheres. It is the birthstone of October. The name possibly derives from the Sanskrit *upala*, "precious stone".

60 **QUARTZITE** (rock)

Quartzite is a metamorphic rock derived from sandstone. It is a very dense, massive, microcrystalline rock. It can be any color, but tends toward light ones (white, tan, pink).

Use of Quartzite: Due to its density and microcrystalline nature, it has been used for projectile points by Native Americans. It is also very durable (hardness 7) and can be used as a decorative stone. Quartzite is generally not included in the kit.

56 **RHYOLITE** (rock)

Rhyolite is an extrusive igneous rock. The name is from the Greek ***rhyo***, from ***rhyax***, "stream of lava". It is formed when molten rock with the same composition as a high silica granite oozes to the Earth's surface. Rhyolite is VERY viscous (sticky) and does not readily flow, but explodes from the volcano. Rhyolite lava therefore cools quickly so only microscopic-sized crystals develop. The volcanoes that produce rhyolite are the very explosive varieties such as Mt. St. Helens, Krakatoa and O'Leary Peak (in the Flagstaff, AZ area). Frequently it is banded due to flow alignment of different associated minerals (quartz, feldspar, mica, and hornblende).

Uses of Rhyolite: It is crushed for use as construction aggregate. Color banded varieties can be polished by lapidarits into beautiful cabochons for jewelry.

70 **SANDSTONE** (rock)

Sandstone is a sedimentary rock made up of fine grained particles (.05-2 mm) of pre-existing rocks. The sand grains (often quartz) were transported mechanically by wind, water or ice to the place of deposition. There, they were cemented together by silica, carbonates, clay, iron oxide, or other minerals.

Sandstone is identified by its sandy texture, which feels gritty like coarse sandpaper.

Uses of Sandstone: Sandstone is a source of sand for construction aggregate and is a silica source for glass. When quarried and separated into plates or sheets along bedding planes, it is used as flagstone (Arizona is the flagstone capital of the United States). Cut into blocks, it is used as a building stone.

61 SCHIST (rock)

	Schist is medium to coarse grained, crystalline, with prominent parallel mineral orientation, especially of mica. Typically, schist is predominately muscovite mica which lends a silvery white to gray sparkly appearance. Accessory minerals (such as garnets, staurolite, tourmaline) commonly grow in the schist.

Uses of Schist: Schist is added to clay mixtures as a strengthening material in vitreous clay pipe (red sewer pipe), clay roof tiles, and drywall joint compounds.

20 SERPENTINE

Serpentine Group of the general formula

$\mathbf{Mg_6(OH)_8(Si_4O_{10})}$ with Fe substituting for Mg and Al substituting for Mg and Si

Serpentine

Cleavage:	None
Fracture:	Uneven, splintery
Hardness:	2.5-5
Sp. Gr.:	2.58-2.59
Color:	Olive green, yellowish green to brown, white
Streak:	White
Luster:	*Non-metallic -- waxy, silky; translucent to opaque
Crystals:	Monoclinic; no known crystals -- chrysotile variety is fibrous; fibers are flexible and tough; most forms are massive
Other:	*Greasy or soapy feel
Name:	The name serpentine is from the Latin *serpentinus*, “resembling a serpent” in reference to the surface pattern of serpentinite rocks, which looks like the skin of a serpent.

Serpentine is a group of minerals that are silicates of magnesium. One variety is chrysotile, a fibrous form also known as ***asbestos***. It is not included in the kit.

Uses of Serpentine: It is used as a decorative material. In its fibrous form, serpentine is a type of asbestos. Asbestos is used to weave fire proof textiles, for high temperature gaskets, and friction products (such as car brakes). Due to the health problems associated with some types of asbestos, all types are being used less and less.

(20) SERPENTINITE (rock)

Serpentinite is the metamorphic rock consisting almost exclusively of members of the serpentine family. These varied rocks form from the alteration of peridot or pyroxene-rich igneous rocks (for example, where basalt contacts limestone in the Salt River Canyon, Arizona).

Uses of Serpentinite: Verde Antique Marble (serpentine & white marble) is a beautiful form of serpentinite. Cut and polished, it is used as a facing stone for building exteriors and interiors. Asbestos is mined out of serpentinites (see serpentine). It is not included in the kit.

75 SHALE (rock)

Shale is a very common dense, sedimentary rock made of silt and clay size particles. These fine-grained particles of pre-existing rocks were transported mechanically to the place of deposition. Shale is generally very thin-bedded and splits along the bedding planes. In fact, the name is probably from the Old English ***scealu***, "shell or husk". Normally gray to black, shale may be brown to dark red, depending on the amount of included iron oxide (limonite or hematite).

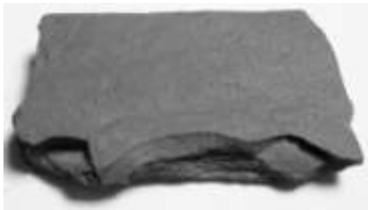
Uses of Shale: Shale is used in the manufacture of ceramic products if the clay mineral content is right.

76 SILICIFIED WOOD (PETRIFIED WOOD)

Silicified wood is a replacement of the original cells or spaces by silica. In permineralization, the empty space in wood is filled with silica to preserve wood grain and cell structure. In replacement, only the form is preserved; the bark texture remains, but no cell structure is visible. Silicified wood is essentially CHERT, a cryptocrystalline variety of quartz. Thus, silicified wood has the same physical properties (conchoidal to subconchoidal fracture, hardness of 7, waxy luster). It is brown to red, yellow, purple and black, depending on the impurities present at the time of replacement.

Uses of Petrified Wood: Silicified wood is used for decorative purposes and in jewelry.

63 SLATE   (rock)



Slate is a metamorphic rock derived from shale. It is a dense, microcrystalline rock. The parallel planes or layers are very evident in its slaty foliation. This foliation is not related to the original sedimentary layers, but occurred when the rock was squeezed by the weight of rocks above it. The slaty cleavage allows it the rock to be split easily into thin layers. It can be gray, black, green or red depending on the composition of the original shale.

Uses of Slate: Slate is used for roofing and flagstone and in the manufacture of roofing granules. Some of the more expensive pool tables have slate table tops. Historically, it was used as chalkboards ("blackboards").

38 SPHALERITE

ZnS Zinc sulfide

Cleavage:	Good cleavage in 6 directions
Fracture:	Conchoidal
Hardness:	3.5-4
Sp. Gr.:	4.1
Color:	Yellow, light to dark brown, black, red-brown, colorless, light blue.
Streak:	Pale yellow to brown (lighter than color of mineral)
Luster:	*Non-metallic -- *resinous, to adamantine, translucent to opaque
Crystals:	Isometric
Other:	Brittle
Name:	From Greek "*sphaleros*", treacherous, which alluded to the ease with which dark varieties were mistaken for galena, but yielded no lead

Uses of Sphalerite: It is the most important ore of zinc. The chief uses for metallic zinc are in galvanizing iron; making brass, which is an alloy of copper and zinc; and in electric batteries. Zinc oxide, or zinc white, is used extensively for making paint. Zinc chloride is used as a preservative for wood. Zinc sulfate is used in dyeing and in medicine. Sphalerite also serves as the most important source of cadmium, indium, gallium, and germanium. **Sphalerite is not included in this study kit.**

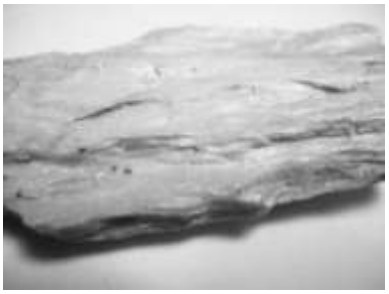
32 SULFUR
S

Sulfur

Cleavage:	Poor in three directions
Fracture:	Conchoidal
Hardness:	*1.5-2.5
Sp. Gr.:	2-2.1
Color:	*Yellow
Streak:	White
Luster:	Non-metallic -- resinous to vitreous; transparent to translucent to opaque
Crystals:	Orthorhombic; crystals common, also massive
Other:	Heat of your hand causes it to crackle; Smells like sulfur
Name:	The origin of the name sulfur is unknown.

Uses of Sulfur: Sulfur is used in the chemical industry, chiefly in the manufacture of sulfuric acid. It is also used in fertilizers, insecticides, explosives, coal-tar products, rubber, medicines, matches, and in the preparation of wood pulp for paper manufacture.

1 TALC
$Mg_3Si_4O_{10}(OH)_2$ (Magnesium Silicate Hydroxide)



Cleavage:	Perfect in one direction
Fracture:	Uneven
Hardness:	*1.1
Sp. Gr.:	2.7-2.8
Color:	Apple green to white, pink, gray
Streak:	White
Luster:	*Non-metallic -- pearly, greasy; translucent to opaque
Crystals:	Rare crystals; usually is foliated, fibrous, compact, and waxy.
Other:	*Powdery or soapy feel
Name:	The name talc comes from the Arabic *talq*, "mica".

Talc develops in an environment of regional metamorphism, such as in schist.

Uses of Talc: As slabs of the rock soapstone, talc is used for laboratory table tops and electric switchboards. Most of the talc and soapstone produced is used in powdered form as a filler in paint, ceramics, rubber, insecticides, roofing, paper, plastics, and foundry facings. The most familiar use is in talcum powder and it is used in many cosmetics. It is used for pitch control in treating wood pulp in the manufacture of paper. The slick coating on pills is talc-based.

8 TOPAZ

$Al_2SiO_4(F,OH)_2$ (Aluminum Silicate Fluoride Hydroxide)

Topaz

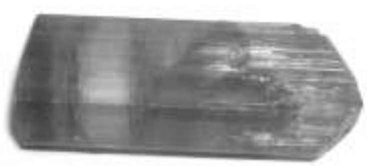
Cleavage:	Perfect one basal direction
Fracture:	Subconchoidal, uneven
Hardness:	*8
Sp. Gr.:	3.4 to 3.6
Color:	White, colorless, yellow, pink, bluish, greenish
Streak:	White
Luster:	Vitreous
Crystals:	*Orthorhombic, usually in stubby to medium-long prismatic crystals often striated lengthwise; also granular, massive
Name:	The name topaz is from Greek *topazos*, a name said to be applied to a gemstone whose identity has been lost; OR from Topazion, an island in the Red Sea (again applied to a different mineral species).

<u>Topaz is generally not included in this study kit.</u>

Uses of Topaz: Topaz is a gemstone and is the birthstone for November.

36 TOURMALINE GROUP

$XY_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$ (Aluminum Borate Silicate Hydroxide)



Tourmaline

Cleavage:	No good cleavage
Fracture:	Conchoidal
Hardness:	*7-7.5
Sp. Gr.:	3.0 to 3.25
Color:	Black (schorl), pink (elbaite and rubellite), bluish (indicolite), greenish
Streak:	None
Luster:	Vitreous to resinous
Crystals:	*Hexagonal (with rounded triangular cross section); usually in stubby to long prismatic crystals, often striated lengthwise
Name:	The name tourmaline is from *turamali*, a name given to the early gems from Ceylon

Topaz is generally not included in this study kit.

Uses of Tourmaline Tourmaline is a semi-precious gemstone. Because of its strong piezoelectric property, it is used in the manufacture of pressure gauges.

72 TRAVERTINE ("ONYX") (rock)

	Travertine is a sedimentary rock. It is limestone that forms in caves and springs. It is generally coarse grained (very sugary looking) and color banded. The latter is a result of the frequent (often seasonal) changes in the chemistry of water in those small terrestrial environments. (See calcite; limestone)

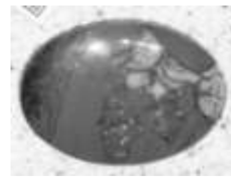
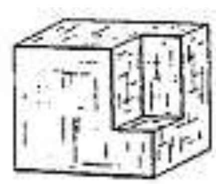
Uses of Travertine: Travertine is soft (composed of calcite, hardness #3) and is fairly easy to carve. Therefore, knick knacks, chess sets, etc. are commonly created out of travertine. Its colors and patterns also make it very decorative and it is used as building facings as well as fireplace fronts, floor tiles, and countertops (although it is subject to dulling from abrasion).

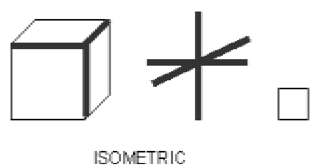
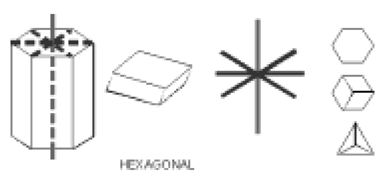
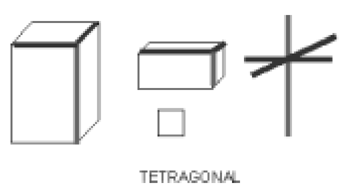
55 TUFF (rock)

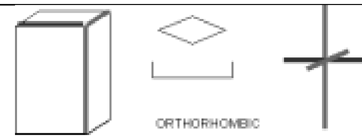
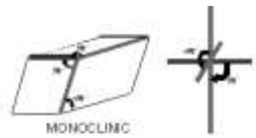
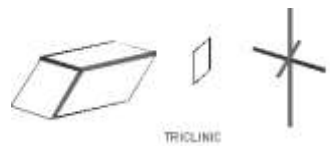
	Tuff is a fine grained igneous rock composed of small volcanic rock fragments and ash. It has a rough gritty feel. (It is different from and should not be confused with tufa, a calcareous precipitate associated with springs.)

Uses of Tuff: Because it is not crystalline, tuff is a lightweight rock. Therefore, it is used as a lightweight building stone and as a lightweight aggregate.

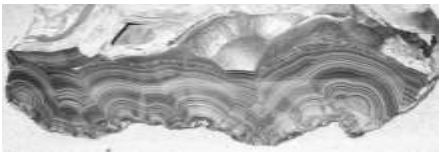
GLOSSARY OF TERMS

Amygdaloidal	Contains holes from gas pockets that are filled with secondary minerals	
Cabochon	A dome-shaped and polished stone (not faceted)	
Cleavage	The tendency of a mineral to break <u>repeatedly</u> along <u>flat</u> surfaces parallel to an atomic plane(s) of weakness (For more information, refer to the mineral key introduction.)	

CRYSTAL SYSTEMS:	The smooth-faced angular shapes assumed by minerals are known as crystals. The crystal's many-sided form is an expression of the regular internal atomic arrangement of the atoms making up any given mineral.	
Isometric	Three axes of equal length oriented 90° to each other (as in a cube)	
Hexagonal	Four axes: three of equal length oriented 60° to each other in one plane, the fourth (longer or shorter) at 90° to that plane	
Tetragonal	Two axes of equal length, the third longer or shorter; all oriented 90° to each other	
Orthorhombic	Three axes of unequal length	

	oriented 90^o to each other	
Monoclinic	Three axes of unequal length; two oriented 90^o to each other, the third <u>not</u> at 90^o	
Triclinic	Three axes of unequal length; No 90^o angles	

CRYSTAL SHAPES	The following terms refer to crystal and crystal aggregate habits (growth forms):	Crystal form is the outward expression of the internal atomic order of a mineral. As such, angles and shapes are consistent and typical within mineral species. This is often a good clue to the identity of a mineral.
Bladed	Long, flat and thin, like a knife blade	
Botryoidal	Cluster of balls (like grapes)	
Cryptocrystalline	Crystals are so minute that they are not distinguishable, even with a microscope	
Fibrous	Mass or aggregate of long, slender, threadlike crystals	

		
Granular	Equidimensional grains	
Lamellar	Thin layers or plates	
Mammillary	Smoothly rounded masses similar to, but larger than botryoidal	
Massive	Structureless; similar in all directions; no layering or foliation	
Pseudomorph	"False form"; the shape of one mineral is occupied by another mineral	
Radial	Long crystals growing and radiating from a central point	
Tabular	Long, flat and thicker than bladed; like a table top	

		
Twin	Two crystals of one mineral that are intergrown in a special fixed relationship	

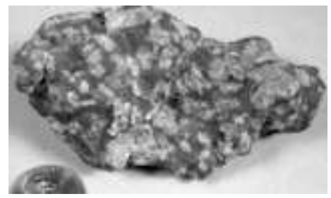
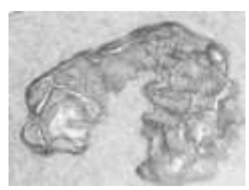
DIAPHANEITY	The way a mineral transmits light	
Transparent	Clear: may be seen through	
Translucent	Cloudy: lets light through, can not be seen through	
Opaque	Does not let light through	

Ductile	Can be drawn into a wire or hammered into a very thin sheet or bent easily without breaking	
Extrusive	Refers to igneous rocks formed from magma that flowed (lava) on the Earth's surface. It is synonymous with volcanic. Its texture is fine-grained, so	

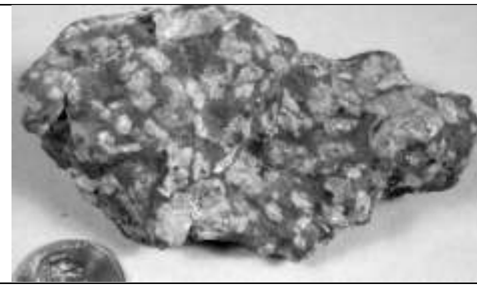
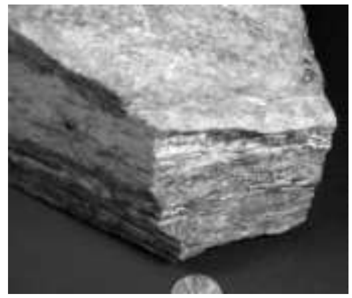
	that you cannot tell which minerals occur in it without a microscope	

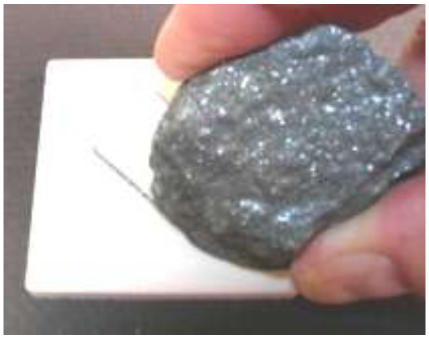
Foliation	a metamorphic feature: the alignment of minerals parallel to each other and perpendicular to pressure, resulting in thin layers or the segregation of minerals of different densities, resulting in banding	

FRACTURE	The tendency of a mineral to break randomly along irregular and non-repeatable surfaces	
Uneven	Irregular surface, but not conchoidal	
Conchoidal	Smooth, shell-like or bowl-like breaks	
Hackly	Jagged, pointy breaks such as occurs in metals	
Splintery	Occurs in aggregates of many	

	slender, brittle crystals	
Hardness	The resistance of a mineral to scratching	See Mohs Scale of Hardness
Igneous Rock	Rock formed from the cooling of molten rock (magma, lava)	
Intrusive	Refers to igneous rocks formed from magma that cooled below the Earth's surface	 gabbro
LUSTER	The way in which a mineral reflects light	
Metallic Luster	Like a metal: shiny, the colors of metals	
Non-metallic Luster	Vitreous (glassy), earthy (like dry mud), resinous (ambers and yellows of resin), pearly (iridescent as a pearl), greasy, dull, adamantine (as a diamond)	
Malleable	Bends easily; will deform	

	under stress (such as when struck with a hammer)	 copper
Metamorphic Rock	Rock which has altered (without melting) under increased temperature &/or pressure &/or the influx/outflux of ions	 gneiss
Mineral	A naturally occurring, inorganic crystalline solid with characteristic physical properties and specific chemical composition or range of compositions	
Mohs Scale of Hardness	An arbitrary scale of 1 to 10 used to determine the scratchability of an unknown sample relative to that of a known. For example, a mineral with an assigned hardness of #3 is softer than one of #4. #4 will scratch #3 (For more information, refer to the Mineral Key introduction.)	1 Talc 2 Gypsum **2.5 Fingernail** 3 Calcite **3 Penny** 4 Fluorite 5 Apatite **5-5.5 Penknife** **5.5 Glass** 6 Feldspar **6.5 Darning needle/steel file** 7 Quartz 8 Topaz 9 Corundum 10 Diamond
Parting	Separation along planes that are NOT cleavage planes (does not usually occur with the same repetition as cleavage) ex. Flat base on ruby crystal.	
Porphyritic	Igneous texture with fine-grained matrix containing	

	some large rectangular crystals	
Regional Metamorphism	Metamorphism which occurs on a very large scale	
Rock	Natural aggregate of minerals (or accumulation of organic material, as in the cases of coal and diatomite)	
Secondary Mineral	A mineral formed by the alteration of pre-existing minerals	
Sedimentary Rock	Rock formed at the Earth's surface either as accumulations of particles (sediment) or as chemical precipitates	
Specific Gravity	The density or relative weight of a mineral; specifically the ratio of the mass of a mineral to the mass of an equal volume of water. This can be	

	determined by the following formula: **Specific Gravity =** $\frac{\text{Weight of mineral in air}}{\text{Weight of mineral in air - weight of mineral in water}}$ (For more information, refer to the Mineral Key introduction.)	
Streak	The color of the powder of a mineral; generally determined by rubbing a mineral across a tile of unglazed porcelain	
Vesicular	Having many small holes that were gas bubbles when the lava came out of the vent	

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EDUCATOR INTERNET RESOURCES

Web Resources

http://www.mii.org/teacherhelpers.html
http://www.mnh.si.edu/earth/main_frames.html?7_0_0
http://www.geosociety.org/educate/LessonPlans/i_rocks.htm
http://geology.com/teacher/
http://www.smithsonianeducation.org/educators/index.html
http://www.proteacher.com/110073.shtml
http://www.lessonplanspage.com/ScienceArtLACIMDRockingWithMineralsUnit4.htm
http://www.calmineraled.org/Teaching.htm
http://www.agiweb.org/geoeducation.html
http://pubs.usgs.gov/gip/2005/17/
http://www.geosociety.org/educate/resources.htm
http://geology.about.com/od/teacher_aids_5_to_8/Grades_51508_Teachers_Resources.htm
http://www.thegateway.org/
http://www.nef1.org/outoftherock/teachers.htm
http://www.womeninmining.org/
http://www.rogersgroupinc.com/ourcommunities/rockology/index.htm
http://www.martinmarietta.com/Education/geology.asp
http://www.mine-engineer.com/
http://www.doi.gov/teachers/index.html
http://www.learnnc.org/lp/pages/1952
http://www.bcminerals.ca/files/teacher_resources.php
http://www.onemine.org/search/index.cfm/teacher-resources
http://geology.about.com/od/teacher_aids_k_to_4/Grades_K1504_Teachers_Resources.htm
http://www.minequest.org/Pages/lessonlinks.htm
http://www.teachers.ash.org.au/jmresources/rocks/links.html
http://www.tasminerals.com.au/educational-links.pdf
http://edtech.kennesaw.edu/web/rocks.html

Mineral and Geology Museums in Arizona

Arizona Mining and Mineral Museum
Arizona State University Center for Meterorite Studies : http://meteorites.asu.edu/
Arizona State University Geology Museum : http://www.asu.edu/museums/ns/dietz.htm
Arizona-Sonora Desert Museum : http://www.desertmuseum.org/
University of Arizona Mineral Museum : http://www.uamineralmuseum.org/
Arizona Mineral and Mining Foundation : http://www.azminfun.com/
Friends of the Arizona Mining & Mineral Museum : http://www.fammm.org/FAMMM/Welcome.html
Mining Foundation of the Southwest : http://www.miningfoundationsw.org/

Mineral Education Information and Resources

American Coal Foundation : http://www.teachcoal.org/
Arizona Foundation for Resource Education : http://www.azresourceed.org/
Copper Info - Worldwide Copper Information : http://www.copperinfo.com/index9.html
Mineral Information from Rockman : http://www.rocksandminerals.com/minfind.htm
Minerals Information Institute : http://www.mii.org/
National Energy Foundation : http://www.nef1.org/
National Mining Association : http://www.nma.org/

U.S. Geological Survey Learning Web (Educational Resources) : http://education.usgs.gov/
Women in Mining : http://www.womeninmining.org/

Mineralogy Links

Athena Mineralogy Earth Science Links : http://un2sg4.unige.ch/athena/mineral/minlinks.html
Links for Mineralogists : http://www.mineralogie.uni-wuerzburg.de/links.html
Glendale Community College - Rocks and Minerals :
http://www.gc.maricopa.edu/earthsci/imagearchive/geology.htm
Mindat.org : http:/www.mindat.org/
Mineralogy Database : http://webmineral.com/
Opaque Mineral Atlas and Ore Minerals: http://www.smenet.org/opaque-ore/

Mineralogical Societies

American Federation of Mineralogical Societies : http://www.amfed.org/
Fluorescent Mineral Society : http://www.uvminerals.org/
Mineralogical Society of America : http://www.minsocam.org/
Mineralogical Society of Arizona : http://www.azminerals.com/
Rocky Mountain Federation of Mineralogical Societies : http://www.rmfms.org/
Tucson Gem and Mineral Society : http://www.tgms.org/

Magazines for the Amateur Mineralogist and Lapidary

American Mineralogist : http://www.minsocam.org/msa/ammin/toc/index.html
Lapidary Journal : http://www.lapidaryjournal.com/
Mineralogical Record : http://www.minrec.org/
Rock and Gem : http://www.rockhounds.com/
Rocks and Minerals : http://www.rocksandminerals.org/


1 talc


2 gypsum

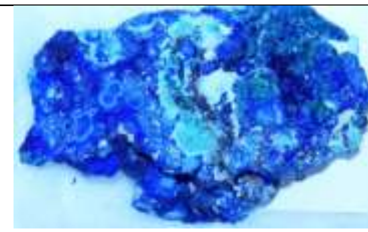

3 calcite


4 fluorite


5 orthoclase


7 quartz


11 chrysocolla


12 azurite

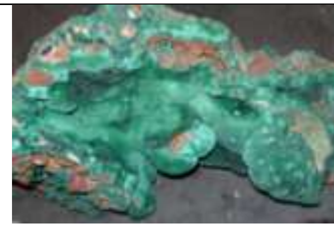

13 quartz (chalcedony)


14 chalcopyrite


15 barite


16 galena


17 hematite

 18 garnet	 19 magnetite	 21 malachite	 22 muscovite	 23 bornite
 24 halite	 26 limonite	 27 pyrite	 28 olivine (peridot)	 20 serpentine
 30 copper	 31 glauberite pseudomorph	 32 sulfur	 33 quartz (rose)	

50 obsidian (Apache tear)

51 basalt (vesicular)

52 pumice

53 perlite

64 gneiss

54 obsidian

55 tuff

56 rhyolite

57 granite

60 quartzite

61 schist

62 marble

63 slate

65 metaconglomerate

66 phyllite

70 sandstone

71 fossiliferous limestone

72 travertine

73 conglomerate

74 breccia

75 shale

76 silicified wood

77 coal

78 diatomite

Drill core

chert