MINERALS/ELEMENTS IN THE EARTH'S CRUST

Nearly all the elements known to man are found in the earth's crust. (8 to 16 miles below surface). A few are found in the atmosphere. However, over 98 percent of all rock materials found at or below the surface are made up of only eight chemical elements as listed below.

Some rock types such as granites, diorites, and diabases contain all of these eight elements. Some minerals may be composed of only two of these elements such

ELEMENT	% EARTH'S CRUST	ROCK OR MINERAL
OXYGEN	46.5	MANY ROCKS & MINERALS
SILICON	27.6	QUARTZ (MANY OTHERS)
ALUMINUM	8.1	KAOLINITE
		PLAGIOCLASE
		MICA
IRON	5.1	MAGNETITE
		HEMATITE
CALCIUM	3.6	CALCITE
		GYPSUM
		ARAGONITE
SODIUM	2.7	HALITE (rock salt)]
		SODIUM FELDSPAR
POTASSIUM	2.6	POTASSIUM FELDSPAR
MAGNESIUM	2.1	TALC
		DOLOMITE
		SERPENTINE

as Quartz(only silicon and oxygen). Oxygen is found in combination in a high percentage of all rocks and minerals.

ROCKS, MINERALS AND MAN

Man has used rocks, minerals and gemstones to his benefit since the beginning of time. Stone age artifacts reveal that since the earliest history the advance of man has been closely associated with his advances in mining and learning uses for rocks and minerals. Rock tools/weapons were fashioned from rocks (obsidian, basalt, quartz etc.) by primitive man. With the discovery of metals, Man's tools became more complex. Bronze (an alloy of tin and copper) was used for thousands of years(the bronze age). When iron and aluminum were discovered, better tools etc. could be made. Man has fashioned colorful minerals (gemstones) into jewelry since the stone age and today jewelry making is a big business. Today, Our lives depend on rocks and minerals and can best be summed up with the slogan: **"IF IT CANNOT BE GROWN, IT HAS TO BE MINED"**

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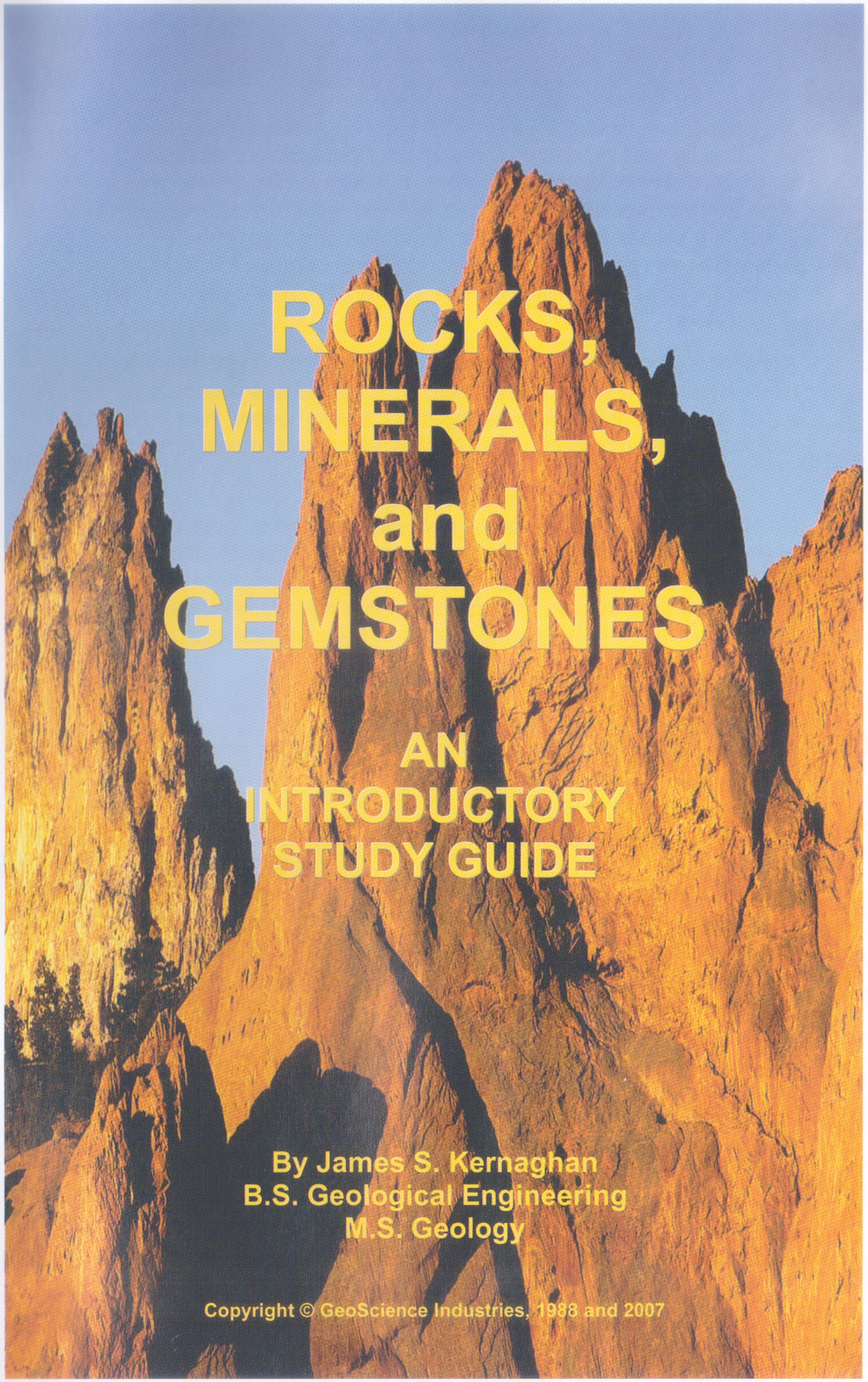


INTRODUCTION

The increasing awareness of a critical shortage of many natural resources helps to emphasize the need for a better understanding of the occurrence, availability, and identification of the natural materials known as rocks, minerals, and gemstones. Man's existence is directly dependent upon his knowledge of rocks and minerals. The earth is composed of a dense core with lighter rock masses toward the surface. The term ***geology*** is used to describe the study of minerals, rocks and the process that form them. ***Mineralogy*** is the study of minerals and ***petrology***, the study of rocks.

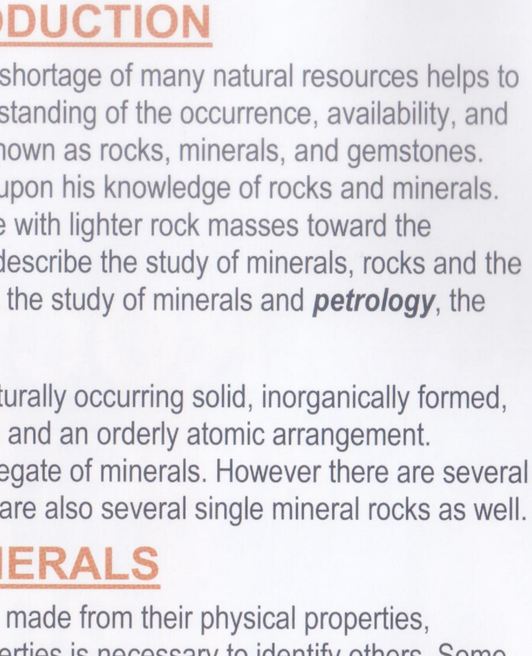
A **mineral** is generally defined as a naturally occurring solid, inorganically formed, having a definite chemical composition and an orderly atomic arrangement.
A **rock** is generally defined as an aggregate of minerals. However there are several exceptions, Coal and obsidian. There are also several single mineral rocks as well.

MINERALS

Identification of many minerals may be made from their physical properties, whereas examination of chemical properties is necessary to identify others. Some of the simpler physical and chemical tests can be done satisfactorily with very little equipment, while identification of some rare minerals may require extensive laboratory equipment in the hands of an expertly trained mineralogist.

MINERAL PROPERTIES

HARDNESS (H) The determination of the hardness of a mineral can be an important step toward its identification. The term hardness is used with a special meaning for the mineralogist. It is the resistance which the smooth surface of a mineral offers to be scratched. A diamond is the hardest of all substances and can be scratched only by another diamond.



Over a century ago, Friedrich Mohs, by experimentation, made up a scale of hardness which is generally referred to as Mohs' scale. It does not imply an exact hardness, but is set up so that any mineral can scratch all those beneath it in the scale, or can be scratched by those above it in the scale. Since *diamond* is the hardest it is given number 10; *talc* is the softest so it is given number 1. *Quartz*, number 7, is often used as a division in the scale and all those 7 or above are called hard minerals.

SPECIFIC GRAVITY (G) The relative weight of a mineral when compared with the weight of an equal volume of water is the specific gravity (G) of that mineral. The specific gravity of *gypsum* is 2.3 (water as 1), *quartz* and *calcite* are both 2.7. *Muscovite mica* is 2.8, *topaz* is 3.5, and gold is 19.3.

MINERAL	SPECIFIC (G) GRAVITY	(H) HARDNESS
Alabaster	2.3	2
Albite	2.6	6
Anorthite	2.7	6
Apatite	3.1-3.2	5
Aragonite	2.9	3.5-4
Augite	3.2-3.4	5-6
Autunite	3.1-3.2	2-2.5
Azurite	3.7	3.5-4
Barite	4.5	3-3.5
Bauxite	2.0-2.5	1-3
Beryl	2.7-2.8	7.5-8
Biotite (mica)	2.8-3.2	2.5-3
Borax	1.7	2-2.5
Bornite	5	3
Calcite	2.7	3
Chalcopyrite	4.1-4.3	3.5-4
Chlorite	2.6-2.9	2-2.5
Chrysocolia	2.0-2.4	2-4
Chrysotile	2.2	2.5
Cinnabar	8.1	2.5
Copper	8.9	2.5-3
Corundum	4	9
Cuprite	6	3.5-4
Diamond	3.5	10
Dolomite	2.8	3.5-4
Epidote	3.4	6-7
Fluorite	3.2	4
Galena	7.5	2.5
Garnet	3.5-4	6.5-7.5
Gold	15-19	2.5-3
Graphite	2.3	1-2
Gypsum	2.3	2
Halite	2.1	2.5

MINERAL	SPECIFIC (G) GRAVITY	(H) HARDNESS
Hematite	5.3	5.5-6.5
Hornblende	3.2	5.6
Kernite	1.9	3
Kyanite	3.5-3.6	5-7
Lepidolite	2.8-3.0	2.5-4
Limonite	3.6-4	5-5.5
Magnetite	5.2	6
Marcasite	4.9	6-6.5
Microcline	2.5	6
Molybdenite	4.6	1-1.5
Muscovite (Mica)	2.7-3	2-2.5
Olivine	3.2-4.3	6.5-7
Opal	1.9-2.2	5-6
Orthoclase	2.6	6
Phlogopite (Mica)	2.8	2.5-3
Plagioclase	2.6-2.7	6
Psilomelane	3.7-4.7	5-6
Pyrite	5	6-6.5
Pyrolusite	4.7	1-2
Pyrrhotite	4.6	4
Quartz	2.7	7
Scheelite	6	4.5-5
Serpentine	2.2	2-5
Sphalerite	3.9-4	3.5-4
Sulfur	2.1	1.5-2.5
Talc	2.7	1
Topaz	3.5	8
Tourmaline	3.0-3.2	7-7.5
Triphylite	3.4-3.6	4.5-5
Uraninite	9.0-9.7	5.5
Vanadinite	6.7-7.1	3
Vermiculite	2.4	1.5

CRYSTAL FORM Most naturally occurring minerals will display a crystal form which is predictable and consistent with that particular mineral. The crystal form indicates the internal molecular arrangement within the mineral. Six systems of crystal forms are recognized which are the basis of a science called crystallography. The six crystal systems are:

Isometric *(cubic) s*ystem includes crystals in which the three axes are of equal length and are at right angles to one another. *Fluorite*, *pyrite*, and *garnet* are examples.

Tetragonal system has two axes of equal length and one unequal. All three axes are at right angles to one another. *Zircon* is an example.

Hexagonal system has three axes of equal length at 120 degree angles arranged in one plane and one more axes at right angles to these. Examples include *quartz, beryl, calcite*, and *dolomite*.

Orthorhombic system has crystals with three axes all at right angles, but all are different lengths (such as *aragonite and barite*).

Monoclinic system has three unequal length axes, two of which are not at right angles. The third makes a right angle with the plane of the other two. Many rock forming minerals such as *orthoclase, mica, augite, epidote*, and *hornblende* crystallize in this system.

Triclinic system has three axes of different lengths all at different angels. Examples are rare in this system, but include *microcline (amazonite)*.

CLEAVAGE The way in which some minerals will split or cleave precisely along planes related to the internal molecular structure is called cleavage. In some minerals the cleavage is parallel to a crystal face. Good cleavage is demonstrated in some minerals such as *mica*, *calcite*, and *orthoclase*, but may be only slight or completely absent in other minerals.

FRACTURE the breakage of a mineral specimen which does not relate to cleavage (along a cleavage plane) is called fracture. Most minerals will show a fracture which can be characterized as typical of that mineral, such as earthy, uneven, Conchoidal, etc.

COLOR In many metallic ores color is a dependable clue for identification, but in some minerals such as *quartz*, *calcite*, *garnet*, *tourmaline*, and others, color may be the result of slight impurities and will vary greatly.

STREAK When a mineral is rubbed against a piece of unglazed porcelain (tile) a streak of powder will result. Especially in metallic ores, the streak may differ from the color of the mineral and then becomes a valuable clue to identification.

LUSTER The surface appearance of a mineral as it adsorbs, reflects, or reacts light is termed its luster. Generally the luster may be described as metallic or non-metallic, and more specifically by several other terms such as glassy, resinous, silky, dull, earthy, etc.

OTHER PROPERTIES The physical properties of some minerals can be identified only with special equipment. Examples are: radioactivity (Geiger counter); magnetism (magnet); fluorescence (ultra violet light).

METALLIC MINERALS

Some of the minerals in this group appear in nature as elements, such as gold or copper, but more commonly the metal is in combination with other elements forming chemical compounds such as sulfides, oxides etc.. The mineral from which a metal (element) is extracted is generally referred to as an ore.

COPPER Nuggets of this element were used by ancient man. He could hammer this metal into various shapes with hard rocks and make useful tools and vessels. Copper today has many uses. The ores of copper are found in many parts of the world. The various copper minerals have distinctive colors ranging from the color of a copper cent to reddish-brown, black, green, and blue.

Some of the more important copper minerals are: *Azurite, bornite*, *chalcopyrite*, *chalcocite*, *chrysocolla*, *covellite*, *cuprite*, and *malachite*.

LEAD This metal rarely found in nature in the native (elemental) form. It has been used by man since ancient times. Commonly found in the mineral *galena*.

Galena, a lead sulfide is the most important source of lead. It is often found in association with zinc, copper, and silver minerals. *Cerrusite*, a lead carbonate, and *anglesite*, a lead sulfate, are other lead minerals found in nature.

GOLD This valuable metal is often found in nature, in the native form, associated with *quartz* and sometimes with *pyrite (fools gold)*. When deposits containing gold are eroded, the heavy gold (G 19.3) may become concentrated in the gravel of stream beds. Used in making jewelry and as the basis of many monetary systems.

Only rarely is visible gold found in gold ore. It does occur as a compound with *tellurium* in rare minerals such as *sylvanite* and *calaverite*.

SILVER This metal has been used by man for many centuries. It sometimes is found as native silver. Silver may be a valuable bi-product when lead, zinc, and other metals are refined from their ores. The sulfide, *argentite*, is another important source.

IRON Soon after man found ways to separate iron from its ores, it became the most used and important metal. Large deposits of various iron minerals are found in many places throughout the world including Wisconsin, Michigan in the United States. Iron oxides such as *hematite*, *limonite*, and *magnetite* provide the most usable iron ores. The sulfides, *pyrite*, *marcasite*, and *pyrrhotite* are also sources of iron.

NICKEL This metal presented problems in smelting in the early days of mining in Europe. However, it was found to have important uses in alloys and for use in coins. *Niccolite*, *millerite*, and *pentlandite* are ores used in obtaining this metal. Large deposits are found in northern Canada.

TIN In its oldest use tin was alloyed with copper and zinc to make bronze. Billions of "tin" cans are made yearly which employ a thin coating of tin over a can made largely of iron. Only one mineral, *cassiterite*, a tin oxide, is of importance as an ore of tin. Tin has been used in some parts of the world to make coins.

ZINC An early use of zinc was to alloy it with copper to produce brass. Zinc now has many other uses. It is used as a coating for iron to prevent rust (galvanized iron) as well as in dry cell batteries, paints, and other products of the chemical industry. *Sphalerite*, (a zinc sulfide) is the most important mineral and ore of zinc.

ALUMINUM Perfecting a satisfactory means of separation of this metal from its ores prevented its commercial use in large quantities until about 100 years ago. It is now widely used in construction and transportation industries and in implements of many kinds. Billions of aluminum cans are produced each year. *Bauxite* is the principal ore of aluminum and is a group of related oxides rather than a single mineral. *Kyanite*, *corundum*, and *kaolinite* are all high in aluminum content but not used for the extraction of aluminum commercially.

MANGANESE This metal is widely dispersed and often found in association with iron, barium, cobalt, and zinc. *Rhodonite*, *psiilomelane*, and *Pyrolusite* are examples of minerals which contain manganese and can be used as ores..

URANIUM This metal was discovered before 1800 but only recently became known as a source of energy. It may be found in as many as 50 minerals, but most of these are rare. *Uraninite*, *carnotite*, *uranophane*, and *autunite* are some of the better known minerals which are a source of uranium. *Pitchblende*, which is more common and better known by that name, is a form of the mineral *uraninite*.

TUNGSTEN This metal is used in lamp filaments and steel-alloy cutting tools. *Wolframite* and *scheelite* are both ores of tungsten.

VANADIUM This metal has an important use in steel alloys. The minerals

MOLYBDENUM This metal has become an essential in tool-steel alloys. *Molybdenite* is the chief mineral source of molybdenum.

BERYLLIUM This metal is used in alloys of copper and in atomic research. *Beryl* is the chief mineral source of beryllium.

TITANIUM This light weight metal is of importance in rocket construction, steel alloys, and white paints. *Rutile* and *Ilmenite* are mineral sources of titanium.

MAGNESIUM This metal which is lighter in weight than aluminum has become a metal of major importance in sheet metal products, and in casting. Its two principal ores, *dolomite* and *magnesite*, are found in many parts of the world.

NONMETALLIC MINERALS

This large group of minerals contains no metal, or are not of importance for the metal they contain. Some very common minerals belong in this group and are of use in insulations, filters, ceramics, and other chemical industry products.

SULFUR This is one of the few nonmetallic minerals which occurs as an element. It also is found in combination with many metals to form the large group known as the sulfides. Examples of this group are *pyrite* (iron), *galena* (lead), *realgar/orpiment* (arsenic), *sphalerite* (zinc), *millerite* (nickel), *cinnabar* (mercury), and *argentite* (silver).

GRAPHITE This is another of the minerals which occurs as a native element. Carbon is the only element in both graphite and diamond. Graphite is very soft (H1). Some of graphite many uses include the manufacture of pencils and lubricants.

CALCITE This versatile mineral is a calcium carbonate and appears in many crystal forms and in masses. Calcite is the principal mineral in limestone and is a vein mineral in many rocks. Iceland spar is a transparent crystal of calcite and is of great value in range finders, and specialized microscopes. Most calcite is opaque and slightly colored by impurities. *Travertine*, *tufa*, and *onyx* are rocks and minerals composed of calcite.

ARAGONITE This mineral is chemically the same as *calcite*, but crystallizes in a different form. Coral, formed by plants and animals, is composed of aragonite. Cave formations are also made of aragonite.

DOLOMITE The mineral dolomite has many similarities to calcite but chemically it is a carbonate of both calcium and magnesium. Dolomite is considered as both a rock and mineral. There are extensive rock deposits such as those in Austria referred to as the Dolomite Alps.

GYPSUM This is a very common mineral and as a sedimentary rock is known a *rock gypsum.* It is found in massive beds or layers throughout the world . It is used extensively in producing plaster and related products. *Selenite* is a variety found in broad transparent cleavages folia. *Alabaster* is a fine-grained massive variety suitable for carving, and *satin spar* is a fibrous gypsum with silky luster.

HALITE This mineral is known in every household as common table salt. Halite came directly from the evaporation of sea water in ancient times. It is rarely pure, usually being associated with other salts of calcium and magnesium.

BORAX This mineral is used as a household cleanser and also in making glass, enamels and other chemical industrial materials. *Kernite* and *colemanite* are minerals closely related to borax.

FLUORITE This attractive mineral is found in various colors and has several uses. It is of value as a flux in steel making and in smelting ores. It is used in making high-test gasoline, freon, and other products of a chemical nature.

BARITE This barium sulfate is found in association with many metallic ore deposits such as the lead deposits of Missouri, Kansas and Oklahoma. It is a heavy mineral (G4.5) and is used in paints, glass, filler in paper, and ceramics.

APATITE This mineral is a calcium phosphate with some fluorine, and appears in a wide variety of colors. It is found in veins with *quartz* and *feldspar* and sometimes associated with iron ores. Used to make phosphate for fertilizers.

TALC This familiar mineral has many uses past and present, the best known being talcum powder. It is generally formed by the alteration of magnesium-rich rocks and is found in association with its parent minerals. It has other uses such as fillers in paints, insecticides, rubber, lubricants, and in paper making.

QUARTZ This is one of the most common and wide-spread minerals in the earth's crust. Quartz in various forms has a valued use as gemstones. In other forms natural quartz crystals are of great value in their ability to generate a minute electrical charge which can be applied to the fields of radio, television, and other forms of communication. Quartz sand is used in making glass. The main ingredient for many igneous rocks, sedimentary sandstones, and metamorphic quartzites. Some of the various forms of quartz are: *rose quartz*, *amethyst*, *citrine*, *chalcedony*, *jasper*, *flint*, *agate*, and *chert*.

OPAL This mineral is a special form of quartz in a non-crystalline form and contains varying amounts of water in the chemical structure. Highly prized as a gemstone because of the red, green, and blue colors found in gem opal. Common opal is the term used for the general opal without the colors. Some opal fluoresces a bright yellow green color under ultraviolet light.

ROCK FORMING MINERALS

The minerals of this group compose the building blocks of the solid earth. They are the substance of the mountains and furnish the minerals and particulates found in soils. Nearly all of the rock-forming minerals are silicates, that is, they contain one or more metals in combination with silicon and oxygen. Some minerals, already considered, are also rock-forming minerals. They are *quartz*, *calcite*, *dolomite*, *gypsum*, and *halite*.

MICAS are an unusual family of minerals. The distinguishing feature is the perfect basal cleavage which causes them to split in thin sheets. All of the micas are silicate minerals, and all have aluminum present in addition to other specific minerals. *Biotite* is a dark mica and is abundant in some granites, schists, and in gneiss. *Muscovite* is a light colored, sometimes nearly colorless mica. Mica crystals, often called books, may reach a considerable size. *Phlogopite* is related to biotite and may be found with it. Brown is its predominant color. *Lepidolite* is the lithium-bearing mica. It is an attractive lavender and less often a pale yellow.

VERMICULITE is a mineral related to the micas and cleaves like a mica.. It is used for insulation, light weight aggregates, and potting soils. It will expand up to 13 times in thickness when heated.

FELDPARS if considered as a single mineral would be even more abundant than quartz. They are all aluminum silicates combined with other metals. *Orthoclase* is described as a potash feldspar because of the potassium present. Other minerals present cause specific varieties of orthoclase. *Microcline* is also a potash feldspar and is more widely dispersed than is orthoclase. *Amazonite* is a particular variety of microcline. *Albite* is one of the plagioclase feldspars and is the sodium member of this group. *Anorthite* is the calcium member of this feldspar group which begins with *albite*(the sodium member).

AMPHIBOLES are a group of hydrous silicates containing varying amounts of calcium, magnesium, and iron. *Hornblende* is a black to dark green and the most common of the amphiboles.

PYROXENES are closely related to the amphiboles. They are described as complex silicates and are found as primary minerals in igneous rocks. *Augite* is the most common pyroxene.

TOURMALINE This is a complex silicate with *aluminum*, *boron*, and several other metals. It is most often black but may occur in many other colors such as blue, green, red, pink, and yellow. Used as a gemstone.

GARNET This group of minerals is placed with the rock forming minerals because of their association with them, but are better known as gems. They all form distinct many sided crystals which become easily recognized with practice.

OLIVINE This mineral is characterized by its various shades of green. It is found in igneous rocks high in magnesium and iron.

CHLORITE This mineral is often found as an alteration product of rocks rich in *pyroxenes*, *amphilboles*, and *biotites*. It usually is greenish but may exhibit other colors. It forms in masses, crusts, fibers, and bladed crystals.

SERPENTINE Massive serpentine may be white and through all shades of green and black. It is a magnesium silicate and may include small amounts of iron or nickel.

EPIDOTE This mineral may appear in crystal or massive form and appears in many types of metamorphic rocks. It is generally pistachio green but can be almost black.

ROCKS

Rocks are the building blocks of the planet earth. A rock may consist of a single mineral but most are composed of several minerals. The individual minerals sometimes are identifiable but they may be composed of glasses or other massive material and as such are a mixture of other rock and mineral forms. Some of the single mineral rocks may be entirely composed of *quartz*. *Gypsum*, or *dolomite*. The three rock classes (igneous, metamorphic and sedimentary) are described on the following pages. Rock classification charts are near the end of this guide.

IGNEOUS ROCKS

Igneous rocks come from magmas which are described as molten mixtures of minerals. If the magmas cool beneath the surface of the earth, they are classified as intrusive rocks. These may later be exposed by erosion. Other magmas which reach the surface are termed extrusive rocks and are commonly called lava or volcanic rocks. See the classification chart near the back of this guide.

INTRUSIVE ROCKS Some of the intrusive rocks formed near the surface grade into the extrusive types. Those that cool in deeper zones form larger crystals because they cool slower and therefore, form a coarse texture with minerals easily visible.

GRANITE This is the best known of the intrusive igneous rocks. It generally is light colored and is composed of varying amounts of *feldspar* and *quartz*, with some *mica (muscovite or biotite)* or *hornblende*. *Granite*, *pegmatite*, and *syenite* are typical light-colored intrusive rocks, while *diorite*, *gabbro*, and *peridotite* are dark with a higher content of ferro-magnesian minerals such as amphiboles and pyroxenes.

EXTRUSIVE ROCKS are formed when molten material is forced out through fissures in the crust of the earth and from volcanoes. Most of these rocks are fine-grained or even glassy because cool rapidly with no time to form large crystals.

RHYOLITE is a light-colored acidic rock which has much the same chemical composition as *granite*. It is fine grained and the individual minerals are hard to see with the naked eye.

OBSIDIAN is also known as natural glass and is formed by rapid cooling of molten material.. Used by ancient man for tools and weapons because it can be flaked.

PUMICE is lava which is frothed by the release of natural gases followed by rapid cooling leaving bubble holes from the gas. Most pumice will float on water.

ANDESITE This form is intermediate in composition between *rhyolite* and *basalt*. It contains little or no *quartz*.

BASALT is widespread in many parts of the world. It is the common dark, heavy lava composed mainly of *pyroxene* and *plagioclase feldspars*.

SEDIMENTARY ROCKS

Erosion of all types, running water, wind, waves, currents, ice, and gravity break-up and transport exposed rocks and minerals. When these eroded materials again become consolidated they are called sedimentary rocks. Soft sedimentary rocks form in layers and some may contain forms of plant and animal life.

SANDSTONE is formed by the long-term action of water and wind on the older exposed rocks. It is composed mainly of quartz grains and cemented with silica, lime, or iron oxides. Arkose, a type of sandstone, contains sand size particles of *quartz*, *mica* and *feldspar* cemented together. Pure quartz sandstone is used to make glass.

SHALES are formed from deposits of clays which have subsequently been hardened into rock. Shales often contain well preserved invertebrate fossils.

OIL SHALE is a reservoir for crude petroleum which was trapped as organic matter when the unconsolidated clay materials were deposited..

LIMESTONES These rocks consist mainly of the mineral *calcite* with minor amounts of *iron, manganese etc.* and vary greatly in color, texture, and origin.

FOSSIL LIMESTONES contain the fragments or complete fossils imbedded in the limestone. The type of limestone known as *coquina limestone* is composed of water worn fragments of fossil pelecypods cemented together in a layer of rock.

TUFA is a light, porous *limestone*, formed when calcite or aragonite is deposited in springs on water plants and other organic debris. Also known as *calcareous tufa*..

CONGLOMERATES are sedimentary rocks composed of rounded pebbles cemented with silica, iron oxides or clay particles. They grade into sandstones as the pebble size decreases.

METAMORPHIC ROCKS

Rocks which have been changed after their original formation are said to be metamorphosed. Any rock, igneous, sedimentary, or another metamorphic rock may be altered to form a new metamorphic rock. The changes result from heat, pressure, or by invasion of another substance or by any combination of these forces. The changes may be slight or an entirely different crystalline structure may result with the formation of new minerals.

SLATE is the result of a change in a *shale*. The original bedding may be seen, but the flat cleavage planes of the slate do not necessarily conform to any of the original structure. Used to make roof tiles for buildings in many parts of the USA.

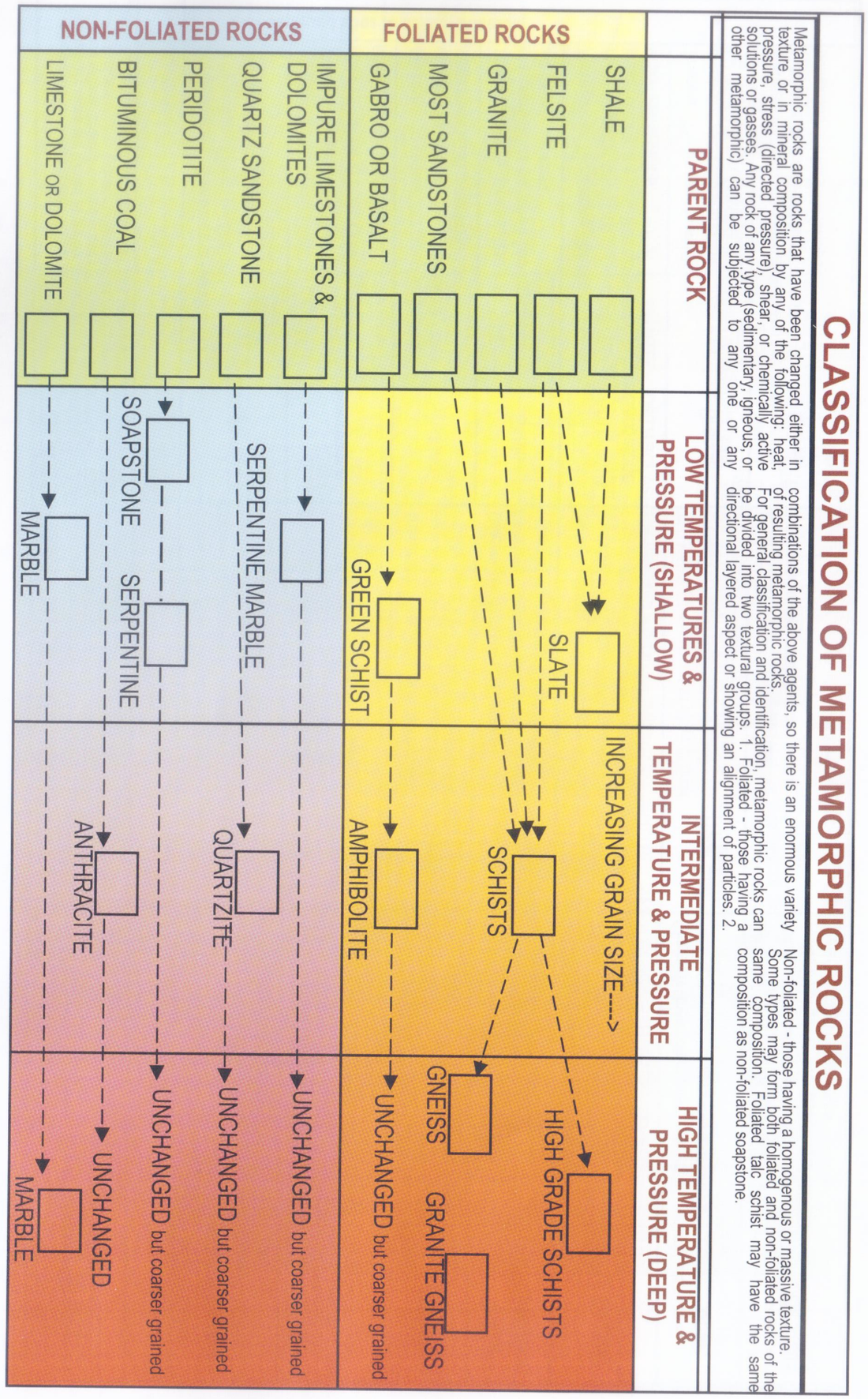
MARBLE is a form of re-crystallized *limestone* and is the result of metamorphism involving heat and pressure. Both coarse grained and fine grained marbles exist. Marbles containing other minerals such a serpentine, amphiboles etc. are produced from the metamorphism of impure limestones.

QUARTZITE is usually the end-product of a sandstone which has been metamorphosed. A re-crystallization forms a hard, tough rock.

PHYLLITES represent the transition in grain size between *slates* and *schists*.

SCHISTS are named for their most dominant mineral present, such as, *mica schist*, *hornblende schist*, *chlorite schist*, etc. Schists may contain other minerals such as *garnet* and *staurolite*.

GNEISS may be a metamorphosed granite or it may be more complex. It generally has a coarse-textured appearance with obvious parallel mineral bands. Gneiss is further characterized by naming its most dominant mineral or apparent origin such as *muscovite gneiss*, *granite gneiss*, *hornblende gneiss*, etc.



CLASSIFICATION OF IGNEOUS ROCKS

Igneous rocks are formed by the cooling and crystallization of a magma. A magma is a natural hot melt composed of a solution of rock forming materials (largely silicates) and some gases that are held in solution by pressure. Rocks that crystallize deep in the earth are termed intrusive (granite and gabbro). Rocks formed at the surface from the action of volcanoes (lava flows) are termed extrusive (rhyolite and basalt). Igneous rocks are classified on the basis of their texture and composition. Texture relates to the size, shape and arrangement of the constituent minerals. Composition relates to the amounts of the different minerals present. The cooling history of the rock generally has considerable influence on the resulting texture. Usually the slower the rate of cooling, the coarser the crystals. Rocks which cool at or near the surface commonly cool more rapidly and are fine-grained. Rocks that cool deep below the surface cool slowly and are coarse-grained.

ESSENTIAL MINERALS The mineral composition of each rock identifies and may influence the name of that rock.	QUARTZ ORTHOCLASE PLAGIOCLASE MUSCOVITE BIOTITE AMPHIBOLE PYROXENE OLIVINE				**ULTRABASIC ROCKS**
	ORTHOCLASE > PLAGIOCLASE MUSCOVITE, BIOTITE OR AMPHIBOLE MAY BE PRESENT		ORTHOCLASE = PLAGIOCLASE BIOTITE< AMPHIBOLE, AND/OR PYROXENE QUARTZ MINOR	PLAGIOCLASE > ORTHOCLASE BIOTITE, AMPHIBOLE, PYROXENE	(Low in silica content) (No Quartz or Feldspar
	Quartz	No Quartz		Quartz Absent	Olivine & Quartz Absent	
Coarse-Grained (Phaneritic) Mineral grains or crystals are nearly equal in size and visible to the unaided eye. Rocks are formed deep in the earth.	GRANITE	SYENITE	MONZONITE GRANODIORITE	DIORITE	GABBRO	PERIDOTITE (Pyroxene & Olivine) DUNITE (Olivine Only) PYROXENITE (Pyroxene Only)
Porphyritic Mineral grains or crystals are of two distinct sizes visible to the unaided eye. The term also applies to a coarse matrix and some even larger crystals.	GRANITE PORPHYRY RHYOLITE PPORPHYRY	SYENITE PORPHYRY	MONZONITE PORPHYRY GRANODIORITE PORPHYRY	ANDESITE] PORPHYRY	BASALT PORPHYRY	
Fine-Grained (Aphanitic) Mineral grains or crystals are too small to be distinguished by the unaided eye.	RHYOLITE	FELSITE GROUP TRACHYTE	This group consists of the light colored rocks (names below) which are too fine grained to be identified with the unaided eye. LATITE DACITE	BASALT-LIKE GROUP This group consists of dark rocks not identifiable by the unaided eye. ANDESITE BASALT		OTHER TYPES: **PEGMATITE** (Extremely coarse type of Granite) **ANORTHOSITE** 90% or more Plagioclase
Glassy- Composed of natural glass-like materials. **Fragmental-**Composed of rock and/or mineral fragments	OBSIDIAN (Dense glass)	PUMICE (Glass froth, light colored)	SCORIA (Coarse cellular, dark colored)	TUFF (Angular, coarse grained fragments)	VOLCANIC BRECCIA (Compacted, fine grained fragments)	

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CLASSIFICATION OF SEDIMENTARY ROCKS

Sedimentary rocks are formed at or near the surface of the earth. Most of these sediments are deposited in beds or layers by water or wind as a result of weathering (erosion). Sedimentary rocks can be classified by their mode of origin as clastic, chemical precipitates, or organic. Clastic rocks are composed of rock fragments or mineral grains broken from any type of pre-existing rock. Precipitated rocks may result from chemical precipitation from fresh or salt water. Organic sediments may form from either plant or animal particles. There is a large variety of sedimentary rocks but approximately 98% of all sedimentary rocks are composed of various types of shales, sandstones, and limestones. Shale is the main weathering product of the feldspars which are the most abundant of the minerals.

Increase in size of rock particles ---->	CLASTIC		CHEMICAL		ORGANIC	
	Conglomerate - Composed of rounded rock of fragments of 2mm, pebbles and up and may have a sandy matrix.	Conglomerate	***Limestone*** - A fine to coarse-grained bedded rock consisting essentially of the mineral calcite (calcium carbonate).	Limestone	***Bituminous Coal*** - Black with a dull luster, sometimes referred to as soft coal and accounting for about 90% of all coal mined. Contains approximately 50% fixed carbon.	Bituminous Coal
	Sandstone - Sandstones may be subdivided according to composition and texture. Particle sizes range 1/6 to 2mm. Quartz grains are often the dominant mineral.	Sandstone	***Dolomite*** - A fine to coarse-grained bedded rock consisting essentially of the mineral dolomite (calcium, magnesium carbonate).	Dolomite	***Lignite Coal*** - Usually brownish in color with a relative low content of fixed carbon, compacted from beds of peat and other organic debris.	Lignite Coal
	Siltstone - In general this group is composed of the same minerals as the sandstone; sizes range from 1/256 to 1/16mm.	Siltstone	***Travertine*** - A general term for massive, non-crystalline calcite as found in caves, usually opaque and often colored.	Travertine	***Asphaltum*** - A completely organic deposit of solid hydrocarbons.	Asphaltum
	Shale - Clay size particles, less than 1/256 mm characterize the clays. Bedding planes are usually apparent.	Shale	***Calcareous Tufa*** - A light, porous limestone formed in springs as deposits on water plants, twigs or debris.	Calcareous Tufa	***Fossil Limestone*** - A fine to coarse-grained bedded rock consisting essentially of calcium carbonate often with identifiable fossil shells.	Fossil Limestone
	Ferruginous Sandstone - the cementing materials of the sandstone particles will often impart color to the rock. Iron oxides may impart red or yellow.	Ferruginous Sandstone	***Rock Gypsum*** - Fine-grained or coarsely crystalline, consisting of the mineral gypsum, a residue from saturated sea waters.	Rock Gypsum	***Coquina*** - A highly porous and loosely cemented formation of shells and fragments mainly calcium carbonate.	Coquina
	Breccia - The fragments which are re-cemented are sharp and angular. They may be of many different origins.	Breccia	***Rock Salt*** - Transparent to white or gray crystalline rock composed essentially of the mineral halite (sodium chloride).	Rock Salt	***Chalk*** - A limestone deposit, calcium carbonate, made up primarily of tiny protozoan shells.	Chalk
	Arkose - Particles are similar in size to sandstone or somewhat larger and are composed of over 20% feldspar.	Arkose	***Chert*** - A fine-grained compact rock composed mainly of chalcedony.	Chert	***Oil Shale*** - This shale may contain a higher percentage of calcium compounds than silica shales and has entrapped plant and animal remains related to petroleum.	Oil Shale

THE ROCK CYCLE

Rocks are the masses of material that make up the earth's crust. A rock may consist of a single mineral, as quartz, gypsum, or dolomite, but most rocks contain several minerals. Soil, gravel, sand, and clay are examples of unconsolidated rock material.

The Rock Cycle is a representation of how rocks interact with the rock forming processes. The rocks of the earth's crust are classified into three types: igneous, metamorphic, or sedimentary, according to their origin. Much of geology is concerned with the interactions among the forces that produce these three rock types.

As illustrated on the Rock Cycle Chart, these forces may be briefly described as follows:

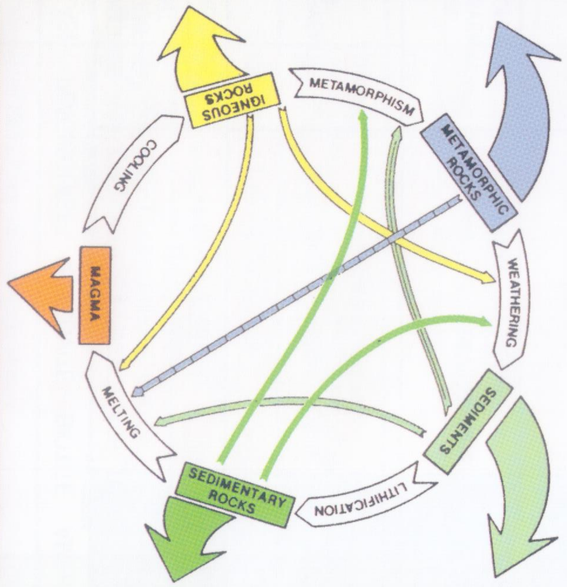
Weathering involves both the chemical and physical breakdown of rock at or near the earth's surface. This erosion results in the accumulation of sediments.

Lithification is the transformation of a sediment into a rock. Processes involved are cementation, compaction with removal of water, and in many instances, recrystallization.

Melting is the heating of rocks to form magma (molten lava) usually at considerable depths.

Cooling is the decrease in temperature of magma at or below the earth's surface resulting in the formation of igneous rocks.

Metamorphism is the process by which rocks of any type are changed by heat, pressure, stress, shear, or chemically active solutions.



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Granite ***Gabbro*** ***Rhyolite*** ***Basalt***

METAMORPHIC ROCKS

Metamorphic rocks are rocks that have been changed either in texture or in mineral composition by any of the following: heat, pressure, stress (directed pressure), shear, or chemically active solutions or gases. Any rock of any type (sedimentary, igneous, or other metamorphic) can be subjected to any one or any combinations of the above agents, so there is an enormous variety of resulting metamorphic rocks.

Gneiss ***Schist*** ***Slate*** ***Marble***

MAGMA

Molten rock material at great depths is called magma. Rock-forming materials (mainly silicates) and some volatile materials (mainly steam) are held in solution or a molten state by extreme pressure. Molten rock material observed in lava flows is no longer under pressure and the trapped gases and steam are free to separate. The cooling process of magma at great depths may occur over a very long period of time.

SEDIMENTS

Sediments are materials deposited by the process of erosion including running water, wind, waves, currents, ice, and gravity. When these deposits are consolidated, they become sedimentary rocks.

Although by volume, sediments and sedimentary rocks comprise only 5 or 6 percent of the crust, they actually cover about 75 percent of the earth's surface. These sediments would include those on the floor of the oceans, as well as the sands of desert areas and the soils used for agricultural purposes, forests, and grasslands.

Gravel ***Sand*** ***Silt*** ***Clay***

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Conglomerate ***Shale*** ***Limestone*** ***Sandstone***

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GEMSTONES

Minerals that can be fashioned into various shapes for jewelry are called gemstones. Gemstones are the most prized of all minerals and are clearer, brighter, and more colorful than the average form of the mineral.

Gems are classified as precious or semi-precious stones. Precious gems include diamonds, rubies, emeralds, etc. Semi-precious gems include agates, various varieties of quartz, etc.

What makes a gemstone? Gemstones are based on the following physical properties:

LUSTER Luster depends on how light is reflected by a mineral. A proper cut gem may reflect light many times through the gem giving added brilliance to the gem.

COLOR Color is very important to the value and rarity of a gem. For example, the rarest and most prized of diamonds are the blue and red ones because these colors are rarely found.

HARDNESS Minerals with hardness above seven (7) make the best gems as they resist scratching and abrasion.

The following is a list of some minerals used as gemstones:

Beryl var. Aquamarine
Beryl var. Emerald
Chrysoberyl
Corundum var. Ruby
Corundum var. Sapphire
Diamond
Feldspar var. Amazonite
Feldspar var. Labradorite
Feldspar var. Moonstone
Garnet
Hematite
Jade
Lapis-Lazuli
Malachite
Obsidian
Opal
Quartz var. Agate
Quartz var. Amethyst
Quartz var. Bloodstone
Quartz var. Carnelian
Quartz var. Chalcedony
Quart var. Chrysoprase
Quartz var. Citrine
Quartz var. Jasper
Quartz var. Onyx
Quartz var. Rock Crystal
Quartz var. Rose
Quartz var. Smokey
Rhodocrosite
Rhodonite
Spinel
Spodumene var. Hiddenite
Spodumene var. Kunzite
Topaz
Tourmaline
Turquoise
Zircon