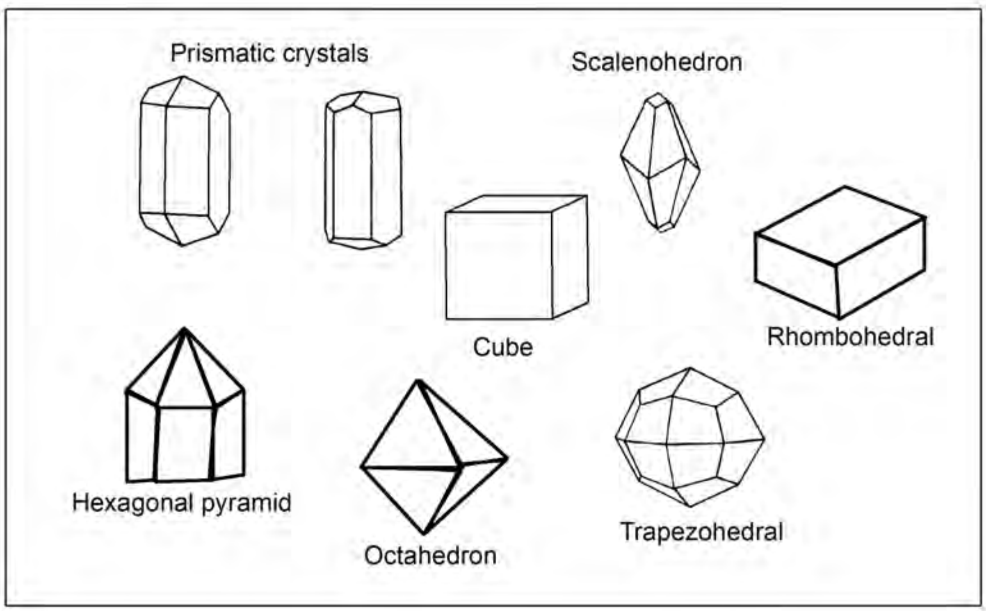
STATE OF ARKANSAS

ARKANSAS GEOLOGICAL SURVEY
BEKKI WHITE, DIRECTOR AND STATE GEOLOGIST

EDUCATIONAL WORKSHOP SERIES 01

Introduction to Minerals and Rocks
(with special emphasis on Arkansas materials)



Angela Chandler

Little Rock, Arkansas
2009

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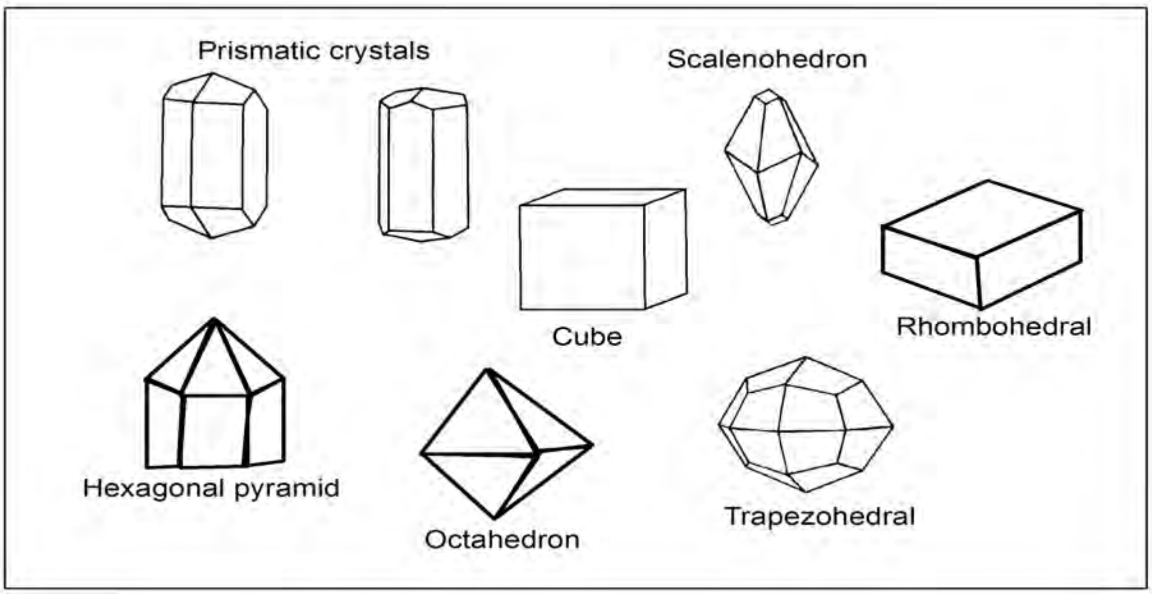

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Little Rock, Arkansas
2009

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Acknowledgments

This laboratory manual is written for Arkansas teachers studying earth science. This was also written with the Arkansas Science Curriculum in mind so that students can meet the requirements and goals set for their age groups. Various staff at the Arkansas Geological Survey contributed material to this manual. Special thanks go to Mike Howard for his mineral pictures and assistance in the classification of the igneous and metamorphic rocks of Arkansas.

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Introduction to Minerals

- We will discuss the physical and visual (optical) properties of minerals that can be readily recognized without a lot of special equipment.
- What is it about a mineral that allows us to identify them?
- What is a mineral? A natural inorganic solid with a definable chemical composition and an orderly internal arrangement of atoms (crystalline structure).
- Optical/visual properties are those that are most readily observable and require little action other than viewing. They include: Color, Streak, Luster, Diaphaneity, Double refraction, Growth habits, and Crystal forms.
- Physical properties may be observed but generally require action before observation. They include: Cleavage, Fracture, Hardness and Magnetism. If you have equipment, then you can check Radioactivity, Fluorescence, and Specific Gravity.

Minerals are made up of elements. Usually two or more elements combine to form a mineral such as Si and O to form SiO_2 (quartz). Oxygen and silicon comprise the bulk of the Earth's crust. The most abundant elements in Earth's crust are listed below. The first eight comprise approximately 98.5% of Earth's crust with additional common elements listed beside the first eight.

Most common elements in Earth's crust.

Element	**Symbol**	**% by weight**
Oxygen	O	46.6
Silicon	Si	27.7
Aluminum	Al	8.1
Iron	Fe	5.0
Calcium	Ca	3.6
Sodium	Na	2.8
Potassium	K	2.6
Magnesium	Mg	2.1

Additional significant elements

Element	**Symbol**
Barium	Ba
Carbon	C
Copper	Cu
Lead	Pb
Zinc	Zn
Chlorine	Cl
Fluorine	F
Hydrogen	H
Sulfur	S

Now let's look at some of the visual properties that are readily observable in minerals.

Color

- Least importance of all visible properties.
- Many minerals occur in a wide variety of colors!

Calcite Quartz

Fluorite

Streak

- ► Made by powdering a mineral on an unglazed porcelain plate. The color of the streak is the color of the powdered mineral and is very reliable.

Luster

- ► Luster is the reflection of light as we observe it from the surface of the mineral, preferably on a broken surface.
- ► Luster is readily divided into two types, metallic and non-metallic.

Quartz (top)
Calcite (left)
Galena (right)

Metallic Luster

- ► Reflected light looks like that of metal.

Non-metallic Luster

Looks like anything but metal!

- ► Includes a variety of descriptions: vitreous (glassy), pearly, satiny, porcelaneous (dull).

Satiny

Pearly

Porcelaneous

Diaphaneity

The light-transmitting quality of a mineral. Termed transparent, translucent, or opaque.

Transparent

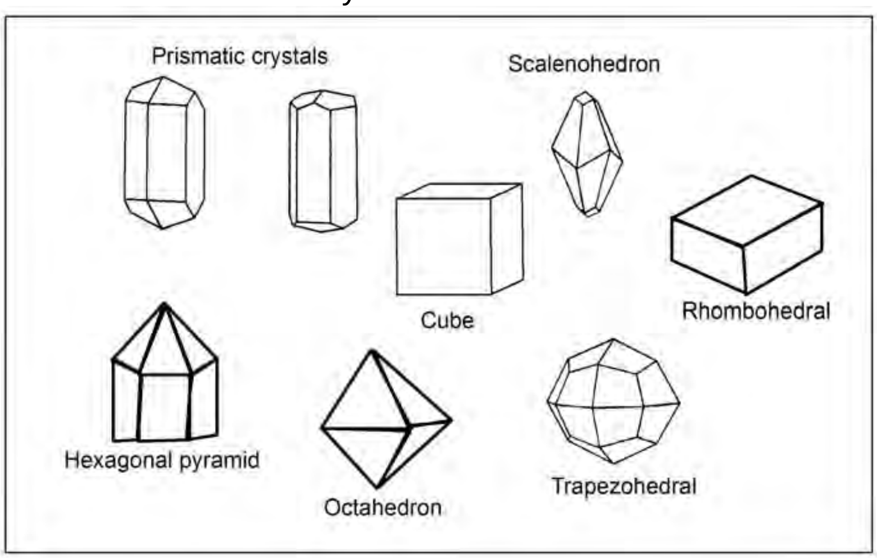
Translucent

Opaque

Crystal Forms

- ► Six crystal systems due to varying degrees of symmetry.
- ► They are Isometric (Cubic), Tetragonal, Hexagonal, Orthorhombic, Monoclinic, and Triclinic.
- ► Study of crystal forms and twinning is its own course called Crystallography!

Some external forms of mineral crystals are shown below.



Cleavage

- ► Defined as preferred directions of breakage due to the internal order of atoms and/or molecules within the crystal structure.
- ► Cleavage may be in one direction, as in mica or graphite; two directions as in feldspars; 3 directions @ right angles, as in galena; 3 directions not @ right angles, as in calcite, siderite, or dolomite; or more as with fluorite (4) and sphalerite (6).
- ► Each cleavage may produce 2 parallel planes.
- ► Cleavage also reflects possible crystal faces, whether formed or not.

1-direction
Mica

3 directions, not at 90° (calcite)

Cleavage is made by breaking the sample. It is not growth faces.

Cubic cleavage of galena
← 3 directions at 90°

4 directions of cleavage in fluorite →

Cleavage for a given mineral is a consistent property!

Fracture

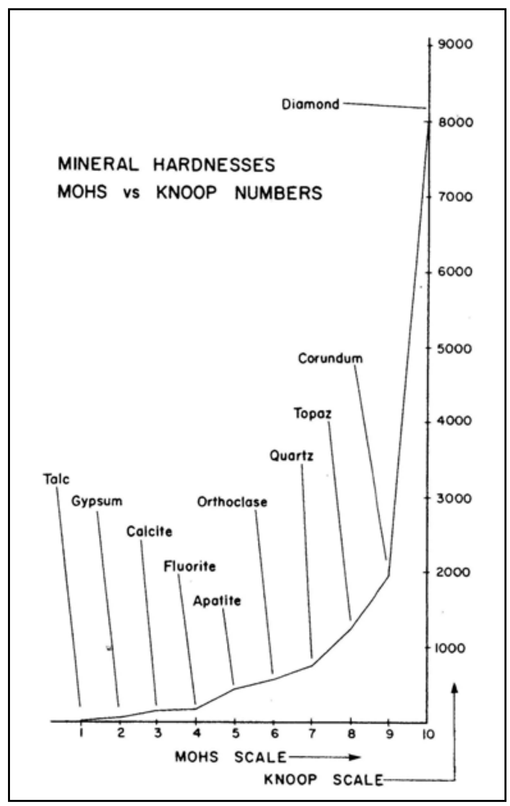
- ► Defined as a breakage face when cleavage is not expressed. Typically has other than a flat surface.


Conchoidal fracture as expressed by quartz. Note curved surface.

Hardness

- ► Defined as a relative scale of scratchability.
- ► First hardness scale originated with German mineralogist Friedrich Mohs.
- ► He ranked mineral hardness from 1 – 10.

10. Diamond
9. Corundum
8. Topaz
7. Quartz
6. Feldspar
5. Apatite
4. Fluorite
3. Calcite
2. Gypsum
1. Talc



Unfortunately, this scale is only relative, not absolute; i. e. diamond is not 10 X harder than talc!

- ► Knoop scale of hardness is actually relative and shows diamond (10 on Mohs) is ~ 8,200 times harder than talc (1 on Mohs). Diamond is also ~ 4 times harder than Corundum (9 on Mohs)!
- ► Handy to know hardness of common items:

Fingernail ~2.5
Stainless steel knife blade ~5.5
Steel file ~ 6 Quartz 7

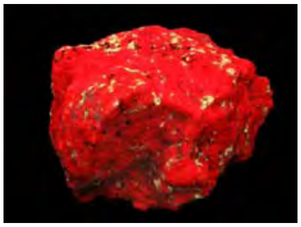
Magnetism

- Will be drawn to a magnet. An uncommon property, only a few minerals are magnetic.


Lodestone is naturally magnetic magnetite. Magnetite will be drawn to a magnet but will not hold filings. Pyrrhotite is also weakly magnetic.

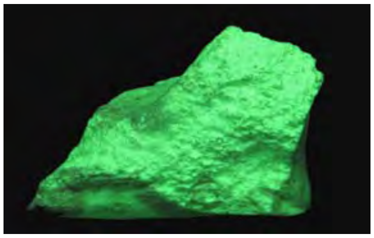
Tests with more equipment

- ► **Fluorescence –** Caused by excitement of electrons in atoms and emission of specific colors of light as they drop back into normal orbits. Need a long or shortwave black light to determine this property. Trace elements in minerals cause different colors. Colors are typically brilliant and dramatically different than when the mineral is viewed by normal light.

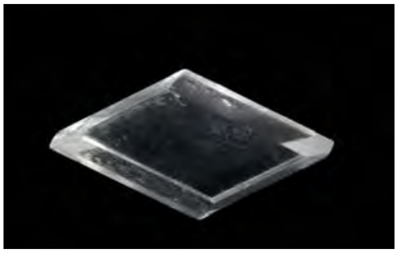
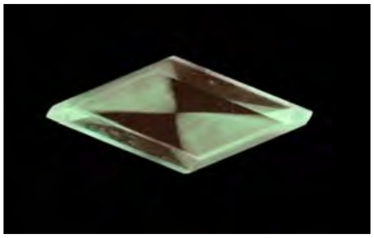



<- Barite

Common opal ->

Gypsum (selenite) ->

Uses of some minerals

Barite – Barite is a heavy mineral used in drilling mud, paint, paper and rubber.
Calcite - Calcite has been used for a variety of purposes, including agricultural lime and rock fertilizer, and in optical applications as transparent crystal cleavages, and carved decorative stone when in the form of onyx.
Chalcopyrite – ore of copper.
Feldspar – Used in making the body composition of several types of porcelain, china and earthenware and also in the preparation of glazes and enamel; as an important ingredient in the glass sand batch and as a bonding agent in the manufacture of bonded abrasives like wheels and discs of garnet, corundum, emery etc.
Fluorite – Flux in metallurgical operations.
Galena – The primary source of lead and often an ore of silver.
Garnet – abrasive; gemstone.
Gypsum – Used in cement, wallboard and plaster of paris.
Halite – Used as an ice control agent.
Hematite – Ore of iron.
Kaolinite – Used in ceramics.
Magnetite – Ore of iron.
Mica - Sheet mica is used in a number of electrical and electronic appliances in different shapes and sizes. As an insulating material it is used in equipment like condensers, transformers, radio and electronic tubes and radar circuits. It is used in the form of washers, discs, tubes and plates.
Pyrite – A source of sulfur and iron.
Sulfur - Sulfur is used in batteries, detergents, the vulcanization of rubber, fungicides, ie skin care soaps, and in the manufacture of phosphate fertilizers. Sulfites are used to bleach paper and as a preservative in wine and dried fruit. Used to make sulfuric acid.
Quartz – Quartz crystals are popular as mineral specimens. Milky quartz has been used to grow synthetic quartz for electronics.
Sphalerite – Ore of zinc.
Talc – used in talcum powder, baby powder. Talc is an effective anti-caking agent, dispersing agent and die lubricant. Used in ceramics, paper, and paint.

Minerals with Metallic Luster

(minerals in red are present in Arkansas)

Hardness	Streak	Other Properties	Mineral
6.5 - 6	Dark gray	brass yellow, may tarnish brown; brittle, no cleavage, cubic crystals common, S.G.= 50.	Pyrite ("fools gold") FeS_2 iron sulfide
6.5 - 6	Dark gray	pale brass yellow to whitish gold brittle, no cleavage, radiating masses and "cockscombs". S.G. = 4.9	Marcasite FeS_2 iron sulfide
6	Dark gray	dark gray to black; magnetic no obvious cleavage S.G. = 5.2	Magnetite Fe_3O_4 iron oxide
6.5 - 5	red to red-brown	silver to gray, may be tiny glittery flakes, may tarnish red S.G. = 4.9-5.3	Hematite Fe_3O_4 iron oxide
5.5 - 5	yellow-brown	yellow-brown to dark brown amorphous, but may be pseudomorphic after pyrite S.G. = 4.1-4.3	Limonite $Fe_2O_3*nH_2O$ hydrous iron oxide
4 - 3.5	Dark gray	golden yellow may tarnish purple brittle, no cleavage S.G. = 4.1-4.3	Chalcopyrite $CuFeS_2$ copper-iron sulfide
3 - 2.5	copper	copper to dark brown, may oxidize green; malleable S.G. = 8.8-8.9	Native Copper Cu copper
2.5	Gray to dark gray	silvery gray, tarnishes dull gray cubic cleavage, not scratched by fingernail. S.G. = 7.4-7.6	Galena PbS lead sulfide
1	Dark gray	gray to black, marks paper easily greasy feel S.G. = 2.1-2.3	Graphite C Carbon

Minerals with Non-metallic Luster

(minerals in red are present in Arkansas)

Hardness	Streak	Other Properties	Mineral
3	white	colorless, yellow, green,brown, red, blue, white rhombohedral cleavage; effervesces in dilute HCL; S.G. = 2.7	Calcite $CaCO_3$ calcium carbonate
3	white	colorless, white, red, brown, yellow blue; platy crystals, massive or in rose-like shapes; very heavy S.G. = 4.5	Barite $BaSO_4$ barium sulfate
3-2.5	gray-brown	very dark brown to black, one perfect cleavage; flexible very thin sheets S.G. = 2.7-3.1	Biotite Mica ferrogmagnesian potassium hydrous aluminum silicate
2.5	white	colorless, white, yellow, red, blue brown; cubic crystals and cubic cleavage, salty taste S.G. = 2.1-2.6	Halite NaCl sodium chloride
2.5-1.5	pale yellow	yellow to red, bright crystals or earthy masses, brittle, no cleavage, conchoidal fracture S.G. = 2.1	Native Sulfur S sulfur
2.5-2	white	colorless, yellow, brown red-brown; one perfect cleavage flexible, elastic sheets S.G. = 2.7-3.0	Muscovite Mica potassium hydrous aluminum silicate
2	white	dark green one perfect cleavage S.G. = 2.6-3.0	Chlorite ferromagnesian aluminum silicate
2	white	one good cleavage ; non elastic sheets, colorless to white, easily scratched with fingernail S.G. = 2.3	Gypsum $CaSO_4*2H_2O$ calcium sulfate
2-1	white	white to very light brown, one perfect cleavage, common as earthy microcrystalline masses S.G. = 2.6	Kaolinite $Al_4(Si_4O_{10}$ hydrous aluminum silicate
1	white	white, gray, green, pink, brown yellow: soapy feel, pearly to greasy luster, massive or foliated S.G. 2.7-2.8	Talc $Mg_3Si_4O_{10}(OH)_2$ hydrous magnesian silicate

Minerals with Non-metallic Luster

Hardness	Streak	Other Properties	Mineral
5.5	white	green to black, dull, stout crystals two cleavage directions that inter-sect at about 87 and 93 degrees S.C. = 3.2-3.5	Pyroxene (Augite) calcium ferro-magnesian silicate
5.5	white	green to black, opaque, two cleavage directions at 60 and 120 slender crystals, splintery or fibrous; S.G. = 3.0-3.3	Amphibole (Horneblende) calcium ferro-magnesian aluminum silicate
5	white	brown, gren, blue, yellow, purple black; one poor cleavage commonly six sided crystals S.G. = 3.1-3.2	Apatite $Ca_5F(PO_4)_3$ calcium fluorophosphate
5.5-1.5	red to red-brown	red, opaque, earthy luster S.G. = 4.9-5.3	Hematite Fe_2O_3 iron oxide
5.5 - 1.5	yellow-brown	yellow-brown to dark brown amorphous, but may be pseudomorphic after pyrite S.G. = 3.6-4.0	Limonite/Goethite hydrous iron oxide
4	white	colorless purple, blue, yellow or green; dioctahedral cleavage crystals usually cubic S.G. = 3.0-3.3	Fluorite CaF_2 calcium fluoride
4 - 3.5	white to yellow-brown	brown to yellow or black submetallic, dodecahedral cleavage S.G. = 3.9-4.0	Sphalerite ZnS zinc oxide
4 - 3.5	light blue	vivid royal blue, earthy masses or tiny crystals, effervesces in dilute HCL S.G. = 3.7-3.8	Azurite $Cu_2CO_3(OH)_2$ hydrous copper carbonate
4 - 3.5	green	green to gray-green laminated crusts or masses of tiny granular crystals; effervesces in dilute HCL; S.G. = 3.9-3.4	Malachite $Cu_2CO_3(OH)_2$ hydrous copper carbonate
4 - 2.0	very light blue	pale blue to blue-green crusts or massive, amorphous conchoidal fracture S.G. = 2.0-2.4	Chrysocolla $CuSiO_3$*$2H_2O$ hydrated copper silicate
4 - 3.5	white	white, gray, pink, brown rhombohedral cleavage effervesces in HCL only if powdered; S.G. 2.8-2.9	Dolomite $CaMg(CO)_3$ magnesian clacium carbonate

Minerals with Non-metallic Luster

Hardness	Streak	Other Properties	Mineral
9	white	gray, red, brown, blue; greasy luster, commonly in six-sided crystals with striated flat ends no cleavage; S.G. = 3.9-4.1	Corundum Al_2O_3 aluminum oxide
8	white	colorless, yellow, blue or brown one perfect cleavage, crystal faces often striated S.G. = 3.5-3.6	Topaz $Al_2SiO_4(OH,F)_2$ hydrous fluoro-aluminum silicate
7.5 - 7	white	green, yellow, pink, blue, brown or black slender crystals with rounded triangular cross-sections striated crystal faces, no cleavage S.G. = 3.0-3.2	Tourmaline complex silicate
7	white	any color to colorless, transparent to translucent, greasy luster, no cleavage, conchoidal fracture S.G. = 2.7	Quartz SiO_2 silicon dioxide
7	white	white, light colors; waxy luster translucent, often banded masses, cryptocrystalline S.G. = 2.5-2.8	Chalcedony SiO_2 cryptocrystalline quartz
7	white	red, opaque, waxy luster cryptocrystalline, conchoidal fracture; S.G. = 2.5-2.8	Jasper SiO_2 cryptocrystalline quartz
7	white	green, black or yellow conchoidal fracture no cleavage S.G. = 3.3-3.4	Olivine $(Fe,Mg)_2SiO_4$ ferromagnesian silicate
7	white	dark red, brown, pink, green or yellow; transparent to translucent, no cleavage S.G. = 3.4 - 4.3	Garnet complex silicate
7 - 6	white	green to yellow-green, striated crystals or dull granular masses one cleavage S.G. = 3.3 - 3.5	Epidote complex silicate
6	white	blue-gray, black or white striations on some cleavage planes; two cleavages at nearly 90 degrees S.G. = 2.6-2.8	Plagioclase feldspar $NaAlSi_3O_8$ to $CaAl_2Si_2O_8$ calcium-sodium aluminum silicate
6	white	white, pink, brown, green exsolution lamellae are present and subparallel, two cleavages at 90 degrees, S.G. = 2.6	Potassium feldspar $KAlSi_3O_8$ potassium aluminum silicate
6	white	colorless, white, orange, gray, yellow green, red, blue; may have play of colors (opalescence) amorphous greasy luster to earthy luster, conchoidal fracture S.G. = 1.9-2.3	Opal SiO_2*nH_2O hydrated silicon dioxide

Introduction to Rocks

What is a rock?

- Any naturally formed, consolidated or unconsolidated material (but not soil) typically composed of two or more minerals (rarely one massive mineral), and having some degree of chemical and mineralogic consistency. Also a representative sample of such material.
- Popular definition: Any hard consolidated material derived from the earth and usually of relatively small size (stone).
- A rock body may be mapped across many square miles of the earth, both on the surface and the subsurface.

General Comments

- We sometimes use mineral descriptive terms when describing rocks, but the meaning of the terms are not the same.
- When referring to rock cleavage, it does not mean the same as cleavage of a mineral. Rock cleavage is developed by pressure.
- Color of rocks is generally referred to as light or dark and may be the result of finely divided organic matter, iron-bearing compounds, or the color of the minerals composing it.
- Rock hardness is not scratchability, but instead refers to resistance to breakage (toughness). So if a geologist says, chalk is a soft variety of limestone, it means it breaks easily.
- Conchoidal fracture does mean the rock breaks with curved surfaces.

Three Types of Rocks

- **Igneous** – those rocks formed from the cooling of magma (molten rock).
- **Sedimentary** – those rocks formed by the deposition of minerals/sediments by either water or wind, then lithified by cementation and/or pressure (compaction).
- **Metamorphic** – those rocks formed by the physical or chemical alteration of pre-existing rocks, usually due to the action of elevated temperature, pressure, or chemically active fluids.

Igneous Rocks

Igneous rocks from from the cooling of magma or lava. Those that form from cooling of magma inside the Earth are called intrusive or plutonic igneous rocks. Those that form at the Earth's suface are called extrusive or volcanic igneous rocks.

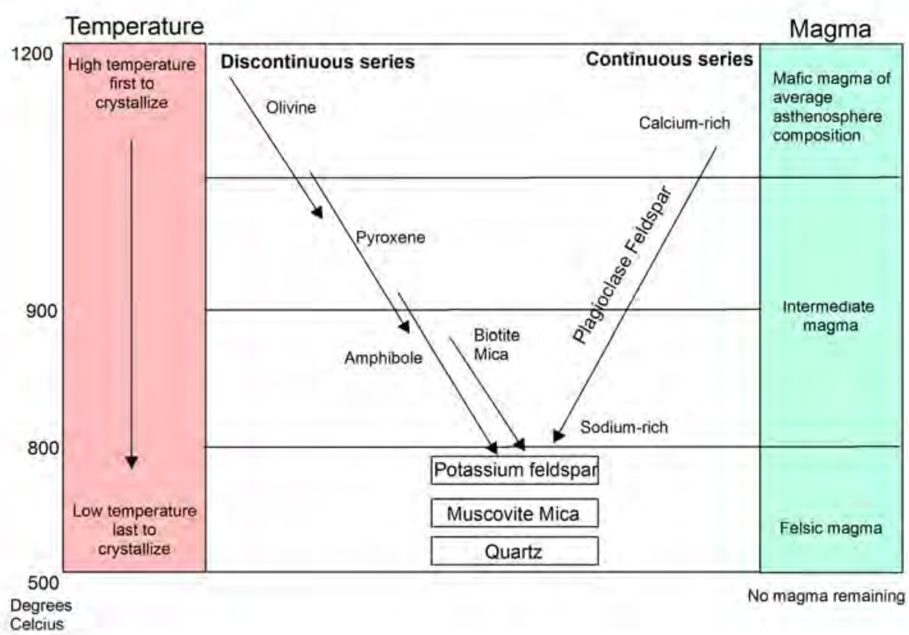
Classification of Igneous Rocks

- Classified on the basis of mineral content and texture.
- Mineral content: presence or absence of quartz and olivine, presence and type of feldspar, presence of mafic minerals.
- Texture: fine-grained cooled fast (glassy or aphanitic), coarse grained cooled slowly, or porphyritic (two cooling rates).
- Color of igneous rock, light or dark, may be a general guide for field work.

Igneous rocks composed of light-colored minerals such as quartz, potassium feldspar and plagioclase are called felsic. Igneous rocks composed of dark- colored minerals are called mafic.

Bowens Reaction Series

American petrologist N.L. Bowen studied magmas and found that as magmas cool, some minerals crystallize in predictable sequences.



The diagram suggests the sequence in which minerals crystallize from an average magma in the asthenosphere when it is slowly cooled. The asthenosphere is the layer or shell of the Earth below the lithosphere, which is weak and in which isostatic adjustments take place, magmas may be generated and seismic waves are strongly attenuated. Note the relation between temperature and mineral composition/stability. T his is approximate because pressure also affects mineral composition/stability. Viewing the diagram in reverse (bottom to top) also suggests the sequence in which minerals will melt to form magma when rocks are heated.

Cooling rate is an important process

- **Different cooling rates result in different textures for rocks formed from the same magma. Note: these examples are the same composition but different textures.**

Fast cooling = fine-grained Rhyolite

Slow cooling = coarse Granite

Rapid cooling = glass → Obsidian

Some Definitions of special rock types

A **PEGMATITE** is an igneous rock distinguished by its abnormally large crystals. The crystals are normally larger that a few centimeters and can often be dozens of centimeters long or much longer (meters long). Unlike other igneous rocks that develop from the molten state, pegmatites grow from aqueous solutions. The solutions allow for ease of movement of the nutrients to the site of crystal growth. Thus pegmatites can produce large crystals in a short (geologically) period of time.

A **PORPHYRITIC** rock is an igneous rock that contains two distinct crystal sizes. These distinctly different crystal sizes were produced by different cooling rates of the liquid rock. Large crystals form slowly beneath the surface of the Earth and small crystals form when rapid cooling takes place (normally at or near the surface). The large crystals in a porphyry are called phenocrysts. The term PORPHYRITIC is used as an adjective to describe this distinct texture of igneous rock, e. g., a PORPHYRITIC basalt.

GLASSY igneous rocks are formed by very rapid cooling. No crystals were formed during the cooling process. Examples are **OBSIDIAN** and **PUMICE**.

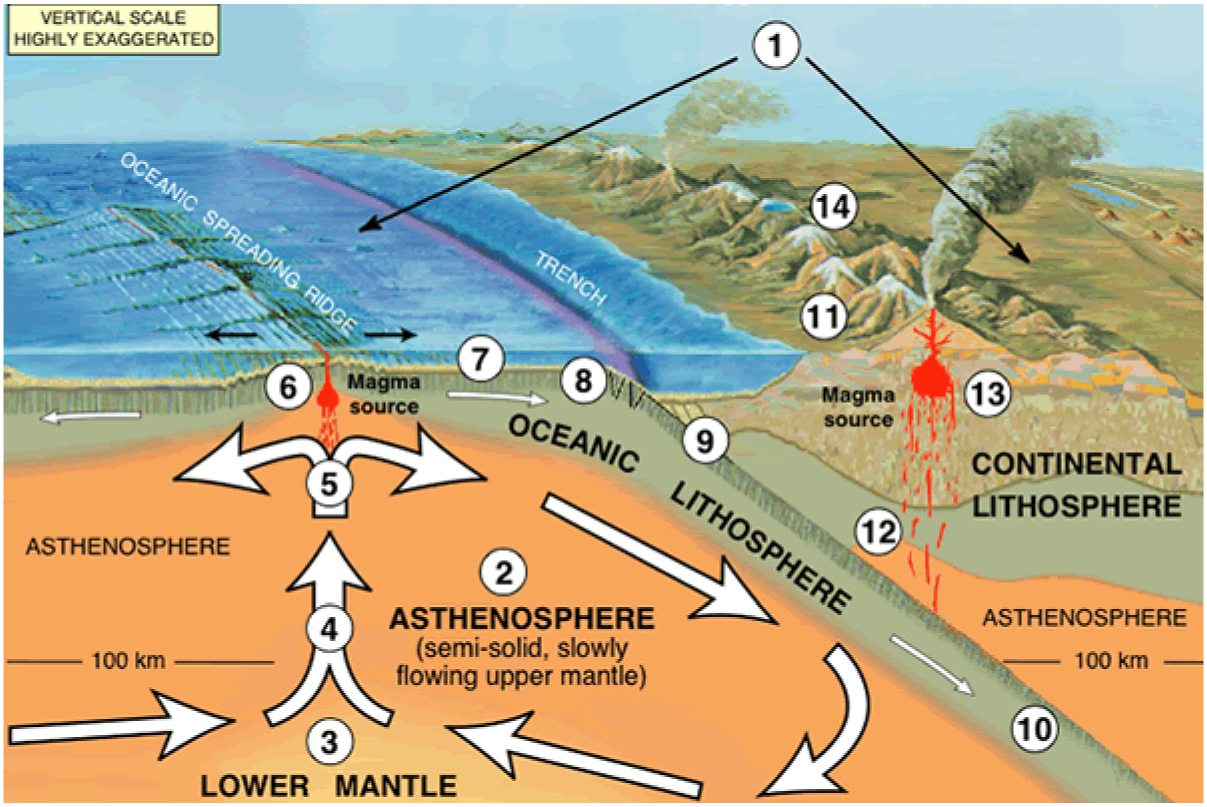
FRAGMENTAL igneous rocks are produced when existing igneous rocks are put under stress or moved causing them to fracture. These fragments are then fused to form a new rock. Obviously there is little change in the composition of the rocks. VOLCANIC AGGLOMERATES or VOLCANIC BRECCIAS are examples of the igneous rock type.

Igneous Rocks in Arkansas

- Nepheline syenite and various types related to basaltic rocks in central Arkansas (Granite Mountain, Magnet Cove, Potash Sulphur Springs.
- Lamproites in Pike County.
- Lamprophyre and syenite dikes in the eastern Ouachita Mountains.
- Rare gabbro masses in the eastern Ouachita Mountains.
- Most notable is absence of granite, rhyolite, and basalt on the surface in Arkansas.
- The igneous rocks of Arkansas are *uncommon types*.


Nepheline syenite from Granite Mountain and Magnet Cove


Lamproite breccia from Prairie Creek and lamprophyre rock from eastern Ouachita Mountains.



Some igneous features of the Earth (USGS). (1) Oceanic and continental lithosphere (2) Asthenosphere – denser semi-solid rock (3) rock softens and partially melts and can flow very slowly (4) convection currents bring hot material from deeper within the mantle (5) divergent plate boundary - mafic (basaltic) magmas from the asthenosphere commonly erupt onto the seafloor along *mid-ocean ridges* and above isolated *hot spots* such as the Hawaiian Islands; basaltic eruptions at mid-ocean ridges (6) gradually force the older basalt rock to move laterally until subsides into trenches beneath the continents. (7-10) the older part of the plate moves away from the ridge where it was originally created (8) the plate gradually cools down, gets heavier and eventrually sinks (9) into the asthenosphere into the (10) subduction zone; Subduction zones are a type of (11) convergent plate boundary; partial melting (12) of the subducted basalt commonly produces magmas (13) that are intermediate (dioritic) to felsic (granitic). partial melting also produces andesitic and rhyolitic eruptions (14). (Mount Saint Helen's in Washington state is an andesitic volcano.)

Uses of some Igneous Rocks

Basalt - Crushed stone, concrete aggregate, railroad ballast, production of high quality textile fibers, floor tiles, acid-resistant equipment for heavy industrial use, rockwool, basalt plastic pipers, basalt plastic reinforcement bars, basalt fiber roofing felt (ruberoid), basalt laminate used as a protective coating, heat-insulating basalt fiber materials, glass wool (fiber glass), etc.

Granite - The nation's most used dimension stone, finding application in interior and exterior building construction, monuments, and curbing.

Lamproite Breccia tuff – the source of diamonds in Arkansas.

Obsidian – Used to make cutting tools, spear points, arrowheads, etc.

Pumice – cleaning and cosmetic stones.

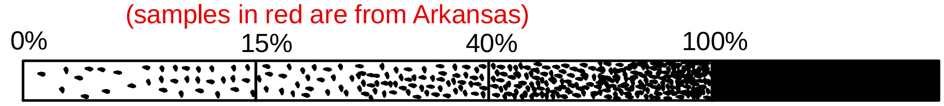
Rhyolite - Decorative stones, scouring stones and abrasives, ornamental stone

Syenite – Used as rock aggregate and roofing granules.

Tuff – Used as rock aggregate.

Classification of Igneous Rocks

(samples in red are from Arkansas)



Textures (all can be porphyritic) / Mineralogic comps	Felsic abundant qtz	Intermediate	Mafic	Ultramafic
	abundant quartz orthoclase>plagioclase <15% ferromagnesian	little or no quartz plagioclase>orthoclase 15-40% ferromagnesian	no quartz, no orthoclase 10-60% plagioclase 40-90% ferromagnesian	> 90% ferromagnesian little if any feldspar

Plutonic or Intrusive Igneous Rocks

Minerals are sufficiently large for identification

Phaneritic (coarse textured)	Granite (light colored)	Diorite (intermediate colored)	Gabbro (dark colored)	Peridotite (very dark colored)
	nepheline syenite pegmatite*			magmatic lamproite
	Igneous breccia			

*Magma is silica deficient. Nepheline formed instead of quartz.

Volcanic or Extrusive Igneous Rocks

Group A: With the exception of possible phenocrysts, minerals are too small for identification; color may be the only guide to classification.

Aphanitic (fine textured)	Rhyolite	Andesite	Basalt (dark colored)
	Felsite (light to intermediate colored)		

Group B: Classification of volcanic rocks below is based solely on texture.

Glassy	Obsidian (can be dark even though felsic)	none	none
Vesicular (bubby, frothy)	Pumice (light colored)		Scoria (dark colored)
Pyroclastic (fragmental)	Volcanic tuff (fragments less than 4mm)		
	Volcanic Breccia (fragments more than 4mm)		
	Pyroclastic lamproite (fragment size highly variable)		

Sedimentary Rocks

Sedimentary rocks are made up of materials derived from preexisting rocks by physical erosion or chemical weathering.

Physical erosion occurs by water, wind and ice and produces clay, silt, sand and pebbles which can become cemented together to form detrital or clastic sedimentary rocks.

Chemical weathering is the process of weathering or alteration of rocks by water which places certain elements and minerals in solution. In time elements in solution can be precipitated to form organic and chemical sedimentary rocks. Some clay minerals can be carried away to be deposited elsewhere as sediments, later for form a detrital rock called shale.

Sedimentary rocks

Sedimentary rocks are classified according to the size of their grains and composition. A definition of the grain sizes are listed below.

Gravel – grains are large and easily seen with the naked eye and consists of grains larger than sand such as pebble, granules or cobbles.

Sand – grains from the size of a match head and down to smaller than the size of a pinhead.
Feels like sandpaper to the touch.

Silt – The upper size limit is approximately the smallest size that can be distinguished with the unaided eye. Gritty if chewed.

Clay – Cannot see grains with the unaided eye. Smooth, sticky when wet. Pasty if chewed, not gritty.

Chemical and Biochemical or Organic Sedimentary rocks

Chemical sedimentary rocks are crystalline sedimentary rocks that from by precipitation of inorganic materials from water. Limestone forms from chemical precipitation of aragonite or calcite. A lime mud formed in shallow seas forms a rock called micrite. Chert forms by precipitation of fibrous varieties of quartz or by chemical alteration of opal.

Biochemical or organic sedimentary rocks form as a result of organic processes. They include peat and coal made of plant fragments, and skeletal limestone, made up of animal shells or skeletons.

Sedimentary rocks from Arkansas

Conglomerate

Sandstone

Shale

Limestone

Novaculite

Chert

Sediments and sedimentary rocks make up 99.9 % of surface materials in Arkansas. Not pictured are chalk and dolostone.

Uses of some sedimentary rocks

Bauxite – the principal commercial source of aluminum
Limestone – used as crushed stone and agricultural limestone; mined for cement and as a source of lime; quarried as a decorative stone.
Sandstone – used as rock aggregate and for building stone.
Novaculite – used as oilstones or whetstones and as a high silica source material.
Dolostone – used as rock aggregate and for building stone.
Coal – used to generate electricity. Other uses include coking coal for steel manufacturing and industrial process heating.

Classification of Detrital Sedimentary Rocks

(samples in red are from Arkansas)

Composition	Grain-size Class	Comments	Name	
Mainly quartz feldspar, rock fragments, and clay minerals	gravel (>2mm)	rounded grains	Conglomerate	
		angular grains	Breccia	
	sand (0.0625 - 2.00, or 1/16 - 2,mm)	mostly quartz grains	Quartz Sandstone	Sandstone
		mostly feldspar grains	Arkose	
		mostly rock fragments	Lithic Sandstone	
		mixed with much silt and clay	Wacke	
	Mud: silt 1/256-1/16 mm	nonfissile (compact)	Siltstone	Mudstone
		fissile (splits easily)	Shale	
	Mud: clay 1/256 mm	nonfissile (compact)	Claystone	
		fissile (splits easily)	Shale	

Classification of Chemical and Organic Sedimentary Rocks

(rocks in red are from Arkansas)

Composition	Comments	Grain-size	Name
Mainly calcium carbonate, $CaCO_3$	shells or shell fragments well cemented to form dense rock	gravel	Calcirudite
		sand	Calcarenite
		silt	Calcisiltite
		clay	Micrite
	shells or shell fragments poorly cemented to form porous, earthy rock	gravel	Coquina
		sand	Calcarenite
		silt and clay	Chalk
	spherical grains with concentric laminations	<2mm	Oolitic Limestone
	crystals formed as inorganic chemical precipitates	coarse-grained to fine-grained	Crystalline Limestone
		very fine-grained	Micrite
Mainly dolomite CaMg $(CO)_3$	commonly altered from limestone	all sizes	Dolostone
Mainly varieties of quartz (flint, jasper, etc.)	layers, lenses or nodules	microcrystalline or amorphous	Chert
	very hard and brittle	sub-microcrystalline	Novaculite
Mainly halite	crystals formed as inorganic chemical precipitates	all sizes	Rock Salt
Mainly gypsum	crystals formed as inorganic chemical precipitates	all sizes	Rock Gypsum
Mainly plant fragments	brown and porous	all sizes	Peat
	black and non porous	all sizes or dense with conchoidal fracture	Bituminous Coal
Mainly gibbsite and boehmite	contains round grains called pisolites	varies in size	Bauxite

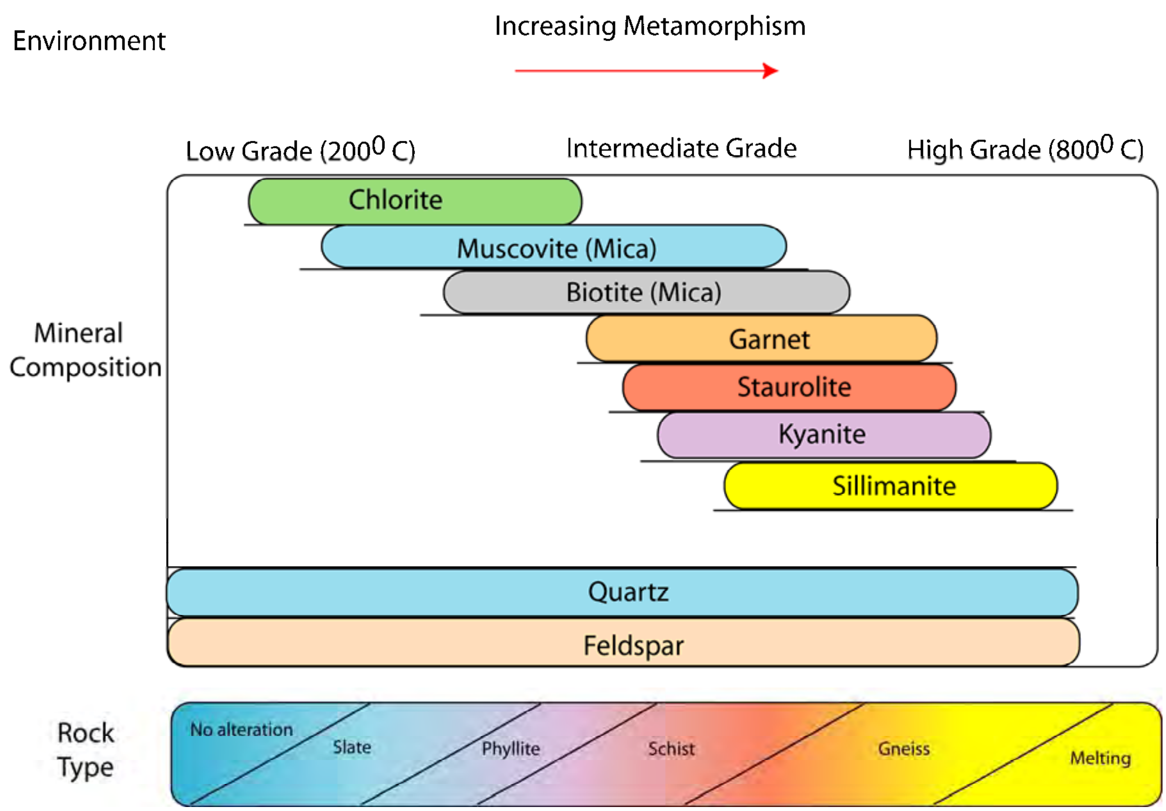
Metamorphic Rocks

- **Any pre-existing rock that has been changed or altered due to heat, pressure, and/or chemically active fluids.**

  Since every metamorphic rock is a changed rock each rock has a precursor: the rock type that existed prior to metamorphism. The precursor rock could be igneous, sedimentary or even metamorphic.

- **Involves both changes in the mineralogy and texture, depending on the initial rock being altered.**

  The changes in mineralogy during metamorphism can be 1) original minerals change to new minerals; for example - shales composed mainly of clay minerals, quartz and feldspar metamorphose to a rock composed mainly of muscovite and garnets; or 2) original minerals recrystallize or convert to fewer, larger crystals of the same mineral; for example – microscopic muscovite crystals in *slate* can recrystallize to large muscovite crystals in *phyllite* which can then recrystallize to even larger muscovite crystals in *schist*.

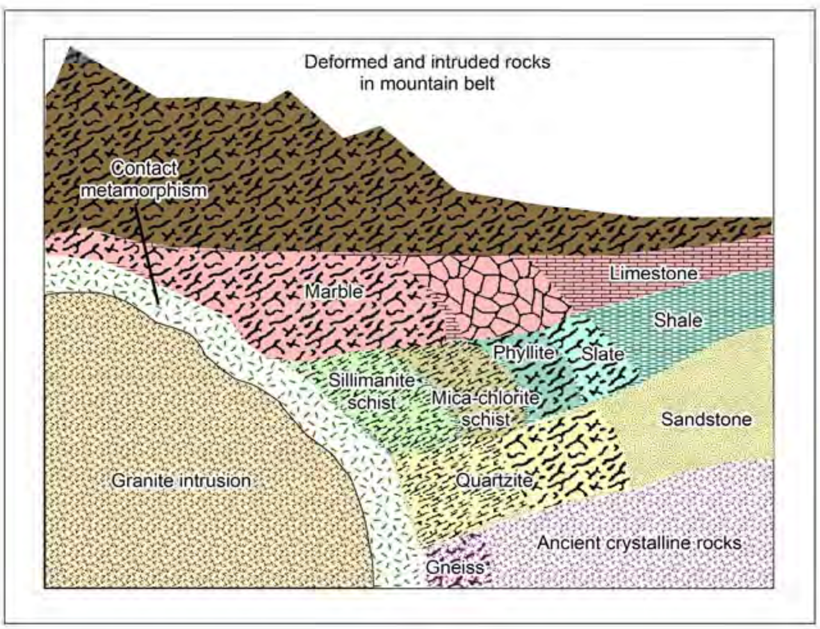


This diagram shows the typical transition in mineralogy that can result from progressive metamorphism of shale.

- **Two types of metamorphism**:
  Widespread regional and local contact adjacent to igneous intrusions.

  Contact metamorphism occurs locally, adjacent to igneous intrusions. It also occurs along fractures that are in contact with hot fluids. The metamorphism is greatest at the contact between the host rock and the intrusive magma and dissipates as one moves away from the contact into the host rock.

  Regional metamorphism occurs over very large areas such as mountain ranges and results from 1) major igneous intrusions that form and cool over thousands to millions of years; 2) the extreme pressure and heat associated with deep burial or tectonic movements of rock; or 3) very widespread migration of hot fluids throughout a region which would involve hydrothermal metamorphism.



The diagram shows a hypothetical vertical section through a mountain range that contains a very large granite intrusion. The cross section illustrates both contact and regional metamorphic effects of the heat and pressure caused by the intrusion. Compare the broad, regional metamorphic changes to the narrow zone of contact metamorphism adjacent to the intrusion.

Changes due to metamorphism in mono-mineral rocks

- Sandstone becomes metaquartzite by recrystallization of the cement.
- Limestone and dolostone become calcite and dolomite marble, respectively.
- Organic beds become higher ranks of coal.
- With contact metamorphism, shale may become hornfels or even pyroxenite with extreme temperatures.

When classifying metamorphic rocks, we look at two main rock textures, foliated and non-foliated. Foliated textures exhibit an alignment (parallel planes)of minerals due to pressure and recrystallization. Some common types of foliated texture are listed below:

- Slaty cleavage – a nearly perfect, planar, parallel foliation of very fine-grained platy minerals – mainly micas.
- Phyllitic texture – a parallel, but wavy, foliation of fine-grained platy minerals (mainly micas and chlorite) exhibiting a shiny or glossy luster.
- Schistosity – a parallel-to-subparallel foliation of medium-to-coarse-grained platy minerals (mainly mica and chlorite).
- Gneissic texture – a parallel-to-subparallel foliation of medium-to-coarse-grained minerals in alternating layers of different composition.

Additional Metamorphic Rocks

Gneiss

Marble

Serpentine

Talc

Calcite Marble →

Arkansas contains three metamorphic rocks that were formed by contact metamorphism adjacent to igneous intrusions. The rocks are listed below:

1) soapstone
2) hornfels
3) pyroxenite

Uses of some metamorphic rocks

Marble – building and decorative stone.
Gneiss – ornamental building stone and aggregate.
Schist – a source for garnets.
Serpentinite – indoor decorative stone.
Soapstone - traditionally used for fireplace hearths, sinks, countertops, and wood stoves.
Slate - used as a roofing material, a flooring material and for electrical insulation.
Quartzite – used as flooring, decorative or building stone.

Classification of common *foliated* metamorphic rocks

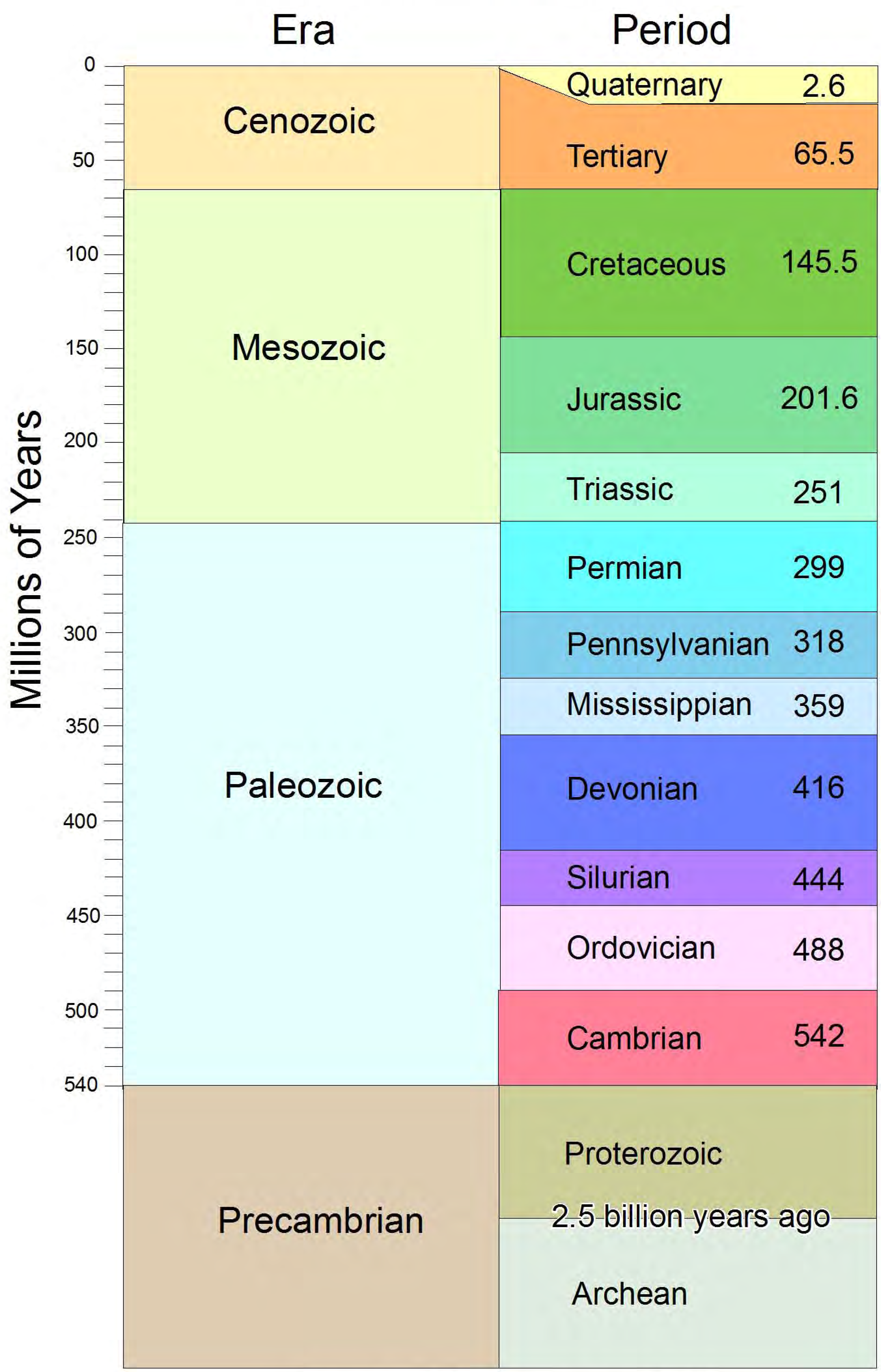
Crystal Size	Rock Names		Comments
Microscopic; very fine-grained	Slate		Slaty cleavage well developed
Fine-grained	Phyllite		Phyllitic texture well developed; silky
Coarse-grained macroscopic; mostly micaceous minerals or prismatic crystals often with porphyroblasts	Schist	Muscovite Schist Chlorite Schist Biotite Schist Tourmaline Schist Garnet Schist Staurolite Schist Kyanite Schist Sillimanite Schist Amphibole Schist	Types of schist recognized on the basis of mineral content
Coarse-grained mostly nonmicaceous minerals	Gneiss		Well developed color banding due to alternating layers of different minerals.

Classification of common *nonfoliated* metamorphic rocks

(rocks in red are from Arkansas)

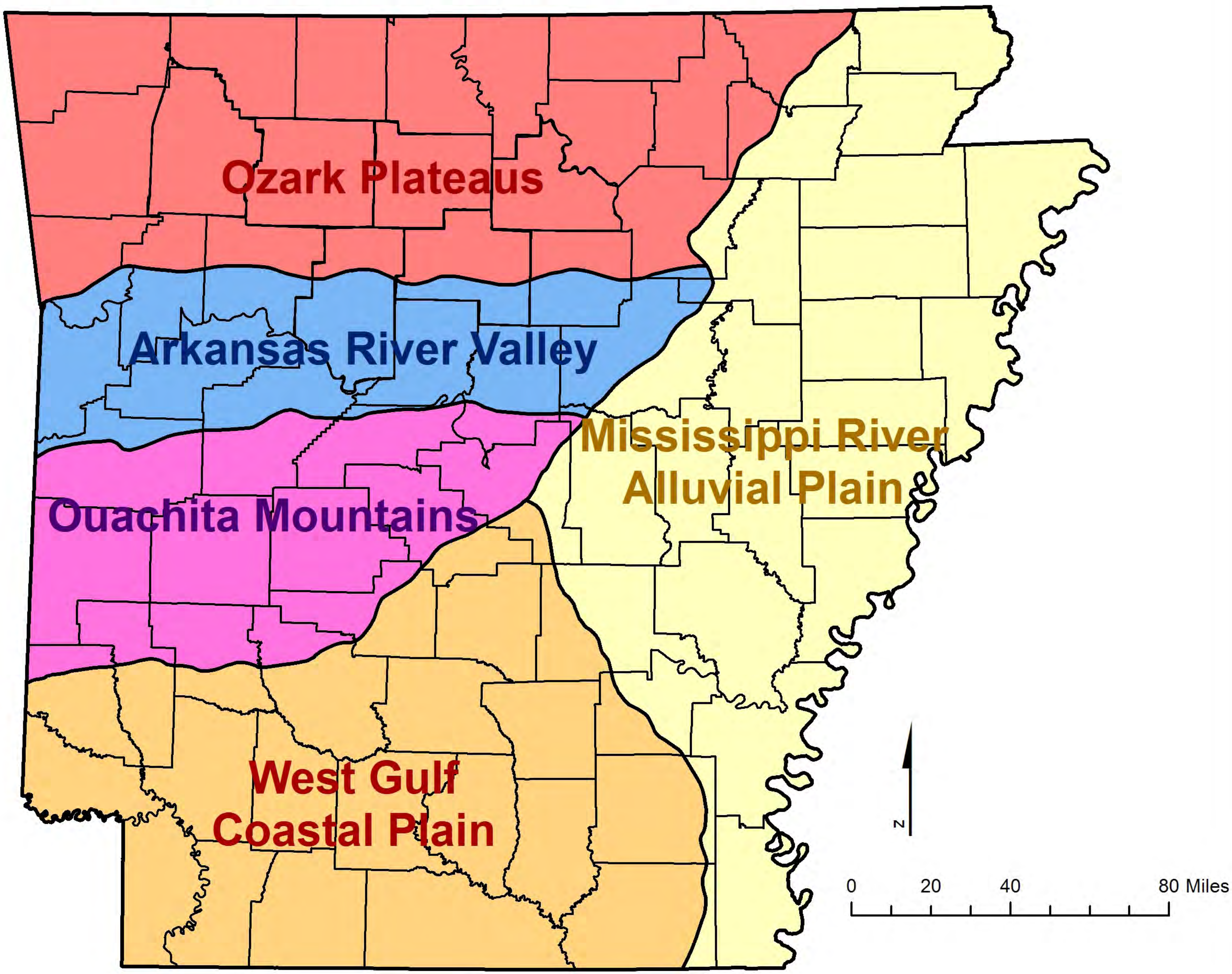
Precursor Rock	Metamorphic Rock	Comments
Quartz Sandstone	Quartzite	Composed of interlocking quartz grains
Conglomerate	Stretched-Pebble Conglomerate	Original pebbles distinguishable but strongly deformed
Basalt or Gabbro	Greenstone	Composed of epidote and chlorite; green
	Amphibolite	Composed of amphibole and plagioclase; coarse-grained
	Hornfels	Composed of pyroxene and plagioclase; fine-grained
Siltstone	Hornfels	Composed of quartz and plagioclase; fine-grained
Shale	Pyroxenite	Composed of fibrous crystals of pyroxene
Limestone/Dolostone	Marble	Composed of interlocking calcite or dolomite grains
	Skarn/Wollastonite	Composed of calcite and added minerals; multicolored
Peridotite	Serpentinite	Composed chiefly of serpentine; green
	Soapstone	Composed chiefly of talc; soapy feel
Bituminous coal	Anthracite coal	Bright, hard coal; breaks with conchoidal fracture

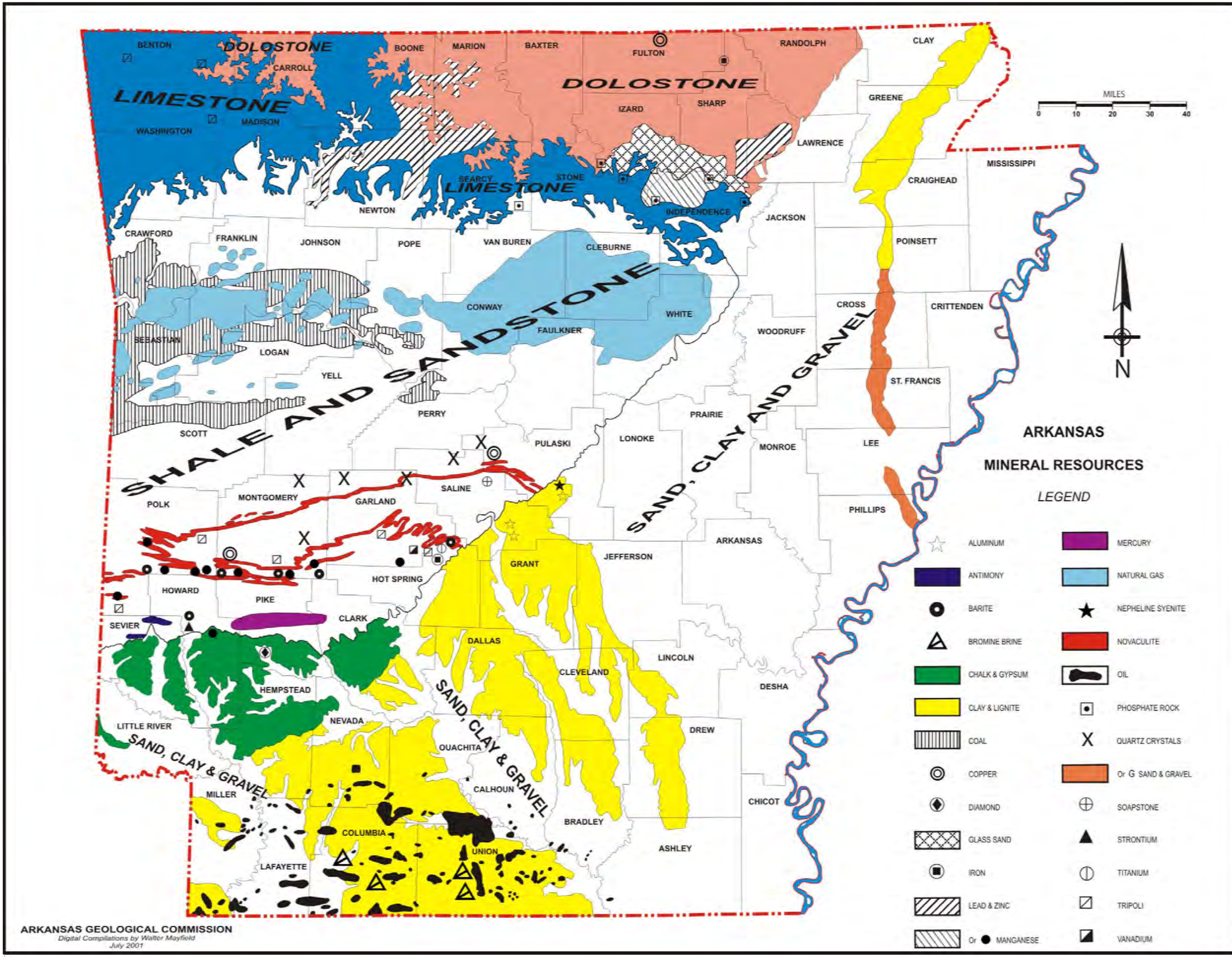
Geologic Time Scale



Based on 2009 Geologic Time Scale
Geological Society of America

Physiographic Regions of Arkansas





ARKANSAS
MINERAL RESOURCES
LEGEND
ALUMINUM
ANTIMONY
BARITE
BROMINE BRINE
CHALK & GYPSUM
CLAY & LIGNITE
COAL
COPPER
DIAMOND
GLASS SAND
IRON
LEAD & ZINC
Or MANGANESE
MERCURY
NATURAL GAS
NEPHELINE SYENITE
NOVACULITE
OIL
PHOSPHATE ROCK
QUARTZ CRYSTALS
Or G SAND & GRAVEL
SOAPSTONE
STRONTIUM
TITANIUM
TRIPOLI
VANADIUM
MILES
0 10 20 30 40
N
LIMESTONE
DOLOSTONE
SHALE AND SANDSTONE
SAND, CLAY AND GRAVEL
SAND, CLAY & GRAVEL
BENTON
CARROLL
BOONE
MARION
BAXTER
FULTON
RANDOLPH
CLAY
WASHINGTON
MADISON
IZARD
SHARP
GREENE
LAWRENCE
SEARCY
STONE
NEWTON
INDEPENDENCE
CRAIGHEAD
MISSISSIPPI
JACKSON
CRAWFORD
FRANKLIN
JOHNSON
POPE
VAN BUREN
CLEBURNE
POINSETT
SEBASTIAN
LOGAN
CONWAY
FAULKNER
WHITE
WOODRUFF
CROSS
CRITTENDEN
YELL
PERRY
ST. FRANCIS
SCOTT
PULASKI
LONOKE
PRAIRIE
MONROE
LEE
POLK
MONTGOMERY
GARLAND
SALINE
PHILLIPS
HOT SPRING
GRANT
JEFFERSON
ARKANSAS
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PIKE
CLARK
SEVIER
DALLAS
CLEVELAND
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DESHA
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July 2001

Geologic Map of Arkansas