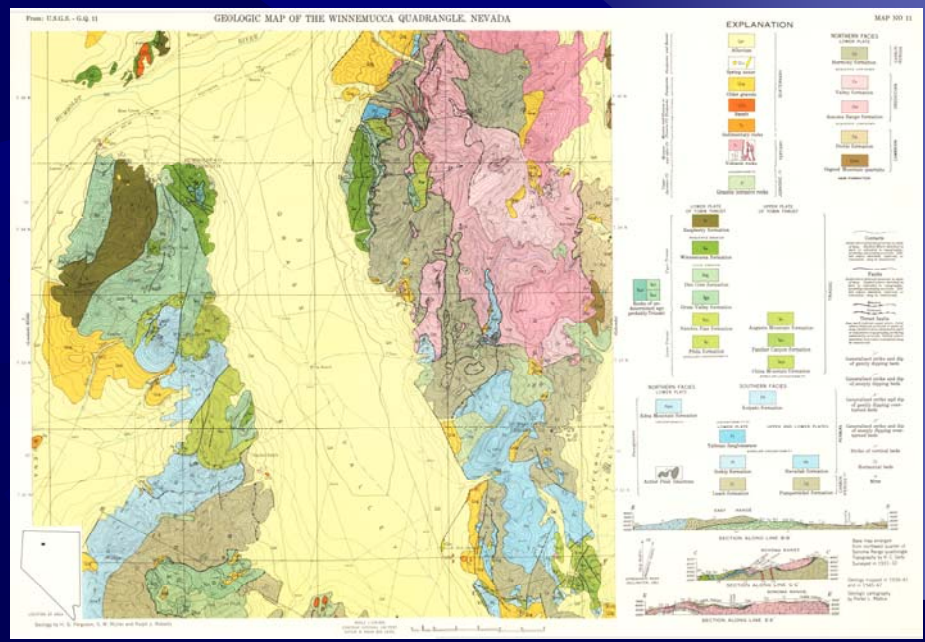
Other Geological Applications to Forensic Investigations –Rocks, Geologic Maps, and Building Materials

Rocks



Geologic maps

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Characterizing Rocks

There are 3 major types of rocks

IGNEOUS formed from molten magma

SEDIMENTARY formed from sediment (soil, sand, etc,)

METAMORPHIC formed by applying heat and pressure to existing rocks

Characterizing Rocks

The three major chacterizing features of rocks are:

- Color
- Composition (Mineralogy/Chemistry)
- Texture

Note: Even the most sophisticated geological classification schemes are based on these features

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Characterizing Rocks

Classification by Color

Color Index (used mainly for igneous rocks)

- Leucoratic
- Mesocratic
- Melanocratic

and/or

- Felsic
- Mafic

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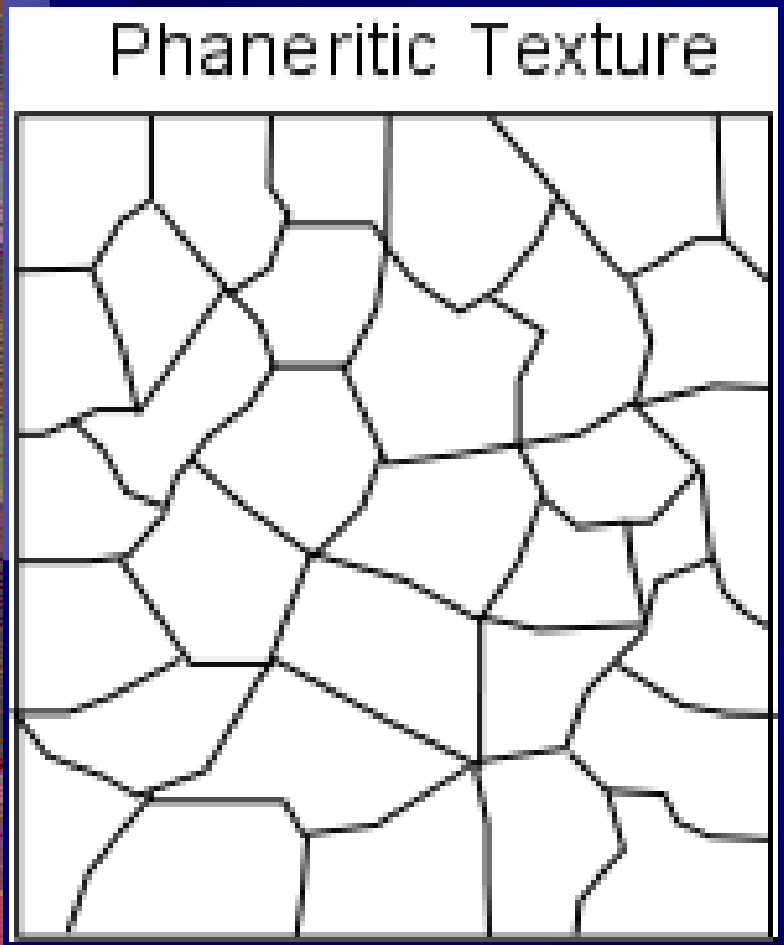
Characterizing Rocks

Textures of Igneous Rocks

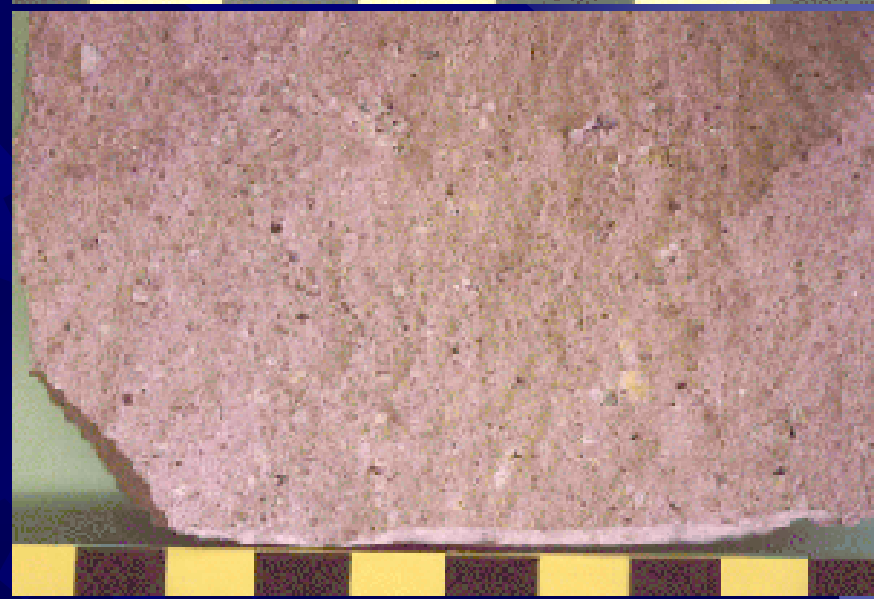
- Aphanitic
- Phaneritic
- Porphyritic
- Inclusions
  - > Xenoliths
  - > Xenocrysts

Phaneritic Texture

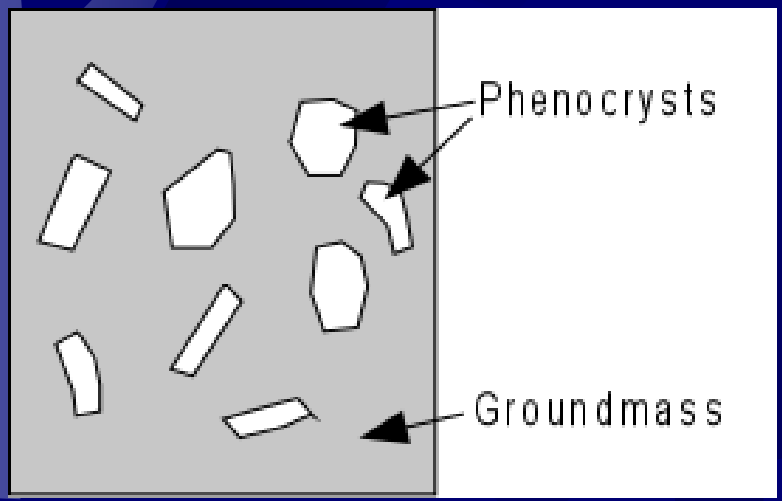


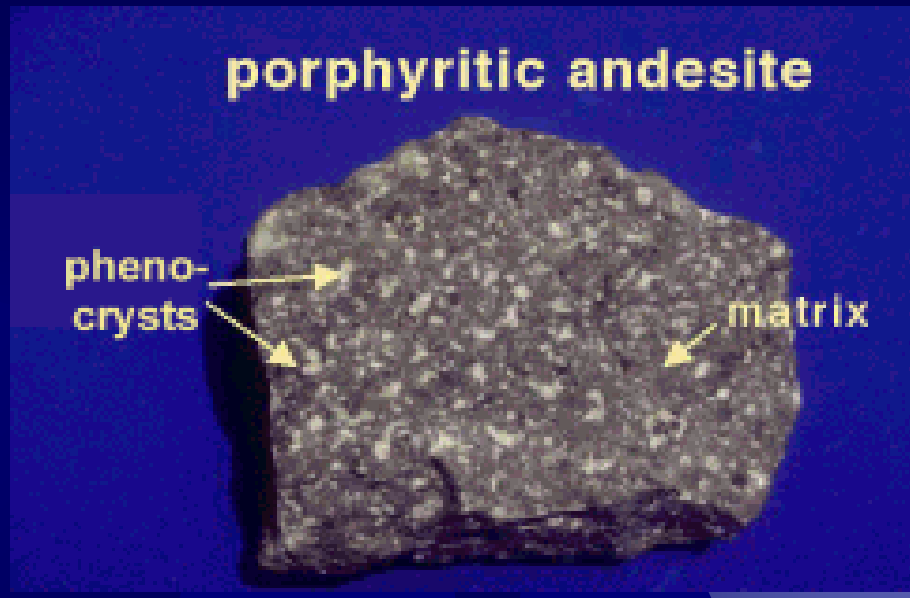
Aphanitic Texture

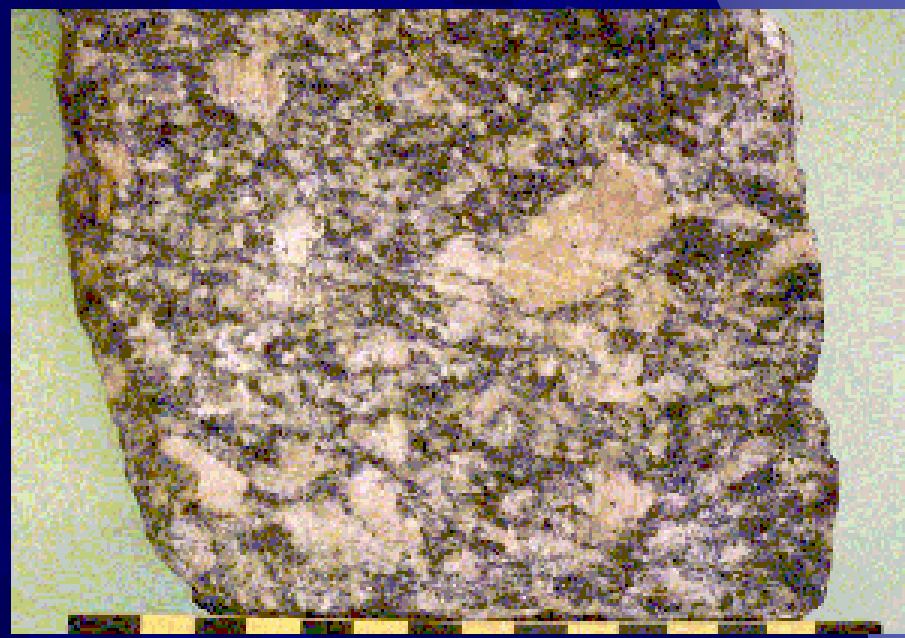
Aphanitic Texture



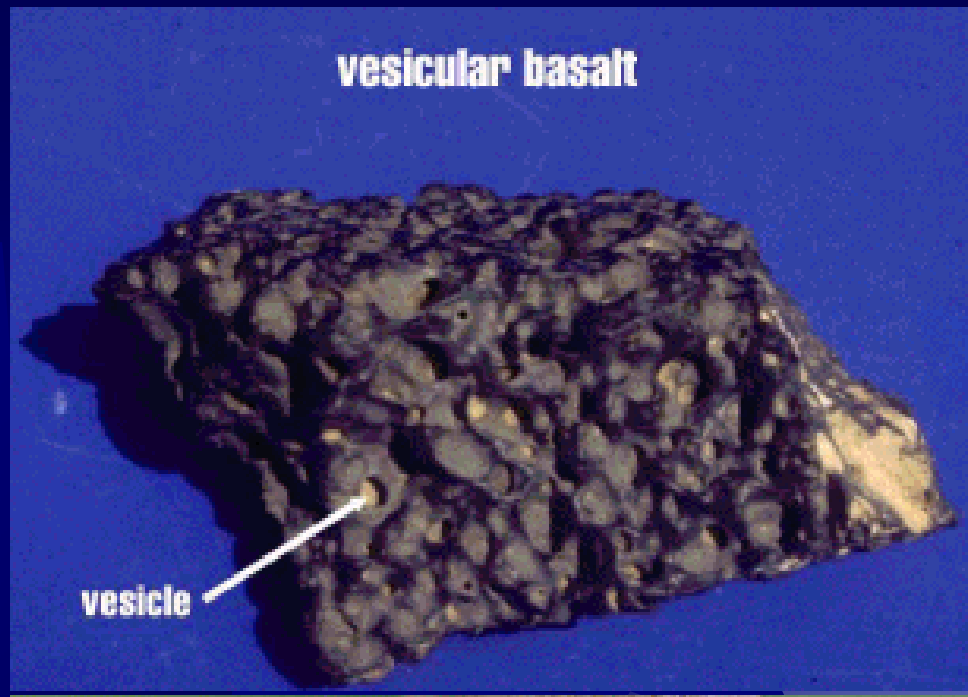
Porphyritic Texture







Vesicular & Glassy Textures



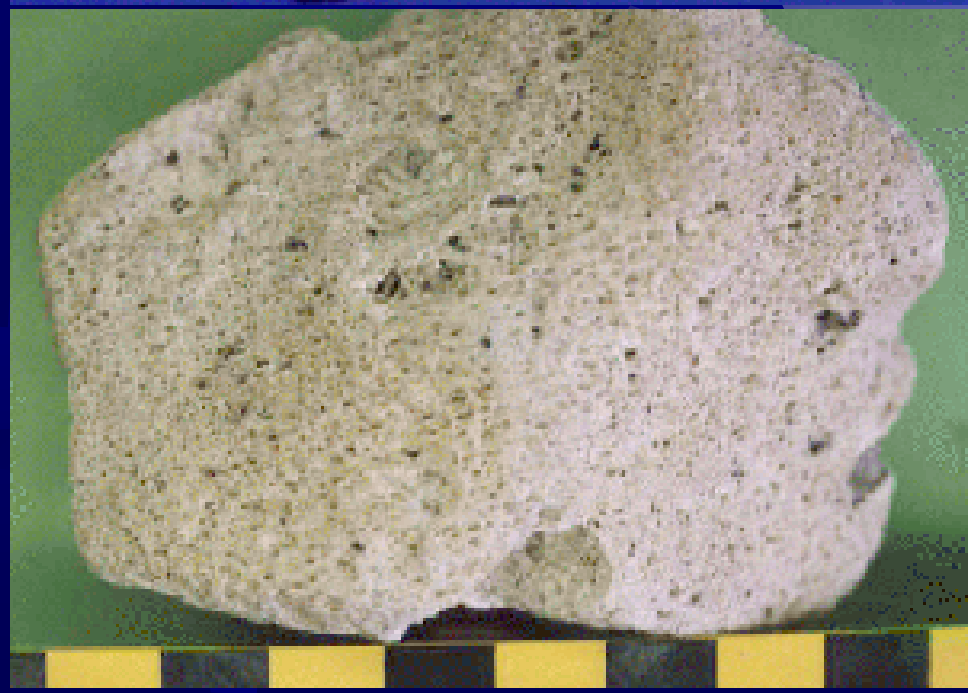
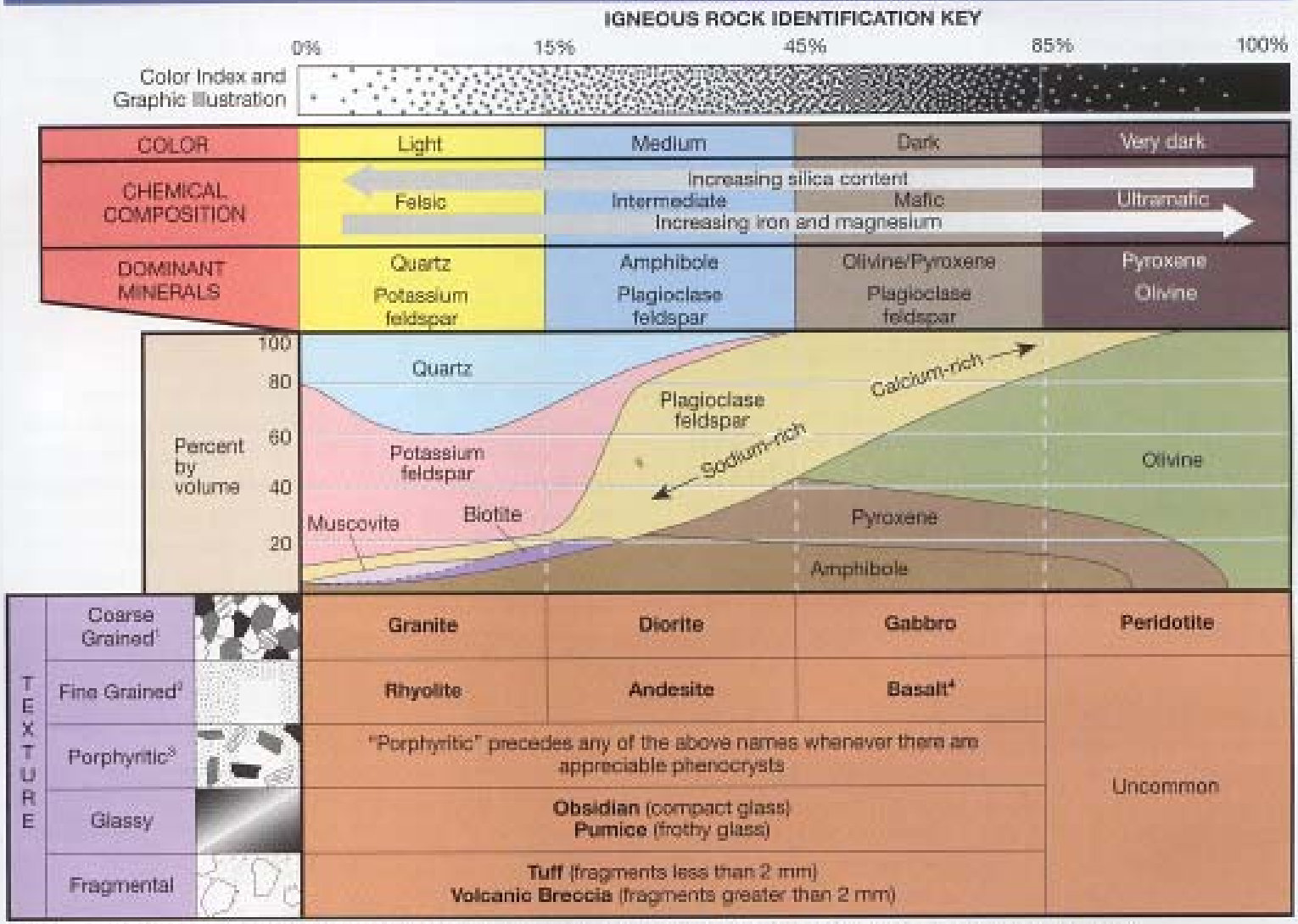


Table 2.1 Igneous rock identification key. Color, with associated mineral composition, is shown along the top axis. Each rock in a column has the color and composition indicated at the top of the column. Texture is shown along the left side of the key. Each rock in a row has the texture indicated for that row.
To determine the name of a rock, intersect the appropriate column (color & mineral composition) with the appropriate row (texture) and read the name at the place of intersection.



[1] Also called *phaneritic*. Crystals generally 1–10 mm (1 cm). The term pegmatite is added to the rock name when crystals are greater than 1 cm; e.g. granite-pegmatite.
[2] Also called *aphanitic*. Crystals generally less than 1 mm.
[3] For example, a granite with phenocrysts is called porphyritic granite.
[4] Basalt with a cinder-like appearance that develops from gas bubbles trapped in cooling lava (a texture referred to as vesicular) is called scoria.

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Sedimentary Rocks

Detrital & Chemical Rock Classification

Detrital Rocks

- **Conglomerate**
- **Sandstones**
- **Siltstone**
- **Shale**

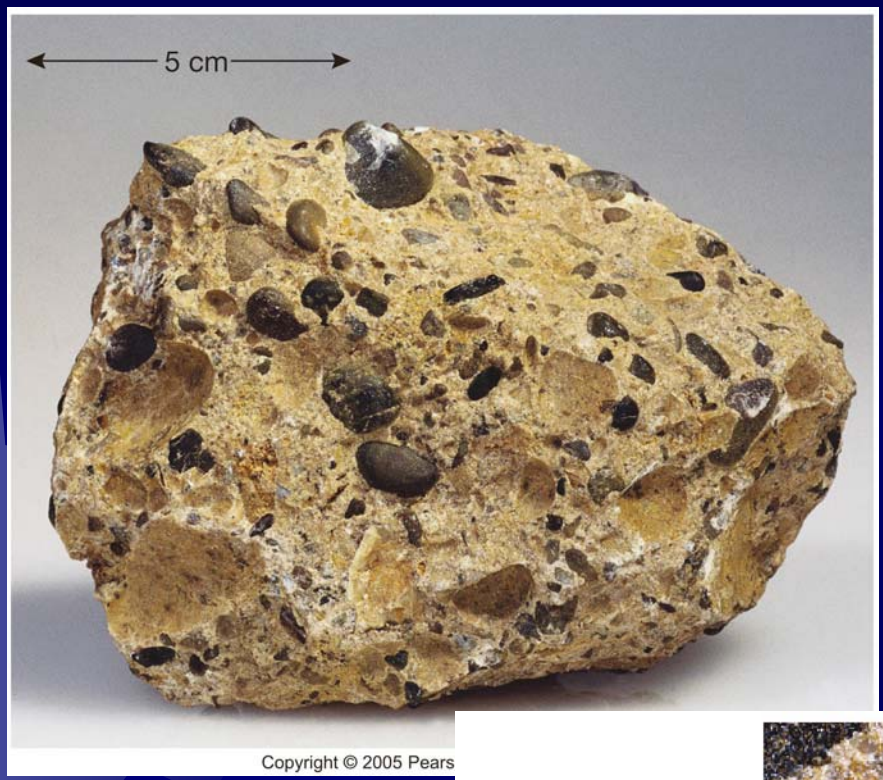
Chemical Rocks

- **Limestone**
- **Chert** (Flint)
- **Salt** (Evaporite)

Detrital Sedimentary Rocks

- Conglomerates
  - Poorly Sorted particle sizes
  - Well-rounded particles
  - Usually particles are gravel sized

Conglomerate



Close up

Detrital Sedimentary Rocks

- **Breccia**
  - **Poorly sorted grains**
  - **Angular grains**
  - **Gravel sized grains**

Breccia

Close up

Detrital Sedimentary Rocks

- Sandstone
  - Well sorted particles
  - Particles can be angular to rounded
  - Sand-sized Particles

Quartz Sandstone

Other types of sandstone

Graywacke – contains rock fragments

Arkose – contains significant feldspar

Close up

Detrital Rocks

- Shale
  - Microscopic grain size
  - Consist of silt and clay size grains
  - Cannot see grains with naked eye
  - Occur in “quiet” depositional environments

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Shale

Chemical Rocks

- Classification
  - Inorganic - Not produced by living things.
  - Biochemical - Are produced by or are remnants of living things (e.g. shell fragments, coral reefs, etc)

Chemical Rocks

- Limestone
  - Most abundant chemical rock
  - Inorganic (oolitic limestone, Travertine) or Biochemical (Chalk, Coquina)

Limestone (Chemical Rocks)

- Travertine
  - Common in caves
  - Happen when calcium carbonate is precipitated out of groundwater

Limestone (Chemical Rocks)

- Coquina
  - Consists of loosely cemented shell fragments

Limestones

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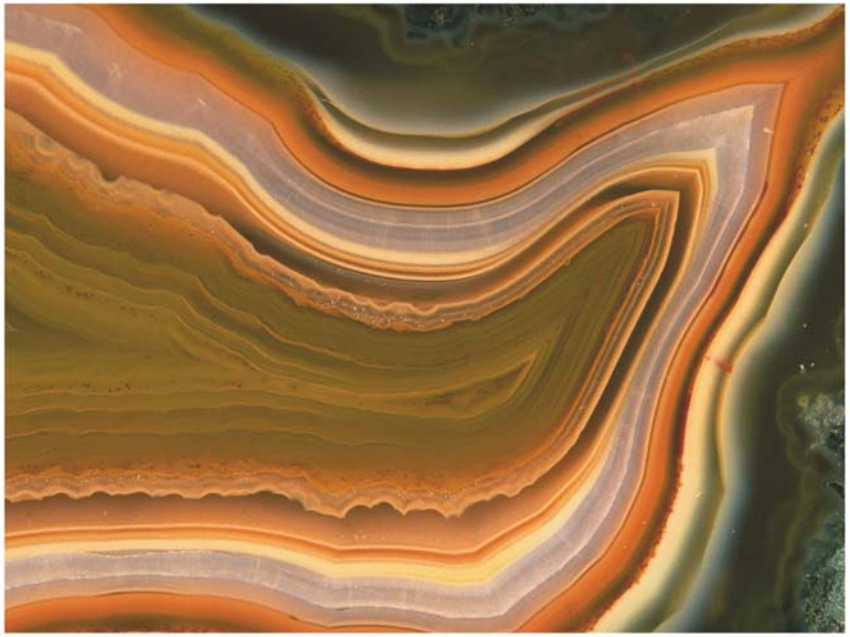
Chemical Sedimentary Rocks

- Chert (Flint)
  - Consists of Microcrystalline Silica
  - Two major occurrences of chert
    - Irregular shaped nodules in limestone
    - layers of rock
  - Most likely Biochemical



A.

Agate

Chert

B.

Table 2.3 Sedimentary rock identification key. Sedimentary rocks are divided into two groups, detrital and chemical, depending upon the type of material that composes them. Detrital rocks are further subdivided by the size of their grains, while the subdivision of the chemical rocks is determined by composition.

DETRITAL ROCKS

Texture (grain size)	Composition	Rock Name
Coarse (over 2 mm) with large grains	Rounded fragments of quartz and/or chert	**Conglomerate**
	Angular fragments of quartz and/or chert	**Breccia**
Medium (1/16 to 2 mm) feels "sandy"	Quartz usually dominates (If abundant feldspar is present the rock is called **Arkose**)	**Sandstone**
Fine (1/16 to 1/256 mm)	Quartz and clay	**Siltstone**
Very fine (less than 1/256 mm)	Quartz and clay	**Shale**

CHEMICAL ROCKS

Composition	Texture (grain size)	Rock Name	
Calcite, $CaCO_3$ (will effervesce)	Fine to coarse crystalline	**Crystalline Limestone**	
	Visible shells and shell fragments loosely cemented	**Coquina**	Biochemical Limestone
	Various size shells and shell fragments cemented with calcite cement	**Fossiliferous Limestone**	
	Microscopic shells and clay	**Chalk**	
Dolomite $CaMg(CO_3)_2$ (will effervesce if powdered)	Fine to coarse crystalline	**Dolostone**	
Quartz, SiO_2	Very fine crystalline	**Chert (light colored) Flint (dark colored)**	
Gypsum $CaSO_4 \cdot 2H_2O$	Fine to coarse crystalline	**Rock Gypsum**	
Halite, NaCl	Fine to coarse crystalline	**Rock Salt**	
Altered plant fragments	Various size fragments	**Bituminous Coal**	

Metamorphic Rocks

- **Classified into two main groups**
  - ***Foliated Rocks***
  - ***Non-foliated Rocks***

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Foliated Rocks

- Progression of Shale to Gneiss
  - Slate — Low Metamorphic Grade
  - Phyllite
  - Schist
  - Gneiss — High Metamorphic Grade

Foliated Textures

- Slaty
- Phyllitic
- Schistosity
- Gneissic

Slate

- Parent Rock
  - Shale
- Slaty Cleavage

(a) Slate

Phyllite

- Parent Rock
  - Slate
- Characteristic sheen/shine
- Phyllitic Texture

Schist

- Parent Rock
  - Phyllite
- Characteristic scaly appearance
- Schistosity

Gneiss

- Parent Rock
  - Schist
- Characteristic of light and dark banding
- Gneissic Texture

Non-foliated Rocks

- Rocks that show no Foliation
  - Crystalline Rocks
  - Marble
  - Quartzite
  - Anthracite

Marble

- Parent Rock
  - Limestone or Dolostone
- Reacts to Acid

(b) Marble

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Quartzite

- Parent Rock
  - Sandstone
- Moderate to high metamorpism
- Very Hard

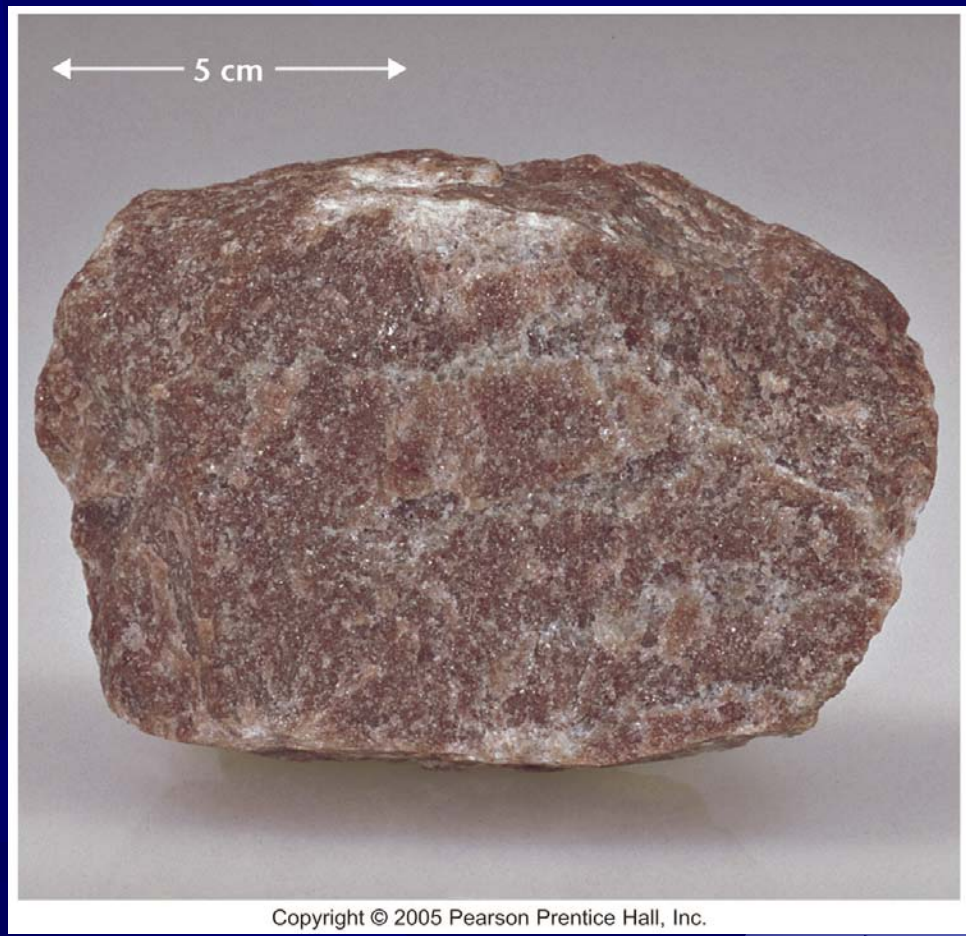
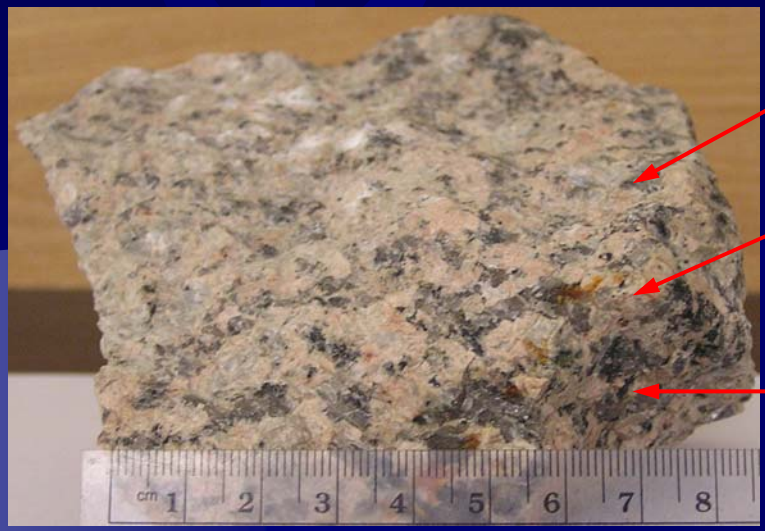


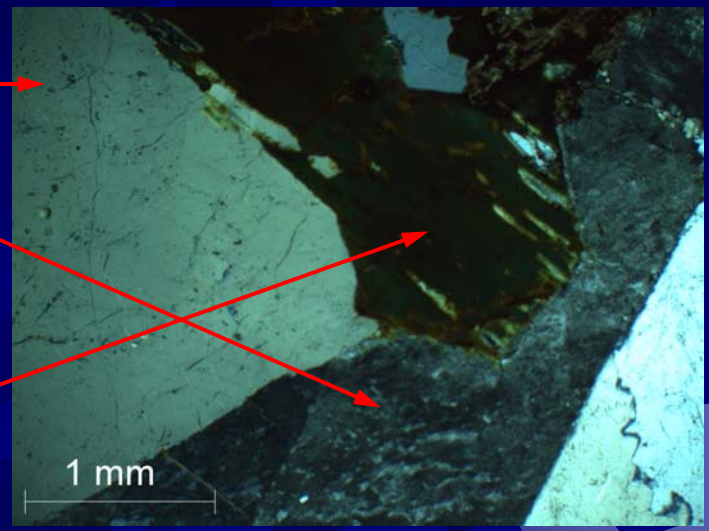
Table 2.5 Metamorphic rock identification key. Metamorphic rocks are divided into the two textual groups, foliated and nonfoliated. Foliated rocks are further subdivided based upon the size of the mineral grains.

Foliated	Oriented		Very fine	Slate	Excellent rock cleavage, smooth dull surfaces	Shale, mudstone, or siltstone
			Fine	Phyllite	Breaks along wavey surfaces, glossy sheen	Slate
			Medium to Coarse	Schist	Micaceous minerals dominate, scaly foliation	Phyllite
	Banded		Medium to Coarse	Gneiss	Compositional banding due to segregation of minerals	Schist, granite, or volcanic rocks
			Medium to Coarse	Migmatite	Banded rock with zones of light-colored crystalline minerals	Gneiss
Nonfoliated			Medium to Coarse	Marble	Interlocking calcite or dolomite grains	Limestone, dolostone
			Medium to Coarse	Quartzite	Fused quartz grains, massive, very hard	Quartz sandstone
			Fine	Hornfels	Usually, dark massive rock with dull luster	Any rock type
			Fine	Anthracite	Shiny black rock that may exhibit conchoidal fracture	Bituminous coal
			Medium to very coarse	Fault breccia	Broken fragments in a haphazard arrangement	Any rock type

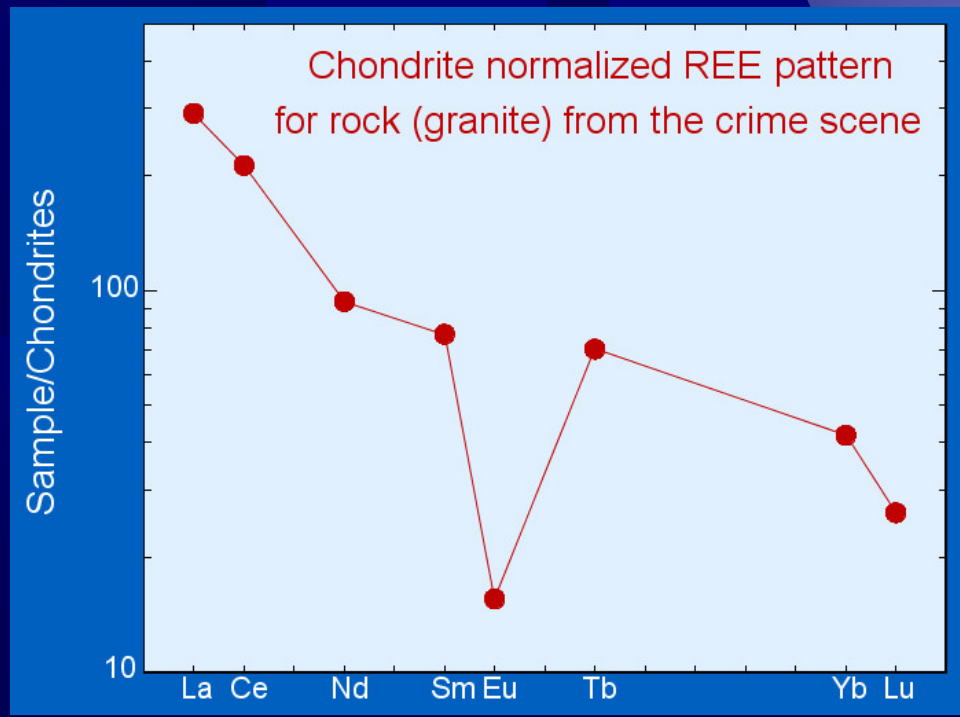
Increasing Metamorphism

Rock Identification





Rock chemistry	
SiO_2	74.89
TiO_2	0.13
Al_2O_3	12.02
Fe_2O_3	1.11
FeO	1.27
MnO	0.06
MgO	0.02
CaO	0.69
Na_2O	3.61
K_2O	4.89



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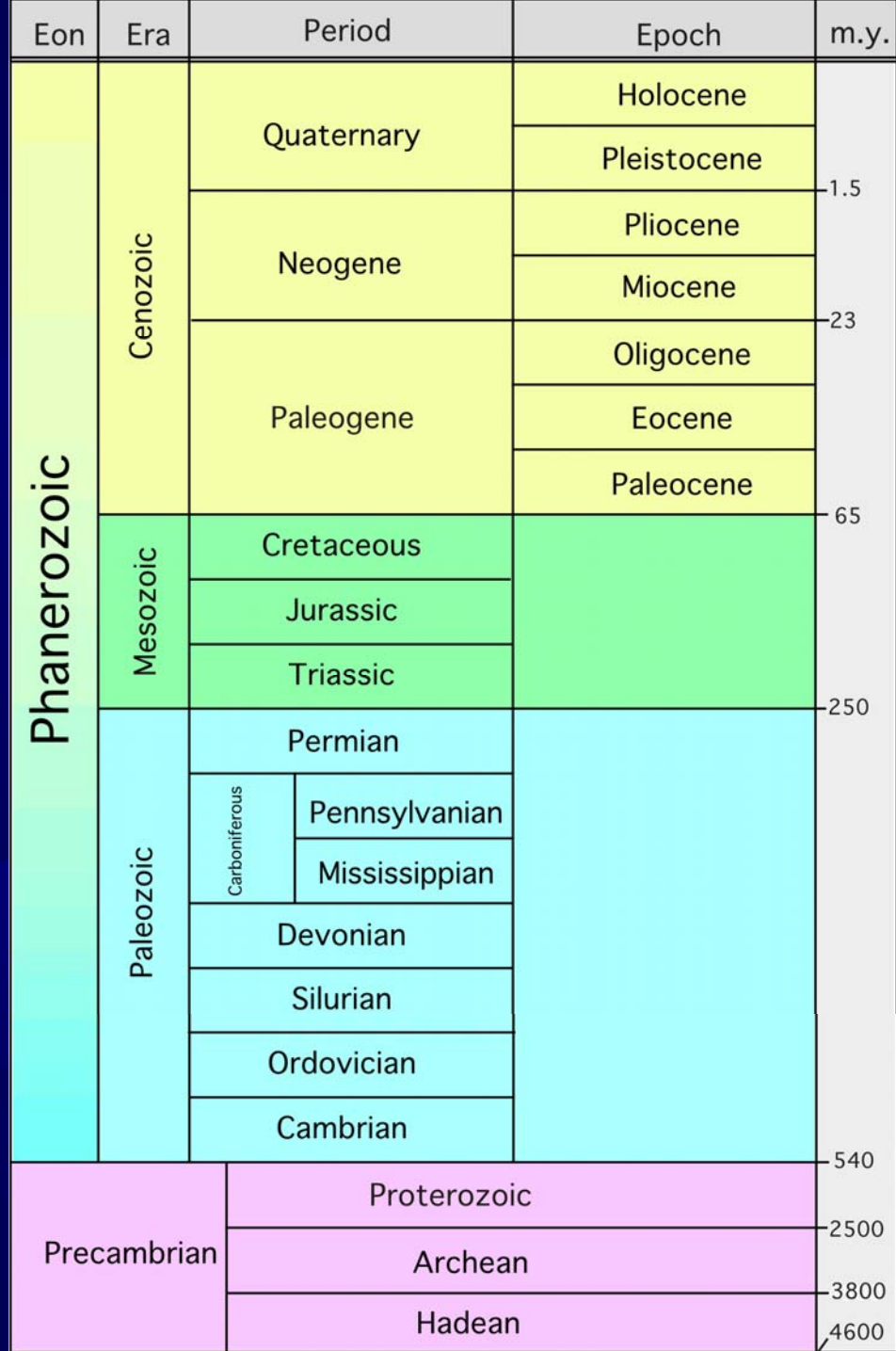
Geologic Time Scale



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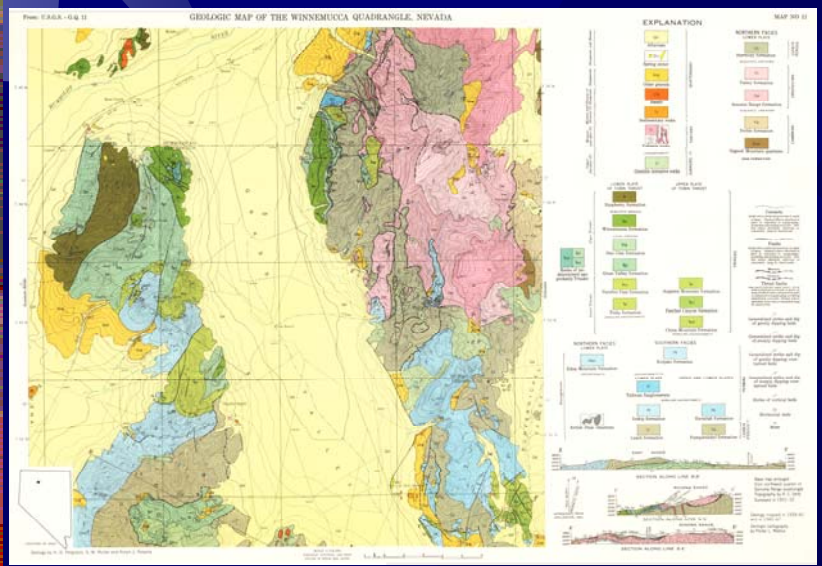
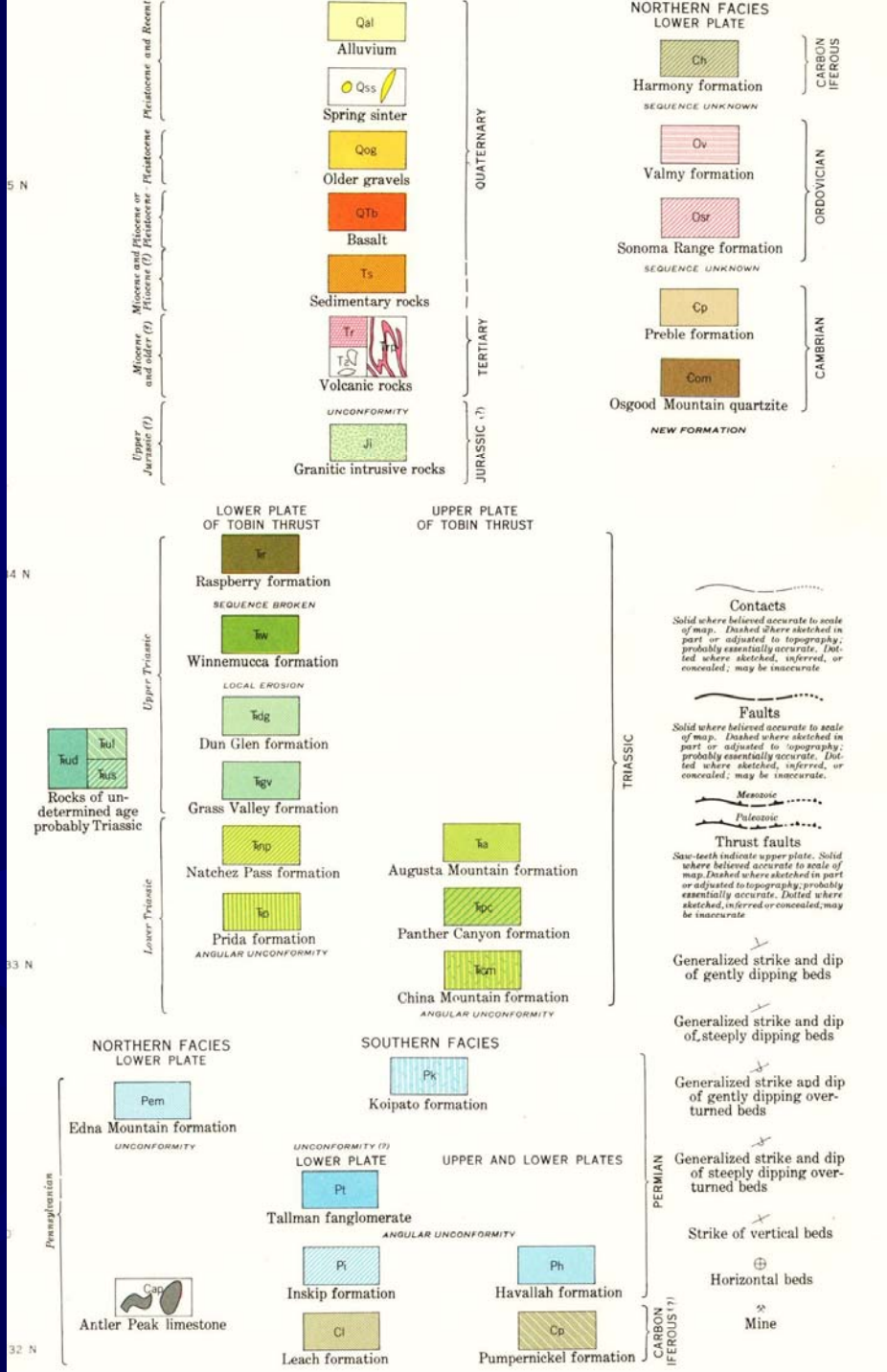
On a geologic map the various rock units are arranged in order of their formation – i.e., according to the geologic time scale





The identification of a rock and linking the sample with a particular location using a geologic map can be useful in solving certain kinds of crimes

Mysterious Glacial Boulders

- At a gas works in Massachusetts igneous boulders showing up in the coal the plant was importing were damaging plant equipment
- When the rocks were examined they were found to be of local origin
- In turned out that a shovel operator that drank on the job was scooping the coal with too deep a setting and picking up the local glacial boulders in the soil under the coal pile
- (thanks to Ray Murray)

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Rawalt/Fiedler Case

Victim: Enrique Camarena

Location: Mexico

Crime: Homicide/Cover-up

Evidence: Rocks from the body recovered during a MFJP raid on a Michoacan farm were shown through a study of Mexican volcanic rocks to have come from near Guadalajara. This information lead to the finding of the original burial site and thus exposed the cover-up.

(thanks to Ray Murray)

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Rocky Scotch Whiskey Case

- When a Canadian importer opened some cases of expensive scotch whiskey he found that the whiskey had been replaced with limestone rocks
- The rocks were traced to their point of origin in central England in a specific limestone quarry
- A specific worker for liquor company had access to the quarry and had been seen taking rocks home
  (thanks to Ray Murray)

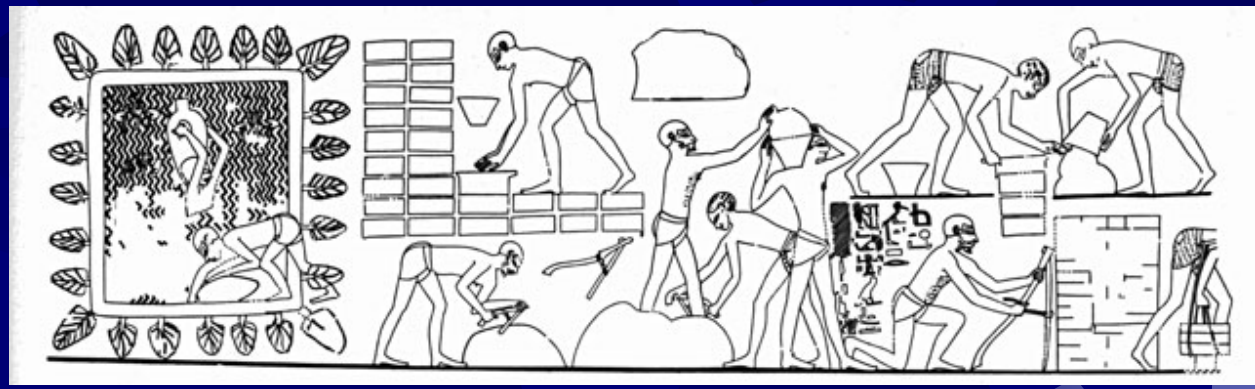
Building Materials

Many building materials are made of or derived from geological materials:

- Stone, gravel, sand, slate, etc.
- Roofing granules
- Bricks, roof and floor tiles
- Cement, concrete, cinder blocks
- Wallboard, plaster
- Glass
- Cleansing powders, abrasives
- Insulation

Brick Making

Bricks have been made since the beginning of civilization



The basic process is to:

* Find a suitable clay
* Press it into a brick mold
* Dry the bricks
* Fire the bricks to 1000°C

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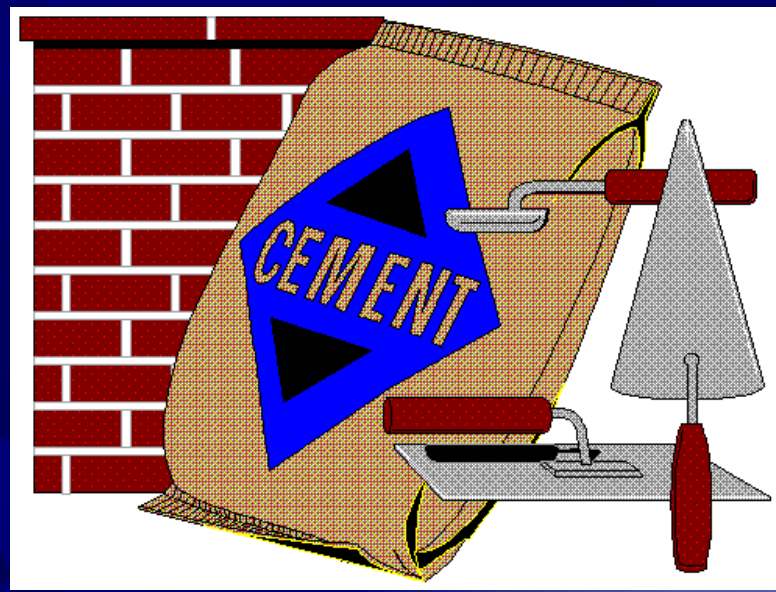
Cement Manufacture

- Cement is made by mixing limestone, sand, clay, and sometimes coal fly ash, with minor amounts of iron and aluminum compounds
- The mixture is fired in a kiln to ~1500°C where the limestone is calcined into lime which reacts with the silicates to form di-and tri calcium silicates, and tri- and tetra calcium aluminates



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Concrete Manufacture

- Concrete is made by mixing cement with sand, gravel, and water.
- This cement slurry coats the aggregate and hardens into a solid mix

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Plaster Manufacture

- Plaster is made by calcining gypsum $CaSO_4 \cdot 2H_2O$ at ~150ºC to its hemi-hydrate $CaSO_4 \cdot \frac{1}{2}H_2O$
- This is an ancient process again going back to the beginning of civilization

Plaster Manufacture

- After the great fire of London in1666 the king of France ordered that all of the wooden structures be coated with plaster to make them fire resistant
- In modern processing various additives, filler, conditioners are added with the result that most plasters can be differentiated from each other

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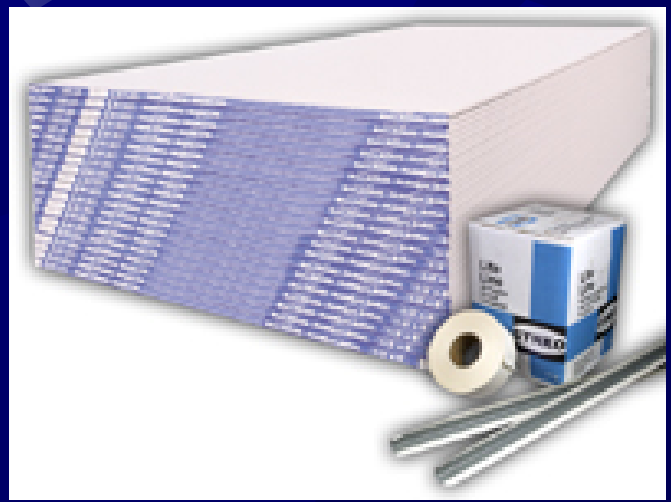
Plaster Manufacture

Today ~88% of the gypsum mined is used in the manufacture of wallboard (39 millions tons/year)



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Glass Manufacture

- Glass making again goes back into ancient times
- Crushed recycled glass, silica sand, soda ash (Na_2CO_3), limestone, and various additives are melted together at temperatures from 1250ºC to 1550ºC
- The molten glass is then rolled, blown, molded into glass products.

Ancient Roman Glass

Abrasives

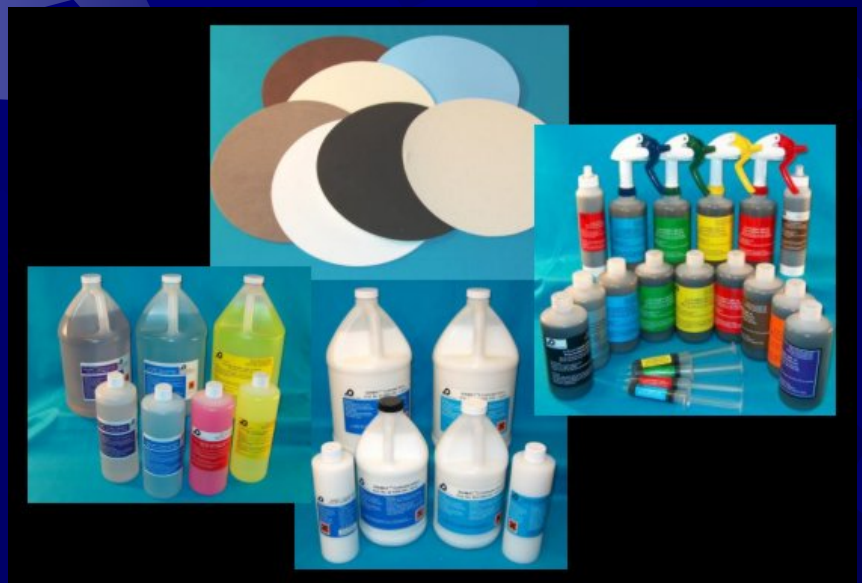
- Abrasive materials are used in a variety of ways from sanding wood to polishing diamonds to cutting steel
- While diamonds are the hardest abrasives, corundum, garnet, SiC, cubic boron nitride, Zi/Al alloys, pumice, and colloidal silica as well as other materials are also used

Diamond

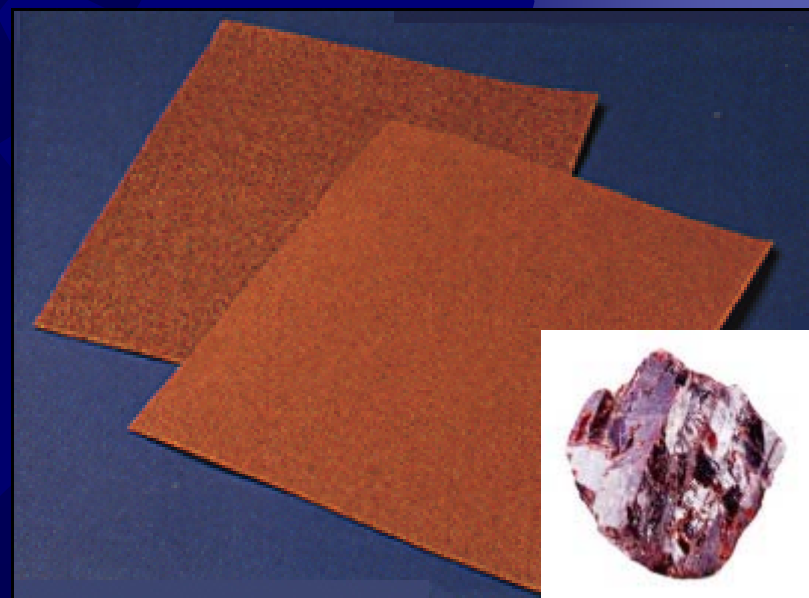
Silicon Carbide

Pumice

Corundum



Garnet



The Role of the Forensic Geologist

- All of these materials have textural and compositional properties well suited to petrographic, chemical, isotopic, x-ray diffraction (except for glass), and spectral analytical methods familiar to geologists

- In fact, it can be argued that the geologist is the ideal scientist to do such a variety of analysis

Building Materials Cases

- In an attempted rape case the rescuer of the victim was followed by the suspect and beaten with an aluminum baseball bat and had the windows of his car smashed out
- Glass adhering to the suspects bat matched the glass from the rescuer's car

  (Murray, 2004, page 101)

Building Materials Cases

- In a classic case a home owner who had insulated his attic with a variety of glass wool insulation bought at various sales
- An intruder who enter the home through the attic was found to have a similar variety of insulation particles on his clothes tying him to the scene

(Murray, 2004, page 103)

Building Materials Cases

- In a diplomatic case the neutral Dutch were accused by the British in WW1 of letting the Germans ship sand and gravel for the construction of military sites through their country

- A British geologist, Capt. W. B. R. King took 39 samples of concrete aggregate from captured German pillboxes and found that 32 of them came from German and not Dutch sources

(Murray, 2004, page 107)

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Building Materials Cases

- In a Japanese case an arsonist tried to conceal his crime by poking a small hole in the outside wall of a building and injecting fuel into the hole

- Investigators found a suspect's screwdriver with fragments of paint and gypsum, that matched the stucco on the house

(Murray, 2004, page 109)

Building Materials Cases

- In a case in Israel a safe cracker stole a safe tried to cut into it using a carbide grinding wheel with two different abrasive discs

- Investigators recovered the grinder and were able to match the grinder to the grinding marks on the safe as well as matching metal particles found on the suspects' shirts to the grinding debris at the scene

  (Zeichner et al., 1993, J. For. Sci., p. 1516-1522)

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Acknowledgements

Many thanks to Jack Crelling (retired), Southern Illinois University, who's classroom PowerPoint presentations form the basis of much of this presentation.