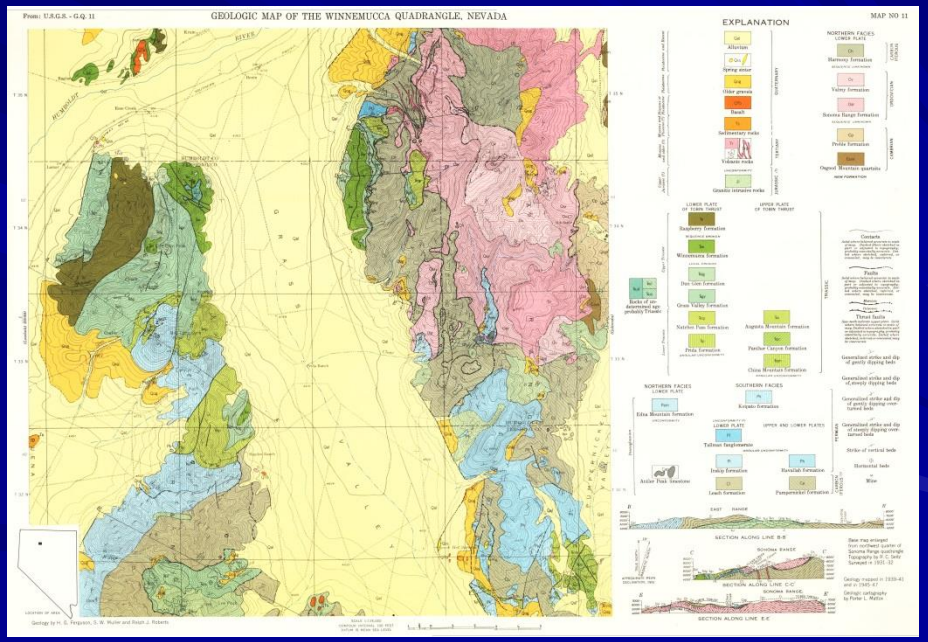
Forensic Geology
Rocks, Geologic Maps, and Building Materials

Rocks



Geologic maps

Characterizing Rocks

There are 3 major types of rocks

Igneous: formed from molten magma

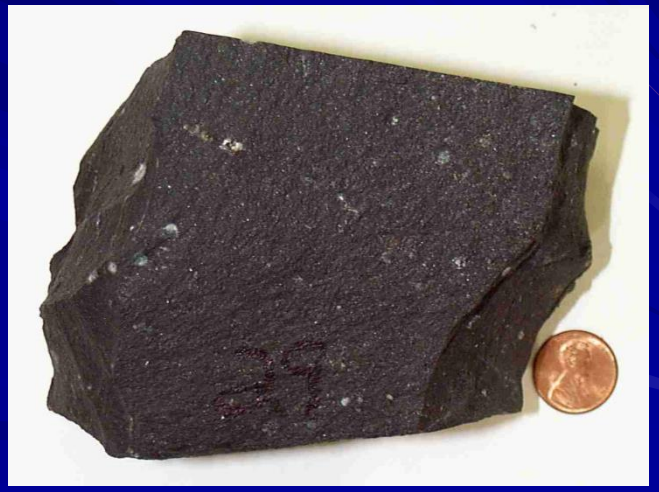
Sedimentary: formed from sediment (soil, sand, etc,)

Metamorphic: formed by applying heat and pressure to existing rocks

The three major characterizing features of rocks are:

- Color
- Composition (Mineralogy/Chemistry)
- Texture

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



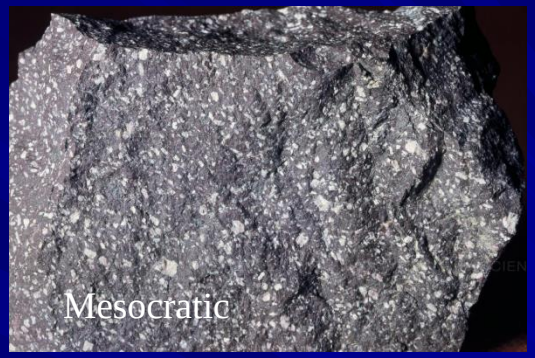
Classification by Color

Color Index (used mainly for igneous rocks)

- Leucocratic
- Mesocratic
- Melanocratic

and/or

- Felsic
- Mafic



Textures of Igneous Rocks

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

Fig. 4. Photograph of a hand specimen of the dyke showing a partially disaggregated cluster of feldspar xenocrysts partially enclosing a biotite phenocryst (to left of coin), a rounded triangular kaersutite cognate xenocryst (black), and a disaggregated granulite xenolith (bottom right corner).

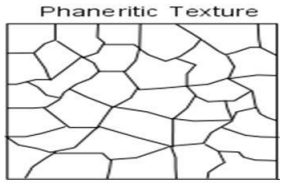
Vesicular

IGNEOUS ROCK TEXTURES

- Phaneritic Texture

Phaneritic textured rocks are comprised of large crystals that are clearly visible to the eye with or without a hand lens or binocular microscope.

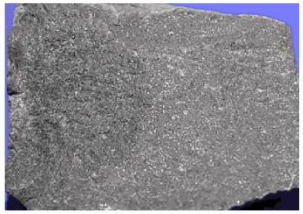
This texture forms by slow cooling of magma deep underground in the plutonic environment.



IGNEOUS ROCK TEXTURES

- Aphanitic Texture

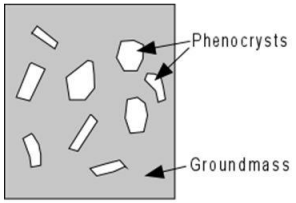
Aphanitic texture consists of small crystals that cannot be seen by the eye with or hand lens. The entire rock is made up of small crystals, which are generally less than 1/2 mm in size.

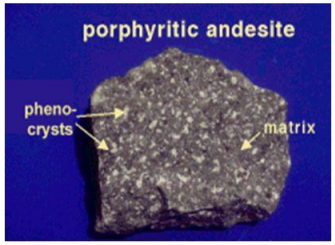


Texture results from rapid cooling in volcanic or hypabyssal (shallow surface) environments.

IGNEOUS ROCK TEXTURES

- Porphyritic Texture





Porphyritic rocks are composed of at least two minerals having a conspicuous (large) difference in grain size. The larger grains are termed phenocrysts and the finer grains either matrix or groundmass

IGNEOUS ROCK TEXTURES

- Glassy Texture

Glassy textured igneous rocks are non-crystalline meaning the rock contains no mineral grains. Glass results from cooling that is so fast that minerals do not have a chance to crystallize.

Simplified Igneous Rock Classification Scheme

Chemical Composition			**Felsic** (Granitic)	**Intermediate** (Andesitic)	**Mafic** (Basaltic)	**Ultramafic**
Dominant Minerals			Quartz Potassium feldspar Sodium-rich plagioclase feldspar	Amphibole Sodium- and calcium-rich plagioclase feldspar	Pyroxene Calcium-rich plagioclase feldspar	Olivine Pyroxene
Accessory Minerals			Amphibole Muscovite Biotite	Pyroxene Biotite	Amphibole Olivine	Calcium-rich plagioclase feldspar
TEXTURE	Phaneritic (coarse-grained)		**Granite**	**Diorite**	**Gabbro**	**Peridotite**
	Aphanitic (fine-grained)		**Rhyolite**	**Andesite**	**Basalt**	**Komatiite** (rare)
	Porphyritic		"Porphyritic" precedes any of the above names whenever there are appreciable phenocrysts			Uncommon
	Glassy		**Obsidian** (compact glass) **Pumice** (frothy glass)			
	Pyroclastic (fragmental)		**Tuff** (fragments less than 2 mm) **Volcanic Breccia** (fragments greater than 2 mm)			
Rock Color (based on % of dark minerals)			0% to 25%	25% to 45%	45% to 85%	85% to 100%

Sedimentary Rocks

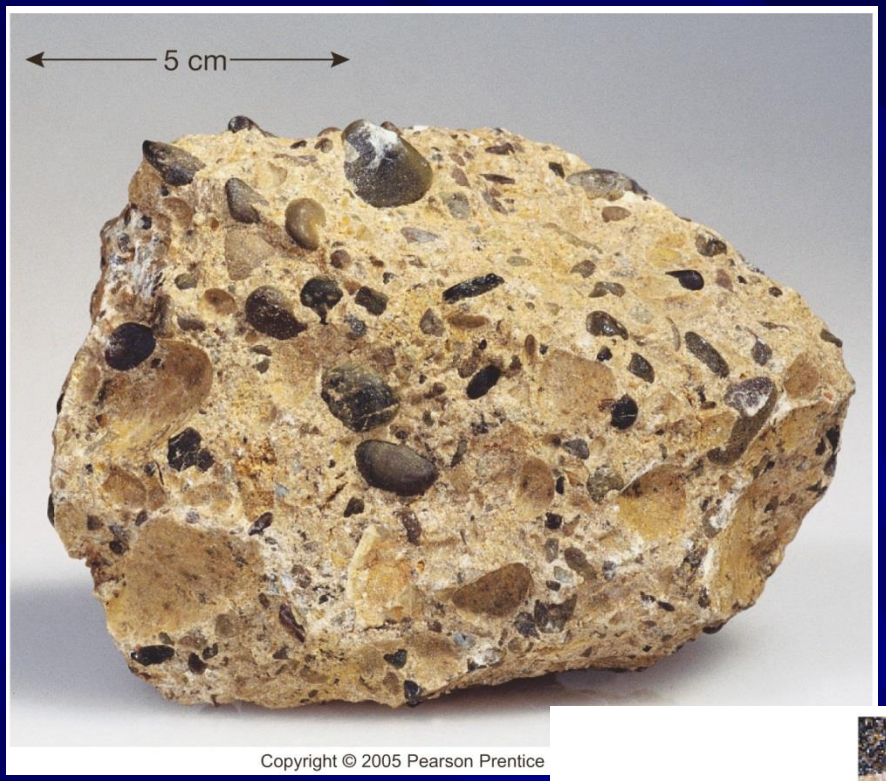
Detrital & Chemical Rock Classification

Detrital Rocks

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

Chemical Rocks

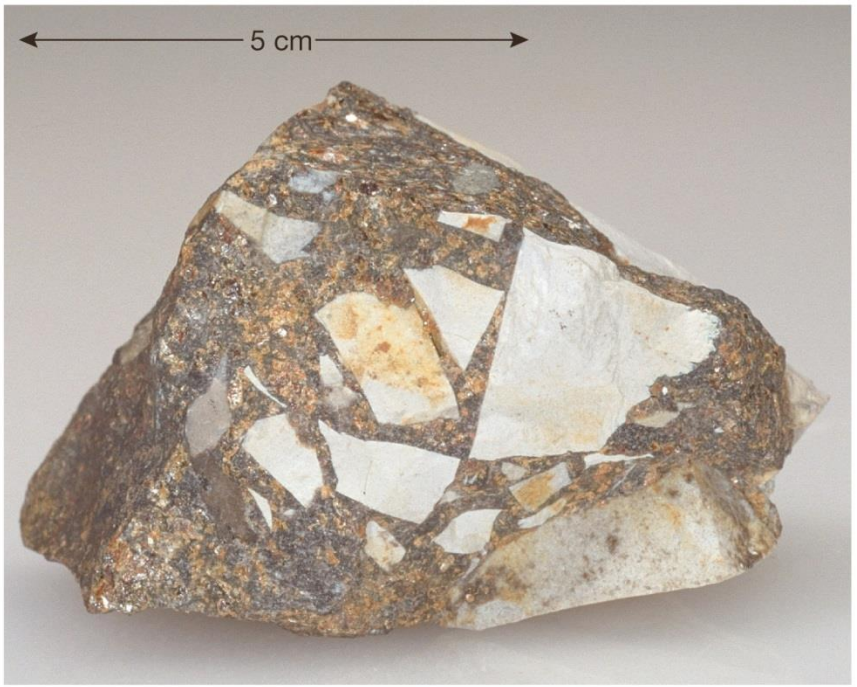
- **Limestone**
- **Chert** (Flint)
- **Salt** (Evaporite)



Conglomerates

- Poorly sorted particle sizes
- Well-rounded particles
- Usually particles are gravel sized

Close up



Breccia

- Poorly sorted grains
- Angular grains
- Gravel sized grains

Close up

Quartz Sandstone

Sandstone

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

Other types of sandstone

- Graywacke – contains rock fragments
- Arkose – contains significant feldspar


Close up

Shale

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

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)

Limestone

- Most abundant chemical rock
- Inorganic (oolitic limestone, travertine) or Biochemical (chalk, coquina)

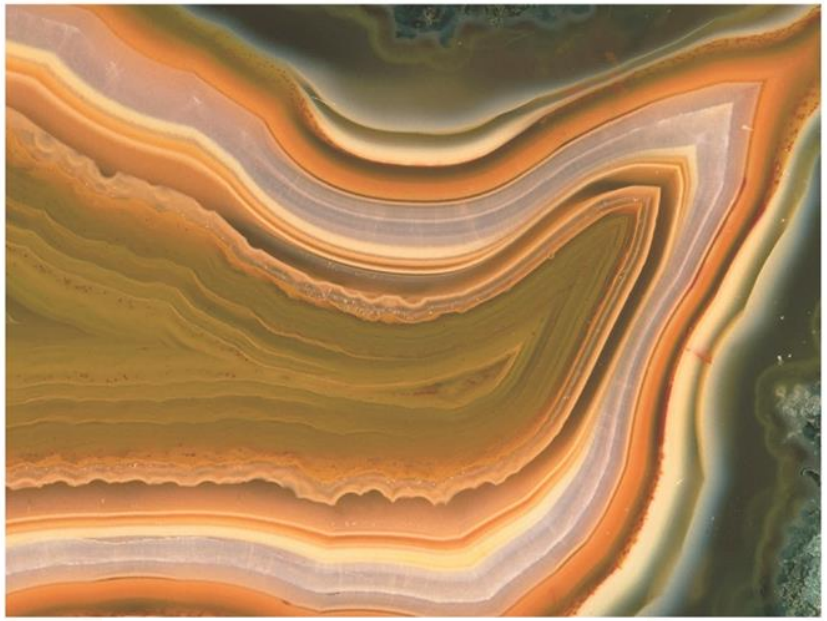
Limestone


Oolitic limestone

Coquina

Chert (Flint)

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



A. Agate

B. Chert

Classification of Major Sedimentary Rocks

Clastic Sedimentary Rocks

Texture (grain size)		Sediment Name	Rock Name
Coarse (over 2 mm)		Gravel (rounded fragments)	**Conglomerate**
		Gravel (angular fragments)	**Breccia**
Medium (1/16 to 2 mm)		Sand	**Sandstone**
Fine (1/16 to 1/256 mm)		Mud	**Siltstone**
Very fine (less than 1/256 mm)		Mud	**Shale**

Chemical Sedimentary Rocks

Composition	Texture (grain size)	Rock Name	
Calcite, $CaCO_3$	Fine to coarse crystalline	**Crystalline Limestone**	
		Travertine	
	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**	
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	Fine-grained organic matter	**Bituminous Coal**	

Metamorphic Rocks

- Classified into two main groups
  - *Foliated Rocks*


Slate


Schist

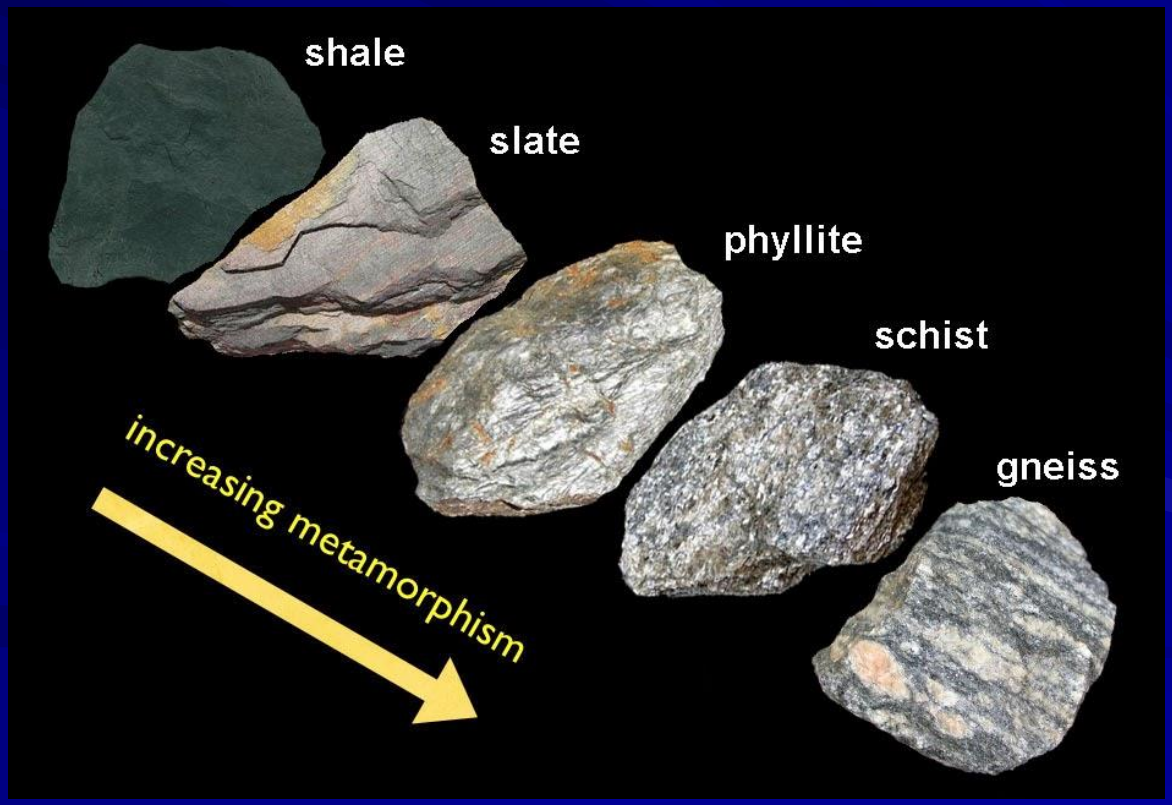
  - *Non-foliated Rocks*


Quartzite


Marble

Foliated Rocks

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

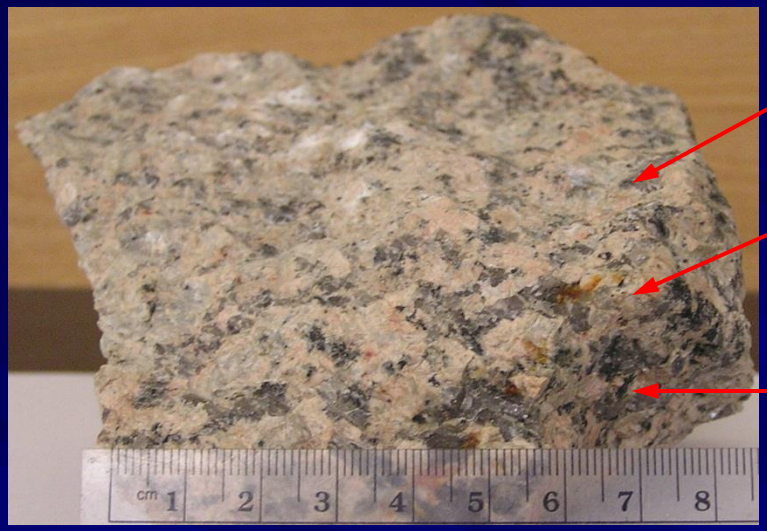


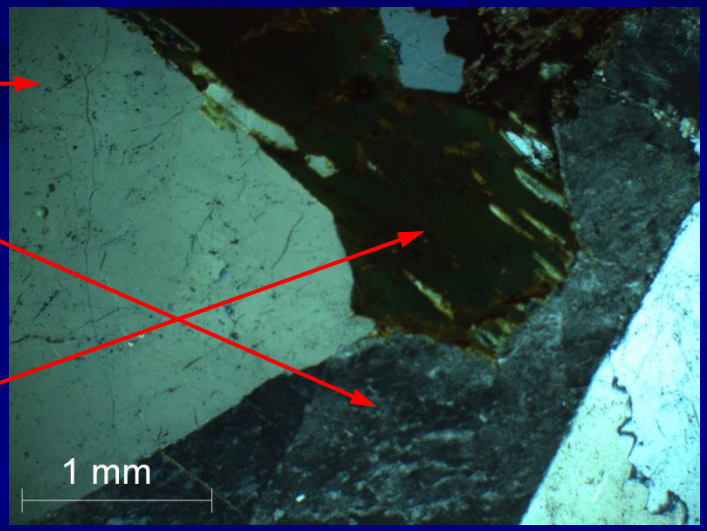
Simplified Metamorphic Rock Classification Scheme

Rock Name	Texture	Grain Size	Comments	Parent Rock
Slate	Foliated	Very fine	Excellent rock cleavage, smooth dull surfaces	Shale, mudstone, or siltstone
Phyllite	Foliated	Fine	Breaks along wavey surfaces, glossy sheen	Slate
Schist	Foliated	Medium to Coarse	Micas dominate, scaly foliation	Phyllite
Gneiss	Foliated	Medium to Coarse	Compositional banding due to segregation of minerals	Schist, granite, or volcanic rocks
Marble	Nonfoliated	Medium to coarse	Interlocking calcite or dolomite grains	Limestone, dolostone
Quartzite	Nonfoliated	Medium to coarse	Fused quartz grains, massive, very hard	Quartz sandstone
Anthracite	Nonfoliated	Fine	Shiny black organic rock that may exhibit conchoidal fracture	Bituminous coal

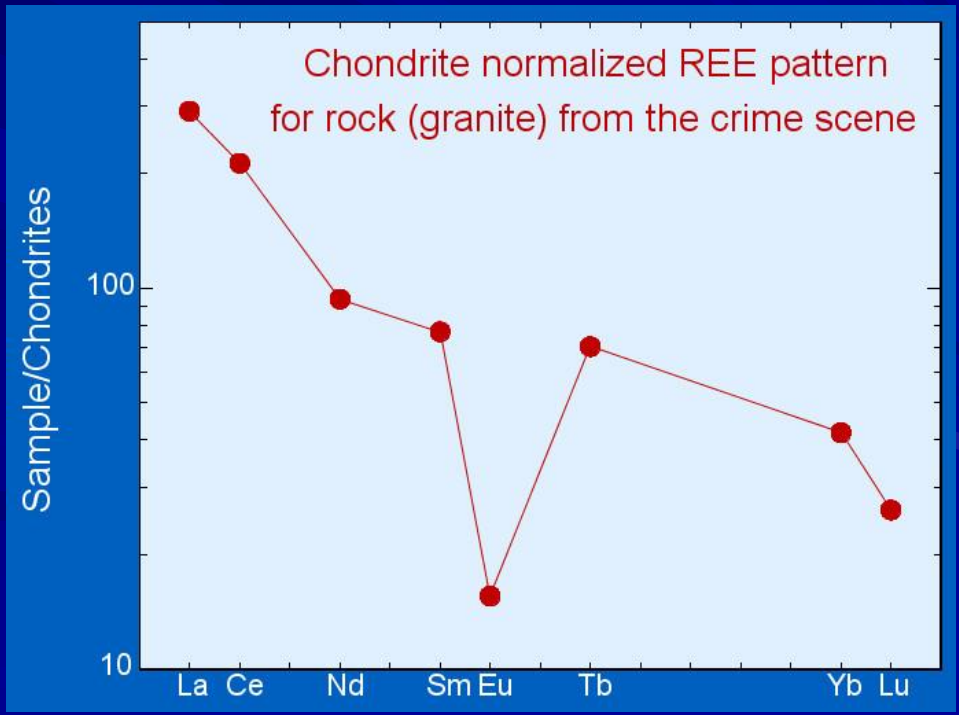
Increasing Metamorphism

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



Macroscopic Observation

Banded iron formation

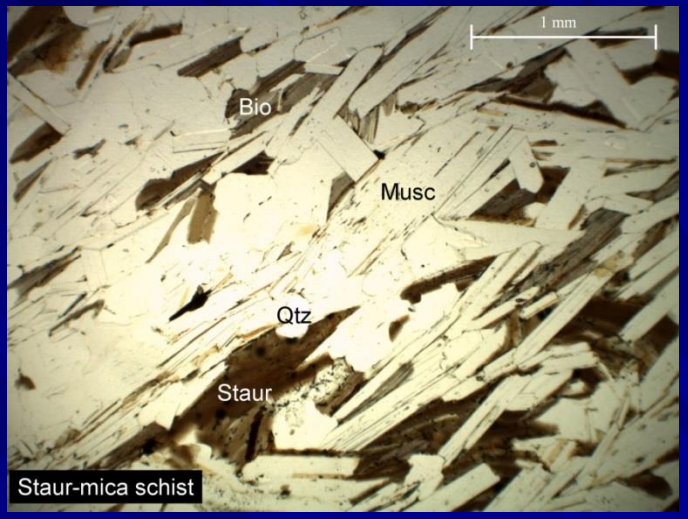
Porphyritic granodiorite

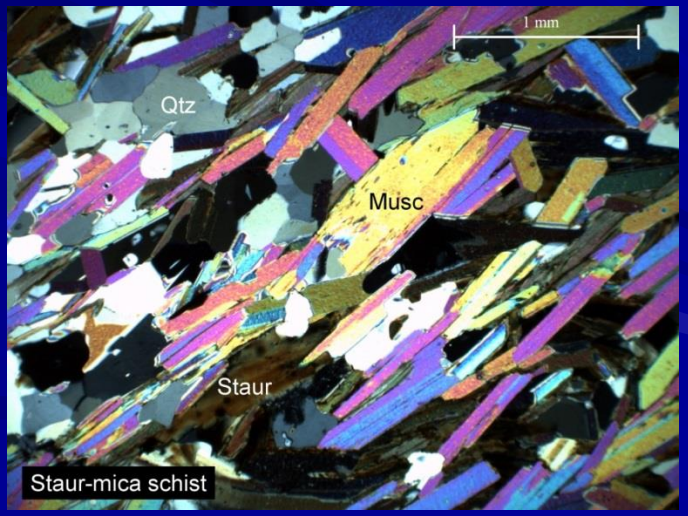
Rapakivi granite

Conglomerate

Microscopic Observation

Thin Section Petrography using the PLM



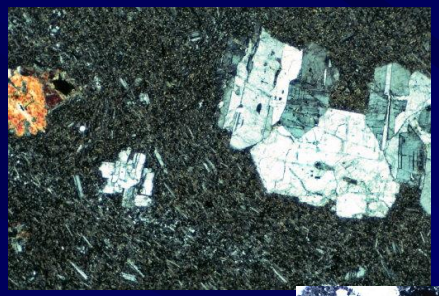


Determining the Chemical Composition of Rocks

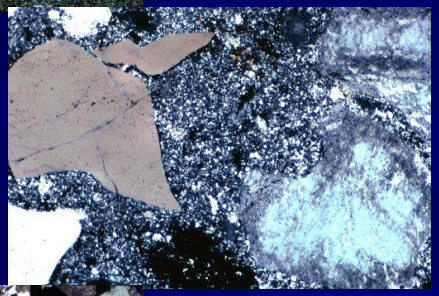
Major elements (oxides) and certain trace elements can be determined by X-ray fluorescence analysis.

Instrumental neutron activation analysis can be used to determine a complementary suite of trace elements.

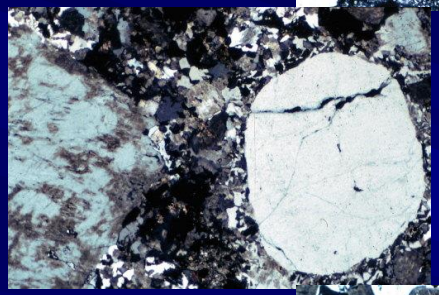
Ossipee ring complex



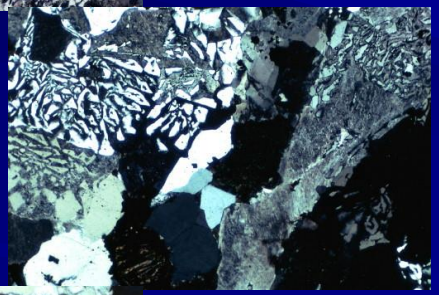
Basalt



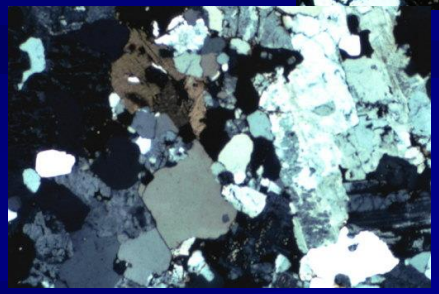
Rhyolite



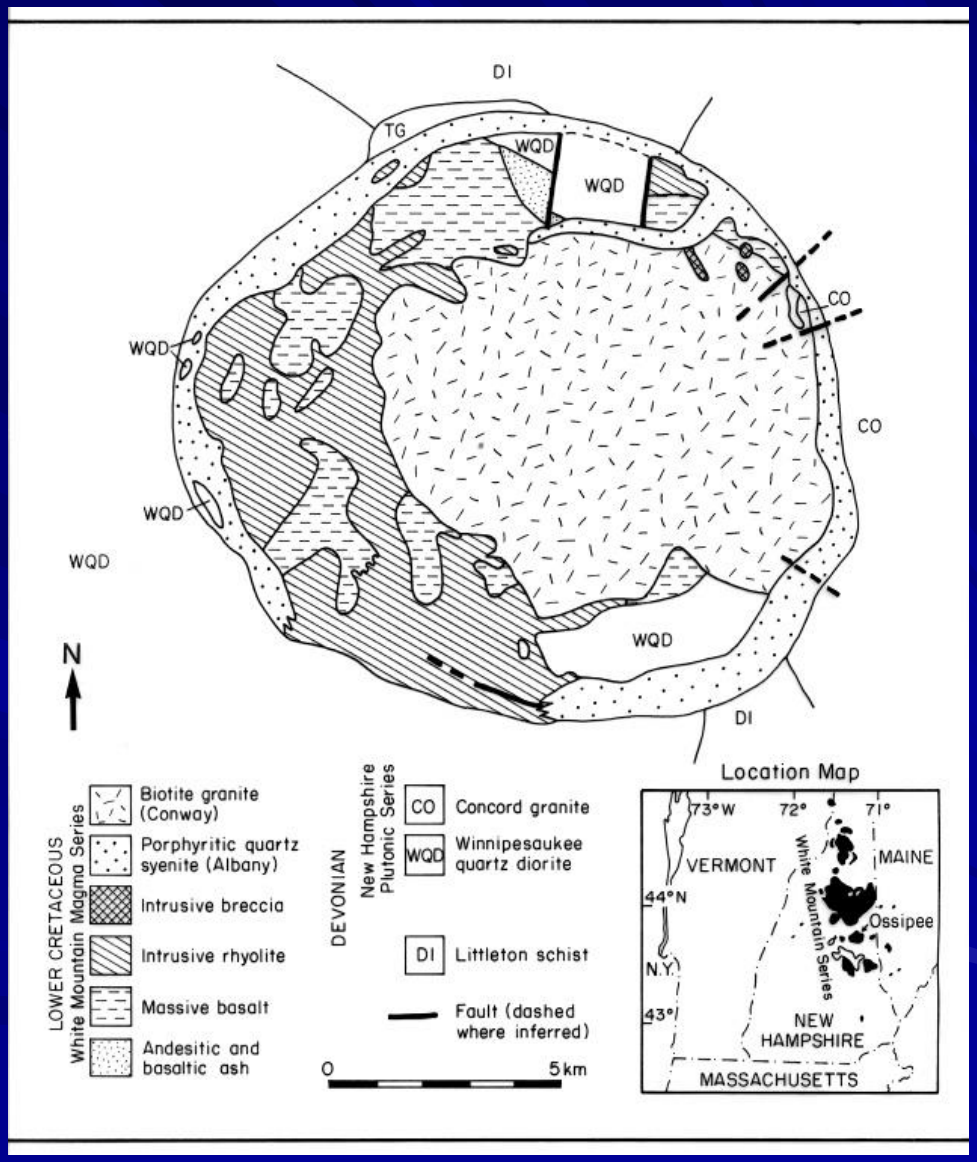
Porphyritic quartz syenite



Microgranite

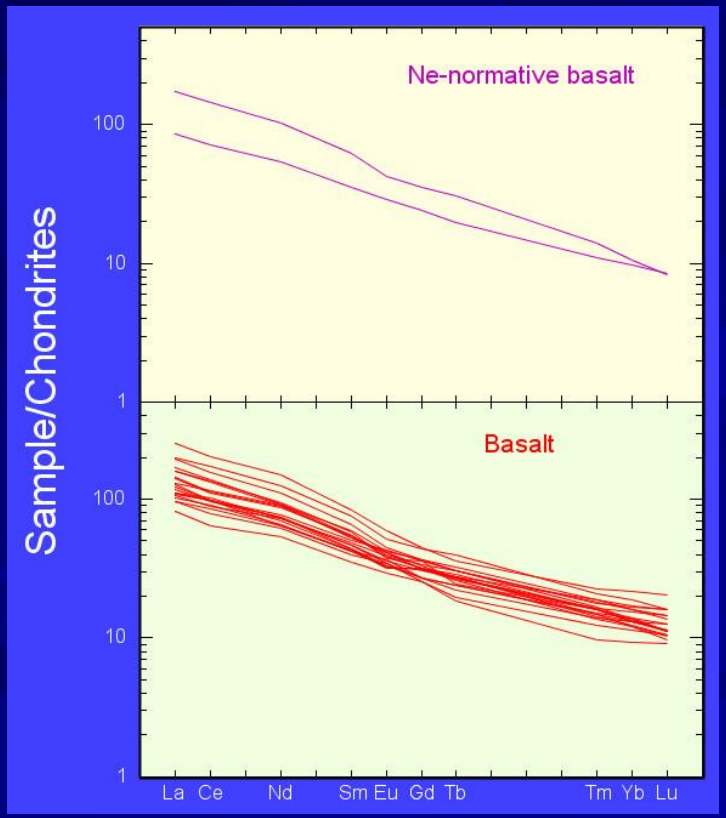


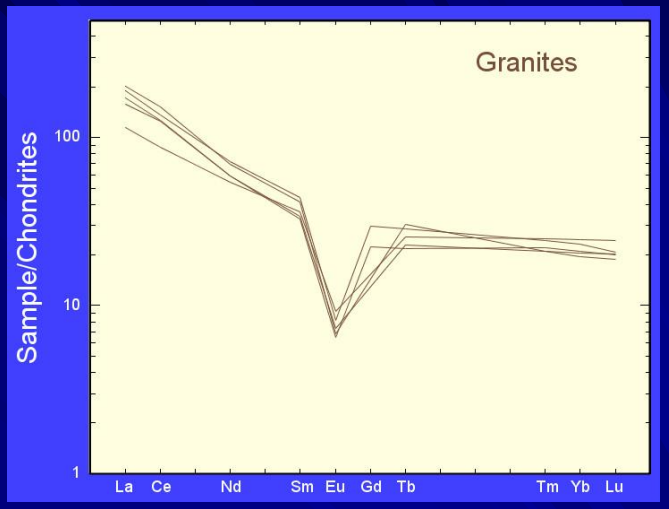
Biotite granite

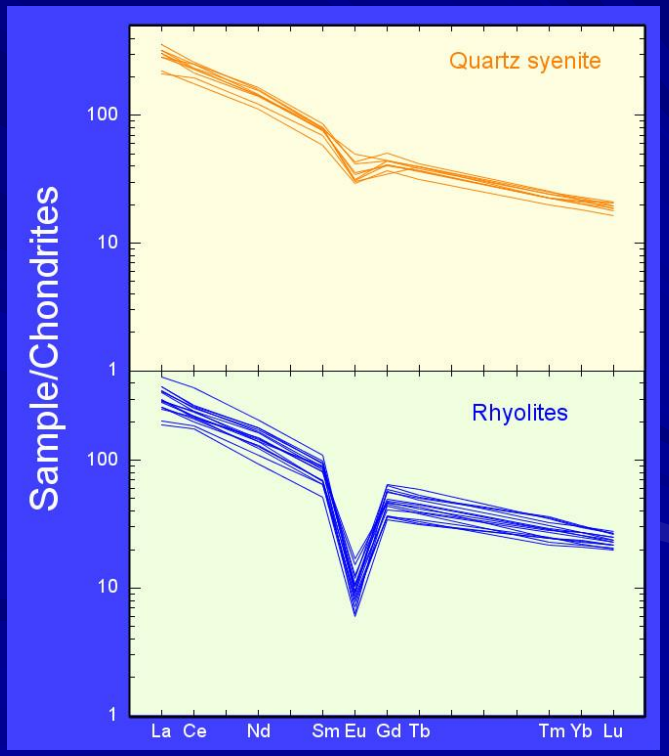


REE patterns for the various lithologies at Ossipee

Each rock type has its own distinctive trace element pattern.

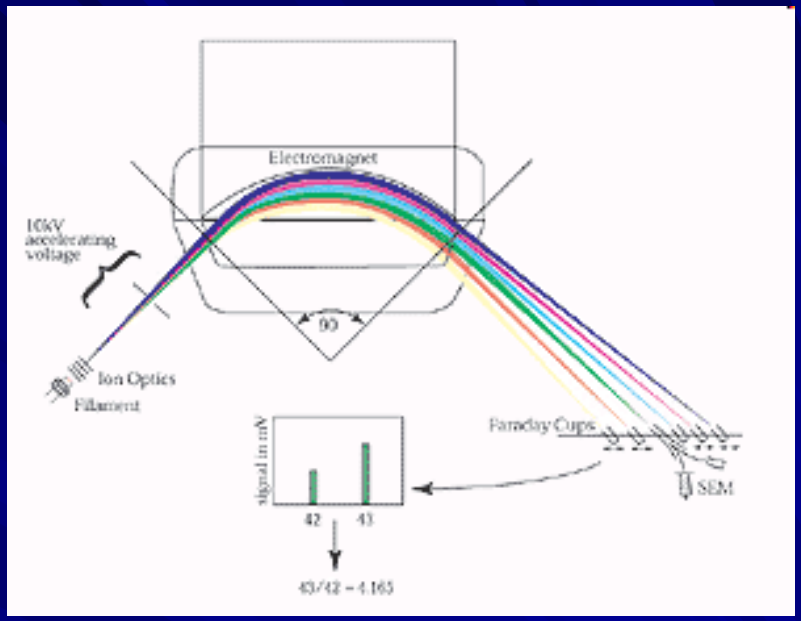




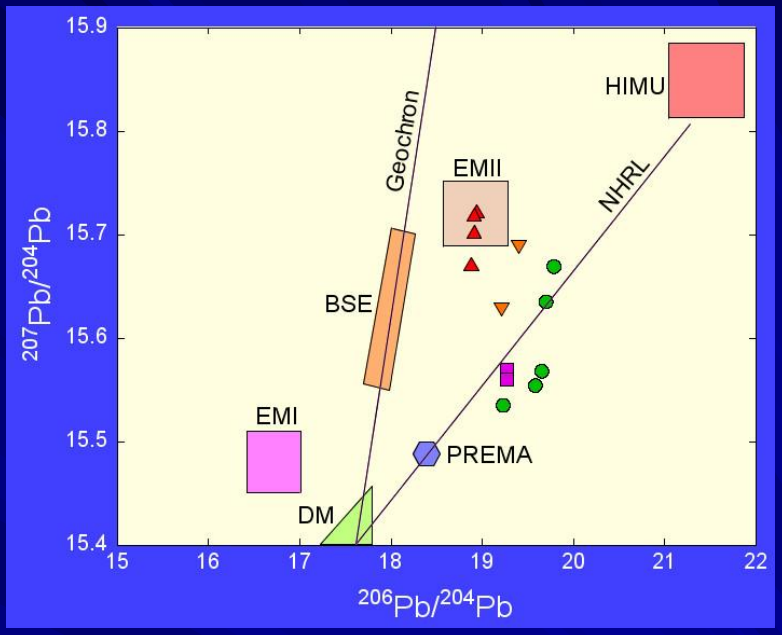


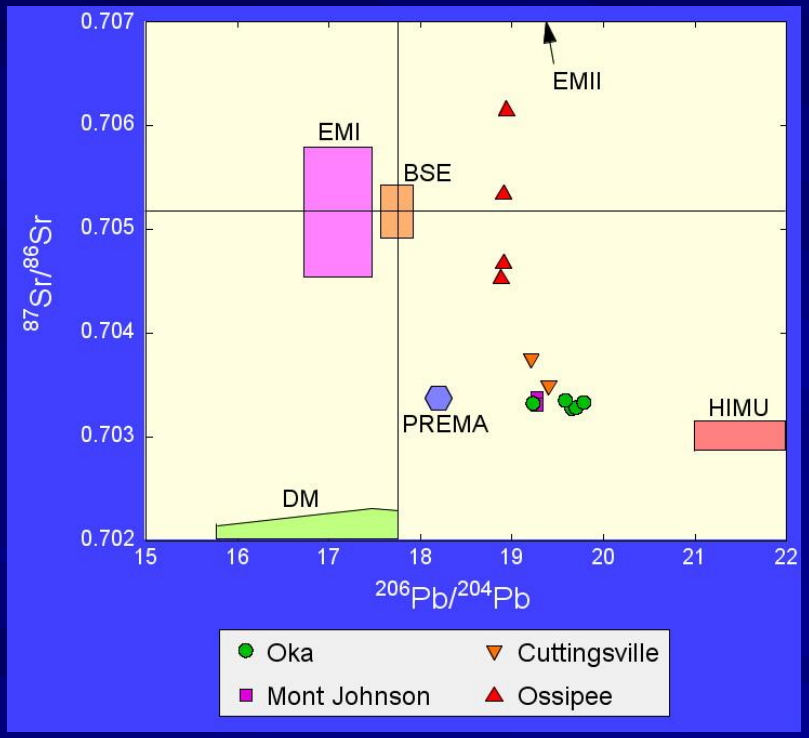
Determining the isotopic composition of rocks and minerals

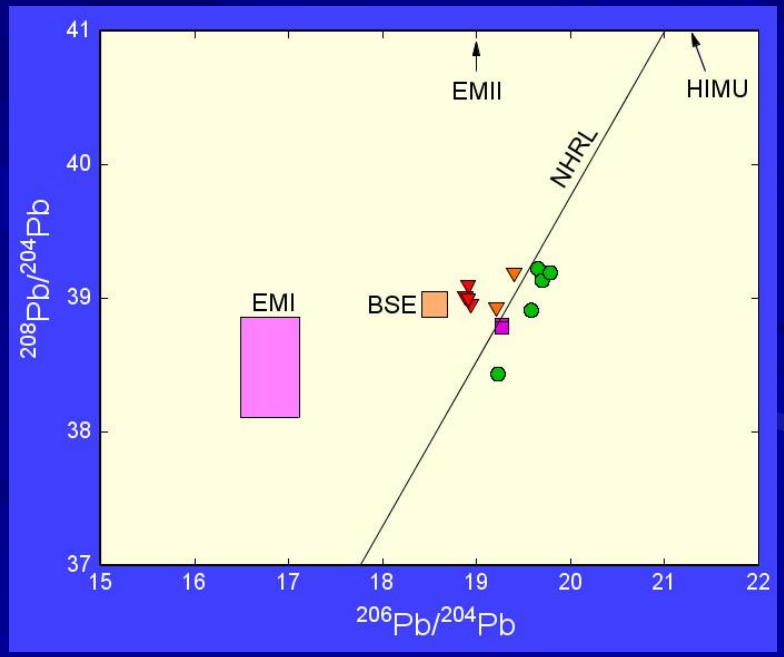
Thermal ionization mass spectrometry can be used to determine the isotopic composition of Sr, Nd, Pb, and Hf in rocks and minerals. Variations in these ratios can be used to fingerprint the source of a particular rock.



Variations in Pb and Sr isotope compositions. The same rock type can show a wide variety of isotopic ratios thus allowing one to identify a specific source.







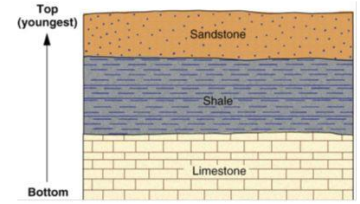
Geologic Time Scale

An arrangement of geologic events in the order in which they occurred.

- Relative time – strata organized from oldest to youngest.

Law of Superposition

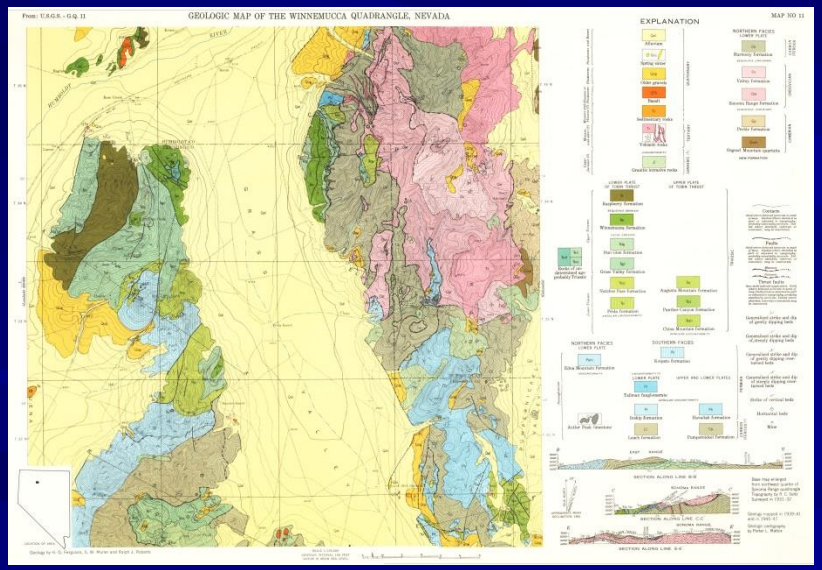
- **a vertical set of strata (layers) is a chronological record of the geologic history of that strata**
- **Youngest layers are on top and oldest on bottom**

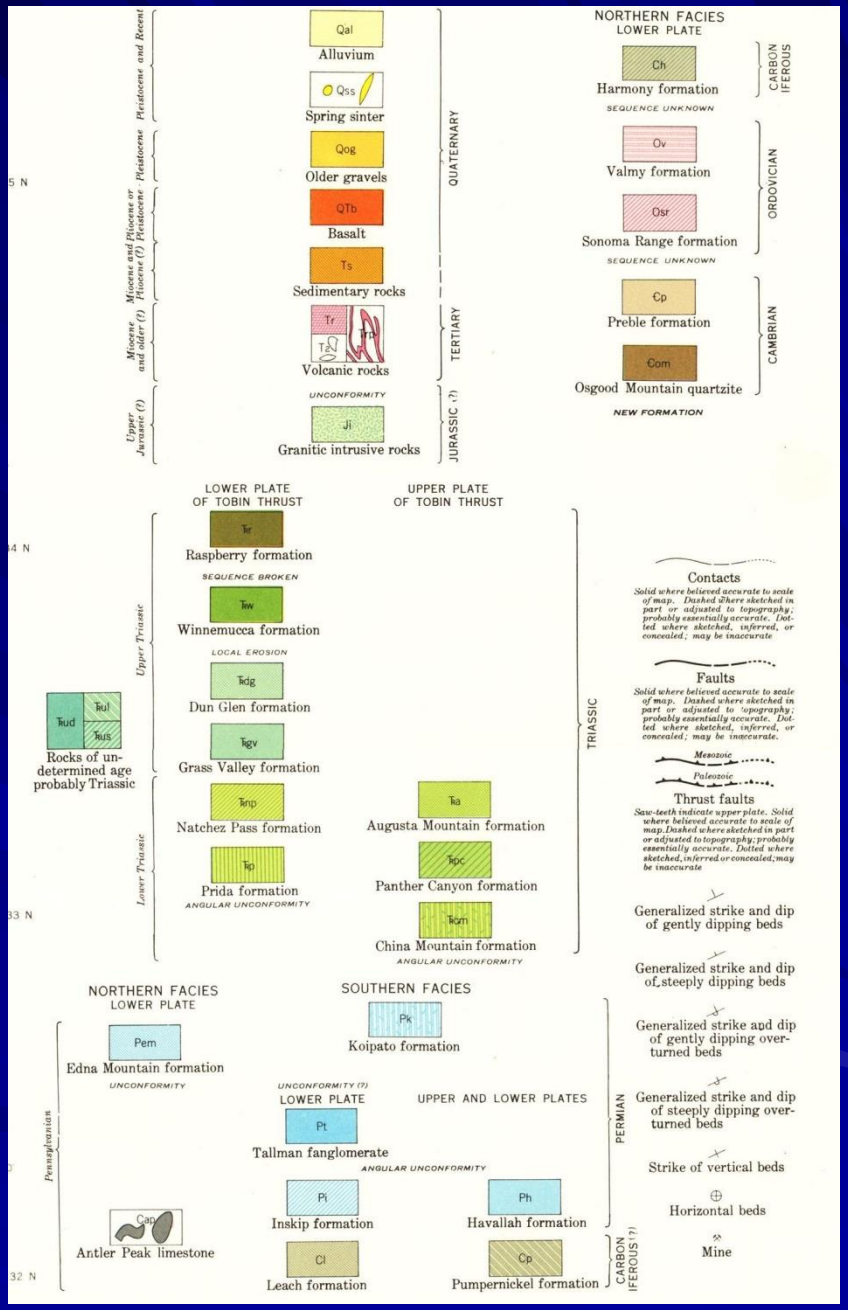


- Absolute time – assign ages using radiometric dating.

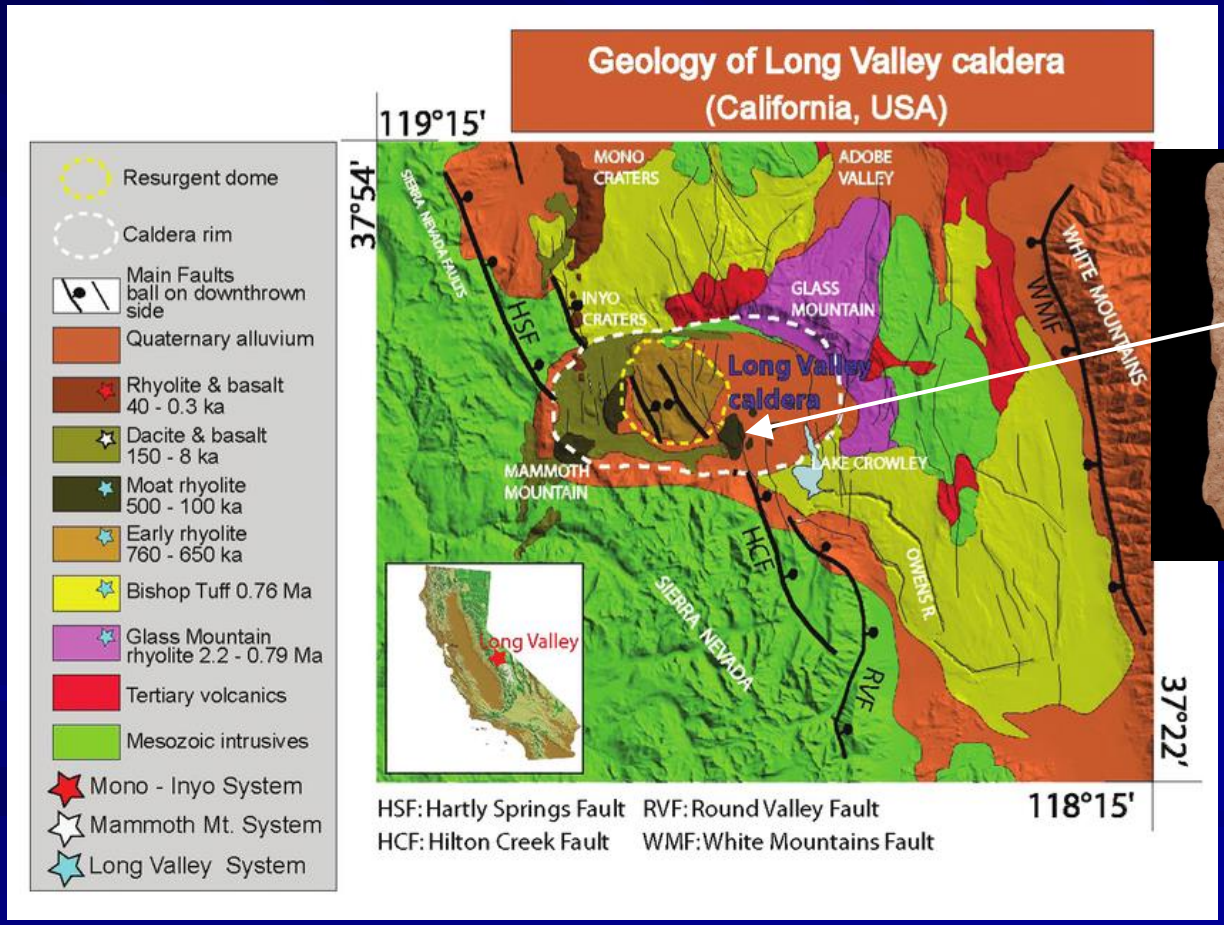
Eon	Era	Period	Epoch	m.y.
Phanerozoic	Cenozoic	Quaternary	Holocene	
			Pleistocene	1.5
		Neogene	Pliocene	
			Miocene	23
		Paleogene	Oligocene	
			Eocene	
			Paleocene	65
	Mesozoic	Cretaceous		
		Jurassic		
		Triassic		250
	Paleozoic	Permian		
		Carboniferous: Pennsylvanian		
		Carboniferous: Mississippian		
		Devonian		
		Silurian		
		Ordovician		
		Cambrian		540
Precambrian		Proterozoic		2500
		Archean		3800
		Hadean		4600

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)

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)

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)

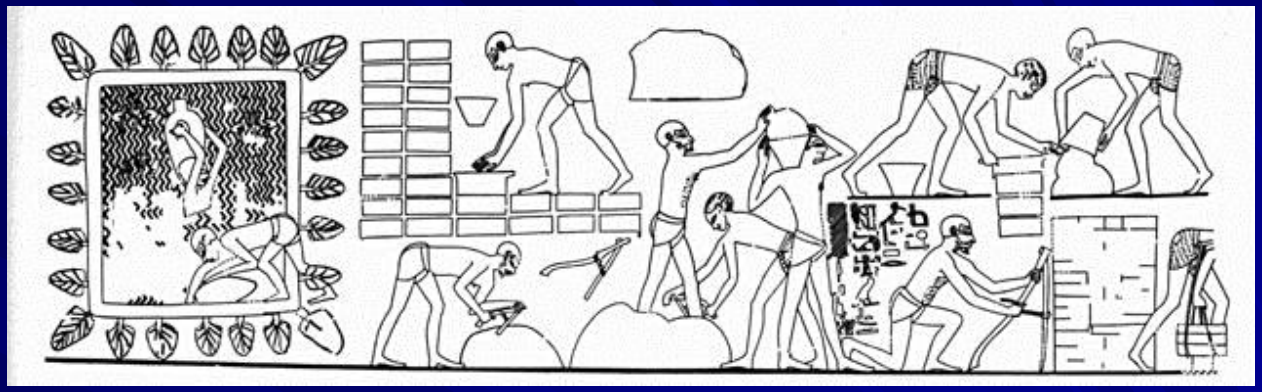
Building Materials

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

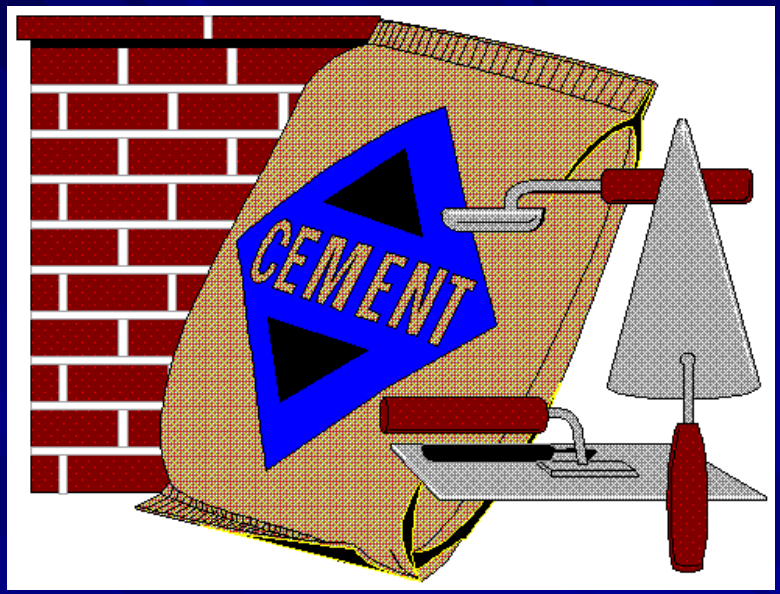


The basic process is to:

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

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

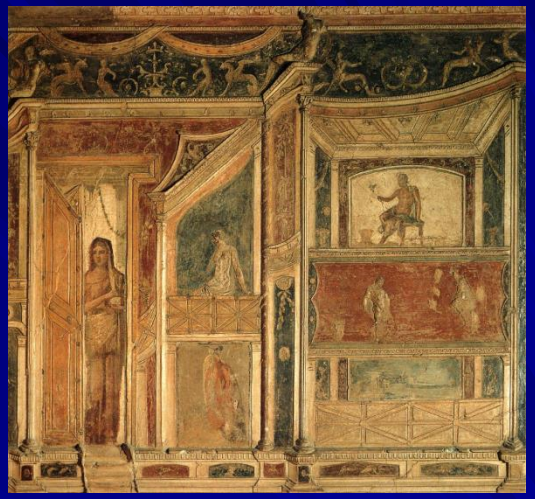


Concrete Manufacture

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

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

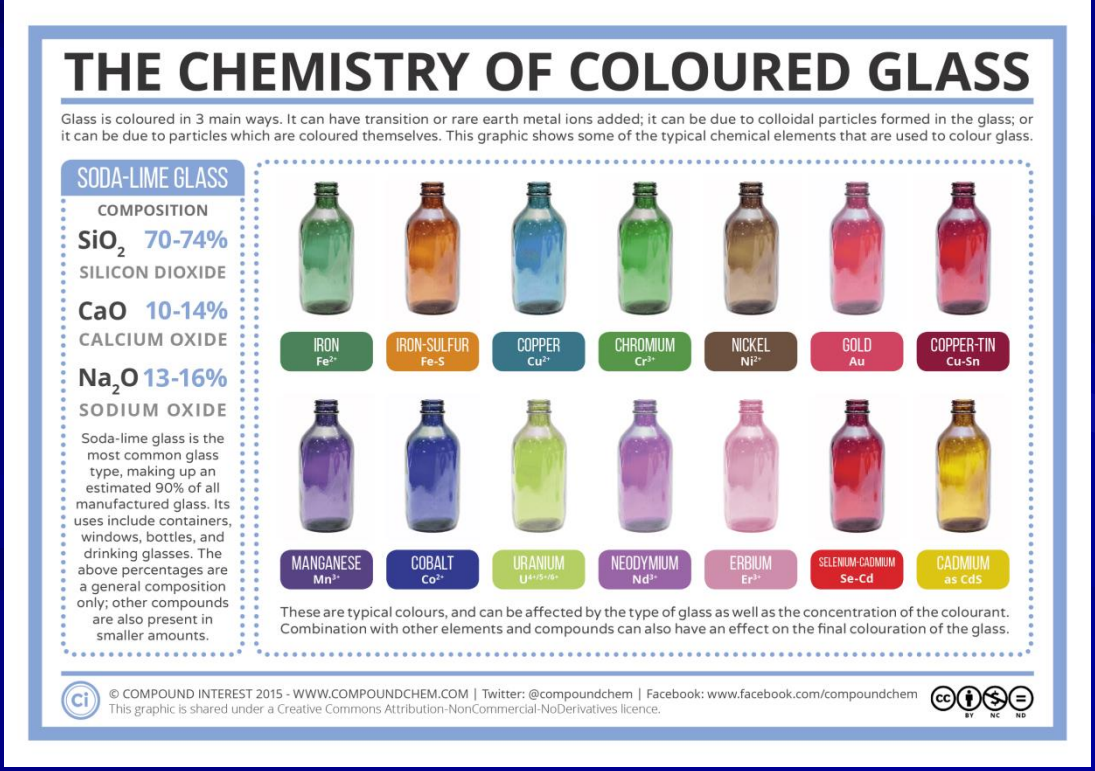


After the great fire of London in 1666 the king of France ordered that all of the wooden structures be coated with plaster to make them fire resistant

In modern processing various additives, filler, conditioners are added with the result that most plasters can be differentiated from each other

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.



Abrasives

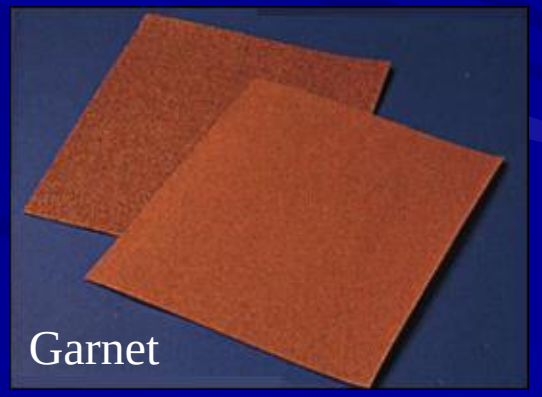
- Abrasive materials are used in a variety of ways from sanding wood to polishing diamonds to cutting steel
- While diamonds are the hardest abrasives, corundum, garnet, SiC, cubic boron nitride, Zi/Al alloys, pumice, and colloidal silica as well as other materials are also used

Diamond

Silicon Carbide


Pumice


Corundum


Garnet

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 had insulated his attic with a variety of glass wool insulation bought at various sales
- An intruder who entered 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)

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 and 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)