Selected Earth Materials Resources


Lepidolite in pegmatite


REE China clays


Lithium-rich brine

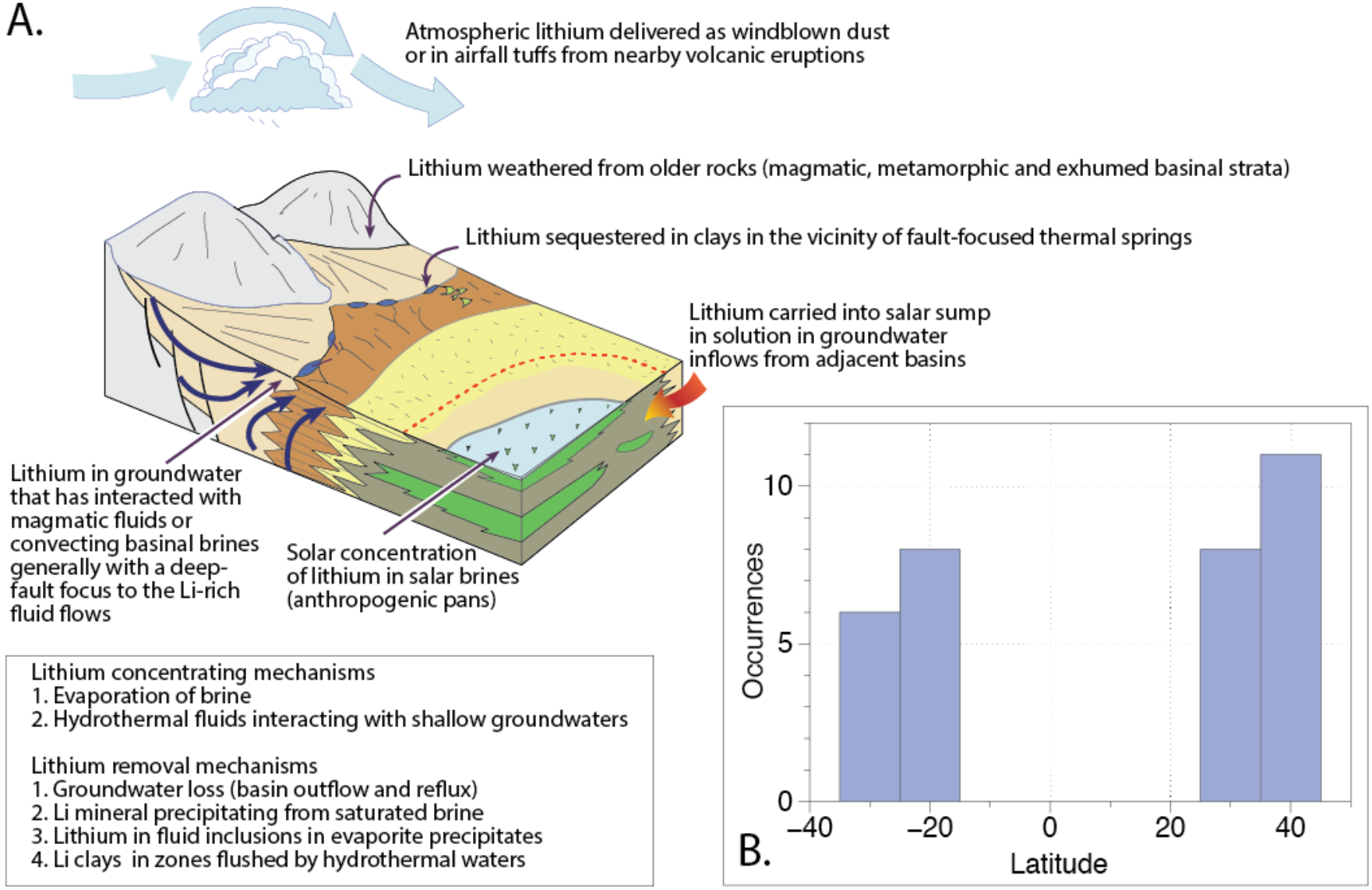
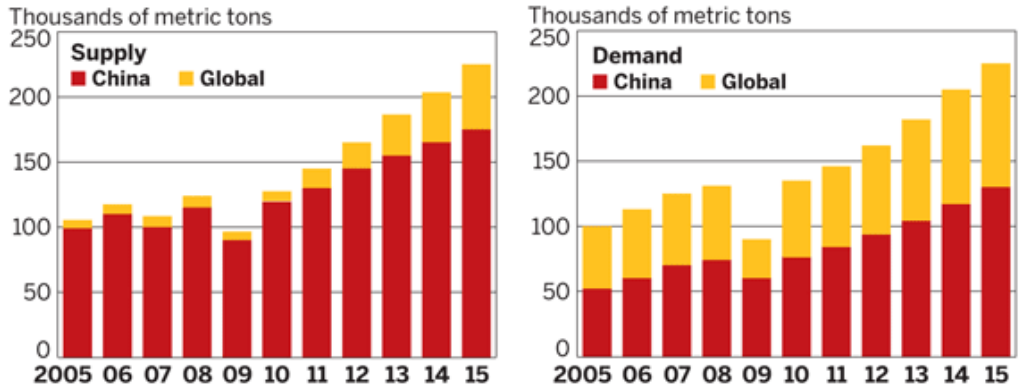


Figure 14. Lithium levels in lake brines and pore waters in various lithium brine lake deposits and prospects in China, South America and North America (plot points extracted from various literature sources compiled in SaltWork® database 1.7)

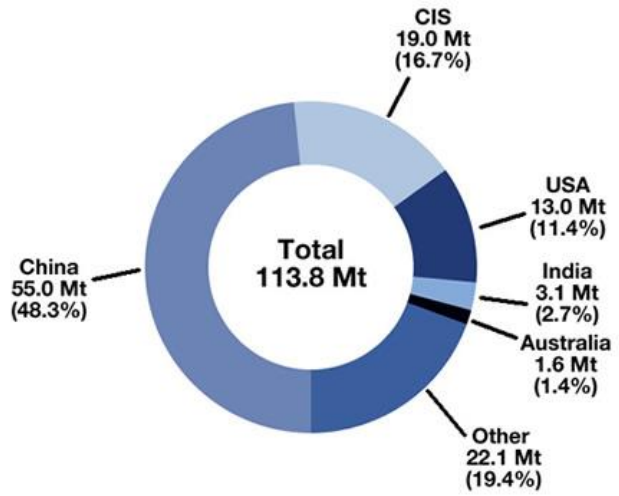
RARE-EARTH SUPPLY AND DEMAND

China's increasing demand for its own rare-earth materials is predicted to drive production in other countries



SOURCE: Dudley Kingsnorth/Industrial Minerals Co. of Australia

2011 Estimate of Global Rare-Earth-Oxide Reserves

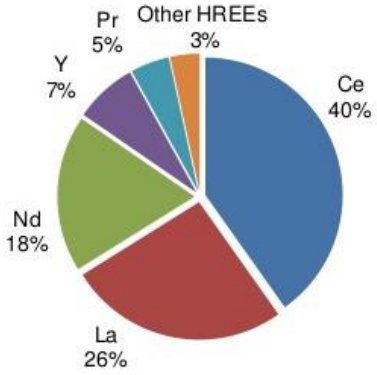


Sources: US Geological Survey, Technology Metals Research

Other HREEs
magnets, lasers, phosphors, glass, metallurgy, other

Pr
magnets, phosphors, ceramics, metallurgy, polishing, other

Y
phosphors, ceramics, other

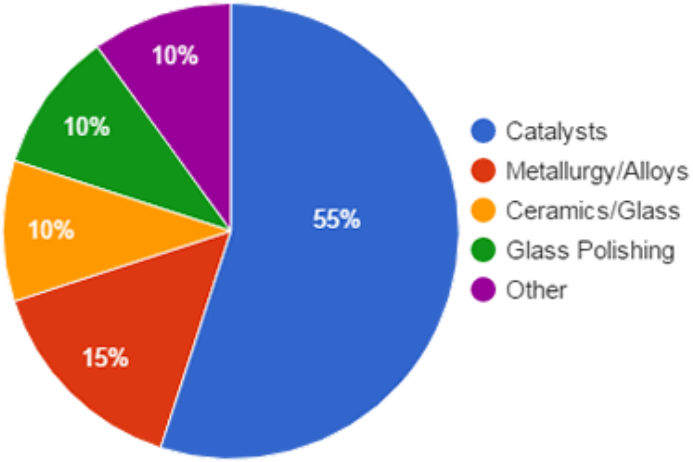


Ce
polishing, metallurgy, catalysts, glass, phosphors, ceramics, other

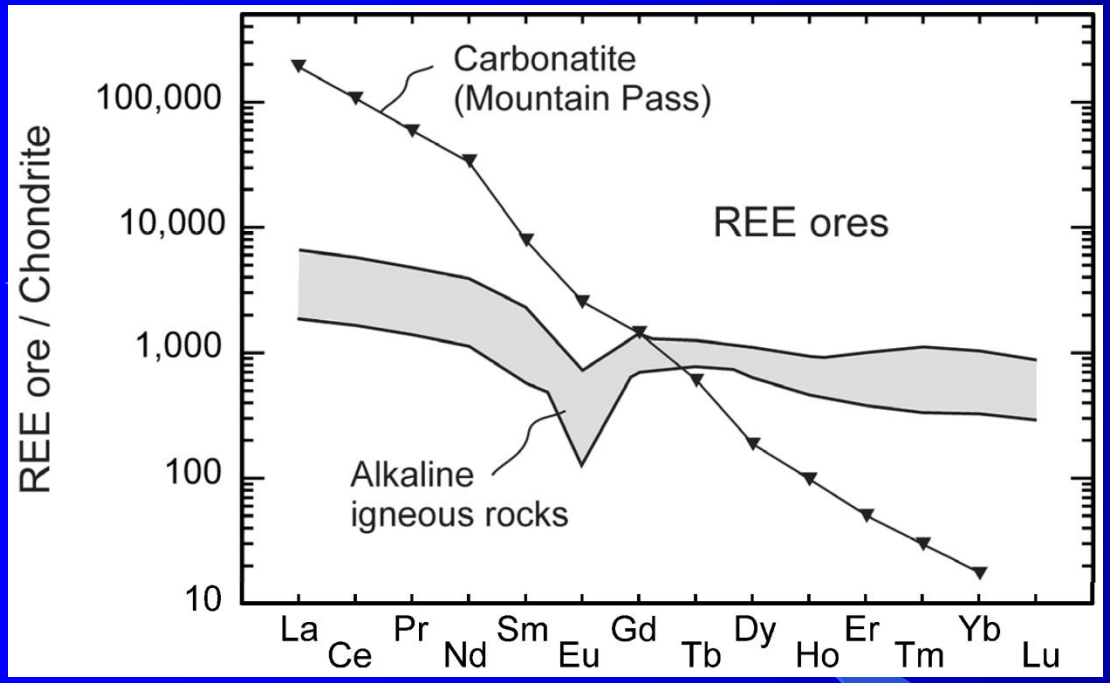
La
metallurgy, catalysts, glass, phosphors, ceramics, polishing, other

Nd
magnets, ceramics, metallurgy, glass, catalysts, phosphors, other

Uses of Rare Earth Elements



Uses in the United States as reported by the United States Geological Survey Mineral Commodity Summary, 2017

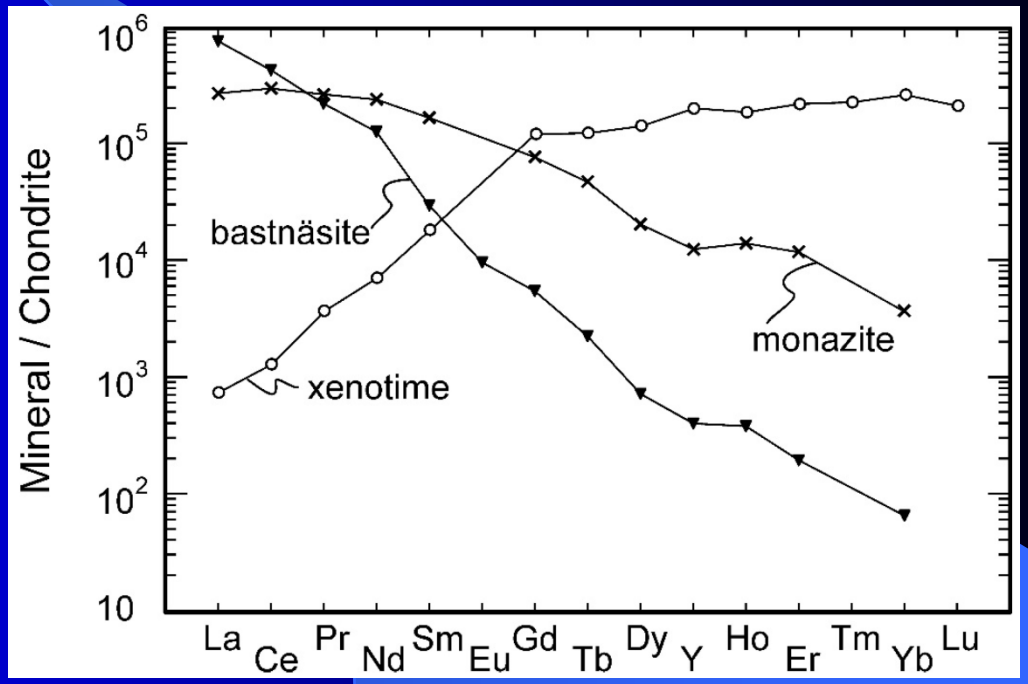


Type of REE ore deposits

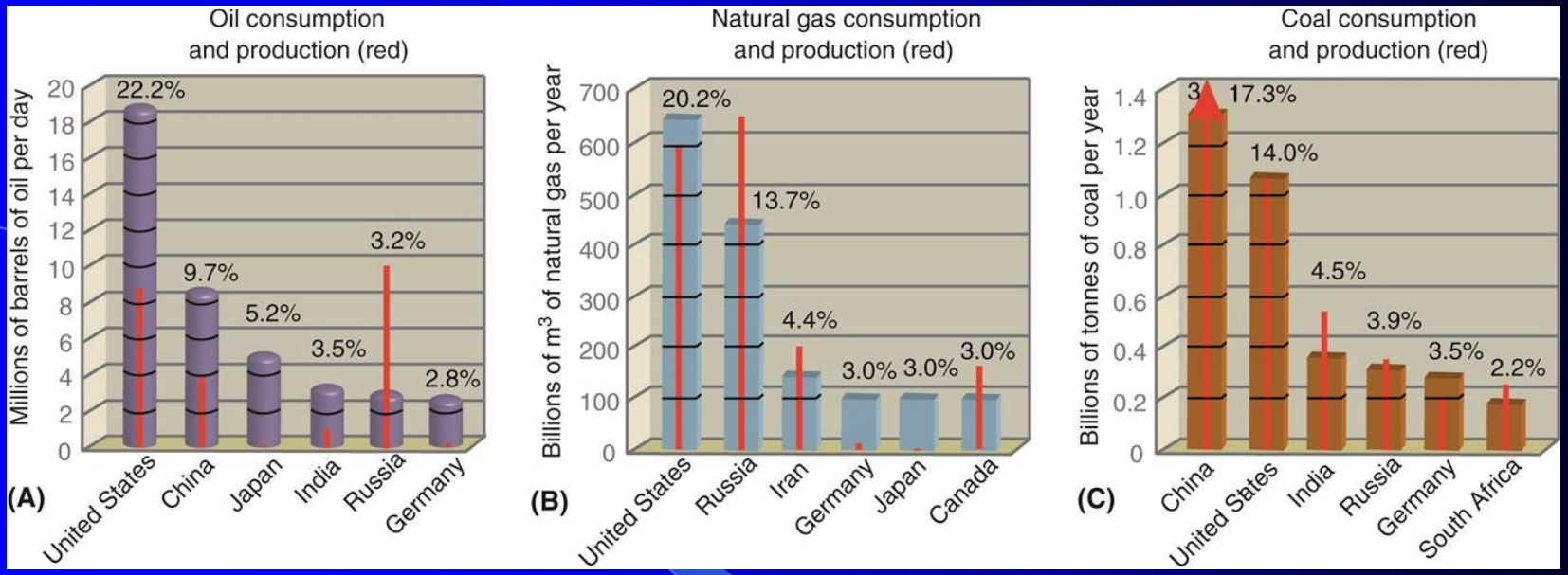
- Primary igneous (Mountain Pass)
- REE clay-rich horizons produced by the wathering of alkaline igneous rocks

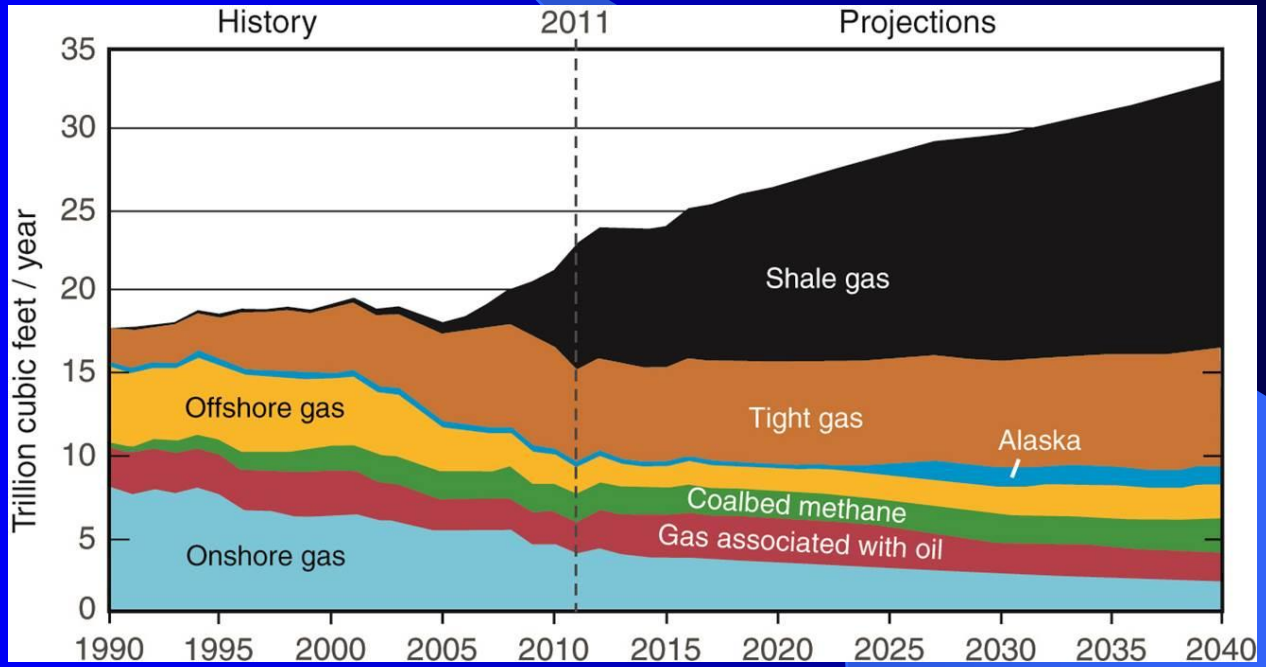
REE Minerals

- Bastnäsite [$(REE)CO_3F$]
- Monazite [$(Ce,La)PO_4$]
- Xenotime [YPO_4]

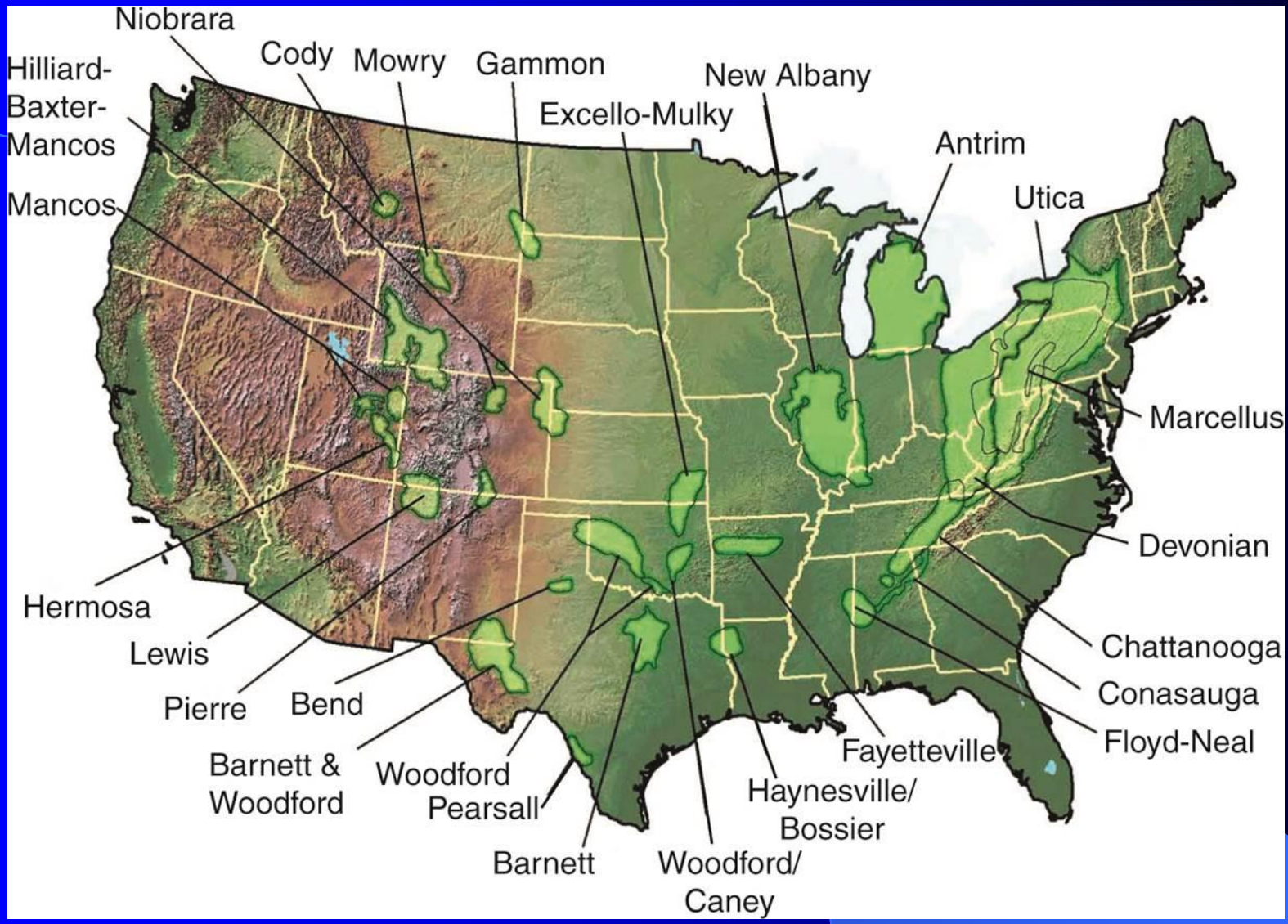


Production, Consumption of Energy Resources

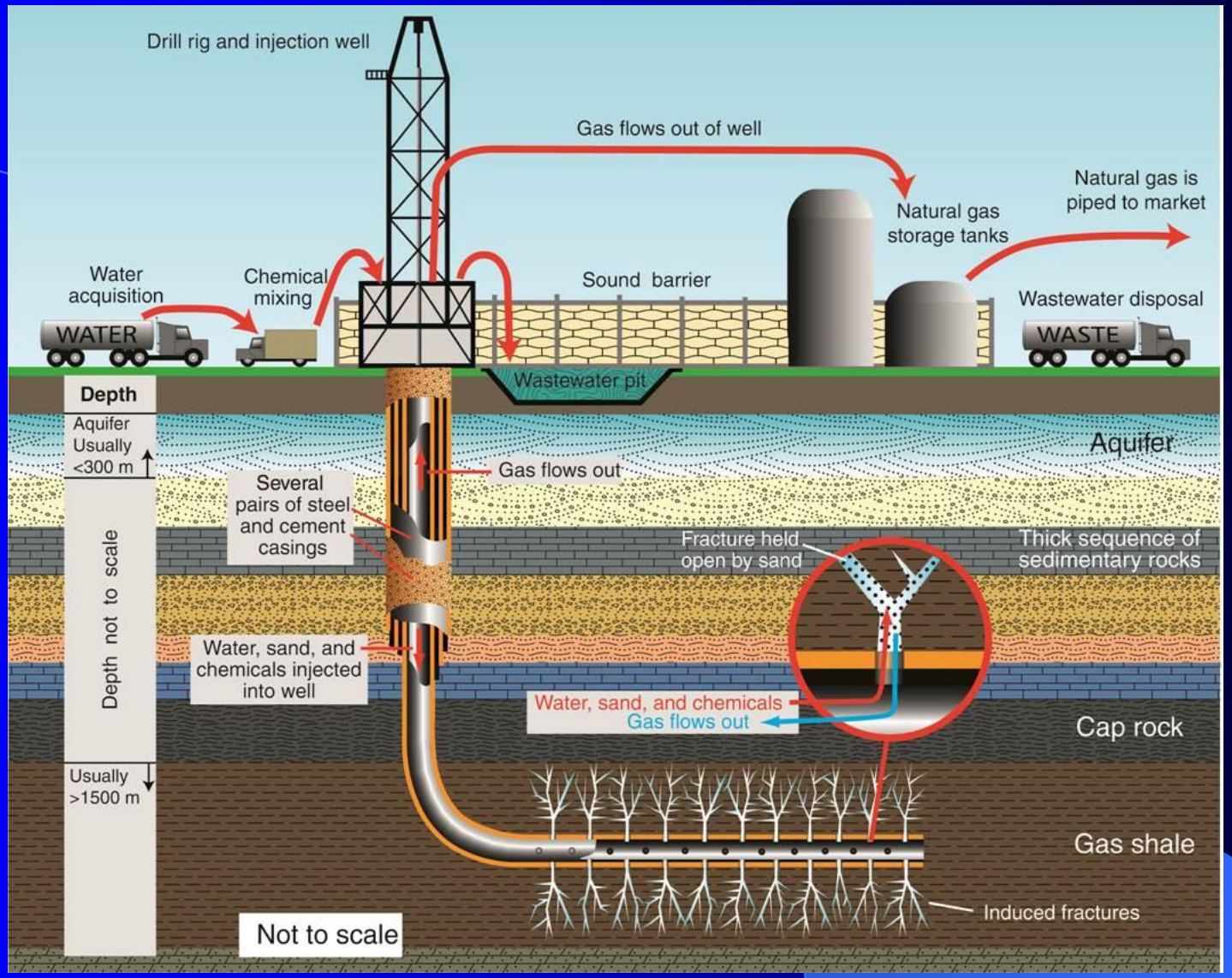




Gas-bearing Shales



Fracking


Drill rig and injection well
Gas flows out of well
Natural gas storage tanks
Natural gas is piped to market
Water acquisition
Chemical mixing
Sound barrier
Wastewater disposal
WATER
WASTE
Wastewater pit
Depth
Aquifer Usually <300 m
Depth not to scale
Usually >1500 m
Aquifer
Gas flows out
Several pairs of steel and cement casings
Fracture held open by sand
Thick sequence of sedimentary rocks
Water, sand, and chemicals injected into well
Water, sand, and chemicals
Gas flows out
Cap rock
Gas shale
Induced fractures
Not to scale

Ceramics

RAW MATERIALS

- The traditional ceramics industry is largely based on various combinations of clay minerals, feldspar and silica.
- The mineral raw materials used in the ceramic industry are mainly inorganic, nonmetallic, crystalline solids formed by complex geologic processes.
- Clays have the ability to form clay-water composition and to maintain their shape and strength during drying and firing

Materials used in making ceramics

- Kaolinite
- K-feldspar
- Silica (quartz)

Materials Used in Glazes	
Material	**Chemistry**
Bentonite	$((Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2 \cdot nH_2O$
Cryolite	Na_3AlF_6
Dolomite	$CaMg(CO_3)_2$
Epsom salts	$MgSO_4 \cdot 7H_2O$
Fluorspar	CaF_2
Gerstley borate	$2CaO.3B_2O_3.5H_2O$
Kaolin (Kaolinite)	$Al_2Si_2O_5(OH)_4$
Lepidolite	$K(Li,Al)_3(Al,Si)_4O_{10}(F,OH)_2$
Lithium carbonate	$LiCO_3$
Nepheline syenite	Various Na-K-Al silicate minerals
Potash feldspar (K-spar)	$KAlSi_3O_8$
Silica (Quartz)	SiO_2
Soda feldspar (Albite)	$NaAlSi_3O_4$
Whiting (Calcite)	$CaCO_3$
Wollastonite	$CaSiO_3$
Zircopax (Zircon)	$ZrSiO_4$
Colorant Oxides	
Cobalt	Co
Copper carbonate	$CuCO_3$
Hematite	Fe_2O_3
Rutile	TiO_2

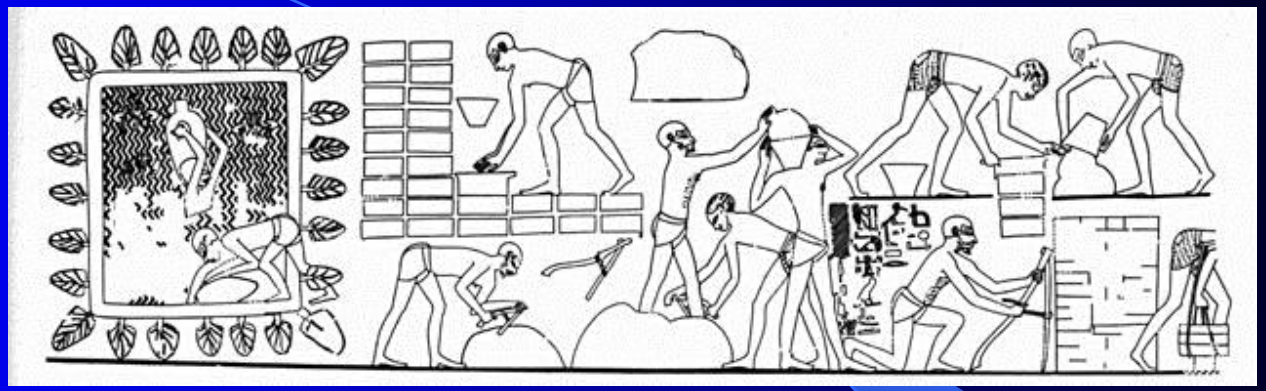
Building Materials

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

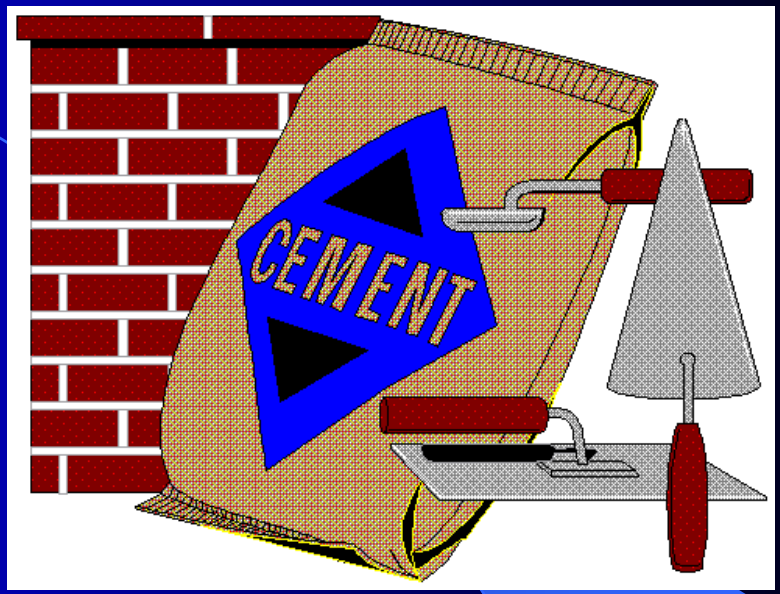


The basic process is to:

* 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

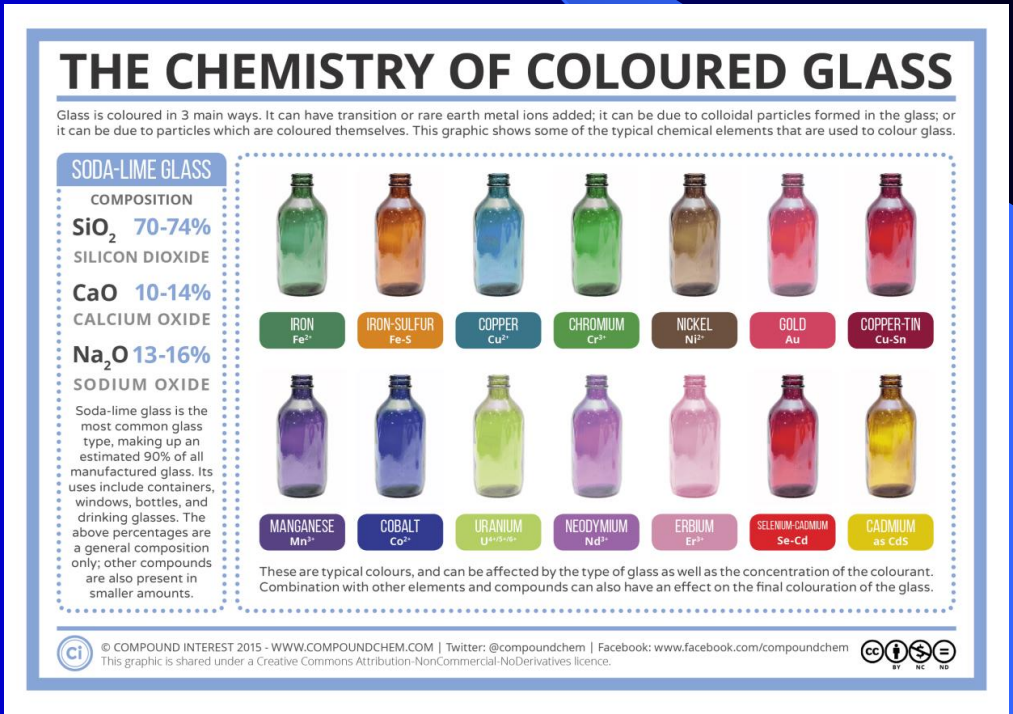
Plaster Manufacture

- 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

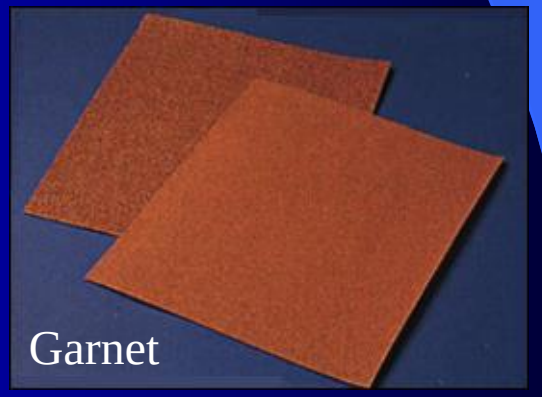
- Abrasive materials are used in a variety of ways from sanding wood to polishing diamonds to cutting steel
- While diamonds are the hardest abrasives, corundum, garnet, SiC, cubic boron nitride, Zi/Al alloys, pumice, and colloidal silica as well as other materials are also used

Diamond

Silicon Carbide


Pumice


Corundum


Garnet


Building Materials and Forensic Investigations
When you have eliminated the impossible, whatever remains, *however improbable*, must be the truth

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)