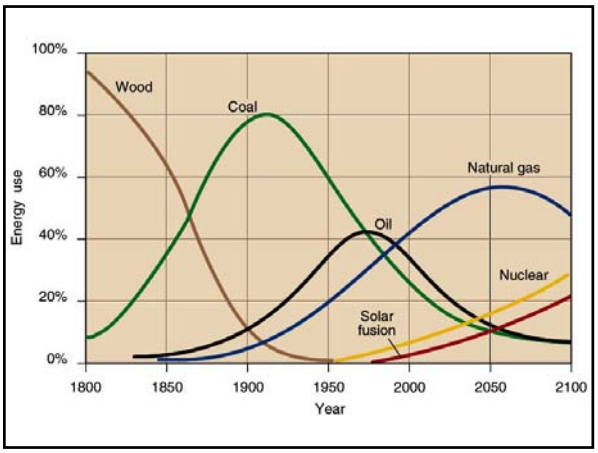
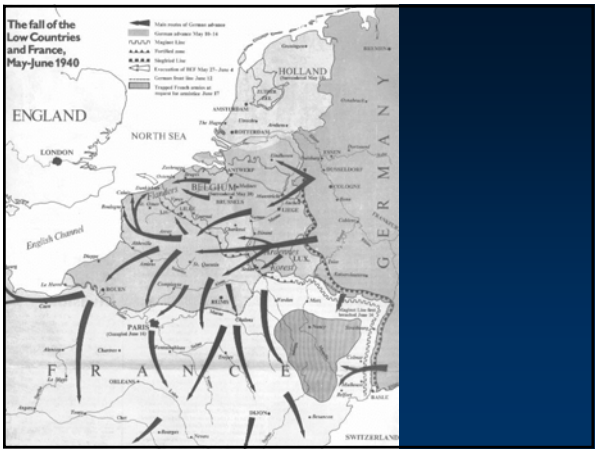
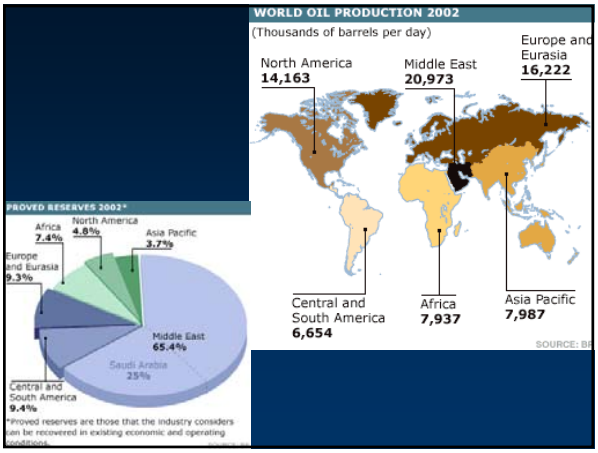
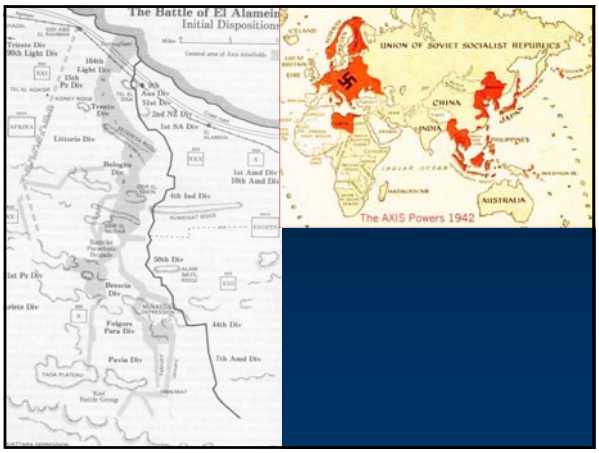

Earth's Resources


100%
80%
60%
40%
20%
0%
Energy use
Wood
Coal
Natural gas
Oil
Nuclear
Solar fusion
1800
1850
1900
1950
2000
2050
2100
Year


ICELAND
NORWAY
SWEDEN
FINLAND
UNION OF SOVIET SOCIALIST REPUBLICS
GREAT BRITAIN
EIRE
ALEUTIAN IS.
OUTER MONGOLIA
MANCHUKUO
KURILE IS.
CHINA
JAPAN
TURKEY
IRAN
TIBET
LIBYA
EGYPT
INDIA
ARABIA
PHILIPPINES
FRENCH WEST AFRICA
ANGLO-EGYPTIAN SUDAN
FRENCH INDO-CHINA
ETHIOPIA
GOLD COAST
KENYA
INDIAN OCEAN
NETHERLANDS INDIES
SOLOMON IS.
BELGIAN CONGO
MADAGASCAR
AUSTRALIA
UNION OF SOUTH AFRICA
The AXIS Powers 1942


The fall of the Low Countries and France, May-June 1940
ENGLAND
HOLLAND
NORTH SEA
LONDON
BELGIUM
English Channel
PARIS
GERMANY
FRANCE
SWITZERLAND


WORLD OIL PRODUCTION 2002
(Thousands of barrels per day)
North America
14,163
Middle East
20,973
Europe and Eurasia
16,222
Central and South America
6,654
Africa
7,937
Asia Pacific
7,987
PROVED RESERVES 2002*
North America
4.8%
Africa
7.4%
Asia Pacific
3.7%
Europe and Eurasia
9.3%
Middle East
65.4%
Saudi Arabia
25%
Central and South America
9.4%
*Proved reserves are those that the industry considers can be recovered in existing economic and operating conditions



Mineral Resources

- Mineral resources - any Earth material used by industry
  - Metals, oil & gas, soil etc.

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Mineral Resources

Deposits formed by slow geologic processes

- Rate of use is much faster than rate of formation

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Mineral Resources

- Divided into two categories
  1. Renewable resources - replenished over short time
     - Few mineral resources fall into this category
     - Some mineral resources are recycled

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Mineral Resources

2. Nonrenewable resources - finite & exhaustible over human time scale

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Mineral Resources

- Most resources occur in naturally low concentration
  - Must be concentrated

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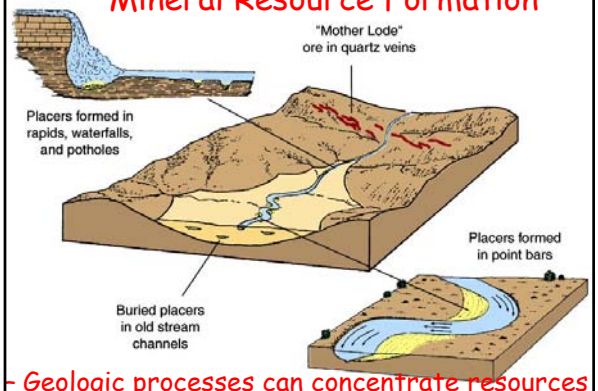
Mineral Resource Formation

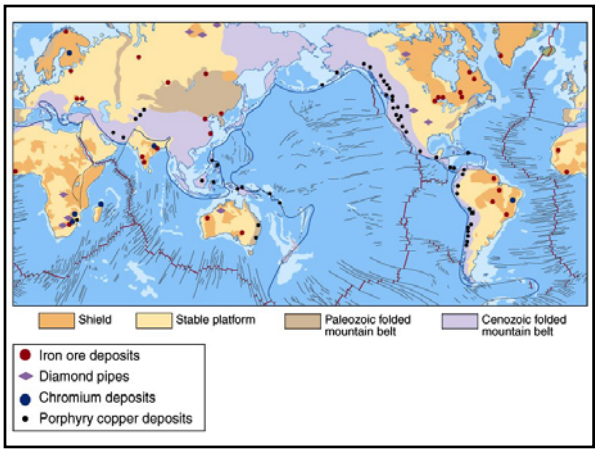


- Geologic processes can concentrate resources

TABLE 24.1 The Major Geologic Processes That Form Mineral Resources

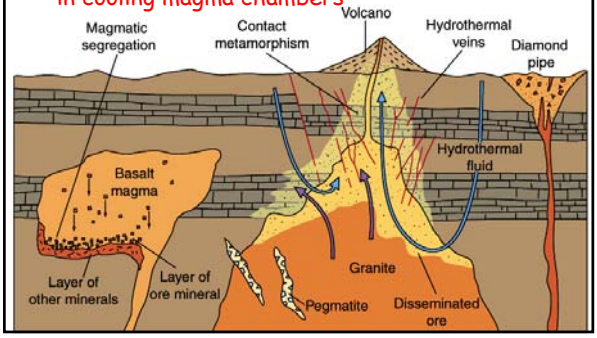
Process	Deposits Formed	Mineral Resource
Igneous processes	Magmatic segregation	Chromium, vanadium, nickel, copper, cobalt, platinum
	Pegmatites	Beryllium, lithium, tantalum
	Hydrothermal deposits	Copper, lead, zinc, molybdenum, tin, gold, silver
Sedimentary		
Clastic rocks	Stream deposits	Sand, gravel
	Placer deposits	Gold, platinum, diamonds, tin, ilmenite, rutile, zircon
	Dune deposits	Sand
	Loess deposits	Soil
Chemical precipitates	Evaporite deposits	Halite, sylvite, borax, gypsum, trona
	Marine sediment	Banded iron formation, phosphate, limestone
Organic precipitates	Hydrocarbon deposits	Oil, natural gas, coal
	Marine deposits	Limestone
Metamorphic processes	Contact metamorphism	Tungsten, copper, tin, lead, zinc, gold, silver
	Regional metamorphism	Gold, tungsten, copper, talc, asbestos
Weathering and groundwater	Residual soils	Clay
	Residual weathering deposits	Nickel, iron, cobalt, aluminum, gold
	Groundwater deposits	Travertine, uranium, sulfur
	Brines in basins	Lead, zinc, copper
	Geothermal wells	Hot water, electricity
	Water	Drinking water, irrigation

(Modified from S. E. Kesler)



Igneous Processes

- Magmatic segregation
  - Mineral grains form layers of different densities in cooling magma chambers

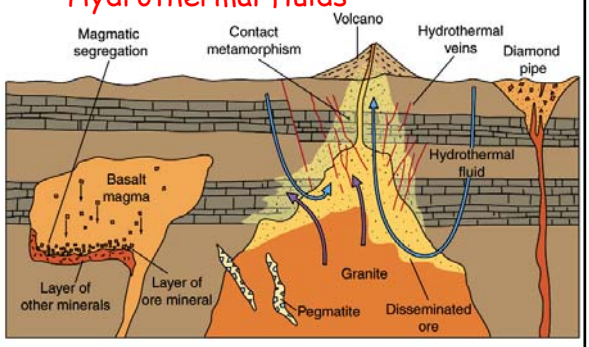


Igneous Processes

- Late stage segregation
  - Many trace elements do not fit into structures of rock forming minerals
  - Rare elements are concentrated in remaining water-rich magma
  - Rare minerals crystallize with these elements
    - e.g., Be, Li, U, Ta

Igneous Processes

- Hydrothermal fluids



Igneous Processes

- Industrial materials
  - Generally nonmetallic rocks or minerals
  - Used for:
    - Building stone
    - Aggregate

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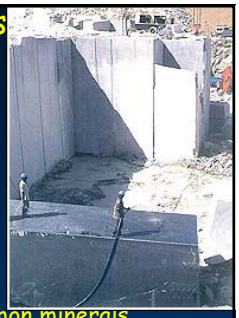
Metamorphic Processes



- Regional metamorphism
  - Form large deposits of common minerals
    - Talc, asbestos, graphite, marble

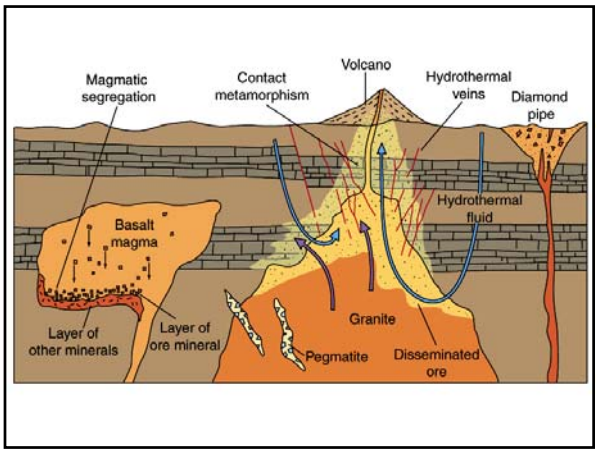
Metamorphic Processes

- Regional metamorphism
  - large mining operations

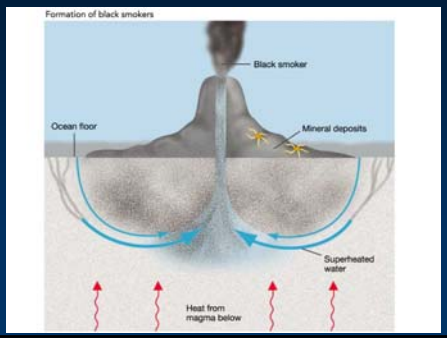
Hydrothermal deposits from fluids expelled during metamorphism

Metamorphic Processes

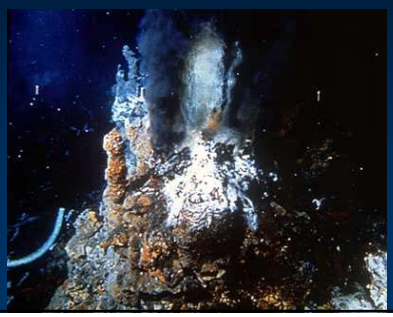
- Contact metamorphism
  - High heat and introduction of new materials from fluids
    - Metasomatism
  - Mineral deposits are concentrated around igneous intrusion



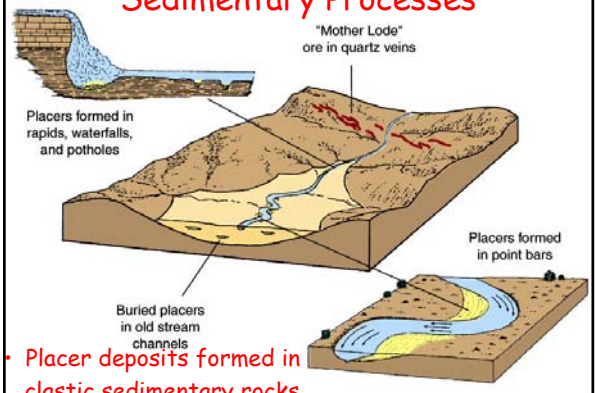
- Seafloor metamorphism - Tectonics
  - Interaction of hot basalt with seawater circulating through it



  - Creates hydrothermal fluid
    - Fluid may dissolve and carry high concentrations
    - Minerals precipitate when they hit cool seawater - black smokers



Sedimentary Processes



- Placer deposits formed in clastic sedimentary rocks

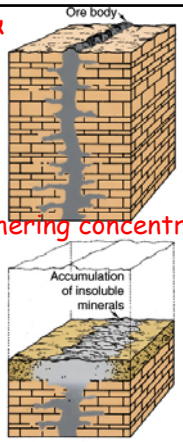
Sedimentary Processes

- Chemical precipitates
  - Banded iron formations
  - Evaporite deposits
    - Halite & gypsum

Sedimentary Processes

- Sedimentary hydrothermal fluids
  - Low T deposits - Mississippi Valley Pb-Zn deposits

Weathering & Groundwater



- Chemical weathering concentrates minerals
  - –Commonly concentrate:
    - Al - bauxite
    - Fe, Ni, Co

Bauxite - Al resource

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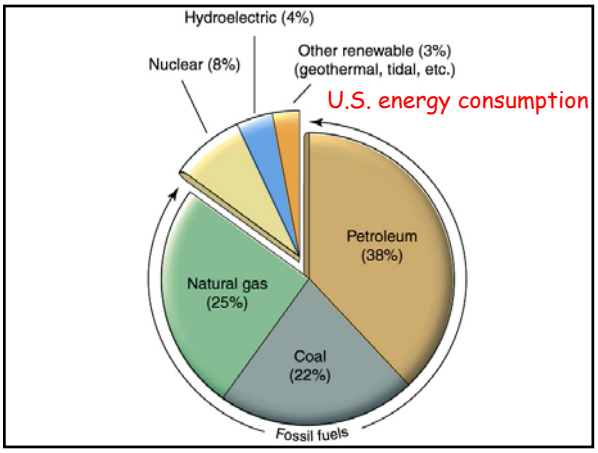
Bauxite - Fe resource

Weathering & Groundwater

- Groundwater is a renewable resource
  - Rate of recharge may be very slow in some areas
  - Groundwater mining
    - Removing more water than is recharged

Energy Resources

- Energy resources are divided into renewable & nonrenewable
  - Modern society is dependent on large energy usage
  - Fossil fuels are used at high rate
  - Renewable resources are not fully developed
  - Individually, most can't meet demand

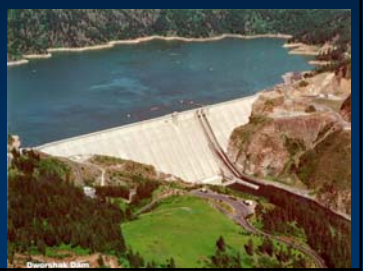


Renewable Energy Resources

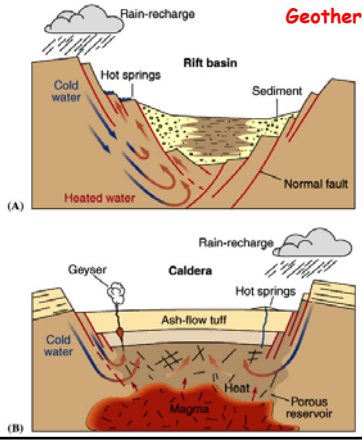
- Solar energy
  - not constant or evenly distributed
  - Heat used to produce steam - passive solar
  - May be converted directly to electricity
    - Photovoltaic cells
    - Cells are relatively inefficient

Renewable Energy Resources

- Hydroelectric power
  - kinetic energy of flowing water
  - Simple technology; inexpensive and clean
  - Environmental & ecological disturbance
    - maintenance



Geothermal Energy



- Wind energy
  - Old technology
  - Pollution free and plentiful

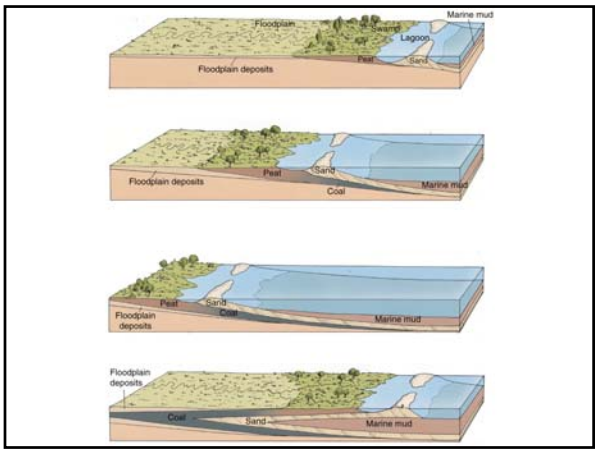
-Expensive to develop
-Not consistent

Fossil Fuels

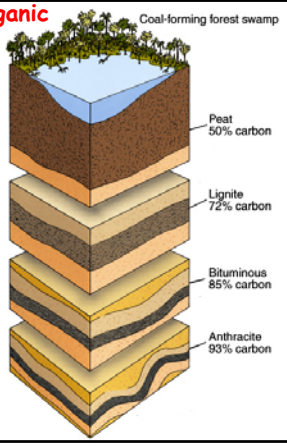
- Coal, oil and natural gas
  - Buried organic matter accumulations

Coal

- Originate as plant material
  1. layers of peat
  2. Burial, heat and pressure
  3. Carbon content increases
  - No deposits older than 440 Ma

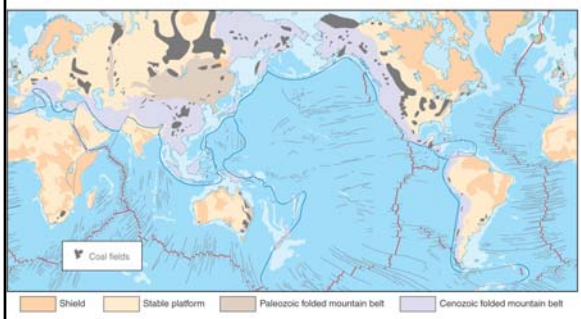


Evolution of Organic Matter to Coal



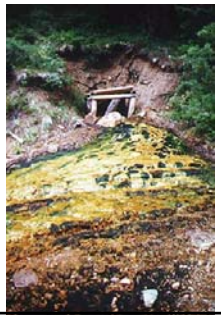
Coal

- Energy resource -All major reserves known



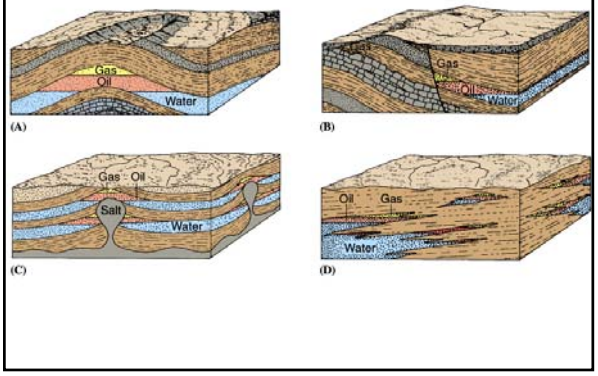
-Coal mining may cause serious environmental problems

- Acid mine drainage from pyrite
- CO_2 & S emissions from burning



Petroleum & Natural Gas

- Four step processes
  1. Source rock with high organic matter content
  2. Burial under appropriate conditions to "crack"
  3. Petroleum or gas must migrate to
  4. Reservoir rock beneath a "trap"

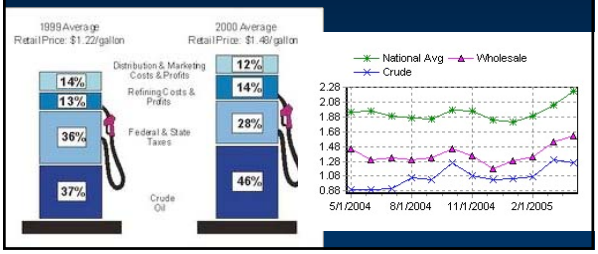


Petroleum & Natural Gas

- Problems are not as great as with coal
  - Pumping may cause subsidence
  - Spills are locally damaging in short term

Petroleum & Natural Gas

- Consumption is high, sustainability of resource is unknown
  - Cost is associated with supply & demand



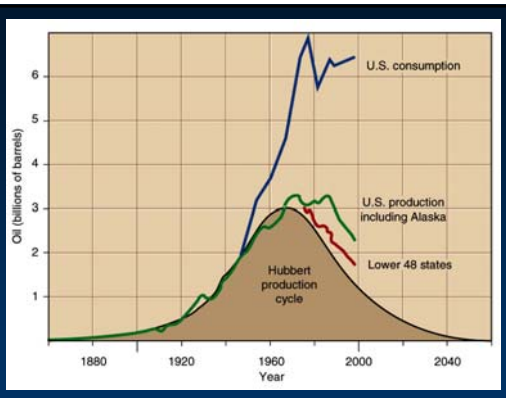


Fig. 24.10. U.S. petroleum consumption

Methane Hydrates

- Methane hydrate ice forms in deeper cold marine waters
  - May contain 2x the C as oil, gas & coal combined
  - Volatile gas may be difficult to mine

Nuclear Energy

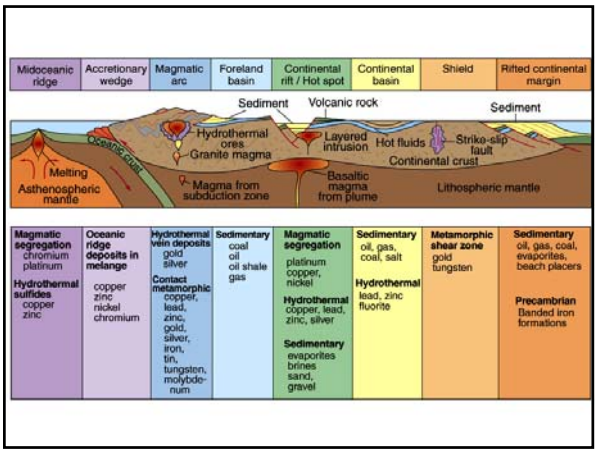
- Controlled fission of U produces large amounts of heat
  - Fission is the splitting of an unstable nucleus into smaller mass elements
  - Heat used to produce steam as with most other energy sources
  - Radiation & thermal pollution are most serious problems

Nuclear Energy

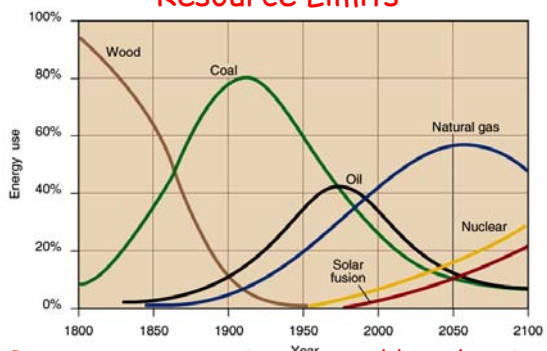
- Some countries have developed programs to deal with these issues
  - France produces ~75% of its energy from nuclear power
- Sources of U are commonly associated with weathering of rhyolites
  - Concentrated in sedimentary aquifers by reduction

Plate Tectonic & Mineral Resources

- Plate tectonics provides information on basic geologic processes and their distribution over time
  - Associations with mineral deposit origin aids in exploration
  - Many deposits associated with geologic processes at plate boundaries

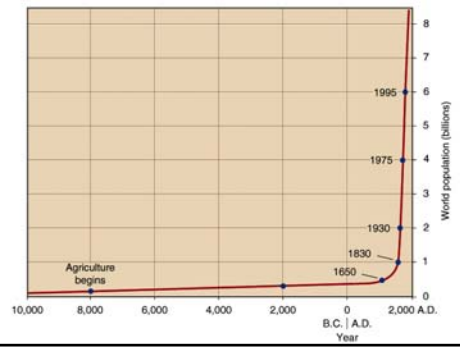


Resource Limits

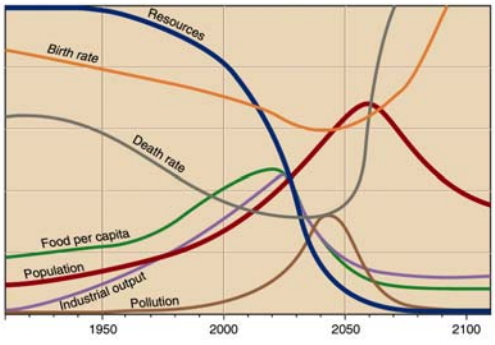


- Resource consumption proceedd at alarming rate

- Resource consumption linked to pop. growth
- Maximum sustainable pop. - Leeuwenhoek (1679)
  - Estimated maximum population of 13.4 bil.

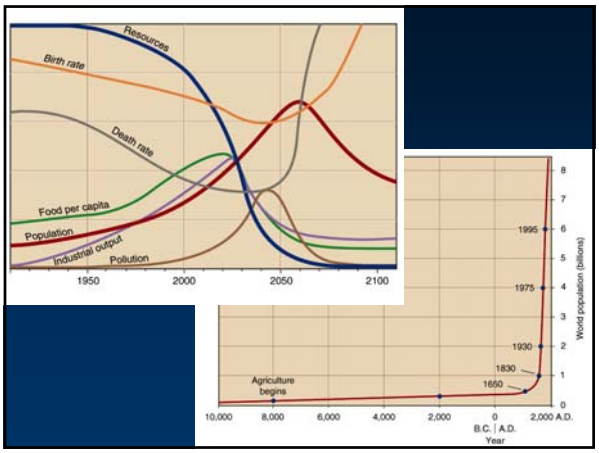


- Current growth rates project reaching this number in the next century



Resource Limits

- Challenge is switch to non-growth
- Resource consumption will still grow due to modernization


Resources
Birth rate
Death rate
Food per capita
Population
Industrial output
Pollution
1950
2000
2050
2100
1995
1975
1930
1830
1650
Agriculture begins
10,000
8,000
6,000
4,000
2,000
0
2,000 A.D.
B.C. | A.D.
Year
World population (billions)
0
1
2
3
4
5
6
7
8