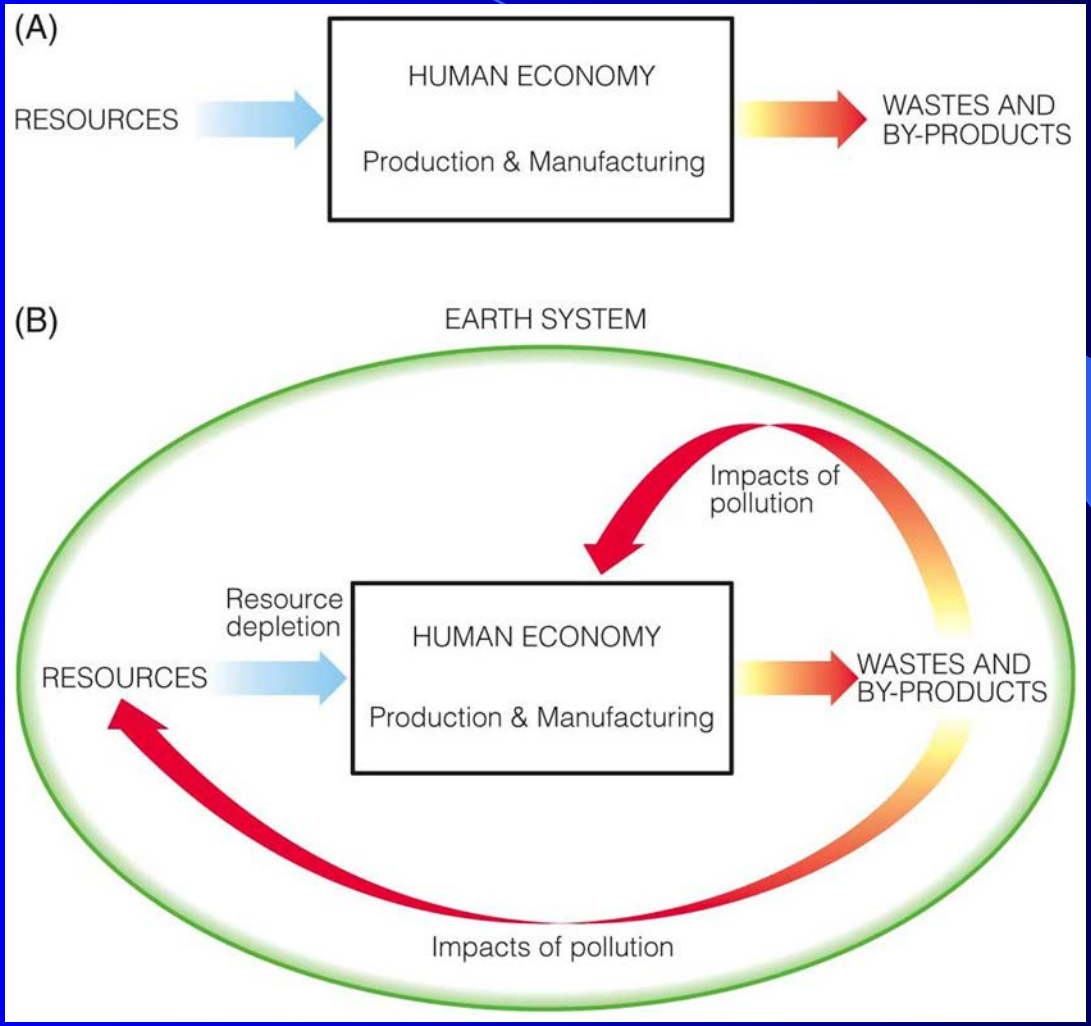
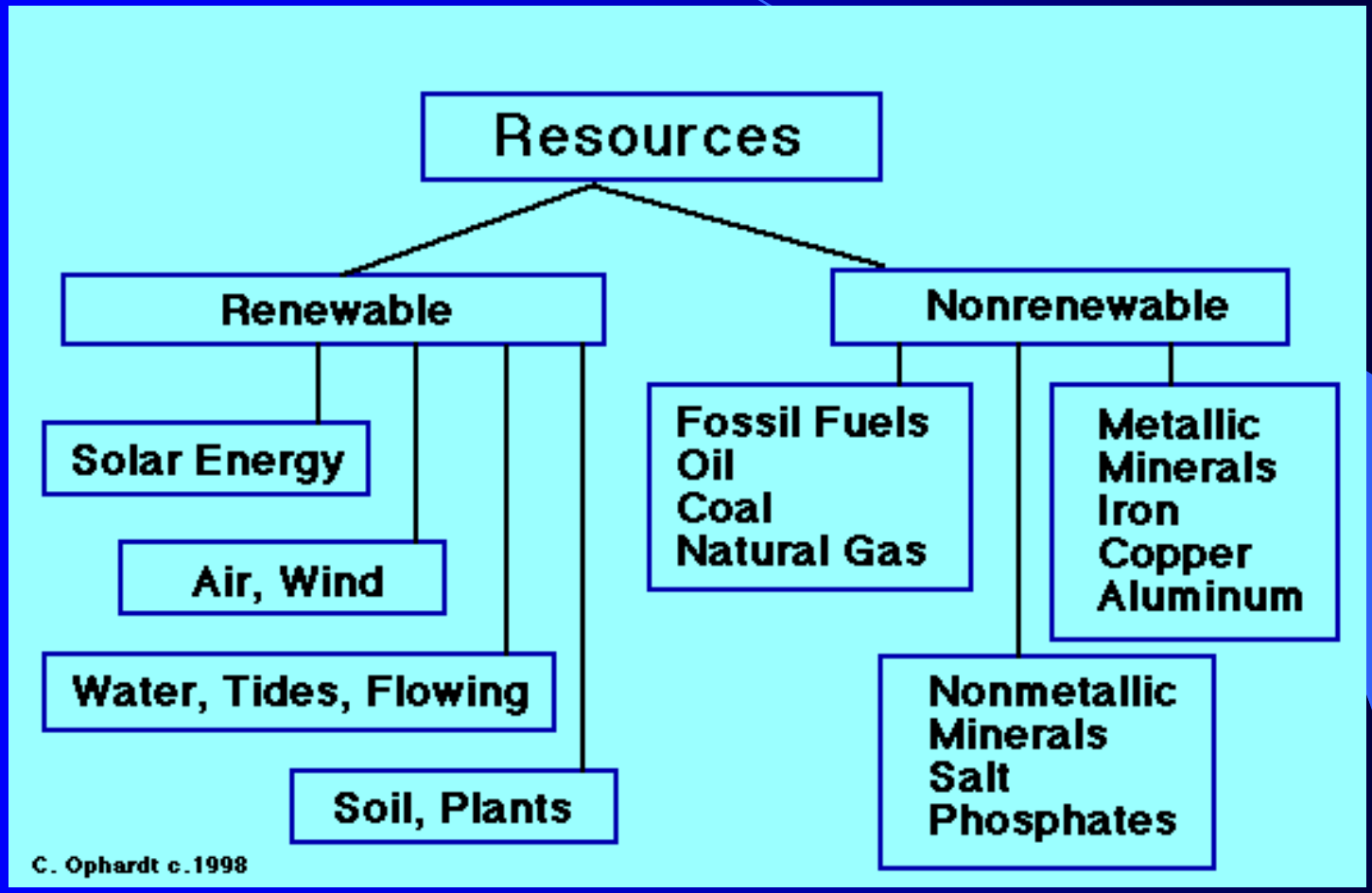
Resources from the Earth System

Human history and civilization are inexorably linked to natural resources



- Renewable resources are replenished by new growth each season
- Nonrenewable resources are renewed naturally, but over millions of years



- Managing **nonrenewable** resources
  - A resource's stock is like the content of a reservoir, the more used, the less remains
  - Resources like copper and oil are not replenished within a human timescale
  - Availability can only be extended through conservation, substitution, reuse or recycling
- Managing **renewable** resources
  - Living resources like fish and trees are renewable if managed properly
  - When resources are used at a rate faster than they replenish, they are depleted
  - When used at exactly their replenishment rate, the stock is at a steady state
  - When renewable resources become severely depleted, they can reach a point where they will never regenerate

- Forest resources
  - 95% are natural, 5% are plantations
  - A forest that has endured hundreds or thousands of years without human intervention is an old-growth forest
  - Timber, fuel, latex, nuts, fruits, oils and bush meat are all forest products
  - Trees also stabilize soil, provide it organic matter, are important in the hydrologic cycle, are an enormous carbon reservoir, and harbor extensive biodiversity

- Fisheries resources
  - Under increasing pressure from overharvesting and environmental change
  - Assessment of the resources is challenging because it relies upon individual fishing vessels to be truthful
  - Capture fisheries account for the majority of world production
  - Atlantic cod were fished to commercial extinction
- Aquaculture
  - The raising of fish, shellfish, crustaceans, and aquatic plants in captivity
  - Focuses on products that have high economic value (salmon, shrimp)
  - Can have significant environmental costs if not properly managed
    - Gene pool contamination
    - Spread of disease
    - Loss of coastal wetlands

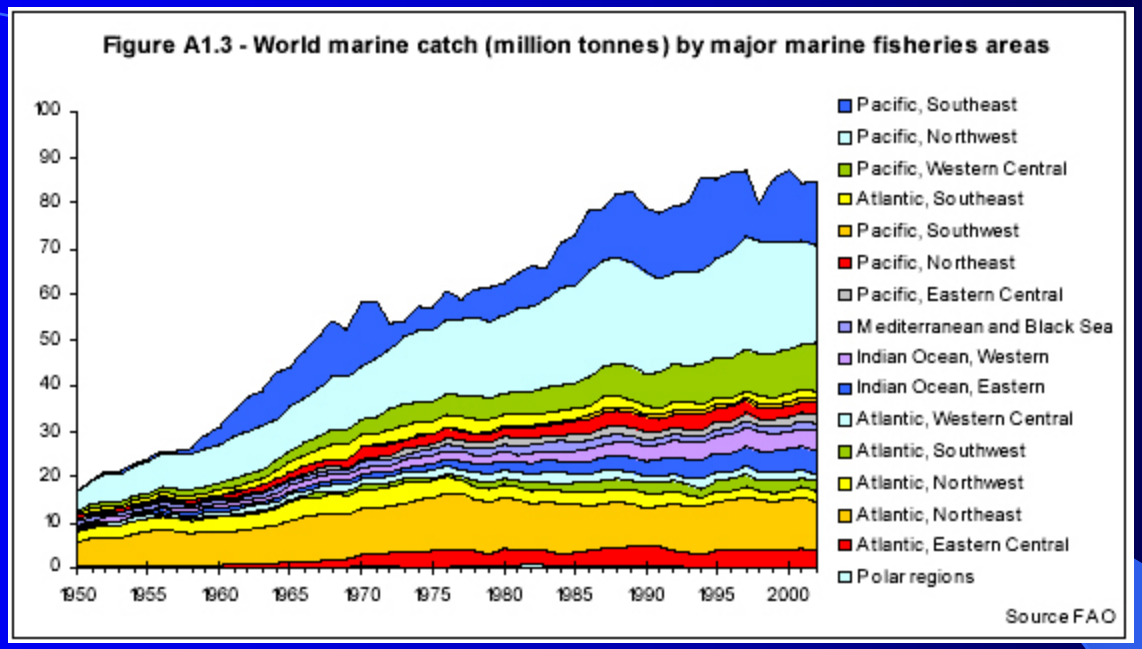
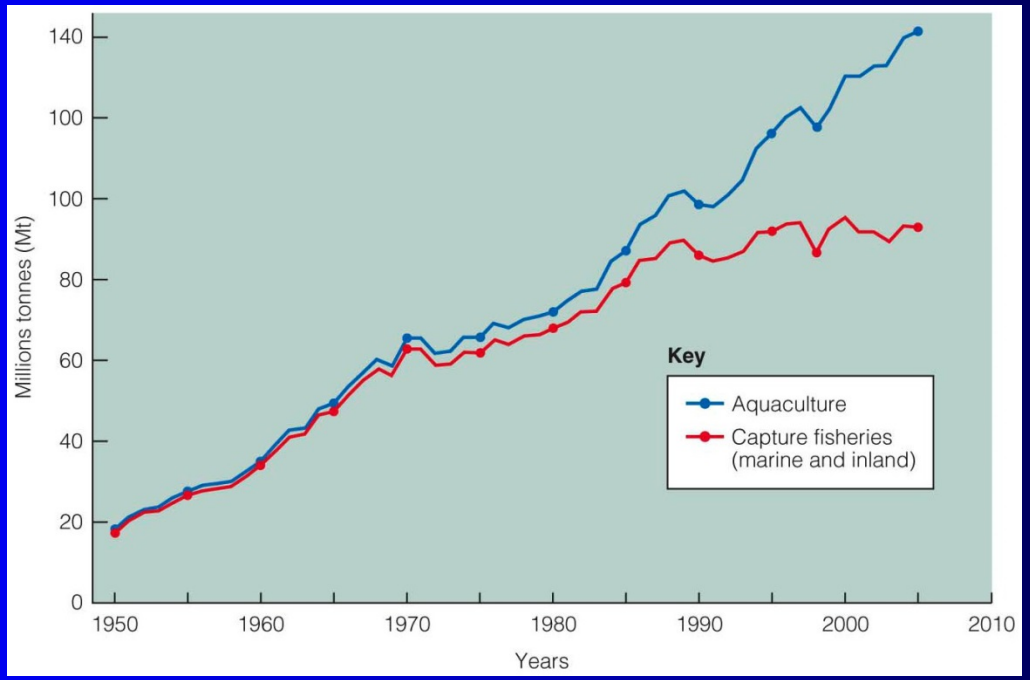
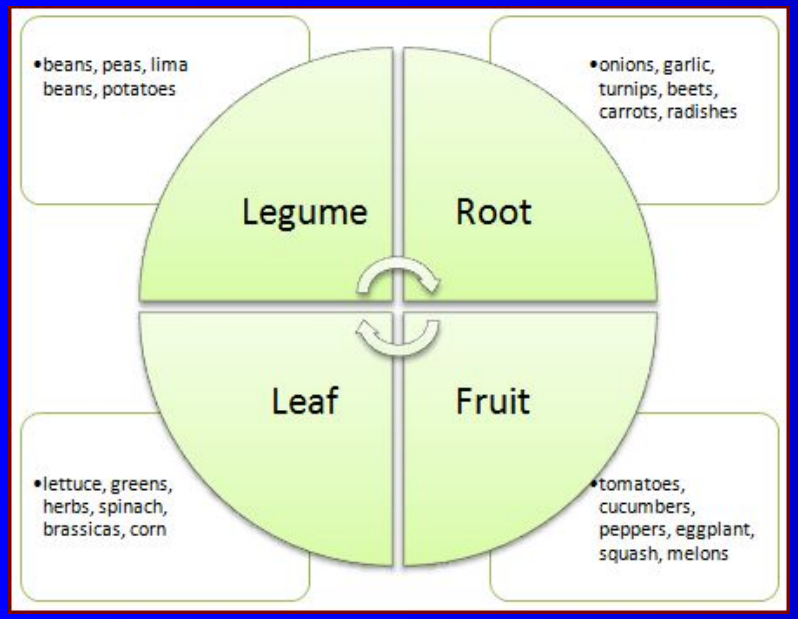
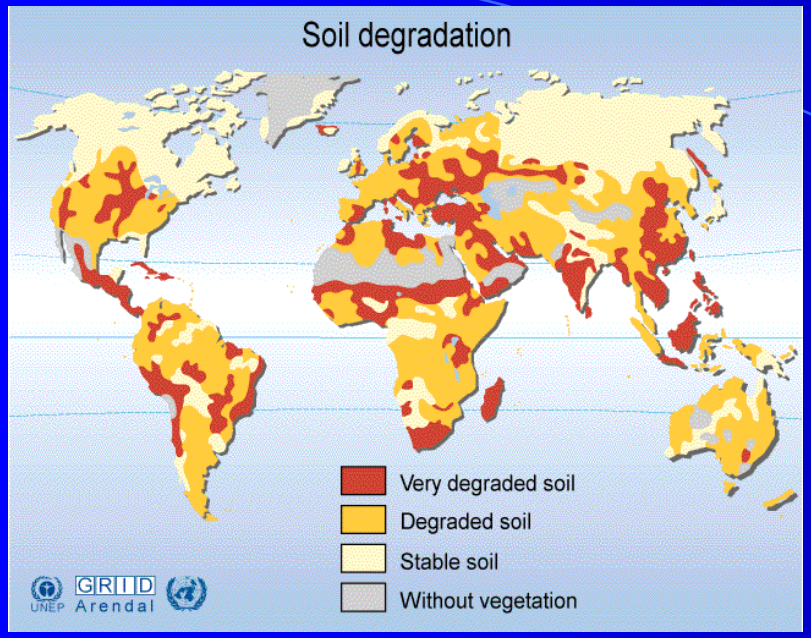


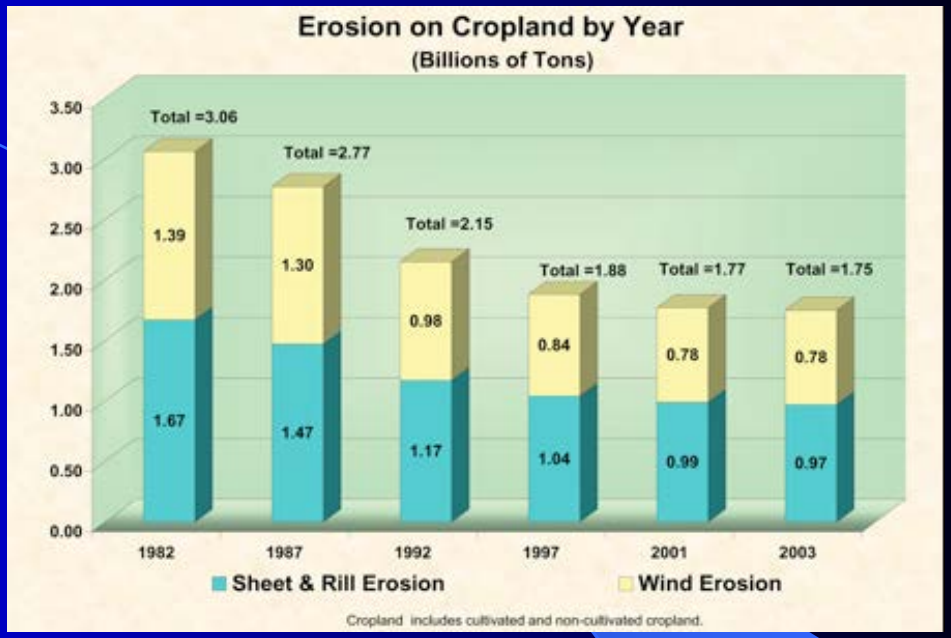
Figure A1.3 - World marine catch (million tonnes) by major marine fisheries areas
100
90
80
70
60
50
40
30
20
10
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Pacific, Southeast
Pacific, Northwest
Pacific, Western Central
Atlantic, Southeast
Pacific, Southwest
Pacific, Northeast
Pacific, Eastern Central
Mediterranean and Black Sea
Indian Ocean, Western
Indian Ocean, Eastern
Atlantic, Western Central
Atlantic, Southwest
Atlantic, Northwest
Atlantic, Northeast
Atlantic, Eastern Central
Polar regions
Source FAO

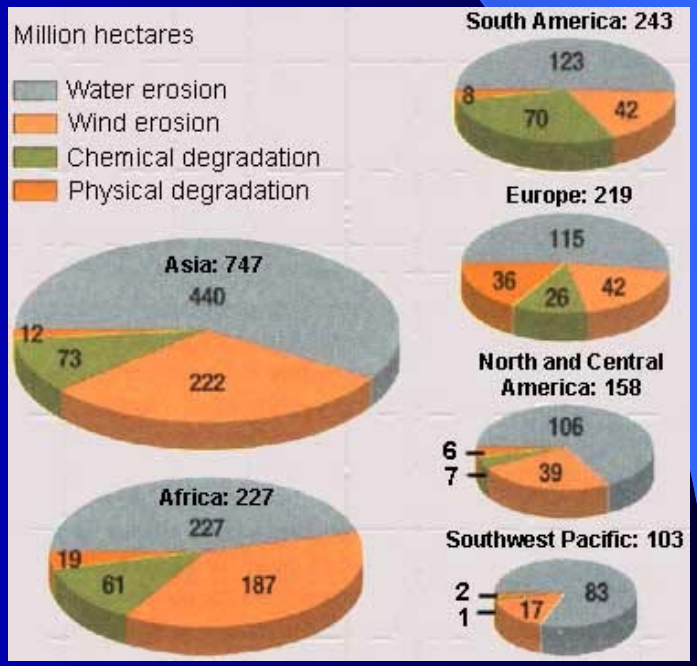

140
100
100
80
60
40
20
0
Millions tonnes (Mt)
1950
1960
1970
1980
1990
2000
2010
Years
Key
Aquaculture
Capture fisheries
(marine and inland)

- Soil resources
  - Arable soil: soil that is suited for agriculture
  - Crucial for the global food supply
  - Soil needs fallow time to replenish nutrients
  - Traditional agriculture had crop diversity in a single field, modern trends to monoculture
  - Soil is degraded by erosion, contamination, compaction and loss of nutrients

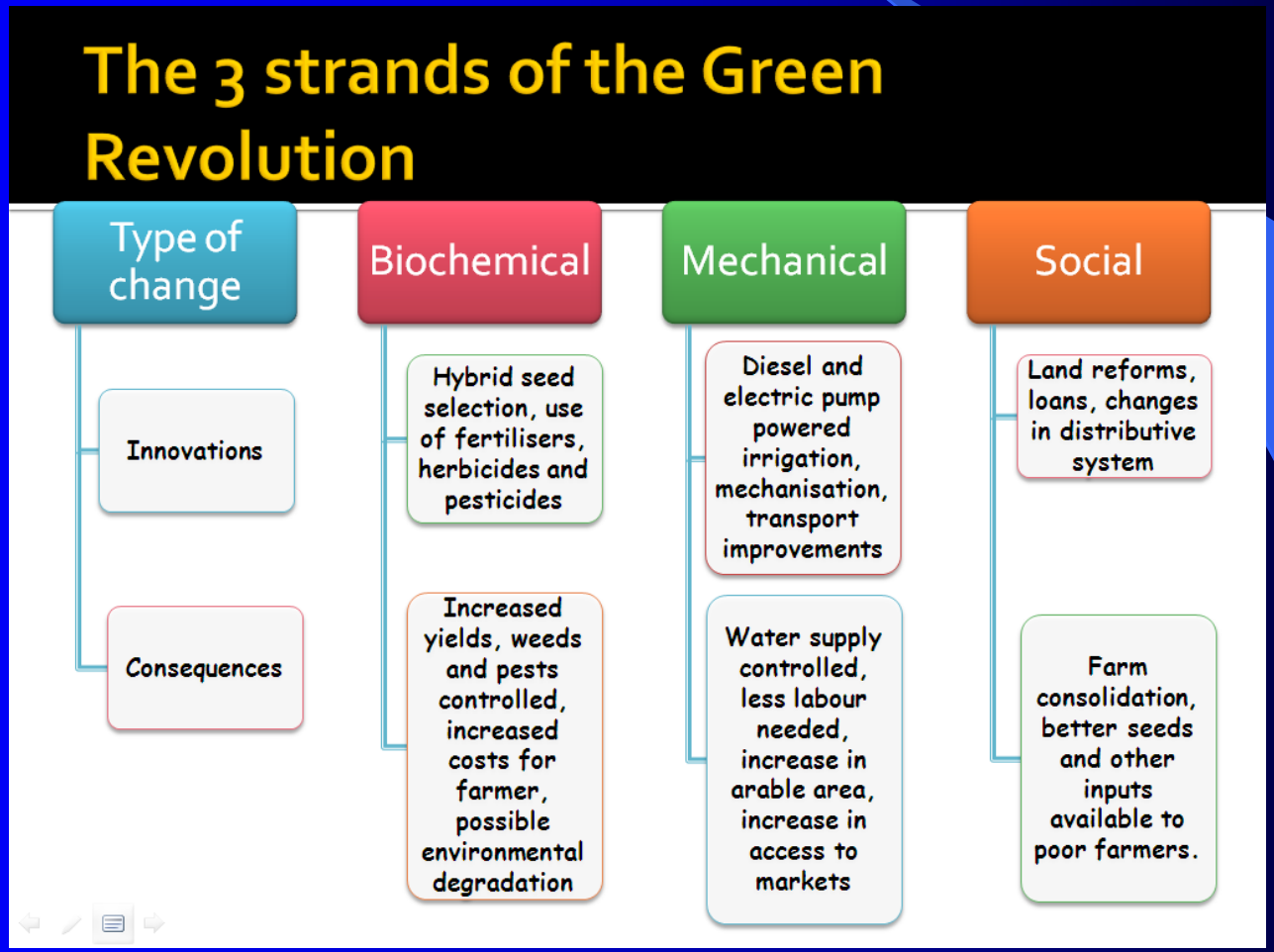



Soil degradation
Very degraded soil
Degraded soil
Stable soil
Without vegetation
UNEP GRID Arendal

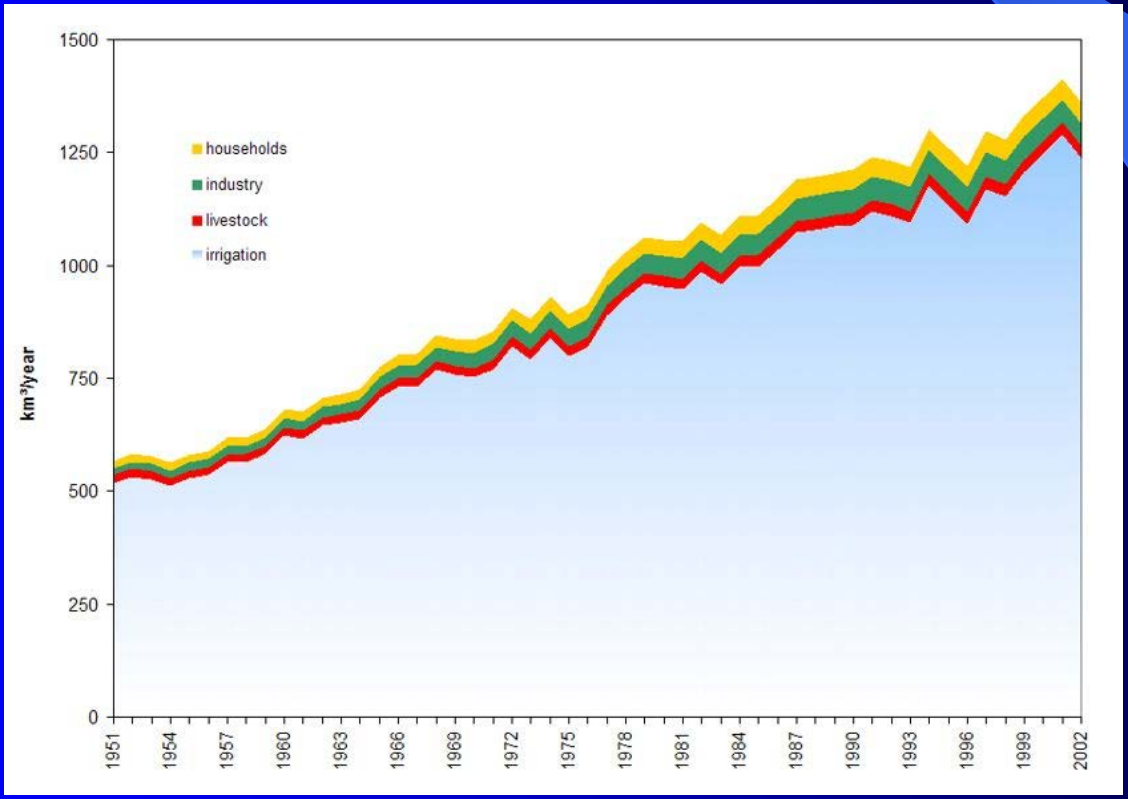

Erosion on Cropland by Year
(Billions of Tons)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Total =3.06
Total =2.77
Total =2.15
Total =1.88
Total =1.77
Total =1.75
1.39
1.67
1.30
1.47
0.98
1.17
0.84
1.04
0.78
0.99
0.78
0.97
1982
1987
1992
1997
2001
2003
Sheet & Rill Erosion
Wind Erosion
Cropland includes cultivated and non-cultivated cropland.


Million hectares
Water erosion
Wind erosion
Chemical degradation
Physical degradation
Asia: 747
440
12
73
222
Africa: 227
227
19
61
187
South America: 243
123
8
70
42
Europe: 219
115
36
26
42
North and Central America: 158
106
6
7
39
Southwest Pacific: 103
2
1
17
83

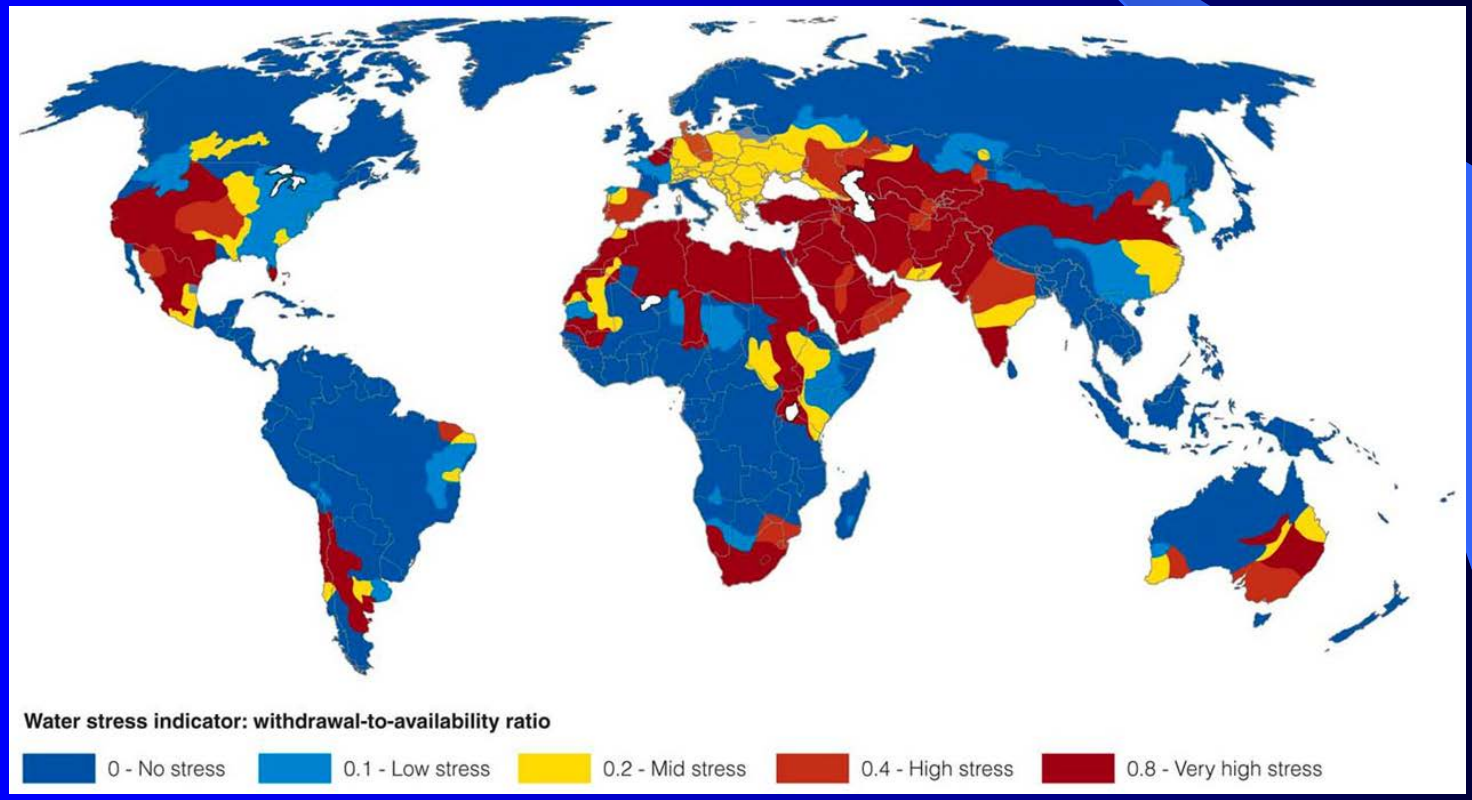
- The green revolution
  - Development of high-yield, disease-resistant seed types through bioengineering
  - Expansion of land use and irrigation, and use of agrochemicals and fertilizers
  - There are limits to these increases
  - With global population growth, per capita yield begins to stagnate and decline



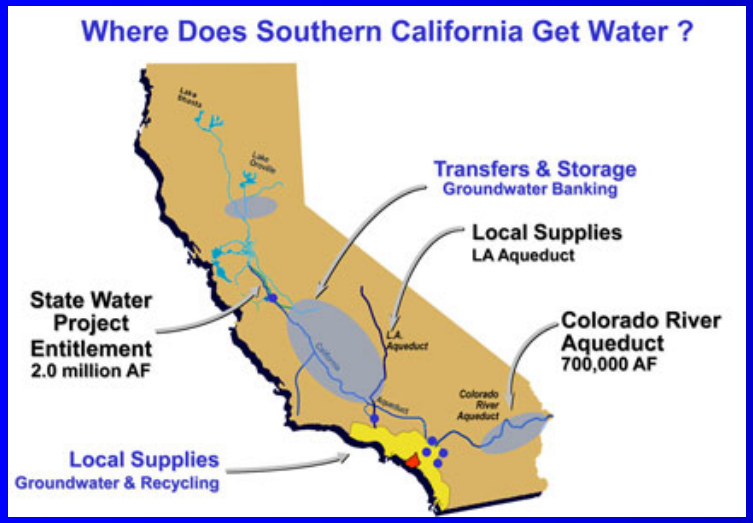
- Water resources
  - Reliable fresh water is crucial for people, ecosystems, industry, agriculture, recreation, transportation, and fisheries
  - Irrigation accounts for 75% of water demand
  - Global water use has tripled since 1950
  - Excessive groundwater withdrawal leads to resource depletion as well as depression of the water table, drying of springs, streams and wells, compaction and subsidence



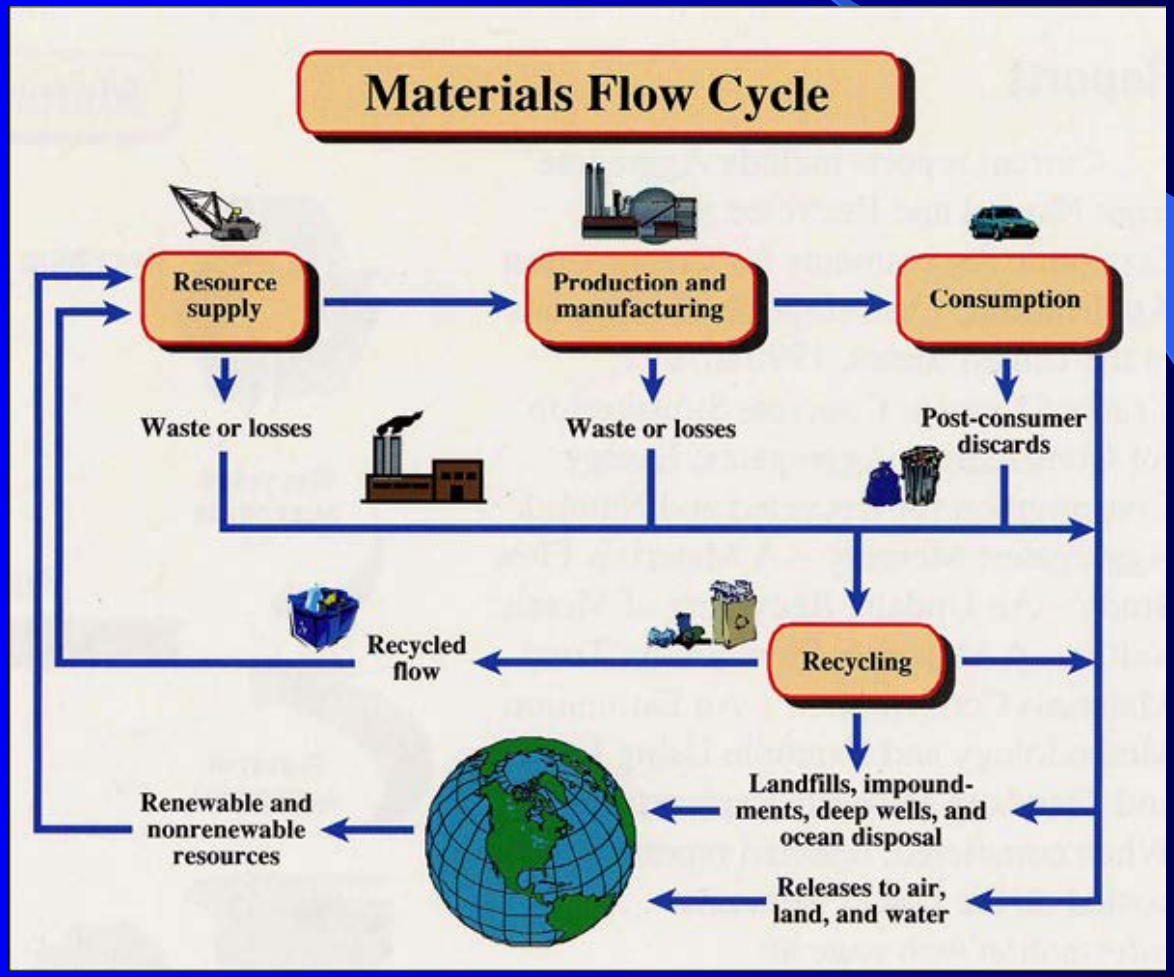
- Irretrievable water consumption results in lost water, water that is not returned to the local hydrologic cycle
- A water-stressed region has supplies of 1000-2000 m^3 per person
- A water-scarce region has <1000 m^3
- 29 countries, 450 million people, suffer from significant water shortages



- A mismatch between local supply and demand of water leads to diversion and inter-basin transfer
  - Northern to southern California
  - Aral Sea
- Issues around allocation and regulation of water and water rights continue



- Conserving nonrenewable resources and minimizing the impacts of their use involves closing the resource cycle
- Waste is generated at every stage of the resource cycle
- Recycling refers to the extraction of usable raw materials from waste products
- Leakage in the resource cycle occurs at the post-consumer stage



- Metallic minerals are mined specifically for the metals that can be extracted by smelting
  - Sphalerite (zinc), galena (lead)
- Nonmetallic minerals are mined for their chemical or physical properties they have, not the metals they contain
  - Clay, gravel, salt, gems

TABLE 18.1 Mineral Resources and Their Uses

Metals	
Abundant metals	iron, aluminum, magnesium, manganese, titanium, silicon
Scarce and rare metals	copper, lead, zinc, nickel, chromium, gold, silver, tin, tungsten, mercury molybdenum, uranium, platinum, and many others
Nonmetals	
Used for chemicals	sodium chloride (halite), sodium carbonate, borax, calcium fluoride (fluorite)
Used for fertilizers	calcium phosphate (apatite), potassium chloride, sulfur, calcium carbonate (limestone), sodium nitrate
Used for building	gypsum (for plaster), limestone (for cement), clay (for brick and tile), asbestos, sand, gravel, crushed rock, shale (for brickmaking), decorative stone
Used for jewelry	diamond, corundum (ruby and sapphire), garnet, amethyst, beryl (emerald), and many others
Used for glass and ceramics	clays, feldspar, quartz (silica sand)
Used for abrasives	diamond, garnet, corundum, pumice, quartz

Mineral Politics

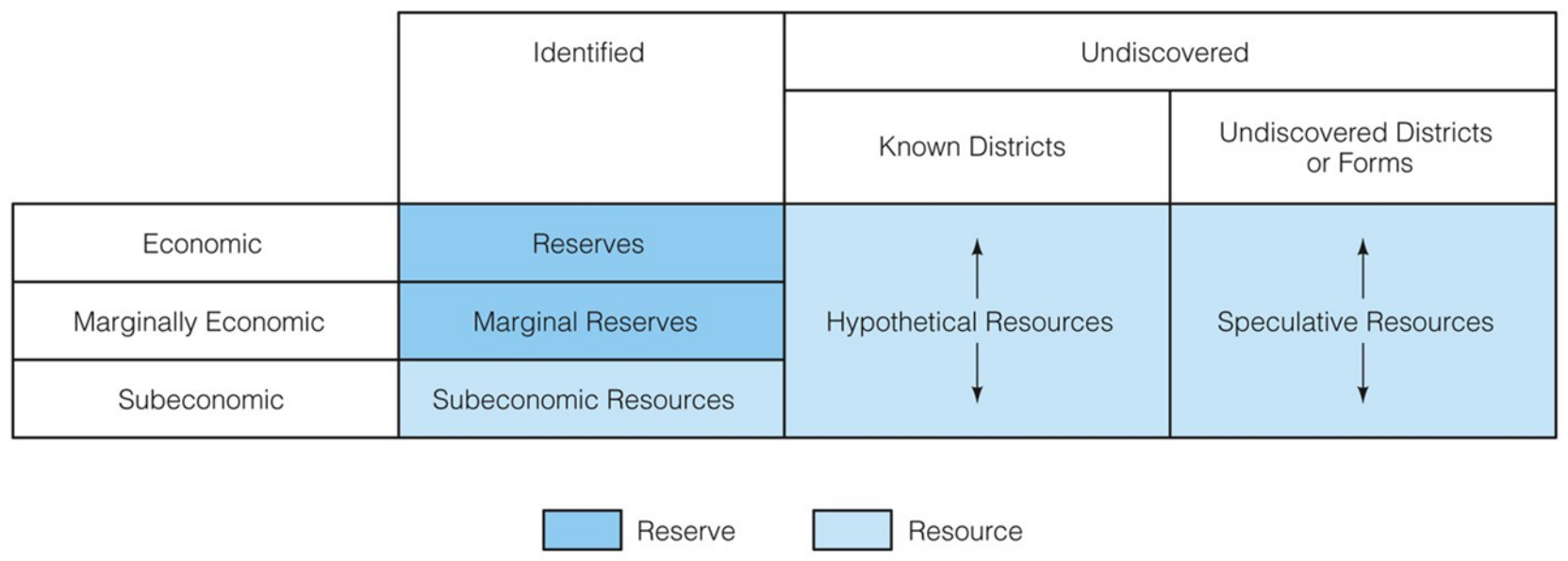
2011 U.S. NET IMPORT RELIANCE FOR SELECTED NONFUEL MINERAL MATERIALS

Commodity	Percent	Major Import Sources (2007–10)[1]
ARSENIC (trioxide)	100	Morocco, China, Belgium
ASBESTOS	100	Canada, Zimbabwe
BAUXITE and ALUMINA	100	Jamaica, Brazil, Guinea, Australia
CESIUM	100	Canada
FLUORSPAR	100	Mexico, China, South Africa, Mongolia
GRAPHITE (natural)	100	China, Mexico, Canada, Brazil
INDIUM	100	China, Canada, Japan, Belgium
MANGANESE	100	South Africa, Gabon, China, Australia
MICA, sheet (natural)	100	China, Brazil, Belgium, India
NIOBIUM (columbium)	100	Brazil, Canada, Germany, Russia
QUARTZ CRYSTAL (industrial)	100	China, Japan, Russia
RARE EARTHS	100	China, France, Estonia, Japan
RUBIDIUM	100	Canada
SCANDIUM	100	China
STRONTIUM	100	Mexico, Germany
TANTALUM	100	China, Germany, Kazakhstan, Australia
THALLIUM	100	Russia, Germany, Kazakhstan
THORIUM	100	France, India, Canada, United Kingdom
YTTRIUM	100	China, Japan, France, United Kingdom
GALLIUM	99	Germany, Canada, United Kingdom, China
IODINE	99	Chile, Japan
GEMSTONES	98	Israel, India, Belgium, South Africa
GERMANIUM	90	China, Belgium, Russia, Germany

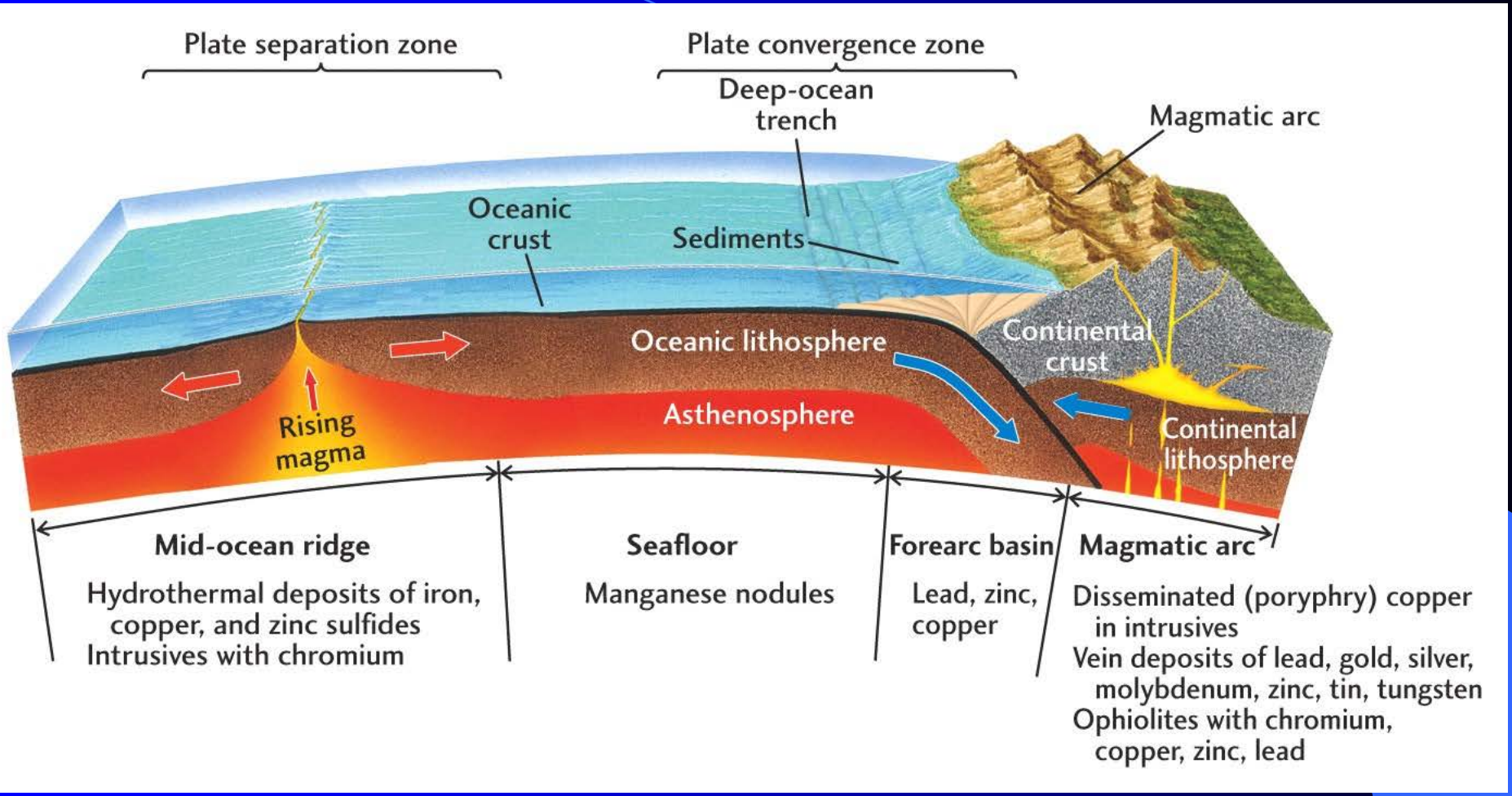
- Geochemically abundant elements
  - Make up more than 0.1% of Earth's crust
  - Only 12 of the 92 naturally occurring elements
- Geochemically scarce elements
  - Make up less than 0.1% of Earth's crust

Metal	Ore Grade	Crustal Abundance	Clarke Value
Cu	0.54%	27 ppm	200
Na	40%	2.3%	17
Zn	5.6%	72 ppm	780
As	0.1%	2.5 ppm	400
Rb	3%	49 ppm	610
Mo	0.19%	0.8 ppm	2,400
W	0.66%	1 ppm	6,600
Pb	2.8%	11 ppm	2,500
V	0.6%	138 ppm	43
Au	10 ppm	1.3 ppb	7,700
Ag	125 ppm	56 ppb	2,200
Ni	1.5%	59 ppm	250

- Mineral resources are mined from concentrations that formed under suitable conditions by geologic processes
  - Weathering, sedimentation, volcanism
- Suitable conditions are rare, and may take millions of years to form a deposit
- Intensive mining, depletion, declining production and dependence on imports can be applied on a local, regional or global scale to estimate the remaining lifetime of a mineral resource
- Today the favorable geologic locations for mineral exploration have mostly been prospected, assessed, and mined



Geological settings for various types of ore deposits

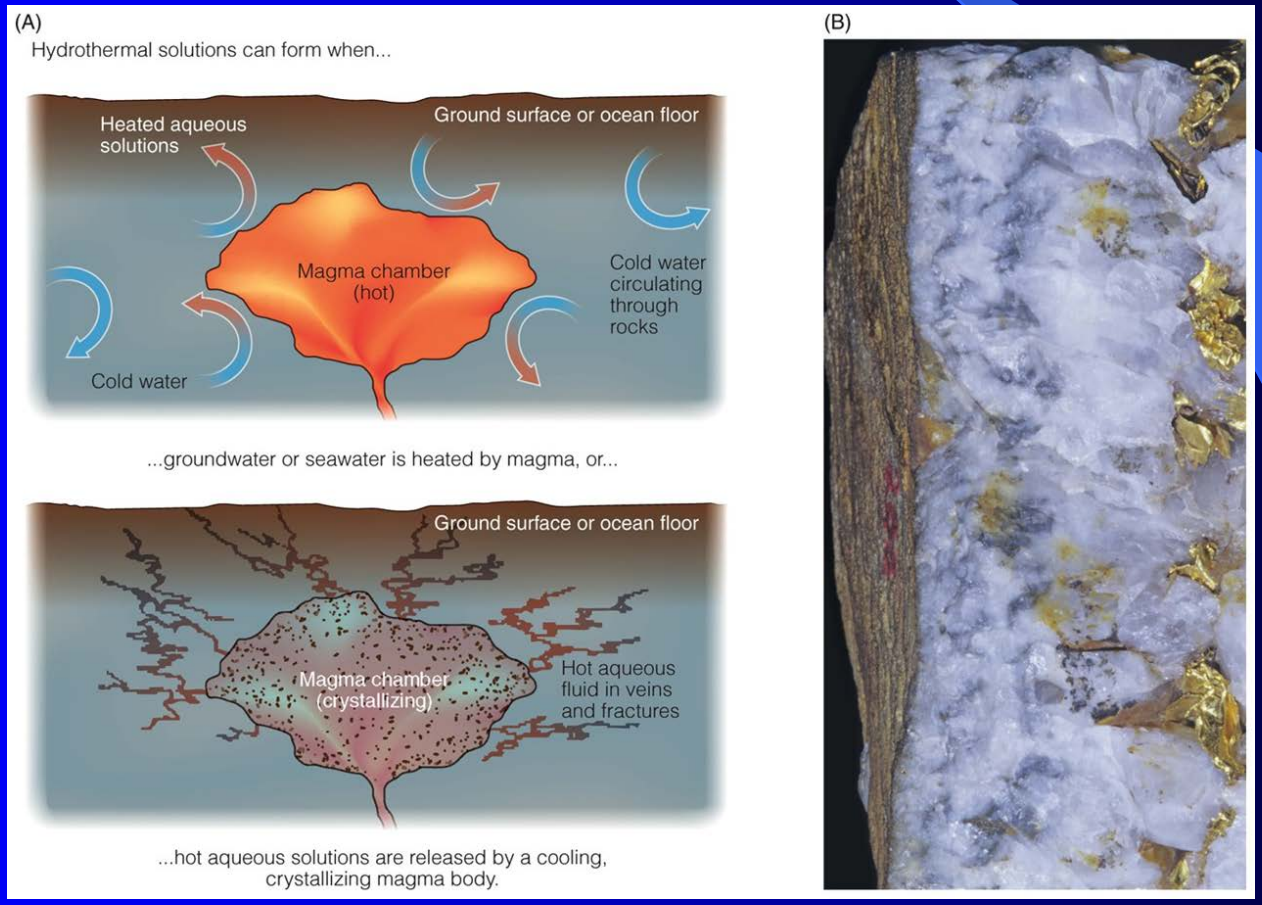


A geologic process or combination of processes must produce a localized enrichment of minerals for a mineral deposit to form

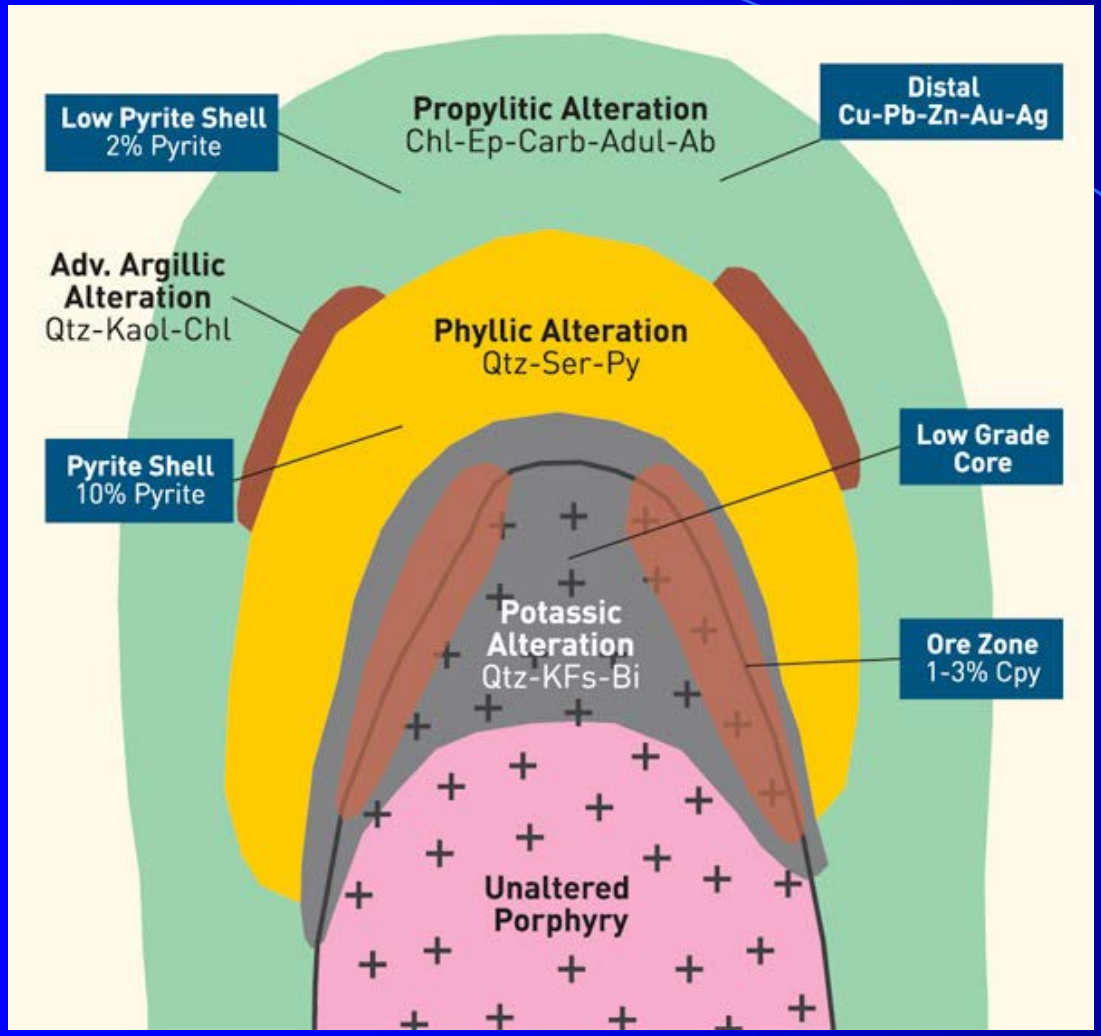
1. Hydrothermal solutions
2. Metamorphic or magmatic processes
3. Chemical sedimentary processes
4. Action of waves or currents
5. Weathering

Hydrothermal ore deposits

- Hot, aqueous, metal-saturated fluids that react chemically with the crust rock
- Most mineral deposits
- Primary sources of metals
- Veins
- Stratabound mineral deposits

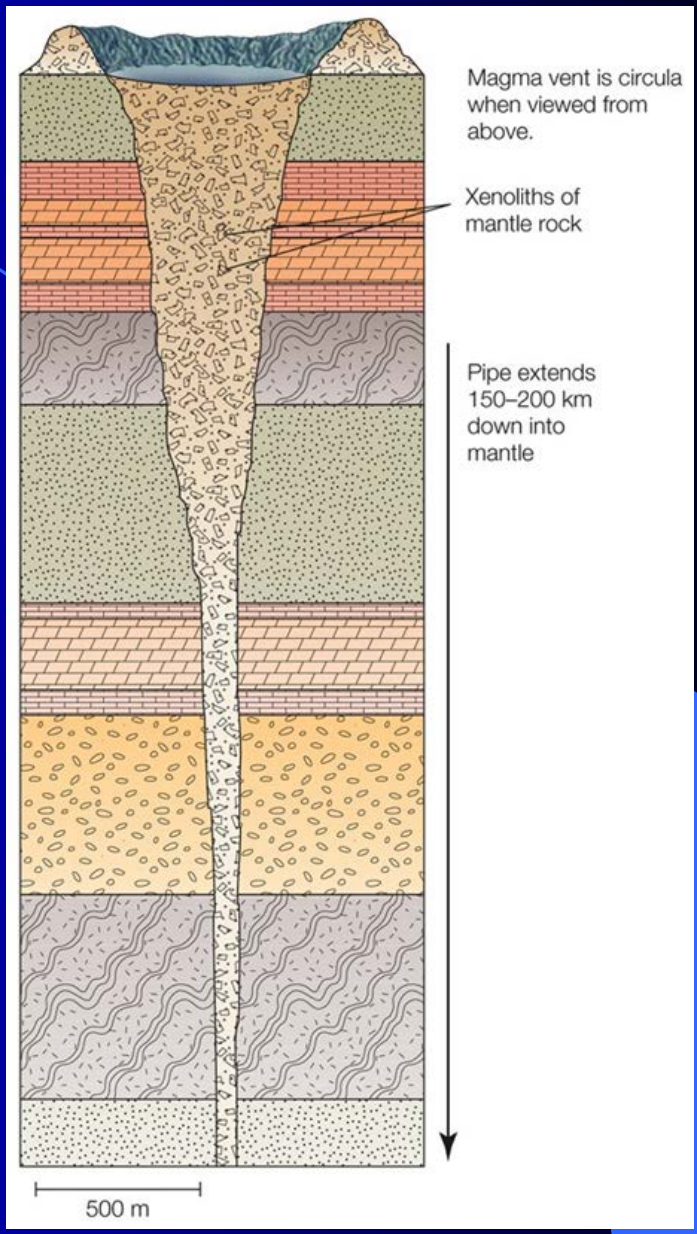


Bingham Canyon

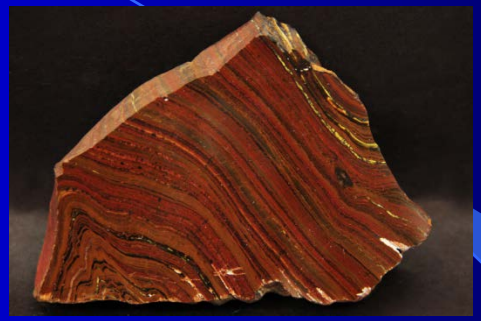


[Bingham Canyon Landslide - GSA Today]

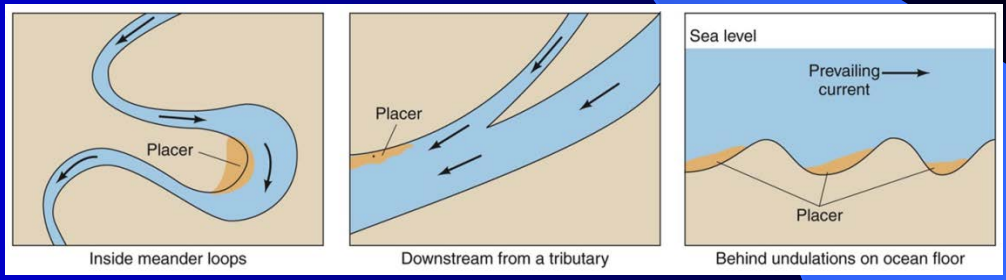
- Metamorphic ore deposits
  - Alteration and recrystallization
- Magmatic ore deposits
  - Fractional crystallization
  - Pegmatites
  - Kimberlite pipes

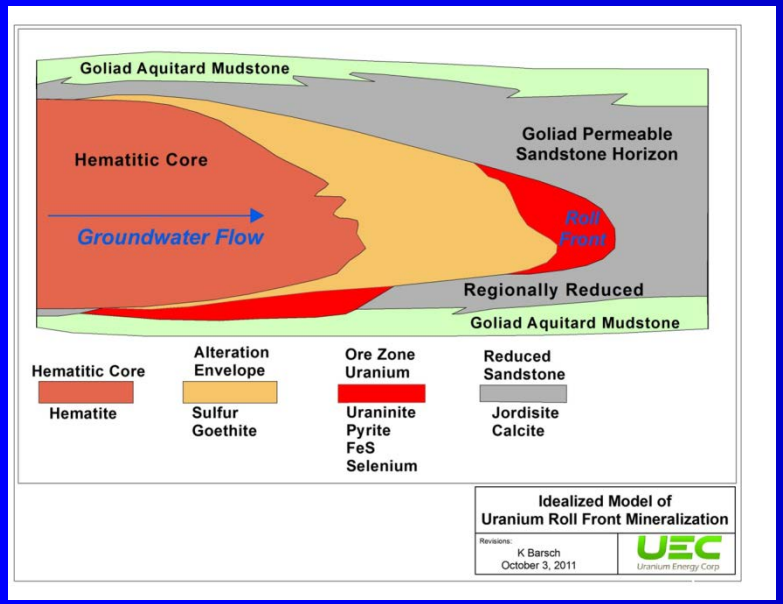


- Sedimentary ore deposits
  - Concentration by sedimentation
    - Precipitation by seawater or lake water
  - Evaporation
    - Evaporite deposits
  - Biochemical reactions
    - Banded iron formations

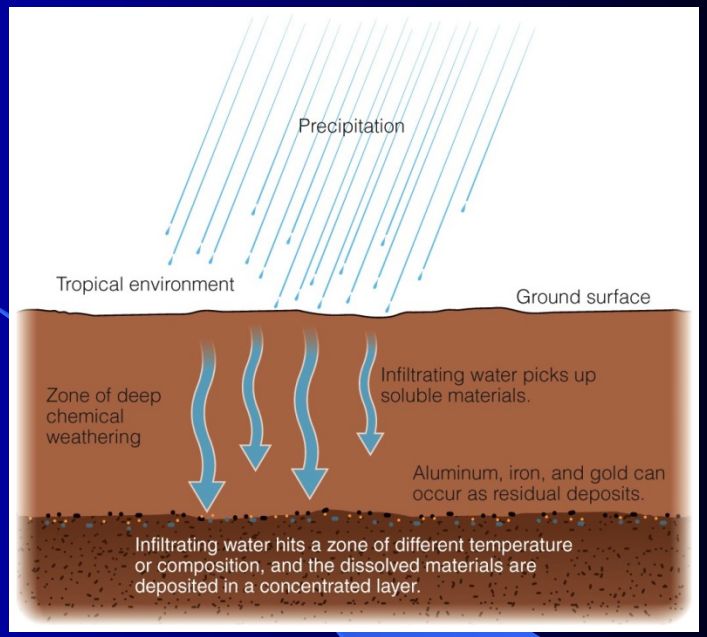


- Placer ore deposits
  - Heavy mineral grains concentrated by sifting or winnowing by flowing water





- Residual ore deposits
  - Chemical weathering
  - Removes soluble materials first, leaving a concentrated layer of insoluble minerals behind
  - Dissolved materials carried by water may be deposited in one concentrated layer
  - Laterites



- Mining
  - Set of processes whereby useful resources are withdrawn from the stock of nonrenewable resource
    - Extraction of mineral resources
  - Sequential land use is the concept of mining and then restoring the land to its former state for use by other purposes
  - Prospecting or exploration
    - An area is assessed for potential
  - Extraction
  - Milling
    - Ore is crushed and concentrated
    - Waste is discarded as tailings
  - Postoperational phase
    - Mine is closed, tailings are contained and monitored: minesite decomissioning

Iron Mining

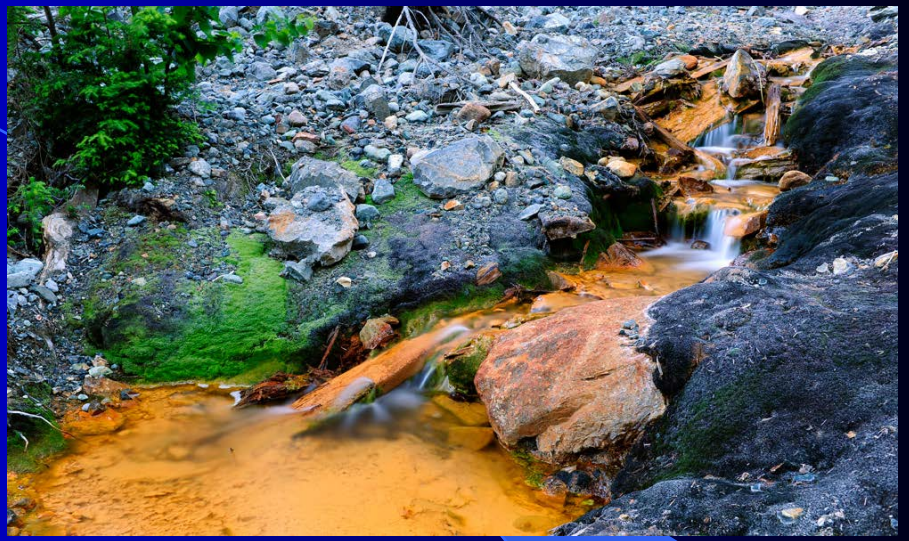
- Impacts of mining
  - Geosphere
    - Open pit mines and strip mines are destructive to the land
    - Abandoned subsurface mines are susceptible to subsidence
    - Construction of mine roads, buildings and tailings piles impact wilderness

- Impacts of mining
  - Atmosphere
    - Smelting and refining emit pollutants:
      - Particulates
      - NO_x SO_x - can cause acid precipitation
      - Vaporized metals
      - Volatile organic compounds
    - Blowing dust from tailings piles


Sudbury


Olympic Dam U mine

- Impacts of mining
  - Hydrosphere
    - Liquid waste (effluent) generated during milling
    - Acid mine drainage from water interacting with sulfide minerals in tailings
  - Biosphere and human health
    - Acid mine drainage on ecosystems
    - Black lung disease, cancer
    - Coal dust explosions
    - Mine collapse



Butte, Montana