

Supplementary Notes (PJ Shlachtman, Miller book):

Minerals and Soil Resources

Geologic Processes

Earth's Structure – three concentric zones

Core – solid inner core of iron and liquid outer core (iron) which gives the Earth its magnetic poles

Mantle – thick solid zone consisting of iron, silicon, oxygen and magnesium.

The outermost layer of the mantle is a thin plastic layer of partially molten rock – the *asthenosphere*

Crust – outermost and thinnest zone of the Earth

- continental crust – 29%
- oceanic crust – 71%

Soil and Mineral Resources

Three types of rock

- igneous
- sedimentary
- metamorphic

The source of virtually all nonrenewable resources:

- fossil fuels
- metallic minerals
- nonmetallic minerals

The source of soil and the elements that make up all living organisms

Chemical makeup of the crust (p.65):

Oxygen	46.6%
Silicon	27.7
Aluminum	8.1
Iron	5.0
Calcium	3.6
Sodium	2.8
Potassium	2.6
Magnesium	2.1
All Others	1.5

Plate Tectonics

Plates – major areas of the Earth's crust whose boundaries are determined by lines of earthquakes and volcanoes

Lithosphere – crust and the rigid outermost part of the mantle above the asthenosphere

The plates move constantly floating on the constantly-moving asthenosphere

Plate Tectonics is the theory that explains the movement of the plates and the processes that occur at their boundaries (developed from the *continental drift* concept).

Plate movement produces mountains, volcanoes, the oceanic ridge system, trenches and other earth features.

Helps explain how certain patterns of biological evolution occurred.

Three types of boundaries

1. **Divergent Plate Boundary** – plates move apart in opposite directions
2. **Convergent Plate Boundary** – plates are pushed together (subduction zone) forming a trench and causes earthquakes and volcanoes
3. **Transform Fault** – plates move in opposite but parallel directions (slide past each other)

Geologic Processes on the Earth's Surface

External processes – those geologic changes based directly or indirectly on energy from the sun and on gravity (rather than heat from the Earth's interior)

Internal Processes generally build up the Earth's surface, external processes tend to wear it down

Erosion – major external process: loosened material is dissolved, or worn away from one part of the Earth's surface and deposited in another

Weathering – mechanical or chemical

Streams – the most important agent of erosion

- produce ordinary valleys and canyons; may form deltas when they flow into lakes and oceans

Wind Erosion –

Human activities can accelerate erosion: activities that destroy vegetation (deforestation...)

Finding and Removing Nonrenewable Mineral Resources

Mineral Resources

A concentration of naturally occurring solid, liquid or gaseous material in or on the earth's crust that can be extracted and processed into useful materials at an affordable cost.

- **Energy resources** – coal, oil, natural gas, uranium, geothermal energy
- **Metallic mineral resources** – iron, copper, aluminum
- **Nonmetallic mineral resources** – salt, gypsum, clay, sand, phosphates, water, soil

Ore – a metal-yielding material that can be economically extracted at a given time

Identified Resources – deposits that have known location, quantity and quality (or estimated from direct geological evidence)

Undiscovered Resources – potential supplies of a particular mineral resource that are assumed to exist on the basis of geologic knowledge and theory

Reserves – identified resources that can be extracted economically at current prices using current mining technology

Other Resources – identified and undiscovered resources not classified as reserves

Finding Mineral Resources

- Aerial photos
- Satellite images
- Effect on the Earth's magnetic and gravitational fields

Types of Mining

Overburden – soil and rock which lies over shallow mineral deposits

Spoil – waste material

Surface mining – used to retrieve shallow mineral deposits

- **Open-Pit Mining** – dig holes and remove ores
- **Dredging** – chain buckets and draglines scrape up underwater mineral deposits
- **Strip Mining** – overburden is removed in strips – coal, phosphate rock

- **Area Strip Mining** – terrain is flat; overburden is stripped away and mineral deposit is removed by power shovels then trench is filled with overburden; Spoil Banks are left – wavy series of hills
- **Contour Strip Mining** – terrain is hilly / mountainous; terraces are cut into the side of the hill; overburden is removed and mineral is extracted. Overburden from each new terrace is dumped onto the one below. Highwall – a wall of dirt left in front of the highly erodible bank of soil and rock.
- **Mountaintop Removal** – mountain tops are completely removed. Debris is dumped into the valleys.
- Restoration is difficult and usually incomplete. Most surface mining in the U.S. is in arid and semiarid regions where soil and climate prevent full restoration. Remember, damage to desert biomes is almost always permanent.

Subsurface Mining – use to remove ores too deep to be extracted by surface mining techniques.

- Room-and-pillar Method
- Longwall Method
- More dangerous and more expensive than surface mining
 - Damages much less of the surface land
 - Mines collapse, trapping and killing miners
 - Dust Explosions and natural gas
 - Prolonged inhalation of mining dust causes lung diseases.

Estimating Supplies of Nonrenewable Mineral Resources

Two factors determine our future supply of nonrenewable resources:

1. Actual or potential supply
2. Rate at which the supply is used

Economically Depleted – when cost of finding, extracting, transporting and processing the remaining deposits exceed the returns. Then our choice becomes one of recycling, reusing, wasting less, using less, finding a substitute or doing without

Depletion Time – the time it takes to use up a certain proportion of the reserves of a mineral at a given rate of use.

Reserve-to-Production Ratio – the number of years that proven reserves of a particular resource will last at current annual production rates.

Prices of most metals have changed little in constant dollars over the past 150 years – due mostly to government subsidies and failure to include the harmful environmental effects of metal mining and processing in their market prices.

Who has the World's Mineral Resources?

Mineral resources are not distributed evenly

Of the world's 20 most important non-fuel resources, supplied by U.S., Canada, Australia, South Africa and former Soviet Union.

Japan has virtually no mineral resources.

Europe depends heavily on minerals from Africa.

Increasing Mineral Resource Supplies

Most mineral prices are low because governments subsidize development of their domestic mineral resources to help promote economic growth and national security.

The cost of non-fuel resources is only a small part of the final cost of goods. Industries and consumers have no incentive to reduce demand for products in time to avoid economic depletion of minerals.

Harmful environmental costs are not included in their pricing.

Exploration is financially risky

- takes a lot of investment capital
- lack of capital limits production of nonfuel minerals

Can We Mine More Lower-Grade Ores?

The average ore mined today is lower than it was 100 years ago.

Factors that limit the mining of low grade ore:

1. costs to mine the ore exceed the expected return
2. large amount of water are needed (mineral-rich areas lack fresh water)
3. the environmental impact of waste material (cost of land restoration and pollution control exceed current value of the minerals)

Mining the Oceans

Most minerals in seawater occur at very low concentrations – not economically practical to recover them.

Only minerals that can be profitably extracted are magnesium, bromine and sodium chloride.

Continental Shelf – sand, gravel, phosphates, sulfur, tin, copper, iron, tungsten, silver, titanium, platinum, and diamonds.

Deep ocean floor – future site for sources of manganese and other metals; uncertainty who own the mineral rights in international waters.

- **Hot volcanic springs** – sources of sulfide deposits of gold, silver, zinc and copper
- Environmental effects of deep-sea mining are unclear and debatable

Substitutes for Scarce Nonrenewable Mineral Resources

Some substitutes are possible – e.g., we are currently using ceramics and plastics as replacements for metals

Substitutes may be found, but the search is costly and it takes time to phase in new materials and processes. Some substitutes are inferior. Finding some substitutes may be very difficult or impossible.

Environmental Effects of Using Mineral Resources

Mining and use of resources requires enormous amounts of energy and often cause land disturbance, erosion, and air and water pollution

Land Surface:

1. scarring and disruption
2. fires in coal mines
3. land subsidence causing houses to tilt, cracked sewer lines, broken gas mains and disrupted groundwater systems.
4. erosion of spoil heaps and tailings by water and wind
5. air and water pollution

Rainwater seeping through a mine or mine waste can carry sulfuric acid to nearby streams

Other mining wastes: radioactive uranium compounds, compounds of lead, mercury, arsenic and cadmium

Beneficiation – separation of ore material from the gangue (waste mineral material); tailings – waste material

Smelting – separates the metals from other metals in the mineral

- emits enormous amounts of air pollutants damaging vegetation and soil
- SO₂, soot, tiny particles of arsenic, cadmium, lead and other heavy metals.
- Pollution control is expensive, but can save millions of dollars of clean-up costs later.

The grade of an ore largely determines the environmental impact of mining it. Lower grade ores require more money, energy, water and other materials.

Soil Erosion and Degradation

Soil Erosion – movement of soil components from one place to another; caused by wind and water

- In vegetated areas, soil is not lost faster than it forms
- Soil becomes vulnerable to erosion as a result of:
 - Farming
 - Logging
 - Construction
 - Overgrazing
 - off-road vehicles
 - deliberate burning of vegetation
 - other activities that destroy plant cover leaving soil exposed
- Most soil erosion is caused by moving water (3 types):
 1. **Sheet erosion** – wide flow
 2. **Rill erosion** – fast flowing little rivulets
 3. **Gully erosion** – rivulets joining together cutting deeper and wider channels (gullies)

Losing topsoil

- makes a soil less fertile and less able to hold water.
- The sediment clogs ditches, boat channels, reservoirs, and lakes.
- Sediment laden water is cloudy, tastes bad, fish die and flood risk increases.

Soil can be renewed: in tropical and temperate areas: 200 – 1000 years depending on climate for 1 inch of new topsoil to form

Global Soil Erosion

World is losing 7-21% of its topsoil from actual or potential cropland each decade.

In developing countries, poverty and erosion interact in a destructive positive feedback cycle.

Soil Erosion in the U.S.

- About 1/3 of nation's original prime topsoil has been washed or blown into streams, lakes and oceans – mostly as the result of overcultivation, overgrazing and deforestation.
- Soil on cultivated land is eroding 16 times faster than it can form. erosion rate is even faster in heavily farmed areas (Great Plains)

Desertification

- process whereby productive potential of arid or semiarid land falls by 10% or more – and results primarily from human activities.
- **Moderate desertification** – 10-25% drop in productivity
- **Severe desertification** – 25-50% drop in productivity
- **Very severe desertification** – >50% drop in productivity (creates huge gullies and sand dunes)

Practices that leave topsoil vulnerable to desertification:

1. overgrazing
2. deforestation without reforestation
3. surface mining without land reclamation
4. irrigation techniques that lead to increased erosion
5. salt buildup and waterlogged soil
6. farming on land that has unsuitable terrain or soil
7. soil compaction by farm machinery and cattle hooves

Consequences of desertification include worsening drought, famine, declining living standards, increasing numbers of environmental refugees

How Can We Slow Desertification?

Reduce overgrazing, deforestation, destructive forms of planting, irrigation and mining
Plant trees, grasses to anchor soil and hold water

How Do Excess Salts and Water Degrade Soils?

Irrigation is needed to produce increased yields of crops
Irrigation leaves behind a thin crust of dissolved salts in the topsoil

Salinization – Accumulation of salts

- stunts crop growth
- lowers yields
- eventually kills plants
- ruins the land

Severe salinization has reduced yields on 20% of the world's irrigated cropland
Cure for heavily salinized soil

- take land out of production for 2-5 years
- install underground network of perforated drainage pipe
- flush soil with large amount of low-salt water
- Flushing water increases the salinity of downstream water unless this water is drained into evaporation ponds

Waterlogging

- Huge amount of irrigation water used to wash salts out of the topsoil accumulate underground – gradually raising the water table. This saline water envelops the roots lowering their productivity and killing them after prolonged exposure
- Approximately 1/10 of all irrigated land worldwide suffers from waterlogging, and the problem is getting worse.

Solutions: Soil Conservation

Soil Conservation

- involves reducing soil erosion and restoring soil fertility
- keep the soil covered with vegetation

Conventional-tillage farming

- land is plowed and the soil broken up and smoothed to make a planting surface.
- land is usually plowed in the fall, left bare during the winter and early spring

Conservation-tillage farming (minimum-tillage or no-till farming)

- special tillers break up and loosen the subsurface soil without turning over the topsoil, previous crop residues and any cover vegetation
- special planting machines inject seeds, fertilizers and weed killers into slits made in the unplowed soil.
- saves fuel, cuts costs, holds more water in the soil, keeps the soil from getting packed down, and allows more crops to be grown during a season (multiple cropping).

How Can Terracing, Contour Farming, Strip Cropping and Alley Cropping Reduce Soil Erosion?

Terracing – reduces erosion on steep slopes (converted into a series of broad nearly-level terraces that run across the land contour)

- Retains water and reduces erosion by controlling runoff
- Good choice for mountainous areas

Contour Farming – on gently sloping land

- plowing and planting crops in rows across rather than up and down the sloped contour of the land.

Strip Cropping

- A row crop (corn) alternates with another crop (a grass or grass-legume mixture).
- The cover crop traps soil that erodes from the row crop.
- They catch and reduce water runoff and help prevent the spread of pests and plant diseases. Soybeans and alfalfa help restore soil fertility.

Alley Cropping (agroforestry)

- is a form of intercropping
- several crops are planted together in strips or alleys between trees or shrubs that provide fruit or fuelwood.
- The trees provide shade (helps to retain moisture).
- Trimmings from the trees and shrubs provide mulch (green manure) for the crops.

Gully Reclamation, Windbreaks, Land Classification and PAM Reduce Soil Erosion

Gully Reclamation

- restore sloping bare land on which water runoff quickly creates gullies
- plant fast growing plants, shrubs, vines and trees to stabilize soil

Windbreaks (shelterbelts)

- reduce wind erosion
- long rows of trees

Land Classification (voluntary system)

- classified as marginal (easily erodible) and should not be planted with crops or cleared of vegetation.

PAM – Polyacrylamide

- used to sharply reduce erosion of some irrigated fields
- can reduce erosion by 70-99%
- increases cohesiveness of surface soil particles

How Can We Maintain and Restore Soil Fertility?

Fertilizers – partially restore plant nutrients lost by erosion, crop harvesting and leaching.

- organic fertilizer – from plant and animal materials
- commercial inorganic fertilizer -produced from various minerals

Three basic types of organic fertilizer:

1. Animal Manure

- Dung and urine of cattle, horses, poultry and other farm animals
- improves soil texture, adds organic nitrogen, stimulates beneficial soil bacteria and fungi

2. Green Manure

- fresh or growing green vegetation plowed into the soil to increase organic matter and humus available to the next crop
- weeds, grasses, clover, legumes, alfalfa, soybeans

3. Compost

- rich natural fertilizer and soil conditioner
- aerates soil
- improves its ability to retain water and nutrients
- helps prevent erosion
- prevents nutrients from being wasted in landfills

Crop Rotation

- Plant corn, tobacco or cotton one year.
- following year plant legumes to add nitrogen to the soil (soybeans, oats, rye, barley, sorghum).
- Also helps reduce crop losses to insects by presenting them with a changing target.

Will Inorganic Fertilizers Save the Soil?

Advantages: Easy to transport, store, apply

Disadvantages

- Do not add humus to the soil (so organic content of soil will decrease) and soil will become compacted.
- Decreased soil porosity leads to reduced oxygen content and prevent added fertilizer from being taken up efficiently.
- Usually supply only two or three of the needed 20 or so nutrients
- Cause water pollution especially on sloped land near streams. the resulting plant-nutrient enrichment causes algae blooms that use up oxygen dissolved in the water – this kills the fish.
- Rainwater leaches nitrates into the groundwater.