


CHAPTER 14: GEOLOGY AND NONRENEWABLE MINERALS

APES 2013

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CASE STUDY: GOLD MINING

- Top gold producers: South Africa, Australia, United States, and Canada
- Rock Removal - 5.5 metric tons (6 tons) of mineral waste is created to make two gold wedding rings
- Disposal - debris (mineral waste) is piled up near the mining site which can cause pollution of air and water

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GOLD MINING TECHNIQUE

- Cyanide heap leaching
  - Level the mountain
  - Spray the crushed rock with a solution of HIGHLY toxic cyanide salts (which react with gold)
  - The solution then drains into storage ponds, and the gold is removed

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GOLD MINING CONSEQUENCES

- Process is “open-air”
  - birds and mammals are drawn to the toxic ponds in search of water
  - ponds can leak or overflow causing problems for underground drinking water supplies and nearby lakes and streams
    - liners are used in ponds, but even the EPA during the Bush Administration confirms all will eventually leak

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WHAT IS GEOLOGY?

- Geology - the study of the dynamic process occurring on the earth’s surface and interior
  - Three major layers (concentric zones):
    - core - innermost zone, extremely hot, solid inner zone surrounded by liquid core of molten (semisolid) material
    - mantle - surrounds the core, most is solid rock, under the rock zone is the asthenosphere (zone of hot, partially melted rock that flows)
    - crust - outermost and thinnest zone, consists of the continental crust (includes continental shelves) and oceanic crust (71% of the earth’s crust)

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MOVEMENT OF THE CRUST, MANTLE, AND CORE

- Convection cells - currents of rock beneath the earth’s surface that heats and cools producing movement
- Tectonic plates - slow-moving, less dense (than mantle) material that moves atop the asthenosphere
  - Composed of the continental and oceanic crusts, as well as the rigid outer part of the mantle. This is called the **Lithosphere**.

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TYPES OF BOUNDARIES

- Divergent - movement apart from each other (oceanic plates)
  - Magma flows up through the resulting crack which creates oceanic ridges
- Convergent - collision between oceanic and continental plates
  - Subduction - continental plate rides on top because the oceanic plate is more dense, pushing the oceanic plate into the mantle where it melts and eventually returns to the crust as magma
  - Subduction zone - areas where subduction takes place
  - Trench - where two converging plates meet
  - When two continental plates collide, they push up mountain ranges (Himalayas)

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TYPES OF BOUNDARIES

- Transform Fault - where plates slide and grind past each other along a fault (fracture line) in the lithosphere
  - Most are located on the ocean floor
  - Land example: North American Plate and the Pacific Plate in the Western US and Canada (San Andreas Fault)

Fig. 14-5

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GEOLOGIC PROCESSES

- Internal geologic processes - generated by heat from the Earth's interior
- External geologic processes - driven directly or indirectly by energy from the sun and influenced by gravity (water and wind)

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EXTERNAL GEOLOGIC PROCESSES

- Weathering - physical, chemical, and biological processes that break down rocks into smaller particles to form soil
- Erosion - material is dissolved, loosened, or worn away and deposited elsewhere
  - Most often caused by flowing water and rain
  - Wind can also cause this, but is a minor contributor compared to water
  - Human activities accelerate this process

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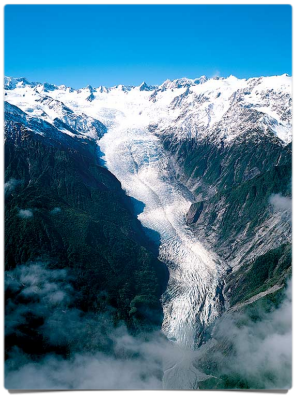
GLACIERS

- Glaciers also cause erosion
- Glaciers are flowing bodies of ice that are driven by gravity
- Glaciers move massive quantities of rock



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VOLCANOS

- Volcano (active) - when magma from reaches the earth's surface through a central vent or a long crack (fissure)
  - Form when one tectonic plate slides under (subduction) or moves away from another plate (diverging area)
  - Release lava rock, hot ash, and gasses (CO_2, water vapor, SO_2)
- Lava - magma that reaches the earth's surface

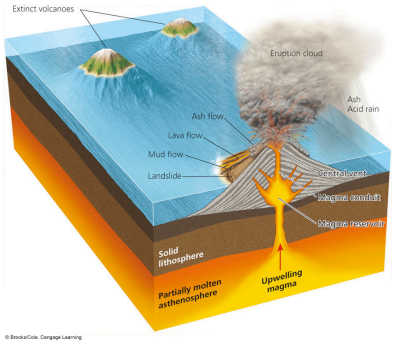

Fig. 14-7

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VOLCANO IMPACT

- 1991 - Mount Pinatubo (Philippines) - spewed enough material into the air that it changed the average temperature of the entire earth for 15 months by reducing the amount of solar energy reaching the earth
- 1980 - Mount St. Helens (Washington, US) - 57 people killed, large areas of forest destroyed

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VOLCANO BENEFITS

- Creates new landforms
- Creates very fertile soil from the weathering of lava rock
- Brings large amounts of essential nutrients from the interior of the earth to the surface

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EARTHQUAKES

- What is an earthquake?
  - Force from the mantle and along the surface pushes, stresses, and deforms rocks. This stress builds up until the rock suddenly shifts or breaks and produces a transform fault (fracture) in the crust
  - This releases energy in the form of seismic waves which move in all directions

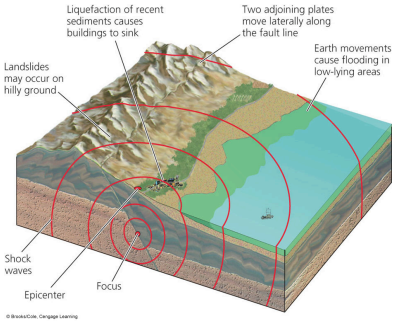

Fig. 14-8

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EARTHQUAKES

- Focus - where the earthquake begins (usually far below the earth's surface)
- Epicenter - the point directly above the focus on the earth's surface
- Measured like all waves (amplitude)
- Richter scale - logistic scale to compare earthquakes (means a magnitude 6.0 earthquake is 10 times greater than a magnitude 5.0 and 100 times greater than a 4.0)

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EARTHQUAKE OCCURRENCE AND SEVERITY

- Scale rate:
  - Insignificant - less than 4.0
  - Minor - 4.0-4.9
  - Damaging - 5.0-5.9
  - Destructive - 6.0-6.9
  - Major - 7.0-7.9
  - Great - above 8.0
- Scientists record over 1,000,000 earthquakes a year, but most are too small to feel
- Worst recorded earthquake was in Chile in 1960 at a 9.5

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EARTHQUAKES

- Foreshocks - occur from seconds to weeks before the main shock
- Aftershocks - occur up to several months after main shock
- Primary Effects of earthquakes
  - Shaking
  - Permanent vertical or horizontal displacement of the ground

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TSUNAMIS

- Tsunami - series of large waves generated when part of the ocean floor suddenly rises and drops
  - Usually caused by and underwater earthquake or landslide caused by an earthquake
  - Rarely caused by a volcanic eruption
  - Usually in subduction zones
  - Can travel at speeds as high as a jet

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TSUNAMIS

- In deep water they are often far apart and the crest is not very high.
- As the wave approaches the coast, it slows down, compresses, and the height grows

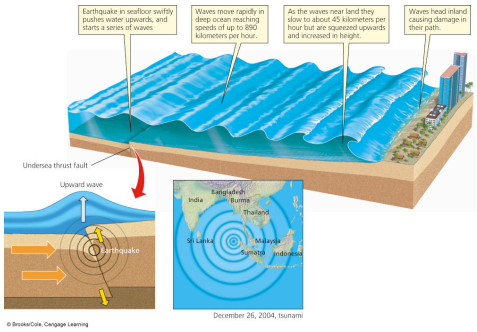

Fig. 14-11

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DETECTION OF TSUNAMIS

- Network of buoys in the ocean can provide early warning
- Pressure recorders on the ocean floor that measure changes in water pressure

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SEVERITY OF TSUNAMIS

- Between 1900 and 2007, tsunamis killed an estimated 278,000 people
- Largest loss of life - 2004
  - Earthquake in the Indian Ocean (9.15)
  - Waves as high as 31m (100 feet)
  - Killed 228,000 people
  - No buoys or gages were placed in the Indian Ocean

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REDUCTION OF SEVERITY

- UN study shows that the areas with the least damage were those with coral reefs and mangrove forests that were undisturbed.
- These areas act as a buffer zone and help to break the wave up.
- Those areas where the reefs have been destroyed and the forests cut down, suffered the most damage.

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LANDSLIDES

- Caused mainly by gravity and earthquakes
- Mass wasting - movement of material in a landslide
- Usually occur on steep sides of mountains or cliffs or slopes near oceans or lakes
- 1970 an earthquake in Peru caused a landslide that burried an entire town (Yungay) and killed 17,000 people
- Human activities increase severity (forest clearing, road building, crop growing, building

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MINERALS AND ROCKS

- Mineral - element or inorganic compound that occurs naturally in the earth's crust as a solid with an regular internal crystalline structure
  - Single Element - Gold, Silver, and carbon/diamonds
  - Inorganic Compounds (formed by combinations of elements) (salts like NaCl, $CaCO_3$, or quartzite SiO_2)
- Rock - solid combination of one or more minerals found in the earth's crust (most contain two or more)
  - One mineral - limestone ($CaCO_3$) or quartzite (SiO_2)
  - Two or more minerals - granite (mix of mica, feldspar, and quartz)

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SEDIMENTARY

- Made up of sediments
- Sediments are transported by water, wind, and gravity to downstream, downwind, downhill, or underwater sites
- The sediments are accumulated over time in layers which increase pressure on underlying layers
- Examples:
  - sandstone and shale (formed by pressure created by deposited layers of mostly sand)
  - dolomite and limestone (formed from compacted shells, skeletons, and other remains of dead organisms)
  - lignite and bituminous coal (derived from compacted plant remains)

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IGNEOUS

- Forms below or on the earth's surface when magma wells up from the earth's upper mantle or deep crust and then cools and hardens
  - Examples: Granite (formed underground), lava rock (formed aboveground)
  - Often covered by sedimentary rocks or soil
  - Compose a majority of the earth's crust

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METAMORPHIC

- Forms when preexisting rock is subjected to high temperatures, high pressures, chemically active fluids, or a combination
  - These forces transform the rock by reshaping its internal crystalline structure, physical properties, and appearance.
  - Examples: anthracite (form of coal), slate (formed from heated shale and mudstone), marble (limestone exposed to heat and pressure)

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ROCK CYCLE

- Rock cycle - interaction of physical and chemical processes that change rock from one type to another
  - Slowest of the earth processes (millions of years)
  - Rocks are broken down, eroded, crushed, heated, melted, fused, cooled, and recrystalized
  - Cycle also concentrates the planets nonrenewable mineral resources (make life possible)

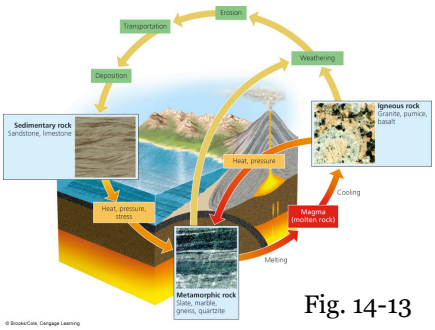

Fig. 14-13

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MINERAL RESOURCES

- Mineral Resource - concentration of naturally occurring mineral from the earth's crust that can be extracted and processed into useful products and raw materials at a reasonable cost
  - Examples: fossil fuels (like coal), metallic minerals (aluminum, iron, and copper), nonmetallic minerals (sand, gravel, and limestone)
  - Because all of these take so long to form, these are classified as nonrenewable mineral resources

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ORES

- Ore - rock that contains large enough concentrations of a particular mineral to make it profitable for mining
  - Classified as high-grade ore or low-grade ore based on the amount of the desired mineral
  - High-grade easier to get. When high-grade materials are gone, low-grade take more energy and usually cause more pollution.

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VALUABLE NONRENEWABLE METALLIC MINERALS

- Aluminum (Al)
- Steel
- Mn, Co, Mo, Cr
- Copper (Cu) Platinum (Pt)
- Gold (Au)

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VALUABLE NONRENEWABLE NONMETALLIC MINERALS

- Most widely used:
  - Sand (silicon dioxide SiO_2)
  - Gravel
  - Limestone (calcium carbonate $CaCO_3$)
  - Phosphate salts

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RESERVES

- Reserves - identified resources from which minerals can be extracted profitably at current prices
  - Reserves increase when new profitable deposits are found
  - Reserves increase when higher prices or improved technology makes it profitable to extract deposits thought to be too expensive to extract

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MINERAL USE

- Advantages:
  - Significant revenue/income (taxes and fees)
  - Provides employment
- Disadvantages:
  - Consumes huge amounts of energy
  - Disturbs land (erodes soil)
  - Produce solid waste
  - Pollute air, water and soil

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MINING

- Surface mining - removal of shallow deposits
  - Equipment strips away the **overburden** (soil and rock over the mineral deposit)
  - Spoils - discarded waste materials
- Subsurface mining - removal of deep deposits

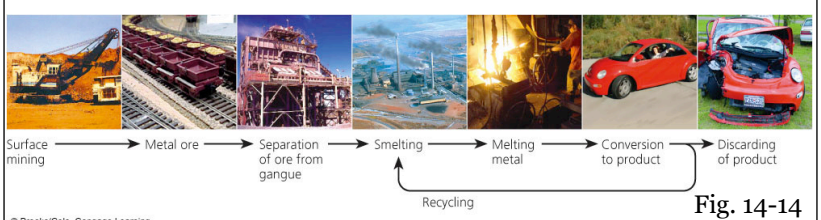

Fig. 14-14

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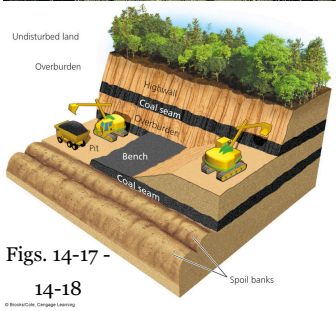
TYPES OF SURFACE MINING

- Strip mining - used for minerals close to the earth's surface in horizontal beds
  - Area strip mining - where terrain is flat, overburden is stripped away and power-shovels remove the mineral deposits. This results in a trench filled with overburden.
  - Contour strip mining - used to mine coal on mountainous terrain. Power-shovel cuts terraces into the side of the hill and the overburden is removed. Shovel extracts the coal and dumps the overburden on a each new terrace



Figs. 14-17 - 14-18

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SURFACE MINING: MOUNTAINTOP REMOVAL

- Prominent in the Appalachian Mountains
- Explosives and large machines are used to remove the top of a mountain and expose the seams of coal which are removed

Fig. 14-19

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SUBSURFACE MINING

- Used to remove coal and metal ores that are too deep to be extracted
- Miners dig a deep vertical shaft, blast open tunnels and chambers to reach the deposits
- Use machinery to remove the ore and transport it to the surface

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MINING EFFECTS

- Scarring and disruption of the land surface
- Spoils banks - caused by strip mining, series of hills
  - susceptible to chemical weathering and erosion by water and wind
  - Regrowth is slow because there is no topsoil
- Produces of all U.S. solid waste
- Wind and water erosion move toxic wastes to other areas
- EPA estimates 40% of the western watersheds are polluted by mining
- Accounts for almost half of toxic emissions in the air

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MINING EFFECTS: MOUNTAINTOP REMOVAL

- Waste rock is dumped into valleys
  - Destroys forests
  - Buries streams
  - Increases flood hazards
  - Toxic wastewater from the production of coal (selenium, arsenic, and mercury)

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APPALACHIAN MOUNTAINS

- EPA estimates at least 1,900 kilometers (1,200 miles) of Appalachia's rivers and streams have been buried
- 470 of the largest mountains have disappeared
  - Leaves behind barren land and gigantic pits (some as large as Manhattan)
- 2007, U.S. Department of the Interior allowed this type of mining to continue

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TROPICAL FORESTS

- Gold Mining
- Hydraulic Mining
  - Outlawed in US
  - Water cannons wash the hillside into collection boxes
- Degrades biodiversity as forests are cleared
- Wastes pollute rivers

Fig. 14-20

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CLEAN-UP

- Very costly
- U.S. Department of the Interior
  - 500,000 surface mining sites (mostly in the west)
  - Cost $70 billion to clean it up

Fig. 14-21

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SUBSURFACE MINING HAZARDS

- Disturbs less than one-tenth as much land
- Produces less waste material
- More dangerous and expensive than surface mining
- Subsidence - collapse of land above underground mine

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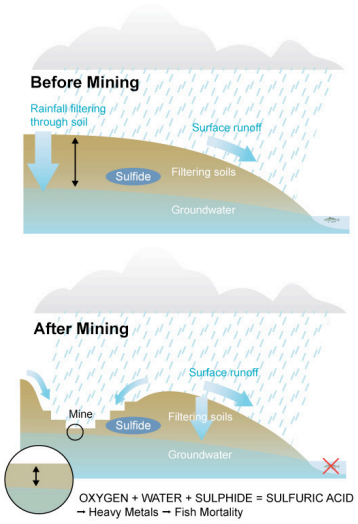
ACID MINE DRAINAGE

- Rainwater seeps through a mine or mine waste and carries sulfuric acid (H_2SO_4, produced by bacteria acting on iron sulfide) to nearby streams



Extraction decreases groundwater depth and natural filtration, and increases the groundwater contamination.

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SMELTING

- Heating ores to release metals
- Emits huge amounts of pollution (SO_2 and suspended particles)
  - Damages vegetation
  - Acidifies soil
  - Cause water pollution
  - Produce hazardous wastes

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MINERAL DISTRIBUTION

- Some minerals are abundant
- Some are more scarce
- Exporting causes depletion of resources in a given country
  - U.S. has depleted much of its lead and iron
- Four strategic metal resources:
  - manganese, chromium, cobalt, platinum

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ECONOMIC DEPLETION

- When the cost of gaining the material is more than it is worth to find, extract, transport, and process
- When it reaches this point there are five choices:
  - Recycle or reuse current supplies
  - Waste Less
  - Use Less
  - Find a substitute
  - Do without

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DEPLETION TIME

- Time it takes to use up a certain proportion (usually 80%) of reserves of a mineral at a given rate

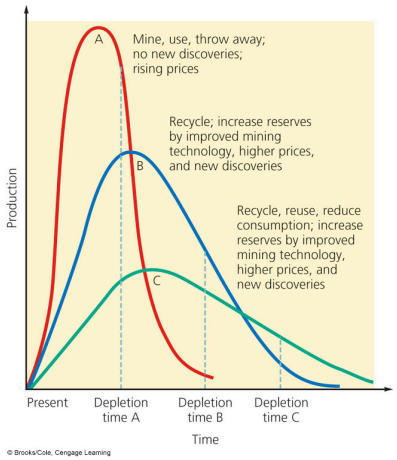

Fig. 14-23

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ECONOMICS

- Mineral is cheap when supply is larger than demand
- When a resources is scarce, the price rises.
  - This causes more exploration for resources and improvement of technology
- In developed countries, the government provides subsidies, taxes, regulations, and tariffs to control supply, demand, and prices

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POSSIBLE SOLUTIONS

- Mining lower grade ores
  - Increase cost of mining
  - Availability of freshwater
  - Environmental impacts
- Biomining - using microbes (very slow)
- Phytoextraction -using plants (very slow, small quantities)
- Minerals from the ocean