Image is from U.S. Geological Survey Bulletin 2220.

15

Mineral Resources

Overview of Chapter 15

- Introduction to Minerals
- Environmental Impact Associated with Minerals
- An International Perspective
- Increasing the Supply of Minerals
- Using Substitution and Conservation to Expand Mineral Supplies

General Mining Law 1872

- U.S. law to encourage settlement in sparsely populated western states
- Stake mining claims on federal lands
  - Keep money from minerals
  - Profits from other natural resources shared with government
- Mining reform contentious

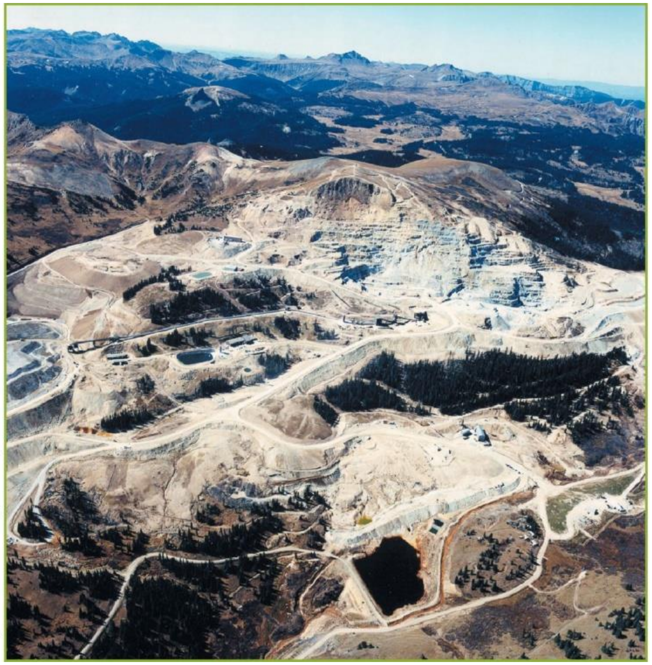
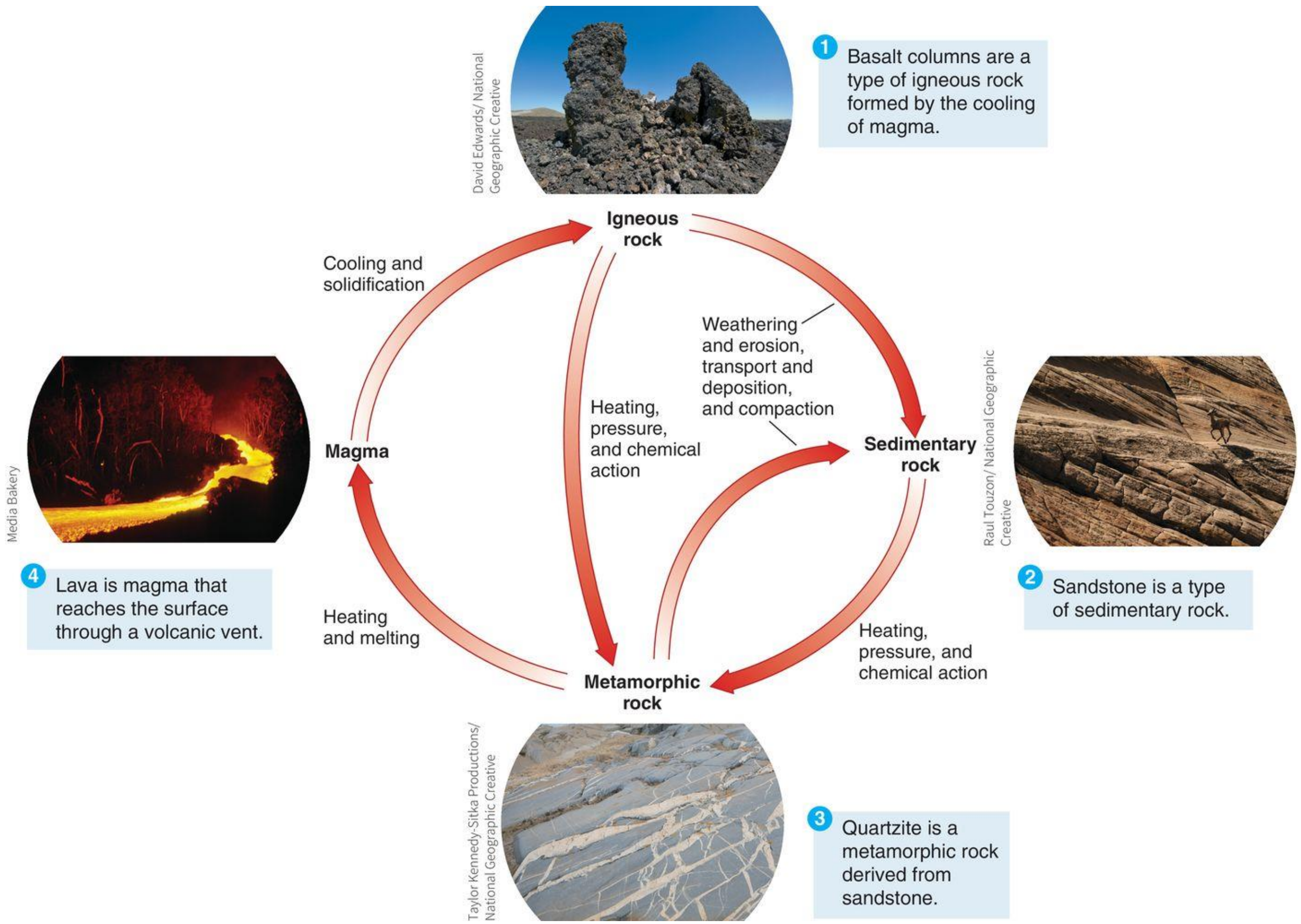


Image is from U.S. Geological Survey Bulletin 2220.

Introduction to Minerals

- Mineral
  - An inorganic solid, occurring naturally in or on the earth's crust with a characteristic chemical and physical properties
- Rock
  - Naturally formed aggregate of minerals
  - Igneous, sedimentary, metamorphic
- Ore
  - Rock that contains enough of a mineral to be profitably mined and extracted

Rock Cycle



David Edwards/ National Geographic Creative
1 Basalt columns are a type of igneous rock formed by the cooling of magma.
Igneous rock
Cooling and solidification
Weathering and erosion, transport and deposition, and compaction
Heating, pressure, and chemical action
Media Bakery
Magma
Sedimentary rock
Raul Touzon/ National Geographic Creative
4 Lava is magma that reaches the surface through a volcanic vent.
2 Sandstone is a type of sedimentary rock.
Heating and melting
Heating, pressure, and chemical action
Metamorphic rock
Taylor Kennedy-Sitka Productions/ National Geographic Creative
3 Quartzite is a metamorphic rock derived from sandstone.

Important Minerals and Their Uses

Table 15.1 Some Important Minerals and Their Uses.*

Aluminum

© mikapp/iStockphoto

Aircraft, motor vehicles, packaging (cans, foil), water treatment

Chromium

© Dominik Pabis/iStockphoto

Chrome plate, dyes and paints, steel alloys (cutlery)

Cobalt

© searagen/iStockphoto

Corrosion and wear-resistant alloys, pigments (cobalt blue)

Gold

© sweetym/iStockphoto

Jewelry, money, restorative dentistry

Iron

© kozmoat98/iStockphoto

Steel (alloy of iron) buildings and machinery

Magnesium

© kickers/iStockphoto

Beverage cans, electronic devices, firecrackers, flares

Mercury

© Oleksandr Chub/Shutterstock

Industrial chemicals, electric and electronic applications, batteries

Molybdenum

© Difydave/iStockphoto

High-temperature alloys for aircraft, industrial motors

*Gypsum, silicon, and sulfur are nonmetals. All other minerals shown are metals.

Important Minerals and Their Uses

Table 15.1 Some Important Minerals and Their Uses.*

Nickel

© canon_jack/iStockphoto

Coins, metal plating, alloys with various uses

Potassium

Martyn F. Chillmaid / Science Source

Fertilizers, photography

Silver

© Michael Interisano/Design Pics/Corbis

Jewelry, silverware, photography, electronics

Titanium

© Wesley VanDinter/iStockphoto

Alloy in steel and other industrial alloys; pigment in paints, plastics

Zinc

© Djapeman/iStockphoto

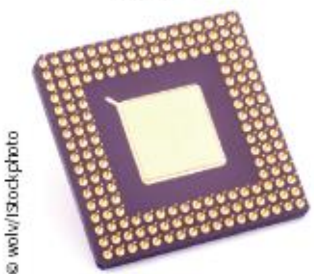
Galvanizing steel, alloys (brass), anode in alkaline batteries

Gysum ($CaSO_4$-$2H_2O$)

© Lowryn/iStockphoto

Drywall, plaster of Paris, Soil conditioner

Silicon



© wolv/iStockphoto

Electronic devices, semiconductors, natural stone, glass, concrete

Sulfur

© icefront/iStockphoto

Industrial chemicals, insecticides, gunpowder, vulcanized tires

*Gypsum, silicon, and sulfur are nonmetals. All other minerals shown are metals.

Mineral Distribution and Formation

- Abundant minerals in crust
  - Aluminum and iron
- Scarce minerals in crust
  - Copper, chromium, and molybdenum
- Distributed unevenly across globe
  - If found in low abundance, mining is not profitable

Formation of Mineral Deposits

- Result of natural processes
  - Magmatic concentration
    - As magma cools, heavier elements (Fe and Mg) settle
    - Responsible for deposits of Fe, Cu, Ni, Cr
  - Hydrothermal processes
    - Minerals are carried and deposited by water heated deep in earth's crust
  - Sedimentation
    - Weathered particles are transported by water and deposited as sediment on sea floor or shore
  - Evaporation
    - Salts are left behind after water body dries up

Discovering Mineral Deposits

- Scientists (geologists) use a variety of instruments and measurements
  - Aerial or satellite photography
  - Seismographs
- Combine this with knowledge of how minerals are formed

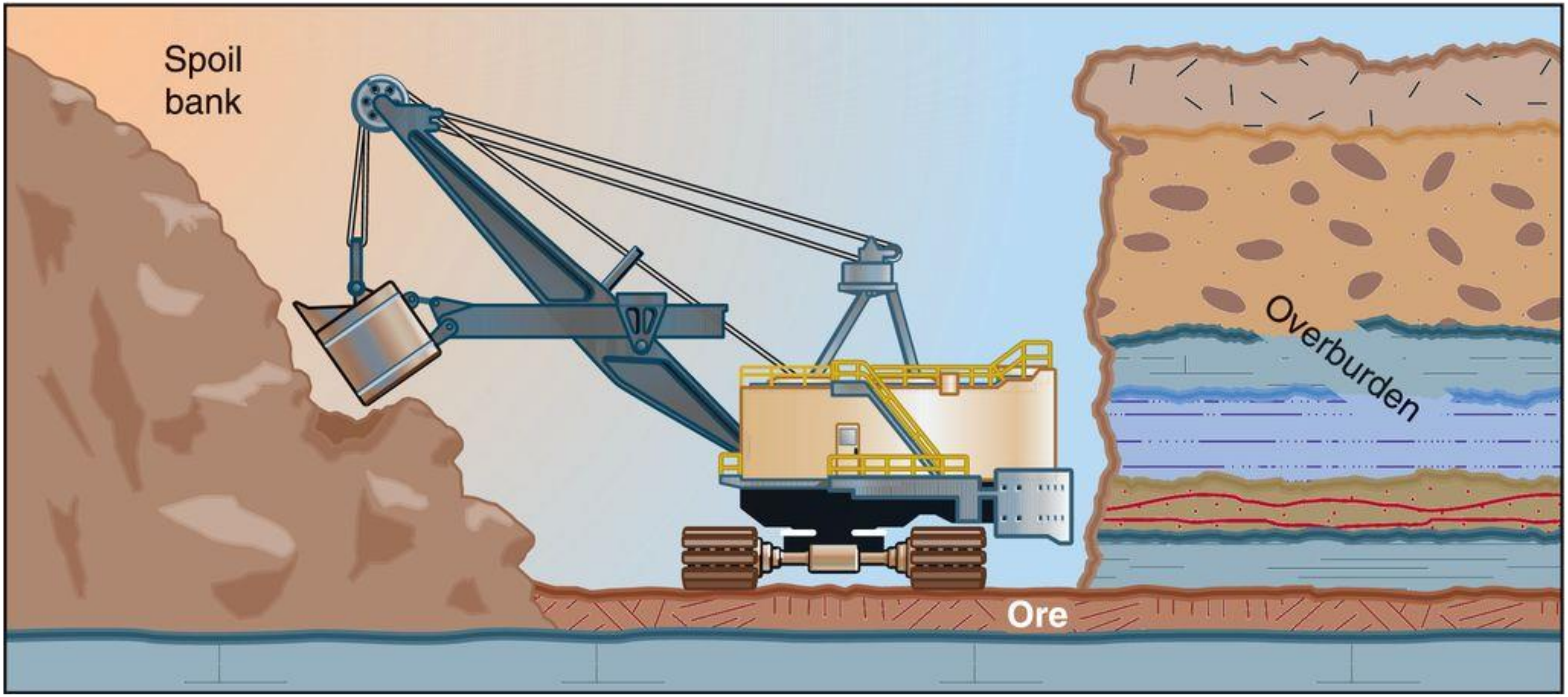
Extracting Minerals

- Surface Mining
  - Mineral and energy resources are extracted near Earth's surface
  - Remove soil, subsoil and over-lying rock strata (overburden)
  - More common because less expensive
  - Two kinds
    - Open pit - large hole is dug
    - Strip Mine - trench is dug

Surface Mining - Open Pit


James L. Amos/ National Geographic Creative

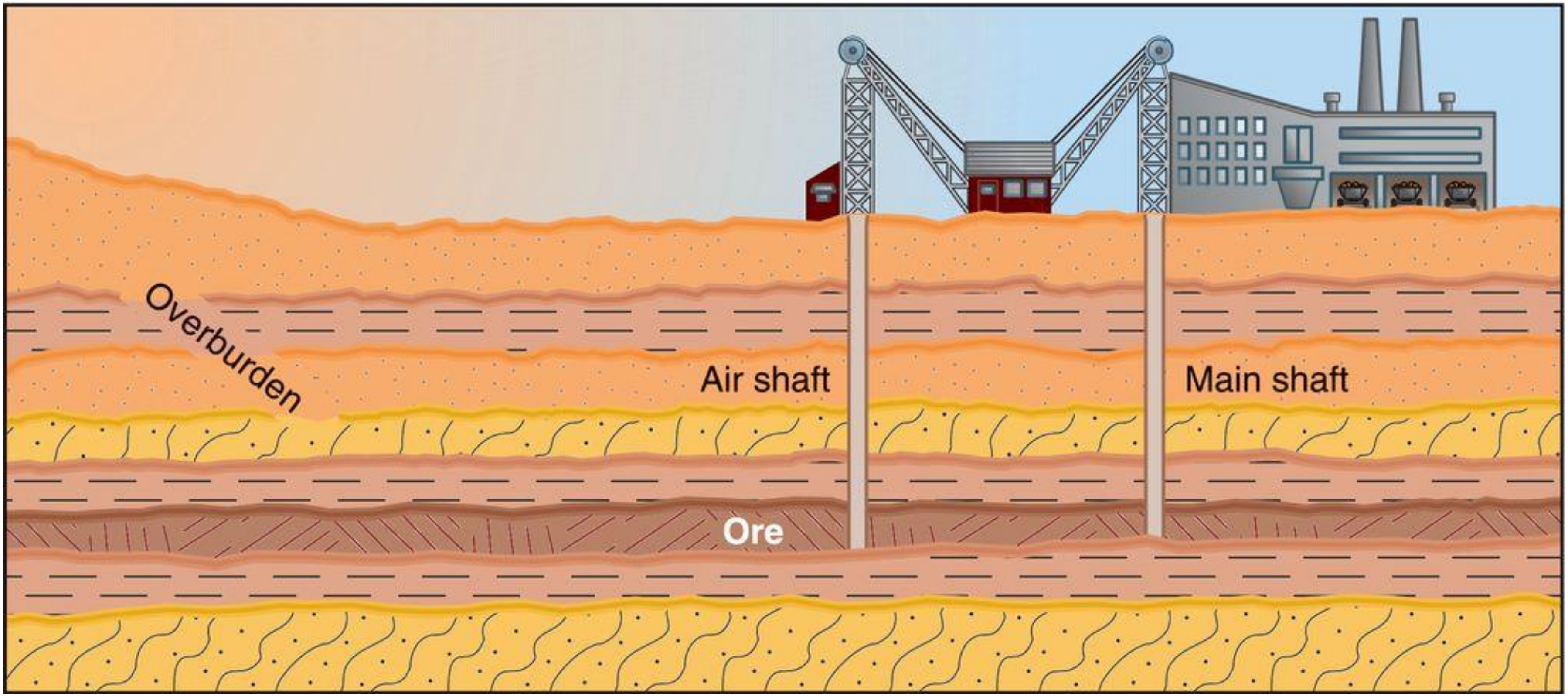
Surface Mining - Strip Mine



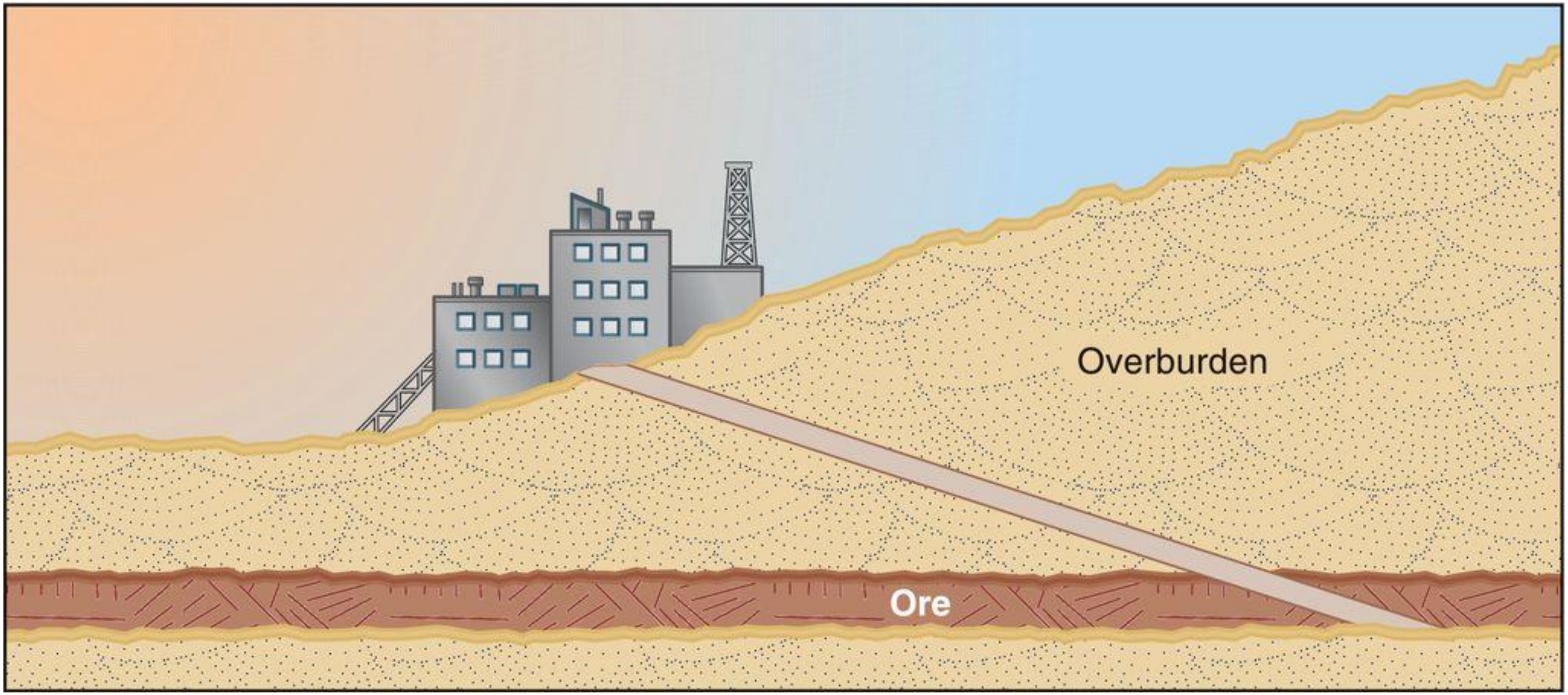
Extracting Minerals

- Subsurface Mining
  - Mineral and energy resources are extracted from deep underground deposits
  - Two kinds
    - Shaft mine - direct vertical shaft into the vein of ore, which is hoisted up using buckets
    - Slope mine - slanting passage where ore is lifted our using carts

Subsurface Mining - Shaft Mine

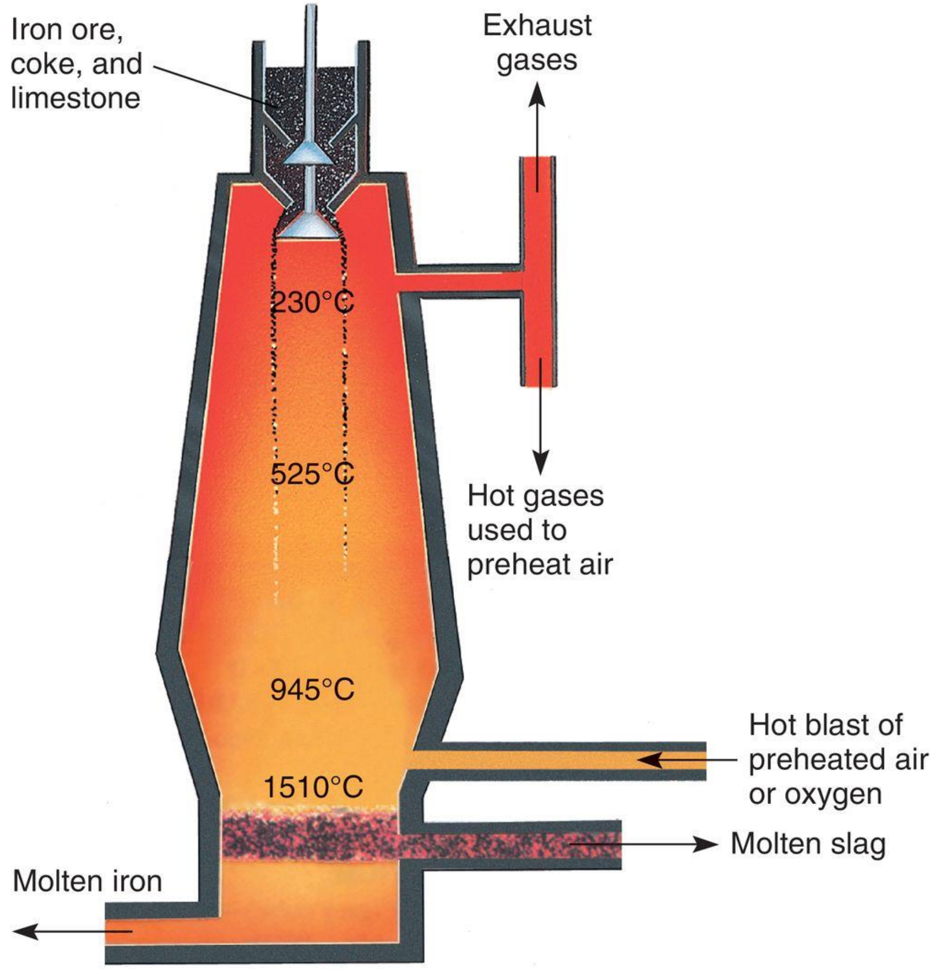


Subsurface Mining - Slant Mine



Processing Minerals

- Smelting- process in which ore is melted at high temps to separate impurities from the molten metal
- Blast furnace



Mining and the Environment

- Disturbs large area
  - U.S.- current and abandoned mines cover 9 million hectares
  - Prone to erosion
- Uses large quantities of water
  - Must pump water out of mine to keep it dry

Acid Mine Drainage

- Acid Mine Drainage (AMD)
  - Pollution caused when sulfuric acid and dissolved lead, arsenic or cadmium wash out of mines into nearby waterways

© Thomas R. Fletcher/Alamy

Environmental Impacts of Refining Minerals

Table 15.2 **Ore and Waste Production for Selected Minerals**

Mineral	*Amount of Mined Ore (Million Tons)*	*Percentage of Ore That Becomes Waste During Refining**
Iron ore	2958	60
Copper	1663	99
Gold	745	99.99
Lead	267	97.5
Aluminum	128	81

*Data do not include the overburden of rock and soil that originally covered the ore deposits.

Source: Adapted from Table 6.4 on page 117 in G. Gardner, et al. *State of the World*, 2003. New York: W.W. Norton & Company (2003) and based on data from U.S. Geological Survey and *Worldwatch*.

Environmental Impacts of Refining Minerals

- 80% or more of mined ore consists of impurities - called tailings (below)
  - Contain toxic materials
- Smelting plants emit large amounts of air pollutants
- Requires a lot of energy (fossil fuels combustion)

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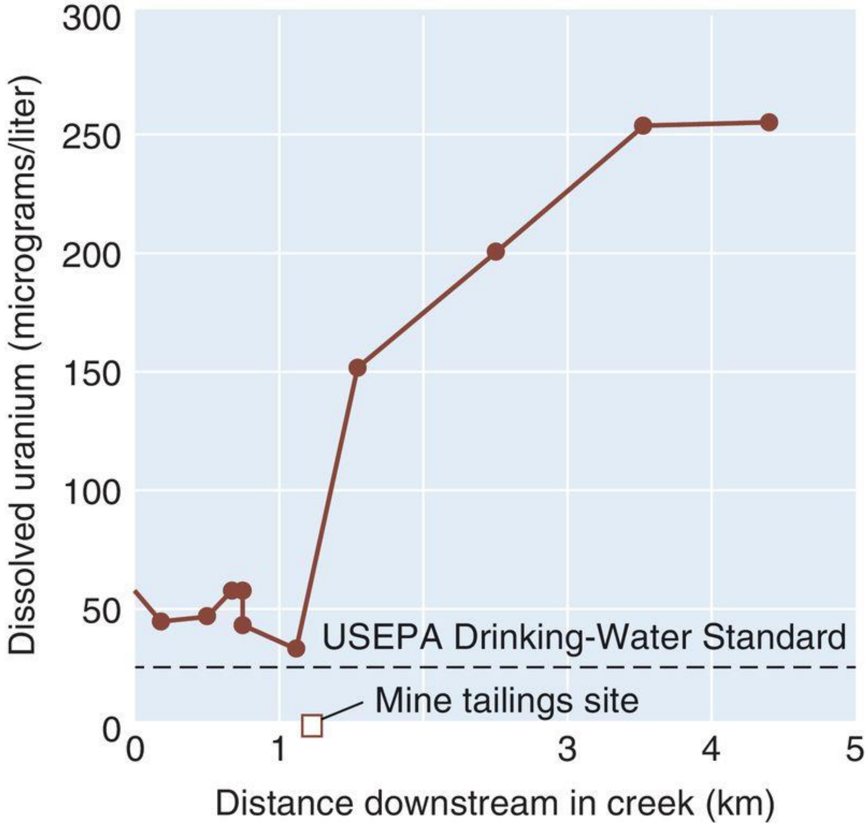
Environmental Impacts of Refining Minerals

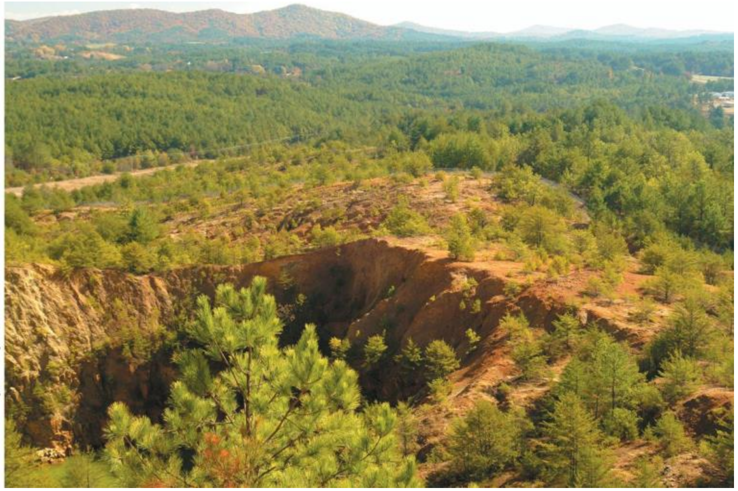
- Mining activities often contaminate nearby drinking water or aquatic ecosystems



Copper Basin, TN

- Cooper ore mined and smelted in open-air pits
- Air pollution causes acid rain
- Resulting deforestation triggered ecological degradation
- New restoration techniques increased establishment of replanted vegetation

Emory Kristof/National Geographic Creative



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Restoration of Mining Lands

- Mining lands called derelict lands
- Goals: prevent further degradation and erosion of land, eliminate local sources of toxins and make land productive for another purpose

AP Photo/Roger Alford

Reclaimed Coal-Mined Land

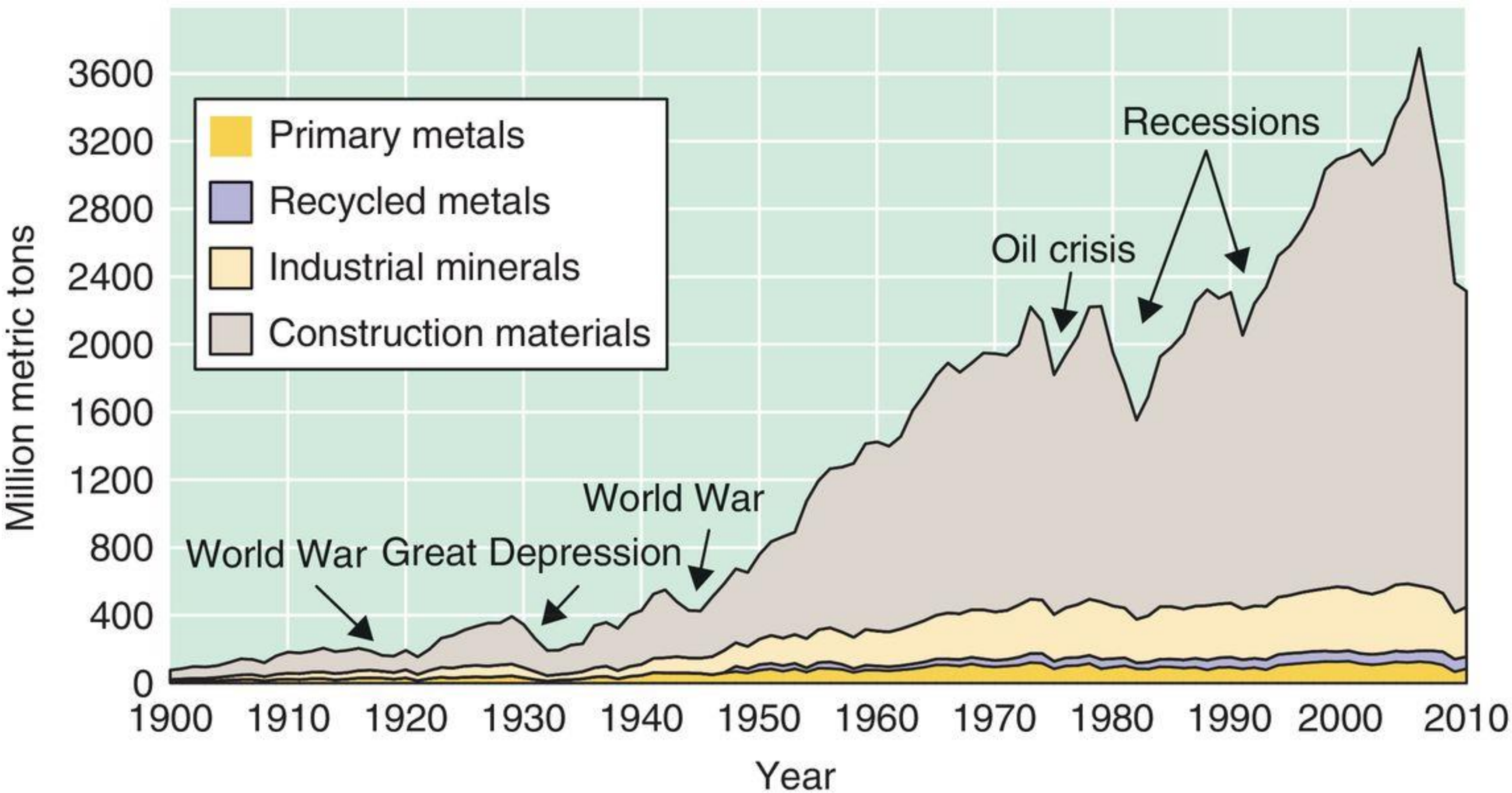
Restoration of Mining Land

- Creative Approaches
- \- Use Created Wetlands
  - Trap and filter pollutants before they get into streams
  - Initially expensive, but cost effective compared to using lime to decrease acidity
- \- Use Phytoremediation
  - Use of specific plants to absorb and accumulate toxic materials in soil

Minerals: An International Perspective

- Highly developed countries
  - Rely on mineral deposits in developing countries
  - They have exhausted their own supplies
- Developing countries
  - Governments lack financial resources to handle pollution
  - Acid mine drainage, air and water pollution

North American Consumption of Selected Metals



Will We Run Out of Important Metals?

- Mineral Reserves
  - Mineral deposits that have been identified and are currently profitable to extract
- Mineral Resources
  - Any undiscovered mineral deposits or known deposits of low-grade ore that are currently unprofitable to extract
- Estimates of reserves and resources fluctuate with economy
  - Difficult to forecast future mineral supplies
  - Often technology based

Increasing Supply of Minerals – Locating and Mining New Deposits

- Many known mineral deposits have not yet been exploited
  - Difficult to access
  - Insufficient technology
  - Located too deep
    - Ex: 10km or deeper

Minerals in Antarctica

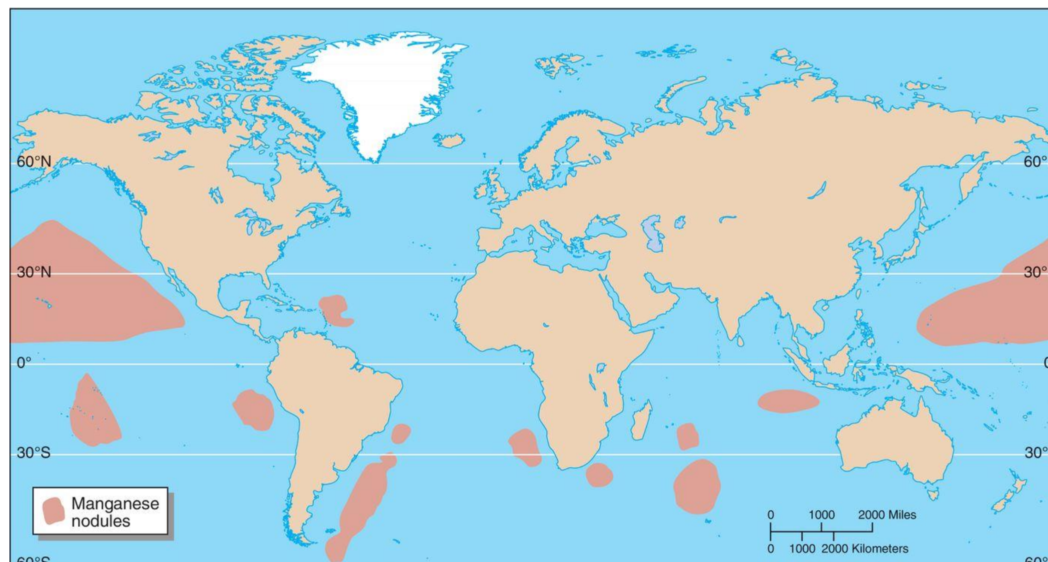
- No substantial mineral deposits identified to date
- Antarctic Treaty (1961)
  - Limits activity to peaceful uses (i.e. scientific studies)
- Madrid Protocol (1990)
  - Moratorium on mineral exploration and development for minimum of 50 years

© Bryan & Cherry Alexander Photography/Alamy

Minerals from the Ocean

- May provide us with future supplies
  - Extracting minerals from seawater
  - Mining seafloor - Manganese nodules
  - U.N. Convention on the Law of the Sea (UNCLOS)

Tom McHugh/Science Source



Advance Mining and Processing Technologies

- Special techniques to make use of large, low-grade mineral deposits world-wide
- Biomining
  - Using microorganisms to extract minerals from low-grade ores
  - Bacteria can recover ~90% compared to 75% for other methods

Finding Mineral Substitutes

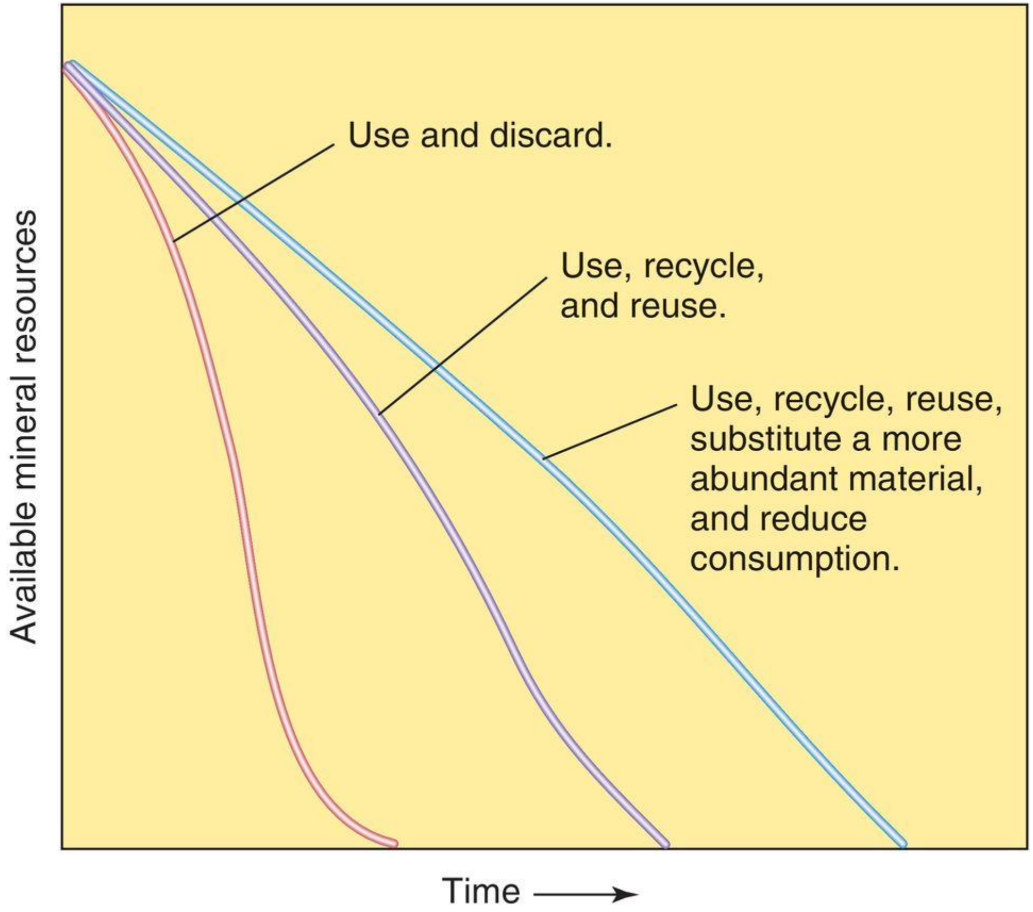
- Important goal in manufacturing
- Substitute expensive/scarce mineral resources for inexpensive/abundant ones
- Examples:
  - Using plastic, glass or aluminum in place of tin
  - Using glass fibers instead of copper wiring in telephone cables

Mineral Conservation

- Includes reuse and recycling of existing mineral supplies
  - Reuse - using items over and over again
    - Reduces both mineral consumption and pollution
  - Recycling- converting item into new product
    - Reduces land destruction from mining
    - Reduces solid waste

Changing Our Mineral Requirements

- Must change our "throw away" mentality



Metal Recycling Rates

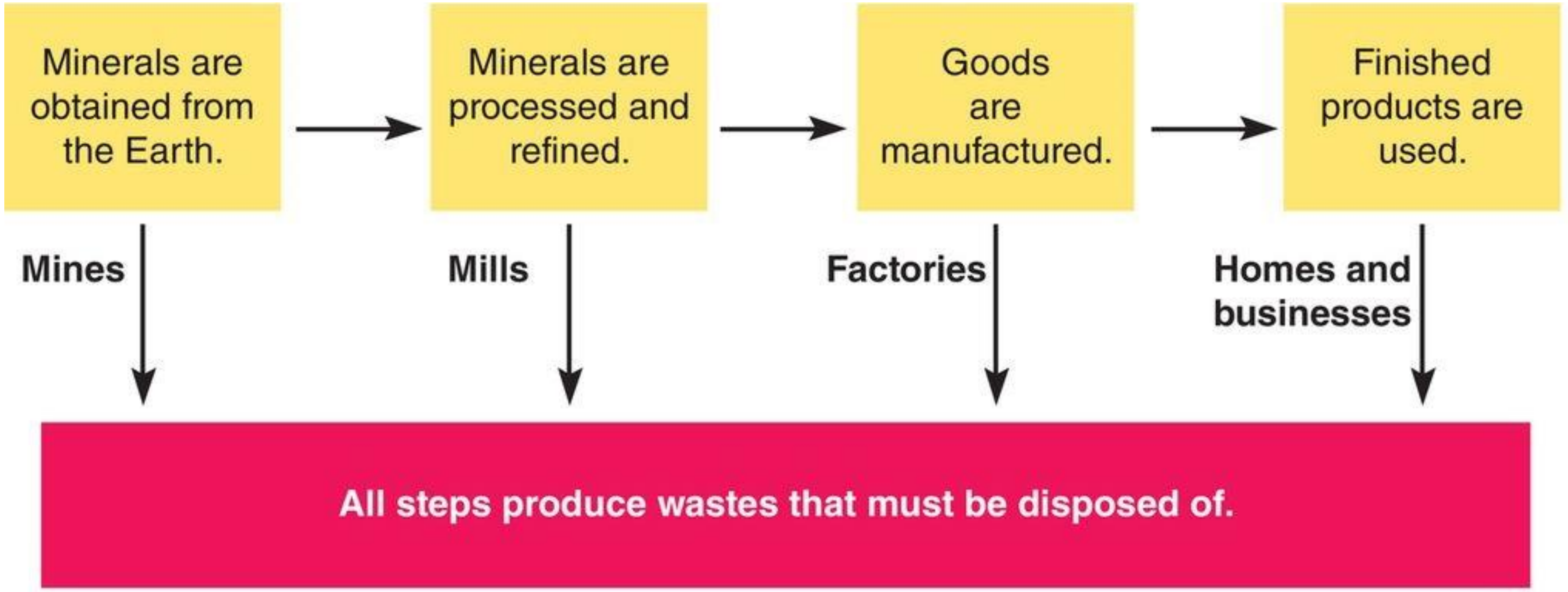
Table 15.3 Recycling Rates for Metals in the United States, 2011

Mineral	*Percent Recycled*
Aluminum	60
Copper	34
Iron and Steel	63
Lead	73
Magnesium	53
Nickel	42
Zinc	29

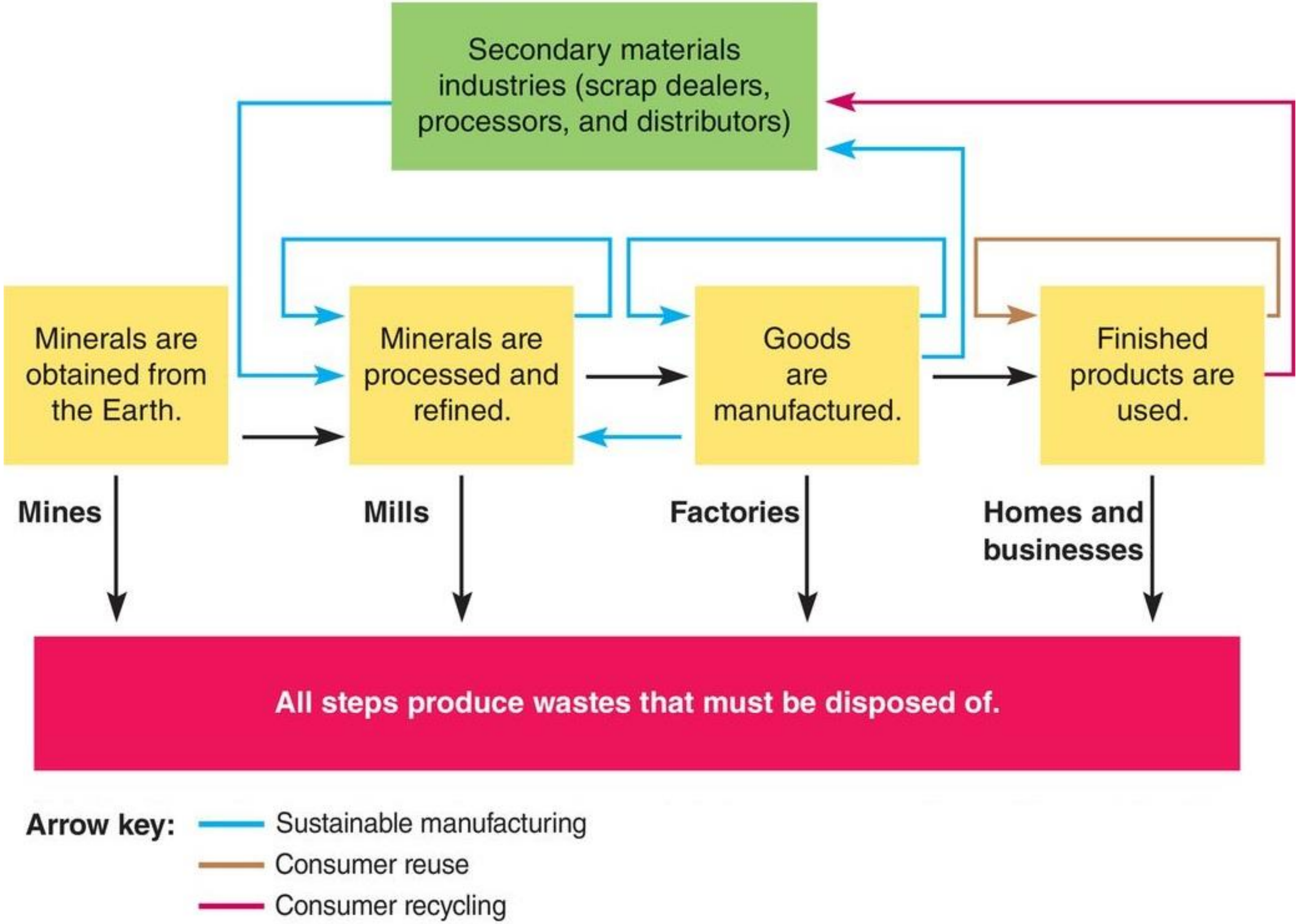
Source: USGS *2011 Minerals Yearbook*.

Traditional Flow of Minerals

- Waste produced in all steps in the production of minerals



Sustainable Manufacturing



Industrial Ecosystems

- Interconnections within industrial cycles
- Studied in field of industrial ecology
- can local inefficiencies and increase profits