Mineral Resources and Environment

Hyo-Taek CHON, Ph.D.
Professor in Applied Geochemistry
Department of Energy Resources Engineering
College of Engineering
Seoul National University
Seoul 151-744, Korea
e-mail : chon@snu.ac.kr

Introduction

Our modern society completely depends on the availability of mineral resources. As world population increases, we face an ever-increasing resource crisis. It is feared that Earth may have reached its capacity to absorb environmental degradation related to mineral extraction, processing, and use.

If we do not have sufficient minerals in store, we live a life of more existence !!!

StarCraft — an award winning real-time strategy computer game developed by Blizzard Entertainment

Introduction - Learning Objectives

- Understand the relationship between human population and resource utilization
- Understand why minerals are so important to modern society
- Know some of the factors that control the availability of mineral resources
- Understand the environment impact of mineral development
- Understand the economic and environment role of recycling mineral resources
- Understand the relationship between sustainability and mineral use

Mineral and Human Use

Our society depends on the availability of mineral resources.

Consider the mineral products found in a typical American home.

TABLE 14.1 A Few of the Mineral Products in a Typical American Home

Building materials	Sand, gravel, stone, brick (clay), cement, steel, aluminum, asphalt, glass
Plumbing and wiring materials	Iron and steel, copper, brass, lead, cement, asbestos, glass, tile, plastic
Insulating materials	Rock, wool, fiberglass, gypsum (plaster and wallboard)
Paint and wallpaper	Mineral pigments (such as iron, zinc, and titanium) and fillers (such as talc and asbestos)
Plastic floor tiles, other plastics	Mineral fillers and pigments, petroleum products
Appliances	Iron, copper, and many rare metals
Computers, phones, videos	Petroleum products, and many minerals
Furniture	Synthetic fibers made from minerals (principally coal and petroleum products); steel springs; wood finished with mineral varnish
Clothing	Natural fibers grown with mineral fertilizers; synthetic fibers made from minerals (principally coal and petroleum products)
Food	Grown with mineral fertilizers; processed and packaged by machines made of metals
Drugs and cosmetics	Mineral chemicals
Other items	Windows, screens, light bulbs, porcelain fixtures, china, utensils, jewelry: all made from mineral products

Source: U.S. Geological Survey Professional Paper 940, 1975.

http://www.fertilizeronline.com

Mineral Resources Depletion Curves

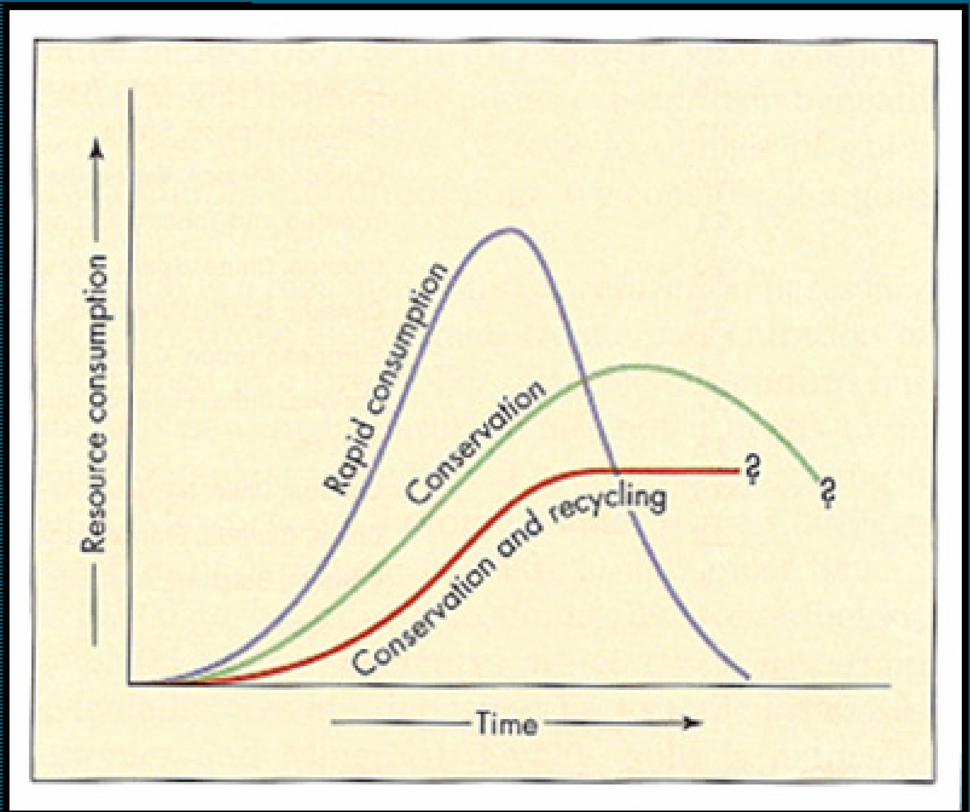
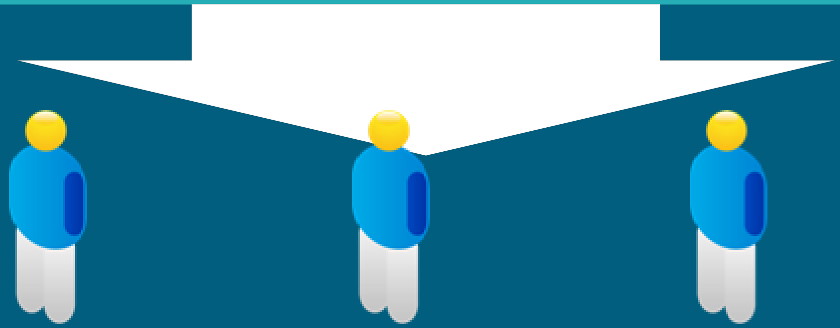


Diagram of three hypothetical depletion curves for the use of mineral resources

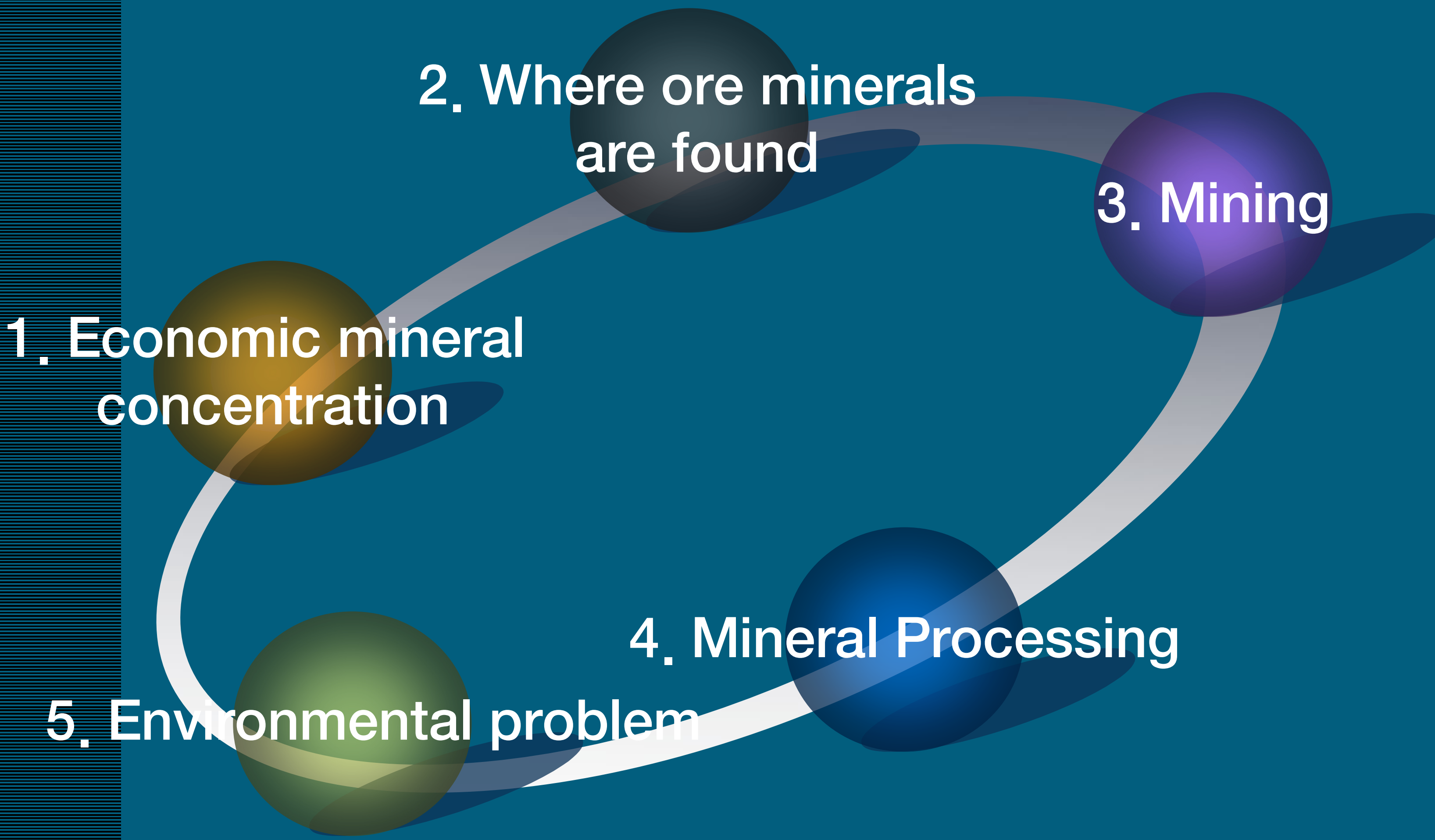
So, what is our mission?

1. Find more sources
2. Find a substitute
3. Recycle what has already been obtained
4. Use less and make more efficient use of what we have
5. ~~Do without~~ It is impossible



Geochemist Mineralogist Geologist

Resource Engineering



Resources and Reserves

Economic mineral concentration

From a practical viewpoint, resources are unsatisfactory because it will not normally be extracted unless extraction can be accomplished at a profit.

	Identified	Undiscovered	
		In known districts	In undiscovered districts or forms
Economic	Reserves	Hypothetical resources	Speculative resources
Marginally economic	Marginal reserves		
Subeconomic	Subeconomic resources		

← Increasing degree of geologic assurance

Classification of mineral resources used by the U.S Geological Survey and the U.S Bureau of Mines.

Resources

Concentration of a naturally occurring mineral in or on the crust of Earth in a form that can now or potentially be extracted at a profit

Reserves

Portion of a resource that is identified and is currently available to be legally extracted at a profit

Economic Mineral Concentration

Economic mineral concentration

Mineral deposit

- locally rich concentration of mineral

Ore

- Metallic mineral resources that can be economically and legally extracted at the tine

Ore minerals

- The minerals comprising the deposits

Classification of Mineral Resources

TABLE 13.1 Classification of Mineral Resources

METALLIC MINERAL RESOURCES	NONMETALLIC MINERAL RESOURCES
Abundant Metals	*Minerals for Industrial and Agricultural Use*
iron, aluminum, manganese, magnesium, titanium	phosphates, nitrates, carbonates, sodium chloride, fluorite, sulfur, borax
Scarce Metals	*Construction Materials*
copper, lead, zinc, tin, gold, silver, platinum-group metals, molybdenum, uranium, mercury, tungsten, bismuth, chromium, nickel, cobalt, columbium	sand, gravel, clay, gypsum, building stone, shale, and limestone (for cement)
	Ceramics and Abrasives
	feldspar, quartz, clay, corundum, garnet, pumice, diamond

SOURCE: James R. Craig, David L. Vaughan, and Brian J. Skinner, *Resources of the Earth* (Englewood Cliffs, N.J.: Prentice Hall, 1988).

Concentration Factor

Concentration factor

- explain a particular ore deposit

Concentration factor of a given metal in an ore

$$= \frac{\text{concentration of the metal in the ore deposit}}{\text{concentration of the metal in average continental crust}}$$

TABLE 13.2 Concentration Factors for Profitable Mining of Selected Metals

	PERCENTAGE ABUNDANCE		CONCENTRATION FACTOR
METAL	*Average in Earth's Crust*	*In Ore Deposit*	
Aluminum	8	35	4
Copper	0.0063	0.4–0.8	80–160
Gold	0.0000004	0.001	2,500
Iron	5	20–69	4–14
Lead	0.0015	4	2,500
Mercury	0.00001	0.1	10,000
Silicon	28.2	[illegible]	[illegible]
Titanium	0.57	[illegible]	[illegible]

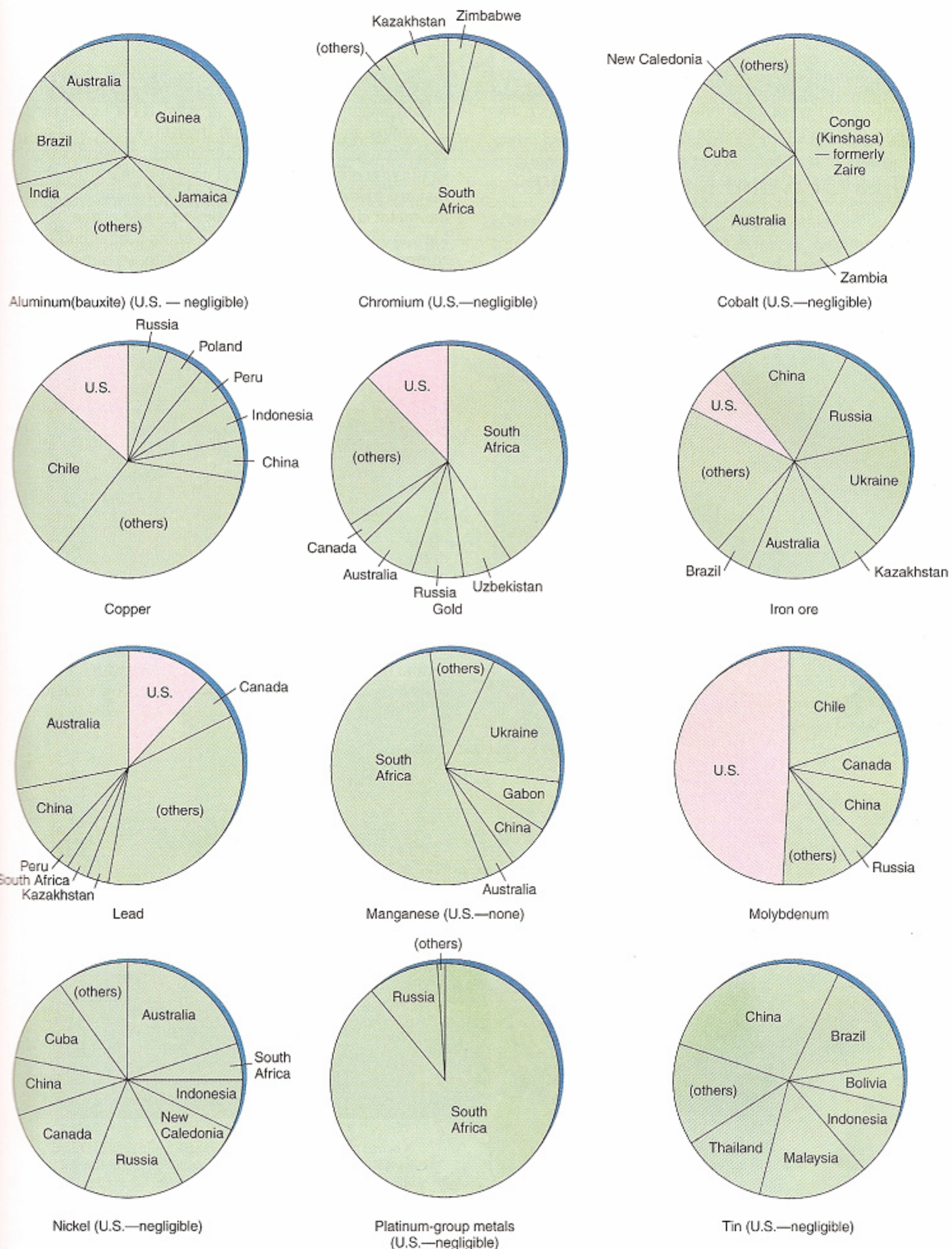
SOURCE: U.S. Geological Survey Professional Paper 820, 1973.

The high concentration Factor

= Rich Ore

Distribution of Mineral Resources

Economic mineral concentration



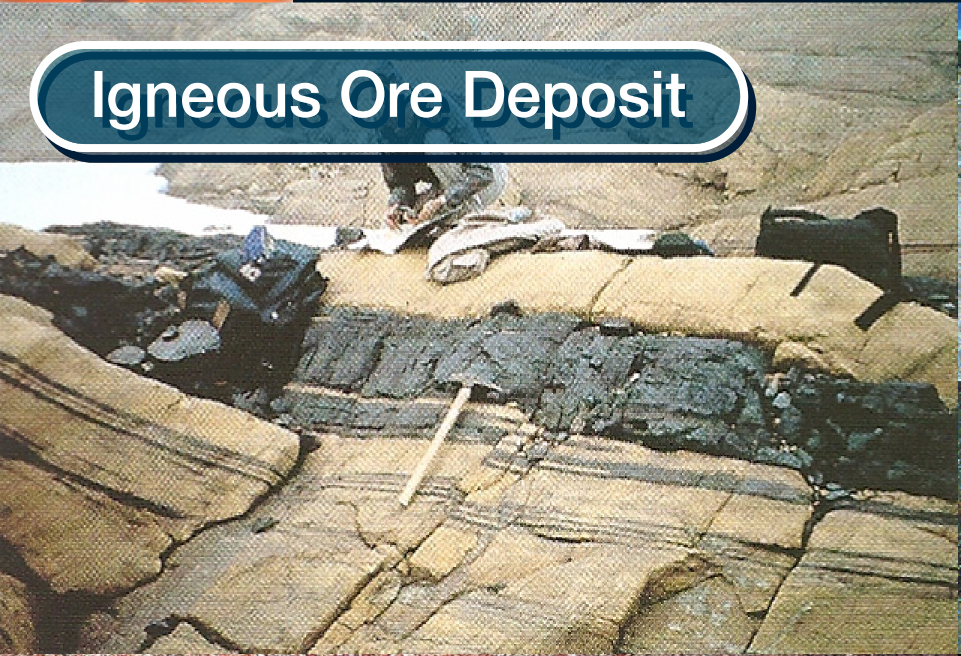
Mineral deposits are highly localized: they are neither uniformly nor randomly distributed.

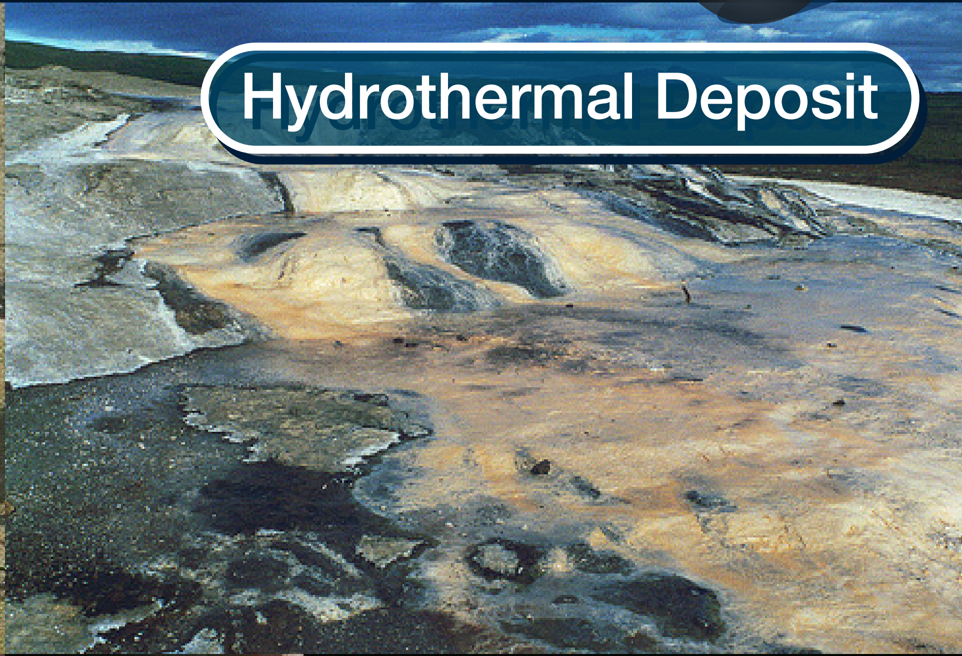
Proportion of world reserves of some nonfuel minerals Controlled by various nation

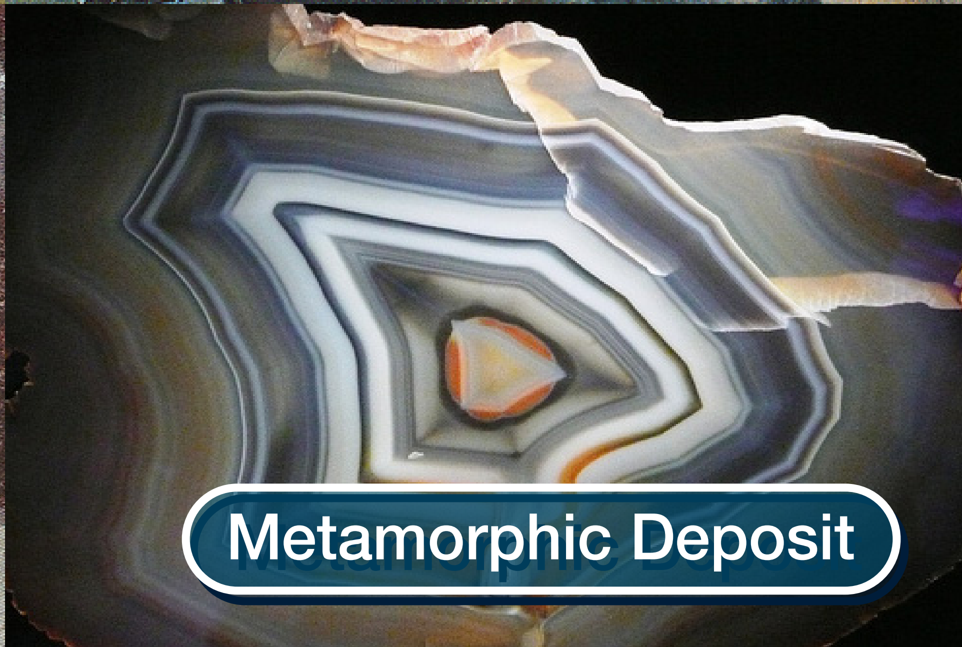
(Mineral Commodity Summaries 2000, U.S.Geology Survey)

The Formation of Mineral Deposit

Where ore minerals are found







The Formation of Mineral Deposit

Where ore minerals are found

Igneous Ore Deposit

Magmatic activity gives rise to several different kinds of deposit.

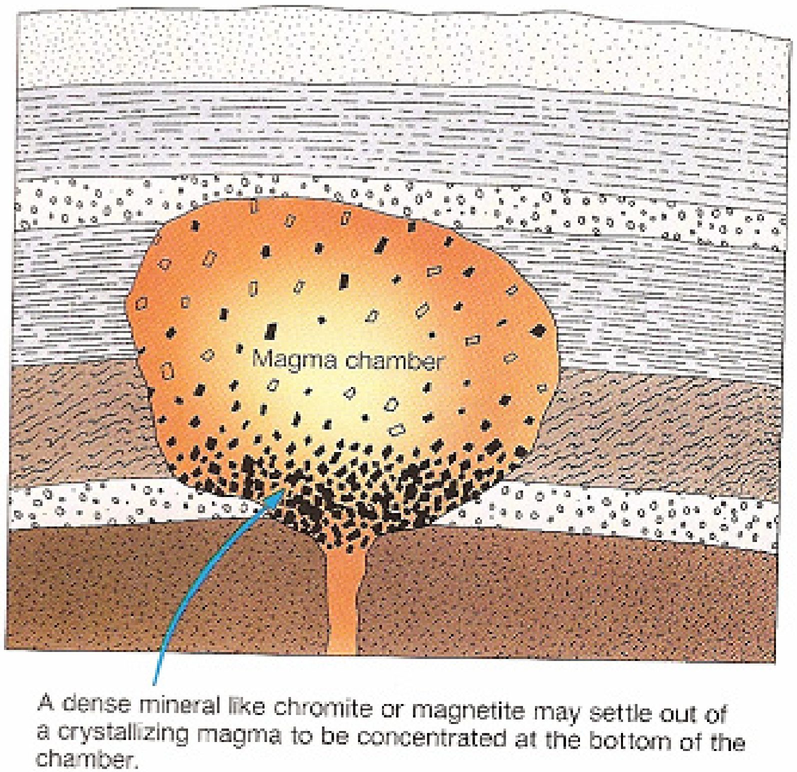


FIGURE 12.3 Formation of magmatic ore deposit by gravitational settling of a dense mineral during crystallization.

Typical types of igneous deposit

1. pegmatite deposit
2. Layered intrusion
3. Kimberlite

Igneous Ore Deposit

pegmatite deposit

In 1845, W. Haidinger was apparently the first to use the word pegmatite to describe "coarse-grained, feldspar-rich granites".

Rocks of very large grains which consisted of orthoclase, quartz and silvery mica, and which occur so commonly in the form of dikes, small stocks and nests in other rocks.

Igneous Ore Deposit

pegmatite deposit

Why are pegmatites important?

Granitic pegmatites are important sources of rare-elements, such as beryllium, niobium, tantalum, tin, lithium, rubidium, cesium and gallium; industrial minerals; gems and mineral specimens.

Some of the world's best-known gem material is obtained from pegmatite deposits.

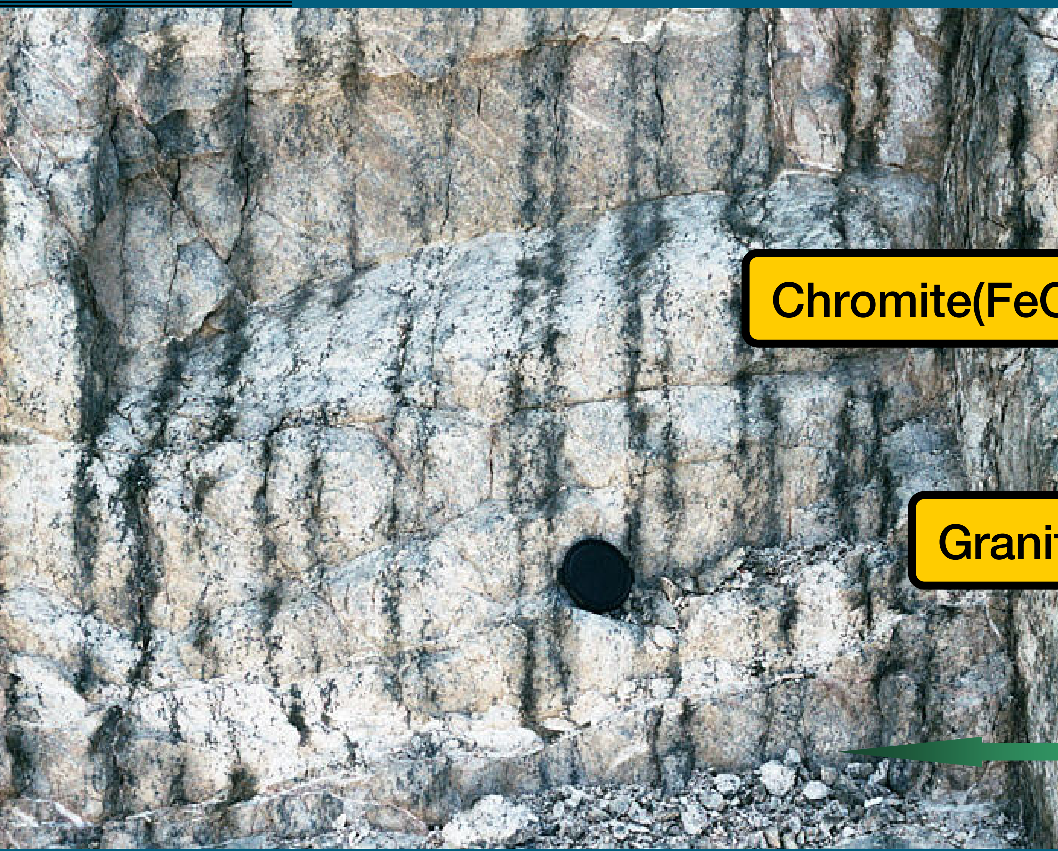
The Formation of Mineral Deposit

Where ore minerals are found

Igneous Ore Deposit

Layered intrusion

Layered intrusions occur at all levels within the crust, from depths in excess of 50km to depths of as little as 1.5 to 5km.



Layered mineral deposit; Red Mountain, Alaska.

The Stillwater Complex is a large fragment of an enormous ~2710 Ma ultramafic-mafic layered intrusion.

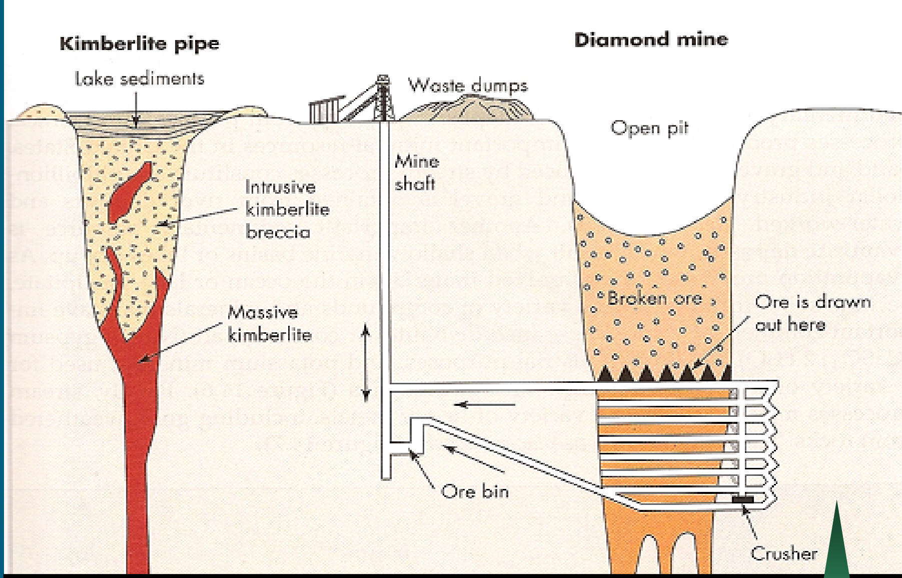
The Formation of Mineral Deposit

Where ore minerals are found

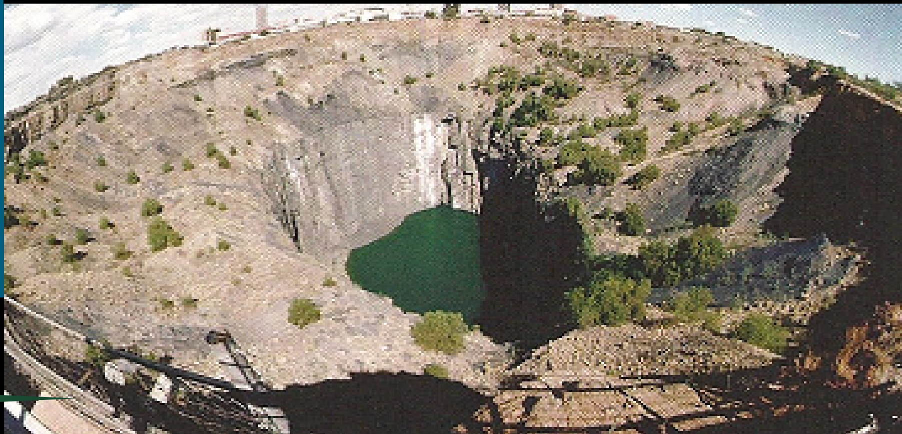
Igneous Ore Deposit

Kimberlite

Kimberlite magma rises through Earth's crust in networks of cracks or dikes. The pipes only form near Earth's surface. This cross-section of a kimberlite pipe shows the carrot-shaped profile produced by explosive eruption. The root zone starts in fissures, where gases are released from the rising magma and drive the eruption; they blow out the fragment-laden kimberlite to form the volcano's tuff ring and fill the pipe.



Idealized diagram showing a typical South African diamond pipe and mine.



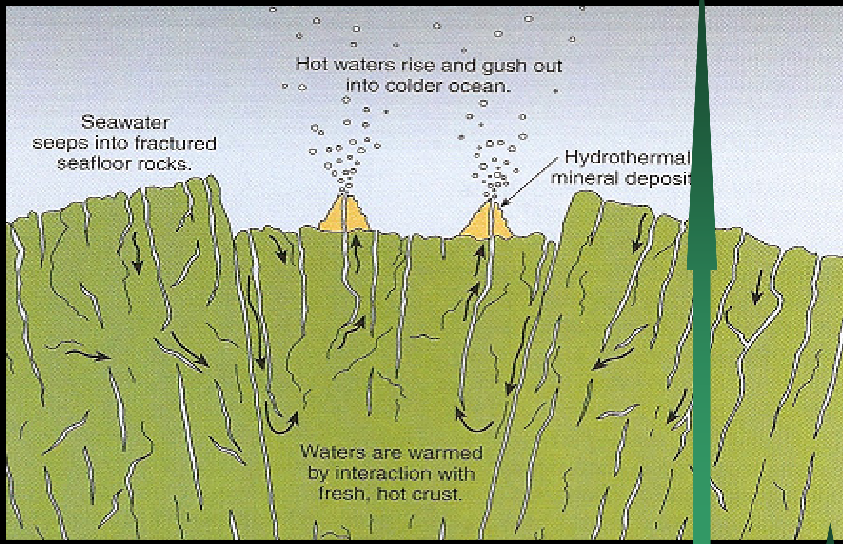
Aerial view of Diamond Mine, Kimberly, South Africa.

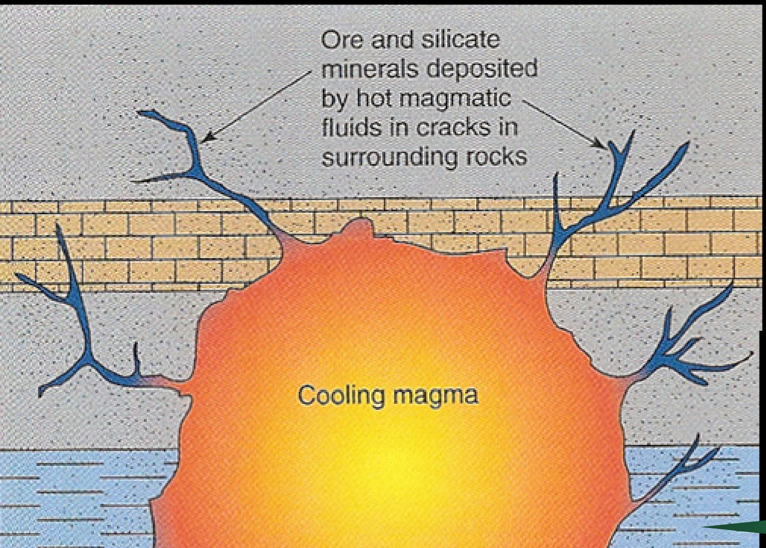
The Formation of Mineral Deposit

Where ore minerals are found

Hydrothermal Deposit

The deposits form along the margins of uplifted sediment fault blocks generated by intrusion of MORB (mid-ocean ridge basalt) laccoliths. Because of hydrothermal fluid interactions with sediments, the deposits are enriched in group IV, V and VI elements, thermogenic hydrocarbons, and radiogenic Pb compared with those deposits forming in sediment-free spreading centers.





Sulfides can be deposited by hydrothermal circulation around a spreading ridge.
Ore deposition in veins around a magma chamber.
Hydrothermal ore deposits from in various ways.

The Formation of Mineral Deposit

Hydrothermal Deposit

Sulfer is a common constituent of magmatic gases and fluids

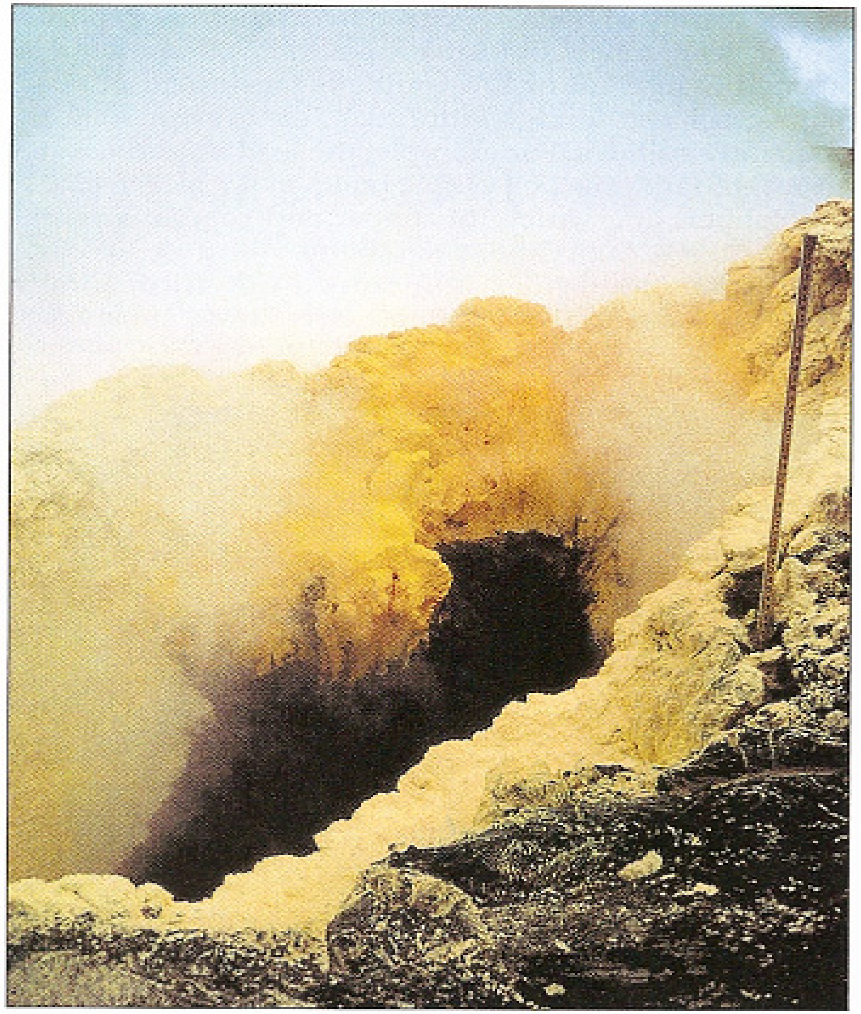
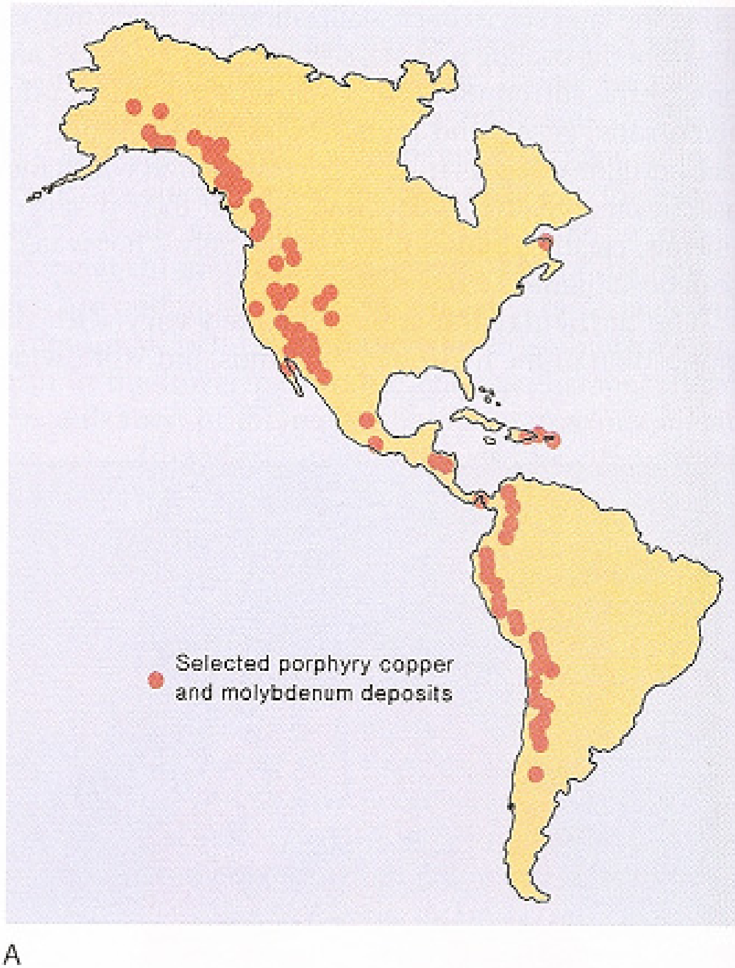


FIGURE 12.5 Sulfur deposition around a fumarole, Kilauea, Hawaii. *Photograph by J.C. Ratté, USGS Photo Library, Denver, CO.*

The Formation of Mineral Deposit

Where ore minerals are found

Hydrothermal Deposit



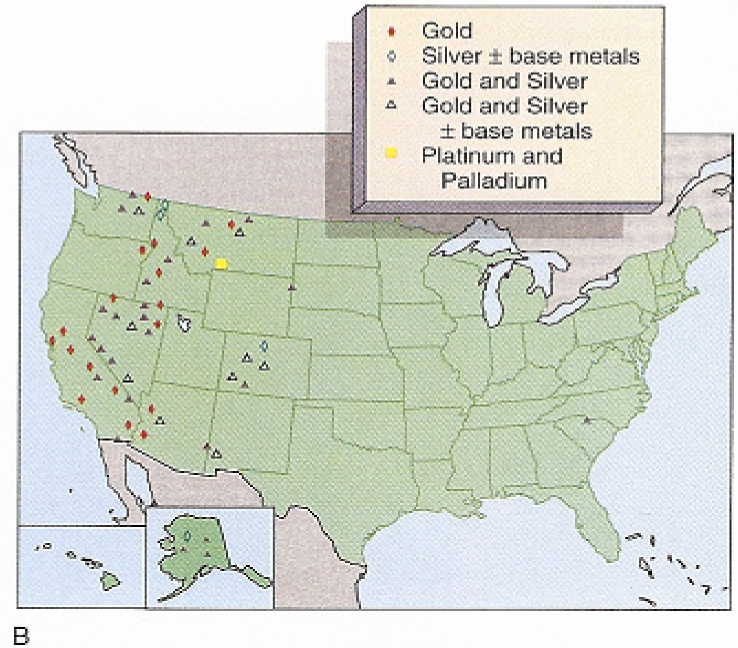


FIGURE 12.6 (*A*) Distribution of copper and molybdenum deposits. (Deposit in eastern Canada relates to an ancient subduction zone rather than to modern subduction.) (*B*) Major precious-metal-producing areas in the United States. ("Base metals" are the more common metals, such as copper and lead, as distinguished from "precious metals" such as gold and silver.) *(A) Data from M.J. Jensen and A.M. Bateman,* Economic Mineral Deposits, *3d ed. Copyright © 1981 John Wiley & Sons, Inc., New York. (B) Data from* Mineral Commodity Summaries 1995, *U.S. Bureau of Mines.*

The Formation of Mineral Deposit

Where ore minerals are found

Sedimentary Deposit

Mineral deposits resulting from the accumulation of precipitation of sediment.

1. Surficial marine and nonmarine precipitation
   - Evaporite deposit
   - Residual deposit
2. Deep ocean precipitation
   - Manganese nodules
3. Mechanical sedimentary deposit
   - Placer deposit

The Formation of Mineral Deposit

Where ore minerals are found

Sedimentary Deposit

Surficial marine and nonmarine precipitation

Evaporite deposit

When water evaporates, dissolved minerals remain behind as a solid residue.

This residue is a chemical deposit of minerals.

Outcrop of banded-iron formation; northern Michigan.

Rock salt from an evaporate deposit.

The Formation of Mineral Deposit

Where ore minerals are found

Sedimentary Deposit

Surficial marine and nonmarine precipitation

Residual deposit

In residual deposits the diluting, non-economic material is removed and the material left behind is of economic value.

This is a fine light pink Halite (simple salt NaCl) specimen with beautiful and well formed cubic crystals from Searles Lake, Trona, California

The Formation of Mineral Deposit

Where ore minerals are found

Sedimentary Deposit

Surficial marine and nonmarine precipitation

Residual deposit - Bauxite

Aluminum ore, called bauxite, is most commonly formed in deeply weathered rocks. In some locations, deeply weather volcanic rocks, usually basalt, form **bauxite deposits**. This sample of bauxite ore is from Western Australia.

The Formation of Mineral Deposit

Where ore minerals are found

Sedimentary Deposit

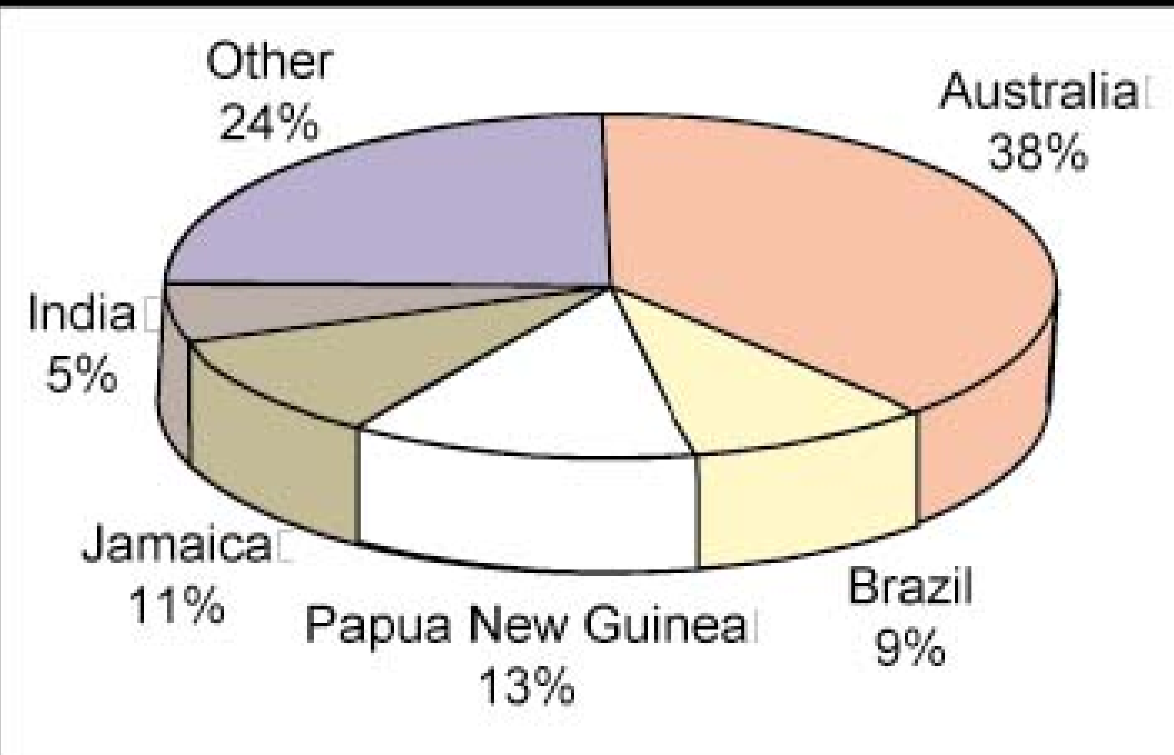
Surficial marine and nonmarine precipitation

Residual deposit - Bauxite

Aluminum has a wide range of common uses.

It is lightweight, strong (especially with alloys), and conducts heat well.

Many kitchen items (pots and pans, foil, dishes) are made of aluminum.



World Supply of Aluminum

About 110 million tonnes of aluminum was produced in 1994. Australia produces most of the world's aluminum. Diagram from ITAM Bauxite by the Minerals Council of Australia.

The Formation of Mineral Deposit

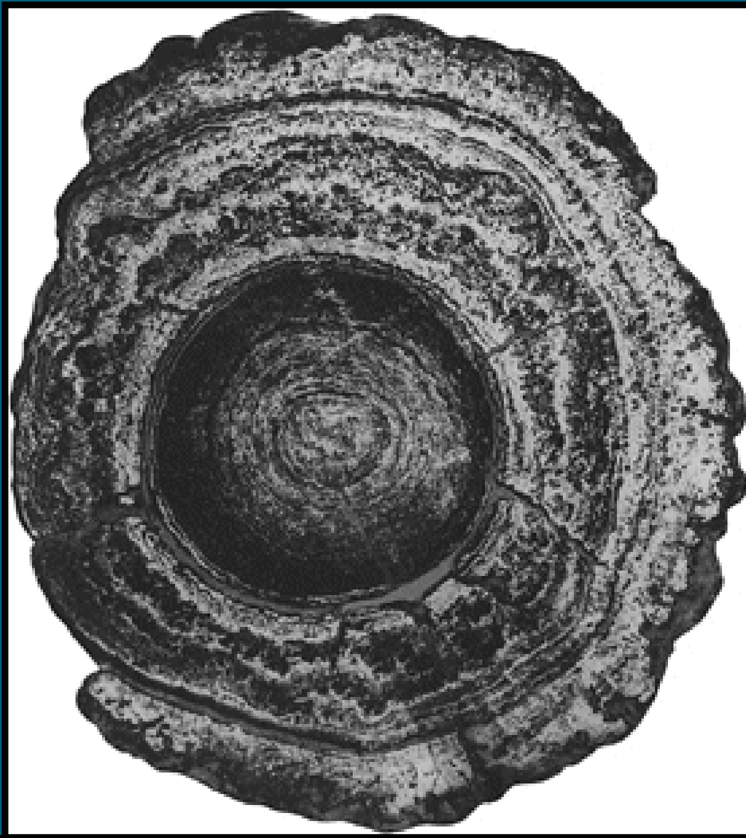
Where ore minerals are found

Sedimentary Deposit

Deep ocean precipitation

Manganese nodules

Concentrations of manganese and iron oxides found on the floors of many oceans. The origin of these potato-shaped metal-rich deposits has been elucidated; their complex growth histories are revealed by the textures of nodule interiors shown in the illustration.



Reflected-light photograph of the polished surface of a sectioned manganese nodule showing the complex growth history of the concretionary deposit

The Formation of Mineral Deposit

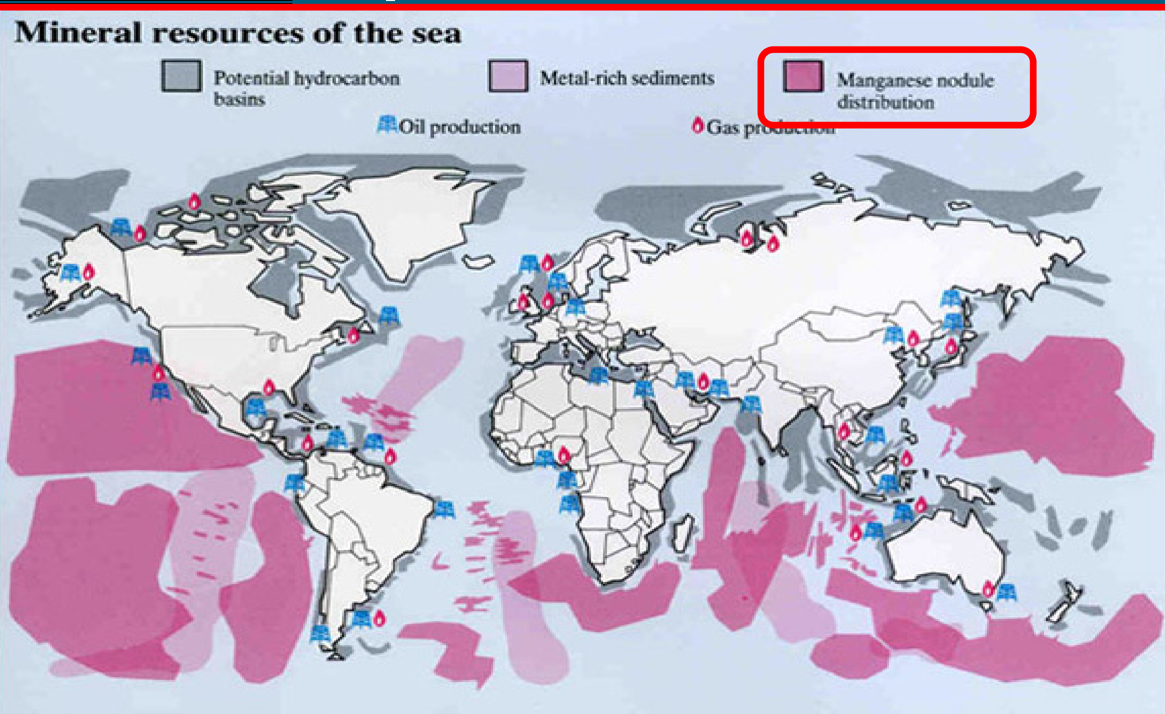
Where ore minerals are found

Sedimentary Deposit

Deep ocean precipitation

Manganese nodules

Marine manganese nodules from certain regions are significantly enriched in nickel, copper, cobalt, zinc, molybdenum, and other elements so as to make them important reserves for these strategic metals.



About 20% is thought to be covered by manganese nodules, which can contain as much as 2.5% copper, 2% nickel, 0.2% cobalt and 35% manganese, as well as titanium, aluminium, potassium, molybdenum, lead, strontium and other substances. (Source: Times Atlas)

The Formation of Mineral Deposit

Where ore minerals are found

Sedimentary Deposit

Mechanical sedimentary deposit

Placer deposit

In geology, a placer deposit or placer is an accumulation of alluvium or eluvium containing valuable minerals which is formed by deposition of dense mineral phases in a trap site.
The name is from the Spanish word *placer*, meaning "sand bank".

FIGURE 13.13 Gold nugget weighing 41.3 troy ounces, mined from a placer deposit in the Brooks Range, Alaska.

The Formation of Mineral Deposit

Where ore minerals are found

Sedimentary Deposit

Mechanical sedimentary deposit

Placer deposit

The formation of placer deposit

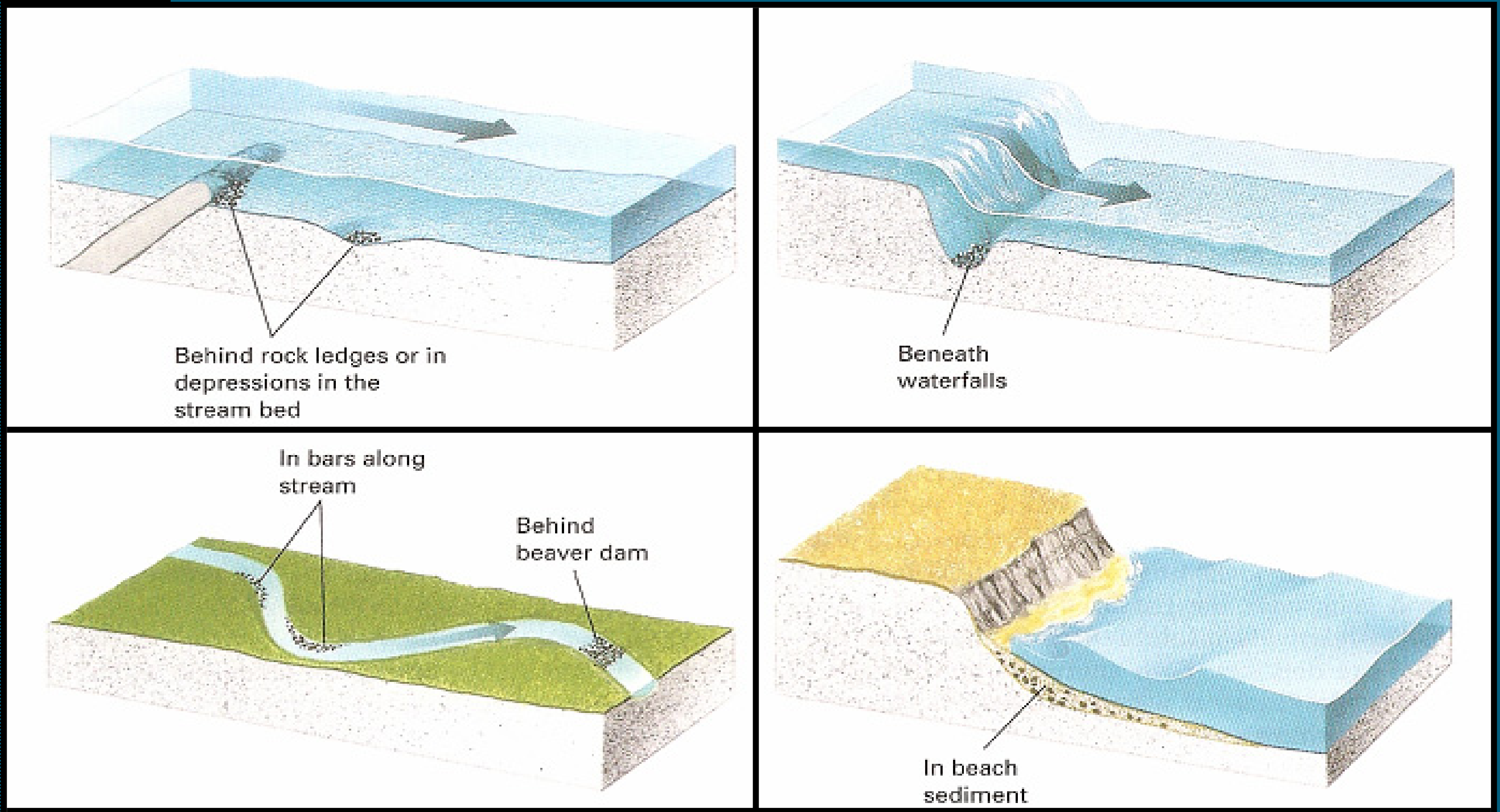


Figure 5.10 Placer deposits form where water currents slow down and deposit high-density minerals.

The Formation of Mineral Deposit

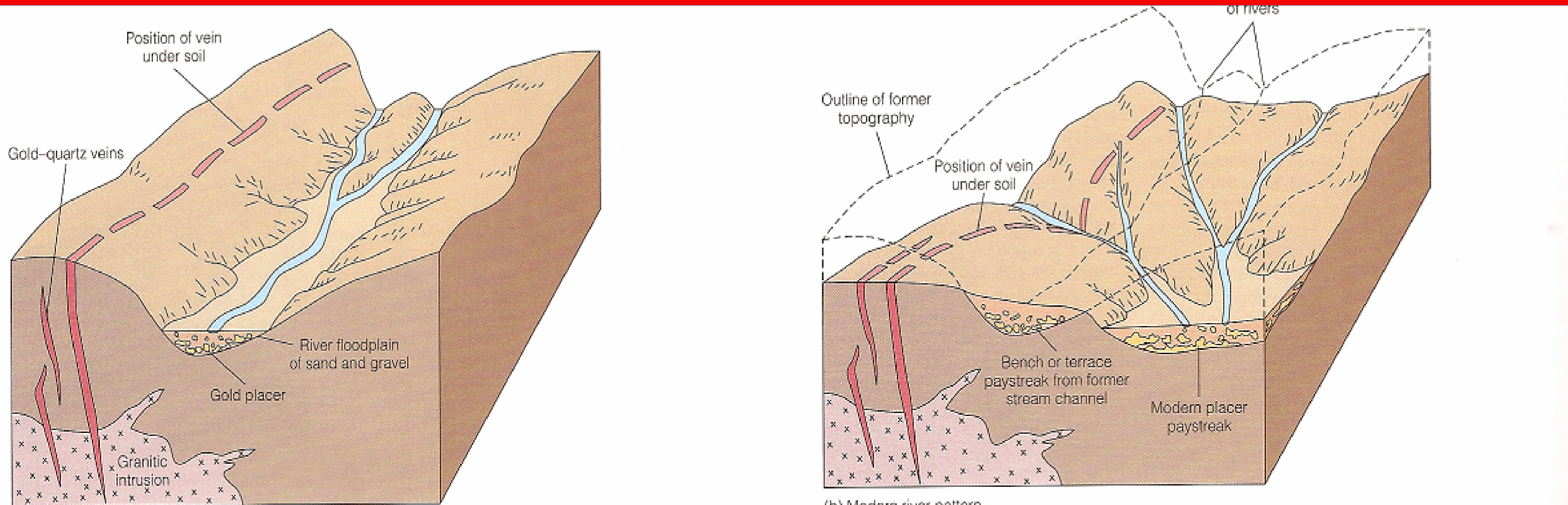
Where ore minerals are found

Sedimentary Deposit

Mechanical sedimentary deposit

Placer deposit

The origin of Gold placer deposit



(a) Ancient river pattern

(b) Modern river pattern

FIGURE 13.12 The origin of gold placer deposits. (a) An ancient landscape with an eroding gold-quartz vein shedding small amounts of gold and other mineral grains that eventually become stream sediments. The gold particles, being heavier, settle to the bottom of the sediments in the channel. (b) The same region in modern time. Streams have eroded and changed the landscape and now follow new courses. The original placer deposits of the ancient stream channels are now elevated above the modern river valley as "bench" placers.

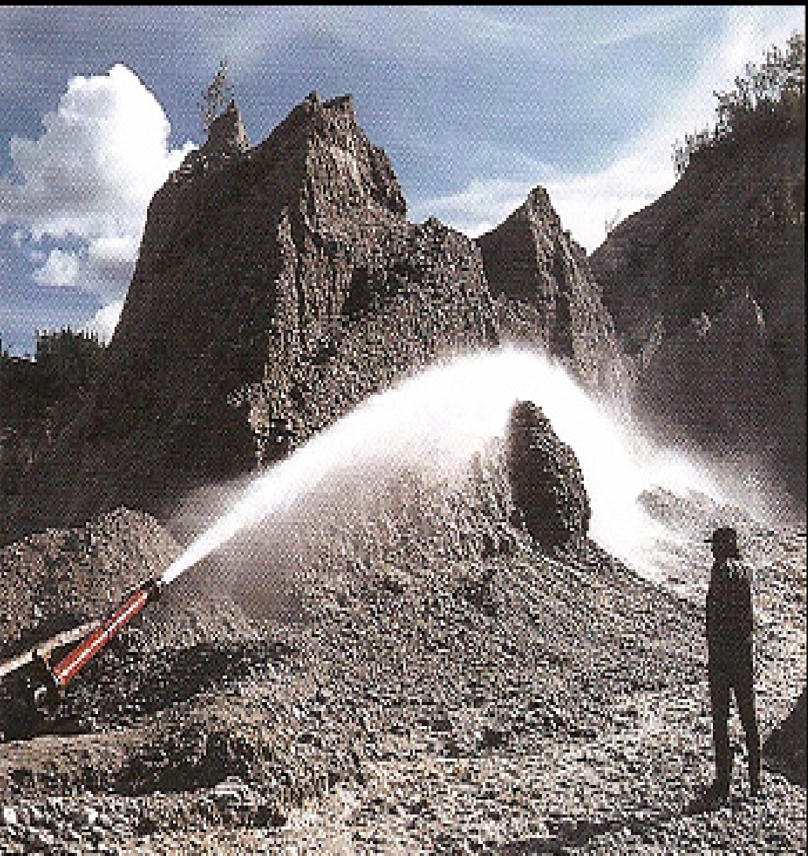
category are copper, lead, zinc, and nickel—which are widely known and used, but nevertheless scarce—along with the more obvious gold and platinum-group minerals. U.S. deposits of chromium, manganese, nickel, tin, and platinum-group metals are scarce or of submarginal grade. Important, less-well-known scarce metals include cobalt, columbium, tantalum, and cadmium, which are important in space-age ferroalloys; antimony, which is used as a pigment and as a fire re-

The Formation of Mineral Deposit

Where ore minerals are found

Sedimentary Deposit

Mechanical sedimentary deposit
Placer deposit



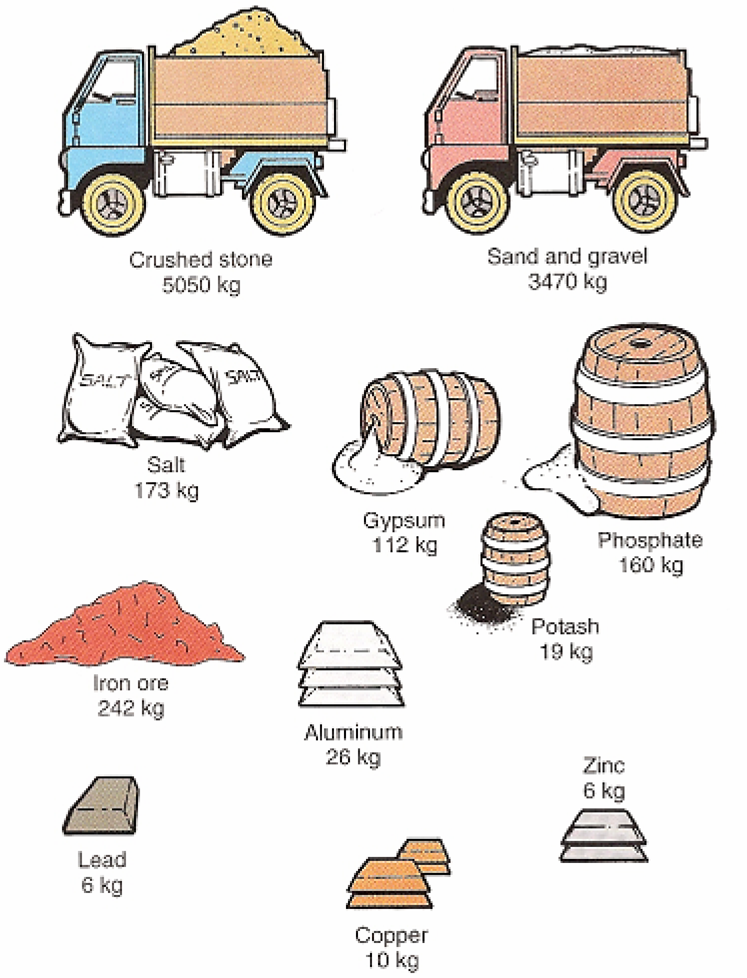
Water flowering from a giant nozzle washed gold-bearing gravels to sluices, in the Yukon, Canada.

Photograph of a retreat placer deposit exposed by northward migration of the Willapa Bay tidal inlet at the southern end of the Grayland subcell.

Mineral and Rock Resources

Where ore minerals are found

Per-capita consumption of mineral and rock resources in the U.S., 1999



● FIGURE 12.11 Per-capita consumption of mineral and rock resources in the United States, 1999. (1 kg = 2.2 lb) *Data from* Mineral Commodity Summaries 2000, *U.S. Geological Survey.*

Mineral and Rock Resources

Where ore minerals are found

Per-capita consumption of mineral and rock resources in the U.S., 1999

	Material	U.S. Primary Production	U.S. Primary Production as % of World	U.S. Consumption	U.S. Consumption as % of World‡	U.S. Production as % of U.S. Consumption■: Primary	U.S. Production as % of U.S. Consumption■: Total
Metals	aluminum[x]	3800	16.7	7500	33.0	51	69
Metals	chromium	0	0	522	4.1	0	20
Metals	cobalt	0	0	11.5	40.6	0	27
Metals	copper	1870	14.8	2950	23.4	56	72
Metals	iron ore	57,000	5.7	68,400	6.9	83	83
Metals	lead	350	11.5	1750	57.6	20	80
Metals	manganese	0	0	830	12.3	0	0
Metals	nickel	0	0	206	18.1	0	0
Metals	tin	0	0	59.7	28.4	0	30
Metals	zinc	775	10.1	1630	21.3	48	70
	gold	340	14.6	240	10.3	142	271
	silver	1860	11.7	4500	28.3	41	130
	platinum group	13.4	4.9	ø	ø	ø	ø
Nonmetals	clays	42,200	*	37,600	*	115	115
Nonmetals	gypsum	19,400	18.0	31,800	29.4	61	71
Nonmetals	phosphate	41,500	30.1	44,700	32.4	93	93
Nonmetals	potash	1300	5.2	5400	21.4	24	24
Nonmetals	salt	41,400	20.7	48,900	24.4	85	85
Nonmetals	sulfur	11,100	19.8	13,900	23.8	83	83
Construction	sand and gravel, construction	1,080,000	*	1,080,000	*	100	100
Construction	stone, crushed	1,560,000	*	1,570,000	*	99	99
Construction	stone, dimension and facing	1040	*	**	*	**	**

†All production and consumption figures in thousands of metric tons, except for gold, silver, and platinum-group metals, for which figures are in metric tons, a construction materials, for which figures are in thousands of tons.

‡Assumes that overall, world production approximates world consumption. This may not be accurate if, for example, recycling is extensive.

■"Primary" and "Total" headings refer to U.S. production; total production includes production from recycled scrap.

*World data not available

øConsumption data not available

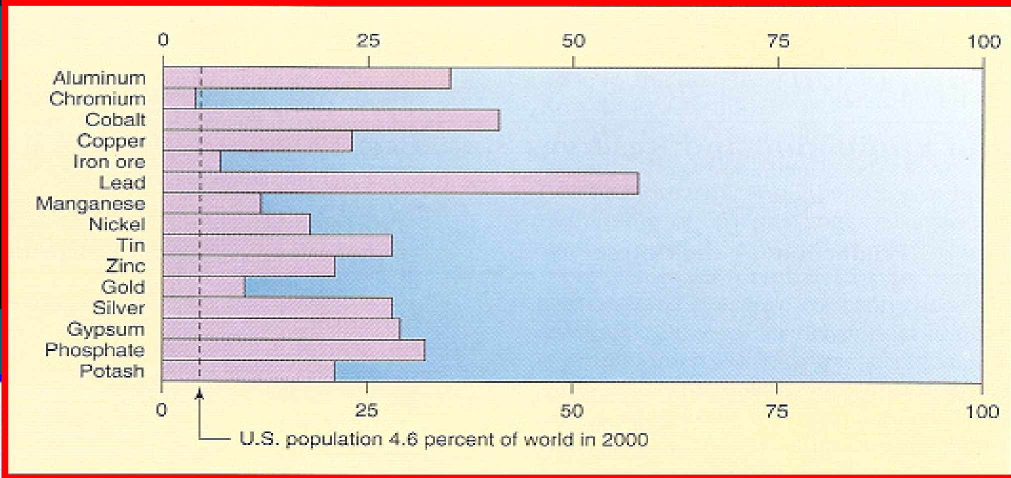
**Consumption not available in tonnage. However, $470 million worth of dimension stone was imported (value of domestic production, $220 million, of whi $51 million worth was exported).

[x]Partly from bauxite imports

Source: *Mineral Commodity Summaries 2000*, U.S. Geological Survey.

Mineral and Rock Resources

Where ore minerals are found

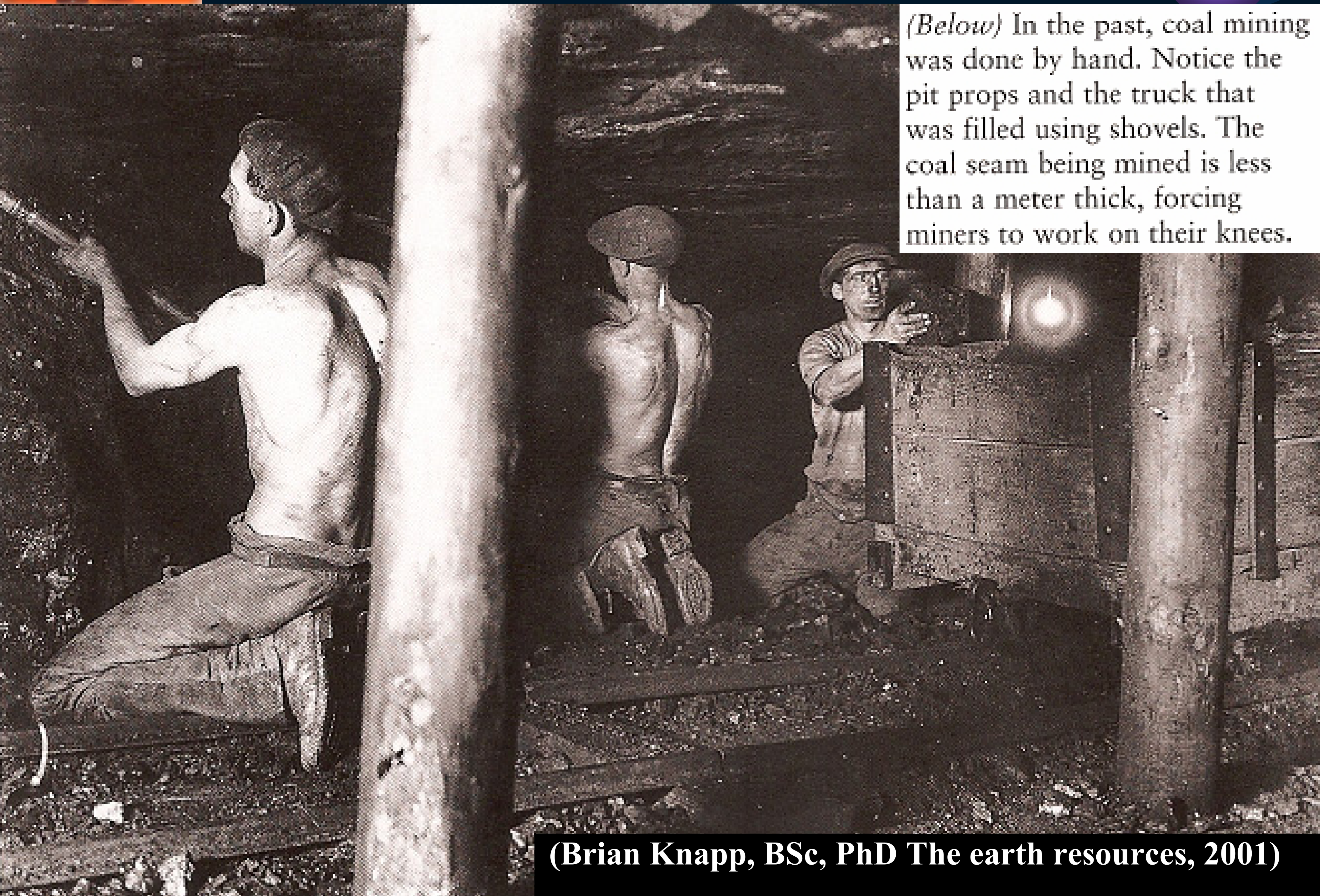


United States share of global consumption of selected materials (Mineral commodity Summaries 2000,U.S. Geological Survey).

Commodity	Percent	Major Sources (1995–1998)
Arsenic trioxide	100	China, Chile, Mexico
Bauxite and Alumina	100	Australia, Guinea, Jamaica, Brazil
Bismuth	100	Belgium, Mexico, United Kingdom, China
Columbium (niobium)	100	Brazil, Canada, Germany, Russia
Fluorite	100	China, South Africa, Mexico
Graphite (natural)	100	Mexico, Canada, China, Madagascar
Manganese	100	South Africa, Gabon, Australia, France
Mica, sheet	100	India, Belgium, Germany, China
Gemstones	99	Israel, Belgium, India
Antimony	85	China, Bolivia, Mexico, South Africa
Tin	85	Brazil, Indonesia, Bolivia, China
Tungsten	81	China, Russia, Bolivia, Germany
Chromium	80	South Africa, Russia, Turkey, Zimbabwe
Potash	80	Canada, Russia, Belarus
Tantalum	80	Australia, Thailand, China, Germany
Stone (dimension)	77	Italy, India, Canada, Spain
Cobalt	73	Norway, Finland, Canada, Zambia
Rare earths	72	China, France, Japan, United Kingdom
Iodine	68	Chile, Japan, Russia
Barite	67	China, India, Mexico, Morocco
Nickel	63	Canada, Russia, Norway, Australia
Aluminum	30	Canada, Russia, Venezuela, Mexico
Silicon	30	Norway, Russia, Brazil, Canada
Zinc	30	Canada, Mexico, Peru
Gypsum	29	Canada, Mexico, Spain
Magnesium metal	29	Canada, Russia, China, Israel
Copper	27	Canada, Chile, Mexico
Nitrogen (fixed), Ammonia	26	Trinidad and Tobago, Canada, Mexico, Venezuela
Lead	20	Canada, Mexico, Peru, Australia
Cadmium	19	Canada, Belgium, Germany, Australia
Iron ore	17	Canada, Brazil, Venezuela, Australia
Sulfur	17	Canada, Mexico, Venezuela
Salt	16	Canada, Chile, Mexico, The Bahamas
Silver	14	Mexico, Canada, Peru, Chile
Asbestos	7	Canada
Phosphate rock	7	Morocco
Talc	6	China, Canada, Japan
Beryllium	2	Kazakhstan, Russia, Canada, Germany

Proportion of U.S. mineral needs supplied by imports a percentage of apparent consumption (Mineral commodity Summaries 2000,U.S. Geological Survey).

Mining Activities



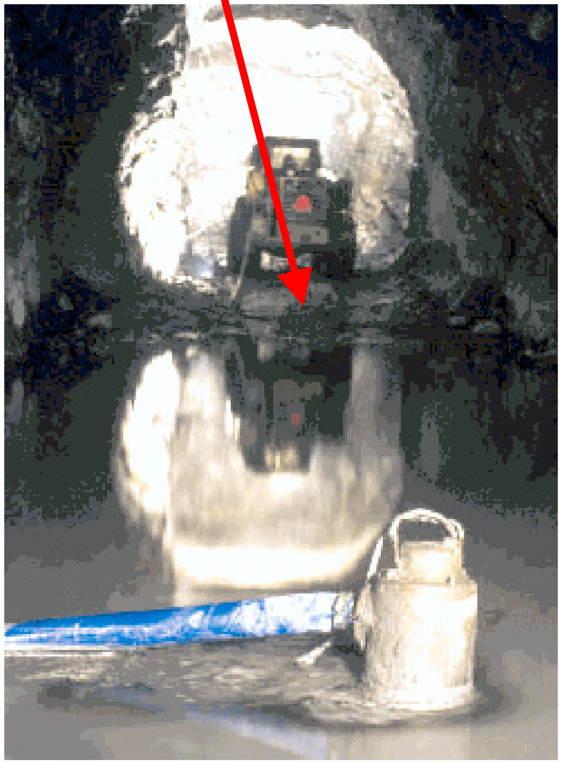
(Below) In the past, coal mining was done by hand. Notice the pit props and the truck that was filled using shovels. The coal seam being mined is less than a meter thick, forcing miners to work on their knees.

(Brian Knapp, BSc, PhD The earth resources, 2001)

Mining Activities

Mining = The process or business of extracting ore or minerals from the ground.

Mining is broadly divided into three basic methods:
1. opencast 2. underground and 3. fluid mining.



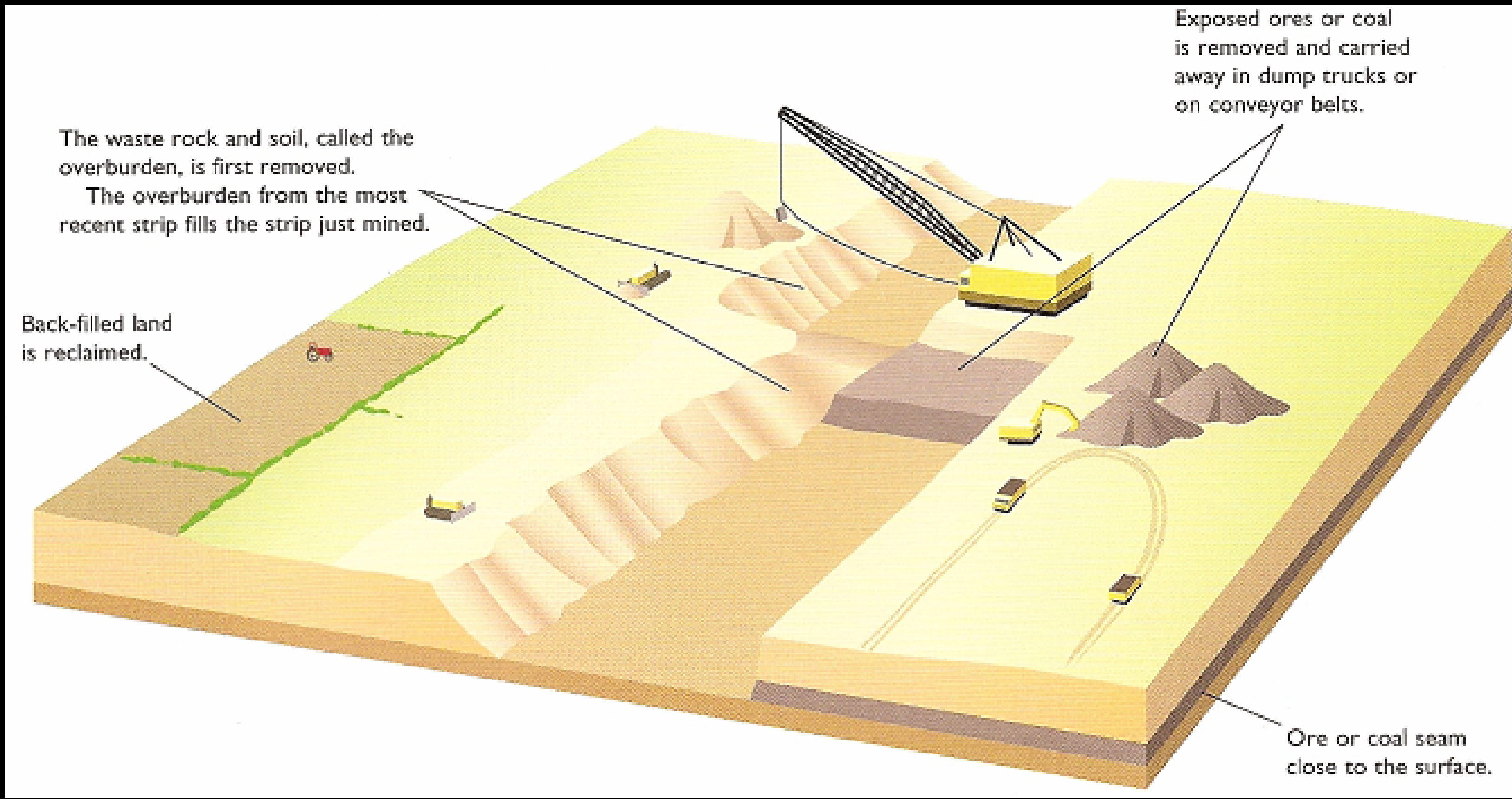
Mining Activities

Mining

opencast

Strip mining

A system used when level beds of mineral lie just below the surface over a large area



(Brian Knapp, BSc, PhD The earth resources, 2001)

Mining Activities

opencast

Open-pit mining

Where the mineral is shallow, and especially when it is compact, mining can be done by digging an open pit

(*Below*) Benches around the sides of a disused open-pit copper mine.

(Brian Knapp, BSc, PhD The earth resources, 2001)

Mining Activities

opencast

Stone Quarrying

Stone quarrying is designed to collect stone for building, cement making, and the like, and also sand and gravel for use in making concrete and other building materials

(Below) Portland limestone, a Jurassic limestone with very few bedding places.

(Brian Knapp, BSc, PhD The earth resources, 2001)

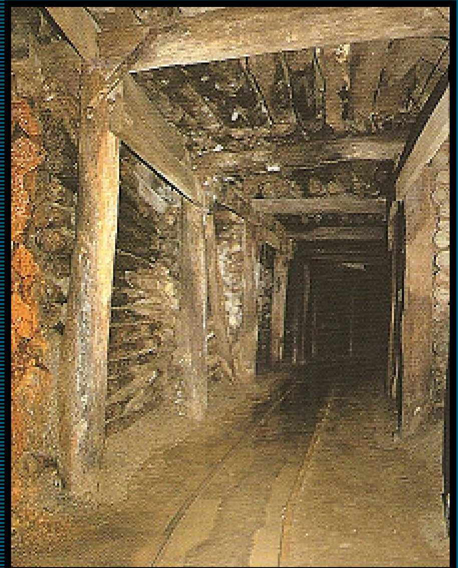
Mining Activities

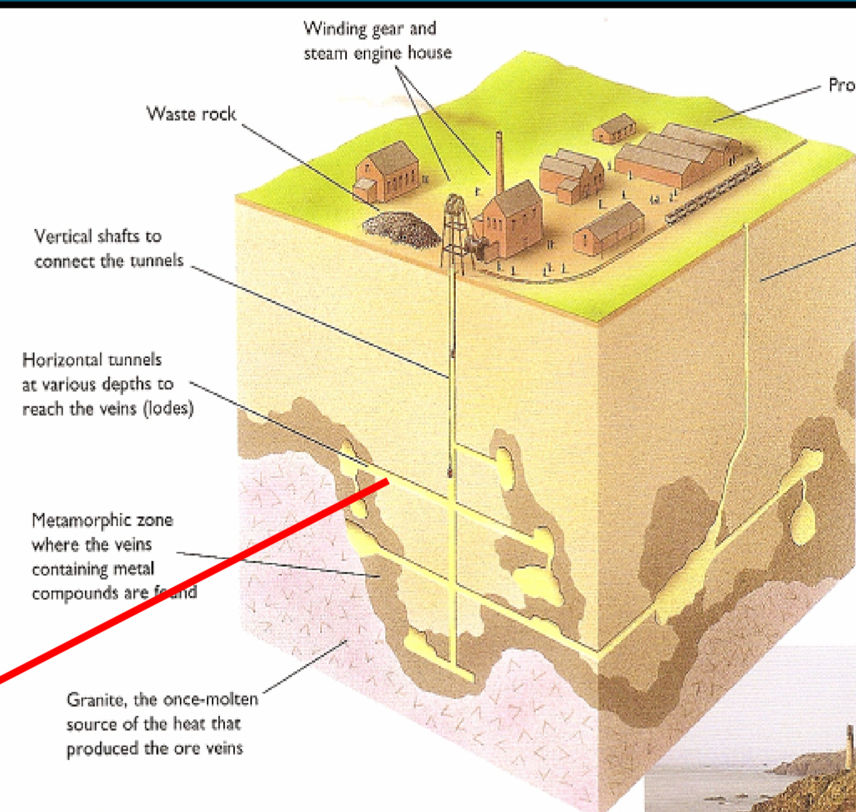
Mining

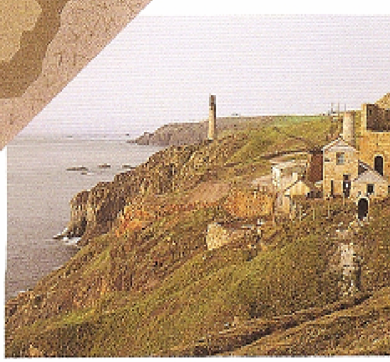
underground

Underground Mining

Underground mining uses either a horizontal tunnel, if there is access through a valley side, a sloping tunnel, or a vertical shaft







(Right) The remains of these 19th-century engine houses perched on a Cornish cliff in southwest England show how, in the past, METAMORPHIC AUREOLES were exploited with a number of small mines. Each independent mine had its own shaft that would be sunk wherever there was the chance of recovering metal—no matter how perilous the location.

(Brian Knapp, BSc, PhD The earth resources, 2001)

Mining Activities

Mining

fluid mining

Petroleum drilling

Las Bonillas, Venezuela - Due to the massive volume of oil removed in the Maracaibo Basin, Lake Maracaibo has sunk, changing the geography of the region. In this photo, you can see the ground level of the town on the right is markedly lower than the water level of the lake on the left (~15 feet). In response, the Venezuelan government was forced to build an earthen dike around sub-sea-level Lagunillas to prevent encroachment by the waters. Many consider the dike to be a disaster in the waiting, with the potential of an earthquake causing soil liquifaction and submerging a large population.

May 13, 2007-- Galveston, Texas, USA-- oil is the blood of Houston, we run because of oil. This oil rig is now a muesum of off shore drilling. -- PHOTO BY ANDIE SMITH

Mining Activities

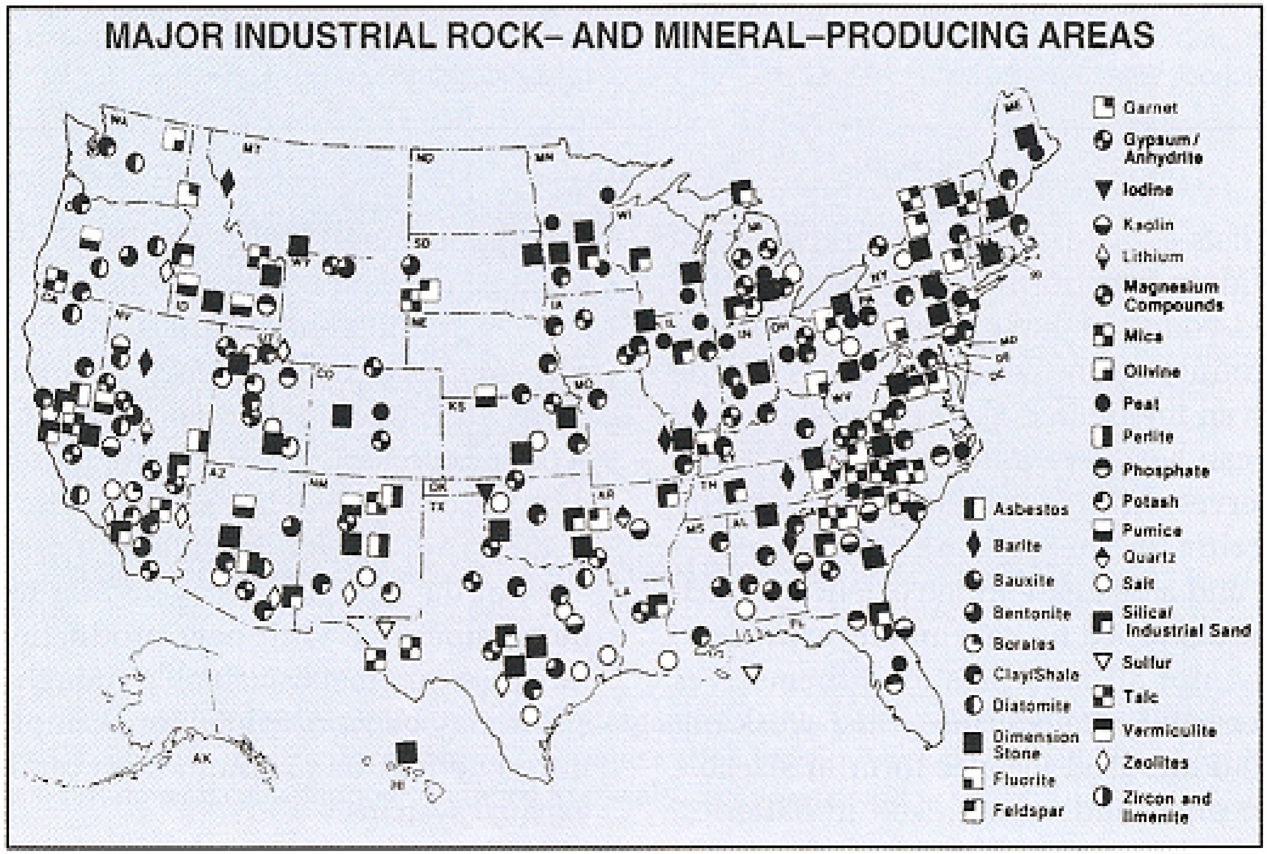


FIGURE 12.22 Even a partial map of sites of mining for industrial rock and mineral resources shows that these activities are widespread in the United States. Still more places are affected by mining for metal ores. Mineral Commodity Summaries 1996, *U.S. Bureau of Mines.*

Mineral Processing

(*Below*) The ore-processing complex at Mount Isa, Australia.

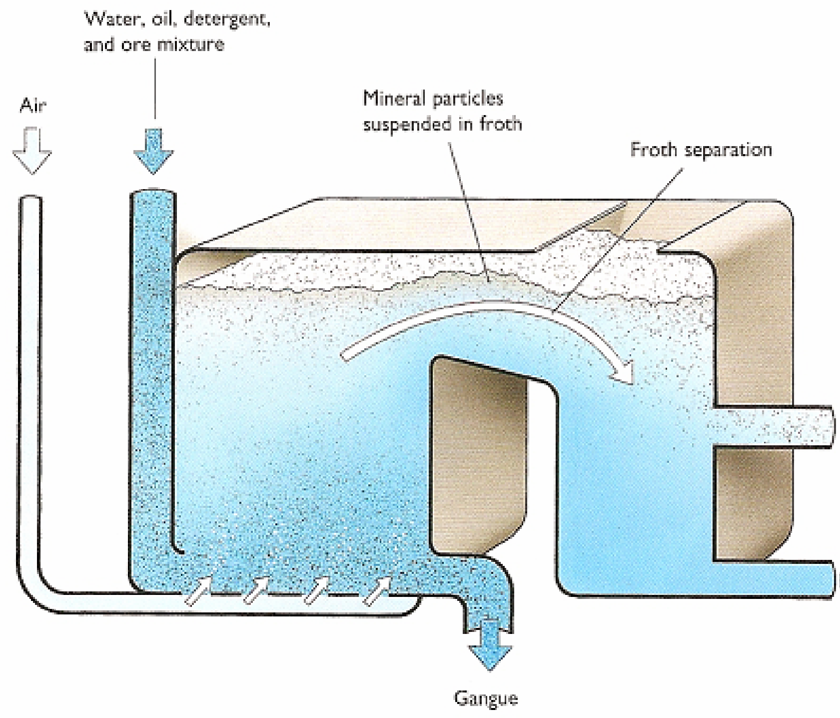
Mineral processing, otherwise known as mineral dressing, is the practice of beneficiating valuable minerals from their ores.

(Brian Knapp, BSc, PhD The earth resources, 2001)

Mineral Processing

Flotation

Froth flotation is achieved when particles are separated based on their surface potential. Hydrophobic particles are recovered to the froth, whereas hydrophilic particles are discharged with the tailings stream.



(Left) This diagram shows the principle of the froth-flotation process.

(Brian Knapp, BSc, PhD The earth resources, 2001)

Mineral Processin

Gravity separation

Particles can be classified based on their specific gravity.

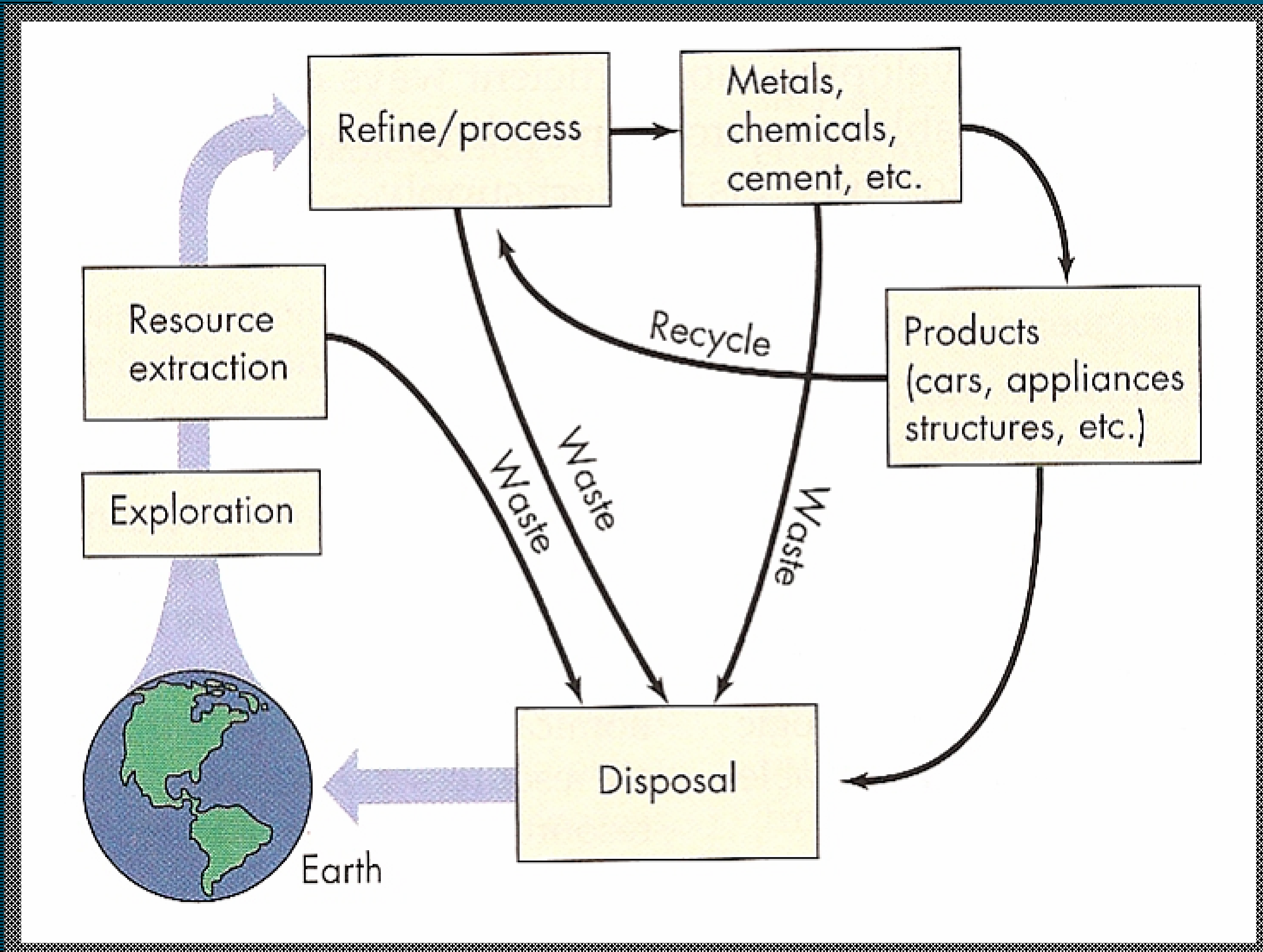
Electrostatic separation

Non-conducting particles maintain an electrostatic charge induced electrically, and so remain pinned to a charged drum.

Magnetic separation

Minerals such as magnetite and pyrrhotite are naturally magnetic, and so can be separated from non-magnetic particles using strong magnets..

Mineral Recycling



Environmental Impact of Mineral Development

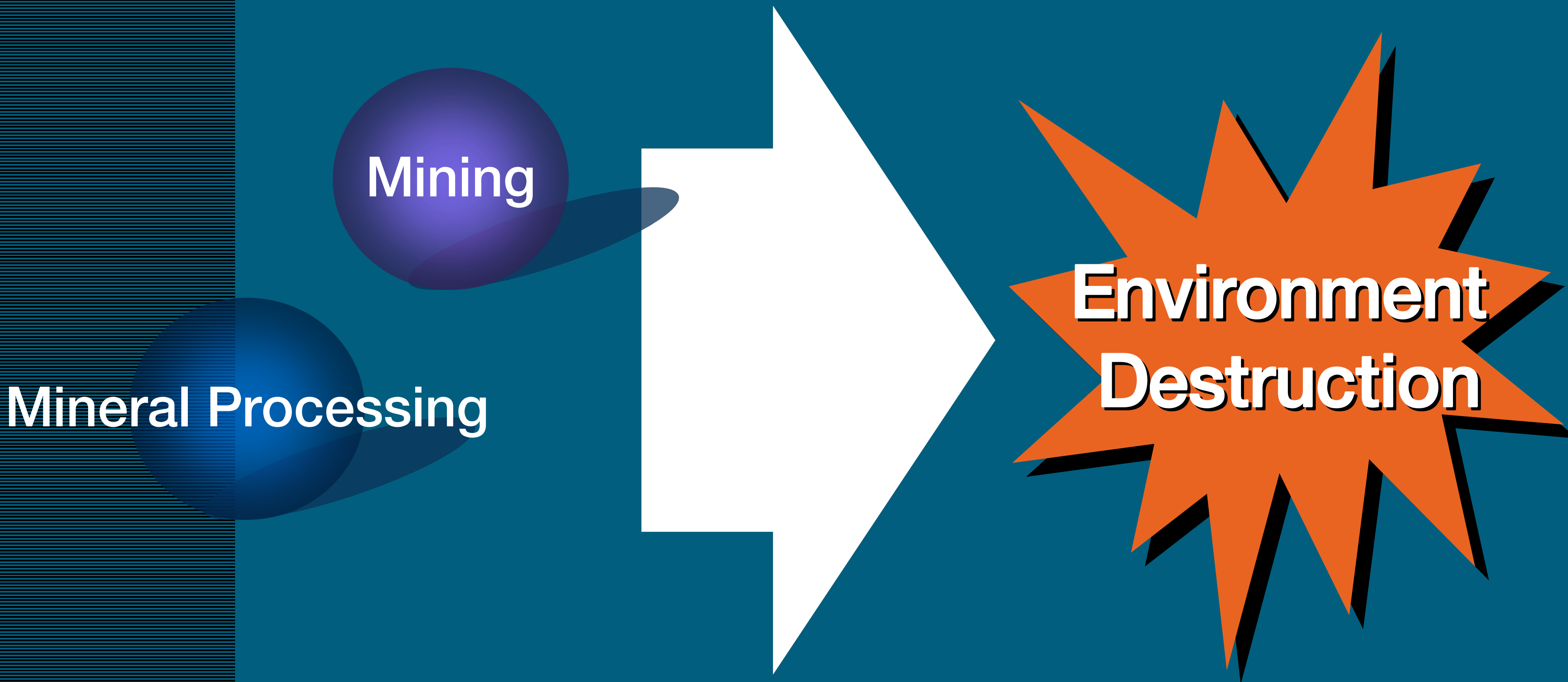
DANGER!!!

Yellow boy discolors water and smothers plant and animal life on the streambed, disrupting stream ecosystems.

Environmental Impact of Mineral Development

Environmental problem

The metals and industrial minerals that mining produces can find their way into the environment and become pollutants.



AMD

Acid mine drainage is polluted water that normally contains high levels of iron, aluminum, and acid (Hadley, Snow 1974). Drainage acidity arises from oxidation of pyrite, the crystalline form of iron sulfide (Hadley, Snow 1974).

The Oxidation of Pyrite

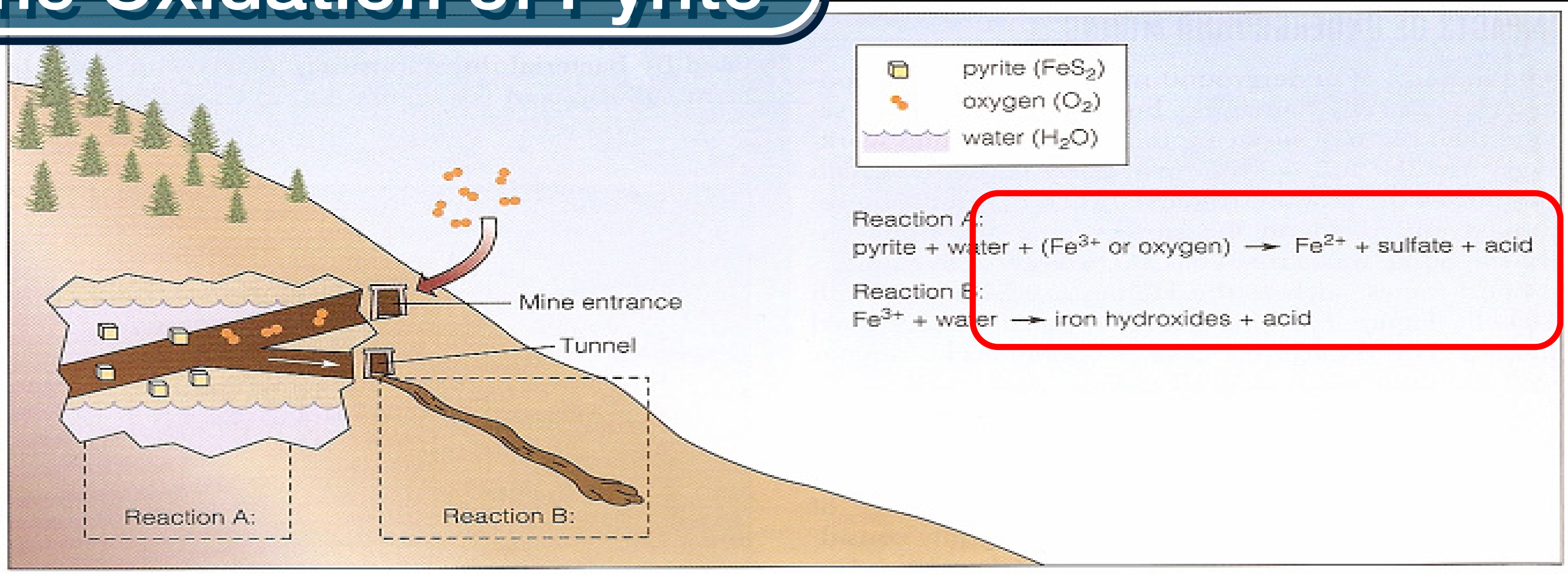


FIGURE 13.22 Pyrite reacts with air and water to produce sulfuric acid.

What Factors Influence the Quality of Mine Drainage?

Primary factors

Primary factors influencing the amount and quality of acidic water are the relative amount of water and oxygen in the environment. In order for pyrite to oxidize, both oxygen and water must be present. Water serves not only as a reactant, but also as a reaction medium and a product-transport solvent (Forstner, Salomons 1988).

Secondary factor

A secondary factor is the neutralization of acids by the alkalinity released from the carbonate minerals in the mine waste and surrounding stratum (Forstner, Salomons 1988).

Tertiary factors

Tertiary factors include the physical characteristics of mining waste, the spatial relationship between wastes, and the hydologic regime.

Environmental Impact of Mineral Development

Environmental problem

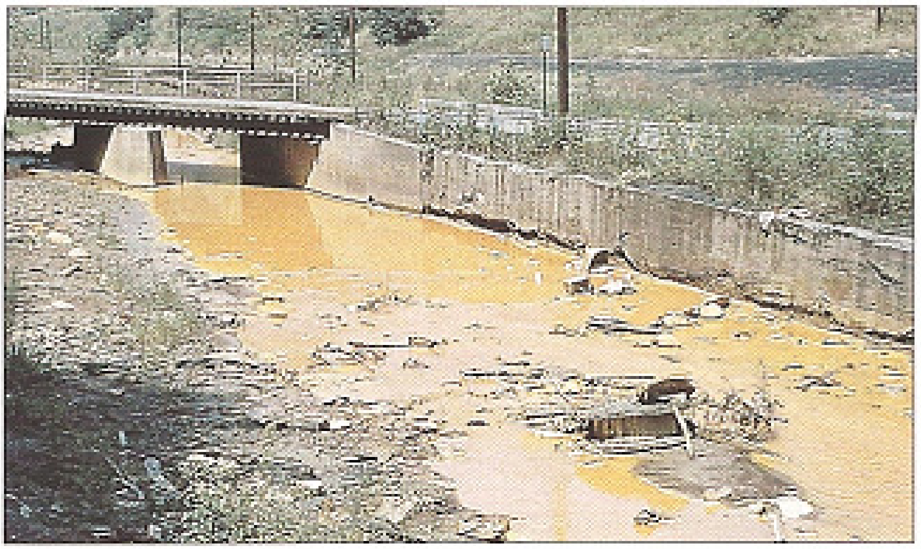


FIGURE 13.23 Rust-red sludge of acid mine drainage from West Virginia coal mines that were abandoned in the 1960s. The acidic water has eaten away at the Portland cement–based concrete retaining wall, and the bridge supports will soon share that fate. Problems such as this are rarely caused by modern surface mines, because current mining and reclamation practices eliminate or minimize acid mine drainage.

Photograph of Tinto River.
(Credit - Carol Stoker)

Environmental Impact of Mineral Development

Environmental problem

Another Contamination

FIGURE 13.32 A placer gold mining operation near Fairbanks, Alaska. A downstream settling pond traps placer tailings from the mine.

FIGURE 13.34 Removal of mill tailings at a Superfund site at Butte, Montana. Immense amounts of material must be moved at some Superfund sites.

FIGURE 13.35 Preparation of a repository site for contaminated smelter-flue dust near Anaconda, Montana. The pit will have a heavy polyethelene liner.

Environmental Impact of Mineral Development

Environmental problem

Another Contamination

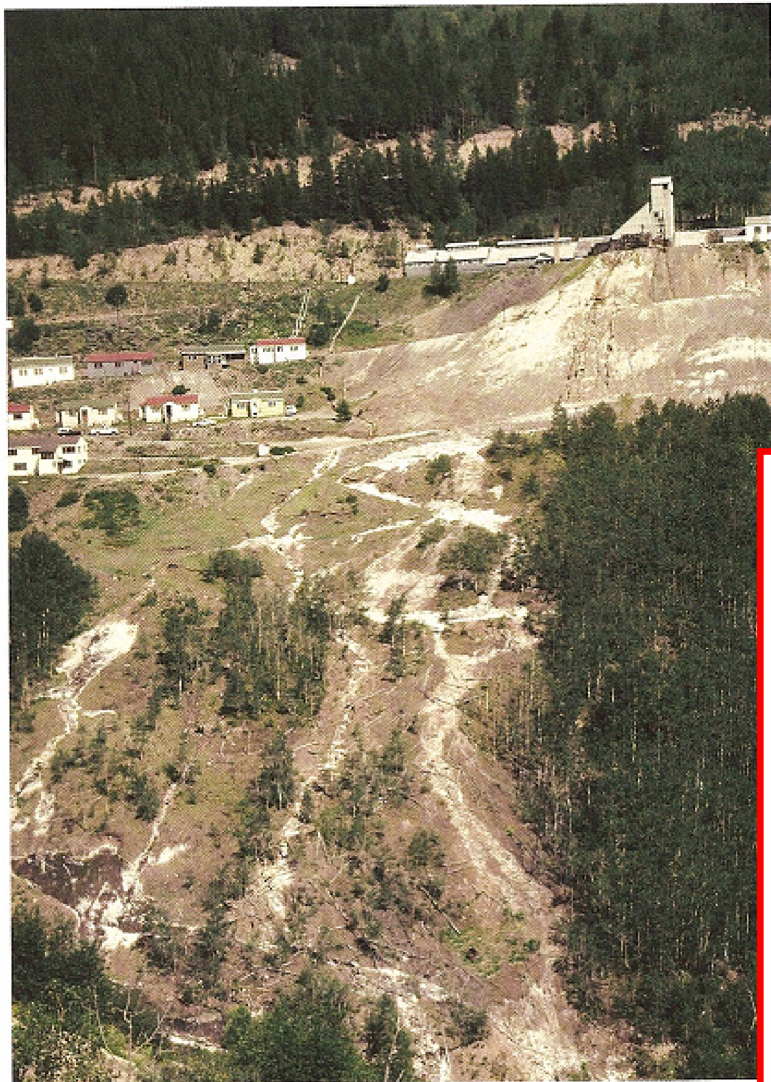


Figure 14.11 Runoff from mine tailings A zinc mine in Colorado. The white streaks are mineral deposits apparently leached from tailings. Many sites such as this one are the result of past mining practices in the U.S. that are not allowed today. *(Edward A. Keller)*

Figure 14.12 Closed mine filling with toxic water The Berkeley Pit near Butte, Montana, a polluted lake in a closed copper mine. *(Calvin Larsen/Photo Researchers, Inc.)*

Conclusion

Mineral and Sustainability

Sustainable Growth ✗

Sustainable Development ○

We need to find ways to use our resources more wisely
by finding substitutes, recycling, and conservation

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THANK YOU

Hallstatt

Site in upper Austria where objects characteristic of the Early Iron Age (from *c.* 1100 BC) were first identified.