



Geologic Resources

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1. GEOLOGIC RESOURCES

- With time, the human use of geologic resources has become increasingly sophisticated. Prehistoric people used **flint and obsidian** to make weapons and hand scrapers. About 7000 B.C., people learned to shape and fire **clay** to make pottery. Archeologists have found **copper ornaments** in Turkey from 6500 B.C.; 1500 years later, Mesopotamian farmers used **copper farm implements**. Today, the **silicon chip** that operates your computer, the **titanium valves** in a space probe, and the **gasoline** that powers your car are all derived from Earth resources



Flint Knife



Obsidian



Obsidian Scraper

1. GEOLOGIC RESOURCES

- Humans use two different types of geologic resources: **mineral resources and energy resources**
- Mineral resources include all useful rocks and minerals. Mineral resources fall into two groups: **nonmetallic resources and metals**.
- A **nonmetallic resource** is any useful rock or mineral that does not have metallic properties, such as salt or sand and gravel
- A **metal** is any chemical element with a metallic luster, ductility, and the ability to conduct electricity and heat. About 40 metals are commercially important. Some, such as **iron, lead, copper, aluminum, silver, and gold**, are familiar. Others, such as **vanadium, titanium, and tellurium**, are less well known but are vital to industry. All mineral resources are **nonrenewable**: We use them up at a much faster rate than natural processes create them



In the early 1900s, miners extracted gold, copper, and other metals from underground mines such as this one 600 meters below the surface in Butte, Montana. (Montana Historical Society)

1. GEOLOGIC RESOURCES

- We use **energy resources** for heat, light, work, and data transmission
- **Petroleum, coal, and natural gas** are called **fossil fuels** because they formed from the remains of plants and animals
- **Nuclear fuels** are radioactive isotopes used to generate electricity in nuclear reactors. **Uranium** is the most commonly used nuclear fuel
- These energy resources, like mineral resources, are **nonrenewable**
- **Alternative energy resources**, such as **solar, wind, and geothermal energy**, are **renewable**.



Coal



Petroleum



Nature Gas

2. NONMETALLIC MINERAL RESOURCES

- When we think about **striking it rich** from mining, we usually think of **gold**. However, more money has been made **mining sand and gravel** than gold
- For example, in the United States in 1994, sand and gravel produced **\$4.26 billion** in revenue, but gold produced **\$4.1 billion**. Sand and gravel are mined from stream and glacial deposits, sand dunes, and beaches



Mining sand and gravel



Gold Ore



Gold ore Mining

2. NONMETALLIC MINERAL RESOURCES

- **Portland cement** is made by heating a mixture of crushed **limestone and clay**. **Concrete** is a mixture of **cement, sand, and gravel**. Reinforced with steel, it is used to build **roads, bridges, and buildings**
- Many buildings are faced with stone—usually **granite or limestone**, although **marble, slate, sandstone**, and other rocks are also used. Stone is mined from **quarries cut into bedrock**



Portland Cement



Concrete Block



The Uses of Marble are numerous and diverse. You will be surprised by how it is used.

3. METALS AND ORE

- If you picked up any rock and sent it to a laboratory for analysis, the report would probably show that the rock contains measurable amounts of **iron, gold, silver, aluminum,** and other valuable metals
- However, the concentrations of these metals are so low in most rocks that the extraction **cost** would be much greater than the **income** gained by selling the metals. In certain locations, however, **geologic processes** have enriched metals many times above their **normal concentrations**

Table. Comparison of concentrations of specific elements in Earth's crust with concentrations needed to operate a commercial mine

ELEMENT	NATURAL CONCENTRATION IN CRUST (% BY WEIGHT)	CONCENTRATION REQUIRED TO OPERATE A COMMERCIAL MINE (% BY WEIGHT)	ENRICHMENT FACTOR
Aluminum	8	24–32	3–4
Iron	5.8	40	6–7
Copper	0.0058	0.46–0.58	80–100
Nickel	0.0072	1.08	150
Zinc	0.0082	2.46	300
Uranium	0.00016	0.19	1,200
Lead	0.00010	0.2	2,000
Gold	0.0000002	0.0008	4,000
Mercury	0.000002	0.2	100,000

3. METALS AND ORE

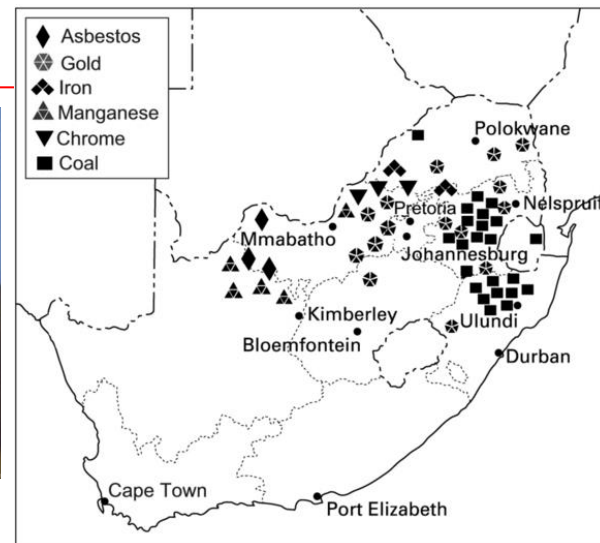
- A **mineral deposit** is a local enrichment of one or more minerals. **Ore** is rock sufficiently enriched in one or more minerals to be mined profitably
- Geologists usually use the term **ore** to refer to **metallic mineral deposits**, and the term is commonly accompanied by the name of the metal—for example, **iron ore** or **silver ore**
- The **concentration of a metal** in ore may exceed its average abundance in ordinary rock by a factor of more than **100,000**
- **Mineral reserves** are the known supply of ore in the ground. The term can refer to the amount of **ore remaining in a particular mine**, or it can be used on a global or national scale.



A mineral deposit



Copper ore



Distribution of metal mineral reserves in South Africa

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4. HOW ORE FORMS

- One of the primary objectives of many geologists is to **find new ore deposits**. Successful exploration requires an understanding of the processes that concentrate metals to form ore
- For example, **platinum** concentrates in certain types of **igneous rocks**. Therefore, if you were exploring for platinum, you would focus on those rocks rather than on sandstone or limestone



Platinum



Platinum ore



**Igneous rocks with
platinum ore**

4. HOW ORE FORMS

4.1 MAGMATIC PROCESSES

- Magmatic processes form mineral deposits as liquid magma solidifies to form an igneous rock. These processes create **metal ores** as well as some **gems** and valuable **sulfur deposits**
- **Layered Plutons**
- Some large bodies of igneous rock, particularly those of **mafic (basaltic) composition**, solidify in **layers**. Each layer contains different minerals and is of a different chemical composition from adjacent layers. Some of the layers may contain **rich ore deposits**. The layering can develop by at least **three processes**:
 - 1. Cooling magma does not solidify all at once. Instead, **higher-temperature minerals** crystallize first, and **lower-temperature minerals** form later as the temperature drops. Most minerals are denser than magma. Consequently, **early-formed crystals** may sink to the **bottom of a magma chamber** in a process called **crystal settling**. In some instances, ore minerals crystallize with other early-formed minerals and consequently accumulate in layers near the bottom of the pluton

4. HOW ORE FORMS

4.1 MAGMATIC PROCESSES

- The layering can develop by at least **three processes**:
- 2. Some large bodies of mafic magma crystallize from the bottom upward. Thus, early-formed ore minerals become concentrated near **the base of the pluton** by this process

- 3. In some cases, a large body of magma may begin to develop **layering** by either of the two processes just described. Then, additional magma of a different composition or temperature may flow into the magma chamber. As a result of these changes, **different minerals may crystallize at different times** to create layering in the pluton

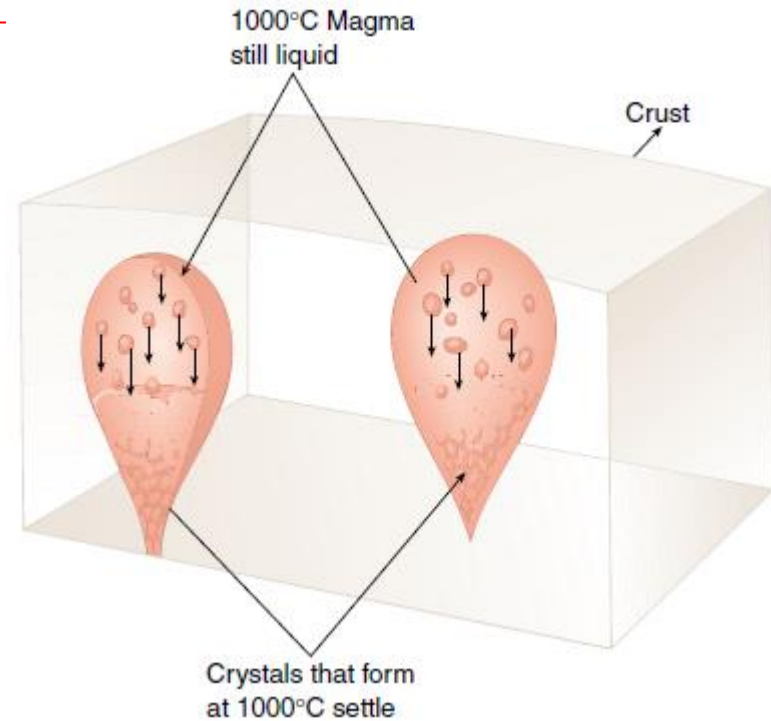


Figure. Early-formed crystals settle and concentrate near the bottom of a magma chamber

4. HOW ORE FORMS

4.1 MAGMATIC PROCESSES

➤ The largest ore deposits found in mafic layered plutons are the rich chromium and platinum reserves of South Africa's Bushveld intrusion. The pluton is about 375 by 300 kilometers in area and about 7 kilometers thick. The Bushveld deposits contain more than 20 billion tons of chromium and more than 10 billion grams of platinum, the greatest reserves in any known deposit on Earth

➤ **Kimberlites**

➤ Kimberlites originate in the mantle and are the world's main source of diamonds. Diamonds are used both for jewelry and as industrial abrasives because of their great hardness. The world's largest known diamond deposit occurs at Kimberley, South Africa. Now, however, most industrial diamonds are produced synthetically

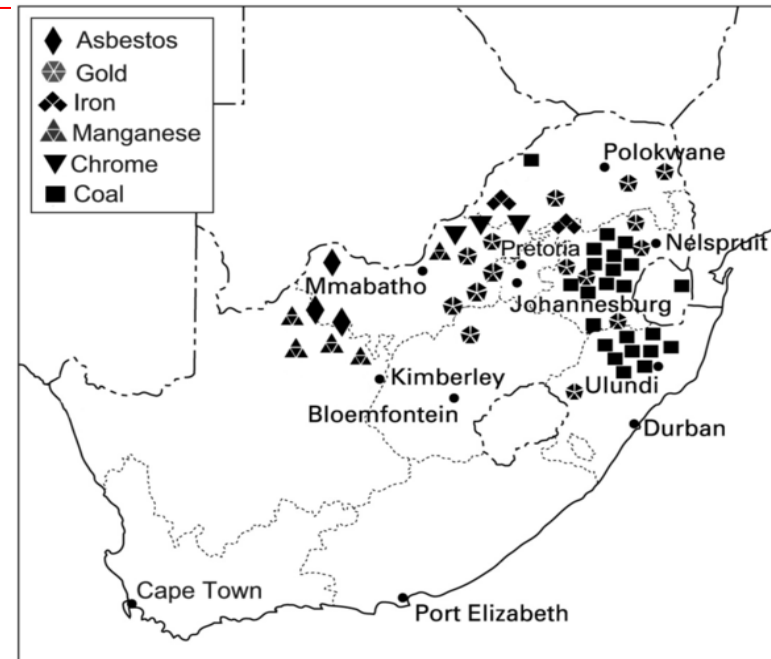


Figure. Distribution of metal mineral reserves in South Africa

4. HOW ORE FORMS

4.1 MAGMATIC PROCESSES

- **Volcanic Vent Deposits**
- **Sulfur**, used primarily for sulfuric acid in industrial applications, precipitates as a pure **yellow deposit** from gases escaping from some volcanic vents
- Such deposits are sometimes mined even as the sulfur-rich fumes continue to escape from the volcano



Figure. Yellow sulfur coats the vent of Ollagüe volcano, southern Bolivia

4. HOW ORE FORMS

4.2 HYDROTHERMAL PROCESSES

- Hydrothermal processes are probably responsible for the formation of **more** ore deposits, and a **larger total quantity** of ore, than all other processes combined
- The magmatic hydrothermal fluid is the heated water **containing** a large amount of valuable elements
- To form a hydrothermal ore deposit, **hot water** dissolves metals from rock or magma. The metal-bearing solutions then seep through cracks or through permeable rock until they **precipitate to form an ore deposit**

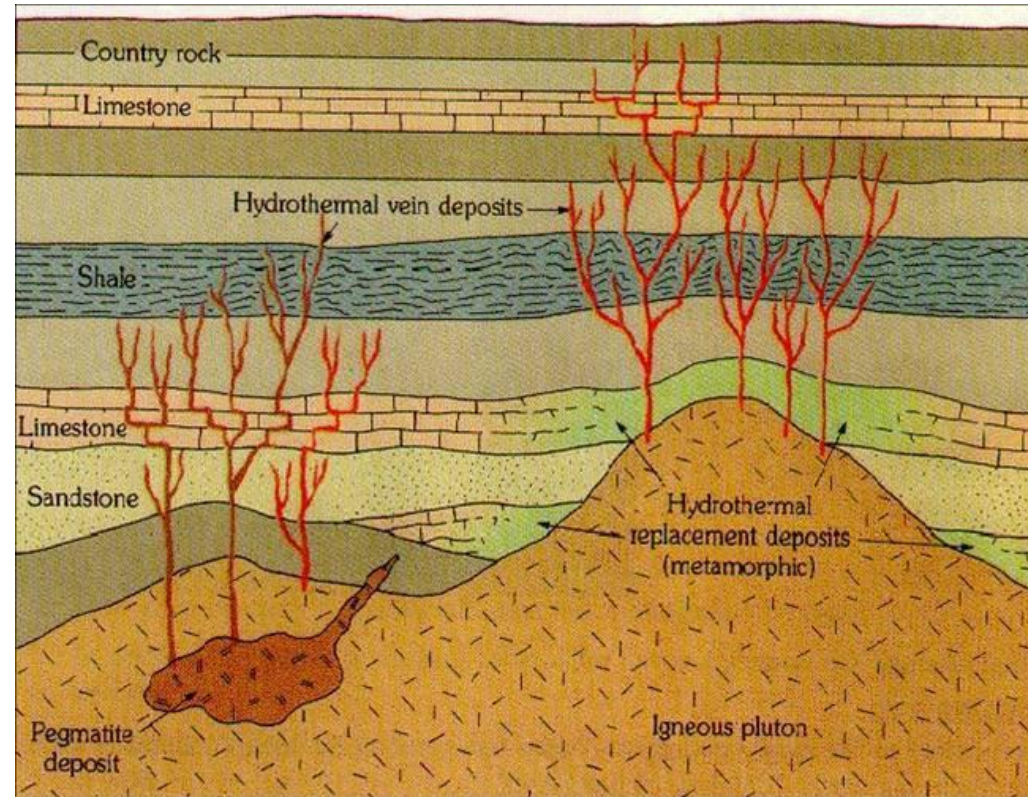


Figure. The formation process of hydrothermal ore deposits

Key word:

Pegmatite, a form of igneous rock consisting of extremely coarse granite resulting from the crystallization of magma rich in rare elements

4. HOW ORE FORMS

4.2 HYDROTHERMAL PROCESSES

- **Three main sources** provide water for hydrothermal activity:
- **1. Many magmas, particularly those of granitic composition, leave behind a water-rich residual fluid after most of the magma has solidified. Under certain conditions, that fluid crystallizes to form pegmatite. Under other conditions, the water and dissolved ions escape from the magma chamber to form hydrothermal solutions. For this reason, hydrothermal ore deposits are commonly associated with granite and similar igneous rocks**
- **2. Ground water** can seep into the crust where it is heated and forms a hydrothermal solution. This is particularly true in areas of active volcanism where hot rock or magma heats ground water at shallow depths. For this reason, hydrothermal ore deposits are also common in volcanic regions
- **3. In the oceans, seawater** is heated as it seeps into cracks along the mid-oceanic ridge and near submarine volcanoes

4. HOW ORE FORMS

4.2 HYDROTHERMAL PROCESSES

➤ Although most of metals are present in very **low concentrations** in country rock, hydrothermal solutions **percolate through** vast volumes of rock, dissolving and accumulating the metals. The solutions then deposit the metals when they encounter changes in temperature, pressure, or chemical environment

➤ In this way, hydrothermal solutions **scavenge** metals from large volumes of average crustal rocks and then deposit them **locally** to form ore.

➤ In addition, some magmas also contain metals, which **concentrate with** the hydrothermal solutions that form as the magma solidifies

Key word:

Scavenge, collect discarded or refused material.

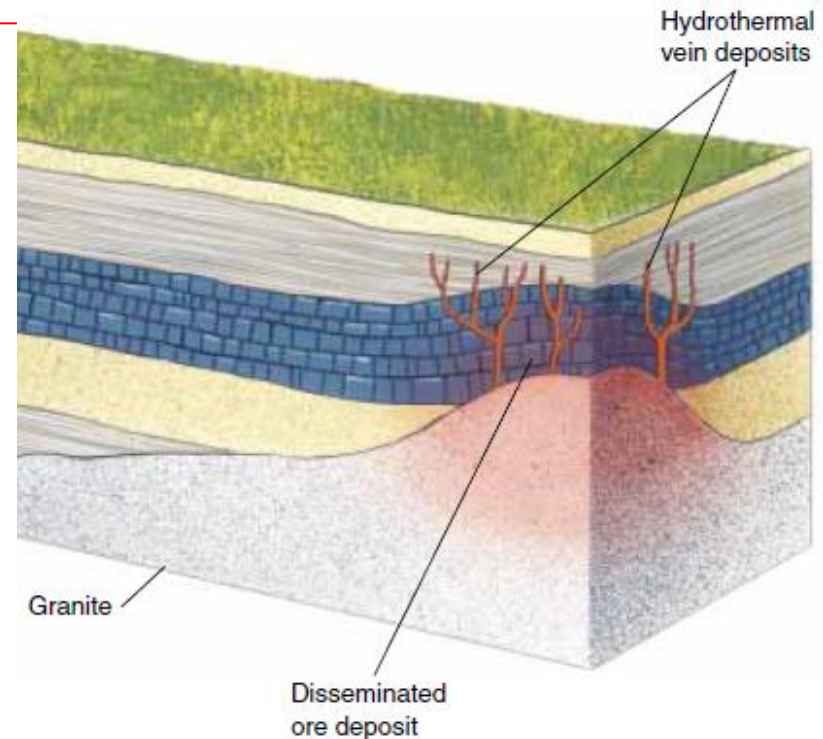


Figure. Hydrothermal ore deposits form when hot water deposits metals in bedrock.

4. HOW ORE FORMS

4.2 HYDROTHERMAL PROCESSES

- **Types of Hydrothermal Ore Deposits**
- **A hydrothermal vein deposit forms when dissolved metals precipitate in a fracture in rock. Ore veins range from less than a millimeter to several meters in width. A single vein can yield several million dollars worth of gold or silver. The same hydrothermal solutions may also soak into country rock surrounding the vein to create a large but much less concentrated disseminated ore deposit. Because they commonly form from the same solutions, rich ore veins and disseminated deposits are often found together**
- **The history of many mining districts is one in which early miners dug shafts and tunnels to follow the rich veins. After the veins were exhausted, later miners used huge power shovels to extract low-grade ore from disseminated deposits surrounding the veins**

Key word:

Shaft, a vertical passage into a mine, such as vertical well.

4. HOW ORE FORMS

4.2 HYDROTHERMAL PROCESSES

- **Types of Hydrothermal Ore Deposits**
- **Disseminated copper deposits, with accompanying veins, are abundant. They are most commonly associated with large plutons and are called porphyry copper deposits**
- **Both the plutons and the copper deposits formed as a result of subduction that occurred as North and South America migrated westward after the breakup of Pangea**
- **Other metals, including lead, zinc, molybdenum, gold, and silver, are found with porphyry copper deposits. Examples of such deposits occur at Butte, Montana; Bingham, Utah; Morenci, Arizona; and Ely, Nevada**

Key word:

Porphyry is a term for an igneous rock in which large crystals, usually feldspar, are set in a finer-grained matrix. Most porphyry copper deposits are found in porphyrys of granitic to dioritic composition.



Figure. Porphyry copper deposits in the Western Hemisphere lie along modern or ancient tectonic plate boundaries.

4. HOW ORE FORMS

4.2 HYDROTHERMAL PROCESSES

- **Types of Hydrothermal Ore Deposits**
- Ore deposits also form at hydrothermal vents near the **mid-oceanic ridge** and submarine volcanoes
- Metal-bearing hydrothermal solutions precipitate **huge deposits of iron, copper, lead, zinc, and other metals** within the sea-floor sediment and basalt. **Tectonic activity** may eventually carry submarine hydrothermal deposits to the Earth's surface
- The copper deposits of Jerome, Arizona, the **Apennine Alps** of northern Italy and Cyprus, and the copper-lead-zinc deposits of New Brunswick, Canada, formed in this manner

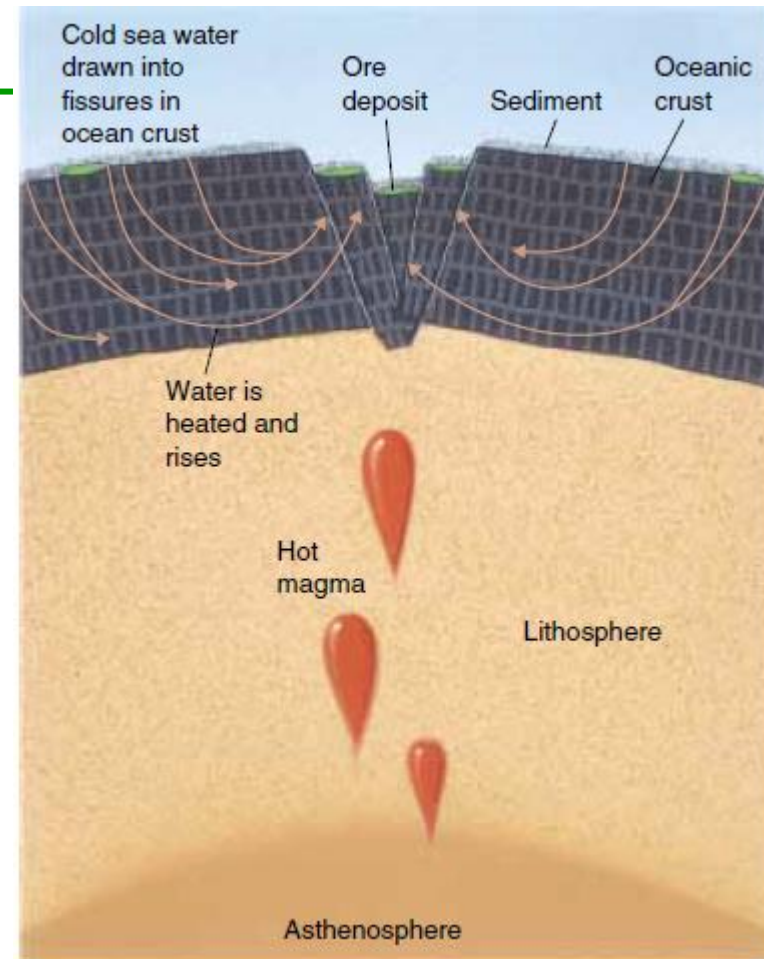


Figure. Submarine hydrothermal ore deposits precipitate from circulating seawater near the mid-oceanic ridge.

Key word:

Apennine Alps is a branch of Alps, ran through the South and the North in Italy, the Italian Mediterranean orientation. **Alps is** a large mountain system in south-central Europe, from the south of France to the east of Austria

4. HOW ORE FORMS

4.3 SEDIMENTARY PROCESSES

- Two types of sedimentary processes form ore deposits: **sedimentary sorting and precipitation**
- **Sedimentary Sorting: Placer Deposits**
- **Placer gold mine. Gold is denser than any other mineral. Therefore, if you swirl a mixture of water, gold dust, and sand in a pan, the gold falls to the bottom first (Seeing the Fig.). Differential settling also occurs in nature**



Figure. Jeffery Embrey panning for gold near his cabin in Park City, Montana, in 1898. (Maud Davis Baker/Montana Historical Society)

Key word:

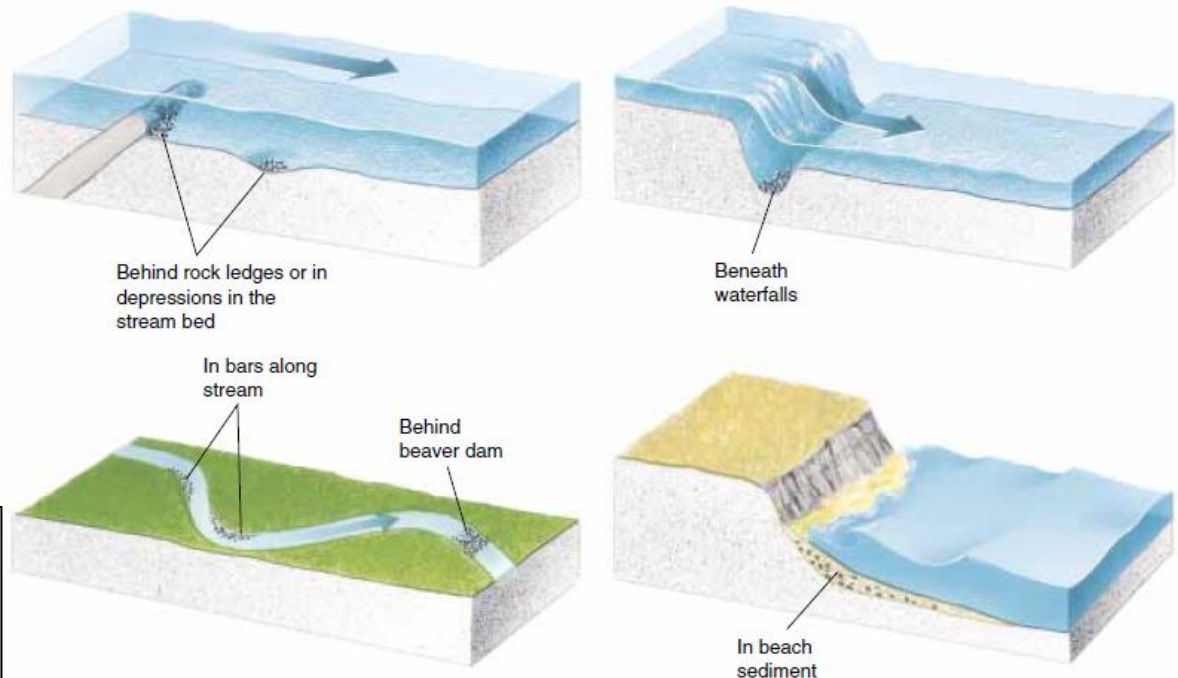
Placer Deposit is an alluvial deposit that contains particles of some valuable mineral. **Placer**, surface sediment containing particles of gold or some other valuable mineral (冲积矿)

4. HOW ORE FORMS

4.3 SEDIMENTARY PROCESSES

- **Sedimentary Sorting: Placer Deposits**
- Many streams carry silt, sand, and gravel with an occasional small grain of gold. The gold settles first when the current slows down. Over years, currents agitate the sediment and the heavy grains of gold work their way into cracks and crevices in the stream bed. Thus, grains of gold concentrate near bedrock or in coarse gravel, forming a **placer deposit**. It was primarily placer deposits that brought prospectors to California in the Gold Rush of 1849

Figure. Placer deposits form where water currents slow down and deposit heavy minerals.



Key word:

Ledge, a projecting ridge on a mountain or submerged under water.

4. HOW ORE FORMS

4.3 SEDIMENTARY PROCESSES

- **Precipitation**
- Ground water dissolves minerals as it seeps through soil and bedrock. In most environments, ground water eventually flows into streams and then to the sea. Some of these dissolved ions, such as **sodium** and **chloride**, make seawater salty. In deserts, however, lakes develop with no outlet to the ocean. Water flows into the lakes but can escape only by evaporation. As the water evaporates, the dissolved ions concentrate until they precipitate to form **evaporite deposits**

- Evaporite deposits formed in desert lakes include **table salt**, **borax**, **sodium sulfate**, and **sodium carbonate**
- These salts are used in the production of **paper**, **soap**, and **medicines** and for the tanning of **leather**



Evaporite deposit



Borax

Key word:

Borax, an ore of boron consisting of hydrated sodium borate; used as a flux or cleansing agent.

4. HOW ORE FORMS

4.3 SEDIMENTARY PROCESSES

- **Precipitation**
- About 1 billion tons of iron are mined every year, 90 percent from sedimentary rocks called **banded iron formations**, which consist of layers of iron-rich minerals sandwiched between beds of silicates. The alternating layers are a few centimeters thick and give the rocks their banded appearance. **The most abundant and economically** important banded iron formations developed between 2.6 and 1.9 billion years ago when iron precipitated from seawater as a result of rising atmospheric oxygen concentration

- **Thick marine evaporite** beds formed in sedimentary process and evaporation
- **Table salt, gypsum** (used to manufacture plaster and sheetrock), and **potassium salts** (used in fertilizer) are mined extensively from these deposits

Key word: *chert*, a microcrystalline form of silica usually occurring as bands or layers of pebbles in sedimentary rock. Formula: SiO_2 . Varieties include flint, lydite (Lydian stone) 燧石 (Also called hornstone)

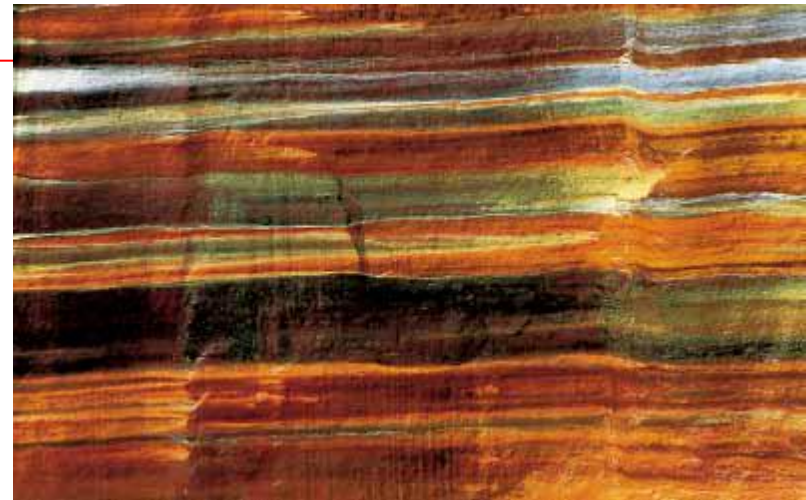


Figure. In this banded iron formation from Michigan, the red bands are iron minerals and the dark layers are chert. (Barbara Gerlach/Visuals Unlimited)

4. HOW ORE FORMS

4.4 WEATHERING PROCESSES

➤ In environments with high rainfall, the abundant water dissolves and removes most of the soluble ions from soil and rock near the Earth's surface. This process leaves the relatively insoluble ions in the soil to form **residual deposits**. Both **aluminum** and **iron** have very low solubilities in water. **Bauxite**, the principal source of aluminum, forms as a residual deposit, and in some instances iron also concentrates enough to become ore

➤ Most bauxite deposits form in warm, rainy, **tropical or subtropical environments** where chemical weathering occurs rapidly, such as those of modern **Jamaica, Cuba, Guinea, Australia**, and parts of the southeastern United States

➤ Some bauxite deposits are found today in regions with dry, cool climates. Most of them, however, formed when the regions had a warm, wet climate, and **they reflect climatic change** since their origin



Figure. Bauxite forms by intense weathering of aluminum-bearing rocks. (H. E. Simpson /USGS)

Key word: *Bauxite*, ['bɔ:ksaɪt], a clay-like mineral; the chief ore of aluminum; composed of aluminum oxides and aluminum hydroxides; used as an abrasive and catalyst.

4. HOW ORE FORMS

4.4 WEATHERING PROCESSES

- Weathering also forms immense amounts of clay, a nonmetallic resource. One clay mineral, called **kaolin**, is the primary constituent of porcelain and other ceramics. Another, **smectite**, is mixed with water and other minerals to make drilling mud, a clay-rich slurry used to cool and lubricate drill bits in the drilling of deep wells.
- Several types of clay are used to line sanitary landfills and irrigation ditches and ponds because wet clay is impermeable



Kaolin



Smectite



A clay-rich slurry

Key word:

Clay minerals, any of a group of minerals consisting of hydrated aluminium silicates: the major constituents of clays.



4. HOW ORE FORMS

4.5 METAMORPHIC PROCESSES

➤ A metamorphic rock forms when heat and pressure alter the mineralogy and texture of any preexisting rock. Metamorphism can also expel water from rocks to create hydrothermal fluids, which, in turn, deposit metal ores. Thus, some hydrothermal ore deposits are of metamorphic origin. Metamorphic processes also form several types of nonmetallic mineral resources

➤ Asbestos is a commercial name for two different minerals (serpentine and amphibole) formed by metamorphism

➤ Manufacturers and builders began using asbestos for its desirable physical properties: sound absorption, average tensile strength, resistance to fire, heat, electricity, and affordability



Fibrous tremolite asbestos on muscovite

Key word: *Asbestos*, $\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$, a thin fibrous magnesium silicate crystals 石棉



4. HOW ORE FORMS

4.5 METAMORPHIC PROCESSES

- Graphite, the main component of the “lead” in pencils, forms when metamorphism alters the carbon in some organic-rich rocks
- Metamorphism also forms marble, a valuable building stone and sculptor’s material, from limestone
- Other mineral resources formed by metamorphism include: talc, corundum, phosphorite, contact metasomatic skarn polymetal deposit and so on



Graphite



Marble



Corundum

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5. MINERAL RESERVES

- **Mineral reserves** are the known supply of ore in the ground. The term can refer to the amount of **ore remaining in a particular mine**, or it can be used on a global or national scale
- Mining depletes mineral reserves by decreasing the amount of ore remaining in the ground; but **reserves may increase in two ways**:
- First, geologists may discover **new mineral deposits**, thereby adding to the known amount of ore
- Second, **sub-economic mineral deposits**—those in which the metal is not sufficiently concentrated to be mined at a profit—can become profitable if the **price** of that metal increases, or if **improvements in mining or refining technology** reduce extraction costs

5. MINERAL RESERVES

- In 1966, geologists estimated that global reserves of iron were about 5 billion tons. At that time, world consumption of iron was about 280 million tons per year. Assuming that consumption continued at the 1966 rate, the global iron reserves identified in 1966 would have been exhausted in 18 years (5 billion tons/280 million tons per year, 18 years), and we would have run out of iron ore in 1984
- But iron ore is still plentiful and cheap today because new and inexpensive methods of processing lower-grade iron ore were developed. Thus, deposits that were sub-economic in 1966, and therefore not counted as reserves, are now ore

5. MINERAL RESERVES

THE GEOPOLITICS OF METAL RESOURCES

- The Earth's mineral resources are unevenly distributed, and no single nation is self-sufficient in all minerals. For example, almost two thirds of the world's **molybdenum** reserves and more than one third of the **lead** reserves are located in the United States. More than half of the **aluminum** reserves are found in Australia and Guinea. The United States uses 40 percent of all aluminum produced in the world, yet it has no large **bauxite** deposits. Zambia and Zaire supply half of the world's **cobalt**, although neither nation uses the metal for its own industry
- Five nations—the **United States, Russia, South Africa, Canada, and Australia**—supply most of the mineral resources used by modern societies. Many other nations have few mineral resources. For example, **Japan** has almost no metal or fuel reserves; despite its thriving economy and high productivity, it relies entirely on imports for both

5. MINERAL RESERVES

THE GEOPOLITICS OF METAL RESOURCES

- Developed nations consume most of the Earth's mineral resources. Four nations—the United States, Japan, Germany, and Russia—consume about 75 percent of the most intensively used metals, although they account for only 14 percent of world population
- Currently, the United States depends on 25 other countries for more than half of its mineral resources. Some must be imported because the United States has no reserves of its own. In fact, the first and second world wars, the main reason is the allocation of resources, including the on-going local wars
- Everybody knows that resources of the Earth are finite and sooner or later we will run out of oil, coal and most of the metals. And when it happens, the consequences will be unimaginably catastrophic. It will be so if we do nothing at all to forestall these consequences

6. COAL

- The three major fossil fuels are coal, petroleum, and natural gas. All form from the partially decayed remains of living organisms. Humans began using coal first because it is easily mined and can be burned without refining
- Coal is an abundant source of energy. Coal-fired electric generating plants burn about 60 percent of the coal consumed in the United States. Coal supplies more than 70% of the electricity consumed by China. The remainder is used to make steel or to produce steam in steam locomotives and factories. Coal is also used in the manufacture of synthetic natural gas
- Although it is easily mined and abundant in many parts of the world, coal emits air pollutants that can be removed only with expensive control devices



6. COAL

- Large quantities of coal formed worldwide during the **Carboniferous Period**, between **360 and 285** million years ago, and later in **Cretaceous and Paleocene** times, when warm, humid swamps covered broad areas of low-lying land. Coal is probably forming today in some places, such as in the **Ganges River delta** in India, but the process is much slower than the rate at which we are consuming coal reserves. As shown in following Figure, widespread availability of this fuel is expected at least until the year 2200

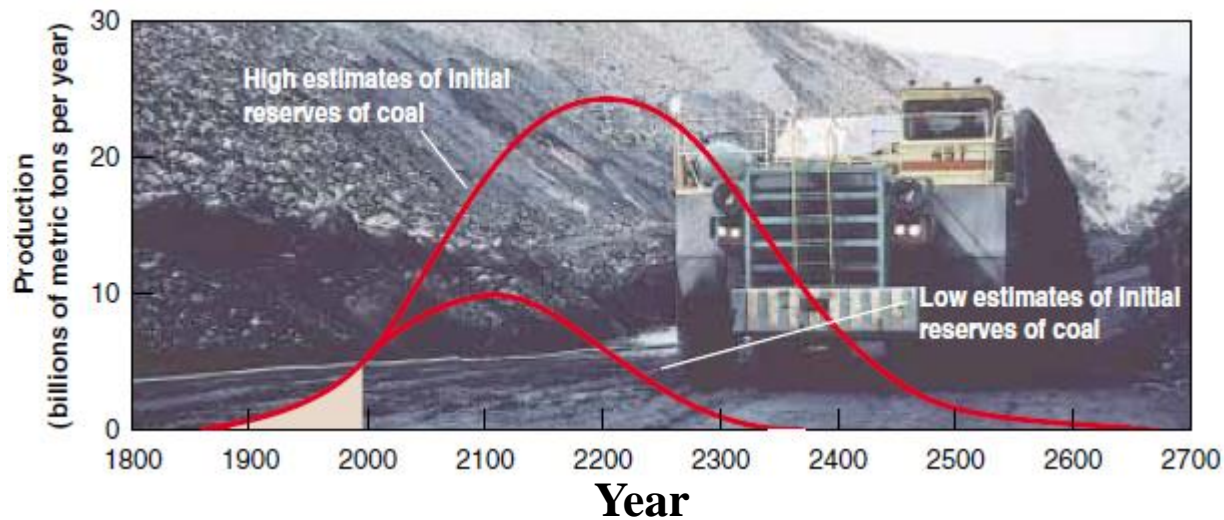
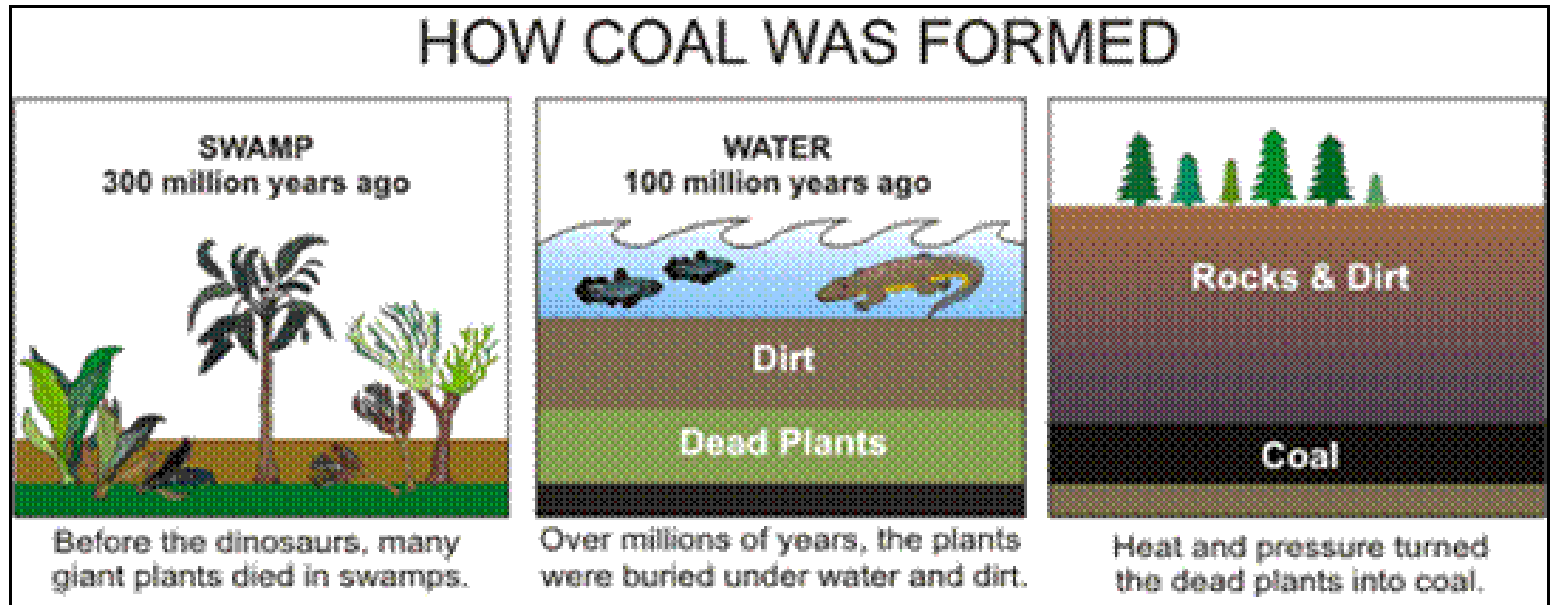


Figure. Past and predicted global coal supplies based on two different estimates of reserves. Shaded area shows coal already consumed. (Adapted from M. King Hubbard)

6. COAL

6.1 COAL FORMATION

- When plants die in forests and grasslands, organisms consume some of the litter, and chemical reactions with oxygen and water decompose the remainder. As a result, little organic matter accumulates except in the topsoil. In some warm swamps, however, plants grow and die so rapidly that newly fallen vegetation quickly buries older plant remains. The new layers prevent atmospheric oxygen from penetrating into the deeper layers, and decomposition stops before it is complete, leaving brown, partially decayed plant matter called peat. Commonly, peat is then buried by mud deposited in the swamp



7. COAL

COAL FORMATION

- Plant matter is composed mainly of carbon, hydrogen, and oxygen and contains large amounts of water. During burial, rising pressure expels the water and chemical reactions release most of the hydrogen and oxygen, and the proportion of carbon increases. The result is coal, a combustible rock composed mainly of carbon

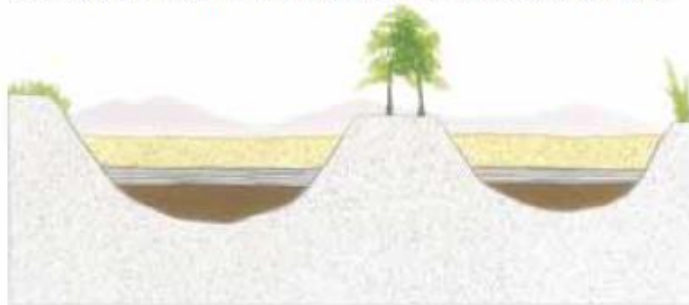
(a) Litter falls to floor of stagnant swamp



(b) Debris accumulates, barrier forms, decay is incomplete



(c) Sediment accumulates, organic matter is converted to peat



(d) Peat is lithified to coal

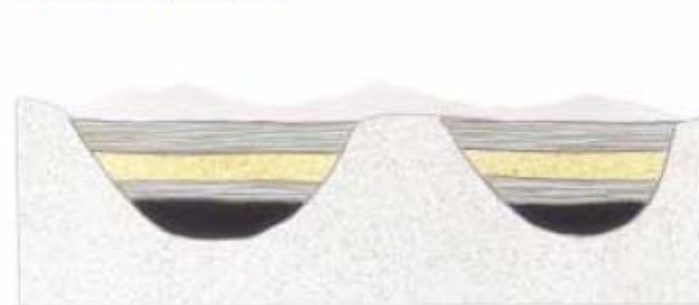


Figure. Peat and coal form as sediment buries organic litter in a swamp.

7. COAL

6.2 COAL TYPES

- In fact, there are four stages in coal formation: peat, lignite, bituminous and anthracite
- **Peat.** Peat is not coal but represent the initial stage of coal development. Peat is generally considered to be partly decomposed biomass (organic materials). This forerunner of coal is a cheap source of fuel but does not contain enough carbon compared to the other elements to be an efficient energy producer
- **Lignite.** Over time these areas with peat accumulation experienced cyclical periods of subsidence and reemergence. During the periods of subsidence, the relatively high temperature and pressure will turn the peat into lignite



Figure. Peat in a swamp.

7. COAL

6.2 COAL TYPES

- Compared to peat, **lignite** has a higher density and higher content of carbon. At this stage, the coal still belongs to sedimentary rock
- Lignite is the youngest type of coal. And some lignite is merely 1 million years old. It is soft and brown in color and mainly used for electric power generation. It is subject to spontaneous combustion as it oxidizes in air



Figure. Lignite.

7. COAL

6.2 COAL TYPES

- **Bituminous.** With the increasing depth, lignite will undertake metamorphism. The higher hydrostatic pressure due to the overlying materials and the resulting higher temperature will finally metamorphose the lignite into bituminous
- At this point, a series of physical and chemical processes take place and the chemical composition and internal structure of lignite are totally altered. **Bituminous** has a higher concentration of carbon than lignite

- Bituminous usually is called **soft coal**. It is an **lower-grade metamorphic rock**. It is used primarily for generating electricity and making coke for the steel industry. Bituminous are dusty to handle, ignite readily, and burn with a **smoky flame**



Figure. Bituminous

7. COAL

6.2 COAL TYPES

- **Anthracite.** When bituminous is subjected to further increasing pressure and temperature, it is converted to anthracite. The Anthracite is the **final product** of coalification. It is actually a **high-grade metamorphic rock** and has the highest carbon content
- Anthracite usually is **called hard coal**. It is denser and contains less moisture and gases and has a higher heat value than lower-ranking bituminous and lignite

- Anthracite, which is nearly **pure carbon**, is very hard and black and is extensively used for **home heating**. Anthracite has **semi-metallic luster** and is capable of burning with little smoke



Figure. Anthracite

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- **NONMETALLIC MINERAL RESOURCES**
- **METALS AND ORE**
- **HOW ORE FORMS**
- **MINERAL RESERVES**
- **COAL**
- **MINES AND MINING**
- **PETROLEUM AND NATURAL GAS**
- **NUCLEAR FUELS AND REACTORS**

6. MINES AND MINING

- Miners extract both coal and ore from underground mines and surface mines. A large underground mine may consist of tens of kilometers of interconnected passages that commonly follow ore veins or coal seams. The lowest levels may be several kilometers deep. In contrast, a surface mine is a hole excavated into the Earth's surface
- The largest human-created hole is the open-pit copper mine at Bingham Canyon, Utah. It is 4 kilometers in diameter and 0.8 kilometer deep. The mine produces 230,000 tons of copper a year and smaller amounts of gold, silver, and molybdenum



Figure. Machinery extracts coal from an underground coal mine.

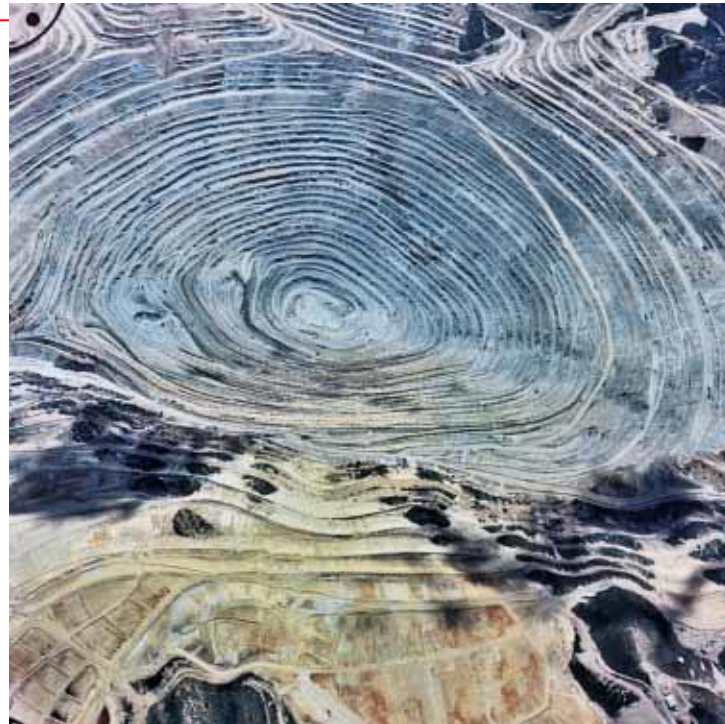


Figure. An aerial view of the Bingham Canyon, Utah, open-pit copper mine. (Agricultural Stabilization and Conservation Service/USDA)

6. MINES AND MINING

- Most modern coal mining is done by large **power shovels** that extract coal from huge surface mines
- Both **metal ore** and **coal** are commonly covered and surrounded by soil and rock that is not of marketable quality. As a result, miners must dig up and discard large amounts of waste rock as they expose and extract the resource. The **waste rock** from both surface and underground mines was usually **piled up near the mine**



Figure. A huge power shovel dwarfs a person standing inside the Navajo Strip Mine in New Mexico. (H. E. Malde/USGS)

- The wastes were **easily eroded**, and the muddy runoff poured into nearby streams, **destroying aquatic habitats**
- Heavy metals, such as **lead, cadmium, zinc, and arsenic**, are common in many metal ores, and rain can leach them from the mine wastes and carry them to streams and ground water. They are **dangerous** for any animals and plants, especially for **human being**

6. MINES AND MINING

- In addition, **sulfur** is abundant in many metal ores as well as in coal. The sulfur reacts with water in the presence of air to produce **sulfuric acid** (H_2SO_4). If pollution control is inadequate, the sulfuric acid then **runs off into** streams and ground water below the mine or mill. Therefore, extracting and using coal produce impacts environment seriously
- Today, **responsible governments and mining companies** use several methods to stabilize mine and mill wastes



Figure. The waste rock from both surface and underground mines was usually piled up near the mine

- For example, they use crushed **limestone** to **neutralize acid waters**; they build well-designed settling ponds to **trap silt**; and they **backfill abandoned mines** and settling ponds
- These measures can be costly, but they greatly **reduce the quantity of pollutants** that escape into streams and ground water
- **New coal technologies** should be developed to meet the world's energy needs in a **sustainable way**

6. MINES AND MINING

ORE SMELTERS AND COAL BURNING

- When sulfide ore minerals are refined or when sulfur-bearing coal is burned without pollution control devices, the sulfur escapes into the atmosphere, where it forms hydrogen sulfide and sulfuric acid. These gases contribute to acid precipitation. Most of the sulfur can be removed by pollution control devices



Figure. Ore minerals smelters and coal burning

- Underground mining can lead to ground subsidence
- Products of coal combustion include the oxides of carbon, nitrogen, and sulfur
- Other toxic elements and compounds, including heavy metals such as lead, cadmium, zinc, and arsenic, can escape from smelters into the atmosphere and water
- They too can be removed by pollution control devices

7. OIL AND NATURAL GAS

- Oil, is often referred to as ‘black gold’ due to its great value to mankind. The products derived from oil are the ‘lifblood’ of modern society. It touches all of our lives
- Today, over 6,000 products are produced wholly, or in part, from petroleum. The petroleum industry is so fundamentally important to modern human society that it even can lead to war. In *The Dynamic Earth*, written by Brian Skinner and Stephen Porter, a wise and insightful paragraph can be found:



美英联军空袭伊拉克回顾



➤ “Iraq invaded Kuwait in 1990 in order to control the gigantic Kuwaiti oil pools; the United Nations went to war in 1991 to expel the Iraqi invaders. How sad it is that we humans find it necessary to kill each other because of tectonic events that happened millions of years ago.”

Figures. Oil War between Iraq and the United States

7. OIL AND NATURAL GAS

- In oil industry, petroleum (from Greek *petra*, rock; and *oleum*, oil) is a broad term that includes **not only crude oil** — the liquid phase, but also **natural gas** — the gaseous phase
- **Crude oil** is a thick, dark brown liquid consisting mainly of complex mixture of various **hydrocarbons**. **Natural gas** is a mixture of hydrocarbon gases consisting principally of simplest hydrocarbon molecule methane (CH_4)
- Oil and natural gas are produced by the **same geological process**. Therefore, they are commonly found together in the field. But that's not always the case. Actually **natural gas** is also generated in swamps, marshes and even landfill sites



7. PETROLEUM AND NATURAL GAS

- The first commercial petroleum well was drilled in the United States in 1859, ushering in a new energy age
- Petroleum is the most versatile of the fossil fuels. Crude oil, as it is pumped from the underground, is a gooey, viscous, dark liquid made up of thousands of different chemical compounds. It is then refined to produce propane, gasoline, heating oil, and other fuels



Figure. An oil refinery converts crude oil to useful products such as gasoline.

- During refining, the crude oil is treated chemically and heated under pressure to break apart its large molecules. The mixture is then separated in multistory distillation columns
- Many petroleum products are used to manufacture plastics, nylon, and other useful materials

7. PETROLEUM AND NATURAL GAS

- Natural gas, or **methane** (CH_4), forms naturally when crude oil is heated above **100 °C** during burial. Many oil wells contain natural gas floating above the heavier liquid petroleum. In other instances, the lighter, more mobile gas escaped and was trapped elsewhere in a **separate reservoir**
- Natural gas is extracted as a nearly pure compound and is used without refining for **home heating, cooking, and to fuel large electrical generating plants**



Figure. Natural gas extraction and offshore drilling platform

- Because natural gas contains few **impurities**, it releases no sulfur and other pollutants when it burns. This fuel has a **higher net energy yield**, produces fewer pollutants, and is less expensive to produce than petroleum
- At current consumption rates, global natural gas supplies will last for 80 to 200 years

7. PETROLEUM AND NATURAL GAS

7.1 THE ORIGIN OF PETROLEUM

- Streams carry **organic matter** from decaying land plants and animals to the sea and to some large lakes, and **deposit it with mud** in shallow coastal waters
- Marine plants and animals die and settle to the sea floor, adding more organic matter to the mud. **Younger sediment** then buries this organic-rich mud. Rising temperature and pressure resulting from burial convert the mud to shale
- At the same time, the elevated temperature and pressure **convert the organic matter to liquid petroleum** that is finely dispersed in the rock
- The activity of bacteria may enhance the process. Typically petroleum forms in the temperature range from **50 to 100 °C**

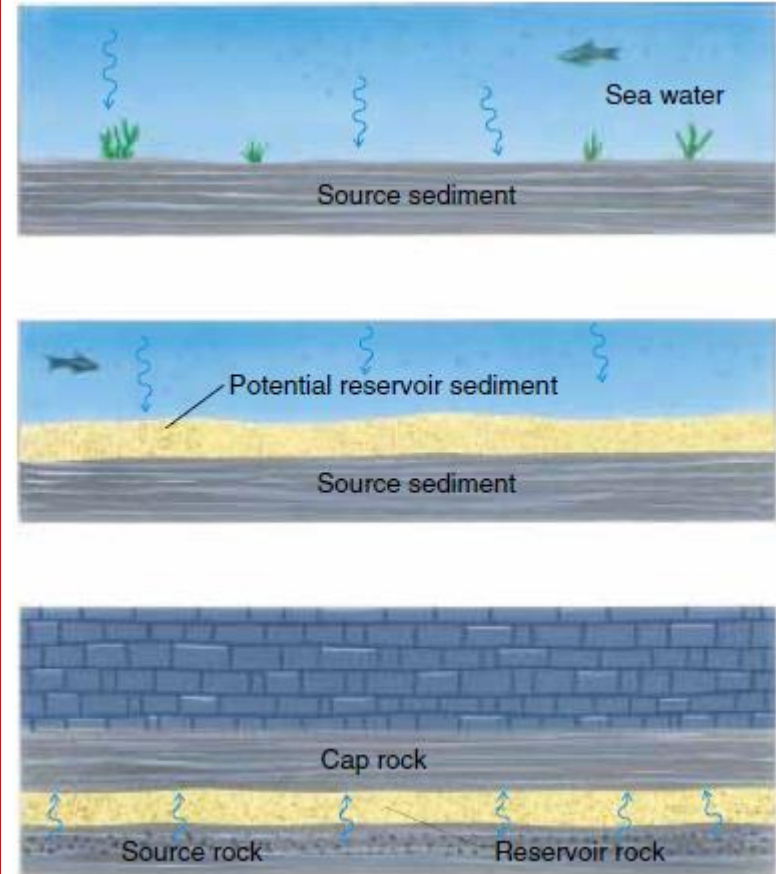


Figure. Most oil forms in shaly source rock. It must migrate to a permeable reservoir and may be recovered from an oil well.

7. PETROLEUM AND NATURAL GAS

7.1 THE ORIGIN OF PETROLEUM

- At temperatures above about 100 °C, oil begins to convert to natural gas. Consequently, many oil fields contain a mixture of oil and gas
- The shale or other sedimentary rock in which oil originally forms is called the **source rock**. Oil dispersed in shale cannot be pumped from an oil well because shale is relatively **impermeable**; that is, liquids do not flow through it rapidly.

- But under favorable conditions, petroleum migrates slowly to a nearby layer of **permeable rock**—usually sandstone or limestone—where it can flow readily
- Because petroleum is **less dense** than water or rock, it then rises through the permeable rock until it is **trapped** within the rock or **escapes** onto the Earth's surface

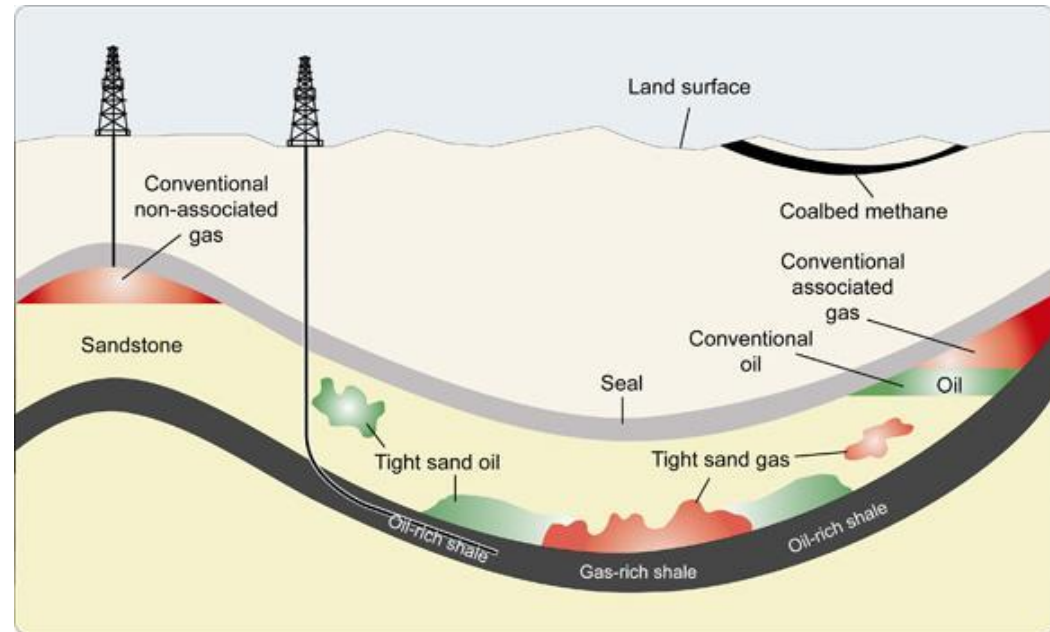


Figure. Most oil forms in shaly source rock. It must migrate to a permeable reservoir and may be recovered from an oil well.

7. PETROLEUM AND NATURAL GAS

7.1 THE ORIGIN OF PETROLEUM

- Many oil traps form where impermeable **cap rock** prevents the petroleum from rising further. Oil or gas then accumulates in the **trap** as a petroleum reservoir. The cap rock is commonly **impermeable shale**
- **Folds and faults** create several types of oil traps, anticline trap and fault trap
- In some regions, large, lightbulb-shaped bodies of **salt** have flowed upward through solid rocks to form **salt domes**. The rising salt folded the surrounding rock to form an **oil trap, salt dome trap**. The salt originated as a sedimentary bed of marine evaporite, and it rose because **salt is less dense** than the surrounding rocks

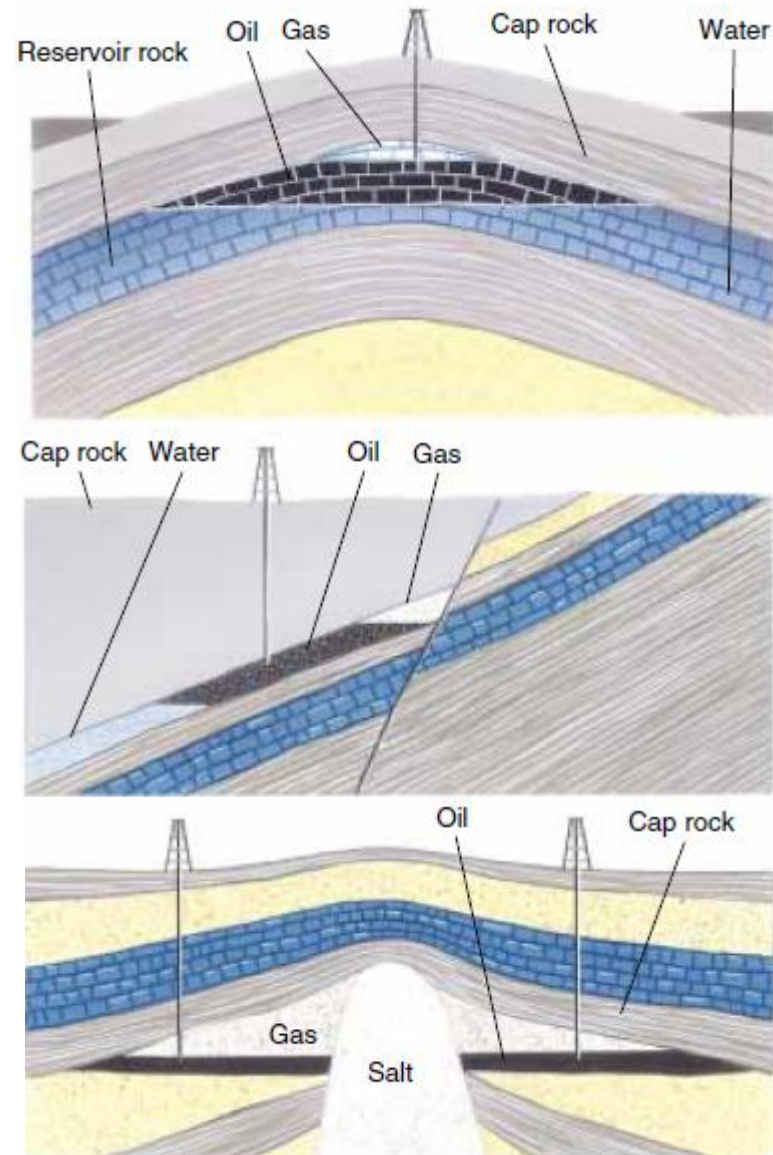


Figure. Different types of oil traps

7. PETROLEUM AND NATURAL GAS

7.1 THE ORIGIN OF PETROLEUM

- An oil reservoir is not an underground pool or lake of oil. It consists of **oil-saturated permeable rock** that is like an oil-soaked sponge
- Geologic activity can **destroy** an oil reservoir as well as **create** one. A fault may fracture the cap rock, or tectonic forces may **uplift** the reservoir and **expose** it to erosion. In either case, the petroleum **escapes** once the trap is destroyed.
- **Sixty percent** of all oil wells are found in relatively young rocks that formed during the **Cenozoic Era**. Undoubtedly, much petroleum that had formed in older **Mesozoic** and **Paleozoic** rocks escaped long ago and decomposed at the Earth's surface

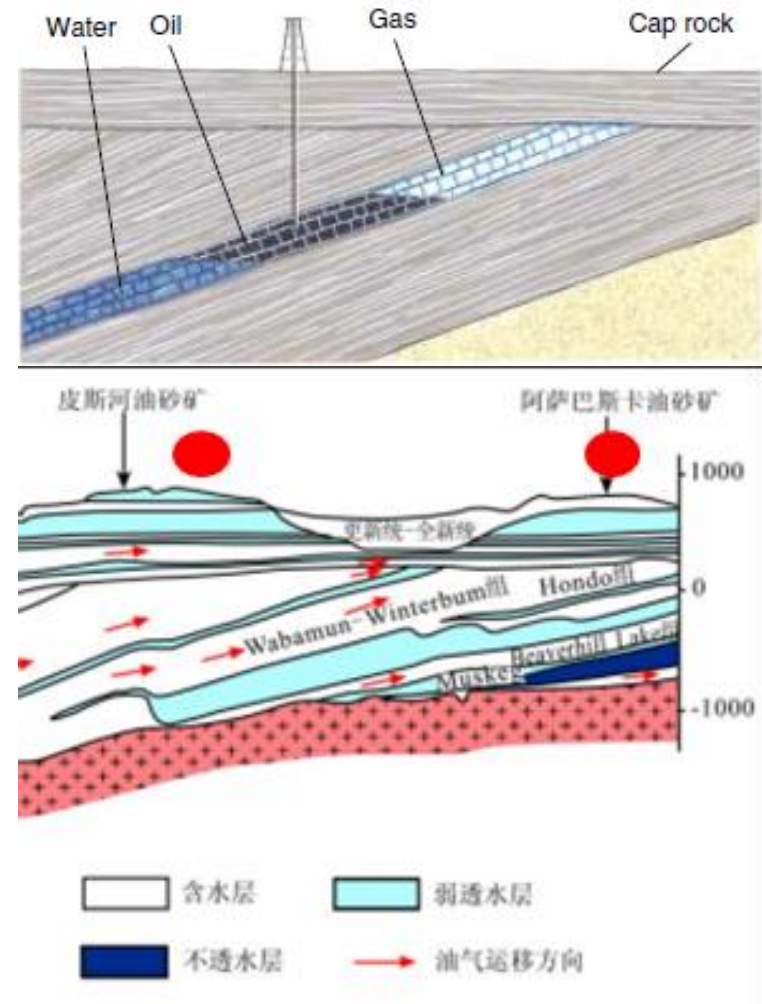


Figure. Different types of oil traps and geologic activity destroy an oil reservoir.

7. PETROLEUM AND NATURAL GAS

7.1 THE ORIGIN OF PETROLEUM

- By current theory, in order for a substantial natural gas or oil deposit to form, **three geologic conditions must be met:**
- **1. Source Rock.** The rock in which oil originally formed is **the source rock**. Oil is made primarily of **phytoplankton, bacteria and plant material** (algae) from the ocean and lake. So the source rock is either black shale or limestone formed in the oceanic and lacustrine basins
- **2. Reservoir Rock.** Once crude oil and natural gas have formed, they migrate upward because they weigh less than the water and rock. And finally, the oil formed in the shale will migrate and concentrate to a place where it is stored. **A reservoir rock** is a place that oil migrates to and is held underground. A **porous and permeable sandstone** has plenty of room inside itself to hold oil, just like a sponge has room inside of itself to soak up spills in your kitchen. Sandstones and carbonate rocks are most common reservoir rocks.

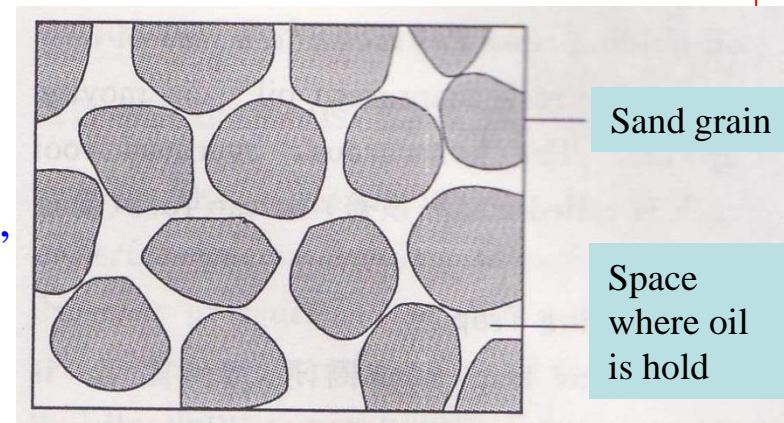


Figure. Reservoir Rock

7. PETROLEUM AND NATURAL GAS

7.1 THE ORIGIN OF PETROLEUM

- By current theory, in order for a substantial natural gas or oil deposit to form, **three geologic conditions** must be met:
- **3. A Trap.** The storing of oil in reservoir needs **some conditions**. Otherwise, they will rise to the Earth's surface and no oil will be preserved!

- The geologic structure in which the oil will accumulate into large quantities is called **a trap**. There is a variety of geologic traps. All of them are composed of **two basic units**:
- Oil-holding **reservoir rock** and a **roof** of non-permeable rock to prevent oil from moving upward
- The non-porous, overhead roof rock is called **a cap or cap rock**

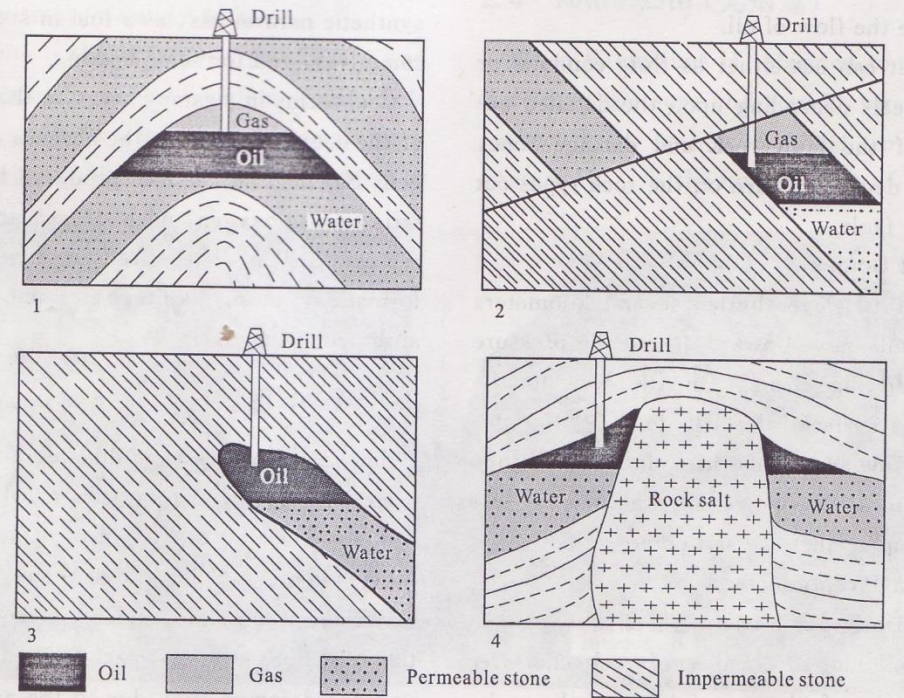


Figure. Various Traps

1. Anticline trap; 2. Fault trap;
3. Stratigraphic trap; 4. Salt dome trap

7. PETROLEUM AND NATURAL GAS

7.1 THE ORIGIN OF PETROLEUM

➤ Anticline Trap

- Anticline trap is the most common oil trap. When the oil moves upward in porous sandstone reservoir rock and reaches the core of the anticline, the overlying shale acts as cap to prevent the upward migration of oil. A reservoir rock that isn't completely filled with oil usually contains large amounts of water beneath and gas above

➤ Fault Trap

- Fault trap form when an impermeable layer above and a fault zone (generally impermeable because the fraction along a fault plane creates poorly sorted, broken rock) impede the flow of oil
- Fault can act either as fluid conduits or fluid seals depending upon the detailed nature of the fault rock and damage zone, which depend in turn on the rock-types cut by the fault



Figure. Anticline Trap

7. PETROLEUM AND NATURAL GAS

7.1 THE ORIGIN OF PETROLEUM

➤ Salt Domes

- The salt layer buried several kilometers deep will move upward due to the pressure of overlying rock. On the way to the Earth's surface, the salt dome pushes aside and bends the country rock, thus creating a trap where oil can come to rest right up against the salt dome

➤ Stratigraphic Traps

- A stratigraphic trap accumulates oil due to changes of rock character rather than faulting or folding of the rock. There are many stratigraphic traps
- For example, the sandstone lens occurring in between the shales can make a perfect stratigraphic trap

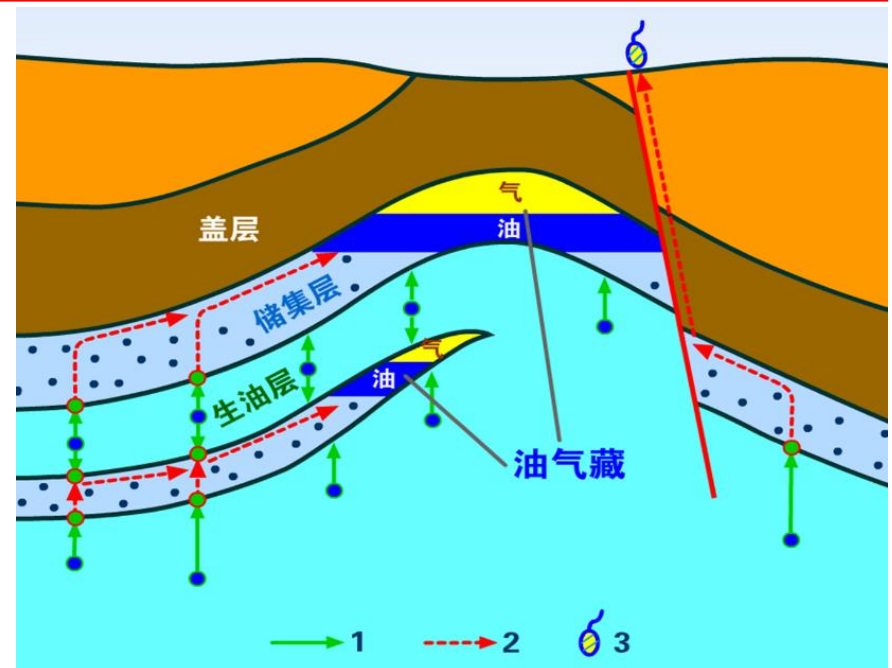


Figure. Various Traps

7. PETROLEUM AND NATURAL GAS

7.1 THE ORIGIN OF PETROLEUM

- There are more than 40,000 oil fields around the globe, on land and offshore. The largest are the Ghawar Field in Saudi Arabia and the Burgan Field in Kuwait, with more than 60 billion barrels estimated in each. The world's top six crude oil-producing countries are: Saudi Arabia, Russia, United States, Iran, China and Mexico

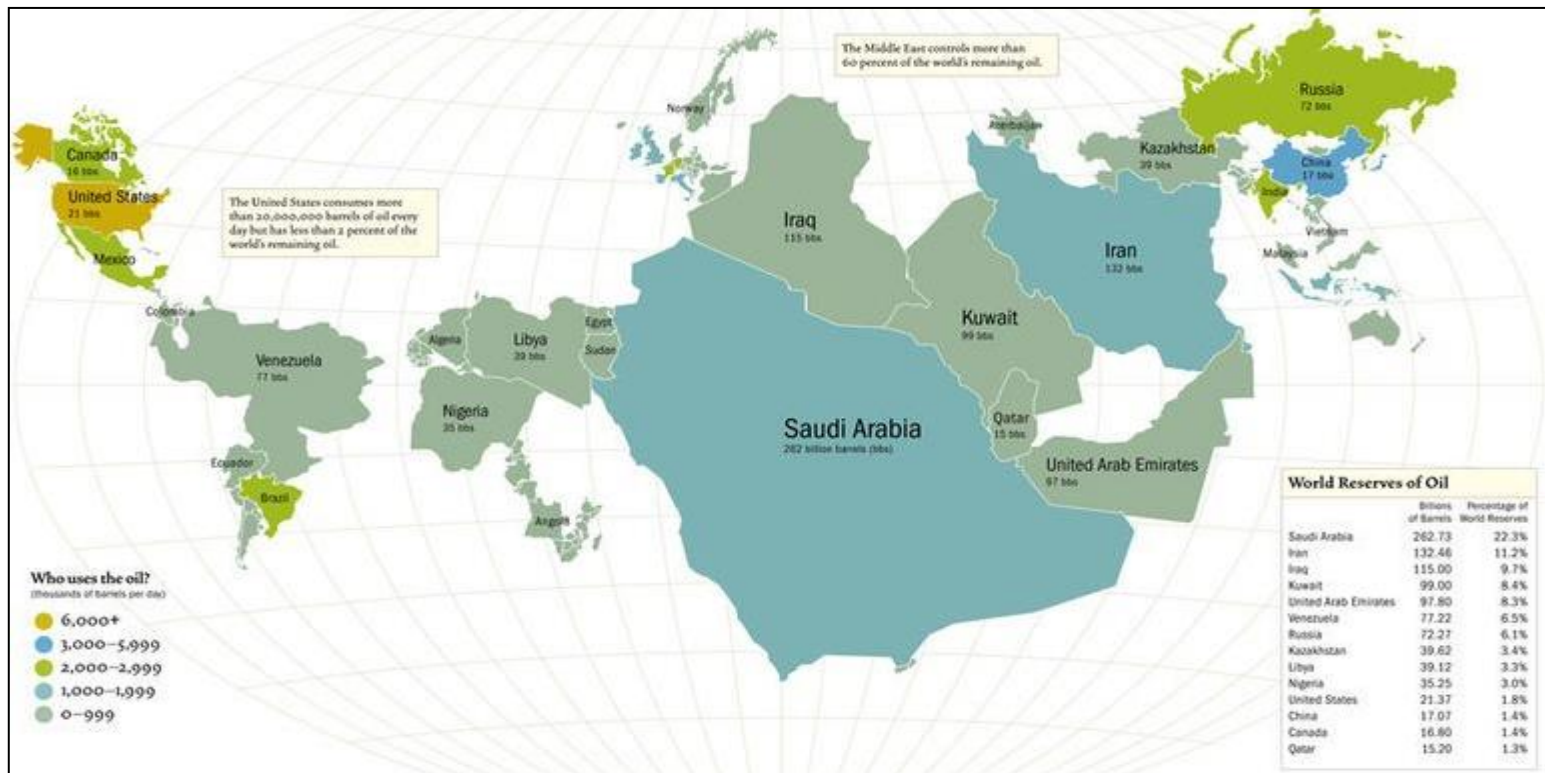


Figure. Distribution of oil field in the world.

7. PETROLEUM AND NATURAL GAS

7.2 PETROLEUM EXTRACTION, TRANSPORT, AND REFINING

- To extract petroleum, an oil company **drills a well** into a reservoir and pumps the oil to the surface. Fifty years ago, many reservoirs lay near the surface and oil was easily extracted from shallow wells. But these reserves have been exploited, and modern oil wells are typically deeper
- For example, in **1949**, the average oil well drilled in the United States was **1,116** meters deep. In **1994**, the average well was **1,629** meters deep. The average cost of drilling a new oil well in **1960** was slightly more than **\$200,000**; by **1993**, the cost had risen to about **\$350,000**
- After the hole has been bored, the expensive **drill rig** is removed and replaced by a **pumper** that slowly extracts the petroleum

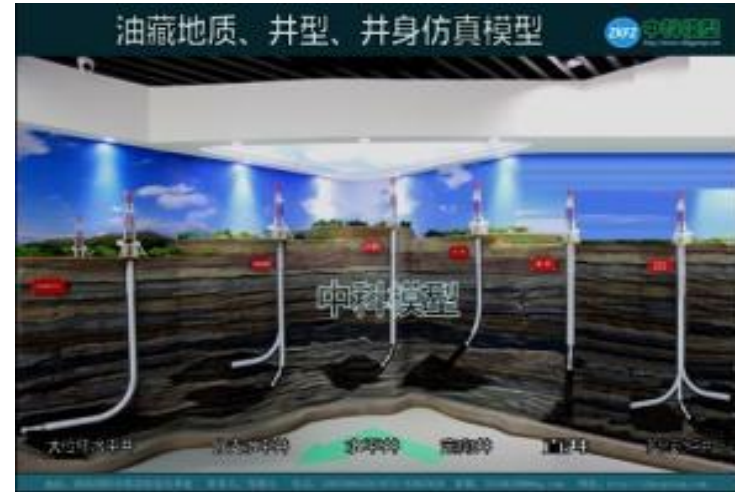
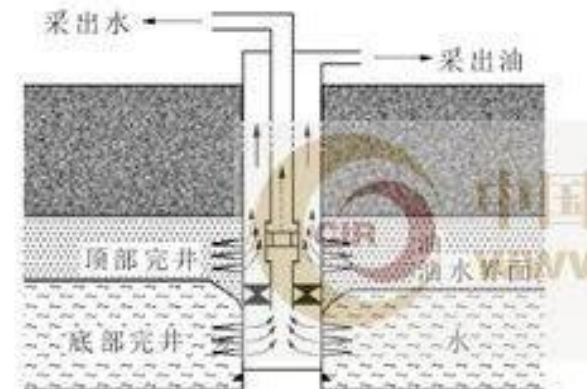
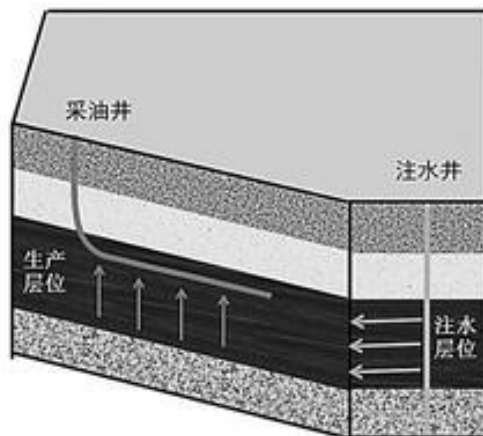


Figure. Different types of oil drilling platform on land and offshore.

7. PETROLEUM AND NATURAL GAS

7.2 PETROLEUM EXTRACTION, TRANSPORT, AND REFINING

- On the average, more than half of the oil in a reservoir is too **viscous** to be pumped to the surface by conventional techniques. This oil is left behind after an oil field has “gone dry,” but it can be extracted by **secondary and tertiary** recovery techniques
- In one simple **secondary process**, water is pumped into one well, called the **injection well**. The water floods the reservoir, driving oil to nearby wells, where both the water and oil are extracted
- At the surface, the water is **separated from** the oil and reused, while the oil is sent to the refinery



7. PETROLEUM AND NATURAL GAS

7.2 PETROLEUM EXTRACTION, TRANSPORT, AND REFINING

- One tertiary process forces superheated steam into the injection well. The steam heats the oil and makes it more fluid so that it can flow through the rock to an adjacent well. Because energy is needed to heat the steam, this type of extraction is not always cost effective or energy efficient
- Another tertiary process pumps detergent into the reservoir. The detergent dissolves the remaining oil and carries it to an adjacent well, where the petroleum is then recovered and the detergent recycled
- However, the energy yield from secondary and tertiary extraction is reduced by the energy consumed by the processes

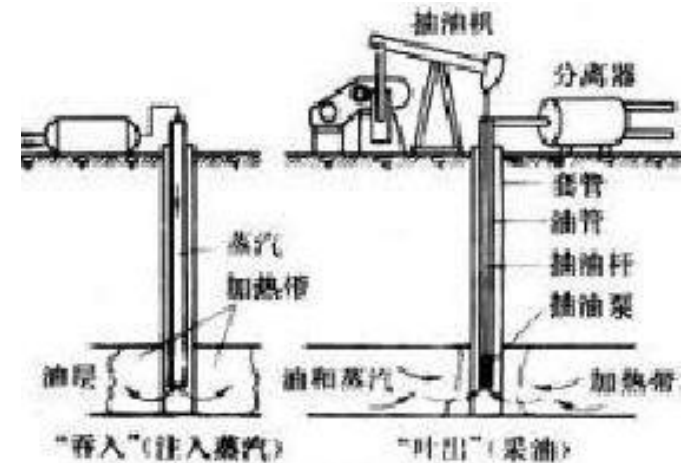


Figure. Gas injection and chemical floods or polymer flooding.

7. PETROLEUM AND NATURAL GAS

7.2 PETROLEUM EXTRACTION, TRANSPORT, AND REFINING

- Because an oil well occupies only a few **hundred square meters** of land, most cause relatively little environmental damage
- However, oil companies have begun to extract petroleum from fragile environments such as the **ocean floor** and the **Arctic tundra**. To obtain oil from the sea floor, engineers build platforms on pilings driven into the ocean floor and mount drill rigs on these steel islands. Despite great care, accidents occur during drilling and extraction of oil.



Key word: *Tundra*, is one of the large flat areas of land in the north of Europe, Asia, and America. The ground below the top layer of soil and the ice cap is always frozen and no trees grow there. 冻原

7. PETROLEUM AND NATURAL GAS

7.2 PETROLEUM EXTRACTION, TRANSPORT, AND REFINING

- When accidents occur at sea, millions of barrels of oil can spread throughout the waters, poisoning marine life and disrupting marine ecosystems. Significant oil spills have occurred in virtually all offshore drilling areas. In addition, tanker accidents have polluted parts of coastal oceans
- Although all oil refineries use expensive pollution control equipment, these devices are never completely effective. As a result, some toxic and carcinogenic compounds escape into the atmosphere



Key word: *carcinogenic compounds*, A substance that is carcinogenic is likely to cause cancer.

7. PETROLEUM AND NATURAL GAS

7.3 TAR SANDS

- In some regions, large sand deposits are permeated with heavy oil and an oil-like substance called **bitumen**, which are too thick to be pumped. The richest **tar sands** exist in Alberta (Canada), Utah, and Venezuela
- In **Alberta** alone, tar sands contain an estimated **1 trillion barrels** of petroleum. About 10 percent of this fuel is shallow enough to be surface mined. Tar sands are dug up and heated with steam to make the bitumen fluid enough to separate from the sand

- The bitumen is then treated chemically and heated to **convert it to crude oil**. At present, several companies mine tar sands profitably, producing 11 percent of Canada's petroleum. Deeper deposits, composing the remaining 90 percent of the reserve, can be extracted using subsurface techniques similar to those discussed for secondary and tertiary recovery



Figure. Mining tar sands in Alberta, Canada.(Syn crude Canada, Limited)

7. PETROLEUM AND NATURAL GAS

7.3 OIL SHALE

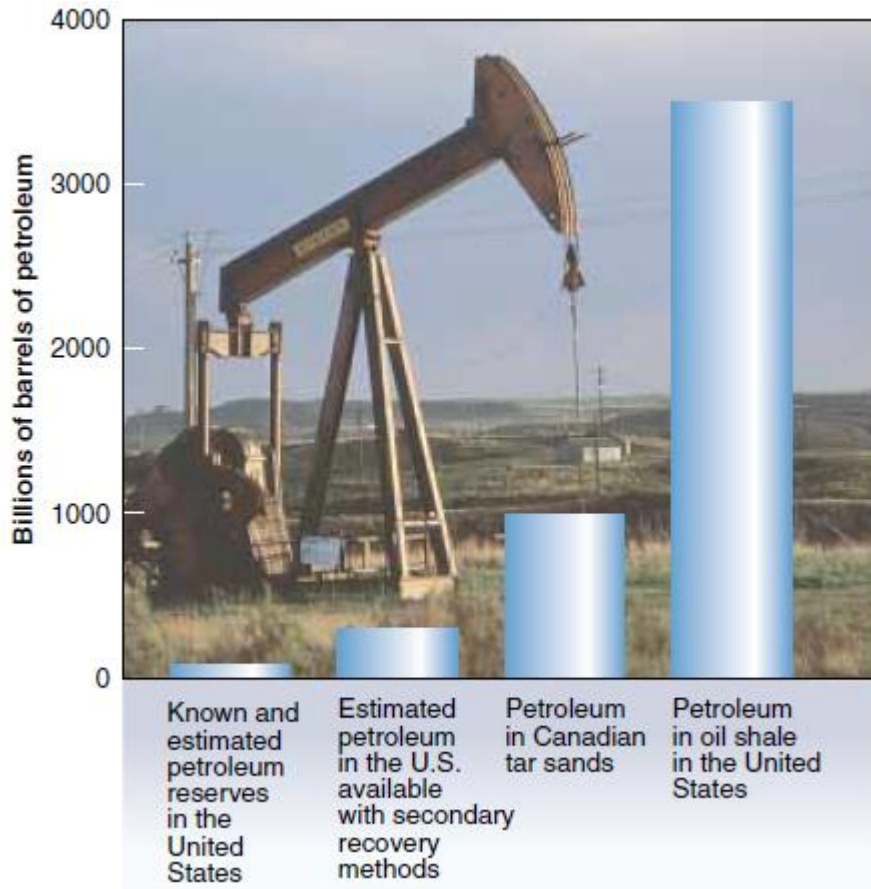


Figure. Secondary recovery, tar sands, and oil shale increase our petroleum reserves significantly.

- Some **shales** and other sedimentary rocks contain a waxy, solid organic substance called **kerogen**. Kerogen is organic material that has not yet converted to oil. Kerogen-bearing rock is called **oil shale**. If oil shale is mined and heated in the presence of water, the **kerogen converts to petroleum**. In the United States, oil shales contain the energy equivalent of **2 to 5 trillion barrels** of petroleum, enough to fuel the nation for **315 to 775 years** at the 1994 consumption rate
- However, many oil shales are of such **low grade** that they require **more energy** to mine and convert the kerogen to petroleum **than** is generated by burning the oil, so they will probably never be used for fuel

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8. NUCLEAR FUELS AND REACTORS

➤ A modern nuclear power plant uses **nuclear fission** to produce heat and generate electricity. One isotope of **uranium**, **U-235**, is the major fuel. When a U-235 nucleus is bombarded with a **neutron**, it breaks apart (the word fission means “splitting”)

➤ The initial reaction releases **two or three neutrons**. Each of these neutrons can trigger the fission of additional **nuclei**; hence, this type of nuclear reaction is called a **branching chain reaction**

➤ Because this fission is initiated by **neutron bombardment**, it is not a spontaneous process and is different from natural radioactivity

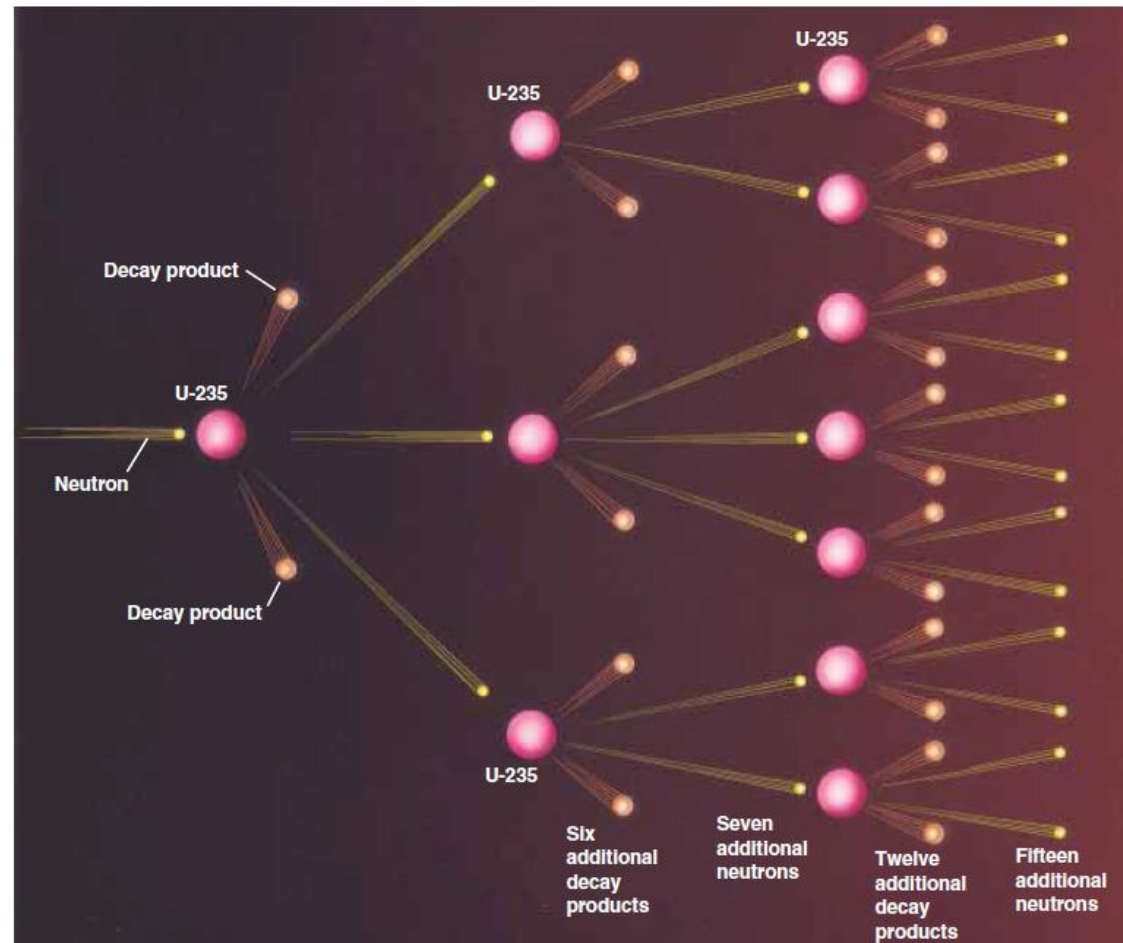


Figure. A branching chain reaction of uranium, U-235

8. NUCLEAR FUELS AND REACTORS

- To fuel a nuclear reactor, concentrated uranium is compressed into small pellets. Each pellet could easily fit into your hand but contains the energy equivalent of 1 ton of coal. A column of pellets is encased in a 2-meter-long pipe called a fuel rod. A typical nuclear power plant contains about 50,000 fuel rods bundled into assemblies of 200 rods each. Control rods made of neutron-absorbing alloys are spaced among the fuel rods



(a)



(b)

Figure. (a) Fuel pellets containing enriched uranium-235. Each pellet contains the energy equivalent of 1 ton of coal. (b) Fuel pellets are encased into narrow rods that are bundled together and lowered into the reactor core. (Courtesy Westinghouse Electric Corp, Commercial Nuclear Fuel Division)

8. NUCLEAR FUELS AND REACTORS

- The control rods fine-tune the reactor. If the reaction speeds up because too many neutrons are striking other uranium atoms, then the power plant operator lowers the control rods to absorb more neutrons and slow down the reaction. If fission slows down because too many neutrons are absorbed, the operator raises the control rods
- If an accident occurs and all internal power systems fail, the control rods fall into the reactor core and quench the fission

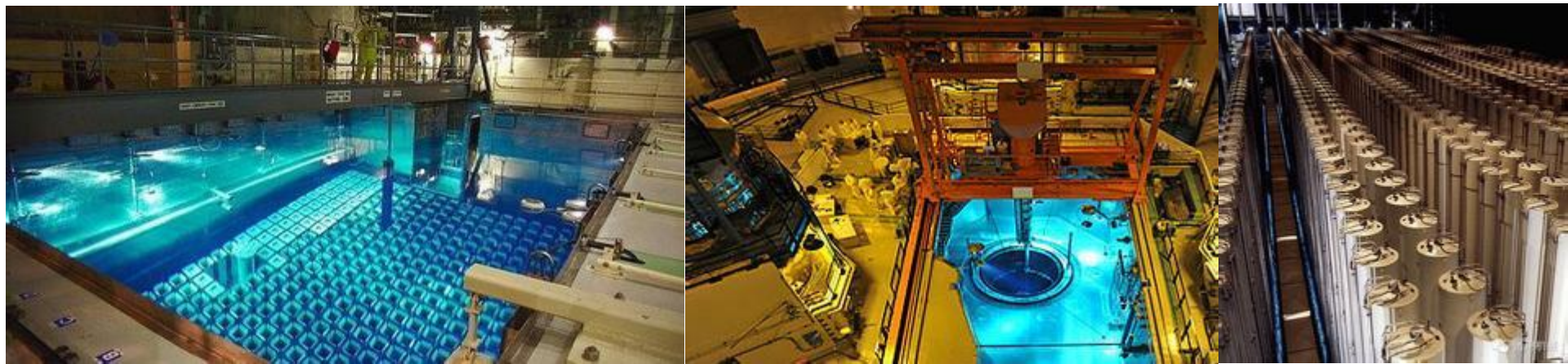


Figure. Control rods and fuel rods

8. NUCLEAR FUELS AND REACTORS

- The reactor core produces tremendous amounts of heat. A fluid, usually water, is pumped through the reactor core to cool it. The cooling water (which is now radioactive from exposure to the core) is then passed through a radiator, where it heats another source of water to produce steam. The steam drives a turbine, which in turn generates electricity

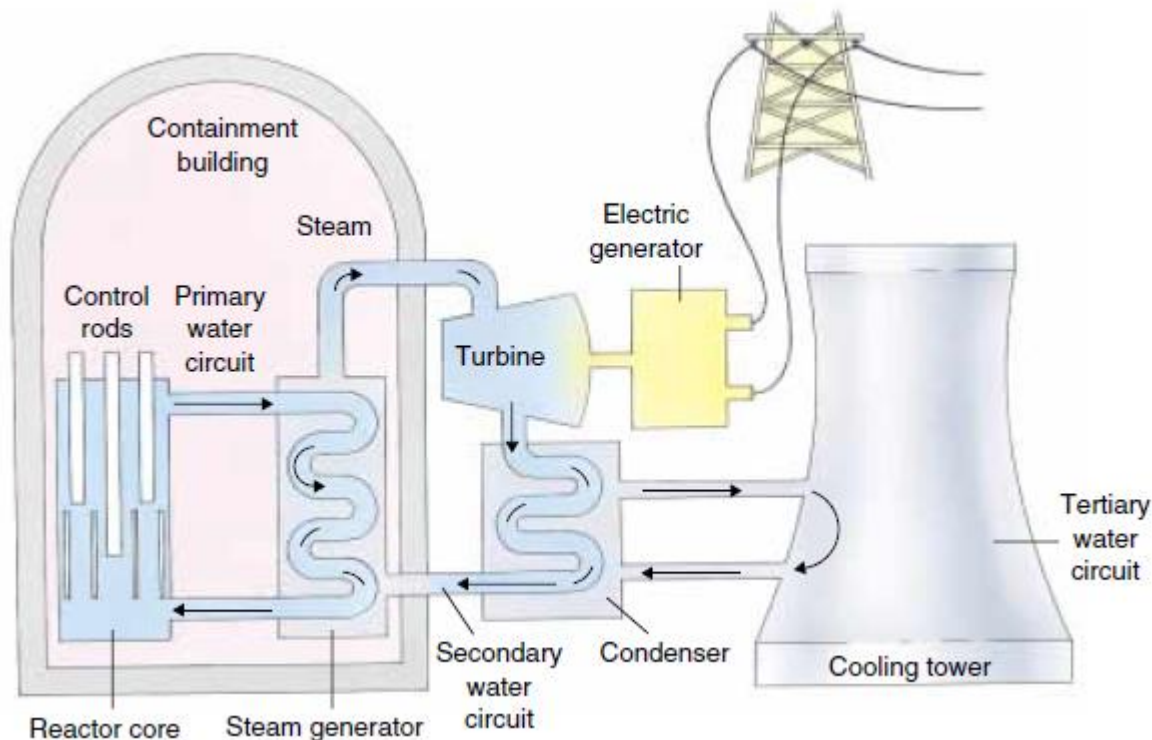


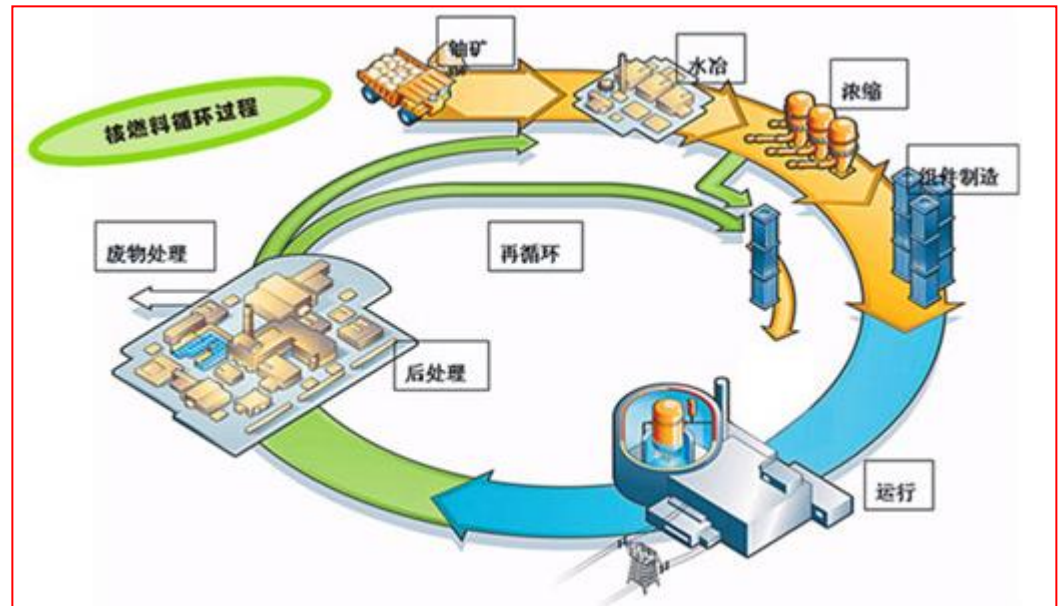
Figure. In a nuclear power plant, fission energy creates heat, which is used to produce steam. The steam drives a turbine, which generates electricity.

8. NUCLEAR FUELS AND REACTORS

THE NUCLEAR POWER INDUSTRY

- Every step in the mining, processing, and use of nuclear fuel produces **radioactive wastes**. The **mine waste** discarded during mining is radioactive. Enrichment of the ore produces additional radioactive waste. When a U-235 nucleus undergoes fission in a reactor, it splits into two useless radioactive nuclei that must be discarded. Finally, after several months in a reactor, the U-235 concentration in the fuel rods drops until the fuel pellets are no longer useful

- In some countries, these pellets are reprocessed to recover U-235, but in the United States this process is not economical and the pellets are discarded. To date, no satisfactory solution has been found

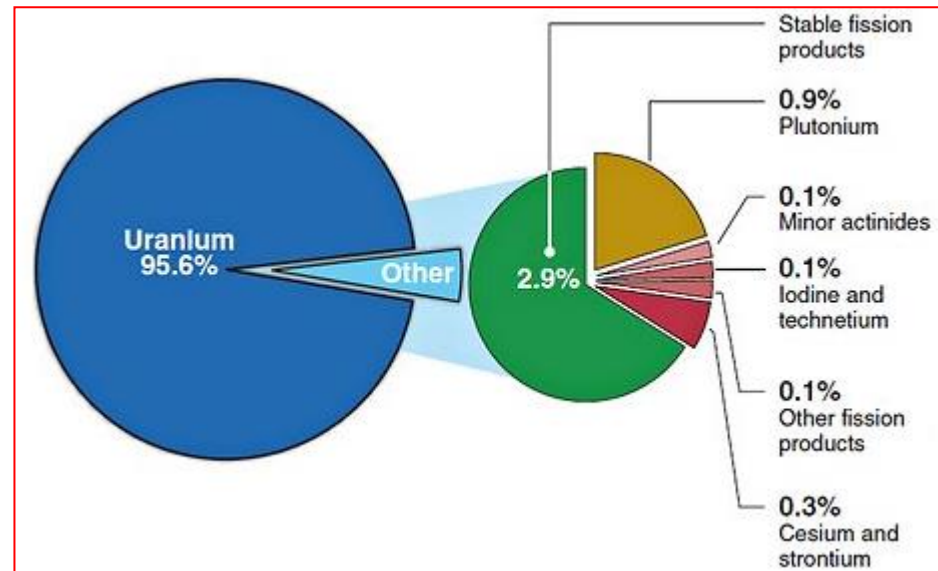


8. NUCLEAR FUELS AND REACTORS

THE NUCLEAR POWER INDUSTRY

➤ In recent years, construction of new reactors has become so costly that electricity generated by nuclear power is more expensive than that generated by coal-fired power plants. Public concern about accidents and radioactive waste disposal has become acute. The demand for electricity has risen less than expected during the past two decades. As a result, growth of the nuclear power industry has halted. After 1974, many planned nuclear power plants were canceled, and after 1981, no new orders were placed for nuclear power plants in the United States.

➤ In 1994, 109 commercial reactors were operating in the United States. These generators produced 22 percent of the total electricity consumed that year. Those numbers will decline in the coming decade because no new plants have been started and old plants must be decommissioned



S U M M A R Y

➤ Geologic resources fall into **two major categories**:

(1) Useful rocks and minerals are called **mineral resources** and include both nonmetallic resources and metals. All mineral resources are nonrenewable;

(2) **Energy resources** include fossil fuels, nuclear fuels, and alternative energy resources

➤ Ore is a rock or other material that can be mined profitably. Mineral reserves are the estimated supply of ore in the ground. **Five types of geologic processes** concentrate elements to form ore:

(1) **Magmatic processes**, such as crystal settling, form ore as magma solidifies.

(2) **Hydrothermal processes** transport and precipitate metals from hot water.

(3) Two types of **sedimentary processes** concentrate minerals. Flowing water deposits dense minerals to form **placer deposits**. Evaporite deposits and banded iron formations precipitate from lakes or seawater.

(4) **Weathering** removes easily dissolved elements and minerals, leaving behind **residual deposits** such as bauxite.

(5) **Metamorphic processes** can create hydrothermal solutions and form **asbestos** and **marble**

S U M M A R Y

- **Metal ores and coal** are extracted from underground mines and surface mines
- Fossil fuels include **oil, gas, and coal**.
- If oxygen and flowing water are excluded by burial, plant matter decays partially to form **peat**. **Peat** converts to coal when it is buried further and subjected to elevated temperature and pressure
- **Petroleum** forms from the remains of organisms that settle to the ocean floor or lake bed and are incorporated into **source rock**. The organic matter converts to liquid oil when it is buried and heated. The petroleum then migrates to a **reservoir**, where it is retained by **an oil trap**. Additional supplies of petroleum can be recovered by **secondary extraction** from old wells and from tar sands and oil shale
- **Nuclear power** is expensive, and questions about the safety and disposal of nuclear wastes have diminished its future. Inexpensive uranium ore will be available for a century or more



Questions

- Which metal is frequently mined in placer deposit?
A: Copper B: Iron C: Lead D: Gold
- Which metal ore deposit can be formed by chemical precipitation?
A: Copper B: Iron C: Lead D: Gold
- Most of the metal ore deposit was formed by_____.
A: Crystal settling B: Concentration by weathering
C: Magmatic-hydrothermal fluid D: Placer deposit
- Which one is not a energy resource?
A: Coal B: Oil C: Gas D: Metal
- Most of the metallic ore deposits are associated with_____.
A: Sedimentary rock B: Igneous rock
C: Metamorphic rock D: All of them
- The most important iron ore is_____.
A: Pig iron B: Hematite C: Magnetite D: Steel



Questions and Homework

- Describe the two categories of geologic resources.
- Describe the differences between nonrenewable and renewable resources.
- What is ore? What are mineral reserves? Describe three factors that can cause changes in estimates of mineral reserves.
- What is the hydrothermal vein?
- List and describe the main types of hydrothermal ore deposits.
- Describe in sketch the placer deposit.
- List ten objects that you own. What resources are they made of?
How long will each of the objects be used before it is discarded?



THANKS FOR YOUR
ATTENTION!

Welcome to the College of
Geosciences and
Engineering!

在挑战中塑造辉煌

Challenge and Success!