Real-Life Applications

UNIT 5
EARTH RESOURCES

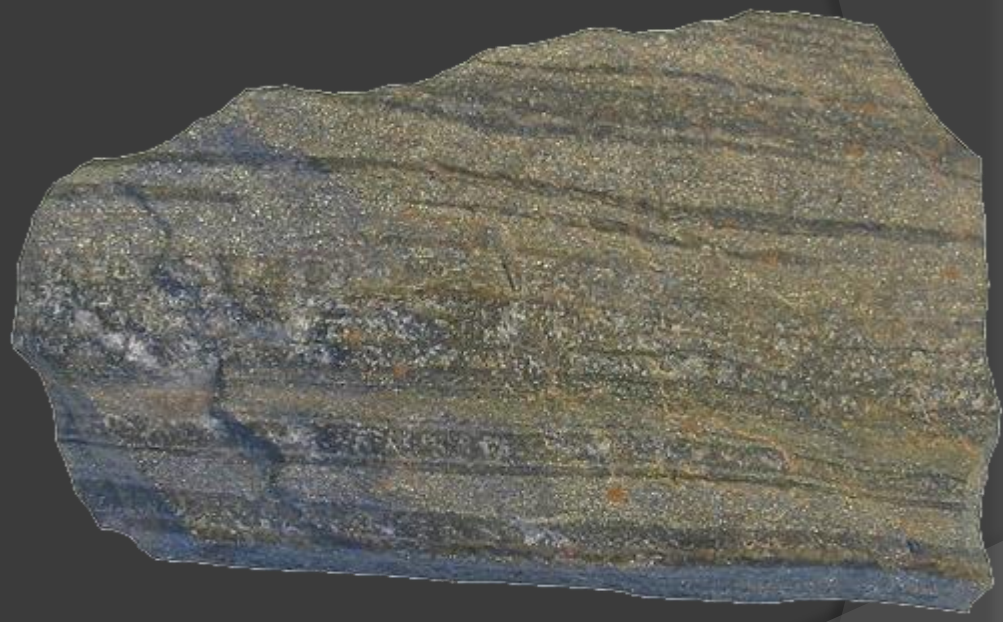
Economic Minerals

- Economic minerals are minerals that can be extracted, processed and marketed for a profit.

- Various factors determine if a mineral is an economic mineral:
  - Interest in mineral
  - Size of deposit
  - Mineral concentration
  - Mineral depth below surface
  - Market value

Ore

- An ore is a type of rock that contains minerals with important elements including metals. The ores, that are profitable, are extracted through mining; these are then refined to extract the valuable element(s).



Iron ore

Ores

Lead Ore

Gold Ore

Economic Mineral Deposits

- There are 5 types of economic mineral deposits:
  - Magmatic
  - Hydrothermal
  - Placer
  - Secondary Enrichment
  - Metamorphism

Economic Mineral Deposits
Magmatic

- Many of the world's most valuable metallic mineral resources are directly associated with magma that ultimately forms igneous rocks.

- Certain metals are naturally enriched in certain magmas, but most only reach economically viable concentrations upon further enrichment during the cooling process.

Magmatic

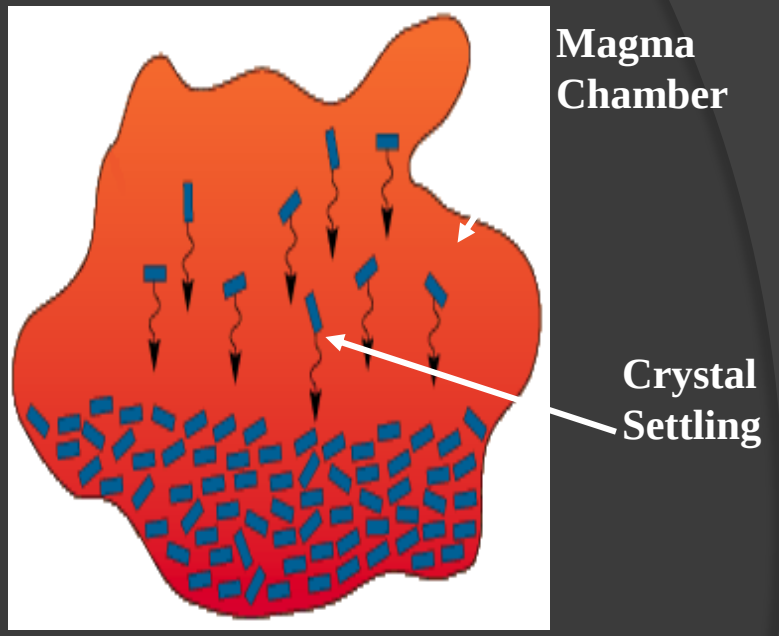
- Two specific types of magmatic deposits we will look at are:
  - Gravitational
  - Dissemination (Magma source hydrothermal)

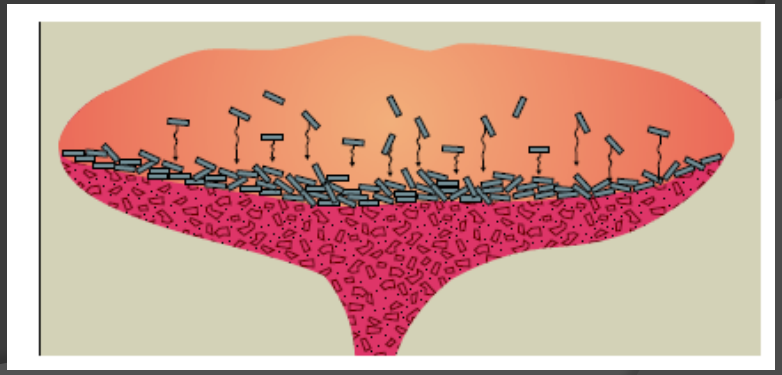
Gravitational

- The igneous processes that generate some metal deposits are fairly straightforward.
- For example, some economically important minerals are concentrated by simple gravitational settling within a magma chamber.
- In essence, crystals of heavy minerals that form during early stages of crystallization settle at the bottom of a magmatic body.

Gravitational

- High-density minerals such as chromites and magnetite crystallize during the early stages of magma crystallization.
- The crystals can sink to the bottom of the magma chamber, forming concentrated layers of these minerals.





Disseminated

- Another important type of accumulation generated by magma-sourced hydrothermal fluids is called a disseminated deposit.

- Rather than being concentrated in well-defined veins, these ores are distributed in small masses throughout a large rock body.

Hydrothermal

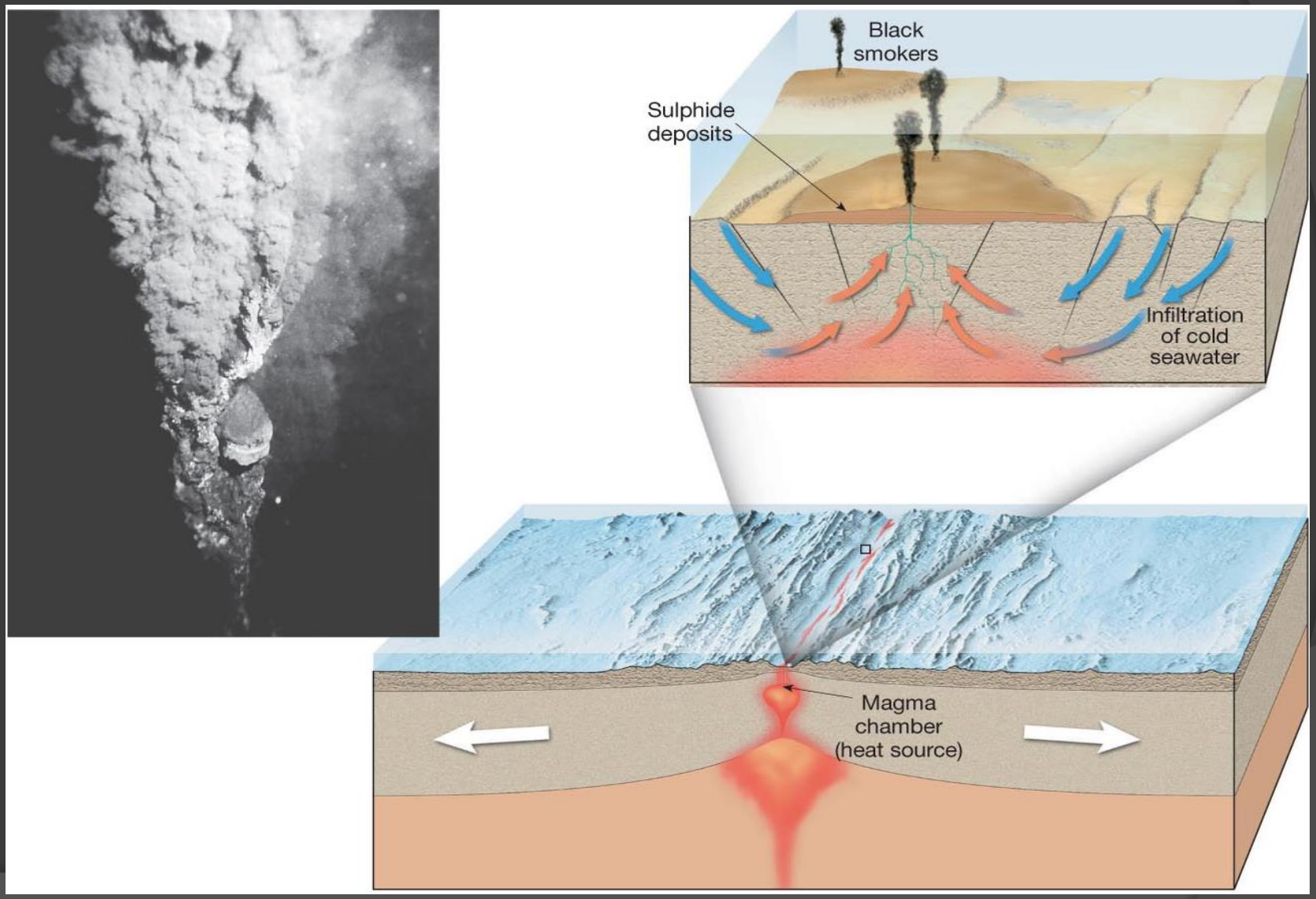
- Among the best-known and most important ore deposits are those generated from hydrothermal **(hot-water)** solutions, which may be produced during the late-stage cooling of magma, by the heating of groundwater or seawater, or by metamorphic processes.

Hydrothermal

- Studies of modern hydrothermal systems have shown that igneous activity serves as a powerful heat engine that drives the production and circulation of mineral rich fluids. (Yellowstone National Park)

- The deposits are forming where heated seawater, rich in dissolved metals and sulphur, gushes from the seafloor as particle filled clouds called *black smokers.*

Hydrothermal Deposits at Black Smokers

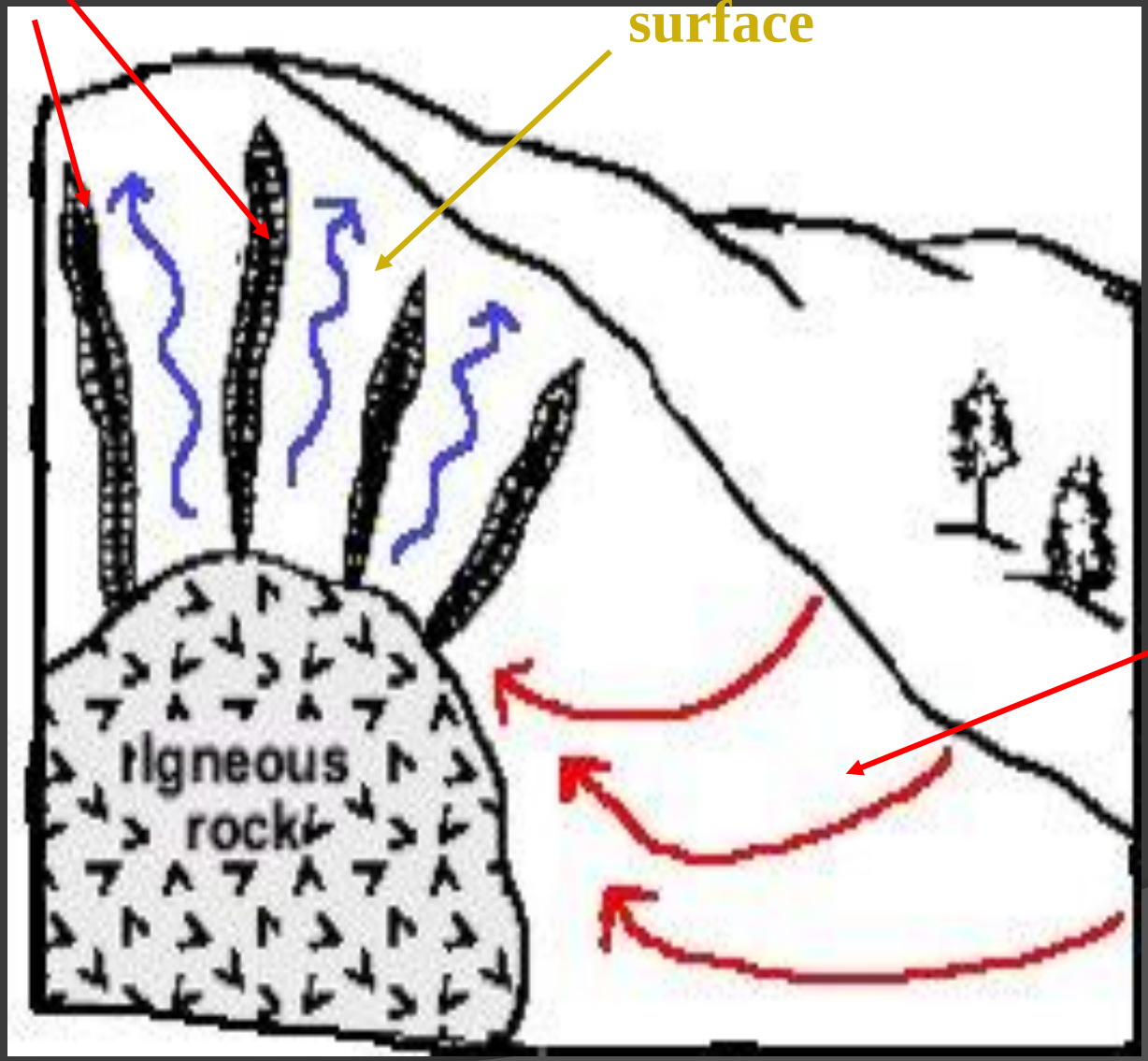


Hydrothermal

- *Vein Deposits*
- Hydrothermal fluids generated by cooling magmas can rise to the surface through fractures, faults, and other features resulting from the brittle deformation of the overlying rocks. Fluids passing through the fractures eventually cool, allowing minerals to precipitate

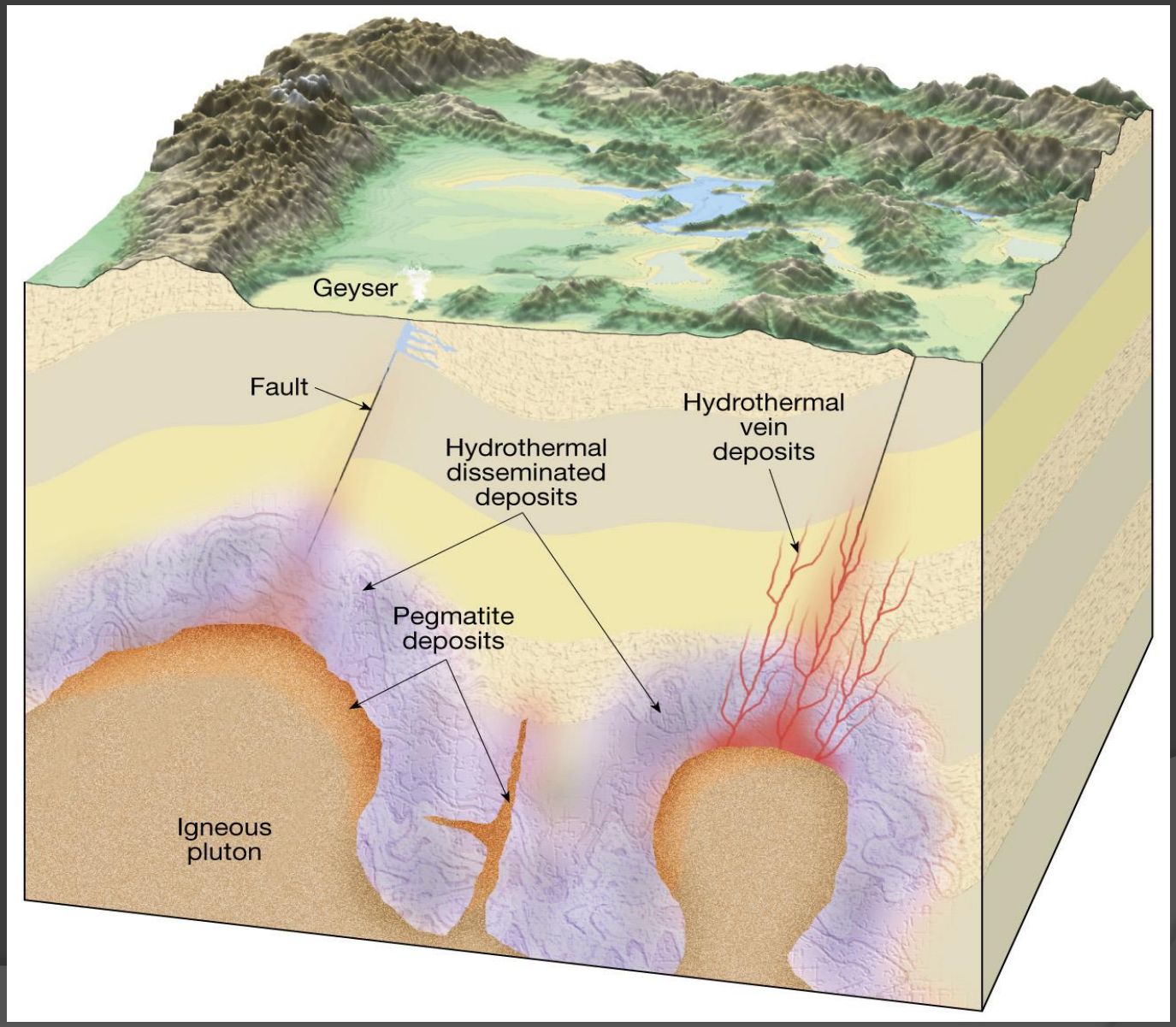
Ore minerals depositing in veins

Cooler water moving toward surface



Hot water moving at depths

Hydrothermal Vein Deposits



Hydrothermal Vein Deposits

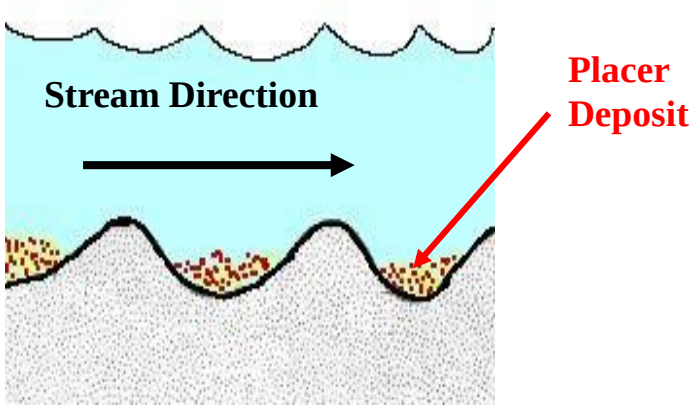
- Gneiss laced with quartz veins at Diablo Lake Overlook, North Cascades National Park, Washington.

Placer Deposits

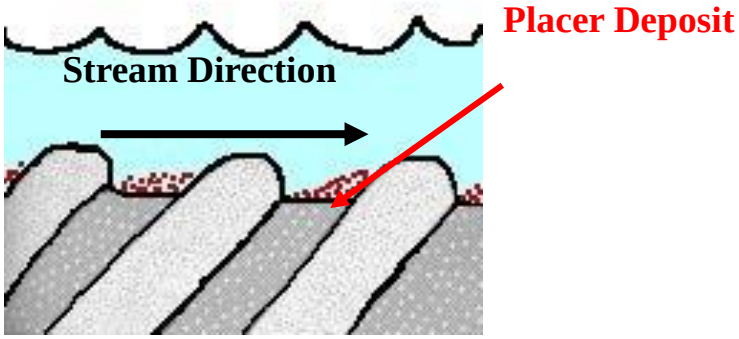
- The formation of placer deposits relates to the sorting action of running water.
- Mineral particles of high density can be concentrated due to the sorting out and washing away of mineral particles of lower density
- Gold, Platinum and Diamonds

Where they form:

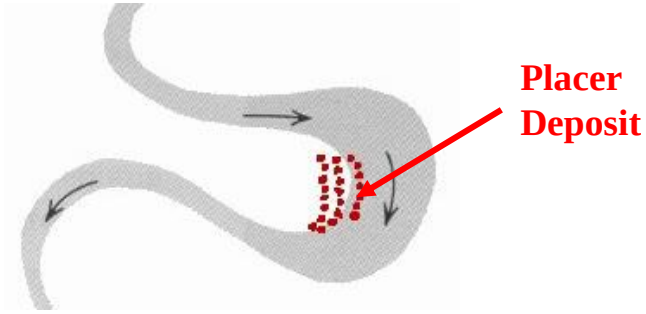
1) **between ripple marks**



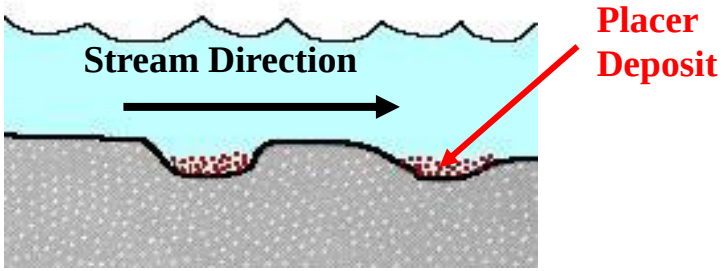
2) **behind rock bars**



3) **on the inside of meandering streams**



4) **in holes on the bottom of a stream**



Placer Deposits

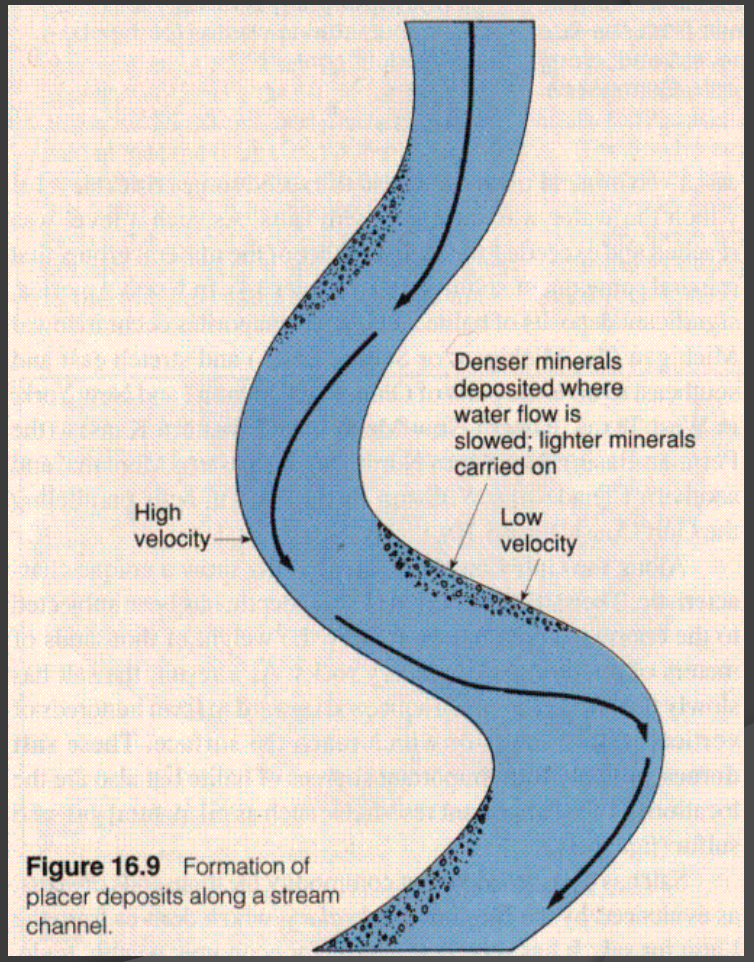


Figure 16.9 Formation of placer deposits along a stream channel.

Secondary Enrichment

- Weathering creates many important mineral deposits by concentrating minor amounts of metals that are scattered through unweathered rock into economically valuable concentrations.

- Such a transformation is often termed **secondary enrichment** and takes place in one of two ways.

Secondary Enrichment

- In one situation, chemical weathering coupled with downward-percolating water removes undesirable materials from decomposing rock, leaving the desirable elements enriched in the upper zones of the soil.

Secondary Enrichment

- The second situation is basically the reverse of the first. That is, the desirable elements that are found in low concentrations near the surface are removed and carried to lower zones, where they are re-deposited and become more concentrated.

Secondary Enrichment

- **Bauxite**
  - Principal ore of aluminum
  - Forms in rainy tropical climates from chemical weathering and the removal of undesirable elements by leaching

Metamorphism

- The role of metamorphism in producing mineral deposits is frequently tied to igneous processes.

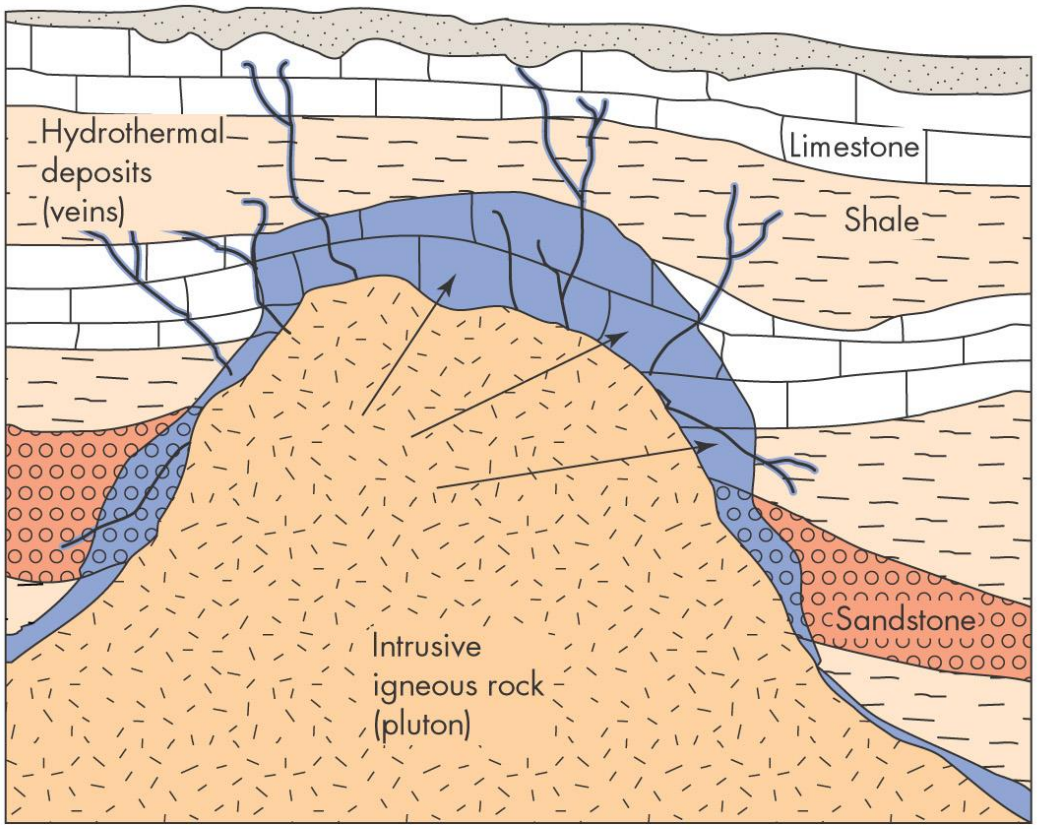
- Many of the most important metamorphic ore deposits are produced by contact metamorphism.

Metamorphism

- Here the host rock is re-crystallized and chemically altered from heat, pressure, and hydrothermal solutions emanating from an intruding igneous body.

- The most common metallic minerals associated with contact metamorphism are zinc, lead, copper andiron.

Metamorphism



Contact metamorphic zone where mineral deposits may be present. Notice the zone is wider in the limestone than in the sandstone or shale. This results because limestone is chemically more active under contact metamorphism.

TABLE 21.2 Occurrences and Uses of Nonmetallic Minerals

Mineral	Uses	Geological Occurrences
Apatite	Phosphorus fertilizers	Sedimentary deposits
Asbestos (chrysotile)	Incombustible fibers	Metamorphic alteration
Calcite	Aggregate; steelmaking; soil conditioning; chemicals; cement; building stone	Sedimentary deposits
Clay minerals (kaolinite)	Ceramics; china	Residual product of weathering
Corundum	Gemstones; abrasives	Metamorphic deposits
Diamond	Gemstones; abrasives	Kimberlite pipes; placers
Fluorite	Steelmaking; aluminum refining; glass; chemicals	Hydrothermal deposits
Garnet	Abrasives; gemstones	Metamorphic deposits
Graphite	Pencil lead; lubricant; refractories	Metamorphic deposits
Gypsum	Plaster of Paris	Evaporite deposits
Halite	Table salt; chemicals; ice control	Evaporite deposits; salt domes
Muscovite	Insulator in electrical applications	Pegmatites
Quartz	Primary ingredient in glass	Igneous intrusions; sedimentary deposits
Sulfur	Chemicals; fertilizer manufacture	Sedimentary deposits; hydrothermal deposits
Sylvite	Potassium fertilizers	Evaporite deposits
Talc	Powder used in paints, cosmetics, etc.	Metamorphic deposits Nonmetallic Mineral Resources

Types of Mines

- Their are two major types of mines:

Open pit

Underground

OPEN-PIT MINING

Open Pit

- Open-pit mining is surface mining in which huge portions of earth are dug from the surface to extract the desired mineral within them, resulting in a large pit.

- Open-pit mines are used when deposits of commercially useful minerals or rock are found near the surface.

Open Pit

- As a result, the potential exists for considerable destruction to both surface soil and vegetation, and the release of significant amounts of mine dust.

Open Pit

- Open pit mines are usually accessed by surface terracing, thereby allowing technological equipment to follow the shape of the deposit.

Open Pit Impacts

Clearing:

First the bulldozing and preparation kills all existing floral and fauna species on the site.

Mining:

Open-pit mining is infamous for its large amount of dust production. Also the noise created.

Chemical and Toxic Pollution:

The chemicals and toxins exuded seep into the nearby water supply and pollute it.

Open Pit Impacts

Soil Degradation:

Strong acidic or alkaline deposits begin to seep into the surrounding soil making them useless in terms of growth.

Exposure:

The exposure to weathering erodes the soil much quicker. Some soils endure mass compaction.

Scree:

Mining operations mountain sides start to cut into the earth creating a scree drop effect.

Open Pit Pros and Cons

- Open-pit mining in relation to underground mining are lower costs, greater safety, and mechanically easier operations.
- Surface mining is more efficient than underground mining in terms of recovery, grade control, economy, and flexibility of operation.
- However, many deposits, are too small or irregular, and or deeply buried to be extracted efficiently by surface mining methods and the mine must be converted to underground operations or abandoned.

Underground Mining

Underground Mining

- Underground mining is done when the rocks, minerals, or gemstones are too far underground to get out with surface mining or is dictated by the shape of the ore body.

- Some techniques are:
  - Drift Mining
  - Shaft Mining
  - Slope Mining

Underground Mining

- Accessing underground ore can be achieved via a decline (ramp), inclined vertical shaft, adit (horizontal entrance) or an elevator.

- Levels are excavated horizontally off the decline or shaft to access the ore body. Stopes are then excavated perpendicular (or near perpendicular) to the level into the ore.

Underground Mining

- The deepest mines in the world are the TauTona (Western Deep Levels) and Savuka gold mines in the Witwatersrand region of South Africa, which are currently working at depths exceeding 3,900 m (12,800 ft).

Exploration techniques

- Seismic records
- Remote sensing
- Prospecting
- Observing drill cores
- Cross sections
- Geological mapping
- Magnetic survey
- Gravity survey
- Geochemistry

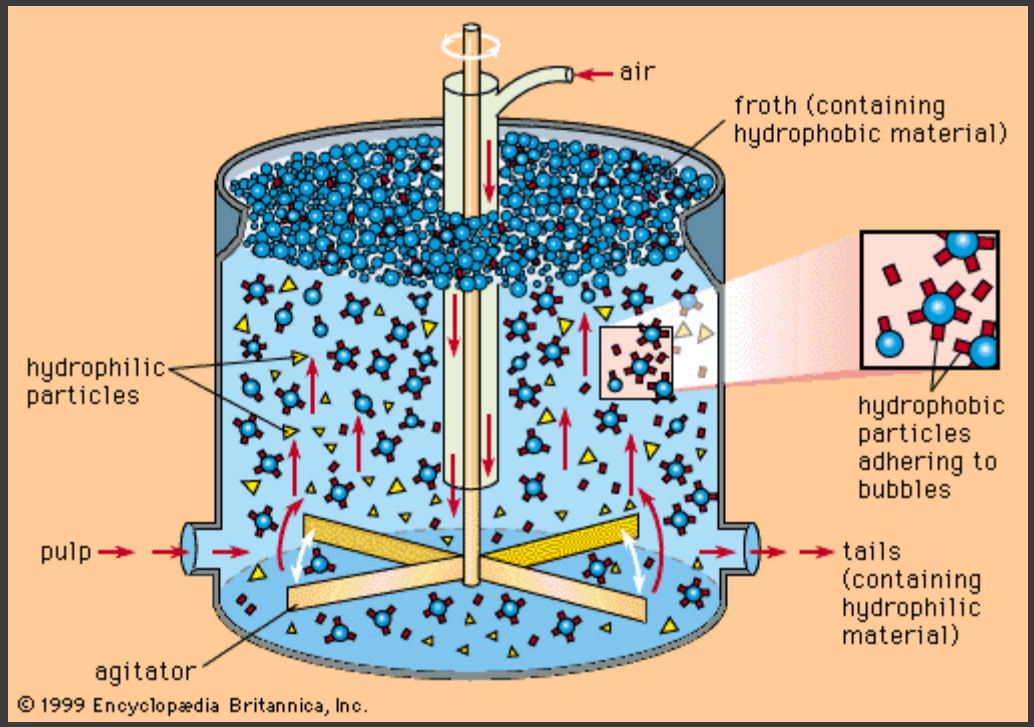
Ore Processing Techniques

1. Floatation
2. Gravity separation
3. Heap leaching
4. Pyromet
5. Hydromet

Flotation

- Floatation involves mixing grounded ore with water, oil, and chemicals.
- The grounded ore becomes suspended in the water and is subjected to bubbles of air.
- This causes the minerals and/or elements of value to float to the top where they can be skimmed off.

Flotation


air
froth (containing hydrophobic material)
hydrophilic particles
hydrophobic particles adhering to bubbles
pulp
tails (containing hydrophilic material)
agitator
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Gravity Separation

- Gravity separation involves feeding grounded ore into a pulsating body of water, which serves to settle out the heavy material while floating away the light material.
  - If the heavy material is what you wishes to keep, then it is taken from the bottom.
  - If the light material is what you wishes to keep, then it is taken from the top.

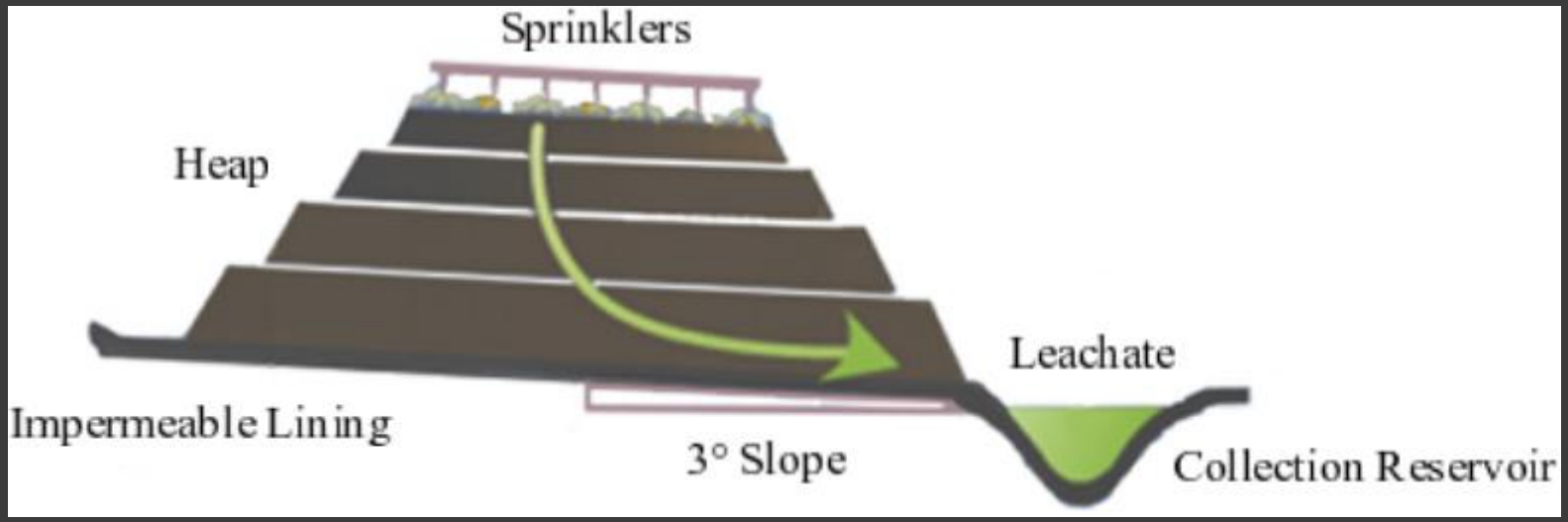
Gravity Separation

Hydraulic Washing

Heap Leaching

- Heap leaching commences by placing the grounded ore as a layer onto impermeable material.
- The “heap” of material is sprayed with a liquid, which percolates down through dissolving away the valuable minerals and/or elements.

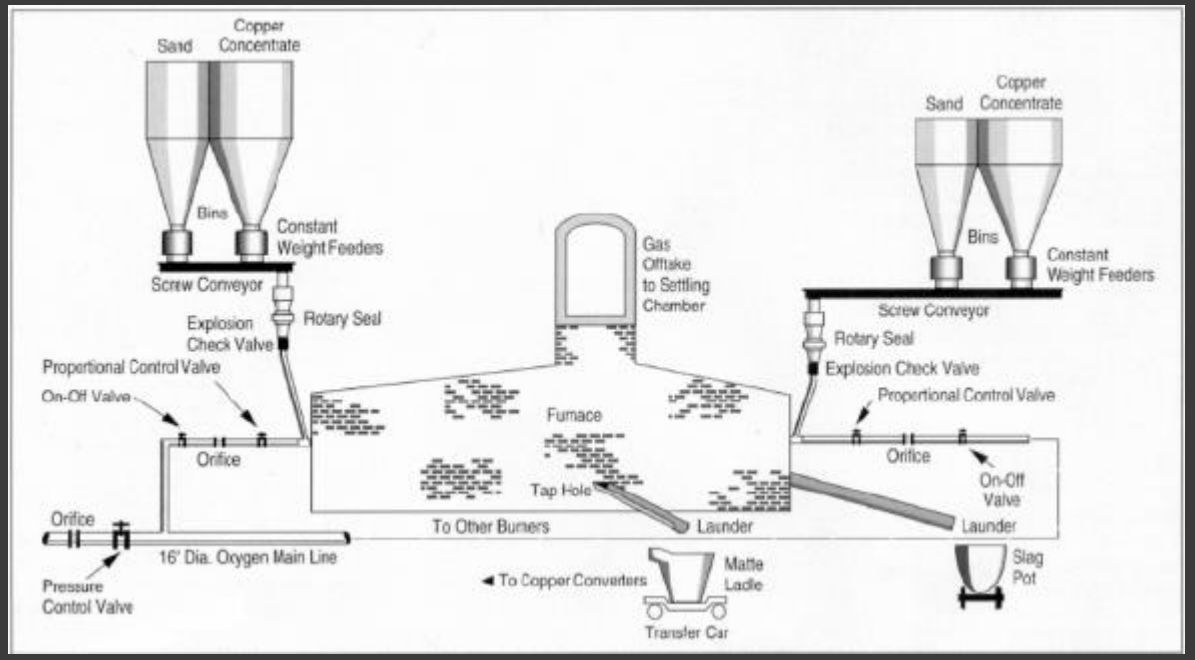
Heap Leaching



Pyromet

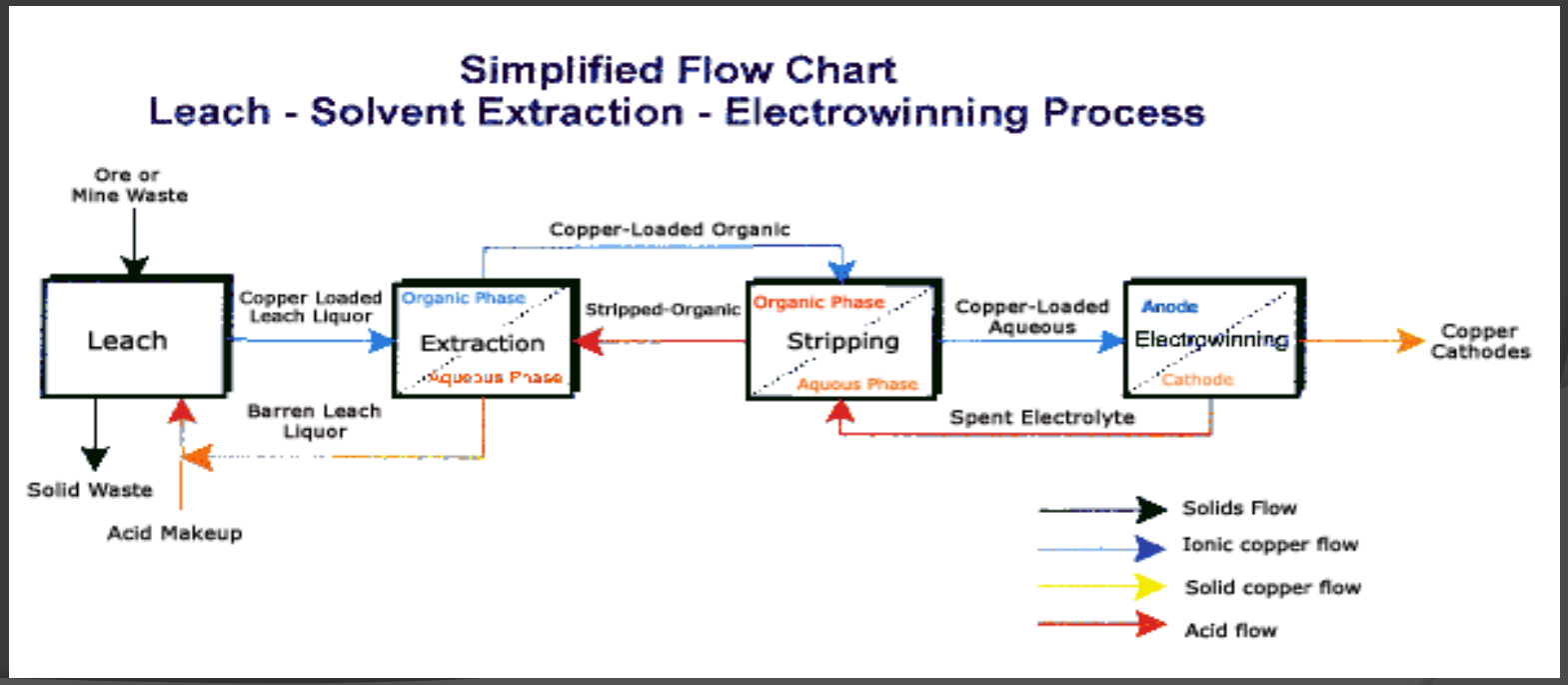
- Pyromet involves using heat to separate the minerals and/or elements of value from the ore.
- Heating separates the materials by density and the desired minerals and/or elements can be removed.

Pyromet


Sand
Copper Concentrate
Bins
Constant Weight Feeders
Screw Conveyor
Explosion Check Valve
Rotary Seal
Propertional Control Valve
On-Off Valve
Orifice
Orifice
Pressure Control Valve
16' Dia. Oxygen Main Line
Gas Offtake to Settling Chamber
Furnace
Tap Hole
To Other Burners
Launder
To Copper Converters
Matte Ladle
Transfer Car
Sand
Copper Concentrate
Bins
Constant Weight Feeders
Screw Conveyor
Rotary Seal
Explosion Check Valve
Propertional Control Valve
Orifice
On-Off Valve
Launder
Slag Pot

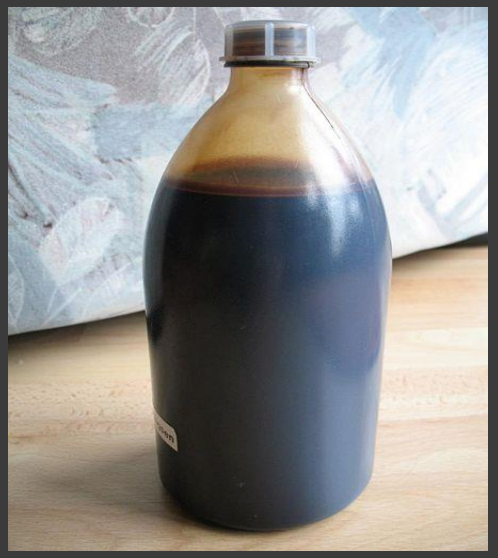
Hydromet

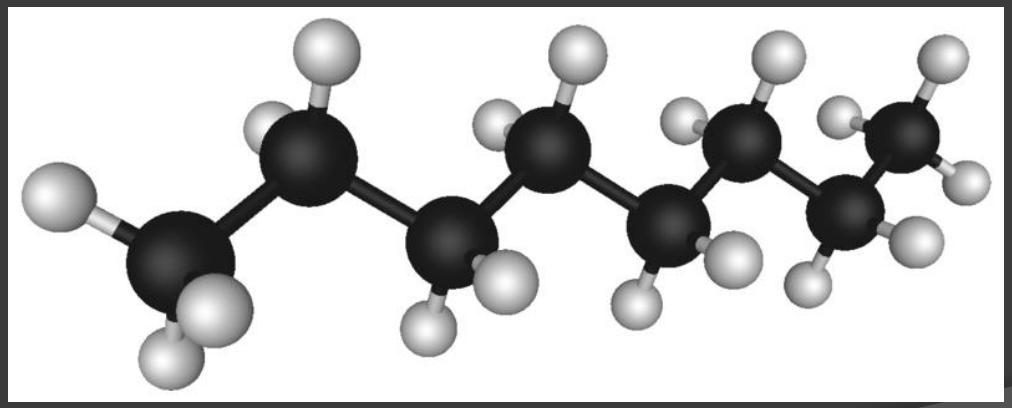
- Hydromet is a chemical method that involves oxidation and acid leaching to separate out the desired minerals and/or elements.



Extraction and Refining Hydrocarbons

- 3 key terms:
  - Petroleum
  - Crude Oil
  - Hydrocarbons





- **Petroleum** is a naturally occurring flammable liquid that is found in geologic formations below Earth's surface and consists of a mixture of hydrocarbons.
- **Crude oil** is a mixture of hydrocarbons that exist in a liquid state in underground reservoirs and remain in a liquid state once subjected to atmospheric conditions.
- **Hydrocarbons** are chemical compounds that involve hydrogen and carbon atoms. Examples include: butane, propane, ethane, and methane (i.e. wet gases).

Origin and the Process of Formation of Petroleum

- Two key terms:
  - Organic Material
  - Preservation Potential

Origin and the Process of Formation of Petroleum

- The origin of petroleum comes from microscopic marine animals (zooplankton) and plants (phytoplankton).
- They are the main sources of *organic matter* in the production of petroleum.
- Examples of such microscopic species are:
  - Diatoms
  - Foraminifera
  - Radiolarian
  - benthic algae

Origin and the Process of Formation of Petroleum

- The abundance of organic matter is determined by the amount of light, water depth, latitude, water temperature, water turbidity, and the abundance of nutrients preferred by plants (e.g. phosphates and nitrates).

Origin and the Process of Formation of Petroleum

- Preservation potential means the conditions that favour the preservation of organic matter.
- The two most important conditions are:
  - 1. anaerobic conditions (low oxygen content)
  - 2. rapid sedimentation by fine-grained material.

Origin and the Process of Formation of Petroleum

- Anaerobic conditions can exist in swamp and lagoon environments.
- Examples of fine-grained material include mud-size, silt-size, and sand-size particles.

Origin and the Process of Formation of Petroleum

- The formation of petroleum is another example of the interconnectedness of the Earth's spheres and thus is a direct reference to a systems approach.

Processes and Techniques Involved in Extracting and Refining Hydrocarbons

- **Key term**:
  - Kerogen
    - a mixture of organic matter in sediments from which petroleum is released.

Processes and Techniques Involved in Extracting and Refining Hydrocarbons

- The three phases in the evolution of organic matter to petroleum.
  - Diagenesis
  - Catagenesis
  - Metagenesis

Processes and Techniques Involved in Extracting and Refining Hydrocarbons

- *Diagenesis:*
  - During diagenesis there is shallow burial of organic matter at near normal temperature and pressure as well as some decay.
  - Methane, carbon dioxide, and water are released leaving behind the complex hydrocarbon called kerogen.

Processes and Techniques Involved in Extracting and Refining Hydrocarbons

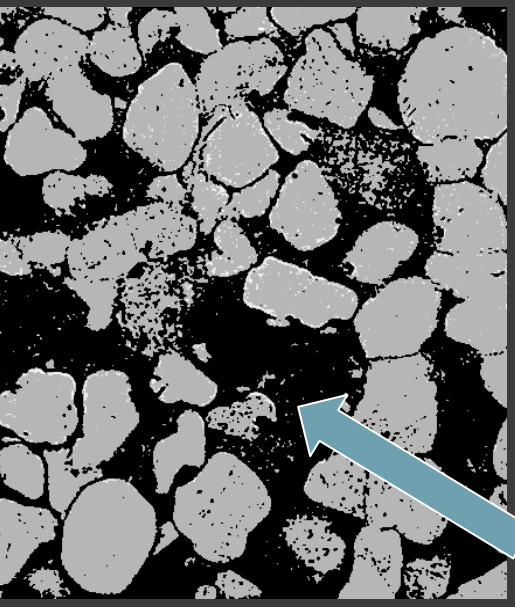
- *Catagenesis:*
  - Deeper burial results in increased temperature and pressure.
  - Petroleum is released from the kerogen
    - first oil is released
    - second gas is released.

Processes and Techniques Involved in Extracting and Refining Hydrocarbons

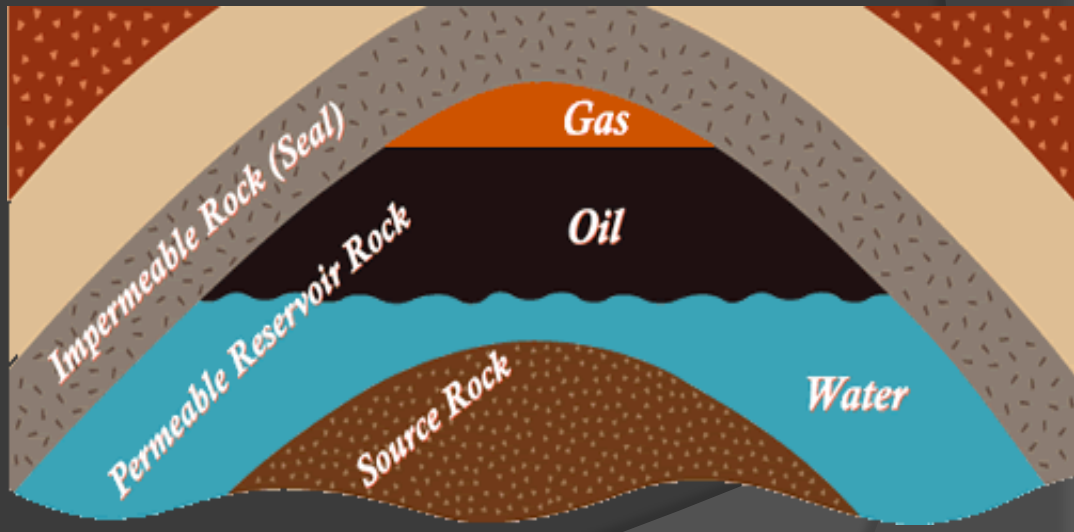
- *Metagenesis:*
  - *The metagenesis phase involves even higher* temperature and pressure verging on metamorphism.
  - The only hydrocarbon that is released during this phase is methane.
  - At this point the petroleum has matured enough to migrate to traps.

Components Involved in the Formation of Petroleum Traps.

- (i) source rock
- (ii) reservoir rock
- (iii) cap rock



As oil migrates it fills up the pores (oil-filled pores shown in black)



Source Rock

Source rocks must contain an abundance of organic matter. Petroleum is often created and released from the source rock while lithification is occurring.

Examples of source rocks are shale and limestone.

- Where sediment contains more than 5% organic matter, it eventually forms a rock known as a Black Shale

Reservoir Rock

- Reservoir rock requires high porosity and high permeability since it is the rock which petroleum moves through and is stored in.

- Note: **Porosity** is the volume of pore spaces or holes between sediment grains.

  Permeability is the inter-connectiveness of the pores, thereby allowing the movement of the petroleum.(rate of flow)

- Porosity of a material is influenced by:

  i) particle shape

  ii) particle size

  iii) the degree of sediment sorting.

  Large, rounded, well-sorted particles offer higher porosity, particularly if the amount of cement between them is limited. Usually, the higher the porosity and the larger the pore spaces, the higher the permeability.

  Examples of reservoir rocks are:sandstone, dolomite, and conglomerate, all have both high porosity and permeability.

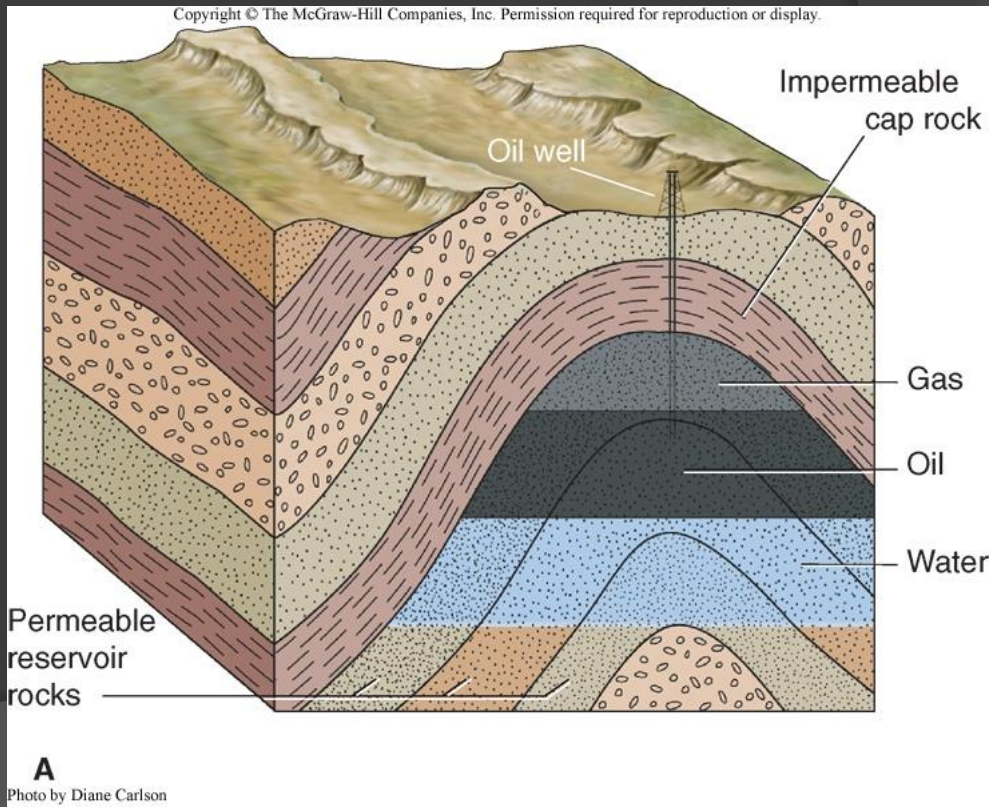
Cap Rock

- Cap rock is an impermeable rock that serves to trap petroleum from either escaping to the surface or spreading throughout the rock as opposed to being confined.

- Note: petroleum exists within reservoir rock between sediment as opposed to being confined as a whole volume of liquid petroleum.
- "There are no ponds of petroleum in the ground".

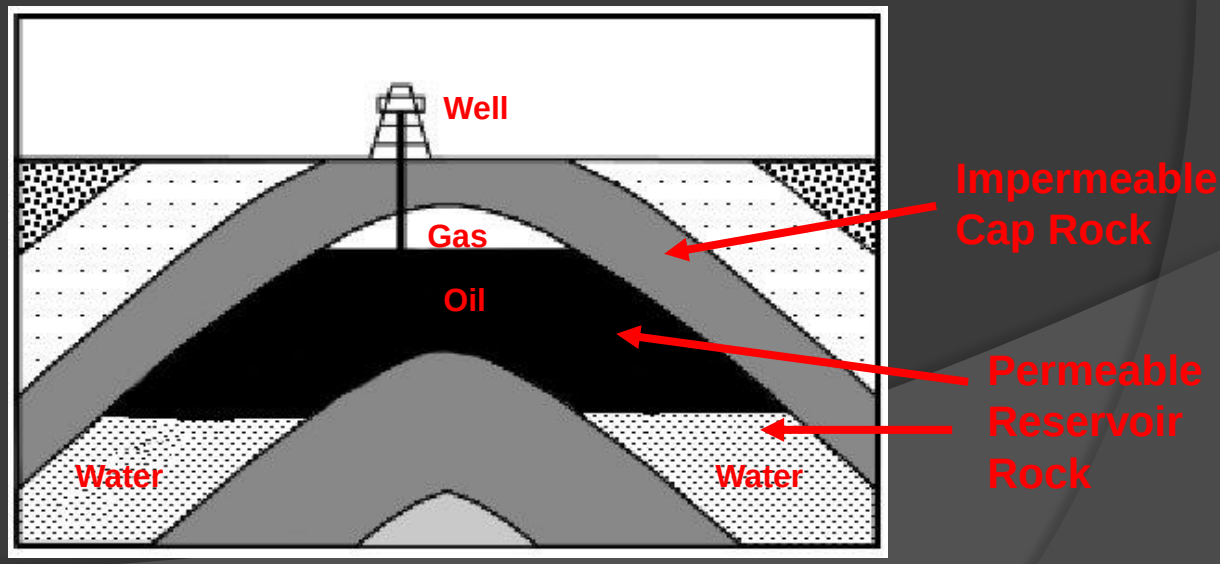
Types of Petroleum Traps

- (i) anticline trap
- (ii) fault trap
- (iii) salt dome trap
- (iv) stratigraphic trap



Anticline Trap:

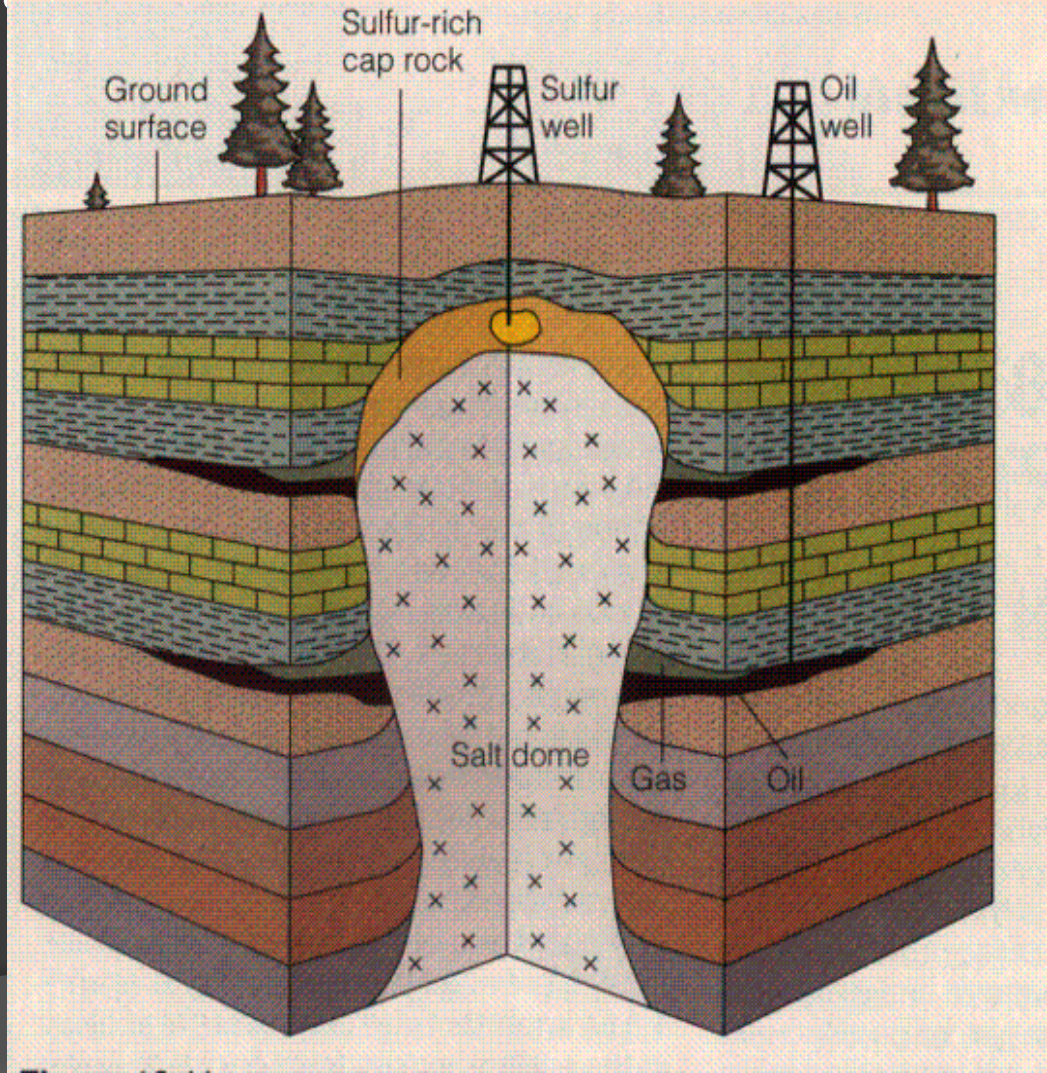
If a permeable rock like sandstone or limestone is located between impermeable rock layers like shale and the rocks are folded into an anticline, oil and gas can move upward in the permeable reservoir rocks, and accumulate in the upper region of the anticline.



Salt Dome Trap

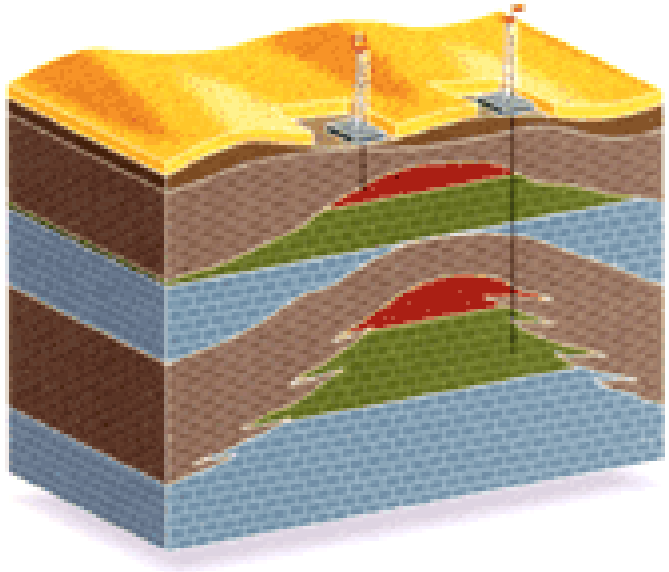
- Here we see salt that has moved up through the Earth, punching through and bending rock along the way.

Oil can come to rest right up against the impermeable salt, which makes salt an effective trap rock.



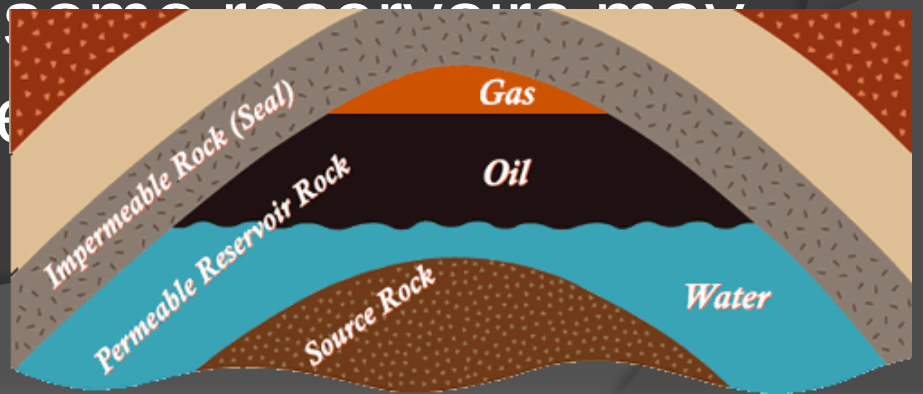
Limestone Reef Trap

- Limestone reef trap is a type of stratigraphic trap, see page 604 text.
- When coral reefs become buried by other impermeable sedim they can form excellent oil sources and reservoirs.



- Note: the physical property density is what distributes petroleum in a reservoir.

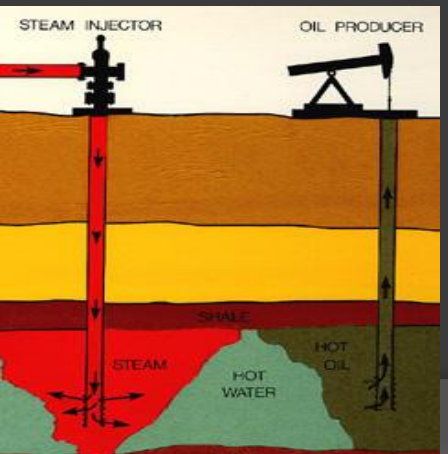
- Water is denser than oil and oil is denser than gas.
- Therefore, when drilling into a petroleum trap, gas is encountered first followed by oil and then water.
- Some reservoirs may have all three components, whereas some reservoirs may only have two compone



Processes and Techniques Involved in Extracting and Refining Hydrocarbons

- The two main means of extracting petroleum from Earth, include:

- (i) drilling
- (ii) surface extraction (open pit mining)



Drilling

- Drilling can take place on land, ice, or water.
- A proportion of petroleum in a trap is under natural pressure and therefore, will be released naturally when tapped by a drill.
- Another proportion of petroleum that will remain in the trap due to loss of pressure.
- Other techniques e.g. pumping in water, gas etc. and filling the reservoir will be required to get the remaining oil from the trap.

- **Surface Extraction (open pit mining)**
- Alberta oil sands,(tar sands)
- Petroleum extracted directly from the surface (open-pit mining).
- The petroleum migrated towards the surface and volatiles (e.g. water) were lost to the atmosphere.
- The increased viscosity (i.e. thickness), prevented the oil from spreading out and/or dissipating.

- The reservoir consisted of loose (unconsolidated) sediment that exhibited high porosity and permeability, but no cap rock.
- In some instances, steam is injected directly into the tar sands to mobilize the hydrocarbons, which are then recovered from pumps much like conventional crude oil.
- Fort McMurray's Athabasca oil sands

Methods of Refining Petroleum.

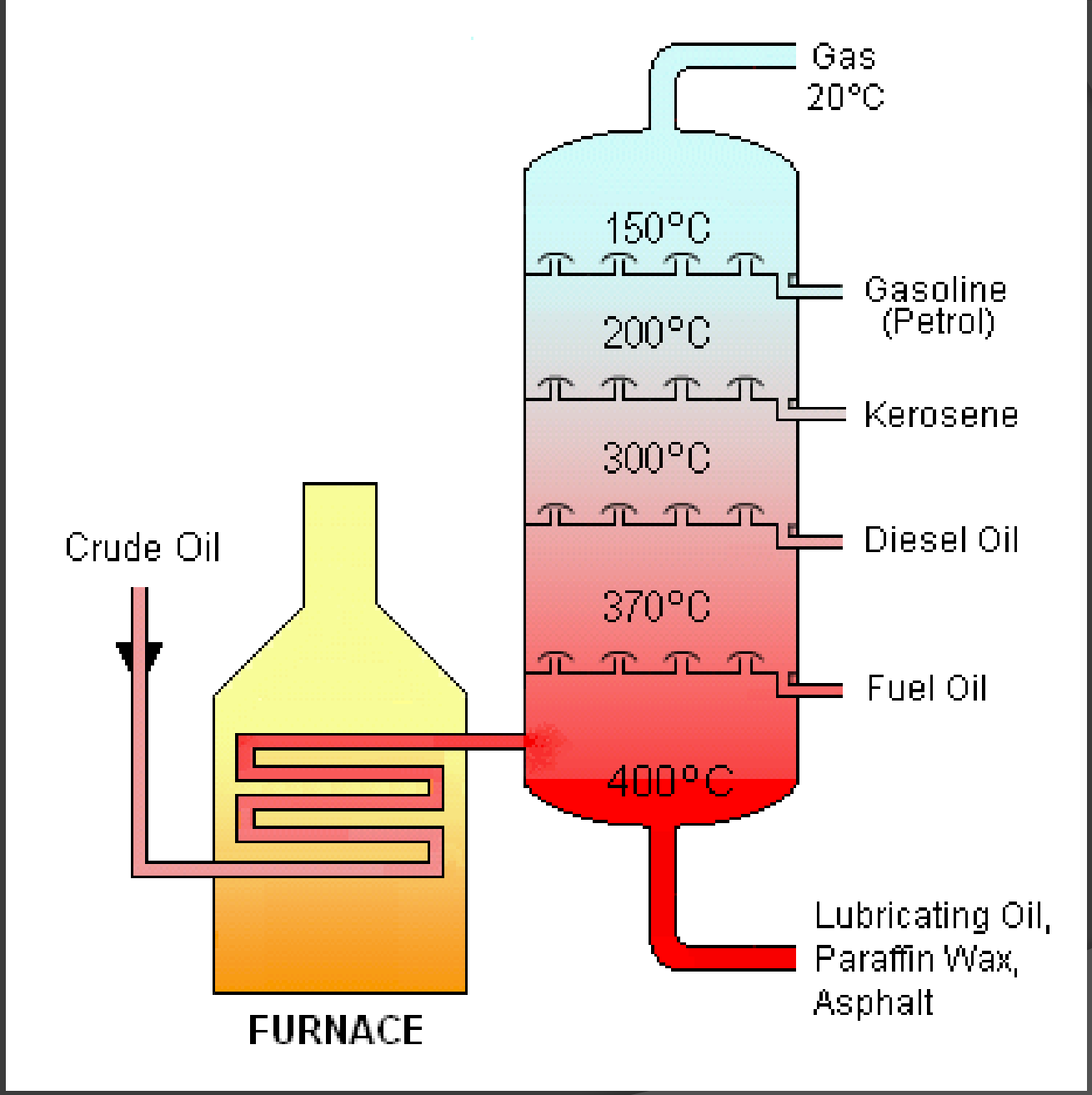
- Include:
- **(i) Distillation**

- crude oil contains hundreds of different types of hydrocarbons all mixed together.

Different hydrocarbon chain lengths all have progressively higher boiling points, so they can all be separated by distillation(heating).

- (ii) **Cracking**
- Cracking processes breaks down heavier hydrocarbon molecules (high boiling point oils) into lighter products such as petrol and diesel. This is done by catalytic cracking, thermal cracking .
- **(iii) Reforming**
- The conversion of straight chain hydrocarbon into branched chain hydrocarbon such as

gasoline. Involves heat, pressure, and the use of catalysts (speed up reaction rates) to reform different hydrocarbon compounds.


Gas
20°C
150°C
Gasoline
(Petrol)
200°C
Kerosene
300°C
Diesel Oil
370°C
Fuel Oil
400°C
Crude Oil
Lubricating Oil,
Paraffin Wax,
Asphalt
FURNACE

Sustainable Development

- What is meant by sustainable development?
- How it relates to extracting and processing Earth Resources?
- What are economic, the environmental, political/social/cultural aspects relate to extraction of resources?
- Realize that the decisions we make today will impact our future.