IIT(BHU) VARANASI

STUDENTS' NOTES

UNDERGROUND METALLIFEROUS MINING

TOPIC-IN SITU LEACHING

In-situ leaching (ISL)

- In-situ recovery (ISR) or solution mining, is a mining process used to recover minerals such as copper and uranium through boreholes drilled into a deposit, in situ.
- This process allows the extraction of metals and salts from an ore body without the need for conventional mining involving drill-and-blast, open-cut or underground mining.

- Drilling of holes into the ore deposit
- Explosive or hydraulic fracturing may be used to create open pathways in the deposit for solution to penetrate.
- Leaching solution is pumped into the deposit where it makes contact with the ore.
- The solution bearing the dissolved ore content is then pumped to the surface and processed.

Process

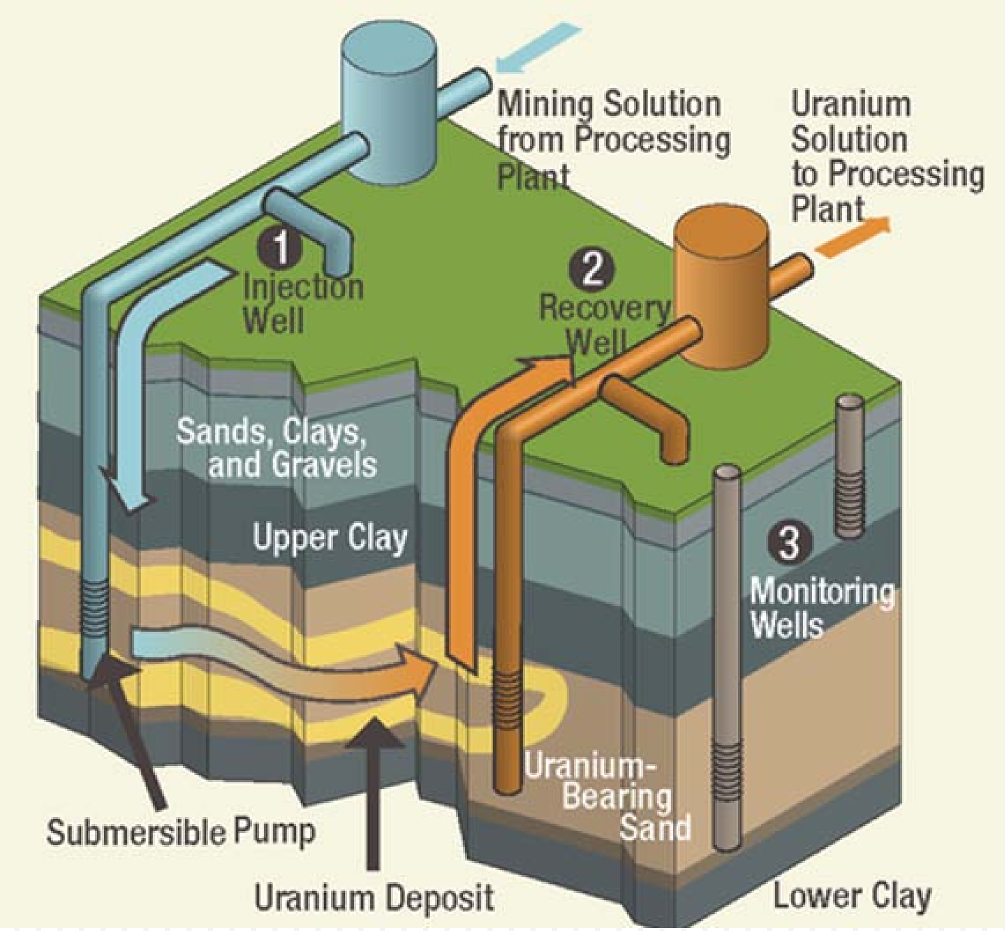
- In-situ leach mining involves pumping of a lixiviant into the ore body via a borehole, which circulates through the porous rock dissolving the ore and is extracted via a second borehole. The lixiviant varies according to the ore deposit.
- For salt deposits the leachate can be fresh water into which salts can readily dissolve.
- For copper, acids are generally needed to enhance solubility of the ore minerals within the solution.
- For uranium ores, the lixiviant may be acid or sodium bicarbonate.

Lixiviant

- A lixiviant is a liquid medium used in hydrometallurgy to selectively extract the desired metal from the ore or mineral.
- It assists in rapid and complete leaching. The metal can be recovered from it in a concentrated form after leaching.
- Lixiviants may work by altering the redox state of an ore, or by altering the pH. Acidic lixiviants, such as sulfuric acid, are commonly used to leach base metals such as copper, whereas basic lixiviants such as a solution of sodium cyanide are used to leach precious metals.

Uranium

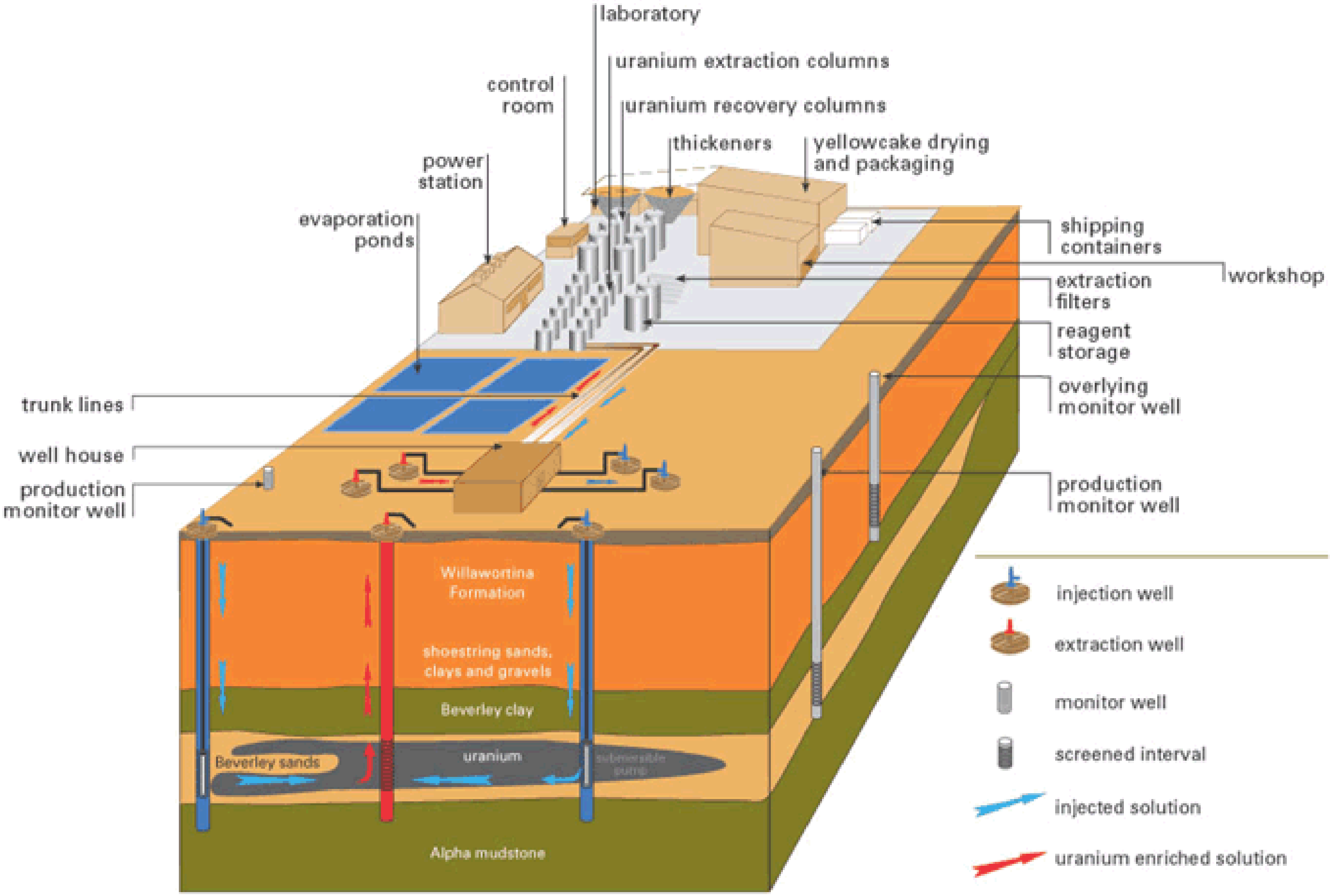
Injection wells (1) pump a chemical solution—typically groundwater mixed with sodium bicarbonate, hydrogen peroxide, and oxygen—into the layer of earth containing uranium ore. The solution dissolves the uranium from the deposit in the ground and is then pumped back to the surface through recovery wells (2) and sent to the processing plant to be processed into uranium yellowcake. Monitoring wells (3) are checked regularly to ensure that uranium and chemicals are not escaping from the drilling area.



- Solutions used to dissolve uranium ore are either acid (sulfuric acid or less commonly nitric acid) or carbonate (sodium bicarbonate, ammonium carbonate, or dissolved carbon dioxide).
- Dissolved oxygen is sometimes added to the water to mobilize the uranium
- In-situ recovery involves the extraction of uranium-bearing water (grading as low as .05% U_3O_8).

- The extracted uranium solution is then filtered through resin beads.
- Through an ion exchange process, the resin beads attract uranium from the solution
- Uranium loaded resins are then transported to a processing plant, where U3O8 is separated from the resin beads and yellowcake is produced.
- The resin beads can then be returned to the ion exchange facility where they are reused.

- It involves leaving the ore where it is in the ground, and recovering the minerals from it by dissolving them and pumping the pregnant solution to the surface where the minerals can be recovered.
- Consequently there is little surface disturbance and no tailings or waste rock generated.
- However, the orebody needs to be permeable to the liquids used, and located so that they do not contaminate groundwater away from the orebody.


laboratory
uranium extraction columns
control room
uranium recovery columns
thickeners
yellowcake drying and packaging
power station
evaporation ponds
shipping containers
workshop
extraction filters
reagent storage
overlying monitor well
trunk lines
well house
production monitor well
production monitor well
Willawortina Formation
shoestring sands, clays and gravels
Beverley clay
Beverley sands
uranium
Alpha mudstone
injection well
extraction well
monitor well
screened interval
injected solution
uranium enriched solution

- Deposits were formed by the lateral movement of groundwater bearing oxidised uranium minerals through the aquifer, with precipitation of the minerals occurring when the oxygen content decreased, along extensive oxidation-reduction interfaces.
- The uranium minerals are usually uraninite (oxide) or coffinite (silicate) coatings on individual sand grains

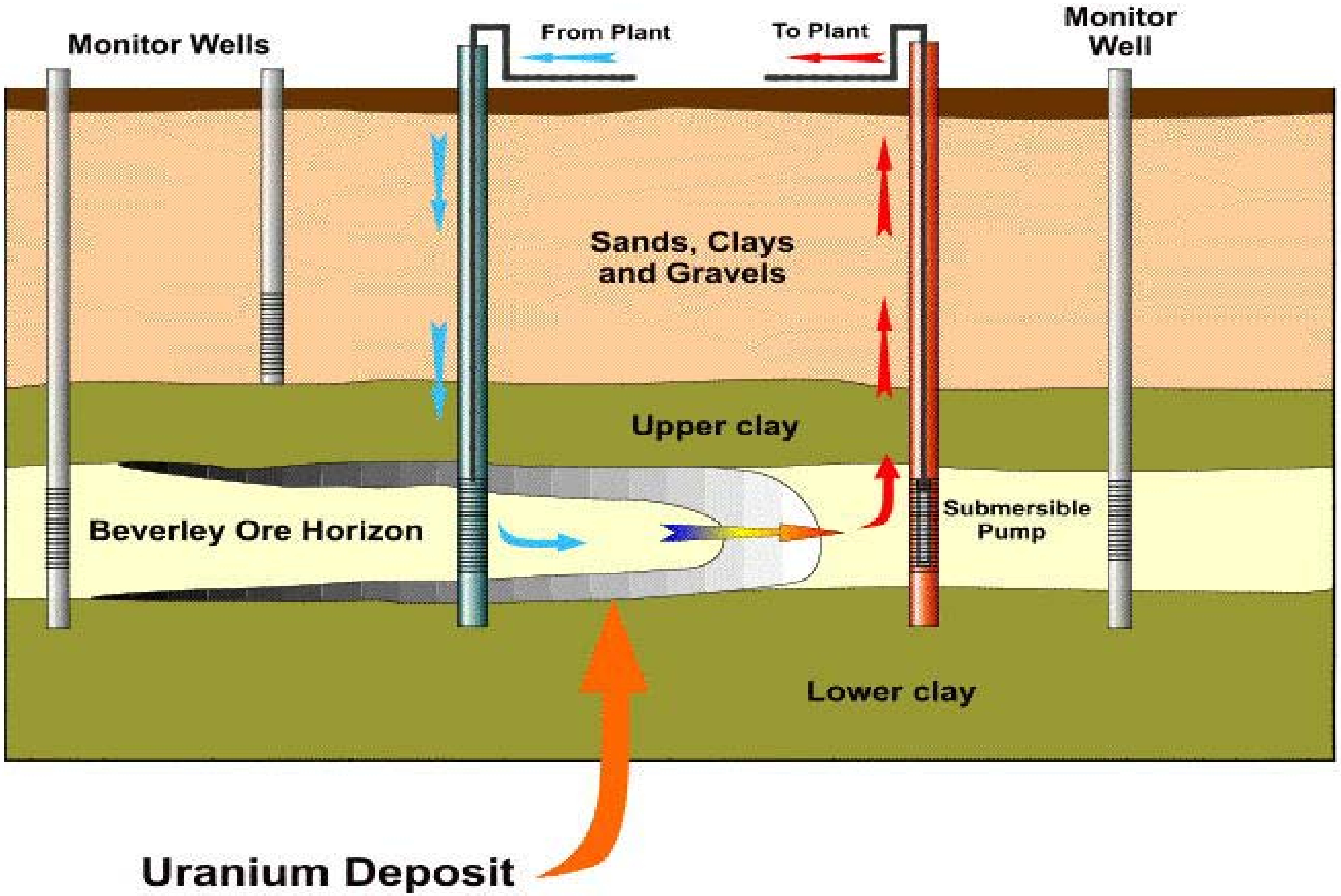
- Methods depend on the geology and groundwater.
- If there is significant calcium in the orebody (as limestone or gypsum, more than 2%), alkaline (carbonate) leaching must be used. Otherwise, acid (sulfate) leaching is generally better.
- Acid leaching recovery – 70-90% –
- Alkaline leach recovery 60-70%
- operating costs are about half those of alkaline leach.

- Uranium deposits suitable for ISL occur in permeable sand or sandstones, confined above and below by impermeable strata, and which are below the water table

- The submersible pumps initially extract native groundwater from the host aquifer prior to the addition of uranium complexing reagents (acid or alkaline) and an oxidant (hydrogen peroxide or oxygen) before injection into the wellfield.
- The leach liquors pass through the ore to oxidise and dissolve the uranium minerals in situ.

- Depending on the type of leaching environment used the uranium will be complex as either a uranyl sulphate, predominantly $UO_2(SO_4)_3^{4-}$, in acid leach conditions or a uranyl carbonate, predominantly $UO_2(CO_3)_3^{4-}$ in a carbonate leach system.
- This can then be precipitated with an alkali, eg as sodium or magnesium diuranate.

- In either case the pregnant solution from the production wells is pumped to the treatment plant where the uranium is recovered in a resin/polymer ion exchange (IX) or liquid ion exchange (solvent extraction – SX) system.


Monitor Wells
From Plant
To Plant
Monitor
Well
Sands, Clays
and Gravels
Upper clay
Beverley Ore Horizon
Submersible
Pump
Lower clay
Uranium Deposit

Examples of in-situ uranium mines

- The Beverley Uranium Mine and The Honeymoon Uranium Mine, South Australia,
- Crow Butte (operating), Smith Ranch-Highland (operating), Churchrock (proposed), Crownpoint (proposed), Alta Mesa (operating), Hobson (standby), La Palangana (operating), Kingsville Dome (operating), are ISL uranium operations in the United States.
- Palangana deposit in Duval County, Texas

Environment & Health

- The quality of the remaining groundwater must be restored to a baseline standard determined before the start of the operation, so that any prior use can be resumed.
- Contaminated water drawn from the aquifer is either evaporated or treated before reinjection.

Copper

- Copper is usually leached using acid (sulfuric acid or hydrochloric acid), then recovered from solution by solvent extraction electrowinning (SX-EW) or by chemical precipitation.
- Ores most amenable to leaching include the copper carbonates malachite and azurite, the oxide tenorite, and the silicate chrysocolla.

- The ores with the highest sulfide contents, such as bornite and chalcopyrite will require more oxidants and will dissolve more slowly. Sometimes oxidation is speeded by the bacteria Thiobacillus ferrooxidans, which feeds on sulfide compounds.

- Copper ISL is often done by stope leaching, in which broken low-grade ore is leached in a current or former conventional underground mine.
- The leaching may take place in backfilled stopes or caved areas

Gold

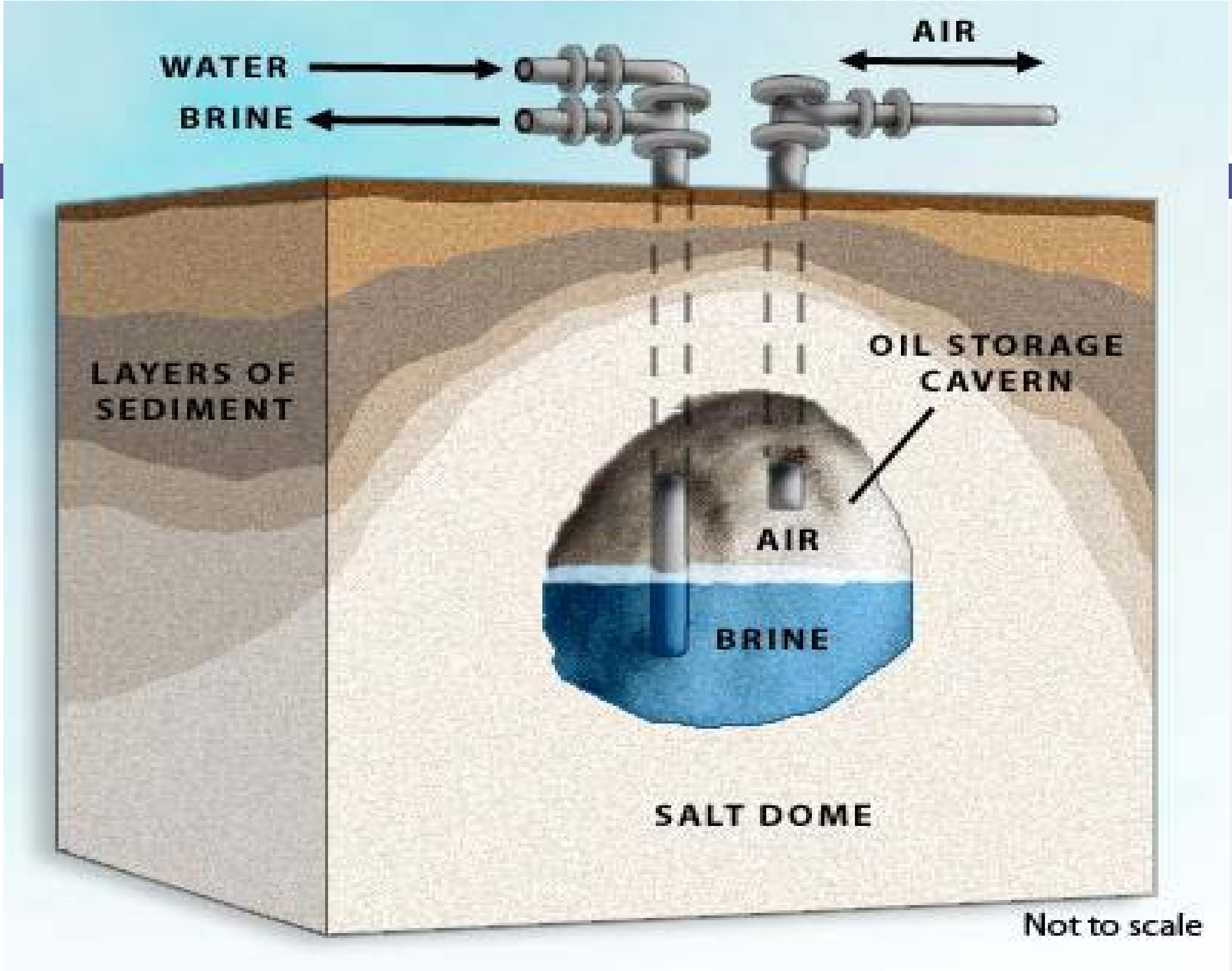
- In-situ leaching has not been used on a commercial scale for gold mining.
- A three-year pilot program was undertaken in the 1970s to in-situ leach gold ore at the Ajax mine in the Cripple Creek district in the US, using a chloride and iodide solution.
- After obtaining poor results, perhaps because of the complex telluride ore, the test was halted

Lithium

- lithium-containing brine is extracted from underground and concentrated via solar evaporation.
- A pilot project aimed at showing the financial feasibility of extracting high-quality lithium from geothermal brine.
- It uses brine from the 49.9-megawatt Featherstone geothermal power plant in California's Imperial Valley.

Magnesium chloride

- The **magnesium chloride** is extracted from over 2000 ft below the surface by gentle solution mining processes, without using harsh chemicals and additives to enhance the speed of the process.
- It remains in this raw, ultra pure natural state throughout manufacturing yielding a highly bio-available magnesium chloride for both dietary and topical use


WATER
BRINE
AIR
LAYERS OF SEDIMENT
OIL STORAGE CAVERN
AIR
BRINE
SALT DOME
Not to scale

disadvantages

- Risk of spreading of leaching liquid outside of the uranium deposit, involving subsequent groundwater contamination
- Unpredictable impact of the leaching liquid on the rock of the deposit, and the impossibility of restoring natural groundwater conditions after completion of the leaching operations.

advantages

- Reduced hazards for the employees from accidents, dust, and radiation,
- Low cost, no need for large uranium mill tailings deposits.