In Situ Leaching and Solution Mining

Douglas F. Hambley, PhD, PE, PEng, PG

AGAPITO ASSOCIATES, INC.
Mining & Civil Engineers & Geologists

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Definitions

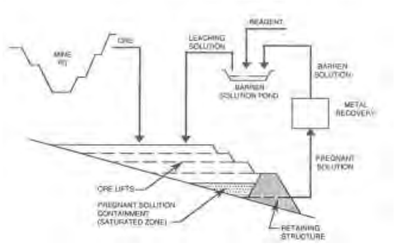
- **Leaching—An ore processing method that uses a *chemical solution* to extract a desired mineral from an *unprepared or prepared* ore stockpile or process feedstock.**
  - Dump Leaching
  - Heap Leaching
  - Vat Leaching
- **In situ Leaching—An ore processing method that uses a *chemical solution* to dissolve a desired mineral from a *geological ore zone* into solution through boreholes, abandoned underground workings, or specially prepared rock.**
  - Uranium
  - Copper
  - Silver

Definitions

- **Solution Mining—The use of *water or hot water* to dissolve a desired mineral from a *geological ore zone* into solution through directional or vertical boreholes or abandoned underground mine workings.**
  - **Salt (Halite, NaCl)**
  - **Potash (Sylvite, KCl)**
  - **Soda Ash (Trona, $Na_2CO_3 \cdot NaHCO_3 \cdot H_2O$)**
  - **Baking Soda, (Nahcolite, $NaHCO_3$)**

- **Mining through Boreholes—A *mining system* designed to extract a specific mineral or a conversion of the mineral from a *geological ore zone* utilizing a small-diameter drilled *borehole*.**
  - **Sulphur**
  - **Coal Gasification**
  - **Tar Sands**
  - **Oil Shale**

Dump Leaching



Dump Leach Diagram

Dump Leaching

- **Ore Grade is too Low for Crushing, Grinding, Concentration, and Smelting**
- **No Crushing or Sizing (*no preparation*)**
- **Low-Permeability Dump Leach Base (*State and Federal permits*)**

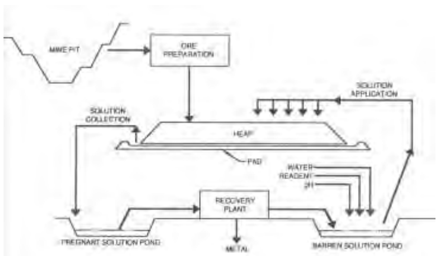
Dump Leaching

- Advantages
  - Metal recovery from low-grade ores
  - Cost effective
- Disadvantages
  - Low recovery (20%–50%)
  - Most effective on oxide ores
  - Slow process (2–7 years)
- Examples
  - SX-EW Copper—Arizona, New Mexico, Utah and Chile

Heap Leaching

- Primary or Supplementary Mineral Processing
- Material is Crushed and Sized (*preparation*)
- Heap Leach is Designed for Optimum Mineral Recovery
- Low-Permeability Heap Leach Base (*State and Federal permits*)

Heap Leaching

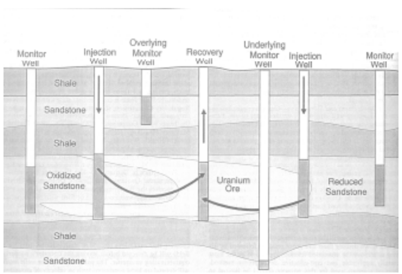


Heap Leach Diagram

Heap Leaching

- Advantages
  - Metal recovery without grinding, concentration, or smelting
  - Cost effective
- Disadvantages
  - Low recovery (40%–80%)
  - Most effective on oxide ores
  - Slow process (2–7 years)
- Examples
  - Copper—Arizona, New Mexico, Utah and Chile
  - Gold—Colorado, Nevada, California

In Situ Leaching



Typical Uranium In Situ Leaching

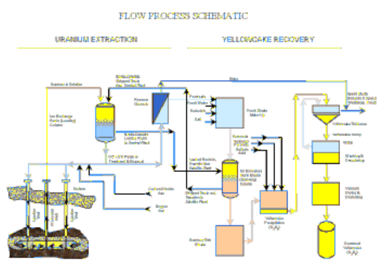
In Situ Leaching

- A Dilute Chemical Solution is Used to Leach a Desired Mineral in Place (*no transport of the ore*)
- Undisturbed or Specially Prepared Ore Body
  - Wells drilled specifically for in situ leaching
  - Inactive or previously mined underground mine

In situ Leaching

- Advantages
  - Low capital costs
  - Low operating costs
- Disadvantages
  - Low recovery (20%–50%)
  - Requires specific geological conditions
  - Environmental concerns
- Examples
  - Uranium—Wyoming and Nebraska
  - Copper—Arizona

Wyoming In Situ Leach Process Flowsheet



Drilling and Completion of a Wyoming Uranium In Situ Well

Wyoming In Situ Uranium Well Completion

Wyoming In Situ Uranium Mine Well Head

Wyoming In Situ Uranium Mine Well House

Wyoming Yellow Cake loaded into 55 gallon Drums for Shipment

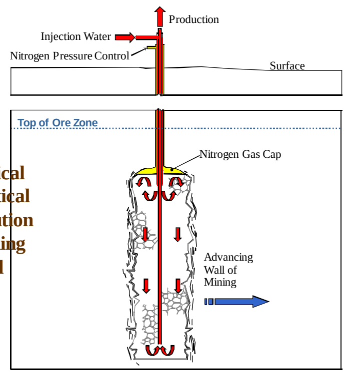
Solution Mining

- Minerals extraction
- Cavern Development for Storage

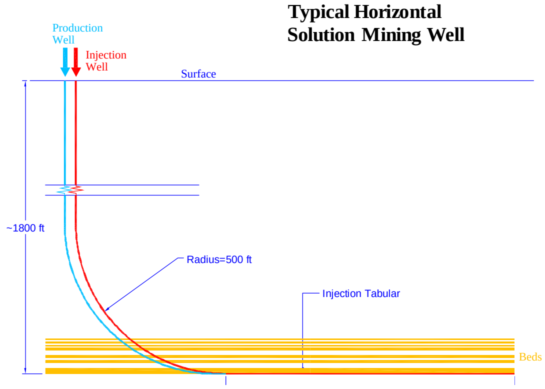
Solution Mining

- Water or Hot Water
- Water Soluble Minerals
- Undisturbed or Previously Mined Ore Body
  - Wells drilled specifically for solution mining
  - Inactive or previously mined underground mine

Typical Vertical Solution Mining Well



Typical Horizontal Solution Mining Well



Solution Mining

- **Advantages**
  - Low capital costs
  - Low labor costs
- **Disadvantages**
  - Low recovery (20%–50%)
  - Water-soluble minerals
  - Possible high energy costs
- **Examples**
  - Salt (Halite, NaCl)—Michigan, Kansas, Texas, Louisiana, Canada
  - Potash (Sylvite, KCl)—Utah, Michigan, New Mexico, Canada, Germany
  - Baking Soda (Nahcolite, $NaHCO_3$)—Western Colorado
  - Soda Ash (Trona, $Na_2CO_3 \cdot NaHCO_3 \cdot H_2O$)—Wyoming, Turkey, China

American Soda Location Map

American Soda Well Head

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Wellhead with Lubricators

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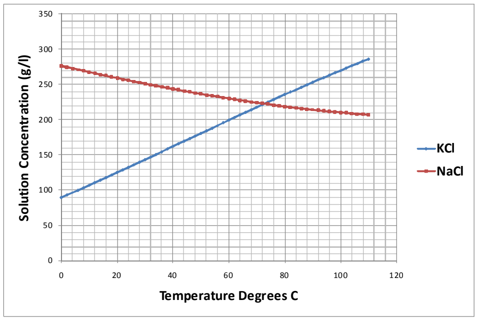
Potash Solubility Curves

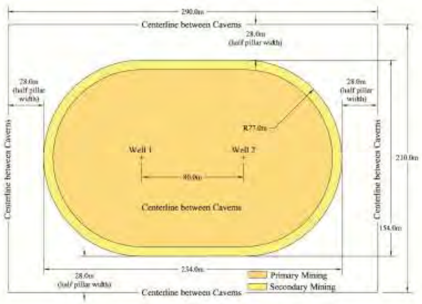


Potassio Rio Colorado (PRC) Project, Argentina

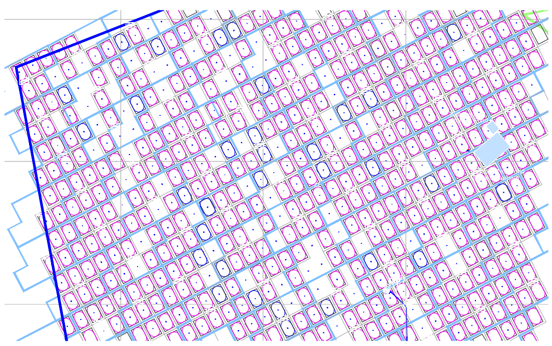
PRC --Vale (previously Rio Tinto)

- **Solution mining method similar to that used by Mosaic in Saskatchewan**
- **Pilot test completed**
- **Commercial development currently halted**

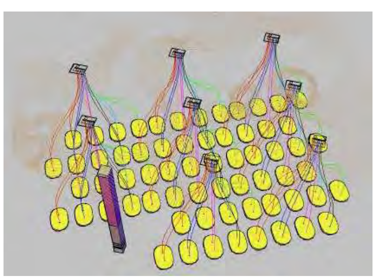
Typical Cavern For PRC



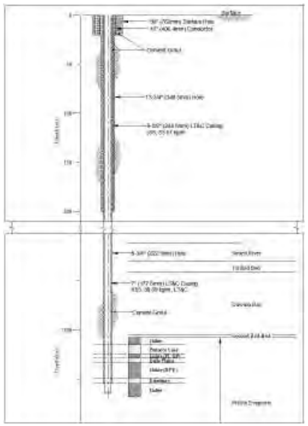
Partial Plan View of Caverns

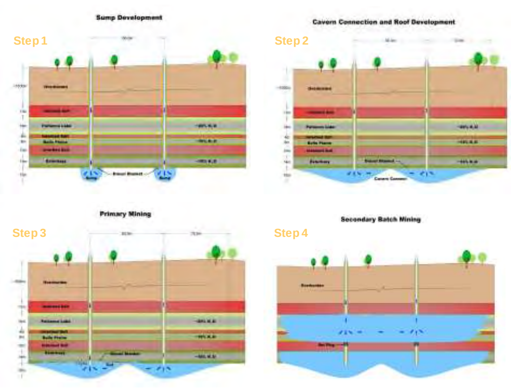


Multiple Caverns from Cluster Pads

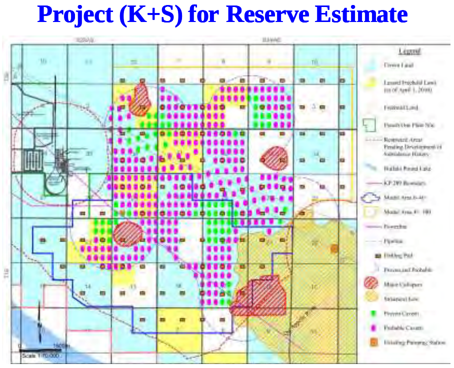


Typical Saskatchewan Potash Well Completion

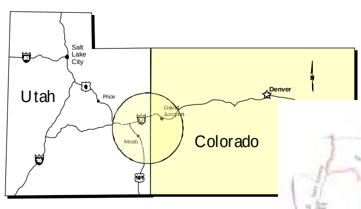


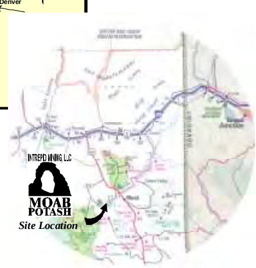


Cavern Layout of Legacy Project (K+S) for Reserve Estimate

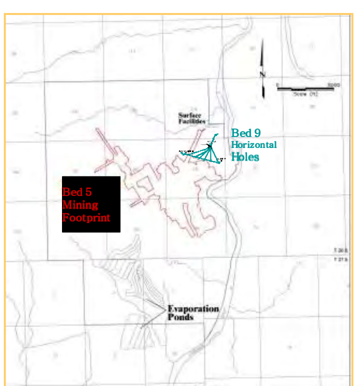


Intrepid Potash's Cane Creek Potash Solution Mine





Location of Cane Creek Mine

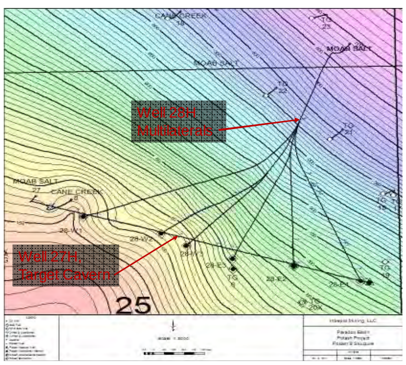


Site Map
Cane Creek Potash Mine, Moab, Utah

Cane Creek Potash Solution Mine, Moab, Utah

Solar Evaporation Ponds

Cavern System Well 27H and 28H



Drill Rig

Intrepid Potash’s Cane Creek Potash Solution Mine

Injection Well

Recovery Well

Cane Creek Potash Solution Mine, Moab, Utah

Harvesting a Pond

Turkish Solution Mining Recovery Well

Turkish Solution Mining Injection Well

Borehole Mining

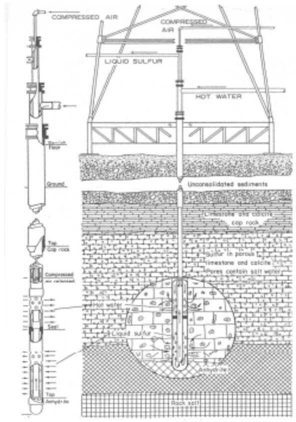
- Mining System
- Extracts or Converts
- Wells Drilled for the Mining of a Specific Mineral
- Oil Shale

Borehole Mining

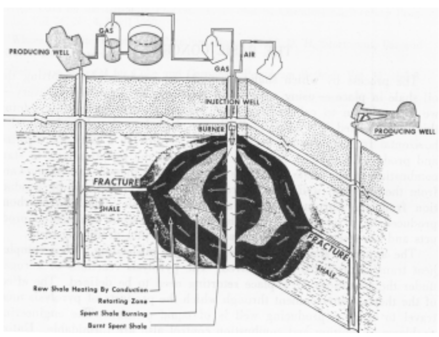
- Advantages
  - Low capital costs
  - Low labor costs
- Disadvantages
  - Low recovery (20%–50%)
  - Specific mineral
  - Possible high energy costs
- Examples
  - Frasch Sulphur—Texas and Louisiana
  - Coal Gasification
  - Oil Shale—Western Colorado
  - Tar Sands (SAG-D)—Canada

Borehole Mining

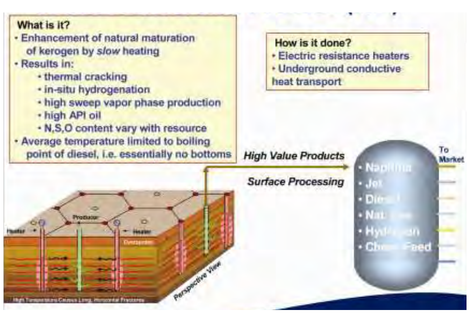
Typical Frasch Sulphur Well



True In Situ Method



RDD Colorado—Shell Frontier Oil and Gas, Inc.



In Situ Conversion (ICP) Process

RDD Colorado—Shell Frontier Oil and Gas, Inc.

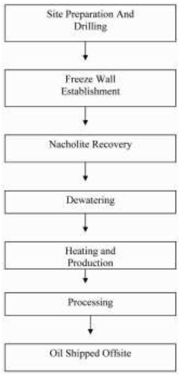


Diagram of Second Generation ICP

Future Trends

- **Wider acceptance of Solution Mining**
- **Environmentally acceptable**
- **BioLeaching (Sulfide Ores)**
- **Coal Gasification**
- **Tar Sands**
- **Oil Shale**
- **Application of Directional Drilling**