

A landscape photograph showing rolling hills in the foreground, a valley with a forested area in the middle ground, and a range of mountains in the background under a blue sky with scattered clouds. The text is overlaid on the upper portion of the image.

Applications of Bauxsol™ in Reclamation, Remediation, and Water Treatment

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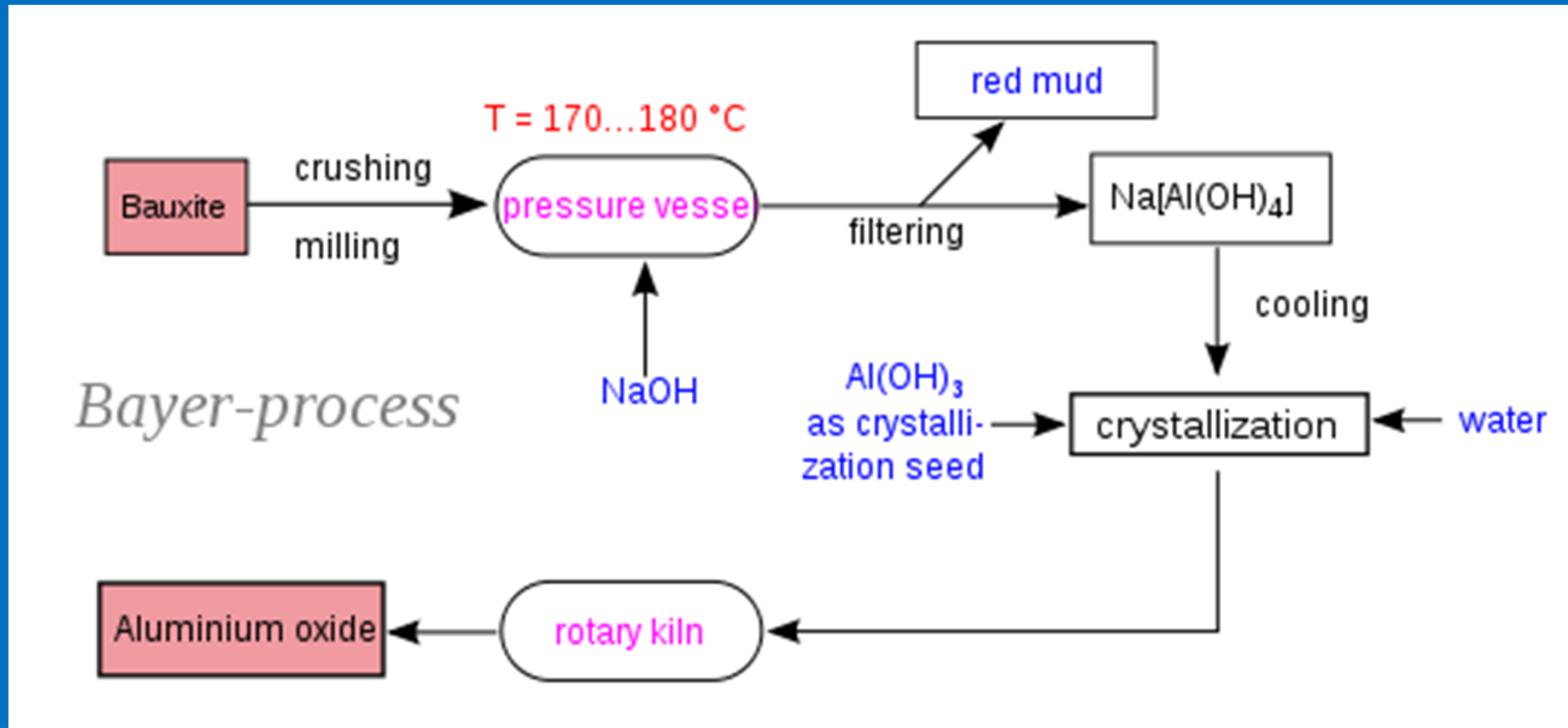
Common Problems at Precious and Base Metal Mines with Sulfide Ores

- Acid rock drainage
- Neutral metal leaching

A possible solution to these problems originated as a waste product in the aluminum industry.

In other words: A waste is a product for which we haven't found a use yet.

Bauxite is refined using the Bayer Process.



Red Mud Properties

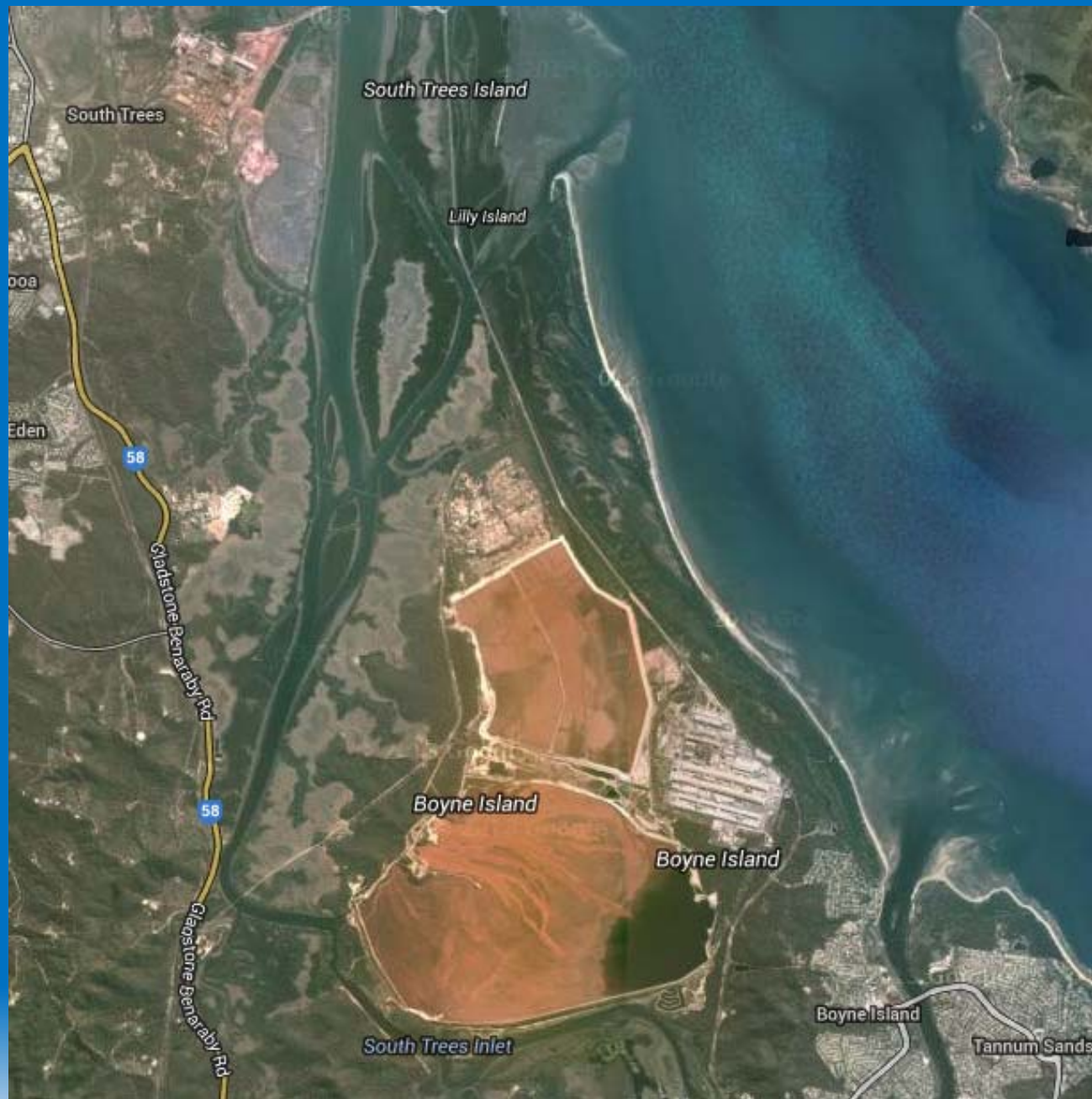
- pH ~ 13
- Gelatinous, high water content; hard to drain.
- Hard to reclaim the ponds.
- Depending on source of bauxite, may contain heavy metals.
- Few industrial applications.

Queensland Alumina Complex Gladstone, Qld.



Queensland Alumina Red Mud Handling

- As a fresh water conservation measure, the red mud is piped to the pond in a slurry with seawater.
- The pond is also flushed with tidewater every day.
- As a result the red mud at QAL is neutralized by seawater.



QAL Research Project

In 1992 QAL hired consultants from Southern Cross University to assess possible hazards and the potential for pollution of ocean water by runoff from the red mud ponds.

Results of Research

- Seawater samples from the South Trees Inlet, which carried drainage from the red mud pond, did not contain elevated levels of pollutants compared to control sites.
- The red mud had a much lower pH than usually seen at bauxite refineries (8-9 vs. 13).
- The mud was well-drained and had a higher density and lower water content.

Quality of Discharged Seawater in South Trees Inlet

- pH 8.3
- Depleted in Ag, Ba, Cd, Co, Cr, Cu, Fe, Li, Mn, Ni, Pb, Sb, Si, Sr, Zn
- Quality of seawater met all ANZECC standards for marine waters.

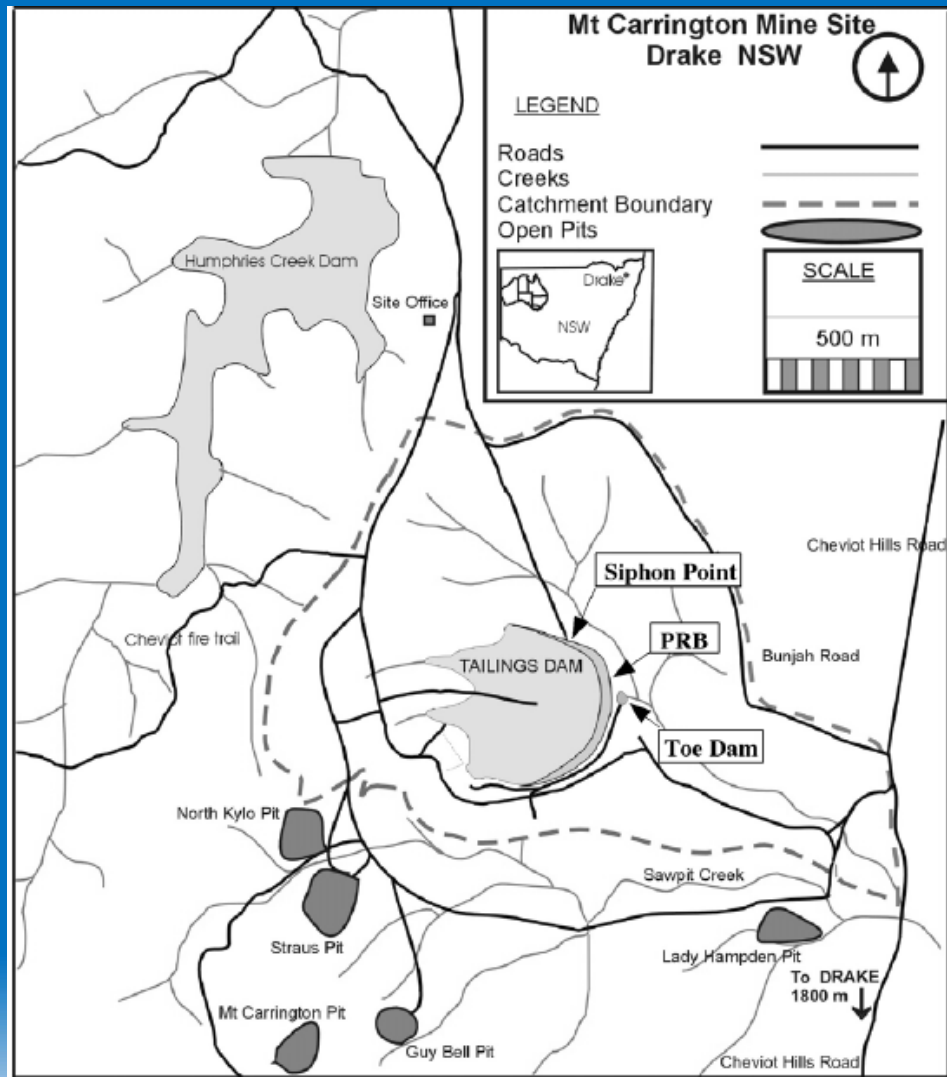
Next Steps

- Patent applications were filed by the researchers.
- Business organization: Mount Carrington Mines became Virotec, Ltd.
- Seawater-neutralized red mud trademarked as Bauxsol™.
- Research continued.

Mount Carrington Mine

- Au + Ag mine at Drake, N.S.W.
- Country rock contained subeconomic levels of Cu, Zn, and Pb.
- Waste rock was highly acid-generating.
- Drainage water from waste piles contained significant Cd, Cu, Zn, and Pb.
- Mine was closed in 1990.

The Mount Carrington Mine



Tailings Pond Area



Mount Carrington Mine – Environmental Problems

- Sulfide-rich rock on tailings dam was main source of ARD and metal leaching.
- During dry season, evaporation concentrates metals in water.
- Toe pond was the route followed by discharges of ARD and leached metals to surface water.
- The toe pond was cleaned up first, followed by the drainage to the toe pond from the dam face.

Toe Pond Cleanup

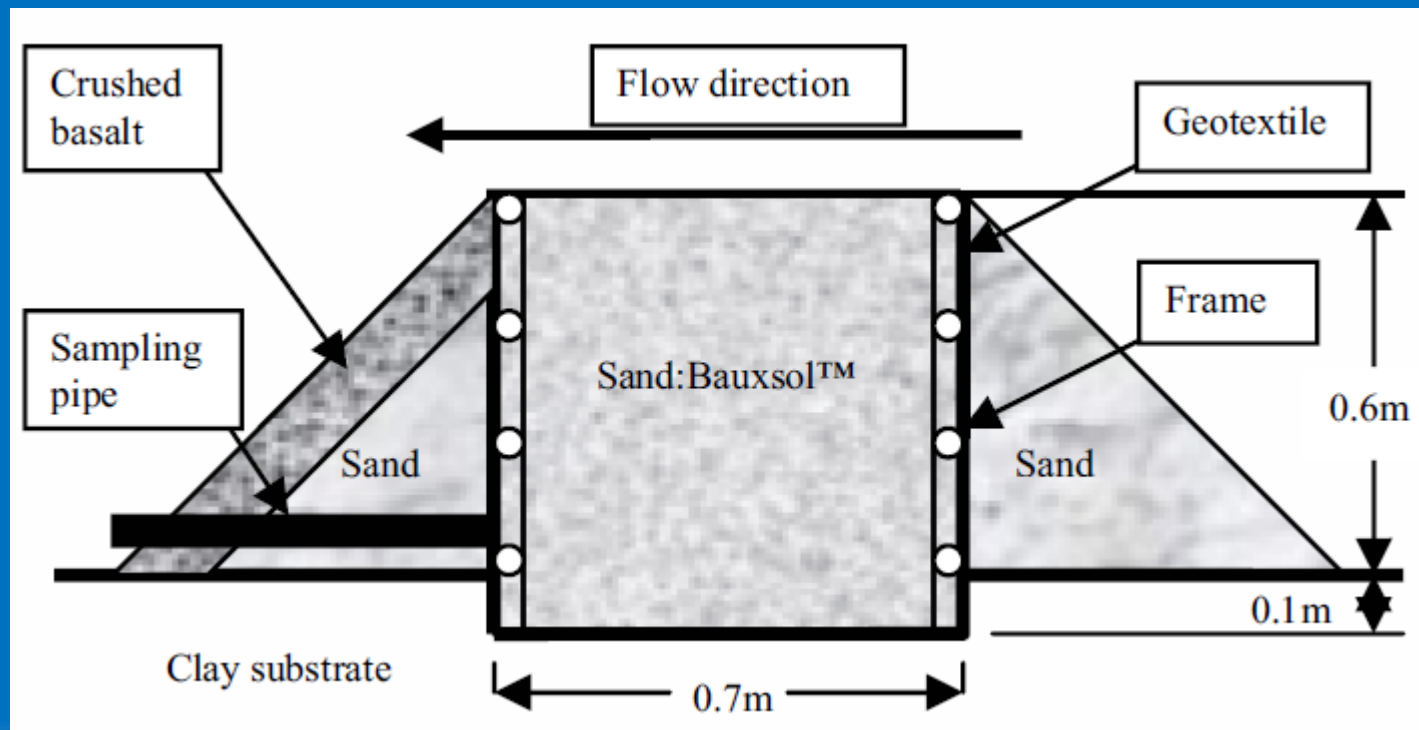
- A Bauxsol slurry was applied to the pond (approx. 100 X 100 ft)
- The Bauxsol raised the pond pH from about 3.0 to 8.5 and achieved ANZECC standards for surface water.
- A layer of Bauxsol lined the bottom of the pond, intercepting and cleaning any metals-laden water infiltrating.



Permeable Reactive Barrier for Tailings Dam Drainage Channel

- A mixture of 25% Bauxsol and 75% sand was used in the barrier.
- Water residence time in the PRB is about 2 hours 20 minutes.
- PRB effluent meets ANZECC standards.

Permeable Reactive Barrier for Tailings Dam Drainage Channel



Tailings Pond Cleanup

- Except for the size of the pond (750 X 1000 ft), the same method was used as in the toe pond.
- Bauxsol slurry was applied using monitors.
- Pond water was suitable for discharge.
- Some water was left in the pond to keep Bauxsol protective blanket and tailings wet.





Revegetation of Tailings Dam Face and Waste Rock Dumps

- Following cleanup of the tailings pond, the waste rock on the dam face was treated with Bauxsol.
- Reclamation soil was amended with Bauxsol and organic matter and was applied to the treated dam face and planted.
- Waste rock dumps elsewhere on the mine site were also reclaimed by this treatment.

Properties of Bauxsol

- Moderate pH
 - Saturated paste pH ≈ 10
 - 1:5 soil reaction pH ≈ 8.6
- Metal binding capacity almost 1500 mg/kg
- Alkalinity is primarily solid (e.g., carbonates)
- Acid neutralizing capacity = 4-7 mol/kg @ pH 7

Major Minerals in Bauxsol

- Hematite (Fe_2O_3)
- Boehmite ($\gamma\text{-AlOOH}$)
- Gibbsite ($\text{Al}(\text{OH})_3$)
- Sodalite ($\text{Na}_8\text{Al}_6\text{Si}_6\text{O}_{24}\text{Cl}_2$)
- Quartz (SiO_2)
- Cancrinite ($\text{Na}_6\text{Ca}_2\text{Al}_6\text{Si}_6\text{O}_{24}(\text{CO}_3)_2$)
- Hydrotalcite [$\text{Mg}_6\text{Al}_2(\text{CO}_3)(\text{OH})_{16}\cdot 4\text{H}_2\text{O}$]

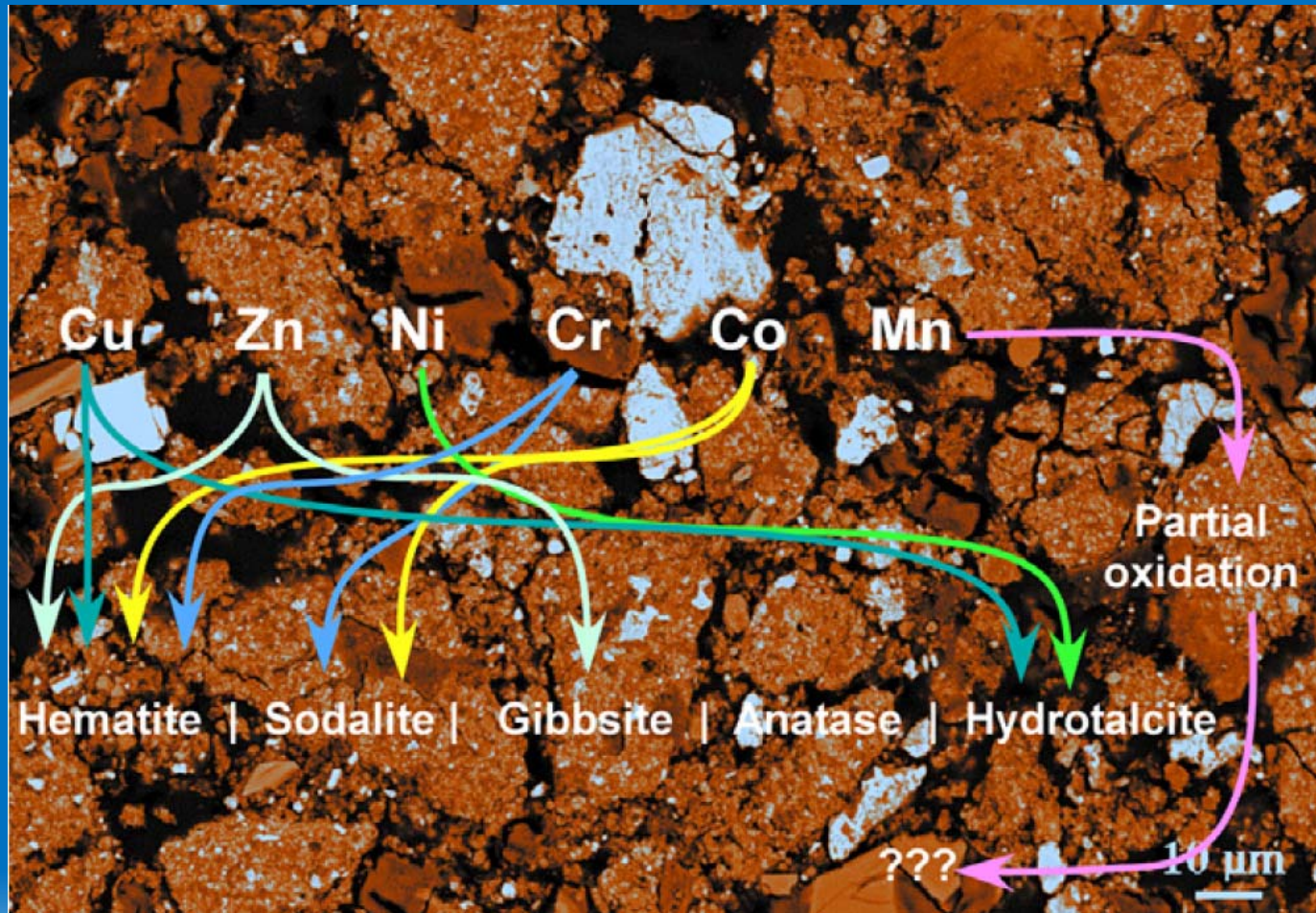
Minor Minerals in Bauxsol

- Meixnerite [$\text{Mg}_6\text{Al}_2(\text{OH})_{18}\cdot 4\text{H}_2\text{O}$]
- Anatase [TiO_2]
- Aragonite, calcite [CaCO_3]
- Brucite [$\text{Mg}(\text{OH})_2$]
- Diaspore [$\alpha\text{-AlOOH}$]
- Ferrihydrite [$(\text{FeOOH})_5(\text{H}_2\text{O})_2$]
- Gypsum [$\text{CaSO}_4\cdot 2\text{H}_2\text{O}$]
- p-Aluminohydrocalcite [$\text{CaAl}_2(\text{CO}_3)_2(\text{OH})_4\cdot 3\text{H}_2\text{O}$]
- Low-solubility trace minerals

Metal Binding Mechanisms

- Precipitation of minerals on Bauxsol mineral surfaces
- Substitution in recrystallized minerals
- Ion exchange and adsorption are minor mechanisms.
- Stability increases with time.

Binding of Specific Metals



Stability of Metals in Bauxsol

- Bauxsol complexes of most heavy metals pass TCLP (pH 2.88) and can be disposed of as nonhazardous solid waste.
- Stability increases with time.

Bauxsol-Based Products for Mining Applications

- A wide variety of products manufactured by Virotec under the name **Viromine™**
- All contain the Bauxsol raw material (BRM)
- Depending on application, the BRM may be altered by acid treatment, heat treatment, or other processes.
- Other ingredients (e.g., plant nutrients, pH buffers) may be added.

Which elements can Viromine products remove?

- Most transition metals that exist as cations
- Aluminum
- Thorium
- Arsenic (specialized Viromine product)
- Other metalloids (e.g., Se) in many environments (specialized Viromine product)
- Thallium in many environments
- Phosphate and vanadate
- Virotec has not tried the entire periodic table yet; other elements may be treatable as well.

Metal Mine Applications in the U.S.

- Tests at the Gilt Edge Superfund site, Lawrence County, South Dakota
- Arsenic cleanup of a mine site in Montana

Gilt Edge Superfund Site

- Historic mining for Au, Cu, and W began in 1876. Intermittent mining until 1941.
- Major open-pit + cyanide heap leach Au mining 1986-1998.

Gilt Edge Superfund Site

- Operator shut down in 1998 and entered bankruptcy in 1999. The \$6.4 million reclamation bond was forfeited.
- In 2000 EPA Region 8 took over under Superfund. \$30 million was recovered from other parties under joint and several liability.
- As of 2004, \$100 million had been spent on the site.

Gilt Edge Trials

- Tests of 3 treatment technologies for acid-producing waste rock were scheduled to begin in 2001, compared with the presumptive method (lime addition).
- EPA invited Virotec to submit a Viromine product for evaluation as an additional alternative for waste rock treatment.
- 3 other pilot-scale tests for Bauxsol were also conducted.

Trench Test for Waste Rock Treatment

- A lined trench was filled with 20 m³ of a mixture of 90% acid-generating rock and 10% Viromine Acid B ExtraTM.
- Water flowed through this trench and was sampled upstream and downstream.
- The test ran from 2001 to 2004.



Trench Test Results

Analyte - Units	Control 2003	Result 2001	Result 2002	Result 2003
pH	1.93	7.9	7.96	
Acidity (mg/L as CaCO ₃)	49,000	4	<LLD (5)	<LLD (5)
Alkalinity (mg/L as CaCO ₃)	<LLD (5)	90	62	66
TDS (mg/L)	77,000	11,500	8,300	3,000
Sodium (mg/L)	9,300	2,970	2,990	570
Sulfate (mg/L)	55,000	6,000	5,800	2,200
Ag (µg/L)	150	<LLD (1)	1.1	<LLD (5)
Al (µg/L)	1,200,000	<LLD (50)	10	66
As (µg/L)	35,000	3.1	3.7	<LLD (10)
Cd (µg/L)	630	<LLD (1)	0.4	<LLD (1)
Co (µg/L)	2,200	1.5	11	<LLD (10)
Cr (µg/L)	390	<LLD (1)	12	<LLD (10)
Cu (µg/L)	33,000	8.2	7.2	<LLD (10)
Fe (µg/L)	21,000,000	<LLD (25)	18	120
Mn (µg/L)	34,000	17	0.3	<LLD (10)
Ni (µg/L)	1,600	2.1	1.4	<LLD (10)
Pb (µg/L)	390	<LLD (2.5)	2.9	<LLD (10)
Sb (µg/L)	500	<LLD (4)	48	<LLD (10)
V (µg/L)	1,700	<LLD (1)	1	<LLD (10)
Zn (µg/L)	29,000	42	21	<LLD (10)

Soil Arsenic Removal

- A gold mine in Montana had a legacy site on its property.
- An arsenic mine and roaster that operated during the 20th Century had left very high levels of arsenic in the soil under the mill site and the flue and stack footprints.
- The site was on the CECRA (State Superfund) list.

Soil Arsenic Removal

- The company cleaned up most of the site by excavating the soil, hauling it to a waste repository, and replacing it with native soil from a nearby location.
- However, a small area under the flue footprint was on a very steep slope. Removing the soil would have taken out a mine road and a power line serving neighboring homes.

Remediation with Bauxsol

- The company decided to immobilize the arsenic rather than try to remove it.
- A slurry of Bauxsol A2™ was applied and mixed with the soil using an excavator.
- Native cover soil was then applied.
- A reclamation seed mix was planted.
- SPLP tests indicated that the arsenic was effectively immobilized.
- The site was removed from the CECRA list.

Non-Metal Mine Applications: Coal

- Viromine products have been successfully used at a number of coal mines in Australia, Portugal, and the U.K. to treat or prevent acid drainage and metal contamination.
- Any coal mine where high-sulfur coal is mined has to deal with problems of this type.
- Viromine might be a useful tool at coal mine remediation sites in Montana such as Belt and Sand Coulee.

Other Virotec Product Lines

- Viroflow™: Products for industries other than mining
- Virosoil™: Products for agriculture, land reclamation, and brownfields soil cleanups
- Virosewage™: Products for wastewater treatment plants, including removal of phosphorus and heavy metals and odor control

Examples of Non-Mine Applications

- Metal and metalloid immobilization and water treatment in power plant ash ponds (Viroflow)
- Brownfields cleanups, particularly in soils (Viroflow and Virosoil)
- Treatment of acid sulfate soils (Virosoil)

Examples of Non-Mine Applications

- Industrial pollution prevention and conversion of hazardous wastes to nonhazardous solid wastes (Viroflow)
- Pollution prevention at concentrated animal feeding operations, dairy farms, etc. (Virosoil and Viroflow)

Contacts

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Questions?