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Developments in Hydrometallurgy Since Mintek 50

Michael J Nicol

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Mintek 50 Conference

Topic	Papers
Leaching	13
Act Carbon	5
SX	3
IX	5
EW	5

Plenary – Mineral sulfide leaching
Separation processes

One paper on heap leaching
No papers on environmental issues

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Developments since 1984

- CIP/CIL
- Leaching – Pressure, heap and bio-
- Mechanisms of sulfide leaching
- SX reagents, processes and equipment
- IX materials/RIP/NIMCIX
- Electrowinning of base metals
- Application of advanced mineralogical techniques

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Hydrometallurgy

2 g/tonne in ore
to
99.999% pure
with
>90% recovery

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Carbon-in-Pulp Process

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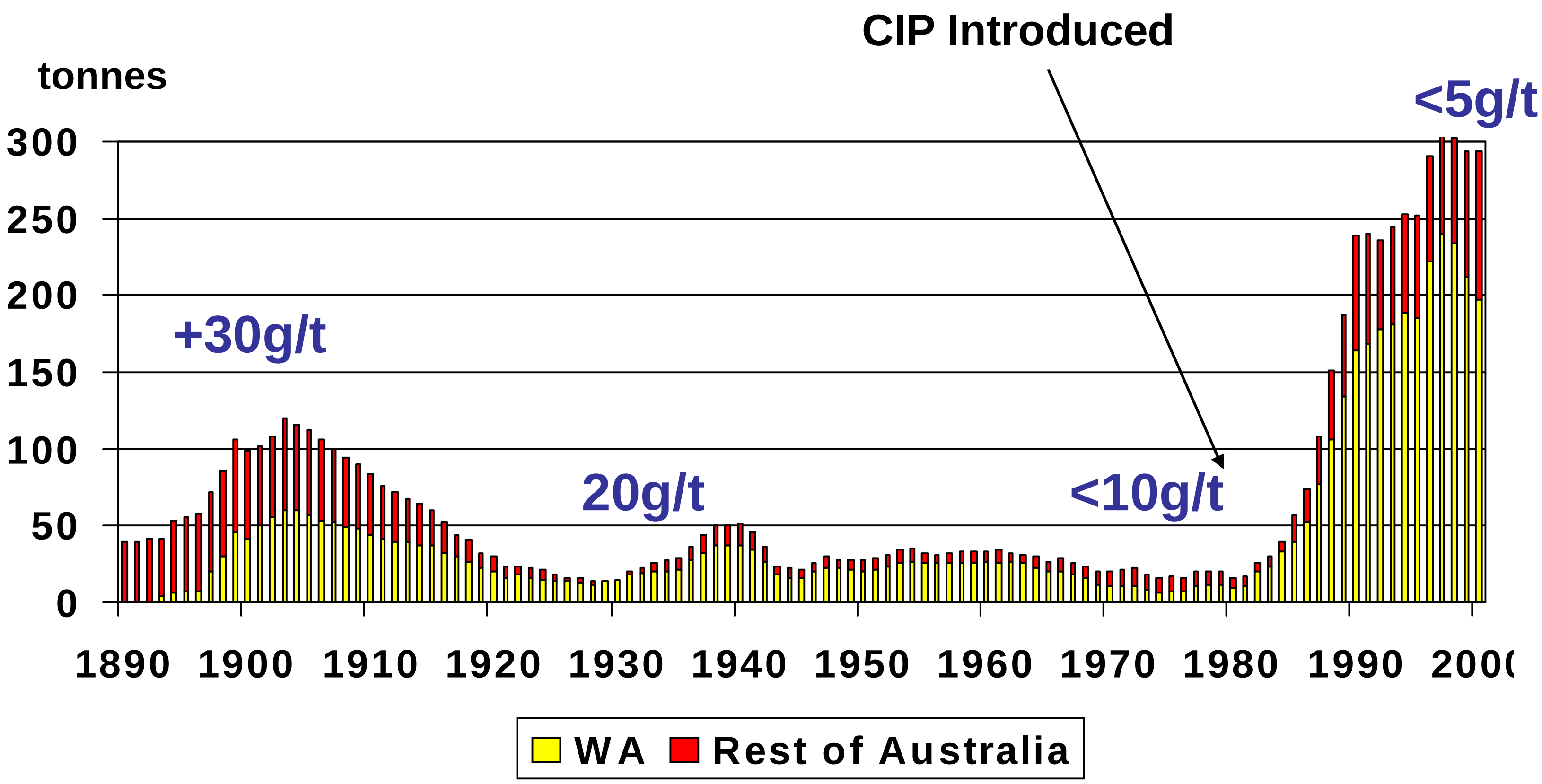
CIP and Declining Gold Grades



Source: Abare

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Adoption of CIP Technology by Industry

- CIP technology rapidly adopted by industry
- Open exchange of technology permitted widespread application
- Advances made possible by large R&D investment throughout world
- **The process is inherently simple and forgiving**

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Pressure Oxidation and Leaching

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After many years of development, processes for the direct leaching of sulfides are becoming a commercial reality. The oxygen-H_2SO_4 pressure leaching of zinc concentrates has been demonstrated successfully at a commercial level, and the use of the technology is expanding.

J Dutrizac, Mintek 50

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Development of Advanced Leaching Processes

1955 : First POX/hydrogen reduction process for Ni/Co, Sherritt Gordon, Canada

1959 : First PAL plant for laterites, Moa Bay, Cuba

1960 : Bacterial innoculation of stopes for U recovery, Gencor, RSA

1981 : First POX plant for Zn, Cominco, BMR at Rustenburg

1985 : First POX plant for Au, McLaughlin (CA, USA)

1986 : First full scale BIOX plant for Au, Fairview

2002 : Bio-leach plant for base metals, Kasese, Uganda

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Barrick Goldstrike Pressure Oxidation

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Laterite Processing

§ 1%Ni, 0.02%Co

n Pressure-acid leaching

n Purification by SX/IX

n Electrowinning/ H_2 reduction

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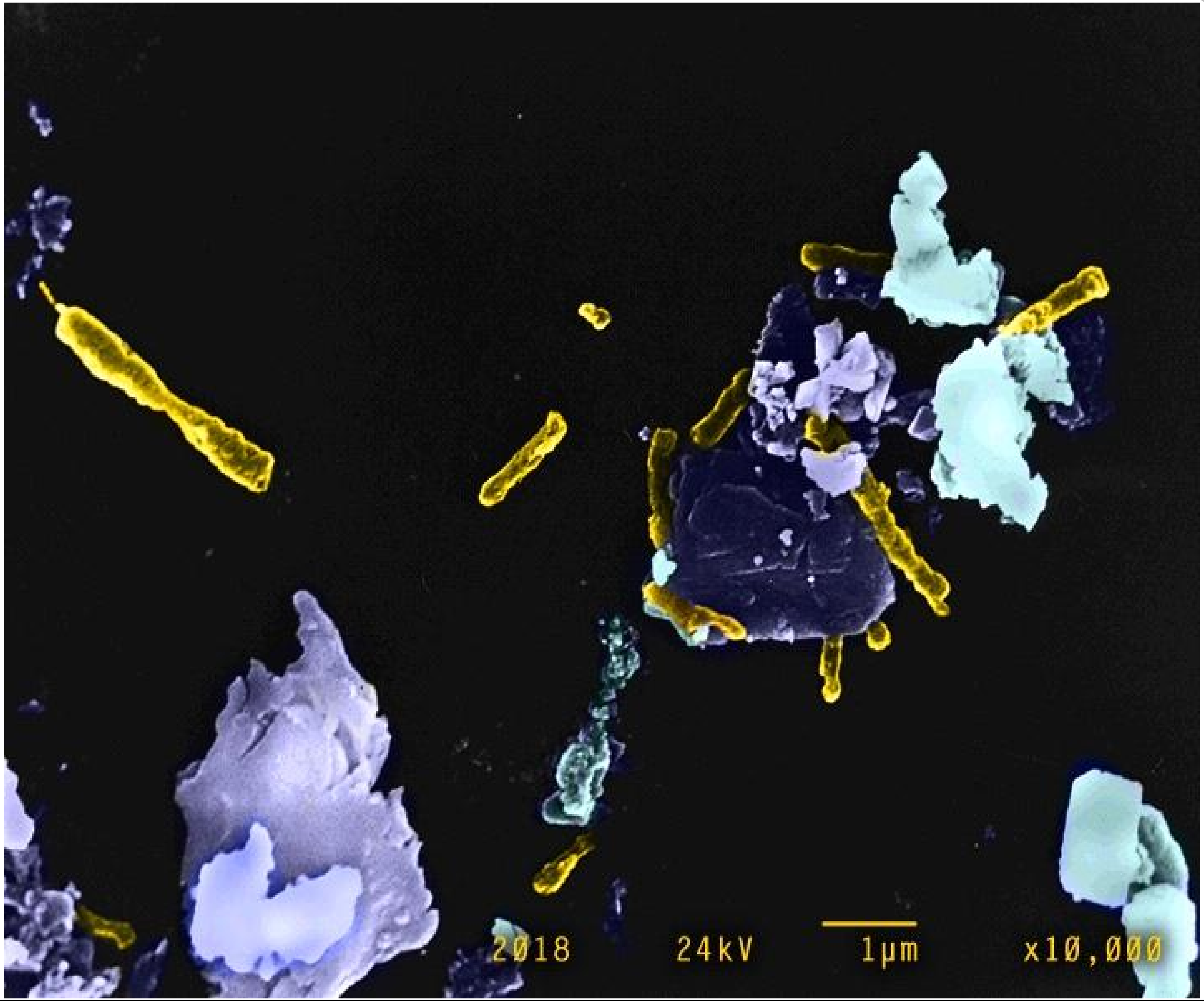
Bacterial Oxidation and Leaching



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Sansui Gold Biox Plant

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Billiton(1999)

- Bioleaching is on the Brink of Commercial Implementation for Treatment of Base Metal Sulphide Concentrates, Including Chalcopyrite

- To Improve the Competitiveness of Bioleaching, Development Work Should Focus on Reducing Residence Times and Improving Oxygen Transfer Rates to Lower Power Costs per Unit of Metal Produced

- Commercial Success is Dependent on the Speed of Development over Next Five Years and Realization of Process Economics Against Competitors

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Impact of POX/BIOX on the Industry

- **Largely driven by environmental pressures for Au**
- **Alternative to smelters for Ni/Co and now Cu(?)**
- **Alternative to roasting for Zn - acid disposal**
- **Major expansion of laterite Ni industry**
- **Heap leaching for sulfides (Cu, Ni/Co)**
- **Lower capital and operating costs than smelting/roasting**

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Adoption of Technology by Industry

- POX: Relatively slow adoption- Sherritt responsible for early implementation.
- BIOX: Assimilation by industry slow (ca 30yr) - increased gold price acted as catalyst
- Excess capacity and advances in smelter technology slowed implementation for both in the case of copper
- POX perceived as too high tech. and BIOX not robust

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Competing Processes for Copper

- Established Smelters
- Bio-Leaching Processes
  - Mintek/Bactech, BHP Billiton
- High Pressure Leaching
  - Dynatech, CESL, Phelps Dodge/Placer, AARL
- Low Pressure Leaching
  - Activox, Mt Gordon
- Atmospheric Leaching
  - MIM, Rio Tinto
- Intec, Nitrox(Cammp)

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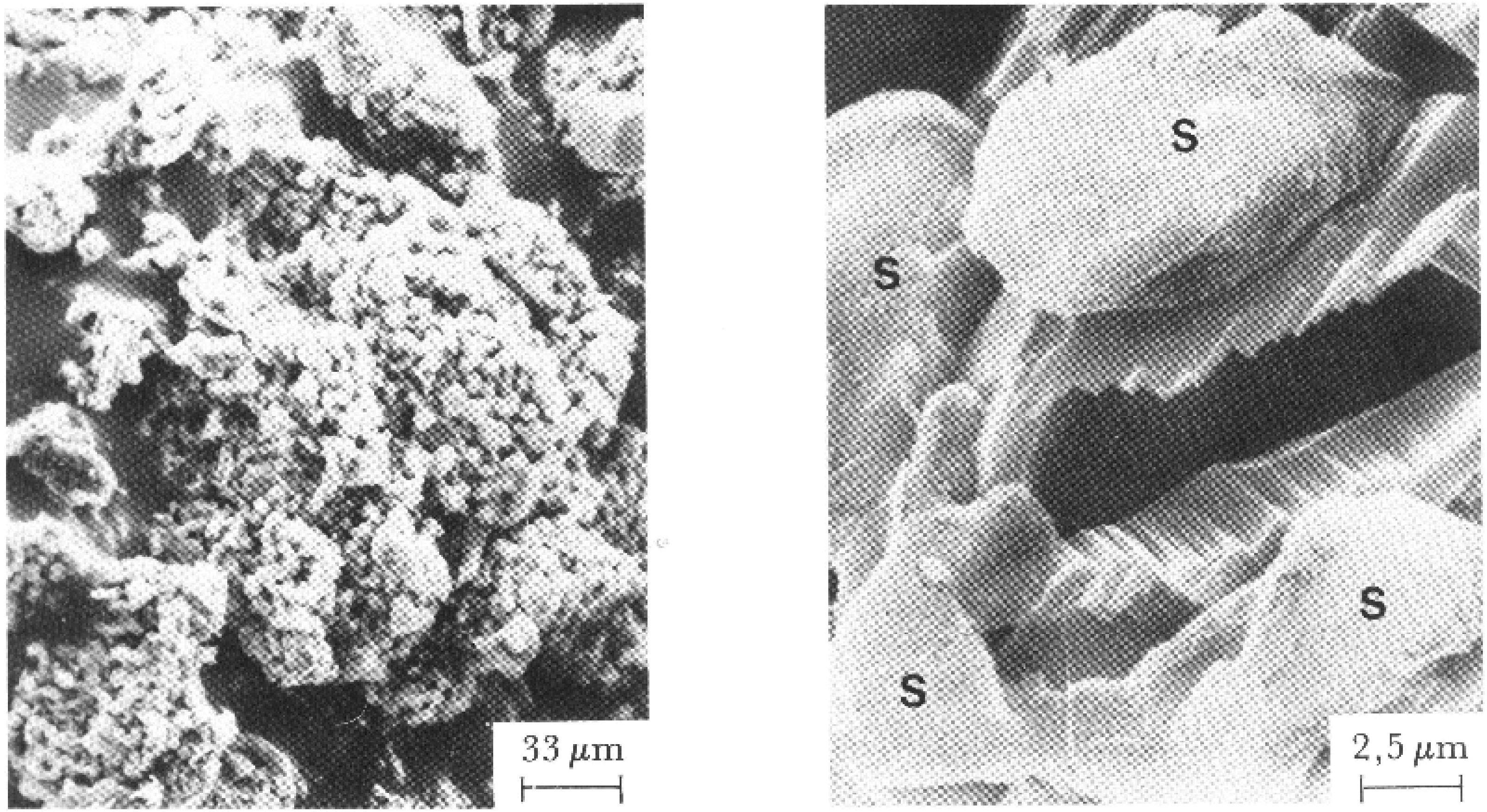
Mechanisms of Leaching of Sulfide Minerals

Sulfur on Chalcopyrite after Leaching of Composite with Graphite



Wan, Miller and Simkovich, Mintek 50

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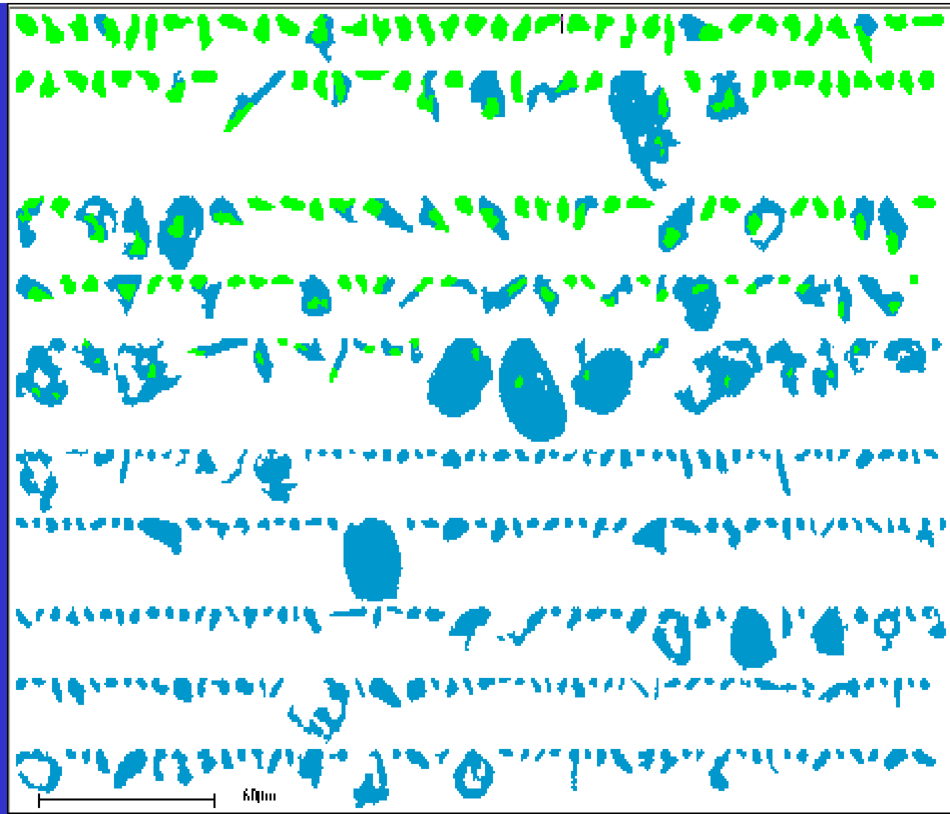
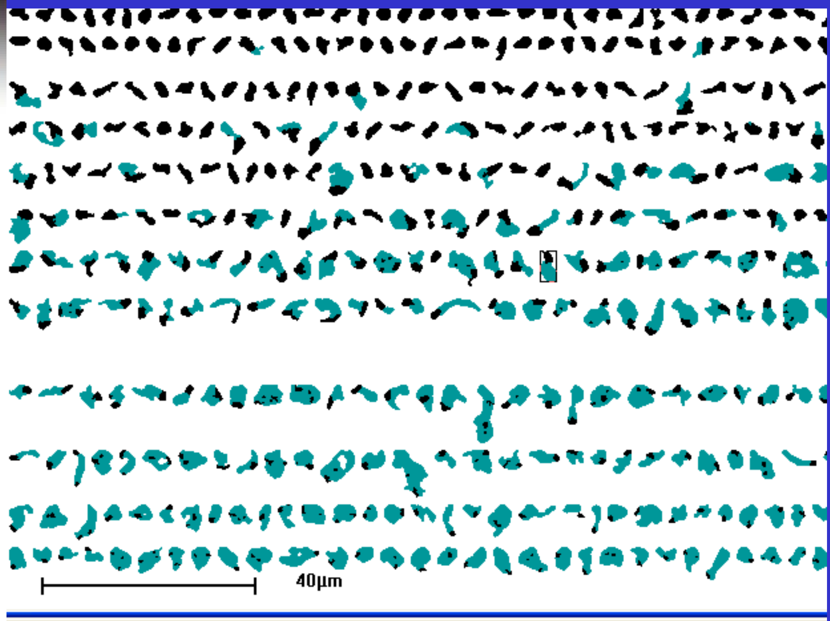
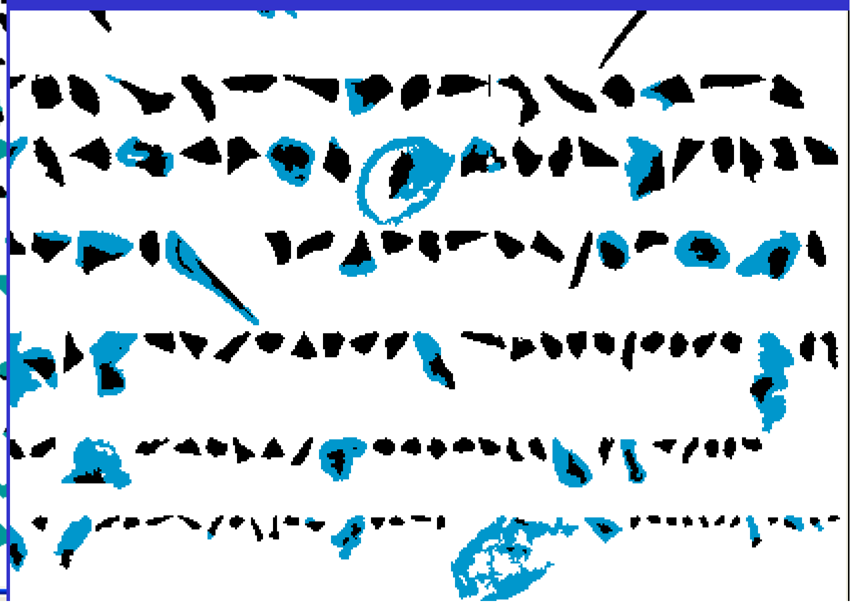
MLA of chalcopyrite leach residue







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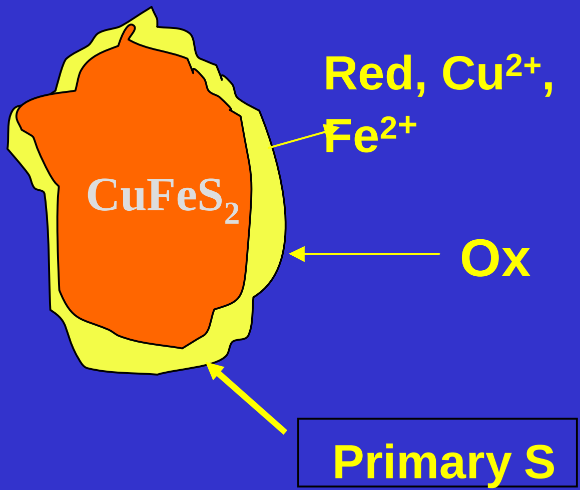
Mechanisms of Chalcopyrite Dissolution

Oxidative Model

$CuFeS_2 + Ox = Cu^{2+} + Fe^{2+} + S + Red$



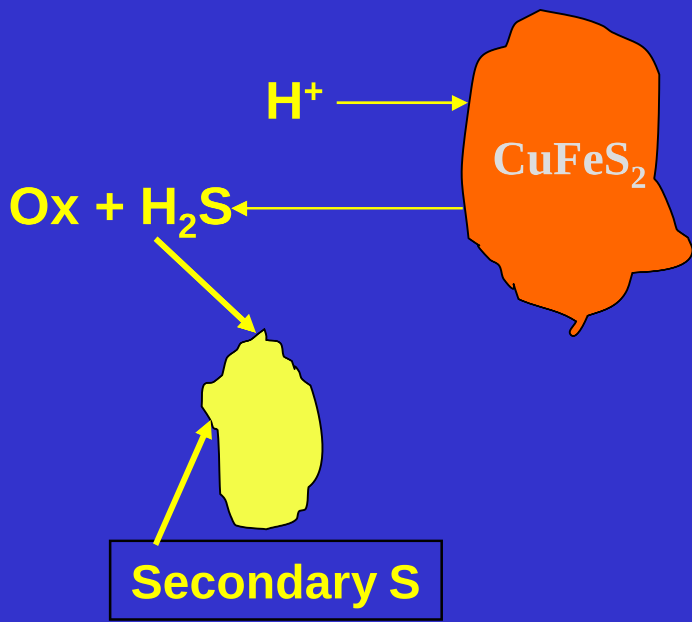
Cpy at high E

Non-Oxidative Model

$CuFeS_2 + 4H^+ \Leftrightarrow Cu^{2+} + Fe^{2+} + 2H_2S$

$CuFeS_2 + 2H^+ \Leftrightarrow CuS + Fe^{2+} + 2H_2S$

$2H_2S + Ox = 2S + Red + 4H^+$



Cpy at low E

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Heap Leaching SX/EW for Copper

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Heap Leaching for Copper

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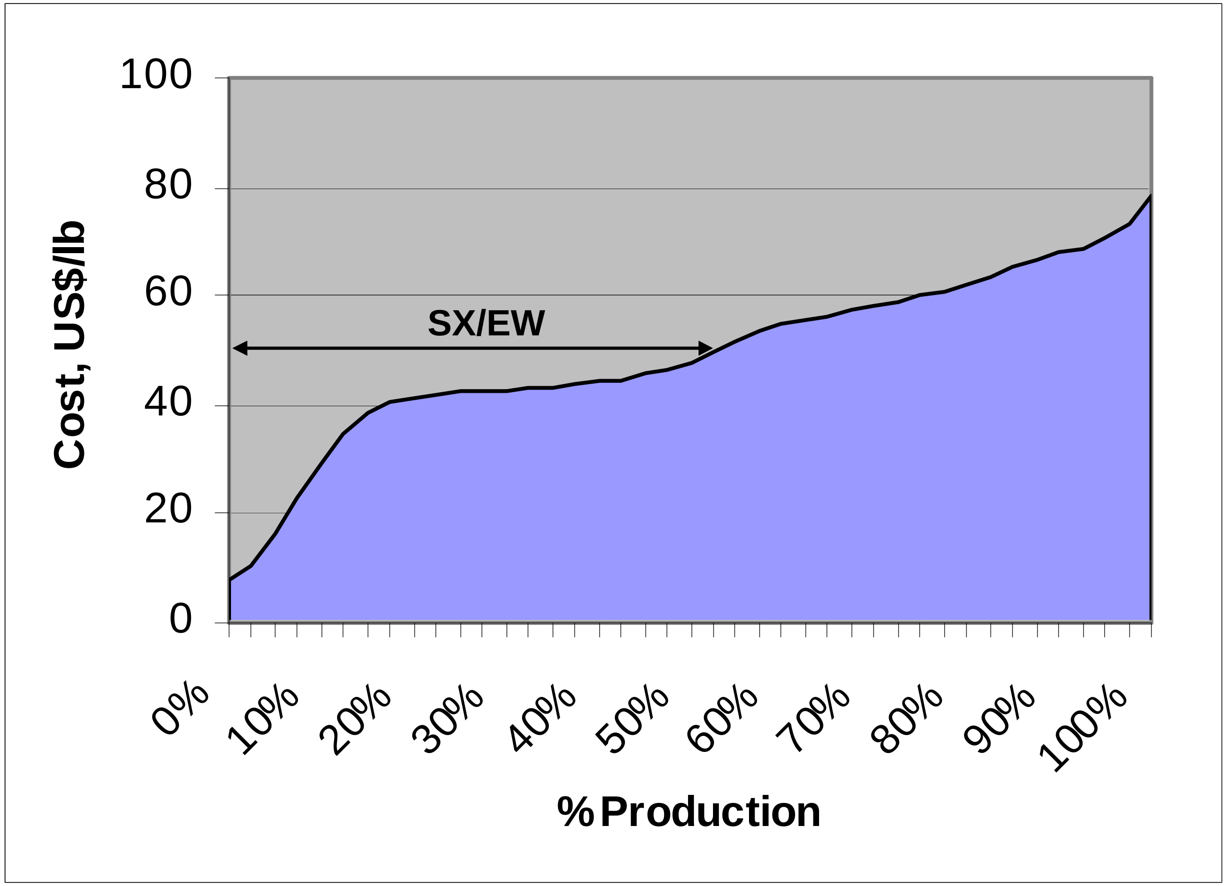
Copper Metal Production Costs



Source: LME

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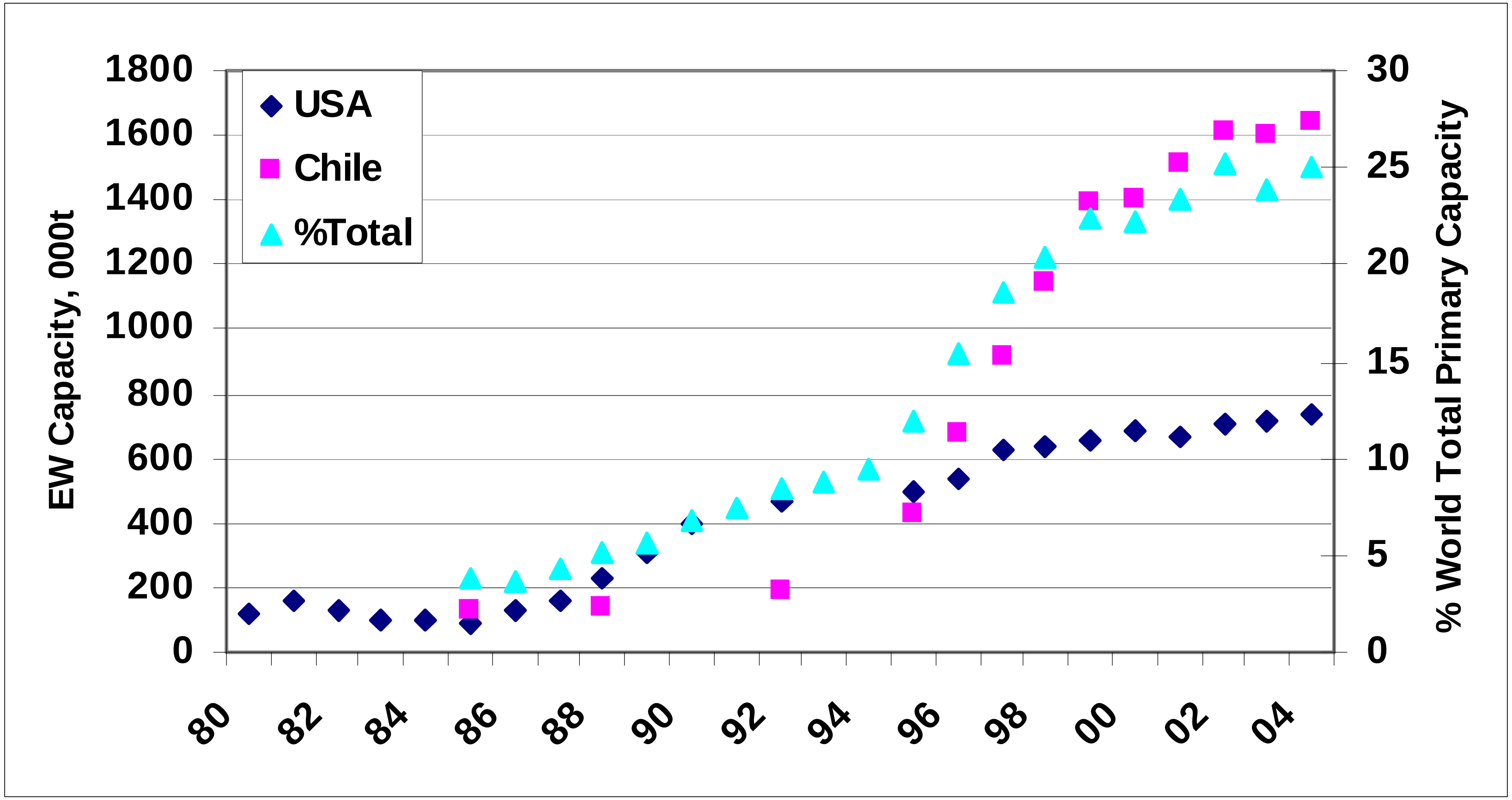
Impact of SX/EW on Copper Technology



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Development of SelectiveExtractants for Copper

1960's : First copper reagents developed

1968 : First SX/EW plant Bluebird Mine (AZ)

1980 : 10 plants in US, Zambia, Peru

1990's : Improvements to reagents, SX contactors, EW technology

2008 : 64 SX/EW plants for Cu world wide

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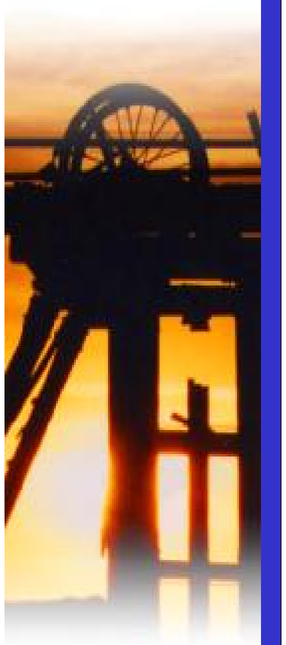

Technological Impact on Production of Other Metals

- Development of selective reagents for other metals, e.g. Ni, Co, Zn, Precious metals
- Improvements and innovations in SX equipment, e.g. pulse columns
- Improvements and innovations in EW processes and equipment, e.g ISA process, Co addition, Anodes
- Parallel development of selective ion exchange resins
- Provided incentive for heap leaching of others

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Adoption of Technology by Industry

- Relatively slow implementation of SX/EW technology
- Rapid expansion after benefits fully demonstrated
- Open technology has permitted widespread adoption even for small operators
- Adoption of advanced SX/EW processes too rapid in some cases - Ni

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Supported liquid membranes seem to be poised for commercialization …. The extension of the process to the processing of dump leach liquors, minewaters etc., cannot be ruled out. The use of supported liquid membranes might at last provide the answer to the problem of design of viable solvent-in-pulp systems.

D Flett, Mintek 50

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Ion Exchange Processes

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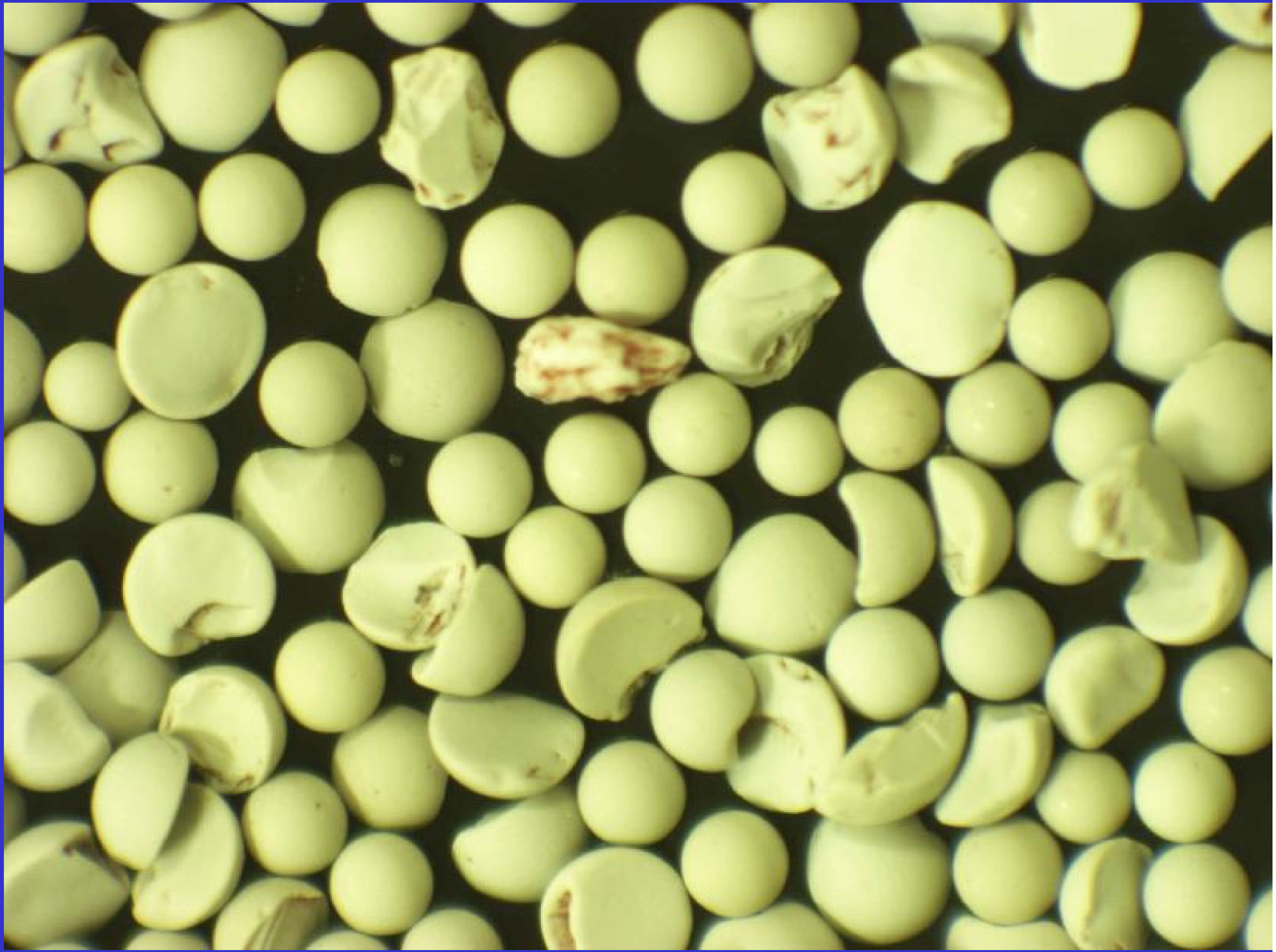

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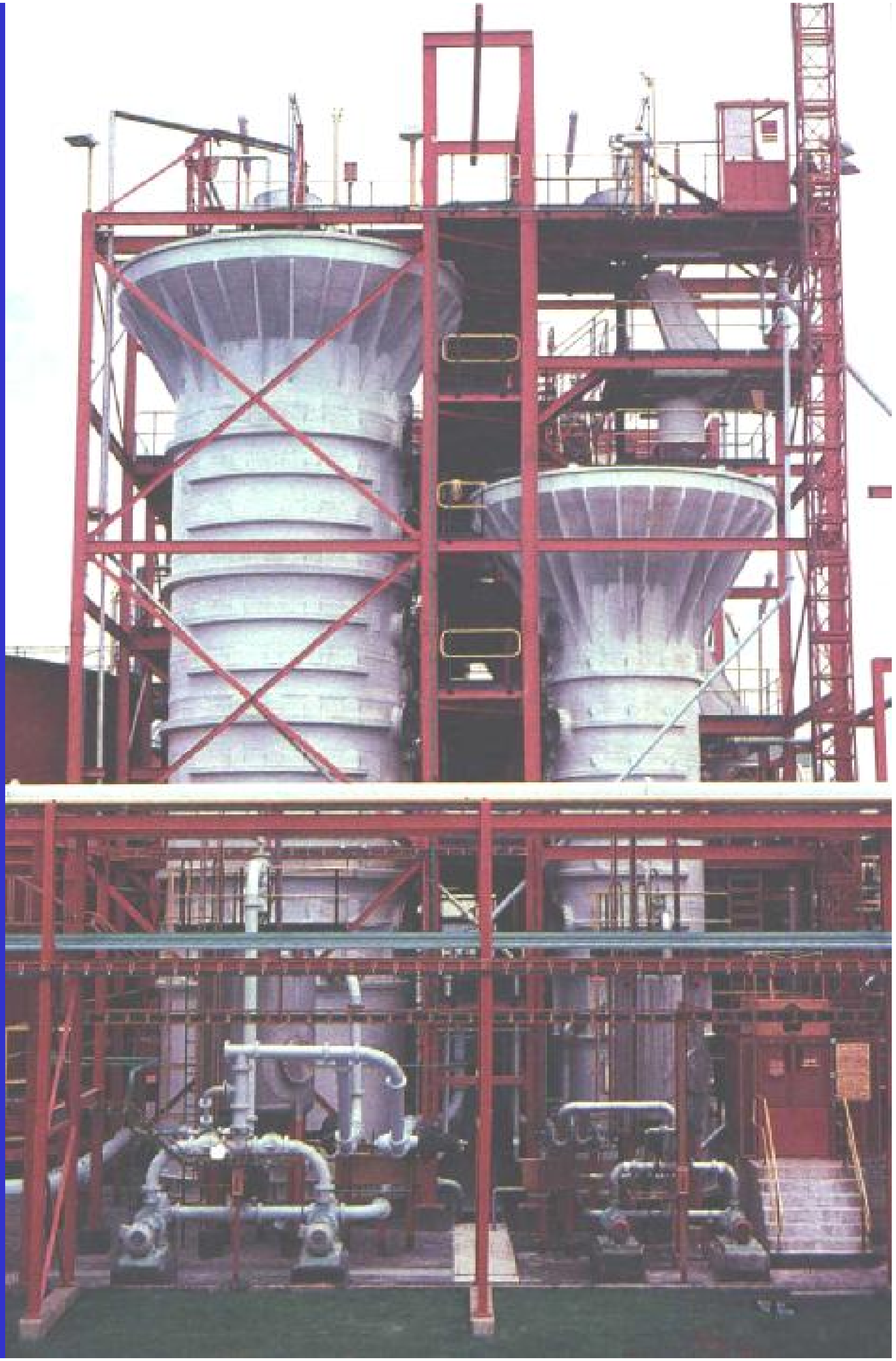
Multi-stage Continuous Ion Exchange

NIMCIX



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RIP Application

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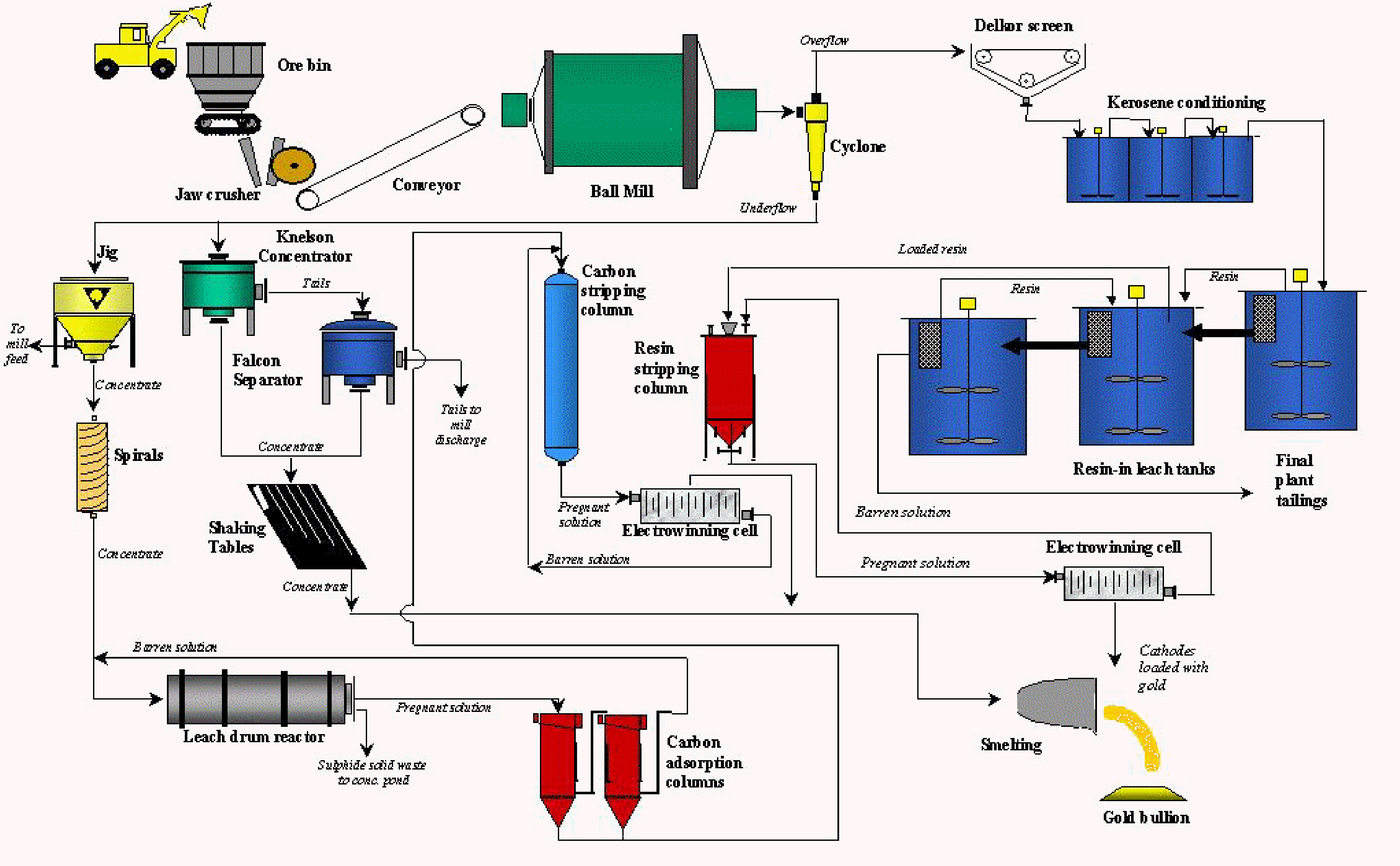

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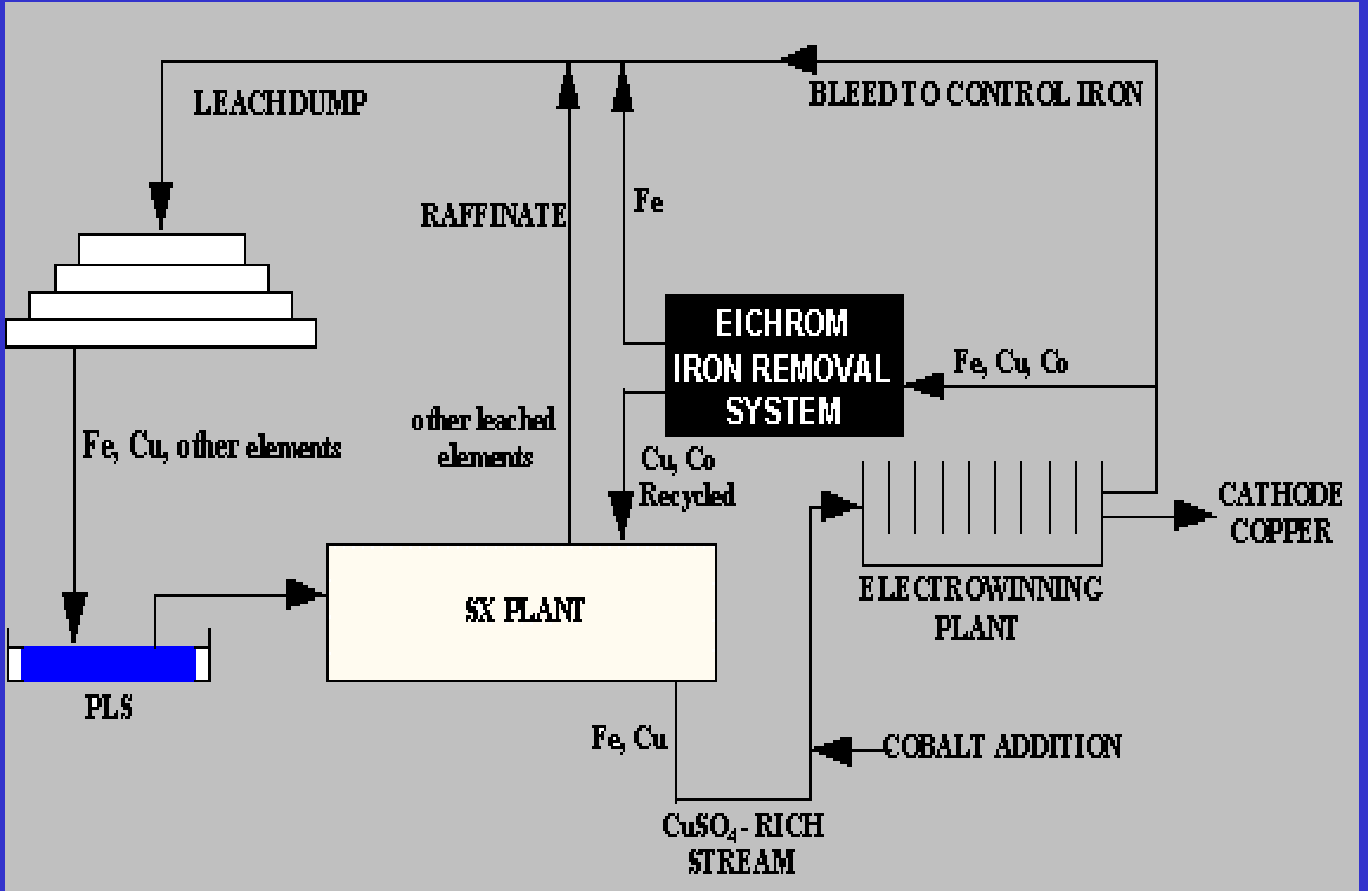
Application in Iron Removal



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Adsorption of $Au(S_2O_3)_2^{3-}$ onto Anionic Resin

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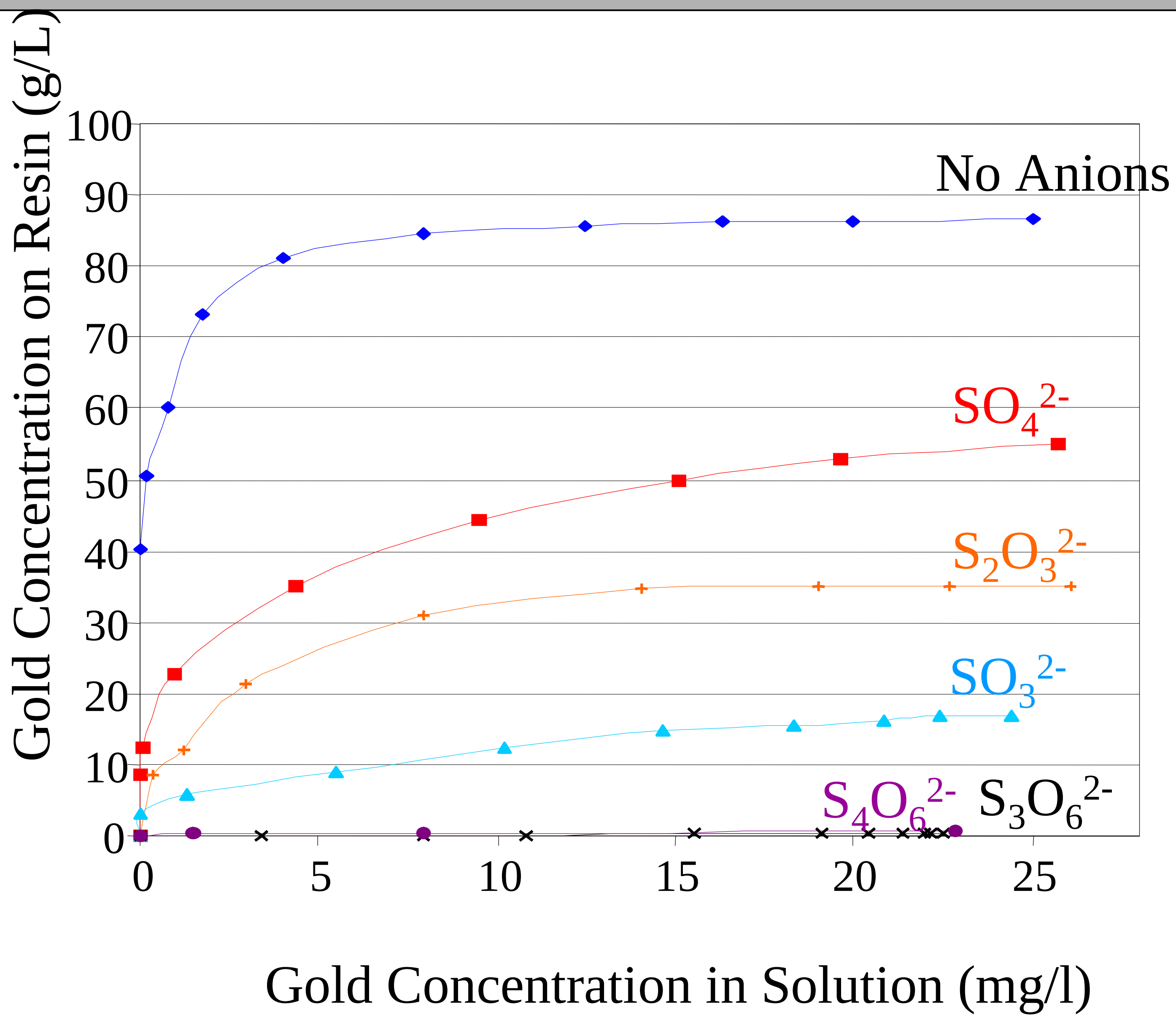

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Electrowinning of Base Metals

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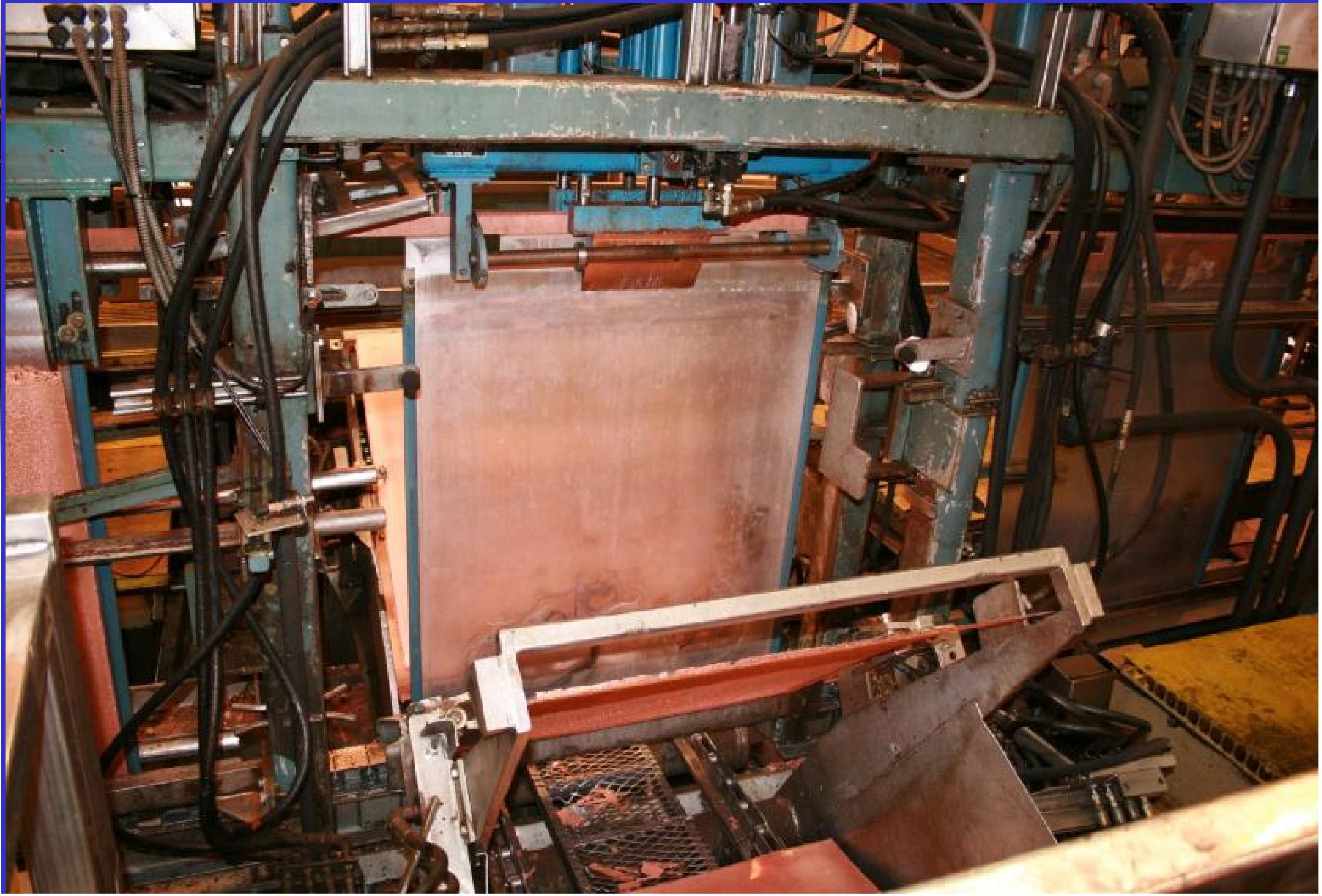
Permanent Stainless Steel Cathodes



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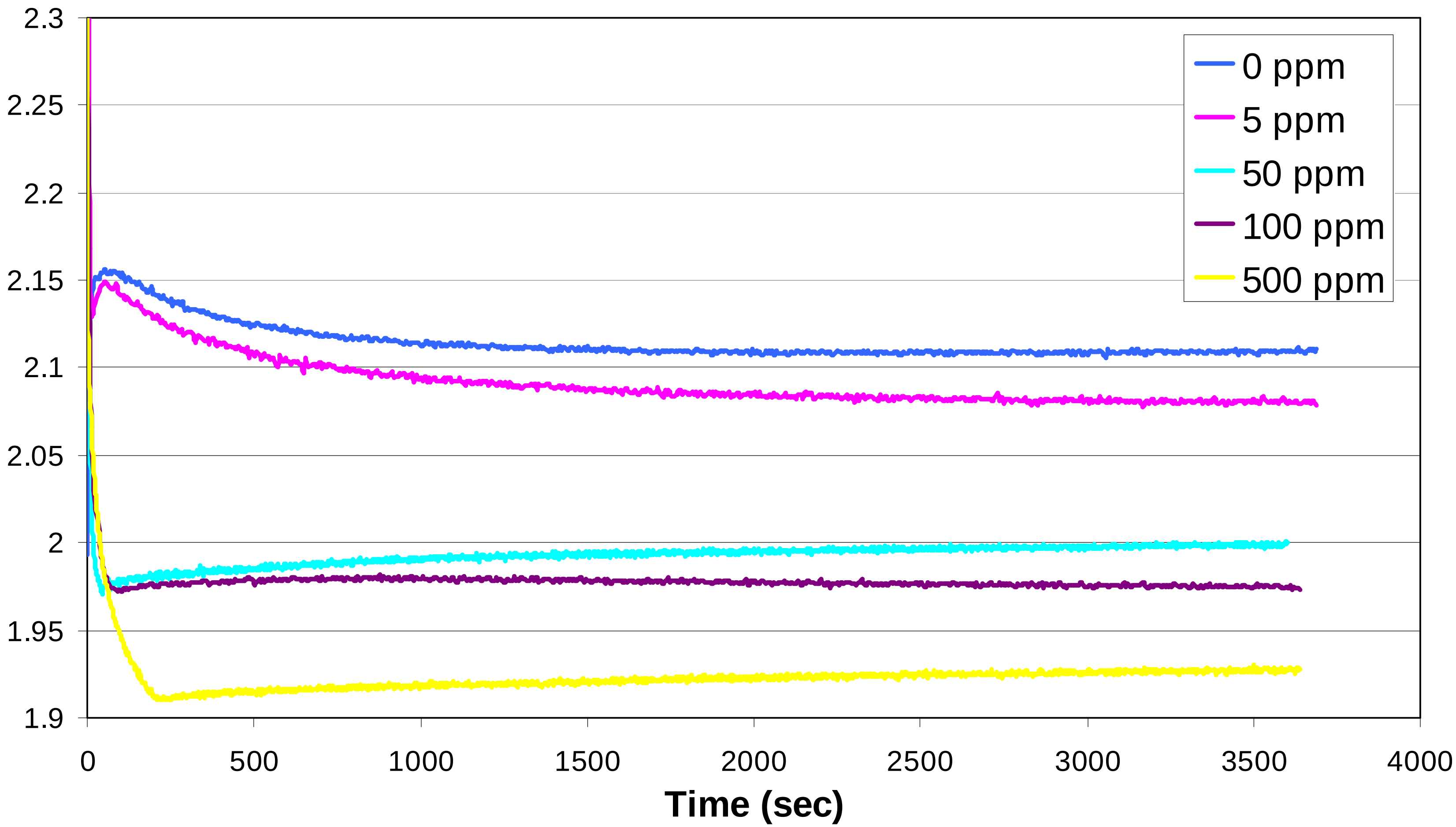
Effect of Co on Anode Potentials
Pb-Ca-Sn Anode – $300 A/m^2$



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LME Grade A Copper

Element	Max.(ppm)
Se	2
Te	2
Bi	2
Sb	4
As	5
Pb	5(2)
S	15(5)
Sn	5
Ni	10
Fe	10
Ag	25

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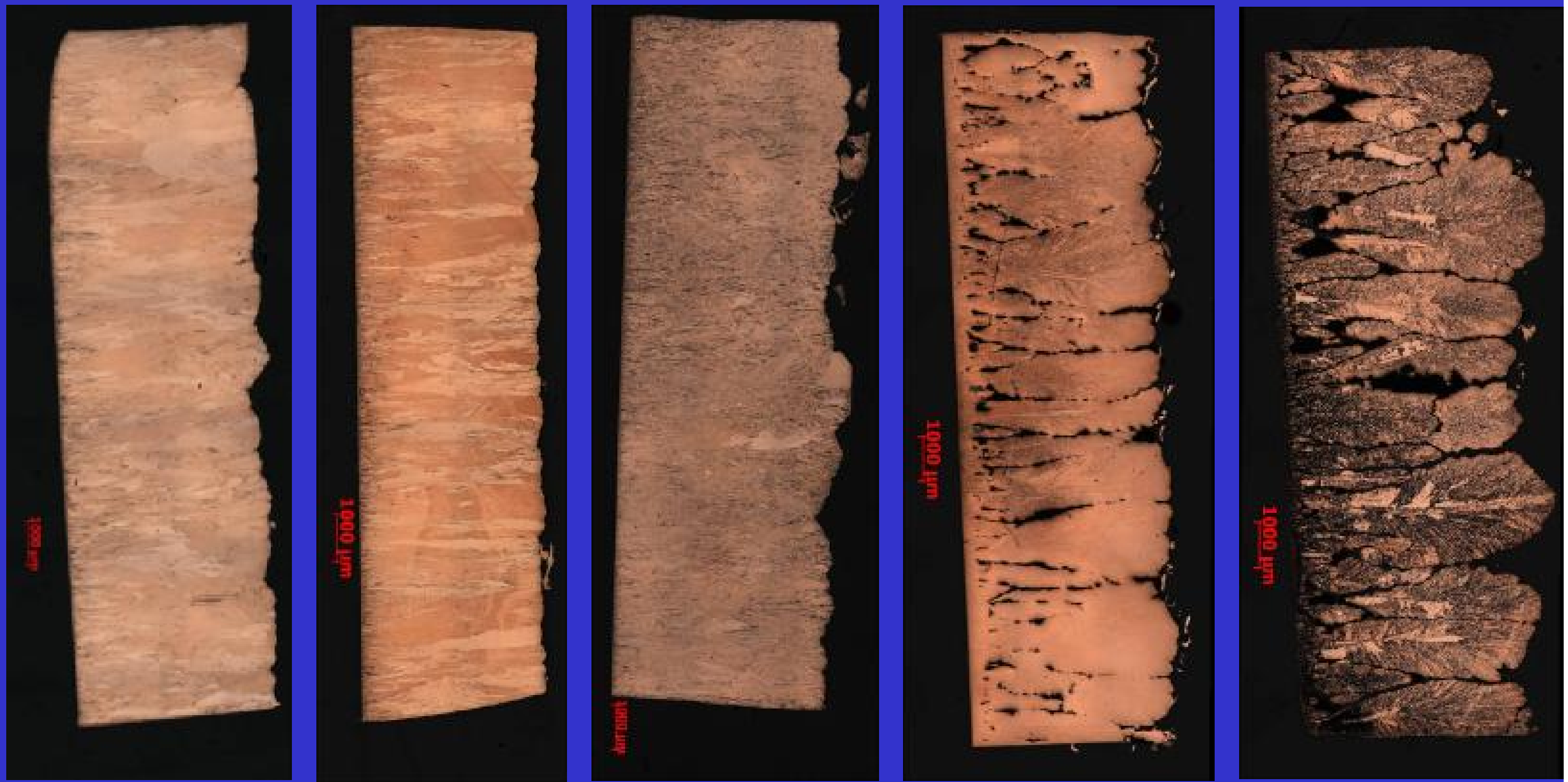
[S] content and cathode porosity



[S] 3 ppm 5 ppm 11 ppm 24 ppm 56 ppm

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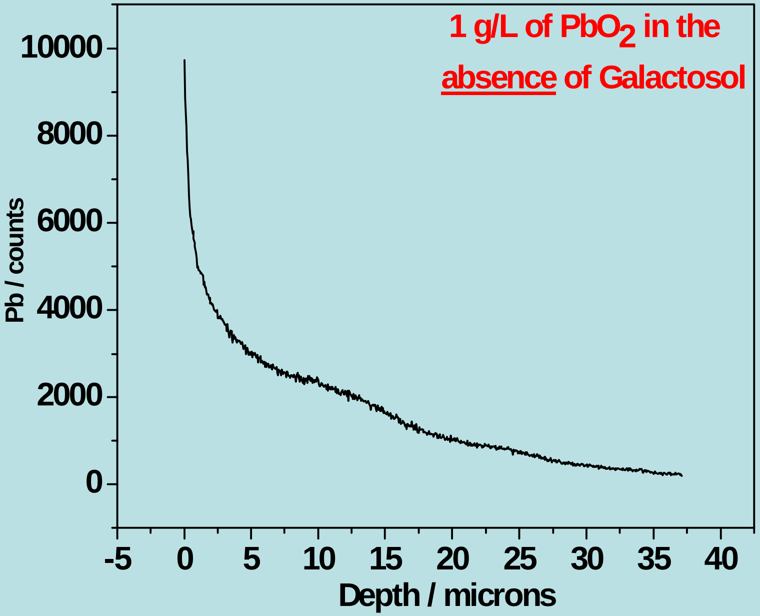
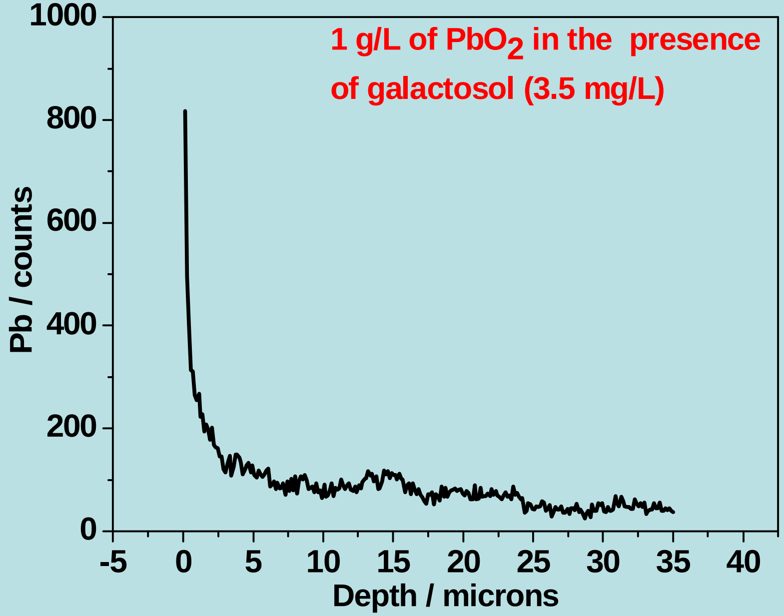
SIMS Depth profile Analysis: Pb content of copper





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Anticipated Developments (1984)

- Expansion of CIP/CIL
- Leaching of base metal sulfide concentrates
- Applications of IX/RIP – Au, U, base metals

Developments not Anticipated

- Heap leaching/SX/EW
- PAL processes for Ni/Co
- Environmental pressures
- Energy as a major driver – U revisited
- Globalization and deterioration in education and R&D

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Next 25 years ?

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