Hydrometallurgy Research & Development at the University of Queensland

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

Associate Professor
James Vaughan

https://researchers.uq.edu.au/researcher/2189
http://www.chemeng.uq.edu.au/hydrometallurgy

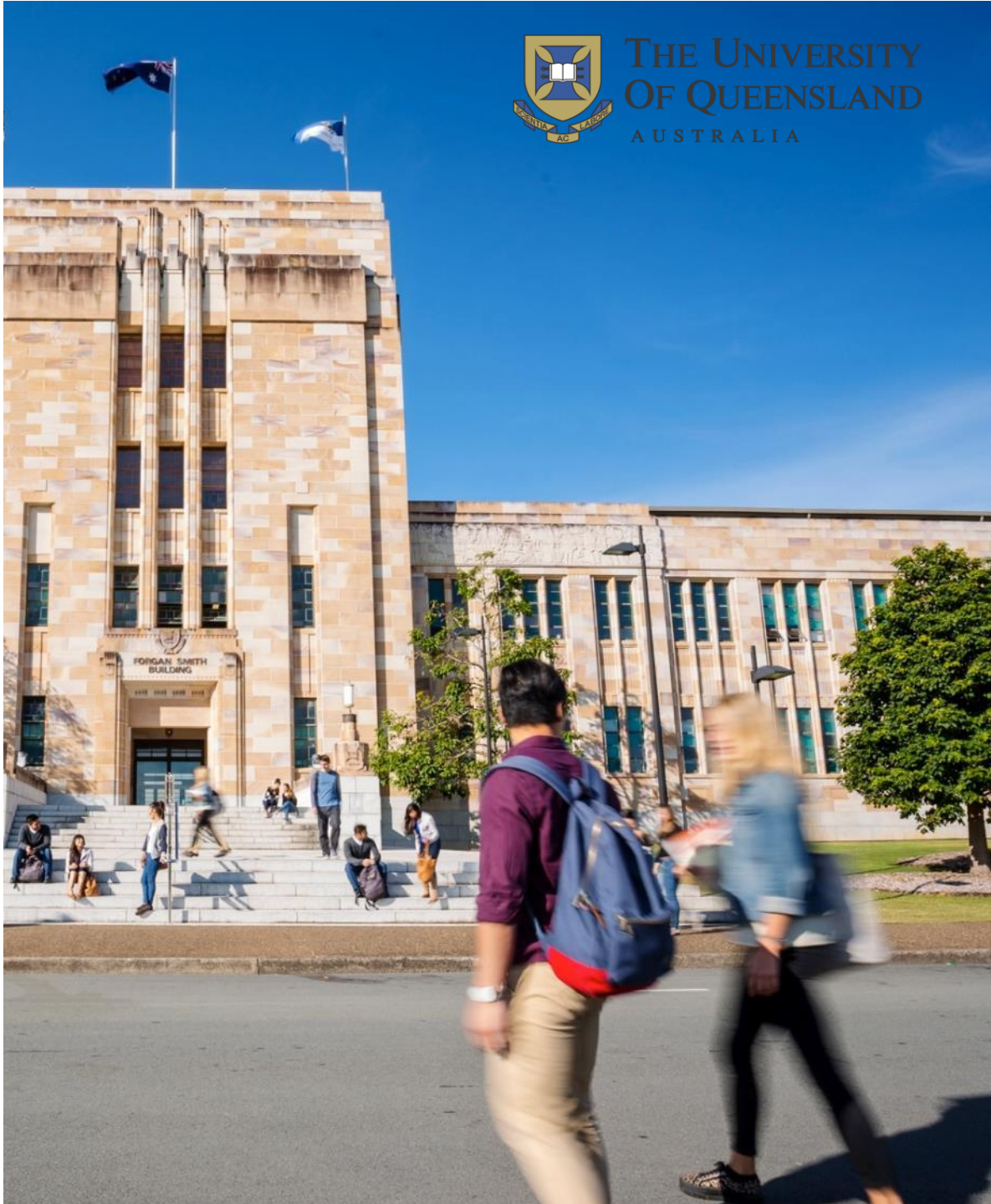
Presentation Outline

- Introduction to UQ / Chem Eng / Metallurgy / Hydrometallurgy
- Background Australian / Brazilian Refineries
- Motivation for Hydrometallurgy Research
- Examples Research Projects
    - Alumina
    - Nickel
    - Gold

The University of Queensland
Brisbane, Australia

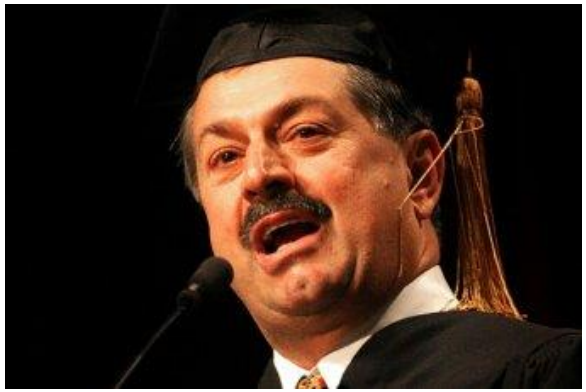
UQ Snapshot

- Founded in 1909
- UQ ranks in the world's top 50 universities
- Around 400 degree programs
- Over 50,000 students, 12,000 international students from over 140 countries
- More than 13,500 postgraduate students
- More than 12,000 PhD graduates
- Almost 7,000 full-time equivalent staff
- A global network of over 232,000 alumni in more than 160 countries
- #1 school of chemical engineering in Australia
- Scientia ac Labore



New Chemical Engineering
"Andrew N. Liveris" Building (opening 2021)

Building Site October 2019



Andrew Liveris
CEO of Dow Chemical
(~2004-2018)

https://campuses.uq.edu.au/article/2018/06/andrew-n-liveris-building-construction-project-update

Chemical and Metallurgical Engineering

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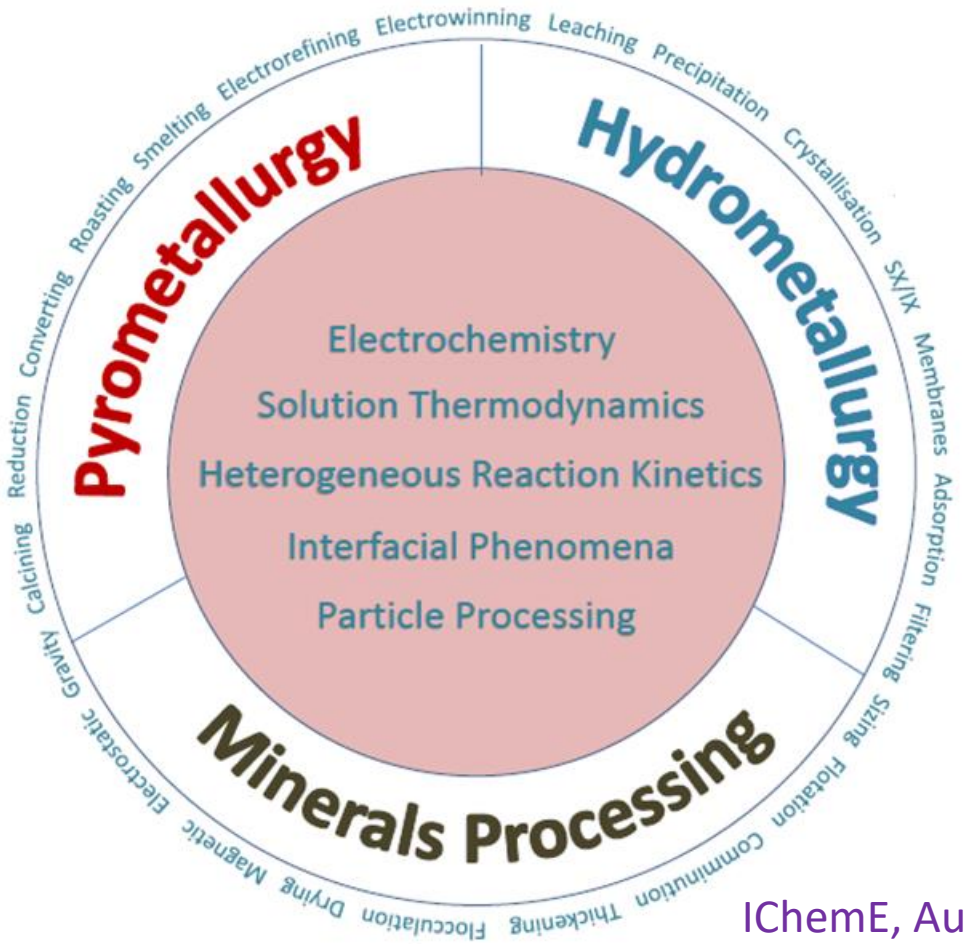
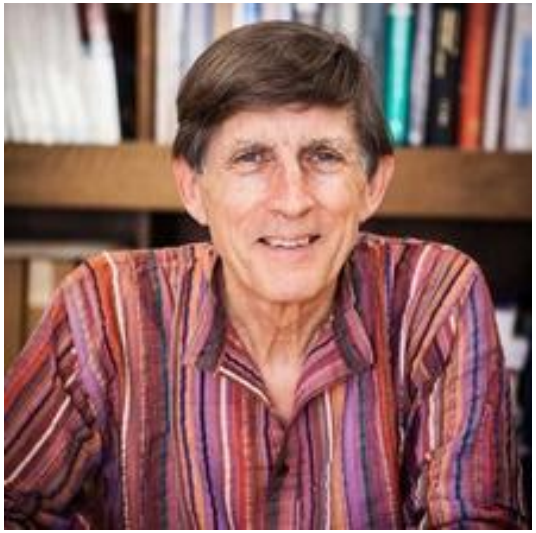
*The **dual major in chemical & metallurgical engineering** provides the best of both worlds - a foundation in chemical engineering combined with specialisation in extractive metallurgy.*





Professor Peter Hayes
Metallurgy Program Leader

IChemE, AusIMM Accredited

Hydrometallurgy

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The treatment of ores, concentrates and other metal-bearing materials by wet processes usually involving the dissolution of some component, and its subsequent recovery from the solution.

People

Professor Peter Hayes – Metallurgy Program Leader
James Vaughan – Associate Professor
Hong Peng – UQ Amplify Research Fellow
William Hawker – Lecturer
Weng Fu – Post Doctoral Researcher
James Gudgeon – Laboratory Manager
Kelly Byrne – Senior Research Technician
Stefan Lakemond – Senior Research Technician
David Mann – Senior Research Technician
Kimiya Bolouri – Senior Research Technician

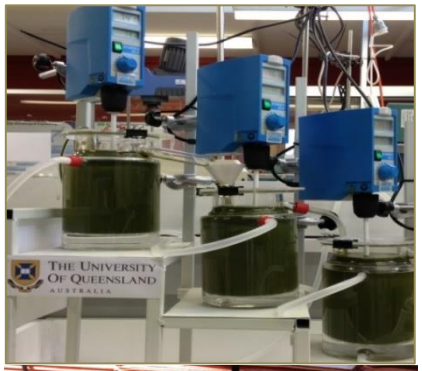
Research Infrastructure

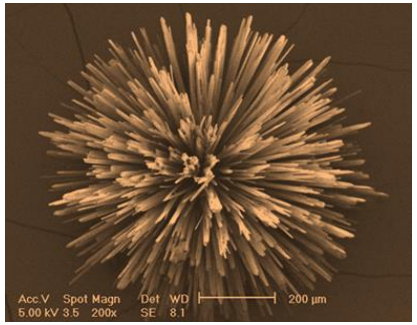
- Comprehensive autoclave facility
- Certified radiation facility
- Electrowinning / electrorefining / electrochemistry
- UV-VIS / TGA / AAS / ICP-OES
- FIMS/DMA for Hg
- Flow through thin film membrane filtration rig
- FIMLAB membrane synthesis / percrystallisation
- Single particle optical sensing and laser sizers
- Factsage and HSC Chemistry software
- Centre for Microscopy and Microanalysis
- Brisbane Surface Analysis Facility
- Pyrosearch / JKMRC
- Bauxite and Alumina Technology Centre

Projects

- Refining mixed nickel-cobalt hydroxide precipitate
- Synergistic hydro-pyro processing of copper
- Separating radionuclides from copper concentrates
- Pressure oxidation chemistry
- Scandium hydrometallurgy
- Ion exchange resin technologies
- Inorganic membrane percrystallisation
- Nickel agromining
- Processing high silica bauxites
- Value-added products

CSTR Pilot Plant





Sodium Oxalate

Pressure Leaching

Solvent Extraction

Copper Cathode

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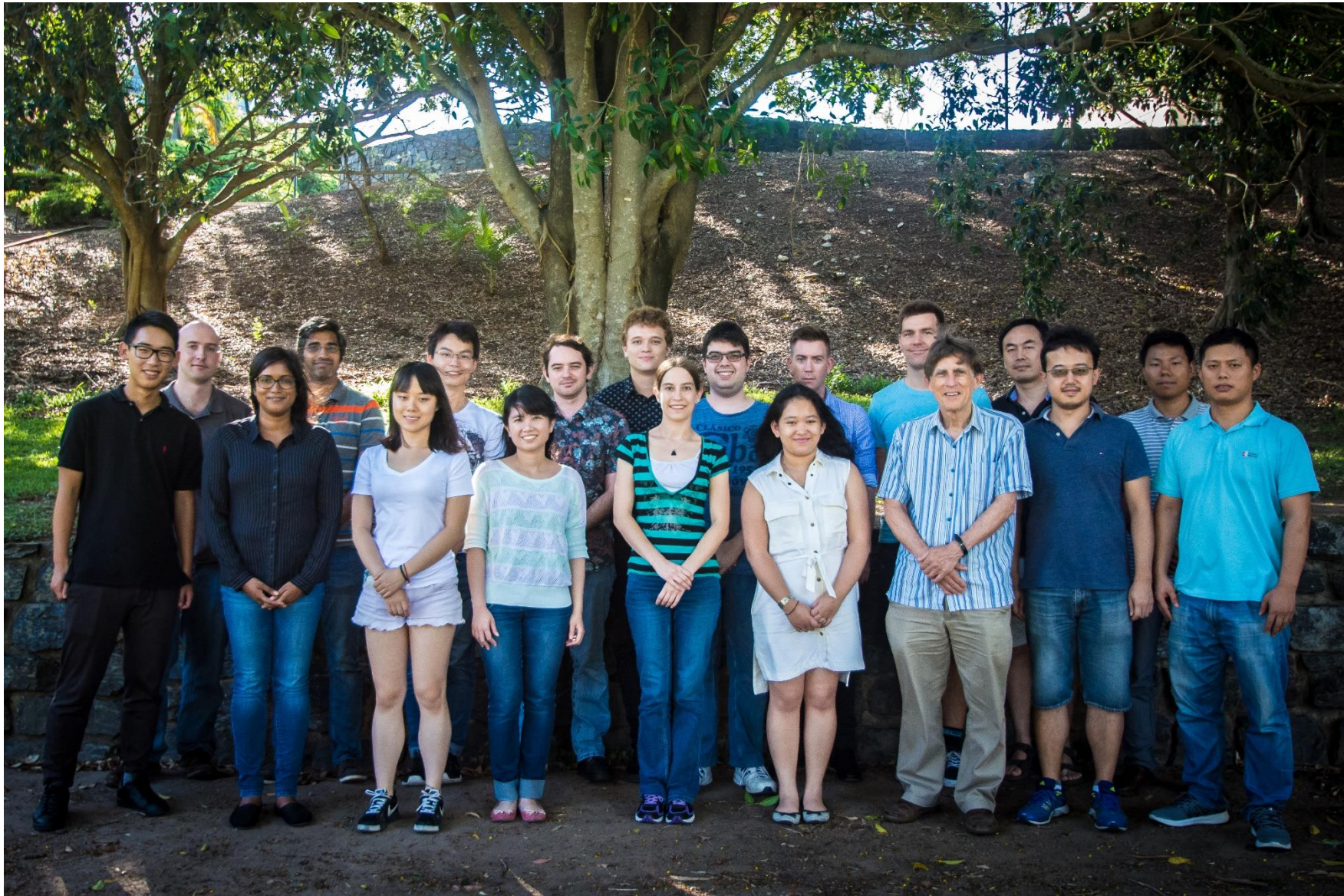
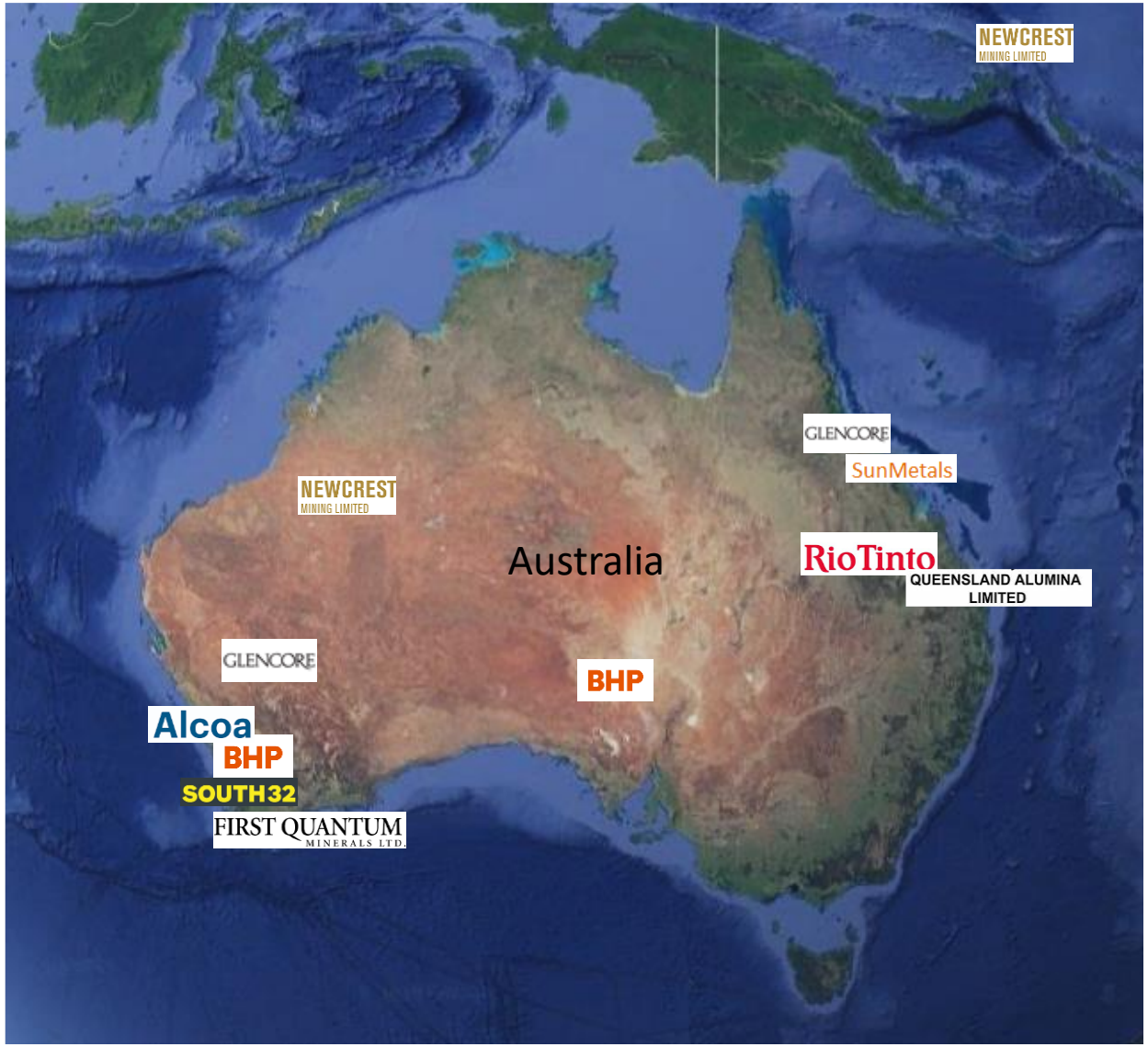
Hydrometallurgy Research Group



Examples of Australian Refineries



Examples of Brazilian Refineries

Hydrometallurgy research and development drivers

- Decreasing ore grade
- Increasing ore complexity
- Increase efficiency of mature technologies
- New feed intermediates or secondary (recycled) materials
- Health, safety, environment, community
- Costs of waste disposal and rehabilitation
- Production of advanced / high purity materials / by-products

Examples of Research & Development Projects

- Alumina
  - The sandy DeSilication Product (DSP) process concept

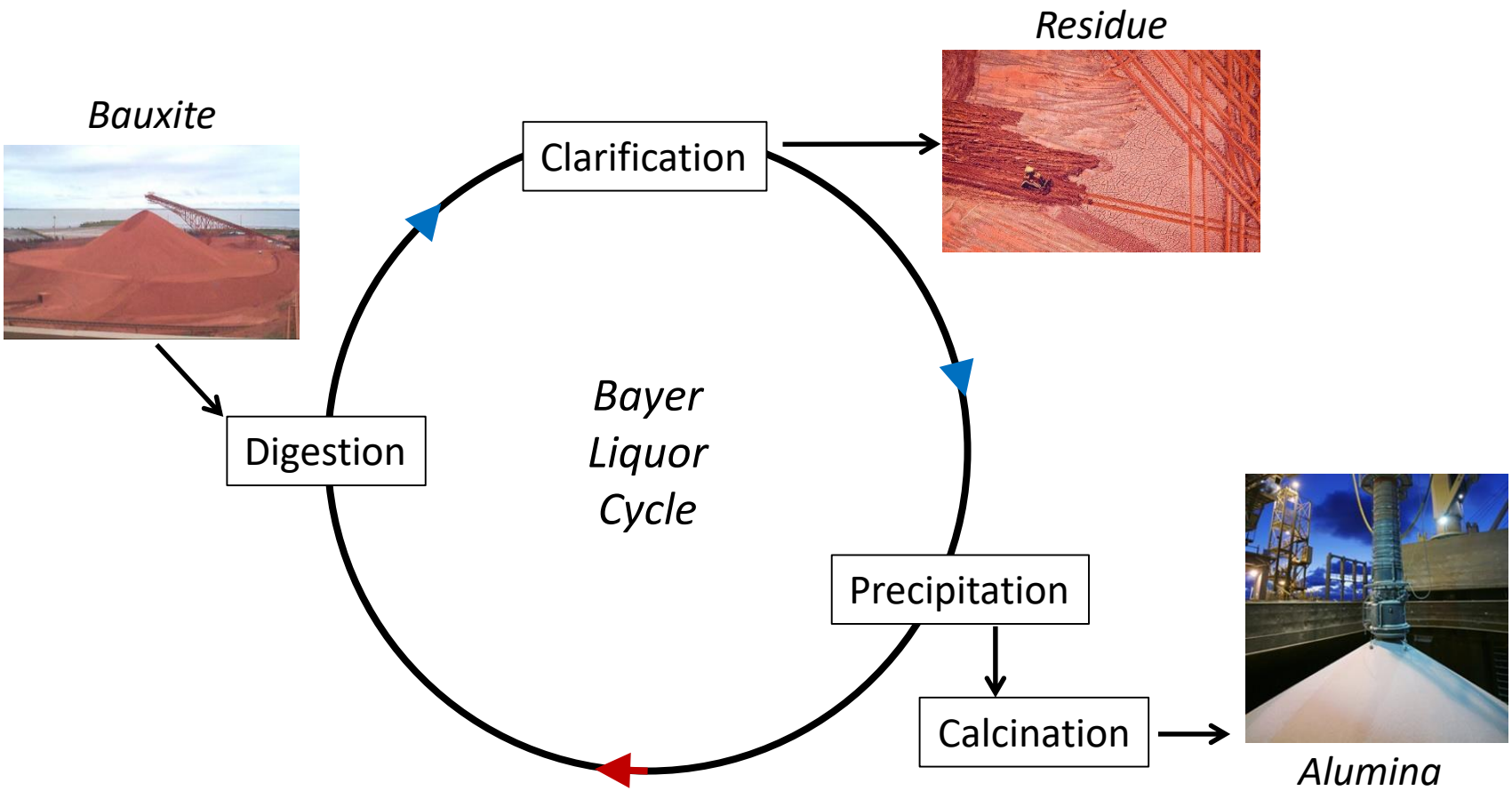
- Nickel
  - Selective acid leaching of nickel from Mixed Ni-Co Hydroxide Precipitate (MHP)
  - Developments in nickel agromining

- Gold
  - A chemical-thermodynamic model for iron at pressure oxidation (POX) conditions

Alumina

Rio Tinto Yarwun Alumina Refinery, Queensland, Australia

Bayer Process



Bayer Process - Digestion

Gibbsite → Aluminate

$Al(OH)_3 + NaOH_{(aq)} \rightarrow NaAl(OH)_{4(aq)}$ at 110-150°C

Boehmite → Aluminate

$AlOOH + NaOH_{(aq)} + H_2O \rightarrow NaAl(OH)_{4(aq)}$ at 180-280°C

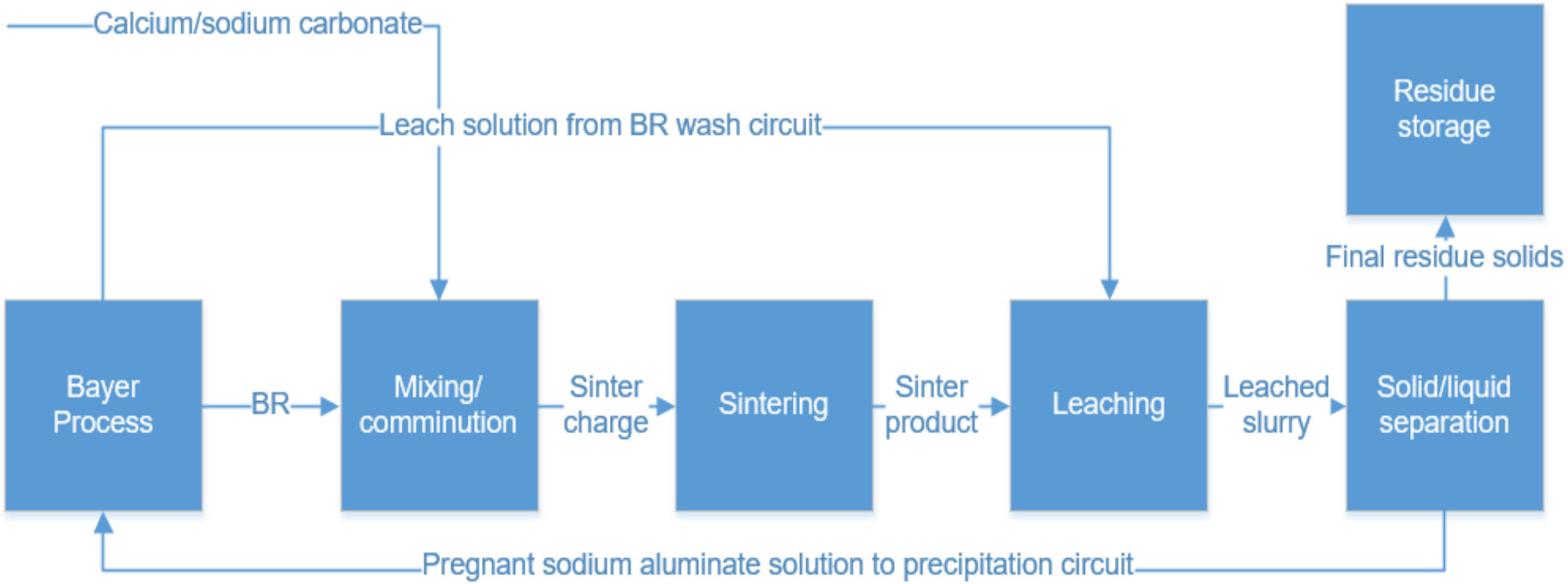
Kaolinite (Reactive Silica) → Sodalite DeSilication Product (DSP)

$3Al_2(OH)_4Si_2O_5 + 8NaOH_{(aq)} \rightarrow Na_8(AlSiO_4)_6(OH)_2.2H_2O + 7H_2O$

DSP is costly in terms of lost NaOH

DSP in residue is an environmental challenge and an impediment to residue reprocessing

Bauxite Residue (BR) Sinter-Leach

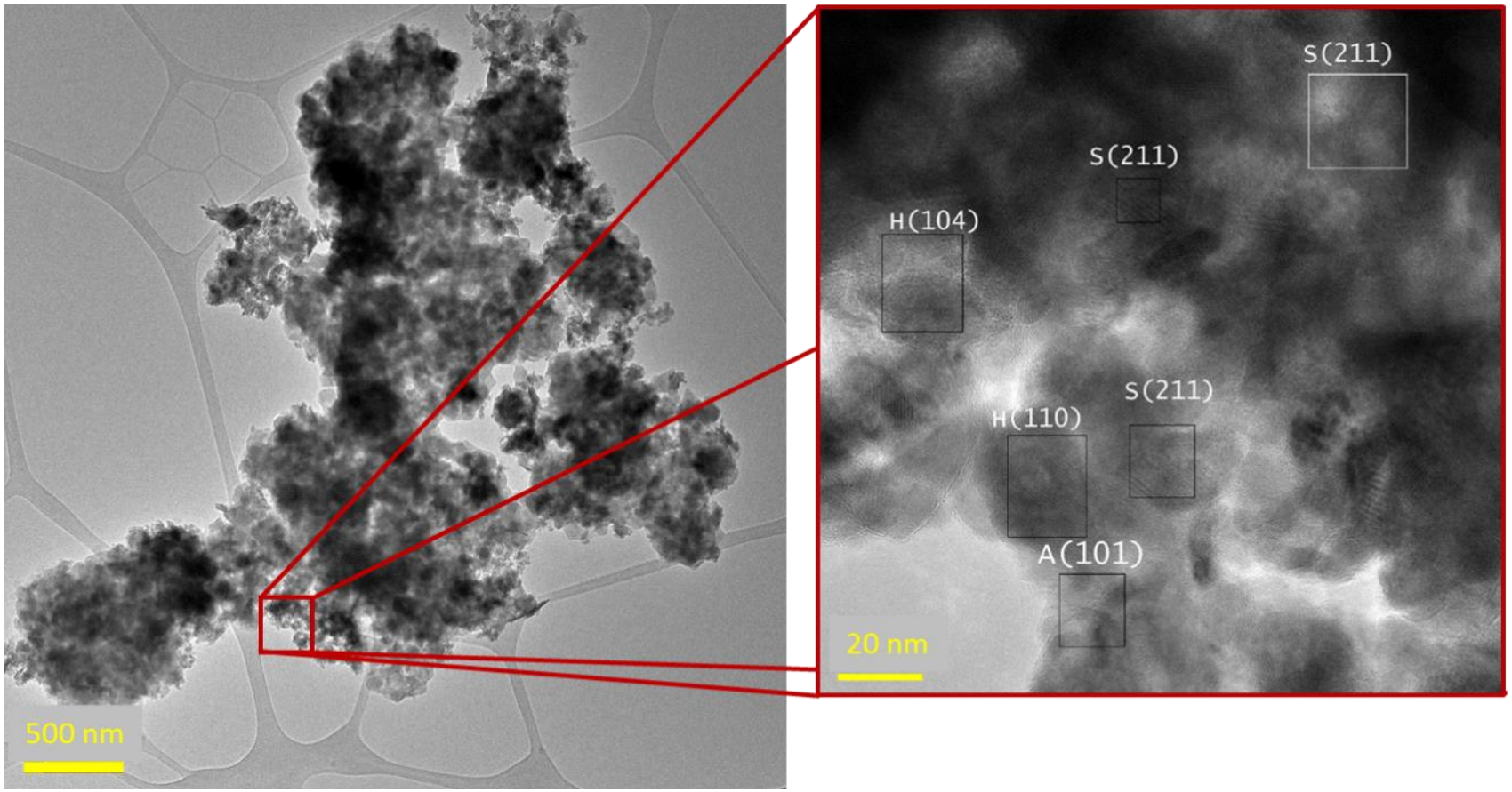


Bayer process: 10 GJ/t-Al_2O_3 but with BR sinter leach: 40 GJ/t-Al_2O_3!

Qi, T., Hodge, H., Hawker, W., Hayes, P. and Vaughan, J. (2018). **A review of the bauxite residue sinter-leach process**. Alumina2018, Gladstone, QLD, Australia, 9-14 September 2018. Australia: AQW Inc.

Bauxite Residue and DSP

Bauxite residue is very fine (< 2 µm), DSP cannot be physically separated



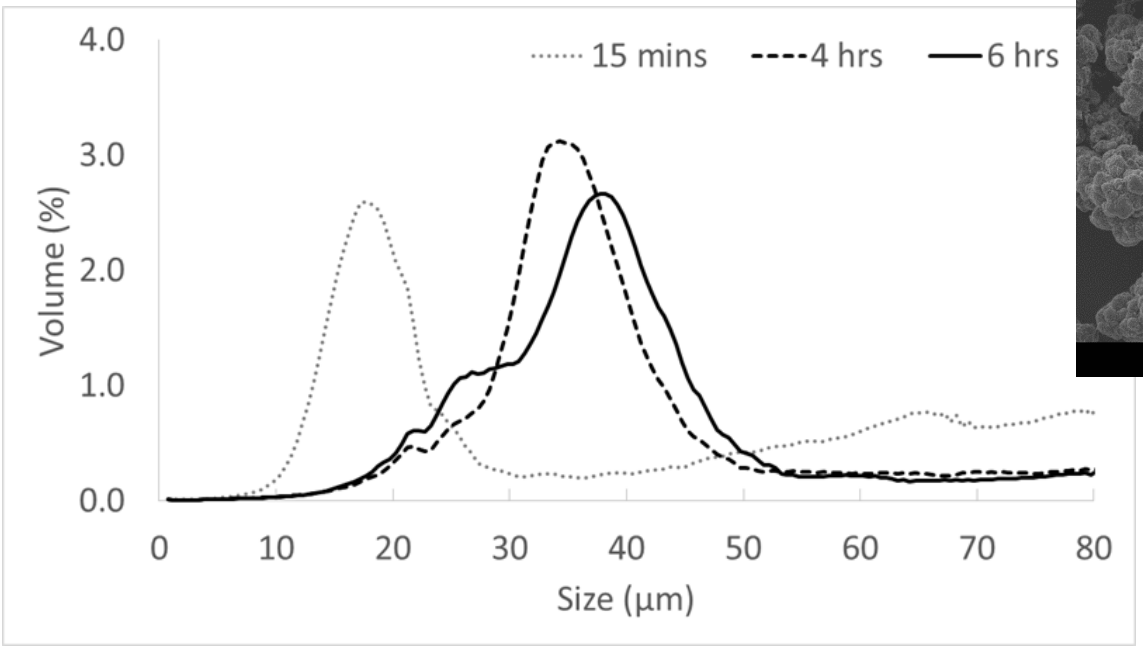
Peng, H., Vaughan, J., Staker, W., Wang, J. and Wen, W. (2018). **Advanced characterisation of bauxite residue**. Alumina2018, Gladstone, QLD, Australia, 9-14 September 2018. Australia: AQW Inc.

Growing DSP Particles

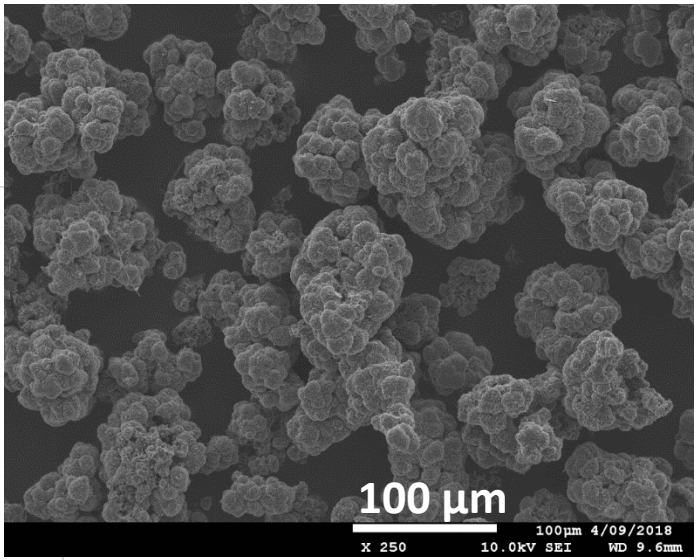
RioTinto

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

We have found conditions where DSP can be grown to > 30 µm

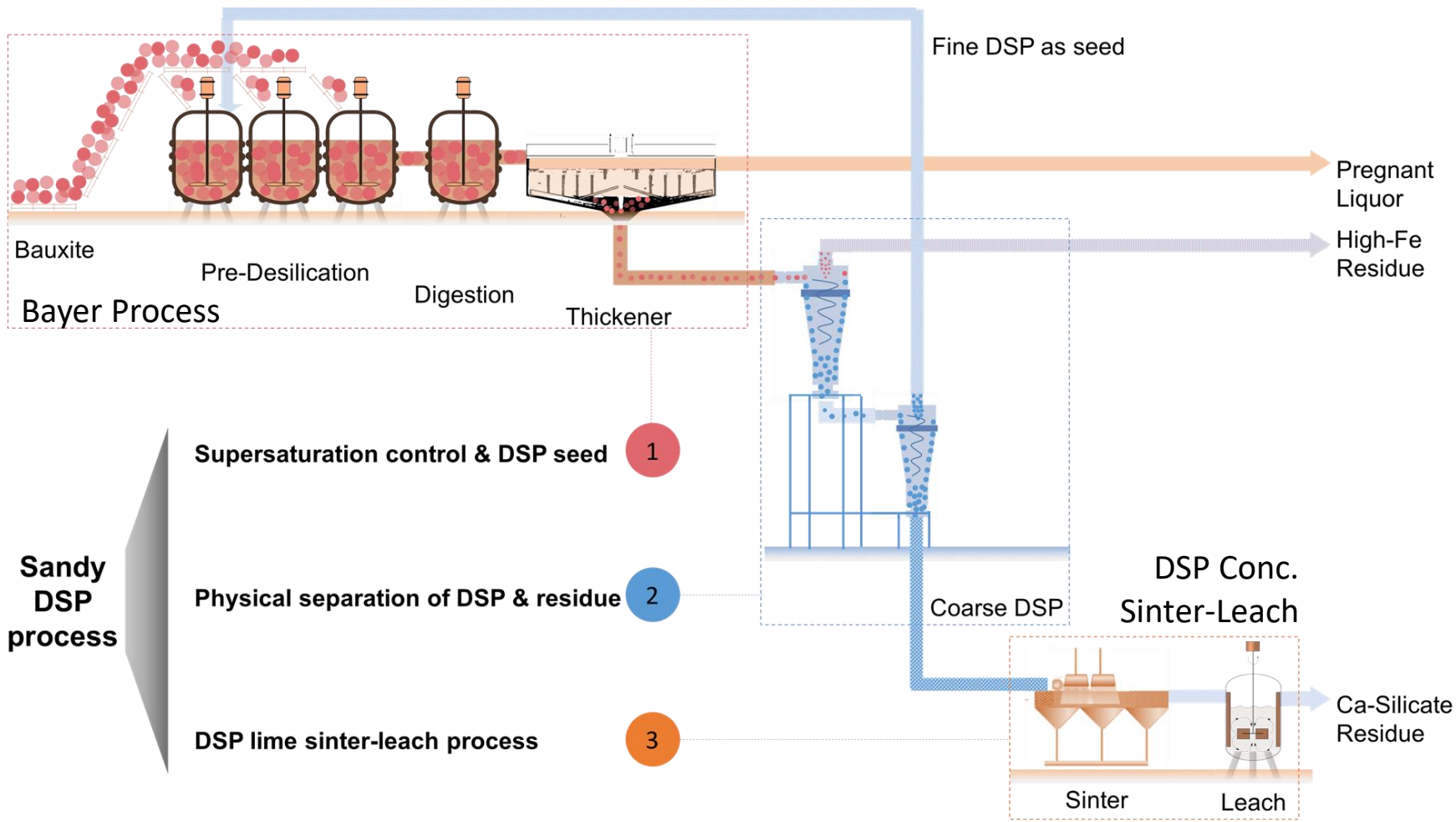


DSP size distribution as a function of reaction time



Coarse DSP agglomerates

The Sandy DSP Process



Vaughan J., Peng H., Seneviratne D., Hodge H., Hawker W., Hayes P., Staker W. The Sandy Desilication Product Process Concept. *JOM* (2019)

The Sandy DSP Process

- Lower mass flow to sinter-leach:

  Reduces energy requirement (OPEX) and size of the plant (CAPEX)

- Lower gangue mineral concentrations;

  Reduces reagent requirement associated with side reactions (OPEX)

Next step: continuous piloting, seeking industry partners

2020 TMS Annual Meeting & Exhibition: Alumina & Bauxite

Light Metals 2020

This is an excellent opportunity to interact with experts from the Light Metals industry and academia from all over the world and get the latest update on key issues in the industry. Based on the importance of improving processes, reduce environmental impact and the global challenges in aluminum production.

Alumina & Bauxite topics:

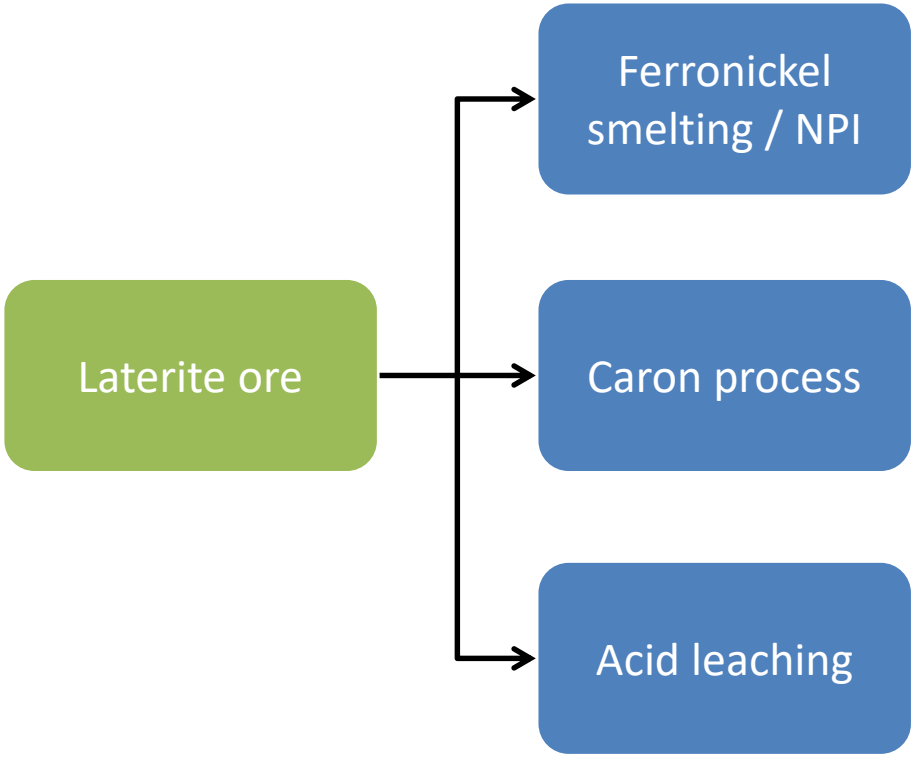
Bauxite Ore Characterisation, Bauxite Mining and Processing, Handling and Processing, Separation of Impurities, Sustainability and Environmental Issues, Processing Bauxite Residue

https://www.tms.org/TMS2020

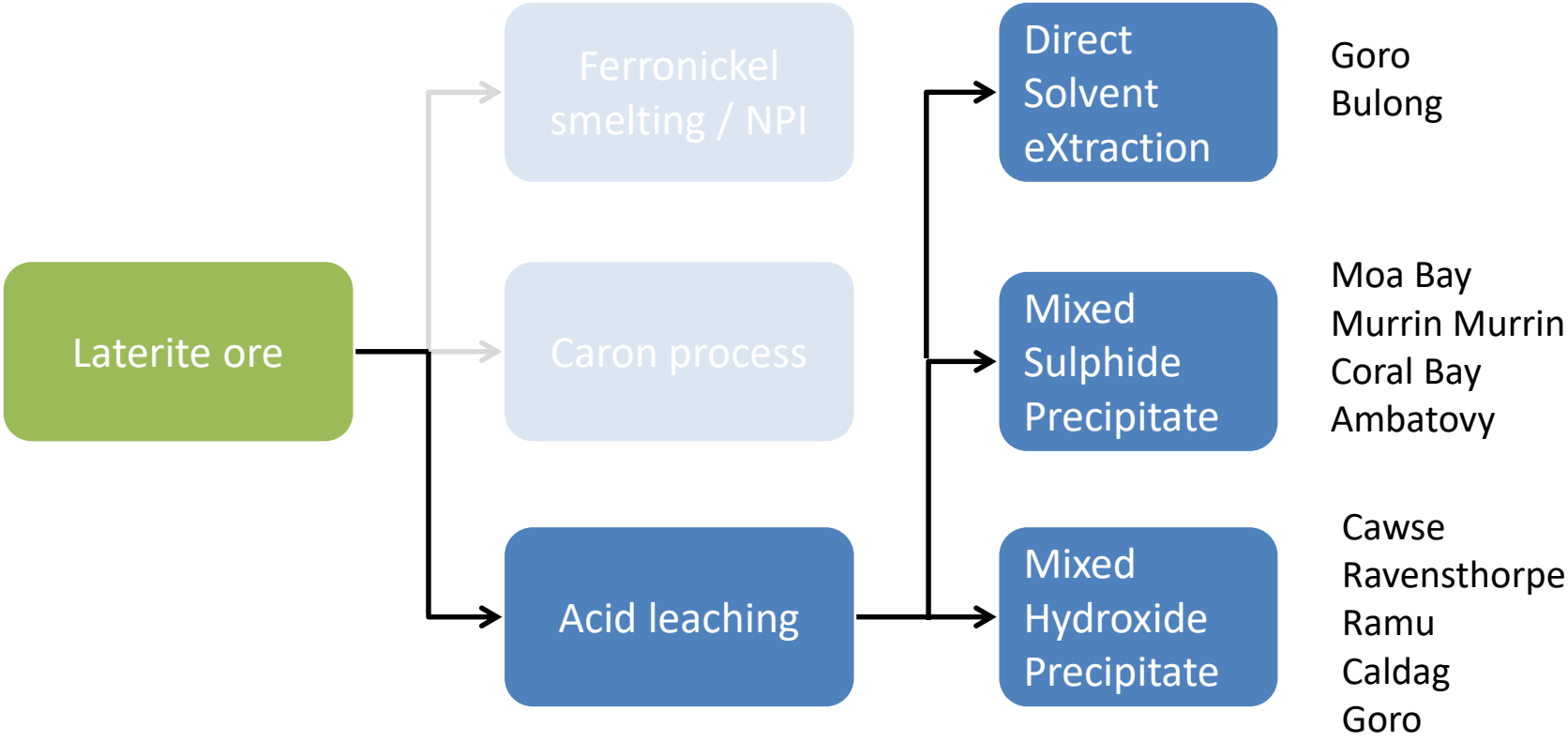
Nickel

First Quantum Minerals
Ravensthorpe nickel operation
Western Australia

Processing nickel laterite ore



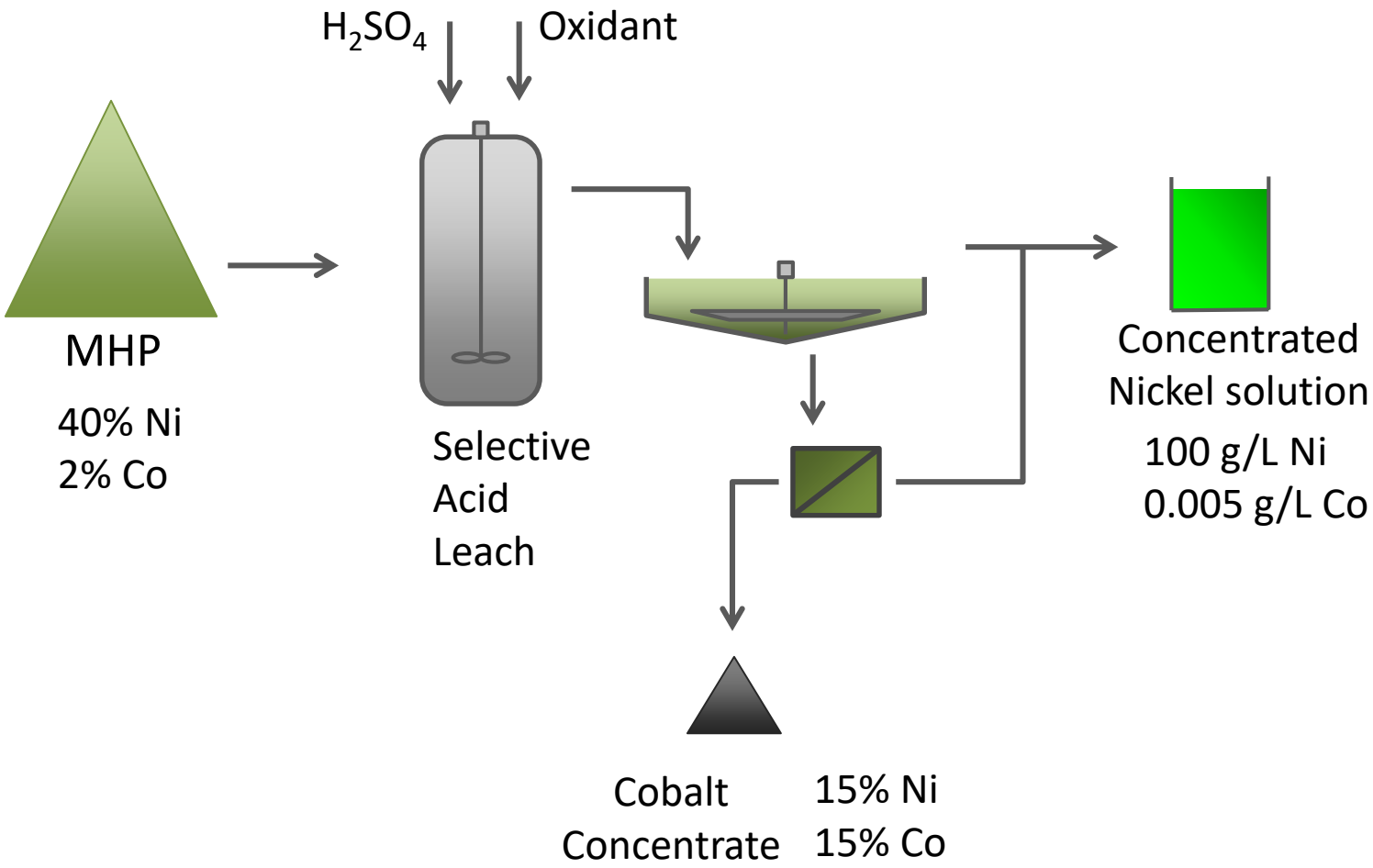
Processing nickel laterite ore



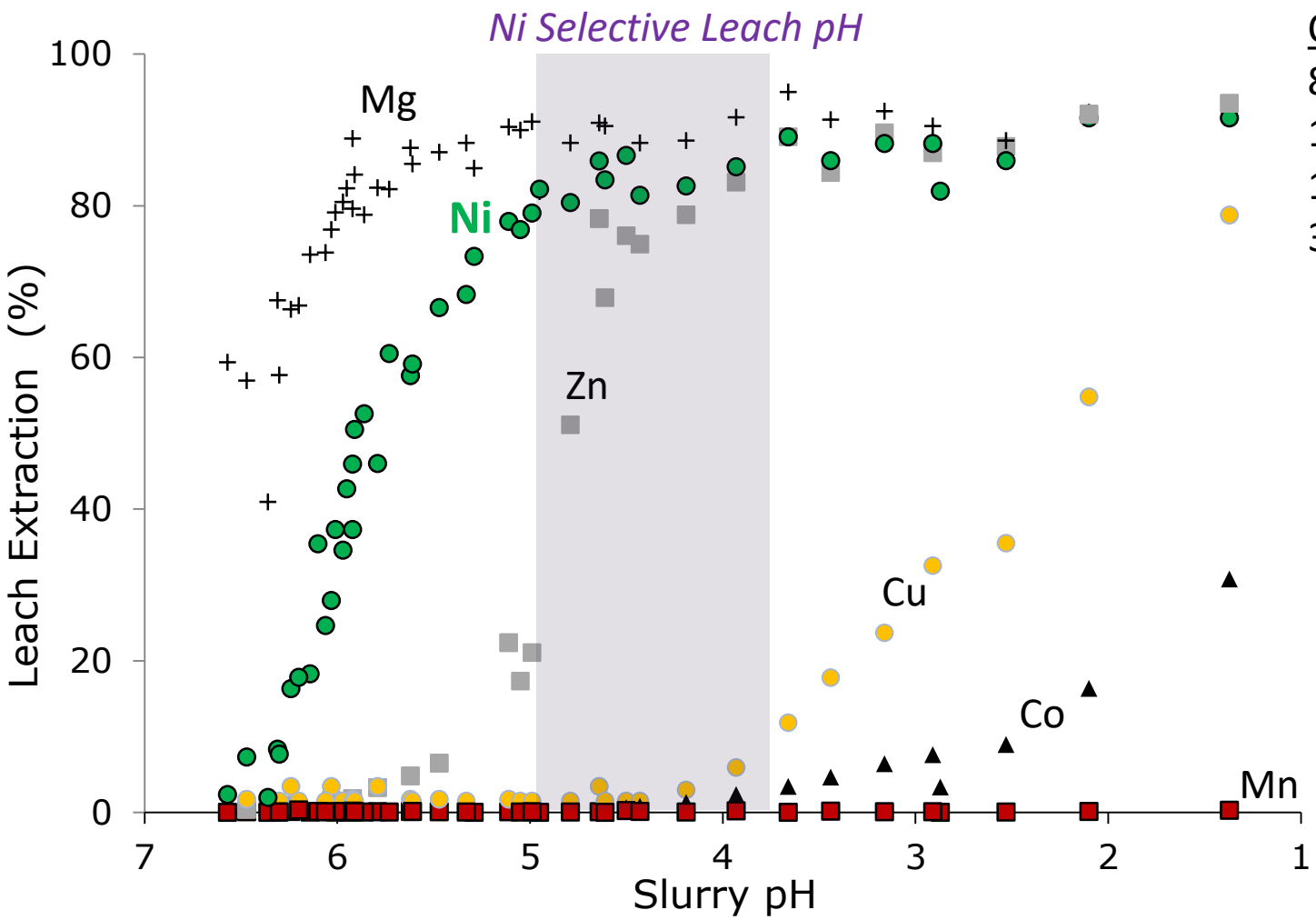
Options for refining MHP

	Conventional AMMONIA LEACH - LIX 84I	Conventional ACID LEACH - C272	New SELECTIVE ACID LEACH
Leach reagents	$NH_3/(NH_4)_2CO_3$	H_2SO_4	H_2SO_4 Oxidant
MHP leach selectivity	Mn	-	Mn, Co, Cu
Leach robustness	Sensitive to: MHP ageing; Fe, Al Oxidation Sulphate	High	High
Co/Ni solvent extraction	Nickel selective	Cobalt selective	Not needed

Selective acid leaching of nickel from mixed hydroxide precipitate (MHP)



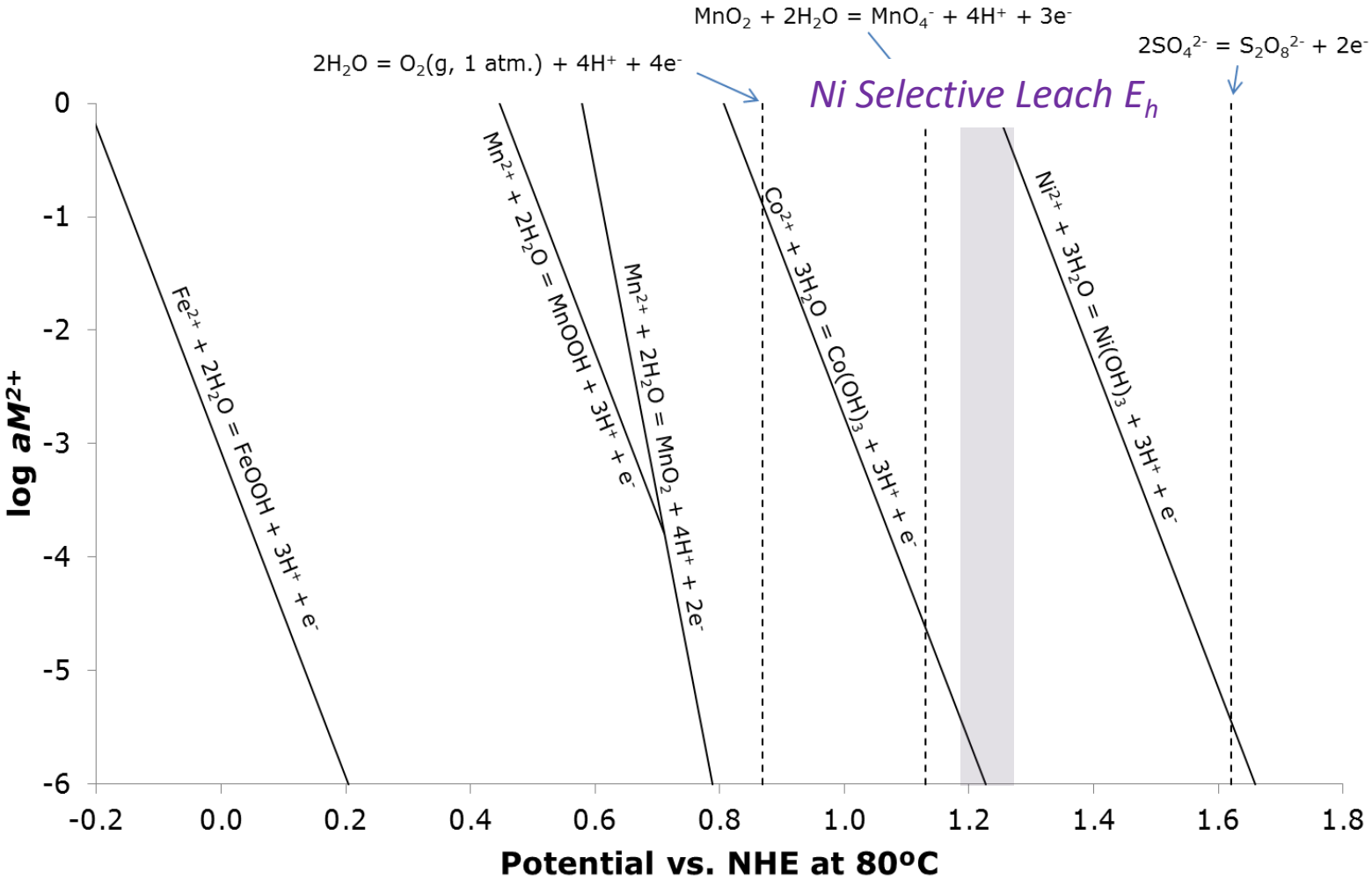
MHP oxidizing leach as a function of pH



Conditions
80°C
100% Oxidant
100 g-Ni/L-Slurry
30 min / pH adjust

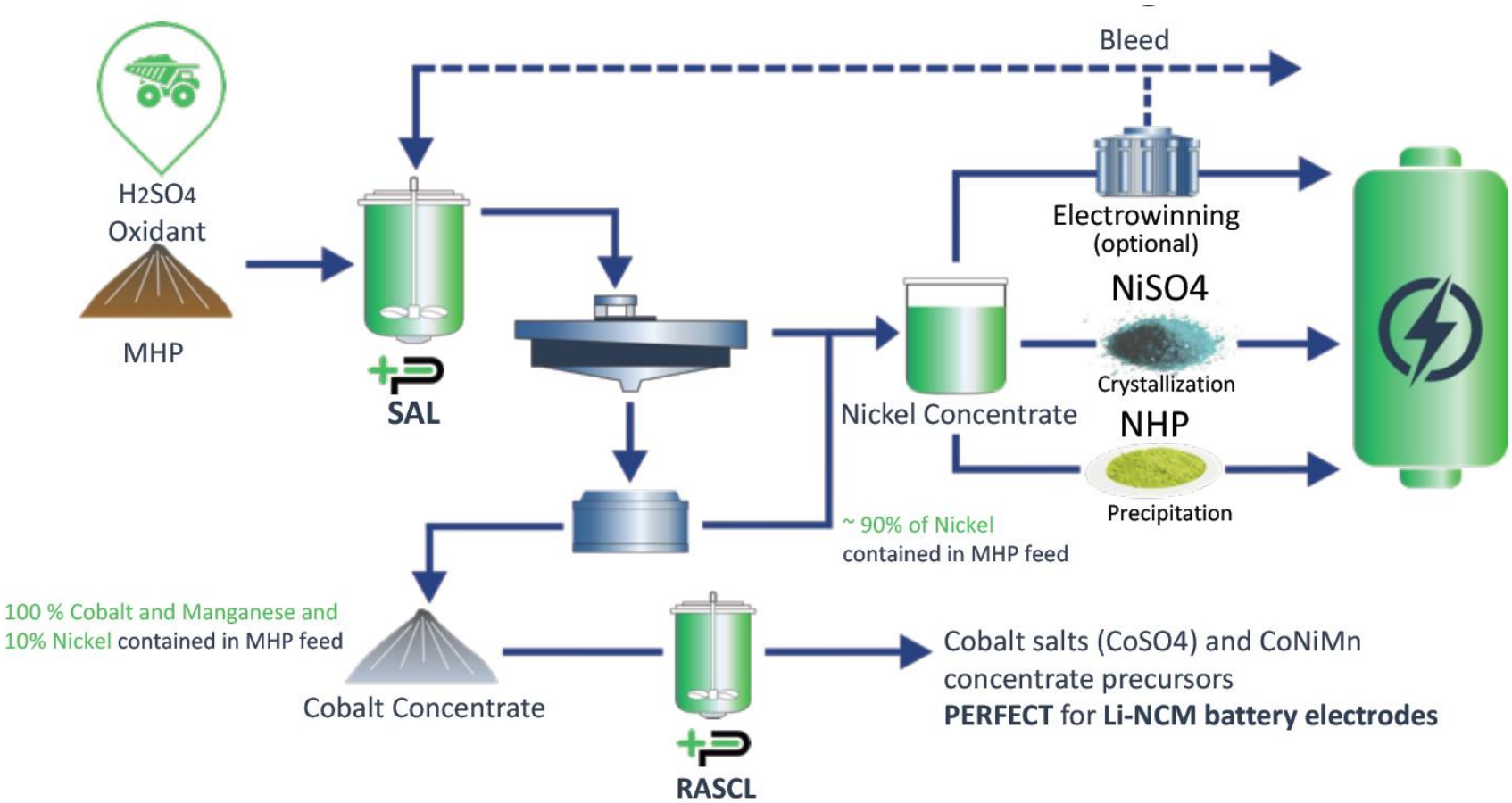
Williams C., Hawker W., Vaughan J. Selective leaching of mixed nickel – cobalt hydroxide. *Hydrometallurgy* 138, 84-92 (2013)

Oxidation precipitation diagram (pH = 4.6)



Williams C., Hawker W., Vaughan J. Selective leaching of mixed nickel – cobalt hydroxide. *Hydrometallurgy* 138, 84-92 (2013)

Selective acid leach technology licensed to

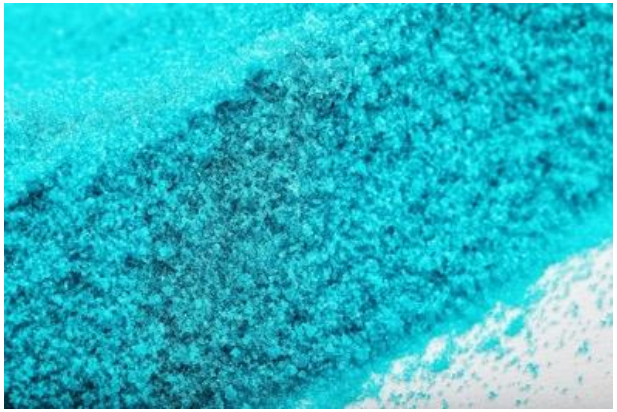


https://purebatterytech.com/

Powering the green energy revolution

2019 Pilot Plant

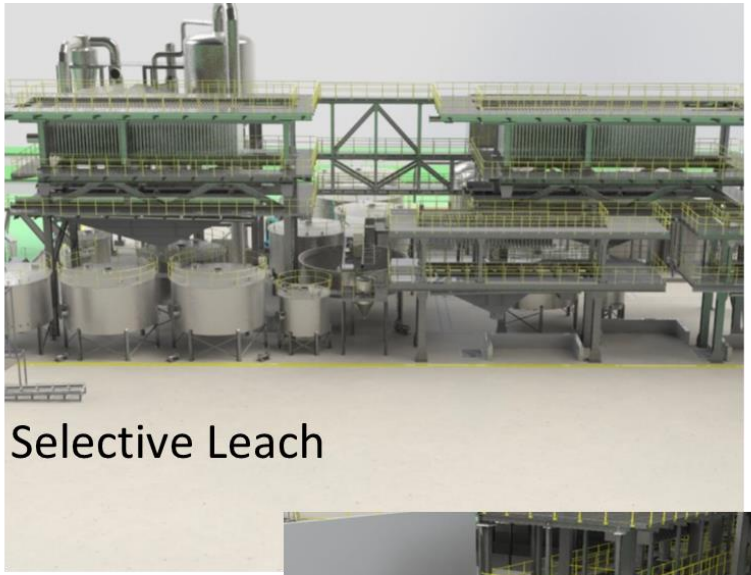
MHP
(40% Ni, 2% Co)

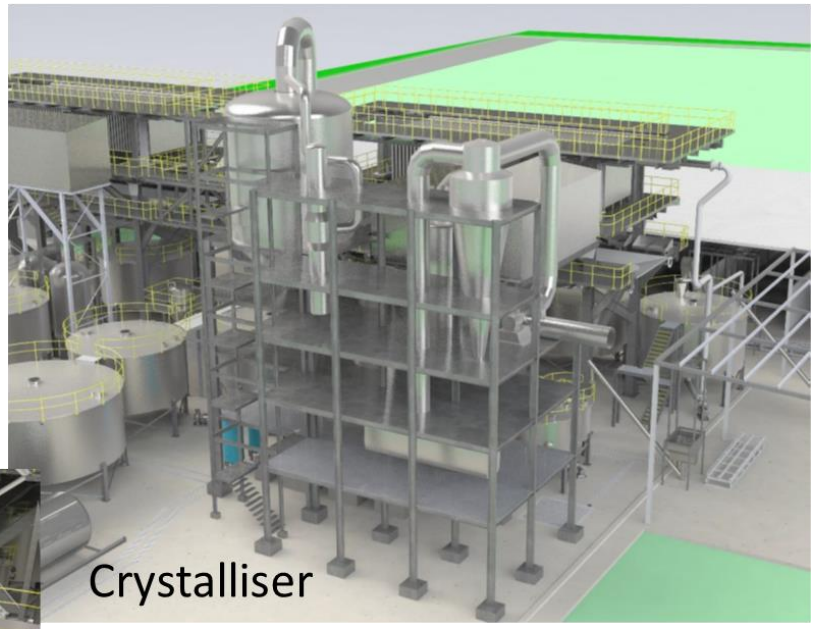


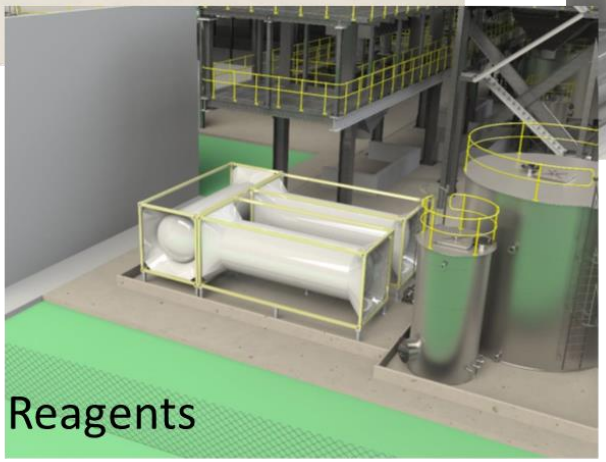
50 kg $NiSO_4.6H_2O$
(>99.9% Pure)

10 kg Cobalt Concentrate
(15% Co)

Refinery feasibility study complete

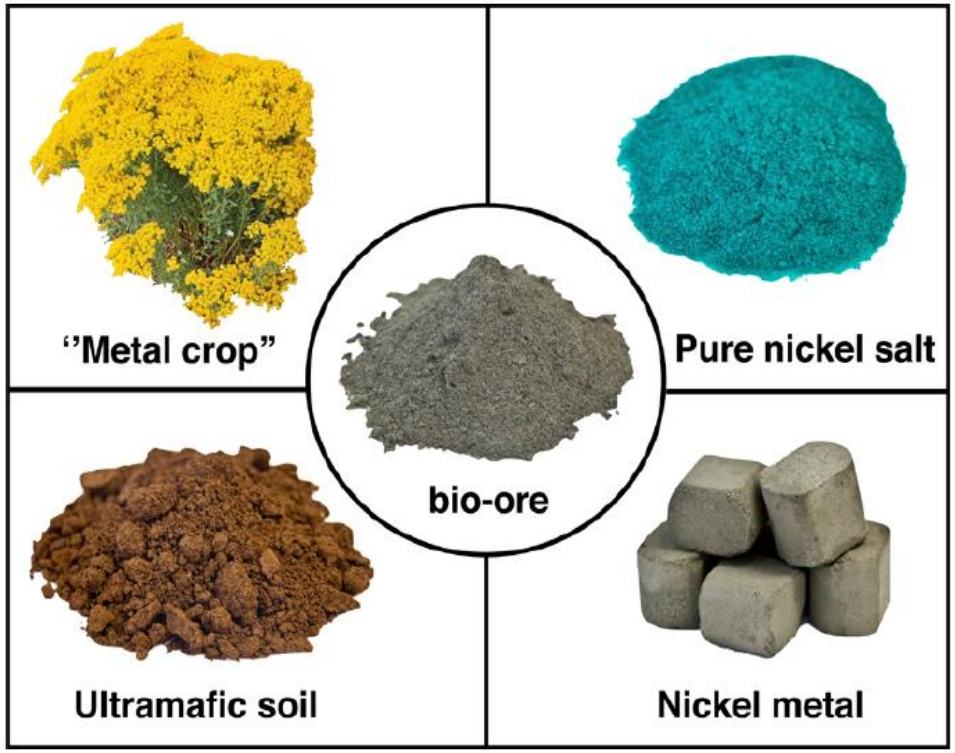






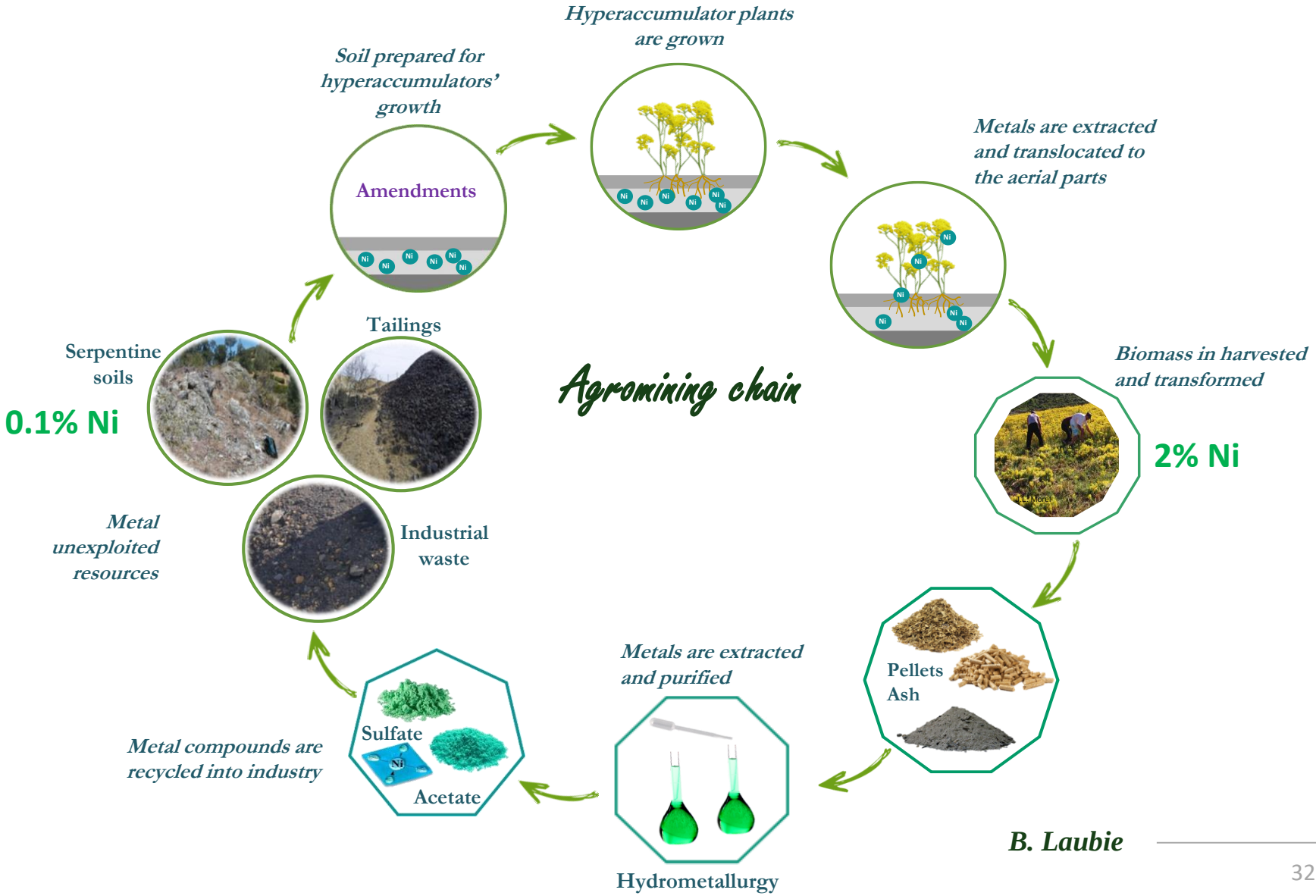
Nickel agromining

Nickel agromining is envisaged to be a part of a progressive mining and rehabilitation strategy where local communities farm metals before and after conventional mining operations.



van der Ent A. et al. Agromining: farming for metals in the future? *Environmental science & technology* (2015)

Nickel agromining



B. Laubie

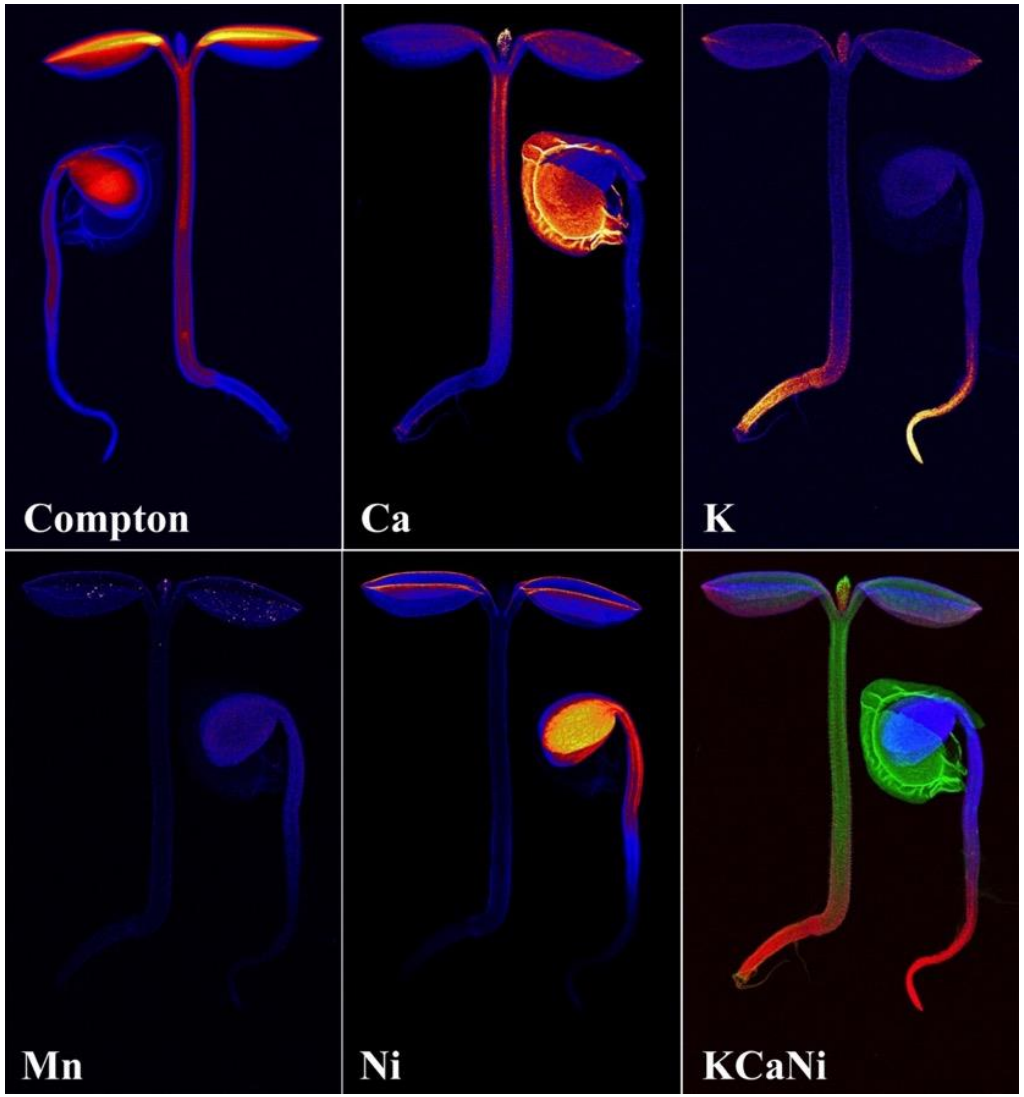
Demonstration farms:
Malaysia, Albania, Austria, France, Greece, Spain

300 kg-Ni / (ha*year) production rates achieved

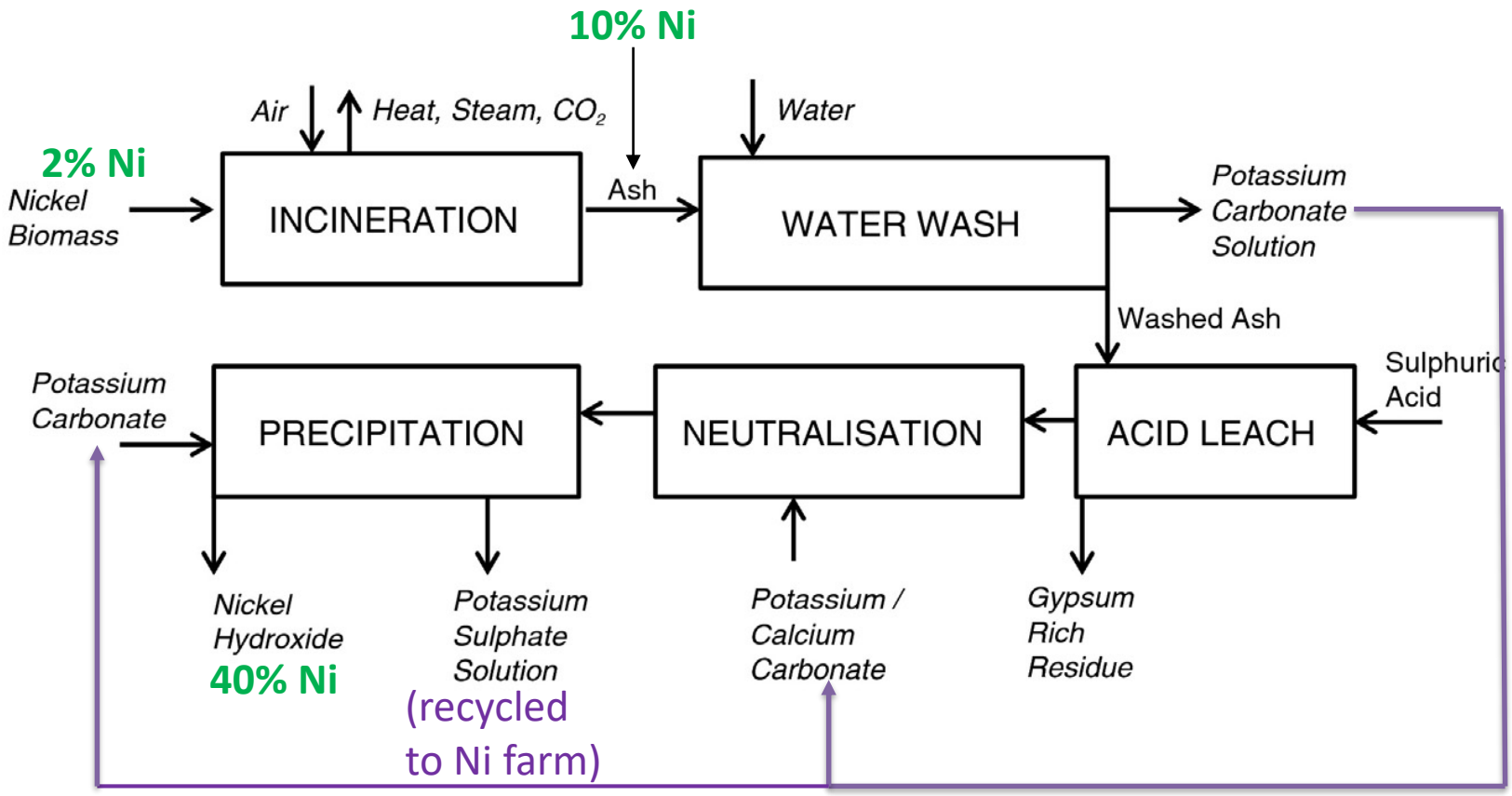
Phyllanthus rufuschaneyi

Alyssum Murale

Element localisation by synchrotron XFM-mXRF (*Alyssum murale*)



Example of a process for agromined nickel

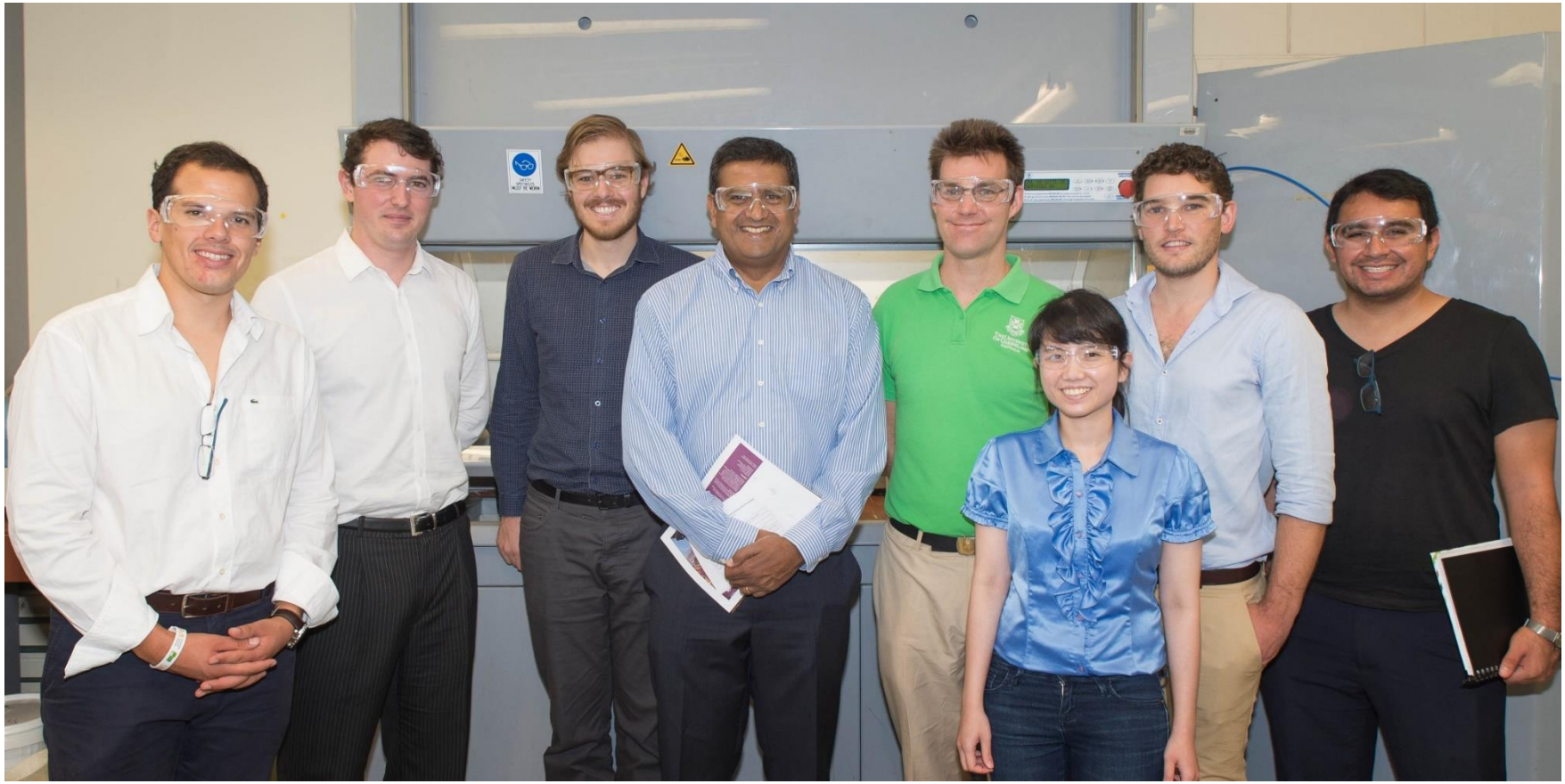


Vaughan J. et al. Characterisation and hydrometallurgical processing of nickel from tropical agromined bio-ore. *Hydrometallurgy* (2017)

Gold

Newcrest Lihir Gold Operation, Lihir Island, Papua New Guinea

Gold

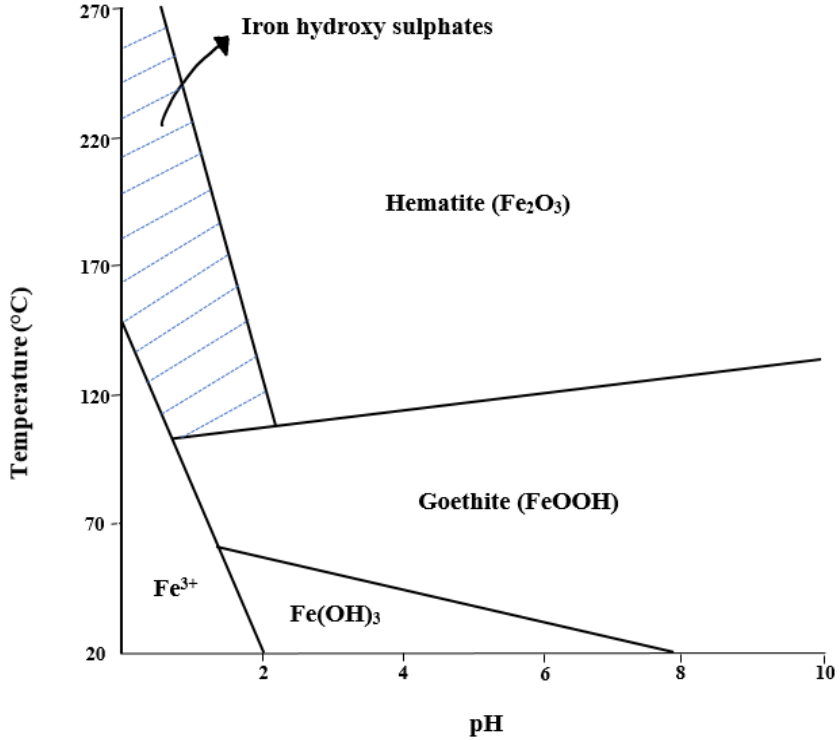


Newcrest-UQ research team (2017)

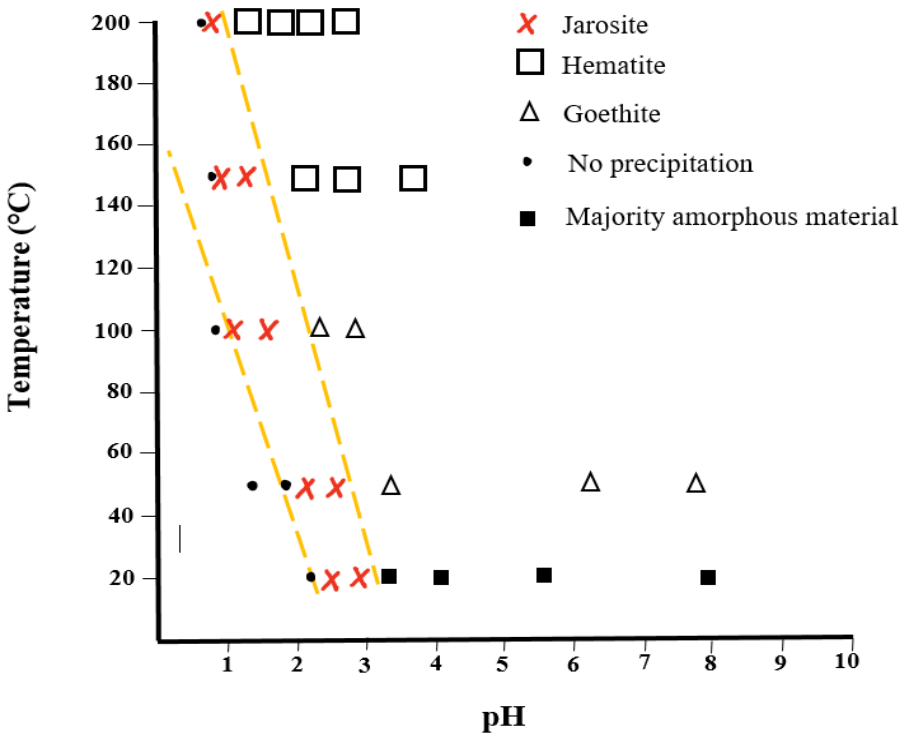
Pressure Oxidation (POX)

Pressure oxidation is used to chemically liberate finely disseminated gold in sulfide minerals, typically pyrite / arsenopyrite.

Conventional understanding of iron phase stability in POX



(adapted from Fleming, 2010)



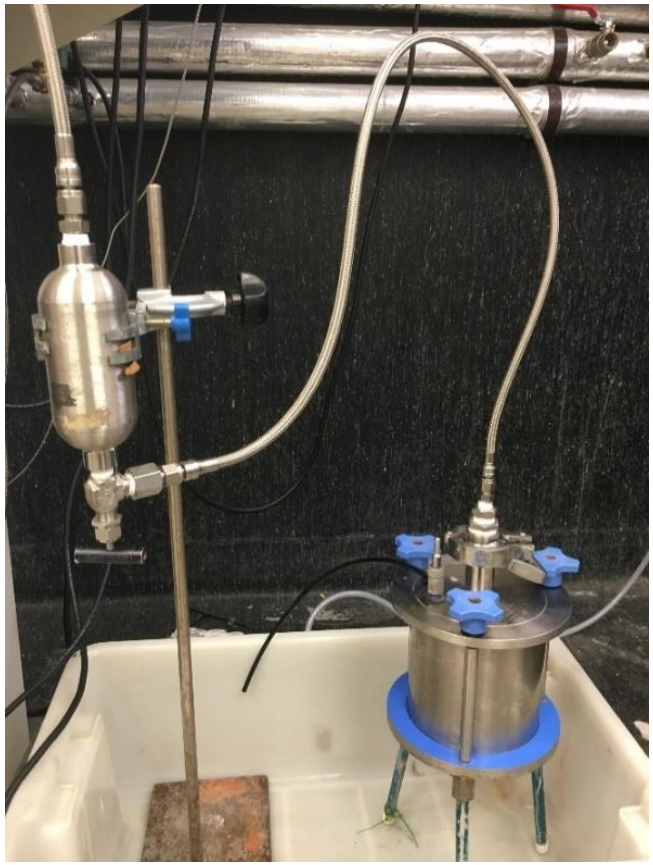
(adapted from Babcan, 1971)

Lack of reliable thermodynamic data at elevated temperatures

UQ Hydrometallurgy
POX Autoclave and Rapid Filtration

Ivana Ambrosia PhD research

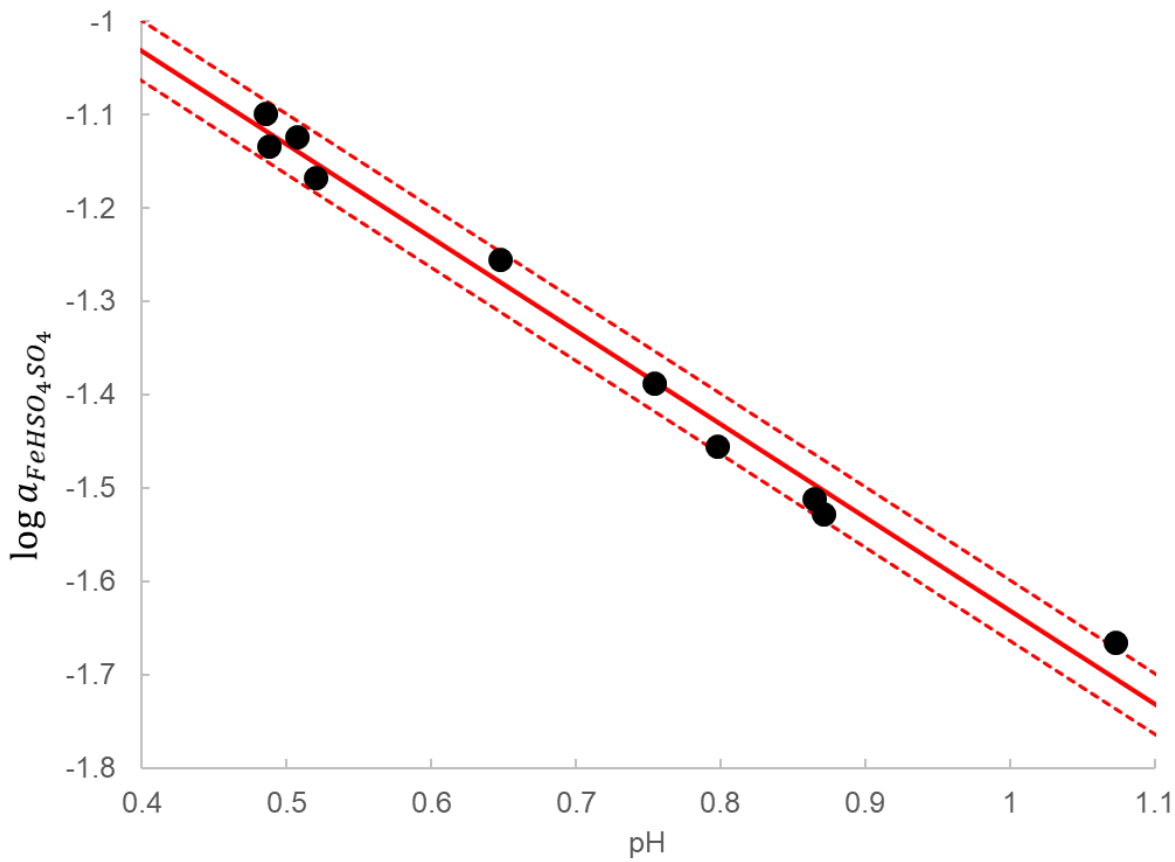
2L Ti Autoclave with internal Cooling / Sampling Port



Sample Flash Vessel and Pressure Filter

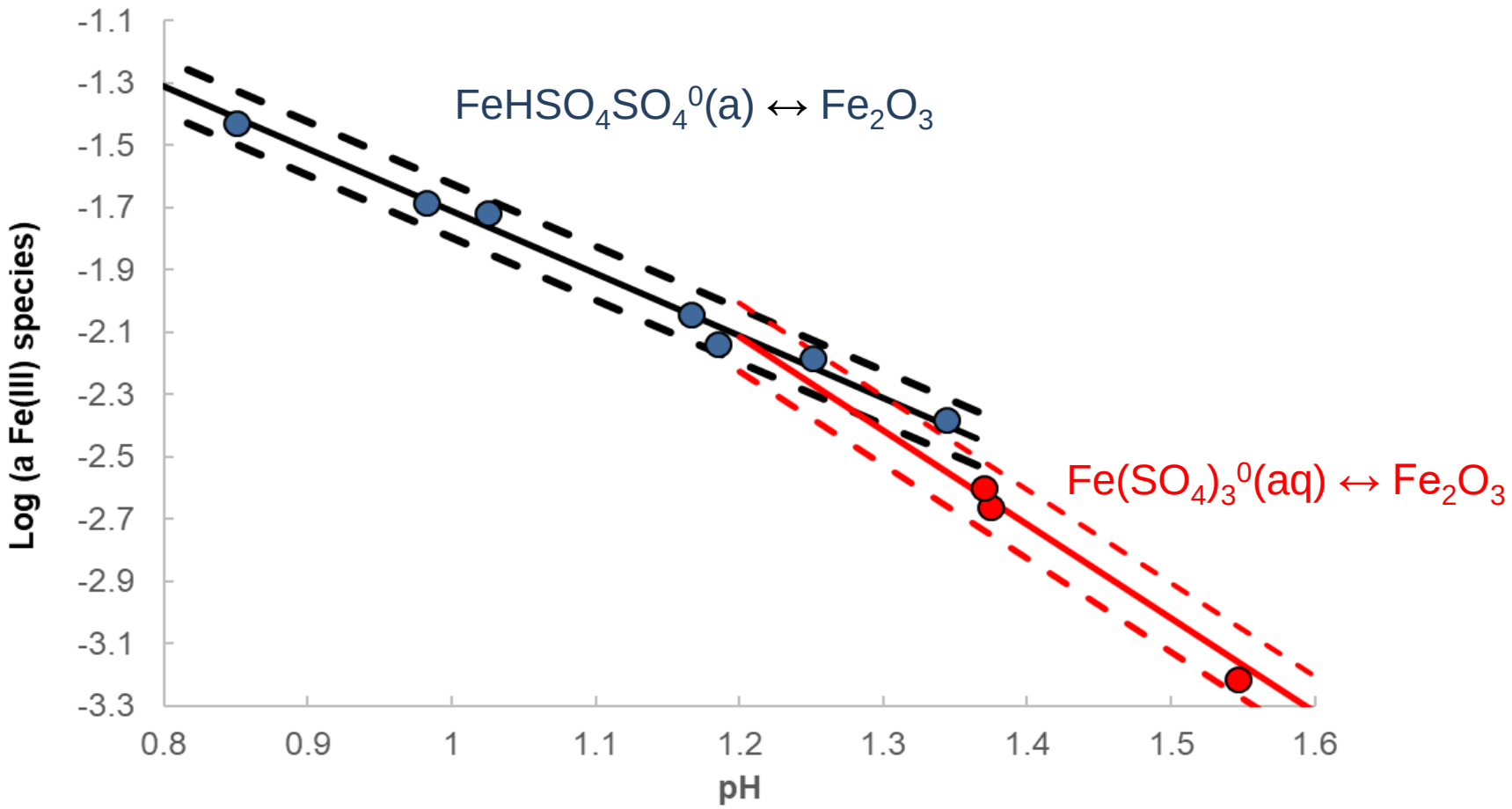
Solubility of Basic Ferric Sulphate at 220°C

$$FeHSO_4SO_4^0(a) + H_2O(l) \leftrightarrow FeOHSO_4(s) + HSO_4^-(a) + H^+(a)$$



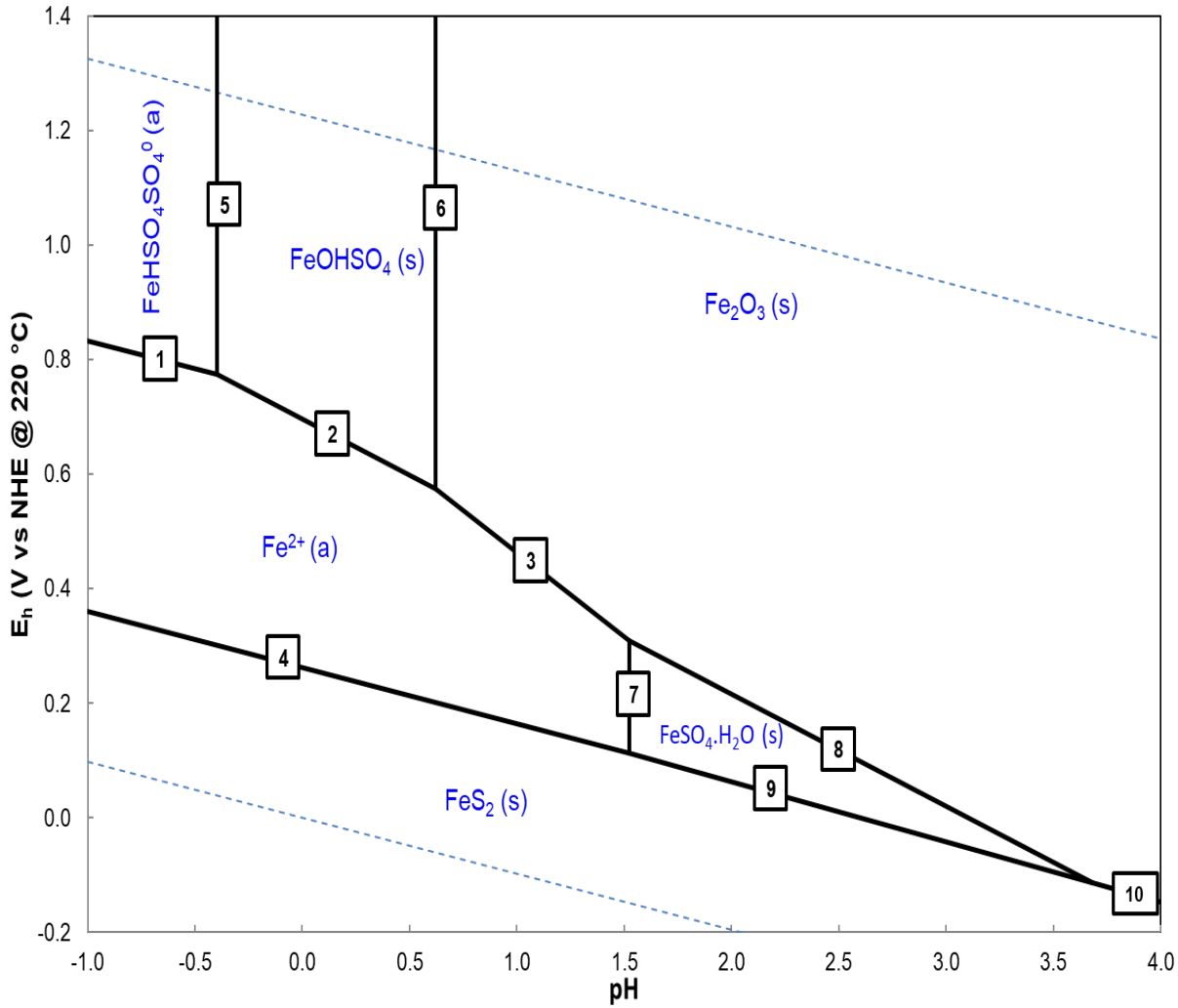
Unpublished results Ivana Ambrosia

Solubility of Hematite at 220°C



Unpublished results Ivana Ambrosia

E_h-pH diagram for Fe-S-H_2O system at 220°C



Using solubility data and simplifying assumptions a self-consistent thermodynamic database was produced providing predictive capabilities at 220°C

Unpublished results Ivana Ambrosia

Summary

	Sandy DSP	MHP Refining	Ni Agromining	POX Chemistry
Ore Grade			■	
Ore Complexity	■			■
Increase Efficiency	■	■		■
New Feed		■	■	
HSEC			■	
Waste Management	■			
High Purity Products		■		

Acknowledgements

Thanks to:

The researchers that contributed to the projects described.

The industry and granting agencies for supporting the projects.

Thanks for inviting me to this wonderful conference on extractive metallurgy.

Sponsors

RioTinto

BHP

NEWCREST MINING LIMITED

PURE BATTERY TECHNOLOGIES

OZ MINERALS

Australian Government
Australian Research Council

UNIQUEST

ADVANCE QUEENSLAND

Queensland Government

Collaborators

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

PYROSEARCH

SMI Sustainable Minerals Institute

UFMG

FIMLab
Films & Inorganic Membrane Laboratory

UNIVERSITÉ DE LORRAINE

USP
Universidade de São Paulo

CENTRAL SOUTH UNIVERSITY
中南大學

UNIVERSITY OF BATH

McGill

UBC

SEEK WISDOM
THE UNIVERSITY OF WESTERN AUSTRALIA