TRENDS IN NICKEL-COBALT PROCESSING

By

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RECENT INDUSTRY TRENDS

General slow down due to financial situation.

- Some production taken off line or reduced.
- Some new projects slowed down.
- Some new projects put on hold.

INDUSTRY TRENDS - LATERITES - PAL

- Two PAL plants closed – Cawse and Ravensthorpe (BHPB reviewing future of Yabulu operation which was to receive MHP from Ravensthorpe).
- Vale Inco's Goro operation in New Caledonia due on stream by the end of the 2009.
- Expansion of Sumitomo's Coral Bay (Rio Tuba). operation in Philippines due on line 2009.
- Sherritt's Ambotovy Project construction slowed, due to be completed by end of 2010.
- MCC/Highlands Pacific Ramu Project in PNG due on stream at end of 2009.
- Expansion project for Moa Bay slowed.
- Vale Brazil's Vermelho Project on hold.
- Gladstone Project in QLD has received approval for EIS and are seeking financing to proceed.

INDUSTRY TRENDS – LATERITES – HEAP LEACHING

- Minara at Murrin Murrin in Western Australia are progressively extending their successful scats heap leaching operation to process ore.
- European Nickel have received their final operating permit for their heap leaching project in Turkey, and are targeting start of construction in second half of 2009.
- European Nickel/Rusina developing Acoje Project in Philippines. Heap leach trials at site planned for 2009.
- NORNICO, QLD, Australia, Metallica Minerals Limited. Feasibility study program deferred.

INDUSTRY TRENDS – LATERITES - SMELTING

- Vale Onça Puma ferronickel project, Brazil, slowed by at least one year, now due on stream in January 2010.
- Koniambo ferronickel project SMSP/Xstrata due on line 2011.
- Large reduction in nickel pig iron production in China due to lower metal price.

INDUSTRY TRENDS – SULPHIDES - HYDROMET

- Construction of Voisey's Bay pressure oxidation operation due to start in 2009 and be complete 2013.
- Tati Nickel Activox Project in Botswana suspended by Norilsk.
- Talvivaara heap bioleaching operation in Finland now on stream.
- PolyMet Mining is in the late stages of the environmental review process for their NorthMet Project in Minnesota USA using the PLATSOL™ pressure oxidation process.

WHAT ARE THE OVERALL EFFECTS?

- Fundamentals are largely unchanged.
- Nickel demand is likely to increase again due to consumption by China, India and other developing countries.
- Most of future new nickel will have to come from laterites.
- Environmental issues will continue to promote hydromet for new sulphide projects.

LATERITE PROCESSING DEVELOPMENTS

- Most new projects will have to process ore too low grade and with unsuitable mineralogy for smelting.
- Thus they will have to use some form of leaching process.
- Commercially applied processes are:
  - PAL
  - PAL with an associated AL circuit
  - Heap leaching
  - Reduction roast-ammonia leach (Caron) process

LATERITE PROCESSING DEVELOPMENTS (CONT.)

PAL:

- Currently selected for all large laterite leaching projects.
- Experience now gained from a number of commercial operations.
- The least sensitive to mineralogy.
- Sensitive to sulphuric acid price.
- Relatively insensitive to climatic conditions

LATERITE PROCESSING DEVELOPMENTS (CONT.)

PAL with associated AL:

Compared with PAL only –

- Extends operation to economically process higher acid consuming portions of deposit.
- Reduces consumption of neutralizing agent.
- Reduces overall capex per unit of nickel production.
- Reduces PAL equipment requirements.

LATERITE PROCESSING DEVELOPMENTS (CONT.)

Heap leaching:

- Lower capex.
- Potentially more suitable than PAL for small and medium size projects.
- Can be applied as a satellite to a PAL operation to treat suitable portions of the deposit.
- Generally has higher acid consumption than PAL, which increases opex and exposure to acid price.
- Lower metal extractions and slow leach kinetics.
- Relatively sensitive to mineralogy.
- More sensitive to climatic conditions than PAL.
- Limited commercial experience to date.

LATERITE PROCESSING DEVELOPMENTS (CONT.)

Reduction roast-ammonia leach:

- Proven technology.
- Mild operating conditions: reduction < 800C, high pH solution leach not aggressive.
- High energy required for ore drying.
- Nickel recovery only moderately high.
- Cobalt recovery relatively low.
- Sensitive to ore mineralogy.
- No recent new plants.

OPPORTUNITY FOR NEW LATERITE PROCESSES

Ideal specifications::

- High recoveries of nickel and cobalt.
- Lower capex and opex than existing processes
- No initial energy intensive drying step.
- Atmospheric pressure operation.
- Low net reagent consumption.
- Ability to provide separate nickel and cobalt products.
- Suitable for large and small projects.
- Low to moderate corrosivity.
- Low environmental impact.

PROCESSES UNDER DEVELOPMENT

- Atmospheric sulphuric acid leaching (AL)
- Sulphation atmospheric leach (SAL Process)
- Atmospheric chloride leaching

AL - POTENTIAL ADVANTAGES

- Low capex than PAL.
- Less aggressive leach conditions than PAL.
- Lower maintenance cost than PAL.
- Atmospheric pressure operation.
- Simpler operation than PAL.
- Higher on-stream availability – individual leach tanks can be by-passed.

AL - CHALLENGES

- High acid consumption.
- Longer retention times than PAL.
- Need to process leach solutions with high impurities, especially iron.
- Lower recoveries than PAL.
- Aggressive conditions – though less so than PAL.

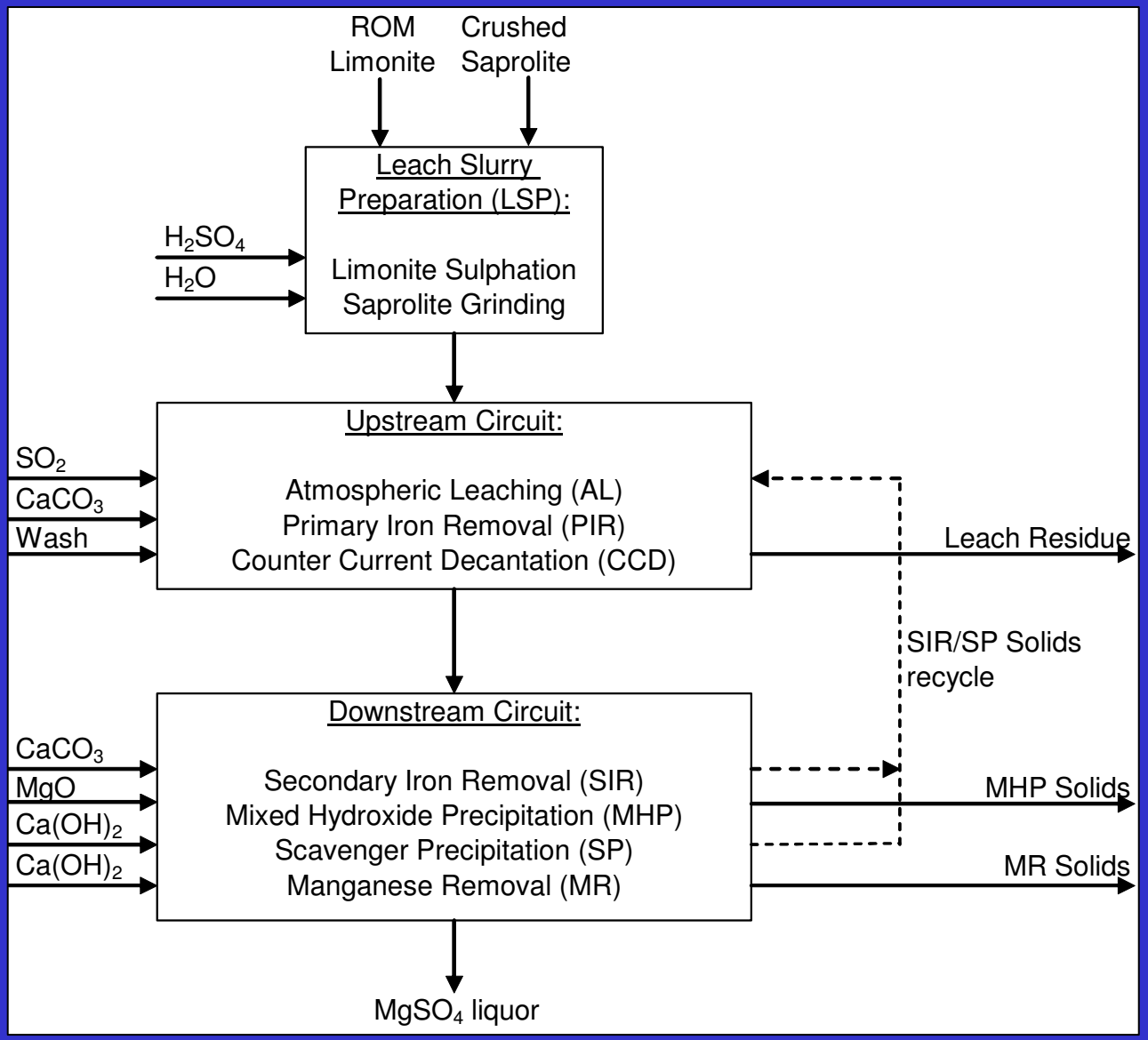
AL - STATUS

- No stand alone commercial operations as yet.
- Operated at Ravensthorpe for treating saprolite ore in parallel with PAL for limonite (EPAL Process). Benefits from availability of “free” acid from PAL discharge.
- A number of projects using sulphuric acid are at various stages of development.

SAL PROCESS

- Skye Resources, Canada, have piloted a sulphation atmospheric leach process (SAL Process) at SGS Lakefield as a possible option for the Fenix Project in Guatemala.
- Features initial sulphation of limonite ore by pugging with strong sulphuric acid, which generates 140C temperature - thus accelerating leach kinetics. Iron forms ferric sulphate.
- Second stage consists of adding crushed saprolite ore and water and grinding in ball mill, then leaching for about 24 hrs in series of agitated tanks with temp. maintained at 95-105C.
- Limestone is added and iron is hydrolyzed to ferric hydroxide. Acid is generated which leaches saprolite. SO_2 is added to reduce cobalt and enhance extraction.

SAL PROCESS (SGS PRESENTATION AT ALTA 2007)



SAL PROCESS (CONT.)

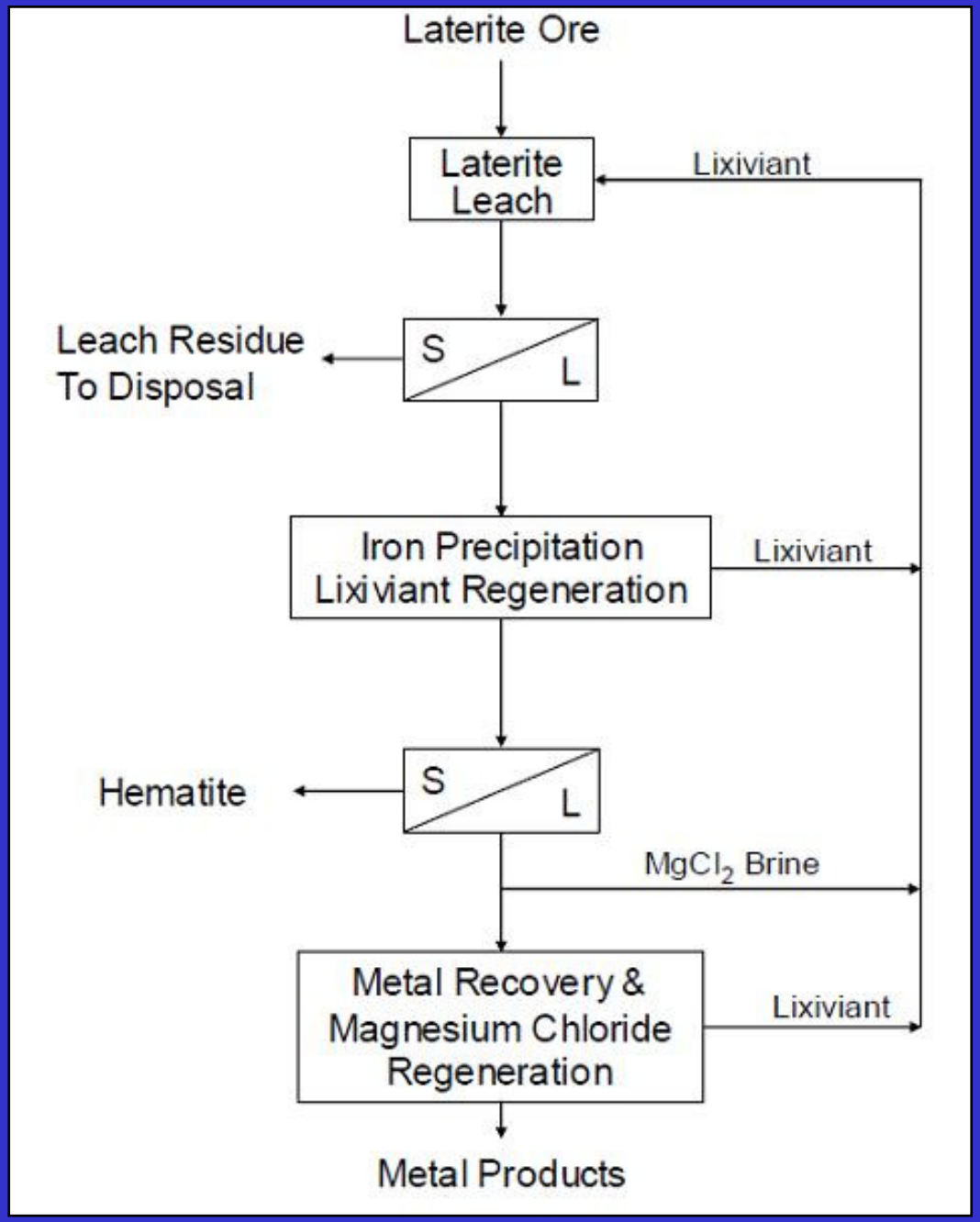
- Pilot plant achieved nickel and cobalt leach extractions of 85-89%.
- Acid consumption 600 kg/t (for 9-10% Mg content)
- Downstream process was conventional MHP circuit.

ATMOSPHERIC CHLORIDE LEACH

- Chloride leaching tested for the Young Laterite Project for Jervois Mining, NSW, Australia, using magnesium chloride-HCl lixiviant.
- Iron is precipitated as hematite and lixiviant regenerated.
- Tests indicate high pulp filtration rate allowing use of belt filters, which is much more favourable than sulphuric acid leach residue solid-liquid separation
- Chloride leaching has also been tested by Chesbar/ Jaguar Nickel in Canada and Intec in Australia.

CHLORIDE LEACH FLOWSHEET TESTED FOR YOUNG PROJECT

(BRYN HARRIS PRESENTATION AT ALTA 2006)



PREVIOUSLY PROPOSED LATERITE PROCESSES

Numerous processes proposed over years involving pyrometallurgy, hydrometallurgy, vapour metallurgy and combinations including:

- Segregation roasting
- Sulphation roasting
- Republic Steel HSO - HTCP Process
- Aqueous chlorination

PREVIOUSLY PROPOSED LATERITE PROCESSES (CONT.)

- Nitric acid leaching
- Carbonyl extraction (Inco)
- Sulphur dioxide leaching
- Reduction roast - sulphuric acid leaching
- Gas phase sulphation with SO_2/air - water leach
- Submerged lance smelting (Ausmelt)

FIELD STILL WIDE OPEN

No one has come up with a real winner to date.

So opportunity still KNOCKS

FURTHER DEVELOPMENTS OF PAL

In the meantime possible further developments of PAL include:

- Flotation for upgrading some saprolitic ores.
- Treatment of blended laterite/sulphide feed for generating acid and heat in autoclaves.
- Extraction and reuse of residual leach acid by SX/IX/membranes.
- Development of more selective SX extractants, including synergistic mixtures.
- Application of RIP to reduce the number of CCD thickeners (or eliminate totally) and reduce soluble metal losses.

SULPHIDE PROCESSING DEVELOPMENTS

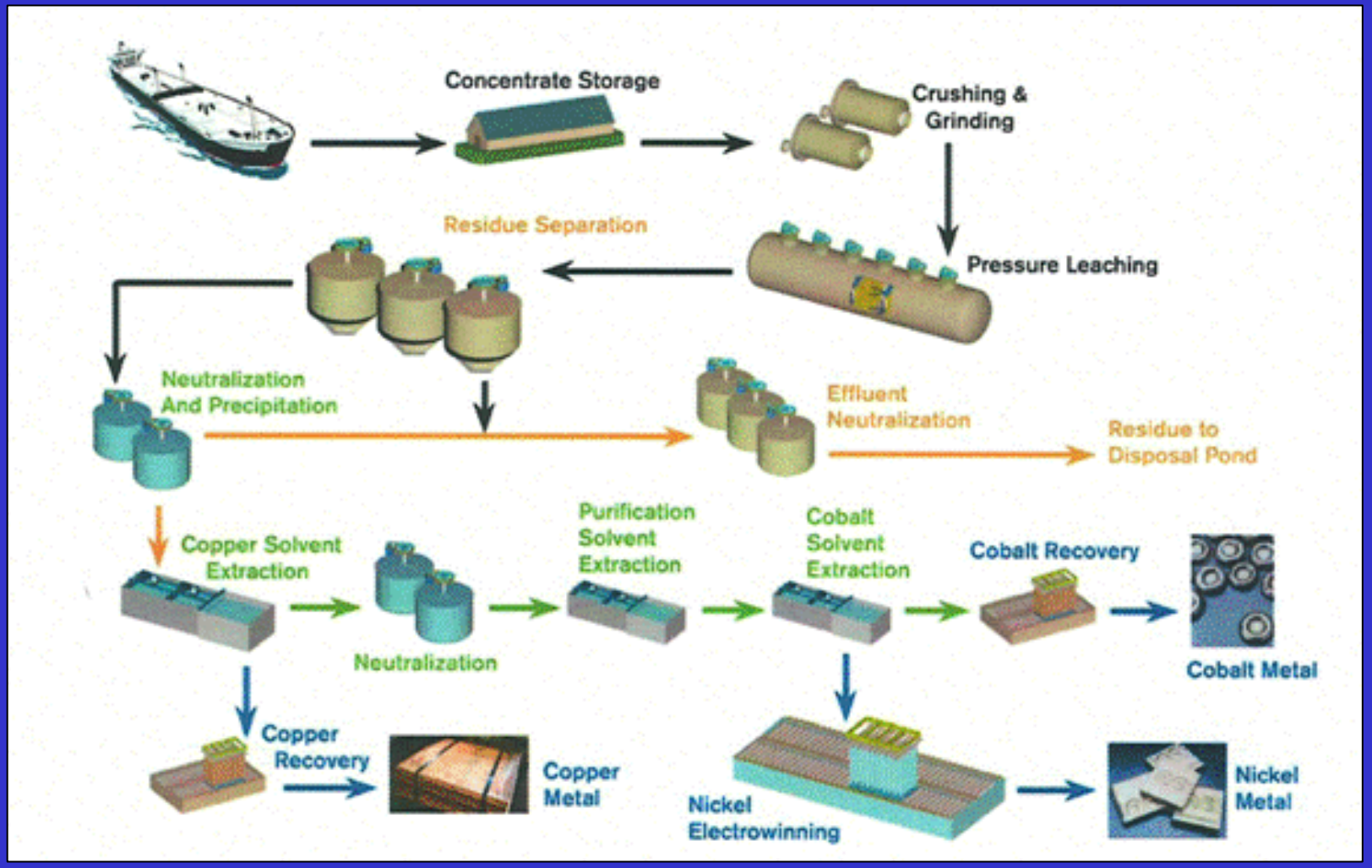
Present trend in hydromet processing appears to be:

- Pressure oxidation for concentrates.
- Heap bio-oxidation for low grade ores.

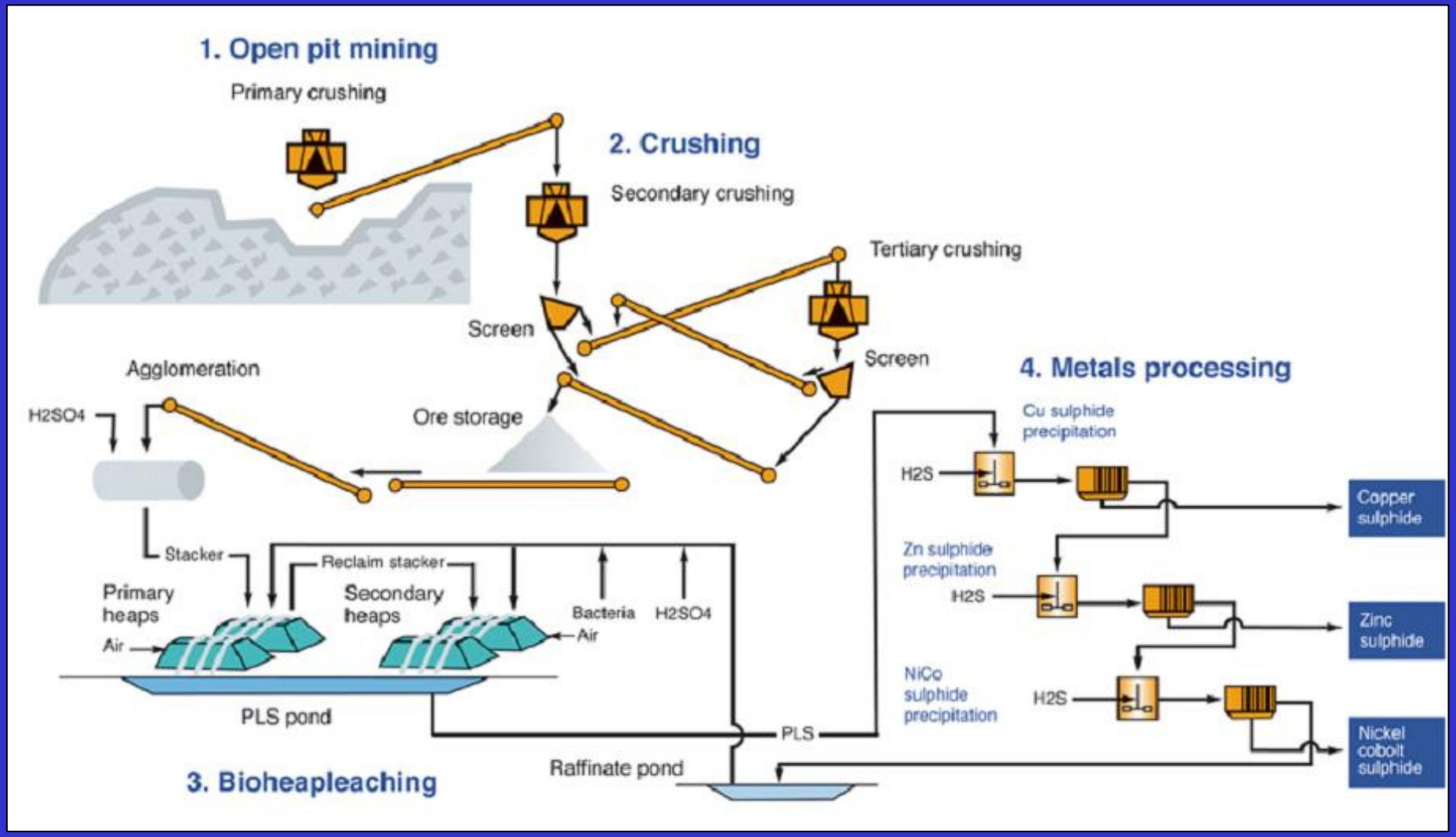
Other possibilities include:

- Tank bioleaching.
- Chloride leaching.

VOISEY'S BAY PRESSURE OXIDATION FLOWSHEET (FROM PUBLISHED PROJECT EIS)



TALVIVAARA HEAP BIOLEACHING FLOWSHEET((PAPER AT ALTA 2007)



FURTHER DEVELOPMENTS FOR SULPHIDE FLOWSHEETS

Additional developments could include:

- Treatment of blended laterite/sulphide feed for generating acid and heat in autoclaves.
- Application of more selective SX extractants, including synergistic mixtures.