The Best Nickel Laterite Heap Leach in the World(?)

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Global Laterite Production

State of the Art
- Pyrometallurgy
- Hydrometallurgy
  - HPAL
  - AL
  - HL

The Perfect HL
- Target resource
- Flow sheets

Conclusions

Q&A
WORLD RESOURCES OF NICKEL

World Resources on Land
- Laterite: 72%
- Sulphide: 28%

Primary Nickel Production
- Laterite: 58%
- Sulphide: 42%
# Global Laterite Production

## Current View on Processing Options for Nickel Laterites

### State of the Art

<table>
<thead>
<tr>
<th>Layer</th>
<th>Approximate Analysis (%)</th>
<th>Extraction Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limonite</td>
<td>Ni 0.8 to 1.5, Co 0.1 to 0.2, Fe &gt;50, MgO 0.5 to 5</td>
<td>Acid Leach</td>
</tr>
<tr>
<td>Transition</td>
<td>Ni 1.5 to 4, Co 26 to 40, Fe 5 to 15</td>
<td>Caron Process</td>
</tr>
<tr>
<td>Saprolite</td>
<td>Ni 1.8 to 3, Co 0.02 to 0.1, Fe 10 to 25, MgO 15 to 35</td>
<td>Smelting</td>
</tr>
</tbody>
</table>

*Graphical representation of laterite profile with symbols for acid leach, Caron process, and smelting.*

*Image source: After Elias 2001*
CURRENT & PLANNED LATERITE PROCESSES

Laterite Operations 2010

Probable Laterite Operations 2020

(source CRU & AVL)
STATE OF THE ART

- Pyrometallurgy
  - Reducing availability of acceptable smelting-grade laterites
  - High Capital costs especially for lower Ni grade (<1.5%) deposits
  - High infrastructure and build costs in many regions with higher grade laterites (eg Koniambo)

Koniambo – New Caledonia (2 x 80 MW DC furnaces)
STATE OF THE ART

HPAL
- High Capital Expenditure
- Ambatovy – last HPAL planned for a while?
STATE OF THE ART

Atmospheric Leach AL

- Forecast Lower capital than HPAL – 2/3 HPAL costs acc Wederburn 2009 Nickel Alta
- Weda Bay – Investment decision 2013 – capital cost > USD 5 Billion
- 2-3 projects in study stage
  - AFE’s Dutwa (Company now in liquidation);
  - ENK’s Acoje (now suspended)

Weda Bay 3D model
(source www.wedabaynickel.com)
STATE OF THE ART

Heap Leach HL

- Lowest capital costs <1/3 HPAL costs acc Wederburn 2009 Nickel Alta
- >2,000,000t commercially HL’d at Murrin Murrin
- > 100,000t demonstrated by various groups incl ENK, CMSA, Vale.
- At least 5 projects in various stages of study >100ktpa
## COMPARISON OF NICKEL PRODUCTION TECHNOLOGIES

<table>
<thead>
<tr>
<th>Process Technology</th>
<th>Typical Capacity tpa of Ni</th>
<th>CapEx US $/pound-Ni capacity</th>
<th>OpEx US $/pound-Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smelting</td>
<td>18,000 to 60,000</td>
<td>23 to 38</td>
<td>2.20 to 4.00</td>
</tr>
<tr>
<td>HPAL / AL</td>
<td>10,000 to 100,000</td>
<td>25 to 60</td>
<td>2.70 to 11.00*</td>
</tr>
<tr>
<td>Heap Leach</td>
<td>10,000 to 80,000</td>
<td>10 to 15</td>
<td>2.20 to 3.00</td>
</tr>
</tbody>
</table>

*High Opex from HPALs like Ambatovy & Goro currently operating at much < nameplate capacity*
WHY HEAP LEACH NICKEL LATERITES

- Nickel demand has been escalating faster than other metals
- Abundant, principally undeveloped but lower-grade nickel laterite sources
- Declining availability of high-grade sulfides
- Allows processing of entire laterite profile (increased resource utilization)
- Heap leaching has been successful on every other mineral attempted
- Low Capital Cost, Low Operating Cost, Low Risk
## Almost All Ni Lats Amenable to HL

<table>
<thead>
<tr>
<th>Country</th>
<th># Deposits Studied</th>
<th># Amenable to Heap Leaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Brazil</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Colombia</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Dominican republic</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Guatemala</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Indonesia</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Philippines</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Poland</td>
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<td>1</td>
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<tr>
<td>Russia</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Turkey</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>USA</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
A Comparison of Laterite Permeability

The graph shows the comparison of permeability against heap height, with permeability values ranging from $1.0 \times 10^{-6}$ to $1.0 \times 10^{-1}$ cm/sec and heap heights ranging from 0 to 10 m. The data points are plotted on a logarithmic scale, indicating the permeability decreases significantly with increasing heap height.
THE PERFECT HEAP LEACH

Target Resource

- >1.0% Nickel
- >30 million tonnes
- High Silica content for
  - good stability
  - good permeability
  - Faster kinetics
  - Lower acid consumption
THE PERFECT HEAP LEACH

- Climatic conditions
  - Low rainfall
  - No typhoons
  - Warm

- Topography
  - Flat terrain
  - Ample Operational Space

- E&S
  - non-sensitive environment
  - Positive social impact
  - Stakeholder support
THE PERFECT HEAP LEACH

- Infrastructure
  - Available choices of water
  - Transport route choices
  - Port choices
CONCLUSIONS

- Lowest Cost Option
- Lowest Risk Option
- Highest Resource Utilisation
- Increased Access to Raw Materials
- Environmental Improvements

Intro - Global Laterite Production
State of the Art
Perfect HL
Conclusions
THANK YOU