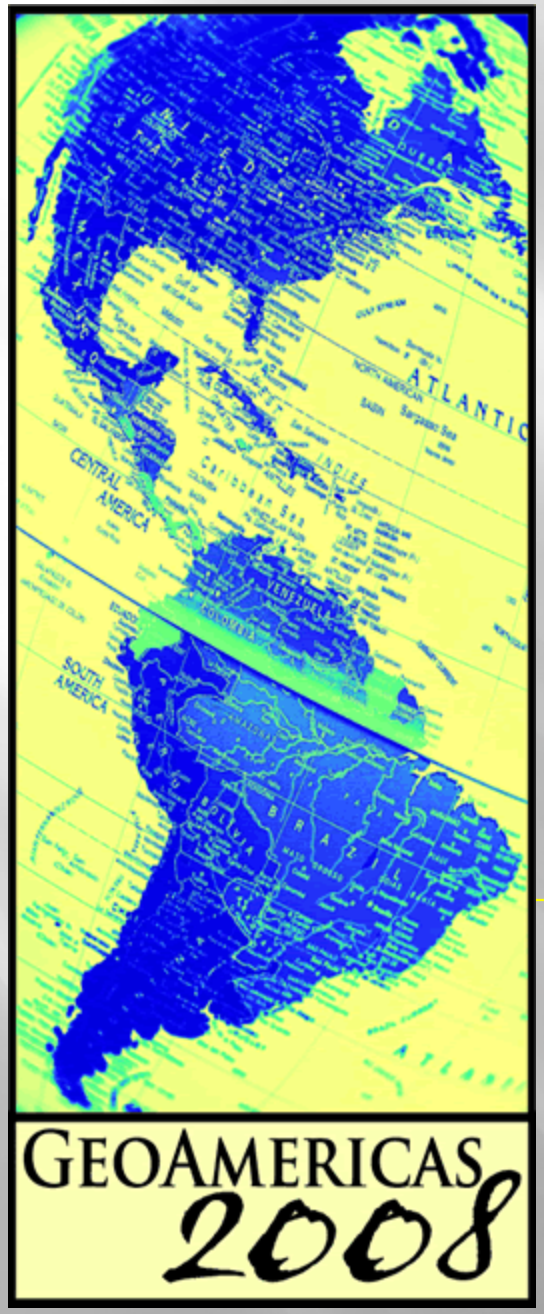

INTRODUCTION TO NICKEL LATERITE HEAP LEACHING

Presented by:
Mark E. Smith

VECTOR
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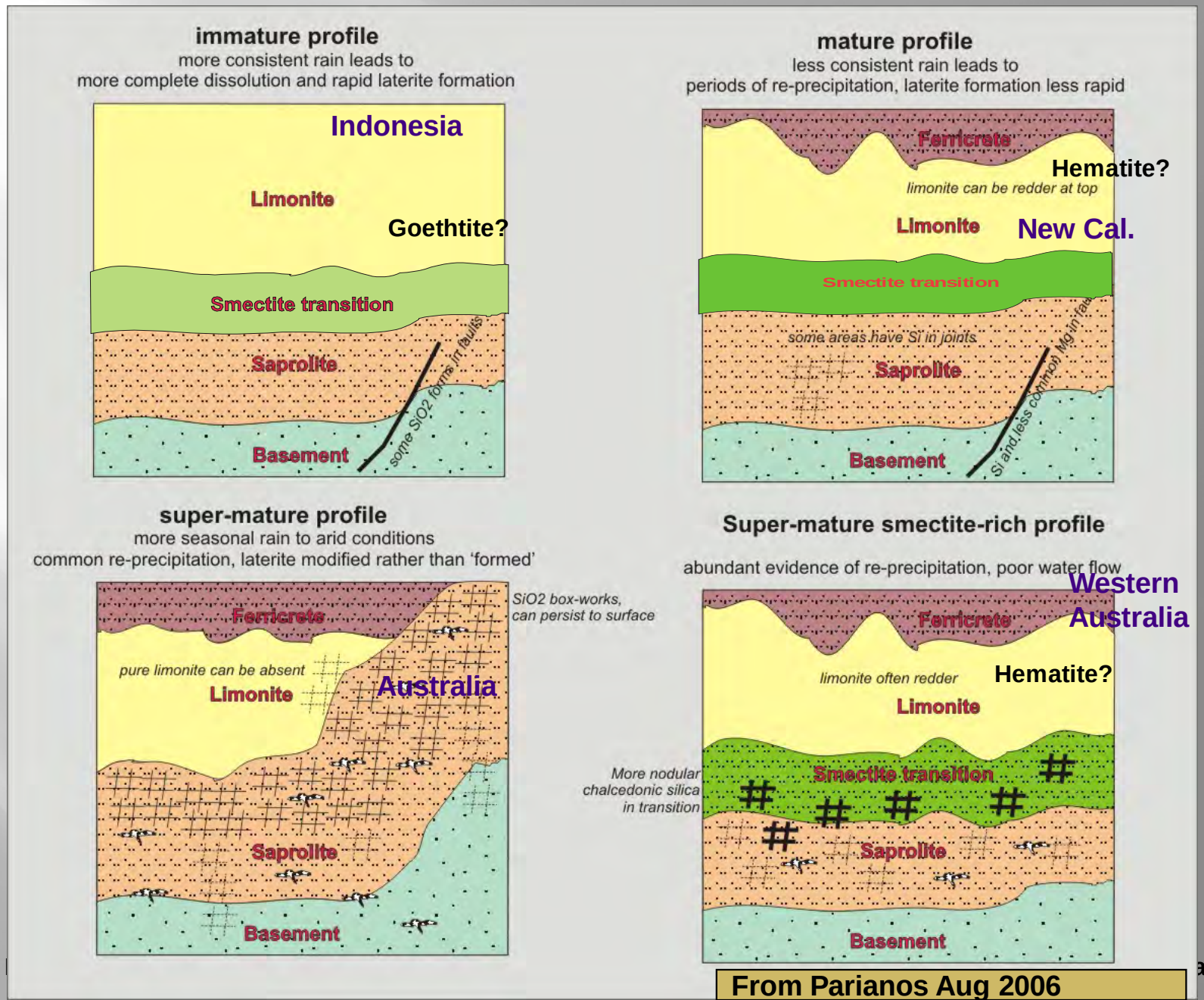
What is a Laterite?

- A "laterite" is a surface formation in tropical (or formerly tropical) areas which is enriched in iron and aluminum.

- Laterites develop by intensive and long lasting weathering of the underlying parent rock ("residual" soil or saprolite).

- Percolating rain water causes dissolution of primary minerals and decrease of easily soluble elements (e.g., sodium, potassium, calcium, magnesium). This gives rise to a residual concentration of more insoluble elements: iron, aluminum, and occasionally nickel & cobalt.

Types of Ni-Co Laterite Profiles



From Parianos Aug 2006

Çaldağ, Western Turkey

Gag Island, Indonesia

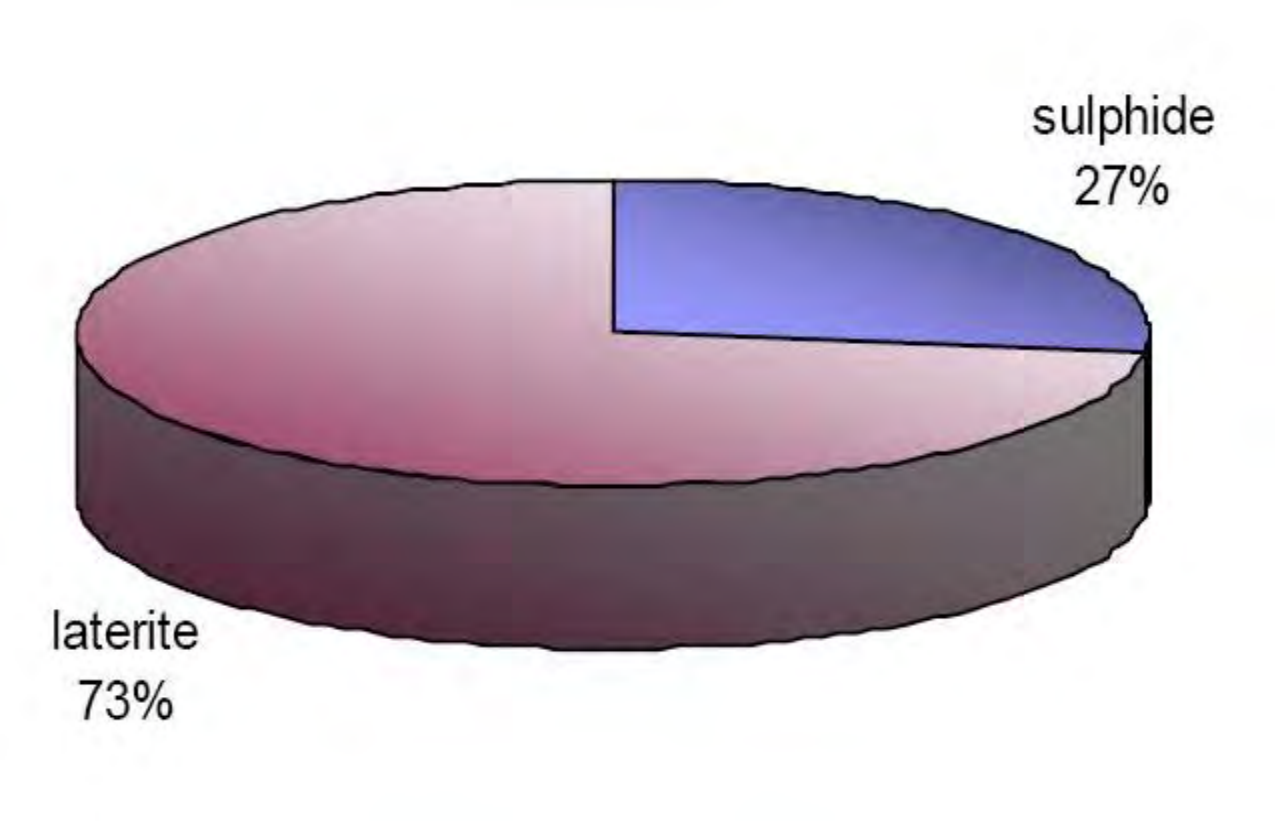
Hallmark, Philippines

Brolga, Australia – Smectite Rich

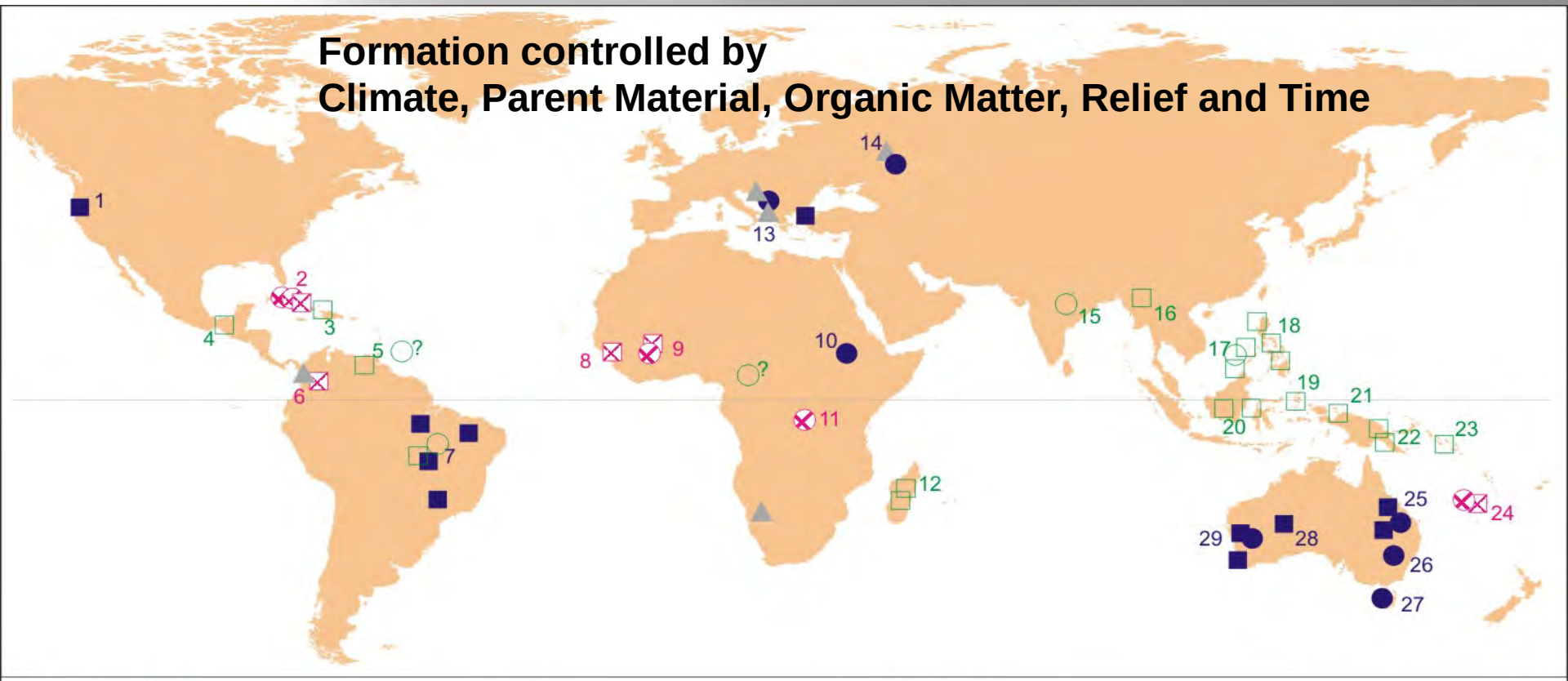
Why Heap Leach Laterite Nickel Ores?

- Nickel demand has been escalating faster than other metals
- Abundant, principally undeveloped nickel sources
- Allows processing of entire laterite profile
- Heap leaching has been successful on every other mineral attempted
- Low Capital, Low Operating, Low Risk

Global Nickel Resources



Distribution of different Ni-Co Laterite Profiles



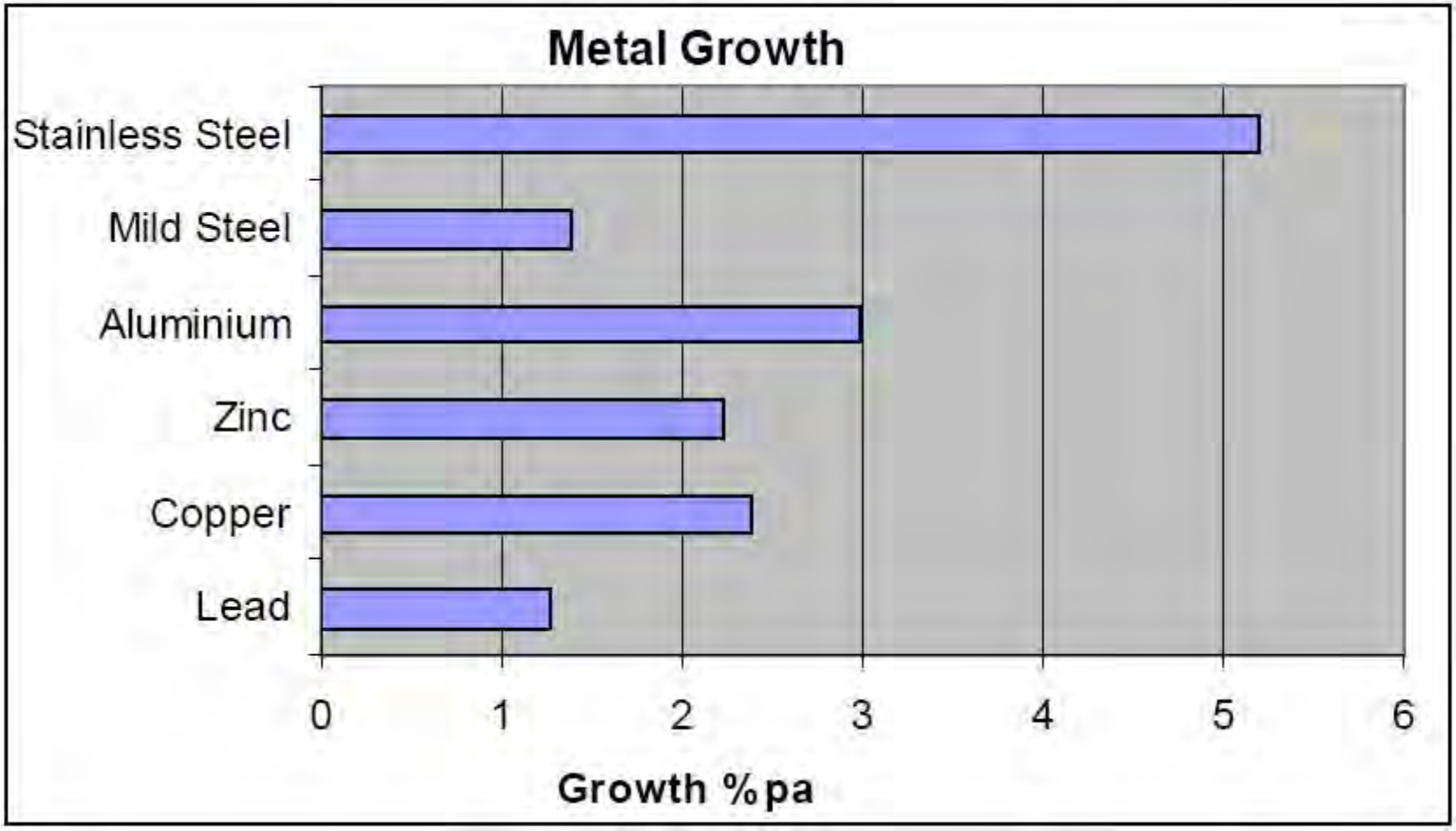
□ immature ⊠ mature ■ supermature ▲ other

○ immature smectite rich ⊗ mature smectite rich ● supermature smectite rich

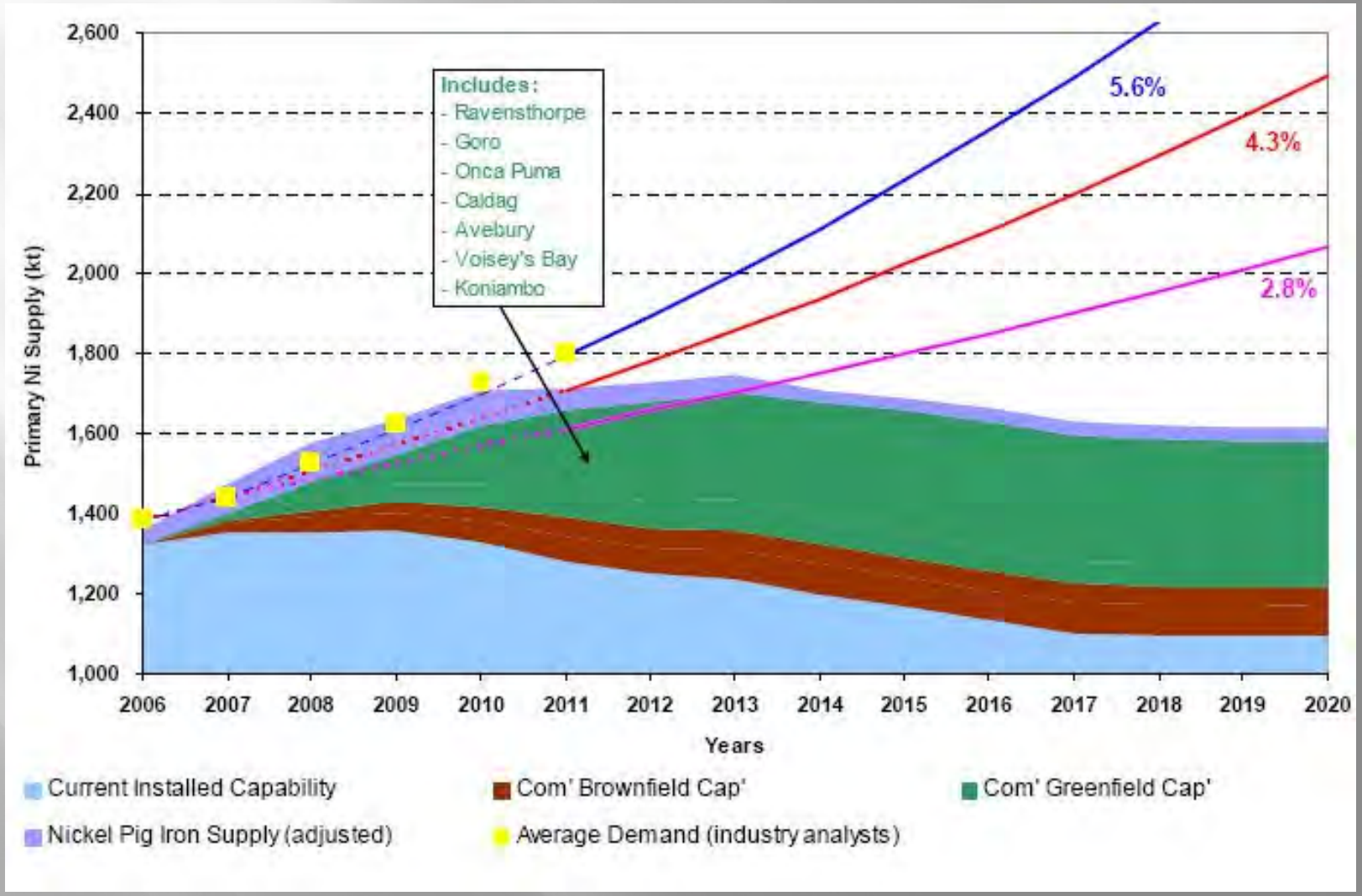
1 - Oregon-northern California; 2 - Central Cuba and SE Cuba; 3 - Dominican Republic; 4 - Guatemala; 5 - Venezuela; 6 - Colombia; 7 - Brazil; 8 - Guinea; 9 - Ivory Coast- Burkina Faso; 10 - Ethiopia; 11 - Burundi; 12 - Madagascar; 13 - Greece - Albania - Yugoslavia - Turkey; 14 - Ukraine - Urals; 15 - India; 16 - Myanmar 17 - Palawan - Sabah 18 - other Philiipines; 19 - Sulawesi - Maluku; 20 - Kalimantan; 21 - West Irian; 22 - Papua New Guinea; 23 - Solomons; 24 - New Caledonia; 25 - Queensland; 26 - New South Wales; 27 - Tasmania; 28 - Central Australia; 29 - Western Australia.

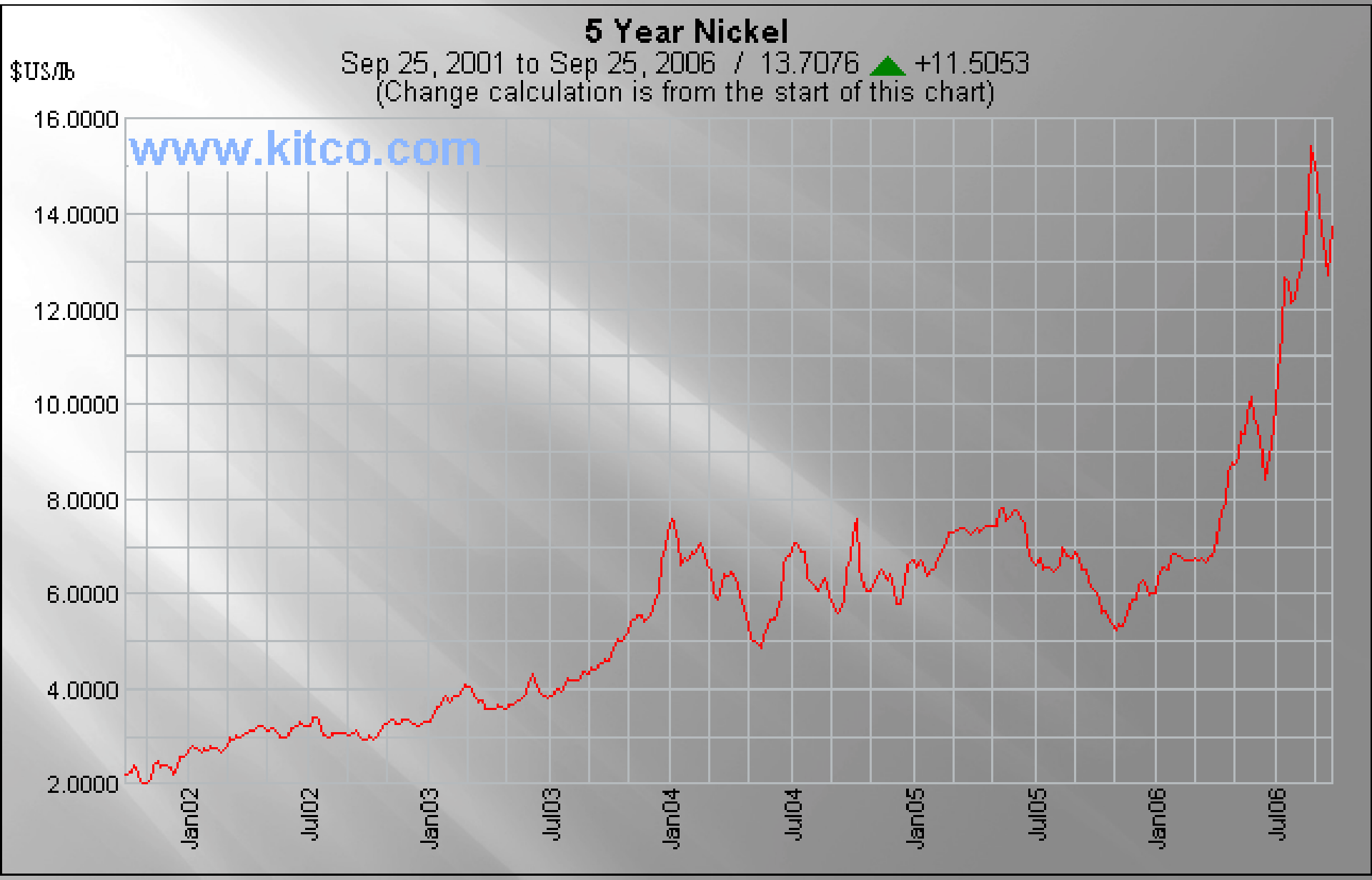
From Parianos Aug 2006, Butt & Elias 1998

Nickel Demand: Outpaces other Metals



Primary Nickel Supply: Committed Projects




5 Year Nickel
Sep 25, 2001 to Sep 25, 2006 / 13.7076 +11.5053
(Change calculation is from the start of this chart)
$US/lb
www.kitco.com
16.0000
14.0000
12.0000
10.0000
8.0000
6.0000
4.0000
2.0000
Jan02
Jul02
Jan03
Jul03
Jan04
Jul04
Jan05
Jul05
Jan06
Jul06

Comparison of Nickel Production Technologies

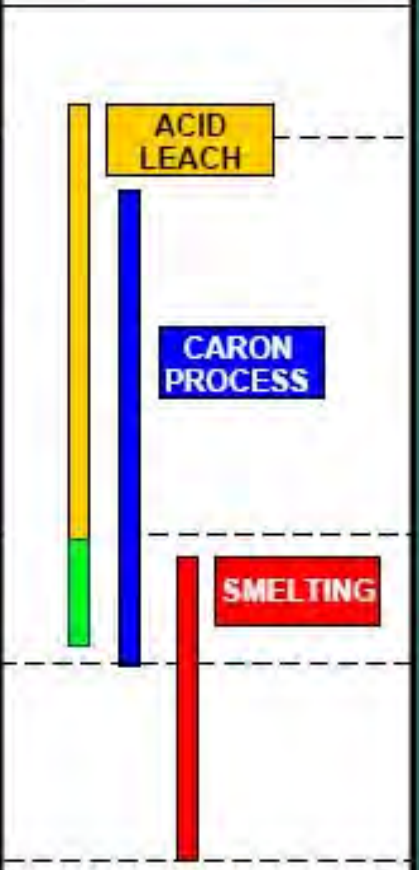
Process Technology	Typical Capacity tpa of Ni	CapEx US $/pound-Ni capacity	OpEx US $/pound-Ni
Smelting	18,000 to 60,000	23 to 38	2.20 to 4.00
HPAL / AL	10,000 to 100,000	19 to 36	2.70 to 5.00
Heap Leach	10,000 to 80,000	10 to 15	2.20 to 3.00

Tropical Laterite Profile

SCHEMATIC LATERITE PROFILE

COMMON NAME	APPROXIMATE ANALYSIS (%)			
	Ni	Co	Fe	MgO
RED LIMONITE	<0.8	<0.1	>50	<0.5
YELLOW LIMONITE	0.8 to 1.5	0.1 to 0.2	40 to 50	0.5 to 5
TRANSITION	1.5 to 2	0.02 to 0.1	25 to 40	5 to 15
SAPROLITE/ GARNIERITE/ SERPENTINE	1.8 to 3		10 to 25	15 to 35
FRESH ROCK	0.3	0.01	5	35 to 45

EXTRACTION PROCESS



Heap leaching is now of interest because:

- Success in gold, silver, copper, nitrates, iodine
- Success in laboratory, bench & pilot testing
- Success in heap leaching low permeability ores
- Abundant deposits of Ni laterites that are unsuitable for smelting, HPAL or AL
- Flexible metallurgy (process wider range of ores)
- Far less complex process than HPAL, AL, etc
- Fraction of the CapEx, lower OpEx v. HPAL
- Ni (and Co) recoveries of ~70% common

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Heap Leaching - Nickel?

- New Technology – R&D started ~15 years ago, but not yet commercialized

- Only started dealing with material handling & containment issues in last 2 years

Nickel Heap Leaching

Several pilot projects are now underway

- Murrin Murrin, Australia (100,000 tonne pilot, on-going)
- Nornico/Metallica, Australia (on-going)
- Cerro Matoso, Colombia (15,000 t pilot, on-going)
- Çaldağ, Turkey (15,000 t pilot, on-going)
- Zambales, Philippines (10,000 t pilot, 2009)
- Piauí, Brazil (2009-2010)

Geosynthetic Issues in Ni HL

- Large Quantity of Geomembranes
- Raincoats, Rain Shields, Floating Covers
- Interlift Liners & Drainage
- Stabilizing Leached Lifts
- Wastes: Ripios, Plant Residue (*tailings*)
- High Temperature Leaching
- Concentrated Acid

Large Quantity of Geosynthetics

- Ni Heap Leaching will require, per project:
  - Base liners of 500,000 to 2,500,000 s.m. for heap
  - Base liners for tailings can equal heap
  - Interlift liners of 500,000 to 1,000,000 s.m. annually
  - Raincoats for Heap of 500,000 to 1,000,000 initially plus partial replacement annually
  - Raincoats for wastes can exceed heap demand
  - Lift Stabilization of 500,000 to 1,000,000 s.m. per year
  - Closure Caps of 1,000,000 to 3,000,000 s.m.
  - Floating Covers on process ponds (in some cases)

Raincoats & Rain Shields

- Tropical Heap Leaching
  - Most Nickel projects are in high rainfall locations
  - Rainfall:
    - Dilutes process solution
    - Increases reagent consumption & interferes with Ni recovery
    - Creates surplus water inventory for treat-and-discharge
    - Damages surface agglomerates, creating impermeable crust

Other Benefits of Raincoats?

Interlift Liners & Drainage

- Technology pioneered by oxide copper leaching – to reduce acid consumption
- In Ni HL, required for acid control & low permeability ores
- Each lift of a conventional or "multi-stack" heap is finished by
  - Stabilizing the top of the leached lift
  - Installing a thin interlift liner & perforated drain pipes – usually concurrently with ore stacking

Stabilizing Leached Lifts

- Multi-stacking of Ni laterites: before stacking the next lift, the prior lift requires stabilization
  - Leached laterites are very wet, highly degraded
  - 25% of solids dissolved in leaching
  - CBR of <<10 common
  - Cannot support stacking equipment without either:
    - Drying time
    - Mechanical or chemical stabilization
  - Stabilization techniques
    - Compact with fly ash or cement (if climate allows)
    - Reinforcing grid + Waste rock


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2006.08.03

Geosynthetic Issues in Ni HL

- Large Quantity of Geomembranes
- Raincoats & Rain Shields
- Interlift Liners & Drainage
- Stabilizing Leached Lifts
- **Wastes: Ripios & Plant Residue (Tailings)**
- High Temperature Leaching
- Concentrated Acid

Nickel Plant Residues

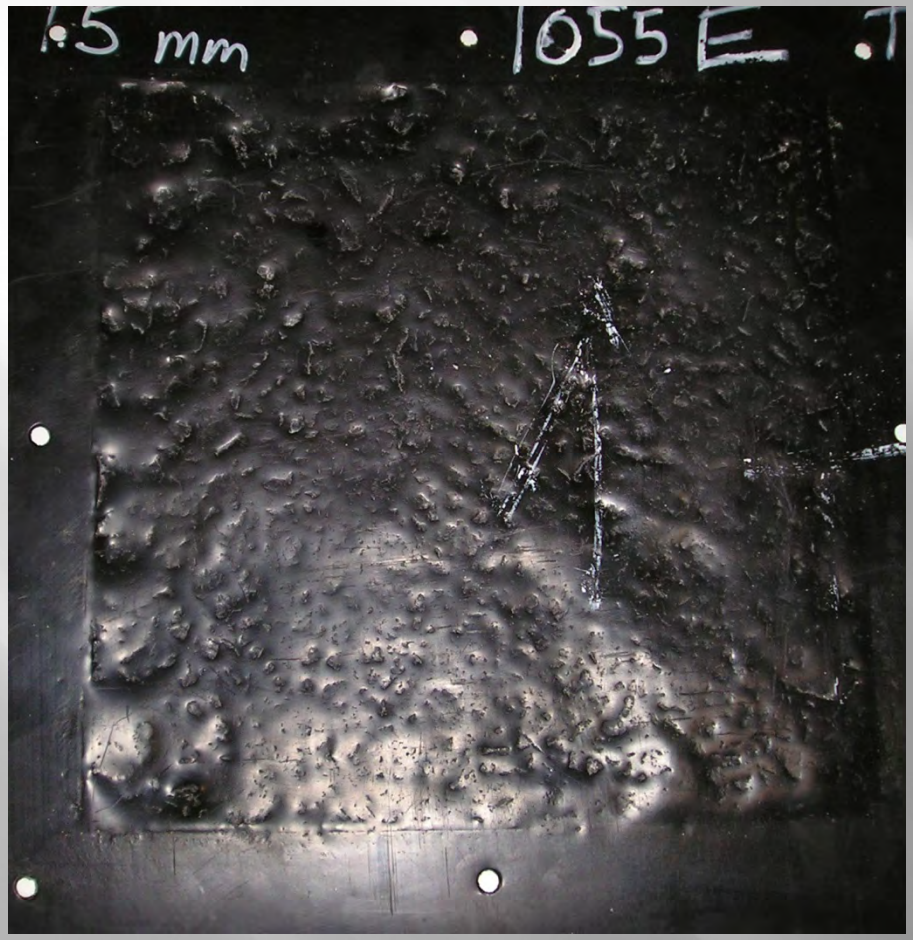
- ~0.4 to 1.1 tonne tailings per tonne leached ore
- Chemical precipitates, not traditional "tailings"
- pH = 2 to 4
- Soluble elements:
  - heavy metals: Mg, Mn, Al, Hg, others
  - sulfates
  - salts
- Physical stability: erosion, slope stability, liquefaction, very difficult to reclaim & stabilize

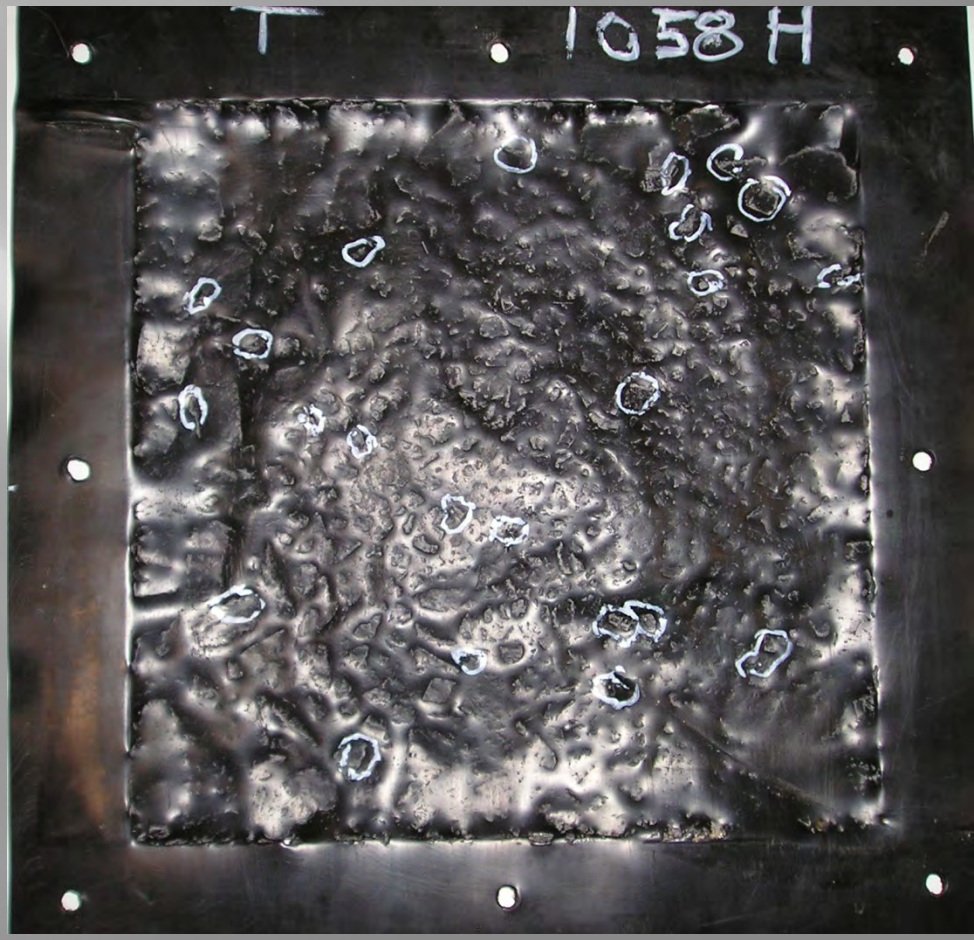
High Temperature Leaching

- Ambient temperatures 40 to 50° c
- Exothermic reaction (acid leaching)
- Internal temperatures of 50 to 75° c expected
- Affects pipes, geomembrane, reinforcing grid

Temperature Affects

1.5mm LLDPE at 120 m ore depth ambient (l) & 60° c (r)





Pipe Deflection v Temperature

Heap Height (m)	Deflection @ 23c (%)	Deflection @ 50c (%)
20	5.0	8.0
60	11.6	17.6
100	16.8	24.9
140	21.4	31.0

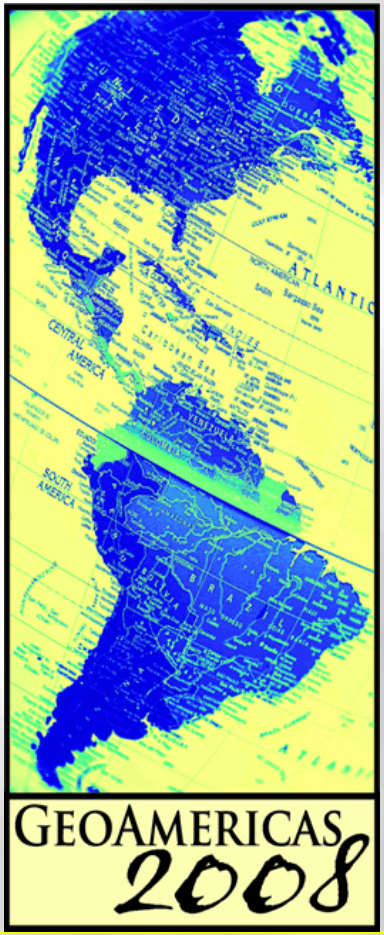
Concentrated Acid

- 2 decades of experience in Copper HL
  - Pre-cure ore with +/-5 to 20 kg acid per tonne ore
  - Leach with 10 to 20 g/l H_2SO_4
  - Operating temp = ambient to ~45° c
- Nickel Heap Leaching
  - Pre-cure with 50 to 150 kg per tonne
  - Leach with +/- 50 to 100 g/l
  - Operating temp = ambient to ~75° c


PVC


PVC

The Final Product: MHP



QUESTIONS?
¿PERGUNTAS?
¿PREGUNTAS?

THANK YOU!
MIL DE GRACIAS!
MUITO OBRIGADO!

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