GEOLOGY, GEOCHEMISTRY AND EXPLORATION OF MINERAL DEPOSITS IN DEEPLY WEATHERED TERRAINS

Estela Nascimento & John Barr
OVERVIEW

• Geology & Geochemistry of Mineralization in Areas with Deep Laterite Weathering - Examples from Brazil.

• Differences between laterite terrains globally and implications for exploration.

• Opportunities for Research.
Ni-Laterite Deposits.

Nb and Phosphate Deposits.

Fe Ore Deposits.
JACARE NI LATERITE DEPOSIT

- From 2002 to 2011: geological reconnaissance, geochemical sampling (stream sediments; soil traverse lines), exploration and infill drilling program for saprolite, ferruginous laterite and siliceous laterite – conceptual study.
- Pre-feasibility stage started in 2012.
JACARE NI LATERITE DEPOSIT

- Main Ore types distribution and regolith profile.

LATERITE CRUST
Overburden

SILICEOUS LATERITE (4 - 20m)
~0.9%Ni and 0.15%Co = 1.10%Ni Eq.
2.24%MgO - 27.57%Fe - 45.48% SiO2
Chalcedony + FeO (OH) Veins

FERRUGINOUS LATERITE (3 - 15m)
~1.10%Ni and 0.18%Co = 1.36%Ni Eq.
2.13%MgO - 46.97%Fe - 13.64% SiO2

FERRUGINOUS LATERITE
High Ni Grades (1 - 8m)
~1.17%Ni and 0.19%Co = 1.44%Ni Eq.

SAPROLITE (5 - 18m)
~1.39%Ni - 14.84%Fe - 1.38 SiO2/MgO
Garnierite + Serpentine Veins

BOULDER ZONE

FRESH ROCK
Dunite or Peridotite
JACARE NI LATERITE DEPOSIT

- Main Ore types distribution and regolith profile.

Ni% distribution in the main ore types:
JACARE NI LATERITE DEPOSIT

- The importance of understanding the structural control influencing the ore thickness.

3D MODEL AND STRUCTURAL CONTROL

- Ore thickness associated to the structure geometry;
- Secondary porosity;
- Supergene garnierite mineral group easily developed.
JACARE NI LATERITE DEPOSIT

- The importance of understanding the ore continuity along the regolith profile.
THREE DIFFERENT ORE TYPES:

PTO: Lower flat elevations;  
(Plain Type Ore) 1.31%Ni - 21%Fe; SiO$_2$/MgO – 1.71  
Weathering profile: 15m.

ETO: Intermediate elevations;  
(East Type Ore) 1.56%Ni - 15%Fe; SiO$_2$/MgO – 1.59  
Weathering profile: 20-25m.

WTO: Higher elevations;  
(West Type Ore) 1.78%Ni - 19%Fe; SiO$_2$/MgO – 3.13  
Associated to fault zones and chalcedony;  
Weathering profile: 50-70m.
BARRO ALTO NI SAPROLITE DEPOSIT

PTO and ETO Weathering Profile - Vertical variation

WTO Weathering Profile - Lateral variation (related to fault zones)
The belt consists of occurrences and Ni saprolite mineralization described at two ultramafic bodies, Morro Sem Bone and Morro do Leme, constituted mainly by serpentinized dunite and peridotite.

The alteration profile on the mineralized areas show an enrichment in silica, iron and cobalt at upper levels, and high grades of Ni and magnesium within argillic and saprolite levels downwards to the fresh rock.
• Regolith Profile from Morro Sem Boné and Morro do Leme ridges.
GUAPORE BELT – REGOLITH MAPPING

- The importance of understanding the erosional stages and the regolith distribution.

On both cases the geochemical surface anomaly won’t reflect the saprolite composition!
COPEBRAS PHOSPHATE DEPOSIT

• Phosphate mine and processing beneficiation plant at Ouvidor and a processing plant in Cubatão.

• Mineralization controls were determined for magmatic, metassomatic and weathering processes (alkaline rocks).

• Role of weathering on the formation of the phosphate deposit is the residual concentration of apatite, mostly in the isalterite level.
COPEBRAS PHOSPHATE DEPOSIT

- Main Lithologies: phoscorites, nelsonites, carbonatites, phlogopitite, bebedourite and picrite.

- Main structure: stockwork.

- Saprolite profile: red aloterite, yellow aloterite, oxide, top micaceous, bottom micaceous, weathered rock and fresh rock.
COPEBRAS PHOSPHATE DEPOSIT

Apatite with secondary apatite edges (oxide ore)

Apatite with quartz edges

Apatite with iron oxide edges

CHAPADÃO MINE – WEATHERING MAP

KINDS OF CEMENTATION

Oxide ore: apatite
Top Micaceous: quartz + goethite
Bottom Micaceous: quartz + monazite + barita
The variation of weathering process making differences in the mineralogy, hardness and texture.
MINAS RIO FE-ORE DEPOSIT

### Average grades:

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Fe (%)</th>
<th>SiO₂ (%)</th>
<th>Al₂O₃ (%)</th>
<th>P (%)</th>
<th>Mn (%)</th>
<th>LOI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineralized Canga</td>
<td>56.97</td>
<td>7.88</td>
<td>3.803</td>
<td>0.168</td>
<td>0.214</td>
<td>6.07</td>
</tr>
<tr>
<td>Soft Hematite</td>
<td>62.49</td>
<td>5.89</td>
<td>2.318</td>
<td>0.040</td>
<td>0.015</td>
<td>1.66</td>
</tr>
<tr>
<td>Friable Itabirite</td>
<td>34.38</td>
<td>47.83</td>
<td>1.687</td>
<td>0.031</td>
<td>0.240</td>
<td>0.81</td>
</tr>
<tr>
<td>Semi-Friable Itabirite</td>
<td>31.29</td>
<td>53.86</td>
<td>0.896</td>
<td>0.019</td>
<td>0.085</td>
<td>0.30</td>
</tr>
<tr>
<td>Itabirite</td>
<td>31.03</td>
<td>54.72</td>
<td>0.562</td>
<td>0.044</td>
<td>0.068</td>
<td>0.17</td>
</tr>
</tbody>
</table>

- The supergene process is responsible for high iron grades on the ridge in all three domains due to silica leaching.
- High iron clusters of along the ridge.
LATERITE TERRAINS IN AUSTRALIA, AFRICA & BRASIL

- Differences in present day climate, palaeoclimatic history, and landscape dynamics and erosional or degradation events create differences in the regolith sequences and geochemical dispersion patterns for different areas. In general, key differences:

  - Recent arid weathering in Australia superimposed on previous humid weathering event, not seen in Africa or the Americas, where the climate changes didn’t affect as radically.

  - Groundwater fluctuations creating leached zone in the saprolite.

  - Red latosols result from the chemical weathering and stone line profiles common in large parts of South America, Africa and India.

Schematic world distribution of stone line profile areas, related to tropical terrains (Modified from Budel, 1982)
IMPLICATIONS FOR EXPLORATION

• Complexity of weathering process within specific areas/deposits needs to be fully understood.
• Along with the forward, implications of sample media, preparation processes, standardized (preferably fusion) analytical methods and careful manufacturing of reference materials (QA/QC) needs to be taken into consideration.
• Soils and ferruginous materials from laterite profiles are valid sample media, but for the right sample media option, it needs to be properly mapped and understood.
• Transported material in depositional areas continues to be a challenge for geochemical exploration.
OPPORTUNITIES FOR RESEARCH

• Real time processing and interpretation of geochemical and mineralogical (IR, XRF & XRD) data.

• Geochronology of weathering and ore formation, and palaeoclimates.

• More case studies of specific deposits, to better understand the complexity of local weathering processes, regolith and landscape dynamics, and geochemical dispersion patterns in different areas – leading to a better characterization of deposit types/models.

• Metallurgical studies, with geochemical and mineralogical characterisation of lateritic and saprolite ore’s in relation to metallurgical processing.

• Training in basic regolith mapping skills and use of regolith maps in planning and interpretation of exploration geochemistry.
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