Nickel in Western Australia
- industry trends and recent developments

Dr P. B. Abeysinghe (Abey)  Dr Tim Griffin*
Senior Geologist          Executive Director
Geological Survey of Western Australia
Nickel production in 2006

<table>
<thead>
<tr>
<th>Project</th>
<th>Operator</th>
<th>Nickel (tonnes)</th>
<th>Mineralization style</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leinster and Mount Keith(^a)</td>
<td>BHP Billiton Ltd</td>
<td>70 068</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Cosmos</td>
<td>Jubilee Mines NL</td>
<td>11 437</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Emily Ann</td>
<td>LionOre Mining International Ltd</td>
<td>9 737</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Long</td>
<td>Independence Group NL</td>
<td>8 291</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Silver Swan – Black Swan</td>
<td>MPI Mines Ltd</td>
<td>7 190</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Sally Malay</td>
<td>Sally Malay Mining Ltd</td>
<td>7 369</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Miitel</td>
<td>Mincor Resources NL</td>
<td>5 779</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Lanfranchi</td>
<td>Sally Malay Mining Ltd and Brilliant Mining Corporation</td>
<td>4 766</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Beta Hunt</td>
<td>Consolidated Minerals Ltd</td>
<td>4 052</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Redross</td>
<td>Mincor Resources NL</td>
<td>3 651</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Mariners</td>
<td>Mincor Resources NL</td>
<td>3 640</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Blair (Area 57 orebody)</td>
<td>Australian Mines Ltd</td>
<td>1 181</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Waterloo</td>
<td>LionOre Mining International Ltd</td>
<td>1 077</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Wannaway</td>
<td>Mincor Resources NL</td>
<td>560</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Radio Hill</td>
<td>Fox Resources Ltd</td>
<td>551</td>
<td>Sulfide</td>
</tr>
<tr>
<td>RAV8</td>
<td>Tectonic Resources NL</td>
<td>77</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Murrin Murrin</td>
<td>Minara Resources Ltd</td>
<td>31 524</td>
<td>Laterite</td>
</tr>
<tr>
<td>Cawse</td>
<td>OJSC MMC Norilsk Nickel</td>
<td>5 686</td>
<td>Laterite</td>
</tr>
<tr>
<td><strong>Total - nickel sulfide</strong></td>
<td></td>
<td><strong>139 426</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total - nickel laterite</strong></td>
<td></td>
<td><strong>37 210</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total - Western Australia</strong></td>
<td></td>
<td><strong>176 636</strong></td>
<td></td>
</tr>
</tbody>
</table>
Nickel production in 2007 (currently available)

<table>
<thead>
<tr>
<th>Project</th>
<th>Operator</th>
<th>March 2007 Qtr</th>
<th>June 2007 Qtr</th>
<th>Sept 2007 Qtr</th>
<th>Dec 2007 Qtr</th>
<th>Total production* Ni (t)</th>
<th>Mineralization style</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel West Operations</td>
<td>BHP Billiton Ltd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sulfide</td>
</tr>
<tr>
<td>Long</td>
<td>Independence Group NL</td>
<td>3,048</td>
<td>2,790</td>
<td>2,838</td>
<td></td>
<td>8,676</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Mittel</td>
<td>Mincor Resources NL</td>
<td>884</td>
<td>1,125</td>
<td>880</td>
<td></td>
<td>2,889</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Wannaway</td>
<td>Mincor Resources NL</td>
<td>116</td>
<td>163</td>
<td>163</td>
<td></td>
<td>442</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Redross</td>
<td>Mincor Resources NL</td>
<td>991</td>
<td>1,077</td>
<td>1,079</td>
<td></td>
<td>3,147</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Mariners</td>
<td>Mincor Resources NL</td>
<td>785</td>
<td>899</td>
<td>739</td>
<td></td>
<td>2,423</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Lanfranchi</td>
<td>Sally Malay Mining Ltd and Brilliant Mining Ltd</td>
<td>1,150</td>
<td>1,278</td>
<td>1,092</td>
<td>1,563</td>
<td>5,083</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Blair (Area 57 orebody)</td>
<td>Australian Mines Ltd</td>
<td>185</td>
<td>200</td>
<td>267</td>
<td>252</td>
<td>904</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Cosmos</td>
<td>Jubilee Mines NL</td>
<td>1,709</td>
<td>1,534</td>
<td>1,799</td>
<td></td>
<td>5,042</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Silver Swan</td>
<td>Norilsk Nickel OJSC MMC</td>
<td>2,424</td>
<td></td>
<td></td>
<td></td>
<td>2,424</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Emily Ann</td>
<td>Norilsk Nickel OJSC MMC</td>
<td>2,587</td>
<td></td>
<td></td>
<td></td>
<td>2,587</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Waterloo</td>
<td>Norilsk Nickel OJSC MMC</td>
<td>726</td>
<td></td>
<td></td>
<td></td>
<td>726</td>
<td>Sulfide</td>
</tr>
<tr>
<td>RAV8</td>
<td>Tectonic Resources NL / Mincor resources NL</td>
<td>5</td>
<td>33</td>
<td>15</td>
<td></td>
<td>53</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Flying Fox</td>
<td>Western Areas NL</td>
<td>966</td>
<td>1,189</td>
<td>758</td>
<td></td>
<td>2,913</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Beta Hunt</td>
<td>Consolidated Minerals Ltd</td>
<td>146</td>
<td>275</td>
<td>566</td>
<td></td>
<td>987</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Radio Hill</td>
<td>Fox Resources Ltd</td>
<td>921</td>
<td>886</td>
<td>1,017</td>
<td>988</td>
<td>3,812</td>
<td>Sulfide</td>
</tr>
<tr>
<td>Sally Malay</td>
<td>Sally Malay Mining Ltd</td>
<td>7,291</td>
<td>7,598</td>
<td>6,676</td>
<td>6,020</td>
<td>27,585</td>
<td>Laterite</td>
</tr>
<tr>
<td>Murrin Murrin</td>
<td>Minara Resources Ltd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cawse</td>
<td>Norilsk Nickel OJSC MMC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total - nickel sulfide</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>42,108</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total - nickel laterite</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>27,585</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total - Western Australia (Ni)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>69,693</strong></td>
<td></td>
</tr>
</tbody>
</table>
Nickel production history W A

- Contained Ni (tonnes)
- Ni sulfide
- Ni laterite
- WA Total (sulfide+laterite)

2007 to 2010 projected
World Nickel production - 2006

- Russia: 20.8%
- Canada: 15.0%
- Australia: 11.5%
- Indonesia: 9.4%
- New Caledonia: 7.3%
- Colombia: 5.9%
- China: 5.1%
- Brazil: 4.8%
- Cuba: 4.8%
- Dominican Republic: 3.0%
- Philippines: 2.7%
- Botswana: 1.8%
- South Africa: 2.7%
- Other countries: 5.1%
- South Africa: 2.7%
- Philippines: 2.7%
- Dominican Republic: 3.0%
- Cuba: 4.8%
- Brazil: 4.8%
- China: 5.1%
- Colombia: 5.9%
- New Caledonia: 7.3%
- Indonesia: 9.4%
- Russia: 20.8%
- Canada: 15.0%
- Australia: 11.5%
- Other countries: 5.1%

- **Kambalda-Kalgoorlie region**
  - **Nickel Sulfide**
    - Miiotel, Wannaway, Redross and Mariners, Mincor Resources NL (Ni, Cu)
    - Silver Swan, LionOre Mining International Ltd (Ni)
    - Beta Hunt, Consolidated Minerals Ltd (Ni, Cu)
    - Blair, Australian Mines Ltd (Ni, Cu)
    - Lanfranchi, Helmut South, Sally Malay Mining Ltd (Ni)
    - Long, Independence Group (Ni)
  
  **Nickel Laterite**
  - Cawse, Norilsk Nickel OJSC MMC (Ni)

- **Northern Eastern Goldfields**
  - Nickel Sulfide: *Cosmos*, Jubilee Mines NL; *Mt Keith and Leinster*, BHPB
  - Nickel Laterite: *Murrin Murrin*, Minara Resources Ltd

- **Lake Johnston region**
  - Nickel Sulfide: *Emily Ann*, LionOre Mining International Ltd
  - Nickel Sulfide: *Maggie Hays*, LionOre Mining (Ni, Cu)

- **Forrestania region**
  - Nickel Sulfide: *Flying Fox*, Western Areas NL

- **Halls Creek region**
  - Nickel Sulfide: *Sally Malay*, Sally Malay Mining Ltd (Ni, Cu, Co)

- **Pilbara region**
  - Nickel Sulfide: *Radio Hill*, Fox Resources Ltd (Ni, Cu, Co)
Nickel projects in WA
- under development or feasibility study (2007)

- **Kambalda region**
  - **Winner**, Sally Malay Mining Ltd

- **Northern Eastern Goldfields**
  - **Prospero** *(Tapinos)* near Cosmos, Jubilee Mines NL
  - **Cliffs and Yakabindi**, BHPB
  - **Honeymoon Well**, LionOre Mining International Ltd

- **Forrestania region**
  - **Diggers Rock**, Western Areas NL

- **Halls Creek region**
  - **Copernicus**, Sally Malay Mining Ltd

- **Pilbara region**
  - **Sherlock Bay**, Sherlock Bay Nickel Corporation Ltd
Recent nickel exploration success in WA (2006/2007)

**Kambalda district** - Junior companies exploring and developing nickel sulfide deposits
- McLeay near Victor South deposit; Independence Group NL
- BSA and Anomaly 11 prospects, Area 57, near Blair; Australian Mines Ltd
- East Alpha near Beta Hunt; Consolidated Minerals Ltd
- Deacon; Sally Malay Mining Ltd

**Kalgoorlie nickel laterite project** - advances by Heron Resources / Vale

**Northern Eastern Goldfields**
- Nickel sulfide at Collurabbie; BHPB Ltd
- Tapinos and Alec Mairs (near Cosmos), Sinclair; Jubilee Mines NL
- Waterloo-Amorac; LionOre International Ltd

**Forrestania** – T5, T Zero nickel sulfides deposits; Western Areas NL

**Musgrave** – Potential Nebo/Babel – 1 Mt contained Ni, 1 Mt Cu; BHPB Ltd

**Geoferret technology** - deep penetrating EM – explores 150 to 500 m
WA exploration expenditure - nickel and base metals
Nickel sulfide and nickel laterite resources in WA

- Laterite (probable+proved+measured+indicated+inferred)
- Sulfide (probable+proved+measured+indicated+inferred)
Ranking of nickel deposits in WA by contained Ni

- **Ni sulfide deposit**
- **Ni laterite deposit**
Nickel laterite mineralization in WA

Major Projects

- Murrin Murrin, Laverton region, NE Goldfields (Yilgarn Craton)
- Ravensthorpe (Yilgarn Craton)
- Kalgoorlie Project, Goongarrie (Yilgarn Craton)
- Wingellina (West Musgraves)

Hosted in regolith as residual and supergene deposits over mafic–ultramafic rocks, including greenstone belts in the Archean Yilgarn Craton
Nickel laterite mines and deposits in WA

LEGEND

- Mine operating, developing or closed
- Deposit

- Phanerozoic rocks
- Proterozoic rocks
- Archaean rocks

Nickel laterite mines and deposits in WA

Yilgarn Craton

Musgrave Complex

WINGELLINA

PERTH

CAWSE

MURRIN MURRIN

RAVENSTHORPE
Ni sulfide mineralization types in WA

Orthomagmatic — komatiites
- Kambalda
- Mount Keith
- Leinster
- Forrestania

Orthomagmatic — mafic–ultramafic intrusions
(similar to Voisey’s Bay in Canada; Bushveld Complex in South Africa; Stillwater Complex in USA)
- Radio Hill (Pilbara Craton)
- Sally Malay (Halls Creek Orogen)
- Nebo/Babel (Musgrave Complex)
Orthomagmatic — mafic-ultramafic rocks in shear zones

- Pilbara Craton: Sherlock Bay and Worthy-Highway deposits
- Pilbara Craton: Sholl and Tabba Tabba Shear Zones
- Halls Creek Orogen, Albany-Fraser Orogen, Paterson Orogen

Orthomagmatic — mafic hosted in large igneous provinces (LIP) (similar to Norilsk –style): deposits not found yet in Western Australia, but potential targets are:

- Edmund Basin, Kimberley and Speewah Basins, Hamersley Basin, Antrim Plateau Volcanics
Warakuna Large Igneous Province

1465 Ma and 1070 Ma dolerite sills of the Western Bangemall Supergroup

1070 Ma sills of the Warakurna large igneous province in the Glenayle area of the eastern Bangemall Supergroup
Nickel sulfide targets in Western Australia

- Orthomagmatic — mafic—ultramafic rocks in major shear zone
- Orthomagmatic — mafic hosted in large igneous provinces
- Orthomagmatic — mafic—ultramafic intrusions
- Orthomagmatic — komatiites

- Phanerozoic rocks
- Proterozoic rocks
- Archean rocks
Summary

- Western Australia - third largest producer of nickel in the world
- Large resource base attracting major players – Vale, BHPB and NORILSK
- Great success stories for small explorers
- Small miners becoming mid-tier companies
- New greenfield provinces
  - Nebo/Babel in Musgrave Complex
  - Collurabbie in Gerry Well greenstone belt, NE Goldfields
- Outlook - additional nickel production from nickel laterite - BHPB’s Ravensthorpe and Vale/Heron’s Kalgoorlie Project
- Enormous large igneous provinces (LIPs) in Kimberley, Capricorn Orogen under explored
Western Australia

- Geological diversity and large size of WA provides opportunities in exploration and mining
- GSWA has on-going programs to collect new data
- Wide ranging opportunities for new explorers
  - join fledgling, mid size or mature projects
  - initiate new projects
  - Geoview
  - Minedex
- Visit websites e.g. [www.intierra.com.au](http://www.intierra.com.au)
- Talk to GSWA or Geoscience Australia
Thankyou

Questions

Geological Survey of Western Australia

www.doir.wa.gov.au/gswa