Copper, lead, and zinc in Western Australia
- an overview

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Senior Geologist  Executive Director
Geological Survey of Western Australia
Base metal prices since 1986

![Base metal prices chart]

- **Copper**
- **Lead**
- **Zinc**
Cu, Pb, Zn production - 2006
World, Australia, and Western Australia

<table>
<thead>
<tr>
<th></th>
<th>Cu (tonnes)</th>
<th>Pb (tonnes)</th>
<th>Zn (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>13 875 000</td>
<td>3 050 000</td>
<td>9 072 000</td>
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<tr>
<td>Australia</td>
<td>862 000</td>
<td>708 000</td>
<td>1 270 000</td>
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<tr>
<td>Western Australia</td>
<td>98 429</td>
<td>74 845</td>
<td>138 842</td>
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</tbody>
</table>

Copper (14 Mt)

Lead (3 Mt)

- China: 31%
- United States: 13%
- Mexico: 4%
- Peru: 10%
- Other countries: 19%

Zinc (9 Mt)

- China: 25%
- Australia: 14%
- Peru: 12%
- United States: 7%
- Canada: 5%
- Mexico: 5%
- Other countries: 25%
Copper-lead-zinc production in WA to 2006

![Graph showing production of copper, lead, and zinc from 1996 to 2006. The graph indicates fluctuations in production levels over the years, with peaks and troughs for each metal.](image)
Copper-Lead-Zinc production in WA, 2006

Copper (Cu)

- **Telfer**, Newcrest Mining Ltd (Au–Cu) 33,583 t Cu
- **Nifty**, Aditya Birla Group (Cu) 25,855 t Cu
- **Whim Creek**, Straits Resources Ltd (Cu) 15,067 t Cu
- **Golden Grove**, Oxiana Ltd (Zn–Cu–Pb) 10,853 t Cu
- **Whundo West**, Fox Resources Ltd (Cu) 5,611 t Cu
- By-product from Ni sulfide mining **Kambalda district, Cosmos, Emily Ann, Radio Hill, Sally Malay**

Lead (Pb)

- **Magellan**, Ivernia (Pb) 63,200 t Pb
- **Golden Grove** Oxiana Ltd (Zn–Cu–Pb) 11,645 t Pb

Zinc (Zn)

- **Golden Grove**, Oxiana Ltd (Zn–Cu–Pb) 138,817 t Zn
Copper-Lead-Zinc production in WA, 2007

Copper (Cu)

- **Telfer**, Newcrest Mining Ltd (Au–Cu) 25,053 t Cu
- **Nifty**, Aditya Birla Group (Cu) 53,550 t Cu
- **Whim Creek**, Straits Resources Ltd (Cu) 15,339 t Cu
- **Golden Grove**, Oxiana Ltd (Zn–Cu–Pb) 15,404 t Cu
- **Jaguar** Jabiru Metals Ltd (Zn-Cu-Ag) 329 t Cu
- **Whundo West**, Fox Resources Ltd (Cu) 253 t Cu
- By-product from Ni sulfide mining **Kambalda district, Cosmos, Emily Ann, Radio Hill, Sally Malay**

Lead (Pb)

- **Magellan**, Ivernia (Pb) 21,400 t Pb
- **Golden Grove** Oxiana Ltd (Zn–Cu–Pb) 8,119 t Pb
- **Pillara** (Pb, Zn) (until June Quarter 2007) 4,800 t Pb

Zinc (Zn)

- **Golden Grove**, Oxiana Ltd (Zn–Cu–Pb) 131,933 t Zn
- **Jaguar**, Jabiru Metals Ltd (Zn-Cu-Ag) 3,464 t Zn
Copper, lead, and zinc production
2006–2007

Vein and hydrothermal mineralization
Stratabound sedimentary — including carbonate-hosted mineralization
Volcanic-hosted massive sulfide mineralization
Orthomagmatic mafic and ultramafic mineralization

Copper, lead, and zinc production 2006–2007

Phanerozoic rocks
Proterozoic rocks
Archaean rocks

KARRATHA
Radio Hill Ni–Cu
Whim Creek Cu
Nifty Cu
Magellan Pb
Cosmos Ni–Cu
Jaguar Zn–Cu
Golden Grove Zn–Cu–Pb
Emily Ann Ni–Cu

Pillara Pb–Zn
Sally Malay Ni–Cu
Telfer Au–Cu
Blair Ni–Cu
Carnilya Hill Ni–Cu
Long Ni–Cu
Kambalda Ni–Cu
Beta Hunt Ni–Cu
Mittel Ni–Cu
Mariners Ni–Cu
Redross Ni–Cu
Wannaway Ni–Cu

Phanerozoic rocks
Proterozoic rocks
Archaean rocks

0 250 500 Km
Commenced production in 2007

**Jaguar (Cu–Zn–Ag) — Jabiru Metals Ltd**
- 8000–10 000 tpa Cu
- 20 000–25 000 tpa Zn
  in concentrate

**Lennard Shelf – Pillara (Zn–Pb) — Teck Cominco Ltd & Xstrata AG**
- 70 000–80 000 tpa Zn
- 15 000 tpa Pb
  in concentrate
Under development or feasibility study (2006/2007)

**Boddington (Au –Cu)** south of Perth — Newmont Australia Ltd / Anglo Gold Ltd

850 000 ozpa Au, 30 000 tpa Cu

**Sulphur Springs (Zn–Cu)** Pilbara — CBH Resources Ltd

*Plans to develop an openpit mine*

50 000 tpa Zn, 20 000 tpa Cu

**Phillips River (Au–Cu)** near Ravensthorpe — Tectonic Resources Ltd

65 000 ozpa Au with Cu byproduct (about 2000 tpa)

**Spinifex Ridge (Mo–Cu)** in Pilbara — Moly Mines Ltd

*Feasibility study completed*

12 000 tpa Cu, 10 800 tpa Mo
Copper, lead, and zinc deposits and prospects
2007

- Volcanic-hosted massive sulfide deposit
- Sediment-hosted deposit (includes MVT deposits)
- Vein and hydrothermal deposit
- Deposit associated with a porphyry system
- Orthomagmatic mafic and ultramafic deposit
- Deposit: mineralization style not defined
- Prospect

Phanerozoic rocks
Proterozoic rocks
Archean rocks

0 250 500 Km
Copper-Lead-Zinc mineralization styles

**Stratabound volcanic hosted massive sulfide deposits**
- Yilgarn Craton (Golden Grove, Jaguar) – Zn, Cu, Pb
- Pilbara Craton (Sulphur Springs, Whundo, Whim Creek) – Zn, Cu; Cu
- Halls Creek Orogen (Koongie Park) – Zn, Pb, Cu

**Stratabound sedimentary carbonate-hosted deposits**
- Lennard Shelf of Canning Basin (Pillara) – Zn, Pb
- Central Canning Basin (Admiral Bay) – Zn, Pb

**Stratabound sedimentary clastic-hosted deposits**
- Edmund Basin (Abra) – Pb, Cu
- Yerrida Basin (Magellan) – Pb
- Yeneena Basin (Nifty, Maroochydore) – Cu
- Albany-Fraser Orogen (Trilogy) – Zn, Pb, Cu

**Vein and hydrothermal hosted deposits**
- Yeneena Basin (Telfer) – Au, Cu
- Yilgarn Craton (Boddington) – Au, Cu

**Felsic porphyry hosted deposits**
- Pilbara Craton (Spinifex Ridge) – Mo, Cu

**Orthomagmatic mafic-ultramafic hosted deposits**
- Yilgarn Craton (Kambalda, Cosmos, Emily Ann) – Ni, Cu
- Pilbara Craton (Radio Hill) – Ni, Cu
- Halls Creek Orogen (Sally Malay) – Ni, Cu
Copper resources in WA

- Total (reserves+resources)
- Reserves
- Inferred
Top ten copper projects in WA - ranked by contained metal (kt)
## Copper projects in WA - ranked by contained copper (above 10 kt)

<table>
<thead>
<tr>
<th>Project</th>
<th>Operator or Owner</th>
<th>Contained Cu (kt)</th>
<th>Tectonic unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nifty</td>
<td>Aditya Birla Group</td>
<td>1081</td>
<td>Paterson Orogen</td>
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<tr>
<td>Telfer</td>
<td>Newcrest Mining Ltd</td>
<td>845</td>
<td>Paterson Orogen</td>
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<tr>
<td>Golden Grove</td>
<td>Oxiana Ltd</td>
<td>595</td>
<td>Yilgarn Craton</td>
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<td>Boddington</td>
<td>Newmont Australia Ltd / Anglo Gold Ltd</td>
<td>565</td>
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<td>Maroochydore</td>
<td>Murchison United NL / Aditya Birla Group</td>
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<td>Paterson Orogen</td>
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<td>Spinifex Ridge</td>
<td>Moly Mines Ltd</td>
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<td>Panorama</td>
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<td>Pilbara Craton</td>
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<td>Whim Creek</td>
<td>Straits Resources Ltd</td>
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<td>Abra Mining Ltd</td>
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<td>Mt Angelo</td>
<td>Platquest Resources Pty Ltd</td>
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<td>Trilogy</td>
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<td>Teutonic Bore</td>
<td>Jabiru Metals Ltd</td>
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<td>Radio Hill</td>
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<td>Anglo Australian Resources NL</td>
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<td>Albany–Fraser Orogen</td>
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<td>Platinum Australia Ltd</td>
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<td>Pardoo - Highway</td>
<td>Westralian Nickel NL</td>
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<td>Heron Resources Ltd</td>
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<td>Phillips River</td>
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<td>Lamboo–Emull</td>
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<td>Halycon Group Ltd / Duketon Consolidated Ltd</td>
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<td>Salt Creek</td>
<td>Straits Resources Ltd</td>
<td>11</td>
<td>Pilbara Craton</td>
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</table>
Lead resources in WA

[Graph showing the contained Pb (kt) from 1996 to 2006 for Total (reserves+resources), Reserves, and Inferred categories.]

- **Total (reserves+resources)**
- **Reserves**
- **Inferred**
Top ten lead projects in WA - ranked by contained metal (kt)

- **ABRA**
- **MAGELLAN**
- **SORBY HILLS**
- **GOLDEN GROVE**
- **PHILLIPS RIVER**
- **PHILLARA - LENNARD SHELF**
- **NAPIER RANGE**
- **SALT CREEK**
- **KOONGIE PARK**
- **PANORAMA**

*Under care and maintenance*

*Operating mine*
### Lead projects in WA - ranked by contained metal (above 10 kt)

<table>
<thead>
<tr>
<th>Project</th>
<th>Operator or Owner</th>
<th>Contained Pb (Kt)</th>
<th>Tectonic unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abra</td>
<td>Abra Mining Ltd</td>
<td>2,032</td>
<td>Edmund Basin</td>
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<tr>
<td>Magellan</td>
<td>Ivernia Inc</td>
<td>1,429</td>
<td>Yerrida Basin</td>
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<td>Sorby Hills</td>
<td>CBH Resources Ltd</td>
<td>853</td>
<td>Bonaparte Basin</td>
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<td>Golden Grove</td>
<td>Oxiana Ltd</td>
<td>140</td>
<td>Yilgarn Craton</td>
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<td>Trilogy</td>
<td>Tectonic Resources NL</td>
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<td>Albany–Fraser Orogen</td>
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<td>Pillara</td>
<td>Teck Cominco Ltd / Xstrata Plc</td>
<td>58</td>
<td>Canning Basin</td>
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<td>Napier Range</td>
<td>Teck Cominco Ltd</td>
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<td>Canning Basin</td>
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<td>Salt Creek</td>
<td>Straits Resources Ltd</td>
<td>35</td>
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<td>Koongie Park</td>
<td>Anglo Australian Resources NL</td>
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<td>Halls Creek Orogen</td>
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<td>Panorama – Sulphur</td>
<td>CBH Resources Ltd / Sipa</td>
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<td>Pilbara Craton</td>
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<td>Springs</td>
<td>Resources Ltd</td>
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<td>Lennons Find</td>
<td>Jabiru Metals Ltd</td>
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<td>Prairie Downs</td>
<td>Prairie Downs Metals Ltd</td>
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<td>Northampton</td>
<td>Woinar B.</td>
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<td>Northampton Complex</td>
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<td>Admiral Bay</td>
<td>Kagara Zinc Ltd</td>
<td>2,760</td>
<td>Canning Basin (very deep deposits &gt;1 km; not fully drilled)</td>
</tr>
</tbody>
</table>

- **Admiral Bay**: Kagara Zinc Ltd

  - **Canning Basin (very deep deposits >1 km; not fully drilled)**
Zinc resources in WA

![Graph of contained Zn (kt) from 1996 to 2006 showing Total (reserves+resources), Reserves, and Inferred data points.](image-url)
Top ten zinc projects in WA - ranked by contained metal (kt)

- GOLDEN GROVE
- PANORAMA-SULPHUR SPRINGS
- LENNARD SHELF-PILLARA
- KOONGIE PARK
- JAGUAR-TEUTONIC BORE
- LAMBOO-EMULL
- SALT CREEK
- ABRA
- STILLY HILLS
- LENNONS FIND

- Operating mine
- Proposed mine
# Zinc projects in WA
- ranked by contained Zn (above 10 kt)

<table>
<thead>
<tr>
<th>Project</th>
<th>Operator or Owner</th>
<th>Contained Zn (Kt)</th>
<th>Tectonic unit</th>
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<tr>
<td>Golden Grove</td>
<td>Oxiana Ltd</td>
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<td>Abra</td>
<td>Abra Mining Ltd</td>
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<td>Bonaparte Basin</td>
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<td>Lennox Find</td>
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<td>Manindi (Freddie Well)</td>
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<td>Pilbara Craton</td>
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Cu, Pb, Zn resources - 2006
World, Australia, and Western Australia

<table>
<thead>
<tr>
<th></th>
<th>Cu (tonnes)</th>
<th>Pb (tonnes)</th>
<th>Zn (tonnes)</th>
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<tbody>
<tr>
<td>World</td>
<td>852 749 000</td>
<td>127 005 000</td>
<td>417 303 000</td>
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<tr>
<td>Australia</td>
<td>39 009 000</td>
<td>25 401 000</td>
<td>72 574 000</td>
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<tr>
<td>Western Australia</td>
<td>5 246 000</td>
<td>4 912 000</td>
<td>3 737 000</td>
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</table>

Copper

Lead

Zinc
COPPER FLATS  (Ord River Resources Ltd)
Rock chips assaying up to 42.5% Cu
(60 m interval averaged 24.49% Cu)

MT ANGELO NORTH  (3D Resources Ltd)
17 m at 2.35% Cu and 2.02% Zn, 13 m at 4.29% Cu
(supergene zone, beneath a gossan)

GOLDEN GROVE  (Oxiana Ltd)
51 m at 6.1% Cu from 1000 m
(beneath undeveloped Xantho deposit)

MAROOCHYDORE  (Aditya Birla Group / Murchison United NL)
7 m at 2.45% Cu from 77 m

BABEL  (BHP Billiton Ltd)
41.6 m at 1.37% Cu from 34 m

YUINMERY  (Empire Resources Ltd)
14 m at 2.63% Cu from 80 m
**ABRA** (Abra Mining Ltd)
92 m at 13.6% Pb from 487 m
50.3 Mt at 4% Pb in Pb domain
9.8 Mt at 0.6% Cu, 0.5 g/t Au in Cu–Au domain

**PRAIRIE DOWNS** (Prairie Downs Metals Ltd)
Discovery of two new lodes near Zed and Main Lodes
22 m at 4.3% Zn, 3.5% Pb, and 19.3 g/t Ag from 37 m

Legend
- Blue: Phanerozoic rocks
- Orange: Proterozoic rocks
- Pink: Archean rocks
Mulgul Project

Abra Deposit - Mineralisation Domains

- Depth to top of mineralisation and depth profile suitable for underground mining
- Mineralisation 250 metres thick
  Selective vs bulk mining options
- Major lead system
  AB16 - 222m @ 7.6% Pb
  including 44m @ 25.3% Pb
  AB24 - 232m @ 5.0% Pb, 0.2% Cu, 0.5% Zn
  AB32 - 68m @ 7.3% Pb, 0.2% Cu
- Copper-gold overlaps the base of the lead domain
  AB12 - 82m @ 0.8% Cu, 0.9g/t Au
- Zinc domains
  AB24 - 72m @ 1.4% Zn, 5.6% Pb
  AB31 - 46m @ 2.2% Zn, 5.3% Pb
- Mineralisation open
Regional Targets

HISTORIC DRILLING INTERCEPTS

Quartzite Well Prospect
QW-7  34m @ 1.1% Zn, 2.0% Pb (from 115m)
QW-8  8m @ 2.4% Zn, 1.3% Pb (from 124m)
QW-10 6m @ 5.9% Pb
8m @ 1.2% Zn, 1.0% Pb (from 106m)
QW-12 29m @ 1.4% Zn (from 192m)

Genie Prospect
GD-1  28m @ 2.4% Pb (from 240m)

Copper Chert Prospect
CCRC003  14m @ 1.1% Cu (from 44m)

Prospective host sequence
>200km of unexplored contact

Image: 1VD of Total Magnetic Intensity

Abra Mining Limited
KOONGIE PARK
(Anglo Australian Resources NL)
41.6 m at 10.89% Zn from 182 m

EMULL
(Northern Star Resources Ltd)
61 m at 1.32% Zn from 38 m

ADimirAL BAY
(Kagara Ltd)
19 m at 6.6% Zn, 1.2% Pb from 1334 m

AYSHIA
(Fox Resources Ltd)
33 m at 11% Zn from 72.7 m

EASTMAN
(Navigator Resources Ltd)
52 m at 1.8% Zn from 125 m

ORCHARD WELL
(De Grey Mining Ltd)
21 m at 4.65% Zn and 2.10% Pb from 301 m

MANINDI
(Metals Australia Ltd)
18.15 m at 10.72% Zn from 122 m

Legend
- Phanerozoic rocks
- Proterozoic rocks
- Archean rocks

PERTH

0 250 500 Km
ADMIRAL BAY
Cross section
(Kagara Ltd)
Mineral occurrences in Kimberley Lamboo Complex

three zones

- Precious metal
- Base metal
- Speciality metal
- Diamond, semi-precious stone
- Energy mineral
- Industrial mineral
- Iron
- Construction material

Sally Malay
Koongie Park
Emull

After Hassan (2000)
Warakurna large igneous provinces

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

After Morris and Pirajno (2005)
Prospective areas for copper, lead, and zinc

Legend

- **Phanerozoic rocks**
- **Proterozoic rocks**
- **Archean rocks**

IN HALLS CREEK OROGEN
- Cu, Zn (Ni, Cu)

IN YILGARN CRATON
- Cu, Zn, Pb) (Ni, Cu) (Au, Cu)

IN CANNING BASIN
- (Zn, Pb)

IN PILBARA CRATON
- (Zn, Cu, Pb) (Cu) Ni, Cu)

IN PROTEROZOIC BASINS
- (Pb) (Pb, Cu) (Pb, Zn) (Cu)

IN PATTERSON OROGEN
- (Au, Cu) (Cu)

IN MUSGRAVE COMPLEX
- (Ni, Cu) (Cu)

IN BONAPARTE BASIN
- (Zn, Pb)

IN YILGARN CRATON
- (Cu, Zn, Pb) (Ni, Cu) (Au, Cu)

IN YILGARN CRATON
- (Cu, Zn, Pb) (Ni, Cu) (Au, Cu)

IN ALBANY FRASER OROGEN
- (Pb, Zn, Cu)
Cu–Pb–Zn–Ag and Ni–Co exploration expenditure in WA (2006-07 dollars)
World demand for Cu-Pb-Zn continues to increase

Increased base metal activities in Western Australia with openings of Whim Creek, Jaguar, Whundo, and Pillara mines

Expansions planned in Nifty

New projects are being considered for mining

Telfer (Au–Cu) back in mining. Boddington (Au–Cu) starts production soon with significant output

Cu–Pb–Zn exploration expenditure in Western Australia is growing
Summary (continued)

- Significant potential for base metal discoveries in Western Australia – size, geological diversity
  - Yilgarn Craton
  - Pilbara Craton
  - Albany–Fraser Orogen
  - King Leopold and Halls Creek Orogens
  - Earaheedy, Edmund Basins (Capricorn Orogen)
  - Canning Basin
  - Musgrave Complex
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 GA
Thankyou

Questions

Geological Survey of Western Australia

www.doir.wa.gov.au/gswa