Supply of minerals to the world for development, financial security and new technologies:
Mr Anthony Senior, Geoscience Australia

Mineral Investment Opportunities in Tasmania:
Dr Andrew McNeill, Mineral Resources Tasmania

Western Australia, the Source of India’s Strategic Minerals:
Mr Jeff Haworth, Department of Mines, Industry Regulation and Safety
Supply of minerals to the world for development, financial security and new technologies

Anthony Senior, Mineral Resources, Advice and Promotion Section
## Australia is a mining nation

Source: Australia’s Identified Mineral Resources 2018

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Resources</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron Ore</td>
<td>1</td>
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<tr>
<td>Mineral Sands</td>
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<td>1</td>
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<tr>
<td>Lead</td>
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<td>2</td>
</tr>
<tr>
<td>Gold</td>
<td>1</td>
<td>2</td>
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<td>Zinc</td>
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<td>Uranium</td>
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<td>3</td>
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<td>Nickel</td>
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<td>Tantalum</td>
<td>1</td>
<td>?</td>
</tr>
<tr>
<td>Bauxite</td>
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<tr>
<td>Cobalt</td>
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<td>Copper</td>
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</table>

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Resources</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver</td>
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<td>6</td>
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<tr>
<td>Tungsten</td>
<td>2</td>
<td>minor</td>
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<tr>
<td>Lithium</td>
<td>3</td>
<td>1</td>
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<tr>
<td>Vanadium</td>
<td>3</td>
<td>0</td>
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<tr>
<td>Manganese</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Black Coal</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Antimony</td>
<td>4</td>
<td>4</td>
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<tr>
<td>Tin</td>
<td>4</td>
<td>7</td>
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<tr>
<td>Diamond</td>
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<td>4</td>
</tr>
<tr>
<td>Rare Earths</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Graphite</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>
New information technology

Data centre (HPC)

Driverless trains

Indo June 2019
Increase in world production of selected battery minerals 2000 vs 2017

- Cobalt: 330% increase
- Lithium: 307% increase
- Manganese: 220% increase
- Graphite: 210% increase
- Vanadium: 186% increase
- Nickel: 168% increase

(Source: from data compiled by Mudd et al., 2019, Table 2.4)
New energy systems

• Under-developed supply chains for new minerals
• New applications driving renewed demand for established minerals
Australia: a wealth of resources
New technology minerals: mines

Australia has the ability to react quickly

Lithium = 8 years to be world’s largest producer

Tianqi: processing plant in Kwinana (WA)

New lithium report by Austrade now available
New technology minerals: by-products

From ores already being mined:
Tailings
Impurities
Processing technologies and demand may make them economic

Australian Critical Minerals Prospectus

India June 2019
Australia is largely unexplored at depth and has significant greenfields potential.

Outcrop and subcrop of limited extent

Extensive regolith cover

Major mines and deposits in bedrock dominated areas

Geological features continue under cover (e.g. aeromagnetics)

More to explore
Australia is largely unexplored at depth and has significant greenfields potential. Outcrop and subcrop of limited extent. Extensive regolith cover. Major mines and deposits in bedrock dominated areas. Geological features continue under cover (e.g., aeromagnetics).

More to explore.

Opportunities in all search spaces:
- Do NEW things in same space
- Do NEW things in NEW space
- Do same things in same space
- Do same things in NEW space

The greyscale background represents aeromagnetic data (0.5 first vertical derivative of magnetic intensity).

J. Vann: AngloAmerican

India June 2019
Pre-competitive geoscience data
Exploring for the Future ($100.5 million 2016–2020)

Current and planned EFTF activities

1. Groundwater survey, East Kimberley
2. Groundwater survey, Northern Stuart Corridor
3. Groundwater survey, Southern Stuart Corridor
4. Groundwater survey, Upper Burdekin
5. Groundwater survey, Galilee Basin
6. Groundwater survey, Surat Basin
7. AusAEM survey, Mt Isa to Tennant Creek
8. Stratigraphic drilling, East Tennant
9. AusARRAY survey, southwest Alice Springs
10. Hydrogeochemistry sampling, Tennant Creek
11. AusLAMP survey, southwest Alice Springs
12. Stratigraphic drilling, South Nicholson
13. Seismic survey, Kidson Sub-basin
14. Solid geology mapping, northern Australia wide
15. Isotopic Atlas of northern Australia
16. Seismic survey, Barkly region

India June 2019
World’s largest Airborne Electromagnetic Survey (AusAEM)

Data released March 2019

Conductivity (<500 m)
Red: High
Blue: Low
National airborne electromagnetic survey: AusAEM

Stage 1 Delivered: 1 million km$^2$

- 60,000 line km PLUS 6,000 line km of company infill

Stage 2 in progress: 1 million km$^2$

- 60,000 line km PLUS 56,000 line km of company infill

India June 2019
Soil geochemistry and ‘Big Data’ analytics
New data acquisition to map the deep
Systems Based: National Mineral Potential Modelling

Dulfer et al., 2014
Systems Based: National Mineral Potential Modelling

Dulfer et al., 2014
Exploring for the Future: Decision-support & data-delivery system

Contains:
- Mineral potential maps
- Decision support tools
- >100 publicly available datasets

Go-live: late 2019

www.ga.gov.au/eftf
Exploring for the Future: Decision-support & data-delivery system
Why Australia?

• Australia Minerals: collaboration of Australia's federal, state and Northern Territory government agencies, working together to offer ground-breaking information to attract investment
  – Scientists and regulators who know their backyards
  – Trade and investment specialists that can connect you with the right people and projects
• Australia has a solid reputation for success in minerals exploration and mining and is pro-actively making it easier to invest
• Australia is committed to efficient and effective, environmentally sound, socially responsible, and economically viable practices for the benefit of communities and investors

www.australiaminerals.gov.au
Take home messages

• Australia is very prospective for new technology minerals
• Australia is a desirable exploration investment location for reliable and ethical supply
• Geoscience Australia is helping to target investment with its world leading national and regional pre-competitive geoscience programs
• New publications now available:
  ➢ Critical Minerals in Australia: A Review of Opportunities and Research Needs
  ➢ Australian Critical Minerals Prospectus
  ➢ Australia’s Critical Minerals Strategy 2019
  ➢ Australia’s Identified Mineral Resources 2018
Thank you
Minerals Investment opportunities in Tasmania

Dr. Andrew McNeill
Mineral Resources Tasmania
18 June 2019
Why Tasmania?

Geology

Current production of, and projects for, a diverse range of commodities:

- **Zn, Pb, Ag**
- **Cu**
- **Au**
- **Sn, W**
- **Ni**
- **Fe (magnetite, hematite)**
- **Mg**
- **Al (bauxite)**
- **Si (silica flour)**
- **Heavy mineral sands**
- **Coal, oil, geothermal**
- **Limestone, dolomite**
Why Tasmania?

Well Developed infrastructure: port, rail and renewable power – ranked 5th of 83 jurisdictions in the 2018 Fraser Institute Survey for infrastructure

Ranked 1st in the 2018 Fraser Institute Survey for availability and skill level of workforce

Established METS and industry support sector

Supportive research environment

Mineral processing sector- three smelters

Minerals industry is Tasmania’s largest exporter (>50%)
Why Tasmania?
Facilitation and support - approvals

*Exploration*
- Single point - all processes, including environmental approvals, managed by Mineral Resources Tasmania (www.mrt.tas.gov.au)

*Mining*
- Mining title – process managed by MRT
- Mining permit – issued by local government with input from State and (possibly) Commonwealth environmental agencies (www.epa.tas.gov.au)

*Investment*
- Single point for advice and information at Office of the Coordinator General (www.cg.tas.gov.au)


Why Tasmania?

Government support

Legislation & policy – streamlining administration

- Mineral Resources Development Act – updated 2017
- Changes with industry consultation
- Strategic Prospectivity Zone Legislation – protection from change of land status

Direct Government Assistance

- Infrastructure development and tax or royalty relief generally for re-start of operations
- Application to independent Tasmanian Development Board (TDB)

Initiatives

- $1.0M Mining Sector Innovation Initiative – environment and geoscience (2017-2021)
- $2.0M co-funded greenfield drilling – EDGI (2018-2022)
- $1.4M Geoscience Initiative – pre-competitive geoscience data (2016-2020)
Why Tasmania?
Low sovereign risk – security of title

Exploration

• Exploration licences initially granted for 5 years – give sole rights to explore and has the exclusive right to apply for a mining lease over part or all of the licence.
• Licences are issued subject to conditions.
• A licensee can apply for extensions of term to the licence and this will be granted if the applicant has made a discovery or has complied with licence conditions.
• Extensions are for 1 or more years and there is no limit to their number.
• A licence can be revoked if the licensee fails to comply with conditions.
• Strategic Prospectivity Zone legislation provides a high level of protection against changes in Crown Land status.
Why Tasmania?

Pre-competitive data

Seamless geology; 55% of state covered at 1:25 000, entire state covered at 1:250 000

Statewide geophysical datasets: airborne magnetics, radiometrics, gravity, MT, physical properties

Geophysically corroborated 3D modelling of prospective regions

Curated data:
>17,000 published maps, tenement charts & mine plans (from 1880)
>14,000 government and company technical reports (from 1823)

Mineral occurrence, drill hole, sample datasets

Ongoing back capture and QA/QC programs

Ranked No.1 for geological databases in 2018 Fraser Institute Survey
Why Tasmania?
Data Delivery

- Free on-line delivery of data
- Can layer relevant datasets to create tailored maps or searches on-line

- TIGER system: MRTs linked databases
  www.mrt.tas.gov.au

- TheLIST: viewer for Tasmanian Government spatial data sets
  www.thelist.tas.gov.au

- AusGIN: Australia-wide data viewer
  www.geoscience.gov.au
Critical and new technology Minerals in Tasmania

Metals most impacted by new technology

- Tin
- Lithium
- Cobalt
- Silver
- Nickel
- Gold
- Tungsten
- Vanadium
- Graphite
- Niobium
- Zinc
- PGM (Pt, Pd)
- Salt

Source: MIT / Rio Tinto
Tungsten

Production since 1880:
• $35,557$ t $\text{WO}_3$
• $>80\%$ from King Island

Defined resources:
• $183,100$ t contained $\text{WO}_3$
• $52\%$ in King Island deposits

$>20\%$ of Australia’s economically demonstrated resources (EDR) are in Tasmania

Opportunities in:
Exploration
Advanced projects
Increased production (Kara)
Tin - The forgotten battery metal

Production since 1880:
- 422,000 t tin
- 50% from Renison mine

Defined resources:
- 528,000 t contained tin
- 33% at Renison mine

> 80% of Australia’s economically demonstrated resources (EDR) are in Tasmania

Opportunities:
Exploration
Advanced Projects
Tailings re-treatment
Tungsten project

King Island Scheelite:

Pre-mining resource of 16.2 mt @ 0.86% WO$_3$ (140 kt contained WO$_3$)

Dolphin resource (2015):
- Reserves (Prob.): 3.1 mt @ 0.73% WO$_3$
- Resources (Indic.): 9.6 mt @ 0.9% WO$_3$

Other resources:
- Bold Head (Ind. + Inf.): 1.65 mt @ 0.96% WO$_3$
- Existing Tailings (Meas.): 2.7 mt @ 0.17% WO$_3$

Exploration ongoing with some good intersections
Tin and Tungsten projects

Venture Minerals Mt Lindsay Project:

Resources (Meas.+Indic.+Inf.): 14 mt @ 0.3% Sn, 0.1% WO$_3$, 0.1% Cu  
28 kt contained Sn, 14 kt WO$_3$)  
• ML granted, environmental permitting in progress  
• Looking at UG mining option

Elementos Cleveland Project:

Tailings resource (Inf.): 3.7 mt @ 0.3% Sn  
Cleveland Mine (Indic.+ Inf.): 7.5 mt @ 0.75% Sn  
Foley Zone(Inf.): 3.98 mt @ 0.3% WO$_3$  
(67 kt Sn, 27 kt Cu, and 11 kt WO$_3$)  
• Recent work focussed on open cut potential
Tin project

ASX-listed Stellar Resources Heemskirk Project

Three Orebodies – Queen Hill, Severn and Montana

Resource: 6.35 mt @ 1.13% Sn (72 kt contained Sn)

PFS completed for U/G operation and optimisation studies in progress

St Dizier - resource of 2.3 mt @ 0.6% Sn (13.7 kt contained Sn) – possible open cut operation
Base metals

• Several styles:
  Polymetallic VHMS (Cu, Pb, Zn, Ag, Au)
  VHMS Copper (Cu, Au)
  Carbonate-hosted (Pb, Zn, Ag)
  Hydrothermal Ni, Co
  Granite-related veins (Pb, Ag, Zn)

• Opportunities in:
  Exploration
  Existing small projects
  Remnant mining
  Tailings & slag re-treatment
Silica Flour

- Used in the manufacture of LCD and OLED screens
- Tasmania currently produces 110-130 kt of saleable silica per annum
- This represents approximately 10-15% of the world supply of high-purity silica flour
- Under-explored
- One advanced project – Maydena Sands
Iron Ore

- Production in 2017-18 was 2.75 mt of magnetite pellets and concentrate (1.79 mt of contained Fe).
- Used or steel production and Coal washing.
- Savage River (Grange Resources) mining and pellet production plant – Pre-mining resource of 724 mt (@ 47% DTR). Ore body is still not closed off.
- Other current and potential production from Low-Sulfur magnetite skarns –small deposits approx. 20 mt) but are clustered.
- Hematite production from weathered magnetite skarns and ultramafics.
Take home messages

• Diverse mineralisation with long-life (>100 years) mining operations

• Mineral processing sector – zinc, aluminium and ferro-manganese smelters

• Products of mining and mineral processing constitute >55 per cent of mercantile exports

• Highly supportive Government with legislation to reduce Sovereign risk

• High quality, freely available geoscience data sets to de-risk exploration

• Battery and new technology minerals including tin, tungsten and silica flour

• Low interest rates and favourable $AU/$US exchange rates and low inflation make an attractive investment destination.

• Many ways in which Indian Groups can become involved, direct and indirect equity interests, off-takes to name several.
Thank you
For more information:
Western Australia
The Source of India’s Strategic Minerals

Jeff Haworth
Executive Director, Geological Survey and Resource Strategy
Department of Mines, Industry Regulation and Safety

June 2019, India
• WA and India
• Resources investment climate
• India’s Strategic minerals and WA source
• Major commodities and investment opportunities
• Discovering WA mineral information
WA and India
## Land and Population

<table>
<thead>
<tr>
<th>WA</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 million square kilometres</td>
<td>3.287 million square kilometres</td>
</tr>
<tr>
<td>2.6 million people</td>
<td>1,330 million people</td>
</tr>
<tr>
<td>About 80% of India land area and</td>
<td>About 0.2% of India population</td>
</tr>
</tbody>
</table>

### Notes
- WA: Western Australia
- India: India
28 years of continuous economic growth – longest sustained growth of any country
WA Merchandise and Resources Export 2018

Western Australian Merchandise Exports 2018
Total: $144.85 billion

- Mineral and petroleum exports: 91%
- Other WA Exports: 9%

Western Australian Mineral and petroleum exports 2018
Total: $131.4 billion

- Gold: 13%
- Iron ore: 47%
- Petroleum: 26%
- Alumina: 7%
- Base metals: 2%
- Nickel: 2%
- Mineral sands: 1%
- Other*: 2%
India is WA 6th export destination in 2018

## Western Australian merchandise exports by country 2018

<table>
<thead>
<tr>
<th>Country/area</th>
<th>Export value (A$ million)</th>
<th>Share percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 China</td>
<td>$68,417</td>
<td>47.2%</td>
</tr>
<tr>
<td>2 Japan</td>
<td>$23,139</td>
<td>16.0%</td>
</tr>
<tr>
<td>3 Korea</td>
<td>$8,613</td>
<td>5.9%</td>
</tr>
<tr>
<td>4 Hong Kong</td>
<td>$6,977</td>
<td>4.8%</td>
</tr>
<tr>
<td>5 Singapore</td>
<td>$6,225</td>
<td>4.3%</td>
</tr>
<tr>
<td>6 India</td>
<td>$3,412</td>
<td>2.4%</td>
</tr>
<tr>
<td>7 Thailand</td>
<td>$2,886</td>
<td>2.0%</td>
</tr>
<tr>
<td>8 Taiwan</td>
<td>$2,874</td>
<td>2.0%</td>
</tr>
<tr>
<td>9 UAE</td>
<td>$2,456</td>
<td>1.7%</td>
</tr>
<tr>
<td>10 Indonesia</td>
<td>$2,260</td>
<td>1.6%</td>
</tr>
<tr>
<td>11 other</td>
<td>$17,613</td>
<td>12.2%</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td><strong>$144,850</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

Total: $144.85 billion
Western Australian Resource Exports to India

Mineral and petroleum commodities accounted for 80 per cent of Western Australia’s merchandise exports to India in 2017-18

India was Western Australia’s 4th largest export market for alumina and bauxite in 2017-18

In 2017-18 WA’s export to India of:
- Gold rose 79% to $732 million
- Petroleum rose 49% to $688 million
- Alumina and bauxite rose 43% to $633 million
Western Australia exports to India 2017-18

2008 – 2018 WA exports to India trend
Geology are similar
India—limited project equity but is active importer of WA resources

- Map shows 7 mineral projects with Indian equity
- Offtake agreements may also apply to these projects and many other projects
- Main WA resource exports to India: gold, petroleum, copper

Value WA Exports to India in 2017-18 ($AUD millions)

- Gold $929.51
- Petroleum $688.00
- Alumina $633.00
- Iron ore $273.00
- Other $744.00
- Base metal $128.00
- Lithium $1.00
- Other $615.00

Total 2017-18: $AUD 3,071 million
Resources Investment Climate
WA Policy Environment Improves

- Commonwealth Mineral Resources Rent Tax and Carbon Tax removed
- Commonwealth Exploration Development Initiative introduced
- Continuation of the State Exploration Incentive Scheme
- Financial Assistance provided for struggling iron ore producers
- Environmental bonds replaced by small annual contribution to the Mine Rehabilitation Fund
- State Government policy of not changing resources policy without extensive consultation
Improving investment climate

Minerals production value and exploration expenditure (adjusted to 2018 dollars)

- WA mining capital investment
- Other
- Salt
- Coal
- Diamond
- Heavy mineral sands
- Nickel
- Petroleum
- Alumina
- Gold
- Iron ore

Production value ($ billions)

Exploration expenditure ($ billions)

Improving investment climate

Mineral exploration expenditure, WA

- Gold
- Iron ore
- Nickel, cobalt
- Base Metals
- Uranium
- Other

Source: ABS
## WA share of Global Production 2018

<table>
<thead>
<tr>
<th>Commodity</th>
<th>WA Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumina</td>
<td>10.3%</td>
</tr>
<tr>
<td>Cobalt</td>
<td>3.5%</td>
</tr>
<tr>
<td>Diamonds</td>
<td>10.7%</td>
</tr>
<tr>
<td>Gold</td>
<td>6.3%</td>
</tr>
<tr>
<td>Ilmenite</td>
<td>10.2%</td>
</tr>
<tr>
<td>Iron ore</td>
<td>32.5%</td>
</tr>
<tr>
<td>LNG</td>
<td>13.9%</td>
</tr>
<tr>
<td>Nickel</td>
<td>6.5%</td>
</tr>
<tr>
<td>Rare Earth Oxides</td>
<td>17.6%</td>
</tr>
<tr>
<td>Rutile</td>
<td>1.6%</td>
</tr>
<tr>
<td>Salt</td>
<td>4.3%</td>
</tr>
<tr>
<td>Zircon</td>
<td>4.4%</td>
</tr>
</tbody>
</table>

Sources: DMIRS, USGS, Office of the Chief Economist, Energy Quest, International Aluminium Institute, GIIGNL Annual Report
## Australia is Top Lithium Producer (2018)

<table>
<thead>
<tr>
<th></th>
<th>Country</th>
<th>Mine production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Australia</td>
<td>51,000 MT</td>
</tr>
<tr>
<td>2</td>
<td>Chile</td>
<td>16,000 MT</td>
</tr>
<tr>
<td>3</td>
<td>China</td>
<td>8,000 MT</td>
</tr>
<tr>
<td>4</td>
<td>Argentina</td>
<td>6,200 MT</td>
</tr>
<tr>
<td>5</td>
<td>Zimbabwe</td>
<td>1,600 MT</td>
</tr>
<tr>
<td>6</td>
<td>Portugal</td>
<td>800 MT</td>
</tr>
<tr>
<td>7</td>
<td>Brazil</td>
<td>600 MT</td>
</tr>
<tr>
<td>8</td>
<td>Namibia</td>
<td>500 MT</td>
</tr>
<tr>
<td>9</td>
<td>United States</td>
<td>unknown</td>
</tr>
</tbody>
</table>

- The latest data from the US Geological Survey shows that the world’s top lithium producers are doing their best to meet rising demand from energy storage and electric vehicles.

- Worldwide lithium supply rose roughly 23 percent from 2017 to 2018.

- Overview of the nine countries that produced the most lithium in 2018. Australia produces more than 50% known world production.

- If the electric vehicle market continues to grow, and if lithium-ion batteries continue their reign as the top batteries for electric vehicles, it’s likely the lithium demand will continue rising in years to come.
India’s Strategic Minerals and Western Australia as a Source
Western Australia has 16 of the 25 strategic minerals that India needs for its industries:

- Strategic minerals
  - Cobalt, fluorite, graphite, gypsum, iron ore, limestone, lithium, molybdenum, platinum, phosphate, rare earths, tantalum, tungsten, vanadium, zinc and zirconium

- Other battery minerals
  - Nickel
Major Commodities and Investment Opportunities
WA is Australia’s only Nickel miner

- Current resources: 34.0 Mt contained Ni
- Production in 2018: 149,642 t
- New discoveries being made
- New mine opening: Nova–Bollinger
- Laterite & sulphide deposits
- Komatiitic and ultramafic intrusive style sulphide deposits as well as lateritic style

WA Ni exports 2018: $AUD 2.615 billion
Cobalt

- Known Co mostly in nickel deposits
- Resources: 2.74 Bt @ 0.05% Co (46 deposits)
- World’s 2\textsuperscript{nd} largest Co reserves (after DRC)
- Produced 4878 t of Co in 2018
- Production ranked 5\textsuperscript{th} globally in 2018
- Production entirely as by-product from nickel mines
- Now a focus on defining standalone cobalt resources
- Also potential in sediment-hosted Cu-Co deposits (several projects in WA)
- One known scandium resource (Kalgoorlie Nickel Project) – 23.9 million tonnes @ 40.3 gpt Sc
• Flake and ‘amorphous’ graphite
• Majority are Archean to Mesoproterozoic graphitic schists or gneisses (metamorphosed carbonaceous sedimentary rocks)
• Defined resources at:
  Donnelly River
  McIntosh
  Munglinup River – Halberts
  Yalbra
Relatively small deposits, but high quality
Manganese

- WA has a +50-year history of producing metallurgical-grade manganese ore
- Current resources are 55.4 Mt (4th largest globally)
- Mostly ‘supergene’ or ‘residual’ on carbonates or iron formation
- One producing Mn project — Woodie Woodie (Consolidated Minerals Ltd)
- Montezuma Mining assessing the Butcherbird–Yanneri Ridge Mn project for battery-grade Mn-dioxide
  - Part of resource at JORC Indicated status and scoping study being conducted
Vanadium – The Underappreciated Battery Mineral?

- 4th largest resources globally (c. 25.4Mt V₂O₅)
- Predominantly in magnetite in mafic intrusions (e.g. Windimurra, Speewah, Barrambie)
- Minor V in weathered pyroxenite (e.g. Medcalf) and in sandstone- and calcrete-hosted U deposits, placers and hydrothermal base metal veins
- Total production in WA since 2000 is 14,100 t V₂O₅
- No mines currently active
- JORC 2012 resources currently 25,895kt V₂O₅
- Speewah: Australia’s largest vanadiferous titanomagnetite deposit (Kimberley)
- Barrambie and Medcalf: Pre-feasibility studies supports production of V₂O₅ and TiO₂ for 12-20 years
Vanadium Resources and Projects in WA

- Total known resources is 6,734 million tonne ore @0.377%
- Contained metal 25,406 tonne

<table>
<thead>
<tr>
<th>Project title</th>
<th>ORE (Mt)</th>
<th>AVE GRADE (%)</th>
<th>CONTAINED METAL/COMMODITY (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrambie Vanadium</td>
<td>47.200</td>
<td>0.624</td>
<td>294.580</td>
</tr>
<tr>
<td>Medcalf - Bremer Range</td>
<td>31.800</td>
<td>0.451</td>
<td>143.300</td>
</tr>
<tr>
<td>Windimurra Vanadium</td>
<td>234.000</td>
<td>0.490</td>
<td>1,145.500</td>
</tr>
<tr>
<td>Balla Balla</td>
<td>455.900</td>
<td>0.655</td>
<td>2,987.500</td>
</tr>
<tr>
<td>Unaly Hill</td>
<td>86.200</td>
<td>0.420</td>
<td>362.040</td>
</tr>
<tr>
<td>Gabanintha Vanadium / Australian Vanadium</td>
<td>683.100</td>
<td>0.576</td>
<td>3,934.350</td>
</tr>
<tr>
<td>Youanmi Vanadium</td>
<td>134.733</td>
<td>0.341</td>
<td>459.265</td>
</tr>
<tr>
<td>Victory Bore</td>
<td>151.000</td>
<td>0.440</td>
<td>664.400</td>
</tr>
<tr>
<td>Canegrass Magnetite</td>
<td>79.000</td>
<td>0.637</td>
<td>503.400</td>
</tr>
<tr>
<td>Speewah Vanadium</td>
<td>4,712.000</td>
<td>0.295</td>
<td>13,922.400</td>
</tr>
<tr>
<td>Gabanintha Vanadium / Technology Metals</td>
<td>119.900</td>
<td>0.826</td>
<td>989.800</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6,734.833</strong></td>
<td><strong>0.377</strong></td>
<td><strong>25,406.535</strong></td>
</tr>
</tbody>
</table>
Alumina and Bauxite production was 15 million tonnes in 2018

- Significant bauxite resources: **3.28 billion tonnes @ 33.9% Al₂O₃** Accounts for all current production for industrial applications

- Also 2.82 billion tonnes of Al₂O₃ reported from:
  - Iron and manganese ores (bulk, not shown)
  - Kaolin deposits (e.g. Cadoux, Meckering)

Minor, but important source for **high-purity alumina**
Rare Earth Elements

Resources mostly carbonatite- or hydrothermal vein-hosted

Current production from:

- **Mt Weld** (carbonatite-hosted)
  - Significant high-grade **dysprosium** (Dy) resource at Duncan
  - Reserves of 1.7 million tonnes TREO, including 6660 tonnes Dy$_2$O$_3$.
- **Browns Range** (hydrothermal vein-hosted)
  - Hydrometallurgical pilot plant to process 150 000 tonnes of ore. Producing mixed rare earth carbonate
- Other significant resources:
  - **Yangibana** - 21.7 million tonnes @ 1.17% TREO) Monazite in heavy mineral sand deposits (but problematic)
Rare Earth Developments Continue

- Both HREE and LREE deposits
- Browns Range HREE project begins mining and construction of pilot plant
- New mineralisation zone discovered at Yangibana

<table>
<thead>
<tr>
<th>Project</th>
<th>Tonnage (Mt)</th>
<th>Average REO (%)</th>
<th>Contained REO (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt Weld (Lynas)</td>
<td>61.0</td>
<td>3.53</td>
<td>2,154,730</td>
</tr>
<tr>
<td>Yangibana (Hastings)</td>
<td>14.3</td>
<td>1.17</td>
<td>167,613</td>
</tr>
<tr>
<td>Brockman (Hastings)</td>
<td>41.4</td>
<td>0.21</td>
<td>87,460</td>
</tr>
<tr>
<td>Browns Range (Northern Minerals)</td>
<td>10.8</td>
<td>0.66</td>
<td>71,107</td>
</tr>
<tr>
<td>Cummins Range (Navigator Resources)</td>
<td>0.7</td>
<td>3.39</td>
<td>23,289</td>
</tr>
</tbody>
</table>
Titanium-Zirconium (and Hafnium)

- All Ti and Zr production is from heavy mineral sands:
  - Perth Basin (e.g. Boonanarring, Cataby, Keysbrook, Yoongarillup, Tutunup South, Cooljarloo)
  - Eucla Basin (e.g. Cyclone)
  - Canning Basin (e.g. Thunderbird)
- Significant Ti resources in layered mafic igneous intrusions (e.g. Speewah, Gabanintha, Buddadoo)
- Zr resources also known at Mt Weld (carbonatite-hosted) and Hastings-Brockman (felsic volcanic-hosted) REE deposits.
- Hastings-Brockman also has a hafnium resource:
  
  36.2 Mt @ 0.032% HfO$_2$ for 11.6 kt HfO$_2$
Iron ore production – Western Australia

Source: DMIRS
Iron Ore Price

Historic Avg. Annual Price

Source: Argus Metals
Western Australia Iron Ore Exports 2018

- Iron ore recorded sales valued at $64 billion in 2018, up slightly (less than one per cent) on last year.
- Marginally higher prices, especially for lower grade (58% Fe) iron ore, offset lower sales volumes (811 million tonnes) from WA producers.
Lithium(-Cesium)

- World’s largest Li supplier (18,700 tonnes, 43% in 2017, USGS)
- 3rd largest reserves globally (USGS 2017):
  1,007.46 million tonnes @ 1.44% Li$_2$O
- All deposits are ‘hard rock’ (pegmatite-hosted)
- World’s largest single such deposit (Greenbushes)
- 7 operating mines:
  Greenbushes, Mt Marion, Mt Cattlin, Wodgina, Altura, Pilgangoora, Bald Hill
- Another advanced project at Earl Grey (Mount Holland)
- All Li currently exported as concentrate or DSO
- Downstream processing imminent in WA
- Also WA’s first cesium (pollucite) mine at Sinclair (Pioneer Dome)
  7,000t @ 16.4% Cs (1,167t Cs)
Western Australia Lithium Production

Spodumene Concentrate
Quantity and Value by Calendar Year

Source: DMIRS
Battery Minerals Price Recovering

Battery Minerals Average Annual Price
Historic Calendar Year

Source: LME via Argus Metals
## Emerging Hub of Lithium Downstream Processing

<table>
<thead>
<tr>
<th>Project</th>
<th>Company</th>
<th>Ore (Mt)</th>
<th>Grade %Li₂O</th>
<th>Contained Li₂O (Mt)</th>
<th>Product and downstream processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenbushes</td>
<td>Talison Lithium (51% Tianqi, 49% Albemarle)</td>
<td>157.1</td>
<td>2.25</td>
<td>3.53</td>
<td>Tianqi constructing LiOH plant at Kwinana. Albemarle announced plans for Li₂CO₃ plant at Kemerton</td>
</tr>
<tr>
<td>Wodgina</td>
<td>50% Mineral Resources, 50% Albemarle</td>
<td>259.2</td>
<td>1.17</td>
<td>3.03</td>
<td>Spodumene concentrate. LiOH plant to be built at Wodgina</td>
</tr>
<tr>
<td>Mt Holland (Earl Grey)</td>
<td>50% Wesfarmers, 50% SQM</td>
<td>189.0</td>
<td>1.50</td>
<td>2.84</td>
<td>Feasibility into WA refinery being examined ~ 30,000 – 40,000 t per year LiOH or Li₂CO₃</td>
</tr>
<tr>
<td>Pilgangoora</td>
<td>Pilbara Minerals</td>
<td>207.9</td>
<td>1.32</td>
<td>2.74</td>
<td>Spodumene concentrate. Downstream Li₂CO₃ production via Korea Lithium JV with POSCO</td>
</tr>
<tr>
<td>Mt Marion</td>
<td>Reed Industrial Minerals (50% Mineral Resources, 50% Jiangxi Ganfeng Lithium Co)</td>
<td>71.4</td>
<td>1.37</td>
<td>0.98</td>
<td>Spodumene concentrate. LiOH plant proposed by Neometals at Kalgoorlie</td>
</tr>
<tr>
<td>Pilgangoora</td>
<td>Altura Mining</td>
<td>50.5</td>
<td>1.02</td>
<td>0.51</td>
<td>Spodumene concentrate</td>
</tr>
<tr>
<td>Kathleen Valley</td>
<td>Liontown Resources</td>
<td>21.2</td>
<td>1.36</td>
<td>0.29</td>
<td>Exploration</td>
</tr>
<tr>
<td>Bald Hill</td>
<td>Alliance Mineral Assets</td>
<td>26.5</td>
<td>0.97</td>
<td>0.26</td>
<td>Spodumene concentrate</td>
</tr>
<tr>
<td>Mt Cattlin</td>
<td>Galaxy Resources</td>
<td>19.4</td>
<td>1.22</td>
<td>0.24</td>
<td>Spodumene concentrate</td>
</tr>
<tr>
<td>Lynas Find</td>
<td>Pilbara Minerals</td>
<td>5.3</td>
<td>1.56</td>
<td>0.08</td>
<td>Exploration</td>
</tr>
<tr>
<td><strong>Currently mining</strong></td>
<td><strong>Total</strong></td>
<td><strong>1007.5</strong></td>
<td><strong>13.72</strong></td>
<td><strong>14.49</strong></td>
<td>Committed or planned downstream processing in WA</td>
</tr>
</tbody>
</table>

Government of Western Australia | Department of Mines, Industry Regulation and Safety | www.dmirs.wa.gov.au
Growing interest in Fertilizer minerals

- The region 150km north of Perth has high potential
- Oxley Potash (Centrex Metals Ltd) — Inferred resource 155Mt @ 8.3% K$_2$O for 12.8Mt K$_2$O
- Dandaragan potash+phosphate (Potash West Ltd)
  - Indicated resources:
    - Potash 910Mt @ 3.8% for 34.7Mt K$_2$O
    - Phosphate 630Mt @ 2.9% for 11.9Mt P$_2$O$_5$
- Close to established roads and ports
Historical potash mining in WA (WWII) was from alunite-rich clay deposits (Lake Chandler, Kanowna).

Currently several advanced projects:

- Sulfate of potash (SOP - $K_2SO_4$) brines from playa lakes (e.g. Beyondie, Lake Disappointment, Lake Wells, Lake Mackay); Total SOP resources: 901 million tonnes

- Greensand glauconite in Perth and Carnarvon Basin sedimentary rocks (e.g. Dinner Hill)

- K-feldspar in Proterozoic ultrapotassic microsyenite (Oxley) and kaolinitic clays (Cadoux)
Number of advanced Tungsten projects

- WA has total WO3 resource of 411 thousand tonnes
- Newcrest’s O’Callaghans deposit (part of Telfer mineral system) is one of the World’s largest W deposits
- Mt Mulgine Project & Big Hill–Cookes Creek projects are both advanced projects (Tungsten Mining NL)
- Both mainly vein-type deposits, though Mt Mulgine has skarn component

<table>
<thead>
<tr>
<th>Project</th>
<th>Owner</th>
<th>Tonnage (Mt)</th>
<th>Grade WO3</th>
<th>Contained WO3 (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilba Tungsten</td>
<td>Tungsten Mining</td>
<td>4.98</td>
<td>0.244</td>
<td>12.14</td>
</tr>
<tr>
<td>Big Hill-Cookes Creek</td>
<td>Tungsten Mining</td>
<td>11.50</td>
<td>0.146</td>
<td>16.81</td>
</tr>
<tr>
<td>O’Callaghans</td>
<td>Newcrest</td>
<td>78.00</td>
<td>0.330</td>
<td>257.10</td>
</tr>
<tr>
<td>Mt Mulgine Tungsten</td>
<td>Tungsten Mining</td>
<td>70.90</td>
<td>0.175</td>
<td>124.29</td>
</tr>
</tbody>
</table>
Titanium-Zircon sands — a large resource

- Major discovery 2011 was Dampier Mineral Sands (223Mt @ av 7% heavy mineral)
- Most production near Perth
- Production 1075 tonnes in 2018
- More than 50% export to China, Malaysia and US

Source: DMIRS
WA Licence Map shows Opportunities

- Many licence holders looking for project JV partners and for company equity funding
- Opportunities at all development stages, including off-take agreements
- Some licences granted in record short periods

Tenement Activity 2017 - 18
WA is World’s most Attractive Mineral Investment Destination
A Strategic Time to Invest
Freely available information

Online and free of charge to view and download at
www.dmp.wa.gov.au

- All geological reports, maps (including GIS & Google Earth files)
- All company exploration reports and data files over 5 years old
- Mineral deposit database including resource/reserves
- Map of exploration and mining leases
- All details of licences and leases (ownership, expiry, conditions, expenditure etc)

Use Online Systems to access all online information
Obtaining Mineral Project Information

Map-based data visualisation and delivery: GeoVIEW.WA
Obtaining Mineral Project Information

Databases:

**MINEDEX** (Mineral occurrences)

**WAMEX** (Statutory mineral exploration reports)
Obtaining Mineral Project Information
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