THE GEOLOGICAL SURVEY OF SOUTH AUSTRALIA AND YOU

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Presentation for Field Geology Club of South Australia. 1 June 2017
This Presentation…

1. Geological Survey of South Australia
2. South Australia Minerals Highlights
3. 2016-17 GSSA Top 10 highlights
Geological Survey of South Australia

South Australia’s premier geoscience agency for over 130 years

Vision

- “Innovative and high quality geoscience for the benefit of South Australians”

Mission

- “To collect, manage and deliver information and knowledge of South Australia’s geology and associated mineral resources prospectivity.”
Geological Survey of South Australia

Major roles:

- Attract and deliver a geoscience framework to assist mineral explorers to make **mineral discoveries in South Australia**

- World-class geoscience towards a better understanding of South Australia’s geological framework and prospectivity

- Delivering geoscience information and advice to Minister, government, mineral explorers and community
Geological Survey of South Australia

46 ongoing staff
1 secondment
2 unfilled positions
Contract staff
Affiliates, collaborators.....
GSSA delivers a foundation for the mineral discoveries needed to ensure the long-term economic prosperity and employment in South Australia.
Mining Scorecard – Value Chain Impact
Mineral & Energy Resources (MER) + Mining Equipment & Technology Services (METS)

MINERAL & ENERGY RESOURCES
Direct Measures 2015-16
- Exploration Expenditure: $185 million
- New Capital Expenditure: $174 million
- Mineral & Petroleum Production: $5.5 billion
- Exports: $4.0 billion
- Royalties: $208 million
- Employment: 10,000 people
- GSP: $3.7 billion

MINING, EQUIPMENT & TECHNOLOGY SERVICES
GSP Modelled 2014-15
- Exploration Expenditure: $0.35 billion
- New Capital Expenditure: $12,510 people
- Mineral & Petroleum Production: $2.8 billion

TOTAL MER & METS IMPACT
- Exploration Expenditure: $185 million
- New Capital Expenditure: $174 million
- Mineral & Petroleum Production: $5.5 billion
- Exports: $4.35 billion
- Royalties: $208 million
- Employment: 22,510 people
- Gross State Product: $6.5 billion

Government of South Australia
Department of the Premier and Cabinet
Major Mines and Projects

South Australia’s major mining operators

- BHPB: Olympic Dam copper-gold-uranium mine
- OZ Minerals: Prominent Hill copper-gold mine
- Arrium: Middleback Ranges iron ore mines
- Heathgate Resources: Beverley and Four Mile operations
- Hillgrove Resources: Kanmantoo Copper mine

New/recommissioned* Mines

- Havilah Resources: Portia gold mine
- WPG Resources: Challenger gold mine*
- Exco Resources: White Dam gold mine
- WPG Resources: Tarcoola gold mine
- Cu-River: Cairn Hill magnetite iron ore mine*
South Australia’s Developing Projects

South Australia has approximately 30 advanced mineral projects moving within the mineral resource development sequence that may lead to further expansion of the sector in the short to medium term.

- OZ Minerals: Carrapateena copper project
- Iron Road: Central Eyre Iron project

There are currently 744 mineral leases granted in South Australia.

This is in addition to the 600 extractive mineral leases and 698 exploration licences registered on the Mining Register.
Central Eyre Iron - Australia's next major iron ore mining and infrastructure project

21 year ML granted 3 May 2107 for the proposed magnetite mining and minerals processing operation near Warramboo on the central Eyre Peninsula.
Carrapateena – Australia’s largest new mine

- NPV $770 million and IRR ~ 20%*
- Short payback period with 20+ year mine life
- LOM C1 costs US$0.82c/lb copper
- Among the lowest sovereign risk of any new mine globally
- Decline development underway with over 850 metres progressed
- Next major investment decision in Q2 2017

OZ Minerals can build Carrapateena from existing cash flows whilst retaining shareholder returns

* Based on post-tax basis at copper/gold AUS$ consensus pricing. See Pre Feasibility Study ASX announcement, 7 November 2016, titled “Confidence in Carrapateena project grows” for further details.
The DISCOVERY challenge…
The covered minerals search space across 80% of South Australia!
Geoscience initiatives in support of improving mineral exploration in Australia

NATIONAL MINERAL EXPLORATION STRATEGY

MISSION: Uncovering Australia's mineral potential to benefit the economy

AIMS:
- To improve mineral exploration outcomes
- To enhance exploration governance
- To provide a clearer image of Australia's mineral potential

OBJECTIVES:
- To increase exploration expenditure
- To improve the rate of discovery
- To enhance the image of Australia as a mineral exploration destination

The Government of South Australia and the Department of the Premier and Cabinet, through Uncover Minerals, are leading this initiative to unlock Australia's mineral potential and support the economic growth of the nation.
2016 GSSA Top 10 Highlights

1. Mineral System Drilling program (MSDP) / Gawler Ranges Targeted Geoscience
2. PACE Copper Western Gawler Craton / Coompana targeted geoscience program
3. PACE Copper Gawler Airborne Geophysical program
4. Magnetotellurics: Lithospheric resistivity / conductivity (PACE Copper)
5. New Releases: Maps and SA 3D Geophysical model; publications, data, conferences
6. Response to Nuclear Fuel Cycle Royal Commission
7. South Australian Drill Core Reference Library operational
8. National Exploration Undercover School (NExUS)
9. Collaborations and Partnerships
10. GSSA restructure
1. Mineral System Drilling program / Gawler Ranges Targeted Geoscience
SA Mineral Systems Drilling Program

Further understanding of 1590 Ma mineral systems

- $2.5m + $0.65m + in-kind = $8m
- 14 cored holes, 7868m, ~ 8 months
- Collaborative partners: GSSA with Deep Exploration Technologies CRC, Kingston Resources, Minotaur Exploration, service sector
A 1590 Ma crustal section for South Australia?
Deep Exploration Technologies - CRC

Has shown the successful collaboration between mining companies, METS suppliers, government Geological Surveys and research organisations

- Lab-at-rig technologies: delivering real-time data collection
- Coiled Tubing Drill rig: cheaper, faster drilling.

In South Australia
- Based at Brukunga
- 2015 Mineral systems Drilling Program Gawler Craton; Minotaur Exploration and Kingston Resources
- Successful trials completed Gawler Craton April 2017
- Next trials now underway in western Victoria (Stavely)
DET CRC – cheaper, faster drilling, rapid data collection

Challenge - collecting sufficient data in covered terranes

MSDP – support the pull through of new technology

Lab-at-Rig  Wireless Sub  AutoSonde
DET CRC – Coiled tubing drill rig

- 1st comprehensive field trial of RoXplorer®
- Initial trials at Brukunga
- Field test utilised drill pad of cored hole MSDP02
Mineral Systems Drilling Program

Want to know more?

• MSDP webpage – 10 part video series

• Core now available for inspection!

• DET CRC Website

minerals.statedevelopment.sa.gov.au/msdp
Epithermal Mineral Systems – Porphyry Copper Potential

Work in progress:

• PACE supported drilling by Investigator Resources testing porphyry Cu targets near Nankivel Hill, northern Eyre Peninsula

• Expanded search area for epithermal Au and Ag mineralisation

• Alteration style permissive of porphyry-style Cu/Au mineralisation at depth

Quartz-alunite breccia Nankivel Hill
Epithermal Mineral Systems – Porphyry Copper Potential

Advanced argillic alteration near the Paris Silver deposit

$^{40}\text{Ar}/^{39}\text{Ar}$ dating program: alunite at Nankivel Hill

• Minimum age of alunite age c.1590 Ma
• Likely Hiltaba/GRV age alteration
• Report Book 2017 / 11

SEM image – alunite, quartz, rutile
2. PACE Copper Western Gawler Craton / Coompana targeted geoscience program

- Previously not under tenement
- Covered Proterozoic basement under the Nullarbor
- Precompetitive data initiative to support discovery, geoscience
- Now attracted uptake of 7 new tenements by OzMinerals (Mithril JV) through competitive application process (ERA)

New Coompana airborne magnetics
PACE Copper – Coompana Province: Lithosphere

- Deep crustal seismic and MT
- Reveal lithospheric architecture

Report Book 2015/00029
PACE Copper – Coompana Geophysics

- 250,000 line kilometres; airborne magnetic and radiometric survey
- >13,000 new gravity observations

Before

After
PACE COPPER – Coompana Drilling Project

- $3M collaborative program between GSSA and GA
- Up to 18 drillholes
- Targeting different geophysical domains
- Boart Longyear selected as drilling service provider
- Drilling commenced 9th April 2017 for ~ 5 month program
PACE COPPER – Coompana Drilling Project

First look at core from CDP001

- First core sample from the SA Coompana Province in 30 years
- Basement at 346m
- Currently 164m HQ3 core
- Mixture of foliated dioritic gneiss and undeformed granitoids
3. PACE Copper Gawler Airborne Geophysical program
PACE Copper – Gawler Craton Geophysical Survey

As at 5/5/17
Region 2A 80% complete
Region 2B 68% complete
Region 3A 53% complete
Region 3B 54% complete
★ Region 4A 87% complete
Region 4B 75% complete
Gawler Craton
Geophysical Survey
Region 4A Preliminary
4. Magnetotellurics (PACE Copper)

- Measures time-varying electric (E) and magnetic (B) fields of the Earth
- Maps the **electrical resistivity** of the earth
- Sensitive to largely minor conducting phases
- Ability to map from a few metres to hundreds of kilometres
- Single station data typically collected over about 3 weeks
AusLAMP Magnetotelluric (MT) Project – mapping ancient fluid pathways

Motivation:

• Mineral occurrences are often associated with ancient magmatic and fluid flux in the crust governed by the lithospheric architecture
• AusLAMP MT can map those fertile areas using electromagnetic signals
• Early results indicate link between deep crustal boundaries and mineral occurrences across the Eastern Gawler
AusLAMP MT – core project of PACE Copper

- $1.3M PACE funding since 2014 to acquire next-generation geophysics AusLAMP grid across SA
- Attraction of ~$0.8M external funding from University of Adelaide, Geoscience Australia and NCRIS to complete SA AusLAMP coverage by Q1 2018
- 317 long-period MT sites acquired to date (~80% of SA)
- 3D resistivity models of the crust and mantle for Gawler, Flinders, Curnamona and Western margins
- Currently acquisition in NE SA funded by $520k PACE Copper
PACE Copper Olympic Domain in-fill MT scale reduction for geoscience discovery

- “Zooming in” on fluid and magmatic pathways into the upper crust informed by AusLAMP
- PACE Copper Olympic Domain in-fill MT survey in planning to scale up into the upper crust
- Mapping mineral systems footprint for fluid pathways in 3D
- ~320 Broadband MT sites with site spacing between 1.5 km to 10 km across ~ 100 km x 100 km
- Data collection Q3 2017
5. New Releases: Maps and SA 3D Geophysical model; publications, data, conferences
Recent GSSA Publications

Stratigraphy and Geochemistry of the 1745-1700 Ma Peter Pan Supersuite

Fluid inclusion data from 23-mile Quartz Quarry and Parkinson Dam, northern Eyre Peninsula

A Mesoproterozoic advanced argillic alteration system: $^{40}\text{Ar}/^{39}\text{Ar}$ thermochronology from Nankivel Hill, Gawler Craton

Gridding of South Australian Ground Gravity Data, using the Supervised Variable Density Method

Geology of the Six Mile Hill 1:75 000 Special Edition Map Sheet.

Mineral Systems Drilling Program Rock Shack - outcrop sample collection for the MSDP southern Gawler Ranges margins

Investigating the potential for bedrock aquifers in the APY Lands.

Magmatic processes of the St Peter Suite, Gawler Craton: New U-Pb geochronological data and field observations.

Modbury North Catena Study in metropolitan Adelaide: geology, regolith, soils and gilgai; their mineralogy, geochemistry, landscape evolution, geomechanics, and implications for civil engineering.

South Australian Spectral Database.

U-Pb geochronological data from drill holes Nundroo 3 DDH and Nundroo 2 DDH, Fowler Domain, western Gawler Craton.

Hydrogeochemistry of South Australia. Data release: Accompanying Notes.
Recent GSSA Publications Maps and Data – available via SARIG

Surface Geology of Six Mile Hill – Mineral Systems Drilling Program Special Map Series, 1:75 000 scale.
   - Krapf, C.B.E.; Werner, M.X.; Pawley, M.J.; McAvaney, S.O. (compilers)

Kalabity 1:100k geological map (Digital version)
   - Preiss, W

Interpreted Proterozoic solid geology of Six Mile Hill – Mineral Systems Drilling Program Special Map Series, 1:75 000 scale.
   - Pawley, M.J.; Werner, M.X.; Krapf, C.B.E.; McAvaney, S.O. (compilers)

Mineral Resource Potential Maps, Upper Spencer Gulf Region
CORRABERRA, PORT AUGUSTA, QUORN, URO, WILLOCHRA and WILKATANA 1:50.000 map sheets

HyLogger/3D Model - South Australian Spectral Database.

Depth To Crystalline Basement Data Package 2016.
   - Cowley, W.M.; Katona, L.F.; Gouthas, G.; Hough, L.P.; Menpes, S.A.
New State Geophysical Grids

(Laz Katona et al – see Discovery Day posters)
The new ALCURRA 100k surface geology map

- 994 field observations
- 54 full suite geochemical analyses
- 30 regolith material and landform units
- 57 rock samples
- 2 new type localities
- 175 full suite biogeochemical analyses
- 7 whole rock Sm-Nd & Hf in Zircon data
- 2 new strat units
- 11 SHRIMP geochronology dates
- 26 thin section petrology
6. Response to Nuclear Fuel Cycle Royal Commission
Plans underway for:

- “…next-generation SARIG” with modelling capabilities from targeted drilling
- **New Drilling** initiative …. eastern Gawler Craton and Curnamona Province…”
- “South Australia Drill Core Reference Library … new Drilling Initiative, research and innovation institutional partners…”
- “Discovery Drilling” focused on priority uranium targets…
- “establish a Drilling Service, Technology and Training Development Centre”
- **Start-up Aboriginal companies** with a focus on drilling, sampling and Aboriginal cultural heritage service opportunities”

Response document at: nuclear.sa.gov.au
GSSA Highlights

Benchmark publications
7. South Australian Drill Core Reference Library operational

- Nelson Discovery Hall
- Woodall Laboratory
- Holloway Geoscience Theatre
South Australia
Drill Core Reference Library

www.minerals.statemdevelopment.sa.gov.au/geoscience
MINALYZE – DOWNHOLE XRF

Technology incubation at SA Drill Core Reference Library

- XRF Geochemistry, 1 cm resolution
- MSDP holes scanned – data evaluation phase
8. National Exploration Undercover School (NExUS)

- Debut 27/11 – 17/12 2016
- Week 1 at Tonsley
- Over 30 registrants from industry, government and academia around Australia
- Presenters from industry, government and academia (>10 GSSA presenters!)
- Strong emphasis on engaging “next generation” on UNCOVER challenges
9. Collaborations and Partnerships

Sernageomin, Chile

China National Nuclear Corporation

China Geological Survey

Saskatchewan Geological Survey
中国地质调查局南京中心 – 南澳地质调查局合作
10. GSSA restructure and into the future

**Budget Savings / FTE Reduction**
- Total 6 FTE reduction (13 abolished positions / 7 new positions)
- Approaching ~$500k salary budget savings (2016-17)

**Strategic Rejuvenation**
- Tiered management structure
- Geoscience Program
  - Strong alignment with **UNCOVER** themes
- Regulation / Legislation Program
  - Contemporary delivery focus
- Greater industry focus, experience and competency
- Include a ‘regional geochemist’!
- Discontinue Seismic Detection function (transition to national GA network)
National Drilling Initiative (NDI)

Regional mapping (undercover) using a drill rig instead of a geological hammer

The next major step change for Australian pre-competitive geoscience?
Eastern Gawler (Olympic Province)

**Task 1:** Drilling and resampling program to identify and map key aspects of the mineral systems under cover

- Crustal level at time of 1590 Ma mineralisation event
- Fe-oxide alteration (esp. magnetite to hematite transition)
- Patterns of sericite-chlorite alteration
- Trace element alteration index as pathfinder
- Regional illite-chlorite-dravite alteration associated with Unconformity U in Pandurra Formation

Combine resampling of previous drilling with ~10 x 10 km drill program

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**Eastern Gawler (Olympic Province)**

**Known Mineralisation**

**Previous Drilling**

**Nominal Drill Pattern**

![Geophysical Extent](image1)

![337 holes](image2)

![10 x 10 km](image3)

Source: SARIG

HyLogger Drill holes

Max DTB 1000 m
Task 1: Drilling and resampling program
Task 3: Close down spacing in priority areas

10 x 10 km pattern
5 x 5 km infill in central corridor
Max depth-to-basement 1000 m
Excluding previous drilling

10 x 10 km pattern less previous drilling
(5 x 5 km infill to 1000 m)

<table>
<thead>
<tr>
<th>Depth to basement</th>
<th>500 m</th>
<th>1000 m</th>
<th>5 x 5 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of drill holes</td>
<td>113</td>
<td>217</td>
<td>255</td>
</tr>
<tr>
<td>Total meters drilled</td>
<td>30,400</td>
<td>113,700</td>
<td>147,100</td>
</tr>
<tr>
<td>Drilling cost @ $75/m</td>
<td>$2.3 M</td>
<td>$8.5 M</td>
<td>$11.0 M</td>
</tr>
<tr>
<td>Area covered (km²)</td>
<td>23,500</td>
<td>41,600</td>
<td>14,000</td>
</tr>
<tr>
<td>Cost per km²</td>
<td>$97</td>
<td>$205</td>
<td>$790</td>
</tr>
</tbody>
</table>

In-ground value of current and mined resources from the exposed Mt Isa Inlier is ~$250 B.*

* Resources from Geoscience Australia OzMin database. In ground value calculated in AUD on commodity prices at 20 May 2016