Distal Footprints of large ore systems – the challenge of exploring through cover and the role of AEM

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CESRE / Minerals Down Under Flagship
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ASEG-WA AEM Workshop
A slide of AEM Systems......we have used.....
UNCOVER
AUSTRALIAN EXPLORATION
GEOSCIENCE RESEARCH

SEARCHING THE DEEP EARTH
A VISION FOR EXPLORATION GEOSCIENCE IN AUSTRALIA
Prepared by UNCOVER under the aegis of the Australian Academy of Science
Exploration Challenge for Australia

1. Over the last century, exploration success for new economic mineral deposits in Australia has declined sharply.

2. Our economy is reliant on mineral discoveries dating well back into the 20th century.

3. These deposits are being depleted much faster than the discovery rate for new deposits.

4. The decline in exploration success is, in large part, due to the difficulty in exploring what lies beneath the regolith and sedimentary basins that cover approximately 80 per cent of Australia.

5. We need improved predictive and detection capabilities for searching under cover to build investment confidence.

Source: Searching the deep earth A vision for exploration geoscience in Australia; 2012
Cover – the Australian challenge

- Outcrop & Shallow Basement
- Basement depth <500m
- Basement depth 500 to 1000m
- Basement depth >1000m

Note: Major defined as >1 moz Au, >1mt Cu, >100kt Ni or equivalent
Excludes Bulk Minerals such as Coal, Bauxite and Iron Ore

Sources: MinEx Consulting August 2010
Geoscience Australia
Regolith – in-situ and transported

Ships! ?
.....Where is the rock?
AEM late time anomalies

- VTEM Late time channel
- Late time anomaly
  i. Follow it up with ground EM,
  ii. Model it
  iii. Drill it…..
1. Can we see a larger petrophysical footprint?
2. Is it gradational?
3. Is it detectable and what do we need to detect it?

Source: AAS 2012 (adapted from J Hronsky)
Geochemical/Mineralogical footprints – is there a petrophysical one?

Map of TOFR Sb (Antimony) distribution in the Kalgoorlie District

- Paddington
- Mt Pleasant
- Kundana
- Kanowna Belle
- KALGOORLIE - Golden Mile

Source: Scott Halley Minmap
Cover issues

1. At a minimum, cover represents a barrier that masks the detectable signature of mineral systems......but it can act as:

*a valuable dispersal medium in a mineral system, expanding the potential geographic footprint of a buried resource*
Cover issues (cont.)

Needs:

Targeted characterisation of

- depth,
- physical, mineralogical and chemical nature
- geometry & variability of cover
- the processes that formed modified it (age etc)

Source: Hough and Cleverley
AEM and Cover

Deep Exploration Targeting

Spatial proxies
- Thickness
- Variability

A New Search Space
How does the cover vary?
On the ground
Bedrock – Tropicana Area

Tropicana

TEMPEST AEM data
Working Though Cover

- A 1D SBS inversion
Mapping and Working with Regolith Complexity

The diagram illustrates a cross-section of geological layers, including:

- Sediments
- Valley fill Sand
- Alluvium colluvium
- Saprolite
- Sediments
- Sand
- Granite gneiss
- Saprock
- Meta granite

The elevation and distance metrics are shown along the axes, with specific coordinates such as 640000 mE, 650000 mE, and 660000 mE.
Exploration in various regolith settings

- Acid red sandy soil
- Sandy clay
- Silicified (hardpanised) sandy silty clay
- Hardpanised gravelly sandy clay
- Red, megamottled or bleached palaeochannel clays
- Concentric pisoliths
- Lateritic residuum
- Mottled/ferruginous saprolite
- Iron segregations
- Saprolite
- Bedrock

Ravi Anand
Bedrock – Tropicana Area

Tropicana
Spatial Proxy - Regolith Thickness
Regolith Thickness & Lithostructure

Regolith thickness

Greyscale image: 1VD mag
Some observations....Tropicana

1. Regolith (particularly saprolite) is conductive...

2. Regolith modelled reasonably well as a 1D body (at scale of AEM resolution)

3. Can map thickness and spatial variability based on conductive response – spatial proxies

4. Spatial character and relationships with basement
Anomaly detection in arid, old complex landscapes of Australia
Exploration in areas of deep cover using palaeo-surfaces, indicator minerals and redox fronts

- Present surface
- Palaeosurface III
- Redox front II
- Palaeosurface II
- Redox front I
- Palaeosurface I

- Primary mineralisation
- Alteration halo

- 3D architecture of sediments
- Secondary dispersion of orebody: Mineralogy and Geochemistry of palaeosurfaces (eg heavy minerals) and redox fronts.
- Hydrogeochemistry
Formation of anomaly at palaeo-redox fronts: Osborne Cu-Au deposit

A. Marine transgression

- Shallow marine environment
- Water-saturated Reduced Mesozoic Sediment
- Unconformity
- Precambrian Metasediment Basement

B. Uplift

- Water-unsaturated Oxidised Mesozoic Sediment
- Water table
- Water-saturated Reduced Mesozoic Sediment

C. Prolonged aridity

- Water-unsaturated Oxidised Mesozoic Sediment
- Water-saturated Reduced Mesozoic Sediment

Lawrance, 1999
Areas of deep cover: Eloise (Cu-Au) deposit

Anand and Robertson, 2011
Cover cross section: Eloise deposit

Anand and Robertson 2011
 Formation of anomaly at interface by mechanical processes, Eloise Cu-Au deposit

- Mineralisation: pyrite, chalcopyrite
- Fresh Mesozoic cover up to 70 m thick over fresh Proterozoic bedrock
- Dispersion both local and distal (up to 3 km) by mechanical processes

Anand and Robertson, 2011
Pre-Mesozoic Palaeotopography, Eloise

Anand and Robertson 2011
Geochemistry of drill holes, Eloise deposit
A digression.....

Smooth 19 layer inversion
HeliTDEM system
Beware: Getting the parameters right....

Wrong timing

Wrong timing less gates
Exploration is an exercise in sequential volume reduction

- an understanding of the multiscale expressions of ore deposits and their entire mineralising systems;
- The basic data, derivative products and tools required to detect mineral systems at the appropriate scales; and
- knowledge of the regional background is critical
Characterising and detecting the distal footprints of ore deposits

• Research opportunity
  ▪ Integrate ore deposit characterisation and proximal to distal footprints for ore deposit types at regional to continent scales,
  ▪ Understand footprints of mineral systems that may be much more subtle than the highly anomalous deposits residing within.
Regional AEM – Context & Opportunity

Pine Creek
Paterson
Frme Embayment (in progress)

Government data sets
GA’s Onshore Energy Program
Distal Footprints – Bryah Basin, WA
Prior AEM Surveys

Targeting base metals, gold, diamonds, uranium & groundwater…

AEM Systems:
- REPTEM
- XTEM
- VTEM
- DIGHEM
- TEMPEST
Larger surveys offer opportunity to look at
Distal Footprints – WA
1D inverted Interval Conductivity – 54-64m BGL
1D inverted Interval Conductivity – 54-64m BGL
1D inverted Interval Conductivity – 110-130m BGL
Regional Scale map of cover thickness
Regional EM

Map showing regional geological features:
- Sedimentary and volcanic rocks
  - Phanerozoic
  - Neoproterozoic
  - Mesoproterozoic
  - Paleoproterozoic
  - Late Archean–Paleoproterozoic
- Igneous and metamorphic rocks
  - Paleoproterozoic
  - Archean

Proposed seismic lines:
- Line 1
- Line 2
- Line 3

Key locations:
- Exmouth
- Onslow
- Pannawonica
- Hamersley Basin
- Ashburton Basin
- Collier Basins
- Gascoyne Complex
- BRYAH and YERRIDA BASINS

Geological features:
- Faults
- Towns
- Highways
- Roads

Distance scale: 100 km
Near surface with MT – mineral system

Blewett et al 2010
How does AEM fit?

Adapted from: Searching the deep earth A vision for exploration geoscience in Australia; 2012
Regional AEM: Opportunities

1. Regolith Thickness and when studied in detail – variability within the regolith (are these palaeo discontinuities/horizons to sample geochemically etc etc).

2. Regolith discontinuities – do they reflect changing patterns of alteration etc?

3. Opportunity to think about joint inversion with other regional geophysical data sets – common earth properties and, by implication, variations in that – significance for exploration through cover.

4. Opportunity for integrated geochemical/geophysical investigations with regolith character and variability in 3D involved – as distinct from 1D (surface approaches) used in past.
Challenge for all explorers/contractors

- AEM offers much more than just direct targeting for drilling (the common approach). Regional coverage – processed carefully(!) offers significant new opportunities to identify new exploration targets based on enhanced geological (weathering) understanding, targets that may not be necessarily conductive. But....

  - Need greater S:N
  - More power to see deep but not at expense of sensitivity (make sure we have lots of gates/channels)
  - Bandwidth important – need to see near surface (top 50m) as well as deep 150m +
Expand our search footprint

1. Can we see a larger petrophysical footprint?
2. Is it gradational?
3. Is it detectable and what do we need to detect it?

Source: AAS 2012 (adapted from J Hronsky)
1. A key advance will be the recognition of unique datasets or proxies to map the various facets of a mineral system, from
   – metal and fluid source,
   – to pathways,
   – depositional sites and
   – fluid exit conduits.

2. To achieve this, we require more comprehensive data on *low-level* geochemical, thermal or geophysical anomalies.

3. In exploring under post-mineralisation cover where direct geochemical techniques may be challenged, translating mineral system characteristics to mappable geophysical parameters will be a major requirement.
Thank You

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