District-Scale Geophysical Surveys: What Works and What Doesn’t for Gold

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13th February 2019
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The Importance of Scale

Traditional focus on local to camp scale. More recent focus on continental to regional scale via “mineral systems” approach.

The better explorers have been informally using this approach for decades.

The talk focuses on regional to camp scale geophysics and looks geophysical techniques/ methods to define geological criteria associated with gold mineralisation
Crustal scale geophysics 25-50km resolution requires data sampled on at least 10km x 10km

At first glance it is just an off the shelf continental scale gravity image... or is it?

It contains bathymetry data, isostatically corrected land data, removes upper crust, gradient calculation, algorithm to vectors gradient etc
The Importance of Scale

Gravity Edges (Gradients) - 50km with Major Gold Deposits

Important to use a consistent set of data that best represents the geology, not necessarily lots of data.
The application of gravity as a regional tool for mapping fundamental structure is well known. More effort should be put into closing in the existing regional gravity spacing to ~1km. The next level of detail is required for explorers to be successful.

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- model ages 200-300 Myr > emplacement ages
- central/western Yilgarn - ?protocraton
- complex eastern Yilgarn

Gravity 1VD (Data Source GSWA)
Crustal scale geophysics 25-50km resolution requires data sampled on at least 5km x 5km.

Regional coverage should be ~1km to try and map the next level of detail in the regional interpretations.

The gravity contour is thought to represent the edge of the continental blocks.

Selwyn Block to the south (and north?). Delamerian Fold belt to the west.

Based on gravity and seismic soundings it is interpreted that there is uplift (~5km) on the northern crustal block and the northern part of the Selwyn. This implies there is a greater thickness of deep marine sediments/prospective stratigraphy in between these blocks causing the gravity low.

The depth slice for the magnetic data is getting close to the Curie point of magnetite (~30km) so the responses probably relate to the preservation of continental crust and more mafic blocks of oceanic crust.
Regional Faults and Lineaments

- Lineaments manifested in many different ways eg. faults, anomalous geology (change in dip/strike/facies), structural windows and doming, grabens/ basin margins/growth faults, localisation of intrusive activity or intrusive corridors, reactivation of basement structures (may not always come to surface as faults)

- Lineament intersection points are generally going to be regions of more complex geology and sights of better “plumbing systems”, and therefore more hydrothermal activity etc.

- Gravity has potential to map out regional to camp scale geological packages and discontinuities (structures etc)

- Magnetics also have the potential to map out regional structures. As magnetite is affected by alteration the structures identified may be secondary to the main structure

- MT has the potential to map regional faults but it can be severely effected by near surface effects (statics, cover) and unless taken into consideration in the modelling can be misleading

(after Dobe, 2004)
Anomalous structural site on a crustal-scale
Intersection of regional structures with cross structures, bends/jogs
Uplifted blocks or anticlinal domes
Geological discontinuity, unconformities, basin margins (conglomerate)
Multiphase intrusions including lamprophyres and alkali intrusions
Size and continuity of supracrustal rocks
Favourable host sequence including shales, Fe-tholeite and dolerite
Putting recent discoveries, existing deposits and competitors in context with your exploration focus is critical at a regional scale. It acts as a means of communicating the significance of your exploration program.

Significant deposits and prospects up to 5km in proximity, along trend, to these major regional structures.

Bends/kinks along these regional structures, together with NNE to ENE structures intersecting these major regional structures, provide high priority target areas.

These types of targets have potential to host major gold deposits.
Regional Structures With Cross Structures, Bends/Jogs

- Keith-Kilkenny Shear
  - Highly prospective zones for mineralisation
- Emu Fault
- Breaker Resources Bombora Deposit
- Silver Lake Resources French Kiss Deposit
Regional Structures With Cross Structures, Bends/Jogs

Uplifted Blocks or Anticlinal Domes

- Black Flag (brown) hosted mineralisation in the Kalgoorlie Region over first vertical derivative image of the regional magnetics
- Mineralisation adjacent to doming via granite emplacement and subsequent structural deformation (folding and faulting)
- Fold closures, granites mapped by detailed magnetics. Sediment/mafic boundaries mapped by gravity/EM

- The location of conglomerates are markers to zones of rapid uplift and structure.
- Polymictic conglomerates containing mafic, porphyritic clasts (Timiskaming equivalent) can be important places to explore as it is proximal to some of the largest known orogenic gold deposits in the world.
- The unconformity can indicate a significant greenstone thickness preserved stratigraphically beneath.
- How can we use this to explore and what are the methods to use?
Geochemical signature: Au > Ag, Te, Mo, V, Ba

Ore style: Qtz vein networks and breccias with telluride.

Alteration: ser-Kspar ± cb, anhydrite, hematite
Unconformities, Basin Margins
Unconformities, Basin Margins
Multiphase Intrusions Including Lamprophyres/Alkali Intrusions

Jundee – Nimary Goldfield, Northern Yandal Belt

(After Newmont Site Presentation)

Regional Geology (Dacitic Porphyry in pink)

Airborne Magnetics (RTP)

Regional Gravity (Bouger 2.67 g/cc residual image)
Multiphase Intrusions Including Lamprophyres/Alkali Intrusions

St Ives, Eastern Goldfield

- 250m/500m regularly spaced gravity data for mapping multi-phase intrusive systems of significant scale
- The intrusives are also resistive and depending on the host produce a significant resistivity anomaly

Regional Gravity (BA 2.67 g/cc)

Regional Gravity (Bouger 2.67 g/cc residual image)
Regional 1VD and 500k bedrock geology. Inferred Mertondale Shear Zone (black).

Regional Bouguer gravity image. Inferred Mertondale Shear Zone (black).

(Images from Government of WA Website)
Mapping Favourable Host Sequence

- Need to be able to discern cover (paleo drainage) versus bedrock response
- Low level airborne surveys (not necessarily tight line spacing) is important!

- If you would like to map it then sample it
- The same principals apply to seismic and MT data. If you don’t adequately resolve the near surface information it can appear like it is a deep geological unit of interest
Mapping Favourable Host Sequence

Plutonic Greenstone Belt (+7 Moz)

RTP Magnetic Image – 20m flight height and 25m line spacing
Open file data

RTP Magnetic image with paleodrainage derived from current drainage and magnetic interpretation
Favourable Host Sequence

RTP Magnetic Image – 20m flight height and 25m line spacing
Open file data

Bouguer Gravity Image – 250m x 250m station spacing
Favourable Host Sequence

1VD Greyscale of RTP magnetics

Interpretation of Airborne Magnetic data
Favourable Host Sequence

Sadiola Hill, Mali (+8 Moz)

RTP magnetics

Airborne EM – Mapping shales, carbonates and structure

Gold Geochemistry
Favourable Host Sequence (and Direct Detection)

- Helicopter time domain VTEM surveys
- Late time channel data (8.9 ms) shown
- Draped over greyscale magnetics (RTP 1VD)
- Tusker 4.54 Moz @ 1.5 g/t Au (2009) – sulphidised BIF
- Killimani anomaly identified as another sulphide response

(After Bourne and Pittard)
Favourable Host Sequence (and Direct Detection)

Killimani test:
7m of 25% pyrrhotite @ 262m depth
No gold…

(After Bourne and Pittard)
Favourable Host Sequence (and Alteration)

Gokona, Tanzania (+5Moz)

Gradient Array IP/ resistivity

- Andesitic tuff: Strong to intense alteration with original texture largely overprinted or destroyed. Often appears cherty. Commonly with very fine disseminated pyrite and arsenopyrite. **3.0 – >60 g/t**
Major Expenditure by Geophysical Technique

**Technique**

- **Airborne Mag/Rads**: 37.0%
- **Induced Polarisation**: 18.0%
- **Electromagnetics**: 6.0%
- **Gravity**: 8.0%
- **Other**: 2.0%
- **Physical Properties**: 29.0%
Orogenic Gold – District Scale Exploration Summary

- Anomalous structural site on a crustal-scale – gravity, +/- magnetics, +/-MT, +/- seismic tomography
- Intersection of regional structures with cross structures, bends/jogs – gravity, magnetics
- Uplifted blocks or anticlinal domes – gravity, magnetics
- Geological discontinuity, unconformities, basin margins (conglomerate) – gravity, +/- magnetics
- Multiphase intrusions including lamprophyres and alkali intrusions – magnetics, +/- gravity
- Size and continuity of supracrustal rocks - gravity
- Favourable host sequence including shales, Fe-tholeite and dolerite – magnetics, +/- gravity, +/- EM, +/- GIP
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