The Implications of the Mineral System Concept for Geophysical Exploration: A Perspective

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‘Traditional’ geophysical exploration strategy:

- Mapping and targeting form end members of a continuous spectrum
Mineral Systems

“... all geological factors that control the generation and preservation of mineral deposits” (Wyborn et al., 1994)

- Source-pathway-trap (physical throttle-chemical scrubber)

A whole new set of targets!
- Source-pathway as well as the trap
- What will these look like – associated with alteration?

“... the major change that is required is a shift from ... direct targeting ... to a staged process ... where geophysical approaches are used initially to help define the pathways ... that carried mineralizing solutions ...”

Source: Witherly (2014)
Mineral Systems

Mineral systems processes occur on a scale of 100s to 1000s of km$^3$

- Need geographically widespread datasets
- Scale is such that these are only likely to come from Government/Geological surveys

Need geophysical methods that can image source/pathway/(trap) at kms to mantle depths

- ‘Academic’ methods
Critical elements in a mineral system

Fertility

Favourable Whole-lithosphere Architecture

Preservation of Primary Depositional Zone

Favourable (Transient) Geodynamics

Ore Genesis

A whole new set of targets!
- Indirect inference of the fluid pathway

Source: McCuaig and Hronsky (2014)

Source: G Begg (pers comm)
Deep Penetrating Geophysics

Whole lithospheric architecture: Geophysical options?

- (Gravity)
- Magnetotellurics (MT)
- Active seismic methods
- Passive seismic methods
Magnetotellurics

Southern Yilgarn Craton, Western Australia

- Intra- and inter-cratonic major faults
- Mantle source zone?
Seismic Methods

Capricorn Orogen, Western Australia

- Mapping cratonic margins/suture zones beneath thick cover
Seismic Methods

Advantages passives surveys
- Do not require expensive artificial sources
- Drilling of shot holes

Disadvantages passive surveys
- Lack resolution
- Long deployment times
  Weeks, months, years

Options
- Ambient noise methods – $V_s$
- Teleseismic methods – velocity contrasts
  Receiver functions, body wave tomography, H-k analysis

Sources:
- Local explosion/vibration
- From Distant Micro Seismic Events
- From Distant Earthquakes
Mapping basement under thick cover

- H-k analysis of teleseismic arrivals
- Ambient noise derived Vs
- Common-conversion-point stacking of teleseismic arrivals
Mineral Systems

Critical elements in a mineral system

Transient dynamics?
- Reservoir of over-pressured fluids below an impermeable barrier
- Barrier is periodically breeched (transient stress event) allowing fluid flow from the reservoir and deposition of metals

Source: McCuaig and Hronsky (2014)
Palaeo-Reservoirs

Reservoirs – a useful camp-scale target?

- Relatively large and shallow targets
- Expect extensive and intensive alteration
- Allow detection-based exploration strategies in the gap between regional- and prospect-scale?

Source: McCuaig and Hronsky (2014)
Palaeo-Reservoirs

Olympic Dam IOCG deposit

- Cu-U-Au-(Ag-REE-Fe)

Source: G Heinson, Univ’ of Adelaide, pers comm
Palaeo-Reservoirs

Gruyere deposit
- Orogenic gold

MT modelling by Jessica Spratt

Slide courtesy of Gold Road Resources Ltd, Minerals Research Institute of Western Australia, Geological Survey of Western Australia
Mineral Systems: Petrophysics

What do mineral system components actually look like?

• Fluid source regions
• Fluid flow conduits (pathways)
• Fluid reservoirs

All are expected to be regions where there is fluid-rock interaction

• Petrophysical databases organised by lithology
• What are the petrophysical consequences of the alteration?
  Detectable physical property contrasts?
• Develop a predictive capability – petrophysics first not last?
Mineral Systems: Petrophysics

Towards a conceptual framework to understand geological controls (lithology+) on physical properties – prediction!

- Recognise end-member ‘behaviour’ of the petrophysical properties
- Need to treat different types of petrophysical data in different ways

Increasing likelihood of correlation with rock type

Decreasing influence of the dominant mineral components

Increasing likelihood of representative sampling

Increasing likelihood of prediction from chemistry/mineralogy

Mineral Systems: Petrophysics

Bulk
(Overall Mineralogy)

Density
Seismic Para-Velocity
magnetism

Electrical Conductivity
Electrical Magnetism
Ferro-Polarisation

Grain
(Volume, size and shape of minor grains)

Texture
(Geometric relationships between minor grains)
Petrophysics & Alteration

Lithology and seismic properties)
• Ultra-mafic, mafic, intermediate, felsic

- Density (g/cm³)
  - 2.0
  - 3.0
  - 4.0

- Velocity (m/s)
  - 3000
  - 4000
  - 5000
  - 6000
  - 7000
  - 8000
  - 9000

Rock-forming Minerals
- Plag' Fsp
- Alkali Fsp
- Olivine
- Amphibole
- Pyroxene
- Quartz
- Mica
- Garnet

Increasing likelihood of prediction from chemistry/mineralogy

Bulk
Grain
Texture
Petrophysics & Alteration

Alteration and seismic properties

- Olivine or Opyx → Serp’ group minerals + mg (Serpentinisation)
- K Feldspar → Muscovite or sericite

![Graph showing velocity and density relationships for different minerals and alteration stages.]

Increasing likelihood of prediction from chemistry/mineralogy
Petrophysics & Alteration

Seismically transparent zones – Stuart Shelf, South Australia

- Alteration by mineralising fluids?
- Probable they are due to alteration of mafic components of the country rock

Source: Wise, et al., 2015
A role for deep-penetrating geophysical methods

- Passive seismic methods, MT

Need a better understanding of the ‘new’ mineral system targets

- Palaeo-reservoirs and camp-scale targets?
- Need for research in petrophysics
  - More than just a constraint for modelling
  - Need to think beyond variation with lithology and include alteration
  - Collect these data ‘early’ and with good geological context

Exploring for mineral system components under cover

- Need to develop a predictive capability
Thankyou!

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