Premise

• The Mineral industry will be forced to undergo a paradigm shift over the next ten years to a focus on seeking quality greenfields discoveries, requiring:
  – Greater dependence on accurate conceptual targeting
  – Exploration systems that closely estimate probability of success and monitor performance
  – Concomitant development of exploration technologies that will allow us to explore new search spaces cost effectively

• The petroleum industry was forced to commence this shift over 30 years ago

We in the mineral industry are behind the times.
Drivers of change

• Growing demand for mineral end energy resources by society
• Declining exploration success
• Resource depletion outstrips replenishment
  – Current resource base cannot meet this demand
• Depletion of residual search space
• Need for targeting new provinces in areas of challenging cover (new search space)
• The expense of detection in this new search space – need to target exploration more effectively
• Social change requiring a reduction of physical, social and environmental footprint (Europe!)
Minerals and energy demand: the case for the supercycle

GFC – major impact on industry funding, limited impact on demand!

Source: ANZ, Maddison

Pyle, 2008
Exploration effectiveness declining

Challenge to maintain production levels

The graph for base metals tells the same story!

5-year rolling average

Decline in spite of a real gold price increase from ~$400/oz to ~$900/oz

Note: Based on primary gold deposits found in the western world versus associated expenditures on grassroots and late stage exploration

Source: GFL/MinEx Consulting
Depletion of the residual search space
Depth of cover for base metal discoveries (>0.1% Cu-equiv) made in the western world

Again, a shift the petroleum industry made decades ago.

Source: BHP Billiton January 2007

Min Ex - SGS
27 March 2007
Understanding the search space concept

• The largest deposits in any search space are usually found early because they generally have the most obvious signatures.

• Any given search space will progressively become exhausted over time, resulting in smaller and higher cost discoveries.

• The most important discontinuities in the exploration business are those which significantly expand the search space through innovation:
  – New technology (extraction and exploration)
  – New concepts (often linked to technology)
SEARCH SPACE OBSERVATION 1:
Most of the mineral industry's wealth is captured by a handful of giant deposits.

Cumulative NPV @ 8% discount rate

2/3rds of wealth comes from 10% of all projects

129 Deposits with total value of US$32Billion in 1994 dollars

Base Metal Mines discovered in Canada & Australia to 1988

Source: Derived from Mackenzie 1995

Hronsky (2004)
SEARCH SPACE OBSERVATION 2:
Within a district, most of the endowment is tied up in handful of deposits.

Gold Endowment (koz) at St Ives

- Junction
- Victory
- Argo
- Revenge
- Leviathan


Endowment = Current Reserves + Cumulative Production
SEARCH SPACE OBSERVATION 3 Largest deposits are generally found first - Yilgarn NiS

Mt Ni

Discovery Year

Total = 12.71mt

excluding 0.14mt in deposits with no published discovery date

Search space depletion with brownfields exploration: deposit size decreases, discovery cost increases

Gold Discoveries at Norseman (koz)

Year of Startup

Note: Excludes “Extensional” exploration

Hronsky (2004)
Source: WMC Dec 1998
Concept of **Residual Endowment**
- e.g. mercury deposits in California

- Largest deposits generally found early in exploration history
- Discovery ‘waves’ through a Search Space leave a Residual Endowment with a lower mean deposit size.

Chung et al., 1992
Links to Targeting Strategy

• Any targeting strategy must be based on an understanding of the degree of depletion of the relevant search space (i.e. “exploration maturity”) for the target province (or district, or camp)

• Need to know when to walk away from an area (in a technical sense) – two requirements
  – Requires you know what success is TO YOU
  – Requires you can estimate residual endowment

• How can we estimate residual endowment?
Largest deposits found early 
but may not be recognised as largest! – how to tell?

Komatiite-associated Ni-Cu deposits, Kambalda Region, 
Eastern Goldfields Province, Western Australia

LARGEST DEPOSITS NORMALLY DISCOVERED IN EARLY YEARS OF EXPLORATION IN DISTRICT

Hronsky and Groves (2008)
Can we use this size-frequency relationship?

Gold Endowment (koz) at St Ives

Endowment = Current Reserves + Cumulative Production

Source: WMC Dec 1999

Hronskey (2004)

35 Deposits
8.1 moz Au

Largest 5 deposits (14% of total) contain 65% of all gold at St Ives
Yilgarn Au endowment - 1973

Total discovered resources = 42.8 Moz
Total predicted endowment = 179.5 Moz
Residual endowment = 136.8 Moz
% discovered = 23.8%
Targets >5Moz = 6
Targets >1Moz = 29

Guj et al. (2011)
Yilgarn Au endowment - 1989

Total discovered resources = 75.5 Moz
Total predicted endowment = 226.9 Moz
Residual endowment = 151.4 Moz
% discovered = 33.3%
Targets >5Moz = 7
Targets >1Moz = 29

Guj et al. (2011)
Yilgarn Au endowment - 2003

Total discovered resources = 251.1 Moz
Total predicted endowment = 401.5 Moz
Residual endowment = 150.4 Moz
% discovered = 62.5%
Targets >5Moz = 3
Targets >1Moz = 35

Guj et al. (2011)
Yilgarn Au endowment - 2008

Total discovered resources = 323.9 Moz
Total predicted endowment = 431.8 Moz
Residual endowment = 107.9 Moz
% discovered = 75%
Targets >5Moz = 2
Targets >1Moz = 14

Guj et al. (2011)
Impact on targeting strategies

• First Mover-Fast Follower
  – Largest deposits are generally found first in a terrane
  – Requires mineral systems targeting, strong conceptual teams, and appetite for risk

• Elephant Country
  – Find deposits where big ones have already been found
  – BUT – remember residual endowment
  – Need competitive advantage to expand search space
New mineral provinces required

Copper consumption over the last 25 years accounted for half of all copper metal ever mined in the world.

World consumption over the next 25 years will exceed all of copper metal ever mined to date.

Sources: US Geological Survey (1900-83), Brook Hunt (1984 onwards)

Schodde, 2007
Social pressures and deposit quality

Physical and socio-economic footprint
Carbon footprint

Success may look different in the future!
- A focus on high quality deposits required
Current industry practice not inline with new paradigm

- External (equity market) and internal (remuneration packages and KPI) measures foster short-term thinking and short term results
- Results in focus on brownfields AT EXPENSE of greenfields
- Trend of majors away from exploration to acquisition, focus on extraction technologies
- Expectation that Juniors will fill the greenfields gap
- A common belief that metal prices will sort out supply

All of these ideologies are fundamentally challenged looking to the future
Commitment to discovery: global non-ferrous exploration expenditures and metal prices 1989-2009

Sources: MEG and IAEA (for uranium 1989-2006)

Richard Schodde
What is our real commitment to discovery?

Long-Term Trend in Greenfields Exploration

Figure 1: Australian Mineral Exploration Expenditure in constant 2006-07 Dollars separating greenfields from brownfields expenditure. Source: Geoscience Australia (based on ABS survey data deflated by CPI)
Juniors will not do the greenfields!

- Fundamental assumption is that greenfields exploration (and its inherent risks) will be outsourced to Juniors
- But structure of Juniors’ funding mitigates against greenfields exploration strategies

- Will metal prices simply sort it out?
- There is a long list of marginal projects that could potentially be economic with a sustained metal price rise
Marginal deposits will not fill the gap
...once a dog, always a dog...

Pre-boom, subecononic  Early boom, economic  Late boom, marginal  Crash, very subecononic

↑  $  ↓  Commodity Price  Production cost  Time →
The minerals industry is at a crossroads

Perception of Supply Shortage

Higher Prices provide incentive for Innovation

Innovative Success

Discovery of New Sources of High-quality Supply

New Period of Supply Security

Hronsky (2009)
Innovation expanding search space: A Petroleum example
After 40 years of technology development...
Think of this as mineral exploration under cover
The Minerals Example: Exploration Cost is the Key Barrier to Mining Deep High-Quality Orebodies

Modelling for a Voisey’s Bay style orebody in remote WA (30 Mt @ 2.5% Ni, 2.0% Cu; 20m thick 60 degree dip)

Hronsky (2005)
Targeting new greenfields discoveries

• Our ability to mine at depth far outstrips our ability to explore at depth
• Requires an innovation in deep exploration technology
• The key innovation is more accurate targeting of mineralised volumes of rock under cover
• Requires a shift from deposit model style concepts to mineral system style concepts
• Requires translation of understanding of mineral system model into effective targeting model