SEVEN STRATEGIES FOR RARE EARTHS HOPEFULS: NAVIGATING THE UNCERTAINTIES OF THE RARE EARTHS INDUSTRY

John P. Sykes, Director, Greenfields Research Ltd (UK)
CONTENTS

– Where now for rare earths?
– Unanswered questions about geology?
  – “Geology” based strategies
– Unanswered questions about mine project development?
– Unanswered questions about delays?
  – “Development” based strategies
– Unanswered questions about the future?
  – “Uncertainty” based strategies
– How do you plan in the face of all these unanswered questions?
TWO FORMS: “LIGHT” & “HEAVY”

“Light” REE
- Lanthanum
- Cerium
- Praseodymium
- Neodymium
- Promethium
- Samarium

“Heavy” REE
- Europium
- Gadolinium
- Terbium
- Dysprosium
- Holmium
- Terbium
- Erbium
- Thulium
- Ytterbium
- Lutetium

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…OR THREE: “LIGHT” “MEDIUM” & “HEAVY”

<table>
<thead>
<tr>
<th>“Light” REE</th>
<th>“Medium” REE</th>
<th>“Heavy” REE</th>
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<tbody>
<tr>
<td>Lanthanum</td>
<td>Samarium</td>
<td>Erbium</td>
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<td>Cerium</td>
<td>Europium</td>
<td>Thulium</td>
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<tr>
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<thead>
<tr>
<th>Other REE</th>
<th>Scandium</th>
<th>Yttrium</th>
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...OR: “CRITICAL” & “NON-CRITICAL”

“Critical” REE
- Yttrium
- Neodymium
- Europium
- Terbium
- Dysprosium

“Non-Critical” REE
- Scandium
- Lanthanum
- Cerium
- Praseodymium

Promethium
- Samarium
- Gadolinium
- Holmium
- Erbium
- Thulium
- Ytterbium
- Lutetium

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…OR: BY END USE

“Magnet” REE
- Praseodymium
- Neodymium
- Samarium
- Gadolinium
- Dysprosium

“Catalyst” REE
- Lanthanum
- Cerium

“Phosphor” REE
- Yttrium
- Europium
- Terbium

“Specialist” REE
- Scandium
- Holmium
- Erbium
- Thulium
- Ytterbium
- Lutetium

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WHERE NOW FOR RARE EARTHS?

Entering “Phase 2” of the recent rare earth industry: mine project development

Image: Shutterstock
ENTERING “PHASE 2”: PROJECT DEVELOPMENT

La Oxide 99% min FOB China (CN) / tonne

Data: Metal Pages; Bloomberg
WHY IS MINING SO DIFFICULT?

1. Relative crustal abundance.
2. Degree of metal concentration by natural processes into mineral deposits.
3. The mechanical ease of obtaining the ore from the earth.
4. The ease of extracting the metal from the ore.

Source: Gupta & Krishnamurthy (2005)
RARE EARTHS AREN’T THAT “RARE”

Source: USGS (2002)
ELECTROPOSITIVITY & ELECTRONEGATIVITY

Atomic radius decreases = ionisation energy increases = electronegativity increases (electropositivity decreases)

TWO PRINCIPAL TYPES OF DEPOSIT

Primary deposit – formed by magmatic process depositing the minerals

- Carbonatites  
  e.g. Mountain Pass, USA

- Alkaline  
  e.g. Thor Lake, Canada

- IOCG  
  e.g. Olympic Dam, Australia

- Hydrothermal  
  Bear Lodge, USA.

Secondary deposit – formed by the weathering & erosion of primary deposits

- Placer  
  e.g. Chavara, India

- Paleoplacer  
  e.g. Elliot Lake, Canada

- Laterite  
  e.g. Mt Weld, Australia

- Ionic clay  
  e.g. Longnan, China

Source: BGS, USGS, Williams et al., Wikipedia, Encyclopedia Britannica, Goldavenue Encyclopedia, Kimberley Rare Earths, New York Times
WHERE WILL NEW SUPPLY COME FROM?

Data: Intierra, USGS, Infomine, Technology Metals Research, Google Earth, IHC Merwerde, Panoramio

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PLENTY OF PROJECTS: NOW TO DEVELOP THEM?

- 1 in operation
- 3 at feasibility stage
- 7 at PFS
- 14 at Scoping / PEA stage
- ~40 with compliant resources
- ~250 known projects
- 1.0Mt in operation
- 3.1Mt at feasibility stage
- 22Mt at scoping / PEA stage
- 17.5Mt at PFS
- ~42Mt as compliant resources
- ~110Mt of estimated reserves (USGS)

Data: Greenfields Research, Company websites, Infomine, Technology Metals Research, USGS
MINING THROUGH STANDARD TECHNIQUES

- **Wet alluvial mining**
- **Dry alluvial mining**
- **Hard rock open pit**
- **Hard rock underground**

Images: Greenfields Research Ltd, BGS, Molycorp, Atlas Copco

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WHY IS MINING SO DIFFICULT?

1. Relative crustal abundance.
2. Degree of metal concentration by natural processes into mineral deposits.
3. The mechanical ease of obtaining the ore from the earth.
4. The ease of extracting the metal from the ore.

1. Rare earths are abundant in the crust.
2. Rare earths do not readily concentrate in the crust by natural processes.
3. Rare earth ore are easily extracted from the earth.
4. Extracting the rare earth metals from their ores is very difficult.

Source: Gupta & Krishnamurthy (2005)

Circa: 2008

Now largely resolved by “exploration” in “Phase 1” (2008-11)

Now entering “Phase 2” where “development” will be the focus
## WHY ARE MINE PROJECTS DIFFICULT?

### CLASSIFICATION AND DESCRIPTION OF PROBLEMS AT MINE PROJECTS

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<th>Risk Category</th>
<th>Examples</th>
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Based on: Trench (2011)
UNANSWERED QUESTIONS ABOUT GEOLOGY

The heavy-light paradigm or “Grade is King” even in the world of rare earths
THE “STANDARD” BASKET VALUE CHART

Data: Greenfields Research Ltd, Company websites

Total Rare Earth Oxide Basket Value (US$/kg)

- Hastings
- Kutessay II
- Norra Karr
- Kangankunde
- Strange Lake
- Bokan
- Thor Lake
- Mt Weld (Duncan)
- Dubbo
- Kvanefjeld
- Zandkopsdrift
- Bear Lodge
- Nolans Bore
- Mt Weld (CLD)
- Steenkampskaal
- Ngualla
- Mt Pass

- Heavy rare earth deposits
- Advanced light rare earth deposits
- Early stage light rare earth deposits

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QUESTION: HOW MUCH HEAVY IN A LIGHT?

Some “heavy” rare earth projects actually have a very low heavy rare earth grade.

The highest grade “heavy” rare earth deposits are actually the advanced “light” projects.

Data: Greenfields Research Ltd, Company websites
Focus is on these projects: mainly “heavy” rare earth projects

Focus should be on these: mainly advanced “light” rare earth projects

Data: Greenfields Research Ltd, Company websites; Idea for original chart from Technology Metals Research
WHY ARE MINE PROJECTS DIFFICULT?
CLASSIFICATION AND DESCRIPTION OF PROBLEMS AT MINE PROJECTS

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Based on: Trench (2011)
THE BCG BOX OR “GROWTH-SHARE MATRIX”

<table>
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<tr>
<th>Market Share (returning investment)</th>
<th>Market Growth (requiring investment)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>QUESTIONS</strong></td>
<td><strong>STARS</strong></td>
</tr>
<tr>
<td>Also known as “problem children”. High growth sector but large capital investment required.</td>
<td>Leading assets/products dominating fast growing markets, still requiring investment.</td>
</tr>
<tr>
<td><strong>DOGS/PETS</strong></td>
<td><strong>CASH COWS</strong></td>
</tr>
<tr>
<td>Not profitable. Usually “pet projects” that provide a non-financial benefit i.e. synergies, labour retention etc</td>
<td>High market share in slow growth industry – “milked” to fund other investments</td>
</tr>
</tbody>
</table>

Based on: Boston Consulting Group (BCG)

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THE BCG BOX FOR MINE PROJECTS

**PROBLEM CHILD**
Challenging projects with scale, that could be stars in a high growth industry, assuming some structural changes.

**PET PROJECTS**
Not profitable. Usually “pet projects” that provide a non-financial benefit i.e. synergies, labour retention etc.

**STARS**
World class assets with high grades and large scale. Will dominate future sector and be hugely profitable.

**CASH COWS**
High grade, small scale projects, which are quickly cash generative, allowing access to an industry and providing cash for investment elsewhere.

Based on: Boston Consulting Group (BCG)
“GEOLOGY” BASED RARE EARTH STRATEGIES

Data: Company websites; Idea for original chart from Technology Metals Research

Gold ore equivalent: 131.7g/t 158.0g/t

TREO Basket Value (US$/kg)

TREO Ore Value (US$/kg)
STRATEGY 1A: THE CASH COW

**Advantages**
- Assets very competitive
- Most already very advanced
- Geology and technology already known
- First mover advantage in geology as best assets picked first

**Disadvantages**
- Financial markets currently very tricky
- First mover disadvantage – all R&D had to be done “in-house”
- Currently not a viable strategy for non-first movers

Gain market share via a low cost, high grade asset

*Examples: Molycorp, Lynas, Great Western Minerals, MbAC Fertilizer?*
STRATEGY 2A: THE “HEAVY” PROBLEM CHILD

Advantages
- Attractive to the equity market
- Seems to be a high growth market
- No major incumbent competitors

Disadvantages
- Projects currently low grade
- Process routes unknown – R&D intensive
- Capital costs will be high
- Development timeframe very lengthy
- Debt financing will be very tricky

Discover and develop a “heavy rare earth deposit”

Examples: Hastings Rare Metals, Stans Energy, Tasman Metals, Quest Rare Minerals
VULNERABLE TO MAGNET SUBSTITUTION

Source: USGS (2011)
THE R&D RACE IS ON!

Likely to be > 10 years for a new material

Likely to be > 10 years for a new mine

Source: Richard Holliday, Material Value Consultancy Ltd
UNANSWERED QUESTIONS ABOUT MINE PROJECT DEVELOPMENT

Why “quality” beats “scale” in this part of the mining industry
**WARNING ABOUT BASKET VALUES**

Data: Company websites; Idea for original chart from Technology Metals Research

- Assumes separated rare earth oxide prices
- Assumes 100% recovery of all rare earths
- No assessment of resource grade
WHICH RARE EARTH PRICE DID YOU MEAN?

- Carbonate (45% REO) FOB China
- Oxide 99% FOB China
- Oxide 99.999% FOB China
- Metal 99% FOB China
- Mischmetal (La 35%, Ce 65%) FOB China

Data: Metal Pages
WHEN IS VALUE ADDED IN RARE EARTHS?

Data: Metal Pages

- **50-60% at the mining stage**
- **25-35% at the refining stage**
- **20-25% in separation**

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CONCAVE VS CONVEX METALS [1]

Convex minerals:
- Gold
- Silver
- Tin
- Copper

Concave minerals:
- Lead
- Zinc
- Nickel
- Rare earths!

Source: Trench (2011)
VALUE ADDED LATER IN THE CHAIN

Data: Metal Pages; Wellmer, Dalheimer & Wagner (2008)

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CONVEX METALS & STRATEGY

Convex minerals:
- Gold
- Silver
- Tin
- Copper

Most value added during processing and smelting:
- Market entrants should build mines with processing plants and smelters
- Fabricators should integrate upstream into smelting & refining
- Smelters should divest downstream assets
CONCAVE METALS & STRATEGY

Most value added during refining and fabrication:
• Market entrants should build refining and fabrication facilities
• Miners should integrate downstream as far as possible into refining and fabrication
• Refiners and fabricators should divest any upstream assets

Concave minerals:
• Lead
• Zinc
• Nickel
• Rare earths!
### WHY ARE MINE PROJECTS DIFFICULT?

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|                         | • Technical: sudden catastrophic technical failure at the mine project     |

*Based on: Trench (2011)*
RECOVERIES: SOME ARE MORE EQUAL THAN OTHERS

Recoveries range: 6.5% to 41.0%

Remember: “basket values” analysis assume even 100% recovery

Sources: Pele Mountain Resources, DNI Metals
RECOVERY: TURNING SOMETHING INTO NOTHING

RARE EARTHS 101

\[
\text{Resources} \times \text{reserve recovery} \times \text{mining recovery} \times \text{grade} \times \text{processing recovery} \times \text{cracking recovery} \times (\text{separation recovery}) = \text{LOM production}
\]

90% recoveries: \(90\% \times 90\% \times 90\% \times 90\% \times 90\% = 59\%\)

75% recoveries: \(75\% \times 75\% \times 75\% \times 75\% \times 75\% = 24\%\)

50% recoveries: \(50\% \times 50\% \times 50\% \times 50\% \times 50\% = 3\%\)
THE MASS LOSS-RECOVERY PARADIGM

Percentages indicate equivalent mass loss to take ore to a 30% concentrate

Concentrating Factor (multiple)

Ore Grade (%)
MINING = THE COST OF MOVING ROCK

<table>
<thead>
<tr>
<th></th>
<th>Mt Weld*</th>
<th>Project X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore tonnage</td>
<td>250,000 tonnes</td>
<td>250,000 tonnes</td>
</tr>
<tr>
<td>Ore grade</td>
<td>10%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Total REO in ore</td>
<td>24,500 tonnes</td>
<td>6,250 tonnes</td>
</tr>
<tr>
<td>Conc. Recovery (x6 upgrade)</td>
<td>65%</td>
<td>65%</td>
</tr>
<tr>
<td>Total REO in conc.</td>
<td>15,925 tonnes</td>
<td>4,063 tonnes</td>
</tr>
<tr>
<td>Concentrate grade</td>
<td>60%</td>
<td>15%</td>
</tr>
<tr>
<td>Concentrate tonnage</td>
<td>26,542 tonnes</td>
<td>27,087 tonnes</td>
</tr>
<tr>
<td>Cracking recovery (x1.5 upgrade)</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>Total REO in cracked conc.</td>
<td>14,333 tonnes</td>
<td>3,657 tonnes</td>
</tr>
<tr>
<td>Cracked conc. Grade</td>
<td>80%</td>
<td>22.5%</td>
</tr>
<tr>
<td>Cracked conc. Tonnage</td>
<td>17,916 tonnes</td>
<td>16,253 tonnes</td>
</tr>
<tr>
<td>Separation recovery</td>
<td>95%</td>
<td>95%</td>
</tr>
<tr>
<td>Separation REO tonnage</td>
<td>13,616 tonnes</td>
<td>3,474 tonnes</td>
</tr>
<tr>
<td>Separated REO grade</td>
<td>99.9%</td>
<td>99.9%</td>
</tr>
</tbody>
</table>

Same size processing, cracking & separation plants required

Is this concentrate marketable?

Same cost to produce x4 less REO

Project X will cost x4 to operate and build on a unit basis!

* Data for Mt weld is rounded and edited for purposes of clarity!
### WHY ARE MINE PROJECTS DIFFICULT?

**CLASSIFICATION AND DESCRIPTION OF PROBLEMS AT MINE PROJECTS**

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Based on: Trench (2011)
CONCAVE VS CONVEX METALS [2]

**Convex minerals:**
- Gold
- Nickel sulphide
- Manganese
- Copper
- Platinum
- Diamonds
- Direct ship iron ore

**Concave minerals:**
- Nickel laterite
- Tantalum
- Molybdenum
- Bauxite
- Magnetite (Fe)
- Silver
- Tungsten
- Vanadium
- Rare earths!
LIFE CYCLE OF A MINING PROJECT

EXPLORATION

High Risk – High Potential
Speculation
Speculators Leave
~1 to 2 years
~2 to 3 years

MINING

Lowered risk
Orphan Period
~2 years
Full Value
~1 year
Institutional Investment

Value

~4 to 5 years

Concept Exploration Discovery Economics Development Mining

Time

Source: Brent Cook / MarketOracle

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WHEN DO RARE EARTH STOCKS RUN?

- Initial resource announced
- Scoping study completed
- Feasibility study completed
- Independent review completed
- Downstream plant moved to Malaysia
- Mining permits and contracts awarded
- Resource upgrade
- GFC
- China Non-Ferrous Metals deal cancelled
- Rare earth prices take-off, not reflected in Lynas share price
- 1st technical study completed
- China Non-Ferrous Metals deal proposed
- Malaysia reviews downstream operations

**Rare earth stocks seem to add most value as downstream plans and marketing agreements take shape, though early stage drilling and technical studies also add value, as with other mining stocks.**

Data: Lynas, Infomine

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## WHY ARE MINE PROJECTS DIFFICULT?

**Classification and Description of Problems at Mine Projects**

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*Based on: Trench (2011)*

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WILL SCALE INCREASE ENVIRONMENTAL ISSUES?

“The Fear of a Toxic Rerun”
New York Times, Keith Bradsher, 29th Jun 2011

“Taking a Risk for Rare Earths”
New York Times, Keith Bradsher, 8th Mar 2011

Images: New York Times
## WHY ARE MINE PROJECTS DIFFICULT?

### CLASSIFICATION AND DESCRIPTION OF PROBLEMS AT MINE PROJECTS

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**CLASSIFICATION AND DESCRIPTION OF PROBLEMS AT MINE PROJECTS**

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*Based on: Trench (2011)*
WHAT IS A “DEVELOPABLE” PROJECT?

- Major late stage light rare earth projects
- Early stage light rare earth projects
- Heavy rare earth projects
- Major early stage light rare earth projects

Data: Company websites

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WHAT IS A “STAR” PROJECT?

Data: Company websites
STRATEGY 2B: THE “LIGHT” PROBLEM CHILD

Advantages
- Metallurgy / processing better known
- Possibilities to leverage scale
- Second mover advantage in development timeframe
- First movers success may make these projects more attractive for debt financing

Disadvantages
- Unattractive to the equity market
- Capital costs still likely to be high
- Light rare earths market has less attractive fundamentals

Develop a large, good grade light rare earth deposit

Examples: Rare Element Resources, Arafura Resources, Peak Resources, Frontier Rare Earths
STRATEGY 3: AIMING FOR THE STARS

Advantages
– Potential to a new Bayan Obo or Ionic Clay?
– Lower short term cash burn
– First movers may provide an exit strategy
– Examples of exploration success in rare earths exist

Disadvantages
– Won’t provide cash flow
– May miss the best years of the market
– Exploration generally unattractive for equity investors currently

Find a world class rare earth deposit

Examples: Tantalus Rare Metals, TUC Resources, Namibia Rare Earths, Vale
UNANSWERED QUESTIONS ABOUT PROJECT DELAYS

Why rare earth “oversupply” may not be imminent

Image: Shutterstock
WHAT IS A REALISTIC DEVELOPMENT TIMEFRAME?

**First mover rare earth projects**
- Delays due to technical problems at feasibility stage
- Faced funding problems throughout due to lack of investor awareness

*Typical development timeframe will be 12-15 years*

**Second mover rare earth projects**
- Shorter development time, and lower development cost
- Maturing new market outside of China

*Targeting 5-10 years from purchase to production?*

### COMPARISON OF AUSTRALIAN RARE EARTH PROJECTS

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<td><strong>ALKANE: Dubbo (Forecast 15 years from purchase to production)</strong></td>
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*Data: Company websites*
TYPES OF DELAY AT MINE PROJECTS

Project Delay

Discretionary

Strategic
Portfolio Sequencing
Governmental

Non-Discretionary

Governmental
Equipment
People
Finance
Resource

Direct
Indirect
Cost
Delays
Skilled
Unskilled
Debt
Equity
Quality
Quantity

Source: Trench (2011)
RARE EARTH PROJECTS PRONE TO DELAY

Length of delays at Australian rare earth projects 1999-2012

- Nolans: 4 years
- Dubbo: 6 years
- Mt Weld: 8 years

Frequency of delays at Australian rare earth projects 1999-2012

- Strategic
- Portfolio Sequencing
- Government (Discretionary)
- Government (Non-Discretionary)
- Equipment
- People
- Finance
- Resource

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DEALING WITH AN UNCERTAIN FUTURE

Developing future rare earth industry scenarios to help guide strategy
THE BCG BOX FOR RARE EARTHS SCENARIOS

- **HEAVY SHORTAGE**
  - Chinese exports of heavy rare earths restricted (i.e. partial Chinese WTO victory) AND/OR continued strong demand growth

- **SHORTAGE**
  - Chinese exports of all rare earths fall (i.e. smuggling stopped, Chinese WTO victory, planned reductions) AND/OR higher than expected demand growth

- **SURPLUS**
  - China increases exports of all rare earths (i.e. increased smuggling or loss of WTO case) AND/OR widespread demand destruction occurs.

- **LIGHT SHORTAGE**
  - Preferential export of heavy rare earths AND/OR unexpected strong demand growth (substitution?)

Based on: Boston Consulting Group (BCG)

Increasing shortage of light rare earths

Increasing shortage of heavy rare earths
STRATEGY 1B: THE BY-PRODUCT CASH COW

Advantages
- Primary commodity provides hedge against rare earth uncertainty
- Potentially easier to finance
- Potential earlier cash flow
- Rare earths extraction remains an “option”

Disadvantages
- Metallurgy likely to be complicated
- Won’t work as a co-product or rare earth “as a by-product” operation
- Difficult to achieve scale
- May be unattractive to equity markets

Extract rare earths as a by-product

Examples: Greenland Minerals, Pele Mountain Resources, Alkane Resources, CBMM
STRATEGY 4A: PET PROJECTS (THE “CASH DOG”)

Advantages
– Quick to implement, whilst market still attractive
– Cash generative
– Simple & cost effective
– Lower risk

Disadvantages
– Not a long term solution
– May be more trouble than it’s worth
– Not many obvious opportunities
– Rare earths not conducive to “quick & easy” development
– May not be attractive to equity markets

Do something quick and easy, then move on

Examples: India Rare Earths?

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STRATEGY 4B: DO SOMETHING ELSE!

Advantages
- Hedge against rare earth market risk
- Potential for faster development & cash flow
- Maybe cheaper / easier / lower risk
- Wider range of opportunities available

Disadvantages
- May be unattractive to “rare earth” focused investors
- Skills may not transfer as planned
- Loss of focus
- Spreading resources too thinly

Get involved in a different commodity

Examples: Alkane Resources, Kimberley Rare Earths, Avalon Rare Metals

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STRATEGIES FOR SCENARIOS OR “HORSES FOR COURSES”

Matching strategies to scenarios and trying to prepare for all possible futures
THE BCG BOX FOR RARE EARTHS SCENARIOS

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<td>Positive for &quot;light&quot; rare earth mine projects.</td>
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<tr>
<td>Negative for &quot;light&quot; rare earth mine projects.</td>
<td>Negative for all ROW rare earth mine projects.</td>
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Shortage

Positive for all rest of world (ROW) rare earth mine developers
Negative for all ROW rare earth consumers

Surplus

Negative for all rest of world (ROW) rare earth mine developers
Positive for all ROW rare earth mine developers

Based on: Boston Consulting Group (BCG)

Increasing shortage of light rare earths

Increasing shortage of heavy rare earths

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THE BCG BOX FOR RARE EARTH STRATEGIES

1a: CASH COWS
1b: BY-PRODUCT CASH COW

2a: HEAVY PROBLEM CHILD
2b: LIGHT PROBLEM CHILD

3: FIND A STAR!

4a: CASH DOG
4b: DO SOMETHING ELSE!

Market Share (beating the competition)

Based on: Boston Consulting Group (BCG)
### The Rare Earth Project Scenarios Matrix

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<th>By-Product Cash Cow</th>
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HOMEWORK: PUTTING STRATEGY INTO ACTION

Now implement the strategy-scenario grid:

– Assign probabilities to each of the scenarios
– Define the parameters of the target asset for each scenario
– Determine where your assets fit into these strategies
– Determine the entrance & implementation cost of each strategy
– Select a blend of strategies that cover as many scenarios as possible for the resources & time available
CONCLUSIONS

– Entering “Phase 2”: Mine project development
– Geology: Ore value NOT heavy versus lights
– Technical: Quality NOT scale
– Delays: Oversupply may NOT be imminent
– Future scenarios: Four possible futures
– Potential strategies: Seven possible company strategies
– Dealing with uncertainty: “Horses for courses”
POTENTIAL RESEARCH AREAS

- **Prices:** *What moves rare earth prices*
- **Value Chain:** *Understanding its structure*
- **Technical:** *Quality NOT scale*
- **Environmental:** *Dealing with radiation*
- **Financing:** *Concave metal financing*
- **Delays:** *Project development risk*
- **Strategy:** *Minor metals industry*
CONTACT DETAILS & FURTHER REFERENCE

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