Using SPE Technology to Develop a New Rare Earth Production Paradigm at Bokan, Alaska

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Presented by: Richard Hammen

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A Collaboration for Success

Innovation

Process Implementation

Onsite Operation
Part One
Bokan Project
Summary
Bokan Mountain: A Leading Rare Earth Development Project

“Rare Earths” are the Lanthanide Elements + Yttrium + Scandium
Where is Bokan Mountain?

- Fully secure mineral title & political domain
- Highest Grade NI 43-101 compliant HREE resource in U.S.
- Significant historical exploration:
  * Barker & Warner; USGS 1989
- Nearest American HREE deposit to production - Lifton/11
We Can Walk from the Mine to the Dock

Ease of Access
- Protected Resource Area
- Temperate Climate
- Deep Water Anchorage

Close to Shipping Routes
- Alaska Marine Highway
- 100 km from Prince Rupert
- Proximity to Western Seaboard and Pacific Rim
The Bokan Team to Develop Mine/SPE Processing of Rare Earths

**Technical:**
- Ken Collison – M. Eng
- Jarda Dostal – PhD
- Richard Hammen - PhD
- Anthony Mariano – PhD
- James Barker – P. Geo
- Mike Power – P. Geo
- James Robinson – P. Geo

**Financial & IR:**
- James McKenzie - B. Comm.
- Peter Manuel - CA
- Brendon Ferguson - CA
- Mark MacDonald - B. Comm.
- Byron Fillmore - B. Comm.
The Bokan Deposit has Unusually High HREE Percentage
Overall Process Summary

- **Ore Sorting**
  - Sorting rejects approx. 52% of mill feed as waste and recovers 95% of rare earths
  - 1,500 tpd mine but 750 tpd grinding circuit
  - RESULT IS ALL TAILINGS WILL GO UNDERGROUND AS BACKFILL

- **Nitric Acid Leach**
  - Recycle 80% and process is at 90°C. vs 225°C
  - Environmentally Friendly Technology

- **Solid Phase Extraction (SPE)**
  - Potential to build a custom separation plant using this technology in Southeast Alaska
  - Small Footprint Nanotechnology
  - Low Capex
  - American Engineered
  - Low Cost per Output Unit
Part Two
The Solid Phase Extraction Difference
What do we mean by the term “Solid Phase Extraction”?

Solid Phase Extraction (SPE) was developed as a logical improvement on Ion Exchange resin technology to address the question:

*Could Ion Exchange with Interstitial SPE Columns be better, faster, cheaper?*

Solid Phase Extraction of Rare Earths is an Ion Exchange process using metal-selective binding agents tethered inside nano-composite materials that allow for the rapid separation and processing of Rare Earths.
Why Our Ion Exchange “Resin” is Different

Chromatography or Synthesis Column

Non-porous Silica Or Polymer Beads

Tethered Ligand Polymers Cross-link the Interstitial Volumes
Interstitial Ion Exchange/Chelating Columns bring 3 Factors Together:

1. **Rapid Processing:** The fast exchange kinetics allows one to attain chemical equilibrium with seconds of residence time. This means that high separation factors can be attained in each process step.

2. **Customizability:** We can synthesize, tweak, and optimize ligand chemistry to make columns that have greater selectivity factors for individual elements.

3. **Established Engineering:** The engineering of ion exchange columns and systems is a mature business and processes with Metals US SPE columns are in fact scaled down ion exchange plants.
Part Three
SPE in Action: 
*The Bokan Class Separation Process*
Separation of REE Elements from Bokan PLS using SPE
Class Separation Summary

1. **Waste Removal:** Metal Waste is Removed in Column 1 as a Citrate Solution, and then removed by carbonate precipitation.

2. **Rare Earth Product:** Rare Earths are recovered in an Acetic Acid Solution that can be converted to an oxalate product via oxalic acid precipitation.

3. **High Purity Product:** Rare Earth solution/product is virtually free of all noxious metals (Fe, Al, U, Th), with only significant impurity being calcium.

4. **Industry Leading Results:** Bokan is the only recent Rare Earth Development project to report >99% Removal of Fe, Th, and U in a Class Purification Process.

<table>
<thead>
<tr>
<th>Component</th>
<th>Bulk Solution Precipitate</th>
<th>Purified Solution Precipitate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron, % Fe2O3</td>
<td>14.87</td>
<td>0.02</td>
</tr>
<tr>
<td>Thorium, % Th</td>
<td>0.4150</td>
<td>0.0027</td>
</tr>
<tr>
<td>Uranium, % U</td>
<td>0.1720</td>
<td>0.0018</td>
</tr>
<tr>
<td>% TREE+Y</td>
<td>18.23</td>
<td>27.17</td>
</tr>
<tr>
<td>% *Other</td>
<td>15.11</td>
<td>6.415</td>
</tr>
<tr>
<td>Loss on Ignition, % LOI</td>
<td>45.51</td>
<td>58.98</td>
</tr>
</tbody>
</table>
The Purification Advantage

1. **Waste Returned to Backfill:** Metal waste concentrated as oxide to be remixed in barren ore backfill.

2. **Low Discharge Improves Permitability/Mine Launch/Remediation Prospects:** Reducing discharge ameliorates long standing concerns about Rare Earth Mining being a “dirty” process.

3. **Avoid Downstream Process Fouling:** REE element purification using solvent extraction is often inhibited/fouled by presence of non-REE contaminants, slowing implementation and disrupting production.

4. **High Purity is Essential for Product Value:** Impurities can reduce product value or even prevent salability. Moving product has been a major difficulty lately for MolyCorp/Lynas.
What can be done with excess acid from class purification circuit?

1. **Neutralization/Disposal:** It can be neutralized with a base and the resulting salt can be disposed of.

2. **Neutralization/Regeneration:** It can be neutralized with a base and the resulting salt can be recycled by electrodialysis (ED), such as the Solvay process used at Molycorp for NaCl recycle to HCl and NaOH.

3. **Direct Extraction/Recovery from PLS:** It can be separated from the Rare Earth salts by diffusion dialysis.
Recovery of HNO3 from PLS by Diffusion Dialysis

Mixed REE to Class Purification Circuit

PLS (4-5 M HNO3) with REE’s

Return HNO3 to Leach Circuit
Environmental and Carbon Footprint Differential

Estimated GHG reduction over life of mine : 284,000 tonnes of CO₂

<table>
<thead>
<tr>
<th>Summary (1,500 tpd mine production case)</th>
<th>Tonne CO₂ reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switching sulfuric to nitric acid</td>
<td>Per Day</td>
</tr>
<tr>
<td>Reduction of freight from Asia (80% recycling of HNO₃)</td>
<td>17.39</td>
</tr>
<tr>
<td>Reduction of acid consumption and leaching temperature</td>
<td>9.71</td>
</tr>
<tr>
<td>Waste heat recovery from power plant</td>
<td>36.67</td>
</tr>
<tr>
<td>Switching diesel to natural gas power generation</td>
<td>5.23</td>
</tr>
<tr>
<td>X-ray ore sorting (52% reduction in grinding energy)</td>
<td>9.89</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>78.90</strong></td>
</tr>
</tbody>
</table>

U/G mine & no tailings on surface at closure results in very small footprint and minimizes impacts.

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Part Four
REE Element
Production With SPE
Element Separation Strategy
Subclass Enrichment – The First Step
Process Simplification Relative to Conventional Processing

1. **Process Simplification** – Process reduced to a discrete two column process rather than many SX columns acting in series.

2. **High Purification Factor** – Substantial purification factors obtained in first processing step. Most of mass transfer (acid/base cost) obtained in one load/elution step.

<table>
<thead>
<tr>
<th>Concentrate</th>
<th>Enrichment Factor</th>
<th>% Byproduct Removal</th>
<th>Major Impurity Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy</td>
<td>2.9</td>
<td>65%</td>
<td>83% Ce/La Removal, 69 % Didymium Removal</td>
</tr>
<tr>
<td>SEG</td>
<td>2.8</td>
<td>64%</td>
<td>78% Ce/La Removal, 68% Yttrium Removal</td>
</tr>
<tr>
<td>Yttrium</td>
<td>1.3</td>
<td>26%</td>
<td>47% SEG Removal</td>
</tr>
<tr>
<td>Didymium</td>
<td>1.2</td>
<td>16%</td>
<td>41% Heavy Removal</td>
</tr>
<tr>
<td>Ce/La</td>
<td>4.0</td>
<td>75%</td>
<td>96% Heavy Removal, 90% SEG Removal</td>
</tr>
</tbody>
</table>

*Metals US*
The Bokan Subclass Enrichment System for 2,200 tpa REO
The Cost Advantage of Step Reduction

<table>
<thead>
<tr>
<th>Factor</th>
<th>Solvent Extraction</th>
<th>Solid Phase Extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of stages</td>
<td>~1000</td>
<td>~100</td>
</tr>
<tr>
<td>Acid/base equivalents</td>
<td>2-3</td>
<td>1.15</td>
</tr>
<tr>
<td>Stages A/B Equivalents</td>
<td>~2000-3000</td>
<td>~115</td>
</tr>
</tbody>
</table>
Reagent Recycling to Reduce Cost/Waste

*Nature Uses Element Cycles to Recycle Valuable Materials and Avoid any Permanent “Waste” in the Environment*

Carbon Cycle

Nitrogen Cycle
Process Cycles To Produce Enriched REO From Acid Leach

SPE Columns Enable Efficient Recycling of Process Reagents
Cost of Rare Earth Element Separation Mines with Solvent Extraction Plants Compared to Solid Phase Extraction?

1. Molycorp: > $1 Billion of capital expense

1. Lynas Corp: > $1 Billion of Capital expenses

2. Quest Rare Minerals announces $ 300 M separation plant for 10,423 tpa of produced elements

3. Ucore’s Preliminary Economic Assessment finds entire capital cost for the mine and the 2500 tpa RE element production plant to be $221M. This includes the SPE plant for less than $30M
Part Five
Summary
Permitting and Organization Usually Wags the Dog

- **Process Intensive:** The mine permitting process is a combination of approvals of mine plan operations and closure and involves the politics of the agencies involved.
- **Agency Support:** Ucore has worked with US Department of Defense to get an initial technical “buy in” for the project.
- **Peer Review:** This was done by means of a grant from DOD to Ucore to IntelliMet to describe the process parameters and economics. We gave DOD a 200+ page report with the model of the RE element separation process for the 2250 tpa plant to purify all of the REE’s.
- **Community Support:** Ucore has established excellent relationship with the regional Native American constituency with the prospect of local jobs.
- **Government Bond Offsets:** Ucore has received legislative approval for $145 M bond issue to support the Bokan Mountain mine.
- **Permitting Support:** This ”buy in” by the State political structure should be helpful in reducing the permitting times.
- **Reducing Footprint:** The mine plan is near-zero emissions.
Attention to Overall Package Pays Off

Alaska Legislature Unanimously Approves $145 Million Bond Funding Legislation for Ucore’s Bokan-Dotson Ridge

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April 28, 2014 – Halifax, Nova Scotia – Ucore Rare Metals Inc (TSX-V:UCU) (OTCQX: UURAF) (“Ucore” or “the Company”) is pleased to comment on the passage of Senate Bill 99 (“SB 99” or “the Bill”) by the Alaska State Legislature in a unanimous vote, with all 38 representatives in attendance voting in favor of the Bill.

SB 99 was introduced by Senator Lesil McGuire (AK-R). Senator Bert Stedman (AK-R) proposed the amendment which would authorize the Alaska Industrial Development and Export Authority (“AIDEA”) to issue bonds to finance the infrastructure and construction costs of the Bokan-Dotson Ridge rare earth element project up to a principal amount of $145 million, subject to its own internal due diligence and Board approval. SB 99 was presented to the House by Representative Feige (AK-R) and cross-sponsored in the House by Representatives Munoz (AK-R), Kito III (AK-D), Kreiss-Tomkins (AK-D), Wilson (AK-R) and Isaacson (AK-R).

“I am thrilled to have been able to take the next step toward realizing Alaska’s potential for rare earth minerals mining,” said Alaska State Senator Lesil McGuire (R- Anchorage). I have long seen the need for a US source of these important materials and the potential benefit for Southeast Alaska and our state economy. Senate Bill 99 offers Ucore the chance to partner with AIDEA and make this tremendous project a reality.”
Summary – How to Streamline Mine Opening/Closure

Reduce – Reduce Size (High Througput units), modularize, and simplify process to reduce cost, permitting, power consumption, and implementation time.

Reuse – Employ processes that minimize waste output and environmental impact to avoid permitting and remediation barriers.

Recycle – Recycle reagents to minimize reagent consumption Opex and tailings pond waste.

With Better Technology you Can Have both kinds of Green.