Comprehensive Extraction

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Comprehensive extraction

- The term “comprehensive extraction” was (re)introduced by Dr. Pingru Zhong (China) during an IAEA UxP Technical Meeting, September 26-30, 2011
- Roots in Russian and Chinese research, 1990s (R. Villas-Bôas)
- 70% of mine tailing presently seen as a resource for one commodity or other
- **Disturb the ground once… extract everything of value in one pass**
- Brought into currency during the follow-on Training Workshop, Marrakech, October 31 – November 5, 2011
- Focus on unconventional U resources, mainly Phosphates; but also applicable for copper, coal, oil shales …
- Rethink the flowsheet… rethink the outcome
- Already happening …

See: New 'Comprehensive' Approaches to Uranium Mining and Extraction
### Unconventional (Green?) U Resources

<table>
<thead>
<tr>
<th>Deposit type-subtype</th>
<th>Resources UDEPO (tU)</th>
<th>Grade (ppm)</th>
<th>IAEA UDEPO deposits</th>
<th>World deposits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porphyry copper</td>
<td>100 000</td>
<td>10-40</td>
<td>7</td>
<td>691</td>
</tr>
<tr>
<td>Peralcaline complexes</td>
<td>393 210</td>
<td>50-250</td>
<td>13</td>
<td>125</td>
</tr>
<tr>
<td>Carbonatites</td>
<td>122 342</td>
<td>30-300</td>
<td>11</td>
<td>848</td>
</tr>
<tr>
<td>IOCG</td>
<td>2 308 602</td>
<td>30-250</td>
<td>14</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>Lignite and coal</td>
<td>7 358 112</td>
<td>1-500</td>
<td>33</td>
<td>1600</td>
</tr>
<tr>
<td>Black shale</td>
<td>1 489 147</td>
<td>10-200</td>
<td>44</td>
<td>Several hundred</td>
</tr>
<tr>
<td>Phosphates</td>
<td>13 553 900</td>
<td>50-150</td>
<td>50</td>
<td>1635</td>
</tr>
<tr>
<td>Total</td>
<td>25 325 313</td>
<td></td>
<td>172</td>
<td>5 - 6000</td>
</tr>
<tr>
<td>Sea water</td>
<td>4 500 000 000</td>
<td>3.3 ppb</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Conventional U resources - 7 096 600 tU (The ‘Red Book’ 2011)*
# U & REE concentration in phosphates

<table>
<thead>
<tr>
<th>Country</th>
<th>Deposit</th>
<th>U (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>Djebel Onk</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Djebel Kouif</td>
<td>100</td>
</tr>
<tr>
<td>Australia</td>
<td>Duchess</td>
<td>80 - 92</td>
</tr>
<tr>
<td>China</td>
<td>Undifferentiated</td>
<td>10 - 39</td>
</tr>
<tr>
<td>Egypt</td>
<td>Abu Tartur</td>
<td>40-120</td>
</tr>
<tr>
<td>Israel</td>
<td>Arad</td>
<td>150</td>
</tr>
<tr>
<td>Jordan</td>
<td>Shidyia</td>
<td>46</td>
</tr>
<tr>
<td>Morocco*</td>
<td>Bucraa</td>
<td>70-80</td>
</tr>
<tr>
<td></td>
<td>Khourigba</td>
<td>80-120</td>
</tr>
<tr>
<td>Peru</td>
<td>Sechura</td>
<td>47-80</td>
</tr>
<tr>
<td>Saudia Arabia</td>
<td>Ma’aden</td>
<td>25-85</td>
</tr>
<tr>
<td>Senegal</td>
<td>Taiba</td>
<td>64-70</td>
</tr>
<tr>
<td>Syria</td>
<td>Khneifiss</td>
<td>75</td>
</tr>
<tr>
<td>Tanzania</td>
<td>Minjingu</td>
<td>390</td>
</tr>
<tr>
<td>Togo 77 to 110</td>
<td></td>
<td>77-110</td>
</tr>
<tr>
<td>Tunisia</td>
<td></td>
<td>12-88</td>
</tr>
<tr>
<td>USA</td>
<td>North Carolina</td>
<td>41-93</td>
</tr>
<tr>
<td></td>
<td>Central Florida</td>
<td>59-200</td>
</tr>
<tr>
<td></td>
<td>North Florida</td>
<td>50-143</td>
</tr>
<tr>
<td></td>
<td>Idaho</td>
<td>60-141</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phosphate rock source</th>
<th>Ln$_2$O$_3$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kola, Russia</td>
<td>0.8-1.0</td>
</tr>
<tr>
<td>Florida, USA</td>
<td>0.06-0.29</td>
</tr>
<tr>
<td>Algeria</td>
<td>0.13-0.18</td>
</tr>
<tr>
<td>Morocco</td>
<td>0.14-0.16</td>
</tr>
<tr>
<td>Tunisia</td>
<td>0.14</td>
</tr>
<tr>
<td>Quebec, Canada</td>
<td>0.18</td>
</tr>
<tr>
<td>Ontario, Canada</td>
<td>1.59% (La$_2$O$_3$+Ce$_2$O$_3$)</td>
</tr>
<tr>
<td>Northern China</td>
<td>1.5 – 6.41 (Total R$_2$O$_3$)</td>
</tr>
</tbody>
</table>

* U in phosphates estimated to be 6.5 million tonnes

- In the estimated 70 billion tons of phosphate deposits within the Tethys realm, REE concentration averages 300 ppm.
- This translates to 2.1 billion tons of REE resources.
- It has been experimentally proven that REE also can be extracted along with U using appropriate solvents.
Operationalizing sustainable development

- Accurate and transparent management of essential materials (Natural capital/geological endowment, EGRC-3/2012/INF.1 N.34)
- **Closed (renewable) systems where possible:**
  - Efficient use of inputs – Energy, water, chemicals
  - Optimisation (and use) of all outputs
  - Waste elimination/waste as designation of last resource
  - Recycling and reuse

UNFC – 2009 provides the framework for assessing projects and accounting materials throughout the life-cycle
Assessing comprehensive extraction

Quantities associated with known and potential resources

Contained in Ore concentrates/Phosphoric acid/other intermediate products

Not extracted; available in Wastes/PG process water
Available in raffinite and slags
Available in tailings and clays

Not Commercial for current extraction
Potential for Commercial extraction
Commercially Extracted quantities
Dissipated in products, wastes, environment

Accurate and transparent management of essential materials
Sustainable outcome through integrated flow sheet

Comprehensive Extraction:
- Use and Reuse of all Mineral Resources
- Uses

Flow sheet integration/ modification

Efficient P use
- Comprehensive Use of Each Resource

Sustainability/ Life-cycle tracking - Control Points and Performance Indicators

Agriculture & Livestock
IT, Cars, Batteries
Electricity
Agriculture, Roads, Construction
Industrial Processes

P S
REE
U
PG
S
Solvent extraction for Uranium

1. **Mining & Benefication**
2. **Transport**
3. **Phosphoric Acid Production**
4. **Fertilizer Production**
5. **Shipping**
6. **Acid Pre-Treatment**
7. **Acid Clarification**
8. **Extraction Preparation**
9. **Uranium Extraction**
10. **Drying**
11. **Thickening**
12. **Precipitation**
13. **Purification**
14. **Packaging**
15. **Shipping**
Energy Neutral Phosphate Fertilizer Production

Low-grade Phosphate rock

Coke & Silicia

Heat/Electricity

Thermal Process

Gases

Ferrophos

Slag

Phosphorus

Incineration

Heat

Heat/Electricity

Extraction

Rare Earth Elements

$\text{U}_3\text{O}_8^{^{232}\text{Th}}$

Reactor fuel

Reactor fuel manufacturing

Phosphate fertilizer
Comprehensive extraction lifecycle

- Conceptual Studies
- Scoping Studies
- Pre-feasibility Studies
- Feasibility Studies
- Project Implementation
- Decommissioning

Additional Quantities in Place
- Extraction Project
  - Development Unclarified
  - Development Not Viable

Non-Commercial Project
- Development Pending

Potentially Commercial Project
- Justified for Development
- Approved For Development
- On Production

Commercial Project
- Sales Production
- Non-Sales Production (Dissipated in wastes, products & environment)

Accurate and transparent management of essential materials throughout the lifecycle
Conceptual study

IAEA Technical Co-operation projects active in:

- **Tunisia** – Extraction of U and REE from phosphates (2012-14)
- **Egypt** – Extraction of U and REE from strong Phos acid and granites (2014-15)
- **Philippines** – Extraction of U and REE from Phos acid; Phosphogypsum utilization (2012-15)
- **Jordan** – Extraction of U from Phos acid (2014-15)
- **Preliminary studies are supported by laboratory and bench level tests.**
Thank you