Elkon Metasomatite Uranium Deposits
Russian Federation

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IAEA TM on Metasomatite Deposits, 17-19 June 2013

Acknowledgments:
Elkon metasomatic type deposits
General information

| Total in situ uranium resources | 383 Kt |
| Gold by-product resources       | 170 t  |
| Host rocks                      | Archean-Proterozoic gneiss |
| Ore alteration                  | Pyrite-carbonate-potassium feldspar |
| Shape of ore bodies             | Vein like |
| Ore control                     | Structural |
| Uranium mineralization          | Brannerite |
| Mining method                   | Underground |
| Processing                      | Autoclave leaching |
Elkon Location and infrastructure

The closest town is Tommot with a population of 10,000 people. Tommot is connected with the Baikal-Amur Mainline and the Trans-Siberian Mainline by railroad. A road and electrical power line are located 10 km north of the deposit.
The history of Elkon discovery, exploration, development

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>Regional greenfield exploration for uranium</td>
</tr>
<tr>
<td>1962</td>
<td>1:25,000 scale exploration – detected 400km long U bearing fault zones</td>
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<tr>
<td>1963-1965</td>
<td>Exploration peak (211km drilling, 23km tunnels) resources preliminary estimation</td>
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<tr>
<td>1984-2006</td>
<td>22 years stand by</td>
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<tr>
<td>2007-2011</td>
<td>Resources delineation, modelling, Pre-Feasibility study, engineering, environmental studies, processing, benefication, mining design</td>
</tr>
<tr>
<td>?</td>
<td>Construction, start up, ramp up</td>
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Elkon resources

RB 2011 - Elkon recoverable resources
307Kt – 38% of metasomatite type deposits
and 4,3% of world total resources

Elkon total 2013 in situ resources 383Kt,
including 122Kt of RAR and 261 Kt of Inferred

Elkon known in situ U resources - 383 Kt at 0,14%, 170t Au
In situ U resources of Yuzhnaya + Severnoe - 357Kt at 0.15% U, 109t Au
Elkon – world class project with tremendous scale

The Largest Undeveloped Uranium Deposit in the World

- Elkon is the largest Non-Producing uranium deposit in the world by uranium resources
- Elkon’s annual design production capacity is up to 5,000 tones of uranium, making it one of the largest primary uranium producing asset
- The Elkon project has one of the longest mine life

Production capacities of largest uranium projects in the world * (tU per year)

<table>
<thead>
<tr>
<th>Project</th>
<th>Production Capacity (tU per year)</th>
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<tbody>
<tr>
<td>Elkon</td>
<td>5,000</td>
</tr>
<tr>
<td>Imouraren</td>
<td>4,000</td>
</tr>
<tr>
<td>Jabiluka</td>
<td>3,000</td>
</tr>
<tr>
<td>Rossing</td>
<td>2,000</td>
</tr>
<tr>
<td>Trekopje</td>
<td>1,000</td>
</tr>
<tr>
<td>McArthur River</td>
<td>6,000</td>
</tr>
<tr>
<td>Cigar Lake</td>
<td>5,000</td>
</tr>
<tr>
<td>Rosing South</td>
<td>4,000</td>
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<tr>
<td>Ranger</td>
<td>3,000</td>
</tr>
<tr>
<td>Prargunsky</td>
<td>2,000</td>
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<tr>
<td>Lethakane</td>
<td>1,000</td>
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<tr>
<td>Yeelirrie</td>
<td>0</td>
</tr>
<tr>
<td>Letthakane</td>
<td>0</td>
</tr>
<tr>
<td>Trekopje</td>
<td>100</td>
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<tr>
<td>Michelin</td>
<td>100</td>
</tr>
<tr>
<td>Kiggavik - Sissons Schultz</td>
<td>200</td>
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<tr>
<td>Valencia</td>
<td>300</td>
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<tr>
<td>Etango</td>
<td>400</td>
</tr>
<tr>
<td>Novokonstantinovskoe</td>
<td>500</td>
</tr>
<tr>
<td>Rossing South</td>
<td>600</td>
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<tr>
<td>Jabiluka</td>
<td>700</td>
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<tr>
<td>Cigar Lake</td>
<td>800</td>
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<tr>
<td>Imouraren</td>
<td>900</td>
</tr>
<tr>
<td>Elkon</td>
<td>1,000</td>
</tr>
</tbody>
</table>

*Excluding Olympic Dam

Source: Companies’ reports
1 – intrusives of the Mesozoic tectonic-magmatic event (Middle Jurassic- Early Cretaceous); 2 – Upper Jurassic terrigeneous deposits; 3 – Cambrian limestones and dolomites; 4 – area of Early Proterozoic intense palingenetic formation of granites; 5 – Archea-Lower Proterozoic schists, gneisses, granites; 6 – faults: observed (a) and inferred (b)
Elkon geological and tectonic setting

1 - Mesozoic intrusions; 2 - Cambrian platform carbonate formations; 3 - Pre-Cambrian metamorphites and granitoids; 4 – Blastomylonite  5 – Rejuvenated old faults  6 - Mesozoic tectonic zones; 7 - Uranium Deposits
1. Rejuvenated ancient fault zones – the main type

2. Mesozoic fault zones with simple structure

Schematic cross section through Yuzhnaya zone

1- gneiss, 2- granite, 3- orthotectite, 4- metamorphosed ancient diorite dikes, 5- blastomilonites and cataclasites, 6- faults, 7- metasomatites, 8- ore bodies

A – cross section of the Pologaya zone, the Snezhnaye deposit; B – internal structure of the ore zone (a sketch drawing of the cross-cut’s wall)

1 – granitized gneisses; 2 – granites; 3 – faults; 4 – metasomatites; 5 – ore bodies; 6 – post-ore quartz breccias
2. Fault zones at the contacts of Mesozoic dikes

3. Variably oriented complicated Mesozoic faults

**A - cross section of the Agdinskaya zone, the Agdinskoye deposit. B - internal structure of the ore zone (a sketch drawing of the trench wall)**

1 - granitized gneiss; 2 - granite; 3 - faults; 4 - metasomatites; 5 - ore bodies

**A - cross section of the mineral deposit in the Interesnaya zone; B - relations between dykes and uranium mineralization (a sketch drawing of the trench).**

1 - granitized plagiogneisses; 2 - granites; 3 - voge-sites; 4 - syenit-porphries; 5 - alkal dykes (solv-bergites, grorudites); 6 - faults; 7 - metasomatites; 8 - ore bodies
Yuzhnaya Zone. Distribution of Uranium and Gold mineralization
(Projection on Vertical Section and plan view)
Yuzhnaya zone. Ore bodies morphology

About 20 ore bodies located in 3 ore zones within the Yuzhnaya fault zone

- Ore bodies have complicated morphology with significant variations in thickness over short intervals.
- Ore zone includes areas with closely-adjacent and parallel veins, making selective mining difficult. Bulk mining will add more dilution requiring radiometric sorting.
- Length of ore bodies along strike: 50 to 400m, up to 700m;
- Length of ore bodies down dip: 100 to 200m.
- Thickness varies from 0.9 to 4m, average about 1.3m
Aldan region, Elkon District, a Plan and b SW-NE cross-section across a U mineralized structure illustrating the distribution of alteration zones and U mineralization along rejuvenated blastomylonite intervals (after Kazansky and Laverov 1977 based on Krupenikov et al. 1968)
Three main uranium mineralization types

**Gold-brannerite mineralization**

- Main importance and typical for U deposits. Ore control is by reactivated ancient faults traced by blastomylonites. Mineralization is of veinlet-disseminated type and commonly located within gold bearing pyrite-carbonate-potassium feldspar altered zones. Brannerite is the only primary U mineral. Gold and silver are bound in pyrite.

**Gold-uraninite mineralization**

- Is known where Mesozoic stocks and dikes are abundant. Ore control and geological setting are similar to gold-brannerite except that the uraninite is restricted to zones of thermal metamorphism. Pyrite tends to be the essential host of native gold (9.1 to 24.5 ppm).

**Brannerite-silver-gold mineralization**

- Is reported in the southwestern part of the horst. Ore control and geological setting are similar to the gold-brannerite. Ore lodes consist of gold-bearing metasomatic rocks intersected by thin brannerite stringers and quartz and carbonate veinlets with pyrite, native gold, native silver, and acanthite.
Uranium mineralization. Textures and structures

At the Elkon deposit uranium mineralization occurs largely as brannerite \((U^{4+},Ca)(Ti,Fe^{3+})_2O_6\)

The mineral is a refractory ore of uranium. In addition other uranium minerals are present in lower amounts such as:

coffinite \((U,\text{Th})[(\text{OH})_{4x}]_{4x-1}[(\text{SiO}_4)_{1-x}]\)

and urannite \(\text{UO}_2\)

The uranium minerals occur in breccia fragments in the calcite-fluorite veins.

Gold occurs as sub-micron grains or micron sized inclusions in pyrite and galena. The sulphides occur in quartz and calcite as inclusions and in fractures and on grain surfaces.
Metallogenesis aspects

• The ore forming process started with the gold-bearing pyrite-carbonate-orthoclase alteration with most of the gold contained in pyrite.

• Subsequently uranium was introduced into the previously altered rocks by hydrothermal fluids initiated by the tectono-magmatic activation of the Aldan Shield.

• Uranium was deposited as brannerite and formed structurally controlled deposits in rejuvenated ancient fault zones.

• Brannerite age 160-113My, major measurements 137-130My (U-Pb method)

• There is no vertical zoning in the uranium-bearing zones.

• Thermobarometric studies indicate variations of temperatures during the entire metallogenetic evolution of the Elkon ores. Pre-ore quartz formed at 230-290 °C, ore post ore quartz at 160-200 °C. Pre ore metasomatic alteration 300 °C.
Ore control and recognition criteria

**Host Environment**
- Archean-Early Proterozoic gneiss and granitoids
- Reactivated in Mesozoic ancient NW steeply dipping ancient faults

**Alteration**
- Pre-uranium Mesozoic pyrite-carbonate-potassium feldspar with dispersed gold.

**Mineralization**
- Principal ore assemblages are gold-brannerite, gold-uraninite and brannerite-silver-gold
- Early gold is dispersed in pyrite of the pyrite-carbonate-potassium feldspar alteration facies
- Brannerite, the only primary U mineral, is superimposed on earlier gold mineralization
- Location, shape, dimensions of deposits largely defined by brecciated intervals of faults and host rocks.
- Veinlike or columnar shape of ore bodies;
Yuzhnaya zone 3-D wire frame modeling

Elkon Data base
- Number of exploration holes, trenches – 7 354;
- Number of samples (measurements) – 976 371;
- Uranium grade variation 0,001% to 8,7%

Data base on Au, Ag, Mo
- Number of samples – 17 785
Block model for one of the Yuzhnaya Zone deposits
In 2010 ARMZ developed a 3-D block model for Yuzhnaya Zone and recalculation of the Yuzhnaya Zone resources according to the JORC Code. The Yuzhnaya Zone JORC resources amounted to 229 834 tU with average grade of 0.143%U. Amounts are similar to 1981 evaluation.
Elkon schematic processing flow sheet

- **Plant recovery**
  - Uranium 91%
  - Gold 43.4%
  - Silver 35.8%
  - Molybdenum 38.9% (Druzhnoye)

Hydro metallurgical works

U3O8 storage area

Productive solutions

Floatation tailings, U

Floatation concentrate, Au

Refining

Sorption

Leaching U

Calcining

Milling

Mines

Piles

U, Au

Heap leach.*

Radiometric sorting

Deposits

Primary radiometric sorting

Waste rock

- Crushing
- Radiometric sorting
- Milling (-0.3 mm)
- Flotation (if the gold is processed)
- Thickening
- Autoclave leaching of flotation concentrate and flotation tails
- Adsorption of uranium onto resin
- Stripping of uranium from the resin,
- Precipitation and dewatering of the uranium
- Cyanide leaching of gold

*Heap Leaching considered as a potential prospective technology for low grade ores processing