Uranium Resources in the Middle East

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\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{map.png}
\caption{Map of the Middle East showing uranium resources.}
\end{figure}
The increase in the use of nuclear power worldwide increases the price of uranium.

These trends are traceable worldwide and it will continue to grow.
Although best known for its hydrocarbon resources, oil, the Middle East together with several North African countries is potential home to uranium bearing deposits that have not been fully investigated and explored.

Thus it is important to know where presently reported uranium resources are located, and further investigate and locate additional ones.
The Red Book

- The Red Book is a document published by the European Union and The International Atomic Energy Agency every two years, and it gives the official uranium resources reported by every member country, according to specified categories.

- However, scientific literature of Uranium Geology does not coincide completely with the information presented in the Red Book especially in the Middle East.
A vast amount of information resides in reports, Master’s theses and Ph.D. dissertations in universities throughout the Middle East region. Compilation from these latter data bases is only in the beginning stages to form a background to move forward in a structured uranium exploration program.

An attempt made through 6ICGM to present the significant findings in form of maps and tables. Integration with large scale geotectonic features is still in process.

Presentations

Introductory Session:

- Meeting Agenda
- Introduction to the Technical Meeting by Jan Slezak, IAEA scientific secretary
- Jordan welcome address - a background situation speech on nuclear issues by HE Khaled Toukan, JAEF
- IAEA subprogramme on uranium production cycle by Jan Slezak, IAEA
- Nuclear developments in the Middle East countries by fores, Kuwait, USA
- Working Group on Uranium Production by Jan Slezak, IAEA

Current uranium production cycle issues:

- Uranium exploration of the Middle East with focus on new, prospective, and mining potential by fores, Kuwait, USA
- IAEA/DEGA-IEA/IAEA Uranium Group recent activities and Red Book 2007 by Jan Slezak, IAEA
- Recent developments in uranium production cycle in Jordan by Ned Koval, IAEA
- Nuclear safety aspects in uranium production cycle by Shaun, Ux, IAEA

Uranium geology and exploration:

- Recent developments in uranium exploration in Canada by Geoff, Canada
- Uranium mineralization of the Barroela deposit, El Aouina, North East, China by Wei, China
- Remote sensing and reflection spectroscopy as useful tools for uranum exploration by fores, Kuwait, USA
- Nuclear exploration methods and techniques by Geoff, Canada
- Methodology for uranium exploration in Jordan by Abdelsalam, Egypt

Uranium production:

- Recent developments in uranium exploration in Australia by Aden, Meloy, Australia
- Reserve estimation for uranium deposits by Abdelsalam, Egypt
- IAEA guide on radiation safety aspects in the uranium production cycle by Shaun, Ux, IAEA
- Results of the IAEA TM on "Implementation of the Sustainable Best Practice in Uranium Mining and Processing" by Jan Slezak, Shaun, Ux, IAEA
- Nuclear power plant site selection by Abdelsalam, Egypt
World Distribution of Uranium Deposits (UDEPO)

UDEPO web site
- It gives list of deposits
- Provides easy navigation and search

- Gives worldwide summaries
- This example gives the initial uranium amounts in the deposits by country and by deposit type
Some global examples from the Red Book

Countries with major Identified uranium resources and countries with major nuclear power

Known Identified Resources: 4.743 million tons U
Undiscovered Conventional Resources (prognosticated+Speculative): 7.07 million tons U
Undiscovered Speculative (cost range unassigned): 2.98 million tons U
Unconventional Resources in Rock Phosphates alone: 22 million tons U

Uranium Production (total 41.360 tU in 2005)

<table>
<thead>
<tr>
<th>Country</th>
<th>Uranium Resources Tons U (Percentage of world)</th>
<th>No. of Operating NPPs (% Electricity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>1 143 000</td>
<td>24%</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>816 000</td>
<td>Nil</td>
</tr>
<tr>
<td>Namibia</td>
<td>382 539</td>
<td>Nil</td>
</tr>
<tr>
<td>Niger</td>
<td>225 459</td>
<td>Nil</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>115 526</td>
<td>2.5%</td>
</tr>
<tr>
<td>USA</td>
<td>34 2000</td>
<td>7%</td>
</tr>
<tr>
<td>Canada</td>
<td>443 800</td>
<td>3.4%</td>
</tr>
<tr>
<td>South Africa</td>
<td>340 936</td>
<td>7%</td>
</tr>
<tr>
<td>Russian Fed.</td>
<td>172 402</td>
<td>3.5%</td>
</tr>
<tr>
<td>Brazil</td>
<td>77 700</td>
<td>0%</td>
</tr>
<tr>
<td>India</td>
<td>64 040</td>
<td>1.4%</td>
</tr>
<tr>
<td>China (excl. Taiwan)</td>
<td>50 720</td>
<td>1.2%</td>
</tr>
<tr>
<td>France</td>
<td>100% from overseas sources</td>
<td>59 (73%)</td>
</tr>
<tr>
<td>Germany</td>
<td>100% from overseas sources</td>
<td>18 (22%)</td>
</tr>
<tr>
<td>Japan</td>
<td>100% from overseas sources</td>
<td>54 (20%)</td>
</tr>
<tr>
<td>Korea (R.O.)</td>
<td>100% from overseas sources</td>
<td>19 (58%)</td>
</tr>
<tr>
<td>UK</td>
<td>100% from overseas sources</td>
<td>23 (19.4%)</td>
</tr>
</tbody>
</table>
The International Atomic Energy Agency assigns the uranium deposits according to their geological settings to 15 main categories of deposit types arranged according to their approximate economic significance [IAEA, 2004]:

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Unconformity-related deposits</td>
<td></td>
</tr>
<tr>
<td>2. Sandstone deposits</td>
<td></td>
</tr>
<tr>
<td>3. Quartz-pebble conglomerate deposits</td>
<td></td>
</tr>
<tr>
<td>4. Vein deposits</td>
<td></td>
</tr>
<tr>
<td>5. Breccia complex deposits (Olympic Dam type)</td>
<td></td>
</tr>
<tr>
<td>6. Intrusive deposits (granite type)</td>
<td></td>
</tr>
<tr>
<td>7. Phosphorite deposits</td>
<td></td>
</tr>
<tr>
<td>8. Collapse breccia pipe deposits (north Arizona)</td>
<td></td>
</tr>
<tr>
<td>9. Volcanic deposits</td>
<td></td>
</tr>
<tr>
<td>10. Surficial deposits (calcrete)</td>
<td></td>
</tr>
<tr>
<td>11. Metasomatite deposits</td>
<td></td>
</tr>
<tr>
<td>12. Metamorphic deposits</td>
<td></td>
</tr>
<tr>
<td>13. Lignite</td>
<td></td>
</tr>
<tr>
<td>14. Black shale deposits</td>
<td></td>
</tr>
<tr>
<td>15. Other types of deposits</td>
<td></td>
</tr>
</tbody>
</table>
Potential occurrences of Uranium in the Middle East

These books have covered global uranium supply, but little to no information on the Middle East!

Several exploration models are available but not applied or tested in the Middle East.

1-Models of origin and guides for exploration include Pena Blanca, Mexico, and Ben Lomond, Australia, mineral districts.

2-Models of origin and guides for exploration include Yeelirrie, Western Australia and Langer Heinrich in Namibia (e.g. S3 and S4 are adjacent and related).

3-Model for the sabkhah (playa) calcrete mineralization is the Lake Way U deposit in Western Australia.

F. M. Howari, May 2009
Regional geology, southern Kazakhstan

Regional geology, southern Kazakhstan

Aden M., Geosciences Australia
Mineralised sequence and underlying hydrocarbon basins

Cenozoic
Mesozoic
Sedimentary basins underlain by Palaeozoic sediments
Archaean, Proterozoic and Palaeozoic metasediments and granitoids
Redox front in Palaeogene sands
Redox front in Upper Cretaceous - upper sands
Redox front in Upper Cretaceous - middle sands
Outline of hydrocarbon region

Uranium mine
Oil/gas field
Gas field

Aral Sea
Kyzl-Orda
Karamurun
Zarechnoye
Chinkent

Turgai Hydrocarbon Region
Chu-Sarysu Hydrocarbon Region
Chu-Sarysu Basin
Karakum

Lake
45° N

Aden M., Geosciences Australia
Sandstone uranium systems

Kazakhstan model (below):
Large basin rimmed by U-rich felsic rocks
Highly permeable sandstones
Very low concentration of organic and inorganic reductant

HC as the main reductant: localised and effective reduction

Single fluid model

Two fluids model

Aden M., Geosciences Australia
Geologically speaking the Middle East could have several distinct types of uranium deposits; these could include unconformity related, sandstone hosted, paleoplacer, phosphate calcrete and pegmatite.

However, by far the most important type of economic uranium deposit in the Middle East is yet to be determined.
The Middle East could be considered to house some 20 billion tons of phosphate resources, which, at 20% P2O5 as an average, would contain 4 billion tons P2O5. Most of the Middle East phosphates contain uranium to some extent. The uranium occurs mainly as a replacement element in the structure of fluorapatite and francolite phosphate minerals.

Resources of phosphate of Late Cretaceous and Paleocene age in the Middle East, defined as Iraq, Iran, Jordan, Saudi Arabia, and Syria have been estimated at about 15.7 billion tons containing about 3.4 billion tons of P2O5.
The concentration of uranium varies from country to country and deposit to deposit. For scoping purposes, taking an average U content of 60-120 ppm, the Middle East phosphate resources would contain 1.2 million tons of uranium.

Uranium extraction requires the conversion of phosphate to phosphoric acid followed by solvent extraction. Thus, recovery of uranium from phosphates is essentially dependent on installed phosphoric acid production capacity and what fraction of that capacity is subject to extraction of uranium.
The Pan African granites (about 600-500 Ma) are one of the most favorable environments to host vein type uranium deposits. This case is very clear in Algeria, Morocco, Egypt, Sudan, Saudi Arabia, Turkey, and other countries as well.

The uranium mineralizations are hosted in these granites within some favorable structures as faults and fractures.

The presence of intra-cratonic basins within many basement rocks exposures are another favorable environment. Often these basins are filled with late Proterozoic molasses type sediments as Hammamat series in Egypt and can form important uranium traps according to their geochemical and geological characteristics.
Selected examples

Jordan

• 1980 - aerial radiometric survey of the entire country

• 1982, 1989, 1997: phosphate evaluation, were close to extraction plant construction

• 1700 trenches
• 15000 car-borne and foot gamma measuring points

• 11000 emanometry and track-etch radon gas points

• Hundreds of boreholes

• Thousands of samples were collected and analyzed
# New Jordanian Discoveries

## NRA Estimated Uranium Ore (U₃O₈) Deposit

<table>
<thead>
<tr>
<th>Central Jordan Uranium Areas</th>
<th>Block</th>
<th>Area km²</th>
<th>Total Area km²</th>
<th>Average Conc. ppm</th>
<th>Total Average Conc. ppm</th>
<th>Average Ore Thick. meter</th>
<th>Estimated Uranium Ore (U₃O₈) Inventory (tones)</th>
<th>Total Estimated Uranium Ore (U₃O₈) (tones)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siwaqa</td>
<td>1</td>
<td>7.1</td>
<td></td>
<td>688</td>
<td></td>
<td>1.25</td>
<td>8.548</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>14.9</td>
<td>28.1</td>
<td>778</td>
<td>592</td>
<td>1.27</td>
<td>20.4</td>
<td>34320</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.82</td>
<td></td>
<td>488</td>
<td></td>
<td>1.42</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5.26</td>
<td></td>
<td>415</td>
<td></td>
<td>1.49</td>
<td>4.57</td>
<td></td>
</tr>
<tr>
<td>Attarat and W. Maghar</td>
<td>1</td>
<td>7.56</td>
<td>22.73</td>
<td>405</td>
<td>345</td>
<td>1.34</td>
<td>5.74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.5</td>
<td></td>
<td>342</td>
<td></td>
<td>1.23</td>
<td>2.06</td>
<td>14965</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4.8</td>
<td></td>
<td>263</td>
<td></td>
<td>1.31</td>
<td>2.315</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>6.87</td>
<td></td>
<td>371</td>
<td></td>
<td>1.36</td>
<td>4.85</td>
<td></td>
</tr>
<tr>
<td>Khan Azzabib</td>
<td>KZ</td>
<td>9.18</td>
<td>9.18</td>
<td>946</td>
<td>948</td>
<td>1.28</td>
<td>15.595</td>
<td>15595</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>60</td>
<td>60</td>
<td></td>
<td>1.32</td>
<td></td>
<td>64880</td>
<td>64880</td>
</tr>
</tbody>
</table>

*Estimated Uranium Ore (U₃O₈) Deposit*

- **Central Jordan Uranium Areas**: Siwaqa, Attarat and W. Maghar, Khan Azzabib
- **Areas**: Central Jordan Uranium Areas
- **Blocks**: 1 to 4
- **Areas**: 7.1 km², 14.9 km², 0.82 km², 5.26 km², 7.56 km², 3.5 km², 4.8 km², 6.87 km²
- **Total Areas**: 22.73 km², 28.1 km²
- **Average Concentrations (ppm)**: 688, 778, 488, 415, 405, 342, 263, 371
- **Total Average Concentrations (ppm)**: 592, 1.25, 1.27, 1.42, 1.42, 1.34, 1.23, 1.36
- **Average Ore Thick. Meter**: 1.25, 1.27, 1.42, 1.49, 1.34, 1.23, 1.31, 1.36
- **Estimated Uranium Ore (U₃O₈) Inventory (tones)**: 8.548, 20.4, 0.8, 4.57, 5.74, 2.06, 2.315, 4.85
- **Total Estimated Uranium Ore (U₃O₈) (tones)**: 34320, 14965, 15595

*Note: Values are rounded for presentation purposes.*
ALGERIA

- Tassili, Tahaggart, Eglab, Ougarta, Tamart, Timouzeline, Timgaouine, Abankor, El-Bema, Ait-Oklan, Abankor, Tinef, Tesnou, Pharusian

- A1: exist in southern Hoggar (north of A2) it belongs to Upper Proterozoic unconformity & basal conglomerates

- A2: exist in continental sandstone and found in Tassili south of the Hoggar. General geological character: Tin-Seririne basin, Tassilian sedimentary cover above the Proterozoic unconformity (A1). Specific locality/deposit names: Tahaggart deposit, southern Tassili; also Eglab, Ougarta Tamart-N-Iblis, Timouzeline,

- A3: it can be found in vein and granitic shear zone. Deposit located in southwestern Hoggar, western Hoggar. General geological character: veins in faults in granite batholiths; specific locality/deposit names: Timgaouine, Abankor, El-Bema, Ait-Oklan; occurrences at Abankor, Tinef, and Tesnou.

- A4: found in western Hoggar; the specific locality/deposit names is Pharusian chain
SAUDIA: Ar Rawdah, Al Hanakiyah; Hulayfah, Jabal Asfar, Shwelil, Tabuk, ad Dumathah, Turayf

S1, exist in volcanic type in north central, and consist of Precambrian felsic volcanics, calderas, Umm Misht formation of the Shammar group.

S2 deposit type: sandstone in Tabuk basin, black shales have high U, and adjacent sandstones are prospective targets. Specific locality/deposit names: locations: Tabuk basin (28 30’N; 36 20’E).

S3 deposit type: calcrete; Hulayfah belong carbonate evaporite facies have between 10 and 350 ppm U;

S4, deposit type: sabka, general geographic region: Sabkhah ad Dumathah, general geological character: lake beds, specific locality/deposit names: locations: Sabkhah ad Dumathah (23 35’N; 40 25’E)

S5, deposit type: phosphate, general geographic region: general geological character: Phosphate beds in the Turayf basin contain U.
Potential occurrences of Uranium in the Middle East e.g. Egypt and Saudi Arabia

“Igneous & Metamorphic-related Vein-types deposits consist of U mineralization in lenses or sheets or disseminations filling joints, fissures, fractures and stockworks in post-accretionary structures which include several fault systems e.g. Najd fault system. The deposits are commonly spatially related to peraluminous granites especially at their contact with host rocks of siltstones and greywackes.”
Some opinions suggest that convective circulating fluids (mixture of meteoric and connate waters), heated in response to intensive tectonism, leached U from the host metasediments and transported it as uranyl-carbonate complexes to the marginal zone of the granite plutons.
Abu Rusheid Shear Zone

Precipitation of secondary U-minerals along walls of joints and fractures

After Hashad, NMA
Distribution of uranium in phosphorite by fission tracks method.

A- Hard phosphorite: different phosphatic elements with coated grain (bone) in natural light.
B- Same sample in A- fission track study:
   - Matrix free of uranium.
   - Uranium is always related to phosphatic grain.
   - The coated grain, uranium in the nucleus is less than in the cortex.
C- Uncoated phosphatic grain-pigmented at the cortex by organic matter-
   natural light-Morocco phosphorite
D- The same sample in C-fission track study: The pigmented cortex is more richer in uranium (363 ppm), than non pigmented internal part of the grain (2, 82 ppm).

After Othman I, (Syria's Atomic Energy Commission ) 2006,
Conclusion: There are lots of potentials for development of Uranium Resource exploration programs in the Middle East.

Hundreds of Anomalies and potential have Identified across the Middle East. Examples were given from Jordan, Saudia, Egypt, Libiya, and Syria, and Algeria.

Recommendation: Utilization of petroleum drill data for oil exploration (Gamma ray Logs!)
Thank You