Sandstone Uranium Deposits Associated with Hydrocarbon-Bearing Basins: Implications for Uranium Exploration in Australia

Subhash Jaireth, Aden McKay, Ian Lambert
**Reductants in Sandstone U Systems**

**Reductant type:**
- **Organic:**
  - Plant material, humic substances etc
  - Hydrocarbons
- **Inorganic**
  - Sulphides, Fe$^{+2}$-bearing silicates etc

**Reductant mode:**
- In-situ
- Introduced
### U-bearing Basins and Content of Reductants in the Sandstones

<table>
<thead>
<tr>
<th>Basin/Sub-Basin</th>
<th>Resources (thousand tonnes $\text{U}_3\text{O}_8$)</th>
<th>Organic Carbon (wt%)</th>
<th>Iron sulphide (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chu-Sarysu and Syrdarya</td>
<td>1,340(^1)</td>
<td>$&lt; \sim 0.03 - 0.05(^2)$</td>
<td>0.1(^3)</td>
</tr>
<tr>
<td>Callabonna (Frome Embayment)</td>
<td>41.2(^4)</td>
<td>$&lt; 0.05$ to 0.5(^5)</td>
<td>Traces(^5)</td>
</tr>
<tr>
<td>Wyoming</td>
<td>320(^6)</td>
<td>0.5(^3)</td>
<td>1 to 4(^3)</td>
</tr>
<tr>
<td>South Texas</td>
<td>45 to 80(^7)</td>
<td>$&lt; 0.16(^8)$</td>
<td>0.5 to 4(^8)</td>
</tr>
</tbody>
</table>

\(^1\) Fyodorov (1999); \(^2\) Petrov (1998); \(^3\) Fyodorov (1996); \(^4\) Ozmin database, Geoscience Australia (2007); \(^5\) Heathgate Resources (1998); \(^6\) after de Voto (1978); \(^7\) Dhalkamp (1993); \(^8\) Goldhaber et al., (1978)
Outline

• Geology of Chu-Sarysu and Syr-Darya Basins in Kazakhstan which host (only briefly; for details see the paper at: http://www.ga.gov.au/ausgeonews/ausgeonews200803/uranium.jsp
  – Large U deposits in Sandstones poor in organic material
• Spatial association between the deposits and the hydrocarbon basin underlying the host
  – Possible role of hydrocarbons as reductants
• Implications for exploration in Australia
  – Where?
  – How?
Two major faults (Late Devonian):
- Karatau
- ZK

Chu-Sarysu Basin: Large continental, intermontane
Cross-Section with Host Sequences

Diagrammatic - not to scale

- Neogene and Quaternary:
  - Alluvium and sediment
  - Palaeogene:
    - Clay/silt - thick aquitard
    - Sand

- Upper Cretaceous:
  - Clay/silt
  - Medium and fine grained sands
  - Coarse grained sand/gravel

- Palaeozoic:
  - Shale, sandstone limestone; locally hydrocarbons-bearing
  - Jurassic - Lower Cretaceous
  - Granite

- Uranium deposits
Mineral Composition and Zoning

- Main minerals: Coffinite and Pitchblende
- Ore enriched in Re, Zn, Cu, Ag, Co, Mo, Ni, V
Age of Mineralisation

Lead-lead model ages of Ore-zone:

- Age of the host rock: Late Cretaceous and Palaeogene
- Mineralisation in two/three more or less continuous stages
  - From Late Oligocene to Middle Miocene (~30 Ma - 15 Ma)
  - To Late Pliocene to Quaternary (<3 Ma)
  - Ongoing re-deposition of ore
- Age related to tectonic re-activation in the Tian-Shan and Karatau
Sources of Uranium

Uranium rich felsic rocks at the margins of the basin

Uranium rich felsic rocks underlying Mesozoic sequence

Uranium rich minerals in the arkosic sandstone
Type of Fluid and Fluid Flow

Palaeo fluid-flow
– From the Tian-Shan highlands (~ E to W)

Present-day fluid-flow
– From the Karatau highlands
– Post Pliocene uplift

Fluid composition
• Low salinity: 900 to 6000 mg/l TDS
• Neutral pH and oxygen saturated
• Host sandstone aquifer: coarse-grained arkosic sandstone
  – Major minerals: Quartz, feldspar, muscovite, biotite, kaolinite, montmorillonite, siderite, pyrite (0.1 wt%)
  – Sandstones poor in organic material (< 0.03 to 0.05 wt%)
• What was the reductant that formed the world’s largest uranium deposits in sandstones poor in organic material?
Basement:
Proterozoic Metamorphics;
Early Palaeozoic volcanics and granites

Host:
• Late Cretaceous to Cainozoic
• Continental and marine (including redbeds)

• M. Carboniferous-Permian (2500m)
  – Alluvial-Lacustraine with redbeds (500 m)
• E. Carboniferous (< 2000 m)
  – Paralic & shallowmarine; coal-bearing strata
• L. Devonian to E. Carboniferous (< 800 m)
  – Lagoonal, marginal marine, salt-bearing strata
Mineralised Sequence and underlying Hydrocarbon-bearing Basins

- Sedimentary basins underlain by Palaeozoic sediments:
  - Redox front in Palaeogene sands
  - Redox front in Upper Cretaceous - upper sands
- Archaean, Proterozoic and Palaeozoic metasediments and granitoids:
  - Redox front in Upper Cretaceous - middle sands
- Cenozoic:
  - Outline of hydrocarbon region
- Mesozoic:
  - Oil/gas field
  - Gas field
  - Uranium mine

Cross-section orientation:
- 65° E to 70° E
- Turgai Hydrocarbon Region
- Chu-Sarysu Hydrocarbon Region
- Karatau Mountains
- Aral Sea
- Lake
- Kyzl-Orda
- Karamurun
- Syrdarya Basin
- Zarechnoye
- Chimkent
Sandstone Uranium and Hydrocarbon Basins

• In Kazakhstan a spatial association exists between:
  – HC-bearing basins and overlying U-hosting sandstones
  – Indicating that HCs and/or H$_2$S from HC-reservoirs (along structures) could have functioned as effective reductants

• Hydrocarbons as reductants been shown in:
  – Organic-poor sandstone hosted deposits in South Texas Costal plains (Adams and Smith, 1981)
  – Several basins in China (Ordos, Song-Liao and Tarim)
Sandstone Uranium and Hydrocarbon Basins in China

- Tarim
- Ordos
- Qaidam
- Song-Lio
Hydrocarbons as Reductants (Ordos Basin, China)

Carbon isotope composition ($\delta^{13}C$) of calcite cement in sandstone

- Very light hence consistent with derivation from hydrocarbons

Fluid inclusions in calcite cement and fracture fills

- contain hydrocarbons

Oil and gas seepage

Oil and gas in sandstones

Residual asphalt

Chunfang Cai et al, 2005; Hunga Xian-fang et al, 2005
Sandstone Uranium Systems

Large basin rimmed on three sides by U-rich felsic rocks
Highly permeable sandstones
Very low concentration of organic and inorganic reductant

Single fluid model

HC as the main reductant: localised and effective reduction

Two fluids model
Possible Hydrocarbon-Associated Sandstone Uranium (Australia)

Outcropping Namba and Eyre Formations and Equivalents in SA and Qld

Cainozoic Basins
- With sandstone aquifers
- In proximity to U-rich felsic rocks
- Overlying HC-bearing basins
Schematic Cross-Section through Western Eromanga Basin

Up to 10 ppb U

Up to 10 ppm U
Conclusions I

Basins with Potential for HC-associated Sandstone Uranium Deposits in Australia:

• Mesozoic and Cainozoic Basins overlying
  - HC-bearing basins
  - Coal-bearing Basins (releasing methane)
• Basins with highly permeable sandstones
• Basins in proximity to U-rich felsic rocks
Useful Datasets: Maps showing distribution of

- permeable sandstones
- U-rich felsic rocks
- HC- and coal-bearing basins underlying such basins
- HC-seals/caps (margins of the seals leak more readily)
- Oil and gas seepage
- Faults that have undergone periodic re-activation