Australian Government

Geoscience Australia

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

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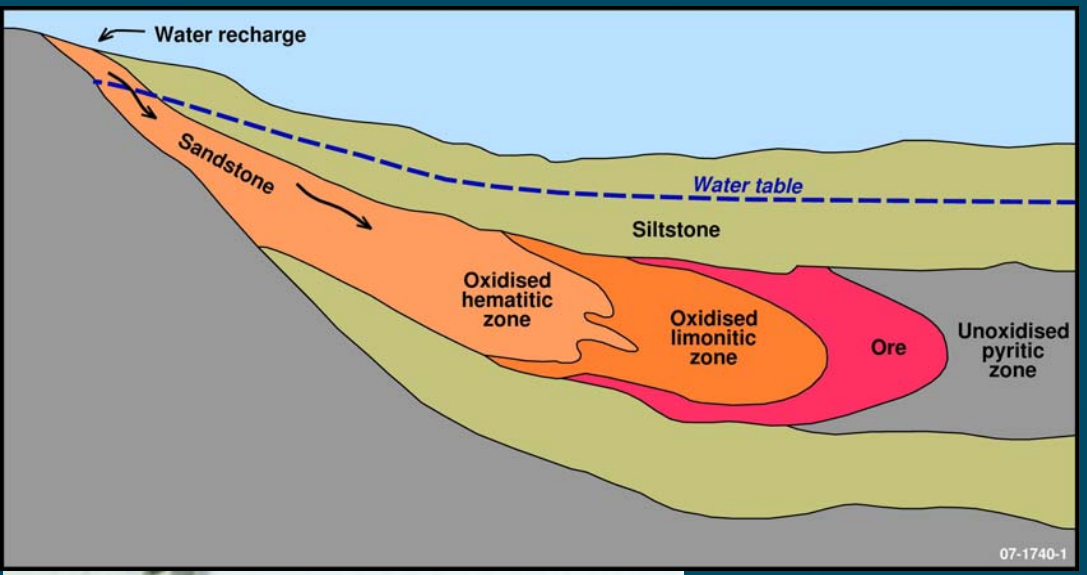
Reductants in Sandstone U Systems



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

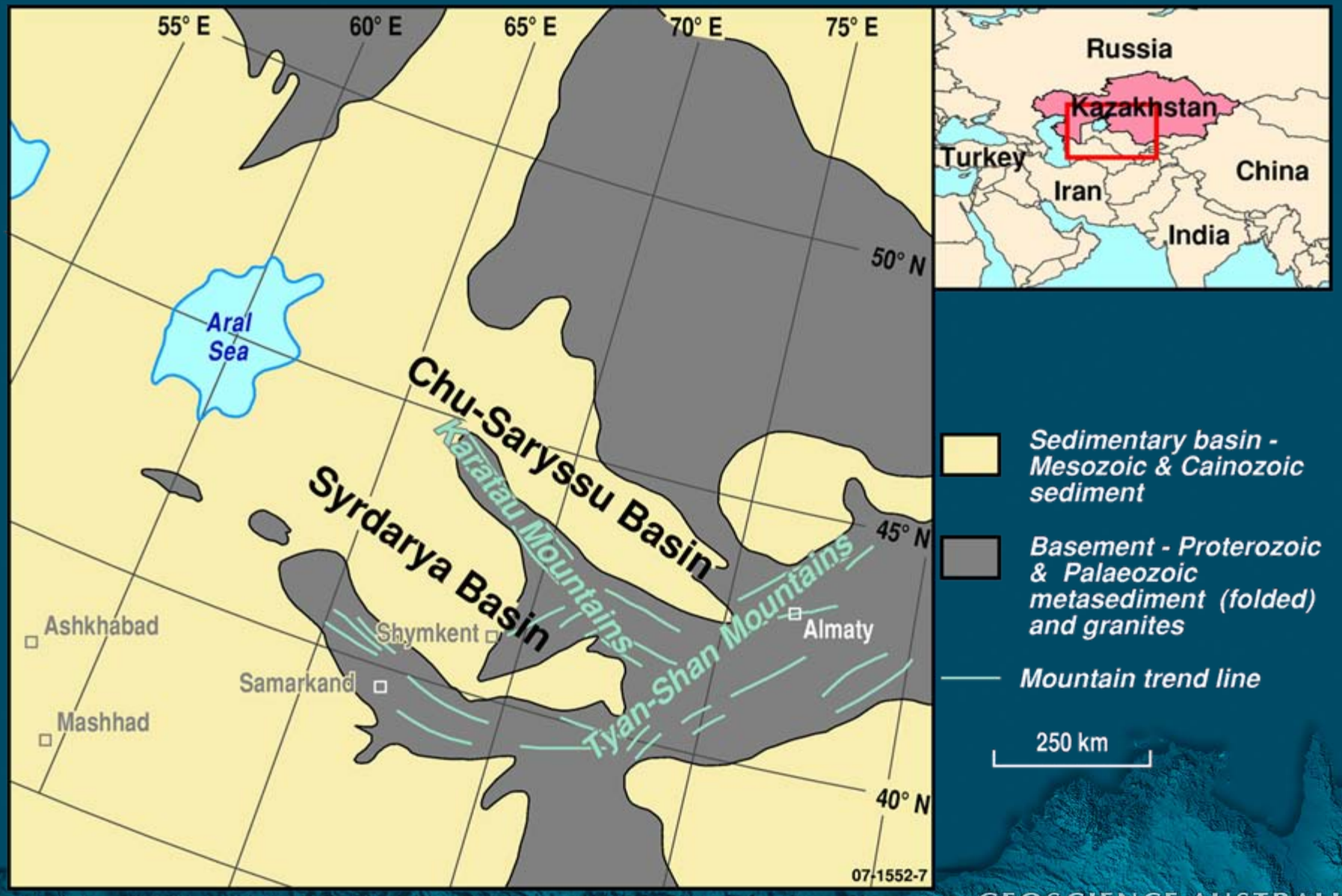
Basin/Sub-Basin	Resources (thousand tonnes U_3O_8)	Organic Carbon (wt%)	Iron sulphide (wt%)
Chu-Sarysu and Syrdarya	1,340[1]	< ~ 0.03 – 0.05[2]	0.1[3]
Callabonna (Frome Embayment)	41.2[4]	< 0.05 to 0.5[5]	Traces[5]
Wyoming	320[6]	0.5[3]	1 to 4[3]
South Texas	45 to 80[7]	<0.16[8]	0.5 to 4[8]

[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)

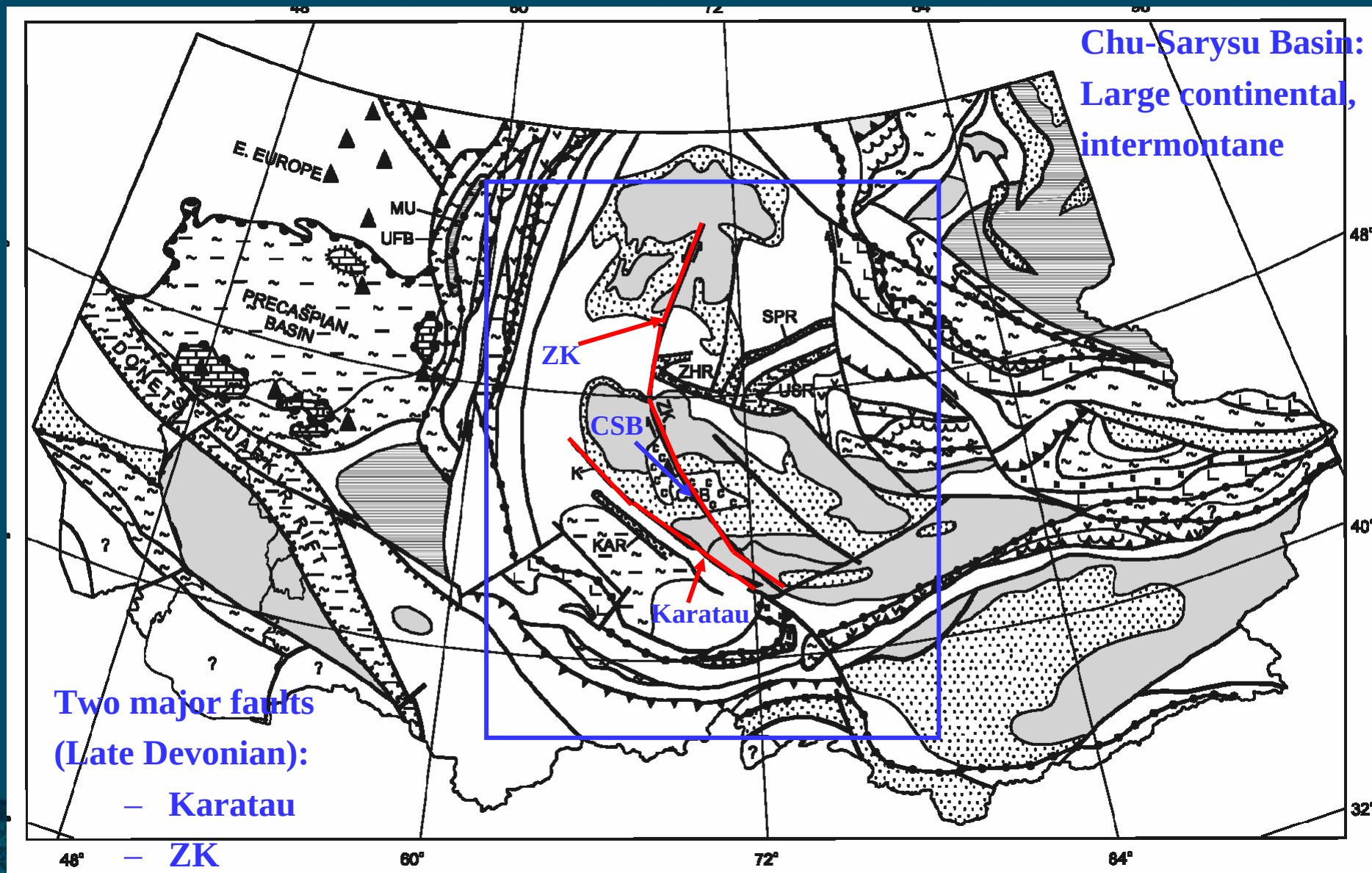
Outline

- **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?**

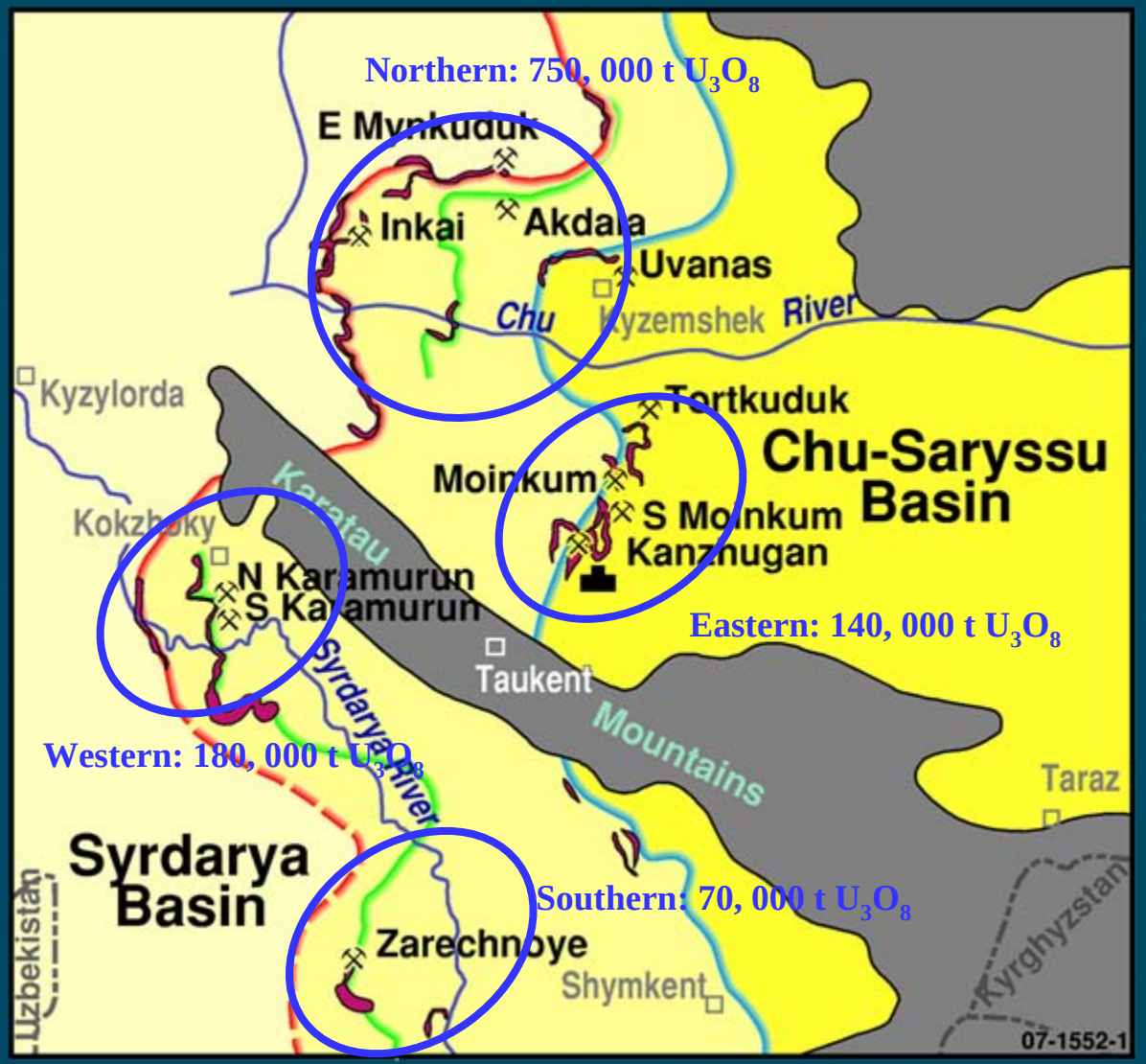
Regional Geology Southern Kazakhstan

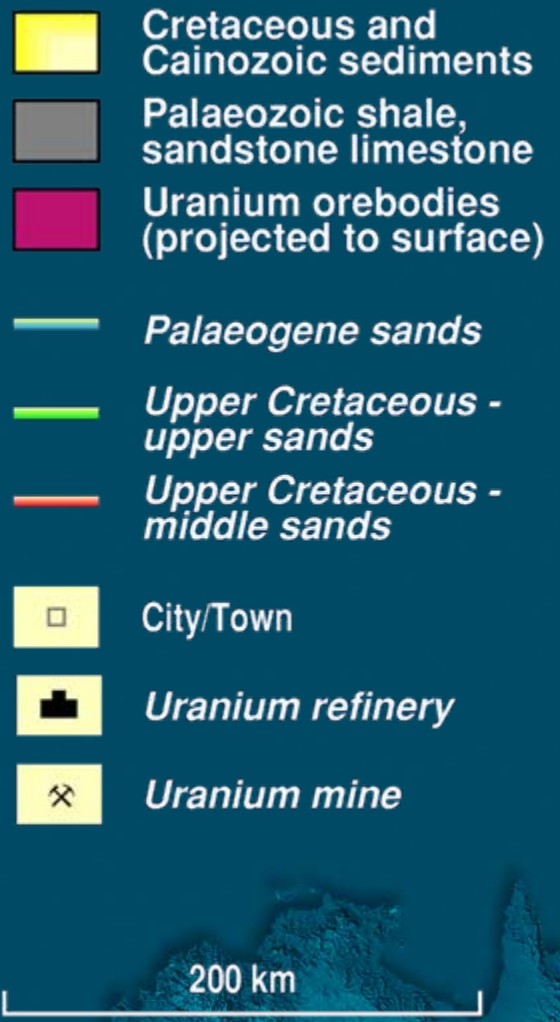


Palaeo-geographic Map of Central Eurasia (Late Devonian)

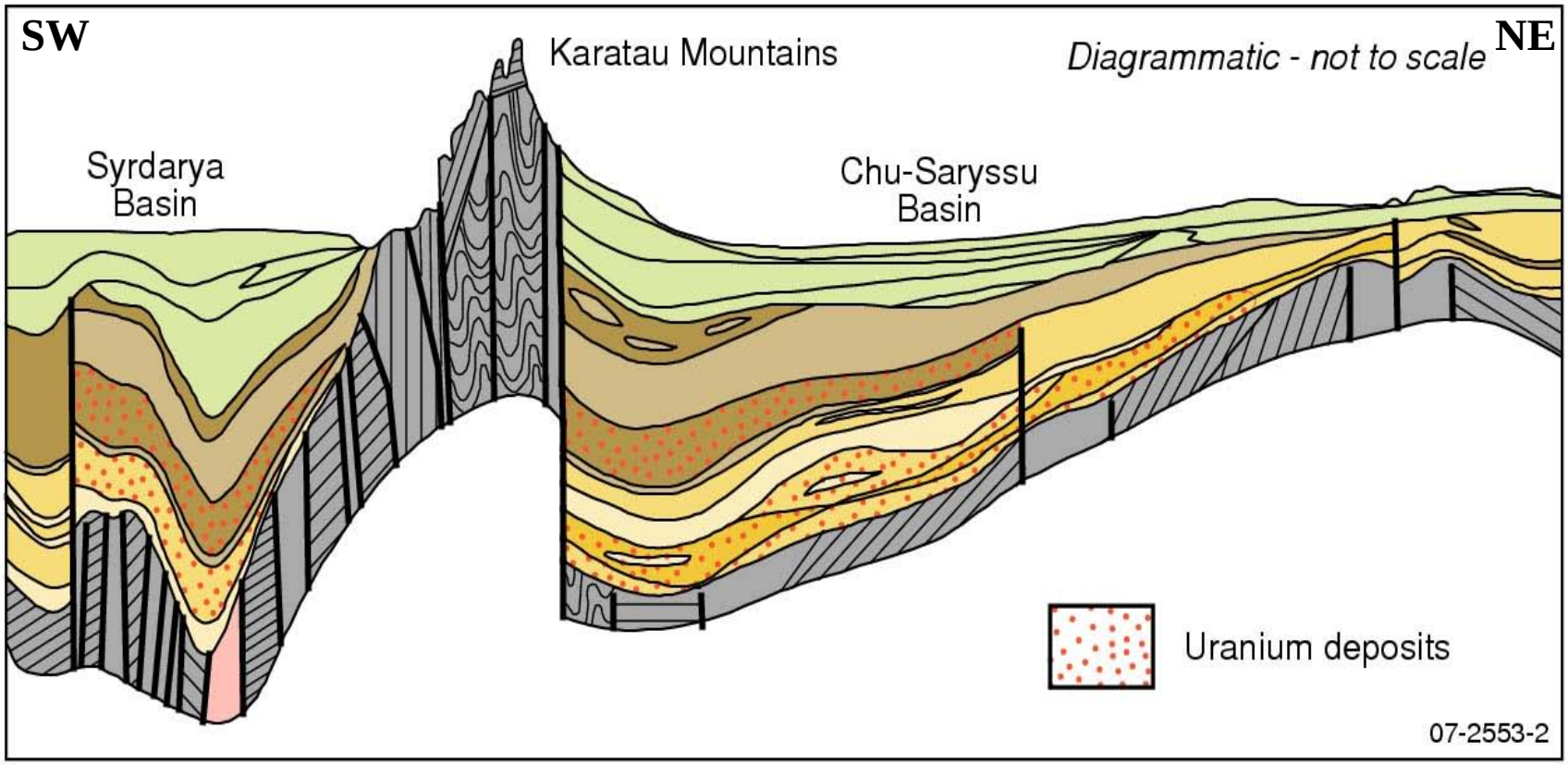


Sandstone Uranium Deposits in Kazakhstan





Cross-Section with Host Sequences



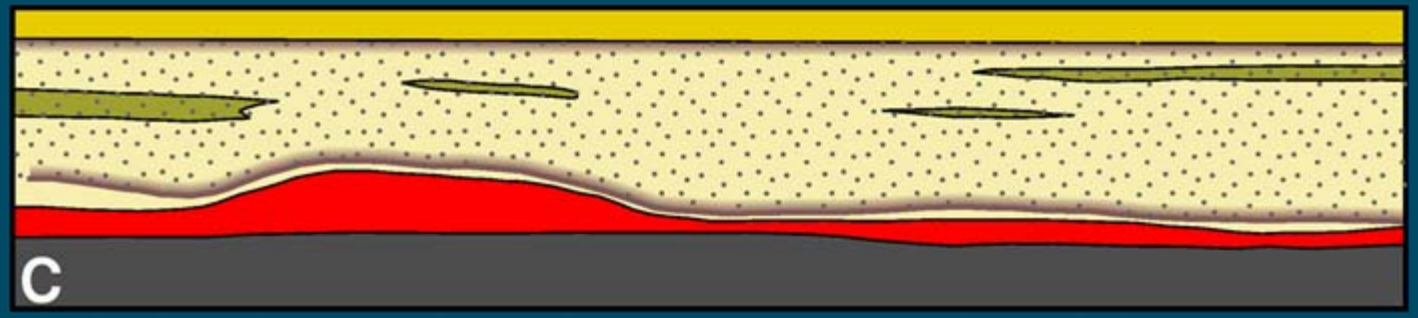
Uranium Ore-bodies (Cross-section)

Roll front

Alluvium
Sand
Clay
Palaeozoic basement
Uranium orebody
Redox front

Scale: diagrammatic

Roll front

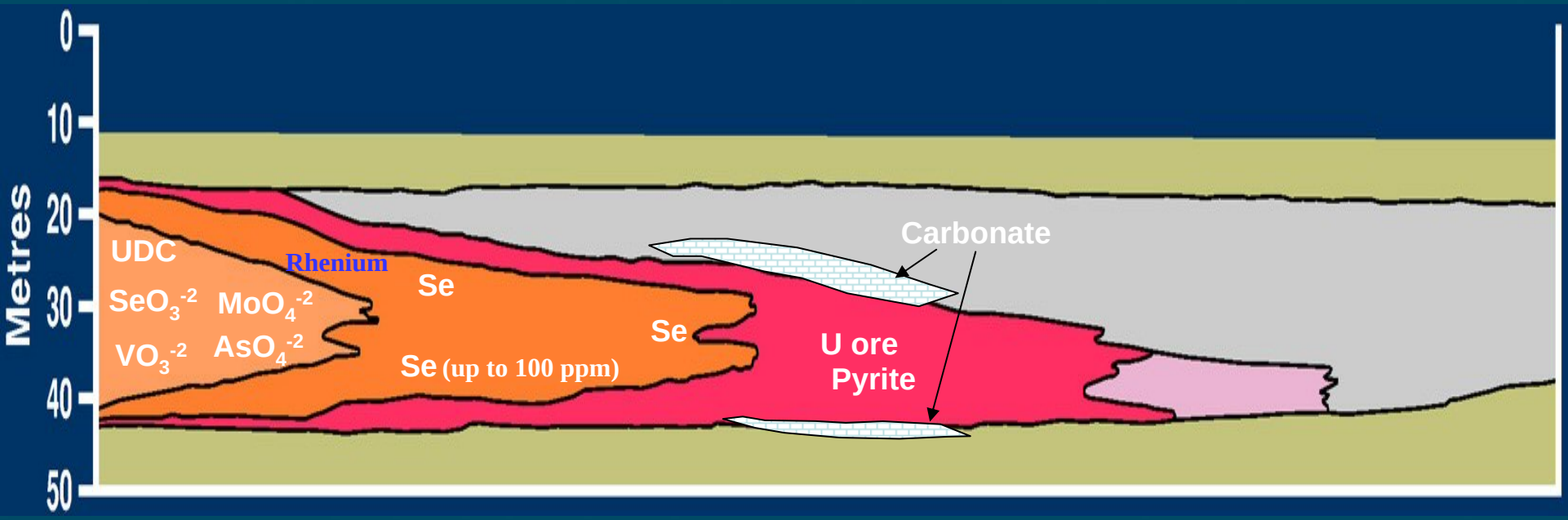


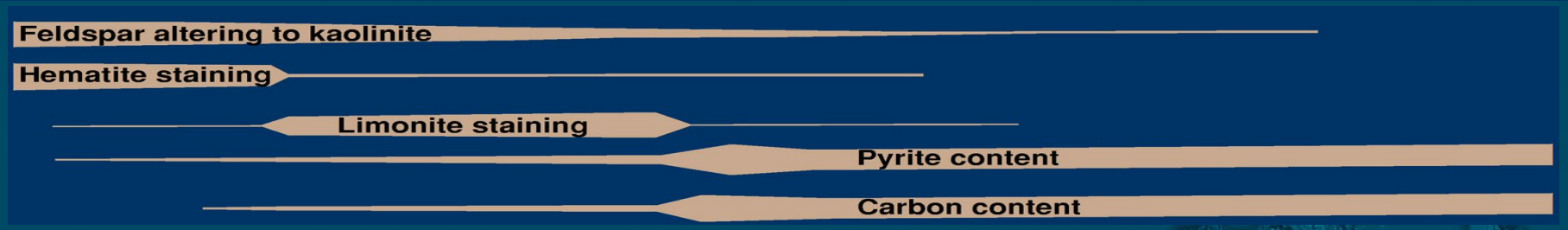
Tabular

Roll front

Mineral Composition and Zoning

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





Light red; reddish orange

Greyish orange; greyish yellow

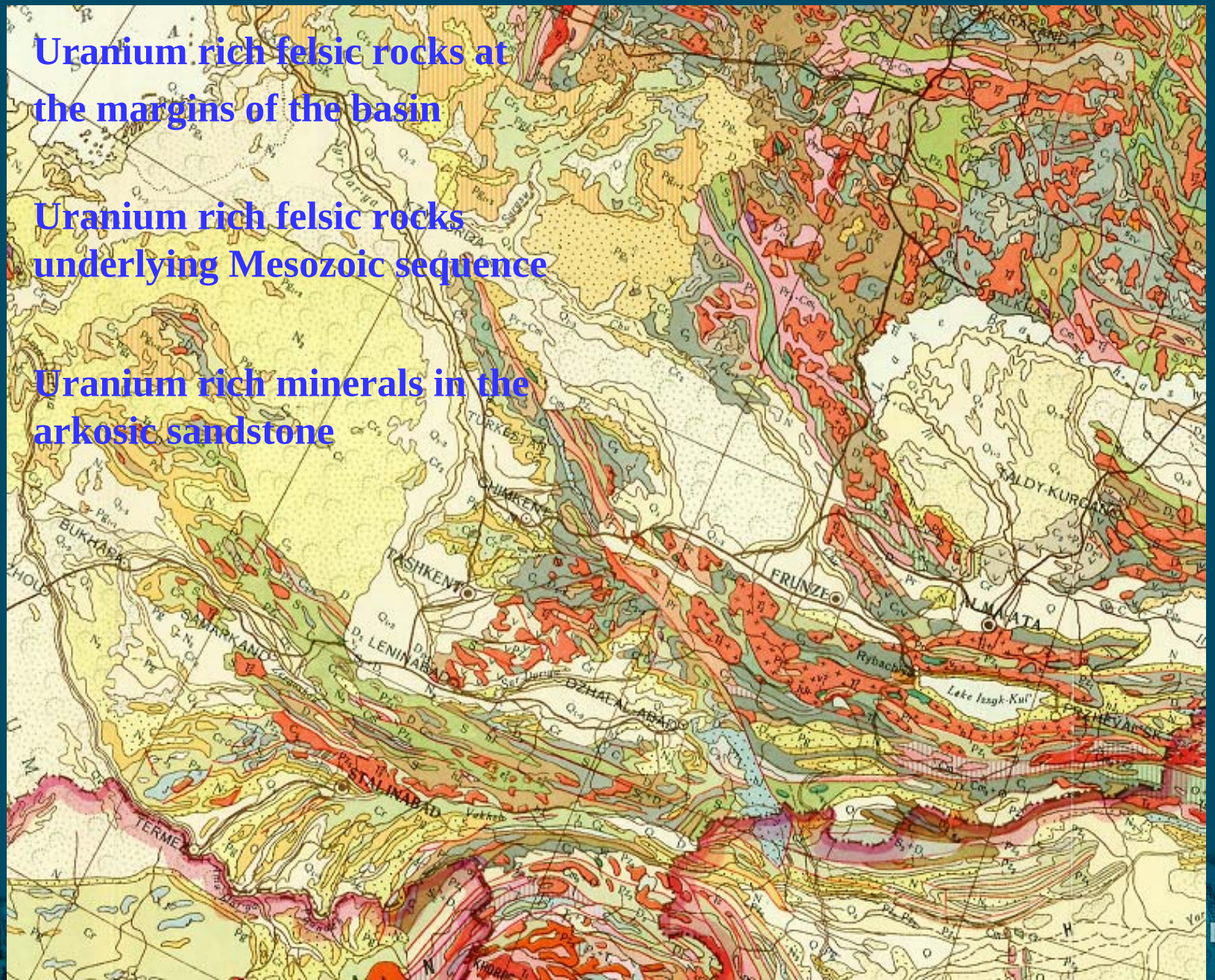
Medium to dark grey

Age of Mineralisation

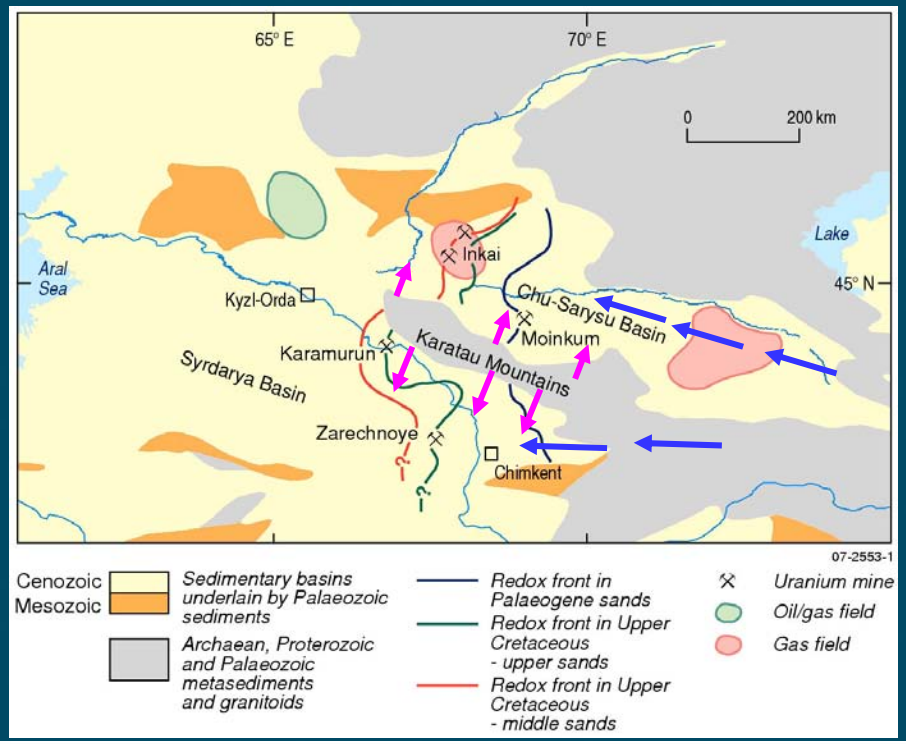
Lead-lead model ages of Ore-zone:

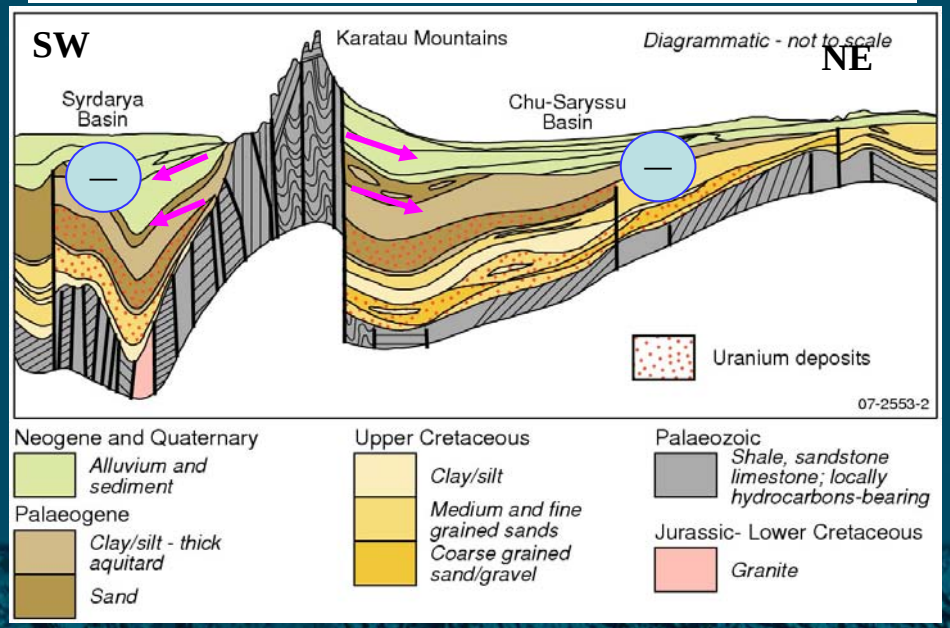
- **Age of the host rock: Late Cretaceous and Palaeogene**
- **Mineralisation in two/three more or less continuous stages**
  - **From Late Oligocene to Middle Miocene (~ 30 Ma -15 Ma)**
  - **To Late Pliocene to Quaternary (< 3 Ma)**
  - **Ongoing re-deposition of ore**
- **Age related to tectonic re-activation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

Sources of Uranium



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

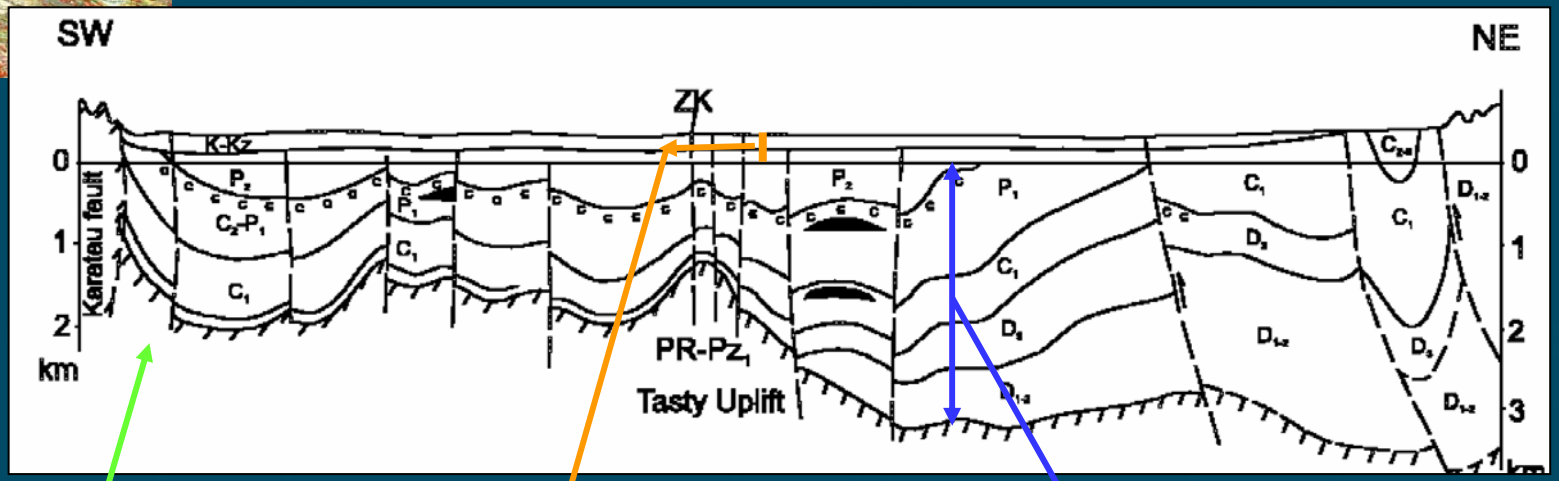
Fluid composition

- Low salinity: 900 to 6000 mg/l TDS
- Neutral pH and oxygen saturated

Reductant

- **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?**

Basin Sequence



Basement:

Proterozoic Metamorphics;

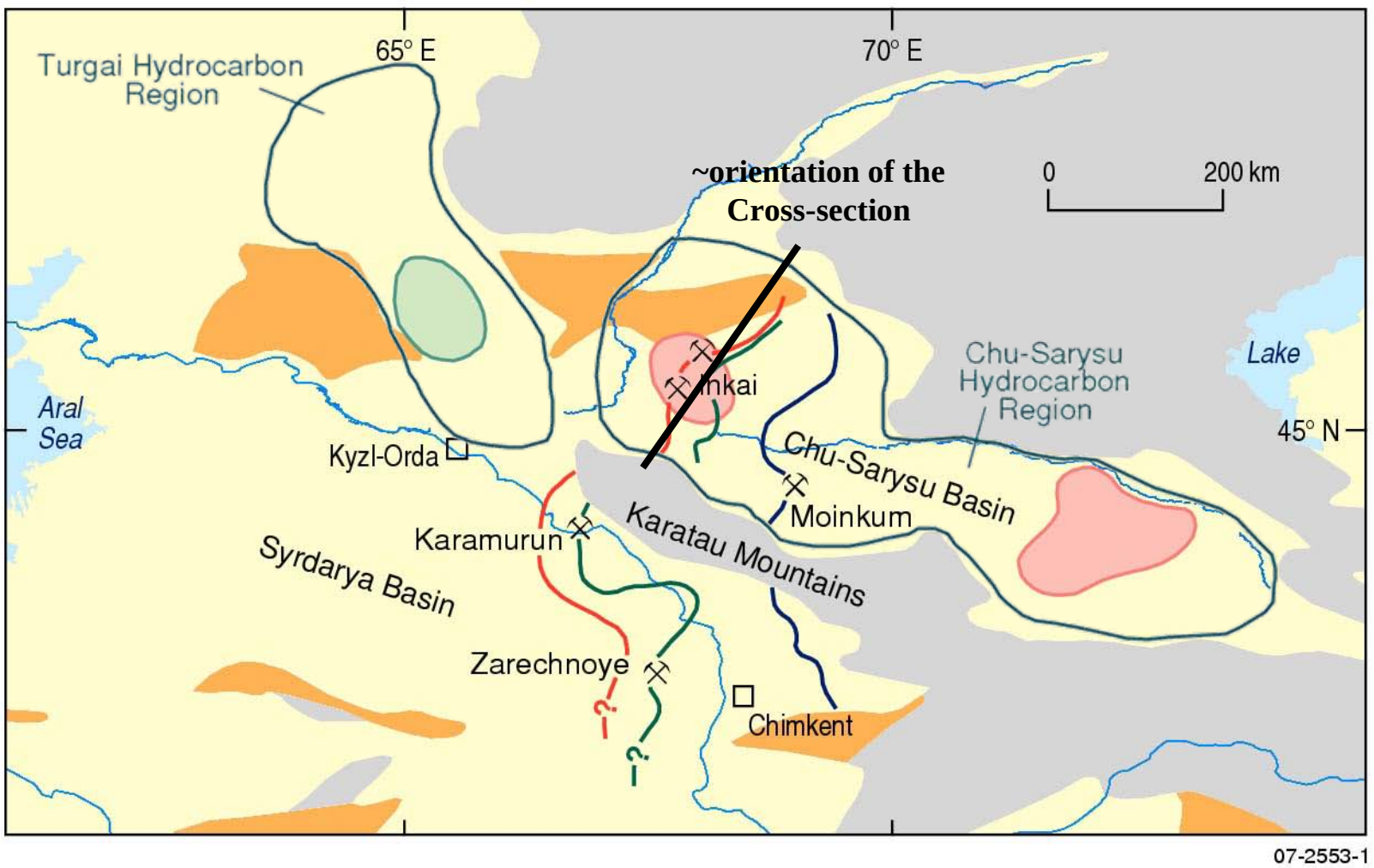
Early Palaeozoic volcanics and granites

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-beaing strata**
- **L. Devonian to E. Carboniferous (< 800 m)**
  - **Lagoonal, marginal marine, salt-bearing strata**

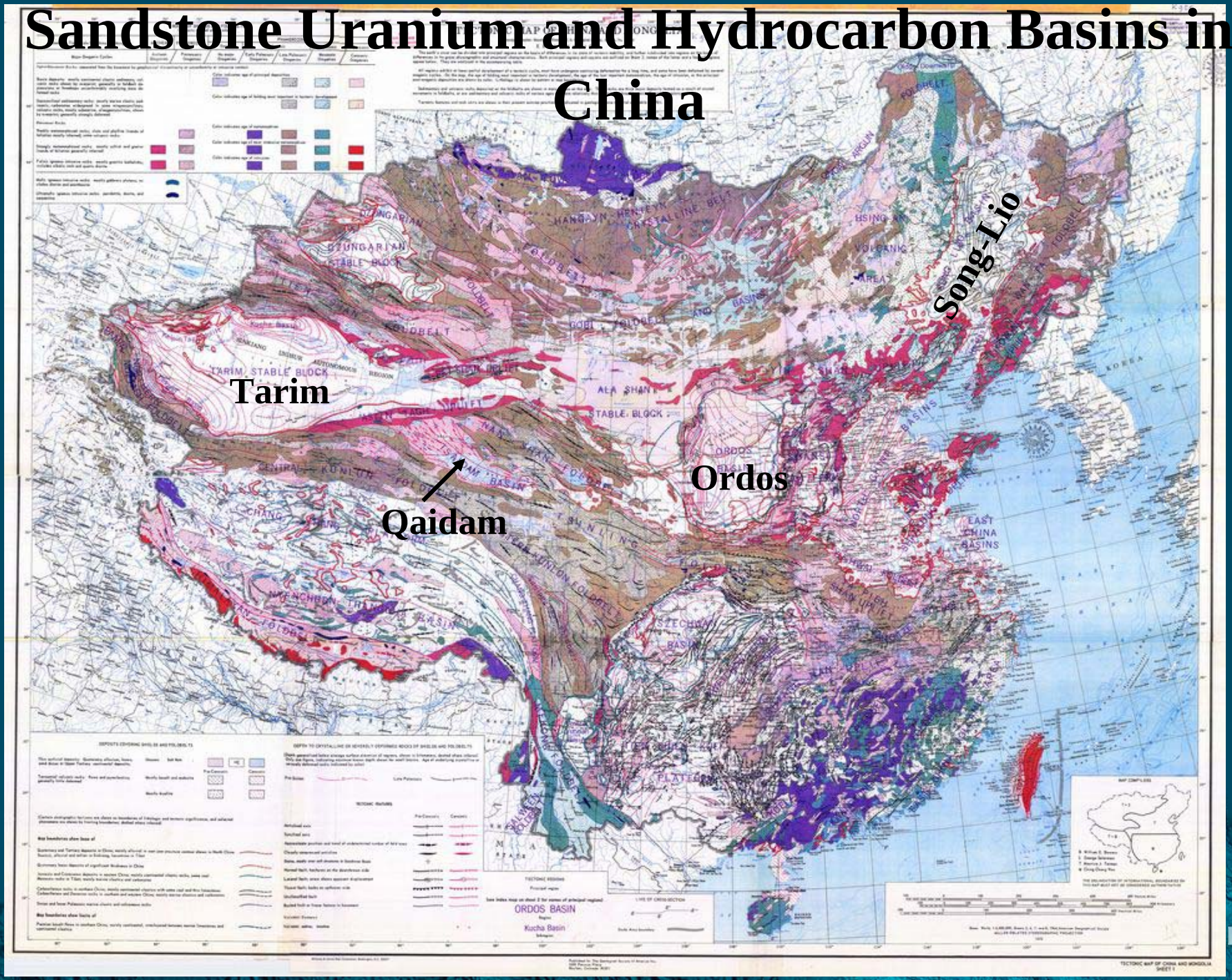
Mineralised Sequence and underlying Hydrocarbon-bearing Basins



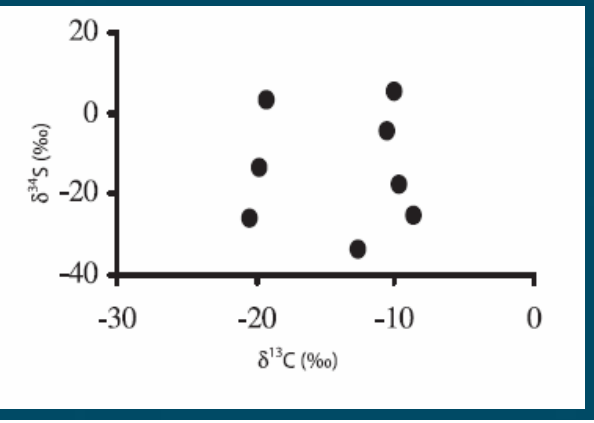
Sandstone Uranium and Hydrocarbon Basins

- In Kazakhstan a spatial association exists between
  - HC-bearing basins and overlying U-hosting sandstones
  - Indicating that HCs and/or H_2S 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)

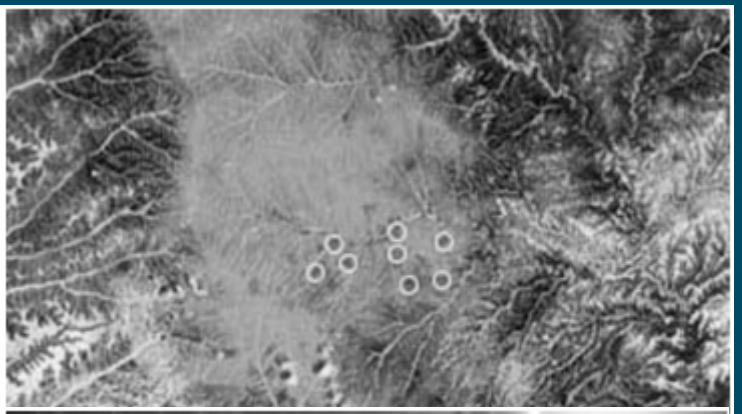
Sandstone Uranium and Hydrocarbon Basins in China



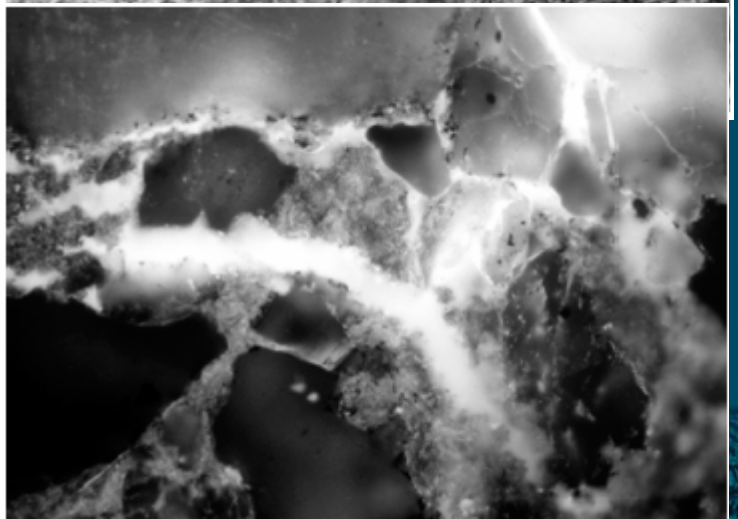
Hydrocarbons as Reductants (Ordos Basin, China)



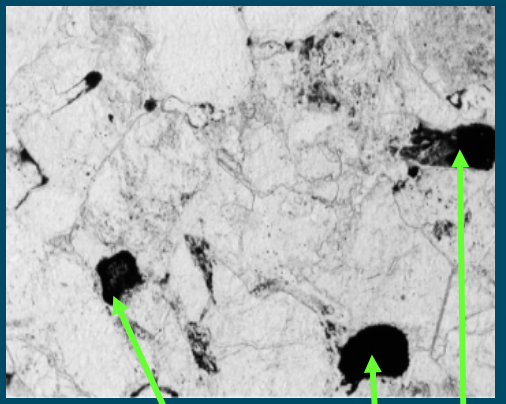
- Carbon isotope composition ($\delta^{13}C$) of calcite cement in sandstone
  - –Very light hence consistent with derivation from hydrocarbons
- Fluid inclusions in calcite cement and fracture fills
  - – contain hydrocarbons



Oil and gas seepage



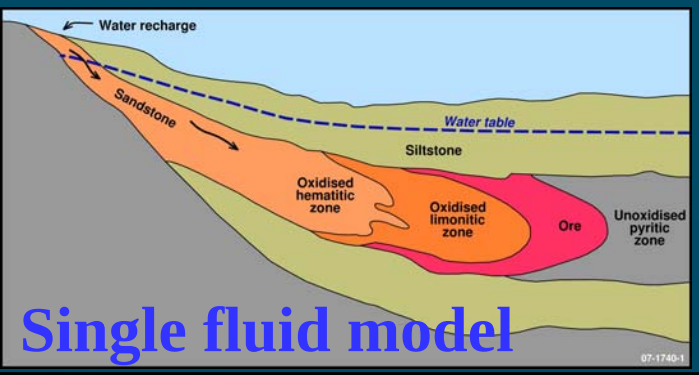
Oil and gas in sandstones



Residual asphalt

Chunfang Cai et al, 2005; Hunga Xian-fang et al, 2005

Sandstone Uranium Systems



Single fluid model

Large basin rimmed on three sides 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

Diagrammatic - not to scale

Oxidised waters dissolved U

Roll front bodies

CH_4 & H_2S

Tabular bodies

Playa Lake

U-rich source rocks

Mudstone

Gas

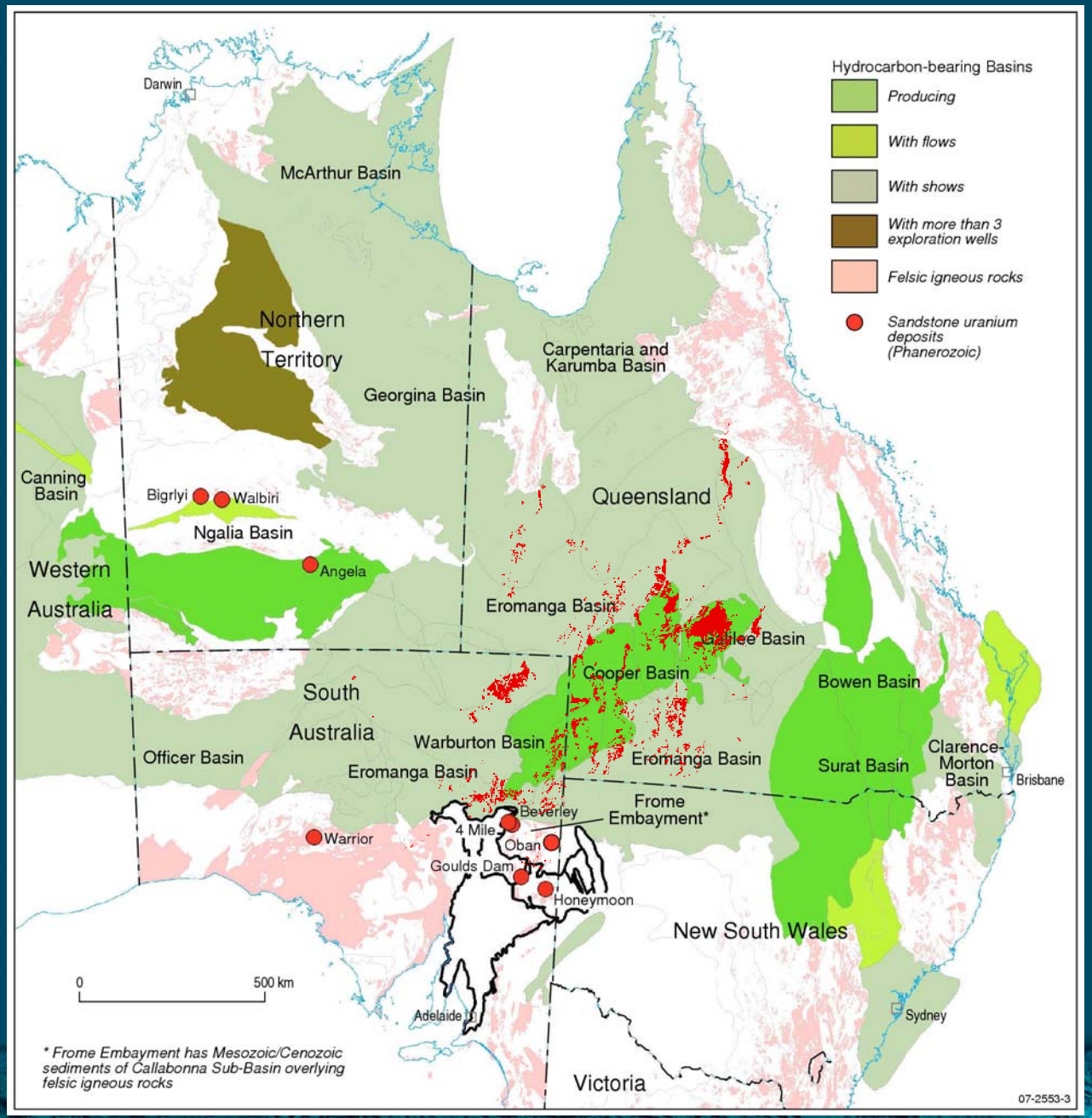
Oil

Caprock

07-1553-4

Two fluids model

Possible Hydrocarbon-Associated Sandstone Uranium (Australia)

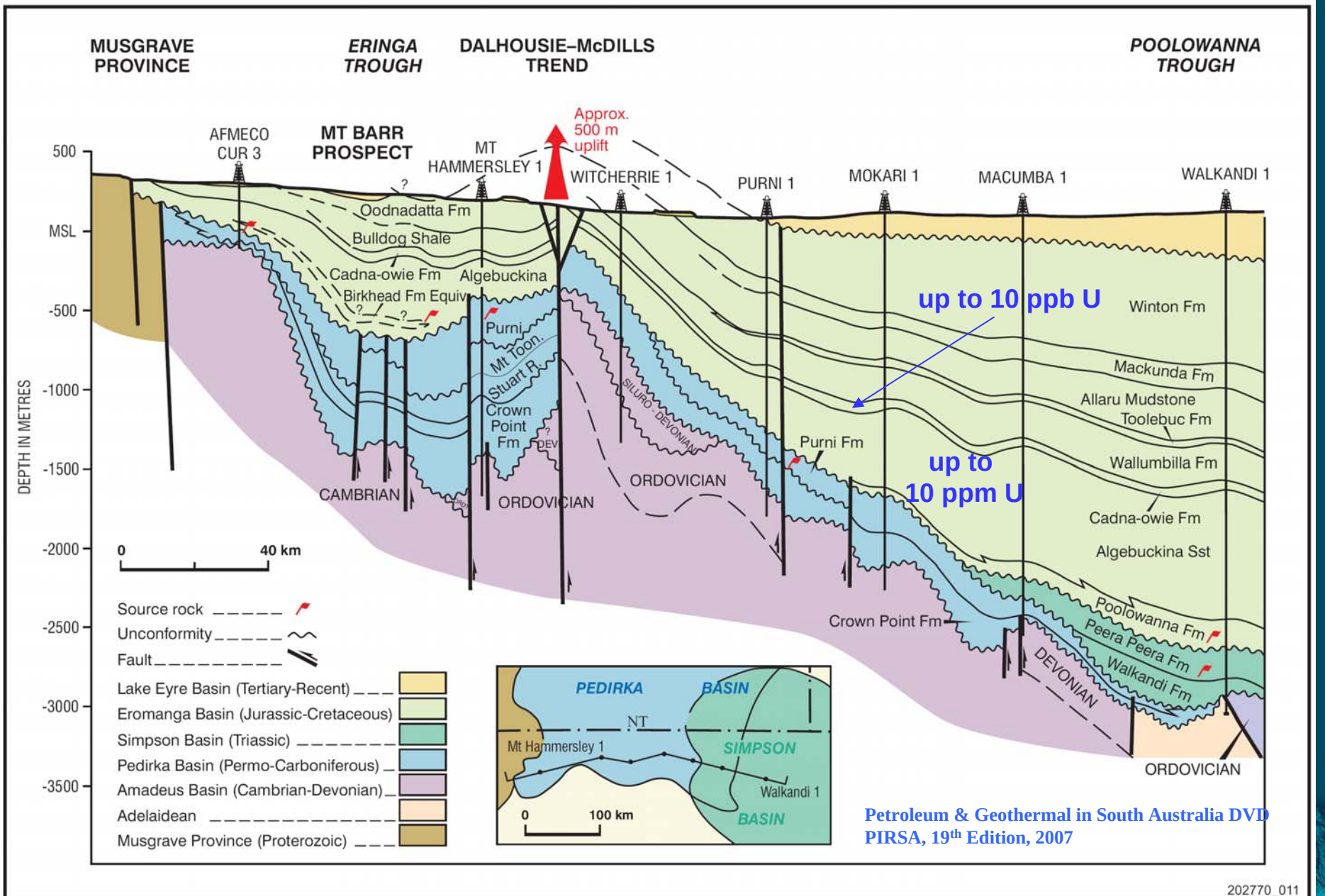


Outcropping Namba and Eyre Formations and Equivalents in SA and Qld

Cainozoic Basins

- **With sandstone aquifers**
- **In proximity to U-rich felsic rocks**
- **Overlying HC-bearing basins**

Schematic Cross-Section through Western Eromanga Basin



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**

Conclusions II

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