Frome uranium province, South Australia: Systems analysis and potential for major basin-hosted uranium deposits

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Frome uranium province – southern Lake Eyre Basin and Eromanga Basin(?)

FROME URANIUM PROVINCE
LAKE EYRE BASIN (CENOZOIC)
EROMANGA BASIN (MESOZOIC)
SEDIMENT-HOSTED URANIUM DEPOSIT
Part A

Sources of energy, uranium and fluids
SCHEMATIC SECTION: PREVIOUS MODELS

From SKM (2009, PER for Heathgate Resources)

Mt Painter Inlier
Four Mile
Beverley
Lake Frome
Mt Painter Inlier
Curnamona Province

GEOLOGY

(From Surface Geology of Australia, 2009)

Cenozoic
Mesozoic
Paleozoic
Proterozoic

RADIOMETRICS

U-channel on DEM backdrop

High-uranium potential sources
Mt Painter Inlier – U source?

Since ~4 Ma

(oblique view looking northwest; U-channel radiometrics over DTM)
Previous models and shortcomings

- Widely held views –
  - Uranium source for both Beverley and Four Mile was Mt Painter Inlier
  - Beverley and Four Mile formed recently within the modern fluid flow regime (i.e., from MPI towards Lake Frome)

- However, Four Mile ‘too close’ to basin margin for a ‘conventional’ sandstone-uranium model of formation (supported by numerical modelling), and deposit ages not known.

Explanation requires system perspective
3 periods of regional uplift.

At least 2 deep weathering events with potential to release & store uranium from Prot basement.

Permeable seds at 4+ strat levels, ± reductants.

Potentially 3 episodes of uranium mineralisation since late Mesozoic.

Constraints on uplift from: Foster et al. (1994), Mitchell et al. (2002), Célérier et al. (2005), Quigley et al. (2006).

Part B

Permeability architecture

• Sandy units in Mesozoic (e.g., Cadna-owie Fm) and Cenozoic formations (e.g., Eyre Fm, Beverley Sands)
• Paleovalleys and paleochannels
• Fault geometry
Paleovalleys/channels marked by reductants?

- Drill logs searched
- Reduced zones = Fe$^{2+}$ minerals, reduced-C, reduced-S, “black”, etc
- Oxidised zones = Fe$^{3+}$ minerals, “red”, etc
- Gridded in 3D
- North-south paleovalleys in Namba Fm as well as Eyre?
FAULT ARCHITECTURE

Depth to pre-Paleozoic basement

Basement-involved faults

From Teasdale et al. (2001 – Arrowie SEEBASE)

From Teasdale et al. (2001 – Arrowie SEEBASE)
PERMEABILITY ARCHITECTURE OF URANIUM SYSTEMS

• Paleovalleys / channels in both Eyre Fm and Namba Fm trend broadly south to north in the region, controlled by reactivated faults.

• Four Mile and Beverley paleovalleys may have trended N or NNE, not E or SE.
Part C

Model of 3 uranium episodes, and potential for major deposits
FROME URANIUM PROVINCE EVOLUTION

Paleogeographic reconstruction from Langford et al. (1995)

Late Cretaceous, Paleocene and early Eocene (~100 to ~52 Ma; episode 1 U system)

uplift, and U leaching from deeply weathered basement
oxidised meteoric water
possible U mineralisation in Eromanga Basin

u-rich Proterozoic basement (Curnamona Province, Mt Painter Inlier, Babbage Inlier)
oil/gas from Cooper Basin

Cambrian Arrowie Basin

GeoScience Australia

IAGOD, Adelaide 2010
FROME URANIUM PROVINCE EVOLUTION

Middle and Late Eocene
(~52 to ~37 Ma)

low relief, deep weathering

inactive U-forming system (grey)
FROME URANIUM PROVINCE EVOLUTION

Late Eocene to Early Oligocene
(~37 to ~28 Ma; episode 2 U system)

uplift, and U leaching from deeply weathered basement

possible U mineralisation in Eyre Fm and Eromanga Basin

reduced fluids
FROME URANIUM PROVINCE EVOLUTION

Late Oligocene to Middle Miocene (~28 to ~10 Ma)

deposition of Namba Fm

deep weathering, low relief
FROME URANIUM PROVINCE EVOLUTION

Pliocene and Pleistocene
(~5.3 to ~0.01 Ma; episode 3 U system)

uplift, high relief;
U leaching from weathered basement

U mineralisation in Eyre Fm
and Namba Fm
Conclusions

1) Frome uranium province: Cenozoic Lake Eyre Basin ± Mesozoic Eromanga Basin.
2) Three episodes of potential uranium mineralisation since late Mesozoic.
3) South-to-north paleovalley/channel systems, controlled by long-lived faults.
4) Potential for larger deposits in north of Frome uranium province within paleovalleys.
Alternative model:

- At least three periods of uplift from late Mesozoic, recorded by geological observations (Celerier et al., 2005), apatite thermo-chronology (Foster et al., 1994; Mitchell et al., 2002), $^{10}$Be studies of erosion rates (Quigley et al., 2006).
- Deep weathering in 3 episodes during/since late Mesozoic (Pillans, 2006; Smith et al., 2009).
- Potential for 3 episodes of uranium mobilisation, with groundwater flow driven by regional basement uplift.
- Uranium, sediment and water transport from south (or southwest) to north (or northeast), to satisfy mass-balance requirements of reductants.
- Or mobile reductant at Four Mile?
High-uranium potential sources

- Proterozoic Mount Painter Inlier and Curnamona Province
- Sediments derived from these sources

From Radiometrics Map of Australia (Geoscience Australia) over SRTM DEM data.
First vertical derivative of TMI (McConachy et al., 2006)

★ GAB mound springs (Draper & Jensen, 1976)

Depth to pre-Paleozoic basement

From Teasdale et al. (2001)
SCHEMATIC SECTIONS: PREVIOUS MODELS

Beverley

Four Mile

Mt Painter Inlier

Lake Frome

From SKM (2009, PER for Heathgate Resources)

Generalised model for roll-front style sandstone uranium deposits

IAGOD, Adelaide 2010
Uranium resources of Australia

- Pine Creek Orogen
- Paterson Province
- Eromanga Basin
- Gawler Craton & Curnamona Province
- Northern Queensland

Geoscience Australia uranium study areas
- Lake Frome study area

Uranium deposits:
- Mineral deposits with up to 100 tonnes of $U_3O_8$ (1)
- Mineral deposits with 100 to 1000 tonnes of $U_3O_8$ (25)
- Mineral deposits with 1000 to 10000 tonnes of $U_3O_8$ (35)
- Mineral deposits with 10000 to 100000 tonnes of $U_3O_8$ (15)
- Mineral deposits with 100000 to 1000000 tonnes of $U_3O_8$ (2)
- Mineral deposits with > 1000000 tonnes of $U_3O_8$ (1)

Geological regions:
- Geological regions with up to 1000 tonnes of $U_3O_8$
- Geological regions with 1000 to 10000 tonnes of $U_3O_8$
- Geological regions with 10000 to 100000 tonnes of $U_3O_8$
- Geological regions with 100000 to 1000000 tonnes of $U_3O_8$
- Geological regions with > 1000000 tonnes of $U_3O_8$

Geological regions boundary, broken where subdivided