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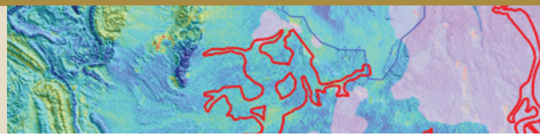
Exploring for sandstone-hosted uranium deposits in paleovalleys and paleochannels



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Significant sandstone-uranium deposits are located in fluvial (or river) sediments filling ancient river channels known as paleochannels. These often occur within buried valley systems cut into bedrock which are known as paleovalleys.

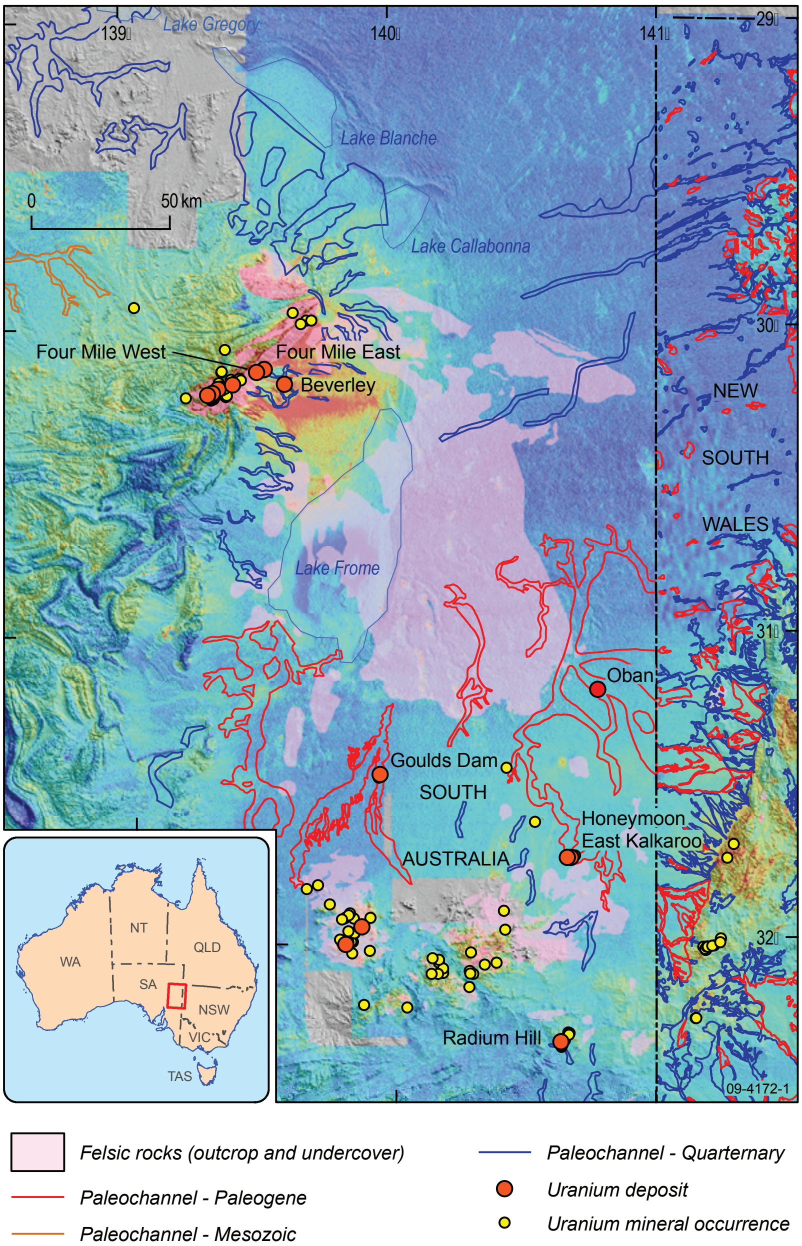

Figure 1. Distribution of paleochannels and paleovalleys in the Lake Frome region. The data for South Australia are after Hou et al (2007). Paleochannels in New South Wales are defined roughly on the basis of the distribution of Cenozoic sediments in the 1:1 million scale Surface Geology of Australia map.

This article briefly outlines the geology of sandstone-hosted uranium deposits in paleovalleys and paleochannels in the Lake Frome region (Australia) and Mountain Valley and White Canyon districts (USA). Uranium deposits in the two areas are commonly localized at the confluences and intersections of channels and/or near bends. It is possible that the location of deposits at these sites is caused by several inter-related factors such as the presence of basement scours, predominance of coarse-grained sediments, and abundance of organic material.

The Lake Frome region

Eocene to Miocene paleochannels and paleovalleys host several uranium deposits in the Lake Frome region (figure 1). The Eocene paleochannels running generally south-north are filled with Eyre Formation sediments. They incise the Proterozoic to Cambrian basement and are covered by Miocene lacustrine (or lake) and fluvial sediments. The main valleys with channels are generally five to ten kilometres wide and extend for more than 200 kilometres, sometimes joined by smaller tributaries. The general gradient of the channels in the south to north direction varies between 1.3 metres per kilometre to 2.1 metres per kilometre in the Billerroo channel (Ellis 1980).

The sediments in these channels were sourced from the Proterozoic basement in the Curnamona Province (Ellis 1980). They comprise an interlayered sequence (70 to 80 metres thick) of sands, silts and clays with most of the organic material concentrated in the basal part of the lower sands filling scours in the basement rocks. These sands also contain abundant pyrite.

Uranium occurrences and deposits often occur at bends (Honeymoon and East Kalkaroo) and/or the site of confluences with tributaries (such as Goulds Dam and Oban; figures 1 and 2). The general shape and orientation of the channels is controlled by basement rocks and structures. According to Skidmore (2005), mineralisation at the Honeymoon deposit is located close to a bend where the channel breached a ridge along a fault zone (figure 2).

The Four Mile East deposit and Pepegoona prospect in the northern Lake Frome region, are also hosted by the Eocene Eyre Formation (Heathgate Resources 2009). Although a paleochannel setting for them is not clear at this stage, the location of Four Mile East deposit in a northeast trending valley-like embayment indicates possible similarities with a paleovalley setting.

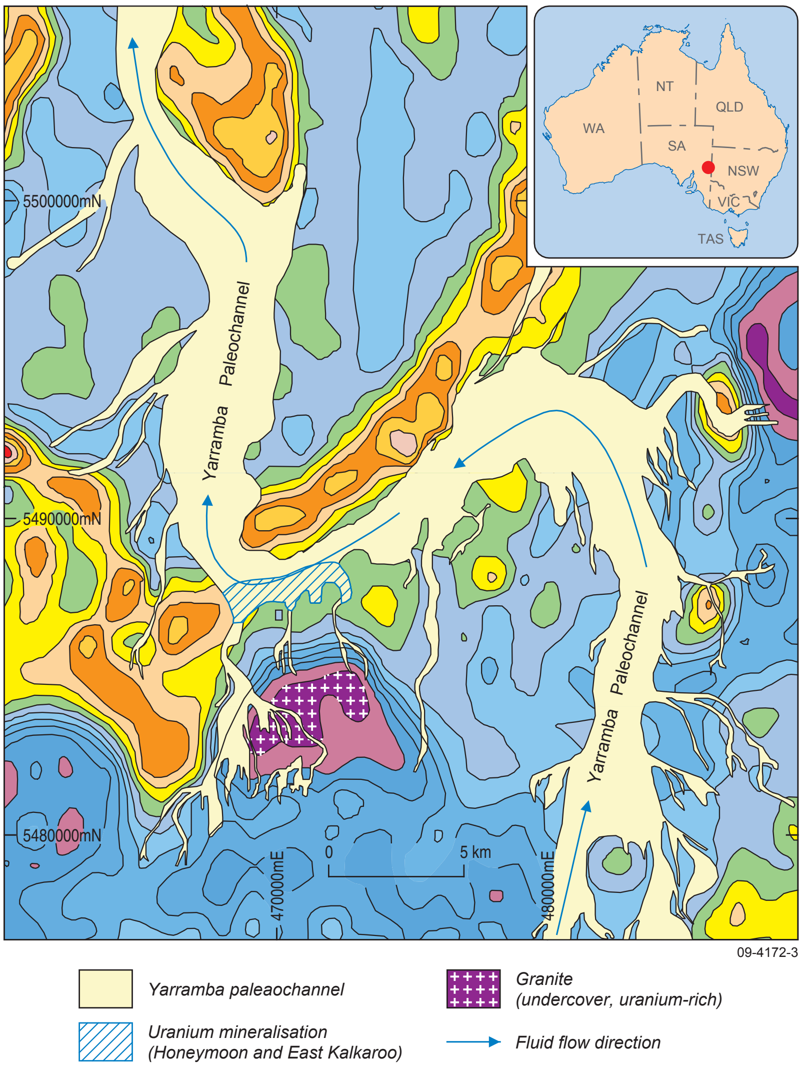

Figure 2. Bends in the main Yarramba Paleochannel and location of mineralisation at the Honeymoon and East Kalkaroo deposits. Paleochannel plotted over gravity high (0.5 mgal residual gravity contour). Modified after Skidmore (2005).

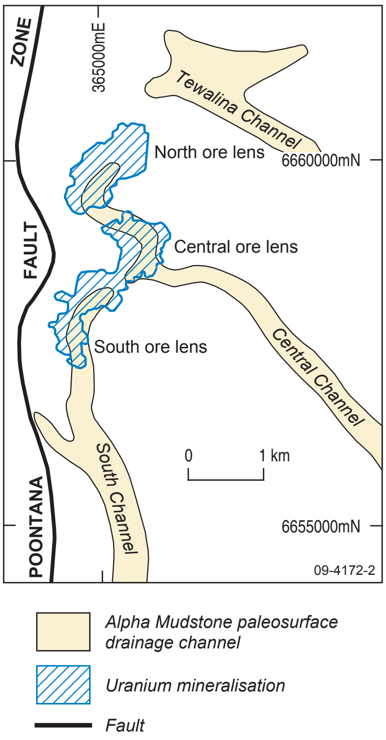

Figure 3. Map of the Beverley uranium deposit (mineralisation outlined) and inferred paleochannels within the Namba Formation. Uranium mineralisation is located in the Beverley Sands unit (modified after Heathgate Resources 1998).

Mineralisation at the Beverley deposit (figure 3) is hosted by the Beverley Sands unit of the Miocene Namba Formation. The mineralised sequence of sand and mudstone fill a channel into the organic-rich Alpha Mudstone (figure 3). Although anomalous uranium is found throughout the channel, ore zones are located at the bends of the main north-south channel and/or near the points of confluence with tributaries (figure 3). The main channel is up to one kilometre wide and filled with 90 to

170 metres of Miocene sediments overlain by 80 to 150 metres thick cover of Quaternary sediments of the Willawortina Formation.

The shape of the paleochannel is determined by a series of faults, such as the Poontana Fault, and the movement of sediments along it has created a system of valleys and rises. The provenance of infill sediments is not clear, although a general north-south trend of the main channel indicates that the sediments could have been derived from the Proterozoic basement to the south of the channel. Palynological studies record a Late Oligocene to Pliocene age (possibly between around 25 and 6 to 4 Ma or million years; Wulser 2009).

Tabular mineralisation is located predominantly at or near the contact with the underlying Alpha Mudstone, primarily because the mudstone is rich in organic material (plant fragments and carbonised wood). Uranium–Lead dating of coffinite and secondary carnotite defines the age of mineralisation between 5.3 and 3.1 Ma (Wulser 2009). Mineralisation thus seems to have occurred just after the deposition of sediments infilling the Beverley paleochannel.

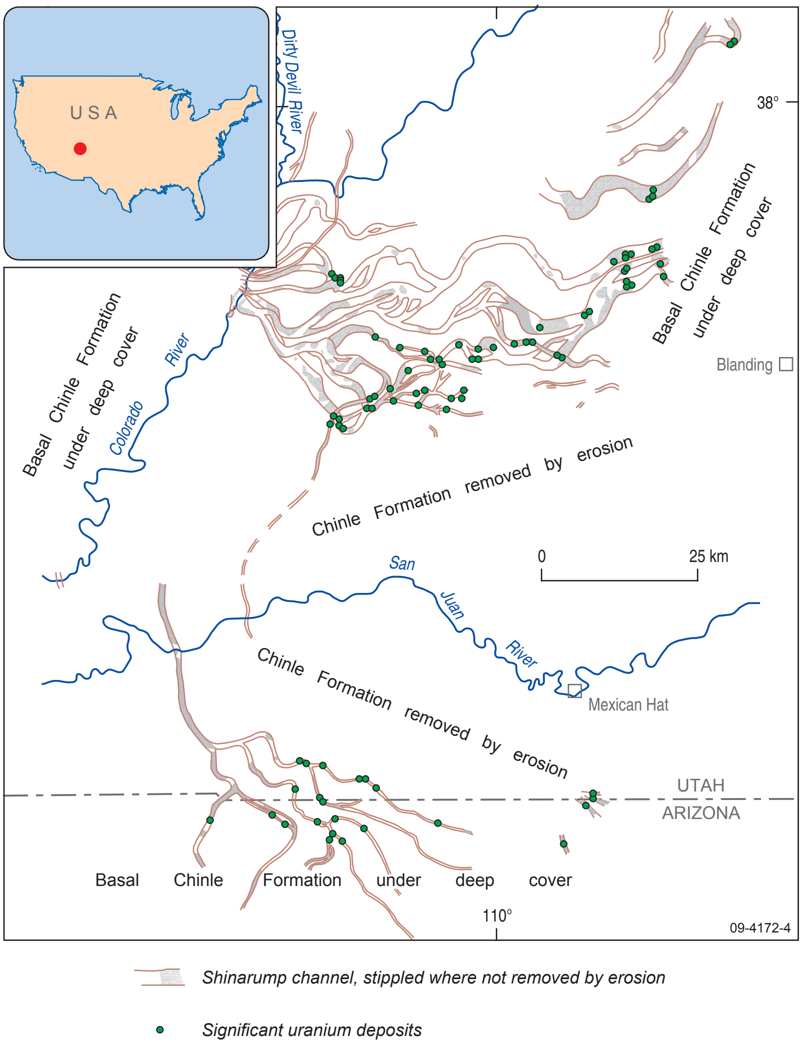

Figure 4. Shinarump channel system in the Monument Valley and White Canyon districts, Arizona and Utah. Modified after Malan (1968).

Monument Valley and White Canyon Districts, USA

The Monument Valley and White Canyon districts near the southeastern border of Utah have produced around 3900 tonnes of uranium oxide (U_3O_8) and 4500 tonnes of vanadium (V_2O_5) at average grades of 0.32 per cent and 0.25 per cent U_3O_8 and 0.23 per cent and 0.94 per cent V_2O_5 (Dahlkamp 1993).

Mineralisation is hosted by the Late Triassic Chinle Formation which is 50 to 600 metres thick and consists of fluvial sediments deposited in braided and meandering river channels. The mineralised channels were incised into the Moenkopi Formation sediments by streams flowing generally northward from a highland area in southern or central Arizona and southern New Mexico (figure 4). The sediment infill was derived from the exposed granitic and felsic volcanics in the highlands. An increase in the volcanic activity in the highland area coincided with the deposition of younger sediments in the Chinle Formation (Malan 1968). Prior to the deposition of the overlying Monitor Butte Member, the earlier flood plain and channel sediments were thinned or completely removed by erosion (figure 4).

All major deposits are confined to the thin Shinarump Member of the Chinle Formation with a few extending downwards in the underlying Moenkopi Formation. The ore-bearing Shinarump Member is composed of lenticular beds of sandstone, conglomerate, siltstone and mudstone with abundant

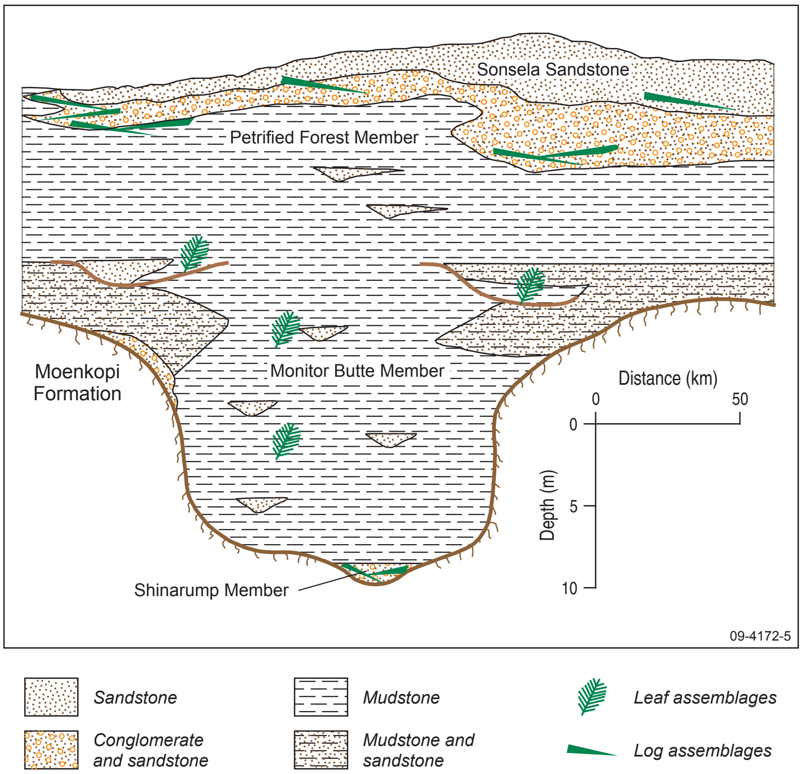

Figure 5. Schematic cross-section of the Painted Desert paleovalley showing stratigraphic relationships of members of the Chinle Formation. Uranium mineralisation is located predominantly in the Shinarump Member. Modified after Demko (2003).

fragments of carbonised and locally silicified wood. Uranium deposits are commonly localised at confluences and intersections of channels and/or near bends. This is interpreted to be caused by stronger currents able to cut deep scours in the basement (Young 1964). Within braided channels coarser sediments (sandstone and conglomerate) were deposited where the channel was narrow and gradients high, whereas carbonaceous-rich mudstone was deposited in channels which were broad, meandering and of low gradient. As the gradients lowered the filled scours were covered by layers of silt and carbonaceous mudstone (Malan 1968).

According to Young (1964), radiometric ages indicate that mineralisation was initiated at around 180 Ma and was remobilised several times by ground water flowing through the channel.

Factors controlling mineralisation

This brief comparison of two areas with sandstone-hosted uranium deposits in paleovalleys and paleochannels shows that mineralisation is often located at the bends and/or sites of confluences of the main channel with tributaries, frequently occupying basement scours filled with coarser sediments. In some deposits tabular mineralisation is located at the contact with organic-rich underlying silt and mudstone. This preferred location could be the result of several inter-related factors which include:

- Changes in the rates of stream flow at the bends and at the sites of confluence determining the type of sediments (sand versus silt) infilling the channel, which in turn determine differences in the permeability of sediments.
- A drop in the rates of stream flow at the inside of bends and at the sites of abandoned channels, channel-widening and bar-heads that favour the trapping of woody material. The presence of large woody debris at these sites can enhance the concentration of benthic organic matter at the bends incorporated later by the sediment-infill (Abbe & Montgomery 1996; Daniels 2006).
- The presence of tributaries flowing into the main channel that can provide an additional hydrological link with local uranium-rich source rocks. For instance, at the Honeymoon deposit a uranium-rich granitoid, intersected in the basement in the upland area of a northward running tributary to the main channel, is proposed as a potential source rock by Skidmore (2005; figure 2). This link with the source rock is important and can explain why uranium mineralisation in the Monument Valley and White Canyon Districts is confined primarily to the Shinarump Member although the overlying younger sediments in the channel contain abundant organic material (figure 5).
- The presence of coarser sediments, particularly in the scours, which may be enriched in uranium-rich detrital minerals sourced from

the erosion of felsic rocks in the upland area, and hence provide an additional local source of uranium.

- The location of ore zones within basement scours increases chances of their preservation by isolating them from interacting with oxidised groundwaters flowing through the sandy aquifers.

The shape and gradients of paleochannels can be used to ascertain the location of the source of sediments and the direction of sediment transport. They can also assist in determining the location of possible source rocks of uranium and the direction of fluid flow of uranium-bearing fluids. In general, uranium-rich fluid will flow along the channel, however if the sandstone uranium system is generated after the channel is filled and covered by younger sediments, fluid can flow across the channel system. It is important to establish the direction of fluid flow at the time of mineralisation because it can help to determine the location of oxidation-reduction front as well as the ore zone within the aquifer.

Implications for exploration

This summary of sandstone-hosted uranium deposits in paleovalleys and paleochannels shows that mineralisation is often located at a number of specific sites within the paleochannels. Consequently exploration of such deposits will benefit by focusing on the following features of the system:

- Meandering bends of channels (including abundant channels), sites of confluence with tributaries, sites of channel-widening, bar-heads, and scours in the basement rocks.
- Architecture of the basement (topography, rock-types, and structures), which often influences the shape and orientation of the channels.
- Basement rocks, some of which may contain source of uranium. Geophysical methods such as gravity and aerial electro-magnetic surveys can be useful to map the basement.
- Paleo-flow direction in the channel, because it can help to determine the position of bars and of sites rich in wood debris.
- The presence of organic-rich fine-grained sediments infilling the channel because in addition to the basement scours, they can also provide favourable sites for uranium mineralisation.

Acknowledgments

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