

# Exploring for calcrete-hosted uranium deposits in the Paterson region, Western Australia

## Modelling points to prospective areas

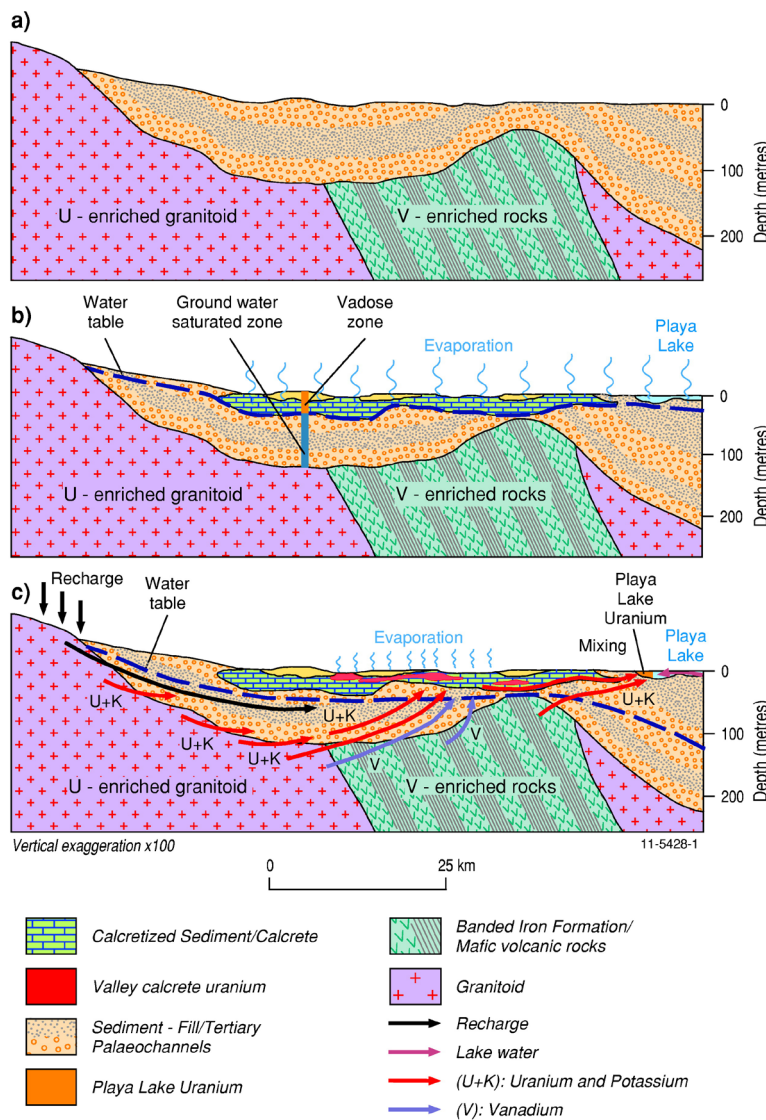
Songfa Liu and Subhash Jaireth

Non-pedogenic calcretes are known to host many large uranium deposits such as Langer Heinrich in Namibia and Yeelirrie and Lake Maitland in Western Australia. In Australia there is an abundance of non-pedogenic calcretes. However many areas with such calcretes are yet to be systematically explored for uranium. Currently calcrete-hosted uranium deposits constitute only one per cent of known

uranium resources in Australia. Most known deposits are associated with Cenozoic drainage systems in the Yilgarn Craton, the Gascoyne Province (both in Western Australia) and the Ngalia Basin (in the Northern Territory).

In the Paterson region of the northern part of Western Australia, calcrete-hosted uranium mineralisation was reported in the Lake Waukarlyarly area but no major deposit of this type has been found. A recent airborne electromagnetic (AEM) survey in the Paterson region conducted by Geoscience Australia has mapped paleodrainage systems that have the potential to form calcrete-hosted uranium deposits (*AusGeo News* 101). The survey was part of the agency's Onshore Energy Security Program.

This article briefly outlines geological and geochemical factors which control the formation of calcrete-hosted uranium deposits. These factors provide the criteria necessary to map areas prospective for calcrete-hosted uranium deposits.



**Figure 1.** Model depicting the formation of calcrete-hosted uranium deposits.

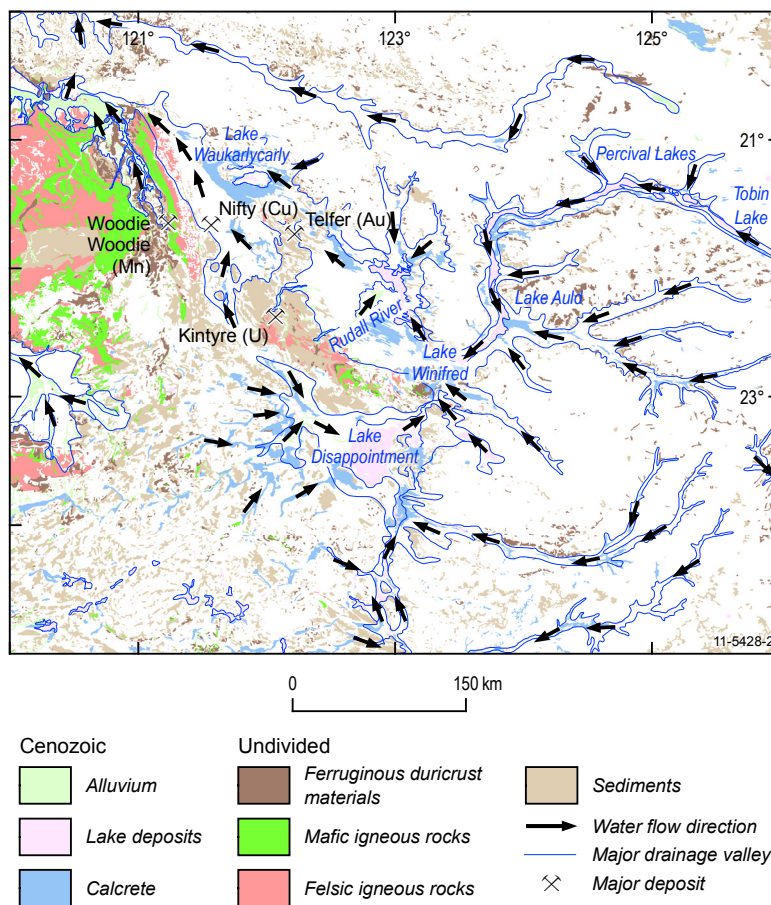
## Formation of calcrete-hosted uranium deposits

In the Paterson region the Archean Pilbara Craton and the Paleoproterozoic Rudall Complex are overlain by the Neoproterozoic Yeneena and Officer basins which are in turn overlain by the Paleozoic Canning Basin. The region is highly prospective for uranium deposits as it hosts a significant number of known uranium occurrences and deposits in the Rudall Complex, including the Kintyre deposit, which is the sixth largest uranium deposit in Australia.

Butt et al (1984) classified calcrete-hosted uranium deposits into three main types: valley, playa, and terrace deposits. Valley-type deposits, such as Yeelirrie, Hinkler–Centipede, Lake Way and Lake Raeside in the Yilgarn Craton, occur in calcretes and associated sediments in the central channels of major drainages, and in the platforms and chemical deltas where these drainages enter playas. Playa-type deposits, such as Lake Maitland and Lake Austin, occur in near-surface evaporitic and alluvial sediments. The calcretes near playas act as principal aquifers to the playas. The terrace deposits are less common and occur in calcrete terraces in dissected valleys, mainly in the Gascoyne Province of Western Australia. Uranium in calcrete-hosted deposits occurs entirely in the mineral carnotite.

As carnotite is a uranium-bearing vanadium oxide of potassium ( $K[U^{+6}O_2][V^{+5}O_4] \cdot xH_2O$ ), its formation in calcrete is determined by geochemical processes that control the concentration of potassium, uranium and vanadium in groundwater and in playa lakes. Other important geochemical factors which may control the concentration of uranium in groundwater and playa-lake-water include the pH of the fluid and the concentration of dissolved carbonate and sulphate in the water (Bastrakov et al 2010).

The formation of calcrete-hosted uranium deposits can be illustrated in a three stage model (figure 1). The first stage represents the filling of paleovalleys with coarse-grained sediments of high permeability (figure 1a). This is followed by the initiation of an active groundwater drainage system. In arid zones dominated by intensive evaporation, the drainage system generates zones of calcrete near the water table (generally in the vadose zone, where the water is saturated with air, figure 1b). Intensive evaporation in the playa lakes causes deposition of evaporites and calcrete. Like other infill sediments, the calcrete also begins to act as an aquifer and is affected by evaporation and a fluctuating water table. Potassium and uranium are leached from felsic rocks (located upstream or in the incised bedrock of the palaeovalley) by saline, oxidised



**Figure 2.** Distribution of key components of calcrete-hosted uranium mineral systems in the Paterson area.

groundwater, whereas vanadium is extracted from sources such as mafic rocks or iron rich (meta)sediments. Evaporation of groundwater can cause changes in the concentration of dissolved potassium, uranium, vanadium and carbonate, triggering precipitation of carnotite (figure 1c). In the vicinity of playa lakes, precipitation of carnotite can occur due to mixing of valley groundwater with potassium-rich saline lake water.

The above model of calcrete-hosted deposits shows that their formation is closely related to the evolution of the drainage system. Factors which favour uranium mineralisation include the presence of :

- source rocks of uranium (such as granites) and vanadium (such as mafic rocks and/or banded iron formations)
- paleovalleys / paleochannels that contain calcrete
- drainage systems of reasonable size with active recharge and discharge areas (such as playa lakes).

**Table 1.** Potential of calcrete–hosted uranium mineral systems in the Paterson region.

Criteria	Lake Waukarlycarly	Lake Dora – Lake Blanche	Lake Winifred
Groundwater flow system	Valley around Nifty–Kintyre – Telfer and from Lake Dora.	Lake Dora– Blanche.	Lake Disappointment–Lake Winifred.
Groundwater flow system size	Large.	Moderate to large.	Large.
Calcrete	Mapped around the Lake; southern part continuous 20 km x 60 km, northern part patchy.	Mapped around Lake Dora, and Lake Blanche.	Large area of continuous calcrete.
Source of uranium	Present. Felsic igneous rocks well exposed in Pilbara Craton west of the Lake. Felsic igneous rocks in the Telfer area. Felsic igneous rocks also exposed Rudall Complex.	Present. Felsic igneous rocks for west and south of Lake Dora–Lake Blanche. Ferruginous duricrust for north and east of Lake Dora.	Present. Felsic igneous rocks exposed in Rudall Complex.
Source of vanadium	Present. Mafic and ultramafic igneous rocks in Pilbara Craton and Rudall Complex.	Present. Mafic and ultramafic igneous rocks in Rudall Complex.	Present. Mafic and ultramafic igneous rocks in Rudall Complex.
Indication of uranium enrichment	Yes, as indicated by uranium anomalies in radiometric data around the lake area and Lamil Hill prospect.	No data	No data
Potential for calcrete-type uranium system (figure 3)	High in the rim of calcrete south of lake for valley- and playa-type (A). Moderate to high for (B), (C) and (D).	Moderate-high west of Telfer. Moderate south of Lake Blanche. Low north and east of Lake Dora.	Moderate–high potential for valley-type in palaeovalley near Lake Winifred (H).
Certainty (figure 3)	Moderate–high for (A), moderate for (B), (C) and (D).	Moderate for (E) & (G). Low to moderate for (F).	Moderate to low (H).

*For other areas in the Paterson region see Table 7.13 in Liu and Jaireth (2010).*

## Potential of valley- and playa-type deposits in the Paterson region

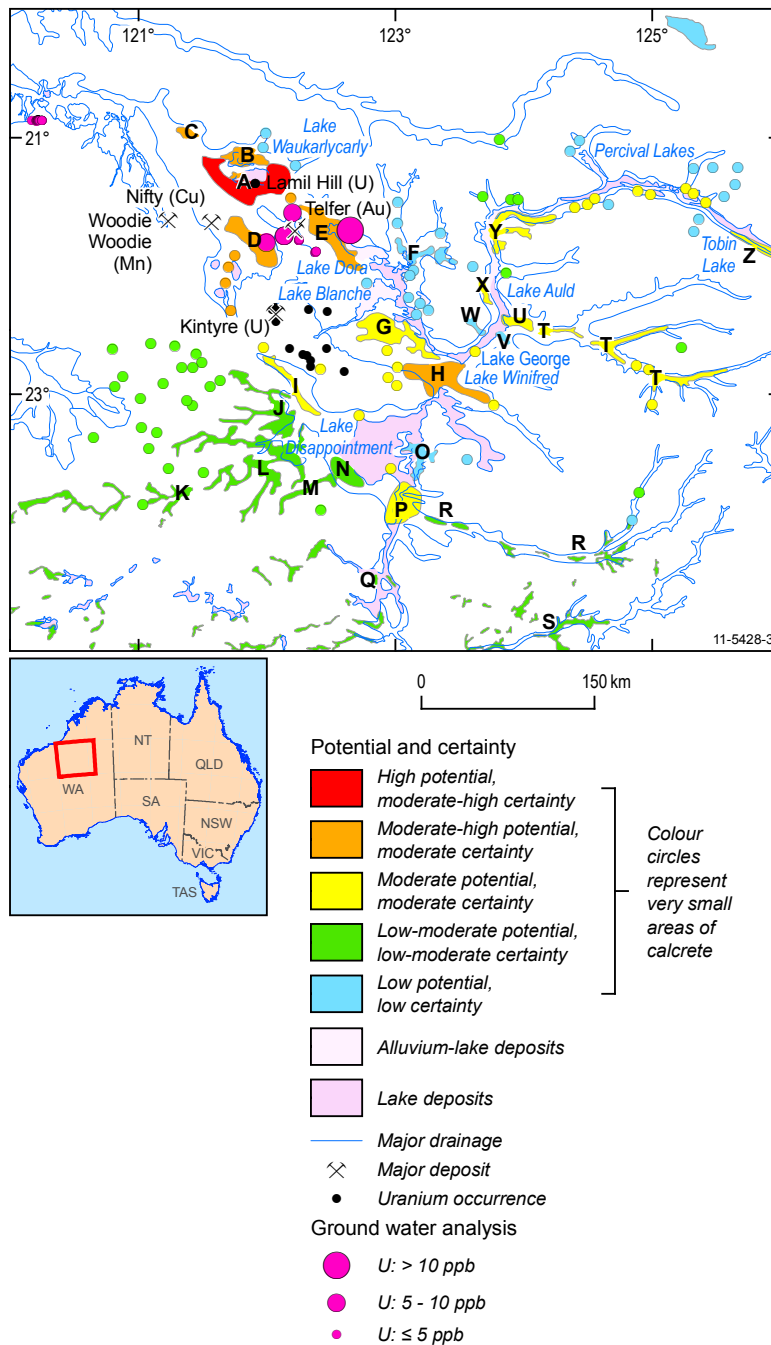
The Paterson region contains abundant source rocks for uranium, which include Archean to Mesoproterozoic felsic igneous rocks of the Pilbara Craton, Rudall Complex and the Neoproterozoic Mt Crofton Granite Suite in the Telfer area (figure 2). Ferruginous regolith materials also have medium to high abundances of uranium (3.5 to 4 parts per million or ppm) although it may be less leachable

than uranium in felsic rocks. The region also contains source rocks of vanadium such as mafic and ultramafic igneous rocks in the Pilbara Craton and Rudall Complex (more than 300 ppm; Bagas and Smithies 1998, Hickman and Clarke 1994), and ferruginous duricrust (figure 2).

The region is characterised by well-developed current and paleo-drainage systems involving (paleo)valleys and lakes (figure 2). Flow directions of surface and groundwater have been determined from topographic maps, a digital elevation model and groundwater work. The Paterson AEM data defined a (paleo)drainage system which included a paleovalley over the Anketell Shelf from Lake Dora to Lake Waukarlycarly, and a palaeovalley connecting water flows from Lake Disappointment towards Lake Winifred and Lake Blanche (figures 5.30 and 5.31 of Roach 2010). The region also contains abundant valley-type calcrete and sulphate-rich sediments in the playa lakes.

The presence of appropriate source rocks, drainage systems and depositional environments makes the Paterson region prospective for calcrete-hosted uranium deposits. Prospective areas are shown on figure 3. Key features of the Lake Waukarlycarly, Lake Winifred, and Lake Dora–Lake Blanche prospective areas and levels of potential are summarised in Table 1. For other areas please see Liu and Jaireth (2010; Table 7.13).

These areas are divided on the basis of drainage systems including



**Figure 3.** Prospectivity map for calcrete uranium mineral systems in the Paterson area. See Roach (2010) for detailed description of the method used for the assessment.



recharge and discharge areas, source areas for uranium and vanadium and water flow directions in drainage systems (figure 3): Lake Waukarlycarly (A to D); Lake Dora–Lake Blanche (E to G); Lake Winifred (H); Lake Disappointment west (I to N); Lake Disappointment southeast (P to S); and Lake Auld–Percival Lakes–Tobin Lake (T to W, X to Z).

Available information suggests that there is high potential for calcrete–hosted uranium mineral systems in the calcrete–rim area south of Lake Waukarlycarly (A). Potential is moderate to high in the area north and northwest of Lake Waukarlycarly (B and C), in the valley between Kintyre & Woodie Woodie-Nifty (D), east of Telfer (E) and south of Lake Winifred (H). Elsewhere the potential is low to low-moderate (figure 3).

### Implications for exploration

The Paterson region contains several areas prospective for valley- and playa-type calcrete-hosted uranium deposits. The area with the highest level of potential is located to the south of Lake Waukarlycarly. A more detailed AEM survey (close line-spacing) may help map the paleochannels in greater detail to delineate more prospective areas. Geochemical surveys of sediment and groundwater can provide additional geochemical indicators (such as a saturation index with respect to carnotite) to map areas for detailed targetting. The presence of the Lamil Hills prospect shows that fertile calcrete mineral systems operated in the region.

### For more information

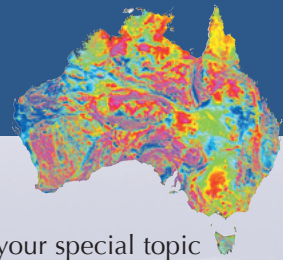
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