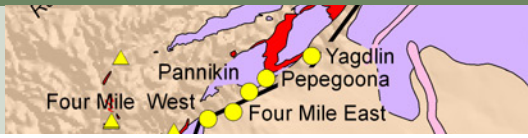
Australian Government
Geoscience Australia

AUSGEO news
ISSUE 107 Sept 2012

Mapping new sandstone-hosted uranium terranes in South Australia

Survey highlights potential new discoveries



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Airborne electromagnetic (AEM) data describe the electrical conductivity of the ground. Electrical conductivity of the ground can be caused by electrically conductive minerals such as clays, sulphides and graphite, but also by saline groundwater. The AEM data can be used to map the stratigraphy and shape of shallow sedimentary basins and paleochannel/paleovalley systems, which may be indistinguishable using other geophysical methods like gravity and magnetics. The data can also be used for mapping groundwater resources.

Geoscience Australia has flown three regional AEM surveys in:

- Western Australia (Paterson Province; Roach 2010)
- Northern Territory (Pine Creek region; Craig 2011)
- South Australia (Lake Frome region; Roach 2012)

as part of the Onshore Energy Security Program (Geoscience Australia 2011). The raw AEM data have been mathematically inverted using in-house software (the GA Layered Earth Inversion or GA-LEI) to produce geologically validated ground conductivity models that are suitable for interpretation (Hutchinson et al 2011).

The Lake Frome region of South Australia is Australia's premier sandstone-hosted uranium province. The region hosts Australia's only two operating In Situ Recovery (ISR) uranium mines at Beverley and Honeymoon (Figure 1), as well as many other deposits and prospects hosted in paleochannel systems within paleovalleys. Paleovalleys are the buried remains of ancient river systems, which are often hidden beneath surface cover (such as sand dunes) in the landscape. These have been described in more detail in the Lake Frome region by Jaireth et al (2010) and as a concept by Clarke (2009). Exploration interest has expanded beyond the Lake Frome region to include the Blanchewater area between the northern Flinders Ranges and Lake Blanche (Figure 1), where there is potential for similar uranium deposits.

The Frome airborne electromagnetic (AEM) survey is the subject of an interpretation report recently published jointly by Geoscience Australia and the Geological Survey of South Australia (Roach 2012). The report provides interpretations of regional AEM data that highlight the potential of this area for sandstone-hosted uranium deposits.

Architecture of sandstone-hosted uranium systems

Sandstone-hosted uranium deposits are generated by reduction-oxidation (redox) chemical reactions. Uranium is dissolved and transported in oxidised groundwaters and is reduced to form uranium oxides, generally formed in proximity to redox fronts within a sandstone aquifer. The architecture of a fertile uranium system is defined by:

- A source region containing readily leachable uranium
- Highly permeable sandstone sediments (aquifers) confined within less permeable shaly sediments (aquitards)
- A suitable *in situ* or mobile reductant
- An effective hydrogeological setting which connects the above three elements.

In the northern Flinders Ranges, uranium-enriched rocks occur in the Mount Painter Inlier (Mount Neill Granite with up to 380 parts per million (ppm) uranium and Hot Springs Gneiss up to 470 ppm uranium; Fraser and Neumann 2010) and the Mount Babbage Inlier (Yerilla Granite up to 270 ppm uranium; Fraser and Neumann 2010). Uranium occurs primarily as the mineral uraninite, which is

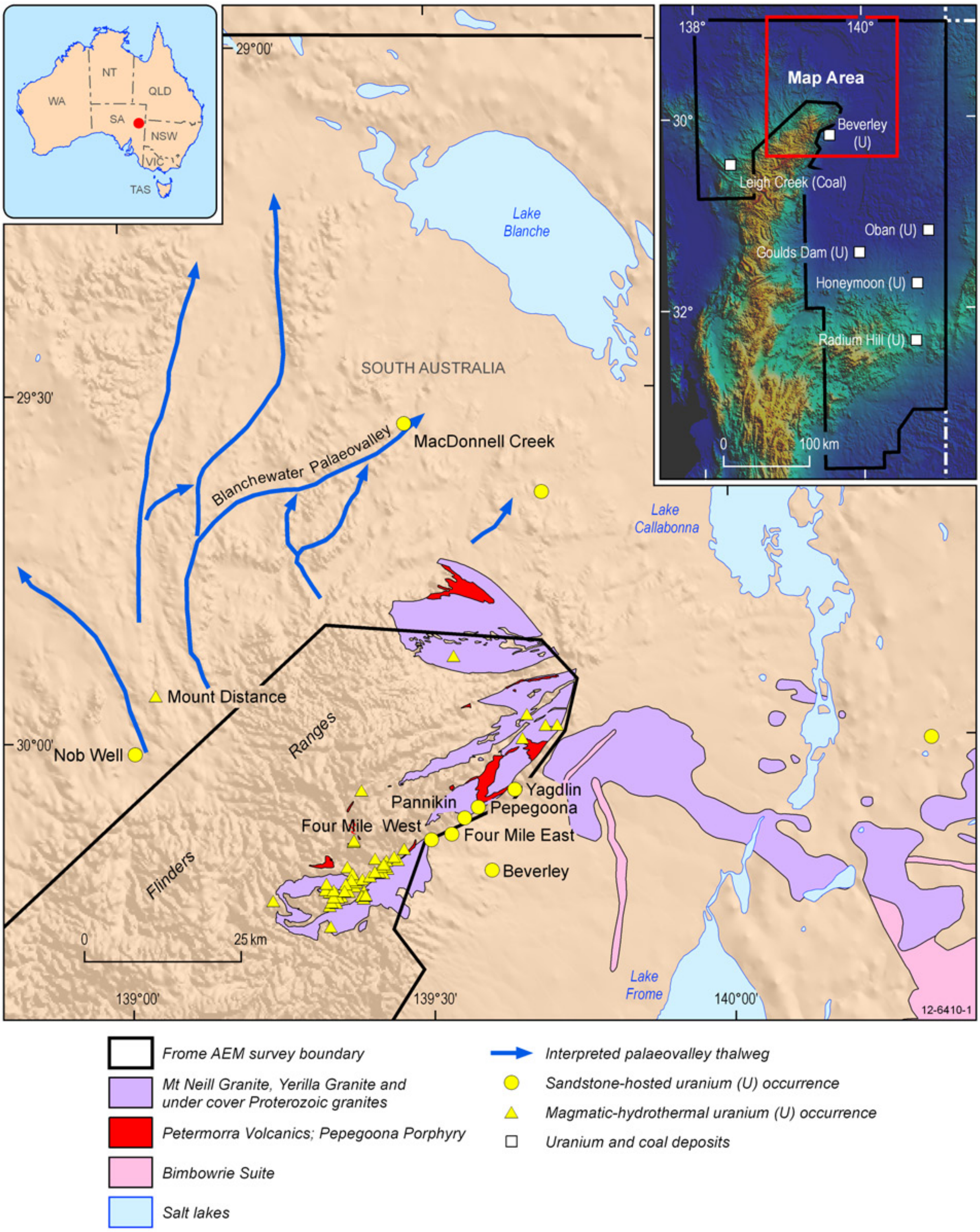

Figure 1. The map shows the solid geology of uranium-bearing granites of the Mount Painter and Mount Babbage inliers (Mt Neill and Yerilla granites) and known uranium occurrences (from SARIG), major lakes and interpreted palaeovalley/palaeochannel courses overlain on a digital elevation model of the region. The uranium-bearing granites outcrop in the northern Flinders Ranges, but occur under cover elsewhere. The inset map shows the location of the Blanchewater area and the Frome AEM Survey.

highly soluble in oxidised groundwater. These rocks also contain several uranium-bearing accessory minerals such as monazite, allanite, xenotime and zircon. In addition to uranium-enriched felsic rocks, the inliers also host a number of magmatic-hydrothermal and epithermal uranium deposits and prospects such as Mount Gee, Mount Painter and Radium Ridge, which can provide leachable uranium.

Once dissolved, uranium is transported laterally by groundwater through fractured rock and sedimentary aquifers into paleochannels nestled within paleovalleys until it meets a suitable reductant. The reductant may be solid (normally carbonaceous material like plant remains or lignite, but also minerals like pyrite), liquid (oil) or gas (a hydrocarbon such as methane or another gas such as hydrogen sulphide; Jaireth et al 2008).

In sandstone-hosted uranium deposits paleochannels/paleovalleys define the shape and size of the hydrogeological system which can transport geologically realistic quantities of uranium to the redox front in the aquifer. The Frome AEM Survey has been able to map the paleochannel/paleovalley systems and delineate the broad distribution of sand- and shale-dominated facies within the sediments filling them.

In the Blanchewater area, mineral explorers are searching for uranium deposits in paleochannels/paleovalleys filled primarily with Cenozoic Eyre Formation sediments. These are known to host most of the uranium mineralisation in the Lake Frome region (for example, Four Mile East, Pannikin, Pepegoona, Honeymoon, Oban, Junction Dam and Goulds Dam). Explorers are also searching secondarily for mineralised Namba Formation sediments which may also host uranium mineralisation (for example, Beverley and Yagdlin). More information on the sandstone-hosted uranium deposits of the southern Lake Frome region is included in Skirrow (2009), Jaireth et al (2010) and Wilson (2012).

Mapping paleochannel/paleovalley systems in the Blanchewater area

Recent reports by exploration companies working in the Blanchewater area highlight the area's potential, with a new discovery in the Blanchewater Paleovalley at MacDonnell Creek (Figure 1). Data from the Frome AEM Survey have not only confirmed the existence of the system but defined its shape and size more accurately. In addition, major fault systems, which have controlled uranium movement and deposition underlining the high potential of this area to form sandstone-hosted uranium deposits, have also been mapped.

In Figure 2, AEM data are displayed as conductivity sections compared to the regional surface geology map at MacDonnell Creek to illustrate the contrasting electrical conductivity conditions of the top 400 metres of the ground. Conductors in the two conductivity sections in the image correlate with geological features in the geology map. These are the Mesozoic Marree Subgroup of the Eromanga Basin, which contains the Bulldog Shale (a pyrite-bearing black shale, recognised as a strong electrical conductor) and the Oodnadatta Formation (another relatively conductive sandy clay unit). A number of other Cenozoic sedimentary units can be mapped within the conductivity sections including the sand-rich Eyre Formation (a relatively electrically resistive unit in this image) and the clay-rich Namba Formation (which includes a relatively conductive layer near its base, interpreted to be a salt water-filled sandy layer). Interpretations are only possible with the addition of surface and borehole geological information; a number of boreholes are included in Figure 2, highlighting the correlation between the borehole geology and electrical conductivity in the conductivity sections.

Geological interpretations from the conductivity sections, together with solid geology and a digital elevation model, were used to compile a 3-dimensional model of the Blanchewater and wider northern Flinders Ranges area (Figure 3). This model illustrates the interpreted Mesozoic-Cenozoic unconformity which separates the Eromanga Basin (containing the Marree Subgroup; below) and the Lake Eyre Basin (containing the Eyre and Namba formations; above). It also includes the outcropping uranium-rich granite source rocks of the Mount Painter and Mount Babbage inliers in the northern Flinders Ranges. The uranium-bearing granites continue under cover of the Eromanga and Lake Eyre basins, as shown in Figure 1. Offsets in conductors in the conductivity sections (Figure 2) generally correlate with faults mapped at the surface and have

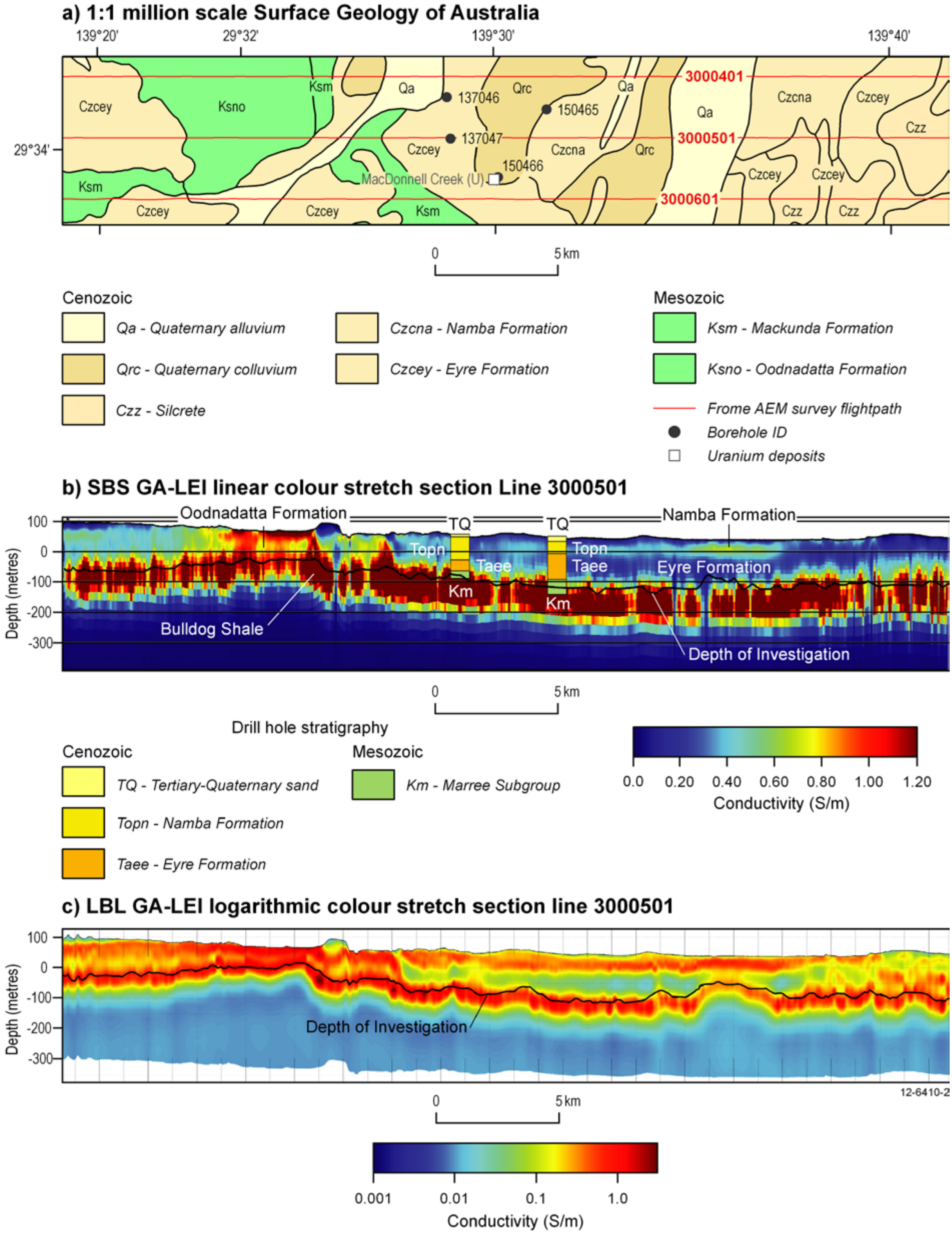

Figure 2. Surface geological map and AEM conductivity sections of flight line 3000501 in the Blanchewater area. Sedimentary units in the surface geology map (top) are correlated with conductivity features in the two conductivity sections (middle, bottom). Two different GA Layered Earth Inversion (GA-LEI) products have been generated for the Blanchewater area: a sample-by-sample GA-LEI (SBS GA-LEI), which enhances vertical features (middle); and, a line-by-line GA-LEI (LBL GA-LEI), which enhances horizontal features (bottom). Stratigraphic drill holes plotted over the SBS GA-LEI conductivity section (middle) are used to correlate conductivity features with under-cover geology. The diagram is modified from Costelloe and Roach (2012) and includes the Surface Geology of Australia map of Raymond (2010).

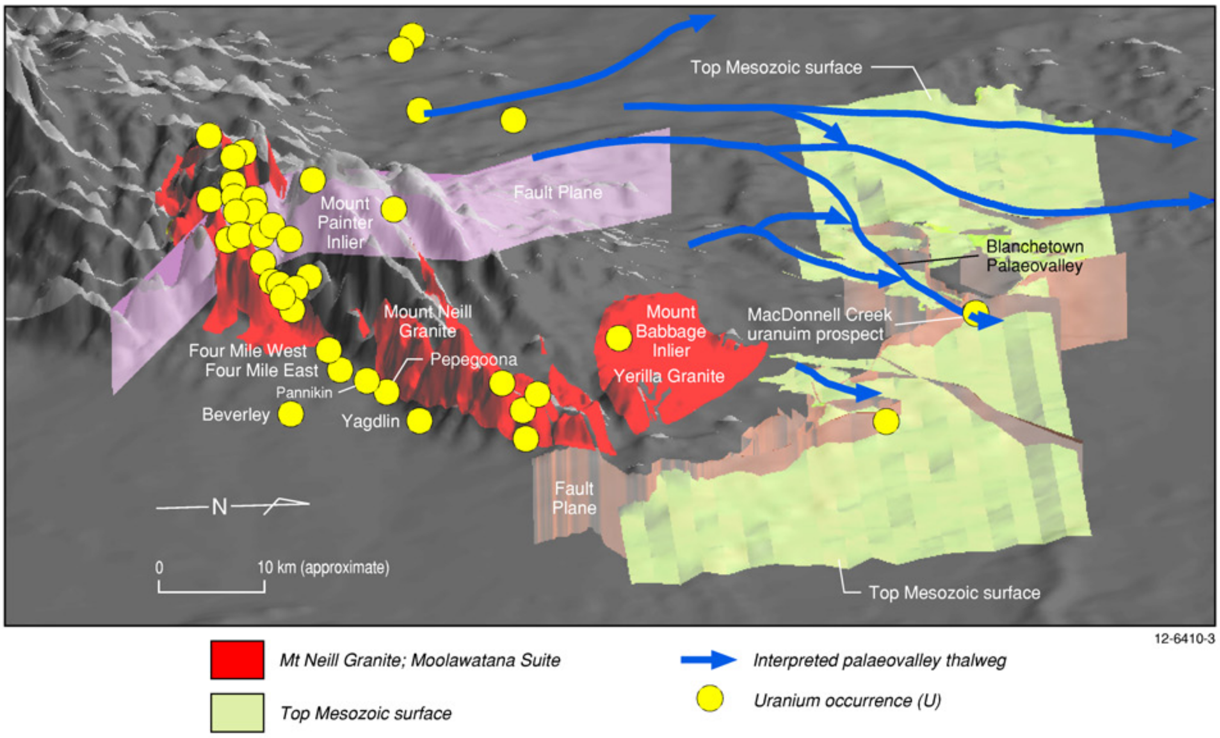

Figure 3. 3D model of the northern Flinders Ranges and Blanchewater region. The model shows solid geology of uranium-bearing granites of the Mount Painter and Mount Babbage inliers and known uranium occurrences (from SARIG) draped over the digital elevation model (shown partially transparent here) and interpreted palaeochannel/palaeovalley courses. A series of neotectonically-active faults offset the interpreted Mesozoic-Cenozoic unconformity which is the boundary between the underlying Eromanga Basin and the overlying Lake Eyre Basin. Some of the faults were mapped by Sheard et al (1996). Uranium-rich groundwaters are interpreted to drain from the Yerilla Granite of the Mount Babbage Inlier (and perhaps the Mount Neill Granite of the Mount Painter Inlier) into the Blanchewater Palaeovalley, depositing uranium at redox fronts on the down-thrown side of the fault system.

been used to more fully map the large, neotectonically-active fault system that wraps around the northern Flinders Ranges. The AEM data have also mapped previously unknown faults under sedimentary cover. Fault offsets of up to 200 metres have been measured in some conductivity sections. Conditions suitable for uranium deposition in the Eyre Formation occur north of the large fault system shown wrapping around the north of the northern Flinders Ranges in Figure 3. On the down-thrown side to the north of the fault system sediments are protected from physical erosion and from chemical stripping of uranium mineralisation by oxidised groundwater. On the up-thrown side, to the south of the fault system closer to the Flinders Ranges, the Namba Formation and some Eyre Formation appear to have been removed by erosion.

Implications for uranium prospectivity

The MacDonnell Creek uranium discovery in the Blanchewater Paleovalley highlights the potential of the Blanchewater area for new uranium discoveries. Mapping using regional AEM allows explorers to interpret the links between source regions of leachable uranium (containing ~250 ppm uranium) and deposition sites, demonstrating the importance of locating the major factors controlling uranium mineral systems. In this example, uranium is most likely sourced from the Mount Babbage Inlier, although the Mount Painter Inlier should not be discounted as a source, with uranium perhaps supplied by groundwater passing through a major fault system potentially linking it with the upper Blanchewater Paleovalley indicated in Figure 3. Uranium was (and perhaps still is) transported by groundwater through the Blanchewater Palaeovalley and has been deposited in carbonaceous Eyre Formation sediments, principally on the down-thrown side of the fault system shown in Figure 3. The regional AEM data allow users to locate similar groundwater flow systems which may also carry uranium-rich waters to suitable reduction sites along the down-thrown side of this major fault system that influences the landscape of the northern Flinders Ranges.

Although the Eyre Formation is considered to be the most important uranium host, sand lenses in the Namba Formation may also be prospective for uranium mineralisation. The analysis presented in this article can be used in other areas of the Lake Frome region where the Frome AEM survey has similarly been able to map the architecture of the paleochannel/paleovalley-type sandstone-hosted uranium deposits. For more information about the features described here please see the detailed interpretations in the Frome AEM Survey interpretation record (Roach 2012).

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