Geophysics and Uranium in the Curnamona and Billeroo Palaeochannel Systems, Frome Embayment, South Australia

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SUMMARY

Tectonism is believed to have exerted a strong control on the current disposition of sedimentary hosted uranium mineral deposits in the Frome Embayment, in South Australia. However the extent of this control has not been well understood, nor documented. Here, we examine the combined use of regional and finer-scale TEMPEST AEM data sets, linked to a structural interpretation of airborne magnetics and ground gravity, to extend our understanding of the evolution, geometry and variability of sediment packages associated with sedimentary uranium mineralisation in the Curnamona and Billeroo Palaeochannel systems. Through the analysis of both smooth and blocky model LEI inversions of these AEM data, we contend that structural control was critical in determining the initial orientation of the palaeovalleys and the location of basal sequences of the Eyre Formation, the host to known uranium mineralisation. We examine this influence in the context of the Goulds Dam uranium deposit. The presence of reactivated basement faults which controlled the initial orientation of the palaeovalley systems may also have a role in providing the loci for mobile reductants from underlying basin sequences, although this requires further investigation.

Key words: AEM, Roll-front Uranium, Structure, Frome.

INTRODUCTION

Much has been written about the development of uranium mineral systems in the Frome Embayment (see, for example, Ellis 1980, Curtis *et al.* 1990, Fabris 2006, Skirrow (Ed) 2009, and Wilson 2012). Similarly, there is a good literature on the role of geophysics in elucidating the nature and geometry of hosts for mineralisation, most particularly the palaeochannel sediment hosts of the Eyre and Namba Formations (e.g. Dentith and Randell, 2003, Skidmore 2005, McConachy *et al.* 2006, and Roach (Ed) 2012).

Skirrow (Ed.) (2009) presented cogent argument for how the lithological and fault architecture presented for the Lake Frome region provided key elements for sandstone hosted uranium mineralisation. He also suggested that the early fault architecture which developed during the Proterozoic exerted a fundamental tectonic-topographic control on the general northwards trend of many of the major Cenozoic paleochannels in the Frome Embayment and Callabonna Sub-basin including those hosting uranium mineralisation at the Honeymoon and Beverley deposits. In this paper, we develop these observations and examine geophysical evidence for structural control on determining the primary orientation of the Curnamona and Billeroo palaeovalleys located in the southern margin of the Callabonna Sub-basin (Fabris 2006). We also consider its role in determining the position of the Goulds Dam uranium deposit, a deposit with an indicated resource of 5.6 Mt at 0.045% U3O8 (Skidmore 2005). The deposit, is located in the Billeroo palaeovalley, drains the Olary Ranges in the south (Figure 1) which contain the highly uraniferous Crocker Well Suite. Mineralisation is restricted to the basal sands of the Eyre Formation and is associated with a redox transition which extends for 5 km from Goulds Dam in a northerly direction within these palaeovalley sediments (Ellis, 1980 and Curtis, *et al*., 1990).

GEOPHYSICAL DATA

TEMPEST AEM data acquired in 2011, as part of the Frome Embayment survey (Roach (Ed) 2012), and a higher resolution data set acquired in 2002 (Skidmore 2005 and Dentith and Randell 2003) were analysed as part of this study. These data were inverted using AarhusInv inversion code (formerly EM1DINV), which is described in detail in (Auken et al 2005). Both smooth (30 layer) and Blocky (2 layer) LEI were employed. Examples of these inversions are presented in Figure 2; in this case results from one flight line over the Billeroo Palaeovalley. The 2 layer model was employed as a means of defining the geometry of the Cambrian basement – overlying Cenozoic sediments boundary, which is represented by a change in bulk resistivity (the basement being resistive) as described by Dentith and Randell (2003). A key component of this study was a detailed examination of subtle conductivity variations with depth across the boundary mentioned above. The aeromagnetic data acquired as part of the 2002 TEMPEST survey were also subject to analysis. No other high resolution magnetics data were available. In addition high resolution ground gravity data covering the Curnamona and Billeroo palaeovalleys were studied (see Figure 3).

INTERPRETATION

A combined structural interpretation of the inverted AEM, the airborne magnetics (not shown) and ground gravity (Figure 3A, and B) building on that undertaken by Teasdale et a.l (2001), is presented in Figure 3. The new structures identified in the high resolution geophysics are marked in red. The interpretation identifies a significant number of what we interpret as previously undefined NW-SE fault systems. Analysis of the TEMPEST interval conductivity data, particularly for depths which transition across the boundary between a Cenozoic sediments and underlying Cambrian Basement, indicate a marked linear NNE orientation in the conductivity structure (Figure 3). This observed conductivity structure is determined by moderately conductive sediments of the Lower Eyre Formation infilling a set of broad palaeovalleys cut into a resistive basement. The palaeovalleys are represented by the Curnamona in the west, and the Billeroo palaeovalley in the east. We suggest that NE orientated normal fault structures, and NW oriented transfer structures, initially developed in the Cambrian (see Teasdale *et al* 2001), were preferentially eroded, at a time of regional denudation between ~90Ma until the Paleocene, by a series of braided stream systems flowing north. These fluvial systems eroded preferentially weathered structural corridors (Figure 4). They cut wide shallow valleys, ranging from hundreds of metres to several kilometres wide in the Cambrian sediments. They then filled with Eyre Formation sediments, comprising sands with clay-rich interbeds, in the early Eocene, (Figure 4). In the vicinity of Goulds Dam the conductivity-depth sections (e.g. Figure 2) that transect the Billeroo palaeovalley, indicate it to be ~ 2km wide, but only ~ 25m deep; that is, wide and shallow.

The NNE trending conductivity structure, representing the Curnamona and Billeroo palaeovalley fill, shows regular lateral offsets (Figure 3A) which we interpret as being related to NW-SE trending transfer faults caused by WNW—ESE compression. These fault systems were also preferentially eroded when the palaeovalleys were developed, and as they filled, these structures would have influenced the location of bends in the river system (see Figure 4). Bends, basal scours, confluences or areas of channel-widening are significant in sandstone hosted uranium mineral systems as these are often where uranium mineralisation is located (Jaireth et al. 2008). In the case of the Goulds Dam deposit, the basement geometry indicates that the Billeroo palaeovalley bends to the north-west, which we interpret as being controlled by a transfer fault(s) cutting the NNE-SSW trending structural controlled corridor along which the channel was first developed (Figure 4). The bend in the channel system may have encouraged the preferential deposition and accumulation of organic reactants (organic material), something that would have had a bearing on the deposition of uranium later on. Interestingly, the coincidence of reactivated Paleozoic basement fault systems, which these are, may provide potential pathways linking Cambrian hydrocarbon fluids with near-surface environments (see Figure 5). Therefore the potential may exist for mobile reductants to catalyse the precipitation of uranium carried in oxidised surface-derived waters Jaireth et al. (2008).

CONCLUSIONS

Episodic tectonism, related structure and resultant topography all played a role in triggering fluid flow, from basement areas in the south, into the Eyre Formation, utilising NNE-SSW trending palaeovalleys which host the Eyre sedimentary sequences. Combined, high resolution AEM, magnetic and gravity data define a strong structural control on the orientation of the Curnamona and Billeroo Palaeovalleys. NW-SE structures are also important in influencing the form of the palaeovalley systems. The coincidence of reactivated basement faults may provide potential paths linking mobile reductants with near-surface environments promoting the precipitation of uranium, although this needs further investigation.

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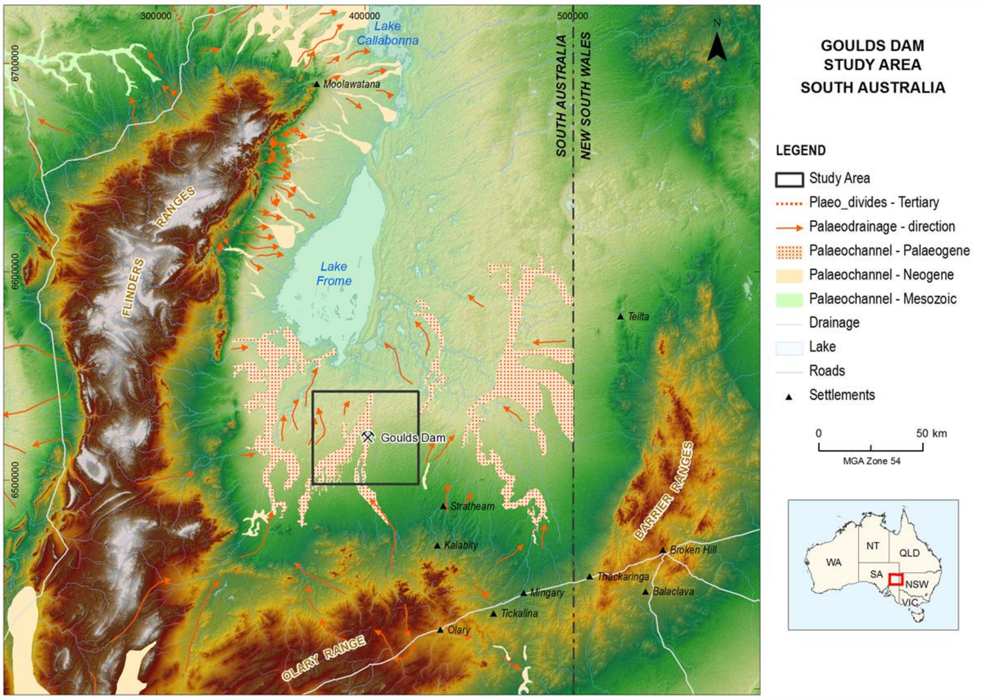

Figure 1. Location of the study area focused on the Goulds Dam uranium deposit in the Frome Embayment of South Australia. The distribution of known palaeodrainage systems is also shown. Goulds Dam is located near the intersection of the Billeroo and Curnamona palaeovalleys which drain north.

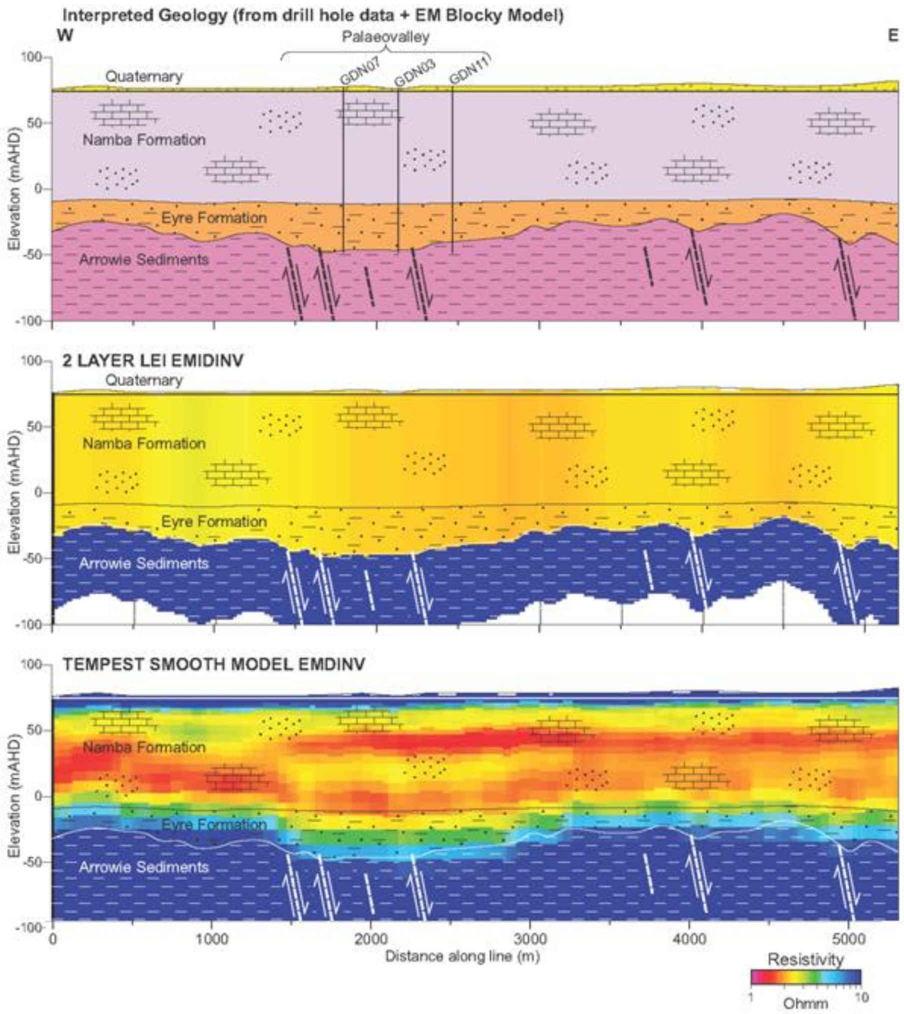

Figure 2. Interpreted geological section (top panel) for a line of TEMPEST data acquired across the Billeroo Palaeovalley. The geological section is derived from a combination of drillhole data and analysis of the inverted TEMPEST data. The middle panel is a conductivity-depth section determined from a 2-Layer LEI, and the bottom panel, a smooth model LEI of the same data. Both results define a broad shallow valley system for the Billeroo Palaeovalley. The positions of possible faults is also shown.

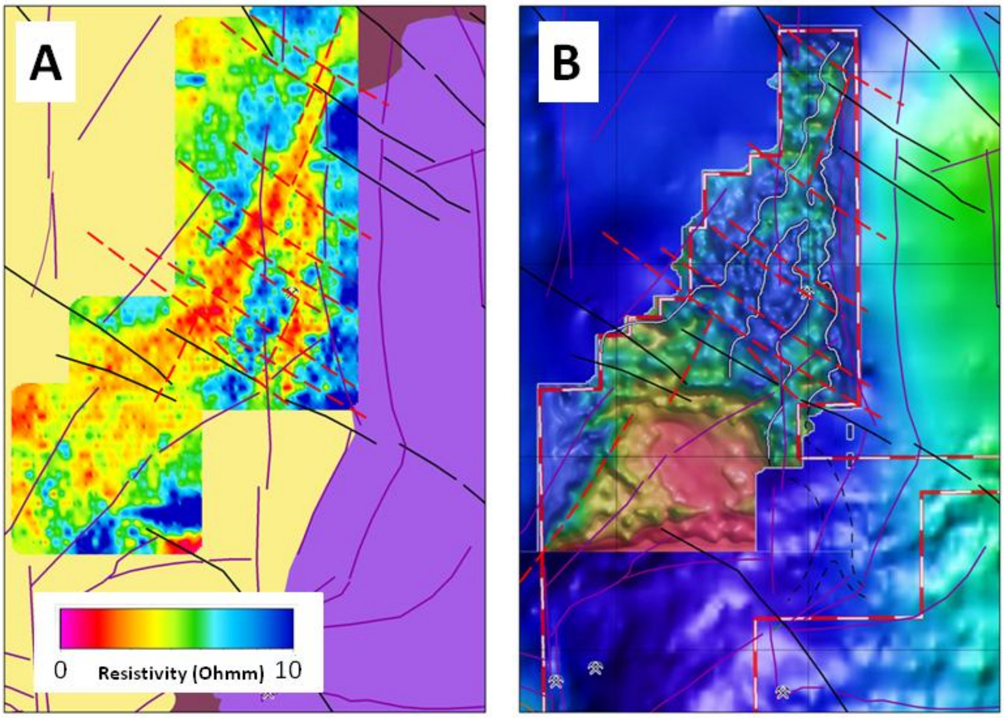

Figure 3. A) pseudo-coloured interval conductivity layer for a depth interval of 90-100m below the ground surface. The image is derived form a smooth model inversion of TEMPEST data covering the Curnamona and Billeroo palaeo-valleys. The image is overlain on a geological map of the basement. Newly interpreted structures are marked as red-dashed lines.

B) high resolution ground gravity data (total field) overlain on regional gravity data

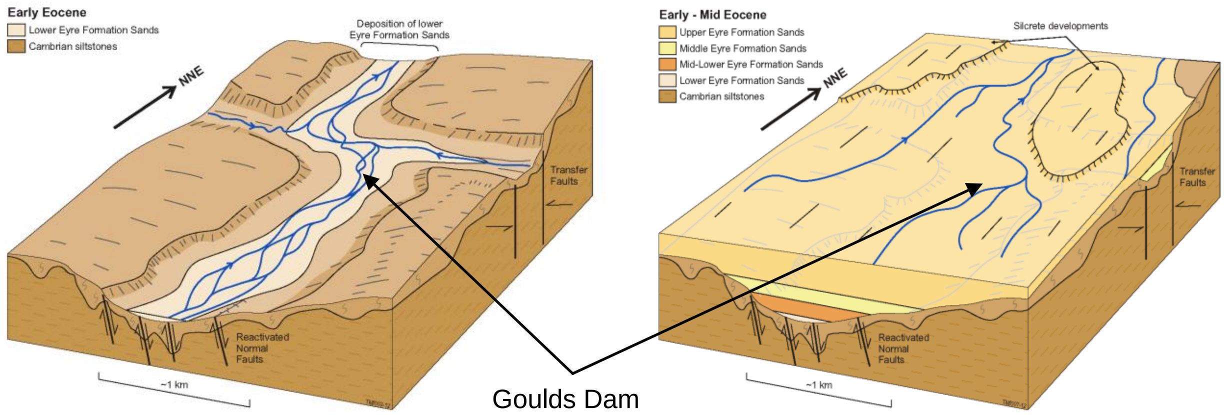

Figure 4. Indicative location of Goulds Dam Uranium Deposit in a schematic time series representation of the Billeroo Palaeovalley from the Early-Mid Eocene.

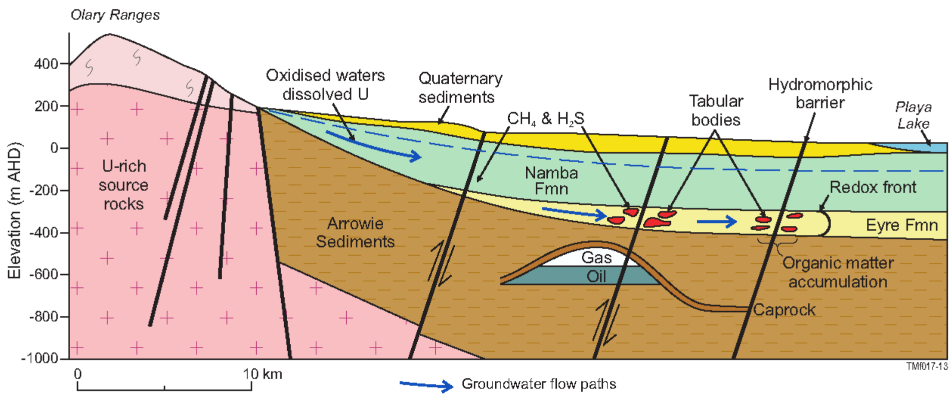

Figure 5. Diagrammatic N-S section of sandstone hosted uranium systems found in the Eyre Formation, showing source of oxidised U-bearing groundwater and formation of tabular styles of uranium deposits. The potential role of mobile and other organic reductants is also shown. Adapted from Jaireth et al. (2008).