

# USING GROUNDWATER TO VECTOR TOWARDS MINERALISATION UNDER COVER: THE CURNAMONA PROVINCE

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## INTRODUCTION

The Curnamona Province (Figure 1) is host to the supergiant Pb-Zn-Ag Broken Hill orebody and numerous smaller deposits, which occur mostly in the limited regions of outcropping Paleo- to Mesoproterozoic basement. It has a high mineral potential for base metal and Fe-oxide Cu-Au style mineralisation, but approximately 90% of the area is concealed by regolith cover.

Hydrogeochemistry is a tool that can fingerprint groundwater-mineralisation interaction through transported cover. We used major and trace element concentrations, stable and radiogenic isotope signatures and batch and reactive-transport geochemical modelling to identify areas of sulfide oxidation at depth.

## METHODS

We collected about 350 groundwater samples from existing boreholes in the Curnamona Province, both in areas of outcrop in the ranges and in areas of cover in the surrounding basins (Figure 1). The samples were analysed for a comprehensive suite of major, minor and trace elements as well as for several stable and radiogenic isotopes.

## RESULTS

The results indicate that groundwater composition is affected by a number of processes: evaporation; evapo-transpiration; mixing; ion exchange; precipitation/dissolution; adsorption/desorption; and, oxidation/reduction. The impact of each of these major processes is teased out using 'conservative' tracers (Cl<sup>-</sup>, Br<sup>-</sup>), isotopes and geochemical modelling.

## DISCUSSION

To develop hydrogeochemistry into a useful tool for mineral exploration we followed a number of steps in the analysis of the data:

- 1) We calculated an index of 'relative sulfur excess' (Rel S<sub>XS</sub>) to gain knowledge of samples that contain more S than can be accounted for by evaporation or mixing (Figure 2).
- 2) The S isotopic composition of dissolved SO<sub>4</sub><sup>2-</sup> enabled us to identify samples containing S from Broken Hill type mineralisation (trend toward "Min" on Figure 2).

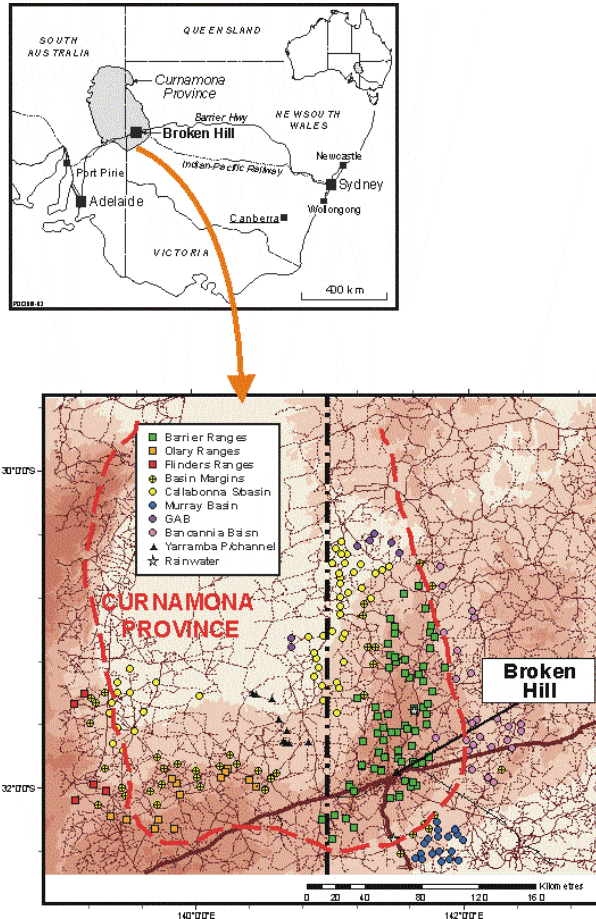
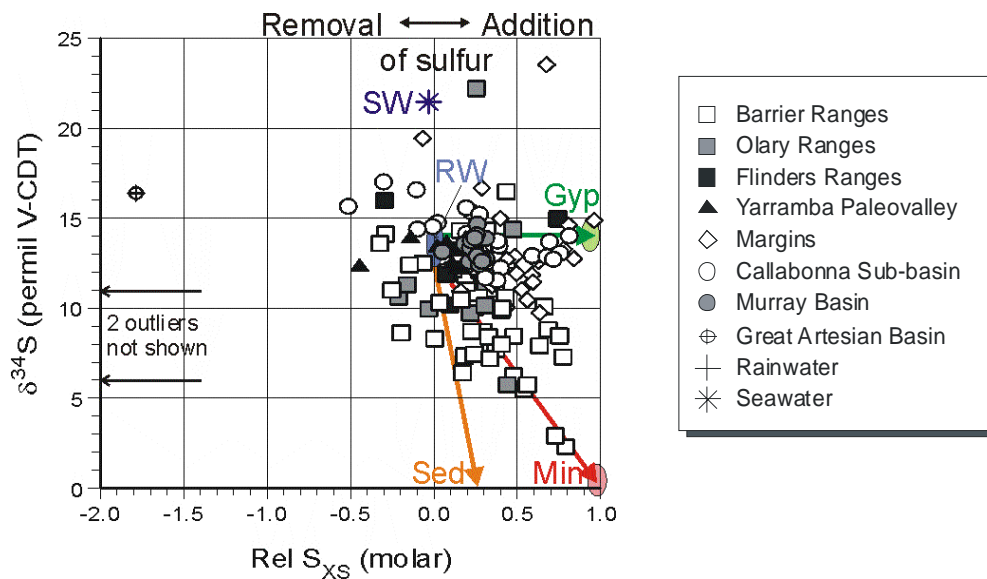
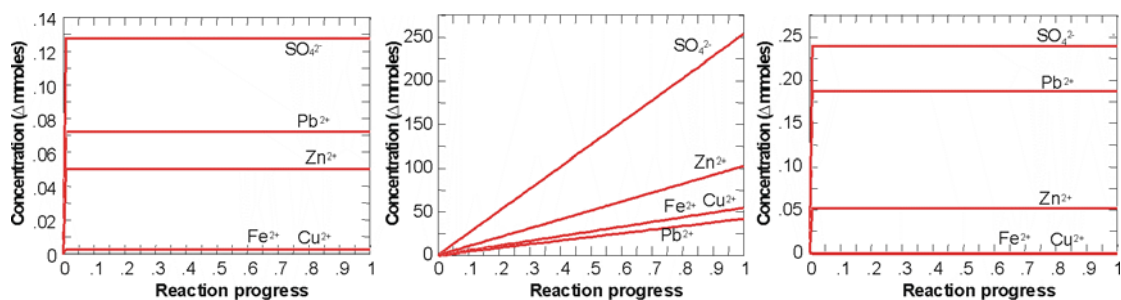


Figure 1: Location of the Curnamona Province.



**Figure 2:**  $\delta^{34}\text{S}$  versus relative S excess plot of groundwater data and end-members (RW: rain water, SW: sea water, Sed: sedimentary pyrite, Gyp: gypsum, Min: Broken Hill type mineralisation).

3) Batch reaction-path modelling of the oxidation of chalcopyrite, sphalerite and galena helped constrain the amounts of  $\text{SO}_4^{2-}$ , Cu, Zn, Pb and Fe released to solution (Figures 3-5).

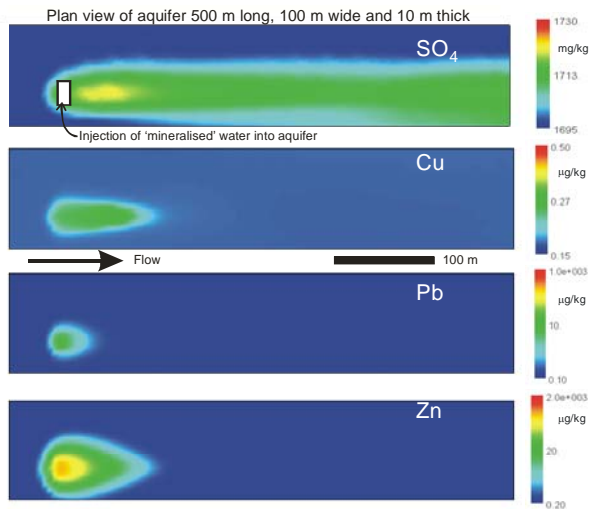


**Figures 3 (left), 4 (centre), 5 (right):** Concentrations of dissolved  $\text{SO}_4^{2-}$  and metals predicted by reaction-path modelling of the oxidation of chalcopyrite, sphalerite and galena with the oxidant being oxygen dissolved in water ( $\text{DO} = 4.1 \text{ mg/L}$ ). **Figure 3 (left):** oxygen at a fixed partial pressure (at atmospheric pressure  $P_{\text{O}_2} = 0.2$ ). **Figure 4 (centre):** or  $\text{Fe}^{3+}$  ( $\text{Fe}^{3+} = 13 \text{ mg/L}$ ). **Figure 5 (right):** as a function of reaction progress (as arbitrary increments of addition of the mineral mixture to the aqueous solution).

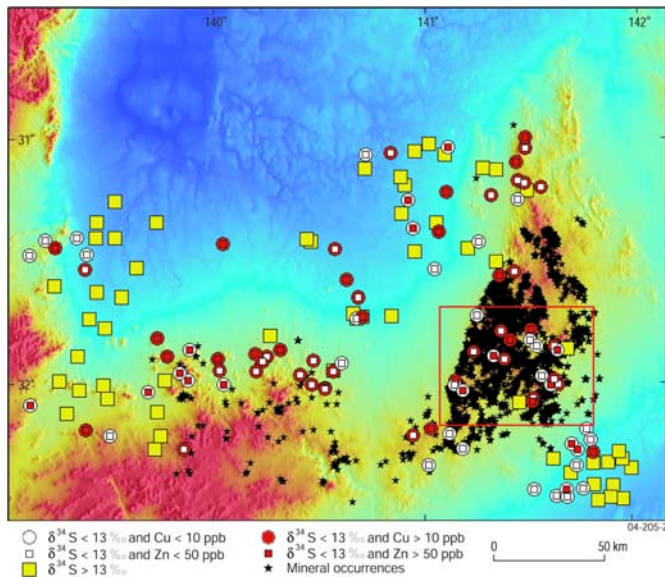
4) 1D and 3D reactive transport modelling was used to predict the ‘decay’ of the  $\text{SO}_4^{2-}$  and trace element concentrations as water moves away from the site of sulfide oxidation through a uniform aquifer containing clay minerals and iron oxyhydroxides (Figure 6).

5) Sr isotopes allowed the differentiation of waters that have been in contact with prospective Paleo- to Mesoproterozoic ( $^{87}\text{Sr}/^{86}\text{Sr}$  from  $\sim 0.715$  to  $0.738$ ) vs non-prospective Adelaidean basement ( $^{87}\text{Sr}/^{86}\text{Sr}$  from  $0.708$  to  $\sim 0.715$ ) rocks.

6) Finally, Pb isotope composition helped evaluate contributions from various mineralisation types (Broken Hill type, Thackaringa type, etc) or mixing with average background Pb.



**Figure 6:** Geochemical plumes resulting from the flux of groundwater that has oxidised sulfide minerals according to the model depicted in Figure 5 (above) into an aquifer with ion exchange and adsorption sites. Reactive transport modelling suggests that  $\text{SO}_4^{2-}$  dispersion haloes will be much larger than metals haloes.



**Figure 7:** Distribution of groundwater samples with low  $\delta^{34}\text{S}$  values (circles) and high Cu (red fill) and/or Zn (solid red squares) concentrations vs 'background' samples with high  $\delta^{34}\text{S}$  values (yellow squares). Framed area is the southern Barrier Ranges where most of the known mineralisation occurs, including the Broken Hill supergiant Pb-Zn-Ag deposit.

## CONCLUSIONS

Hydrogeochemistry can help: (1) delineate areas of interest for further mineral exploration under sedimentary cover (area selection); (2) rank geophysical anomalies; and, (3) vector towards mineralisation (Figure 7). It has the potential to reduce exploration risk and cost in areas of cover.