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Petroleum exploration opportunities – *2005 Acreage Release*

The 2005 offshore acreage release offers explorers new opportunities to build on recent successes that have significantly increased known oil and gas reserves.

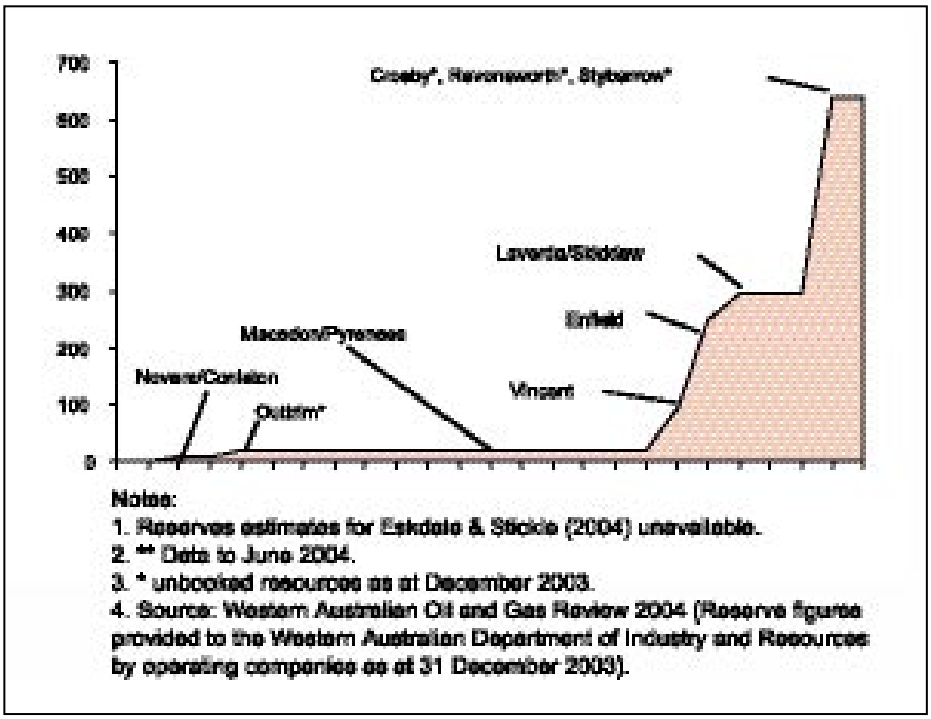
Interest in offshore exploration for oil and gas is rising, with 15 of the 35 areas offered in 2003 awarded and others still under consideration. This uptake rate is underpinning increases in associated exploration expenditure.

Commercial interest in the 2004 offshore acreage release is just as encouraging, with bids received on nine of the eleven areas offered in the first closing round. New entrants to the Australian exploration scene include Canadian companies Avery Resources and Vermillion Energy Trust, the UK's Paladin Resources and the French super major Total. Six permits in the 2004 acreage release will attract a 150% tax uplift as an incentive for oil exploration in frontier areas. Several permits in the 2005 acreage release will also receive this tax uplift, subject to approval by the Minister for Industry, Tourism and Resources, the Hon. Ian Macfarlane.

Gas: giant discoveries and accelerating development

The reputation of Australia's North West Shelf as a world-class gas province was confirmed in 2000 by the discovery of two super giant gas accumulations—Jansz in the Carnarvon Basin, and the Brewster–Ichthys complex in the Browse Basin.

The Jansz accumulation of 20 trillion cubic feet is the largest gas field yet found in Australia; more importantly, the gas is found in a type of structure very different from those previously explored for. The gas is reservoired in Late Jurassic channel sands rather than in a Triassic fault block—the usual habitat of major fields on the North West Shelf. The success of Wheatstone-1, drilled by ChevronTexaco in August 2004, demonstrates that more large gas discoveries remain to be made.



▲ **Figure 1.** Cumulative oil reserves, Exmouth Sub-basin. Source: Oil and Gas Resources of Australia 2003, Geoscience Australia.

Well-established LNG export markets for Australian gas are growing in Japan, Korea and China. The North West Shelf Joint Venture's fourth production train commenced operation in September 2004, and there are plans for a fifth train in 2005. Construction has begun on the Darwin LNG project, which will develop the Bayu/Undan gas/condensate field in the Timor Sea. Other giant gas fields being considered for development to supply export markets are Greater Gorgon and Scarborough in the Carnarvon Basin, Scott Reef and Brecknock in the Browse Basin, and Evans Shoal in the Bonaparte Basin.

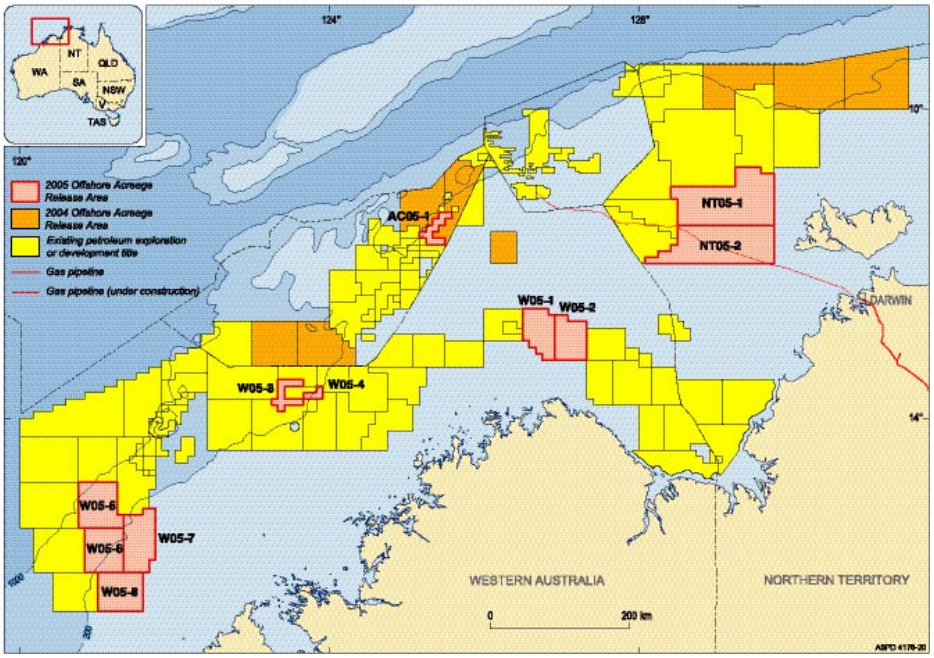
New domestic gas developments are well advanced in southeastern Australia, in the offshore Bass and Otway basins. First gas has flowed this year from the Bass Gas project's Yolla field, and from the Otway Basin Minerva development. In northern Australia, the Blacktip gas field in the Bonaparte Basin is slated for development, with the building of a pipeline across the Northern Territory to the Gove alumina refinery.

Oil: new discoveries in the north, west and east

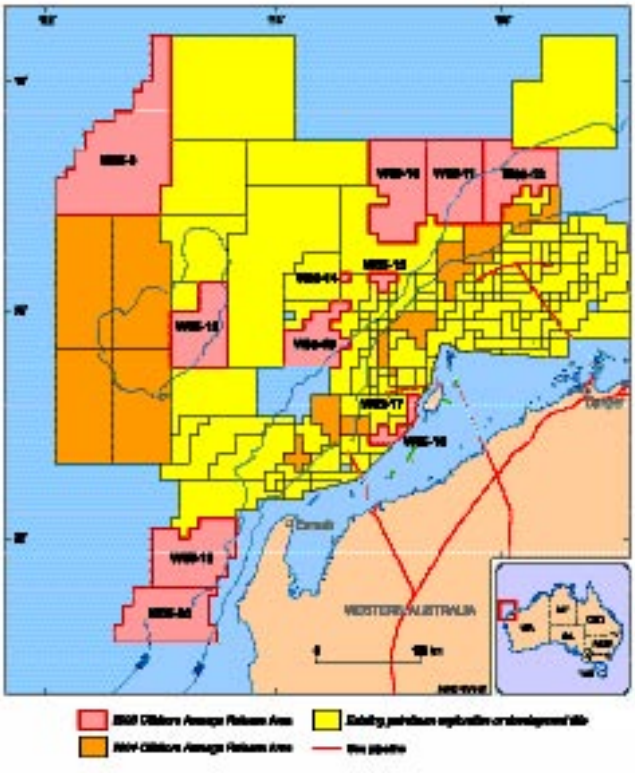
Several significant new oil discoveries inboard of the giant gas fields in the Carnarvon Basin have extended known oil reserves to both the north and the south.

At the northern end, the Exeter field in the Dampier Sub-basin was discovered in 2002. Together with the 1998 Mutineer discovery, this province has some 120 million barrels which is expected to be brought into production in 2005. In the Exmouth Sub-basin at the southern end of the oil trend, discoveries over the past five years include Vincent, Enfield, Laverda, Stybarrow, Ravensworth, Crosby, and Stickle. This significant new oil province with several hundred million barrels of reserves is expected to begin production by 2006 (figure 1).

Explorers have also enjoyed success in areas beyond the North West Shelf. The Cliff Head discovery, drilled in December 2001, is the first major oil find in the offshore Perth Basin, where there have been recent onshore oil and gas discoveries. Development plans are well underway, and production is planned to start this year.



▲ **Figure 2.** 2005 offshore release areas in northwest Australia.



◀ **Figure 3.** 2005 offshore release areas in north Western Australia.

In Bass Strait, development drilling of the Yolla gas field intersected an oil leg and the exploration well Trefoil 1 recovered significant condensate. The most recent oil discovery has been in the Vulcan Sub-basin, where OMV's Katandra well identified a seven-metre oil column. This well, located on the Jabiru trend, is significant for assessment of the 2005 new acreage release area.

New acreage for petroleum exploration

Australia's Offshore Petroleum Exploration Acreage Release for 2005 was announced on 11 April. Twenty-nine areas are available in 13 different regions (see figures 2–5). Areas on offer include:

- large frontier blocks in the Outer Exmouth Plateau, Bremer Sub-basin and Otway Basin (figures 3, 4 and 5)
- moderate to smaller blocks in the midst of large gas accumulations in the Northern Browse Basin and the Carnarvon Basin (figures 2 and 3)
- moderately sized blocks under various water depths in the immature to sub-mature basins of the Northern Exmouth Plateau, the Barcoo Sub-basin, the Southern Exmouth Sub-basin and the Vlaming Sub-Basin (figures 2, 3 and 4)
- shallow water blocks over the Darwin Shelf and Londonderry High (figure 2) and Otway Basin (figure 5).

All areas are available for bidding through a work program bidding system. Closing dates for bids will be October 2005 and April 2006, depending on the size and relative exploration maturity of the areas.

Geoscience Australia has a number of products that could help explorers to review potential acreage. For more information on these products or services, or about the offshore acreage release, phone Jenny Maher on +61 2 6249 9111 (email jenny.maher@ga.gov.au) or visit our website at www.ga.gov.au

Information on the 2005 Release of Offshore Petroleum Exploration Areas can also be obtained from the Department of Industry, Tourism and Resources website at www.industry.gov.au/petexp

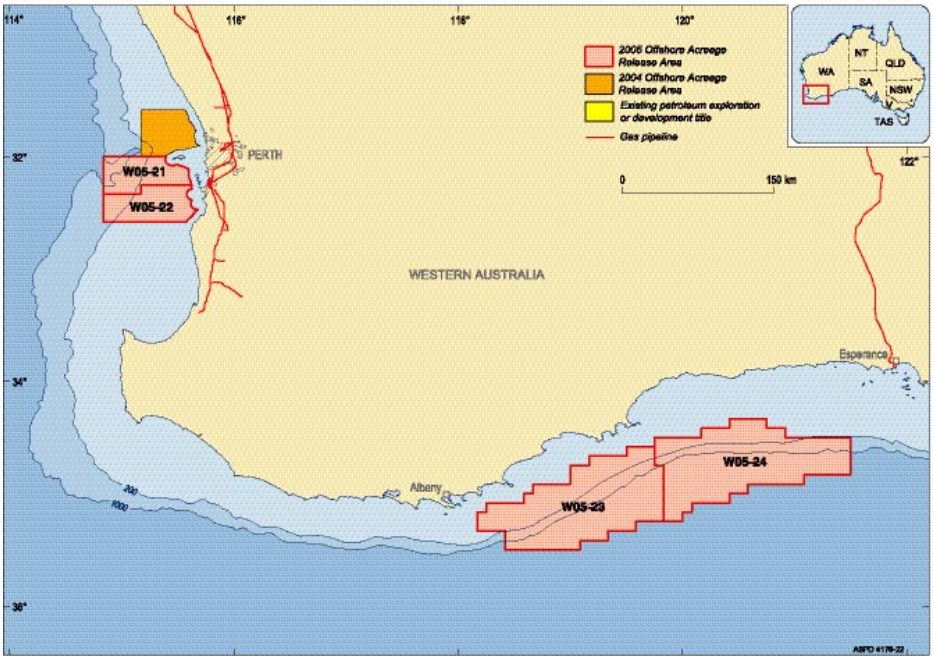


Figure 4. 2005 offshore release areas in south Western Australia.

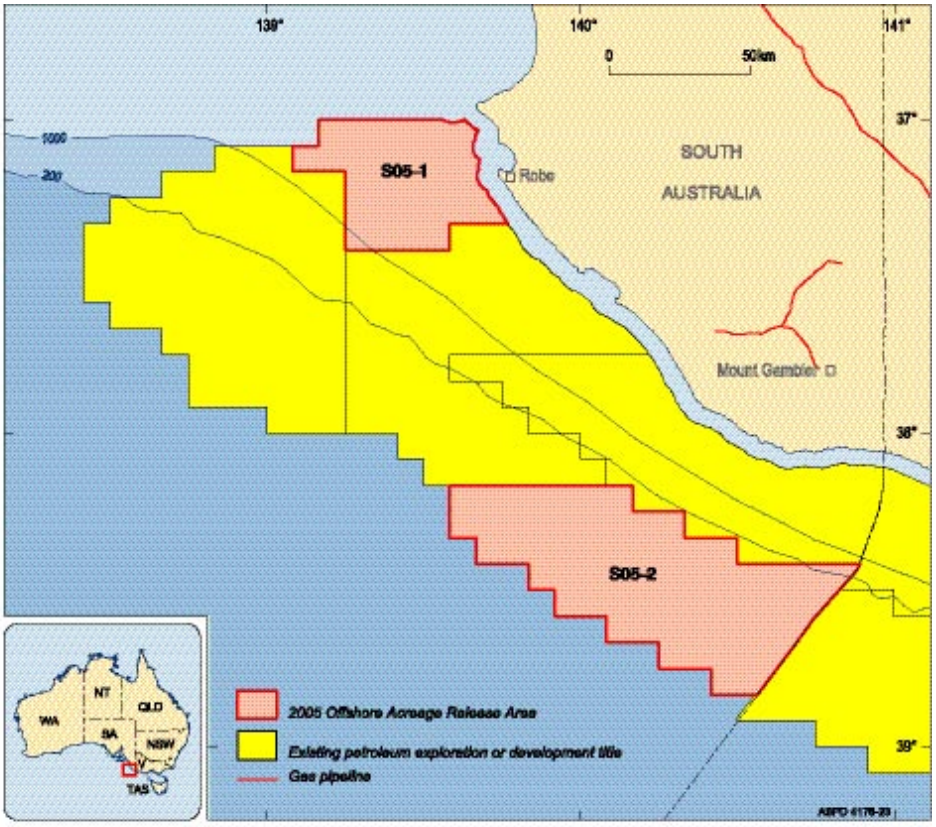


Figure 5. 2005 offshore release areas in South Australia.

HYDROGEOCHEMISTRY —*clues to hidden mineralisation*

Patrice de Caritat (CRC LEME, Geoscience Australia) and Dirk Kirste (CRC LEME, Australian National University),

Can groundwater collected from existing pastoral and exploration bores provide evidence of buried mineralisation? Can groundwater assays be used to guide exploratory drilling in areas of transported cover? Can the groundwater's chemical and isotopic composition help rank geophysical anomalies? Our study in the Curnamona Province attempts to answer these and other questions.

This region hosts a supergiant lead–zinc–silver ore body at Broken Hill and numerous smaller deposits (including lead–zinc–silver, copper–gold, tin, tungsten and uranium), which mostly occur in the limited outcrop regions of the Paleo- to Mesoproterozoic basement rocks. The basement includes the metasedimentary and metavolcanic Willyama Supergroup, which contains the Broken Hill mineralisation (Burtt et al 2004). However, approximately 90 per cent of the Curnamona Province basement is concealed by variable thicknesses of Neoproterozoic (meta) sediments, Cambrian and/or Mesozoic sediments, overlain by the Cainozoic sedimentary sequence of the Callabonna Sub-basin and soils.

The areas of exposed basement have undergone mineral exploration for over a century, yet few significant new mineral discoveries have been made. Thus, the province's high potential for Broken Hill style and iron-oxide/copper–gold mineralisation is more likely to be fulfilled under cover.

Traditional mineral exploration methods used in regions of outcrop face challenges when applied to areas of transported cover, especially where this cover is greater than a few metres thick. Different exploration tools are needed to explore effectively in this environment. Groundwater is a geochemical sampling medium that moves through the subsurface, is easily collected and can be analysed with great accuracy and sensitivity. It may have flowed near mineralisation and retained a chemical 'memory' or fingerprint of such an encounter.

Sampling and analysis

We have collected about 350 groundwater samples from existing boreholes in the southern Curnamona Province, both in areas of outcrop in the ranges and in areas of cover in the surrounding basins (figure 1). The aim of this scientific investigation was to test whether groundwater could be helpful in the search for hidden mineral deposits in the Broken Hill region. We determined the major, minor and trace element concentrations of the groundwaters. On selected samples, we also determined the isotopic composition of hydrogen, oxygen (in water and in dissolved sulfate), carbon, chloride, sulfur, strontium and lead.

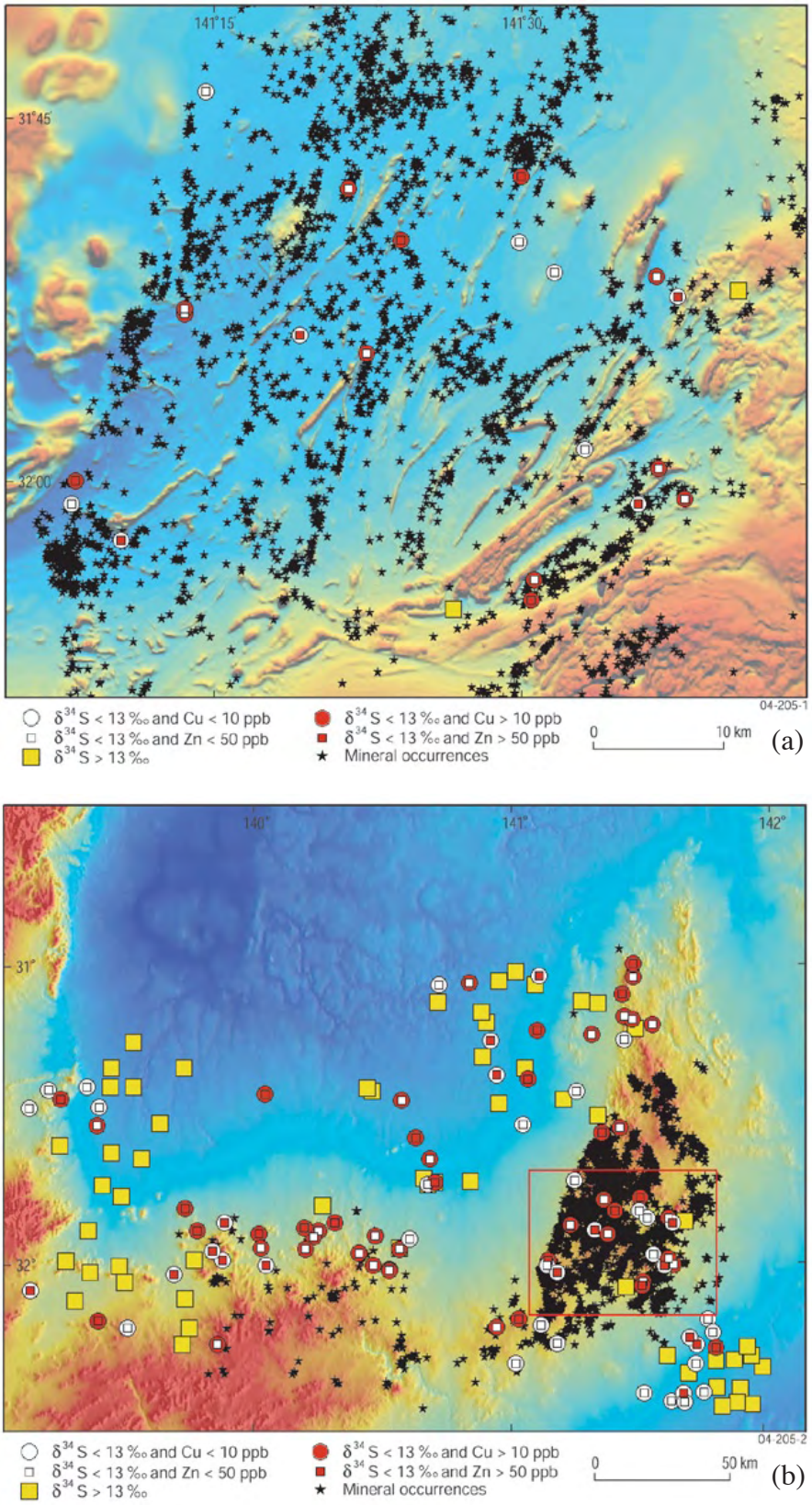
The results indicate that the groundwater's present composition is affected by a number of processes: evaporation, evapotranspiration, mixing, precipitation/dissolution and oxidation/reduction. These occur during an often complex and—in many instances—long evolution. The impact of each of these major processes is teased out using 'conservative' tracers such as chloride or bromide, isotopes and geochemical modelling. To develop hydrogeochemistry into a useful tool for exploration, we have followed a number of steps in the analysis of the data:

1. Calculation of a 'sulfur excess' index to gain knowledge of which samples contain more sulfur than can be accounted for by evaporation or mixing.
2. Determination of the sulfur isotopic composition of dissolved sulfate to identify samples that may have experienced an addition of Broken Hill type (i.e. isotopically light; Bierlein et al 1996) sulfur. Consideration of the oxygen isotopic composition of dissolved sulfate in conjunction with its sulfur isotopic composition can shed light on where sulfide oxidation occurred with respect to the groundwater table (Kirste et al 2003).
3. Evaluation of the specific mineralisation types (Broken Hill type, Thackaringa type etc.) that are compatible with the lead isotope ratios of the groundwater or imply mixing with background lead.

▲ **Figure 1.** Sampling groundwater from a windmill-driven pastoral bore in the southern Curnamona Province.

4. Geochemical reaction-path modelling of oxidation of sulfide minerals (e.g. chalcopyrite, sphalerite, galena) and reactive-transport modelling of the dispersion of reaction products along the groundwater flow path (Kirste et al 2004).

We tested this methodology in the southern Barrier Ranges region, where Broken Hill and a series of minor mineral deposits are located. Of the 23 groundwater samples collected in this mineralised subprovince, 16 (70 per cent) suggest proximity to mineralisation: they have positive sulfur excess, 'low' sulfur isotopic composition and 'elevated' copper and/or zinc concentrations. Inspection of figure 2a shows that most of the 'positive' samples are indeed located within two kilometres of known mineralisation. We subsequently applied the same procedure to the full regional dataset. This revealed several locations under sedimentary cover where our vectors suggest proximity to sulfide mineralisation (figure 2b). More details of the methods and results of this study can be found in Caritat et al (2005).



▲ **Figure 2.** Distribution of groundwater samples in the southern Broken Hill Domain on airborne electromagnetic background (a) and in the southern Curnamona Province on digital elevation model background (b; location of (a) shown as yellow rectangle). Symbols show groundwaters that have 'high' sulfur isotopic compositions as yellow squares and 'low' sulfur isotopic compositions as circles; the latter are coloured red if copper concentrations are greater than 10 parts per billion, or contain a red square if zinc concentrations are greater than 50 parts per billion. Thus background sites (unrelated to mineralisation) are repesented by yellow squares, those related to - but distant from - mineralisation are symbolised by white circles, and those close to (> ~2 km) potential Broken Hill type mineralisation are depicted by red circle and/or squares.

Conclusion

We concluded that hydrogeochemistry may well be one of the novel tools needed to assist mineral exploration under cover. We have demonstrated its potential to fingerprint groundwater–mineralisation interaction through analysing major and trace element concentrations, establishing stable and radiogenic isotope signatures, and modelling geochemical reactions and transport. There are indications that this approach can help delineate areas of interest for subsequent mineral exploration under sedimentary cover, to rank geophysical anomalies and to vector towards mineralisation.

Hydrogeochemistry is a very useful tool and should be part of any multidisciplinary mineral exploration campaign.

Acknowledgments

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