A hydrogeochemistry atlas for Western Australia

by

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In collaboration with the Geological Survey of Western Australia (GSWA), CSIRO is undertaking the processing, modelling and interpretation of hydrogeochemical data from various sources (Fig. 1) for Western Australia. This will include results from soon-to-be-completed programs (Capricorn and Eucla; Fig. 1), and will be released as the Hydrogeochemical Atlas of Western Australia in 2018.

The Atlas will include:

- a summary of main data sources, QA/QC metadata (when known) and their availability
- description of data modelling techniques
- brief geological description of Western Australia (GSWA)
- discussion of Western Australian-relevant groundwater processes
- plots of various solutes and other variables, including
  i. salinity and other environmental/health parameters
  ii. individual elements, with their application to lithology (e.g. F) or exploration (e.g. U)
  iii. major elements (Na, K, Mg, Ca, Sr, Rb, B, Cl, Br, SO_4), also plotted as various indices (e.g. Fig. 2) to emphasize geochemical trends (Gray et al., 2016)
  iv. mineral saturation (e.g. gypsum, carnotite) as a guide to geochemical processes (Gray et al., 2016)
  v. isotopes, particularly ^{2}H and ^{18}O, as a guide to aquifer processes.

  Each of these will be a double-page spread (e.g. Fig. 3), including an Australia-wide, and a Western Australia-wide distribution map, a discussion of the chemical parameter being mapped, and summary of implications.
- a geological modelling section, detailing the uses of the chemical data and some implications for Western Australia with regard to mineral exploration, health and environment.

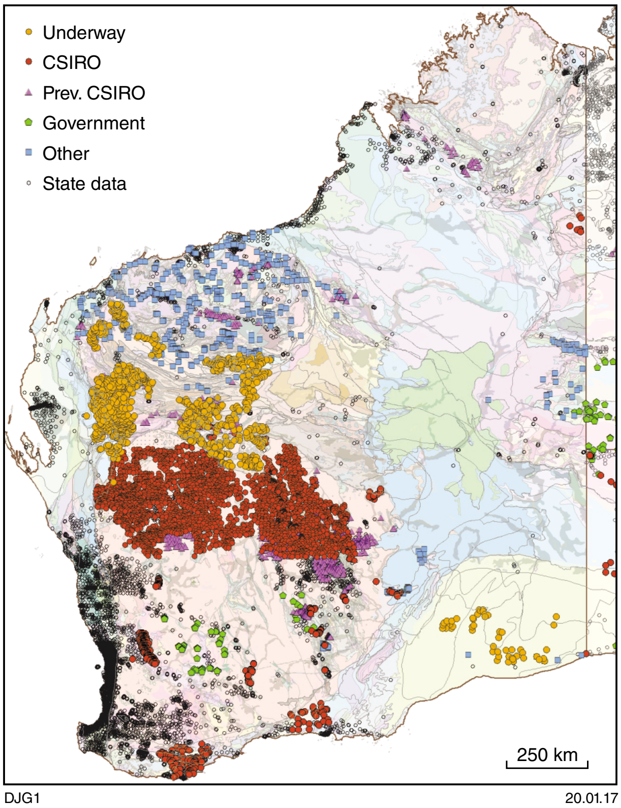

Figure 1. Hydrogeochemical datasets for Western Australia already identified, with the yellow dots showing the Capricorn and Eucla hydrogeochemical surveys still underway. Many of the data sources are listed in Bardwell and Gray (2016).

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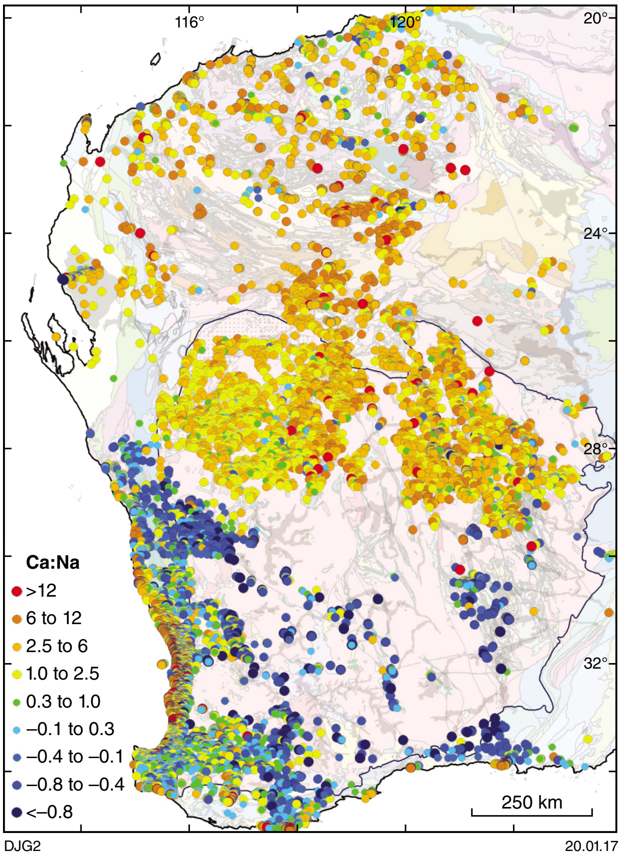

Figure 2. Example of the use of ion indices (in this case Ca:Na, for the Yilgarn and Pilbara) in lithological and regolith discrimination

There has been extensive groundwater sampling (>3000 samples) in the northern Yilgarn by CSIRO (Fig. 1; Gray et al., 2016), which is now being extended into the Capricorn Orogen. The northern Yilgarn data are available online (http://doi.org/10.4225/08/5756B35D5B217), along with other datasets. This initial research has demonstrated the utility of groundwater chemistry for lithological discrimination and prospectivity analysis for the northern Yilgarn Craton (Gray et al., 2016). It is presently being developed for other areas of Western Australia, including the Capricorn, Pilbara, Albany–Fraser and the Eucla (Fig. 1). As part of the Atlas, hydrogeochemistry will be used to demonstrate critical geochemical trends and boundaries across the State, correlated with established (and potentially new) geological transitions. Once resolved and understood, this should be a source of important geological information. Additionally, at the exploration scale, a regional understanding of groundwater 'baseline' chemistry would enable better resolution of hydrogeochemical anomalism.

Two major controlling factors in groundwater are salinity and pH. There is a broad saline zone across the south of Australia, from the southern part of Western Australia, through the southern half of South Australia, and into the SW Murray Basin. In Western Australia, this saline region is strongly correlated with low pH groundwaters, sitting south of the EW Menzies Line, a botanical, soil, and groundwater (Gray, 2001) division of the Yilgarn Craton. In these acid/salty groundwaters, base levels for various ion ratios differ from the north (e.g. Fig. 2), base metals, rare earth elements (REE) and U (which are highly soluble in these waters; Gray, 2001) have much higher background concentrations (Fig. 3), and oxyanions such as As and Mo (which have low solubility in acid groundwaters; Gray, 2001) will work poorly for prospecting using groundwater. Further delineating these processes will be critical to mapping anomalies and prospectivity mapping in these regions.

Ion ratios identify deviations from the seawater evaporation trend for ion pairs. For example, the Ca:Na index (Fig. 2) identifies the Eromanga Basin as a zone of low Ca:Na, although with internal differentiation. Critically, the saline groundwaters of the southern Yilgarn also have low Ca:Na, which is indicated to be an absolute Ca depletion (based on ion difference calculations; Bardwell and Gray, 2016). Many other ion indices show spatial patterns related to geology or landform effects (Gray et al., 2016), as will be demonstrated in the Atlas.

Mineral saturation analysis can complement these studies. There is high SO_4:Cl across much of central Australia. Where this correlates with waters at or near gypsum ($CaSO_4.H_2O$) saturation (Bardwell and Gray, 2016), this suggests S dissolving into the groundwaters, probably from gypsum beds. In contrast, the southern Yilgarn groundwaters are saline, with low SO_4:Cl, low Ca:Na (Fig. 2), and close to gypsum saturation. This suggests that salinization via evaporation is precipitating gypsum, with reduced dissolved Ca and SO_4.

Where present, minor and trace element data can be particularly useful in lithological discrimination and prospectivity analysis. Albany–Fraser rocks around Esperance show high dissolved F, and in the northern Yilgarn Craton, there is a correlation of relatively higher dissolved F with granitic rocks. Dissolved U is higher in granitic rocks, whereas mafic–ultramafic elements such as Cr and Ni can effectively discriminate more basic rocks.

Dissolved U can reach particularly high concentrations (>100 µg/L) in specific areas of the Yilgarn Craton and elsewhere in Australia such as the Curnamona Basin (Fig. 3; de Caritat et al., 2005), reflecting active and potential secondary U deposits in these regions. Other elements such as Mo are high sporadically across the Yilgarn Craton and in specific regions, such as the western Olary and the Stuart Shelf in South Australia. Such data for varying elements such as As and W may become useful for lithological discrimination and detection of hydrothermal dispersion (e.g. Gray et al., 2016).

Additionally, delineation of salinity can be important for agricultural use of groundwater, and better discriminating areas with high levels of solutes of health concern, such as NO_3, may be important for remote communities.

This brief introduction to the Atlas is to indicate the potential of this publication. This will also be followed up through meetings and workshops, presentations in industry and scientific conferences, and through related publications.

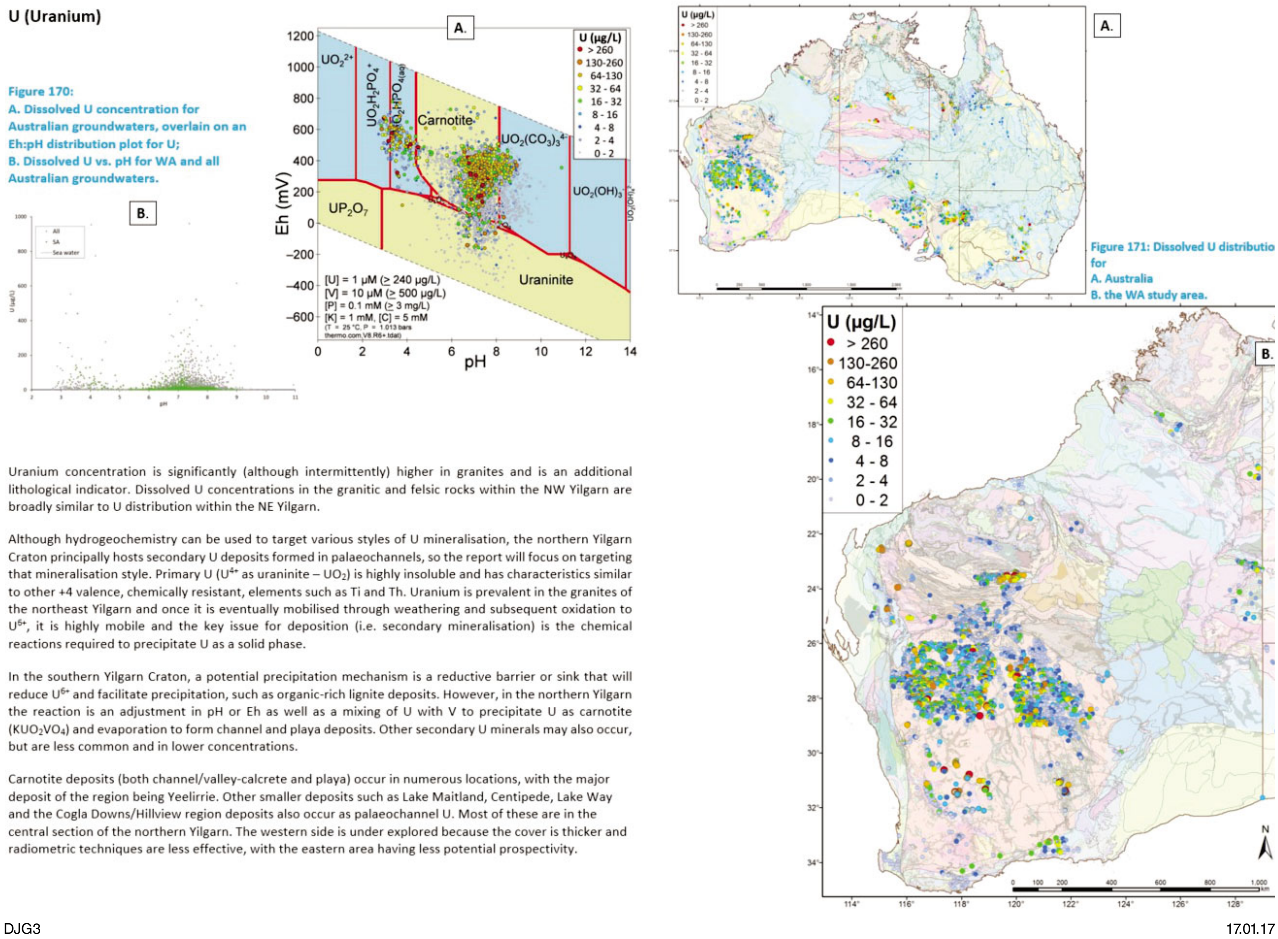
U (Uranium)

Figure 170:
A. Dissolved U concentration for Australian groundwaters, overlain on an Eh:pH distribution plot for U;
B. Dissolved U vs. pH for WA and all Australian groundwaters.

Uranium concentration is significantly (although intermittently) higher in granites and is an additional lithological indicator. Dissolved U concentrations in the granitic and felsic rocks within the NW Yilgarn are broadly similar to U distribution within the NE Yilgarn.

Although hydrogeochemistry can be used to target various styles of U mineralisation, the northern Yilgarn Craton principally hosts secondary U deposits formed in palaeochannels, so the report will focus on targeting that mineralisation style. Primary U (U^{4+} as uraninite – UO_2) is highly insoluble and has characteristics similar to other +4 valence, chemically resistant, elements such as Ti and Th. Uranium is prevalent in the granites of the northeast Yilgarn and once it is eventually mobilised through weathering and subsequent oxidation to U^{6+}, it is highly mobile and the key issue for deposition (i.e. secondary mineralisation) is the chemical reactions required to precipitate U as a solid phase.

In the southern Yilgarn Craton, a potential precipitation mechanism is a reductive barrier or sink that will reduce U^{6+} and facilitate precipitation, such as organic-rich lignite deposits. However, in the northern Yilgarn the reaction is an adjustment in pH or Eh as well as a mixing of U with V to precipitate U as carnotite (KUO_2VO_4) and evaporation to form channel and playa deposits. Other secondary U minerals may also occur, but are less common and in lower concentrations.

Carnotite deposits (both channel/valley-calcrete and playa) occur in numerous locations, with the major deposit of the region being Yeelirrie. Other smaller deposits such as Lake Maitland, Centipede, Lake Way and the Cogla Downs/Hillview region deposits also occur as palaeochannel U. Most of these are in the central section of the northern Yilgarn. The western side is under explored because the cover is thicker and radiometric techniques are less effective, with the eastern area having less potential prospectivity.

Figure 171: Dissolved U distributio for
A. Australia
B. the WA study area.

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Figure 3. Example of a double-page spread from the Hydrogeochemical Atlas (describing U chemistry and distribution). Note that this will include additional data from Capricorn, Eucla and elsewhere in the final version.

References

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