Tracers for potential gas reservoir-aquifer leakage: $^{87}Sr/^{86}Sr$

J.K. Pearce [A,B], G.K.W. Dawson [B], M. Matsui [A], F. Brink [C], K. Baublys [B], A. Nguyen [B], N. Leonard [B]*

[A] Gas and Energy Transition Research Centre, University of Queensland, QLD, Australia. [B] School of the Environment, University of Queensland, QLD, Australia
[C] Centre for Advanced Microscopy, ANU, ACT, Australia. [*]Correspondence to Email: j.pearce2@uq.edu.au

ABSTRACT: Groundwater tracers such as strontium isotopes ($^{87}Sr/^{86}Sr$) are increasingly used by governments and regulators to identify gas reservoir-aquifer leakage or connectivity.
For example, they are used to identify potential connectivity between the Surat Basin Walloon Coal Measures (WCM) Coal Seam Gas (CSG) reservoir and the overlying Springbok Sandstone aquifer. Generally, values of the $^{87}Sr/^{86}Sr$ signature of groundwaters sampled from the Springbok Sandstone that are overlapping with the CSG reservoir have been interpreted as a potential leak. However, overlapping $^{87}Sr/^{86}Sr$ signatures *may not* be an indicator of connectivity/leakage, rather of similar rock formations/ minerals sources. $^{87}Sr/^{86}Sr$ signatures of groundwater can be a combination of water recharge and also its interaction with the host rock. This study characterised $^{87}Sr/^{86}Sr$ signatures and sources in rock cores and interburden of the Springbok Sandstone and WCM. Both formations have a wide range of mineral components, with calcite and plagioclase potential Sr sources; and clays and K-feldspars rubidium (Rb) sources. Core whole rock digestions and acid extractions were characterised, with whole rock signature $^{87}Sr/^{86}Sr$ = 0.703 to 0.710, and acid extracts 0.7032 to 0.7048. Our recent groundwater measurements from the WCM and Springbok Sandstone aquifer overlap in the range 0.7034 to 0.7043.
The overlapping signatures from acid extractions of the WCM and Springbok Sandstone indicate that the similarity of the two host formations may be the reason for overlapping groundwater signatures, not necessarily any occurring leakage. Future work should expand the study sites, and also investigate reservoir aquifer pairs in the Bowen Basin.

Introduction

- Gas reservoirs can over or underlie groundwater aquifers with competitive uses e.g. with water extraction for town water supply, agriculture or feedlots. In the Surat Basin, Queensland, a major coal seam gas (CSG) reservoir the Walloon Coal Measures (WCM) is part of the Great Artesian Basin (GAB). Since various aquifers overlie the reservoir, stakeholders are sensitive to the potential for leakage of gas or water from the reservoir. The Springbok Sandstone is a tight aquifer overlying the WCM and part of the GAB. Monitoring of the aquifers in the CSG regional areas is ongoing and more recently $^{87}Sr/^{86}Sr$ signature of the groundwaters are used as a monitoring tool.
- Generally, $^{87}Sr/^{86}Sr$ signatures of groundwater can be a combination of the water recharge signature, which formations the groundwater has moved through, which processes have occurred, and the host rock signature (Baublys et al. 2019; Pearce et al. 2024; Raiber et al. 2024). Overlapping $^{87}Sr/^{86}Sr$ signatures in the groundwater of two formations (Fig. 1) therefore may not be an indicator of connectivity/leakage, and rather the similar host rock formation minerals.
- There have been no rock core $^{87}Sr/^{86}Sr$ signature data for the Springbok Sandstone to inform the argument on groundwater connectivity with the WCM.

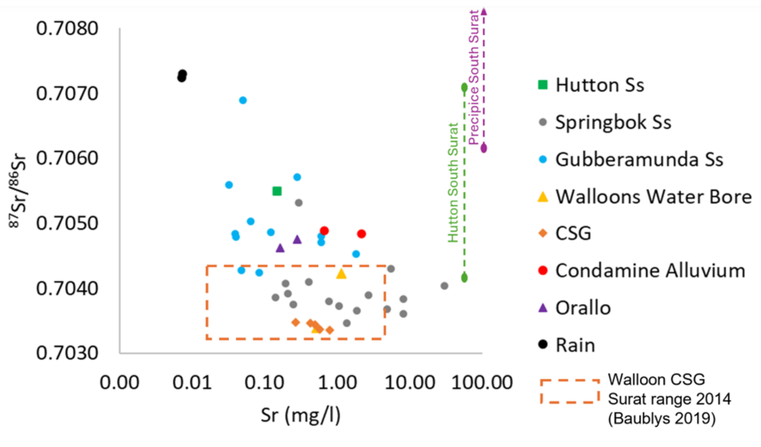
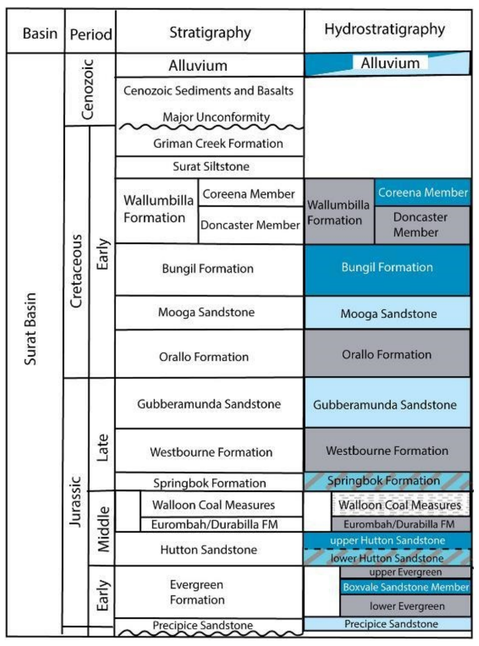


Figure 1: $^{87}Sr/^{86}Sr$ of *groundwaters* in our recent study (Pearce et a., in prep). Note overlapping Springbok Ss groundwaters and CSG production waters. (Orange box is the range for CSG production waters from Baublys et al., 2019)

Methods

- Drill core sampled were taken from 3 well cores, with 20 samples of the Springbok Ss and WCM interburden. Mineral characterisation and imaging via QEMSCAN and spot SEM-EDS was completed on polished thin sections at ANU and UQ.
- Powdered whole core was subject to total digestion and analysis of a wide range of element and Sr concentrations at the Environmental Geochemistry Laboratory, UQ.
- $^{87}Sr/^{86}Sr$ isotope signatures of the whole core digest fluids were analysed at the Radiogenic Isotope Facility, UQ. Weak acid extractions were also performed on the powdered core material. With element concentrations and $^{87}Sr/^{86}Sr$ signature also determined on the extracts. Weak acid extracts can help to understand potential Sr isotope signatures from water-rock interaction where for example carbonate dissolution is controlling the groundwater signatures



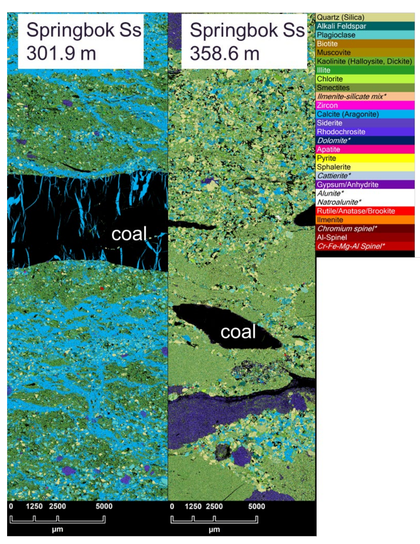


Figure 2: Hydrostratigraphy of the aquifers in the Surat Basin, and the Walloon Coal Measures CSG formation (modified after Baublys 2019). Two examples of Qemscan images of minerals in the Springbok Sandstone.

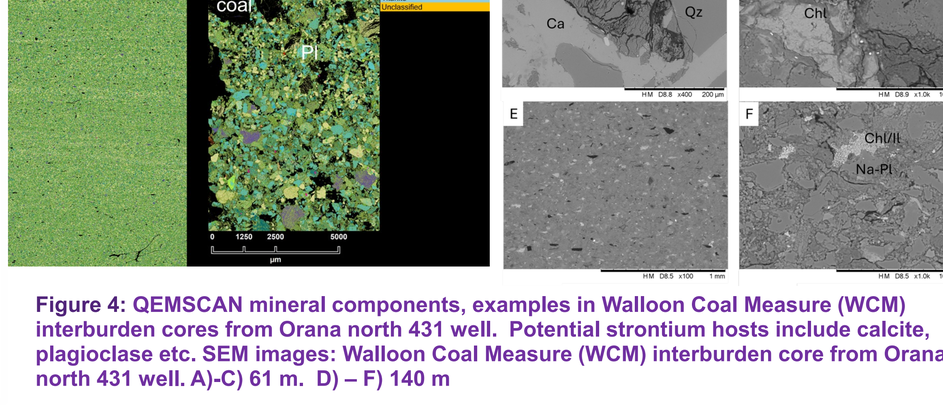


Figure 3: Map of the sampled well cores (stars), circles show corresponding groundwater sample locations for data in Fig. 1. Note many are nested bores.

Figure 4: QEMSCAN mineral components, examples in Walloon Coal Measure (WCM) interburden cores from Orana north 431 well. Potential strontium hosts include calcite, plagioclase etc. SEM images: Walloon Coal Measure (WCM) interburden core from Orana north 431 well. A)-C) 61 m. D) – F) 140 m

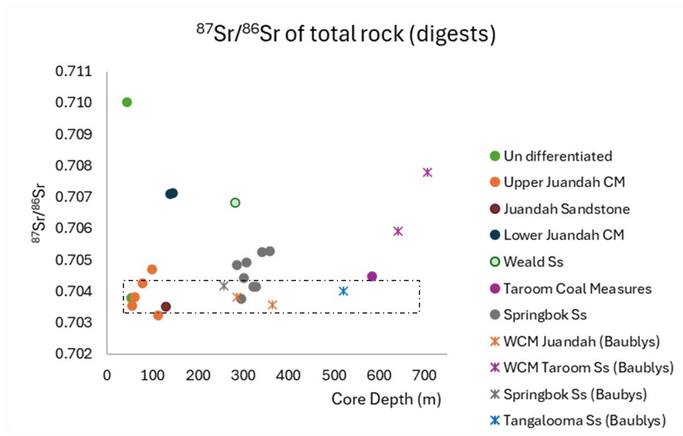


Figure 5: $^{87}Sr/^{86}Sr$ signatures of Springbok and WCM interburden rock cores, note some overlapping signatures. The dashed box indicates the range of groundwater signatures of both the WCM and Springbok Ss
***Crosses show data from Baublys et al., 2019 from Chinchilla 4 core**

Results

- The Springbok Ss cores across different depth sections analysed here have a diverse mineral content even within one well core(Fig. 2). The Springbok Ss contains dispersed coals and minerals including calcites cements, plagioclase, and clays etc. The WCM interburden core samples also contain calcite cements, Na and Ca-rich plagioclase, altered feldspars, chlorite, and kaolinite etc. (Fig. 4). Both formations contain several potential mineral sources of Sr and Rb.
- Figure 5 shows that there is an overlap of Springbok Ss and WCM $^{87}Sr/^{86}Sr$ isotope signatures in the majority of whole rock core analyses.
- Weak acid leaching of core material revealed a narrower range in signatures of $^{87}Sr/^{86}Sr$ isotopes in the majority of Springbok Ss and WCM samples compared to the whole rock signatures (Fig. 6).
- The range of $^{87}Sr/^{86}Sr$ signatures from weak acid core leachates overlap the range of $^{87}Sr/^{86}Sr$ in groundwater samples (dashed box in Fig. 6). The range of signatures in Springbok Ss and WCM weak acid leachates is also close/overlapping.
- The groundwater-rock reaction of minerals in the cores, as simulated through the weak acid leaching, can produce the same $^{87}Sr/^{86}Sr$ signatures in both the Springbok Ss and the WCM as we see in groundwater samples. This indicates that the similarity of the host rock composition of the two formations may be the reason for overlapping *groundwater* $^{87}Sr/^{86}Sr$ signatures, not necessarily any occurring leakage or connectivity.

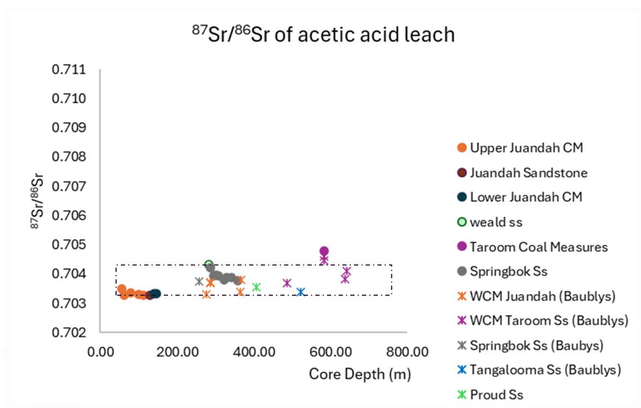


Figure 6: $^{87}Sr/^{86}Sr$ signatures of Springbok and WCM interburden acid leaches, note some overlapping signatures.
***Crosses are data from Baublys et al., from Chinchilla 4, Pleasant Hills 25, and other well core leaches. Below with an expanded Y axis.**

Conclusions

- There is diversity within drill core but also similar potential Sr host minerals e.g. plagioclase, calcite cements in both formations.
- Whole rock analysis of $^{87}Sr/^{86}Sr$ isotope signatures of Springbok Ss and Walloons CM interburden well cores were performed. The two formations have some overlapping signatures of $^{87}Sr/^{86}Sr$ from whole rock with a relatively wide range of signatures.
- The weak acid extracts of drill core material show $^{87}Sr/^{86}Sr$ isotope signatures in the two formations are mainly overlapping each other. The acid extracts also have the same signature range as we have measured previously from groundwaters.
- This indicates that the similarity of the two formations (both contain coals, similar minerals) may be the reason for overlapping groundwater signatures, not necessarily any occurring leakage.

Suggested Future Work
Analysis so far was on drill core from a few wells, it is suggested to broaden the geographical area investigated. Additionally, comparison on core/cuttings from further south in the Springbok Ss and WCM out of the CSG region is suggested. Other options include investigating different geological formations in the Surat Basin, or reservoir – aquifer pairs in the Bowen Basin.
The methods used here are applicable to other formations (e.g. Hutton Ss aquifer, Condamine Alluvium, or to aquifer – reservoir pairs in the Bowen Basin, or other basins e.g. in the NT.

J.Pearce2@uq.edu.au
Julie Pearce
uq.edu.au

Gas and Energy Transition Research Centre

Acknowledgements
This research has been conducted with the support of the Centre's industry members – APLNG, Arrow Energy, and Santos.

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA
CREATE CHANGE