Groundwater – reservoir (dis)connectivity with strontium isotopes

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Acknowledgement of Country

The University of Queensland (UQ) acknowledges the Traditional Owners and their custodianship of the lands on which we meet.

We pay our respects to their Ancestors and their descendants, who continue cultural and spiritual connections to Country.

We recognise their valuable contributions to Australian and global society.

Image: Digital reproduction of *A guidance through time* by Casey Coolwell and Kyra Mancktelow

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 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 site geographical coverage of core, and also investigate reservoir aquifer pairs in the Bowen Basin.

Why? Groundwater data

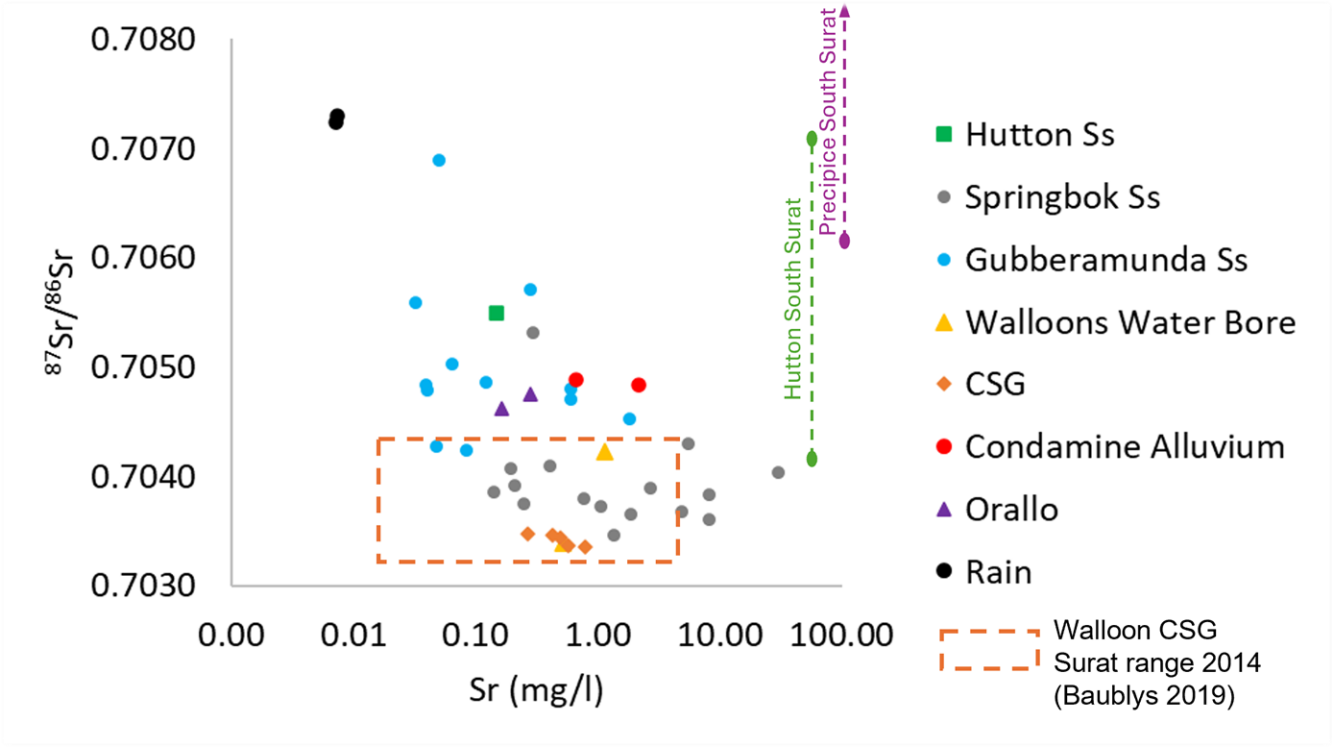
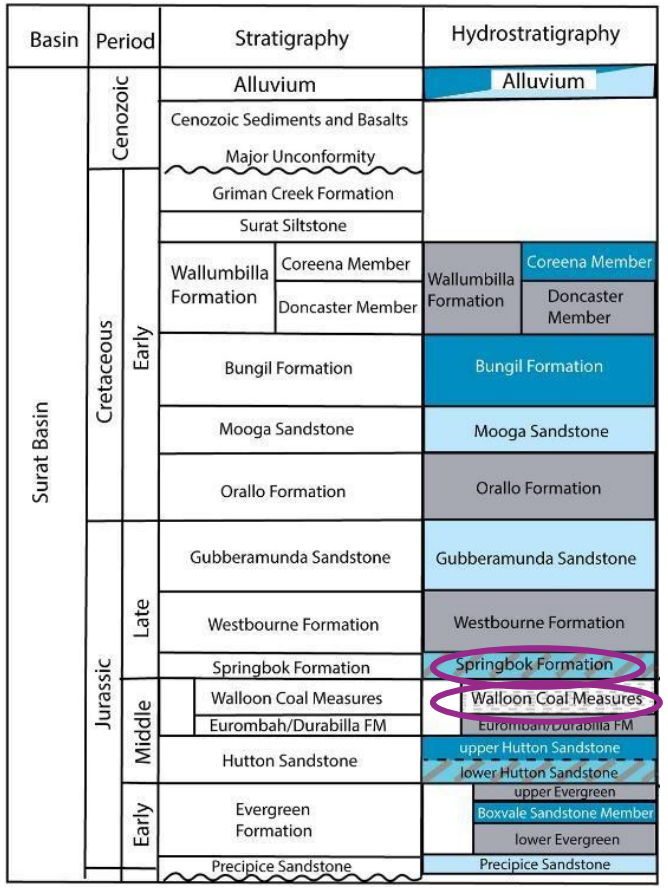


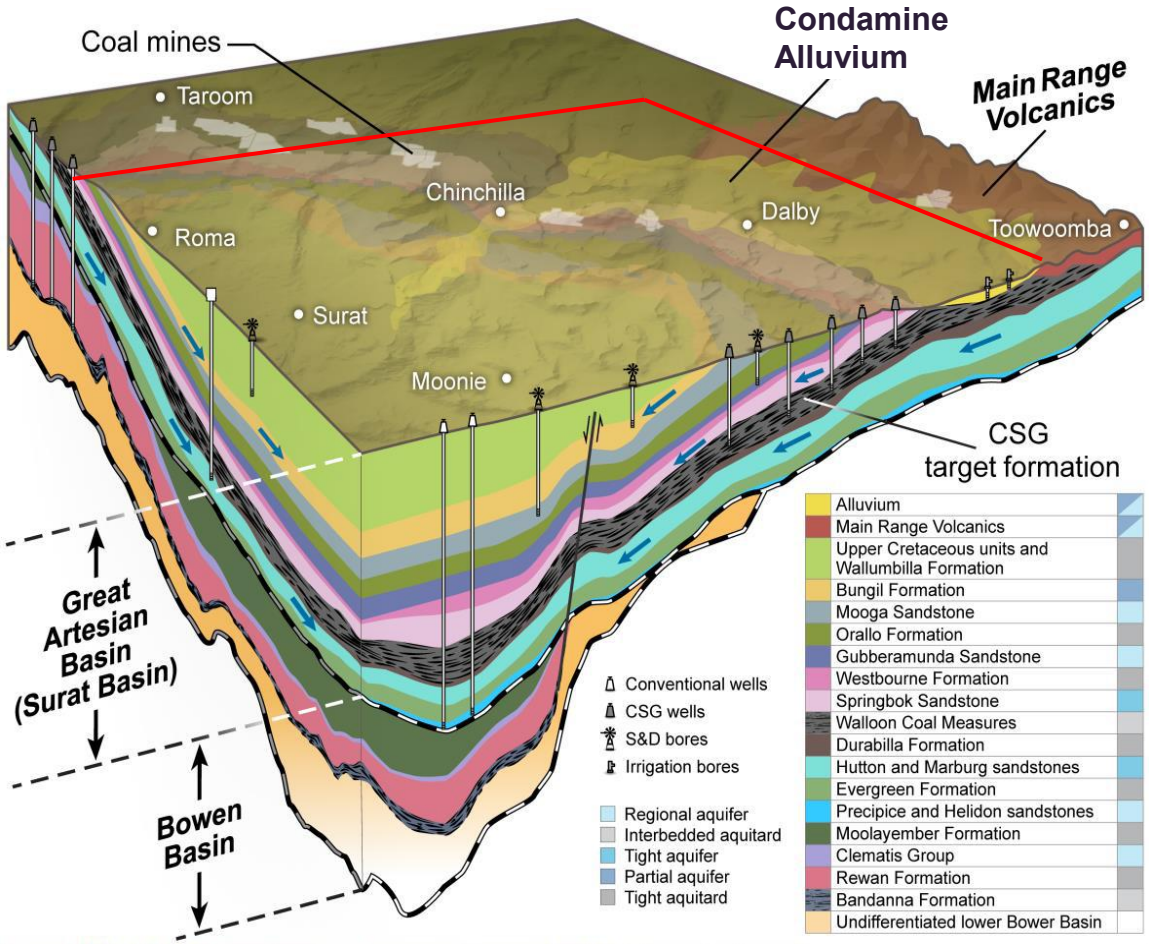
Fig 1: $^{87}Sr/^{86}Sr$ of *groundwaters* in our recent groundwater study. Note overlapping Springbok Ss groundwaters and CSG production waters. (Orange box is the range for CSG production waters from Baublys et al., 2019)

- $^{87}Sr/^{86}Sr$ signatures of groundwater can be a combination of water recharge and the host rock (e.g. Pearce et al., 2024; Raiber et al.,2024; Baublys et al., 2019)
- Overlapping $^{87}Sr/^{86}Sr$ signatures *may not* be an indicator of connectivity/leakage, rather similar rock formation minerals
- There are *no rock core* $^{87}Sr/^{86}Sr$ signature data for the Springbok Sandstone to inform the argument on groundwater connectivity
- Methods are applicable to other formations (e.g. Hutton Sandstone, Condamine Alluvium, or the Bowen Basin, or other basins e.g. in NT.

Surat Basin CSG region Roma to Dalby

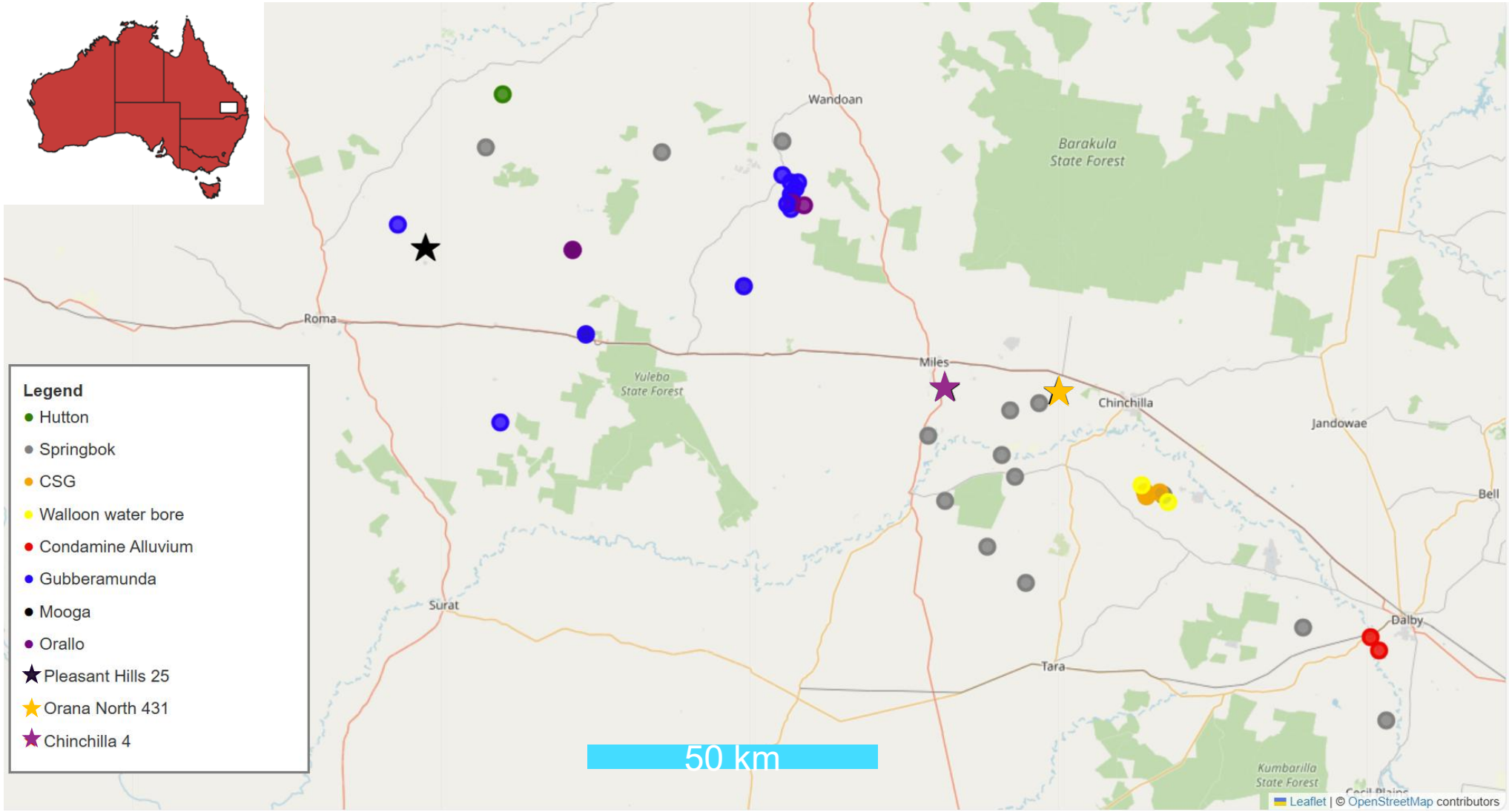
Reservoir –aquifer connectivity? Springbok Ss in CSG extraction region





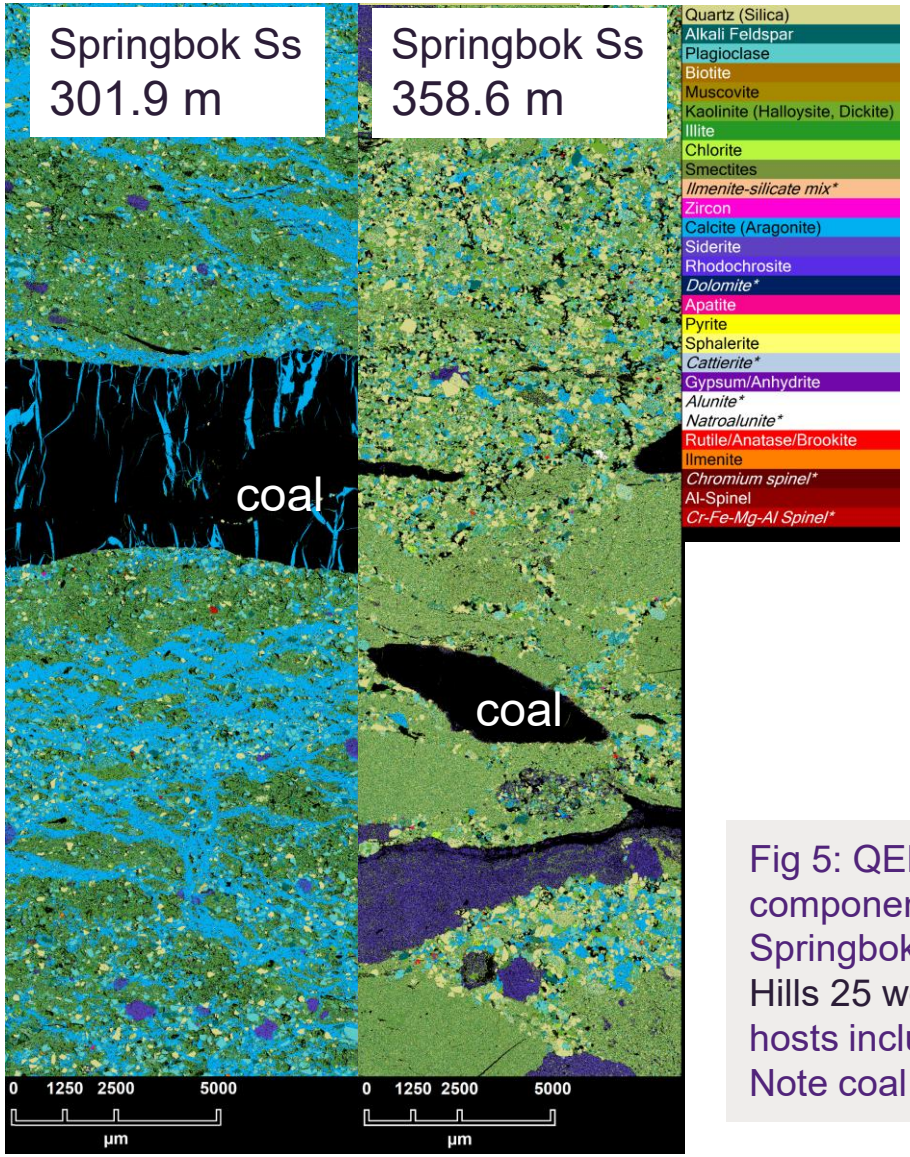
Cross section modified from OGIA 2021

Map shows groundwater samples (slide 3), and stars core from 3 wells



Methods

- 3 well cores
- 20 samples Springbok Ss and Walloon Coal Measures interburden
- Mineral characterisation and imaging
- Total digestion of powdered whole core – analyse metal and Sr concentrations
- Sr isotope signatures of whole core
- Acid extractions of Sr, element and metal concentrations from core material
- Sr isotope signatures of extracts to understand if water-rock interaction with carbonates is controlling the groundwater signatures

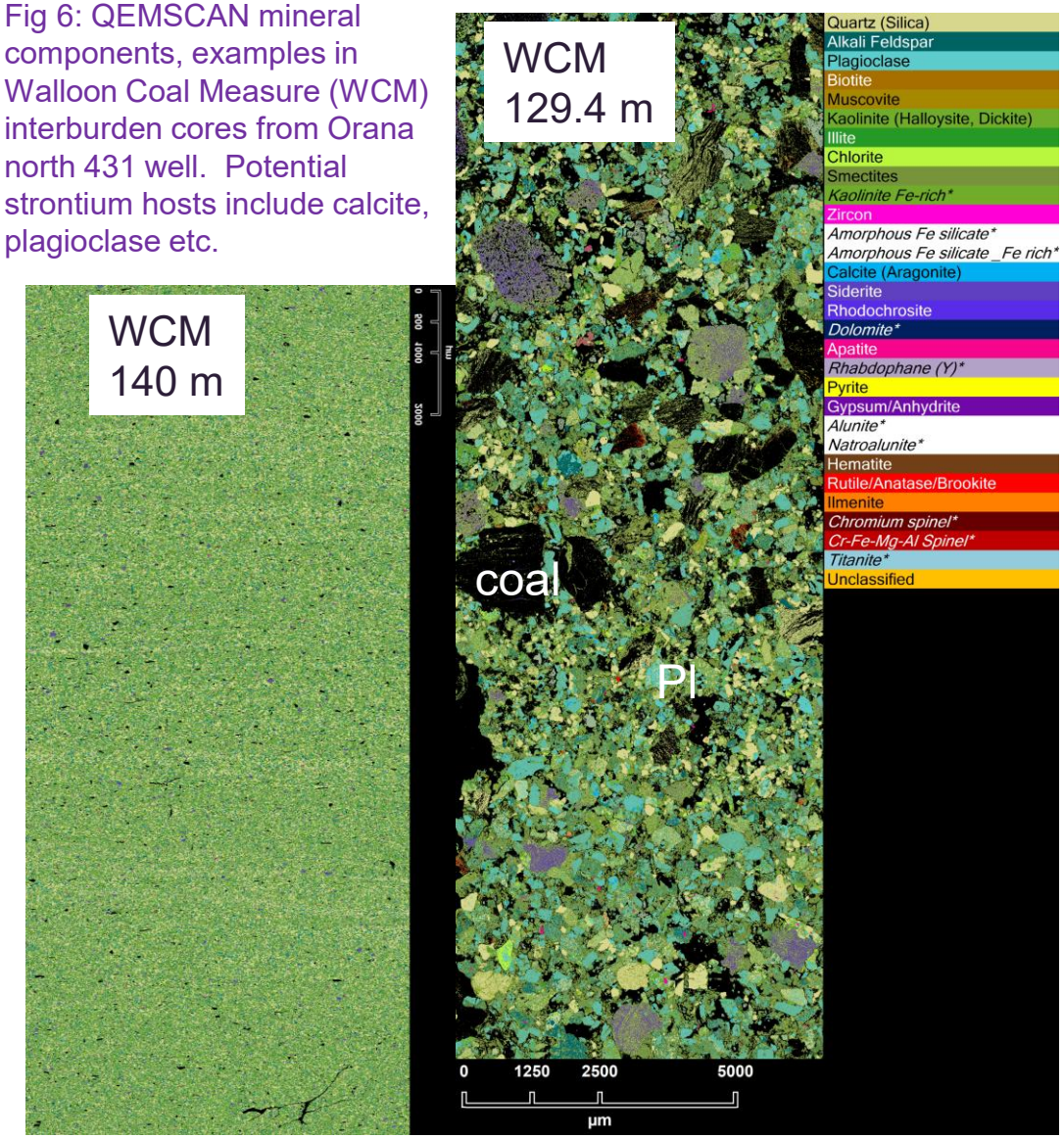


Mineral components

- Examples of QEMSCAN: images of mineral components
- Springbok Ss diverse mineral content even within one well core
- Coals
- Calcites, plagioclase, clays etc

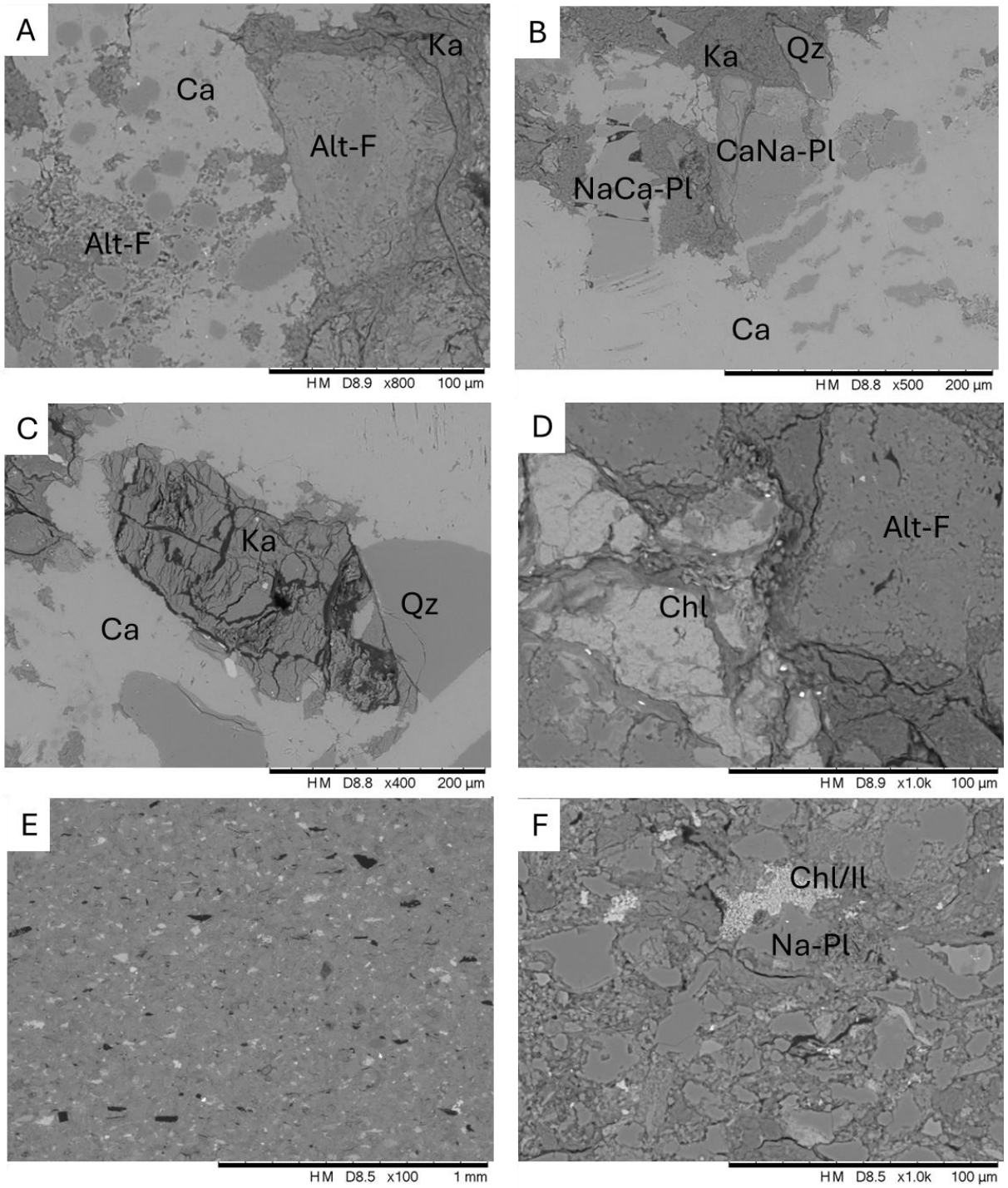
Fig 5: QEMSCAN mineral components, examples in Springbok Ss cores Pleasant Hills 25 well. Potential strontium hosts include calcite, plagioclase. Note coal layers.

Fig 6: QEMSCAN mineral components, examples in Walloon Coal Measure (WCM) interburden cores from Orana north 431 well. Potential strontium hosts include calcite, plagioclase etc.



Mineral components

- Examples of mineral components in WCM interburden cores
- Calcites, siderite, plagioclase, coals, clays….
- Diverse lithologies



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Scanning Electron Microscope (SEM) images

- WCM interburden examples
- Calcite cements
- Na and Ca rich plagioclase
- Altered feldspars, chlorite, kaolinite etc
- Several potential sources Sr and Rb

Fig 7: SEM images: Walloon Coal Measure (WCM) interburden core from Orana north 431 well. A)-C) 61 m. D) – F) 140 m.

Scanning Electron Microscope (SEM) images

- WCM interburden examples
- Fe-rich Chlorite clay, siderite cements
- Mica, apatite, illite/smectite
- Altered K-feldspar weathered to kaolinite etc
- Several potential sources Sr and Rb

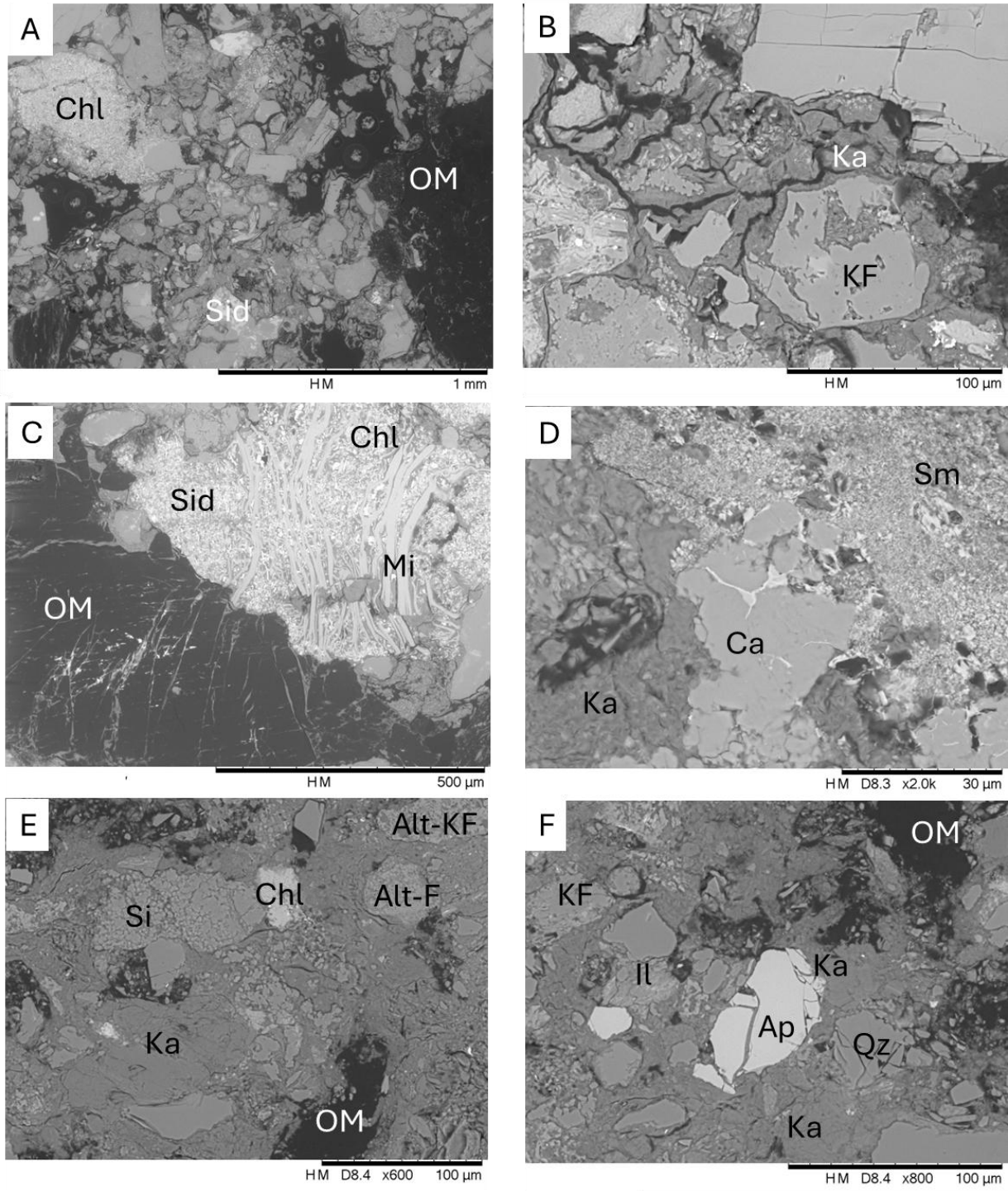


Fig 8: SEM images: Walloon Coal Measure (WCM) interburden core from Orana north 431 well. A)-C) from129 m, D)-F) from 99 m.

Scanning Electron Microscope (SEM) images

- Some sections of the Springbok Sandstone in Pleasant Hills 25 well have evidence of fracturing / fracture fills siderite, kaolinite etc.

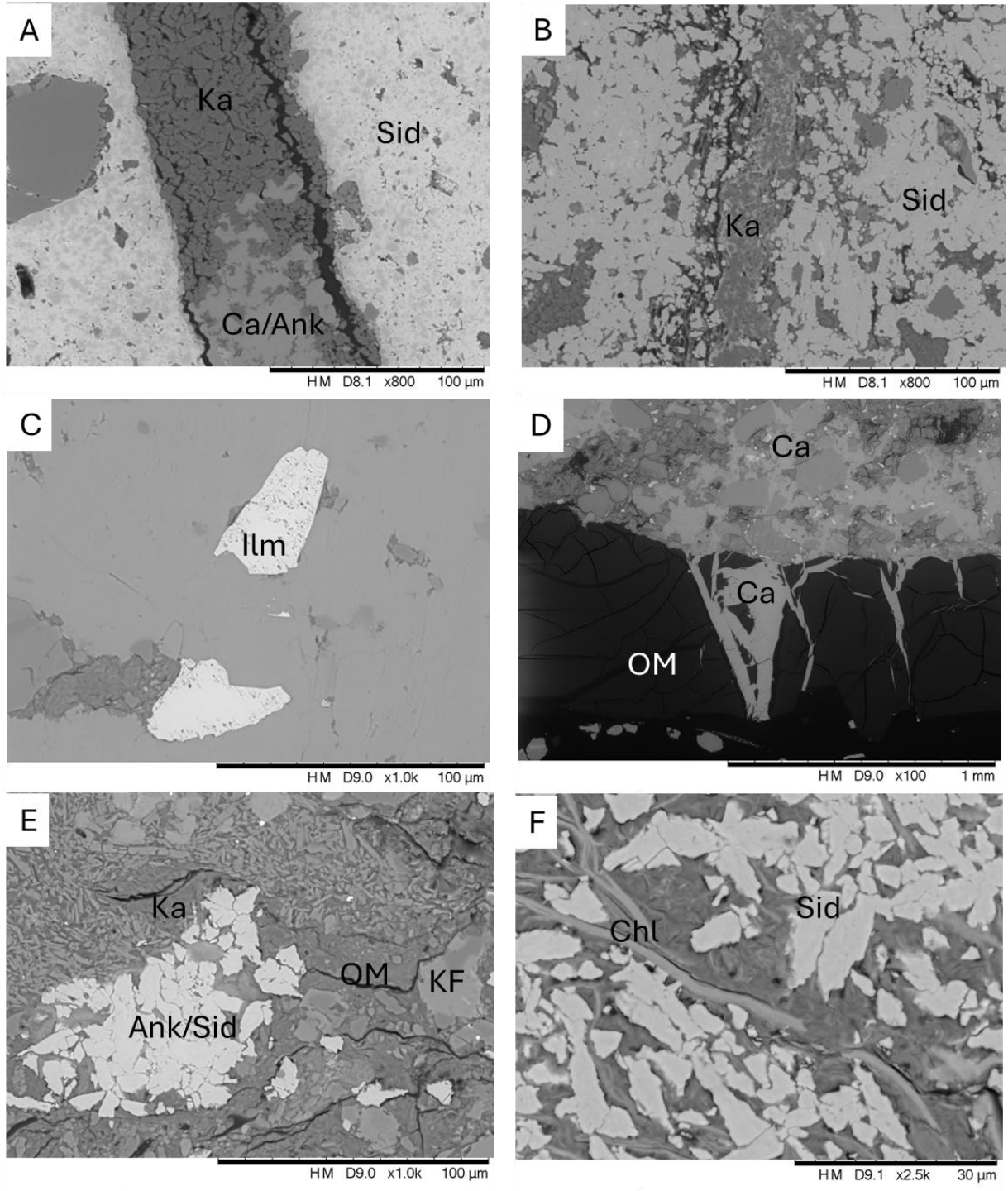


Fig 9: Springbok ss Pleasant Hills 25 well. 287 m (a-b), and 301 m (c-f) Calcite and kaolinite fracture fills, siderite cements

Sr isotope signatures from whole rock core

- Overlap in signatures of Sr isotopes in majority whole rock cores of Springbok Ss and Walloon coal Measures
- Some core samples have higher signatures, more radiogenic
- The dashed box indicates the range of groundwater signatures of both the WCM and Springbok Ss (Figure 3 and Baublys et al)

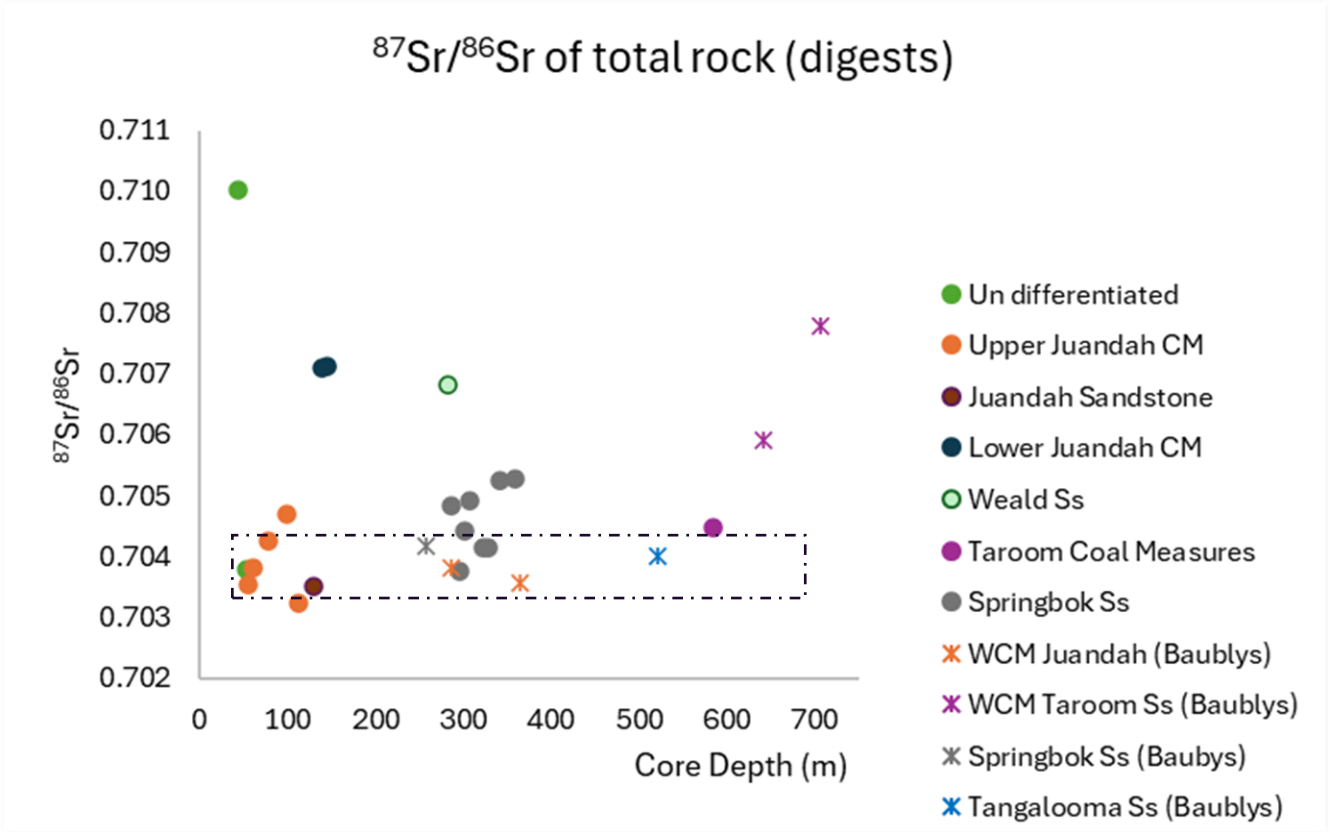


Fig 9: $^{87}Sr/^{86}Sr$ signatures of Springbok and WCM interburden rock cores, note some overlapping signatures.
*Crosses show data from Baublys et al., from Chinchilla 4 core

Sr isotope signatures from rock leaching

- Weak acid leaching of cores to determine signature likely from groundwater-rock interaction
- likely signatures from calcites
- Narrower range in signatures of $^{87}Sr/^{86}Sr$ isotopes in majority of Springbok and WCM compared to whole rock signatures.
- The dashed box indicates the range of groundwater signatures of both the WCM and Springbok Ss

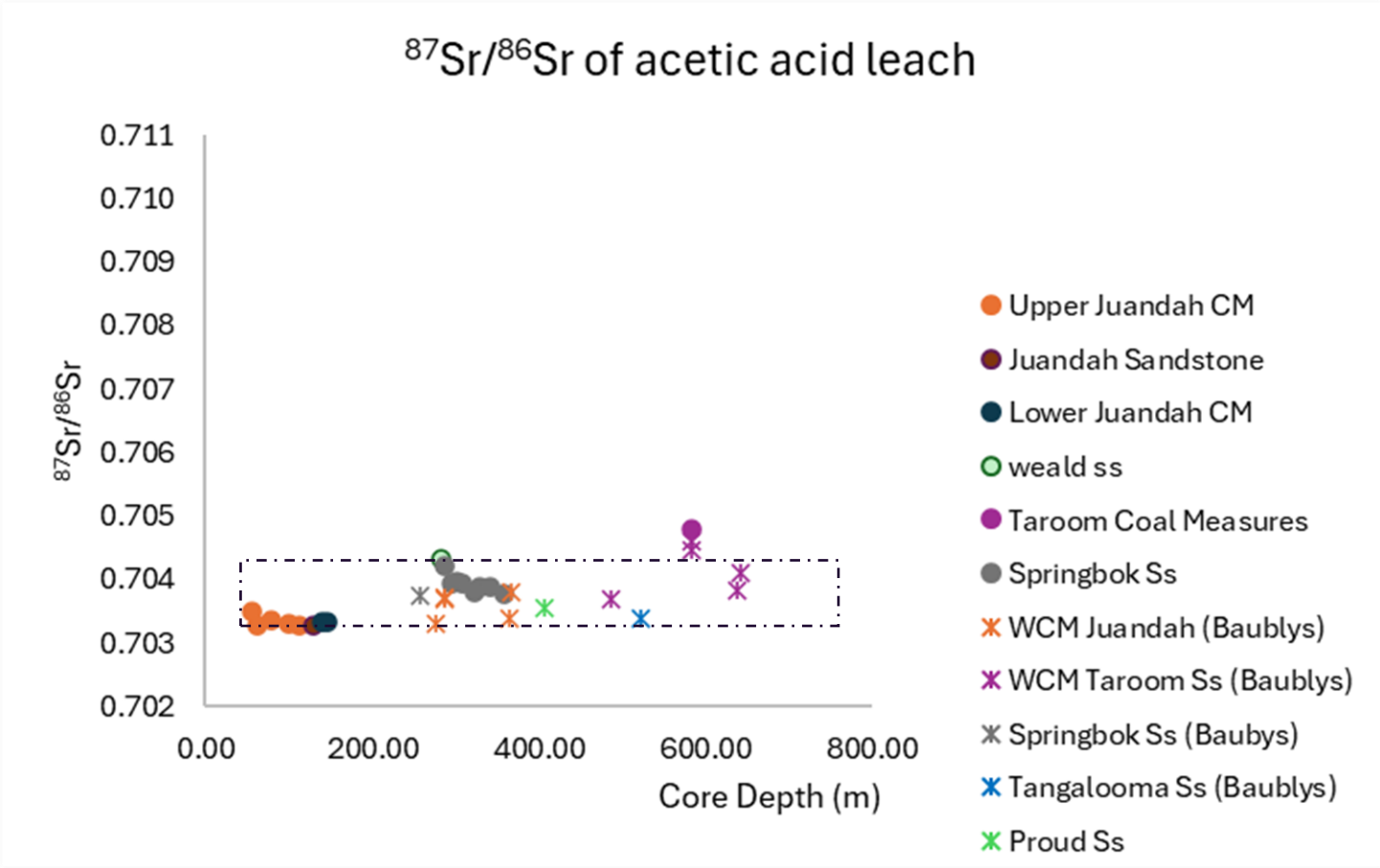


Fig 10: $^{87}Sr/^{86}Sr$ signatures of Springbok and WCM interburden acid leaches, note some overlapping signatures.
* Crosses are data from Baublys et al., from Chinchilla 4, Pleasant Hills 25, and GG leaches

Sr isotope signatures from rock leaching

- Showing the expanded y axis range.
- Dashed box indicates range of groundwater signatures from Springbok Ss and WCM (see Fig. 3 and Baublys et al., 2021).
- Potentially some differences between wells or formations but unclear without further data.

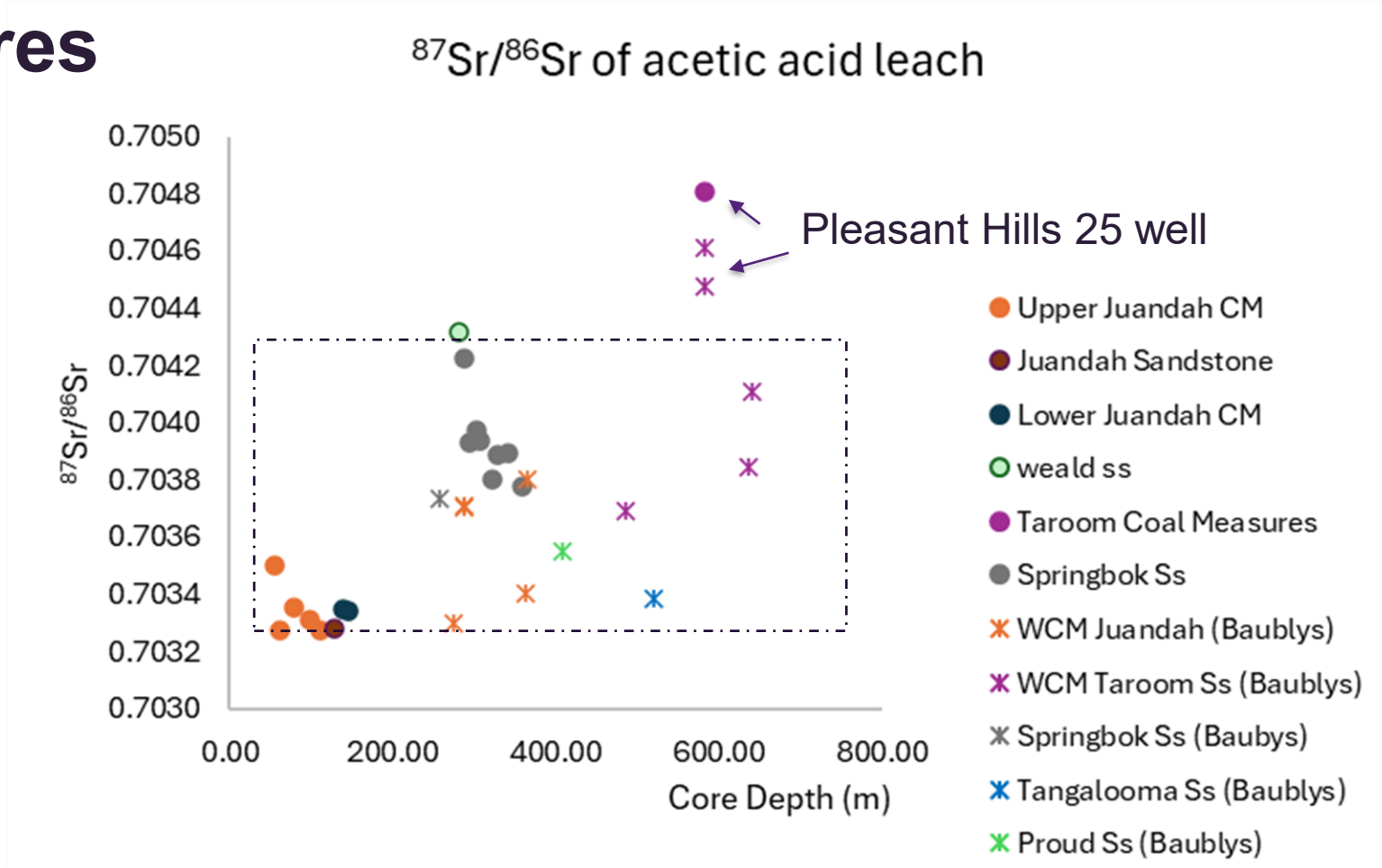
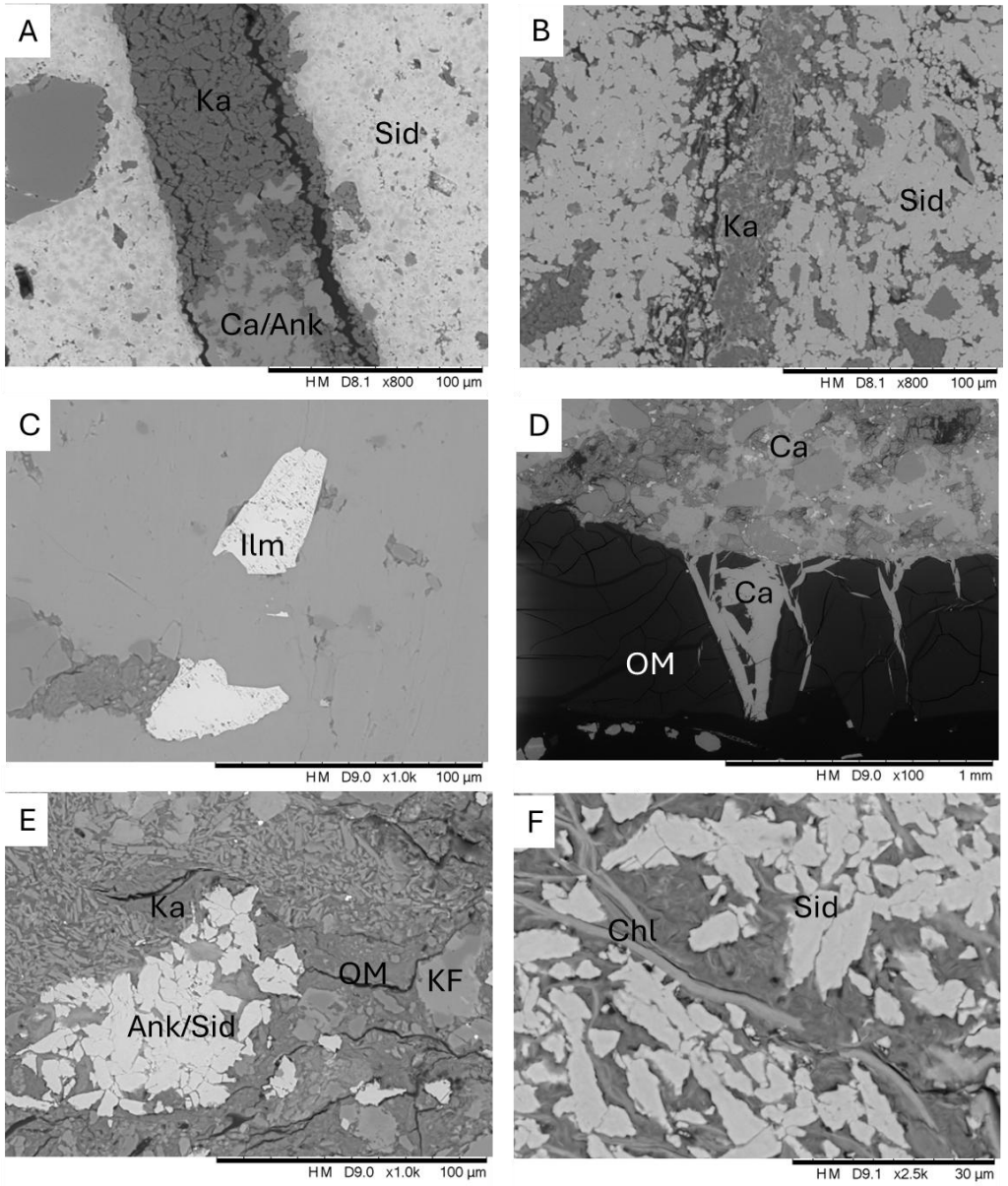


Fig 11: $^{87}Sr/^{86}Sr$ signatures of Springbok and WCM interburden acid leaches, note some overlapping signatures.
* Crosses are data from Baublys et al., from Chinchilla 4, Pleasant Hills 25, and GG leaches

Summary

- Springbok vs Walloon CM in CSG region - Groundwater signatures of Sr isotopes often overlap
- Whole rock analysis of Sr isotope signatures of Springbok Ss and Walloons CM interburden well core.
- Diversity within core but also similar potential Sr host minerals e.g. plagioclase, calcite cements in both formations
- The two formations have some overlapping signatures of Sr isotopes from whole rock
- The weak acid extracts of Sr isotopes in the two formations are mainly overlapping
- **Indicates that the similarity of the two formations may be the reason for overlapping groundwater signatures, not necessarily any occurring leakage**
- **Suggested future work**: Analysis so far was on core from two wells (Orana north 431, Pleasant Hills 25), broaden geographical area e.g. core from Chinchilla 4 well, Origins well cores e.g. from Talinga. Additionally on core/cuttings from further south in the Springbok/Walloons out of the CSG region. Other options are investigating different formations in the Surat, or reservoir – aquifer pairs in the Bowen Basin.
- Also do different mineral occurrences have different signatures? Could fracture fill calcites have localised differences?



Acknowledgements

- This research has been conducted with the support of UQ and the Centre's industry members – APLNG, Arrow Energy, and Santos.
- QEMSCAN was performed at ANU CAM by Frank Brink.
- Strontium isotopes were run at the UQ Radiogenic Isotope Facilities lab.

Thank you

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