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Geoscience Australia

AUSTRALIAN critical minerals RESEARCH & DEVELOPMENT HUB

The prospectivity of high purity quartz in Australia

Developing a new quartz and high purity quartz (HPQ) mineral systems model, mineral prospectivity map and accompanying Explorers' Toolbox

Dr Jessica Walsh

Acknowledgement of Country

Geoscience Australia acknowledges the traditional owners and custodians of Country throughout Australia and acknowledges their continuing connection to land, waters and community. We pay our respects to the people, the cultures and the elders past and present.

Image: Caterpillar Tracks: Artwork by Roseanne Kemarre Ellis on Geoscience Australia's Alice Springs antenna

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CSIRO

ANSTO Science. Ingenuity. Sustainability.

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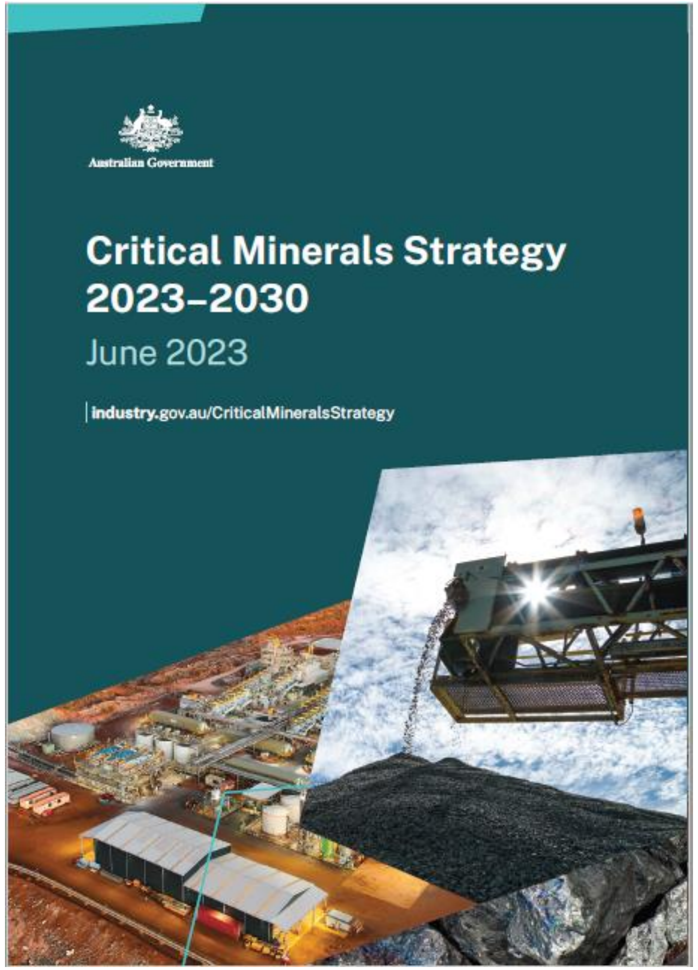


Supports strategic Australian priorities including achieving **Net Zero by 2050, diversifying supply chains** and **growing Australia's resources sector**

Geoscience Australia participating in four projects:

- High Purity Silica Mineral Potential (leading)
- Mineral Criticality Assessment (leading)
- By-product potential of Australian resources (leading)
- Accelerating Development of Australia's Rare Earth Resources – clay hosted REE deposits (supporting ANSTO)

An Introduction to *High Purity Silica*

- **Silica (SiO_2)** is a common compound with many mineral polymorphs, including **quartz**.
- Silica is also used in the production of **silicon (Si)**, a critical mineral used to produce **photovoltaic solar cells** and **semiconductors**.
- **High purity silica** (HPS; including high purity quartz (HPQ)) has a number of applications, including the manufacture of fused quartz glassware and crucibles. Direct application.

Metallurgical grade silica >98 % SiO_2

High purity silica >99.995 % SiO_2

Orders of magnitude different when it comes to impurity profiles

An Introduction to *High Purity Silica*

- High purity silica (HPS) can be recovered from a variety of different source rocks in a range of geological settings.
    - Grain size of silica sand is prohibitive to the silicon smelting process – therefore, the HPS project is only investigating **hard rock sources**.
- **Demand for HPS is forecast to increase**, driven by the ambition to reach net zero emissions.
    - To meet solar energy requirements, the global demand for lump quartz feedstock will increase by nearly a factor of 40 by 2050[1].
- The current HPS market is dominated by production from the **Spruce Pine Deposit**, USA (Sibelco & The Quartz Corp), which provides ~70 % of global supply.
- Australia has **one domestic producer** – *Simcoa Operations Pty Ltd* operates a HPS mine in Moora and a silicon smelter in Kemerton, Western Australia.

[1] IRENA; PwC (2022)

Spruce Pine Pegmatite
Appalachian State University, earth.appstate.edu

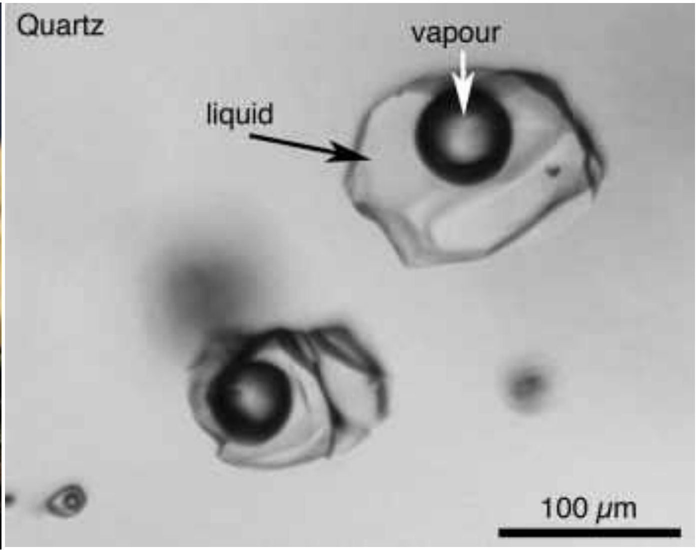
Spruce Pine Mining District
Bryan Mims, Ourstate.com

Geochemical Complexities: Quartz Impurities

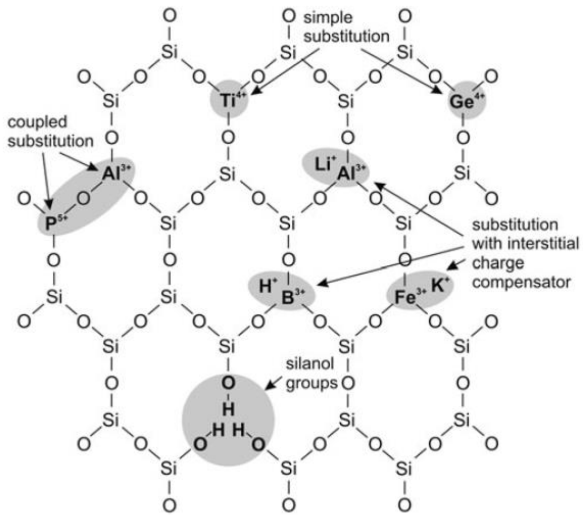
Impurity types: (i) accessory minerals, (ii) mineral inclusions, (iii) fluid inclusions and, (iv) lattice-bound.

Arjen van Ooyen, Mindat.org

Cristian Biagioni, Mindat.org



Ronald Baker, Montana University



Müller et al., 2012

Grinding & crushing
Gravity/magnetic separation
Flotation
Calcination

**High Al concentrations associated with elevated Li, K, Na and H, and possibly B and P

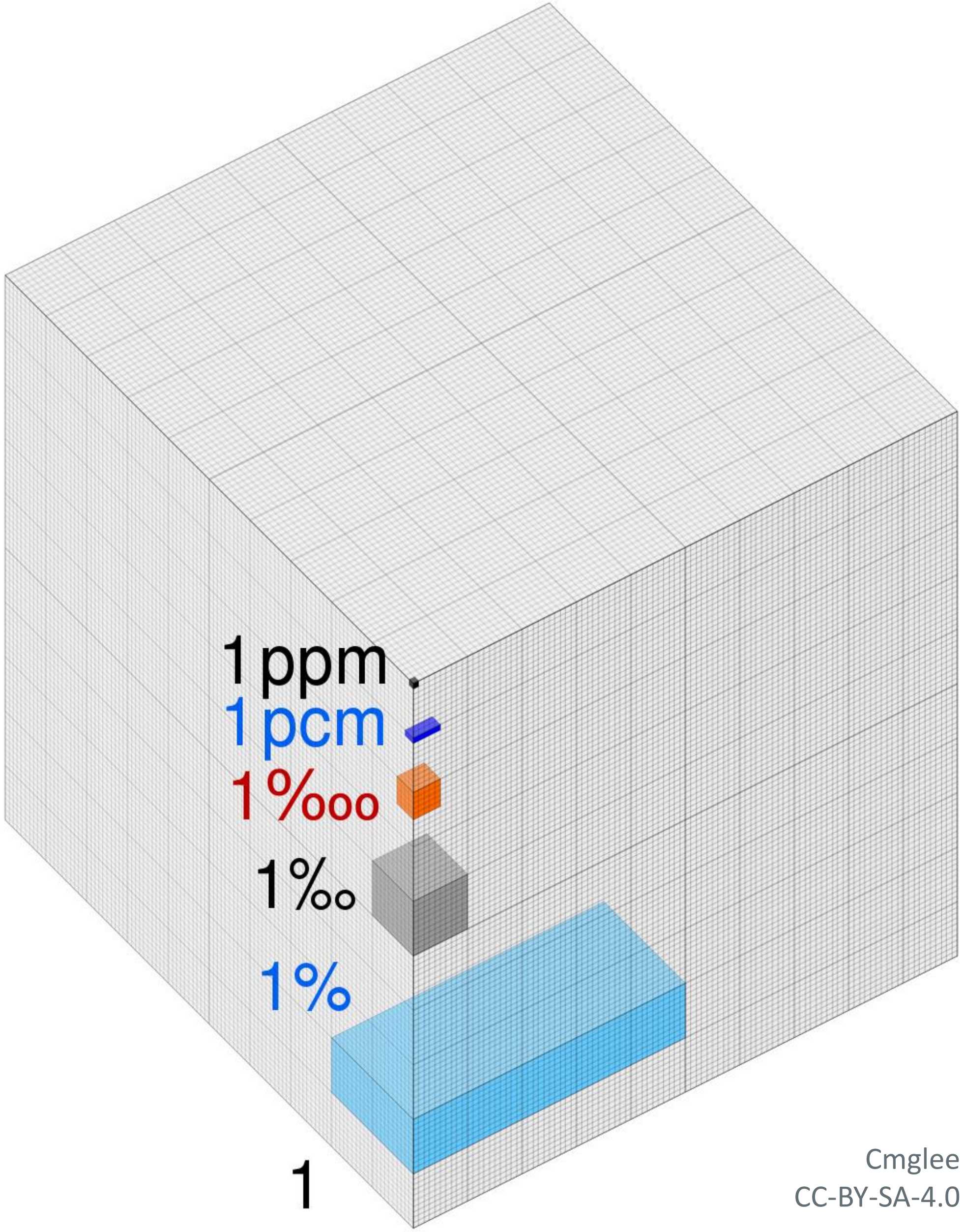
∴ Al concentration good quality indicator

Geochemical Complexities: Defining Purity

Commonly defined in the literature as being <50 ppm impurities (>99.995 % SiO_2).

	Al	Ti	Na	K	Li	Ca	Fe	P	B	∑trace elements
Max concentration (ppm)	30	10	8	8	5	5	3	2	1	50

Amethyst
10-100 ppm Fe^{+3}
Photo: Mindat.org



Cmglee
CC-BY-SA-4.0

A national-scale silica and quartz mineral potential assessment

Aim

Develop:

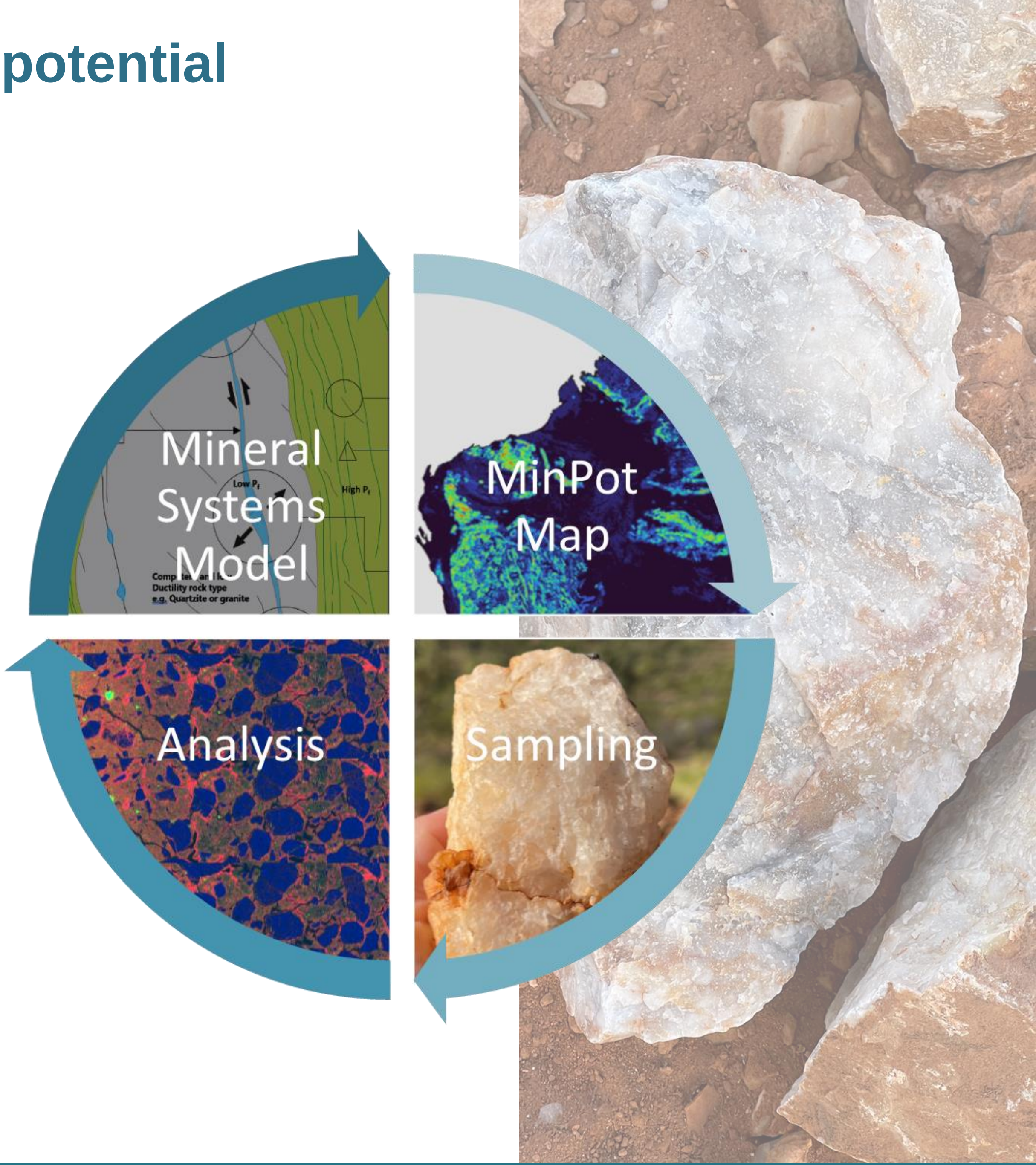
1) **Mineral systems models *(for pegmatites and hydrothermal quartz*)** and
2) **Mineral potential map**

The current problem(s) with high purity silica (HPS):

- There is ***no publicly available mineral systems models*** for silica/quartz and HPS/HPQ deposit formation.
- ***Lack of regional HPS-specific datasets*** – e.g., are certain settings more prospective? Are pegmatites generally better than hydrothermal quartz veins?
- ***Lack of exploration, discovery*** and knowledge in Australia. Both inventory, and potential inventory are unknowns.

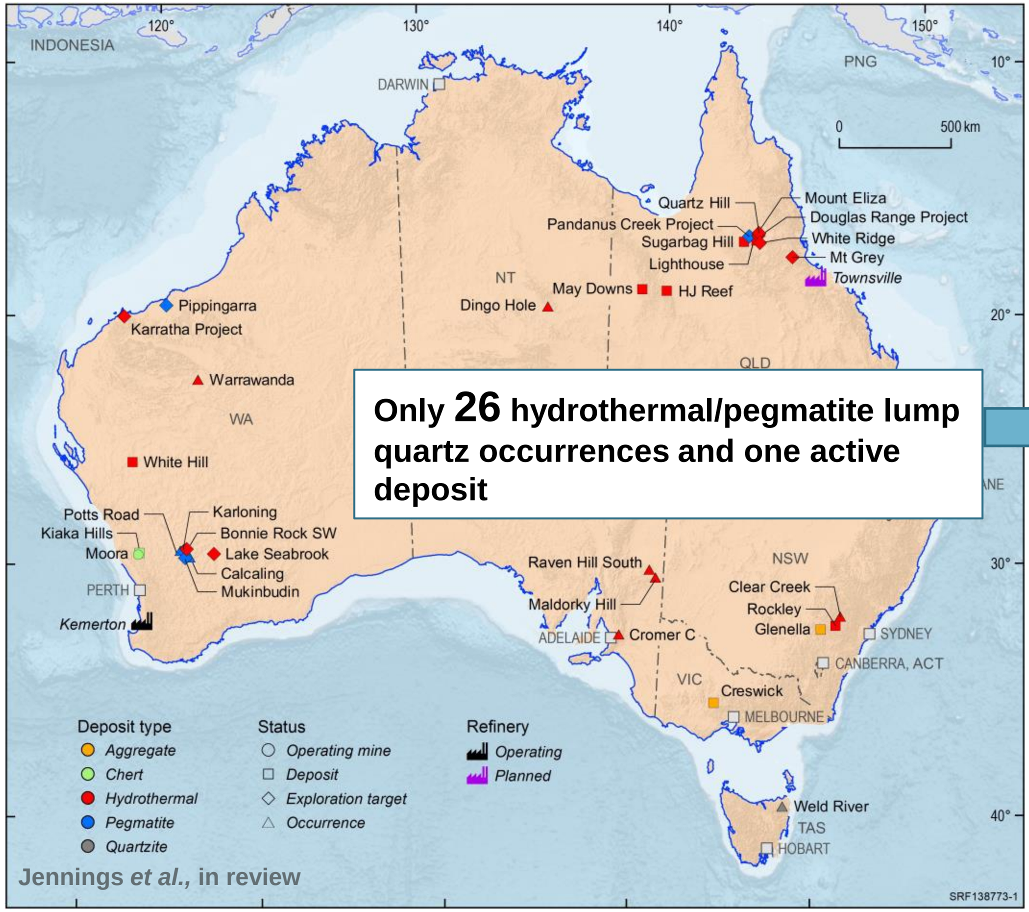
Product or output:

- The development of a practical, industry-focussed **(i) mineral system model** and associated **(ii) national-scale mineral potential map of Australia** (Generation 1).
- Identify **sites for sample collection and geochemical analysis**.
- **Iterative geochemically-informed mineral potential map focussed on HIGH PURITY silica/quartz** (Generation 2, 3, 4…)



Silica and Quartz Occurrences (and Deposits) in Australia

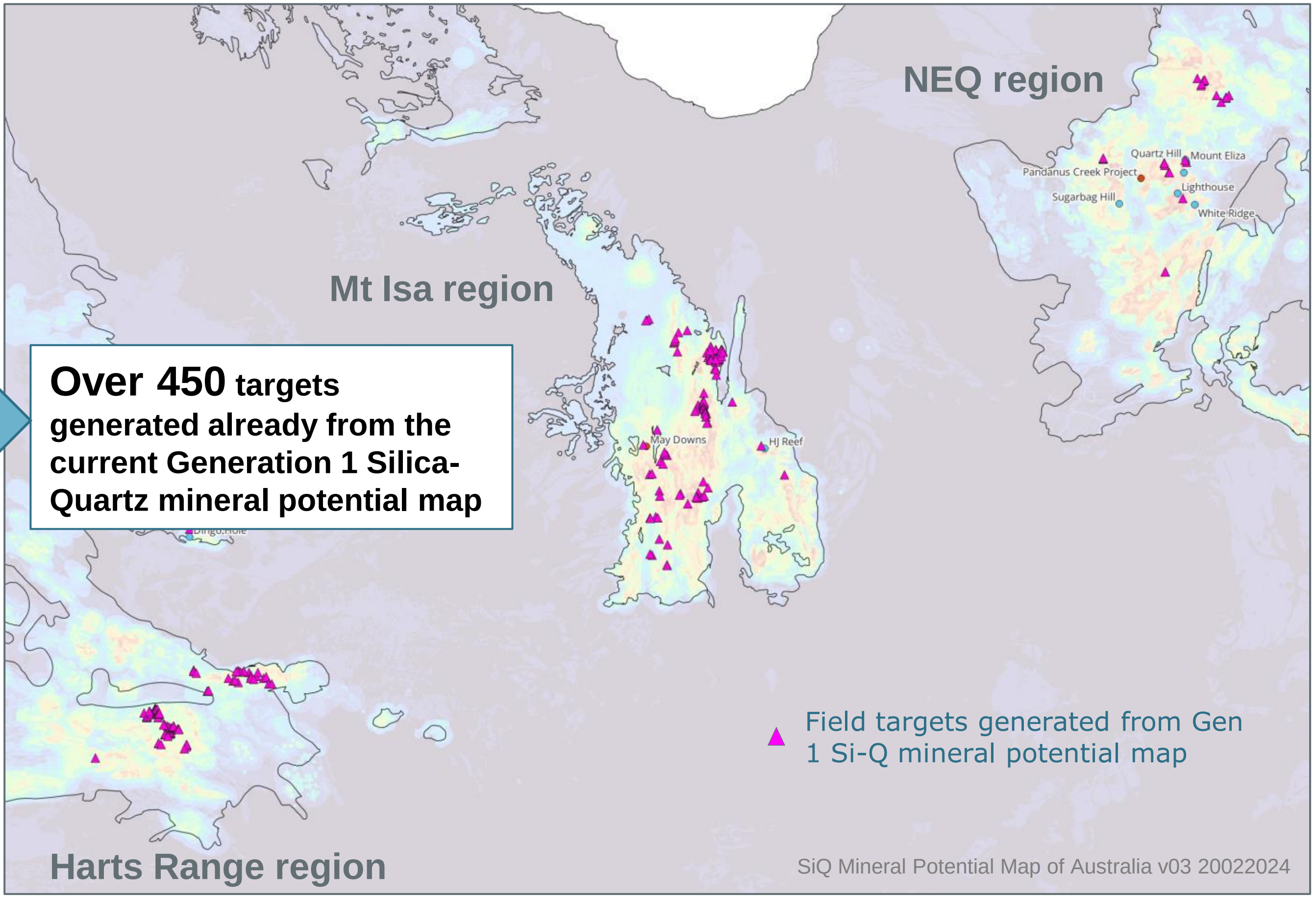
- **Very few proven deposits** in Australia.
- **OUTCOME**: over 450 target sites already identified for sampling = **new potential** identified for HPQ (Δ)



Jennings *et al.*, in review

Only 26 hydrothermal/pegmatite lump quartz occurrences and one active deposit

Over 450 targets generated already from the current Generation 1 Silica-Quartz mineral potential map



SiQ Mineral Potential Map of Australia v03 20022024

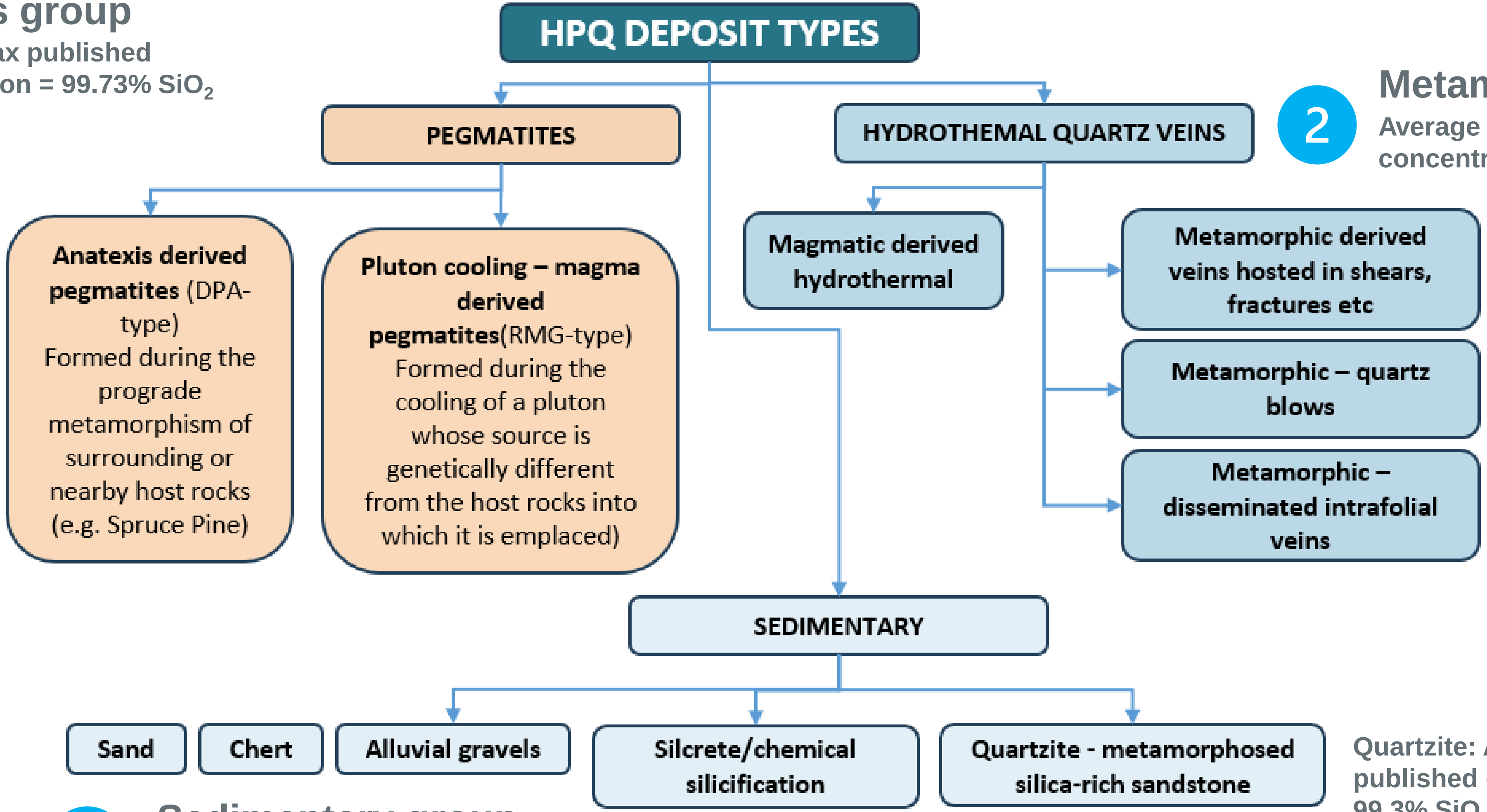
Primary HPS/HPQ Sources – Separate Mineral Systems

1

Igneous group

Average max published concentration = 99.73% SiO_2

RMG and DPA classification from Muller *et al.*, (2021).



2

Metamorphic group

Average max published concentration = 99.71% SiO_2

Quartzite: Average max published concentration = 99.3% SiO_2

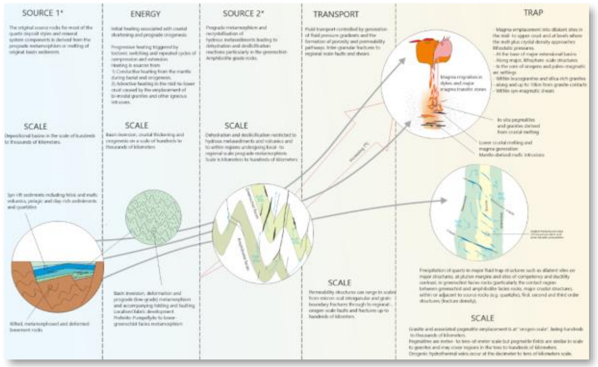
3

Sedimentary group

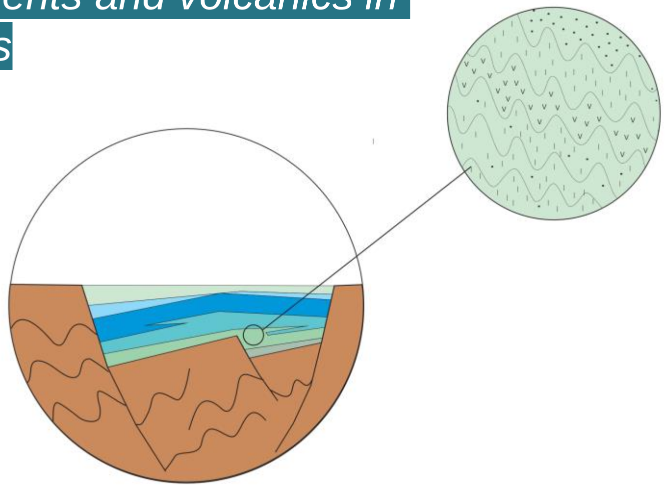
Chert: Average max published concentration = 99.2% SiO_2

The silicon and HPQ mineral systems simplified

Pegmatite + Hydrothermal quartz

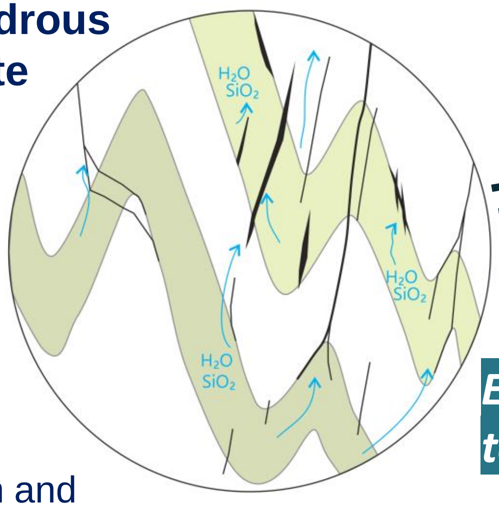


***SOURCE #1**: Deposition of sediments and volcanics in basins*



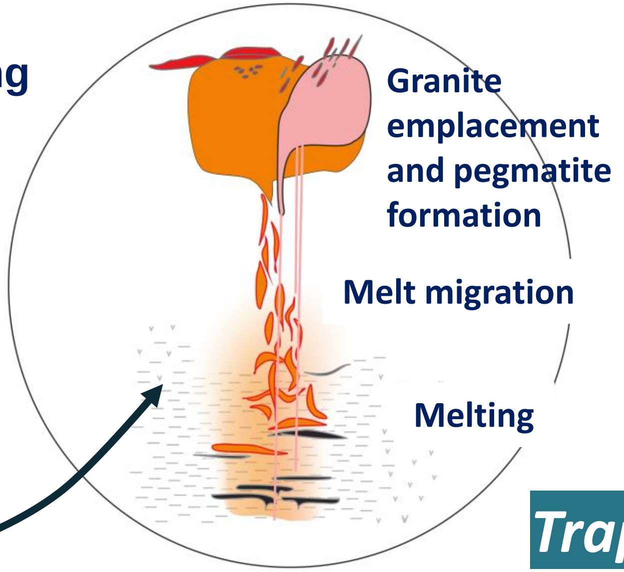
Basin inversion and metamorphism

Heating and prograde metamorphism of hydrous sediments and silicate minerals
= Fluids (H_2O) + SiO_2



Energy = High temperatures

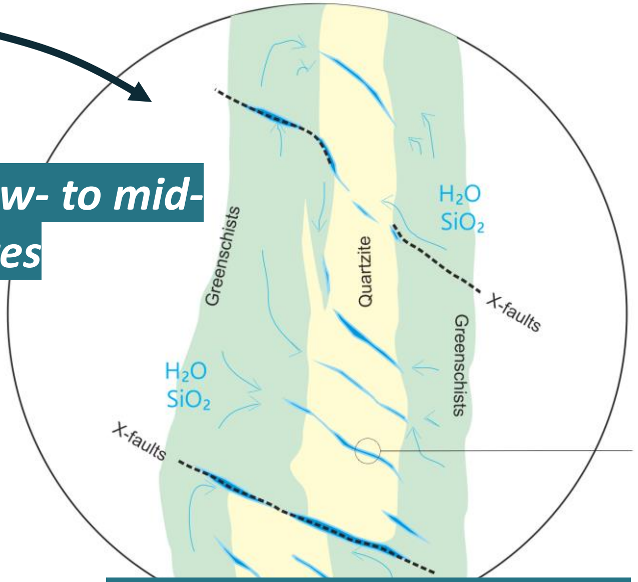
Heating and melting to produce granites and pegmatites



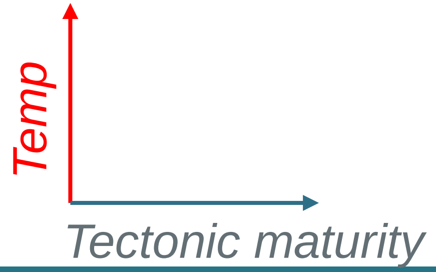
Trap

Energy = Low- to mid-temperatures

Dehydration and deformation to produce hydrothermal quartz veins



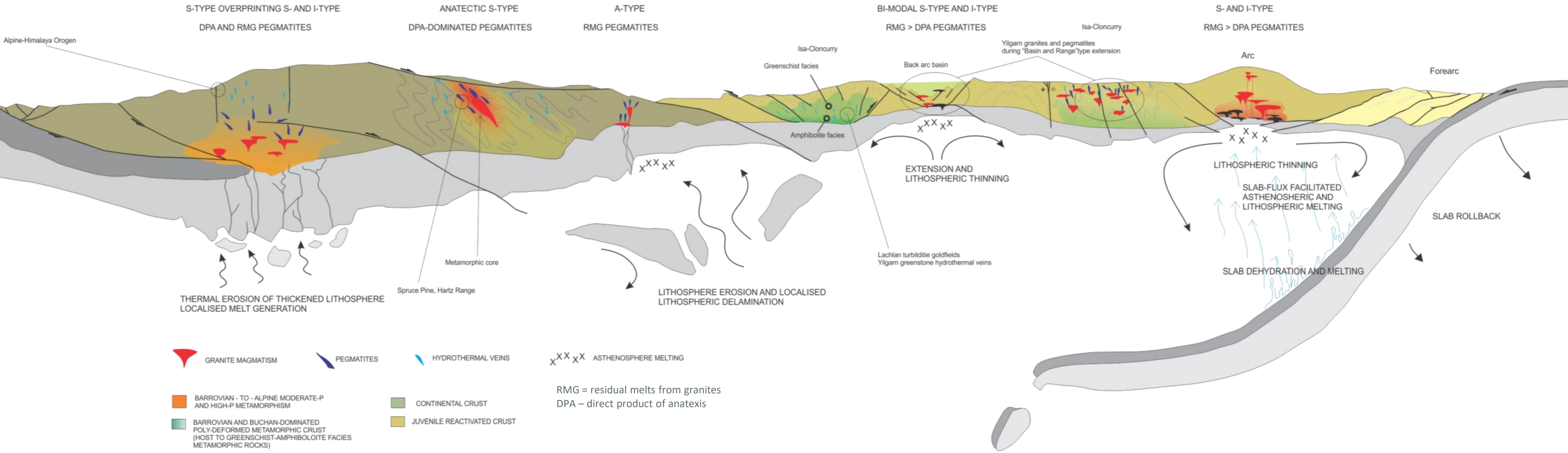
***SOURCE #2**: metamorphic derived fluids and SiO_2*



Gen 1 silicon and quartz mineral systems components

https://www.ga.gov.au/data-pubs/data-and-publications-search/publications/critical-commodities-for-a-high-tech-world/mineral-systems-framework

Mineral system (commodity)	Tectonic/geodynamic setting	Geological setting	Geodynamic drivers	Fluid drivers
• SiO_2 • Hydrothermal quartz veins • Pegmatite-hosted HPQ • Quartzite • Chert/Silcrete	• Continent-Continent & Continent-Oceanic convergent and extension settings • Continental extensional basins and rift settings • Orogenic belts • Forearc and intra-cratonic basins • Back-arc and Inverted back arc basins	• Competency contrasts • Low- to high-grade metamorphic belts • Shear zones and highly fractured crust • Granite and intrusion-dominated terranes	• Extension, collision, transpressional and transtensional continental settings. • Changes in geodynamic setting from compression to extension.	• Steepening of local and regional geothermal • fluid pressure gradients caused by metamorphism across variable rock types • Deformation and deformation partitioning • Competency contrasts



Mineral Potential Map – Key Mappable Components *(some examples)*

Energy

- **Heating** associated with conduction or from the emplacement of granites and granite batholiths for example

Architecture

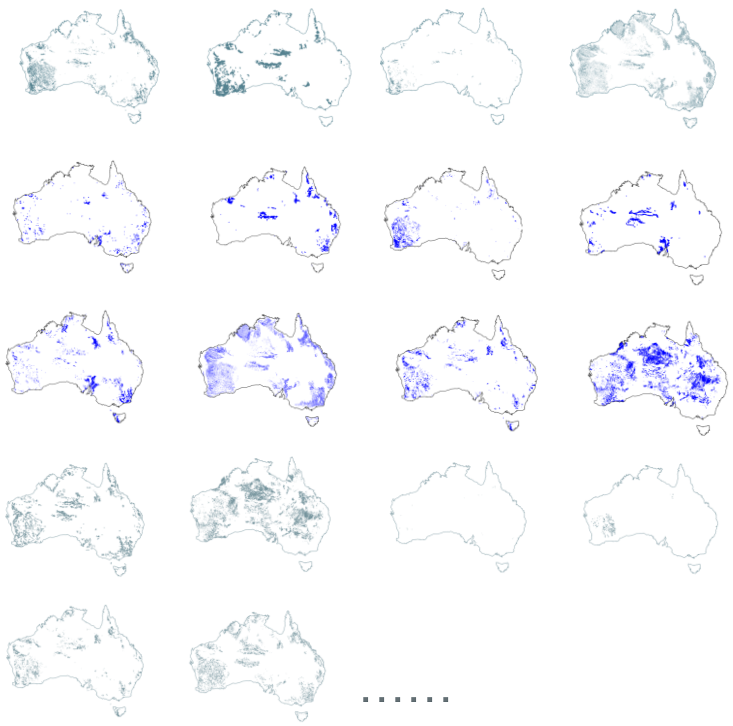
- Regions of **magmatism**
- **Faults** and regional structures
- **Extensional terranes**

Source

- **Granites** as a source of RMG pegmatites
- **Anatexites** as a source for DPA migmatites, granites and pegmatites
- **Quartzites** as a source for hydrothermal quartz and Quartz veins
- **Metamorphic rocks** (greenschist facies) as a source of metamorphic-derived quartz

Depositional site

- **Third order structures?** (not mappable)
- **Competency contrasts**
- **Thermal/metamorphic gradients**
- **Granite contacts** (<10km)



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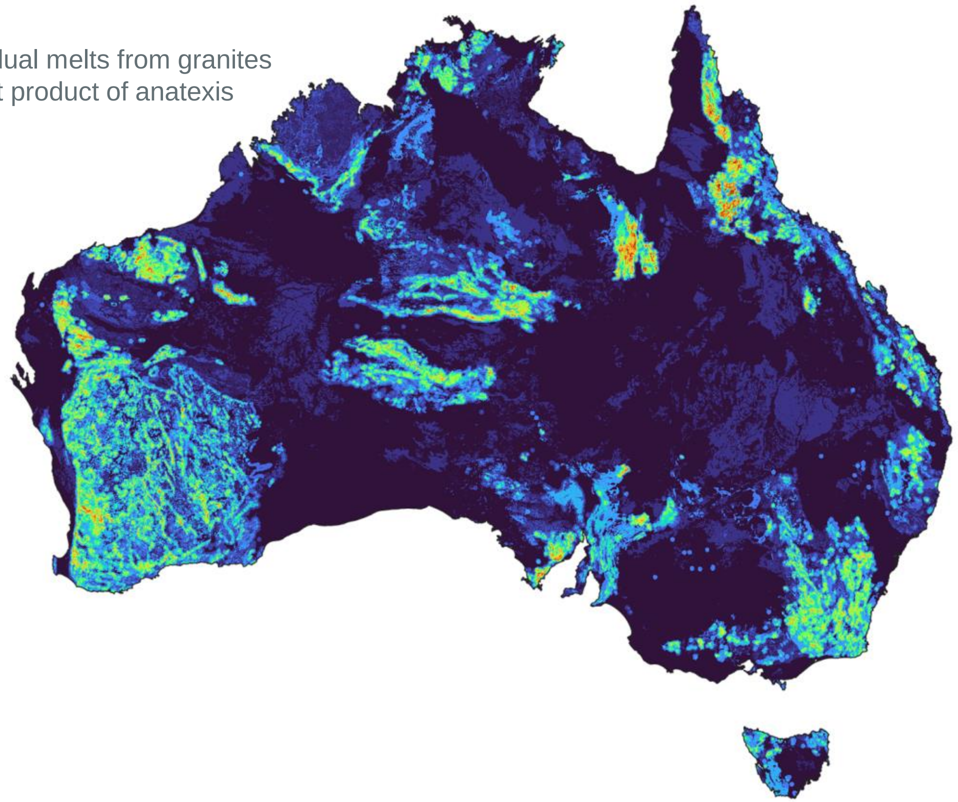
ENERGY
N = 4

SOURCE
N = 16

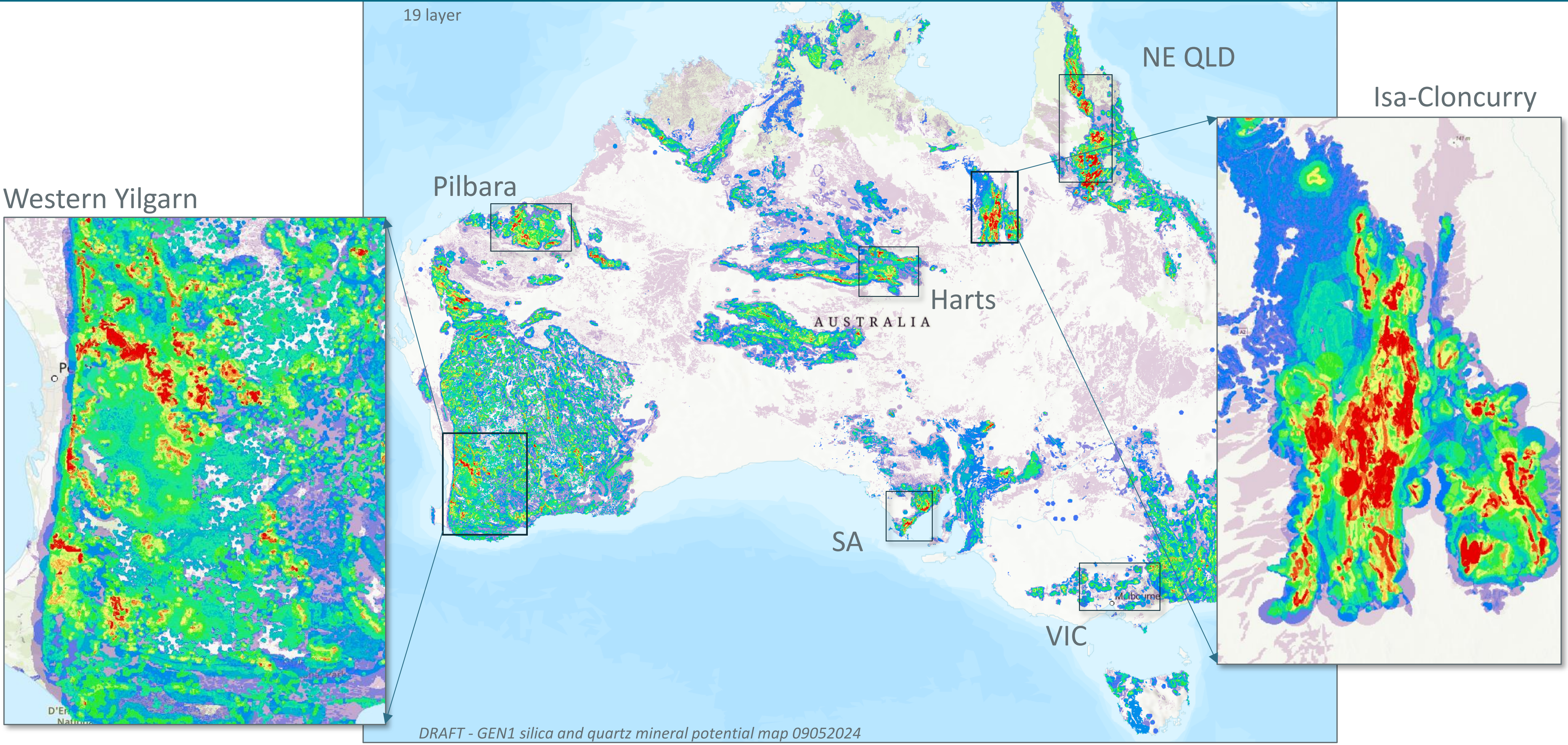
DEPOSITIONAL SITE/ ARCHITECTURE
N = 16

RMG = residual melts from granites
DPA = direct product of anatexis



GEN 1 silica mineral potential and prospectivity map of Australia

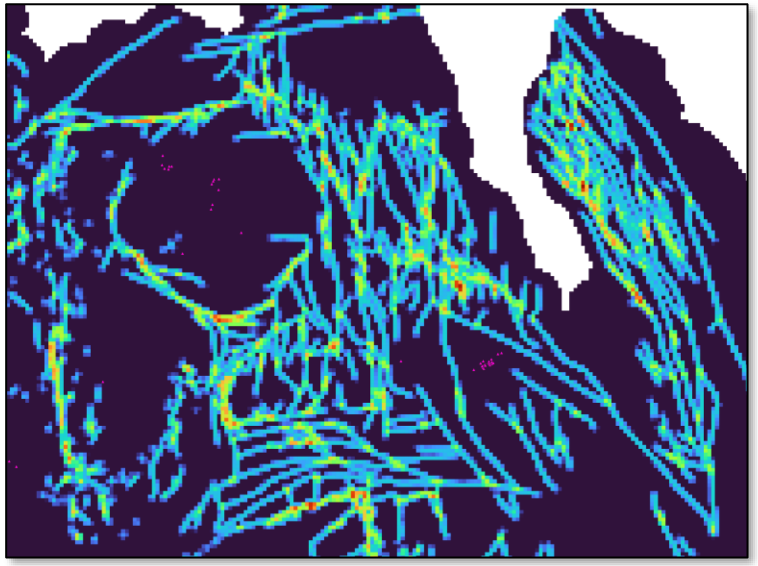
Pegmatites, Hydrothermal Quartz Veins, Quartzites and Silcretes



Fieldwork: Pilbara, WA

Some key layers that were investigated, but not included in Gen1

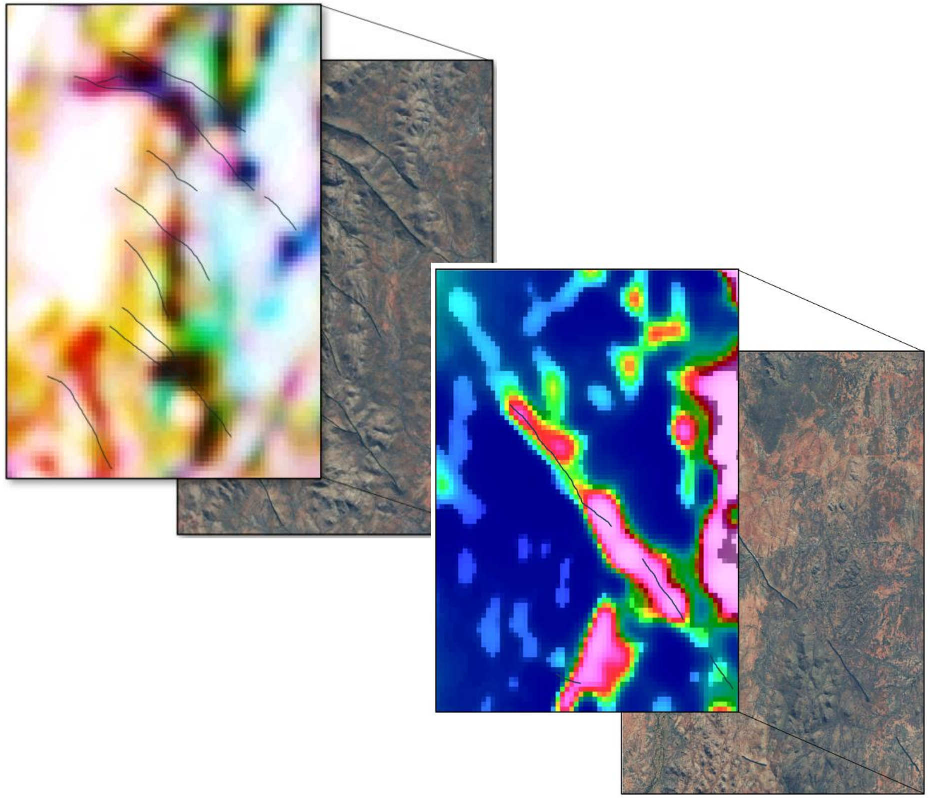
- National faults and linear structures map



Issues at national scale:

- Mapping density not equal in all areas
- Only major (1st order) structures are typically mapped but these don't always host quartz
- Brittle fractures such as late conjugate faults with little to no offset are not mapped
- Little to no documented studies showing a genetic relationship between faults and pegmatite emplacement

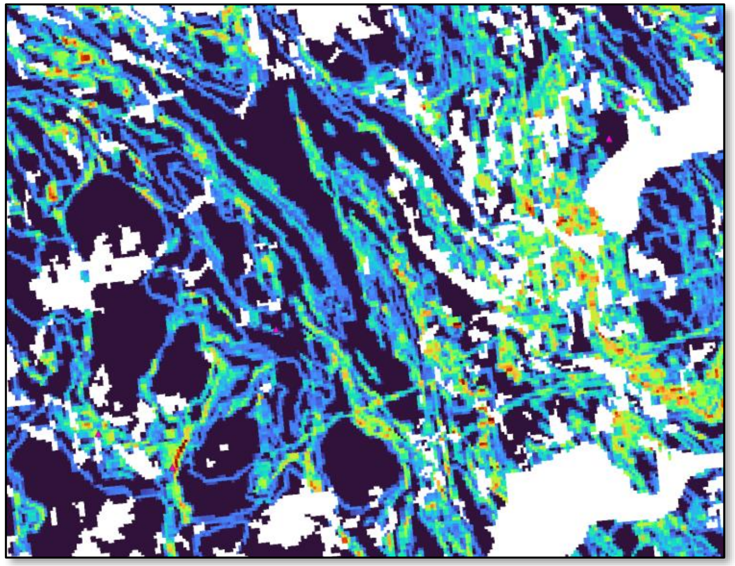
- Radiometrics, magnetics as well as derivatives of radiometrics + magnetics



Issues at national scale:

- Only the very largest quartz occurrences are poorly imaged
- Heavily biased towards outcropping rocks only
- Resolution of data more suitable for a regional/terrane-scale MinPot study

- Contact density mapping as a proxy for high/abundant competency and rheological complexity



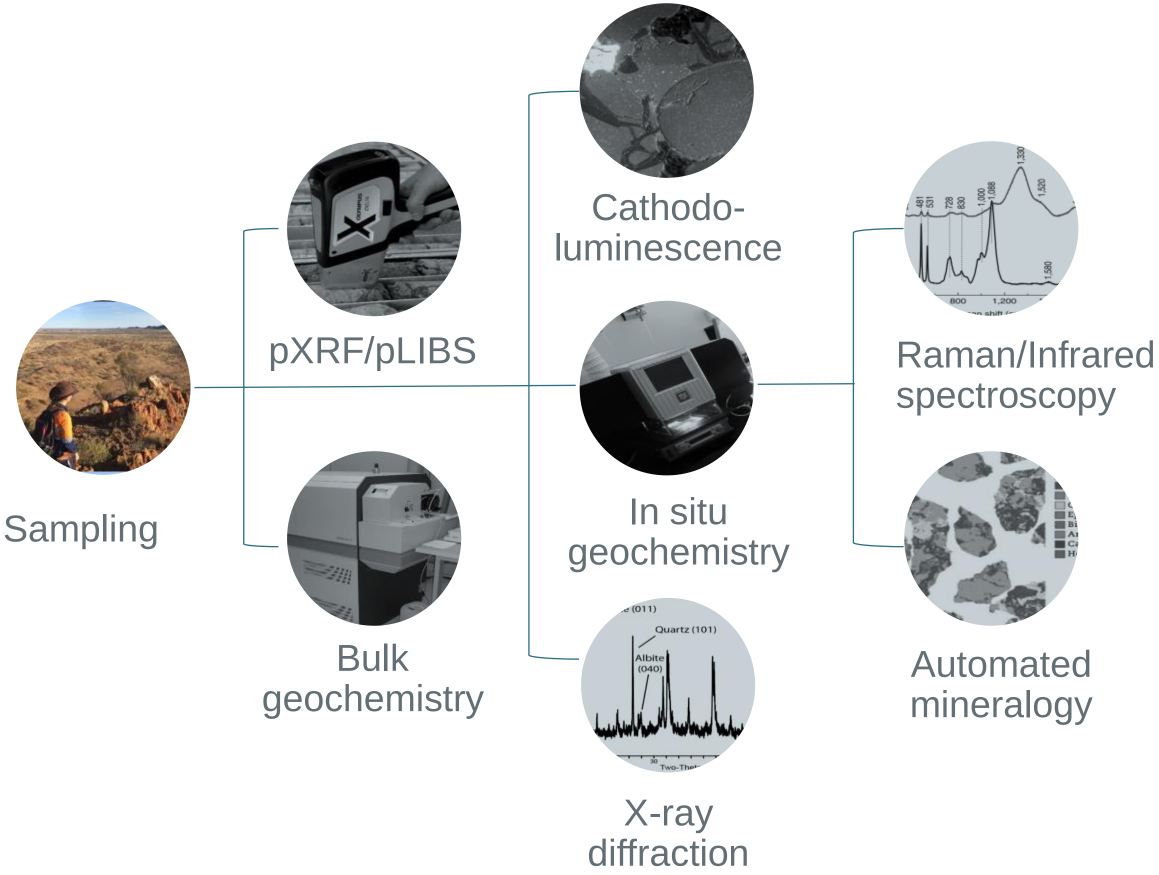
Issues at national scale:

- Variable resolution of contact mapping
- Issues using 1M-scale national solid geology versus surface geology, e.g. stacked contacts in solid geology interp.
- Not specific to measured rock competencies so only a proxy.

HPS sampling and analytical campaign

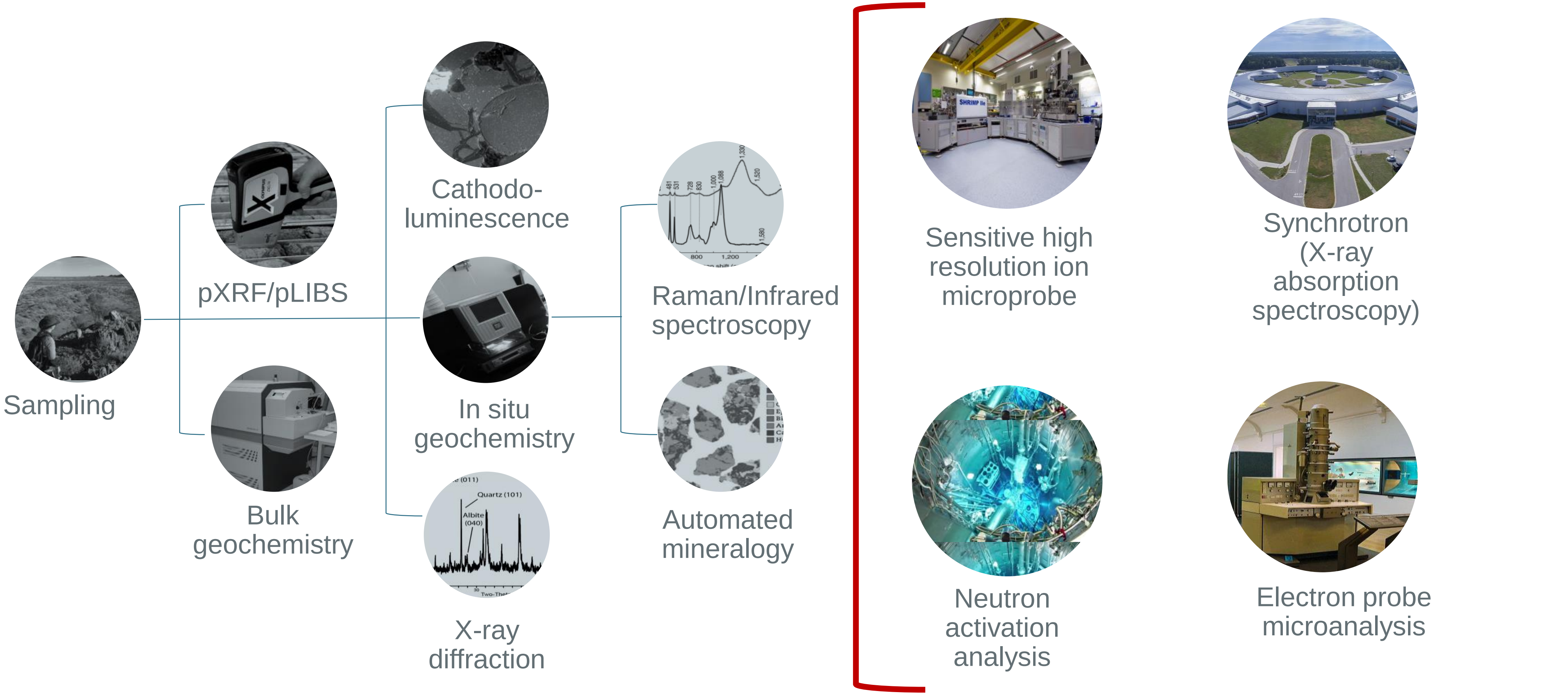
Sampling areas of interest identified in Gen1 of MinPot map:

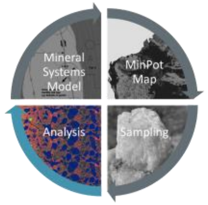
- **Legacy samples:** GA and state surveys
- **External samples:** industry and state surveys
- **Field work:** Mt Isa/Cloncurry QLD, Pilbara WA, Harts Range NT



HPS sampling and analytical campaign

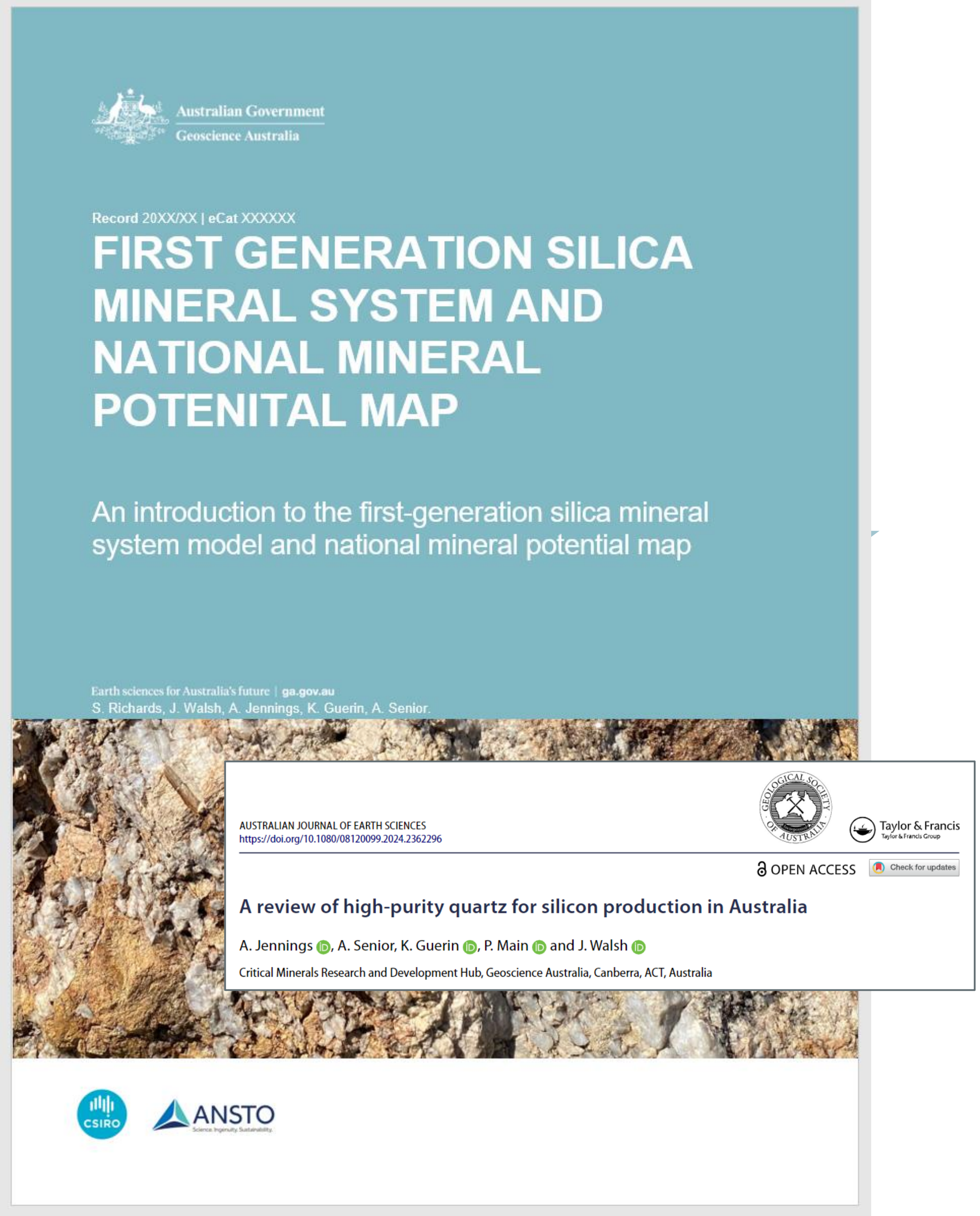
Detection limits required for high purity samples are a challenge for many common analytical techniques.





Next steps

- Review released: Jennings et al. (2024), "*A review of high-purity quartz for silicon production in Australia*".
- Generation 1: Mineral Potential map (silica/quartz).
- Commencing Economic Fairways study:
  - Determine economically favourable locations for processing.
  - Identify sustainable processing pathways.
- Results from analytical work to feed back into Mineral Potential map – defining more prospective minerals systems for HPS.
- Detailed case study of sites identified as having high potential and favourable geochemistry:
  - Better understand spatial variability in HPQ within deposits.
  - Test the guidelines developed for the *Explorers' Toolbox*.



Explorers' Toolbox

Encourage exploration and provide data and interpretations to underpin future exploration success.

<u>Aims to</u>:

1. Provide an HPQ/HPS National Scale Mineral Potential Map identifying areas of high prospectivity → ***Encourage nation-wide sampling of quartz***
2. Determine industry-applicable analytical techniques for analysis of quartz/silica samples and associated guidelines → ***Help take the guesswork out of sample analysis***
3. Identify early quality indictors to inform whether further analysis is necessary → ***Build confidence from early, cost effective analysis***
4. Provide best practice guidelines for characterisation of potential HPS resources → ***Help standardise techniques for sampling and analysis***

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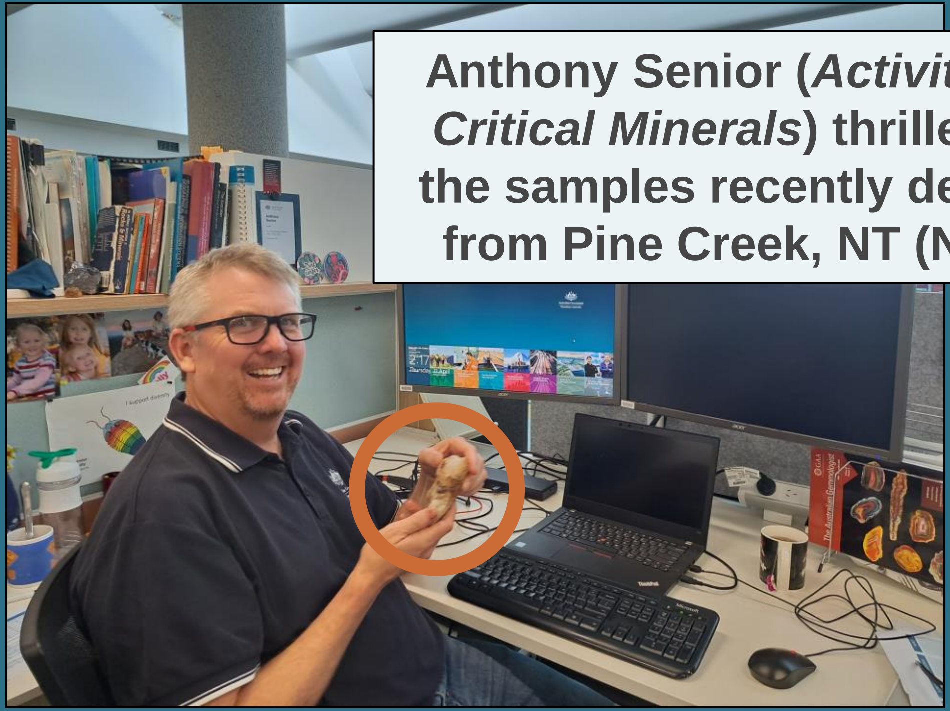
Critical Conversations (1 pm): "*How can government research, data and tools support accelerated discovery and development*?"

Workshop (2:45 to 3:45 pm): "*Shaping the new Resourcing Australia's Prosperity initiative*". Room M1.



Anthony Senior (*Activity Lead Critical Minerals*) thrilled with the samples recently delivered from Pine Creek, NT (NTGS).

On behalf of the High Purity Silica project team at Geoscience Australia – Anthony Senior, Kristy Guerin & Allyson Jennings. Special thanks to Simon Richards.

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Rachael Morgan, Anthony Schofield, Marina Costelloe, Access Engagement team, MPA & MEG team, ANSTO

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THANK YOU

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