

Natural hydrogen exploration in South Australia

Elinor Alexander

Director Geoscience and Exploration Branch

Energy Resources Division

Department for Energy & Mining



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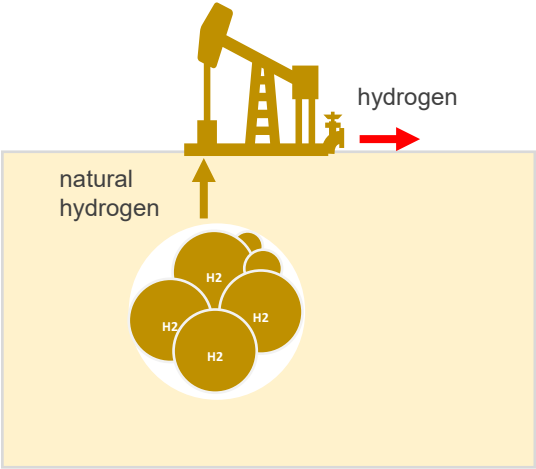
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Legislative framework

Petroleum and Geothermal Energy Act 2000

Provides a single window into government for natural hydrogen, includes underground storage and transmission pipelines for all 'colours' of hydrogen.

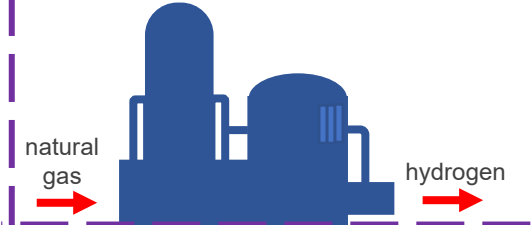
Natural (gold, white) hydrogen



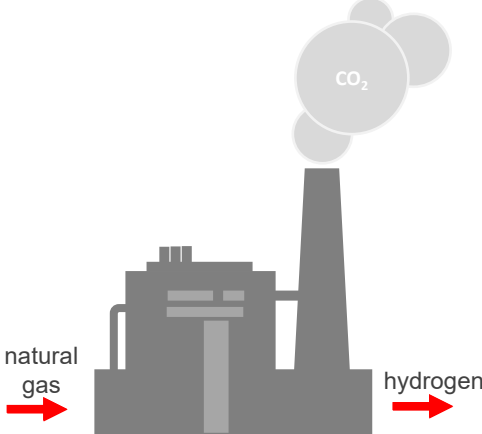
Hydrogen Production Act 2022

This will provide a single window into government for all manufactured/generated hydrogen

Blue hydrogen



Grey hydrogen



Green hydrogen



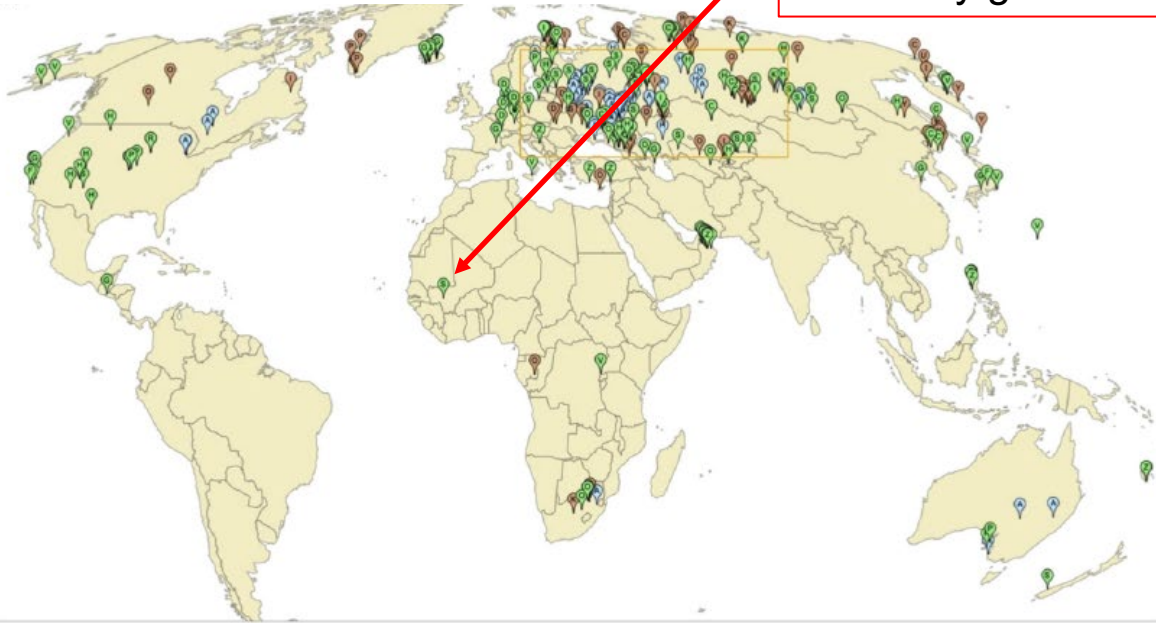
Global natural hydrogen occurrences



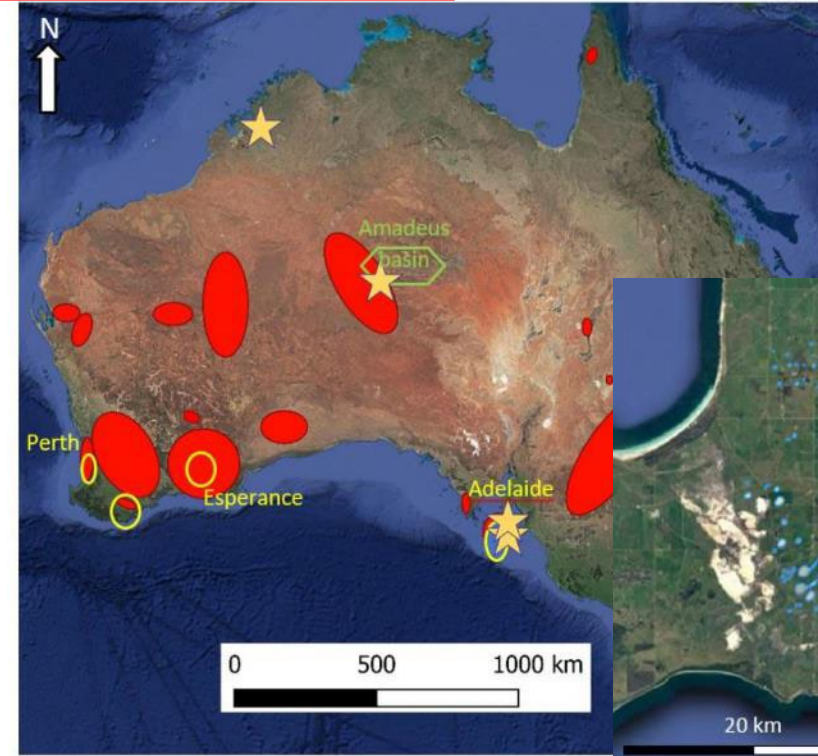
SA was put on the global map of natural hydrogen occurrences in recent scientific papers as a result of gas contents measured from drillholes and possible ‘fairy circles’ (natural seeps). Regulatory changes to enable natural hydrogen exploration have also attracted global interest.

Zgonnik (2020)

Mali - Bourabougou Field is the world's only current hydrogen producer – used for local electricity generation over the last 7 years.



| | | | |
|-------------------------------------|--------------------------------|-------------------|------------------------------------|
| Discoveries of H ₂ > 10% | Kimberlites [2] | Gas in inclusions | Sediments and Metamorphic [4] |
| Free gas | Orebodies [27] | Coal basins [12] | Ultrabasic [3] |
| Coal basins [10] | Precambrian [10] | Igneous [23] | Volcanic [8] |
| Faults [3] | Rift zones [4] | Kimberlites [6] | Dissolved gas |
| Geysers, hot springs, etc. [12] | Salt deposits [12] | Orebodies [21] | Aquifers [54] |
| Hydrocarbon fields [16] | Sediments and Metamorphic [26] | Precambrian [11] | Water from hydrocarbon fields [15] |
| Igneous [5] | Serpentinization [25] | Salt deposits [7] | |
| | Volcanic [17] | | |



Moretti et al. (March 2021)



Figure 5. Location of the areas with many circular depressions in Australia (red areas). The yellow stars are the location of the wells that found H₂, the yellow circles highlight the areas where depressions that look like fairy circles can be observed and where statistic has been done in this study.

Australian natural hydrogen occurrences



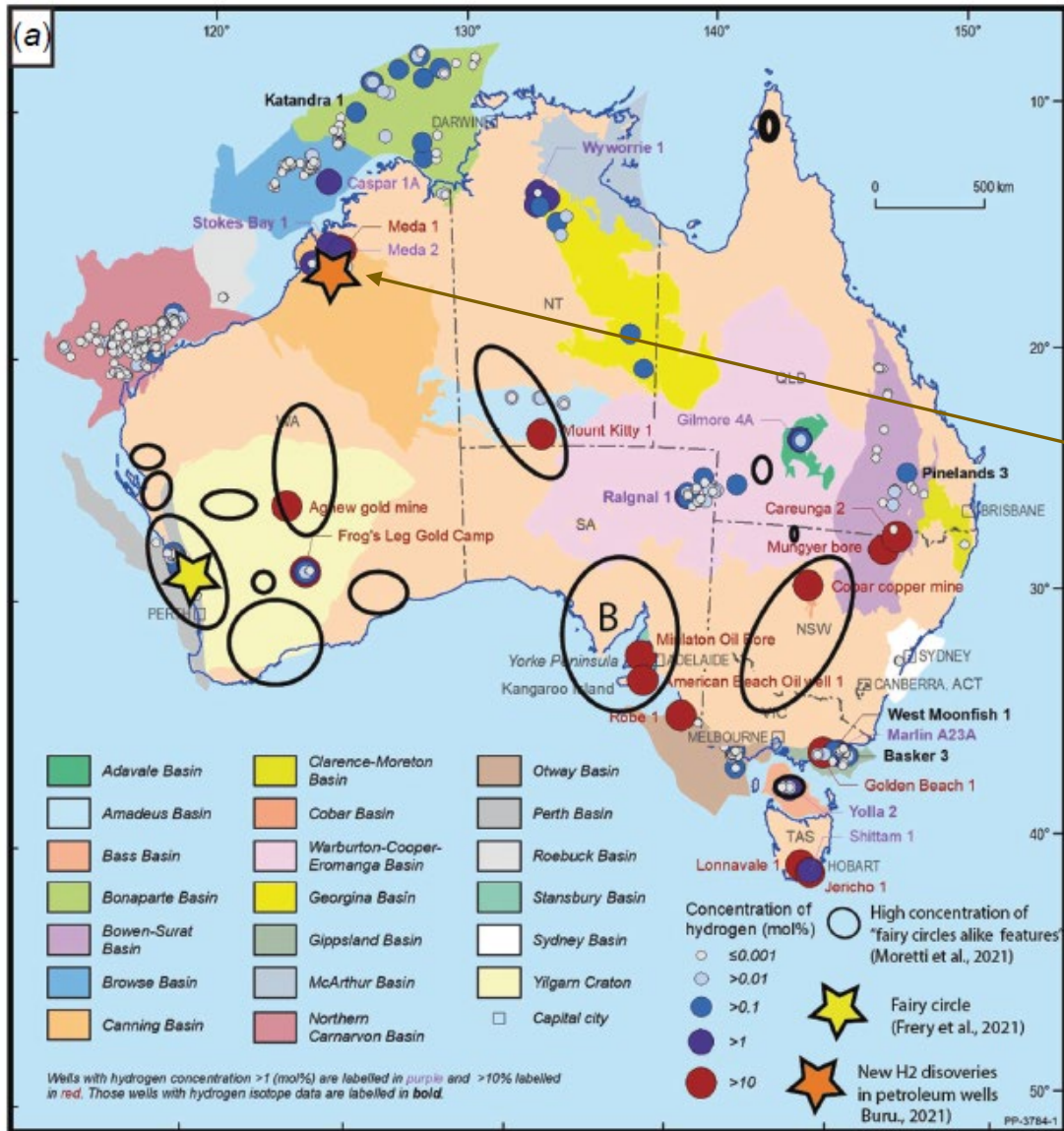
Natural hydrogen has been discovered in petroleum and shallow mineral drillholes as well as seeping from faults and 'fairy circles' in WA. Most Australian natural gases contain trace-low levels of natural hydrogen (Boreham et al., 2021).

Petroleum drilling rigs can only detect natural hydrogen with a specialised hydrogen detection unit (e.g. Buru Energy in 2 recent wells). Since the mid-1960s equipment has been calibrated to prioritise hydrocarbon detection. Mineral explorers typically don't measure gas contents.

So it's likely that natural hydrogen occurrences have been missed by explorers in Australia and globally.

CSIRO Energy researchers are developing exploration techniques suitable for Australian conditions and have successfully identified natural hydrogen seeps in WA (Frery et al., 2022).

Geoscience Australia (Boreham et al. 2021) estimate enormous onshore Australian potential for natural hydrogen.



Frery et al. 2022 modified from Boreham et al. (2021)



Why SA?

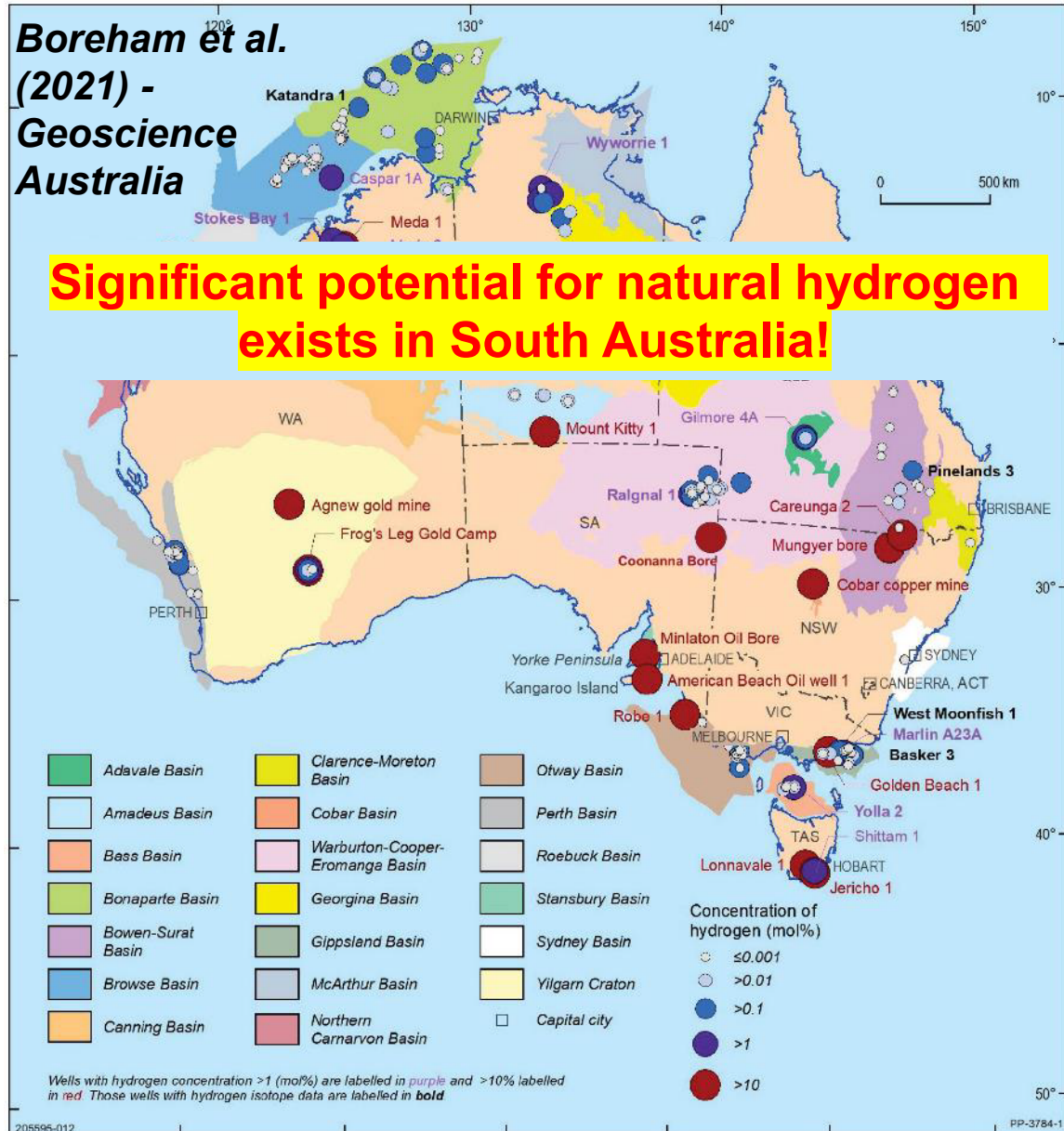
South Australia has taken the national lead in enabling natural hydrogen exploration.

- Effective licensing, regulatory and investment frameworks are in place. Since natural hydrogen exploration became possible in February 2021, explorers have responded with 35 licence applications.
- DEM's online records show significant hydrogen contents from Government analyses of gas samples from three historic drillholes:
 - **1915 – Robe 1**
 - **1921 – American Beach Oil 1**
 - **1931 – Ramsay Oil Bore 1**
- SA has potential hydrogen source rocks - iron-rich and uranium-rich rocks in basement provinces (Archaean-Precambrian).
- Salt lakes on Yorke Peninsula and Kangaroo Island have been postulated to be 'fairy circles' caused by hydrogen seeps (international researchers e.g. Moretti *et al.*, 2021).
- Easy access to extensive spatial data and maps, databases and reports via DEM website. Access to cores and rock samples at the Tonsley Drill Core Storage Facility.



Collecting gas from the Ramsay Oil Bore 1 near Minlaton in 1931. The well reached ~550m, and a small gas flow of almost pure hydrogen was recorded.

Potential natural hydrogen sources and indications

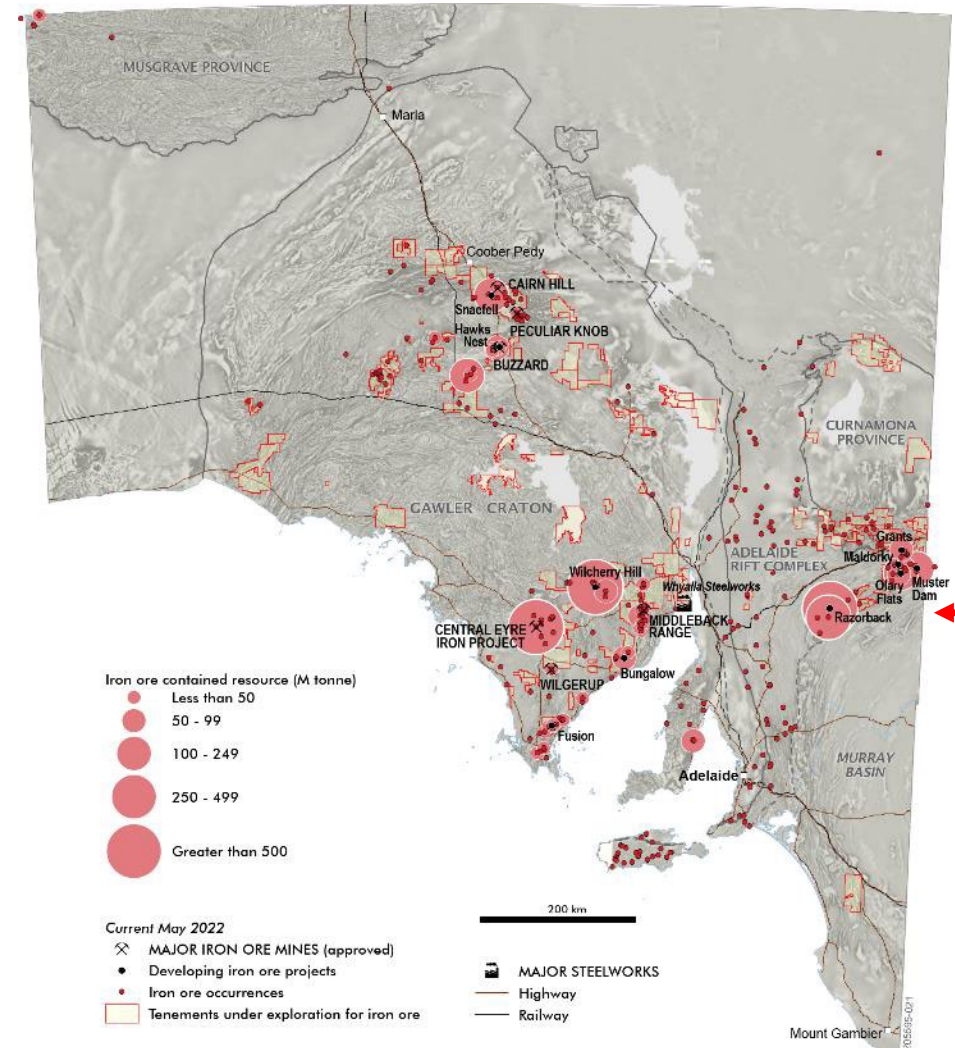
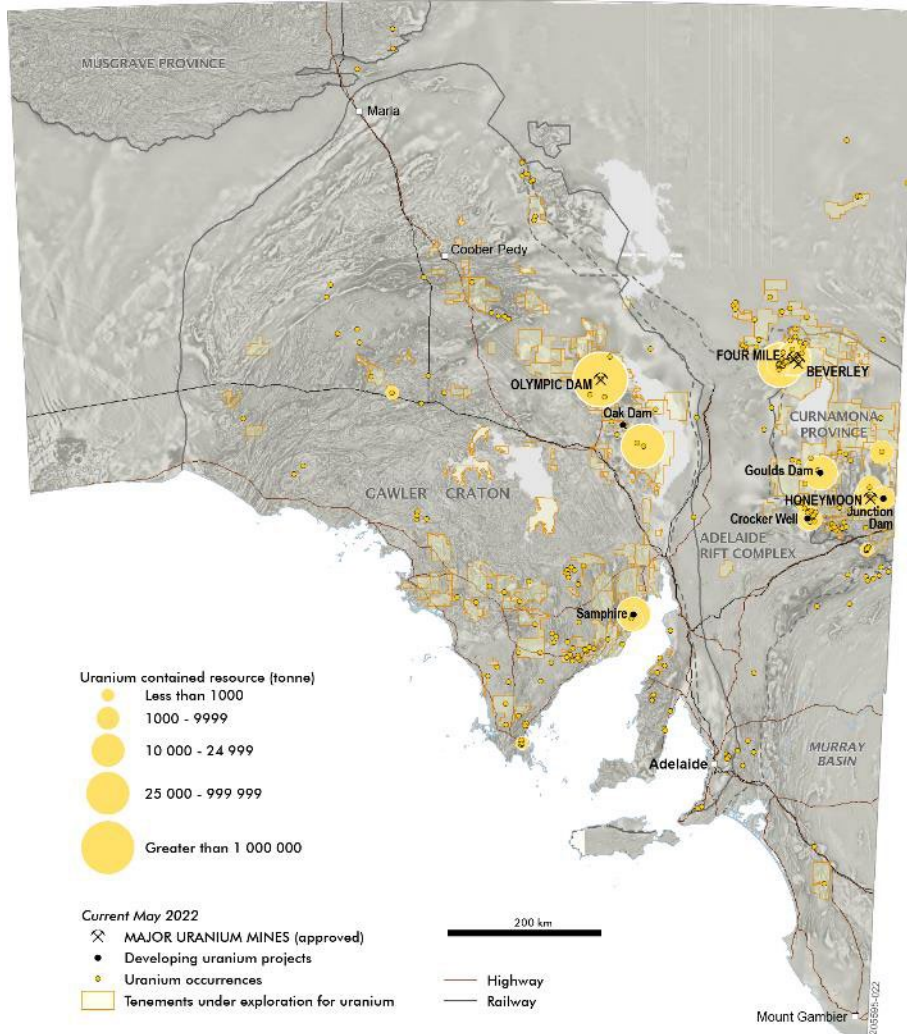


- ✓ **Ancient basement complexes which contain iron and/or uranium rich rocks** - generate hydrogen via radiolytic and oxidation processes (e.g. Archaean greenstone and Precambrian basement terranes – old igneous and metamorphic rocks).
- ✓ **fractured and seismically active source areas** - deep-seated faults can both channel migrating hydrogen up from deep sources to surface and introduce water downward for further chemical reactions with exposed iron rich rocks.
- ✓ sedimentary cover may reservoir and trap migrating hydrogen particularly if **aquifer systems and /or evaporites (seals)** are present. **Over-mature petroleum source rocks (e.g. Cooper Basin).**
- ✓ Surficial hydrogen seeps? Seeps can be blind or coincident with visible sub-circular topographic depressions on the metre to kilometre scale (**'fairy circles'**).
- ✓ **Hydrogen indications in drillholes:**
 - **Robe 1 (25% hydrogen in gas sample)**
 - **American Beach Oil 1 (51-68% hydrogen in gas sample)**
 - **Ramsay Oil Bore 1 (60-84% hydrogen in gas sample)**
 - **Coonanna Bore (16.5% hydrogen – Zgonnik, 2020)**
 - **Some Cooper Basin gas wells (Boreham et al., 2021)**

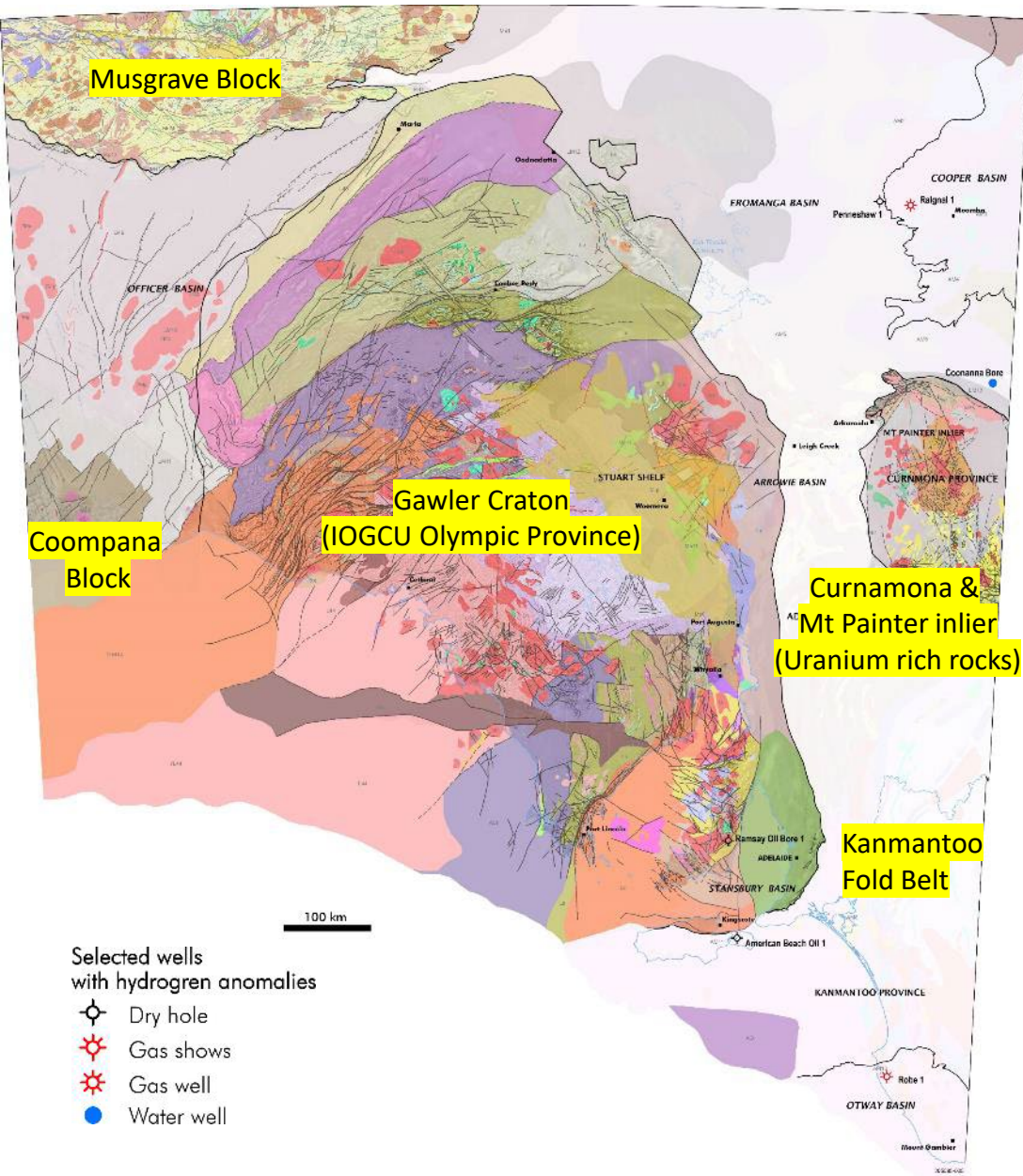
Thanks to Dr Betina Bendall (DEM-ERD) for her input to this overview

Uranium and iron occurrences and mines in SA

- uranium and iron ore in the right setting are potential hydrogen sources



Prospectivity – basement provinces (~1-3 billion years old)



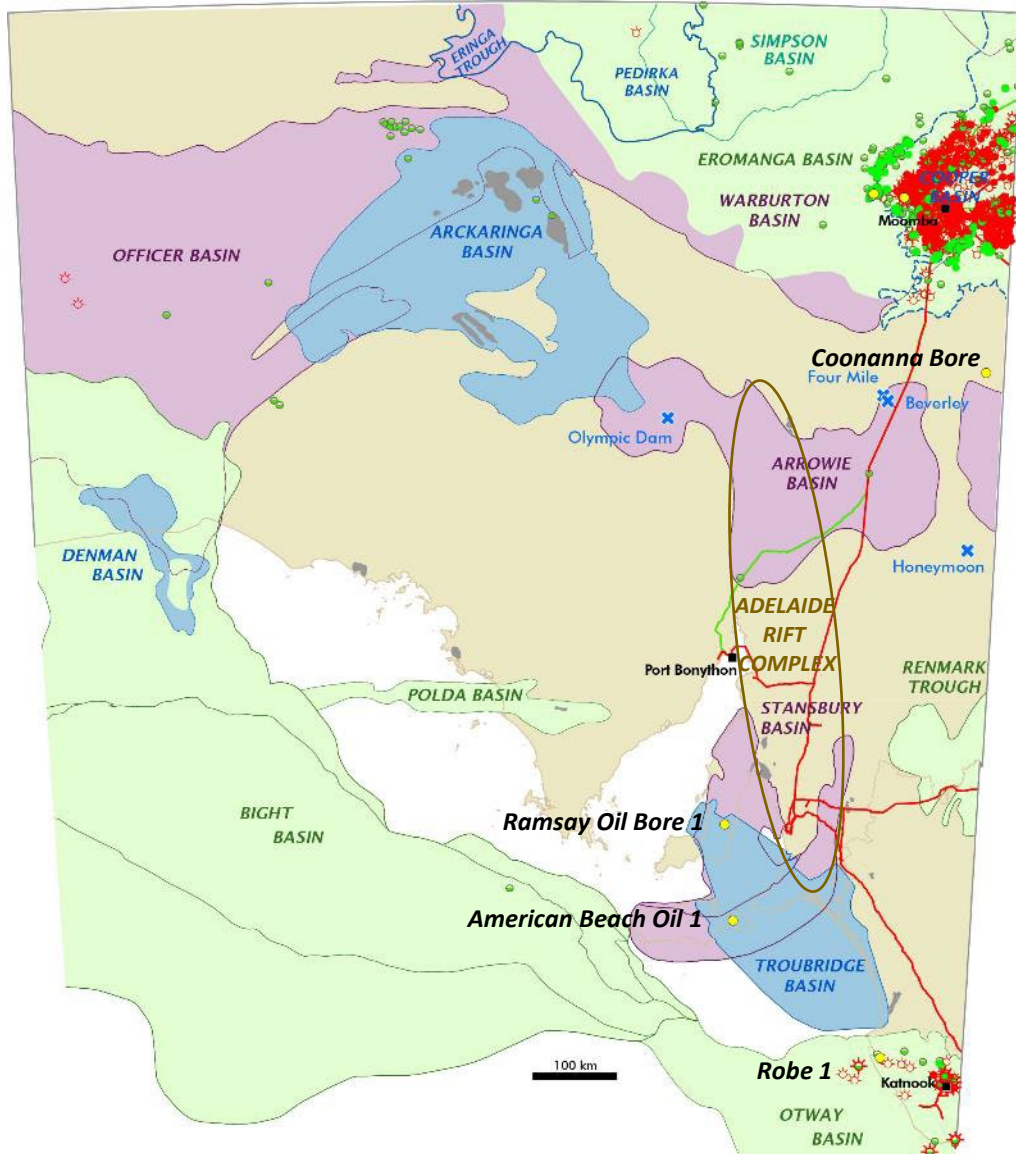
| | Province | | | | |
|--|----------|----------|--|-------------------------------|---|
| | Coompana | Musgrave | Gawler | Curnamona & Mt Painter inlier | Kanmantoo Fold Belt |
| Hydrogen play elements | | | | | |
| Gabbros, mafics, ultramafic intrusives | | | | | |
| Iron-rich granitoid/intrusives | | | | | |
| Uranium-rich rocks | | | IOCGU* | | |
| Banded iron formations | | | | | |
| Ferruginous duricrusts | | | | | |
| Structural complexity/deep active faults | | | | | |
| Hydrogen shows | | | Ramsay Oil Bore. Fairy circles on Yorke Peninsula? | | American Beach Oil Bore 1 Fairy circles on KI? |

* Iron Ore Copper Gold Uranium deposits

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Prospectivity – basins (~0-800 million years old)



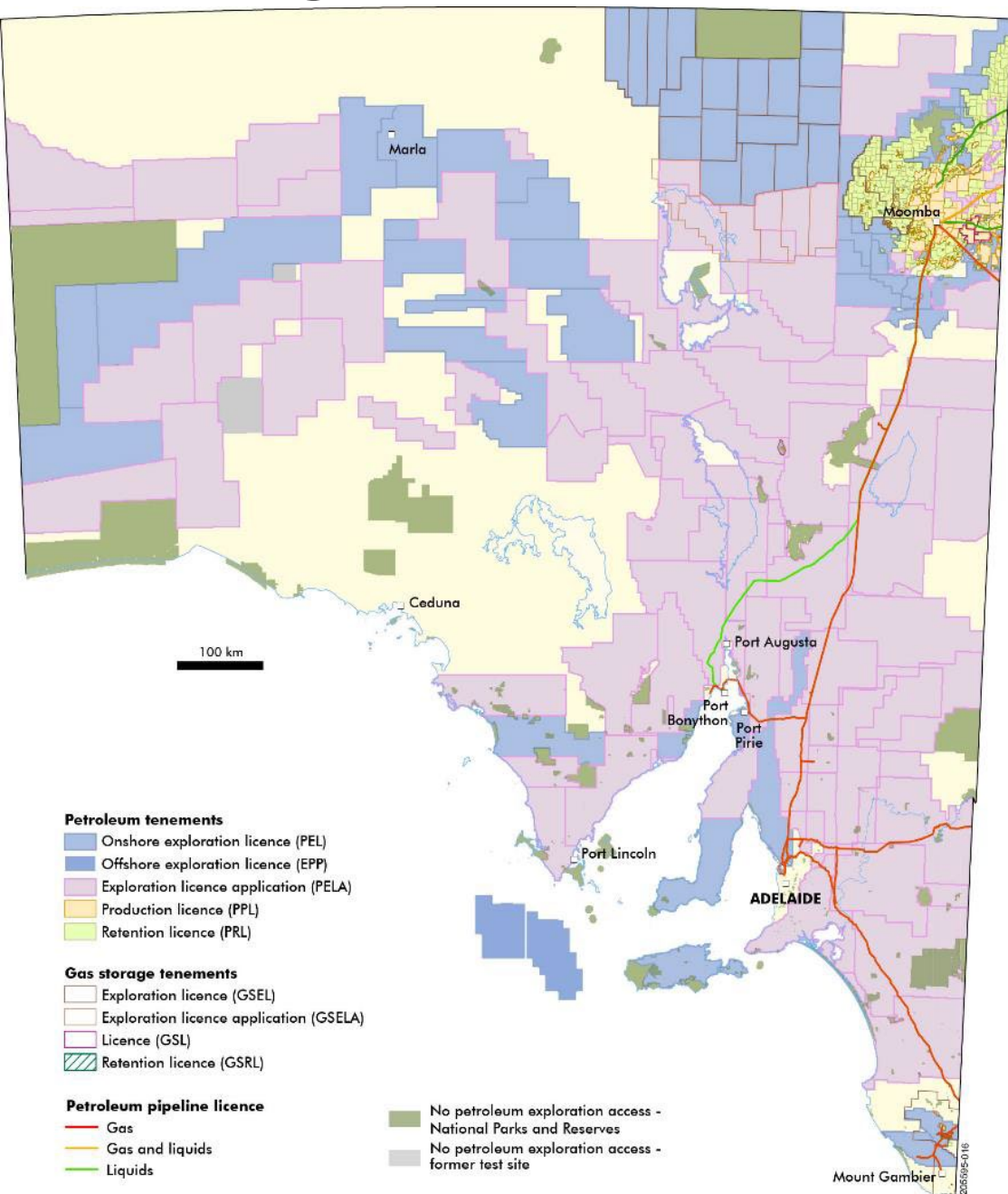
| | Basin | | | | |
|---|---|---------------|--------------------------------------|---|---|
| | Adelaide Rift Complex/ Arrowie Basin | Officer Basin | Stansbury Basin | Cooper/ Eromanga/ Warburton basins | Otway Basin |
| Hydrogen play elements | | | | | |
| Mafic intrusives/extrusives (source and seal) | | | | | |
| Iron stones | | | | | |
| Salt/anhydrite, aquifers (seal) | | | | | |
| Deep Faults | | | | | |
| Over-mature source rocks | | | | | |
| Hydrogen shows | | | Ramsay Oil Bore 1. Fairy circles? | Coonana 1, Ralgnal 1 etc. | Robe 1 (mantle derived CO ₂ in Caroline 1) |

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- Petroleum wells**
- Wells with hydrogen anomalies
 - Dry hole with oil shows
 - ⊛ Gas shows
 - Gas well
 - ⊛ Gas well with oil shows
 - ⊛ Oil and gas well
 - ⊛ Oil and gas shows
 - Oil well
 - Processing plant
 - Gas pipeline
 - Liquids pipeline
 - Gas and liquids pipeline



Licensing

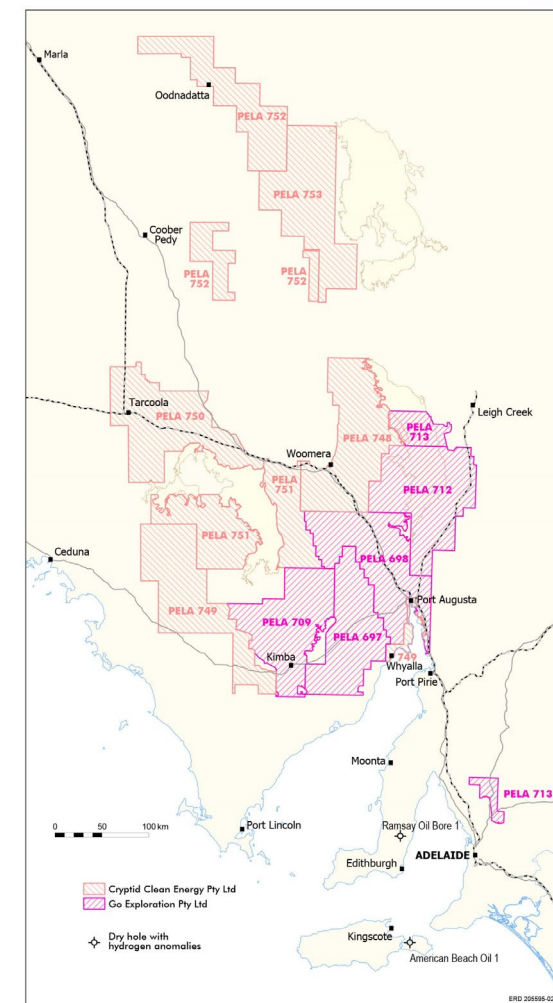
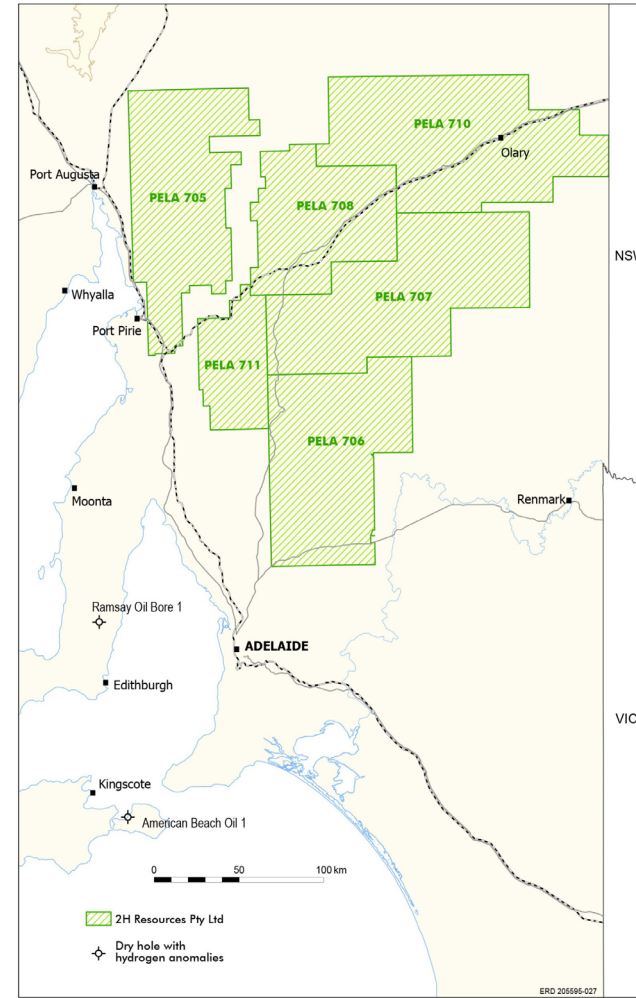
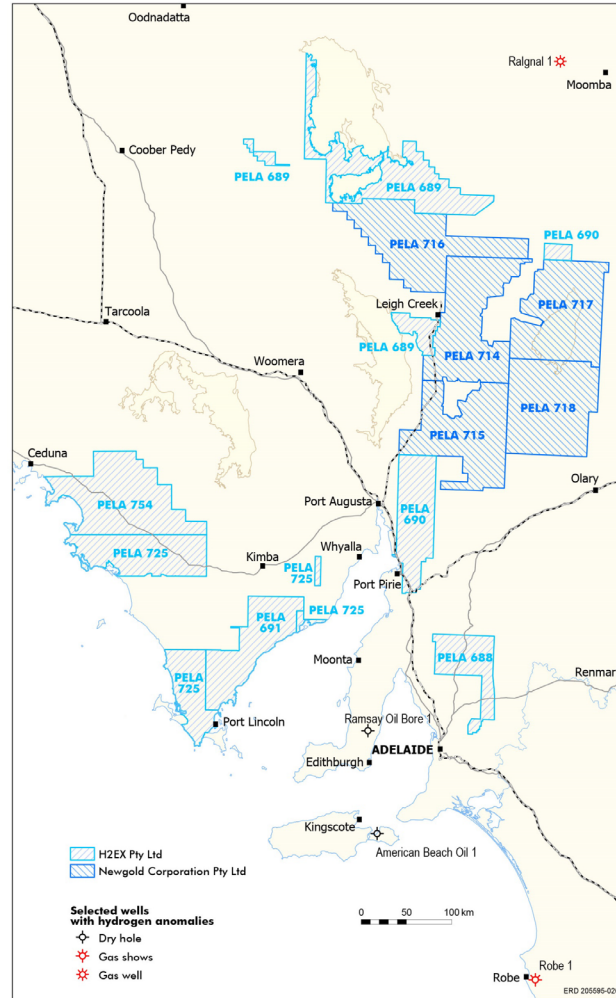
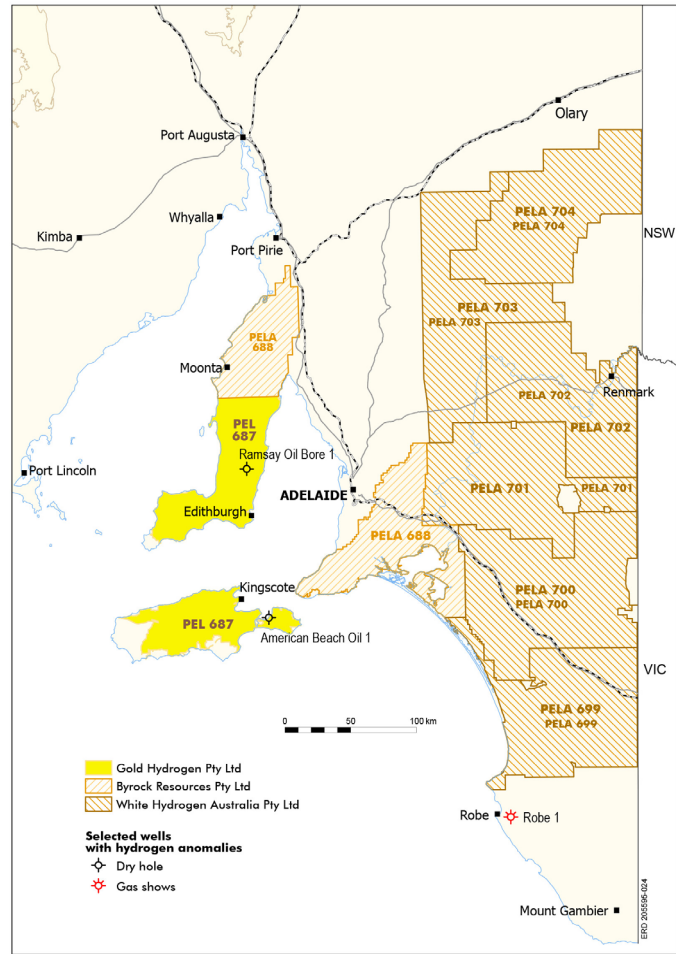


Enabling hydrogen exploration

- In February 2021 the definition of a ‘regulated substance’ under the *Petroleum and Geothermal Energy Regulations 2013* was expanded to include “hydrogen, hydrogen compounds and by-products from hydrogen production regulated substances under the *Petroleum and Geothermal Energy Act 2000*”.
- Companies can now apply to explore for natural hydrogen via a Petroleum Exploration Licence (PEL).
- Hydrogen, hydrogen compounds and by-products can now be transmitted via a Pipeline Licence.

PEL applications:

- Maximum 10,000 sqkm.
- Three 5 year licence terms.
- A valid application requires:
 - Fee paid (currently \$4,845)
 - Map,
 - 5 year work program to evaluate prospectivity (e.g. soil + sniffer surveys, seismic surveys, airborne geophysics, drilling),
 - evidence of technical & financial capacity to undertake work program - including rehabilitation.



<https://www.goldhydrogen.com.au/>

<https://au.linkedin.com/company/h2ex-pty-ltd>

<https://www.2hresources.com/site/content/>

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Conclusions

- It is early days for natural hydrogen exploration in Australia and globally.
- Geoscience Australia have concluded that Australia has enormous natural hydrogen potential.
- South Australia has the right rocks and evidence of natural hydrogen occurrences.
- South Australia is currently leading the nation with regulatory, licensing and investment frameworks enabling grant of Australia's first exploration licence targeting natural hydrogen last year.
- Upcoming company exploration activity in SA will test a diversity of natural hydrogen plays.
- More questions? See me at the SA Government stand during lunch.

