Hydrogen in Australian natural gas: occurrences, sources and resources

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Why use Natural Hydrogen?
Molecular hydrogen ($H_2$) is the most energy-rich gas. The global energy sector is transforming and $H_2$ will play an increasingly prominent role as a clean energy carrier. There are many sources of $H_2$:

- Green (water electrolysis) and blue (natural gas/coal reforming with carbon capture and storage) $H_2$ are produced using evolving industrial processes with relatively high costs;
- Natural (native, golden or white) $H_2$ is found in the subsurface and is timeless but an often unquantified potential resource. Where it is associated with natural gas it should be considered an important resource:
  - $H_2$ could be produced as a by-product of the LNG process similar to helium (Boreham et al. 2018); and
  - Where natural gas is $H_2$-rich (i.e. >10 mol% $H_2$), it may be suitable for direct injection into pipeline networks.

Exploration and production of natural $H_2$ can use well established drilling methodologies employed by the petroleum and mineral sectors.

Where is Natural Hydrogen found in Australia?

Historically, $H_2$-rich natural gas has been found in Palaeozoic basins and Precambrian terranes across the Australian continent (Figure 1a). Geoscience Australia has analysed the $H_2$ content of ~1000 natural gases from 470 wells drilled in both sedimentary and non-sedimentary basins with reservoir rocks ranging in age from the Neoproterozoic to Cenozoic.

The majority of natural $H_2$ concentrations are very low to low, with only a small proportion regarded as being $H_2$-rich (Figure 1b). However, most gases analysed are from Phanerozoic petrolierous sedimentary basins, which are not the ideal setting to find $H_2$-rich gas. Indeed, $H_2$-rich gas associated with a WA gold deposit have C/$(C_2+H_2)$ ratios from 23 to 67 (Figure 1c), typical of abioticogenic gas.

How much Natural Hydrogen is there in Australia?

The two most studied (and amenable to modelling) natural $H_2$ sources are:

- Radiolysis of water associated with the radioactive decay of U, Th and K-bearing minerals: $H_2O \rightarrow 2H_2 + O_2$; and
- Oxidation of ferrous to ferric iron coupled with mineral hydration (e.g. serpentinisation of olivine): $3(Fe^{2+}O_{rock}) + H_2O \rightarrow Fe_3O_4 + H_2$.

The radiogenic $H_2$ production rate (molecules $H_2$ kg$^{-1}$ yr$^{-1}$) was calculated for onshore Australia using zonal statistics for radiometric K, Th, U concentrations and rock density with the 1:1,000,000 scale surface geology map (Figure 2).

Together with rock porosity, a radiolytic $H_2$ production rate of 0.5 MM$m^3$ H$_2$ yr$^{-1}$ is calculated for onshore Australia to a depth of 1 km. Using global estimates of radiolytic versus hydration $H_2$ production rates in combination with onshore Australia’s proportion of global Precambrian cratons (Sherwood Lollar et al. 2014), onshore Australia’s total $H_2$ production rate is estimated to be between ~1.6 and ~58 MM$m^3$ yr$^{-1}$ (Boreham et al. 2021).

Where to explore for more Natural Hydrogen in Australia?

$H_2$ exploration should be focussed in both sedimentary and non-sedimentary basins (Figure 3) that include:

- Precambrian terranes (iron-rich) associated with deep-rooted basement faults and at the interface with sedimentary rocks;
- Sedimentary basins where salt forms seals, which can also be used for $H_2$ storage; and
- Mineralised zones and ore deposits.

A case study is presented on the historical $H_2$-rich gas with up to 89 mol% (air-free) $H_2$ found in the Minlaton Oil Bore (Figures 4a and b). In the vicinity, there are many clusters of surface depressions (Figure 4c) regarded as surrogates for $H_2$ seepage, where the $H_2$ source likely involves a hydration-iron redox reaction within granite (Figure 4d).

Conclusions
The wide range in natural $H_2$ sources necessitates diverse exploration strategies that must take into account migration pathways and trapping mechanisms. An obvious starting point for $H_2$ exploration is with the characterisation of $H_2$ surface seepage proxies using remote sensing techniques coupled with physical sample collection. Precambrian rocks are the obvious exploration choice given the large number of known $H_2$ discoveries globally, their prevalence across the Australian continent, and their composition and the extensive time available for serpentinisation and radiolysis processes.

References:
Moretti et al. (2021). Geoscience 11, 145. https://doi.org/10.1038/s41522-021-00417-0

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