Natural hydrogen: indications from onshore Western Australian sedimentary basins

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Introduction: Natural Hydrogen

- Numerous natural processes (chemical, biological, radiolytic, mechanical) can generate H₂ – questions centre around production rates, volumes, trapping and preservability in geological environments
- Ignitable H₂-bearing vents known since antiquity
- H₂-rich vents at mid-ocean ridges discovered in 1970s
- H₂ sometimes detected during hydrocarbon, water or mineral drilling (but detection equipment rarely onsite)
- Recent availability of hand-held detection equipment has led to reports of H₂ surface seeps world-wide
- Accidental discovery of a potentially economic H₂ field in Mali encourages active exploration for natural H₂
- Legislation permitting H₂ exploration/production enacted in SA & TAS; amendments to Act in progress in WA

**H₂ from electrolysis**
- Renewable energy source
- Mixed energy source
- Nuclear energy source

**H₂ from fossil fuels**
- Coal/hydrocarbons with CO₂ captured/stored
- Methane pyrolysis with solid carbon by-product
- Steam reformation of natural gas (no CO₂ capture)
- Gasification of brown / black coal (no CO₂ capture)

**Natural “geological” H₂**
- From underground sources
Mechanisms of generation

- Abiotic/inorganic chemical reactions – e.g. rock-water interactions involving oxidation of iron (ferrous to ferric iron), including serpentinization and other oxidation of mafic rocks and BIF
- Radiolysis of water
- Over maturation of organic matter including hydrocarbons
- Biogenic processes
- Mechano-radical processes associated with active faulting
- Volcanic degassing
- Primordial hydrogen

Accumulation

- Generation greatest in crystalline rocks at depth and moderately high temperatures
- Reservoirs most likely in overlying sedimentary basins
- \( \text{H}_2 \) difficult to trap – temporary trapping (baffling) in porous reservoirs in active migration pathways might be economic (e.g. Mali field); fossil accumulations possible if very good seal (e.g. Mt Kitty 1 in NT - ancient salt seal)
Indications of Hydrogen in WA basins

- Boreham et al. (2021 APPEA Journal) report H₂ in archived natural gas samples from WA
- Up to 5% H₂ from shallow drilling (6 m) near Gingin gas field (Gole & Butt 1985 AAPG Bull)
- Unquantified reports of “high hydrogen” from water bores in the south Perth Basin
- Surface H₂ seeps (‘fairy circles’) reported in north Perth Basin (Frery et al., 2021 Internat. J Hydrogen Energy; Frery et al., 2022 APPEA Journal)
- Unpublished GSWA data provides similar evidence for H₂ seeps in the northern Canning and south Perth basins; potential seep in the south Perth Basin showed a weak periodic H₂ flux when autonomously monitored for several weeks
- GSWA search of openfile petroleum well data (mostly well completion reports) indicated 38 wells in state jurisdiction (excluding Barrow Island) for which H₂ was detected during drilling or from lab analysis of gas samples
Stokes Bay 1
2.23% H₂ in gas sample
(Borsham et al., 2021)

Booran 1
Up to 0.068% H₂ in mud gas (WCR)

Meda 1
Up to 95.3% H₂ in DST9 (WCR)

Meda 2
Up to 1.8% H₂ in DST4 (WCR)

Yulleroo 1
Up to 0.4% H₂ in DST (WCR)

Currajong 1
Up to 6% H₂ in mud gas (ASX)

Raphael 1
Up to 4.9% H₂ in mud gas (ASX)

Notabilis 1
Up to 0.8% H₂ in mud gas (WCR)

Cyrene 1
Up to 4.87% H₂ in isotope mudgas samples (WCR)

Hedonia 1
Up to 0.03% H₂ in cuttings gas (WCR)

Matches Spring 1
H₂ in mud gas, unquantified (WCR)

Pictor 1
Trace H₂ in mud gas (WCR)

Musca 1
H₂ in ‘aerated mud’, unquantified (WCR)

Nicolay 1
22.8% H₂ in mud gas sample, major air contamination (WCR)

Hydrogen concentration
- >50%
- 10 – 50%
- 1.0 – <10%
- 0.1 – <1.0%
- <0.1%
- unquantified

WCR = well completion report

Meda 1: 1958

Meda 1: Sept 2021
**Pudovskis 1959 Meda 1 well completion report**

**Crostella 1998 GSWA Report 56**

- **DST 9:** H₂ 95.3%
- **DST 2:** initial flow 100,000 CFD, 0.9% H₂
- **GSWA unpub:** >100 ppm soil H₂

**McKay 1987 BMR Record 1987/22**

Meda gas reported to average 0.5% He presumably based on archived gas samples at BMR (which were heavily air contaminated).
Meda 1 Fluid Inclusion Stratigraphy (FIS)

DST 9: Up to 95.3% H₂
DST 3: Up to 0.7% H₂
DST 7C: 2.9% H₂
DST 2: initially 100 MCF/D; up to 0.9% H₂
DST 4C: 1.4% H₂
DST 6C: up to 1.0% H₂

H₂  |  He  |  CH₄  |  C₂H₆  |
--- | --- | --- | --- |
AMU2 = H₂ | AMU4 = mostly methane | AMU4 = mostly methane | AMU4 = mostly methane |
DST with H₂ | 1000000 | 2000 | 2000000 | 100000 |

Depth (m)  | 1500 | 1800 | 1900 | 2000 |
Stratigraphy  | Fairfield Group | Devonian reef complex | basement | 1800 |

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Whicher Range 5 well completion report 2004

**Whicher Range 3 DST 2 pre-acidization**
- 4039 m
- Gas flow 10,000 SCFD
- $\text{H}_2$: 0.5%
- $\text{CH}_4$: 61.15%
- Higher HC: 6.19%
- $\text{CO}_2$: 0.19%
- $\text{N}_2$: 31.55%
- Drilled 1982
- Tested formation consisted of sandstone, siltstone and coal beds
- Acidization to remove CaCO₃ mudcake (drilling mud additive)
- High $\text{H}_2$ in DST 3 blamed on acid-metal reaction
- Low $\text{CO}_2$ implies acid spent at time of testing
- High $\text{N}_2$ in DST 2 due to added $\text{N}_2$ cushion gas

**Whicher Range 3 DST 3 post-acidization (12% HCl + corrosion inhibitor)**
- 4039 m
- Gas flow 5000 SCFD
- $\text{H}_2$: 22%
- $\text{CH}_4$: 69.8%
- Higher HC: 6.73%
- $\text{CO}_2$: 0.12%
- $\text{N}_2$: 1.35%
- Drilled 1982
- Tested formation consisted of sandstone, siltstone and coal beds
- Acidization to remove CaCO₃ mudcake (drilling mud additive)
- High $\text{H}_2$ in DST 3 blamed on acid-metal reaction
- Low $\text{CO}_2$ implies acid spent at time of testing
- High $\text{N}_2$ in DST 2 due to added $\text{N}_2$ cushion gas
• H₂ ‘prospecting’ in shallow auger holes (~1 m) with hand held Geotech GA5000 gas monitor indicates transient local anomalies up to ~500 ppm in Meda area (Canning Basin) and ~1000 ppm in south Perth Basin (H₂ in atmosphere ~0.5 ppm)
• Source of H₂ in specific cases (shallow or deep; natural or artefact) remains unresolved
• An anomalous area in the south Perth Basin, originally identified via GA5000, was investigated over an extended period (weeks) with a more sensitive autonomous instrument (WHALI, Axiom Sensing) that continuously records multi gas (H₂, CO₂, H₂S and CH₄) and meteorological parameters; indication of small diurnal flux
Conclusion

- Hydrogen is expected to play a significant role in a future nett zero carbon emission energy world
- Natural hydrogen from geological sources is emerging a potential component of the hydrogen mix
- WA contains good potential hydrogen source rocks (Fe-rich, mafic, ultramafic rocks) in older domains, but overlying basins have the greatest chance of providing economic reservoirs
- Hydrogen in WA basins is indicated by surface seeps, and historic detections in petroleum, water bore and other shallow drilling
- GSWA’s search of onshore petroleum well files has revealed 38 reports of hydrogen from trace amounts to significant concentrations
- Our investigations of the hydrogen-bearing Meda wells in the northern Canning Basin show potential correlation with a basement-tapping fault, and a Proterozoic metamorphic basement possibly conducive to the production of hydrogen
- Reconnaissance soil measurements suggest the area around the Meda wells may be locally anomalous in hydrogen
- Studies aimed at investigating surface hydrogen anomalies in the south Perth Basin by long term autonomous monitoring suggest a small diurnal flux is present