
GEOLOGICAL SURVEY
WESTERN AUSTRALIA
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Natural hydrogen: indications from onshore Western Australian sedimentary basins

Peter Haines, Basin Custodian

Co-authors: Leon Normore, Norman Alavi, Charmaine Thomas

Introduction: Natural Hydrogen

GREEN	H_2 from electrolysis with renewable energy source
YELLOW	H_2 from electrolysis with mixed energy source
PURPLE / PINK	H_2 from electrolysis with nuclear energy source
BLUE	H_2 from coal/hydrocarbons with CO_2 captured/stored
TURQUOISE	H_2 from methane pyrolysis with solid carbon by-product
GREY	H_2 from steam reformation of natural gas (no CO_2 capture)
BROWN / BLACK	H_2 from gasification of brown / black coal (no CO_2 capture)
WHITE / GOLD	**Natural "geological" H_2 from underground sources**

- Numerous natural processes (chemical, biological, radiolytic, mechanical) can generate H_2 – questions centre around production rates, volumes, trapping and preservability in geological environments
- Ignitable H_2-bearing vents known since antiquity
- H_2-rich vents at mid-ocean ridges discovered in 1970s
- H_2 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 H_2 surface seeps world-wide
- Accidental discovery of a potentially economic H_2 field in Mali encourages active exploration for natural H_2
- Legislation permitting H_2 exploration/production enacted in SA & TAS; amendments to Act in progress in WA

Mechanisms of generation and accumulation

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

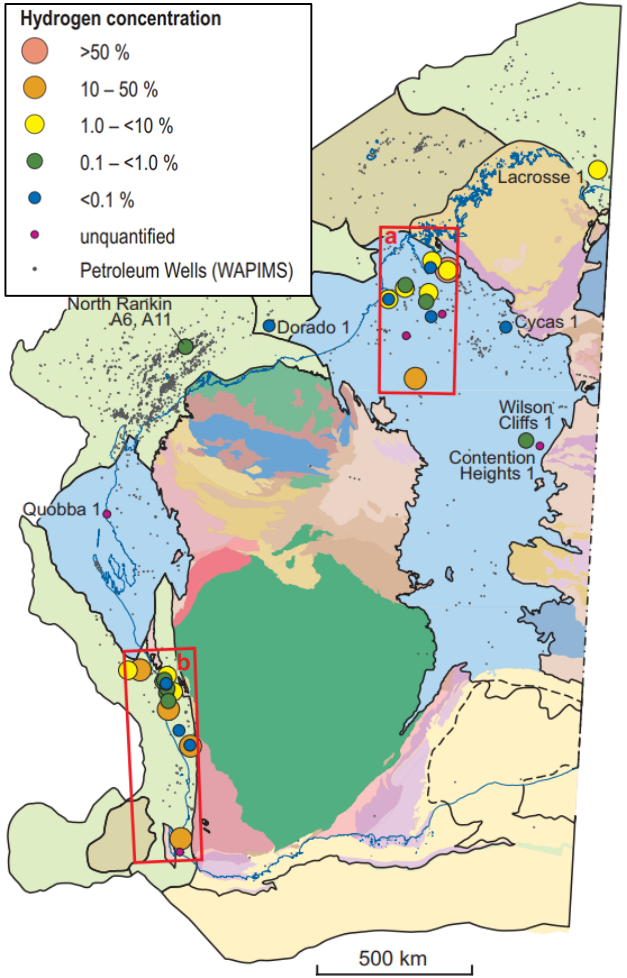
- Radiolysis of water
- Over maturation of organic mater including hydrocarbons
- Biogenic processes
- Mechano-radical processes associated with active faulting
- Volcanic degassing
- Primordial hydrogen

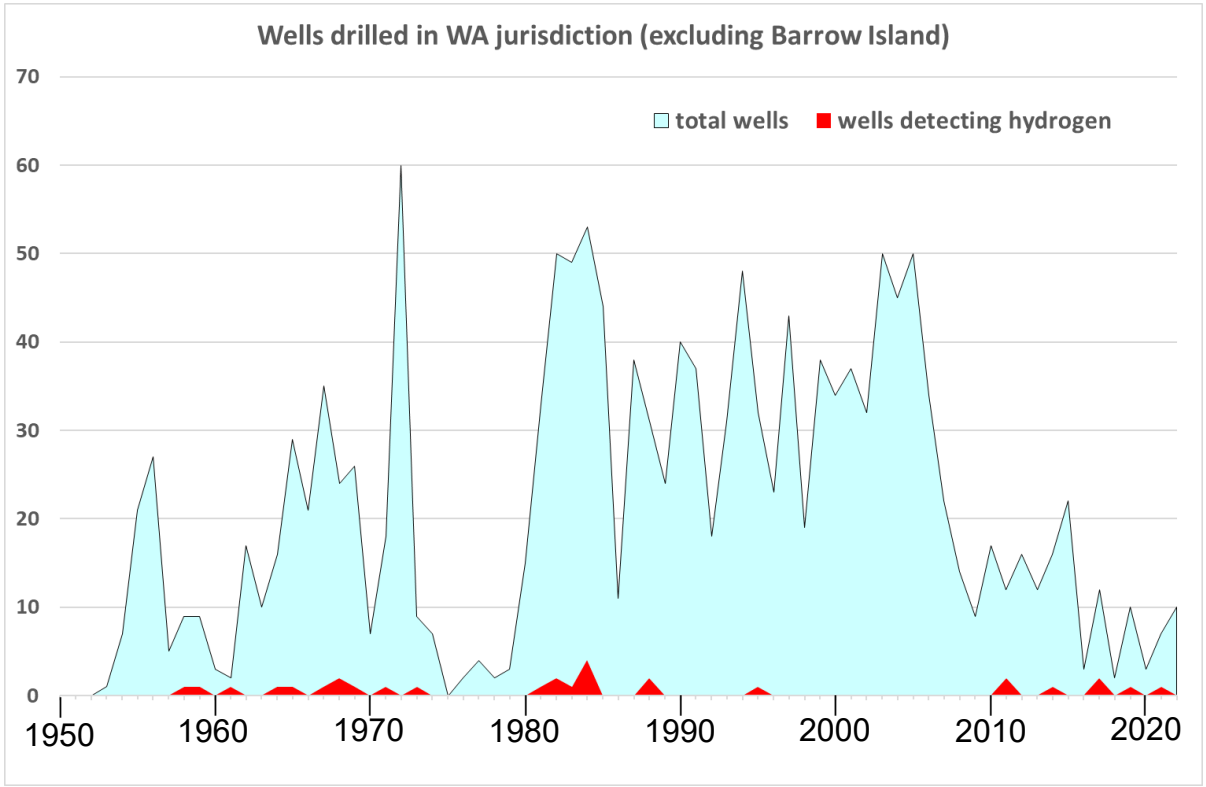
Accumulation

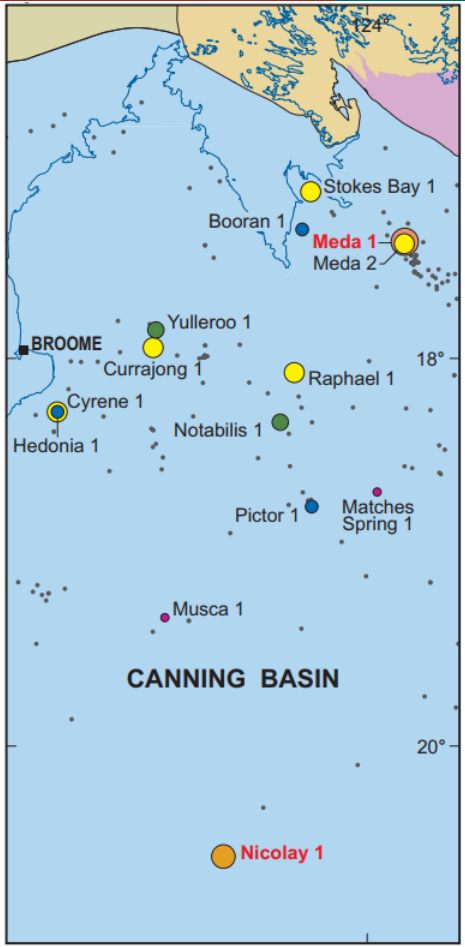
- Generation greatest in crystalline rocks at depth and moderately high temperatures
- Reservoirs most likely in overlying sedimentary basins
- H_2 difficult to trap – temporary trapping (baffling) in porous reservoirs in active migration pathways might be economic (e.g. Mali field); fossil accumulations 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 H_2 in archived natural gas samples from WA
- Up to 5% H_2 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 H_2 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 H_2 seeps in the northern Canning and south Perth basins; potential seep in the south Perth Basin showed a weak periodic H_2 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 H_2 was detected during drilling or from lab analysis of gas samples


Hydrogen concentration
>50 %
10 – 50 %
1.0 – <10 %
0.1 – <1.0 %
<0.1 %
unquantified
Petroleum Wells (WAPIMS)
Lacrosse 1
a
North Rankin A6, A11
Dorado 1
Cycas 1
Wilson Cliffs 1
Contention Heights 1
Quobba 1
b
500 km


Wells drilled in WA jurisdiction (excluding Barrow Island)
total wells
wells detecting hydrogen
70
60
50
40
30
20
10
0
1950
1960
1970
1980
1990
2000
2010
2020



Stokes Bay 1
2.23% H_2 in gas sample (Boreham et al., 2021)

Booran 1
Up to 0.068% H_2 in mud gas (WCR)

Meda 1
Up to 95.3% H_2 in DST9 (WCR)

Meda 2
Up to 1.8% H_2 in DST4 (WCR)

Yulleroo 1
Up to 0.4% H_2 in DST (WCR)

Currajong 1
Up to 6% H_2 in mud gas (ASX)

Raphael 1
Up to 4.9% H_2 in mud gas (ASX)

Notabilis 1
Up to 0.8% H_2 in mud gas (WCR)

Cyrene 1
Up to 4.87% H_2 in isotube mudgas samples (WCR)

Hedonia 1
Up to 0.03% H_2 in cuttings gas (WCR)

Matches Spring 1
H_2 in mud gas, unquantified (WCR)

Pictor 1
'Trace' H_2 in mud gas (WCR)

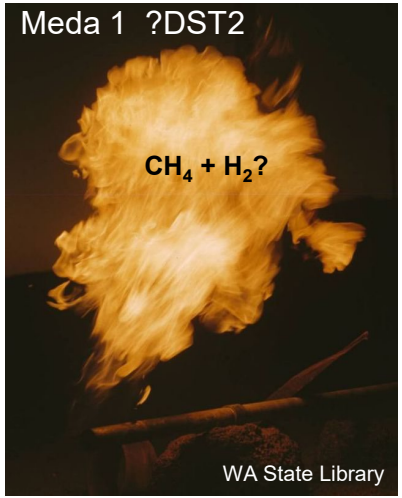
Musca 1
H_2 in 'aerated mud', unquantified (WCR)

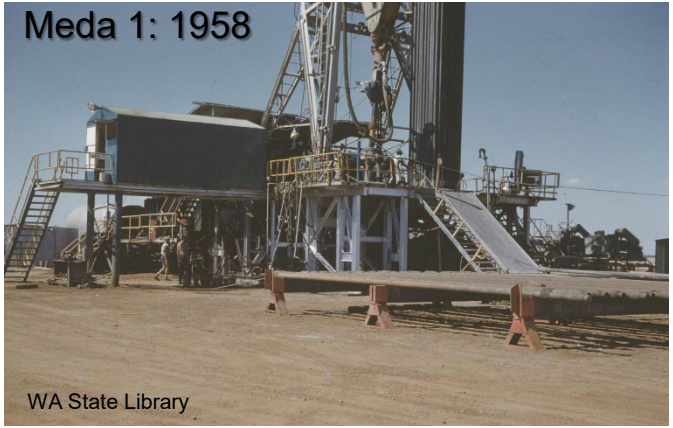
Nicolay 1
22.8% H_2 in mud gas sample, major air contamination (WCR)

Hydrogen concentration

- >50 %
- 10 – 50 %
- 1.0 – <10 %
- 0.1 – <1.0 %
- <0.1 %
- unquantified
- Petroleum Wells (WAPIMS)

WCR = well completion report





Pudovskis 1959 Meda 1 well completion report

Basin: FITZROY Field or Structure: MEDA State: WESTERN AUSTRALIA

Company : West Australian Petroleum Pty Ltd.
Well Name : Meda No. 1
Well Location: 17° 24' 00" S 124° 11' 30" E
Interval Tested (Feet): 7594-7669 6594-6695 5110-
Formation - Age & Name: Dev. Fairfield (Reef Complex) ditto DST 7C L. Carb.-Laurel DST 9 ditto
Type of Test : DST 6C GCW
Flow Rate - Gas (MMCF/D)
- Liquid (BBLS/D)
Date of Sampling 29-10-59 14-11-58
Date of Analysis : 19- 2-59 19-11-58
Analysis by, and Method: BMR GC BMR GC W.A.G.L. GC BMR GC

DST 9

COMPONENT (MOLE %)

Methane	75.2	56.7	0.5	0.4	0.4
Ethane	0.9	1.2			0.03
Propane	0.14	0.37			0.005
Isobutane	0.02	0.12			
N-Butane	0.02	0.09			
Isopentane					
N-Pentane					
2-Methyl Butane					
2-Methyl Pentane					
3-Methyl Pentane					
Hexane					
Heptanes+					
Nitrogen	19.4	21.2			61.1
Oxygen	3.1	11.2	0.5	0.5	18.8
Argon					
Hydrogen		2.9	95.3	91.2	19.3
Helium					
Carbon Monoxide					
Carbon Dioxide	1.5	6.5	3.7	3.6	0.5
Hydrogen Sulphide					

DST 9: H_2 95.3%

Air contamination

Table 2 HELIUM CONCENTRATIONS IN AUSTRALIAN NATURAL GAS

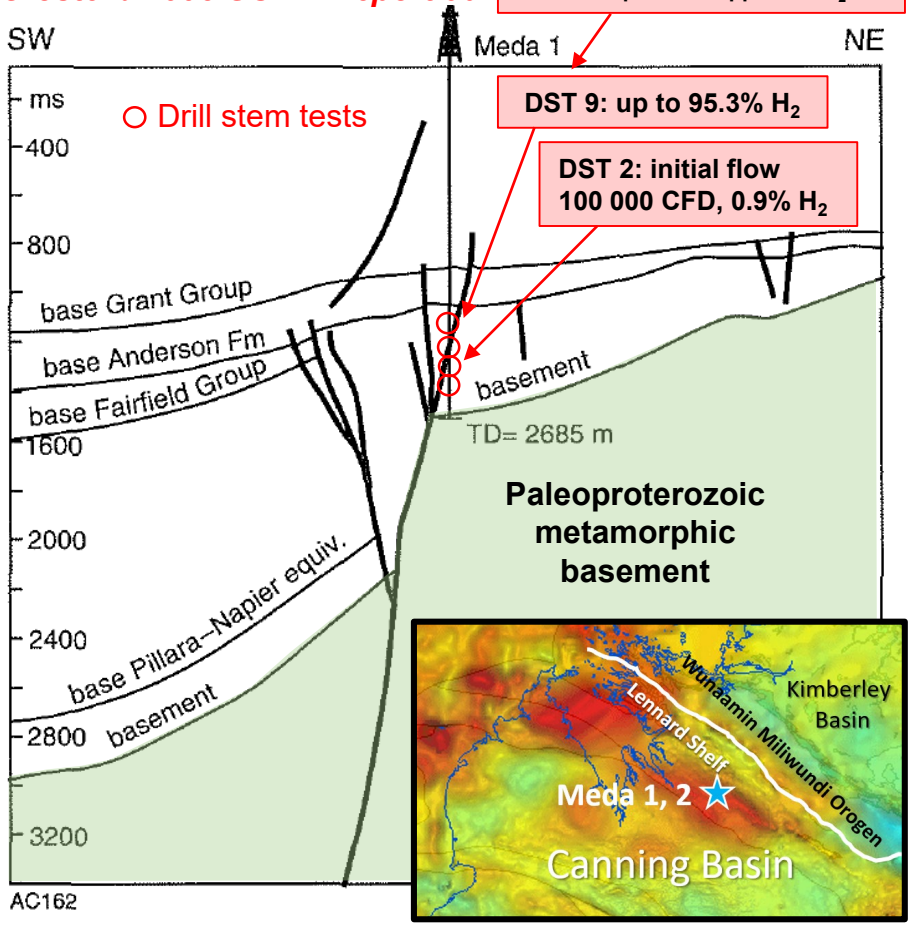
BASIN	DEPOSIT	AGE OF RESERVOIR	OPERATOR	AV. He CONC.(%)
AMADEUS	MEREENIE	ORDOVICIAN	TMOC RESOURCES	0.21
	PALM VALLEY	ORDOVICIAN	MAGELLAN	0.21
CANNING	MEDA	CARBONIF.	WAPET	0.50
CARNARVON	NTH. RANKIN	CRETACEOUS	WOODSIDE	0.013
COOPER	BURKE	PERMIAN	SANTOS	0.03
	FLY LAKE	PERMIAN	SANTOS	0.035
	MOOMBA	PERMIAN	SANTOS	Trace
	TOOLACHEE	PERMIAN	SANTOS	0.025
GIPPSLAND	BARRACOUTA	EOCENE	ESSO	Trace
	MARLIN	EOCENE	ESSO	Trace
GUNNEDAH	WILGA PARK	PERMIAN	HARTOGEN	0.45
PERTH	WOODADA/ INDOON	PERMIAN	STRATA	0.21

McKay 1987 BMR Record 1987/22

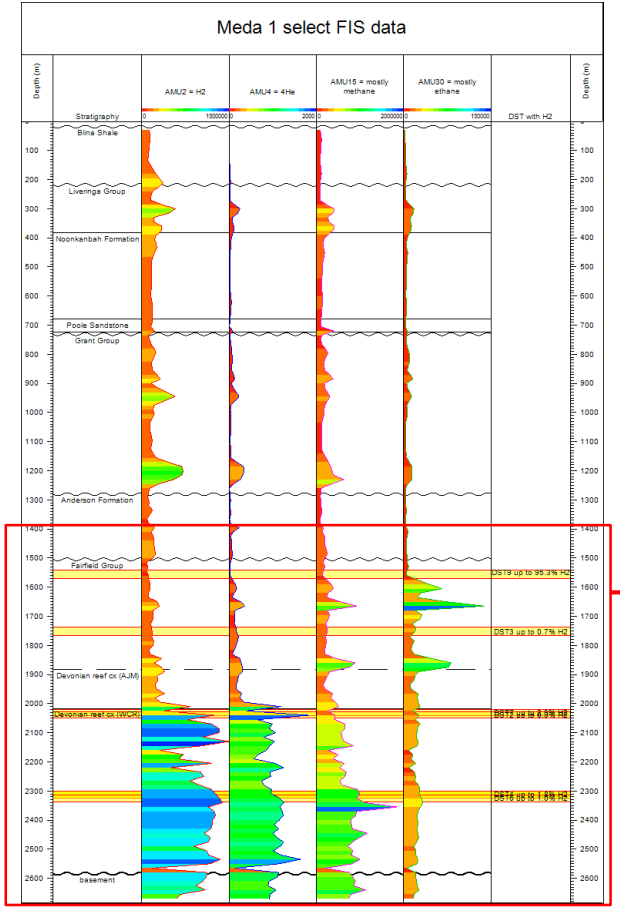
Meda gas reported to average **0.5% He** presumably based on archived gas samples at BMR (which were heavily air contaminated)

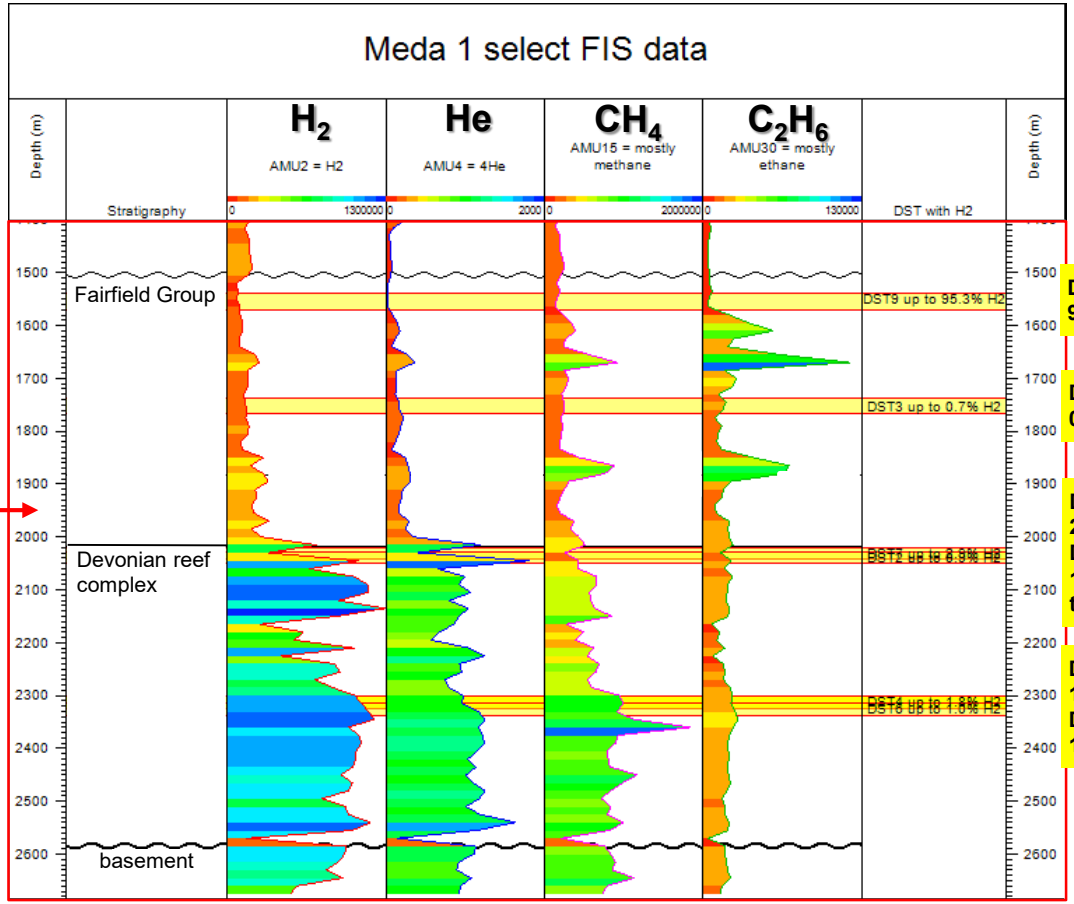
Crostella 1998 GSWA Report 56

GSWA unpub: >100 ppm soil H_2



Meda 1 Fluid Inclusion Stratigraphy (FIS)



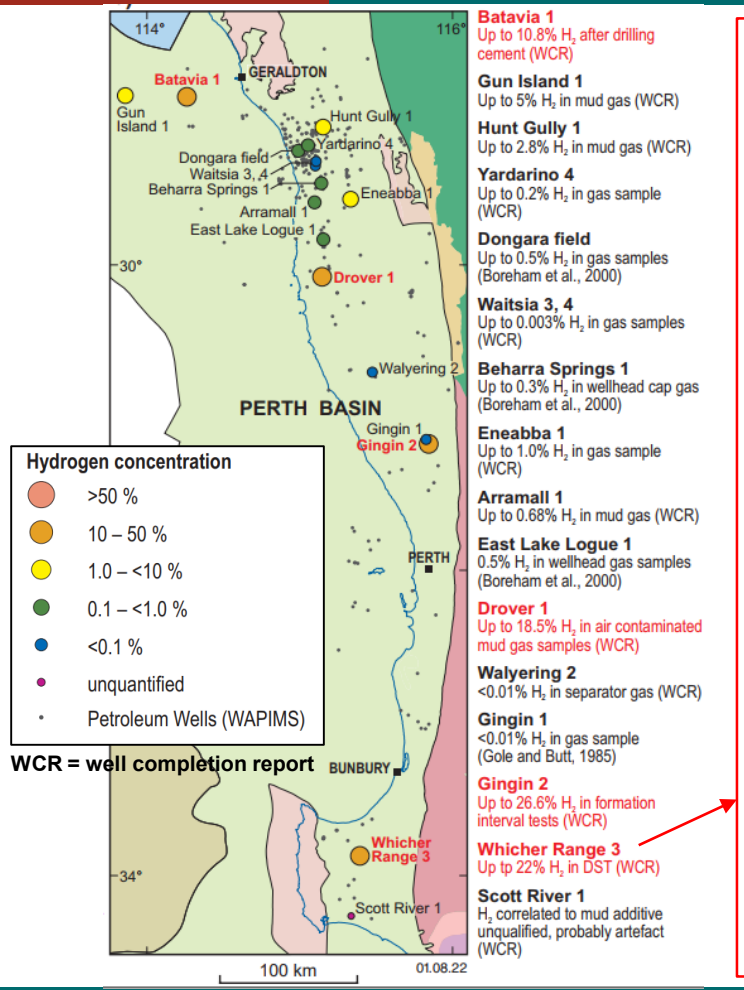


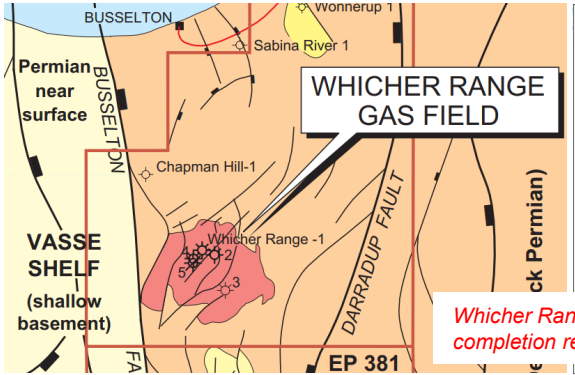
DST 9: Up to 95.3% H_2

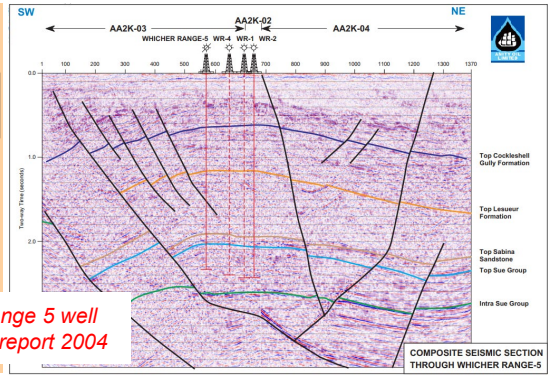
DST 3: Up to 0.7% H_2

DST 7C: 2.9% H_2
DST 2: initially 100 MCF/D; up to 0.9% H_2

DST 4C: 1.4% H_2
DST 6C: up to 1.0% H_2







Whicher Range 5 well completion report 2004

Whicher Range 3
DST 2 pre-acidization

4039 m

Gas flow 10 000 SCFD
H_2: 0.5%
CH_4: 61.15%
Higher HC: 6.19%
CO_2: 0.19%
N_2: 31.55%

4360 m

Whicher Range 3
DST 3 post-acidization (12% HCl + corrosion inhibitor)

4039 m

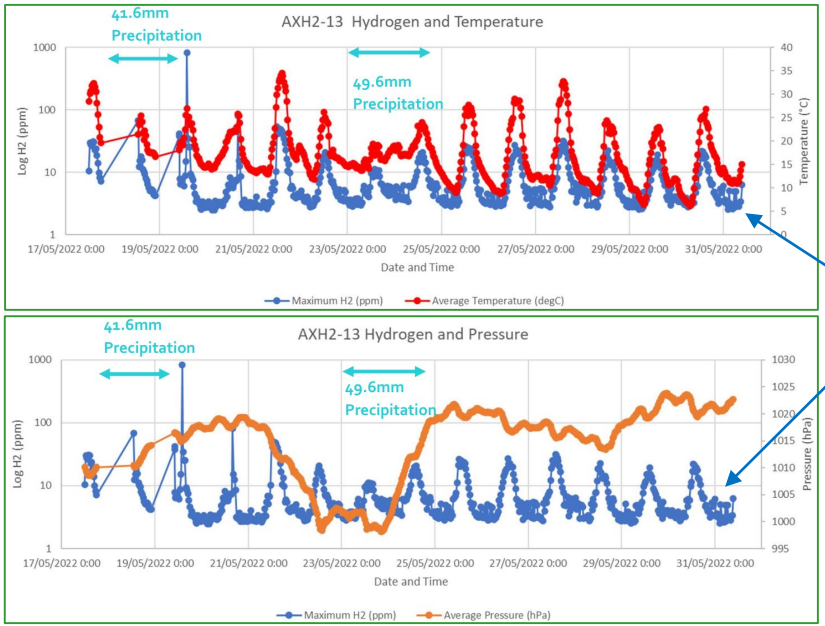
Gas flow 5000 SCFD
H_2: 22%
CH_4: 69.8%
Higher HC: 6.73%
CO_2: 0.12%
N_2: 1.35%

4275 m

- Drilled 1982
- Tested formation consisted of sandstone, siltstone and coal beds
- Acidization to remove $CaCO_3$ mudcake (drilling mud additive)
- High H_2 in DST 3 blamed on acid-metal reaction
- Low CO_2 implies acid spent at time of testing
- High N_2 in DST 2 due to added N_2 cushion gas

GSWA work in progress

- H_2 '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 (H_2 in atmosphere ~0.5 ppm)
- Source of H_2 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 (H_2, CO_2, H_2S and CH_4) 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