Unconven'onal gas

Chamber of Commerce – Alice Springs

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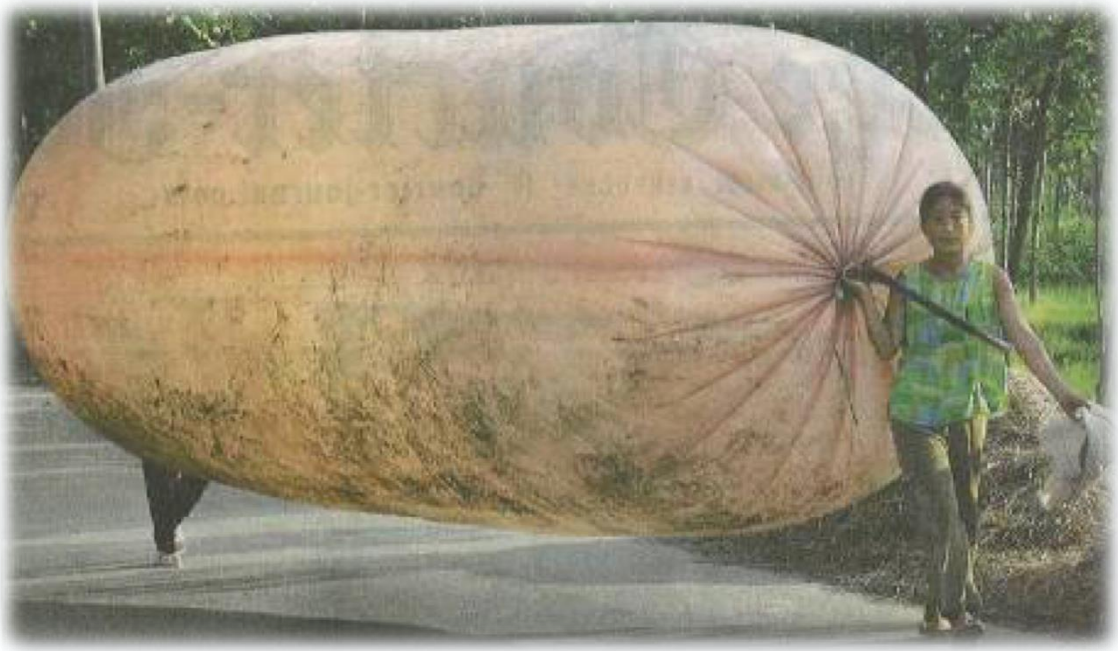
ENERGY BUSINESS UNIT
www.csiro.au

GISERA
Gas Industry Social and Environmental Research Alliance

Australian Government
Department of Industry, Innovation and Science

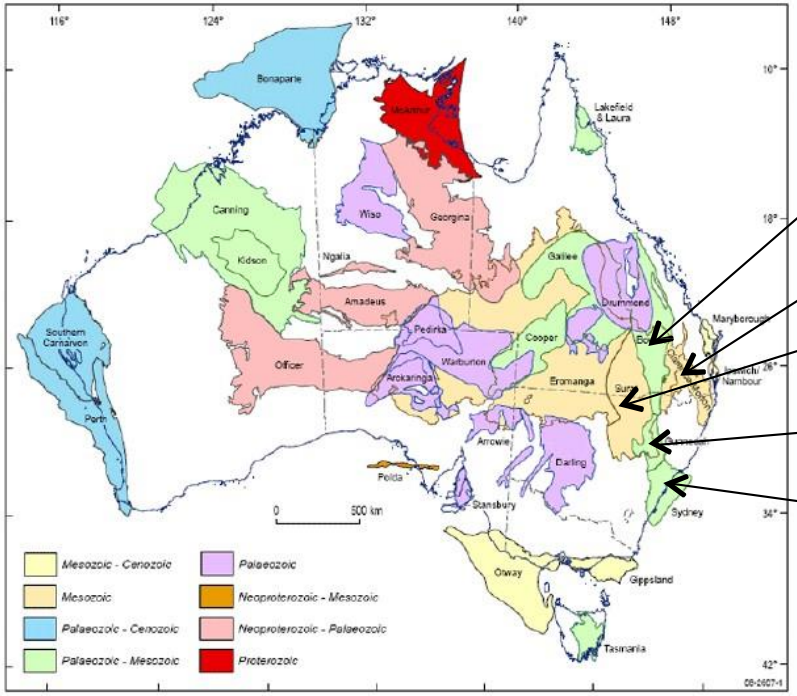
Energy demand outside Australia



- 502,960 PJ
- 17,360 PJ
- 5,772 PJ
- Gas 21% Aust. energy needs
- Largest gas exporter
- (Largest coal exporter)
- ~50% < GHGs

Photo: Associated Press

Proven and probable reserves of CSG



Bowen 27%

Clarence-Moreton 2%

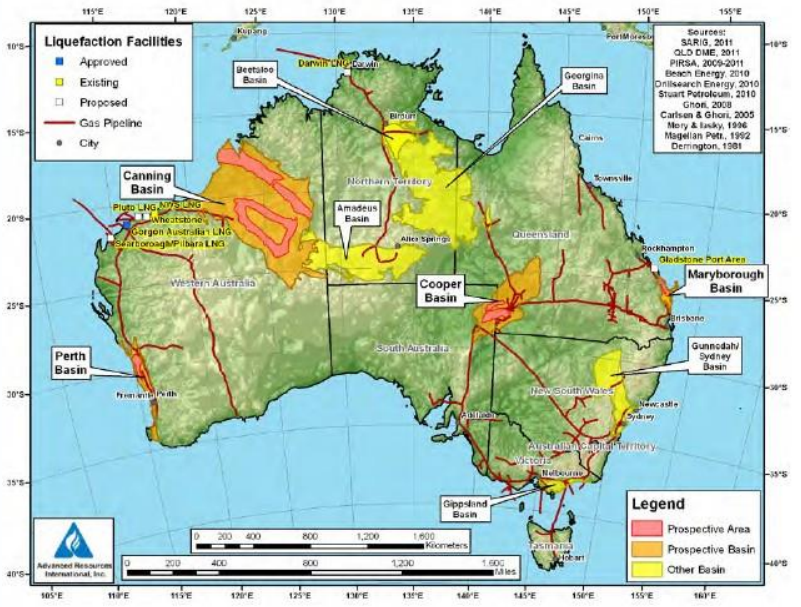
Surat 61%

Gunnedah 7%

Sydney & Gloucester 3%

330,000 PJ 2P Reserves (10x)

Shale gas reserves

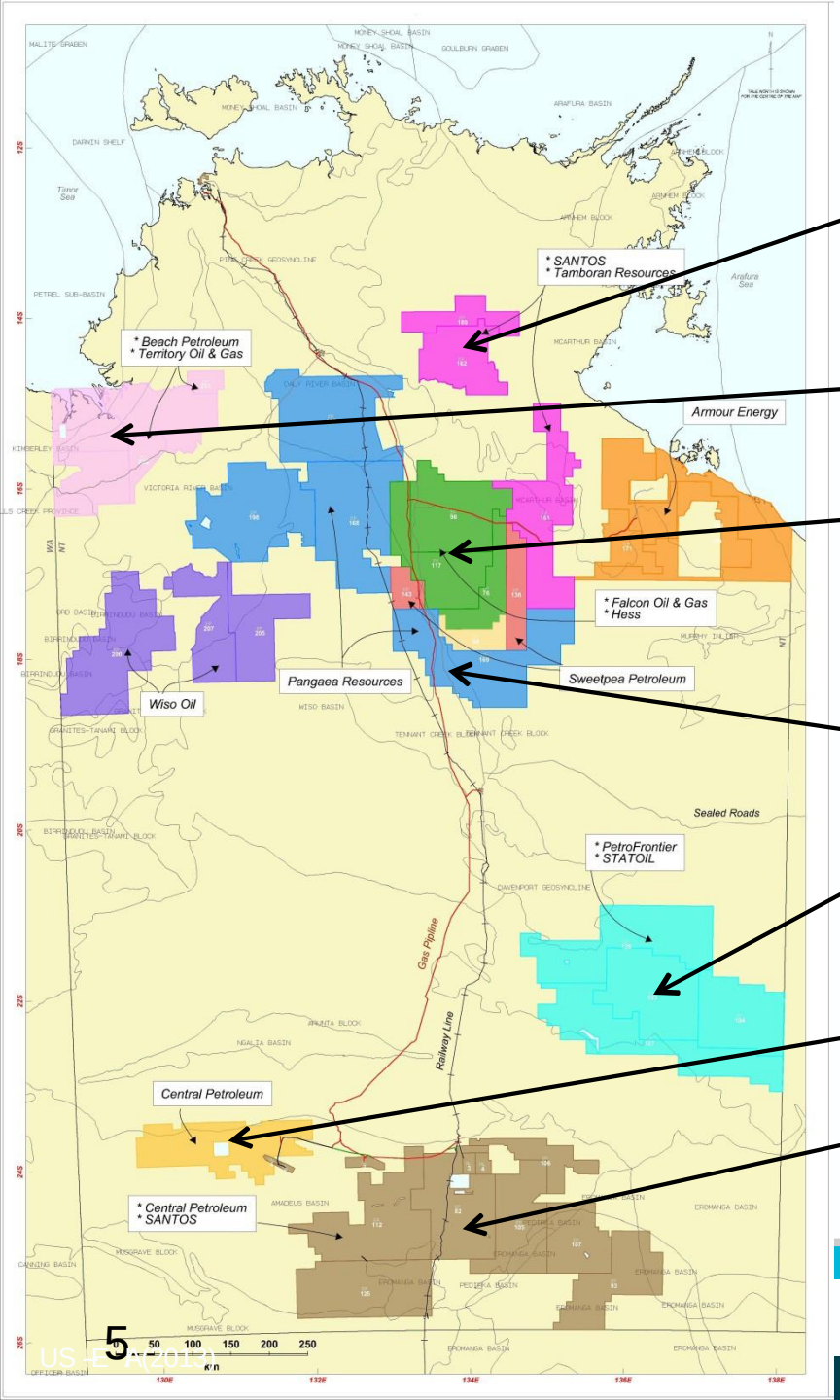


"Australia is poised to commercialise its shale gas resources on a large scale"

Technically recoverable shale resources are at least 1.5 Nmes larger than possible CSG reserves (461,000 PJ)

Shale gas sufficient to meet Australia's rising electricity needs for ca 80 years

Canning Basin (58%) holds the largest reserves



Northern Territory

McArthur Basin

- Armour Energy: 3 gas wells in 2012
- Tamboran / Santos: EP 161 seismic 3Q 2013

Bonaparte Basin

- Territory Oil & Gas/ Beach: 2 wells in 2014

Greater Beetaloo Basin

- Falcon: 3,500 km 2D seismic in 2011 & 2012.
- Pangaea: Airborne survey completed and seismic underway. Planning 3 wells in 2Q 2014.

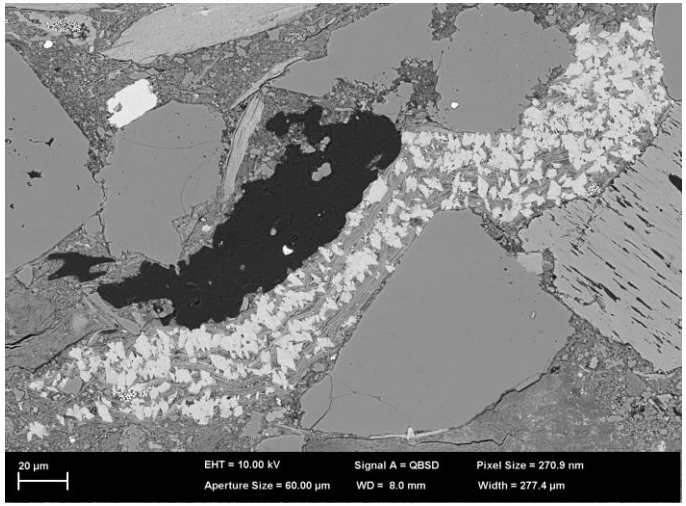
Georgina Basin

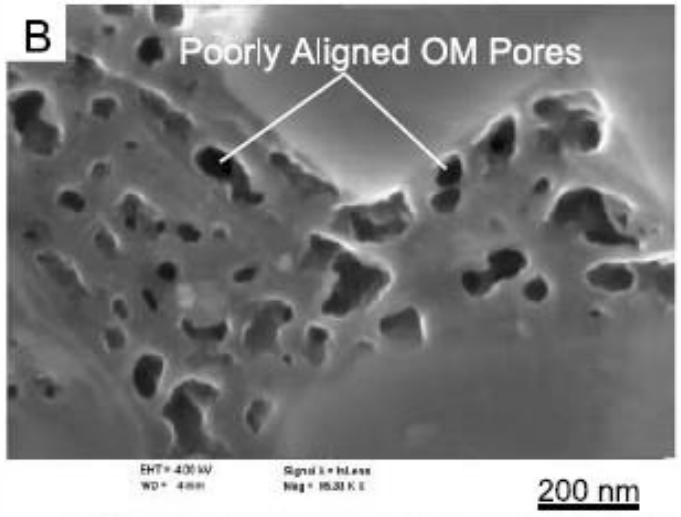
- PetrofronNer: 3 horizontal wells drilled and fractured in 2012. 310km seismic in 2013
- Statoil: 4 – 6 verNcal wells planned for 2014
- Central Petroleum/Total: 985km seismic underway

Amadeus Basin

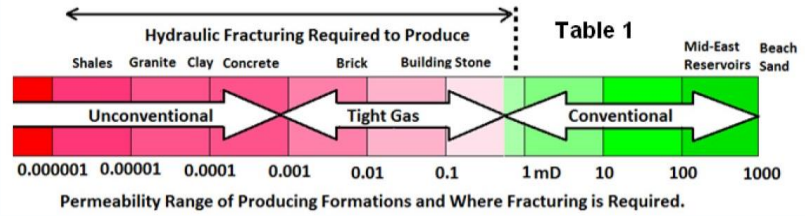
- Central Petroleum: Surprise-1 oil discovery in 2012, 1 well in 2014
- Santos $100m drilling & faciliNes upgrade on Mereenie

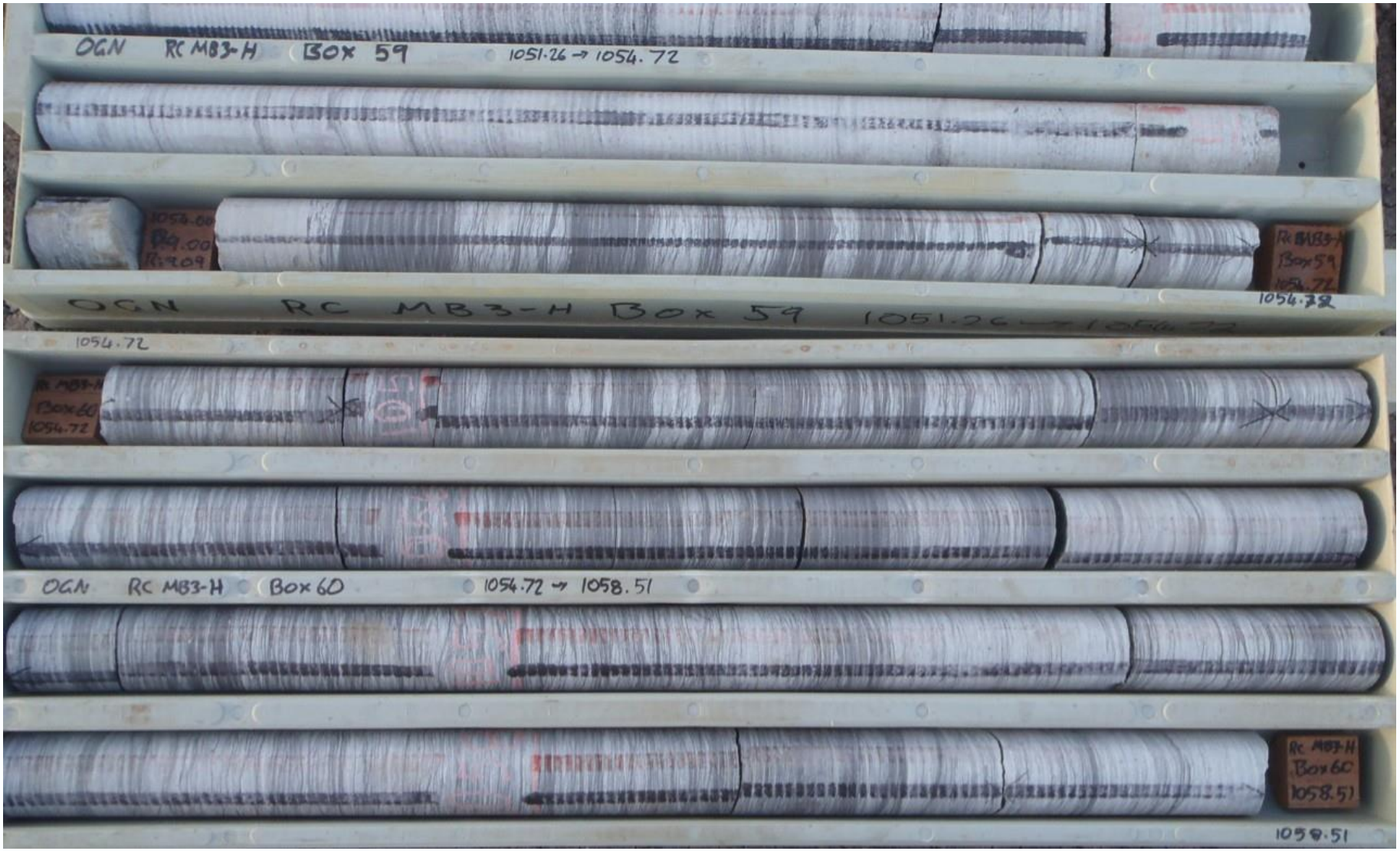
Shale: Extremely low porosity





- Gas is stored in nanopores and adsorbed onto organic matter
- Shale porosity (mD) < 10^{-6} sand
- High pressures within formation (>1.5 km depth) drive gas through fractures to well
- Fracture fluid is designed for specific rock conditions within a basin
- Test production wells aimed at understanding how to place wells within formations and hydraulically fracture rock to maximise gas recovery during production phase

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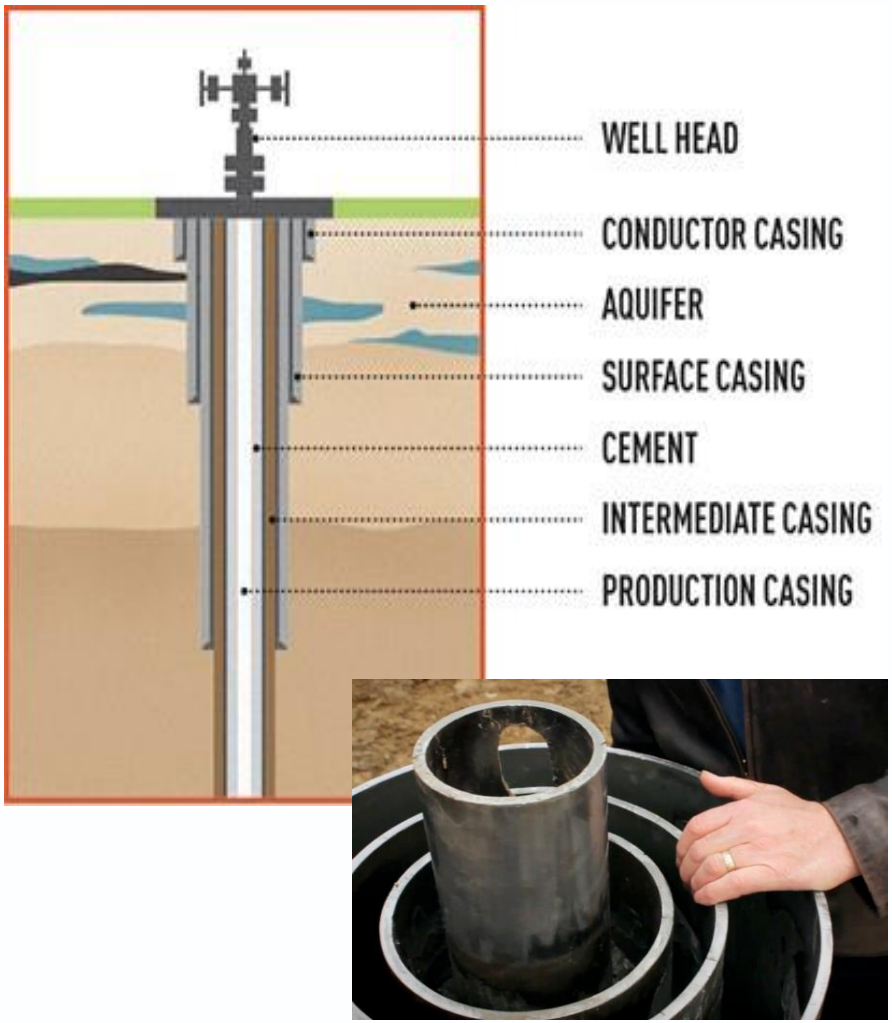
Well construc'on



- Three layers of ‘cement’ and steel casing separate a well from aquifers
- Specially formulated cement mixture.
- Cement lab tested prior to pumping.
- Casing is pressure tested above operaNng pressures to ensure integrity
- Wellbore design, construcNon and operaNons heavily regulated
- Well compleNon must be tested and reported in drilling reports to govt

NT Regula'ons: Well Construc'on

- Only water (or air) based drilling fluids
- Oil based muds banned
- All casing strings cemented to surface
- CBL: Valid placement/integrity of barriers
- Casing to isolate aquifers
- Baseline water monitoring and testing when hydraulic fracturing undertaken
- Demonstrated separation between aquifers and hydraulic fractures

CBL = Cement Bond Log

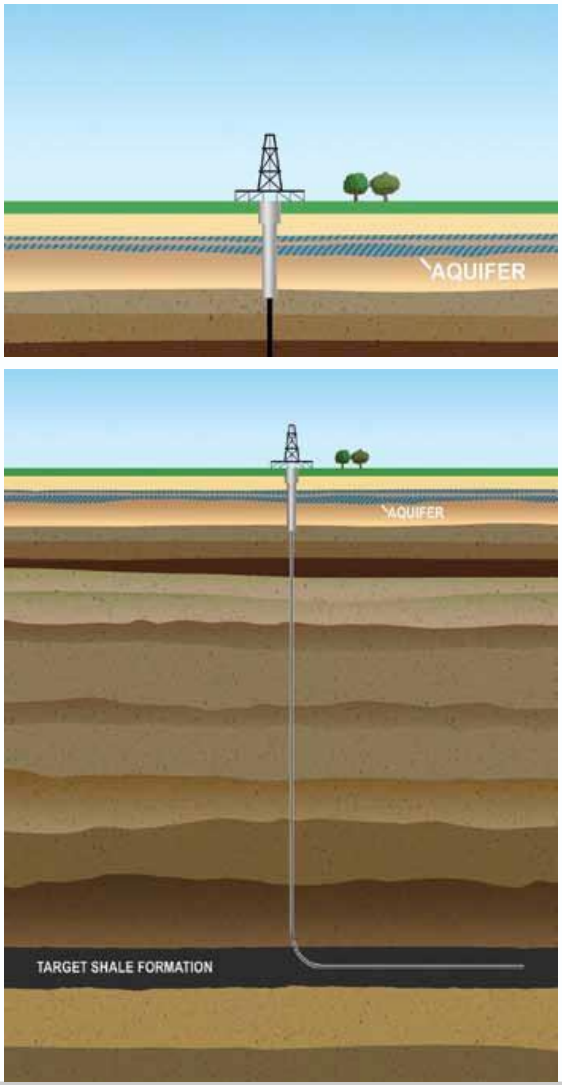
NT Regula'ons: Well ‘Abandonment’

- Cement plugs isolate aquifers from depleted hydrocarbon shale seams
- Geophysical measurements and pressure testing to verify placement and integrity of plugs
- Well head cut off below ground level
- Well head capped with cement and back-filled
- Well pad, lease and access roads rehabilitated
- Top soil returned and site rehabilitated to former condition
- DME approval after compliance with regulations

CBL = Cement Bond Log

BTEX = Benzene, Toluene, Ethyl-benzene, Xylene

Drilling and hydraulic fracturing

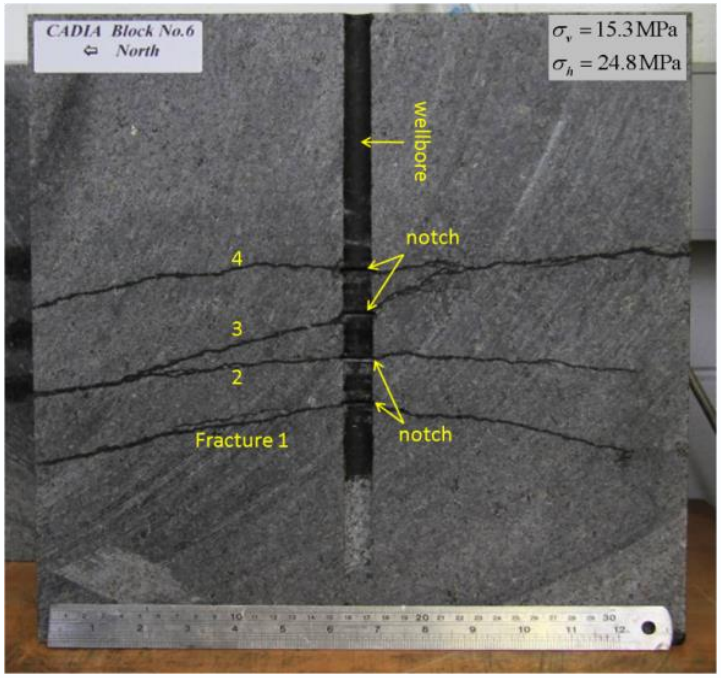


1. Drilling through upper geological layers using concrete and steel casing as barrier to aquifer.
2. VerNcal drilling up to 4km to target formaNon and horizontal drilling through to gas-bearing zone
3. Perforate the well to access gas bearing rocks
4. Pump water, sand and chemical addiNves into the well to fracture the gas-bearing rock
5. Gas flows through the fissures into the well bore

Hydraulic fracturing in shale

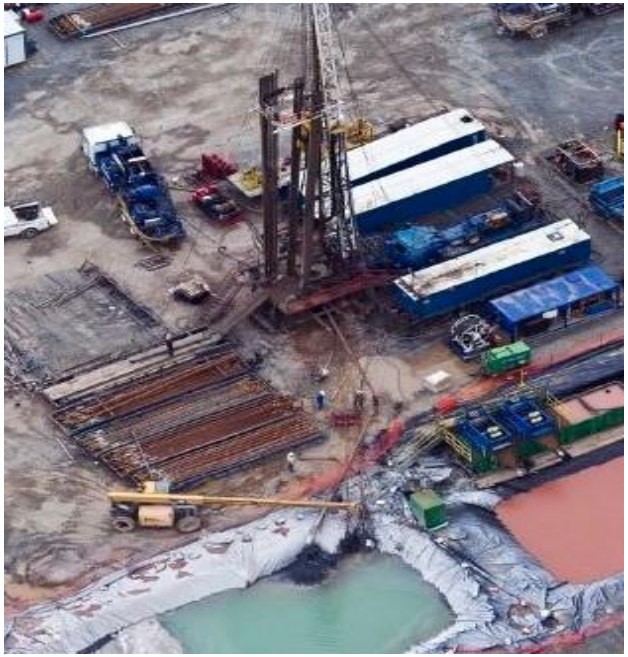
- 'Well stimulation' method: Economic gas production
- Increases rate + volume of gas extraction
- Fracture length:
  - Hardness
  - Fracture characteristics
  - Water pressure
- Fracture depths >1.5 – 2.0 km.
- Fracture lengths ~90m
- Hydraulic fracturing fluid: Water (~90%), proppant (~5-9%), 1-3% additives
- In Australia, additives present at concentrations in hydraulic fracture fluids presents low risk *via*:
  - Intrinsic low toxicity
  - Transparent disclosure

Hydraulic fracturing in shale



- Vertical drilling to shale depth (>1.5 km)
- Horizontal drilling (1 – 2 km)
- Multiple wells per pad (4 – 12)
- 7 – 15 ML per hydraulic fracture (up to 25ML)
- Flowback ~10% – 50% (up to 70%)
- Water + friction reducer ('slick water')
- Biocide, scale inhibitor, corrosion inhibitor
- Thickener (gel)
- Hydrochloric acid
- Proppant volume (1000's tonnes)
- Settlement ponds: Solids to landfill. Liquid to WTP
- Fractures a few mm's wide
- 'Barrier rock' or 'leakoff' halt fracture growth

NT Regula'ons: Hydraulic Fracturing



- CBL validated showing integrity of well cement
- Pressure testing of casing
- Baseline water monitoring and testing
- EMP must include water management (source, consumption, treatment, disposal)
- Modelling of fracture max propagation height
- Separation between aquifers and fracture zone
- MSDS for public disclosure on DME's website.
- Approved fracture fluids only
- 90% water, 9.5% sand, 0.5% 'chemicals'
- BTEX products and additives banned

CBL = Cement Bond Log EMP = Environmental Management Plan

Poten'al risks of hydraulic fracturing

Photos: John Veil 2011

- Surface transportaNon spills
- Well casing leaks
- ConnecNvity through rock fractures
- Drill site discharge
- Wastewater disposal
- RetenNon pond release

- Largest risk: Wastewater disposal
  - High epistemic uncertainty
  - High flow back volumes
  - Large number of wells

Rozzell and Reaven (2012) Water Pollution Risk Associated with Natural Gas Extraction from the Marcellus Shale. Risk Analysis, 32, 1382-1393

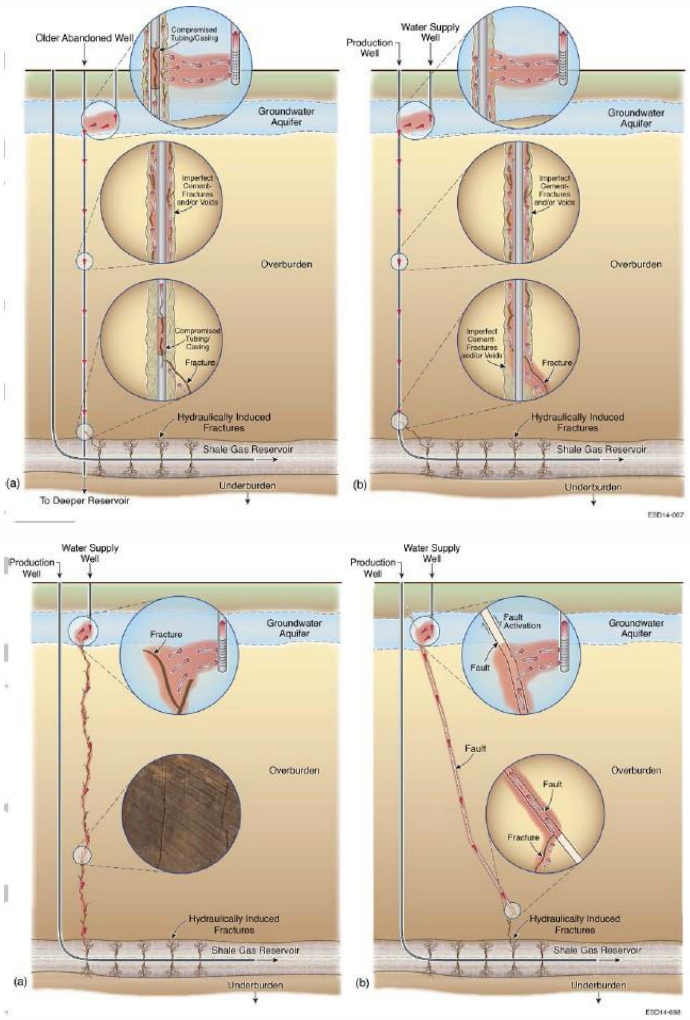
Probabili'es…

DME

- Well casing failures 1 – 3% (Marcellus Shales)[++]
- Probability well casing failure 1:700 to 1:7000 in any year
- Texas*: Barrier 1:50. Integrity 1:1250
- Probability hydraulic fracture contamination is virtually zero
- >1,000,000 hydraulic fractures since 1940's ~1 documented case of direct groundwater pollution
- Best practice well drilling observes setback distances from faults

* 250,000 wells over 16 years Kell (2011); [++] Vidic et al (2013)

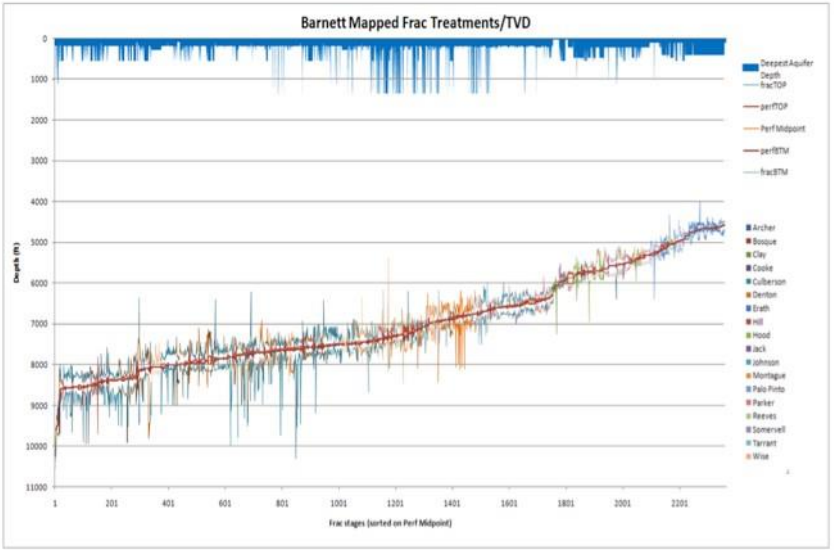
Hydraulic fracturing & near surface aquifers



- Shallow tight gas formation/shallow FW aquifer
- Separation distances 200m and 800m
- Explored risk of gas connectivity to FW aquifer by fault or corroded well by numerical modelling
- Biggest risk of methane contamination occurs with high permeability of connection pathway, high volume of free gas in reservoir and close proximity of gas reservoir/FW aquifer
- Risk of gas transport to FW aquifer is higher early in life of reservoir (when pressures are higher) and immediately following well stimulation (when free gas is available)
- Risk rapidly drops as free gas pressure drops
- Risk rapidly drops with increased separation

Reagan et al (2015) Water Resources Research.

Barne2 Shale (Texas, USA)



- 48,000 km^2 >16,700 wells
- 1500 – 2400 m depth
- Sampled 100 drinking wells
- Elevated As, Se, Sr, and TDS
- No evidence of BTEX
- As occurs naturally in soils (volcanic origin)
- As solubilised at pH >8.5 (GW pH 7.9 – 9.3)
- Aquifers natural elevated TDS

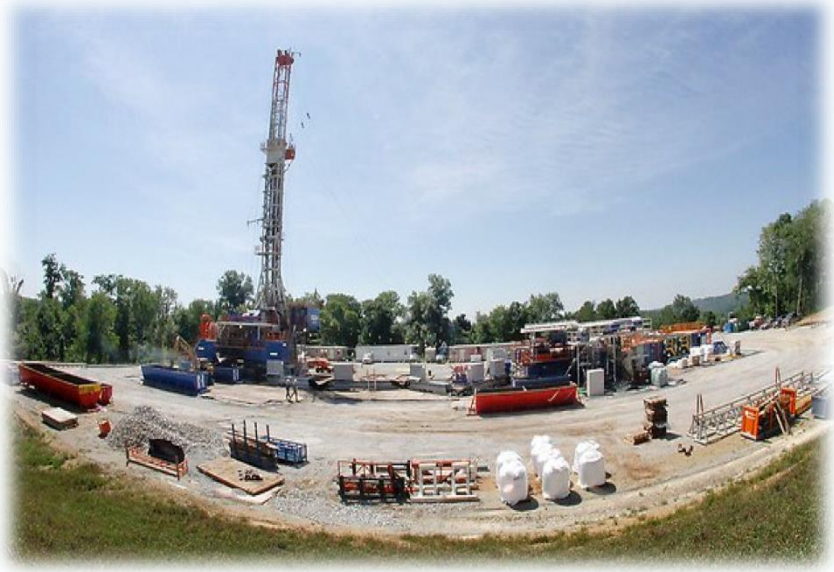
  "These constituent concentrations could be due to mechanisms other than contamination of aquifers with fluids used in natural gas extraction."

- Faulty gas well casing/cement?

Image: Pinnacle (Haliburton)

Fontenot et al (2013) Environ Sci Technol.

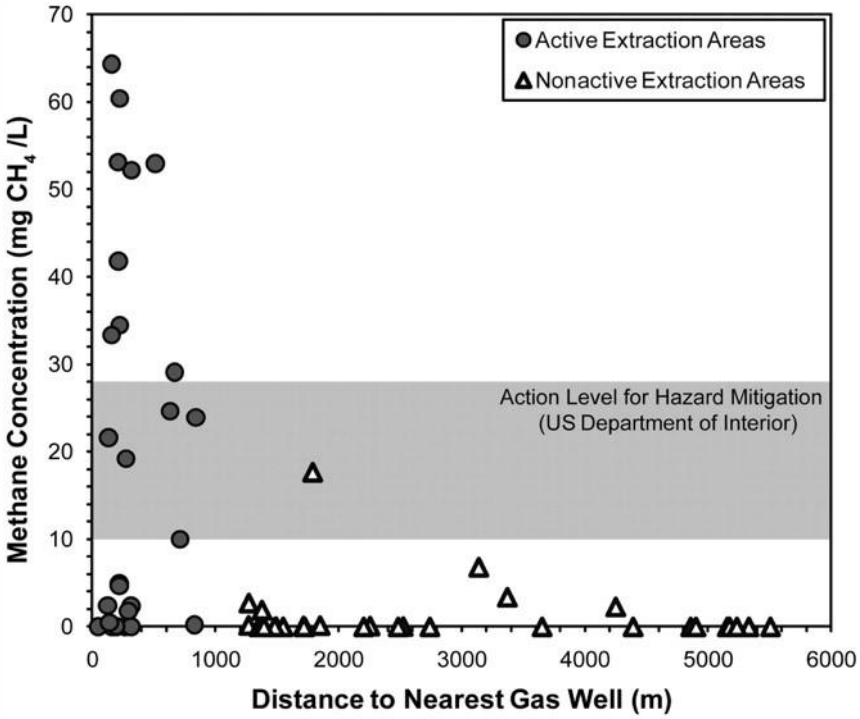
Niobrara Shale (eastern Colorado, USA)



- Colorado Oil & Gas Conservation Commissions database, Weld County
- 25,000 wells, July 2010 – June 2011
- 77 reported surface spills (0.5% wells)
- No incidents from hydraulic fracturing or well casing failure
- 26 spills contained within bunds
- BTEX chemicals exceeded national drinking water standards
- 84% remediated within 6 months
- No spills associated with holding ponds
- Equipment failure rather than operator error

Gross et al (2013) *Journal of the Air and Wastewater Management Association*.

Marcellus Shale (Pennsylvania, USA)



- Drinking water wells 60 – 90 m depth.
- Gas wells 1200 – 1800 m depth

- Associated or 'Formation' water:
  - TDS > 250,000 mg L^{-1}
  - $\delta^{13}C$-CH_4 > -50 $^{o}/_{oo}$
  - Ethane, propane + hydrocarbons

- High [CH_4] drinking wells 1km gas wells
  - 70 - 10 mg L^{-1} > 1km from gas wells
  - No hydraulic fracturing contamination

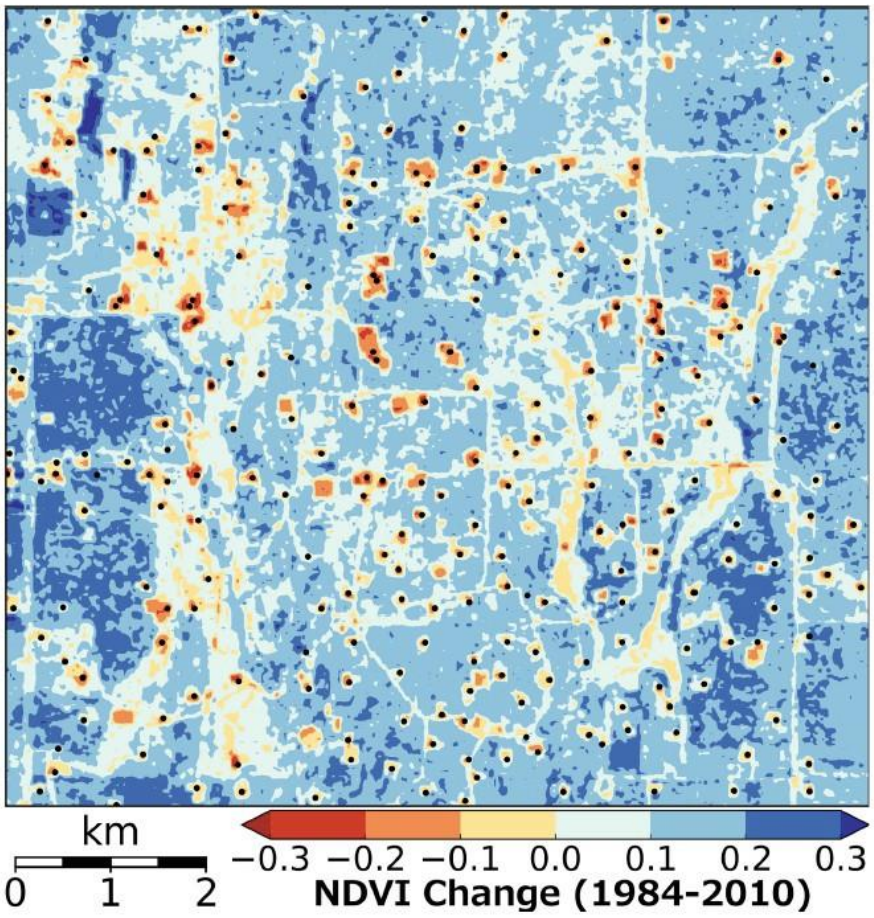
Osborn *et al.* (2011) PNAS

Marcellus Shale (Pennsylvania, USA)

- High [CH_4] in drinking water predates shale gas
- Methane in drinking wells occurs due to natural migration from shale to the surface
- Dataset was too small: 60 wells out of ~20,000 water wells
- Highest risks: Surface transport and wastewater disposal
- Lowest risks: Hydraulic fracturing, well casing leaks, underground connectivity

Schon et al (2011) PNAS. Saba and Orzechowski (2011) PNAS. Davies (2011) PNAS. Rozzell and Reaven (2013) Risk Analysis

Land surface impacts of gas wells



Wheeler Country Texas

- Direct impacts of well pads, roads and storage facilities on ecosystem NPP across central North America
- 2.5 million wells drilled since 1900
- 90% on private land (+ gas ownership)
- 2000 – 2012: 4.5 Tg/year loss in NPP
- 2000 – 2012: 7,000 – 33,000 GL water HF
- Rangelands, croplands, forests (wetlands)
- 3 million ha of land area converted
- 50% loss in grazing on public land
- 6% loss of wheat cropping land
- Fragmentation of landscapes
- Increased competition for water

Allred et al (2015) Science.

Thank you

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