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Presentation from

Stuart Haszeldine

In the Matter of

Ontario Power Generation Inc.

OPG's Deep Geological Repository (DGR) Project for Low and Intermediate Level Radioactive Waste

Joint Review Panel

September 2014

Présentation de

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Ontario Power Generation Inc.

Installation de stockage de déchets radioactifs à faible et moyenne activité dans des couches géologiques profondes

Commission d'examen conjoint

septembre 2014

Canada

Gas Generation Pressures in the Proposed Repository Post-Closure Safety Case

Professor Stuart Haszeldine
University of Edinburgh

Presentation to the Joint Review Panel – September 2014

Prepared for Northwatch and The Inverhuron Commitee

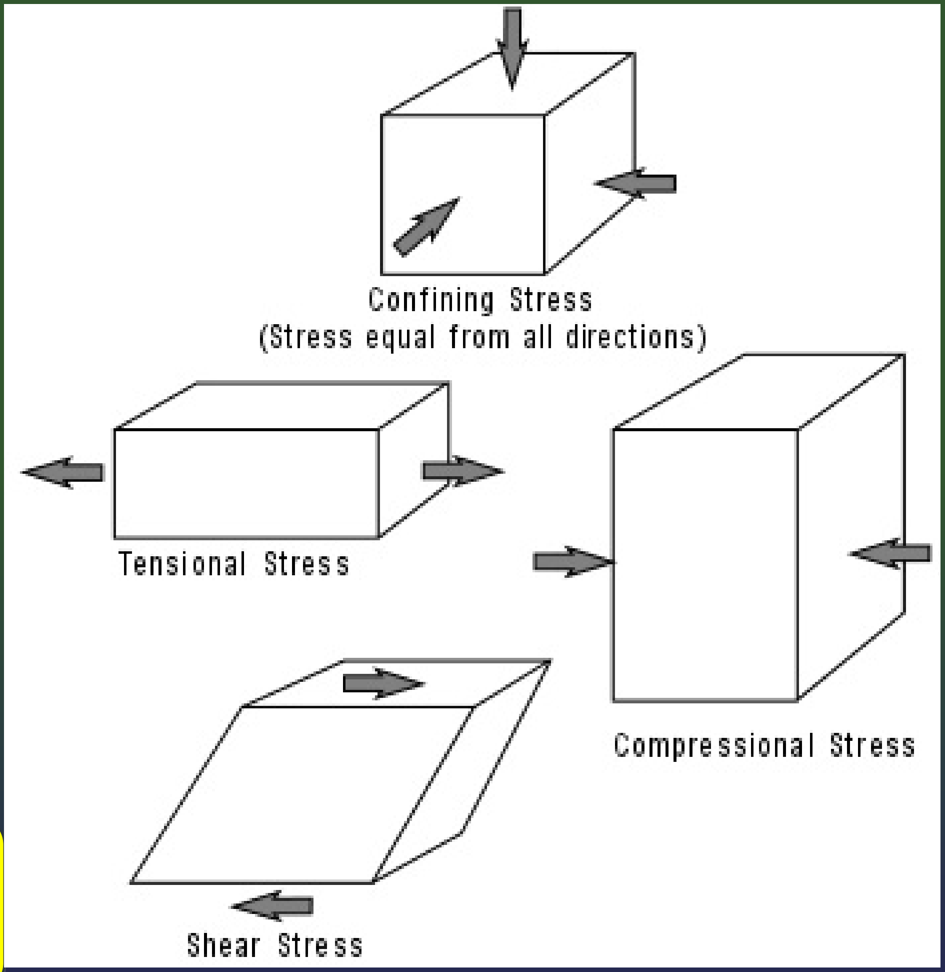
Review of Ontario Power Generation's Proposed Deep Geologic Repository for Low and Intermediate Level Nuclear Wastes

Introduction

- Submission summarizes new evidence, which derives from the additional information provided by OPG, NWMO and by CNSC.
- Also draws on recently published public academic evidence, and evidence and documents provided to this inquiry before the previous 2013 evidence sessions
- Evidence questions the secure short to long-term performance of this DGR, because the gas generated within the DGR will provide increased subsurface pressure sufficient to reactivate existing fractures.

Stress in rocks

If stress is not equal from all directions then we say that the stress is a differential stress. Three kinds of differential stress occur. ***Tensional stress (or extensional stress)***, which stretches rock; ***Compressional stress***, which squeezes rock; and ***Shear stress***, which result in slippage and translation.



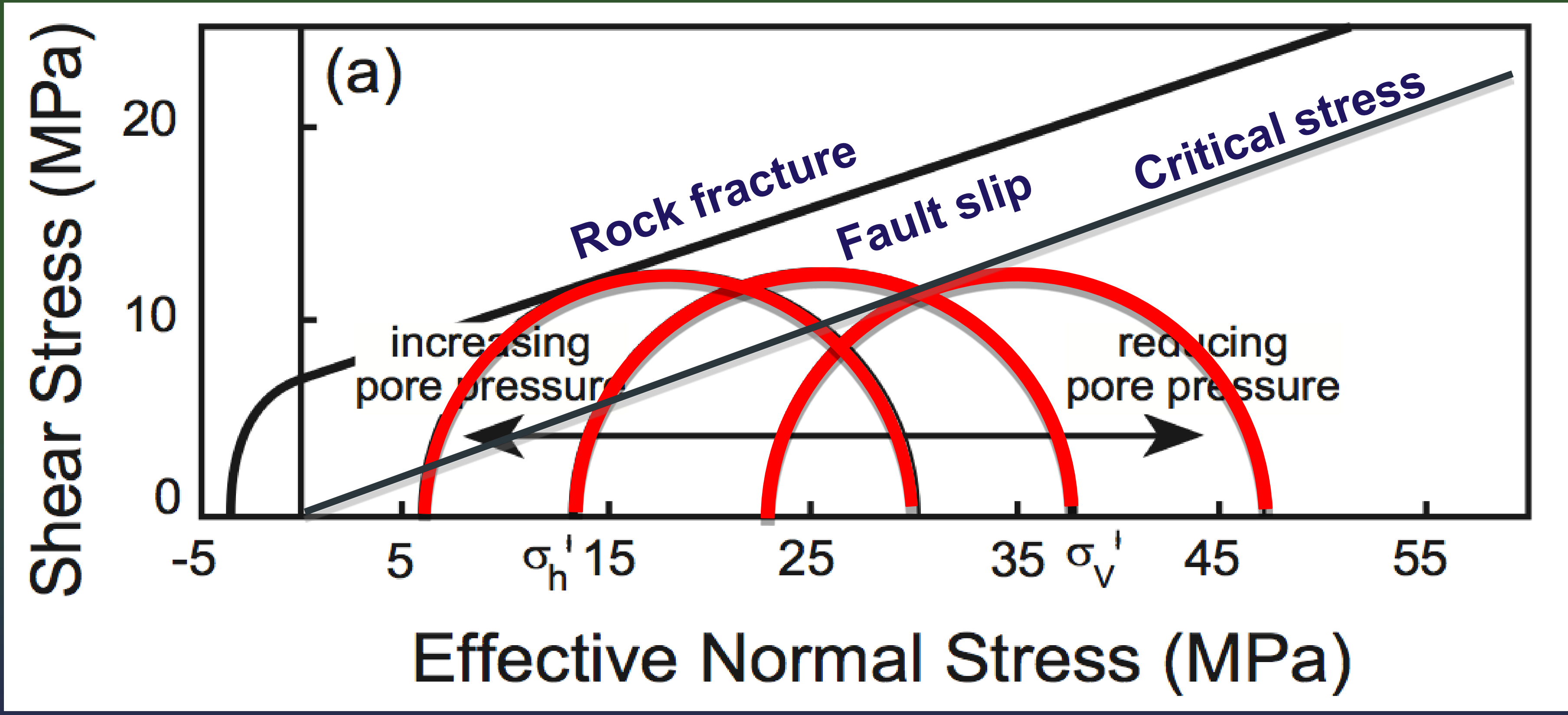
http://www.tulane.edu/~sanelson/geol111/deform.htm

Rock strong if compressed
Weak if tensioned

Increased pore pressure

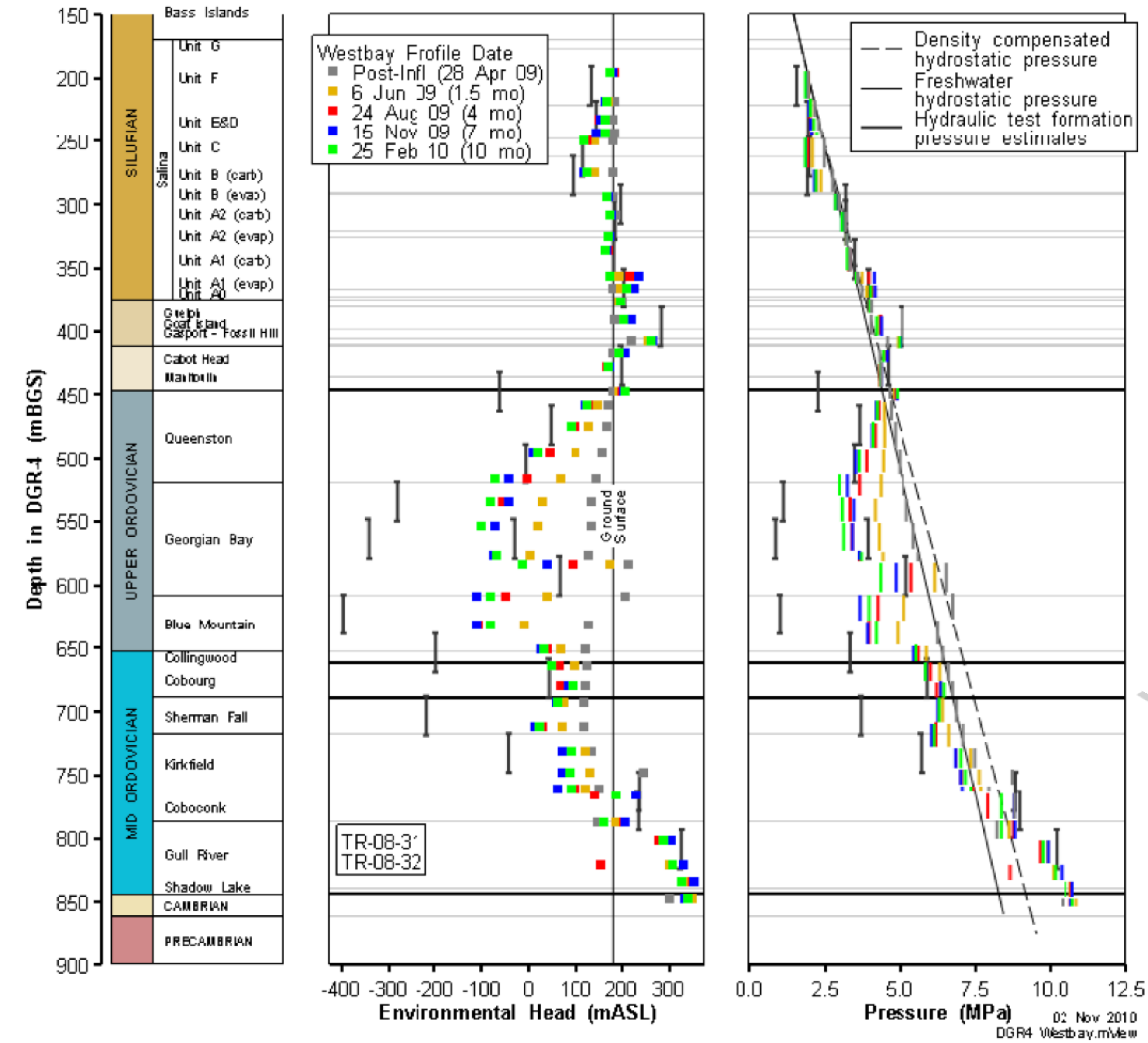
Increasing pore pressure does not change the stress difference between Ó 1 and Ó 3, but does decrease the mean stress.

Critical stress intersects envelope ➔ fault reactivates ➔rock fails fractures



Increased pore pressure can fracture rock – principle of fracking"

Fluid geopressure at Bruce DGR site



Note: From (INTERA 2011).

Figure 2.15: DGR-4 Formation Pressure and Environmental Head Profiles, April 2009 (Post Inflation), June 2009, August 2009, November 2009 and February 2010

Under-pressure

DGR Depth Pressure 7.3 MPa, normal hydrostatic

Cambrian aquifer Over-pressure

Gas generation in Repository

Assumes:
Water in waste. And water enters Repository, to restore subsurface pressure
Generates gas by microbial degradation and by anaerobic corrosion

Does gas leave Repository   Or, does gas build pressure ?   Add hydrocarbons ?

Table B-1: Estimated Maximum Repository Gas Pressures

Gas Generation	Initial Mass of Metals or Organics (kg)	Maximum Gas Pressure (MPa)			
		Case 1	Case 2	Case 3	Case 4
		Anaerobic Corrosion & Degradation	Case 1 with $FeCO_3$ Formation	Case 1 with Methano-genic Reaction	Case 1 with $FeCO_3$ and Methano-genic Reactions
H_2 from metal corrosion	5.8E+07	10.0	8.8	0.0	0.2
CO_2 from organic degradation	2.2E+07	3.6	0.0	1.2	0.0
CH_4 from organic degradation		5.3	5.3	7.8	7.6
N_2 from initial air	-	0.1	0.1	0.1	0.1
Total	**8.0E7**	**19.0**	**14.2**	**9.0**	**7.9**

Gas generation is additional to normal water pressure – in all cases **large 7-15 MPa**

Why is gas generation tricky ?

NWMO have assumed that gas will leak from Repository at generation rate

BUT
1)This depends on gas moving through the bentonite backfill, which is designed to have a very high entry pressure to gas (ie resists gas ingress until gas exceeds hydrostatic plus clay swelling pressure = 19MPa) **ie leakage is blocked**

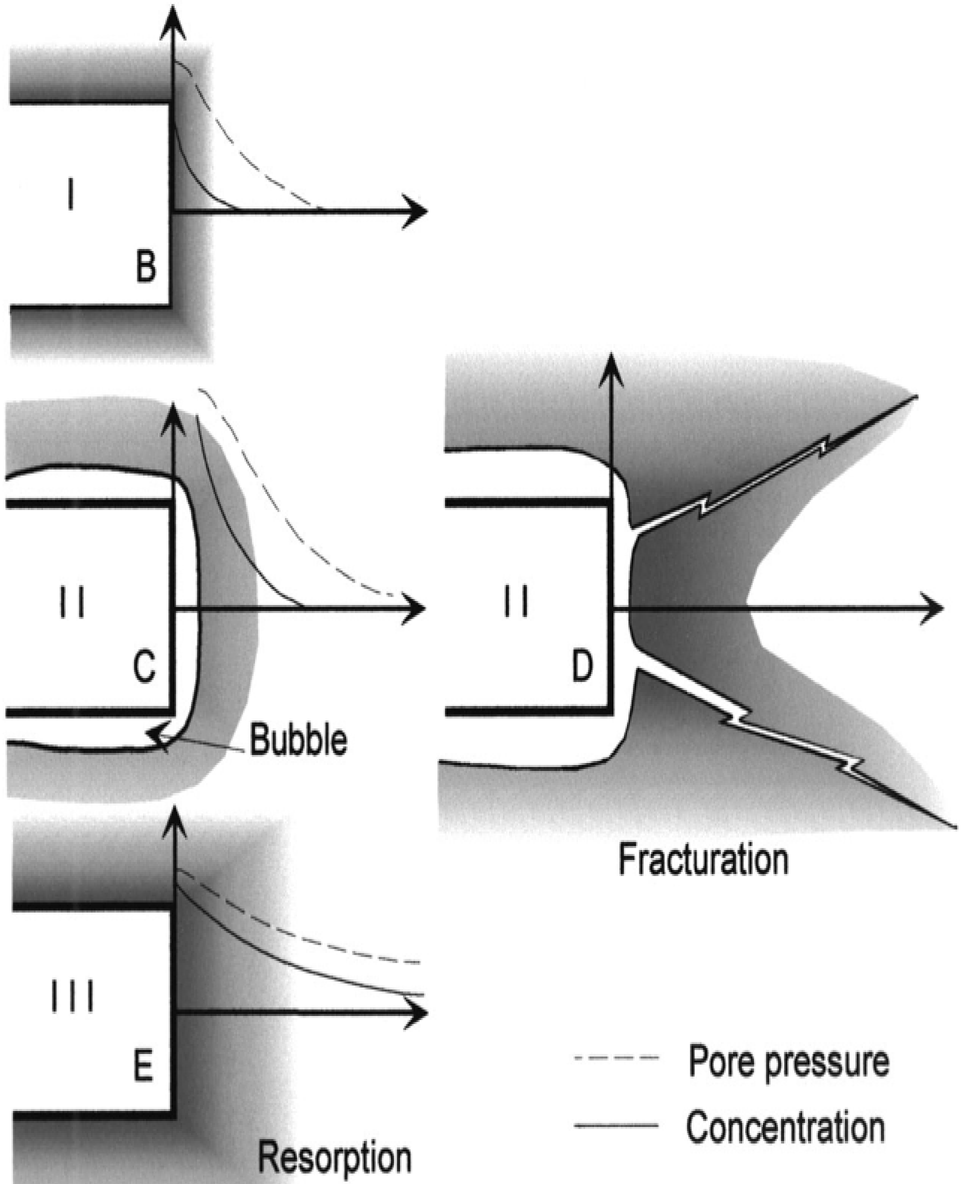
2)This depends on gas generation rate being slower/the same as the gas leakage rate But gas generation is fast (decades) ie **a bubble of gas builds up, creating pressure**

S.T. Horseman et al. / Engineering Geology 54 (1999) 139–149

Compare the times
Re-saturation of bentonite clay - 100yr ➔ Repository wet soon after closure
Thermal heating by waste – hundreds years - warmth speeds reaction rates
Corrosion of metals - 15,000 to 60,000 yr – plenty of metal to provide hydrogen

Balance between gas generation and leakage RATES

Gas generation fractures bentonite, and rock



Bonin et al (2000) Journal of Nuclear Materials 281, 1 – 14

Bulk of gas originates by corrosion of iron

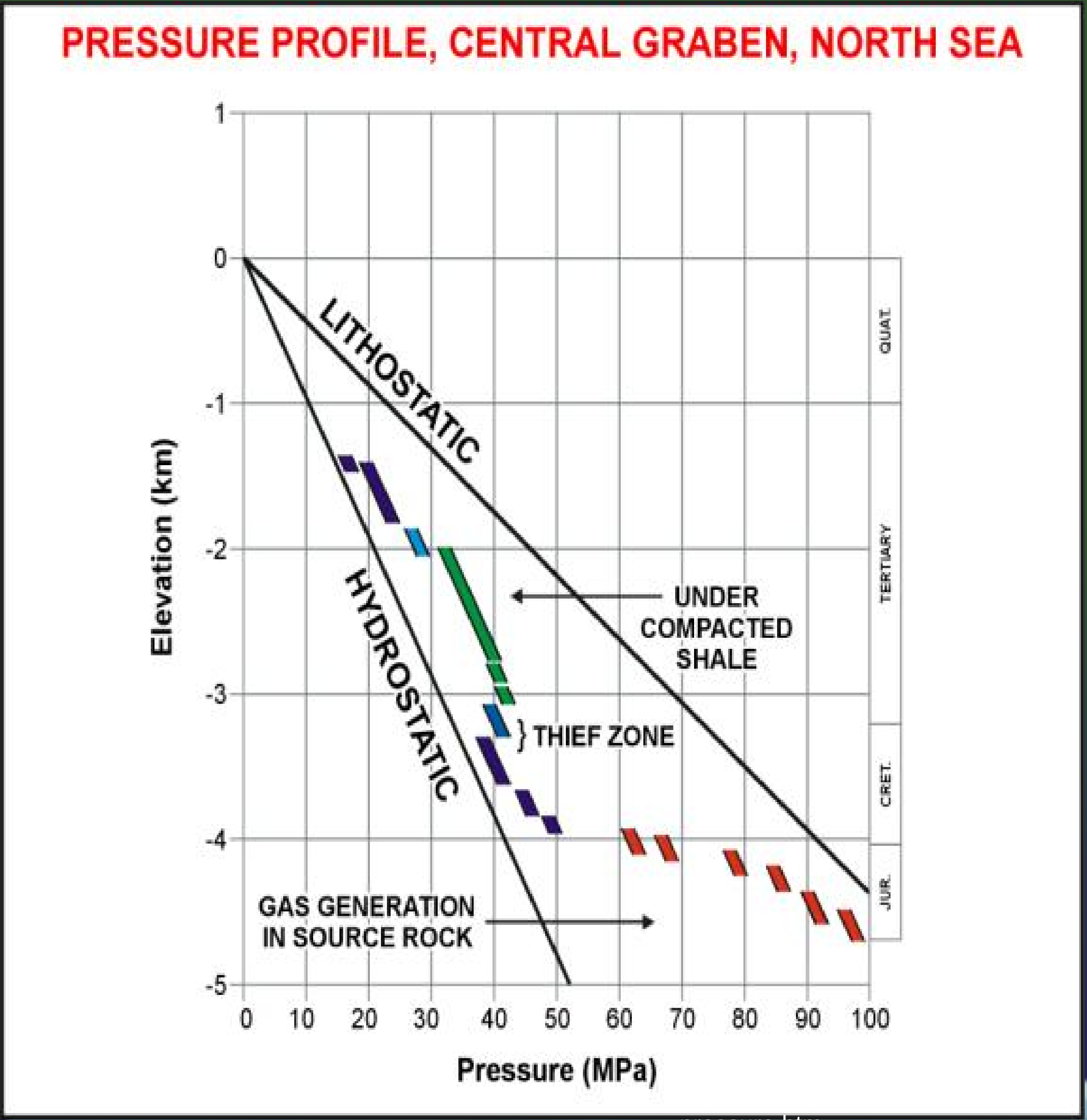
Thus, more iron in waste produces more gas

Bentonite will fracture before matrix flow gas escapes

Commentary by CNSC PMD 14-P1.2 June 2014 (p25) suggests that **greater content of iron** emplaced after decommissioning, **will produce more gas**

More iron = more gas = fractures more

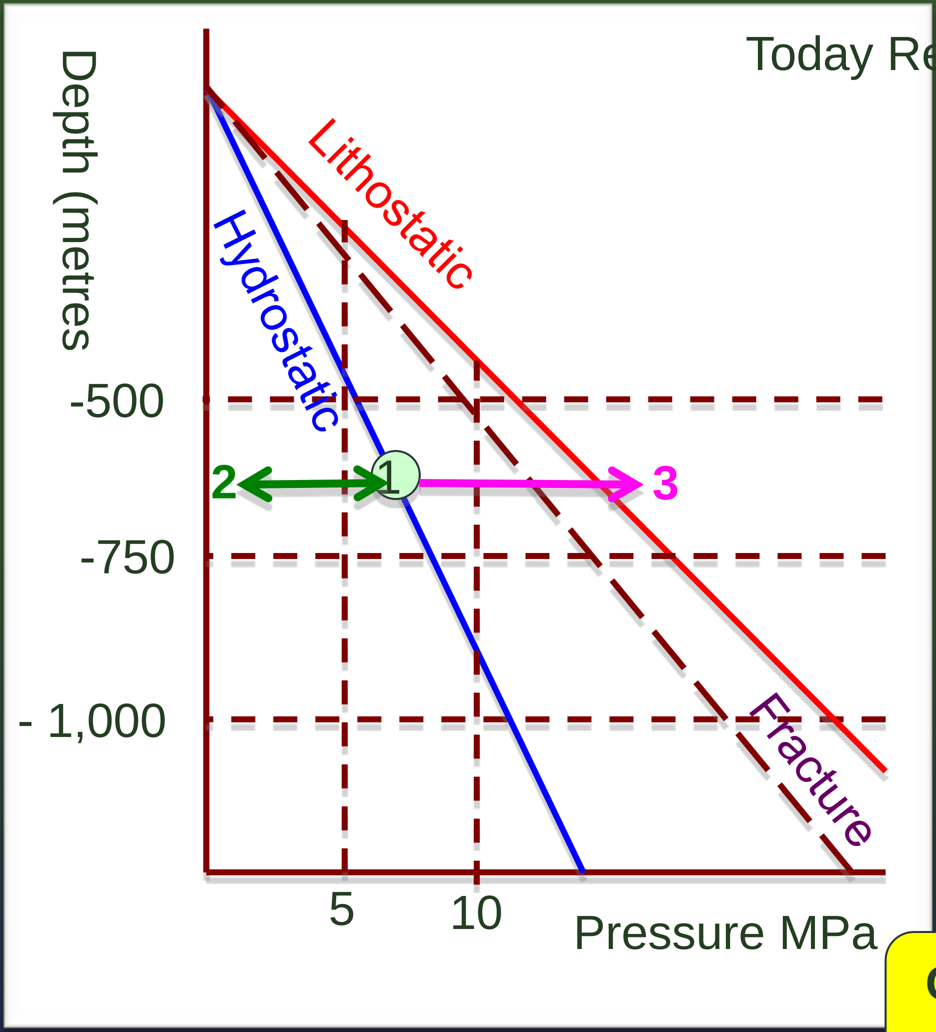
Fluid geopressure with depth : conventional



Open connection – hydrostatic (water column). Closed connection Lithostatic (rock column) Rock fractures at 70-80% lithostatic

pressure.htm

Fluid geopressure : DGR changes



Today Repository is at 1 – approximately hydrostatic

After excavation at 2 - atmospheric

After sealing at 1 – refills groundwater

After gas generation at 3 - 7MPa extra

Bentonite fractures, rock fractures

A fine balance of hydrostatic
PLUS extra gas pressure
PLUS hydrocarbon pressure
= breaks clay and rock

Containment depends on minimal water
Water inflow = gas = inevitable fracture

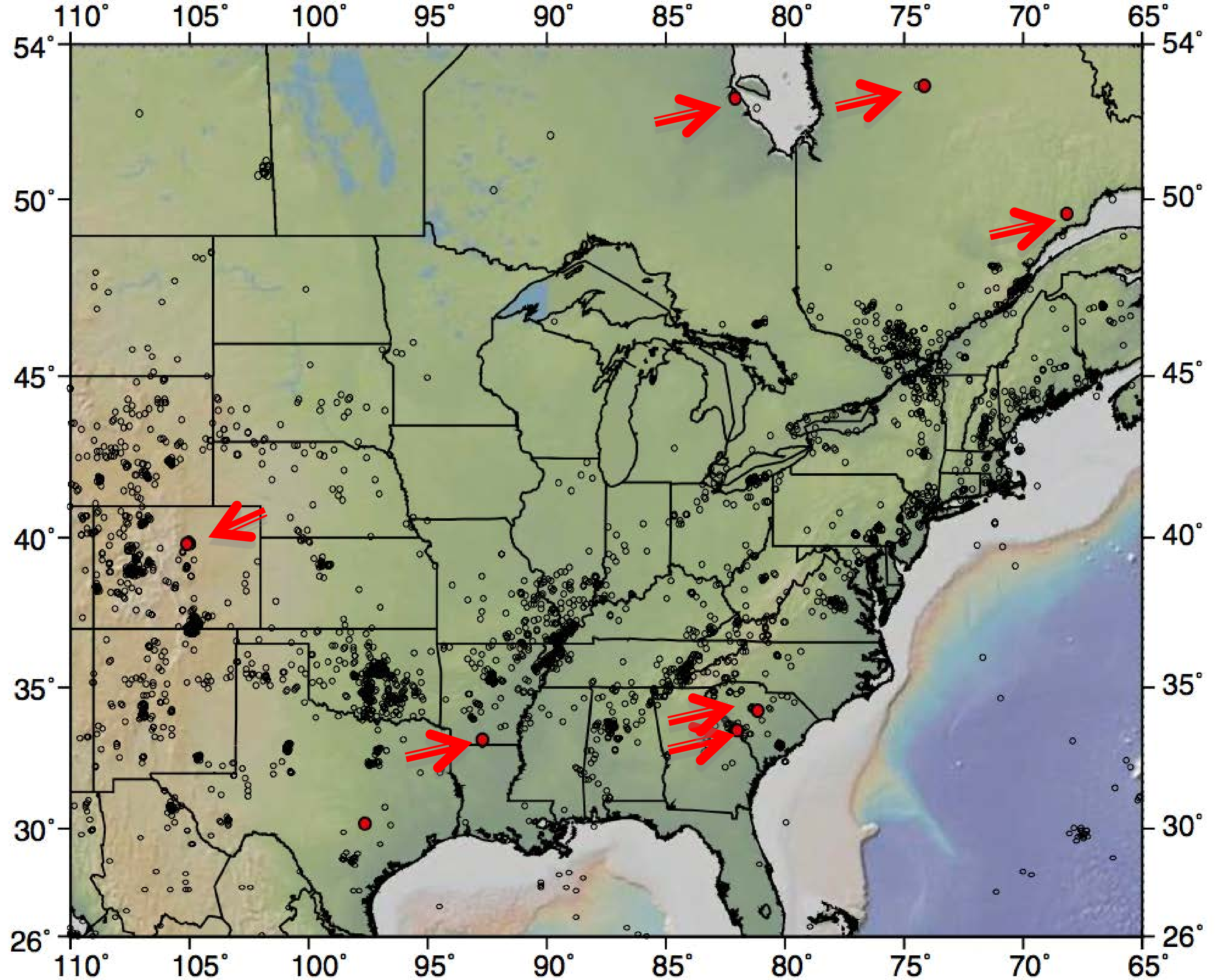
How will pressure be monitored and controlled ?

Critical stress

Since the 1980's, it has been apparent that the earths crust is in critical stress

Pre-existing faults, are ready to be reactivated as small to large earthquakes. By small to very small

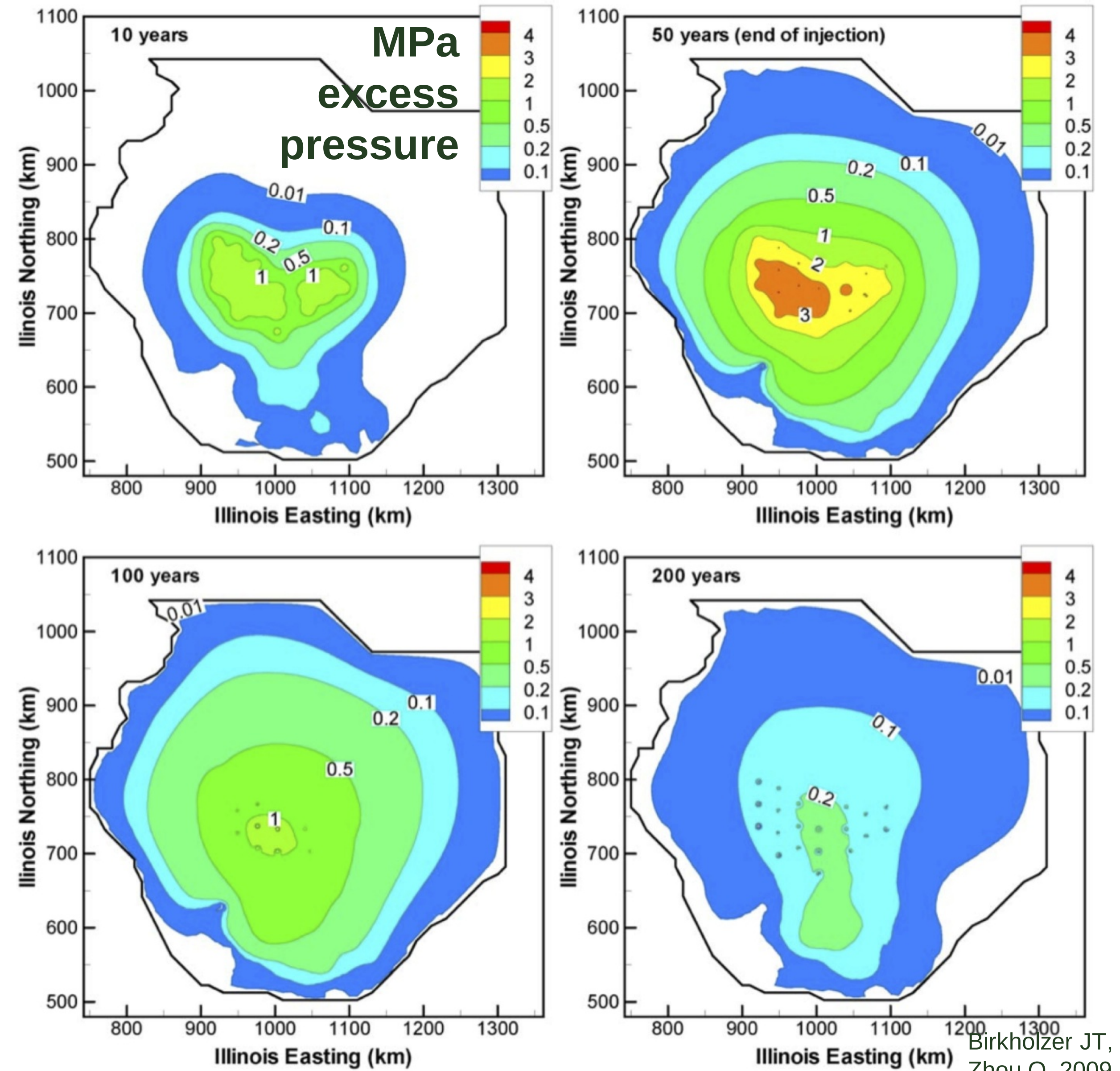
Black = earthquakes
Red = induced by dammed reservoirs, eg 0.9 MPa water



Zoback 2012 PNAS

There are 150 years of experience in decreased pressure from extracting fluids.
But only recently is experience accumulating on raised pressure from injected fluids

Impacts of pressure bubble : CO2



Birkholzer JT, Zhou Q 2009

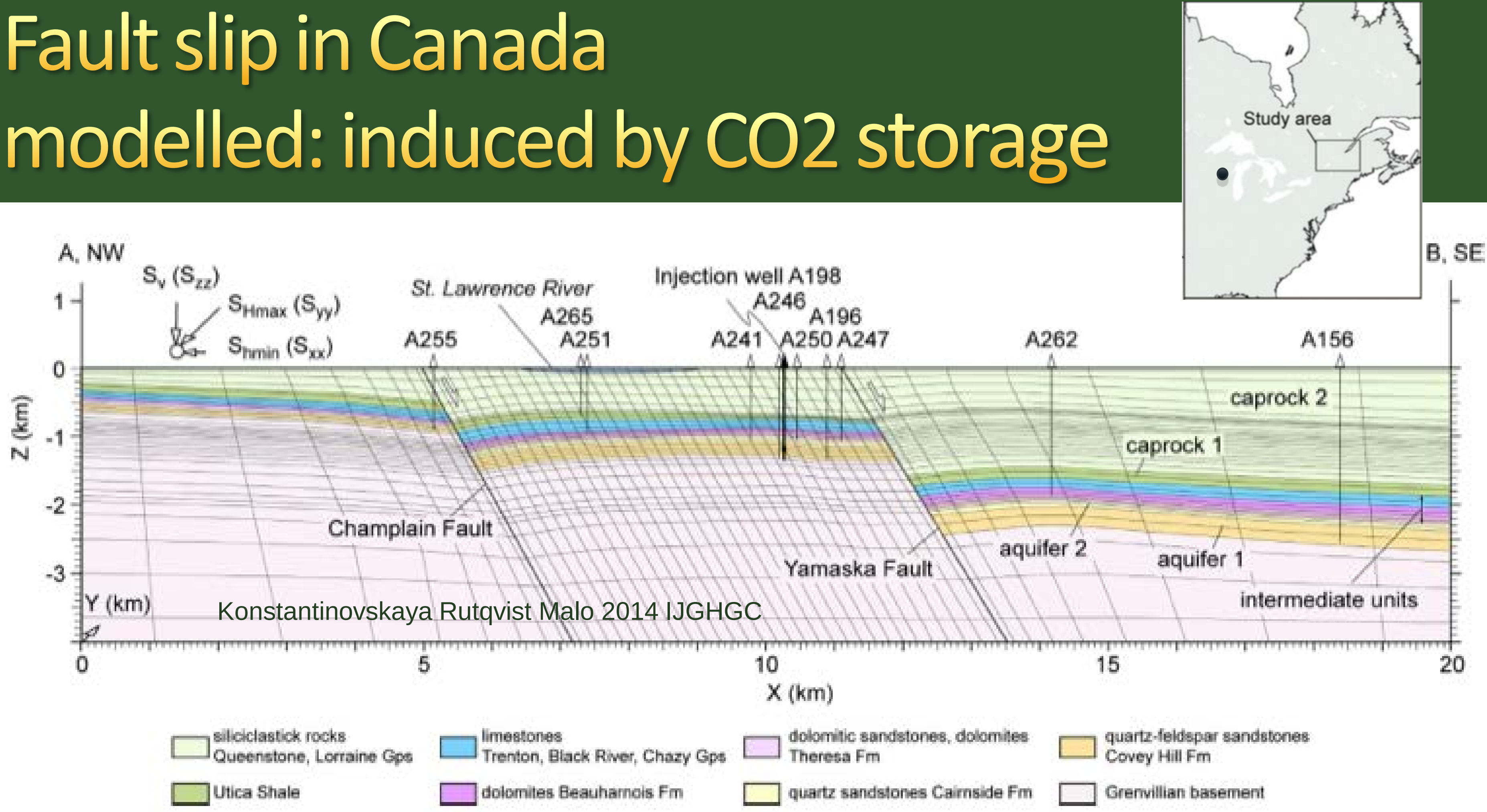
Modelled injection of CO_2 into Cambrian sandstones of Illinois basin. 20 projects 5Mt/yr x 50yr 5 km^3 fluid
GDR is similar - 2.5km^3

Pressure spreads through groundwater – with NO FLOW, like sound through air ……

Effects from 4 MPa excess pressure extend for 200km, within a 50 year timescale

Bruce DGR may have 7-15 MPa excess pressure

Fault slip in Canada modelled: induced by CO2 storage



St Lawrence graben CO2 injection reactivates faults at 0.5 – 1.0 km, not at surface. Accurate prediction depends on orientation and friction on individual faults

Will GDF pressures or CO2 disposal CAUSE fault slip, or small earthquakes ?

Pressurised fluid injection is probable Ontario: gas and shale gas,

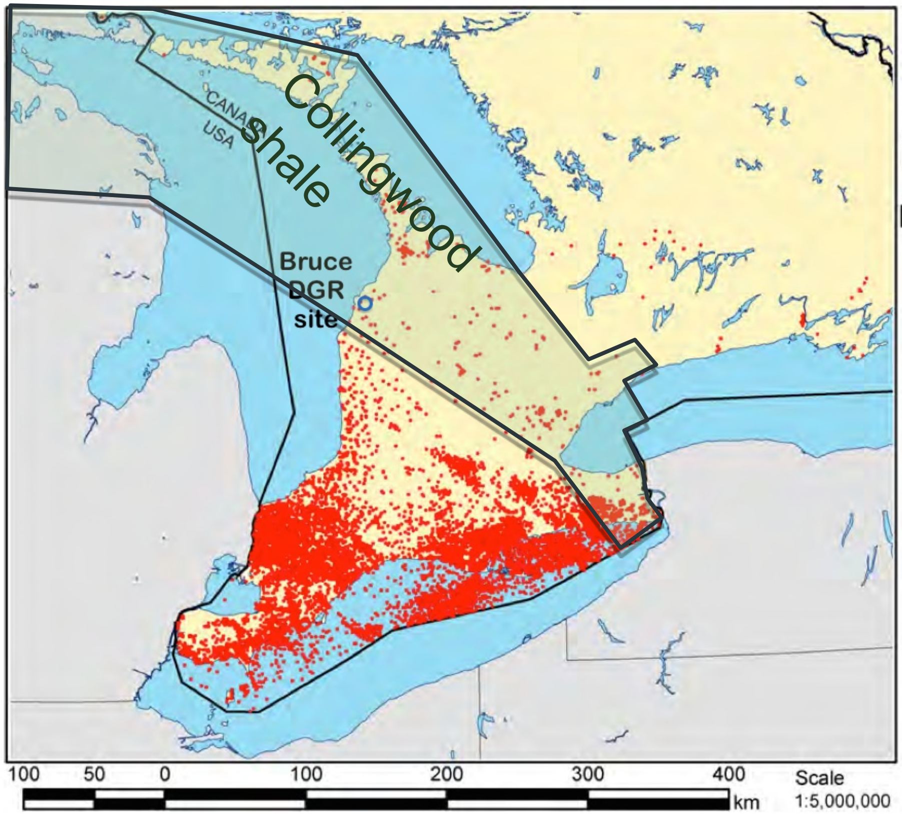
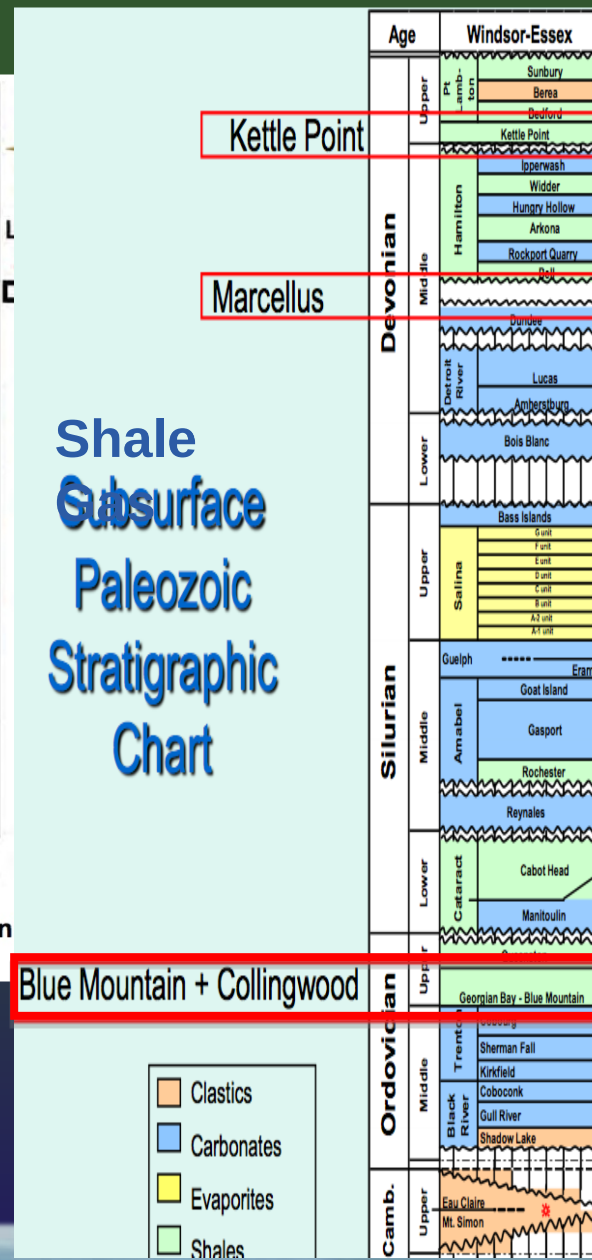
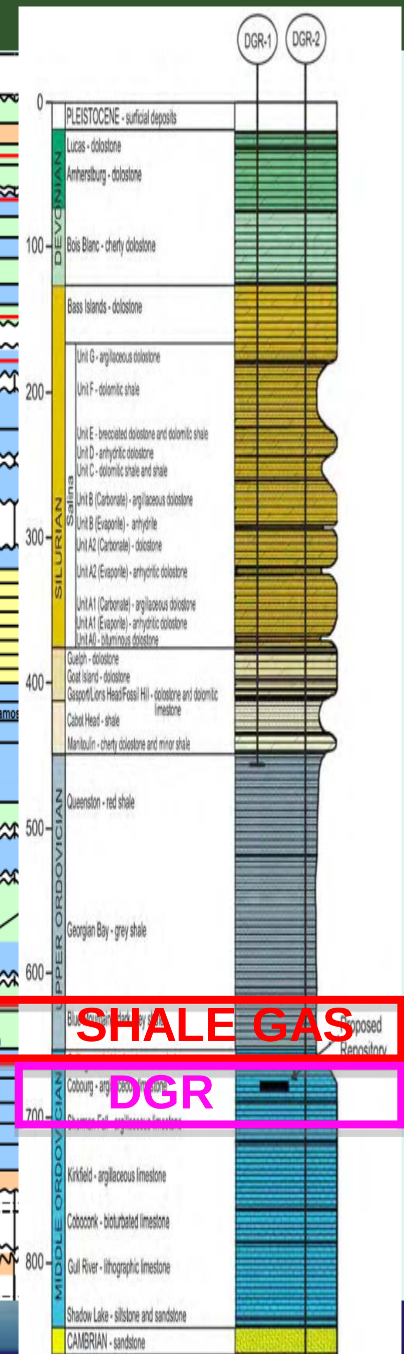


Figure 2.5: Locations of Oil, Gas and Salt Resources (OGSR) Boreholes in

Collingwood and Blue Mountain shales are gas prospects, above DGR. Who safeguards exclusion ?





Discussion Topics : gas in near field

- **Stress in rock**
- **Pressure of the DGR site not well understood**
- **Groundwater content post-closure DGR - RATE**
- **Gas generation after closure – Volume & RATE**
- **More gas generation – depends on waste**
- **Gas overpressure fractures bentonite and rock**

Discussion Topics : far field pressure consequences

- **How will gas pressure be monitored and controlled ?**
- **Far field effects of gas pressure, extend 100's km**
- **Pressure causes minor earthquakes and faults**
- **Bruce DGR in a shale gas zone – extra fracking?**

1) Pressure increase in the DGR is a major problem
2) Very likely to fracture bentonite and rock → leaks
3) Pressure buildup is hard to control, difficult to monitor
4) More pressure with decommissioning metal waste
5) Pressure effects extend for 100's km
6) May cause earthquakes, especially when added to CCS
7) Unconventional gas …… fracking

Contact Information

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