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Supplementary Information
Oral Intervention

Presentation from
John D. Bredehoeft

In the Matter of

Ontario Power Generation Inc.

Proposed Environmental Impact Statement for OPG's Deep Geological Repository (DGR) Project for Low and Intermediate Level Waste

Joint Review Panel

September 16 to October 12, 2013

Renseignements supplémentaires
Intervention orale

Présentation par
John D. Bredehoeft

À l'égard de

Ontario Power Generation Inc.

Étude proposée pour l'énoncé des incidences environnementales pour l'Installation de stockage de déchets radioactifs à faible et moyenne activité dans des couches géologiques profondes

Commission d'examen conjoint

16 septembre au 12 octobre 2013

Canada

Slide 0

MODELING THE HYDROGEOLOGY OF THE BRUCE SITE

(to accompany written submission)

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Prepared For Northwatch

Slide 1

Model Calibration

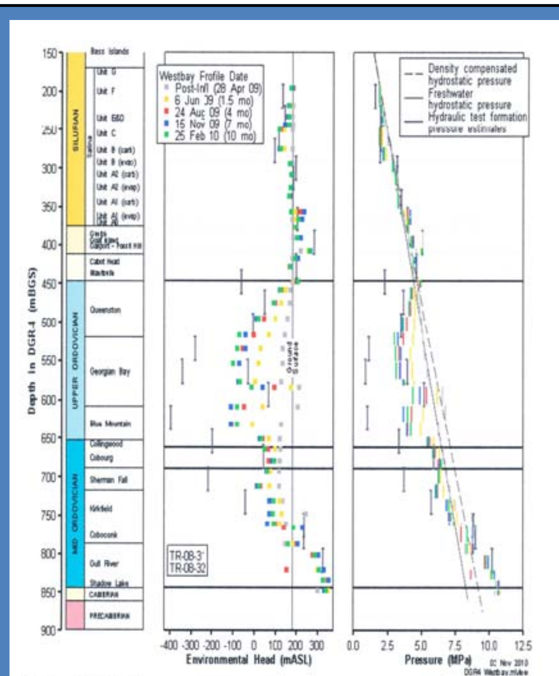
Models allows projection future system response
  Sequester Waste ?

Usual procedure: 1) history match (calibrate); 2) then project
  Oil field production history
But--Repository there is no history to match

Alternative is to reproduce observed hydrogeology of the site

Slide 2

head pressure



Note: From (INTERA 2011).

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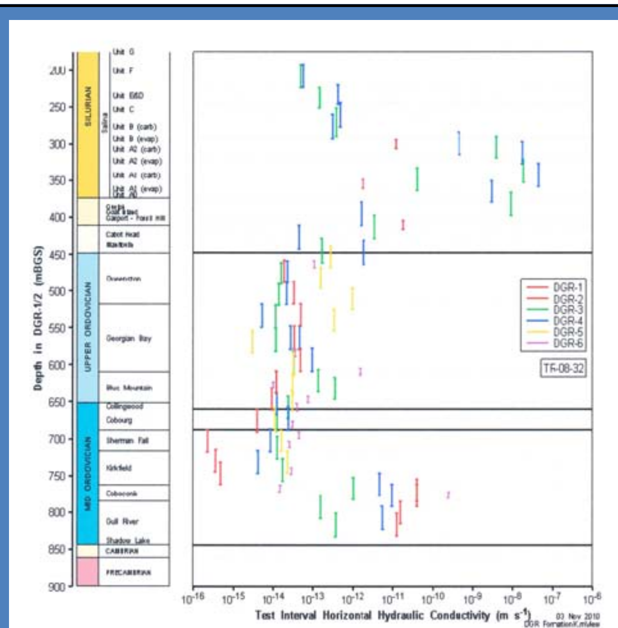
hydraulic conductivity

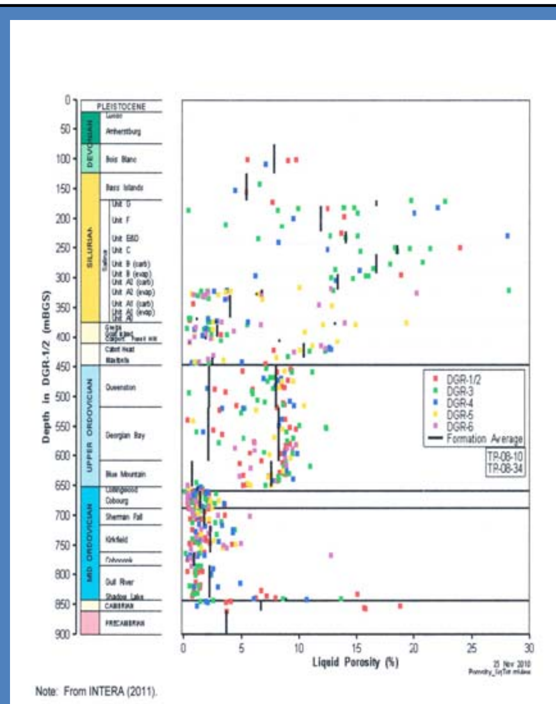


Note: From (INTERA 2011).

Figure 2.18: Profile of Test Interval Hydraulic Conductivity Estimates Determined from Field Straddle-Packer Testing in DGR Boreholes

Slide 4

porosity



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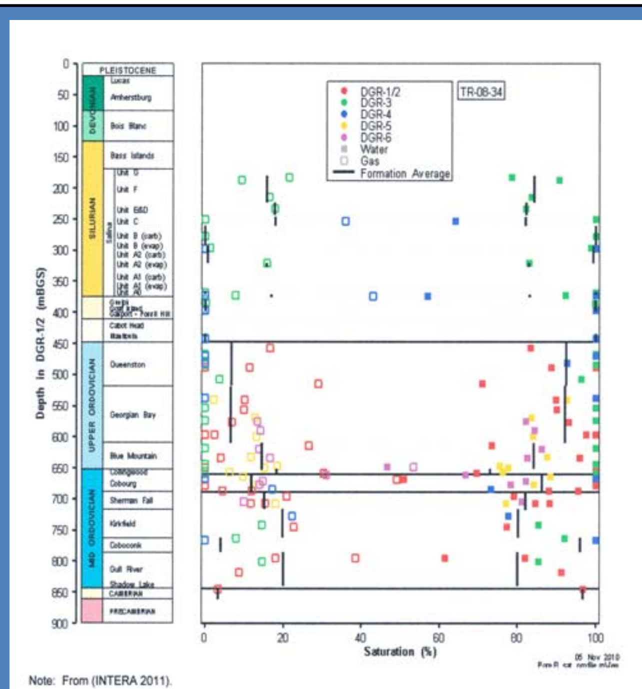
saturation

$S_w + S_g = 1.0$



Slide 6

Sykes et al
model
FRAC3D

Table 4.14: Parameters and Initial Conditions for Site-Scale Analyses

		fs-base	fs-base-hkp	fs-1km	fs-5km	fs-base-under-pressure	fs-10kv-under-pressure	fs-100kv-under-pressure	fs-1km-under-pressure
Initial Heads	Steady State	•	•	•	•				
	Under-pressured					•	•	•	•
Hydraulic Conductivity of the Upper Precambrian	1×10^{-8} m/s		•						
	1×10^{-10} m/s	•		•	•	•	•	•	•
Fracture Zone Distance from DGR Site	1 km			•					•
	5 km				•				
Anisotropy in the Black River Group (K_H:K_V)	10:1						•		
	100:1							•	
	1,000:1	•	•	•	•	•			•

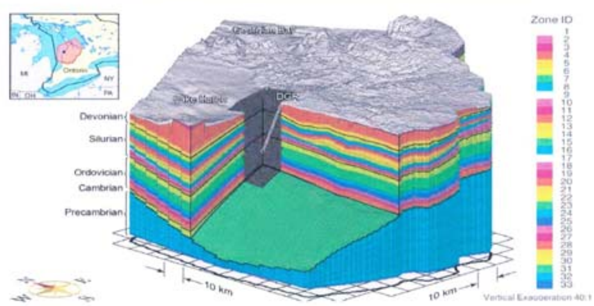


Figure 4.28: Regional-Scale Discretization Showing Location of Site-Scale Spatial Domain

Slide 7

Sykes et al
10 million
years

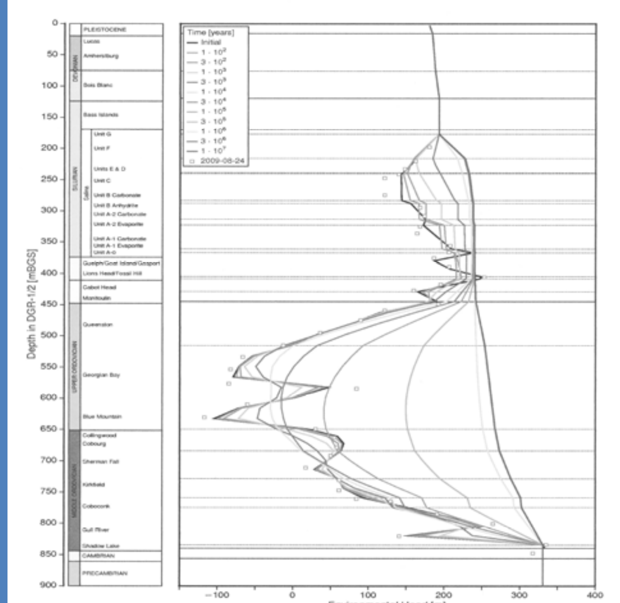


Figure 4.40: Predicted Evolution of Environmental Heads with Pressure Support in Both the Niagaran Group and Cambrian

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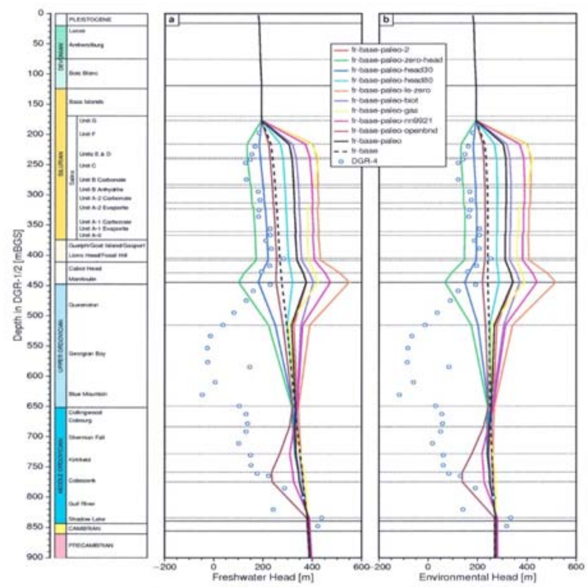
Sykes et al
Glacier Loading



Note: (a) freshwater head, and (b) environmental head versus depth are plotted at for all paleohydrogeologic simulations. Freshwater and environmental heads for DGR-4 are shown as measured on August 24, 2009.

Figure 5.25: Summary of Freshwater and Environmental Heads Vertical Profile Plots for All Paleohydrogeologic Simulations

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Sykes et al:

Nine different paleohydrogeologic scenarios were investigated in this study. Based upon these it is concluded that glaciation and deglaciation is unable to yield the abnormal pressures observed in the DGR boreholes.

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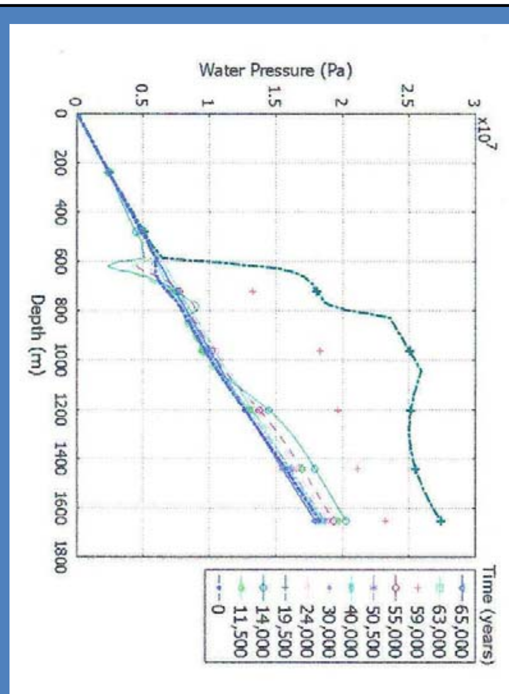
Nasir et al (2011):

First, past glaciation, particularly the second cycle (22,000 abp) had a great impact on pore water pressure gradient and effective stress distribution. The results are consistent with field observations of persistent pressure to the present time. However, the predicted values of anomalous water pressure is less than the observed values at the site…



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Gas?

(TOUGH2 model)

On this basis (the Hydrogen Index),the Collingwood sample and the Blue Mountain cores are considered as being thermally mature (Type II kerogen)….Most Georgian Bay and all Queenston cores contain Type III kerogen, which is derived from terrestrial organic matter, eg., ligin and cellulose and is more gas prone than Type II kerogen (Geosphere Site Model Report).

Questions: 1) generated when?
2) generation continuing?

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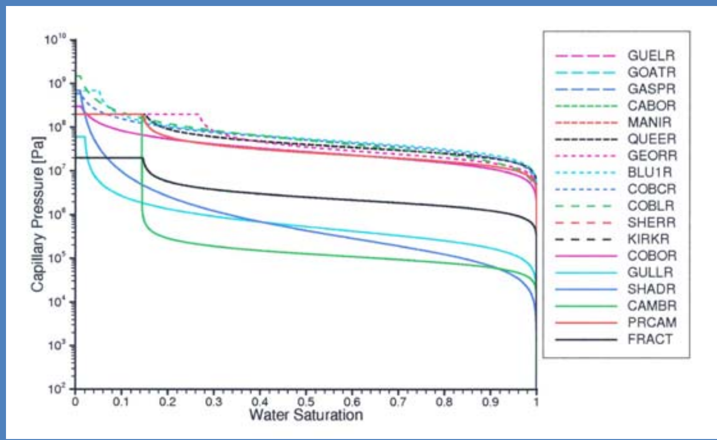
two phases: gas & water (capillary pressure)



$$p_c = p_g - p_w$$

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relative permeability

$K_w = k_{rw}\, k_w$
$K_g = k_{rg}\, k_g$

(k_r is relative permeability)

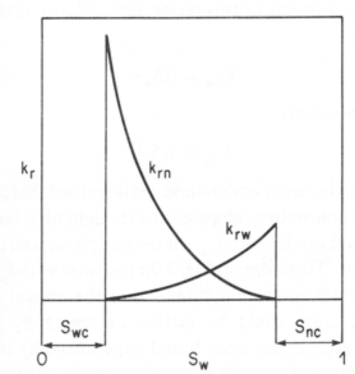

FIG. 2.6. Typical k_r curves.

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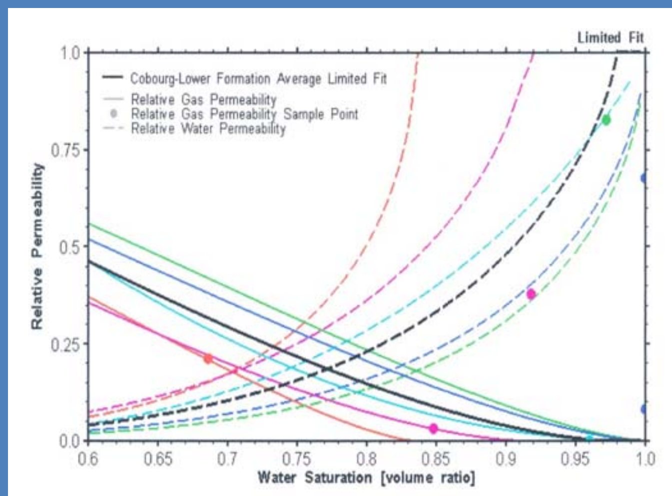
relative gas permeability



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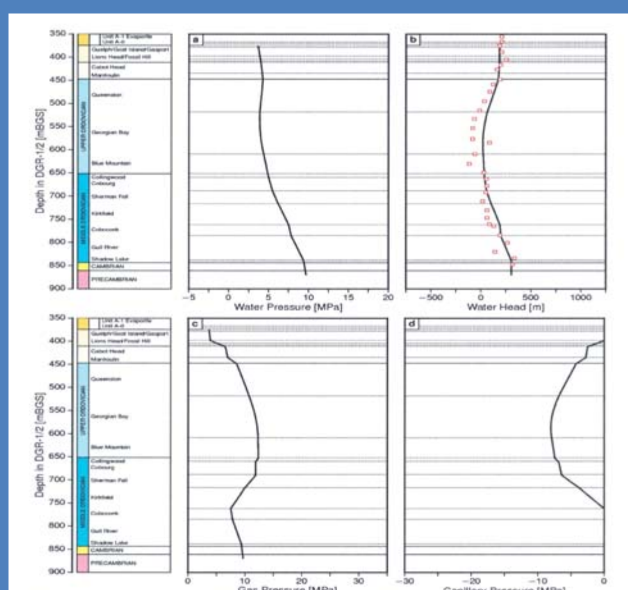
Sykes et al
TOUGH2



Note: (a) water pressure, (b) freshwater head with posted August 24, 2009 measurements in DGR-4, (c) gas pressure, and (d) capillary pressure.

Figure 6.33: Two-Phase Gas-Water Flow Analysis at 1 Ma Without a Discontinuity at 585 m Depth and Air Generation

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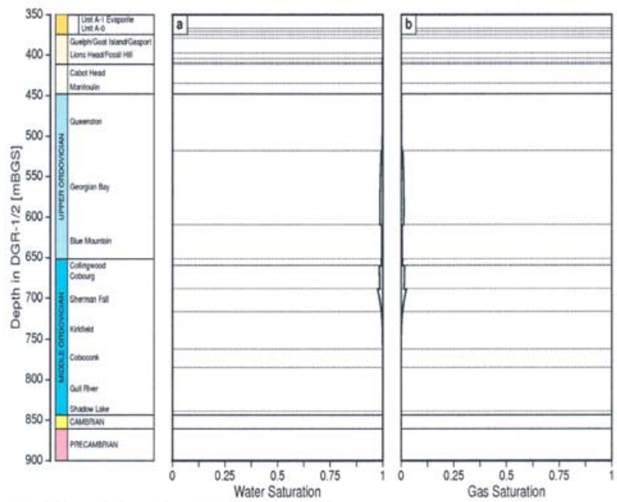
Sykes et al TOUGH2



Note: (a) gas saturation profile, and (b) water saturation profile.

Figure 6.34: Saturations for the Two-Phase Gas-Water Flow Analysis at 1 Ma Without a Discontinuity at 585 m Depth and Air Generation

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closure

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**

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Geofirma Quintessa

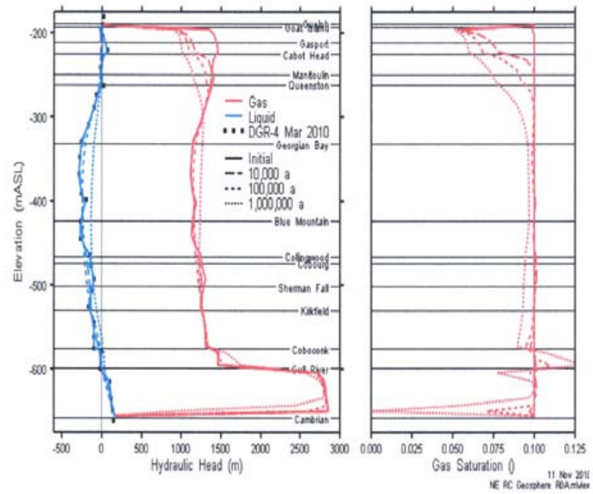

Figure 5.37: NE-RC: 3DSRS Geosphere (No Repository) Gas and Liquid Head and Gas Saturation Profile

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a dry mine

What happens hydrogeologically when we open a mine?

The mine fluid (air) is at atmospheric pressure.

The fluids in the country rock (gas & water) are at high pressure. At the Brue Site the water is at 4 MPa (40 atmospheres pressure).

The pressure gradient causes water & gas to flow into mine. But the permeability is very low so the rate of inflow is low.

The ventilation system carries the water away as vapor.

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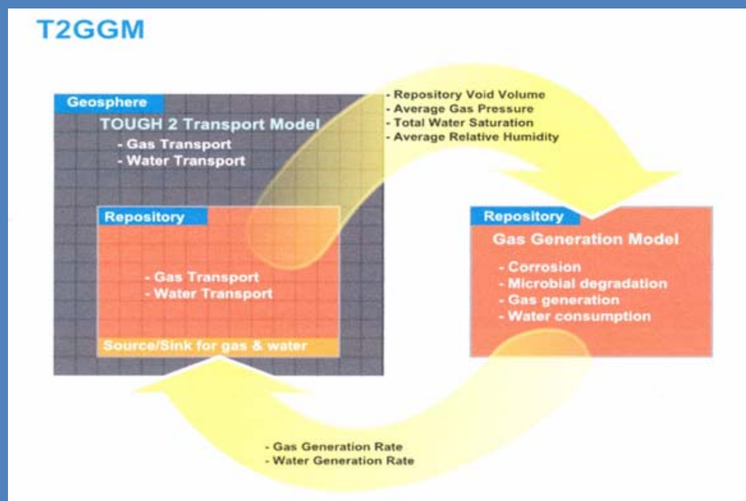
TOUGH2 & GAS GENERATION



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Geofirma Quintessa

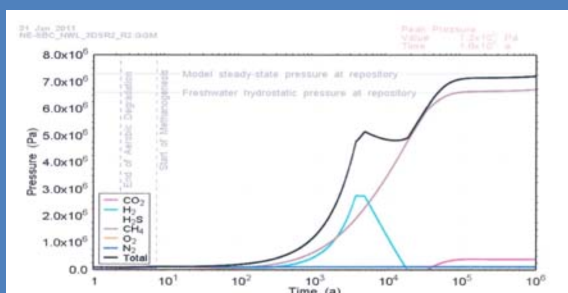

Figure 5.45: NE-SBC: Total and Partial Gas Pressures within the Repository

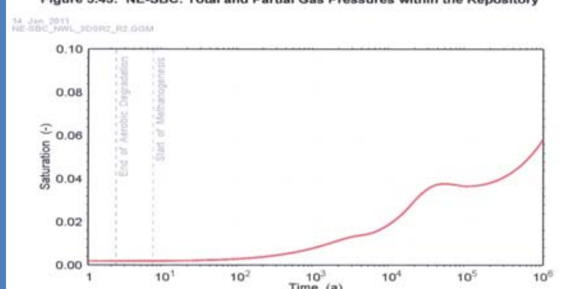

Figure 5.46: NE-SBC: Water Saturation within the Repository

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my questions:

What was the source of the gas?

When was gas emplaced in the Ordovician rocks?

Is gas continuing to be generated?

Are the under pressures created by glacial loading?
(what creates the under pressures?)