Effect of Non-Hydrostatic Pore Pressure from the Depth to the Base of the Hydrate Stability Zone*

By
Robert W. Lankston[1]

Search and Discovery Article #40327 (2008)
Posted August 20, 2008

*Adapted from oral presentation at AAPG Annual Convention, San Antonio, Texas, April 20-23, 2008

[1]Geoscience Integrations, Missoula, MT (rlankston@msn.com)

Abstract

The pressure term in the hydrate stability equation can be converted to depth to facilitate estimating the vertical extent of the hydrate stability zone (HSZ). The conversion from pressure to depth is generally made assuming that hydrostatic conditions exist downward from the surface, and a gradient of 0.0100 MPa/m is often applied. While being a convenient factor, it is about 5% less than the widely accepted value for hydrostatic pressure, i.e., 0.0105 MPa/m. This gradient can be expressed as 8.94 lb/gallon mud weight.

Using the larger factor for the gradient yields a higher pressure at any given depth, which means that hydrate would be stable at a higher temperature at that depth. For a given geothermal gradient, the base of the HSZ is deeper with higher pressure gradients.

Gas is commonly trapped above hydrostatic pressure. Higher pressure in the reservoir causes the base of the stability zone in that reservoir to become deeper. This effect may help to explain why the base of the hydrate stability zone reported for the Hot Ice well on the North Slope was approximately 120 m shallower than the gas hydrates that dissociated contributing to the 1992 blowout of the Cirque 1 well, which was just a few miles to the west. Reported mud weights from the Cirque 1 well were between 9.1 and 9.4 lb/gallon. Mud weights from Cirque 1 and nearby Cirque 2 can be used to estimate a base of hydrate stability in the reservoir that is approximately 300 m deeper than would be estimated based on a hydrostatic assumption.

In the case of deepwater hydrates, varying gas pressure in reservoir sands helps to explain why sets of bright reflections in steeply dipping sands, interpreted as indicating the base of the HSZ, do not track the sea floor reflection as a BSR might be expected to do.

Effect of Non-Hydrostatic Pore Pressure on the Depth to the Base of the Hydrate Stability Zone

Bob Lankston
Geoscience Integrations
Missoula, MT

www.geogrations.com

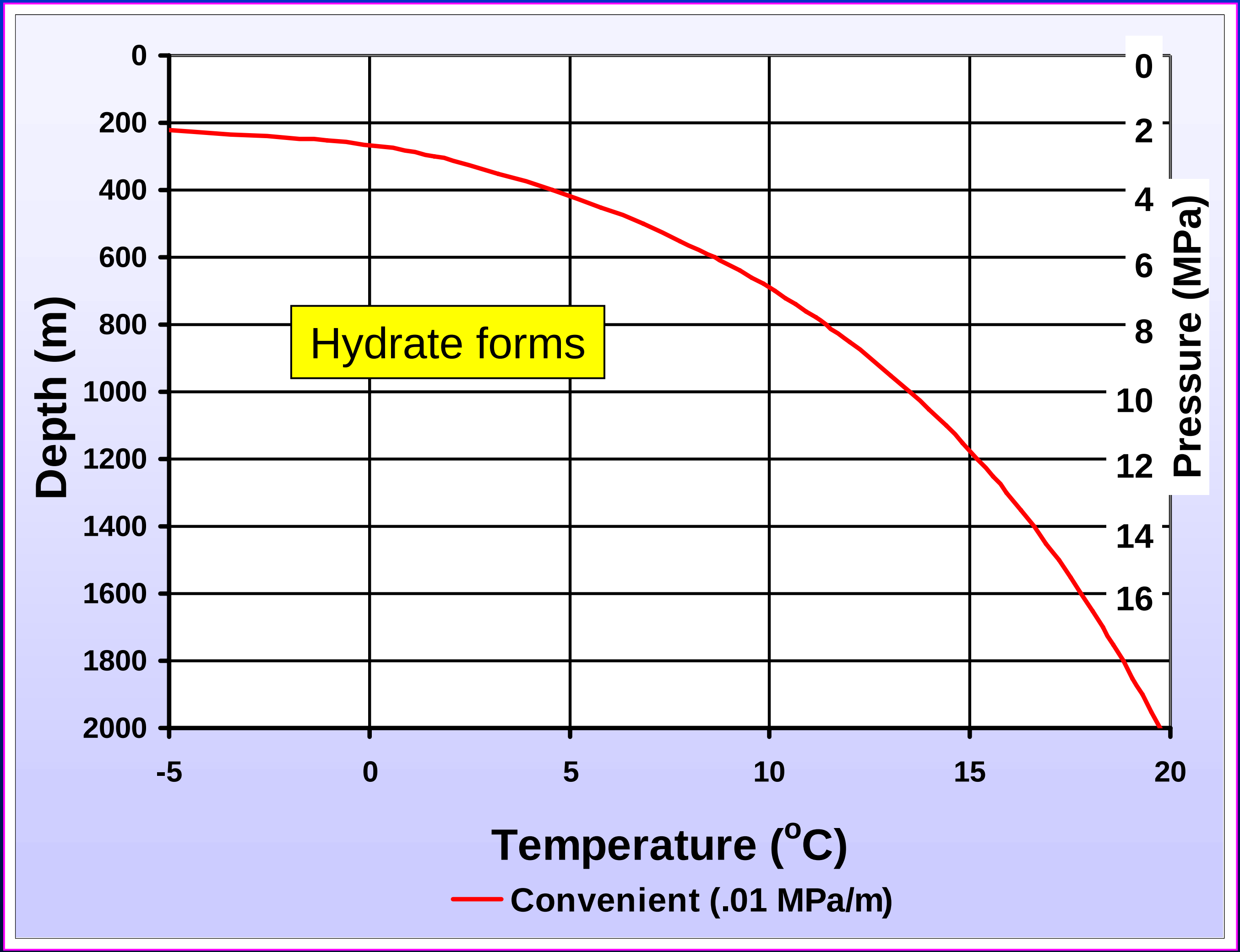
Acknowledgements

Aspects of this work were begun in 2003 while I was employed in Upstream Technology at ConocoPhillips Company. The company's on-going support of my interest in gas hydrate exploration, including providing data and technical review for this presentation, is gratefully acknowledged.

Howard Okland, of the Alaska Oil and Gas Conservation Commission, provided log data from the Cirque area.

Frances Toro, of the DOE's NETL, provided log data for the Hot Ice well.

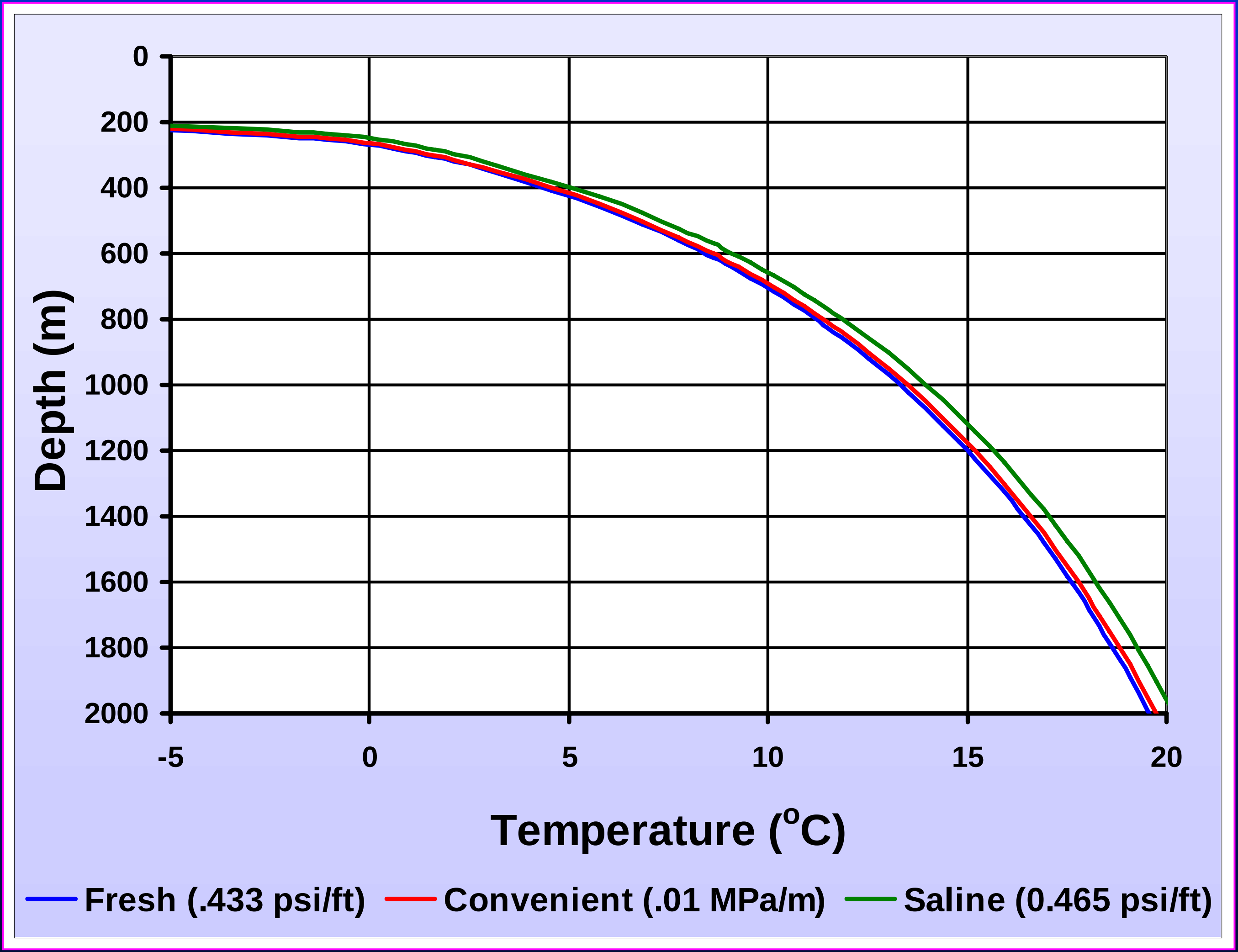
Methane Hydrate Stability Curve



Model: Sloan's CSMHyd program
100% Methane
Pure water

Hydrate formation factors:
Temperature and pressure
Gas composition
Water salinity

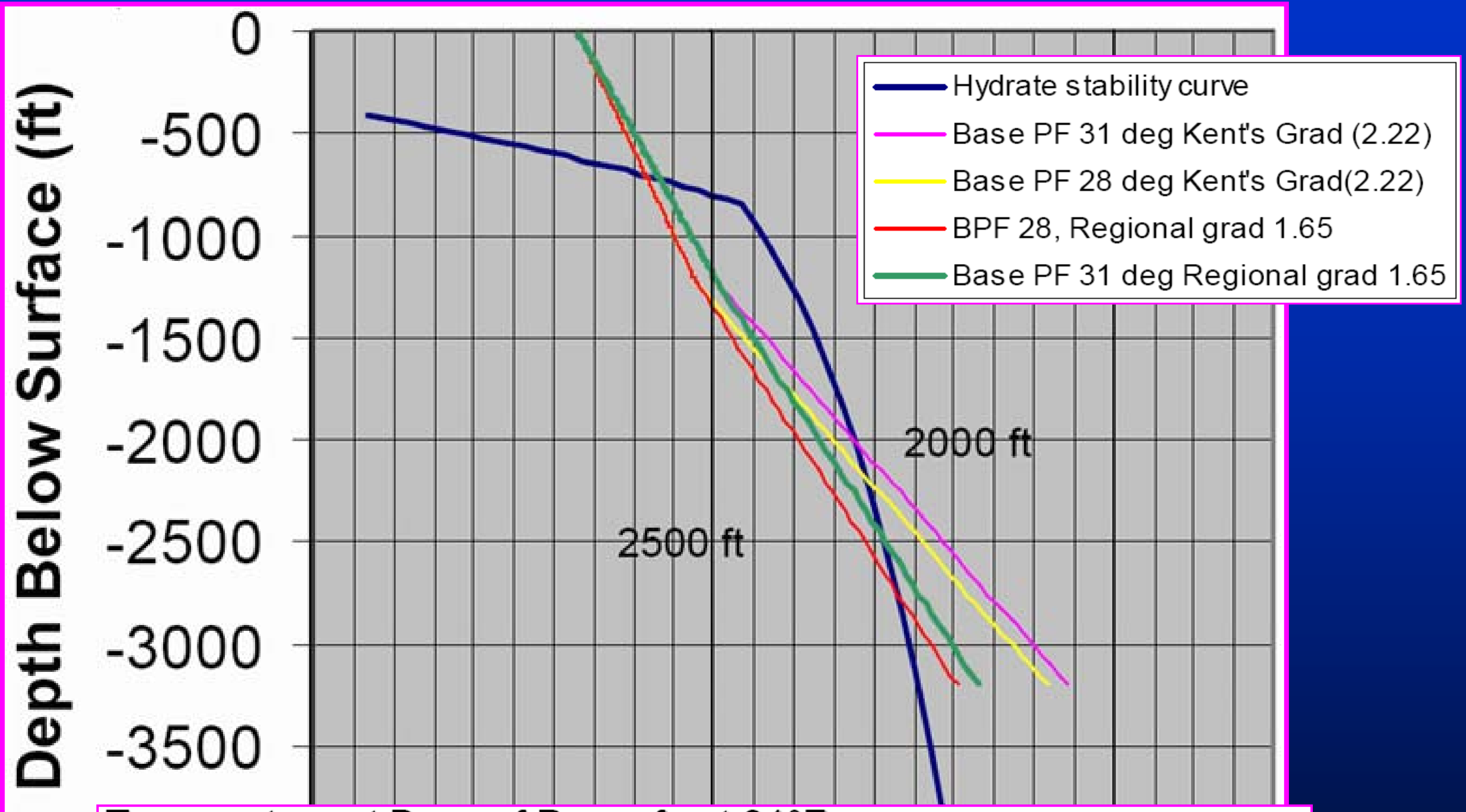
Effect of Hydrostatic Pressure



Specific Gravity	(g/cm^3)	1.00	1.02	1.07
Gradient	MPa/m	0.0098	0.0100	0.0105
Gradient	psi/ft	0.433	0.442	0.465
Mud Weight	ppg	8.33	8.50	8.94

Does the geothermal gradient
get more attention
than the pore fluid pressure gradient
in gas hydrate assessments?

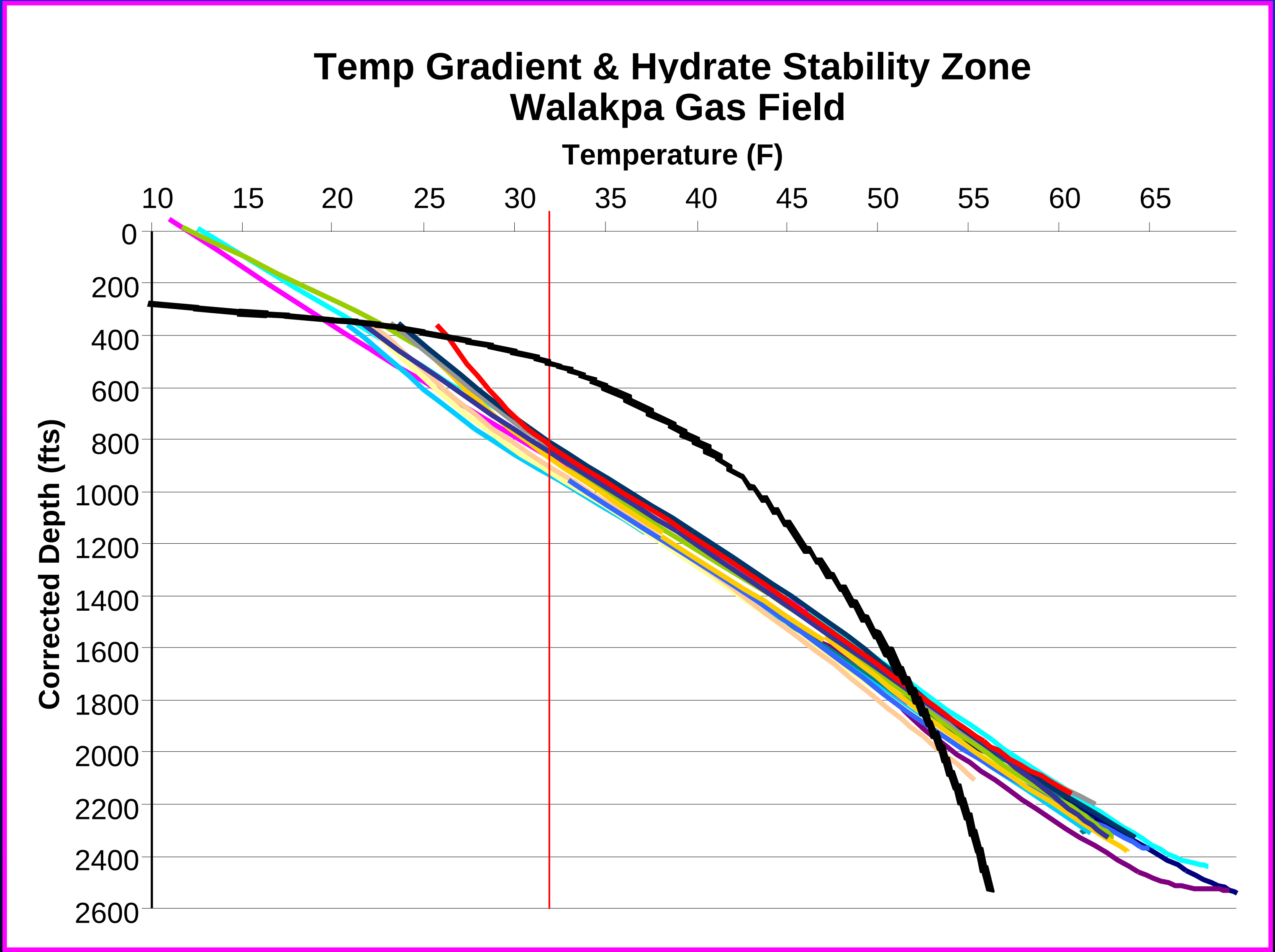
Hot Ice Stability Zone Analysis



Temperature at Base of Permafrost 31°F
Local Thermal Gradient (2.2°F/100ft) gives 2000 ft Subsurface
Regional Thermal Gradient (1.65°F/100 ft) gives 2500 ft Subsurface
Assumed Normal Pressure Gradient

NETL (Anadarko)

North Slope Borough Stability Zone Analysis

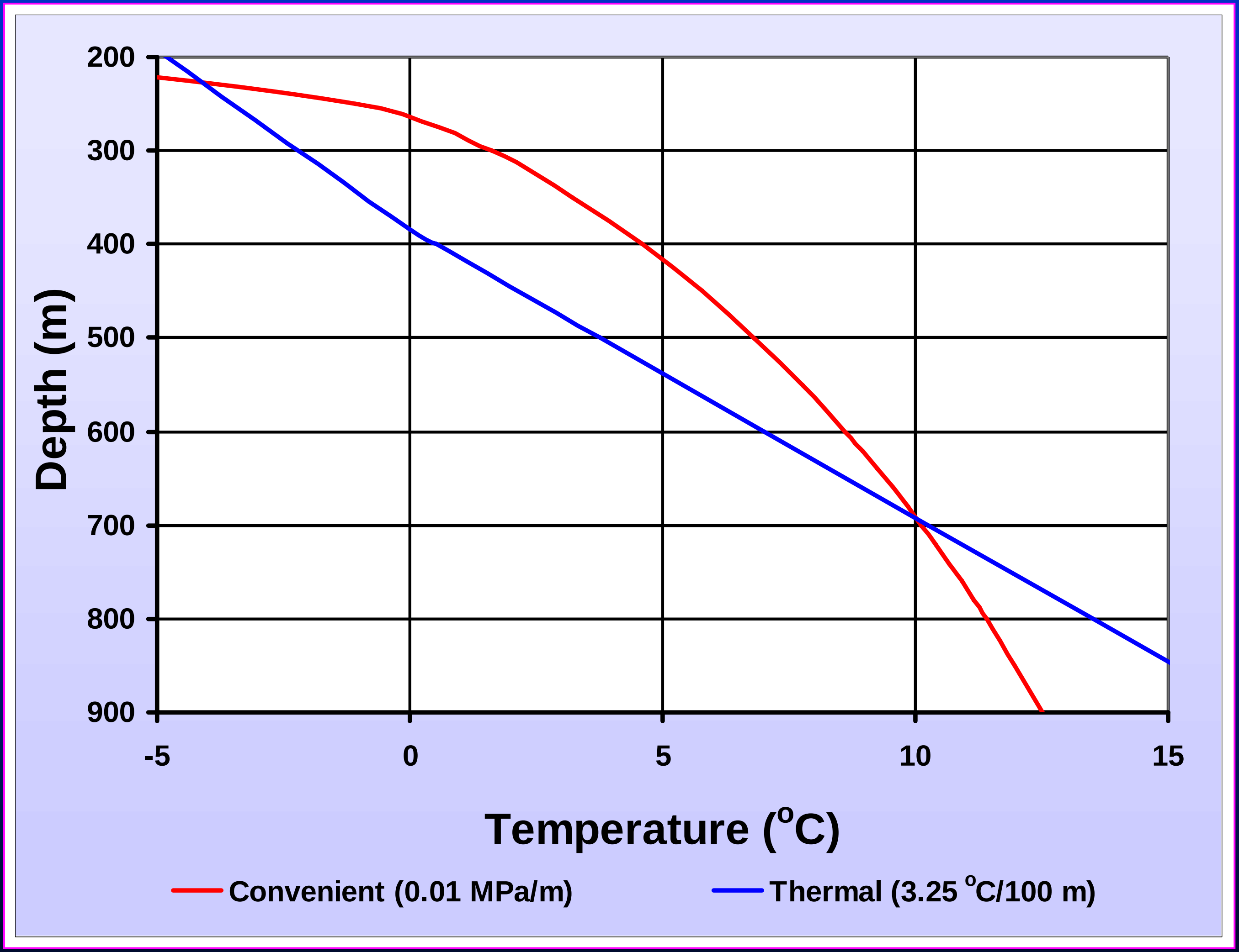


Courtesy Tom Walsh, North Slope Borough

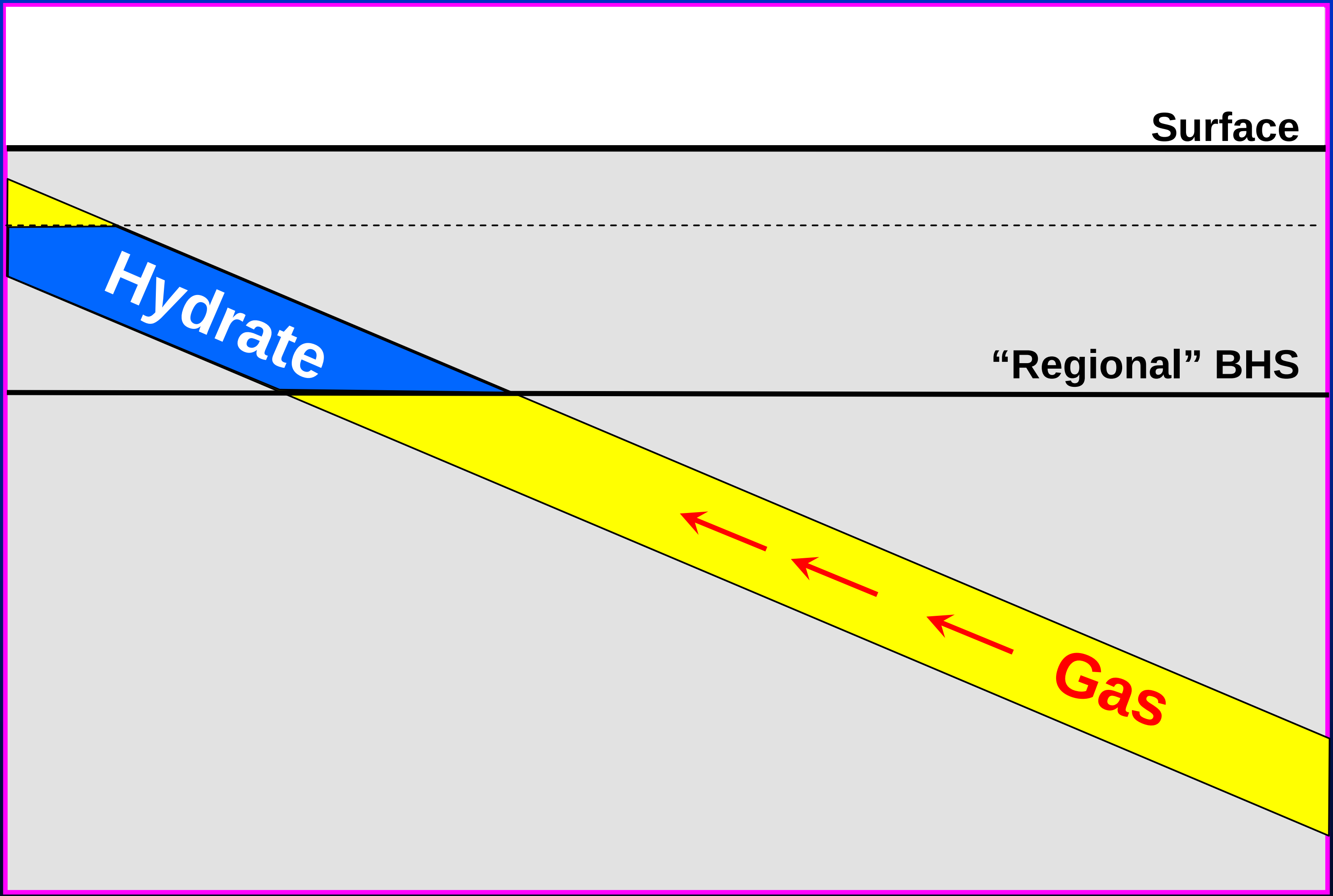
What about pore fluid pressure in these studies?

- Collett, in the early 1990's, took the mean of measured pressures to estimate a hydrostatic gradient (0.433 psi/ft, 0.0098 MPa/m)
- Hot Ice project assumed hydrostatic gradient
- BP Alaska consortium assumed hydrostatic gradient
- North Slope Borough took means of measured pressures (0.450 and 0.500 psi/ft, 0.0108 and 0.01130 MPa/m)
- McConnell used 0.442 psi/ft (0.0100 MPa/m) in the Gulf of Mexico

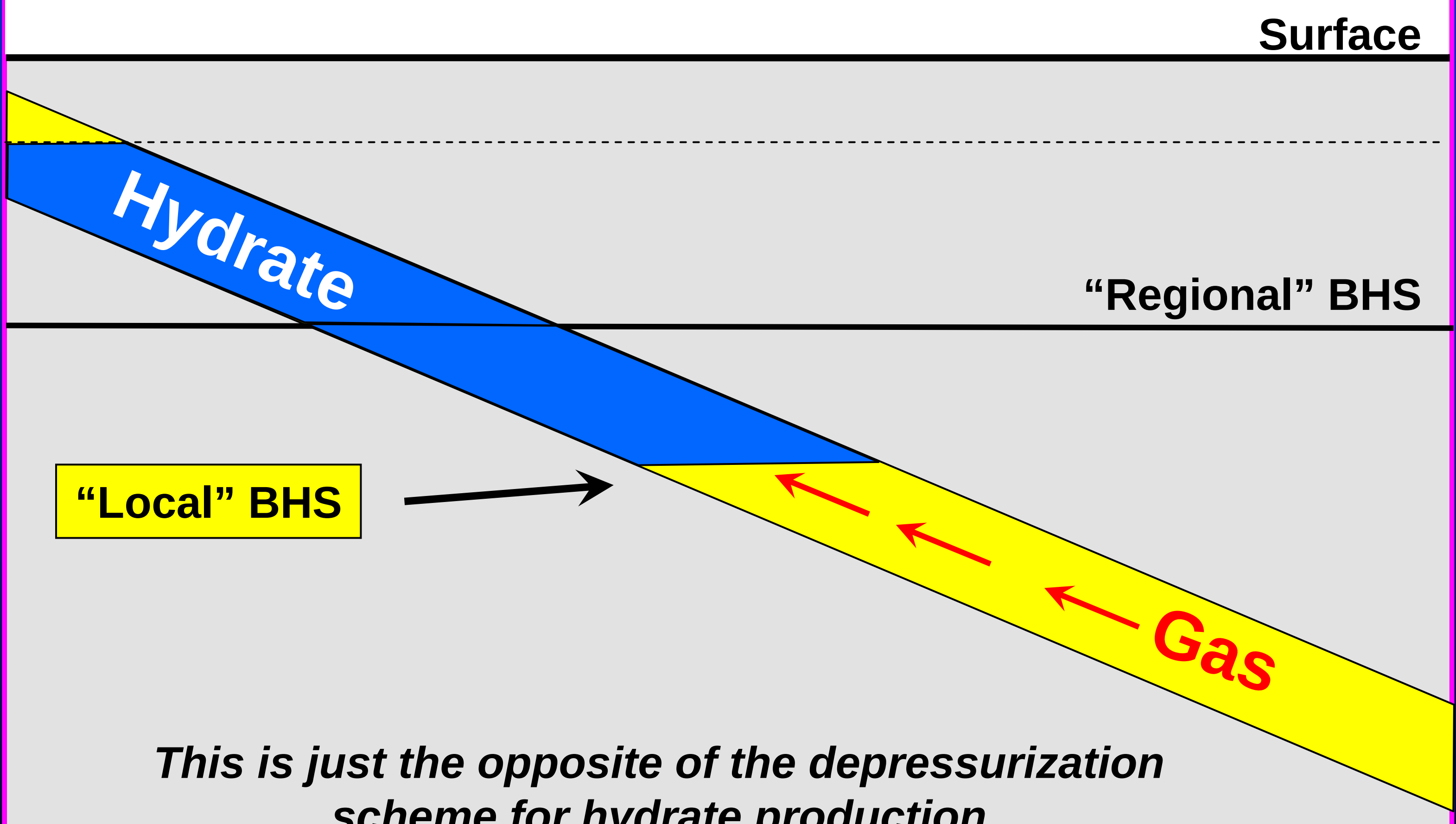
Basic Hot Ice-Cirque Area Stability Diagram



Normally-pressured Arctic Gas Reservoir

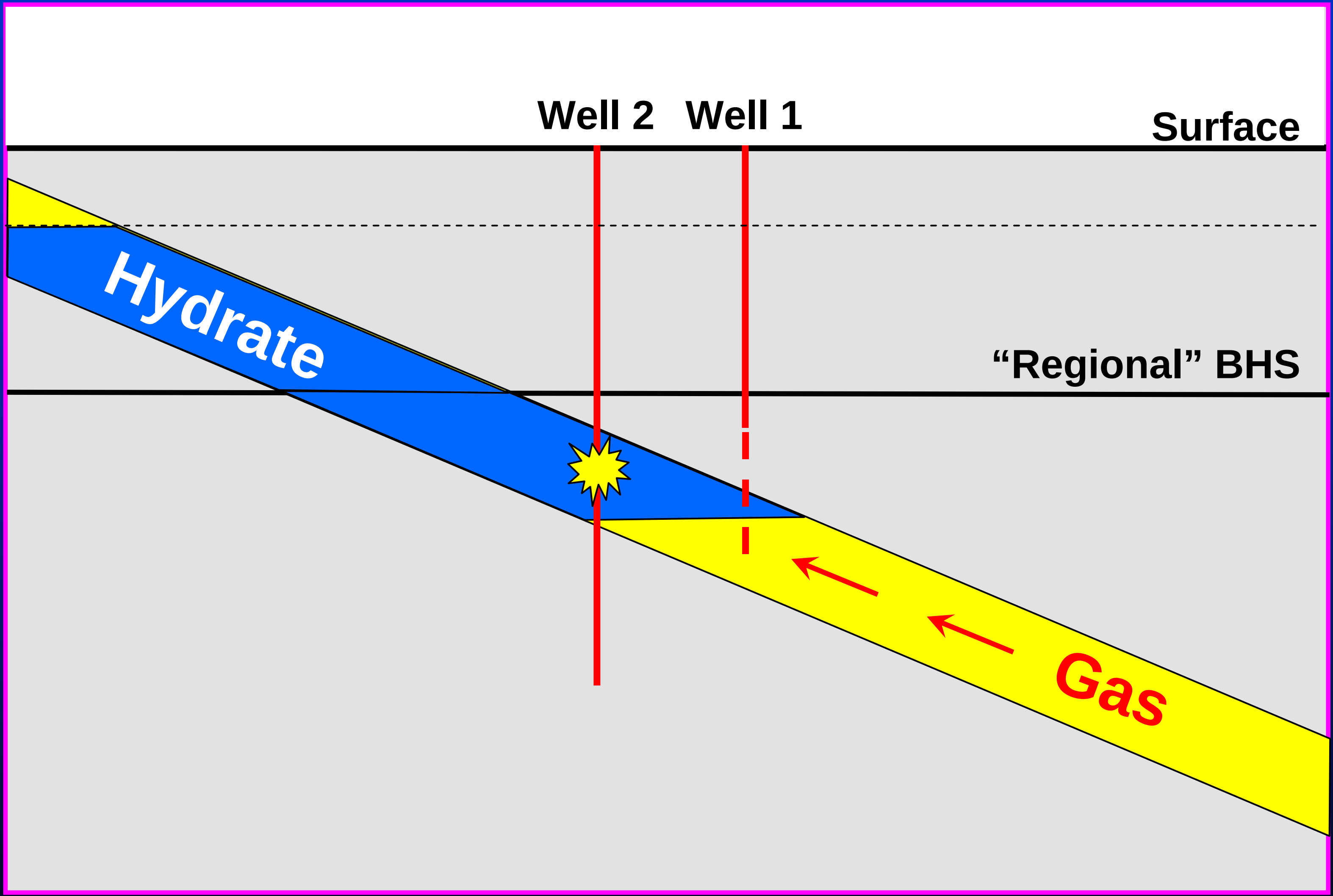


Overpressured Arctic Gas Reservoir



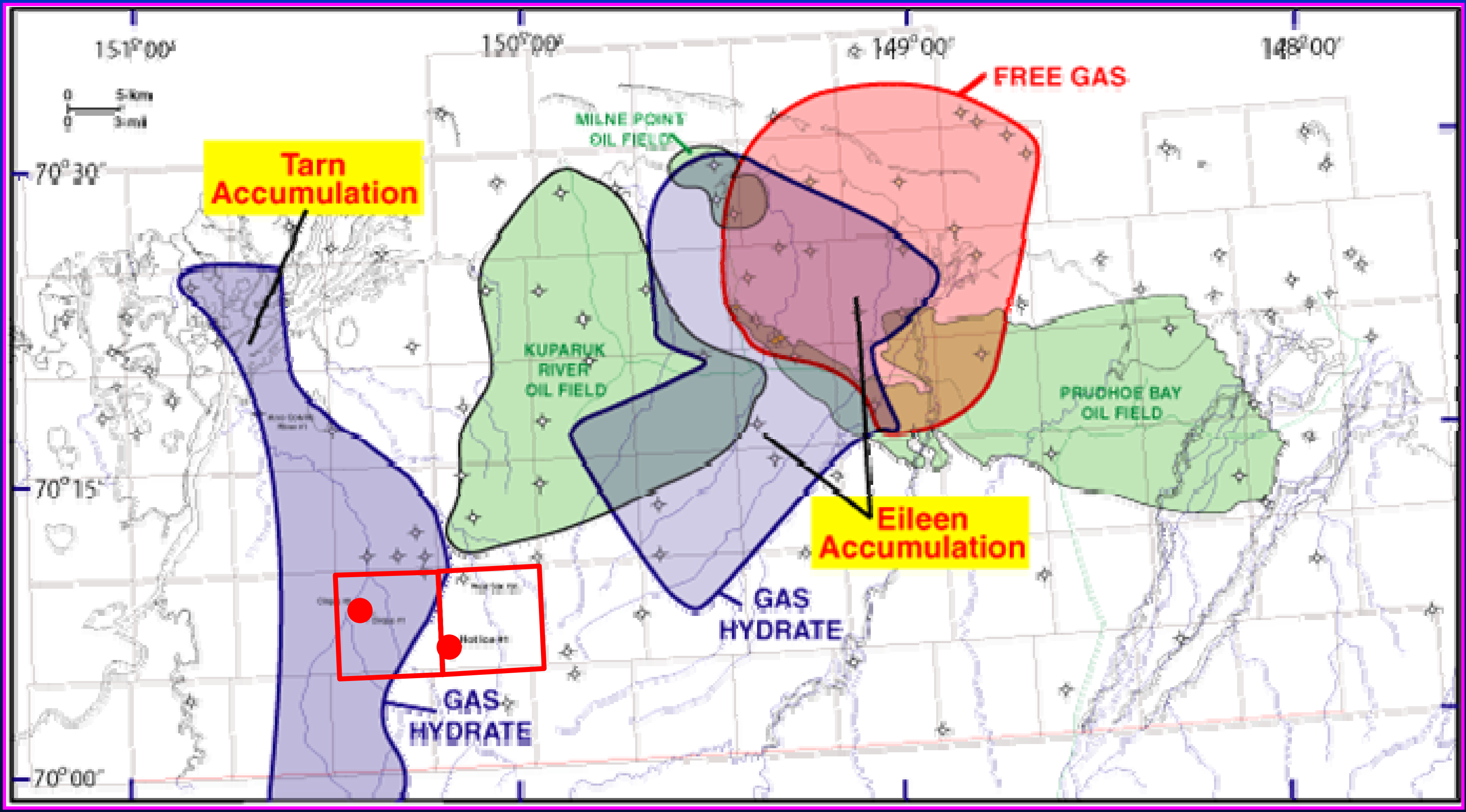
This is just the opposite of the depressurization scheme for hydrate production.

Overpressured Arctic Gas Reservoir



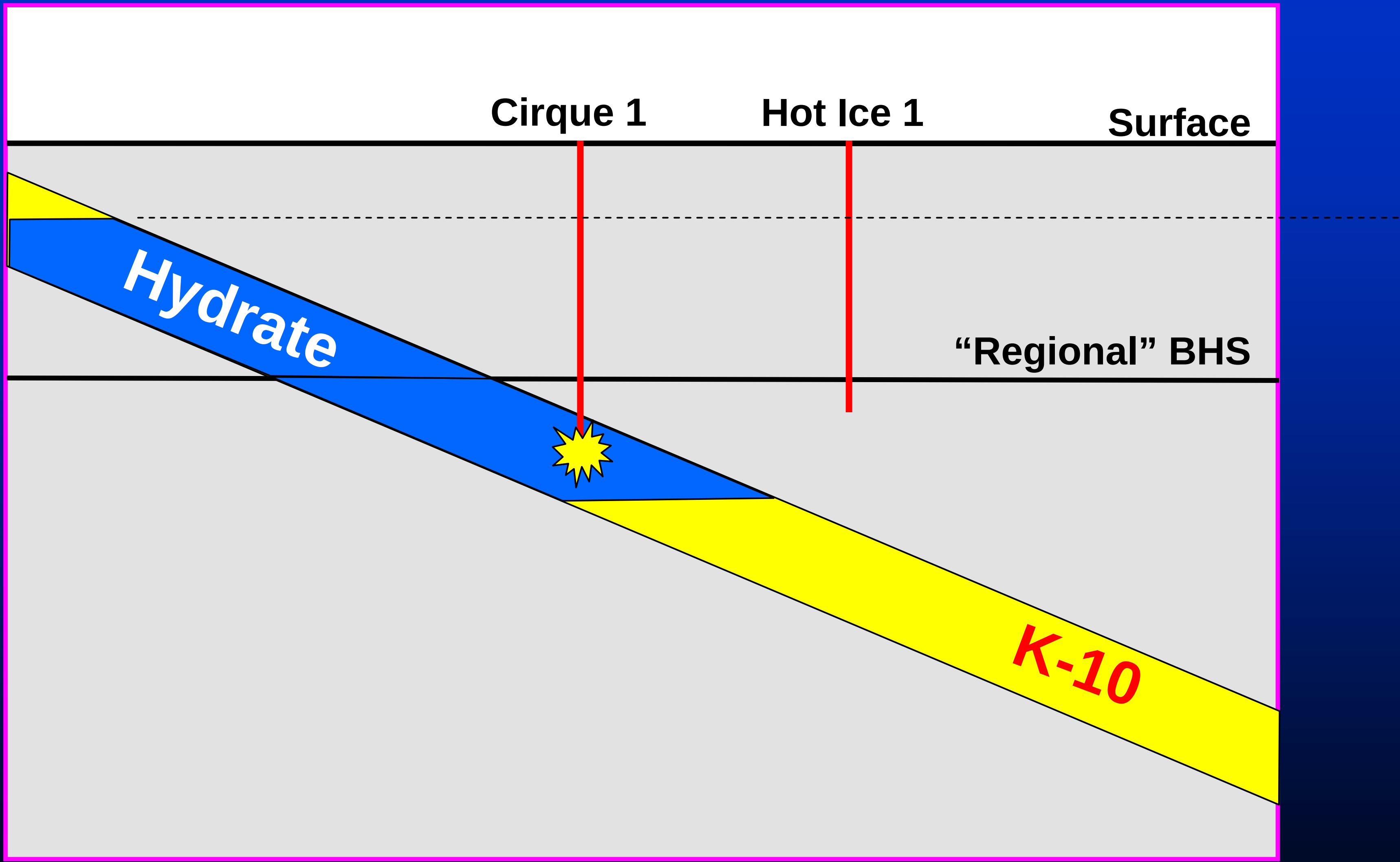
Has this happened on the North Slope?

Cirque-Hot Ice Locations in Tarn Trend

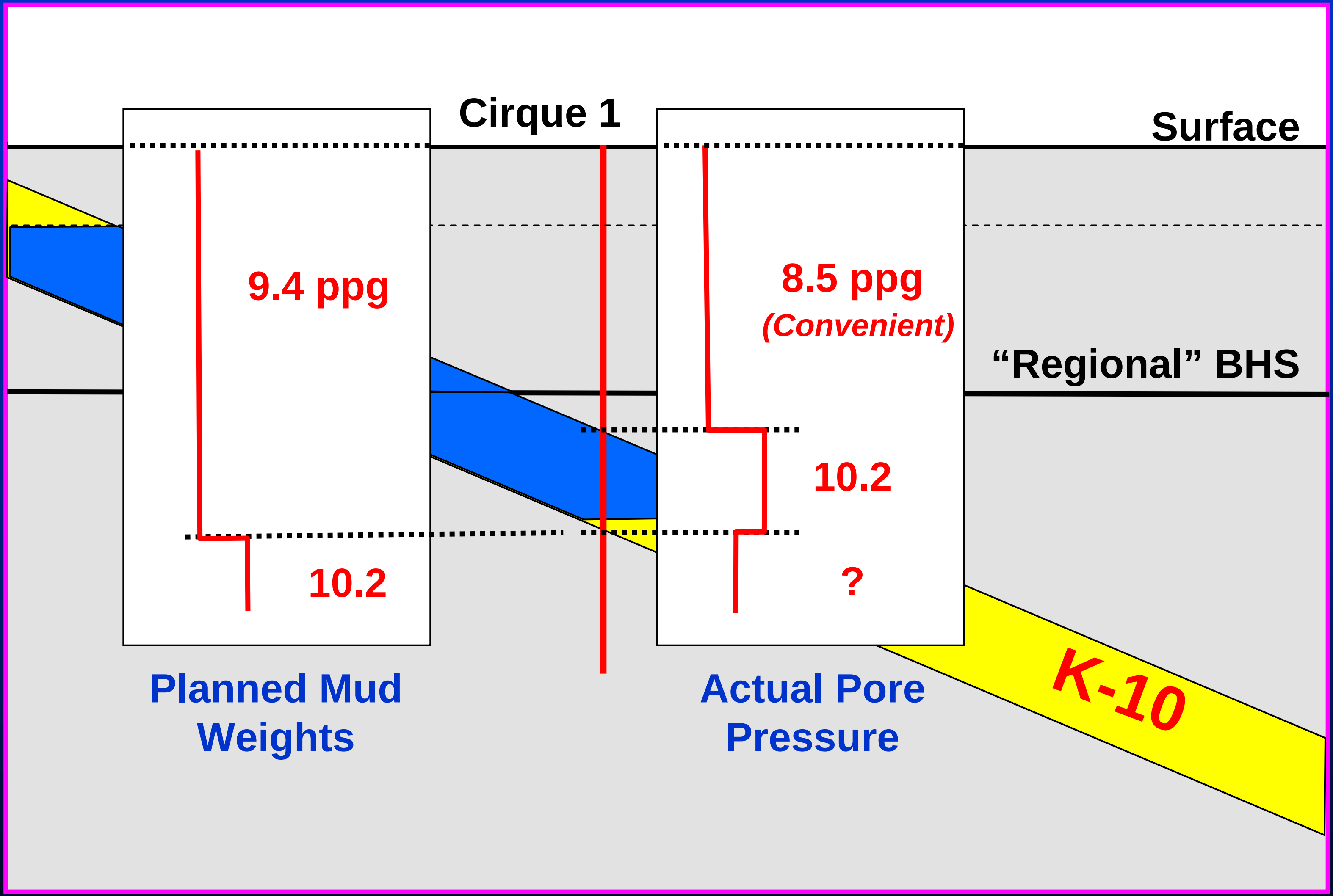


USGS

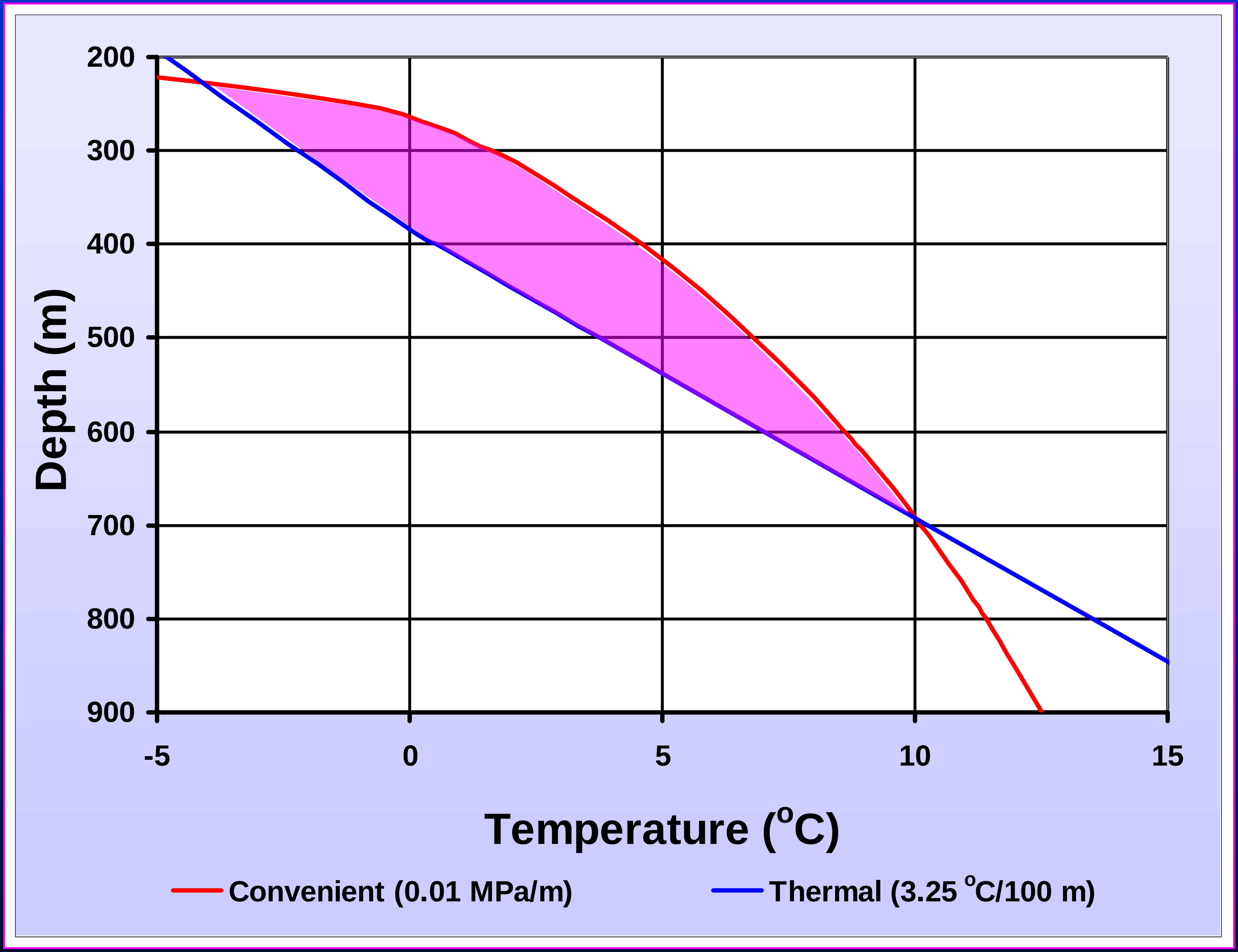
Overpressured Arctic Gas Reservoir



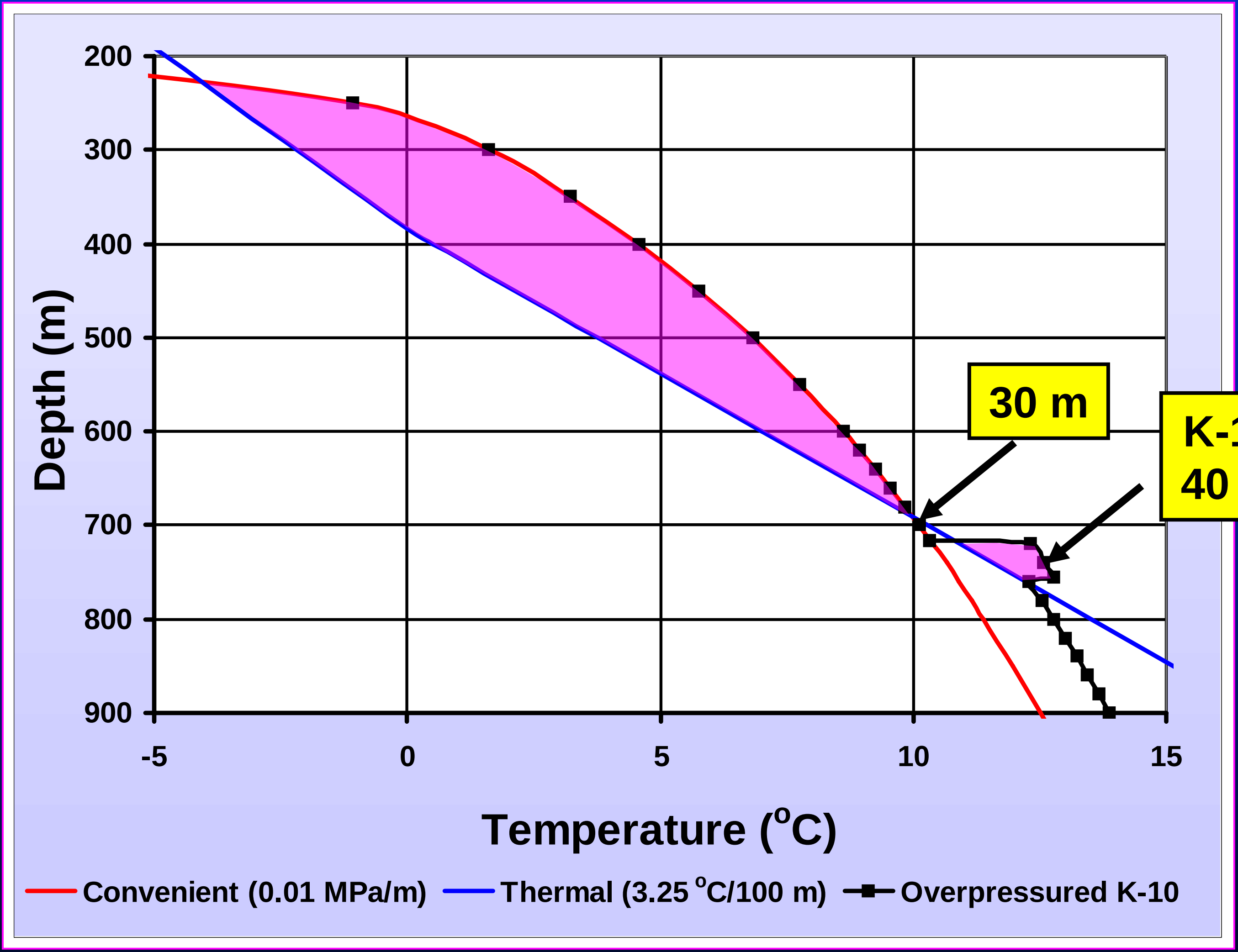
Overpressured Arctic Gas Reservoir



Basic Hot Ice-Cirque Area Stability Diagram

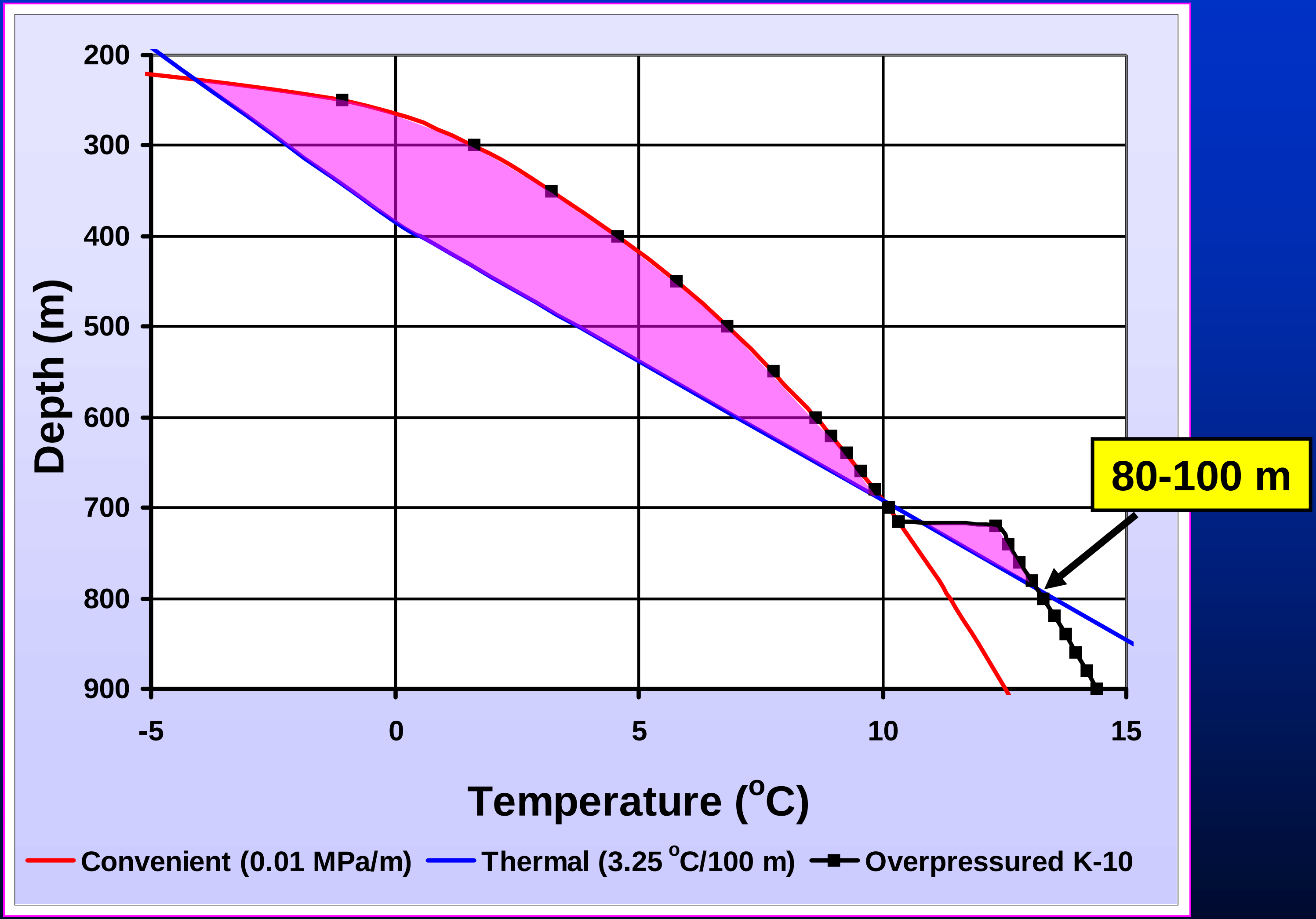


Effect of Overpressure in K-10



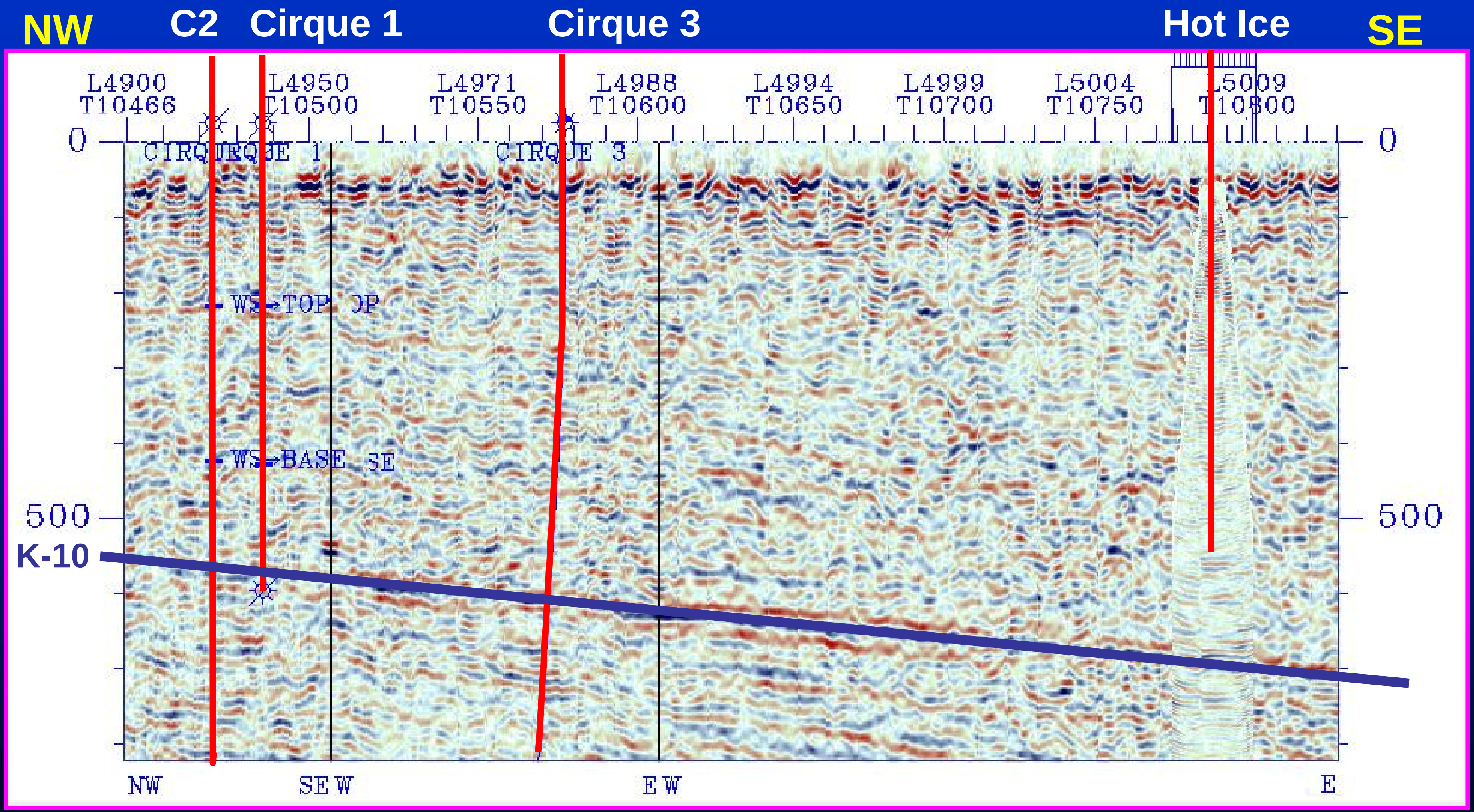
Drilling vertically through K-10

Effect of Overpressure in K-10



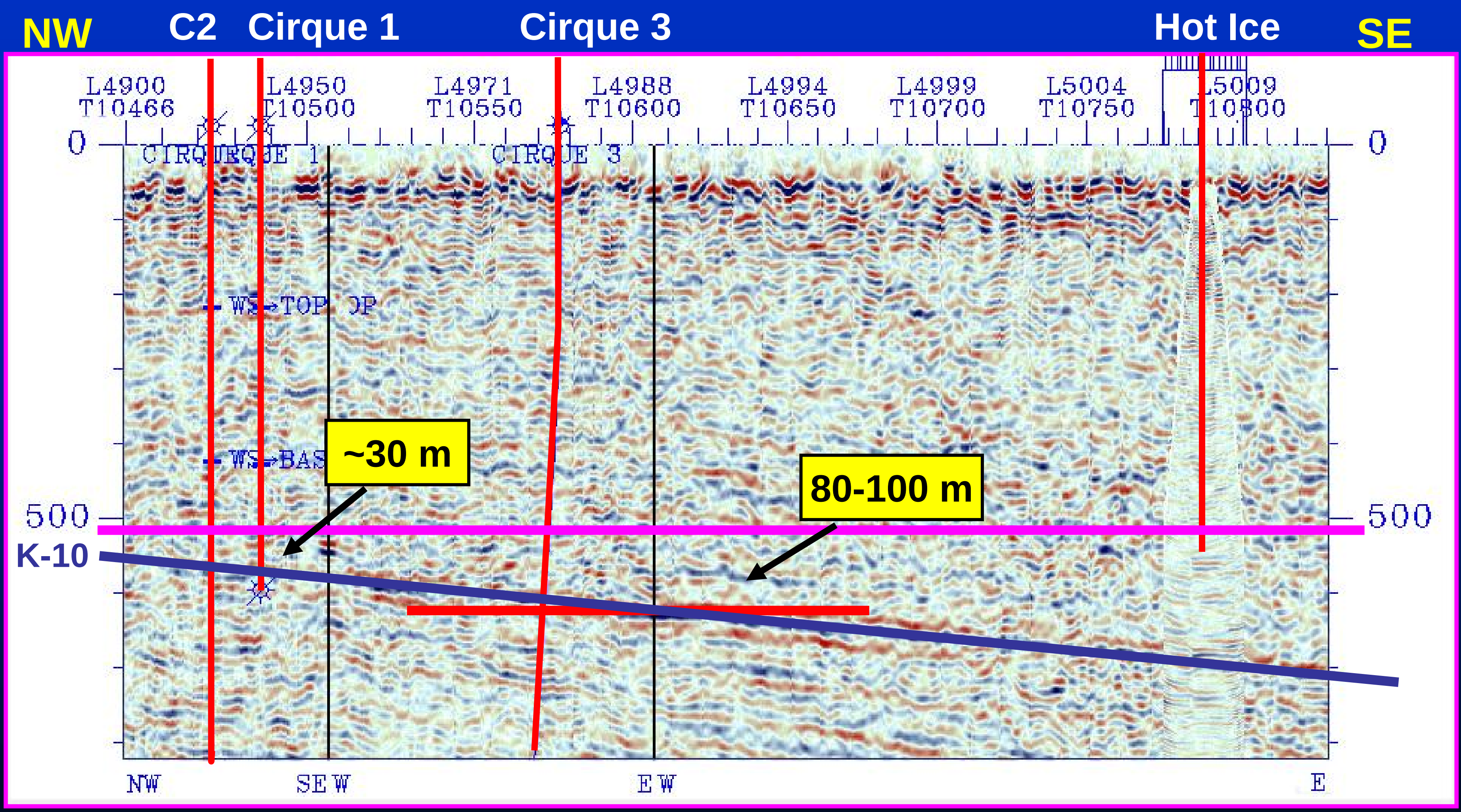
Down dip in K-10

The K-10 Sand



NW
C2
Cirque 1
Cirque 3
Hot Ice
SE
L4900 T10466
L4950 T10500
L4971 T10550
L4988 T10600
L4994 T10650
L4999 T10700
L5004 T10750
L5009 T10800
0
0
CIRQUE 1
CIRQUE 3
TOP
BASE
500
500
K-10
NW
SE W
E W
E

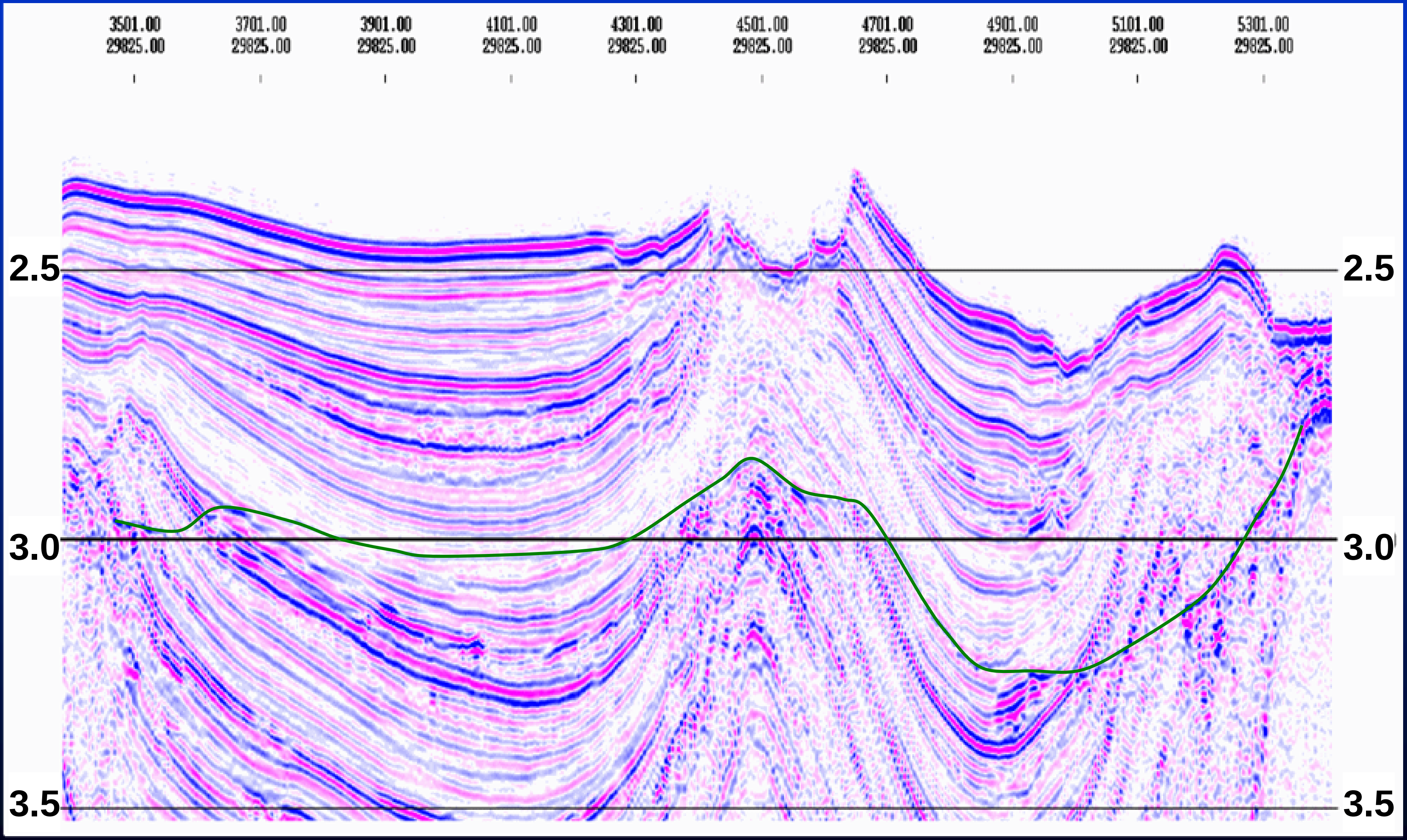
“Regional” vs “Local” BHS



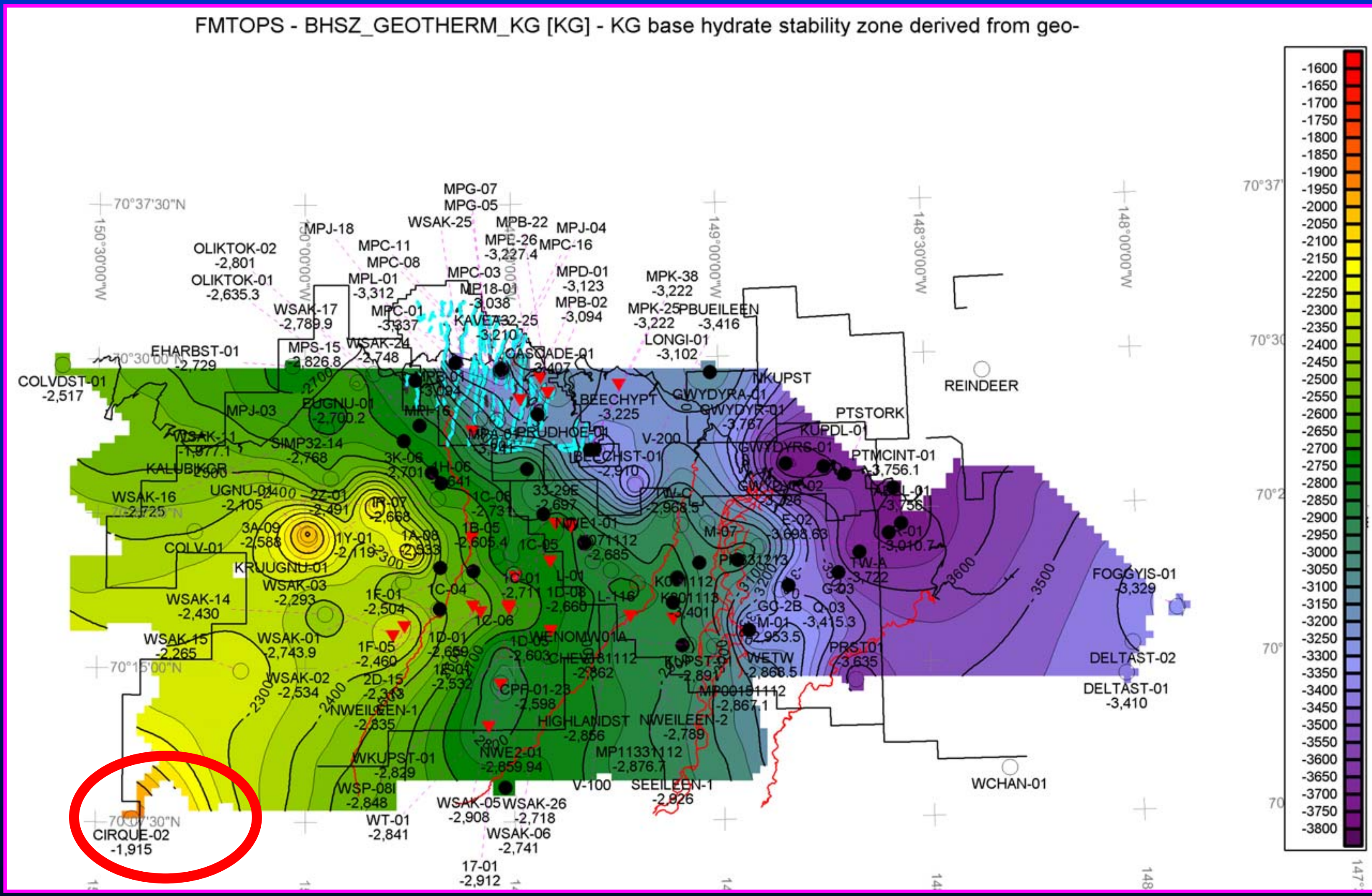
Conclusions

- Locally, in a reservoir, the BHS could be considerably deeper than would be estimated with a hydrostatic model for the surrounding region
- Work the pressure aspect of the subsurface as hard as the other factors using conventional geopressure analysis tools applied to logs and seismic data

Possible Marine Example
Gulf of Mexico Walker Ridge

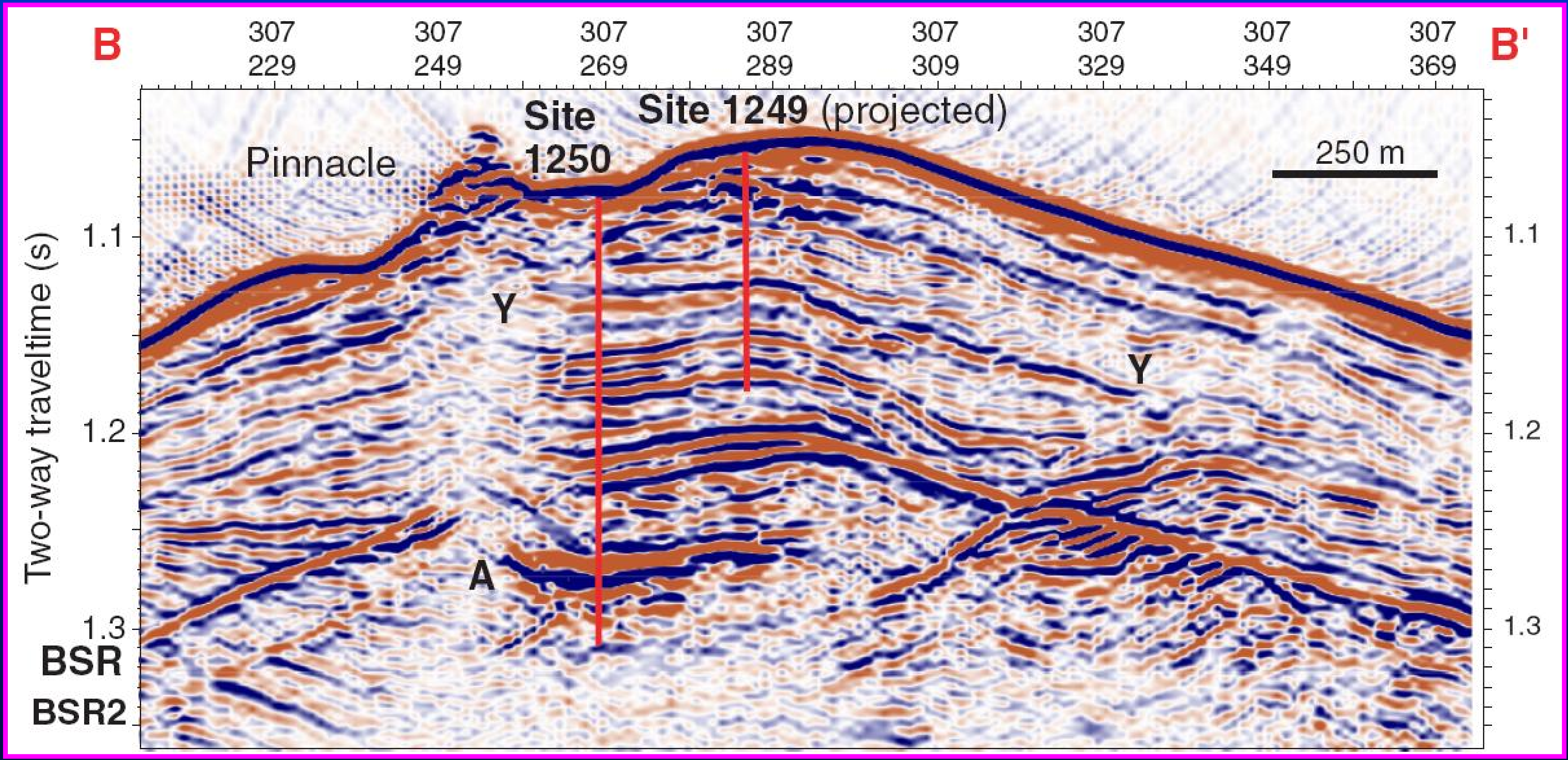


BP Alaska-UAz BHSZ Map

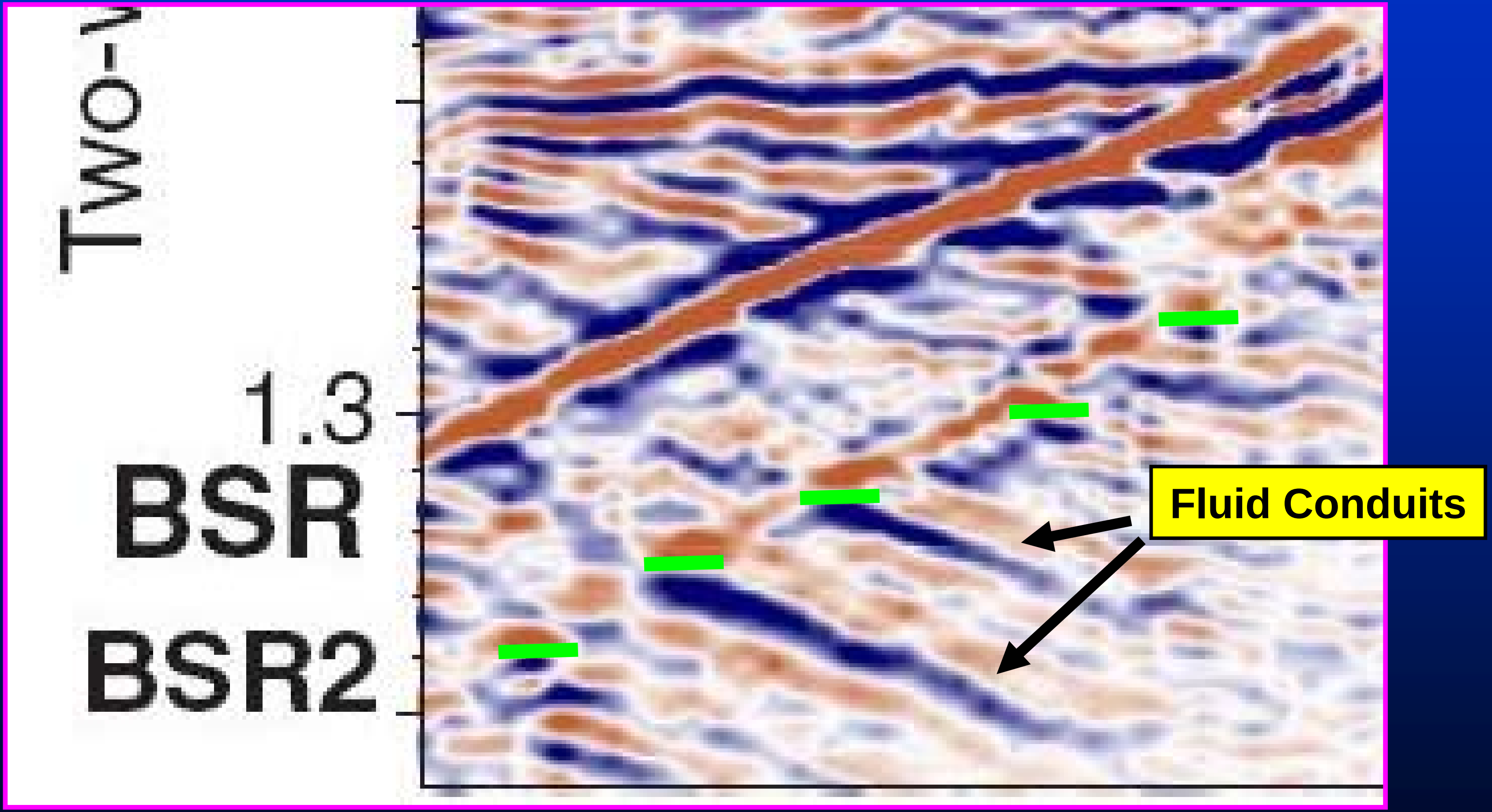


NETL (BP Alaska)

A Possible Marine Example
ODP 204 – Hydrate Ridge



A Possible Marine Example
ODP 204 – Hydrate Ridge



McConnell section with estimated BHSZ points or Walker Ridge line